Attachment L

Additional Documentation
Attachment to Comment 2-F1

ESA

California Energy Commission

FINAL CONSULTANT REPORT

Forecast of Medium- and Heavy-Duty Vehicle Attributes to 2030

Prepared for: **California Energy Commission**
Prepared by: **H-D Systems**



California Energy Commission
Edmund G. Brown Jr., Governor

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Primary Author(s):

Gopal Duleep
H-D Systems
4417 Yuma St. NW
Washington DC
(202)-966-0286
www.h-dsytems.com

Contract Number: 800-16-005

Prepared for:

California Energy Commission

Sudhakar Konala
Contract Manager

Bob McBride
Project Manager

Siva Gunda
Office Manager
DEMAND ANALYSIS OFFICE

Sylvia Bender
Deputy Director
ENERGY ASSESSMENTS DIVISION

Drew Bohan
Executive Director

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ABSTRACT

This California Energy Commission report documents the forecast of vehicle fuel economy and price for medium- and heavy-duty vehicles for the 2016-to-2030 period and the technological and modeling assumptions used to derive the forecast. The Energy Commission uses transportation energy demand models that require projections of these vehicle attributes. The fuel economy and greenhouse gas emissions of medium- and heavy-duty vehicles are required to meet specific mandated levels by federal regulations through 2027 and beyond. Since the standards necessitate the use of more fuel-saving technologies than would otherwise be demanded by the market, the regulatory analysis developed by United States Environmental Protection Agency and National Highway Traffic Safety Administration (in support of the standards) is used extensively, though some modifications were made to derive the projections for the Energy Commission. This report also summarizes the technologies available to improve the fuel economy of trucks powered by conventional gasoline or diesel engines, as well as those using alternative fuels like ethanol, natural gas, electricity, and hydrogen. H-D Systems developed projections for two scenarios in this analysis.

Keywords: California Energy Commission, vehicle attributes, heavy-duty trucks, attribute forecast, fuel economy, alternative fuels

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EXECUTIVE SUMMARY

The California Energy Commission estimates fuel consumption in the transportation sector and projects the market penetration of alternative fuel vehicles as a part of the *2017 Integrated Energy Policy Report* and other state projects. To forecast these values, the Energy Commission uses transportation demand models that require projections of vehicle attributes for the 2016-to-2030 period. This report presents H-D Systems' forecast of medium- and heavy-duty vehicle fuel economy and vehicle prices, which are used as inputs into the Energy Commission's transportation models. The report also documents the technological and modeling assumptions used to derive the attribute forecast.

The second phase of the federal *Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles* require medium- and heavy-duty vehicles to meet specific mandated fuel economy levels through 2027. The United States Environmental Protection Agency and the National Highway Traffic Safety Administration completed a comprehensive analysis of technological improvements available to improve fuel economy and reduce greenhouse gas emissions in support of the Federal Phase 2 regulations. The analysis by the agencies is documented in the Regulatory Impact Assessment of the federal Phase 2 standards. H-D Systems' forecast of vehicle attributes for the Energy Commission uses many elements of the standards derived in the Regulatory Impact Assessment.

The Energy Commission's transportation demand models require medium- and heavy-duty attributes by vehicle class and fuel type. Medium- and heavy-duty trucks are classified into six industry weight classes (Classes 3 to 8), and the Energy Commission subdivides Class 8 trucks by vocation. Furthermore, the Energy Commission classifies buses as urban transit buses, shuttle buses, school buses, and motor coaches. Finally, the fuel types requested by the Energy Commission include:

- Gasoline-electric hybrid.
- Diesel-electric hybrid.
- Diesel-hydraulic hybrid.
- Battery-electric.
- Direct or catenary electric.
- Fuel cell electric.
- Ethanol (E85).
- Compressed natural gas.
- Liquefied natural gas.
- Propane.

In general, gasoline and diesel engines are common in smaller (Classes 3 to 5) trucks, while heavier vehicles are typically powered by diesel engines. In the highest weight classes, diesel engines are used in more than 95 percent of all trucks. Hence, the focus

of the analysis starts with diesel-powered vehicles, while alternative powertrains are considered relative to diesel.

To generate forecasts of fuel economy, H-D Systems considered several fuel efficiency technologies in this analysis, including:

- Improvements in engine efficiency and reduction of losses in the engine, transmissions, and axles.
- A reduction in vehicle weight, aerodynamic drag, or tire-rolling resistance.

The technologies available and the respective costs and benefits are summarized in this report.

This report provides forecasts for two scenarios. The first is a high electricity demand case that assumes electric vehicles are successful and uses the high-volume production forecast to generate electric vehicle prices. The second is a low electricity demand case that uses the current (low-volume production) prices of electric vehicles and assumes manufacturers are able to achieve cost reductions through increasing manufacturing experience but not of scale for the forecast. This scenario also uses the high transit bus prices from the California Air Resources Board as the starting point for prices in 2017 and assumes benefits of learning but not of scale for the forecast. The forecasts project that for all internal combustion engine-powered vehicles from 2017 to 2030

- Vehicles in Classes 3 and 4 (mostly large pickups and vans) will increase fuel economy by about 25 to 29 percent.
- Medium-duty trucks in Classes 6 and 7 that operate in mixed suburban and urban routes will increase fuel economy by 22 to 25 percent.
- Vehicles in mostly urban use like garbage trucks and urban buses will have improvements in fuel economy of 9 to 12 percent.
- Long-haul trucks in Classes 7 and 8 will see the largest improvement of 29 to 32 percent in fuel economy.

Electrical vehicles in each class will see smaller improvements in fuel efficiency because the electric motor is already very efficient and future gains in efficiency will be small; hence, most of the efficiency improvement is associated with improvements to body technology. Costs of electric vehicles, however, are forecast to decline mostly due to battery cost reduction and improved economies of scale.

CHAPTER 1: Introduction

The California Energy Commission's Transportation Energy Forecasting Unit (TEFU) has a set of transportation energy demand models that require forecasts of medium- and heavy-duty vehicle attributes (fuel economy and price) from 2016 to 2030. The models are used by TEFU to estimate future fuel consumption and the market penetration of alternative fuel vehicles, which help inform the *2017 Integrated Energy Policy Report (IEPR)* and provide analytical support for implementing state policy goals. This report documents the forecast of medium- and heavy-duty vehicle fuel economy and price, and the technological and modeling assumptions used to derive the forecast.

The fuel economy and greenhouse gas (GHG) emissions of medium- and heavy-duty vehicles are required to meet specific mandated levels by the federal *Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-duty Engines and Vehicles* for the 2010-to-2017 period. They have recently been extended to the 2018-to-2027 period by the "Phase 2" regulations. The standards require a high level of effort from heavy-duty vehicle manufacturers and essentially make the future fuel economy levels for each vehicle weight class virtually independent of future fuel prices unless prices rise to unanticipated levels. Fuel prices could still affect the mix of vehicle weight classes and fuel types sold, but for a given weight class and fuel type, fuel economy improvements are forced by standards rather than economics.

The way to meet the fuel economy standards is by improving the technology of trucks. A comprehensive analysis of technological improvements has been completed by the United States Environmental Protection Agency (U.S. EPA) and the National Highway Traffic Safety Administration (NHTSA) in support of the 2014-2017 Phase 1 and 2018-2027 Phase 2 regulations. The analysis builds on earlier work on heavy-duty vehicle technology by the U.S. EPA, National Academy of Sciences (NAS), and H-D Systems (HDS). The forecast relies on technologies being added to a known baseline (2017) of vehicle characteristics. The more recent work by U.S. EPA/NHTSA is documented in the Regulatory Impact Assessment (RIA) released in 2016,[1] and this forecast uses many elements of the standards derived in the RIA. Since the standards are technology-forcing,[2] the analysis in the RIA is used extensively with some modification to derive the forecast for the Energy Commission.

Chapter 2 of this report describes the weight classes and fuel types used by the Energy Commission and maps the Commission's vehicle class definitions to those used by the EPA and NHTSA. In addition to the weight class and fuel type classifications, trucks in the same weight classes are used in applications with different use-based duty cycles.

1 U.S. EPA/NHTSA. August 2016. *Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Vehicles, Regulatory Impact Assessment, EPA Report 420-R-16-900.*
2 "Technology forcing" refers to regulations that require (force) the use of more technology than demanded by the free market to achieve performance standards.

The Energy Commission's weight class by application is matched to the appropriate duty cycle definitions used in the RIA.

Chapter 3 summarizes the technology analysis in the RIA and provides a listing of the technologies used to improve fuel economy. Based on earlier HDS analysis of medium- and heavy-duty technology for the U.S. Department of Energy (DOE),[3] aspects of the RIA that H-D Systems believes overstate on-road fuel economy potential of some technologies are corrected for in the forecast developed for the Energy Commission, and these corrections are described. HDS' analysis for DOE is provided as an attachment to this report. The Energy Commission's forecast also requires data for battery-electric, fuel cell electric, and direct electric drive vehicles, which are not covered in the RIA, and HDS' assumptions are documented in this section.

Chapter 4 summarizes HDS' forecast, which is similar to the EPA/NHTSA forecast except for the correction to some of the technology benefits employed by EPA and NHTSA. The forecasts in the RIA (from which the HDS forecasts are derived) are shown in this section, and the forecasts developed for the Energy Commission are listed.

The attached supplement (the DOE report) also provides some limited historical data on medium- and heavy-duty truck fuel economy derived from the 2002 Vehicle Inventory and Use Survey (2002 VIUS)[4] and other data sources. VIUS was known as the Truck Inventory and Use Survey, or TIUS, before 1997.

3 EEA/ICF. December 2011. *Technological Potential to Reduce Heavy-Duty Truck Fuel Consumption to 2025*, report to the DOE Office of Policy.
4 Found at www.census.gov/svsd/www/vius/2002.html.

CHAPTER 2:
Vehicle Classes Used in Forecast

Weight Classes

The California Energy Commission's transportation energy demand models require medium- and heavy-duty vehicle attributes by vehicle weight class and fuel type. Medium- and heavy-duty trucks are generally classified by industry weight Classes 3 to 8, and the class definitions, as well as the typical vehicle types in each class, are provided below.

Weight Classes 3, 4, and 5 are referred to as *light heavy-duty (LHD) trucks* by the automotive industry and EPA (but as medium-duty by the Energy Commission) and span the 10,000-to-19,000 pound gross vehicle weight (GVW) range. Class 3 consists mostly of pickup trucks and cargo vans, like the Ford F-350 and Dodge D-3500, as well as a few small size "cabover" Japanese trucks. Classes 4 and 5 are increasingly dominated by the Japanese models, although pickup trucks like the Ford F-450 and 550 have significant market share. Vehicle sales in this class are about 70 percent diesel and 30 percent gasoline. Trucks in this class are used for light commercial activity like plumbing, lawn maintenance, and utility support, while the Japanese trucks are used typically for local pickup and delivery.

Weight Classes 6 and 7 are referred to as *medium heavy-duty (MHD) trucks* and span the 19,000-to-33,000 pound GVW range. These classes are dominated by conventional two-axle straight trucks and were almost completely diesel-powered, although Ford reintroduced gasoline-powered models in the last two years in response to high diesel fuel prices. Trucks in this class are used for urban pickup and delivery, as well as suburban and rural freight distribution. A significant fraction of these vehicles are vocational trucks used by local gas and electric utilities and by city services.

Class 8, which is referred to as *heavy heavy-duty (HHD) trucks*, is usually split into two subclasses, 8A and 8B. Trucks in Class 8A are typically three-axle trucks covering the 35,000-to-55,000-pound weight range and include trucks used in construction and waste disposal, as well as suburban and rural freight distribution. Class 8B trucks are four- and five-axle trucks in the 60,000-to-80,000 pound weight range, with the majority of these trucks devoted to medium- (between 100 and 500 miles) and long-haul (greater than 500 miles) freight distribution. Heavy construction trucks, tanker trucks, and specialized vocational trucks have a smaller share of the 8B market. Trucks in Class 8A and 8B are usually diesel-powered.

Motorhomes and buses – including school buses, transit buses, and long-haul coaches – are derived from truck chassis. School buses and small motorhomes are typically Class 5 or 6 (depending on length) and are about 60 percent diesel-powered, with gasoline and alternative fuels like compressed natural gas (CNG) or propane used in many buses. Large motorhomes, transit buses, and motor coaches are in the 30,000-to-35,000-pound

GVW range (that is, Class 7 or 8A) and are usually diesel–powered, although a significant portion of transit buses use compressed (CNG) or liquefied (LNG) natural gas.

The RIA provides an overview of the use type for all vocational vehicles; these data from Table 2-65 of the RIA are shown in Table 2-1. Long-haul Class 8 trucks operate more than 80 percent of total miles on highways. Multipurpose driving involves a mix of city and urban highway driving, while regional driving is on suburban and state highway routes.

Table 2-1: Operating Duty Cycle for Vocational Vehicles

		REGIONAL	MULTIPURPOSE	URBAN
Class 4-5 straight truck		9%	41%	50%
Class 6-7 straight truck		15%	50%	35%
Class 8 straight truck		20%	60%	20%
Long haul Class 6 to 8 straight truck, motorhome		100%	0%	0%
School Bus		0%	10%	90%
Transit Bus		0%	0%	100%
Refuse truck		0%	10%	90%

Source: U.S. EPA/NHSTA RIA. Figures are percentages of VMT.

Alternative Fuels and the Energy Commission's Class/Fuel Matrix

The Energy Commission's Truck Choice model estimates market share by vehicle weight class, vocation, and fuel type. The truck fuel types modeled by the Energy Commission include the:

- Gasoline-electric hybrid.
- Diesel-electric hybrid.
- Diesel-hydraulic hybrid.
- Battery–electric.
- Direct or catenary electric.
- Fuel cell electric.
- Ethanol (E85).
- Compressed natural gas (CNG).
- Liquefied natural gas (LNG).
- Propane.

Not all combinations of fuel types and weight classes are expected to be introduced into the market. Hence, a matrix of expected combinations was agreed upon by H-D Systems and Energy Commission staff, and the combinations are shown in Table 2-2.

Table 2-2: California Energy Commission Vehicle Class and Fuel Type Matrix

# CEC Vehicle Class		Gasoline	Gasoline Electric Hybrid	Diesel	Diesel Electric Hybrid	Diesel Hydraulic Hybrid	Battery-Electric Vehicles	Direct (Catenary) Electric	Fuel Cell Vehicles	E85 (ethos engine)	Compressed Natural Gas (CNG)*	Liquefied Natural gas (LNG)*	Propane (LPG)
GVWR 3	GVWR 3	O	O	O	P		P			O	A		A
GVWR 4 to 6	GVWR 4	O	O	O	P	A	O			O	A		A
	GVWR 5	O		O		A	O			O	A		
	GVWR 6			O	P	P	O				A		
GVWR 7 & 8	GVWR 7			O	P						A		
	GVWR 8 Single Unit			O							A	A	
GVWR 8	Combination (California)			O				P			A	A	
GVWR 8	Garbage			O	O	A					A	A	
GVWR 8	Combination (Interstate)			O								O	O
Motorhomes	GVWR 3	O		O									
	GVWR 4 to 6	O		O							A		
Bus	Urban Transit			O	O	A	P	O	P		A		
	Motor Coach			O									
	School Bus	O		O			P				A		A
	Shuttle Bus	O				A	O		A		A		

Source: California Energy Commission and H-D Systems
O – Original Equipment Manufacturer P – Pilot Production** A – Aftermarket
* Includes Low NOx engines.
** Pilot production refers to production of less than 100 units per year.

H-D Systems' Observations on Truck Availability by Fuel Type

The low oxides of nitrogen (NO_x) natural gas engine was included in the standard natural gas category as it is a transient product for the 2018-2022 time frame (after 2022, HDS expects all natural gas trucks to have low NO_x natural gas engines).

Gasoline electric hybrids are not offered in Classes 3 to 5 but may be offered in 2019 and later years as full-size pickup manufacturers plan to introduce hybrids in the light-duty versions of these pickups that have similar bodies and drivetrains. Diesel hybrids have also been recently introduced into the market by select Japanese manufacturers in Classes 5 and 6 trucks.

Hydraulic hybrids **do not** appear to be under serious consideration by truck manufacturers but are available as aftermarket conversions by manufacturers such as Bosch-Rexroth and Parker Hannifin. Both series and parallel types are offered, but because of lower costs, HDS has included only the series type in the forecast as an aftermarket product.

Electric vehicles of many types are expected to be introduced into the market. Two Asian manufacturers, BYD and Fuso, are offering battery-electric vehicles in Classes 5, 6, and 7, while there is pilot production of transit and school buses. (*Pilot production* is a term used in this report to refer to production of fewer than 100 units per year.) Electric trucks operating like trolleys with a catenary but also having a battery for short-range unconnected use are also being discussed, with a pilot program underway in the South Coast Air Quality Management District. Fuel cell trucks are not yet available, although there is pilot production of fuel cell buses.

E85 vehicles are available directly from manufacturers of Classes 3, 4, and 5 gasoline-powered trucks and are sold as gasoline- and E85-compatible flex-fuel vehicles. CNG vehicles and propane vehicles in these classes are aftermarket conversions of gasoline vehicles (not diesel engines), as no manufacturer offers alternative fuel vehicles directly, but some like Ford have "qualified" aftermarket suppliers. In 2015, one manufacturer (Cummins-Westport) offered a 6.6 liter diesel engine conversion to CNG suitable for this market, but anecdotal evidence suggests only minor sales in markets for Classes 4 and 5 trucks. Aftermarket gasoline engine conversions to CNG also have modest sales, accounting for less than 1 percent of Classes 3, 4, and 5 sales nationally.

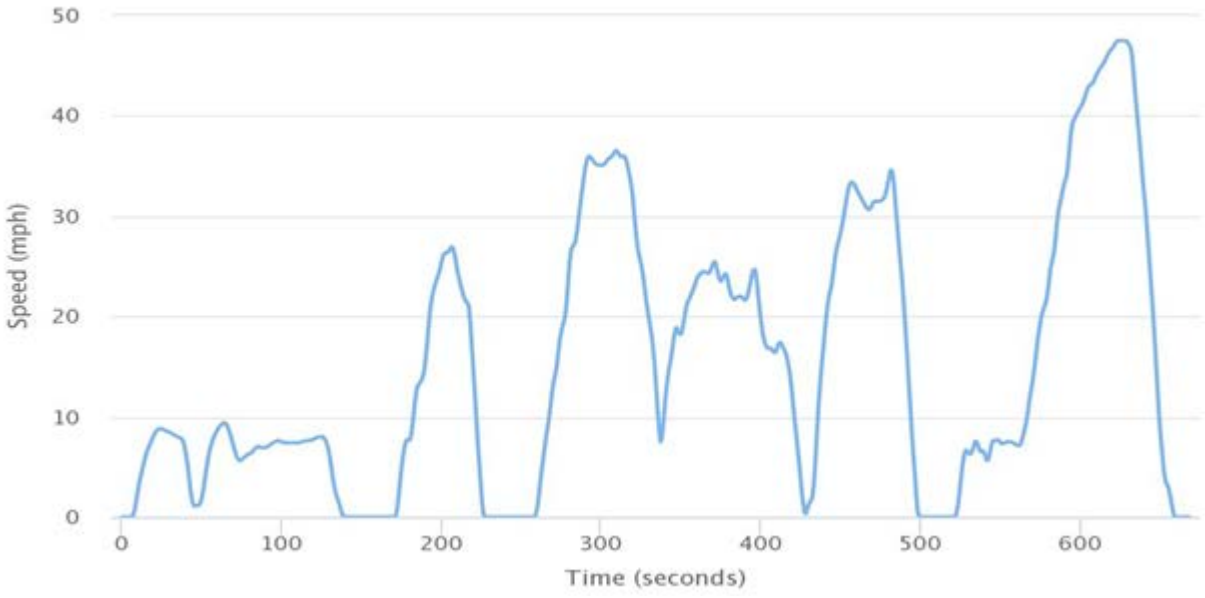
CNG and LNG vehicles in Classes 6, 7, and 8A use specially converted diesel engines, and there is only one supplier for these engines – Cummins-Westport, which provides the 6.6 liter and 9 liter engines. CNG and LNG have found significant market penetration in the urban transit bus market and in garbage trucks, where local or state regulations sometimes require the use of natural gas. Westport introduced a compression ignition natural gas engine for the Class 8B market but withdrew it in 2014 due to poor sales. A new 12 liter Cummins-Westport spark ignition engine suitable for this market was introduced in 2016. All the available diesel engine-based conversions use spark ignitions for CNG and are less energy-efficient than the comparable power diesel engine.

Cross-Classification Matrix

The Energy Commission's weight classifications and vehicle types are not the same as the EPA/NHTSA-based vehicle use type and weight classes, and a mapping between the two classifications is required to translate the regulatory requirements applicable to each Energy Commission class.

The translation is based upon an understanding of the class-specific duty cycles used by EPA for testing the vehicles for compliance. EPA has settled on using three test cycles and two idle tests for assessing compliance, and class-specific figures are determined by different weightings of each cycle used to construct a composite figure. The three test cycles are the 65 mph steady-state cruise, the 55 mph steady-state cruise, and the California Air Resources Board (CARB) transient test. The cruise tests for the 2018-2027 Phase 2 standards involve simulation of road gradients, whereas the same cruise modes for the Phase 1 standards did not have any gradient. The CARB transient test, shown as a speed-time trace in Figure 2-1, represents typical urban driving and includes some higher speed portions in the 40-to-50-mph range that occurs along major arterials and urban highways. The two idle modes are in parked and drive (transmission engaged) modes, respectively. Each truck type class is assigned a mix of the five modes to derive the composite fuel economy and GHG emissions standard.

Figure 2-1: CARB HHDDT Transient Segment



Source: Diesel.net (www.dieselnet.com/standards/cycles/index.php).

The EPA specified duty cycle mix from Tables 3-16 and 3-19 of the RIA, according to the related classification, is shown below. The nonidle modes add to 100 percent.

Table 2-3: EPA Duty Cycle Mix

		Transient	55 mph	65 mph	Idle Drive	Idle-Park
Vocational Regional		20%	24%	56%	0%	25%
Vocational Multipurpose		54%	29%	17%	17%	25%
Vocational Multipurpose (Class 8)		54%	23%	23%	17%	25%
Vocational Urban		92%	8%	0%	15%	25%
Regional Day Cab		19%	17%	64%	NA	NA
Long Haul (Sleeper)		5%	9%	86%	NA	NA

Source: U.S. EPA/NHSTA RIA. Percentages are in terms of VMT, except for idle, which is in percentage of operating time.

Based on these considerations, HDS developed a cross-classification matrix, as shown in Table 2-3, mapping the Energy Commission's medium- and heavy-duty vehicle classes to the EPA truck regulatory categories

Table 2-4: Cross-Classification Matrix

CEC Class	EPA Regulatory Category
GVWR 3	LHD Multipurpose
GVWR 4	LHD Multipurpose
GVWR 5	LHD Multipurpose
GVWR 6	MHD Multipurpose
GVWR 7	MHD Regional
GVWR 8 Single Unit	HHD multipurpose
GVWR8 Combination (California)	Class 8 Mid-roof Day cab
Garbage	Refuse Truck
GVWR8 IRP (Combination)	Class 8 High Roof Sleeper cab
GVWR 3 motorhome	LHD Regional
GVWR 4 to 6 motorhome	Motorhome
GVWR 7 & 8 motorhome	MHD regional
Urban Transit	Transit bus
Motor Coach	Coach bus
School Bus	School bus

Source: H-D Systems.

CHAPTER 3: Technology to Improve Heavy-Duty Vehicle Fuel Economy

Overview

Diesel engines power the majority of heavy-duty vehicles and are used in more than 95 percent of all trucks in the highest weight classes. Hence, the focus of the analysis is on diesel-powered vehicles, with all other alternatives considered relative to diesel. Fuel efficiency technologies can be broadly separated into those that improve the efficiency by which energy in a fuel is converted to motive power, and by those that reduce the power demand to travel a specific distance. Technologies affecting the former are those that improve engine efficiency and reduce losses in the engine, transmission, and axles. Technologies affecting power demand are those that reduce the weight, aerodynamic drag, or tire-rolling resistance. In the case of trucks, some operational factors like limiting cruise speed or preventing extended idle can improve fuel consumption. The technologies available and the related costs and benefits in both categories are summarized below. The analysis is based on the detailed RIA from the U.S. EPA/NHTSA. Electric vehicles change the entire drivetrain but still benefit from power demand reductions. All the data and fuel efficiency estimates cited in this chapter are from the RIA unless specifically stated otherwise.

Diesel Engines

EPA and NHTSA considered available diesel engine technologies that could improve engine fuel efficiency. A detailed description of each technology can be found in H-D Systems' report on truck fuel economy, which was created for the U.S. Department of Energy and is included as an attachment to this report. The technologies considered were

- Combustion system optimization.
- Model-based control.
- Advances to turbocharging systems.
- Engine air handling systems improvement.
- Parasitic and friction loss reduction.
- After-treatment integration.
- Downsizing and downspeeding.

Combustion System Optimization

Combustion system optimization, featuring piston bowl, injector tip, and the number of holes, in conjunction with the advanced fuel injection system, is able to improve engine performance and fuel efficiency. Examples include the combustion development programs conducted by diesel engine manufacturers funded by the U.S. Department of Energy as part of the Super Truck program. The manufacturers found improvement due to combustion alone was 1 to 2 percent. The agencies determined that it is feasible that fuel consumption could be reduced by as much as 1.0 percent in the agencies' certification cycles in the 2027 time frame by using these technologies.

Some technologies such as homogeneous charge compression ignition, premixed charge compression ignition (PCCI), low-temperature combustion, and reactivity-controlled compression ignition technologies were not included in the agencies' feasibility analysis, as they were unlikely to be commercialized by 2027.

Model-Based Control

Another important area of potential improvement is advanced engine control incorporating model-based calibration to reduce losses of control during transient operation, that is, when operating at varying speeds. Improvements in computing power and speed would make it possible to use more sophisticated algorithms that are more predictive than today's controls. Detroit Diesel recently introduced the next-generation model-based control concept, achieving 4 percent thermal efficiency improvement while reducing emissions in transient operations. More recently, this model-based control technology was put into one of the vehicles for final demonstration under DOE's Super Truck program. The model-based concept features a series of real-time optimizers[5] with multiple inputs and outputs. Real-time model control could be in production during the 2017-2027 time frame, thus significantly improving engine fuel economy.

Advances to the Turbocharging System

Many advanced turbocharger technologies are available in the time frame between Model Years 2021 and 2027, and some of them are already in production, such as the mechanical or electric turbo-compound, the higher-efficiency variable-geometry turbine, and the asymmetric turbocharger.

A turbo-compound system extracts energy from the exhaust to provide additional power. Mechanical turbo-compounding includes a power turbine located downstream of the turbine, which, in turn, is connected to the crankshaft to supply additional power. It was first used in heavy-duty production by Detroit Diesel, which claims a 3 to 5 percent fuel consumption reduction due to the system, while Volvo reports a 2 to 4 percent improvement. Results depend on the duty cycle and require significant time at high load to see an improvement in fuel efficiency. Light load-factor vehicles can expect little or no benefit. Electric turbo-compound is another potential technology that can improve

5 Engine control is optimized for the actual operating cycling of the engine as it occurs, which depends on factors such as the age of the engine.

engine brake efficiency. Since the electric power turbine speed is no longer linked to crankshaft speed, this allows more efficient operation of the turbine. Navistar reports on the order of a 1 to 1.6 percent efficiency improvement over mechanical turbo-compound systems. This concept, however, does not work well with lower engine emissions due to lower exhaust gas temperatures.

Two-stage turbocharger technology has been used in production by Navistar and other manufacturers. Ford's newly developed 6.7 liter diesel engine features a twin-compressor turbocharger. Higher boost with a wider range of operations and higher efficiency can enhance engine performance and, thus, fuel economy. It is expected that this type of technology will continue to be improved by better matching with system requirements and developing higher compressor and turbine efficiency.

Engine Air-Handling System

Various high-efficiency air-handling (air and exhaust transport) processes could be produced with efficiently designed flow paths (including those associated with air cleaners, chambers, conduit, mass airflow sensors, and intake manifolds) and by designing such systems for improved thermal control. Improved turbocharging and air handling systems must include higher-efficiency exhaust gas recirculation (EGR) systems and intercoolers that reduce pressure loss while maximizing the ability to thermally control induction air and EGR. Other components that offer opportunities for improved flow efficiency include cylinder heads, ports, and exhaust manifolds to further reduce pumping losses. Manufacturers report a 1.4 percent to 2 percent fuel efficiency improvement through air-handling system development. Navistar predicts almost 4 percent improvement through a combination of variable intake valve closing timing, which may include a partial Miller cycle,[6] as well as turbocharger efficiency and match improvements.

Engine Parasitic and Friction Reduction

Engine parasitic[7] and friction reduction is another key technical area that can be improved in the 2020-to-2027 time frame. Reduced friction in bearings, valve trains, and the piston-to-liner interface can improve efficiency. Friction reduction opportunities in the engine valve train and at the roller/tappet interfaces exist for several production engines. The piston at the skirt/cylinder wall interface, wrist pin, and oil ring/cylinder wall interface offers opportunities for friction reduction. More advanced lubricating oil will be available in the future and will play a key role in reducing friction. Lube oil and water pumps are another area where efficiency improvements are planned.

Manufacturers report 2 to 3 percent reductions in fuel consumption from a combination of improvements to friction and water/oil pump improvements. Water pump improvements include pump efficiency improvement and variable-speed or on/off

6 The *Miller cycle* is a thermodynamic cycle used in a type of internal combustion engine, where fuel is combusted to extract useful mechanical energy. It is a variant of the standard Otto/Diesel cycle that improves performance at partial (or less than maximum) engine load.
7 *Engine parasitic losses* are energy losses due to vehicle accessories such as the oil and water pumps.

controls. Lube pump improvements are primarily achieved using variable displacement pumps and may include efficiency improvement. EPA contractor reports show that if the exact certification cycles, weighting, and vehicle weights are used, the friction reduction in the Phase 2 time frame is in the range of 1.5 percent compared to a 2018 baseline engine.

Integrated Aftertreatment System

All manufacturers now use diesel particulate filters to reduce particulate matter (PM) and selective catalytic reduction (SCR) to reduce NO_x emissions, and these types of aftertreatment technologies are likely to be used for compliance with criteria pollutant standards for many years to come. There are three areas considered to improve integrated aftertreatment systems, which result in a reduction of fuel consumption. The first is better combustion system optimization through increased aftertreatment efficiency. The second is reduced back pressure (the pressure in an exhaust pipe due to restriction of air flow that an engine must work against) through further development of the devices themselves. The third is reduced ammonia slip, or unreacted ammonia, out of SCR during transient operation, thus reducing net urea consumption. Cummins reports a 0.5 percent improvement through improved aftertreatment flow. Detroit Diesel projects a 2 percent fuel efficiency improvement through reduced use of EGR, thinner wall diesel particulate filters, improved SCR cell density, and catalyst material optimization[8].

Engine Downsizing and Downspeeding

Engine downsizing[9] can be more effective if it is combined with downspeeding[10] when total power demand is reduced. This lower power demand shifts the vehicle operating points to lower load zones, which moves the engine operating point to a less efficient area. Downspeeding allows the engine to move back into the optimum operating points, resulting in reduced fuel consumption. Detroit Diesel also shows that engine downsizing can result in friction reduction due to a reduction in engine surface area when compared to a bigger bore engine.

Engine downspeeding can also be an effective fuel efficiency technology even when used alone (that is, not in combination with engine downsizing), especially when a vehicle uses a fast axle ratio. In this situation, downspeeding can allow the engine to operate in a lower speed zone closer to or just in the middle of the optimal efficiency operating point of the engine. On the other hand, from a vehicle operating standard point, the benefit of downspeeding is realized primarily by using a lower axle ratio, allowing the engine to operate in an optimal zone.

8 Catalyst material optimization is the selection of catalytic material to optimize emissions reductions of particulate matter and NOx.
9 Engine downsizing represents the reduction the engine size with no loss in power.
10 Engine operation at lower RPM to reduction friction losses and operate the engine at a lower fuel consumption point.

Waste Heat Recovery

Organic Rankine cycle waste heat recovery (WHR) systems have been under development for decades, but performance and cost issues have prevented commercialization. The basic approach of a WHR system is to use engine exhaust waste heat from multiple sources to evaporate a working fluid in a heat exchanger. This evaporated fluid is then passed through a turbine or equivalent expander to create mechanical or electrical power. The working fluid is then condensed back to the fluid in the fluid reservoir tank and returned to the flow circuit via a pump to restart the cycle.

With support of the U.S. Department of Energy, three major engine and vehicle manufacturers have developed WHR systems under the Super Truck program.[11] The agencies recognize the many challenges that would need to be overcome but believe with enough time and development effort, this can be done. Manufacturers have stated that the WHR systems in the literature and used in the DOE Super Truck program are still in the research and development stage and are a long way from reaching production. The U.S. EPA and NHTSA have been optimistic and have included WHR systems in their forecast. HDS does not estimate that the WHR will be cost–effective, and EPA's own estimates show that the cost is more than $1,500 per 1 percent improvement in fuel consumption, which is significantly higher than those for other technologies. While the agencies project a 5 percent market penetration in 2024 and 25 percent market penetration in 2027 for WHR, HDS has set it to zero. This constitutes the only major difference in the diesel engine technology forecast from the 2027 forecast in the RIA.

Gasoline Engines

The U.S. EPA and NHTSA did not set aggressive standards for gasoline engines as they believed that the 2016 standard overstated the performance of actual 2016 gasoline engines. Many technologies developed for use with light-duty pickup trucks are also available for the light heavy-duty class. The most prominent technologies are:

- Direct injection with increased compression ratio.
- Engine friction and parasitic loss reduction.
- Variable-cylinder management (or cylinder cut).
- Downsizing and downspeeding.

The number of engine families in the light heavy-duty vehicle segment is relatively few (about six) and are derived mostly from light-duty V8 engines. (Ford has a V10 engine.) As of 2017, all employ port fuel injection and conversion to direct injection, like many of their light-duty counterparts, where a one-unit increase in compression ratio can provide fuel consumption reduction of 2 to 2.5 percent.

11 The Super Truck program is a U.S. DOE program to test advanced truck technology.

Engine friction and parasitic loss reduction uses technologies similar to those described for diesel and offer a 1 to 1.5 percent fuel consumption reduction over the next 10 years. Cylinder-cut technology is widely employed in light-duty V8 engines and some light-heavy V8 models, but the benefit in fuel consumption is smaller than for light-duty vehicles, since the engines are more heavily loaded. The benefit for light-duty engines is about 6 percent, while in the light heavy-duty segment, it falls to about 3 percent.

Downsized turbocharged engines are less likely in the light heavy-duty segment as such engines offer no benefit over naturally aspirated engines at high loads. As a result, HDS agrees with the U.S. EPA/NHTSA position that such engines will have limited penetration in the Classes 3 to 5 vehicle segments. Downsizing and downspeeding are closely related to turbocharging and increasing engine specific power, so that the impact of these technologies will also be limited, except to the extent made possible by transmission changes.

The net benefit of all technological improvements is in the 6 to 7 percent range but some engines feature cylinder cut technology in 2017, and not all engines will receive all technology improvements by 2027, especially in the absence of forcing standards. Hence, we estimate a net average fuel consumption reduction of 4 to 5 percent between 2017 and 2027, which is quite similar to the benefits forecast from diesel engine improvements over the same time frame.

Natural Gas Engines

As noted in Chapter 2, CNG engines for the light heavy-duty segment are usually conversions of gasoline engines in the aftermarket. (The "aftermarket" refers to modifications made to a vehicle after purchase by a third party and not the manufacturer.) These conversions do not change the basic engine calibrations or hardware but add gas injectors to provide a stoichiometric mixture of air-fuel to the engine. The net result is usually no significant change in the energy efficiency of natural gas engines relative to the unconverted gasoline engine, in terms of vehicle energy consumption per mile.

Natural gas engines used in Classes 6, 7, and 8A trucks are conversions of diesel engines to gasoline (or spark ignition) engines. These engines feature turbocharging and have a relatively high compression ratio; so they are more efficient than conventional gasoline engines but still significantly less efficient than comparable diesel engines. The engines operate at a stoichiometric air-fuel ratio that allows the use of a cheaper emission control system to meet standards relative to the complex system used in a diesel engine. The RIA suggests that these engines are about 15 percent less fuel-efficient than a diesel engine over the same duty cycle.

While the only natural gas engine available for Class 8B trucks today is also a spark ignition engine, there have been examples of natural gas engines in limited production that more closely resemble diesel-cycle engines and use a small amount of diesel fuel for a pilot injection to initiate combustion. However, the emission control system is as

expensive as the one used for diesel engines, and the two fuel systems result in higher engine costs and complexity. Fuel efficiency is expected to be only 3 to 5 percent worse than a comparable diesel engine, according to the RIA. Such engines could be introduced into the market in 2018 or 2019.

Transmissions and Axles

Transmissions and axles are part of the drivetrain, and ways to improve transmissions include electronic controls, shift strategy, gear efficiency, and gear ratios. The relative importance of having an efficient transmission increases when vehicles operate in conditions with a higher shift density. Each shift represents an opportunity to lose speed or power that would have to be regained after the shift is completed. Further, each shift engages gears that have inherent inefficiencies. Optimization of the vehicle gearing to engine performance through selection of transmission gear ratios, final drive gear ratios, and tire size can play a significant role in reducing fuel consumption and GHGs. Optimization of gear selection versus vehicle and engine speed accomplished through driver training or automated transmission gear selection can provide additional reductions.

Manufacturers of light and medium heavy-duty vehicles can replace six-speed transmissions with eight-speed or more automatic transmissions. Additional ratios allow for optimizing engine operation over a wider range of conditions, but this is subject to diminishing returns as the number of speeds increases. Also, the additional shifting of such a transmission can be perceived as bothersome to some consumers, so manufacturers need to develop strategies for smooth shifts. The RIA rulemaking projected that eight-speed transmissions could incrementally reduce fuel consumption by 2 to 3 percent from a baseline six-speed automatic transmission over some test cycles. The efficiency of gears can be improved by reducing friction and minimizing mechanical losses. During operation, the controller of an automatic transmission manages the transmission by scheduling the upshift or downshift, and locking or allowing the torque converter to slip based on a preprogrammed shift schedule. This aggressive shift logic[12] can be employed to maximize fuel efficiency by modifying the shift schedule[13] to upshift earlier and inhibit downshifts under some conditions, allowing the engine to operate at higher efficiency points.

The manual transmission has traditionally been more efficient than automatic transmissions, and advances in electronics and computer processing power allow for more efficiency from a manual transmission architecture with fully automated shifting. The two primary manual transmission architectures employing automated shifting are the automated manual transmission (AMT) and the dual-clutch transmission. When implemented well, these more mechanically efficient designs provide better fuel efficiency than conventional automatic transmission designs and, potentially, even fully

12 *Aggressive shift logic* refers to maximizing fuel economy by forecasting when transmission shift changes may be needed.
13 The shift schedule refers to when a transmission shift change is scheduled to occur.

manual transmissions. An AMT is mechanically similar to a conventional manual transmission, but shifting and launch functions are automatically controlled by electronics. The term *AMT* generally refers to a single-clutch design (differentiating it from a dual-clutch transmission), which is essentially a manual transmission with automated clutch and shifting. Because of shift quality issues with single-clutch designs, dual-clutch designs are more common in light-duty applications, where driver acceptance is of primary importance. For heavy-duty vehicles, shift quality remains important but is less so when compared to light-duty vehicles. As a result, the single-clutch AMT can be an attractive technology for heavy-duty vehicles and provides up to 2 percent fuel consumption reduction.

Axle efficiency is improved by reducing two categories of losses: mechanical losses (due to friction) and spin losses (due to energy transfer to unwanted axle fluid churning or spin). Mechanical losses can be reduced by reducing the friction between the two gears in contact. Frictional losses are proportional to the torque on the axle but are not a function of rotational speed of the axle. Spin losses, on the other hand, are a function of speed, not torque. One of the main ways to reduce the spin losses of the axle is by using a lower-viscosity lubricant. Some high-performance, lower-viscosity oil formulations have been designed to have superior performance at high operating temperatures and may have extended change intervals. Axle efficiency improvements can contribute up to 2 percent improvement in fuel consumption. In dual-rear-axle vehicles, using only one axle for traction power reduces losses but can be traction limited under slippery conditions. An axle-disconnect system allows the rear axle to be engaged as required and provides a 1.5 percent gain in fuel economy.

Aerodynamics

Up to 25 percent of the fuel consumed by a line-haul tractor traveling at highway speeds is used to overcome aerodynamic drag forces, making aerodynamic drag a significant contributor to the GHG emissions and fuel consumption of a Class 7 or 8 tractor. Because aerodynamic drag varies by the square of the vehicle speed, small changes in the tractor aerodynamics can have significant impacts on GHG emissions and fuel efficiency of that vehicle. With much of the driving at highway speed, the benefits of reduced aerodynamic drag for Class 7 or 8 tractors can be significant, but for vehicles that operate primarily in urban areas and at low speed, aerodynamics are not a significant factor in fuel consumption. The common measure of aerodynamic efficiency is the coefficient of drag (C_d). The aerodynamic drag force (the force the vehicle must overcome due to air) is a function of C_d, the area presented to the wind (the projected area perpendicular to the direction of travel or frontal area) known as the drag area, and the square of the vehicle speed. C_d values for today's line-haul fleet typically range from greater than 0.80 for a classic body tractor to about 0.58 for tractors that incorporate a full package of widely commercially available aerodynamic features on both the tractor and trailer.

Aerodynamic drag reduction is accompanied by smoothing the shape of the vehicle to make it more aerodynamically efficient, redirecting air to prevent entry into areas of high drag (for example, wheel wells), maintaining smooth air flow in certain areas of the vehicle, or a combination of these. Improving the vehicle shape may include revising the fore components of the vehicle such as rearward canting/raking or smoothing/rounding the edges of the front-end components (for example, bumper, headlights, windshield, hood, cab, mirrors) or integrating the components at key interfaces (for example, windshield/glass to sheet metal) to alleviate vehicle drag. Finally, redirecting the air to prevent low-pressure areas and eliminating areas where turbulent vortices are created reduce drag. Techniques such as blocking gaps in the sheet metal, ducting of components, shaping or extending sheet metal to reduce flow separation and turbulence are methods being considered to direct air from areas of high drag (for example, the underbody, tractor-trailer gap, underbody, or rear of trailer, or a combination of these).

The heavy-duty transport industry implemented significant aerodynamic refinements, but improvements were integrated mostly into tractor bodies with no trailer contribution. Most of the future aerodynamic improvement potential will come from further refinement of the gap between tractor and trailer, underbodies, and the trailer itself, and, to a much lesser extent, improvements in tractor aerodynamics. Operators traditionally resisted aerodynamic trailer add-on technology because of cooling problems, ground clearance, durability, and length limitations imposed on highway trucks. The use of devices such as inflatable adjustable gap seals or retractable skirts (or active devices) should reduce incompatibility issues but will be more difficult to justify for add-on costs and reliability. The institutional trailer issues have been addressed in the Phase 2 rulemaking for 2017 to 2027 to force the aerodynamic devices for trailers to be actually implemented widely in the market.

The U.S. EPA/NHTSA rulemaking for Phase 1 standards had very similar data and identified aerodynamic “packages” which were labeled as Bin 1 to Bin 10. Each bin represents a combination of discrete technologies. Bin 1 is the baseline package with a C_d of 0.79, consistent with HDS data for the “classic” tractor-trailer. EPA has defined Bins 2, 3, and 4 packages in terms of values of 0.72, 0.63, and 0.56, respectively, for C_d. The technologies are generally defined but not specific, as manufacturers have to evaluate the actual aerodynamic performance to compute the $C_d \times A$ parameter that must fall within predefined values. EPA had also defined a Bin 5 with a C_d value of 0.51 for unspecified future improvements. In its Phase 2 rulemaking, EPA shifted the scale to $C_d \times A$ units and specified levels for Bins 1 to 6 that are specific to each tractor type, but generally follow the same principles invoked in the 2017 rulemaking.

The aerodynamic simulations for the RIA rely on the two constant speed cycles at 55 mph and 65 mph, respectively. HDS believes that the results overstate the importance of aerodynamics for two reasons. First, most highways with significant freight traffic in California are congested with frequent slowdowns. Even if the average speed is 55 mph or 65 mph, the speedup and slowdown cycles increase energy use, and the fraction of

energy lost to aerodynamic drag becomes smaller. Second, the drag values are based on a truck moving in an empty track and does not account for the other vehicles ahead of it that reduce the drag due to the wake effect. Informal platooning of trucks is common on highways as truckers try to capture this aerodynamic benefit at no cost. Data cited in the DOE report in Appendix B suggest that at highway speeds, each 10 percent drag reduction results in a fuel consumption improvement of 3.8 percent rather than 5.2 percent in EPA simulations. Hence, one change made to the U.S. EPA/NHTSA forecast is the reduction of benefits from aerodynamic devices by 27 percent (in other words, 27% = 100% - 3.8%/5.2%). This change affects the fuel economy of regional and long-haul use trucks only.

Improved Rolling Resistance

Research indicates that the contribution of a tire to overall vehicle fuel efficiency is roughly proportional to the vehicle weight. Energy loss associated with tires is mainly due to deformation of the tires under the load of the vehicle, known as *hysteresis*, but smaller losses result from aerodynamic drag, and other friction forces between the tire and road surface and the tire and wheel rim. Collectively, the forces that result in energy loss from the tires are referred to as *rolling resistance*. Rolling resistance is a factor considered in the design of the tire and is affected by the tread and casing compound materials, the architecture of the casing, tread design, and the tire manufacturing process. It is estimated that 35 to 50 percent of the rolling resistance of a tire is from the tread, and the other 50 to 65 percent is from the casing. In addition to the effect on fuel consumption, design and use characteristics of tires also influence durability, traction, vehicle handling, ride comfort, and noise. Tires that have higher rolling resistance likely represent a different trade-off with one or more of these other tire attributes. Tire inflation can also affect rolling resistance in that under-inflated tires can result in increased deformation and contact with the road surface.

According to an energy audit cited in the RIA, tires were shown to be the second largest contributor to energy losses for a Class 6 delivery truck at 50 percent load and speeds up to 35 mph (a typical average speed of urban delivery vehicles). For Class 8 tractor-trailers, the share of vehicle energy required to overcome rolling resistance is estimated at nearly 23 percent. On a cycle basis, the energy use attributed to tires varies from 20 to 35 percent, depending on weight class and duty cycle.

Differences in rolling resistance of up to 50 percent have been identified for tires designed to equip the same vehicle. Low-rolling-resistance tires are commercially available from most tire manufacturers and can be applied to vehicles in all medium- and heavy-duty vehicle classes. Low-rolling-resistance tires can be offered for dual-assembly tires and as wide-base singles.

Wide-base singles (WBS) are intended primarily for combination tractor-trailers, but some vocational vehicles are able to accommodate them. In the early years of this technology, some states and local governments restricted use of WBS, but many of these

restrictions have since been lifted. A *wide-base single* is a larger tire with a lower profile that replaces two standard tires. Generally, a wide-base single tire has less sidewall flexing compared to a dual assembly; therefore, less hysteresis occurs. Compared to a dual-tire assembly, wide-base singles also produce less aerodynamic resistance or drag. Wide-base singles can contribute to improving the fuel efficiency of a vehicle through design as a low-rolling-resistance tire or through vehicle weight reduction or both. The use of fuel-efficient wide-base singles can reduce rolling resistance by 3.7 to 4.9 percent compared to the most equivalent dual tire. The data collected based on field testing indicate that tractors equipped with wide-base singles on the drive axle experience better fuel efficiency than tractors equipped with dual tires, independent of the type of tire on the trailer. This field study in particular indicated a 6.2 percent improvement in fuel efficiency from wide-base singles. There are also weight savings associated with wide-base singles compared to dual tires. Wide-base singles can reduce the weight of a tractor and trailer by as much as 1,000 pounds when combined with aluminum wheels.

Tire Inflation Monitoring and Maintenance Systems

Proper tire inflation is critical to maintaining proper stress distribution in the tire, which reduces heat loss and rolling resistance. Tires with reduced inflation pressure exhibit more sidewall flexing and tread shearing, resulting in greater rolling resistance than a tire operating at its optimal inflation pressure. Tractor-trailers operating with all tires underinflated by 10 psi have been shown to increase fuel consumed by up to one percent. Tires can gradually lose pressure from small punctures, leaky valves, or simply diffusion through the tire casing. Changes in ambient temperature can also affect tire pressure. Trailers that remain unused for long periods between hauls may experience any of these conditions. To achieve the intended fuel efficiency benefits of low-rolling-resistance tires, it is critical that tires are maintained at the proper inflation pressure. Tire pressure monitoring (TPM) and automatic tire inflation (ATI) systems are designed to address underinflated tires. Both systems alert drivers if tire pressure drops below the set point. TPM systems monitor the tires and require user-interaction to reinflate to the appropriate pressure. Unless the vehicle experiences a catastrophic tire failure, simply alerting the driver that the tire pressure is low may not necessarily result in reinflation as the driver may continue driving to the destination before addressing the tires. Current ATI systems take advantage of air brake systems of trailers to supply air back into the tires (continuously or on demand) until a selected pressure is achieved. In the event of a slow leak, ATI systems have the added benefit of maintaining enough pressure to allow the driver to get to a safe stopping area. The RIA estimates the fuel consumption reduction due to TPM and ATI systems to be 1 and 1.2 percent, respectively.

Weight Reduction

Weight reduction is a technology that can be used in a manufacturer's strategy to meet the Phase 2 standards. Vehicle weight reduction (also referred to as "light-weighting") decreases fuel consumption by reducing the energy demand needed to overcome inertia

forces and rolling resistance. Reduced weight in heavy-duty vehicles can benefit fuel efficiency and reduce carbon dioxide (CO_2) emissions in two ways. If a truck is running at the gross vehicle weight limit with high-density freight, more freight can be carried on each trip, increasing the payload efficiency of the truck in ton-miles per gallon. If the vehicle is carrying lower density freight and is below the GVWR (or gross combination weight of the tractor and trailer) limit, the total vehicle mass is decreased, reducing rolling resistance and the power required to accelerate or climb grades.

Although many gains have been made to reduce vehicle mass, many of the new features being added to modern tractors to benefit fuel efficiency, such as additional aerodynamic features or idle reduction systems, increase vehicle mass, causing the total mass to stay relatively constant. Hybrid powertrains, fuel cells, and auxiliary power would not only present complex packaging and weight issues; they would increase the need for reductions in the weight of the body, chassis, and powertrain components to maintain vehicle functionality.

Substitution of a material used in an assembly or a component for one with lower density or higher strength or both includes replacing a common material such as mild steel with higher-strength and advanced steel, aluminum, magnesium, and composite materials. It is the typical method to reduce weight. In practice, material substitution tends to be specific to the manufacturer and situation. The agencies recognized that like any type of mass reduction, material substitution has to be conducted not only with consideration to maintaining equivalent component strength, but to maintaining all the other attributes of that component, system, or vehicle, such as crashworthiness, durability, noise, vibration, and harshness. The principal barriers to overcome in reducing the weight of heavy vehicles are associated with:

- The cost of lightweight materials.
- The difficulties in forming and manufacturing lightweight materials and structures.
- The cost of tooling for use in the manufacture of relatively low-volume vehicles (when compared to automotive production volumes).
- The extreme durability requirements of heavy vehicles.

Moreover, because of the limited production volumes and the high levels of customization in the heavy-duty market, tooling and manufacturing technologies that are used by the light-duty automotive industry are often uneconomical for heavy vehicle manufacturers.

As a result, weight reduction is a relatively costly technology, at about $3 to $10 per pound for a 200-pound package estimated by the U.S. EPA. Even so, for vehicles in service classes where dense, heavy loads are frequently carried, weight reduction can translate directly to additional payload. The agencies project that only modest weight reduction is feasible for all vocational vehicles. The U.S. EPA and NHTSA are predicating the final standards on relatively minor weight reduction comparable to what can be

achieved by using aluminum wheels. This package is estimated at 150 pounds for LHD and MHD vehicles and 250 pounds for HHD vehicles, based on 6 and 10 wheels, respectively. The RIA projects an adoption rate of 10 percent, in MY 2021, 30 percent in MY 2024, and 50 percent in MY 2027. The agencies project that manufacturers will have sufficient options of other components eligible for material substitution so that this level of weight reduction will be feasible, even where aluminum wheels are not selected by customers.

Hybrid Drivetrains

Hybridization of the truck drivetrain is, in principle, similar to the hybridization of passenger cars, and many of the same design types are under consideration: series, parallel, and two-mode.[14] One interesting addition to the available hybridization technologies is the hydraulic hybrid, which stores power in the form of a compressed fluid rather than in a battery. However, the series hybrid appears too expensive and heavy for most truck applications. (It may be suitable for buses.) The two-mode hybrid may also be too complex and expensive for most truck applications except those in Class 3, and the manufacturers appear to be considering only the parallel single-motor hybrid for most applications and the hydraulic hybrid for selected applications. Details below are from the report in the attached supplement.

The most popular parallel hybrid configuration is similar in the European Union and the United States. The parallel hybrid uses an electric motor sandwiched between the engine and transmission, with either a single clutch (between motor and transmission) or two clutches (also between engine and transmission). The single-clutch system is more dominant, since motor sizes do not permit pure electric drive. Physically, this system closely resembles the Honda Integrated Motor Assist hybrid system used in passenger cars, although the motor size and battery are three to four times larger for truck application. Typically, motor sizes are in the 50 ± 10 kW (peak) range, and the vast majority of systems have been used on medium-duty Classes 5, 6, and 7 vehicles operating on city cycles ranging in speed from 4 to 20 mph. The Eaton system used by Kenworth and Navistar on their vehicles has a motor rated at 44 kW peak and a battery with energy storage capacity of 1.8 kilowatt-hours (kWh), as an example. The system is mated to a six-speed AMT. ZF, a German transmission manufacturer, has a very similar design with the motor rated at 60 kW. The current system strategy is to provide launch and acceleration assist to the engine and recover braking energy, but the systems do not provide engine idle shutoff and do not downsize the engine to preserve full-load continuous operating performance.

Most of the available data for trucks come from on-road testing in the United States on the Eaton system, and the following results have been reported:

14 In a series hybrid, all motive power is provided by the electric motor. In a parallel hybrid, the gasoline engine and electric motor, either separately or together, can provide motive power, depending on the engine operating mode.

- Hybrid Class 4 vans operating in city pickup and delivery service for UPS showed an average fuel economy improvement of 29 percent for a cycle speed of about 20 mph.
- Hybrid Class 6 trucks tested by Navistar on the dynamometer over the city cycle showed a benefit of 24 percent in fuel economy and about 20 percent on road cycles in California, with speeds in the 20-to-30 mph range.
- Hybrid Class 6 trucks tested in New York over duty cycles with an average speed of about 5 mph showed a fuel economy benefit of 40 percent.

In general, hybrid benefits increase with decreasing speeds and increased number of stop-and–go cycles. The UPS van was an AMT hybrid, while vans tested in California were equipped with automatic transmissions. Since the AMT is about 8 percent more efficient than a conventional automatic, the hybridization benefit for the UPS van was in the low 20 percent range, consistent with Navistar data from California.

Although there has not been any detailed testing of Class 8 hybrids in the United States operating on long-haul routes, Volvo testing in Europe has shown that typical long-haul operation (potentially similar to the long-haul cycle discussed in Chapter 2) has enough acceleration and braking events to provide a 3 to 4 percent improvement in this application with a 25 kW motor. Simulations by the Southwest Research Institute (SwRI) with a 55 kW motor showed a hybrid benefit of 5.7 percent in fuel economy, although the cycle specifics were not provided. Volvo also claimed that hybridization made accessory electrification easier, so that it was able to attain 5 to 6 percent fuel economy benefit in European testing even with the smaller motor size. Accessory electrification is possible in all vehicles but much easier in hybrids, where large amounts of electric power are available. The A/C compressor and power steering are two options with small but significant fuel savings possible.

Current hybrid systems with a 50 kW motor and about 2 kWh of energy storage add about $40,000 to $50,000 to the price, but this is at very low annual sales volumes (probably fewer than 100 units per year) indicative of pilot production. Manufacturers are contemplating using essentially the same system across a wide range of truck weights and applications, with different benefits. Near-term (2014-2015) target prices assuming volumes of about 5,000 to 10,000 per year are in the $20,000 range, and it appears possible that an additional 25 to 35 percent reduction in costs could occur from 2017 levels by 2025 if expected battery and motor price reductions occur from both scale economies and technology evolution. Plug-in hybrids are also being contemplated, although a 40-mile range would require a battery of 50 kWh or more for a medium-duty Class 6 truck with attendant very high costs.

Hydraulic hybrids can absorb high power spikes due to the mechanical nature of energy storage, but total energy storage capacity is limited. In addition, the system is bulky, and space and weight requirements for the hydraulic tanks limit applicability. Truck manufacturers believed that hydraulic hybrids are well suited for some applications with extreme stop-and-go cycles like garbage trucks and urban transit buses. At the

same time, they did not believe that these market niches could support adequate sales volume to attain scale and scope economies, unlike an electrical hybrid powertrain, suggesting that markets for such hybrids would not develop to commercial scale.

Electric Vehicles

All-electric vehicles in the truck sector can be of three types. The battery-electric vehicle is widely recognized for cars, and it has been recently introduced in light-heavy and medium-heavy trucks that typically offer 70-to150-mile range and may be suitable for urban pickup and delivery. The fuel cell electric vehicle has been researched for many decades, and some examples have been developed for pilot production, especially for transit buses. Catenary trucks rely on direct attachment to the power grid by means of an overhead wire and a catenary on the truck, like a trolley, but also have some battery storage to allow off-catenary operation for 10 to 20 miles. Some prototypes have been displayed, and a pilot demonstration program is underway in the South Coast air basin.

Battery-electric vehicle characteristics for the base year were developed from actual products offered by Build Your Dreams Auto (BYD). For example, the company offers a Class 5 truck with 155-mile range at 50 percent payload, when using a 145 kWh battery. If the range is associated with 85 percent of battery capacity (as batteries are not discharged below 10 percent of capacity to avoid damage), the actual on-road energy consumption is 0.79 kWh per mile or 1.25 miles/kWh. Since this is at light loading and manufacturers cite the most favorable conditions in advertising, the miles per kWh were derated by 20 percent to derive a fuel efficiency of 1.05 miles per kWh. The consumption for other weight classes was derived either by scaling this figure or by using BYD advertised data. Battery-electric vehicles in a given GVW class have much lower payload than equivalent diesel-powered vehicles due to the current high battery weight of about 7 to 8 kg/kWh.

Estimates for other electric vehicle types were based on a recent paper by researchers at the University of California, Davis[15] (UC Davis) that contrasted the costs and benefits of the three electric truck types outlined above. However, HDS corrected some assumptions in the paper used to calculate energy efficiency and costs. The calculation of energy efficiency was based on steady-state energy consumption on a flat road with zero wind. Transient operation (acceleration and braking), road gradients, and wind result in on-road energy consumption being much higher than the value computed in the paper. The paper also examined a 56,000-pound truck instead of the more typical weight of 66,000 pounds for a 70 percent loaded truck with an 80,000 pound rating and a 33,000 pound empty weight. These corrections increase the estimated electric consumption to 3.57 kwh/mile for a Class 8 electric truck, which is 40 percent higher than the estimate in the UC Davis paper. Estimates for the fuel cell truck energy consumption were similarly adjusted but included another adjustment for the high fuel cell efficiency used in the UC Davis paper. Fuel cells have a peak efficiency point around

15 Zhao, H., et. al. May 2017 (draft). *Zero-Emission Highway Trucking Technologies*. UC Davis Institute of Transportation Studies.

70 percent efficiency at relatively light loads of 20 percent of maximum power, however efficiency declines to about 50 percent at full power. Trucks operate at high loads of 60 percent of maximum power at highway speed (using the estimate of 180 kW at 65 mph), and efficiencies are about 60 percent rather than 65 percent assumed in the UC Davis paper. The energy consumption of all electric trucks will decline with improvements in aerodynamics, rolling resistance, and weight reduction, and the benefits from these technologies was set equal to those for diesel trucks.

Costs for the catenary electric and fuel cell truck were also modified from those in the UC Davis paper. The UC Davis study used costs of electric motors and controllers from studies of light-duty vehicle costs. However, light-duty vehicle motors are rated based on short-term peak power (30 second rating), while heavy-duty trucks must operate continuously at or near peak power. Thus light-duty vehicle motor ratings inflate continuous power ratings by 60 to 80 percent so that a motor rated at 100 kW continuous power for heavy-duty vehicles could be rated at 160 to 180 kW of peak power for light-duty vehicles. In addition, high continuous power ratings of 200 kW or more require a motor cooling system to reject the high heat developed, making the truck motor twice as expensive as a light-duty motor with a similar numerical power rating. Costs of fuel cells also used DOE “target values” for costs, although current costs are an order of magnitude higher. Fuel cells for light-duty vehicles are also not rated for continuous power operation and would need significant upgrades in cooling and durability to operate at high continuous power. H-D Systems’ cost estimates for the catenary and fuel cell truck compared to diesel truck are shown below.

The diesel truck is a day cab, 80,000 lb. GVW tractor trailer with a 425 HP engine, while the electric vehicles are equipped with a 300 kW continuous power electric motor. For example, the battery for the catenary vehicle is sized at 75 kWh to provide about a 20-mile range off-grid, while the battery for the fuel cell vehicle is half that size. Costs for the fuel cell are estimated at $200/kW continuous, which is optimistic since current costs are about $500/kW for a light-duty fuel cell, based on the cost of current light-duty fuel cell vehicles. Costs of hydrogen tanks are based on Davis estimates of $500/kg of hydrogen stored, which appears optimistic as current costs are $2,500/kg. The costs based on these assumptions are shown in Table 3-1.

Table 3-1: Cost Estimates for a Class 8 Diesel, Catenary, Electric and Fuel Cell Truck in Volume Production in 2020

Component	Diesel	Catenary	Fuel cell (optimistic)
Glider	50,000	50,000	50,000
Engine or Motor/Controller	20,000	13,000	13,000
Emission Control or Battery	12,000	26,250	13,000
Transmission	6,750	2,000	2,000
Catenary/Fuel Cell	-	7,000	60,000
Hydrogen Tanks	-	-	36,000
Retail Price/Cost Markup	53,250	53,750	83,000
Total	**142,000**	**152,000**	**227,000**

Source: H-D Systems. Assumptions: 300 kW engine, 75kWh battery for catenary, 37 kWh battery for fuel cell

The costs listed above are 2020 direct manufacturing costs (assuming high-volume production of greater than 5,000 units per year globally), while the retail price equivalent is based on a 55 to 60 percent markup. Costs of batteries and motors decline over the forecast period, but costs of other improvements to aerodynamics, tires, weight, and accessories are added to the costs above. The cost data for motors and batteries are based on the CARB technology assessment of battery-electric trucks and buses published in 2015.[16] Truck battery costs, in particular, are expected to decline from $350/kWh (wholesale) in 2020 to $200/kWh in 2030. Motor and controller costs are estimated at $40/kW plus $1,000 in fixed costs, so the cost of a 200 kW (continuous rating) motor and controller is $12,000. This cost is expected to decline to $9,000 by 2030.

Summary

The available technological options are summarized in Table 3-2, the Vehicle Technologies Worksheet. Because technology costs for body-related technologies vary by weight class, the worksheet provides ranges or averages for costs and benefits for several technologies. The RIA provides significant additional detail on costs and benefits, and those can be accessed easily. As noted, benefits for aerodynamics have been reduced relative to the RIA for regional and long-haul trucks to better reflect on-road conditions, but the RIA information is used for all other technologies. Electric vehicles are not included in the RIA forecast, and costs and benefits are from the analysis shown above.

16 California Air Resources Board. October 2015. *Technology Assessment: Medium and Heavy-Duty Battery Electric Trucks and Buses.*

In addition to the technologies in the worksheet, the RIA examined some operational features that include:

- Speed limiters that control maximum speed to 65 mph.
- Adaptive cruise control that permits a look ahead of terrain.
- Extended idle shutoff.
- APU or external power for providing HVAC to sleeper cabs.

All these features have been available for several years in the market, and the benefits of these features through 2030 depend on the extent of use in the base year. Extended idle shutoff is already required in California, and APU/external power for sleeper cabs has been required since 2008 and is included in the baseline. Speed limit enforcement for heavy trucks is also more stringent in California, but the main truck routes are already speed limited by heavy traffic. Hence, these factors may have only small benefits in California and are not considered in this analysis.

Table 3-2: Vehicle Technologies (Costs in 2027)

Technology	Fuel Consumption Benefit %	Cost, 2017$	Comment
Diesel Engines			
Air Handling Improvements	1.1	195	Intake and Turbo Improvement
Combustion/Control	1.1	23	
Friction/Parasitic Loss	1.4	170	
Aftertreatment Improvement	0.6	15	
Downsize/Downspeed	0.4	-126	Cheaper smaller engine
Transient Control	2.0	101	Vocational Trucks only
Turbo-Compound	1.8	890	Regional/Long-haul
CNG Diesel SI Conversion (Class 6/7/8A)	-15 (BTU basis)	35,000	Includes CNG fuel system, tanks, after market installation
CNG Diesel Pilot Injection Conversion (Class 8B)	-4 (BTU basis)	75,000	Includes CNG fuel system, tanks, aftermarket installation
Gasoline Engines			
Direct Injection/Higher CR	2.5	418	Used in light-duty
Friction/ Parasitic Loss	1.2	244	
Cylinder Cutout	3.5	182	Used in some HDT engines
CNG Conversion	0	12,000 to 15,000	Includes CNG fuel system, tanks, aftermarket installation
High-Efficiency Gearbox	1	267	Both manual and automatic
Improved Axle Efficiency	2	116/174	Costs for MDT/HHDT
Tag Axle	1.2	116	For dual-rear-axle trucks
AMT	2	3,850	Relative to manual trans.

Technology	Fuel Consumption Benefit %	Cost, 2017$	Comment
Strong Hybrid	25	6,400	Classes 3,4 only, mixed use
Mild Hybrid	20	13,500	Classes 6/7/8A urban use
10% Drag Reduction	3.8	1,600 for Bin 4	Regional/Long-range trucks
10% Drag Reduction	1.6	170	Mixed-use trucks
10% RRC Reduction	2.9	25 per tire	Regional/Long-range trucks
Weight Reduction 200 Pounds.	0.8	587	LHD/MHD mixed-use
High-Efficiency Alternator	1.0	697 MHD to 1,393 HHD	Vocational trucks only
Electric Power Steering	1.0/0.5		MHD/HHD
Electric A/C Compressor	1.0/0.5		MHD/HHD

Source: H-D Systems.

CHAPTER 4:
Forecast of Heavy-Duty Vehicle Attributes

U.S. EPA/NHTSA Standards

As noted in the introduction, the new federal fuel economy standards for medium- and heavy-duty trucks are so stringent that fuel economy to 2030 will be governed by the standards and not by fuel prices (as projected by the Energy Commission) or other economic factors. Two changes have been made to the standards in the RIA to better reflect on-road conditions. First, HDS has assumed that waste heat recovery technology will not be used, which reduces the fuel economy forecast for regional and long-haul Class 8 trucks by 0.7 percent and costs by $1,210. Second, the benefits of aerodynamic drag reduction devices have been reduced by the ratio of 0.38/0.48 or 0.792 to account for the non-steady-state operation[17] on most highways, as well as interference wake drag.[18] Both changes affect only the Classes 7 and 8 regional and long-haul duty cycle segments.

The forecasts for 2021, 2024, and 2027 are shown in the RIA and are reproduced in the following pages. The RIA lists the fuel economy standards at the class level in ton-miles per gallon, with the conversion based on payload in short tons.[19] The conversion back to miles per gallon is relatively simple, since the RIA analysis assumes constant payload by weight class as follows:

- Class 8 tractor trailer: 38,000 pounds
- Class 7 tractor trailer: 25,000 pounds
- Class 8 vocational: 15,000 pounds
- Classes 6/7 vocational: 11,200 pounds
- Classes 3/4/5 vocational: 5,700 pounds

Assumed payloads for special categories (custom chassis) like coaches, transit buses, and others are identical to the above values, depending only on the GVW category these vehicles fall into. The mapping of the EPA classes to Energy Commission medium- and heavy-duty vehicle classes can be found in Chapter 2 of this report. Results for intermediate years were interpolated from the 2017, 2021, 2024, and 2027 values.

17 *Non-steady-state operation* refers to an operation of vehicle with stops and starts.
18 *Interference wake drag* refers to a term from fluid dynamics and represents drag increases or reductions from the wake of the vehicles ahead of a particular vehicle.
19 A *short ton* is equal to 2,000 pounds.

Table 4-1: RIA Estimates for 2021 Fuel Economy by Class (Reproduced From RIA)

REGULATORY SUBCATEGORY	CO_2 GRAMS PER TON-MILE	FUEL CONSUMPTION GALLON PER 1,000 TON-MILE	AVERAGE INCREMENTAL COST PER VEHICLE RELATIVE TO PHASE 1 COSTS IN MODEL YEAR 2021 [A]	AVERAGE PERCENT FUEL CONSUMPTION AND CO_2 IMPROVEMENT IN MY 2021 RELATIVE TO MY 2017
Tractors				
Class 7 Low Roof Day Cab	105.5	10.36346	$5,134	11%
Class 7 Mid Roof Day Cab	113.2	11.11984	$5,134	11%
Class 7 High Roof Day Cab	113.5	11.14931	$5,240	12%
Class 8 Low Roof Day Cab	80.5	7.90766	$5,228	12%
Class 8 Mid Roof Day Cab	85.4	8.38900	$5,228	12%
Class 8 High Roof Day Cab	85.6	8.40864	$5,317	13%
Class 8 Low Roof Sleeper Cab	72.3	7.10216	$7,181	14%
Class 8 Mid Roof Sleeper Cab	78.0	7.66208	$7,175	14%
Class 8 High Roof Sleeper Cab	75.7	7.43615	$7,276	14%
Class 8 Heavy-Haul	52.4	5.14735	$5,063	8%
Trailers				
Long Dry Box Trailer	78.9	7.75049	$1,081	5%
Short Dry Box Trailer	123.7	12.15128	$772	2%
Long Refrigerated Box Trailer	80.6	7.91749	$1,081	5%
Short Refrigerated Box Trailer	127.5	12.52456	$772	2%
Vocational Diesel				
LHD Urban	424	41.6503	$1,106	12%
LHD Multi-Purpose	373	36.6405	$1,164	11%
LHD Regional	311	30.5501	$873	7%
MHD Urban	296	29.0766	$1,116	11%
MHD Multi-Purpose	265	26.0314	$1,146	10%
MHD Regional	234	22.9862	$851	6%
HHD Urban	308	30.2554	$1,334	9%
HHD Multi-Purpose	261	25.6385	$1,625	9%
HHD Regional	205	20.1375	$2,562	7%
Vocational Gasoline				
LHD Urban	461	51.8735	$1,106	8%
LHD Multi-Purpose	407	45.7972	$1,164	8%
LHD Regional	335	37.6955	$873	6%
MHD Urban	328	36.9078	$1,116	7%
MHD Multi-Purpose	293	32.9695	$1,146	7%
MHD Regional	261	29.3687	$851	5%

Source: U.S. EPA/NHSTA RIA.

Table 4-2: RIA Estimates for 2024 Fuel Economy by Class (Reproduced From RIA)

REGULATORY SUBCATEGORY	CO_2 GRAMS PER TON-MILE	FUEL CONSUMPTION GALLON PER 1,000 TON-MILE	AVERAGE INCREMENTAL COST PER VEHICLE RELATIVE TO PHASE 1 COSTS IN MODEL YEAR 2024 [A]	AVERAGE PERCENT FUEL CONSUMPTION AND CO_2 IMPROVEMENT IN MY 2024 RELATIVE TO MY 2017
Tractors				
Class 7 Low Roof Day Cab	99.8	9.80354	$8,037	16%
Class 7 Mid Roof Day Cab	107.1	10.52063	$8,037	16%
Class 7 High Roof Day Cab	106.6	10.47151	$8,210	18%
Class 8 Low Roof Day Cab	76.2	7.48527	$8,201	17%
Class 8 Mid Roof Day Cab	80.9	7.94695	$8,201	16%
Class 8 High Roof Day Cab	80.4	7.89784	$8,358	18%
Class 8 Low Roof Sleeper Cab	68.0	6.67976	$11,100	19%
Class 8 Mid Roof Sleeper Cab	73.5	7.22004	$11,100	19%
Class 8 High Roof Sleeper Cab	70.7	6.94499	$11,306	19%
Class 8 Heavy-Haul	50.2	4.93124	$7,937	12%
Trailers				
Long Dry Box Trailer	77.2	7.58350	$1,204	7%
Short Dry Box Trailer	120.9	11.87623	$1,171	4%
Long Refrigerated Box Trailer	78.9	7.75049	$1,204	7%
Short Refrigerated Box Trailer	124.7	12.24951	$1,171	4%
Vocational Diesel				
LHD Urban	385	37.8193	$1,959	20%
LHD Multi-Purpose	344	33.7917	$2,018	18%
LHD Regional	296	29.0766	$1,272	11%
MHD Urban	271	26.6208	$2,082	18%
MHD Multi-Purpose	246	24.1650	$2,110	16%
MHD Regional	221	21.7092	$1,274	11%
HHD Urban	283	27.7996	$2,932	16%
HHD Multi-Purpose	242	23.7721	$3,813	16%
HHD Regional	194	19.0570	$4,009	12%
Vocational Gasoline				
LHD Urban	432	48.6103	$1,959	13%
LHD Multi-Purpose	385	43.3217	$2,018	9%
LHD Regional	324	36.4577	$1,272	12%
MHD Urban	310	34.8824	$2,082	11%
MHD Multi-Purpose	279	31.3942	$2,110	9%
MHD Regional	251	28.2435	$1,274	13%

Source: U.S. EPA/NHSTA RIA.

Table 4-3: RIA Estimates for 2027 Fuel Economy by Class (Reproduced From RIA)

REGULATORY SUBCATEGORY	CO_2 GRAMS PER TON-MILE (FOR HD PUV, GRAMS PER MILE)	FUEL CONSUMPTION GALLON PER 1,000 TON-MILE (FOR HD PUV, GALLONS PER 100 MILES)	AVERAGE INCREMENTAL COST PER VEHICLE RELATIVE TO PHASE 1 COSTS IN MODEL YEAR 2027 [A]	AVERAGE PERCENT FUEL CONSUMPTION AND CO_2 IMPROVEMENT IN MY 2027 RELATIVE TO MY 2017
Tractors				
Class 7 Low Roof Day Cab	96.2	9.44990	$10,235	19%
Class 7 Mid Roof Day Cab	103.4	10.15717	$10,235	19%
Class 7 High Roof Day Cab	100.0	9.82318	$10,298	21%
Class 8 Low Roof Day Cab	73.4	7.21022	$10,439	20%
Class 8 Mid Roof Day Cab	78.0	7.66208	$10,439	19%
Class 8 High Roof Day Cab	75.7	7.43615	$10,483	22%
Class 8 Low Roof Sleeper Cab	64.1	6.29666	$13,535	24%
Class 8 Mid Roof Sleeper Cab	69.6	6.83694	$13,574	23%
Class 8 High Roof Sleeper Cab	64.3	6.31631	$13,749	25%
Class 8 Heavy-Haul	48.3	4.74460	$9,986	15%
Trailers				
Long Dry Box Trailer	75.7	7.43615	$1,370	9%
Short Dry Box Trailer	119.4	11.72888	$1,204	6%
Long Refrigerated Box Trailer	77.4	7.60314	$1,370	9%
Short Refrigerated Box Trailer	123.2	12.10216	$1,204	5%
Vocational Diesel				
LHD Urban	367	36.0511	$2,533	24%
LHD Multi-Purpose	330	32.4165	$2,571	21%
LHD Regional	291	28.5855	$1,486	13%
MHD Urban	258	25.3438	$2,727	22%
MHD Multi-Purpose	235	23.0845	$2,771	20%
MHD Regional	218	21.4145	$1,500	12%
HHD Urban	269	26.4244	$4,151	20%
HHD Multi-Purpose	230	22.5933	$5,025	20%
HHD Regional	189	18.5658	$5,670	14%
Vocational Gasoline				
LHD Urban	413	46.4724	$2,533	18%
LHD Multi-Purpose	372	41.8589	$2,571	16%
LHD Regional	319	35.8951	$1,486	11%
MHD Urban	297	33.4196	$2,727	16%
MHD Multi-Purpose	268	30.1564	$2,771	15%
MHD Regional	247	27.7934	$1,500	10%
Class 2b and 3 HD Pickups and Vans [b]				
HD Pickup and Van	460	4.88	$1,486	17%

Source: U.S. EPA/NHSTA RIA.

Table 4-4: RIA Estimates for 2021 to 2027 Fuel Economy – Custom Chassis (Reproduced From RIA)

REGULATORY SUBCATEGORY	CO_2 GRAMS PER TON-MILE	FUEL CONSUMPTION GALLON PER 1,000 TON-MILE	AVERAGE INCREMENTAL COST PER VEHICLE RELATIVE TO PHASE 1 COSTS IN MODEL YEAR 2021 [A]	AVERAGE PERCENT FUEL CONSUMPTION AND CO_2 IMPROVEMENT IN MY 2021 RELATIVE TO MY 2017
Vocational Custom Chassis				
Coach Bus	210	20.6287	900	7%
Motor Home	228	22.3969	600	6%
School Bus	291	28.5855	800	10%
Transit	300	29.4695	1000	7%
Refuse	313	30.7466	700	4%
Mixer	319	31.3360	300	3%
Emergency	324	31.8271	400	1%

REGULATORY SUBCATEGORY	CO_2 GRAMS PER TON-MILE	FUEL CONSUMPTION GALLON PER 1,000 TON-MILE	AVERAGE INCREMENTAL COST PER VEHICLE RELATIVE TO PHASE 1 COSTS IN MODEL YEAR 2027 [A]	AVERAGE PERCENT FUEL CONSUMPTION AND CO_2 IMPROVEMENT IN MY 2027 RELATIVE TO MY 2017
Vocational Custom Chassis				
Coach Bus	205	20.1375	1400	11%
Motor Home	226	22.2004	900	9%
School Bus	271	26.6208	1300	18%
Transit	286	28.0943	1800	14%
Refuse	298	29.2731	1300	12%
Mixer	316	31.0413	600	7%
Emergency	319	31.3360	600	6%

Source: U.S. EPA/NHSTA RIA.

Forecast of Vehicle Prices

Base-year prices for vehicles in each class were determined from three sources. First, Energy Commission staff had collected some retail prices for vehicles in specific classes. Second, manufacturer websites provided MSRP information on models for many vehicle classes from Class 3 to Class 7. Third, reports by transit and bus association provided price information that was anecdotal (citing transit or bus company staff). Prices for alternative fuel (CNG, propane, and electric) vehicles were based on the information listed in Chapter 3 on price increments added to the base price of the diesel or gasoline vehicle in the market. In the case of transit buses, the CARB provided[20] a set of price estimates for transit buses with diesel, diesel-electric hybrid, CNG, battery–electric, and fuel cell powertrains. The base year diesel bus price reported by CARB is higher than reported in other areas, and prices for hybrid, battery-electric, and fuel cell buses reflect extremely low volume (or pilot) production status. The volume production[21] and pilot production costs for electric and fuel cell vehicles are reported to Energy Commission in two scenarios.

The "learning curve" or "experience curve" describes the reduction in unit production costs as a function of accumulated production volume. The curve describes costs as a function of cumulative production volume measured at the level of a manufacturer, although it is often assumed—as both EPA and NHTSA have done in past regulatory analyses—to apply industrywide, particularly in industries that use many common technologies and component supply sources. Research into the costs of manufacturing has consistently shown that, as manufacturers gain experience in production, they are able to apply innovations to simplify machining and assembly operations, use lower-cost materials, and reduce the number or complexity of component parts. All these factors allow manufacturers to lower the per-unit cost of production (that is, the manufacturing learning curve).

In past rulemaking analyses, as noted above, EPA and NHTSA have used a learning curve algorithm that applied a learning factor of 20 percent for each doubling of production volume. For example, NHTSA has used this approach in analyses supporting recent corporate average fuel economy (CAFE) rules. This is, however, different from scale economies, as the RIA estimates apply uniformly to high-volume production. Scale effects are associated with changes in processes going from low- to high-volume production. At very low volumes, components are individually manufactured, and assembly is by skilled workers. At high volumes, components use highly automated production, and vehicles are produced in assembly lines. The general experience is that each order of magnitude change in annual production volume changes the manufacturing method and results in a 30 percent cost decrease at the same level of technology. If pilot production is at 100 units per year, direct manufacturing costs will decrease by 30 percent as production volumes increase to 1,000 per year and by another

20 CARB Mobile Source Control Division. May 2017. "Advanced Clean Transit," presentation to the board.
21 For this report, *volume production* is defined as global sales of at least 10,000 units per year.

30 percent when production hits roughly 10,000 per year. Thus, high-volume costs cited by the EPA in the RIA are 49 percent (or 0.7*0.7) of pilot production costs. Of course, this is a general estimate as the exact reduction will be based on the level of production automation possible and material costs for the components themselves, which may be high for items like batteries or fuel cells. In addition, overheads and fixed cost amortization decline as the inverse of production volume.

A detailed analysis of low-volume costs was not possible in this effort, and as a result, the low-volume costs were based on actual MSRP cited by manufacturers for alternative fuel vehicles, whereas high volume costs are based on the data presented in in Chapter 3.

Forecasts

HDS provided forecasts for two scenarios. The first is a high electricity demand case that assumes electric vehicles are successful and uses the high-volume forecast of electric vehicle prices. The second is a low electricity demand case that uses the current (low-volume) prices of electric vehicles and assumes benefits of learning but not of scale (high-volume) for the forecast. The low case also uses the higher transit bus prices from the CARB as the starting point for prices in 2017 and assumes benefits of learning but not of scale for the forecast. The forecasts are shown in Tables 4-5 and 4-6, respectively.

The forecasts project that for all internal combustion engine-powered vehicles from 2017 to 2030:

- Vehicles in Classes 3 and 4 (mostly large pickups and vans) will increase fuel economy by about 25 to 29 percent.
- Medium-duty trucks in Classes 6 and 7 that operate in mixed suburban and urban routes will increase fuel economy by 22 to 25 percent.
- Vehicles in mostly urban use like garbage trucks and urban buses will have improvements in fuel economy of 9 to 12 percent.
- Long-haul trucks in Classes 7 and 8 will see the largest improvement of 29 to 32 percent in fuel economy.

The forecasts in Tables 4.5 and 4.6 project improvements in fuel economy (in miles per gallon), while the EPA forecasts decrease in fuel consumption (a 25 percent fuel consumption decrease is a 33.3 percent increase in fuel economy). Electric vehicles in each class will see smaller improvements in fuel efficiency because the electric motor is already very efficient and future gains in efficiency will be small; hence, most of the efficiency improvement is associated with improvements to body technology. Costs of electric vehicles, however, are forecast to decline mostly due to battery cost reduction and improved economies of scale.

Table 4-5: Forecast Vehicle Attribute Data Worksheet for High Electricity Demand Case

	Attribute	Unit	Type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CLASS 3 GASOLINE	Fuel economy	MPGG	OEM	14.90	15.10	15.30	15.80	16.30	16.73	17.16	17.59	18.02	18.34	18.65	18.97	19.15	19.33
	Price	2017 $		42,500	42,700	42,900	43,050	43,250	43,300	43,350	43,400	43,525	43,650	43,775	43,900	43,950	44,000
CLASS 3 DIESEL	Fuel economy	MPDG	OEM	17.45	17.66	17.87	18.10	18.32	18.81	19.30	19.78	20.27	20.63	20.99	21.35	21.45	21.55
	Price	2017 $		49,900	50,100	50,300	50,450	50,650	50,700	50,750	50,800	50,925	51,050	51,175	51,300	51,350	51,400
CLASS 3 E85	Fuel economy	MPEG	OEM	10.73	10.87	11.02	11.38	11.74	12.05	12.36	12.66	12.97	13.20	13.43	13.66	13.79	13.92
	Price	2017 $		42,500	42,700	42,900	43,050	43,250	43,300	43,350	43,400	43,525	43,650	43,775	43,900	43,950	44,000
CLASS 3 CNG	Fuel economy	MPGGE	AFM	14.16	14.35	14.54	15.01	15.49	15.89	16.30	16.71	17.12	17.42	17.72	18.02	18.19	18.36
	Price	2017 $		55,000	55,200	55,400	55,550	55,750	55,800	55,850	55,900	56,025	56,150	56,275	56,400	56,450	56,500
CLASS 3 LPG	Fuel economy	MPPG	AFM	11.29	11.45	11.60	11.98	12.36	12.68	13.01	13.33	13.66	13.90	14.14	14.38	14.52	14.65
	Price	2017 $		53,500	53,700	53,900	54,050	54,250	54,300	54,350	54,400	54,525	54,650	54,775	54,900	54,950	55,000
CLASS 3 EL.HYBRID	Fuel economy	MPGG	OEM				20.86	21.52	22.08	22.65	23.22	23.79	24.20	24.62	25.04	25.28	25.52
	Price	2017 $					49,550	49,555	49,416	49,282	49,154	49,107	49,064	49,027	48,994	48,892	48,793
CLASS 3 BEV	Fuel economy	MPKWH	OEM	1.20	1.21	1.22	1.24	1.25	1.26	1.27	1.29	1.30	1.31	1.33	1.34	1.35	1.37
	Price	2017 $		63,500	62,650	61,853	61,055	60,355	59,549	58,787	58,065	57,457	56,885	56,348	55,845	55,298	54,780
CLASS 3 MOTORHOME GAS	Fuel economy	MPGG	AFM	14.16	14.35	14.54	15.01	15.49	15.89	16.30	16.71	17.12	17.42	17.72	18.02	18.19	18.36
	Price	2017 $		107,500	107,700	107,900	108,050	108,250	108,300	108,350	108,400	108,525	108,650	108,775	108,900	108,950	109,000
CLASS 3 MOTORHOME DIESEL	Fuel economy	MPDG	AFM	16.58	16.78	16.98	17.20	17.40	17.87	18.33	18.79	19.26	19.60	19.94	20.28	20.38	20.47
	Price	2017 $		114,500	114,700	114,900	115,050	115,250	115,300	115,350	115,400	115,525	115,650	115,775	115,900	115,950	116,000
CLASS 4 /5 GASOLINE	Fuel economy	MPGG	OEM	6.9	7.09	7.28	7.47	7.66	7.81	7.95	8.10	8.19	8.29	8.38	8.45	8.51	8.58
	Price	2017 $		46,400	46,690	46,980	47,270	47,560	47,847	48,133	48,420	48,603	48,787	48,970	49,047	49,123	49,200
CLASS 4/5 DIESEL	Fuel economy	MPDG	OEM	8.63	8.87	9.11	9.34	9.58	9.85	10.11	10.38	10.53	10.67	10.82	10.90	10.98	11.06
	Price	2017 $		54,300	54,590	54,880	55,170	55,460	55,747	56,033	56,320	56,503	56,687	56,870	56,963	57,057	57,150
CLASS 4/5 E85	Fuel economy	MPEG	OEM	4.97	5.10	5.24	5.38	5.52	5.62	5.73	5.83	5.90	5.97	6.03	6.08	6.13	6.18
	Price	2017 $		46,400	46,690	46,980	47,270	47,560	47,847	48,133	48,420	48,603	48,787	48,970	49,047	49,123	49,200
CLASS 4/5 CNG	Fuel economy	MPGGE	AFM	6.56	6.74	6.92	7.10	7.28	7.42	7.56	7.70	7.78	7.87	7.96	8.02	8.09	8.15
	Price	2017 $		58,900	59,190	59,480	59,770	60,060	60,347	60,633	60,920	61,103	61,287	61,470	61,547	61,623	61,700
CLASS 4/5 LPG	Fuel economy	MPGGE	AFM	5.23	5.37	5.52	5.66	5.81	5.92	6.03	6.14	6.21	6.28	6.35	6.40	6.45	6.50
	Price	2017 $		57,400	57,690	57,980	58,270	58,560	58,847	59,133	59,420	59,603	59,787	59,970	60,047	60,123	60,200
CLASS 4/5 EL.HYBRID	Fuel economy	MPGG	OEM				9.86	10.11	10.30	10.50	10.69	10.82	10.94	11.06	11.15	11.24	11.33
	Price	2017 $					54,770	54,835	54,903	54,978	55,060	55,044	55,034	55,030	54,925	54,825	54,731

	Attribute	Unit	Type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CLASS 4/5 DIESEL HH	Fuel economy	MPDG	OEM	10.79	11.08	11.38	11.68	11.98	12.31	12.64	12.98	13.16	13.34	13.53	13.63	13.73	13.83
	Price	2017 $		78,300	78,590	78,880	79,170	79,460	79,747	80,033	80,320	80,503	80,687	80,870	80,963	81,057	81,150
CLASS 4/5 BEV	Fuel economy	MPKWH	OEM	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.13	1.14	1.15	1.16	1.17	1.18	1.19
	Price	2017 $		70,900	69,965	69,091	68,276	67,515	66,804	66,143	65,529	64,857	64,228	63,639	62,982	62,362	61,777
CLASS 6 DIESEL	Fuel economy	MPDG	OEM	6.24	6.40	6.55	6.71	6.86	7.04	7.21	7.39	7.50	7.62	7.73	7.77	7.81	7.85
	Price	2017 $		55,300	55,588	55,875	56,163	56,450	56,770	57,090	57,410	57,630	57,850	58,070	58,213	58,357	58,500
CLASS 6 DIESEL EL. HYBRID	Fuel economy	MPDG	OEM	7.49	7.67	7.86	8.05	8.23	8.44	8.66	8.87	9.00	9.14	9.28	9.32	9.37	9.42
	Price	2017 $		75,300	74,988	74,693	74,416	74,156	73,945	73,749	73,570	73,305	73,055	72,818	72,519	72,234	71,961
CLASS 6 DIESEL HY. HYBRID	Fuel economy	MPDG	AFM	7.36	7.55	7.73	7.91	8.09	8.30	8.51	8.72	8.85	8.99	9.12	9.17	9.22	9.26
	Price	2017 $		79,300	79,588	79,875	80,163	80,450	80,770	81,090	81,410	81,630	81,850	82,070	82,213	82,357	82,500
CLASS 6 CNG	Fuel economy	MPDG	AFM	5.30	5.44	5.57	5.70	5.83	5.98	6.13	6.28	6.38	6.47	6.57	6.60	6.64	6.67
	Price	2017 $		90,300	90,588	90,875	91,163	91,450	91,770	92,090	92,410	92,630	92,850	93,070	93,213	93,357	93,500
CLASS 6 BEV	Fuel economy	MPKWH	OEM	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03
	Price	2017 $		85,800	85,173	84,572	83,999	83,451	82,961	82,496	82,053	81,534	81,037	80,561	80,030	79,519	79,027
CLASS 6 MOTORHOME DIESEL	Fuel economy	MPDG	AFM	7.33	7.44	7.55	7.66	7.77	7.92	8.07	8.22	8.26	8.30	8.34	8.36	8.38	8.40
	Price	2017 $		142,000	142,213	142,425	142,638	142,850	142,992	143,133	143,275	143,350	143,425	143,500	143,533	143,567	143,600
CLASS 6 MOTORHOME GASOLINE	Fuel economy	MPGG	AFM	5.79	5.86	5.94	6.01	6.08	6.16	6.24	6.32	6.36	6.39	6.43	6.46	6.49	6.52
	Price	2017 $		134,000	134,213	134,425	134,638	134,850	134,992	135,133	135,275	135,350	135,425	135,500	135,550	135,600	135,650
CLASS 7 SINGLE UNIT DIESEL	Fuel economy	MPDG	OEM	6.96	7.15	7.34	7.53	7.72	7.87	8.01	8.16	8.26	8.36	8.47	8.49	8.52	8.55
	Price	2017 $		93,400	94,684	95,967	97,251	98,534	99,502	100,469	101,437	102,170	102,902	103,635	103,723	103,812	103,900
CLASS 7 DIESEL ELECTRIC HYBRID	Fuel economy	MPDG	OEM				8.43	8.65	8.81	8.97	9.14	9.25	9.37	9.48	9.51	9.54	9.58
	Price	2017 $					133,251	133,454	133,374	133,326	133,308	133,084	132,889	132,722	131,938	131,180	130,447
CLASS 7 CNG	Fuel economy	MPDGE	AFM	5.98	6.15	6.31	6.47	6.64	6.77	6.89	7.02	7.11	7.19	7.28	7.30	7.33	7.35
	Price	2017 $		128,400	129,684	130,967	132,251	133,534	134,502	135,469	136,437	137,170	137,902	138,635	138,723	138,812	138,900
CLASS 8 SINGLE UNIT DIESEL	Fuel economy	MPDG	OEM	4.77	4.88	4.99	5.09	5.20	5.34	5.47	5.61	5.71	5.80	5.90	5.92	5.94	5.96
	Price	2017 $		96,950	97,363	97,775	98,188	98,600	99,333	100,067	100,800	101,192	101,583	101,975	102,150	102,325	102,500
CLASS 8 SINGLE UNIT CNG	Fuel economy	MPDGE	AFM	4.10	4.19	4.29	4.38	4.47	4.59	4.71	4.82	4.91	4.99	5.07	5.09	5.11	5.13
	Price	2017 $		151,950	152,363	152,775	153,188	153,600	154,333	155,067	155,800	156,192	156,583	156,975	157,150	157,325	157,500
CLASS 8 SINGLE UNIT LNG	Fuel economy	MPDGE	AFM	4.10	4.19	4.29	4.38	4.47	4.59	4.71	4.82	4.91	4.99	5.07	5.09	5.11	5.13
	Price	2017 $		161,950	162,363	162,775	163,188	163,600	164,333	165,067	165,800	166,192	166,583	166,975	167,150	167,325	167,500
CLASS 8 CA COMBINATION DIESEL	Fuel economy	MPDGE	OEM	5.54	5.72	5.90	6.08	6.26	6.36	6.46	6.56	6.69	6.82	6.95	6.98	7.02	7.05
	Price	2017 $		119,500	120,830	122,160	123,490	124,820	125,500	126,180	126,860	127,273	127,687	128,780	128,887	128,993	129,100

	Attribute	Unit	Type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CLASS 8 CA COMBINATION CNG	Fuel economy	MPDGE	AFM	5.26	5.43	5.61	5.78	5.95	6.04	6.14	6.23	6.36	6.48	6.60	6.63	6.67	6.70
	Price	2017 $		194,500	195,830	197,160	198,490	199,820	200,500	201,180	201,860	202,273	202,687	203,780	203,887	203,993	204,100
CLASS 8 CA COMBINATION LNG	Fuel economy	MPDGE	AFM	5.26	5.43	5.61	5.78	5.95	6.04	6.14	6.23	6.36	6.48	6.60	6.63	6.67	6.70
	Price	2017 $		204,500	205,830	207,160	208,490	209,820	210,500	211,180	211,860	212,273	212,687	213,780	213,887	213,993	214,100
CLASS 8 CA COMBINATION EL	Fuel economy	MPKWH	AFM			0.280	0.295	0.310	0.313	0.315	0.318	0.323	0.327	0.332	0.333	0.334	0.335
(Direct / Catenary Electric)	Price	2017 $				132,160	133,160	134,160	134,690	135,220	135,750	136,260	136,770	137,280	137,353	137,427	137,500
CLASS 8 CA COMBINATION FC	Fuel economy	MPKGH2	AFM			5.82	6.14	6.45	6.50	6.56	6.61	6.71	6.80	6.90	6.92	6.94	6.96
(Fuel Cell)	Price	2017 $				207,160	206,790	206,454	205,501	204,581	203,693	202,570	201,477	201,095	199,755	198,445	197,162
CLASS 8 COMBINATION DIESEL	Fuel economy	MPDGE	OEM	6.21	6.41	6.62	6.82	7.02	7.16	7.31	7.45	7.68	7.90	8.13	8.14	8.15	8.16
	Price	2017 $		142,000	143,818	145,635	147,453	149,270	150,530	151,790	153,050	153,533	154,017	154,500	154,700	154,900	155,100
CLASS 8 COMBINATION CNG	Fuel economy	MPDGE	OEM	5.90	6.09	6.28	6.48	6.67	6.81	6.94	7.08	7.29	7.51	7.72	7.73	7.74	7.75
	Price	2017 $		217,000	218,818	220,635	222,453	224,270	225,530	226,790	228,050	228,533	229,017	229,500	229,700	229,900	230,100
CLASS 8 COMBINATION LNG	Fuel economy	MPDGE	OEM	5.60	5.79	5.97	6.15	6.34	6.46	6.59	6.72	6.93	7.13	7.34	7.35	7.36	7.36
	Price	2017 $		302,000	303,818	305,635	307,453	309,270	310,530	311,790	313,050	313,533	314,017	314,500	314,700	314,900	315,100
CLASS 8 GARBAGE DIESEL	Fuel economy	MPDGE	OEM	4.22	4.25	4.28	4.31	4.34	4.37	4.41	4.44	4.48	4.51	4.55	4.57	4.59	4.61
	Price	2017 $		191,600	191,933	192,265	192,598	192,930	193,463	193,997	194,530	194,937	195,343	195,750	195,900	196,050	196,200
CLASS 8 GARBAGE DIESEL EL. HYBRID	Fuel economy	MPDG	OEM	5.06	5.10	5.14	5.17	5.21	5.25	5.29	5.33	5.37	5.42	5.46	5.48	5.51	5.53
	Price	2017 $		231,600	230,733	229,901	229,104	228,342	227,813	227,316	226,849	226,286	225,753	225,247	224,512	223,804	223,121
CLASS 8 GARBAGE DIESEL HY. HYBRID	Fuel economy	MPDG	AFM	4.98	5.02	5.05	5.09	5.12	5.16	5.20	5.24	5.28	5.33	5.37	5.39	5.42	5.44
	Price	2017 $		226,600	226,933	227,265	227,598	227,930	228,463	228,997	229,530	229,937	230,343	230,750	230,900	231,050	231,200
CLASS 8 GARBAGE CNG	Fuel economy	MPDG	AFM	3.59	3.61	3.64	3.66	3.69	3.72	3.75	3.77	3.81	3.84	3.87	3.88	3.90	3.92
	Price	2017 $		246,600	246,933	247,265	247,598	247,930	248,463	248,997	249,530	249,937	250,343	250,750	250,900	251,050	251,200
CLASS 8 GARBAGE LNG	Fuel economy	MPDG	AFM	3.59	3.61	3.64	3.66	3.69	3.72	3.75	3.77	3.81	3.84	3.87	3.88	3.90	3.92
	Price	2017 $		256,600	256,933	257,265	257,598	257,930	258,463	258,997	259,530	259,937	260,343	260,750	260,900	261,050	261,200
URBAN TRANSIT DIESEL	Fuel economy	MPGD	OEM	3.42	3.45	3.47	3.50	3.52	3.56	3.60	3.64	3.67	3.71	3.75	3.77	3.78	3.80
	Price	2017 $		250,000	250,333	250,665	250,998	251,330	251,800	252,270	252,740	253,210	253,680	254,150	254,267	254,383	254,500
URBAN TRANSIT DIESEL EL HYBRID	Fuel economy	MPGD	AFM	4.55	4.58	4.62	4.65	4.68	4.73	4.78	4.83	4.89	4.94	4.99	5.01	5.03	5.05
	Price	2017 $		290,000	289,133	288,301	287,504	286,742	286,149	285,589	285,059	284,560	284,089	283,647	282,879	282,137	281,421
URBAN TRANSIT DIESEL HY. HYBRID	Fuel economy	MPGD	AFM	4.28	4.31	4.34	4.37	4.40	4.45	4.50	4.54	4.59	4.64	4.69	4.71	4.73	4.75
	Price	2017 $		285,000	285,333	285,665	285,998	286,330	286,800	287,270	287,740	288,210	288,680	289,150	289,267	289,383	289,500
URBAN TRANSIT CNG	Fuel economy	MPDGE	AFM	2.91	2.93	2.95	2.97	2.99	3.02	3.06	3.09	3.12	3.15	3.19	3.20	3.22	3.23
	Price	2017 $		305,000	305,333	305,665	305,998	306,330	306,800	307,270	307,740	308,210	308,680	309,150	309,267	309,383	309,500

	Attribute	Unit	Type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
URBAN TRANSIT BEV	Fuel economy	MPKWH	OEM	0.250	0.251	0.251	0.252	0.252	0.253	0.253	0.254	0.254	0.255	0.255	0.256	0.256	0.257
	Price	2017 $		500,000	495,333	490,765	486,296	481,922	477,780	473,731	469,771	465,901	462,117	458,418	454,450	450,563	446,756
URBAN TRANSIT FCEV	Fuel economy	MPKGH2	OEM					5.16	5.17	5.18	5.19	5.20	5.21	5.22	5.23	5.24	5.25
	Price	2017 $						501,330	496,800	492,370	488,038	483,802	479,660	475,611	471,298	467,074	462,937
SHUTTLE BUS GASOLINE	Fuel economy	MPGG	OEM	6.9	7.09	7.28	7.47	7.66	7.81	7.95	8.10	8.19	8.29	8.38	8.45	8.51	8.58
	Price	2017 $		76,400	76,690	76,980	77,270	77,560	77,847	78,133	78,420	78,603	78,787	78,970	79,047	79,123	79,200
SHUTTLE BUS DIESEL	Fuel economy	MPGD	OEM	8.63	8.87	9.11	9.34	9.58	9.85	10.11	10.38	10.53	10.67	10.82	10.90	10.98	11.06
	Price	2017 $		84,300	84,590	84,880	85,170	85,460	85,747	86,033	86,320	86,503	86,687	86,870	86,963	87,057	87,150
SHUTTLE BUS E85	Fuel economy	MPGE	OEM	4.97	5.10	5.24	5.38	5.52	5.62	5.73	5.83	5.90	5.97	6.03	6.08	6.13	6.18
	Price	2017 $		76,400	76,690	76,980	77,270	77,560	77,847	78,133	78,420	78,603	78,787	78,970	79,047	79,123	79,200
SHUTTLE BUS CNG	Fuel economy	MPGGE	AFM	6.56	6.74	6.92	7.10	7.28	7.42	7.56	7.70	7.78	7.87	7.96	8.02	8.09	8.15
	Price	2017 $		88,900	89,190	89,480	89,770	90,060	90,347	90,633	90,920	91,103	91,287	91,470	91,547	91,623	91,700
SHUTTLE BUS DIESEL HYD. HYBRID	Fuel economy	MPGP	AFM	10.53	10.82	11.11	11.40	11.69	12.01	12.34	12.66	12.84	13.02	13.20	13.30	13.40	13.49
	Price	2017 $		108,300	108,590	108,880	109,170	109,460	109,747	110,033	110,320	110,503	110,687	110,870	110,963	111,057	111,150
SHUTTLE BUS BEV	Fuel economy	MPKWH	OEM	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.13	1.14	1.15	1.16	1.17	1.18	1.19
	Price	2017 $		524,500	518,608	512,876	507,301	501,877	496,738	491,740	486,881	482,155	477,558	473,087	468,385	463,801	459,332
SCHOOL BUS GASOLINE	Fuel economy	MPGG	OEM	6.25	6.42	6.60	6.77	6.94	7.05	7.17	7.28	7.39	7.51	7.62	7.63	7.64	7.65
	Price	2017 $		77,300	77,588	77,875	78,163	78,450	78,770	79,090	79,410	79,630	79,850	80,070	80,213	80,357	80,500
SCHOOL BUS DIESEL	Fuel economy	MPGD	OEM	7.81	8.87	9.11	9.34	9.58	9.85	10.11	10.38	10.53	10.67	10.82	10.90	10.98	11.06
	Price	2017 $		85,300	85,588	85,875	86,163	86,450	86,770	87,090	87,410	87,630	87,850	88,070	88,213	88,357	88,500
SCHOOL BUS BEV	Fuel economy	MPKWH	OEM	0.904	0.913	0.922	0.931	0.941	0.950	0.960	0.969	0.979	0.989	0.999	1.009	1.019	1.029
	Price	2017 $		112,300	111,538	110,807	110,106	109,435	108,826	108,244	107,689	107,061	106,458	105,880	105,249	104,641	104,056
SCHOOL BUS CNG	Fuel economy	MPGGE	AFM	5.94	6.10	6.27	6.43	6.59	6.70	6.81	6.92	7.02	7.13	7.24	7.25	7.26	7.27
	Price	2017 $		97,300	97,588	97,875	98,163	98,450	98,770	99,090	99,410	99,630	99,850	100,070	100,213	100,357	100,500
SCHOOL BUS LPG	Fuel economy	MPGP	AFM	4.74	4.87	5.00	5.13	5.26	5.35	5.43	5.52	5.60	5.69	5.78	5.78	5.79	5.80
	Price	2017 $		95,300	105,588	105,875	106,163	106,450	106,770	107,090	107,410	107,630	107,850	108,070	108,213	108,357	108,500
MOTOR COACH DIESEL	Fuel economy	MPDG	OEM	6.96	7.15	7.34	7.53	7.72	7.87	8.01	8.16	8.26	8.36	8.47	8.49	8.52	8.55
	Price	2017 $		350,000	351,284	352,567	353,851	355,134	356,102	357,069	358,037	358,770	359,502	360,235	360,323	360,412	360,500
MOTOR COACH CNG	Fuel economy	MPDGE	OEM	5.91	6.07	6.24	6.40	6.56	6.69	6.81	6.94	7.02	7.11	7.20	7.22	7.24	7.27
	Price	2017 $		385,000	386,284	387,567	388,851	390,134	391,102	392,069	393,037	393,770	394,502	395,235	395,323	395,412	395,500

Source: H-D Systems.

Table 4-6: Forecast Vehicle Attribute Data Worksheet for Low Electricity Demand Case

	Attribute	unit	type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CLASS 3 GASOLINE	Fuel economy	MPGG	OEM	14.90	15.10	15.30	15.80	16.30	16.73	17.16	17.59	18.02	18.34	18.65	18.97	19.15	19.33
	Price	2017 $		42,500	42,700	42,900	43,050	43,250	43,300	43,350	43,400	43,525	43,650	43,775	43,900	43,950	44,000
CLASS 3 DIESEL	Fuel economy	MPDG	OEM	17.45	17.66	17.87	18.10	18.32	18.81	19.30	19.78	20.27	20.63	20.99	21.35	21.45	21.55
	Price	2017 $		49,900	50,100	50,300	50,450	50,650	50,700	50,750	50,800	50,925	51,050	51,175	51,300	51,350	51,400
CLASS 3 E85	Fuel economy	MPEG	OEM	10.73	10.87	11.02	11.38	11.74	12.05	12.36	12.66	12.97	13.20	13.43	13.66	13.79	13.92
	Price	2017 $		42,500	42,700	42,900	43,050	43,250	43,300	43,350	43,400	43,525	43,650	43,775	43,900	43,950	44,000
CLASS 3 CNG	Fuel economy	MPGGE	AFM	14.16	14.35	14.54	15.01	15.49	15.89	16.30	16.71	17.12	17.42	17.72	18.02	18.19	18.36
	Price	2017 $		55,000	55,200	55,400	55,550	55,750	55,800	55,850	55,900	56,025	56,150	56,275	56,400	56,450	56,500
CLASS 3 LPG	Fuel economy	MPGP	AFM	11.29	11.45	11.60	11.98	12.36	12.68	13.01	13.33	13.66	13.90	14.14	14.38	14.52	14.65
	Price	2017 $		53,500	53,700	53,900	54,050	54,250	54,300	54,350	54,400	54,525	54,650	54,775	54,900	54,950	55,000
CLASS 3 EL.HYBRID	Fuel economy	MPGG	OEM				20.86	21.52	22.08	22.65	23.22	23.79	24.20	24.62	25.04	25.28	25.52
	Price	2017 $					49,550	49,555	49,416	49,282	49,154	49,107	49,064	49,027	48,994	48,892	48,793
CLASS 3 BEV	Fuel economy	MPKWH	OEM	1.20	1.21	1.22	1.24	1.25	1.26	1.27	1.29	1.30	1.31	1.33	1.34	1.35	1.37
	Price	2017 $		84,500	82,600	80,805	79,060	77,459	75,799	74,224	72,730	71,389	70,120	68,922	67,790	66,645	65,560
CLASS 3 MOTORHOME GAS	Fuel economy	MPGG	AFM	14.16	14.35	14.54	15.01	15.49	15.89	16.30	16.71	17.12	17.42	17.72	18.02	18.19	18.36
	Price	2017 $		107,500	107,700	107,900	108,050	108,250	108,300	108,350	108,400	108,525	108,650	108,775	108,900	108,950	109,000
CLASS 3 MOTORHOME DIESEL	Fuel economy	MPDG	AFM	16.58	16.78	16.98	17.20	17.40	17.87	18.33	18.79	19.26	19.60	19.94	20.28	20.38	20.47
	Price	2017 $		114,500	114,700	114,900	115,050	115,250	115,300	115,350	115,400	115,525	115,650	115,775	115,900	115,950	116,000
CLASS 4 /5 GASOLINE	Fuel economy	MPGG	OEM	6.9	7.09	7.28	7.47	7.66	7.81	7.95	8.10	8.19	8.29	8.38	8.45	8.51	8.58
	Price	2017 $		46,400	46,690	46,980	47,270	47,560	47,847	48,133	48,420	48,603	48,787	48,970	49,047	49,123	49,200
CLASS 4/5 DIESEL	Fuel economy	MPDG	OEM	8.63	8.87	9.11	9.34	9.58	9.85	10.11	10.38	10.53	10.67	10.82	10.90	10.98	11.06
	Price	2017 $		54,300	54,590	54,880	55,170	55,460	55,747	56,033	56,320	56,503	56,687	56,870	56,963	57,057	57,150
CLASS 4/5 E85	Fuel economy	MPEG	OEM	4.97	5.10	5.24	5.38	5.52	5.62	5.73	5.83	5.90	5.97	6.03	6.08	6.13	6.18
	Price	2017 $		46,400	46,690	46,980	47,270	47,560	47,847	48,133	48,420	48,603	48,787	48,970	49,047	49,123	49,200
CLASS 4/5 CNG	Fuel economy	MPGGE	AFM	6.56	6.74	6.92	7.10	7.28	7.42	7.56	7.70	7.78	7.87	7.96	8.02	8.09	8.15
	Price	2017 $		58,900	59,190	59,480	59,770	60,060	60,347	60,633	60,920	61,103	61,287	61,470	61,547	61,623	61,700
CLASS 4/5 LPG	Fuel economy	MPGGE	AFM	5.23	5.37	5.52	5.66	5.81	5.92	6.03	6.14	6.21	6.28	6.35	6.40	6.45	6.50
	Price	2017 $		57,400	57,690	57,980	58,270	58,560	58,847	59,133	59,420	59,603	59,787	59,970	60,047	60,123	60,200
CLASS 4/5 EL.HYBRID	Fuel economy	MPGG	OEM				9.86	10.11	10.30	10.50	10.69	10.82	10.94	11.06	11.15	11.24	11.33
	Price	2017 $					54,770	54,835	54,903	54,978	55,060	55,044	55,034	55,030	54,925	54,825	54,731

	Attribute	unit	type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CLASS 4/5 DIESEL HH	Fuel economy	MPDG	OEM	10.79	11.08	11.38	11.68	11.98	12.31	12.64	12.98	13.16	13.34	13.53	13.63	13.73	13.83
	Price	2017 $		78,300	78,590	78,880	79,170	79,460	79,747	80,033	80,320	80,503	80,687	80,870	80,963	81,057	81,150
CLASS 4/5 BEV	Fuel economy	MPKWH	OEM	1.050	1.061	1.071	1.082	1.093	1.104	1.115	1.126	1.137	1.148	1.160	1.171	1.183	1.195
	Price	2017 $		140,900	136,465	132,266	128,292	124,531	120,969	117,600	114,413	111,297	108,345	105,551	102,798	100,187	97,711
CLASS 6 GASOLINE	Fuel economy	MPGG	OEM	4.99	5.12	5.24	5.36	5.49	5.63	5.77	5.91	6.00	6.09	6.18	6.22	6.25	6.28
	Price	2017 $		58,300	58,588	58,875	59,163	59,450	59,770	60,090	60,410	60,630	60,850	61,070	61,213	61,357	61,500
CLASS 6 DIESEL	Fuel economy	MPDG	OEM	6.24	6.40	6.55	6.71	6.86	7.04	7.21	7.39	7.50	7.62	7.73	7.77	7.81	7.85
	Price	2017 $		67,300	67,588	67,875	68,163	68,450	68,770	69,090	69,410	69,630	69,850	70,070	70,213	70,357	70,500
CLASS 6 DIESEL EL. HYBRID	Fuel economy	MPDG	OEM	7.488	7.674	7.86	8.046	8.232	8.444	8.656	8.868	9.004	9.14	9.276	9.324	9.372	9.42
	Price	2017 $		87,300	86,988	86,693	86,416	86,156	85,945	85,749	85,570	85,305	85,055	84,818	84,519	84,234	83,961
CLASS 6 DIESEL HY. HYBRID	Fuel economy	MPDG	AFM	7.36	7.55	7.73	7.91	8.09	8.30	8.51	8.72	8.85	8.99	9.12	9.17	9.22	9.26
	Price	2017 $		91,300	91,588	91,875	92,163	92,450	92,770	93,090	93,410	93,630	93,850	94,070	94,213	94,357	94,500
CLASS 6 CNG	Fuel economy	MPDG	AFM	5.30	5.44	5.57	5.70	5.83	5.98	6.13	6.28	6.38	6.47	6.57	6.60	6.64	6.67
	Price	2017 $		102,300	102,588	102,875	103,163	103,450	103,770	104,090	104,410	104,630	104,850	105,070	105,213	105,357	105,500
CLASS 6 BEV	Fuel economy	MPKWH	OEM	0.904	0.913	0.922	0.931	0.941	0.950	0.960	0.969	0.979	0.989	0.999	1.009	1.019	1.029
	Price	2017 $		179,300	178,468	177,646	176,836	176,037	175,281	174,536	173,801	172,977	172,164	171,361	170,491	169,632	166,797
CLASS 6 MOTORHOME DIESEL	Fuel economy	MPDG	AFM	7.33	7.44	7.55	7.66	7.77	7.92	8.07	8.22	8.26	8.30	8.34	8.36	8.38	8.40
	Price	2017 $		142,000	142,213	142,425	142,638	142,850	142,992	143,133	143,275	143,350	143,425	143,500	143,533	143,567	143,600
CLASS 6 MOTORHOME GASOLINE	Fuel economy	MPGG	AFM	5.79	5.86	5.94	6.01	6.08	6.16	6.24	6.32	6.36	6.39	6.43	6.46	6.49	6.52
	Price	2017 $		134,000	134,213	134,425	134,638	134,850	134,992	135,133	135,275	135,350	135,425	135,500	135,550	135,600	135,650
CLASS 7 LR	Fuel economy	MPDG	OEM	6.96	7.15	7.34	7.53	7.72	7.87	8.01	8.16	8.26	8.36	8.47	8.49	8.52	8.55
	Price	2017 $		93,400	94,684	95,967	97,251	98,534	99,502	100,469	101,437	102,170	102,902	103,635	103,723	103,812	103,900
CLASS 7 EHEV	Fuel economy	MPDG	OEM				8.43	8.65	8.81	8.97	9.14	9.25	9.37	9.48	9.51	9.54	9.58
	Price						133,251	133,454	133,374	133,326	133,308	133,084	132,889	132,722	131,938	131,180	130,447
CLASS 7 CNG	Fuel economy	MPDGE	AFM	5.98	6.15	6.31	6.47	6.64	6.77	6.89	7.02	7.11	7.19	7.28	7.30	7.33	7.35
	Price	2017 $		128,400	129,684	130,967	132,251	133,534	134,502	135,469	136,437	137,170	137,902	138,635	138,723	138,812	138,900
CLASS 8 SINGLE UNIT	Fuel economy	MPDG	OEM	4.77	4.88	4.99	5.09	5.20	5.34	5.47	5.61	5.71	5.80	5.90	5.92	5.94	5.96
	Price	2017 $		96,950	97,363	97,775	98,188	98,600	99,333	100,067	100,800	101,192	101,583	101,975	102,150	102,325	102,500
CLASS 8 SINGLE UNIT CNG	Fuel economy	MPDGE	AFM	4.10	4.19	4.29	4.38	4.47	4.59	4.71	4.82	4.91	4.99	5.07	5.09	5.11	5.13
	Price	2017 $		151,950	152,363	152,775	153,188	153,600	154,333	155,067	155,800	156,192	156,583	156,975	157,150	157,325	157,500
CLASS 8 SINGLE UNIT LNG	Fuel economy	MPDGE	AFM	4.10	4.19	4.29	4.38	4.47	4.59	4.71	4.82	4.91	4.99	5.07	5.09	5.11	5.13
	Price	2017 $		161,950	162,363	162,775	163,188	163,600	164,333	165,067	165,800	166,192	166,583	166,975	167,150	167,325	167,500

	Attribute	unit	type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CLASS 8 CA COMBINATION	Fuel economy	MPDGE	OEM	5.54	5.72	5.90	6.08	6.26	6.36	6.46	6.56	6.69	6.82	6.95	6.98	7.02	7.05
	Price	2017 $		119,500	120,830	122,160	123,490	124,820	125,500	126,180	126,860	127,273	127,687	128,780	128,887	128,993	129,100
CLASS 8 CA COMBINATION CNG	Fuel economy	MPDGE	AFM	5.26	5.43	5.61	5.78	5.95	6.04	6.14	6.23	6.36	6.48	6.60	6.63	6.67	6.70
	Price	2017 $		194,500	195,830	197,160	198,490	199,820	200,500	201,180	201,860	202,273	202,687	203,780	203,887	203,993	204,100
CLASS 8 CA COMBINATION LNG	Fuel economy	MPDGE	AFM	5.26	5.43	5.61	5.78	5.95	6.04	6.14	6.23	6.36	6.48	6.60	6.63	6.67	6.70
	Price	2017 $		204,500	205,830	207,160	208,490	209,820	210,500	211,180	211,860	212,273	212,687	213,780	213,887	213,993	214,100
CLASS 8 CA COMBINATION EL	Fuel economy	MPKWH	AFM			0.280	0.295	0.310	0.313	0.315	0.318	0.323	0.327	0.332	0.333	0.334	0.335
(Direct / Catenary Electric)	Price	2017 $				162,160	163,160	164,160	164,690	165,220	165,750	166,260	166,770	167,280	167,353	167,427	167,500
CLASS 8 CA COMBINATION FC	Fuel economy	MPKGH2	AFM			5.82	6.14	6.45	6.50	6.56	6.61	6.71	6.80	6.90	6.92	6.94	6.96
(Fuel Cell)	Price	2017 $				207,160	206,790	206,454	205,501	204,581	203,693	202,570	201,477	201,095	199,755	198,445	197,162
CLASS 8 COMBINATION DIESEL	Fuel economy	MPDGE	OEM	6.21	6.41	6.62	6.82	7.02	7.16	7.31	7.45	7.68	7.90	8.13	8.14	8.15	8.16
	Price	2017 $		142,000	143,818	145,635	147,453	149,270	150,530	151,790	153,050	153,533	154,017	154,500	154,700	154,900	155,100
CLASS 8 COMBINATION CNG	Fuel economy	MPDGE	OEM	5.90	6.09	6.28	6.48	6.67	6.81	6.94	7.08	7.29	7.51	7.72	7.73	7.74	7.75
	Price	2017 $		217,000	218,818	220,635	222,453	224,270	225,530	226,790	228,050	228,533	229,017	229,500	229,700	229,900	230,100
CLASS 8 COMBINATION LNG	Fuel economy	MPDGE	OEM	5.60	5.79	5.97	6.15	6.34	6.46	6.59	6.72	6.93	7.13	7.34	7.35	7.36	7.36
	Price	2017 $		302,000	303,818	305,635	307,453	309,270	310,530	311,790	313,050	313,533	314,017	314,500	314,700	314,900	315,100
CLASS 8 GARBAGE DIESEL	Fuel economy	MPDGE	OEM	4.22	4.25	4.28	4.31	4.34	4.37	4.41	4.44	4.48	4.51	4.55	4.57	4.59	4.61
	Price	2017 $		191,600	191,933	192,265	192,598	192,930	193,463	193,997	194,530	194,937	195,343	195,750	195,900	196,050	196,200
CLASS 8 GARBAGE DIESEL EL. HYBRID	Fuel economy	MPDG	OEM	5.06	5.10	5.14	5.17	5.21	5.25	5.29	5.33	5.37	5.42	5.46	5.48	5.51	5.53
	Price	2017 $		231,600	230,733	229,901	229,104	228,342	227,813	227,316	226,849	226,286	225,753	225,247	224,512	223,804	223,121
CLASS 8 GARBAGE DIESEL HY. HYBRID	Fuel economy	MPDG	AFM	4.98	5.02	5.05	5.09	5.12	5.16	5.20	5.24	5.28	5.33	5.37	5.39	5.42	5.44
	Price	2017 $		226,600	226,933	227,265	227,598	227,930	228,463	228,997	229,530	229,937	230,343	230,750	230,900	231,050	231,200
CLASS 8 GARBAGE CNG	Fuel economy	MPDG	AFM	3.59	3.61	3.64	3.66	3.69	3.72	3.75	3.77	3.81	3.84	3.87	3.88	3.90	3.92
	Price	2017 $		246,600	246,933	247,265	247,598	247,930	248,463	248,997	249,530	249,937	250,343	250,750	250,900	251,050	251,200
CLASS 8 GARBAGE LNG	Fuel economy	MPDG	AFM	3.59	3.61	3.64	3.66	3.69	3.72	3.75	3.77	3.81	3.84	3.87	3.88	3.90	3.92
	Price	2017 $		256,600	256,933	257,265	257,598	257,930	258,463	258,997	259,530	259,937	260,343	260,750	260,900	261,050	261,200
URBAN TRANSIT DIESEL	Fuel economy	MPDG	OEM	3.42	3.45	3.47	3.50	3.52	3.56	3.60	3.64	3.67	3.71	3.75	3.77	3.78	3.80
	Price	2017 $		485,000	485,333	485,665	485,998	486,330	485,800	485,270	484,740	485,877	487,013	488,150	488,600	489,050	489,500
URBAN TRANSIT DIESEL EL HYBRID	Fuel economy	MPDG	AFM	4.55	4.58	4.62	4.65	4.68	4.73	4.78	4.83	4.89	4.94	4.99	5.01	5.03	5.05
	Price	2017 $		750,000	742,383	735,004	727,856	720,933	713,365	706,008	698,855	693,569	688,475	683,567	678,155	672,918	667,852
URBAN TRANSIT DIESEL HY. HYBRID	Fuel economy	MPDG	AFM	4.28	4.31	4.34	4.37	4.40	4.45	4.50	4.54	4.59	4.64	4.69	4.71	4.73	4.75
	Price	2017 $		535,000	535,333	535,665	535,998	536,330	535,800	535,270	534,740	535,877	537,013	538,150	538,600	539,050	539,500

	Attribute	unit	type	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
URBAN TRANSIT CNG	Fuel economy	MPDG	AFM	2.91	2.93	2.95	2.97	2.99	3.02	3.06	3.09	3.12	3.15	3.19	3.20	3.22	3.23
	Price	2017 $		530,000	530,333	530,665	530,998	531,330	530,800	530,270	529,740	530,877	532,013	533,150	533,600	534,050	534,500
URBAN TRANSIT BEV	Fuel economy	MPKWH	OEM	0.250	0.251	0.251	0.252	0.252	0.253	0.253	0.254	0.254	0.255	0.255	0.256	0.256	0.257
	Price	2017 $		800,000	794,033	788,191	782,473	776,876	770,535	764,310	758,200	753,867	749,644	745,528	740,830	736,236	731,742
URBAN TRANSIT FCEV	Fuel economy	MPKGH2	OEM					5.16	5.17	5.18	5.19	5.20	5.21	5.22	5.23	5.24	5.25
	Price	2017 $						986,330	975,800	965,470	955,336	947,061	938,974	931,071	922,663	914,432	906,374
SHUTTLE BUS GASOLINE	Fuel economy	MPGG	OEM	6.9	7.09	7.28	7.47	7.66	7.81	7.95	8.10	8.19	8.29	8.38	8.45	8.51	8.58
	Price	2017 $		76,400	76,690	76,980	77,270	77,560	77,847	78,133	78,420	78,603	78,787	78,970	79,047	79,123	79,200
SHUTTLE BUS DIESEL	Fuel economy	MPDG	OEM	8.63	8.87	9.11	9.34	9.58	9.85	10.11	10.38	10.53	10.67	10.82	10.90	10.98	11.06
	Price	2017 $		84,300	84,590	84,880	85,170	85,460	85,747	86,033	86,320	86,503	86,687	86,870	86,963	87,057	87,150
SHUTTLE BUS E85	Fuel economy	MPGE	OEM	4.97	5.10	5.24	5.38	5.52	5.62	5.73	5.83	5.90	5.97	6.03	6.08	6.13	6.18
	Price	2017 $		76,400	76,690	76,980	77,270	77,560	77,847	78,133	78,420	78,603	78,787	78,970	79,047	79,123	79,200
SHUTTLE BUS CNG	Fuel economy	MPGGE	AFM	6.56	6.74	6.92	7.10	7.28	7.42	7.56	7.70	7.78	7.87	7.96	8.02	8.09	8.15
	Price	2017 $		88,900	89,190	89,480	89,770	90,060	90,347	90,633	90,920	91,103	91,287	91,470	91,547	91,623	91,700
SHUTTLE BUS DIESEL HYD. HYBRID	Fuel economy	MPGP	AFM	10.53	10.82	11.11	11.40	11.69	12.01	12.34	12.66	12.84	13.02	13.20	13.30	13.40	13.49
	Price	2017 $		108,300	108,590	108,880	109,170	109,460	109,747	110,033	110,320	110,503	110,687	110,870	110,963	111,057	111,150
SHUTTLE BUS BEV	Fuel economy	MPKWH	OEM	1.050	1.061	1.071	1.082	1.093	1.104	1.115	1.126	1.137	1.148	1.160	1.171	1.183	1.195
	Price	2017 $		824,500	817,308	810,302	803,479	796,831	789,493	782,320	775,309	770,121	765,085	760,197	754,766	749,475	744,319
SCHOOL BUS GASOLINE	Fuel economy	MPGG	OEM	6.25	6.42	6.60	6.77	6.94	7.05	7.17	7.28	7.39	7.51	7.62	7.63	7.64	7.65
	Price	2017 $		89,300	89,588	89,875	90,163	90,450	90,770	91,090	91,410	91,630	91,850	92,070	92,213	92,357	92,500
SCHOOL BUS DIESEL	Fuel economy	MPDG	OEM	7.81	8.87	9.11	9.34	9.58	9.85	10.11	10.38	10.53	10.67	10.82	10.90	10.98	11.06
	Price	2017 $		97,300	97,588	97,875	98,163	98,450	98,770	99,090	99,410	99,630	99,850	100,070	100,213	100,357	100,500
SCHOOL BUS BEV	Fuel economy	MPKWH	OEM	0.904	0.913	0.922	0.931	0.941	0.950	0.960	0.969	0.979	0.989	0.999	1.009	1.019	1.029
	Price	2017 $		124,300	123,538	122,807	122,106	121,435	120,826	120,244	119,689	119,061	118,458	117,880	117,249	116,641	116,056
SCHOOL BUS CNG	Fuel economy	MPGGE	AFM	5.94	6.10	6.27	6.43	6.59	6.70	6.81	6.92	7.02	7.13	7.24	7.25	7.26	7.27
	Price	2017 $		109,300	109,588	109,875	110,163	110,450	110,770	111,090	111,410	111,630	111,850	112,070	112,213	112,357	112,500
SCHOOL BUS LPG	Fuel economy	MPGP	AFM	4.74	4.87	5.00	5.13	5.26	5.35	5.43	5.52	5.60	5.69	5.78	5.78	5.79	5.80
	Price	2017 $		107,300	117,588	117,875	118,163	118,450	118,770	119,090	119,410	119,630	119,850	120,070	120,213	120,357	120,500
MOTOR COACH DIESEL	Fuel economy	MPDG	OEM	6.96	7.15	7.34	7.53	7.72	7.87	8.01	8.16	8.26	8.36	8.47	8.49	8.52	8.55
	Price	2017 $		350,000	351,284	352,567	353,851	355,134	356,102	357,069	358,037	358,770	359,502	360,235	360,323	360,412	360,500
MOTOR COACH CNG	Fuel economy	MPDGE	OEM	5.91	6.07	6.24	6.40	6.56	6.69	6.81	6.94	7.02	7.11	7.20	7.22	7.24	7.27
	Price	2017 $		385,000	386,284	387,567	388,851	390,134	391,102	392,069	393,037	393,770	394,502	395,235	395,323	395,412	395,500

LIST OF ACRONYMS

A	Area
AMT	Automated manual transmission
APU	Auxiliary power unit
ATI	Automatic tire inflation
CAFE	Corporate average fuel economy
CARB	California Air Resources Board
C_d	Coefficient of drag
Energy Commission	California Energy Commission
CNG	Compressed natural gas
CO_2	Carbon dioxide, a greenhouse gas
DOE	United States Department of Energy
E85	A blend of 15 percent gasoline and 85 percent ethanol used to fuel dedicated ethanol powered vehicles and flex-fuel vehicles
EGR	Exhaust gas recirculation
U.S. EPA	United States Environmental Protection Agency
EU	European Union
GHG	Greenhouse gas
GVW	Gross vehicle weight
GVWR	Gross vehicle weight rating
HDS	H-D Systems
HHDT	Heavy-heavy duty truck
HVAC	Heating, ventilation, and air conditioning
IEPR	*Integrated Energy Policy Report*
kg	Kilogram
kW	Kilowatt, a unit of power
kWh	Kilowatt-hour, a unit of energy
LHD	Light-heavy duty (truck)
LNG	Liquefied natural gas
MDT	Medium-duty truck

MHD	Medium-heavy-duty (truck)
MPDG	Miles per diesel gallon
MPDGE	Miles per diesel gallon equivalent
MPEG	Miles per E85 gallon
MPG	Miles per gallon
MPGG	Miles per gasoline gallon
MPGGE	Miles per gasoline gallon equivalent
MPH	Miles per hour
MPKGH2	Miles per kilogram of hydrogen
MPKWH	Miles per kilowatt-hour
MPGP	Miles per gallon of propane
NHTSA	National Highway Traffic Safety Administration
NO_X	Nitrogen oxide
OEM	Original equipment manufacturer
PCCI	Premixed charge compression ignition
PM	Particulate matter
RIA	Regulatory Impact Assessment
SCR	Selective catalytic reformer
SwRI	Southwest Research Institute
TIUS	Truck Inventory and Use Survey
TPM	Tire-pressure monitoring
V10	Internal combustion engine with 10 cylinders
V8	Internal combustion engine with 8 cylinders
VIUS	Vehicle Inventory and Use Survey
WBS	Wide-base singles
WHR	Waste heat recovery

ATTACHMENT I:
H-D Systems (EEA) Report to Department Of Energy on Heavy-Duty Truck Fuel Economy

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ENERGY AND ENVIRONMENTAL ANALYSIS, INC.



TECHNOLOGICAL POTENTIAL TO REDUCE HEAVY-DUTY TRUCK FUEL CONSUMPTION TO 2025

REVISED FINAL REPORT

PREPARED FOR:

U. S. DEPARTMENT OF ENERGY

UNDER SUBCONTRACT NO.4000106324
UT-BATELLE LLC
OAK RIDGE NATIONAL LABORATORY

PREPARED BY:

H-D SYTEMS
WASHINGTON DC 20016

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1 INTRODUCTION

While there has been considerable attention paid to the costs and benefits of reducing fuel consumption and greenhouse gases from light-duty vehicles, heavy-duty commercial vehicles have received much less attention in spite of the fact that total fuel consumption is a significant and growing part of total transportation related fuel consumption. Some of this lack of attention is due to the widespread belief that trucking is an efficient market for fuel economy technology since fuel cost is a significant component of total cost of truck operation, and the commercial nature of the operation suggests that market inefficiencies will be resolved. However, discussions with truck fleet operators and truck manufacturers show that customers are unwilling to pay for technology that cannot demonstrate simple payback from fuel savings in about 3 years or less, which implies a steep discount on the value of lifetime fuel savings. This is partly due to the fact that new trucks are intensively used for the first 4 to 5 years of operation and then sold to second owners who use them much less intensively. Hence, the first owner usually expects to recapture the value of additional technology investment within the ownership period rather than expect some payback in the resale market. This report examines available technology to improve truck fuel efficiency and estimates their cost and benefit to develop a supply curve of fuel efficiency. The outcomes from different assumptions on the payback in terms of fuel savings allow a detailed computation of fuel savings and the cost of GHG reduction from the commercial truck sector.

Section 2 provides a summary of the characteristics of the existing fleet of heavy trucks, sub-divided into three classes based on the gross vehicle weight, termed light-heavy, medium-heavy and heavy-heavy. The data shows the use, annual mileage and fuel economy of each of these sub-classes and this type of data is used to gauge the applicability and benefit of different technologies to each sub-class. The data is from the 2002 VIUS which is relatively old but is unfortunately the only source of comprehensive data on truck use and real world fuel economy at the disaggregate level desired for this

analysis. In addition, section 2 discusses the typical drive cycles over which fuel consumption should be evaluated. Trucks are used in a variety of applications ranging from long haul to vocational use. The lack of a fixed reference drive cycle by application is a major drawback in the analysis of fuel economy potential and this section makes a preliminary attempt to define specific drive cycles and the attendant energy losses for a number of different uses. These cycles and energy loss estimates form the basis for the technology benefit estimates over different applications. Since the completion of the draft of this report, the EPA and DOT have issued HDT fuel economy and GHG standards for 2014 and 2017, and have specified drive cycles for reference. The new drive cycles are compared to our findings in this report.

Section 3 provides a discussion of the available drive-train technology to improve fuel economy and most of this data was obtained from interviews of the staff of different heavy-duty engine manufacturers. The DOE's 21st Century Truck Program has sponsored a series of conferences on engine efficiency to assess the goal of attaining 50 percent thermal efficiency in the near term and 55 percent efficiency in the longer term for the diesel engine. Technologies identified to meet these goals were assessed for their potential to meet the goals at reasonable cost, and be brought to market in the time frame of interest. Based on engine manufacturer inputs, technologies were classified by cost and potential time frame of introduction.

Section 4 provides an analysis of technologies affecting aerodynamic drag, rolling resistance and weight reduction, i.e., body technologies. Many of these technologies have been available in the aftermarket for a long time but most have yet to attain significant market penetration. Our analysis focuses on the actual as opposed to claimed benefits and also examines potential negative attributes that may have contributed to the limited market penetration to date. In addition, our analysis focuses on the fact that many technologies' benefits are dependent on the baseline; for example, the benefits of many drag reducing technologies depends on the aerodynamic characteristics of the base truck and technology benefits cannot be treated as additive. This analysis creates a framework for examining marginal benefits based on the drag coefficient of current trucks versus the drag coefficient thought to be ultimately attainable.

Unlike the light-duty sector, fuel savings are also available from operational enhancements that range from reducing idle time to improved maintenance and driving practices. Operational strategies are not a focus of this effort but are summarized since many reports on truck fuel economy add these benefits to those attained by technology improvements, Data on these operational enhancements were largely derived from existing studies conducted by regulatory agencies such as the EPA, and the benefits and costs of these operational improvements are also included in section 5. One improvement is associated with idle reduction devices that fall between a pure vehicle technology enhancement and an operational enhancement, since the engine is often used to provide HVAC services for sleeper cabs overnight. This technology is considered in some detail in this report.

Section 6 documents the construction of the supply curves and the cost-benefit of technology in broad categories. The supply curves are developed by vehicle class, range of operation and body style for a total of 14 different truck sub-classes The analysis provides some insight into the future potential for fuel economy improvements under a free market and GHG based intervention scenario. One of the interesting findings of this analysis is that the potential maximum technology benefits in reducing fuel consumption are similar across most vehicle classes and use types but have very different cost and payback implications. The revised report also examines compliance with the new fuel economy standards and the expectation for real world fuel economy.

2 BASELINE DATA ON TRUCK CHARACTERISTICS AND OPERATIONS

2.1 OVERVIEW

The objective of this study is to develop estimates of the costs and benefits of a variety of fuel economy improvement options for the heavy-duty trucking sector in order to create a supply curve of fuel efficiency. This section provides an outline of the data that are used in the construction of this curve. This study considers technology-based fuel economy improvements as well as improvements in trucking operational efficiencies. The functional fleet-wide impact of the fuel economy improvement available from some of the technology options, and all of the operational options, are a function of both the per vehicle fuel economy potential of the option as well the operational characteristics of the fleet – that is, the portion of the fleet for which the option is applicable. This section presents data that are relevant for the entire fleet, and also documents the operational characteristics that are relevant for particular fuel efficiency improvements applicable to a sub-set of the trucking population.

Data for this study about the composition of the heavy-duty trucking vehicle fleet, and operational characteristics of vehicle use are drawn from the VIUS. The VIUS was conducted every five years from 1967 through 2002 (but suspended since). The VIUS data is from a survey conducted by the US Census Bureau that includes data on the physical and operating characteristics of the US truck population. The survey, the most recent version of which was collected in 2002/3, includes 98,682 observations with 453 variables on each truck.

The Motor Fuel Consumption model (MFCM) was used to estimate future fuel use and GHG emissions. The MFCM provides detailed projections of fuel demand by fuel type and vehicle type, given detailed inputs on the fleet characteristics. In this sense, the MFCM is an accounting model and has no built-in econometric framework, so that its

projections are directly connected to inputs with no intermediate processing involving assumptions on consumer behavior. This simplicity has been useful for examining the potential impact of changes in vehicle fleet or fuel characteristics. Since the MFCM outputs are so input driven, the inputs have been periodically revised. DOE has used the MFCM since the late 1970's to project on-highway fuel demand.

In this analysis, the heavy-duty truck segment is broken into three sub-categories – Light Heavy-Duty Trucks (LHDT), Medium Heavy-Duty Trucks (MHDT), and Heavy Heavy-Duty Trucks (HHDT) – in order to properly represent the technological and operational differences between the vehicles in each sub-category. LHDT, mostly large pickups and large cargo vans, share many components with vehicles in the light-duty vehicle sector and for this analysis include all vehicles in GVW classes 3, 4 and 5. These vehicles are generally operated about 27,000 $\pm$ 3000 miles per year, and a substantial fraction of the fleet is powered by gasoline engines (~50% in 2002). MHDT include a broad range of vehicle types (pickup and delivery, rough duty for construction and mining applications, municipal waste, fire and emergency, and city buses), the majority of which are used in local or regional operations. This category included GVW classes 6, 7 and 8A and trucks in this class are typically used 35,000 $\pm$ 3000 miles per year, and the fleet is over 90% diesel. Gasoline engines for this subclass were phased out in the 1990s. HHDT (GVW class 8B) dominate heavy trucking fuel demand and are comprised mostly of long-haul tractor trailers (70% of HHDT) along with some construction and mining trucks. The trucks are used for long haul applications and average 98,000 miles per year. These trucks have been 100% diesel powered for many decades. Due to the differences in the technological make up and operational characteristics of each of the heavy-duty trucking segments, each sub-class is considered separately in this analysis. Data at this level of aggregation is utilized in this report to estimate the applicability and cost-effectiveness of different technological options to reduce fuel consumption

The VIUS dataset includes a variable for GVW classification with 15 categories. These GVW categories were combined to create LHDT, MHDT and HHDT distinctions according to the following definition: LHDT covers vehicles in the 8,500 to 19,000 pounds GVW range, MHDT covers vehicles in the 19,001 to 50,000 pounds range and HHDT covers vehicles over 50,000 pounds GVW.

2.2 HEAVY-HEAVY DUTY TRUCK (HHDT) SEGMENT

HHDT dominate demand for highway diesel fuel. The MFCM projects that HHDT will account for 67% of total highway diesel demand in 2020. This is a modest decline in percentage terms from the share in 2007 of 72%; however it represents an absolute increase of 23%, with annual consumption increasing from 26.6 billion gallons to 32.7 billion gallons, over the period as shown in Figure 2-1.

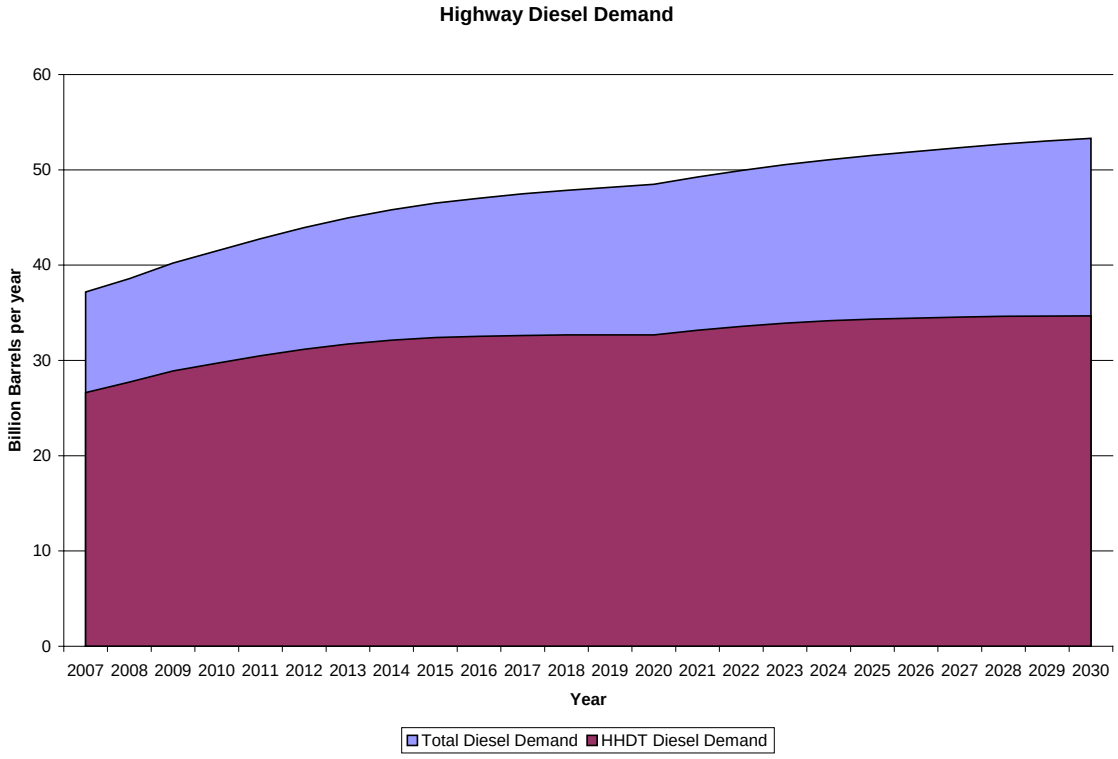


Figure 2-1: HHDT Diesel Demand

HHDT use is the greatest in the first 5 or 6 years of the vehicle lifetime, with annual mileage dropping steadily over the life of the vehicle. Figure 2-2 shows the decline in VMT by vehicle age for HHDT. The consideration of the operational characteristics of HHDT 5 years old or less is important because it represents the vehicle uses for the first-owners of HHDT – those that buy from the new vehicle market. Typically, trucks are used most heavily in their first 3 to 5 years, and are then sold into the secondary market. Efficiency improvements for new vehicles added to the fleet are chosen based on the operational characteristics of vehicles less than 5 years old, while efficiency improvements that are operational or retrofits apply to the entire existing fleet. While

figure 2-2 shows that mileage decreases with age, over a third of all HHDTs travel over 75,000miles annually as shown in Figure 2-3.

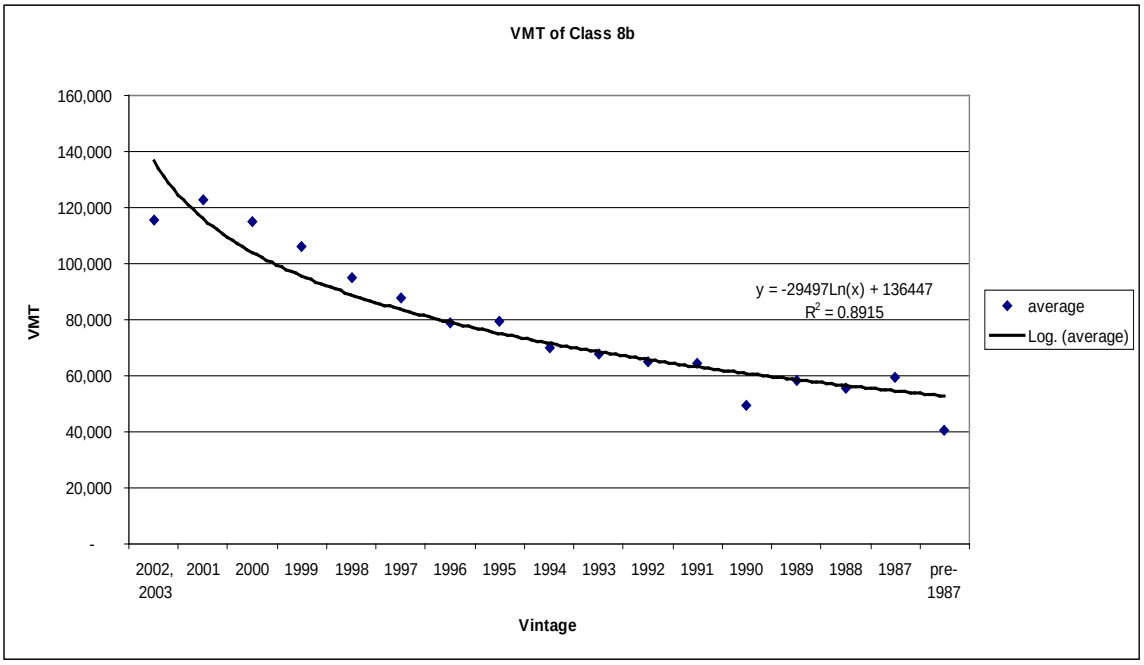


Figure 2-2: VMT by Vintage

Of all HHDT, 69% are tractors, rather than single unit vehicles. VIUS includes a survey question that asks respondents what percent of miles are driven with less than truckload service. This value is useful for calculating the population of vehicles for which fuel economy, on a per ton-mile basis, could be improved by changing government regulations limiting trailer length. 16% of miles, on average, are at less than truckload for tractor-style HHDT, leaving around 58% of total HHDT miles (69% times 84%) applicable for efficiency improvement from changes to trailer length limits.

Mileage is also characterized within VIUS according to the trip-length category in which mileage is accumulated. The largest portion of miles for all heavy-duty trucks up to Class 8A is in trips that are less than 50 miles per trip one-way. The HHDT category has trip length significantly shifted toward longer distance trips compared to the other heavy-duty subcategories as indicated in Figure 2-3. Almost 45% of all Class 8B trucks are used for trips whose length is over 200 miles, and this number is even higher for tractors with van body trailers. Off-road trip mileage is used to indicate vehicles for which advanced

tires are not applicable because of the increased risk of tire damage, and for vehicles for which evolutionary improvements in the front-end aerodynamics are not applicable. Off-road miles are disproportionately distributed among HHDT – that is, most trucks have nearly zero off road mileage and the trucks that do make off road trips account for the majority share of total off-road mileage. The majority of total off-road mileage is accounted for by approximately the small percentage of HHDT that make a relatively high proportion of off-road trips – typically construction or mining vehicles.

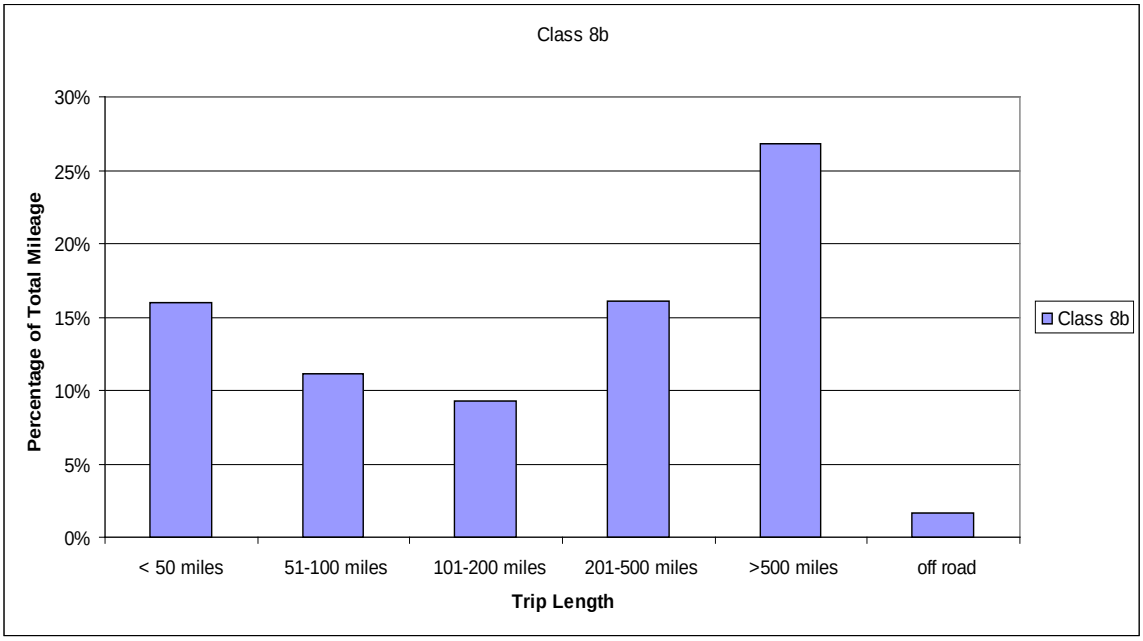


Figure 2-3: Mileage By Trip Length HHDT

For aerodynamic improvements that are related to the trailer, rather than to the front end of the vehicle (tractor related), the vehicle population is limited to HHDT that haul a van-style trailer. Of the entire HHDT fleet, approximately 42% haul a van style trailer while for younger vehicles (again, 5 years old or less) this figure rises to 63%.

Another opportunity for operational fuel savings is via driver training to educate drivers on how to optimize vehicle performance to minimize fuel use and costs. Fleet size is used as a metric of the applicability of this option to improve fuel economy – vehicles in small fleets are expected to benefit from driver training while drivers in large fleets (>20 tractors) usually already have a driver training program in place. The distribution of

HHDT population by fleet size (not including the vehicle surveyed) for both the entire fleet and for the fleet limited to vehicles 5 years old or less show that (summing the categories that are >20 tractors in a fleet) driving training can be applicable for 79% of the existing fleet and 61% of the new vehicle fleet.

Fuel economy by model year shows statistically significant increases over time. As of 2002, the year in which the VIUS data were collected, the average HHDT fuel economy was 5.86 miles per gallon with newer vehicles showing higher fuel economy. Vehicles 5 years or younger average 5.98 miles per gallon and the newest model year vehicles (2002/2003 in this survey) averaging almost 6.1mpg. Figure 2-4 shows the trend of fuel economy against vehicle vintage, and it should be noted that in this case that this is not an effect of truck age, but due to the fact that truck technology improves over time. The rate of improvement observed is about 0.5% per year for all Class 8B trucks but increases to about 0.7% per year for long haul use trucks over the 1987 to 2001 period. Anecdotal evidence suggests that about 0.4% to 0.45% was due to engine improvements and the vehicle improvements account for 0.25% to 0.3% per year on the long haul segment. Trucks used in rough duty applications or short haul appear to have much lower fuel economy gains of only about 0.25% per year, potentially only from engine improvements.

The fuel economy changes after 2001 have been measured by DOT in its comparative evaluation of rail versus truck efficiency, but the data is less reliable than VIUS data due to the much smaller sample size. The lower figure in Figure 2-4 shows that fuel economy actually declined from around 5.9 mpg attained in 2000/2001 to about 5.4 mpg in 2002, which is a decline of about 8.5%, associated with the phase-in of the NOx standard of 4 g.bhp-hr. The incorporation of urea-SCR systems in 2010 appear to have more than reversed the trend and the data shows newest trucks attaining 6.6 mpg. However, the data appears to exaggerate the effects of the NOX standards, and truck manufacturers suggest that the decline from the 4 and 2 g/bhp-hr standards were on the order of 5% which has

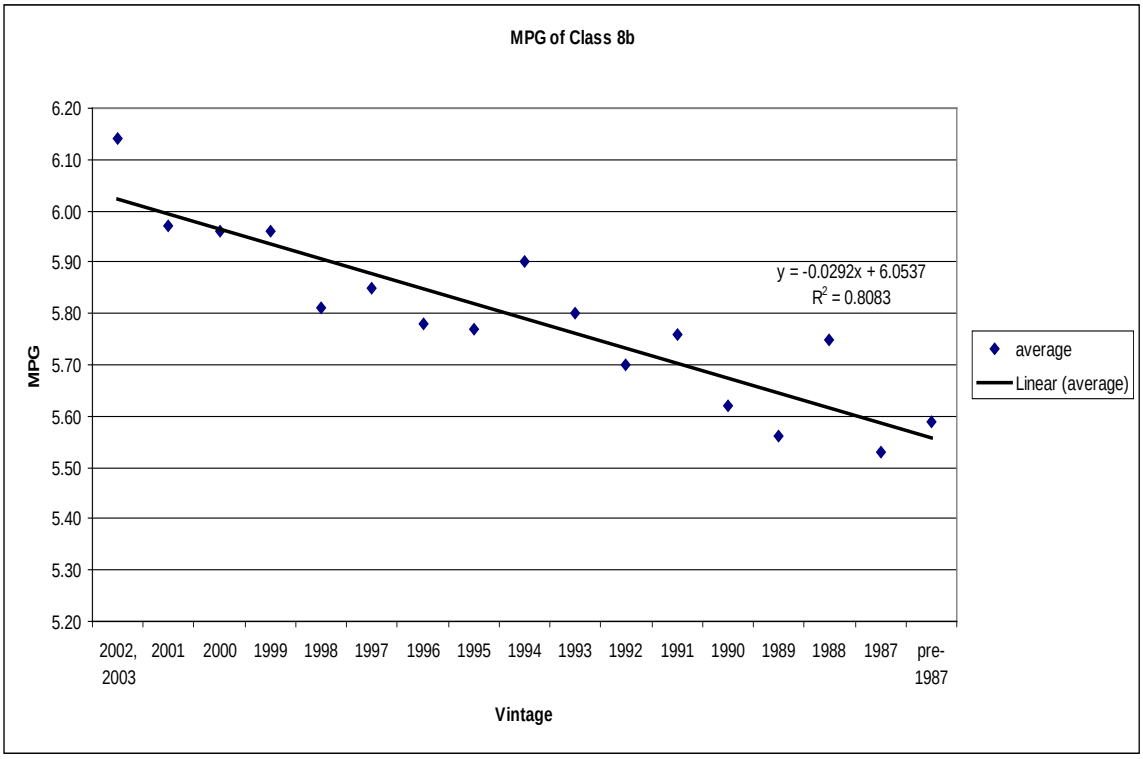
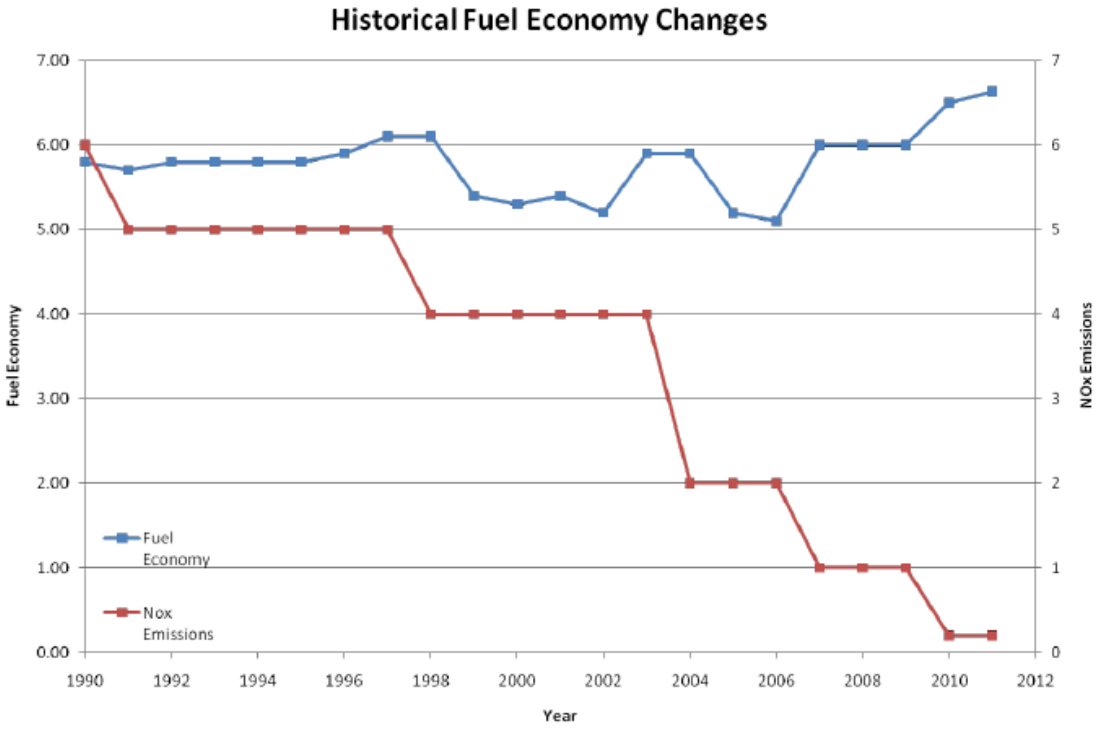


Figure 2-4: HHDT Fuel Economy by Vintage in 2002(above) from VIUS and in 2010(below)



been recovered by the urea-SCR so that new truck FE is about 6 mpg, which is similar to the level attained in 2000.

2.3 LIGHT-HEAVY AND MEDIUM-HEAVY SEGMENTS

Together, LHDT and MHDT account for over a quarter of total highway diesel demand, and this share is projected by the MFCM to increase modestly by 2030. MHDT engines tend to be around 7L to 10L displacement, varying across models by ±1.5L, while LHDT engines have a larger size range, with some domestic trucks having engines as large as 6L to 7L while some import truck models have engines as small as 3 or 4L. The LHDT population is more than double that of MHDT in the fleet, but LHDT consume only slightly more fuel on the whole (by around 12% in 2007) than MHDT as shown in Figure 2-5. As with HHDT, VMT per vehicle drops over time for LHDT and MHDT. Average LHDT mileage for the typical vehicle in the fleet is just over 25,000 annually, and for MHDT the average is just below 35,000 annually. However in the first five years of operation, the average annual mileage for LHDT and MHDT is over 20,000 and 45,000 miles, respectively a shown in Fig 2-6.

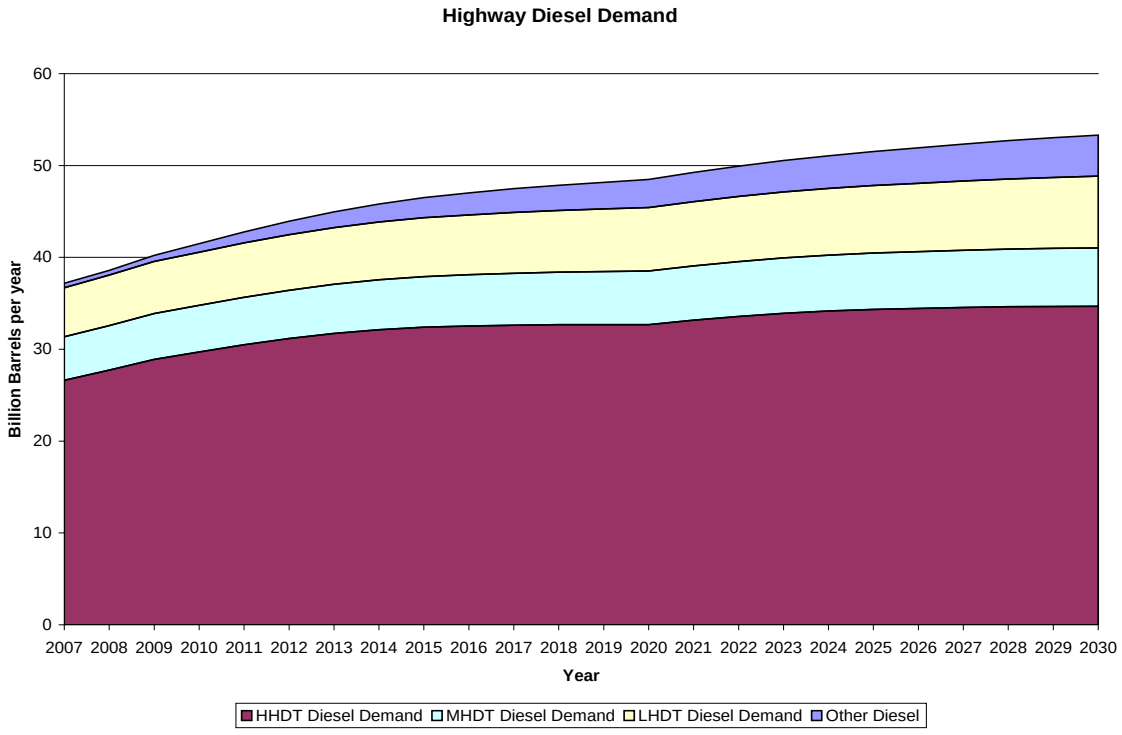


Figure 2-5: Highway Diesel Demand

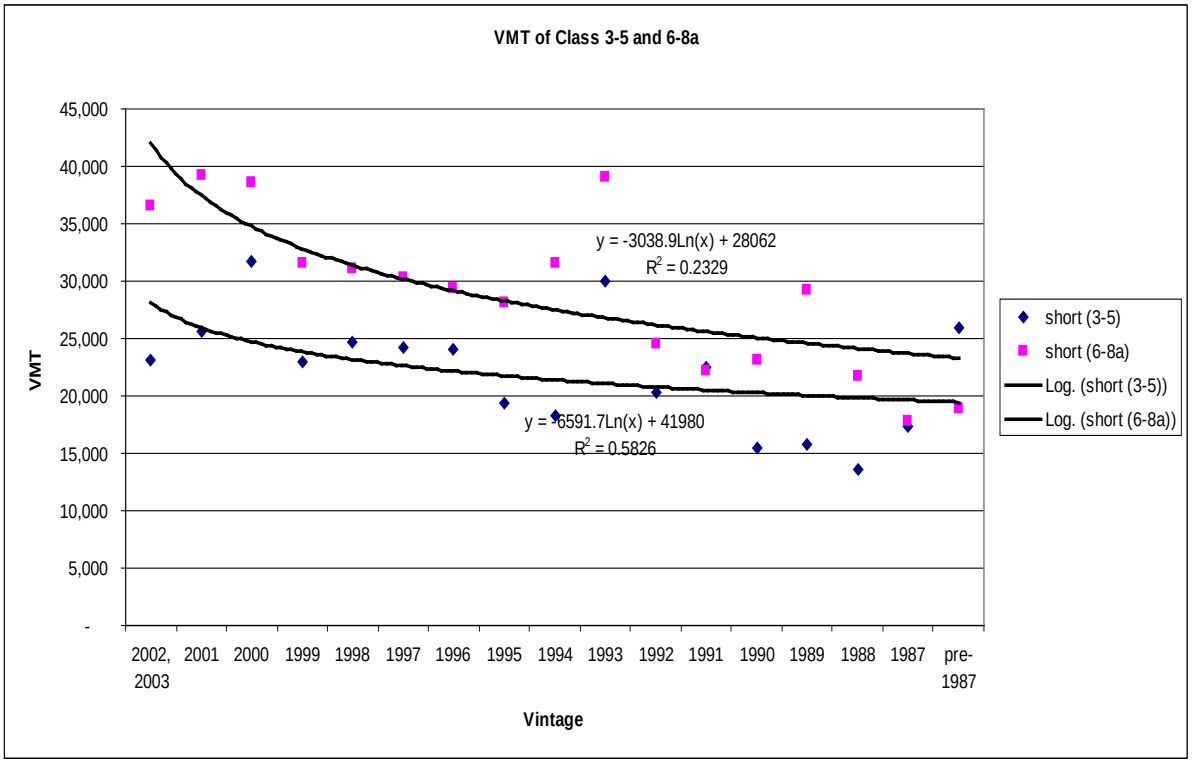


Figure 2-6 Annual Miles by Vintage and Class

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The distribution of mileage among the LHDT and MHDT subcategories is also much less variable than for the HHDT subcategory. Just over 10% of LHDT travel more than 30,000 miles annually, and fewer than 5% travel more than 50,000 miles annually. Similarly, just over 6% of MHDT travel more than 50,000 miles on an annual basis. On the other hand, over a third of MHDT travel less than 5,000 miles on an annual basis and over 70% of both LHDT and MHDT travel less than 20,000 miles annually, as shown in figure 2-7 below

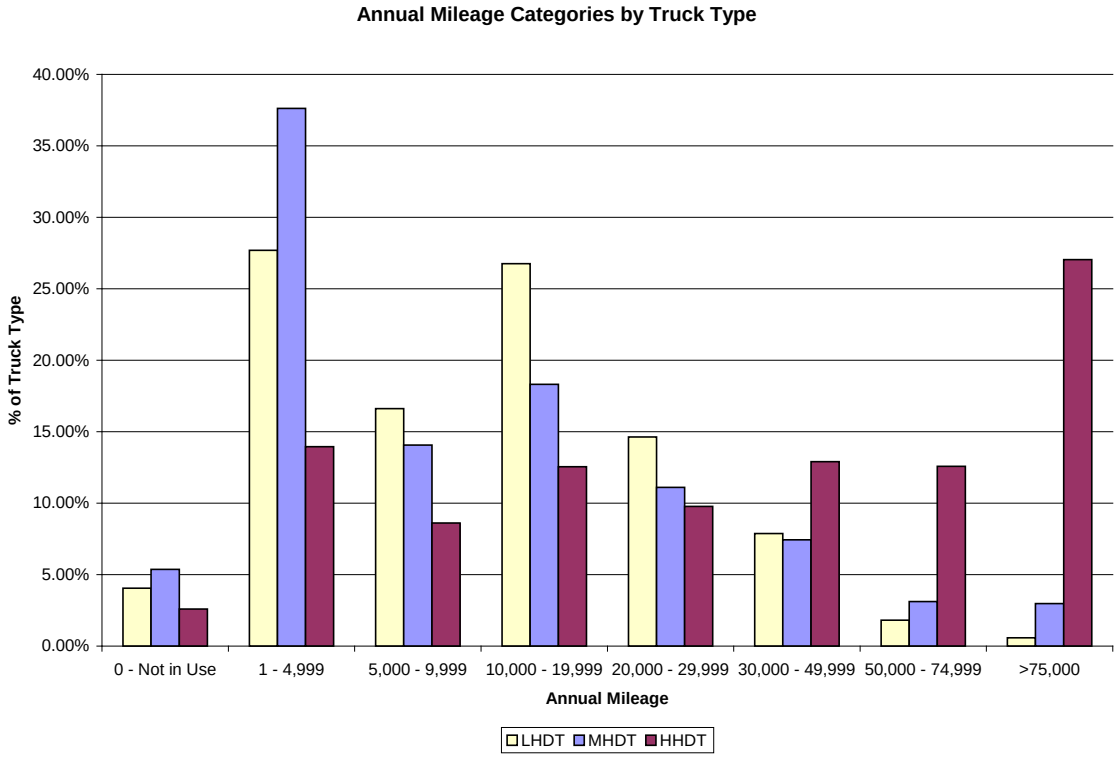


Figure 2-7 Annual Mileage Categories by Truck Type

Travel for LHDT and MHDT is skewed much more strongly to shorter trip lengths than HHDT. Around two-thirds of mileage for both LHDT and MHDT occurs on trips that are less than 50 miles. Less than 12% of mileage for both sub-categories is accumulated on trips over 200 miles.

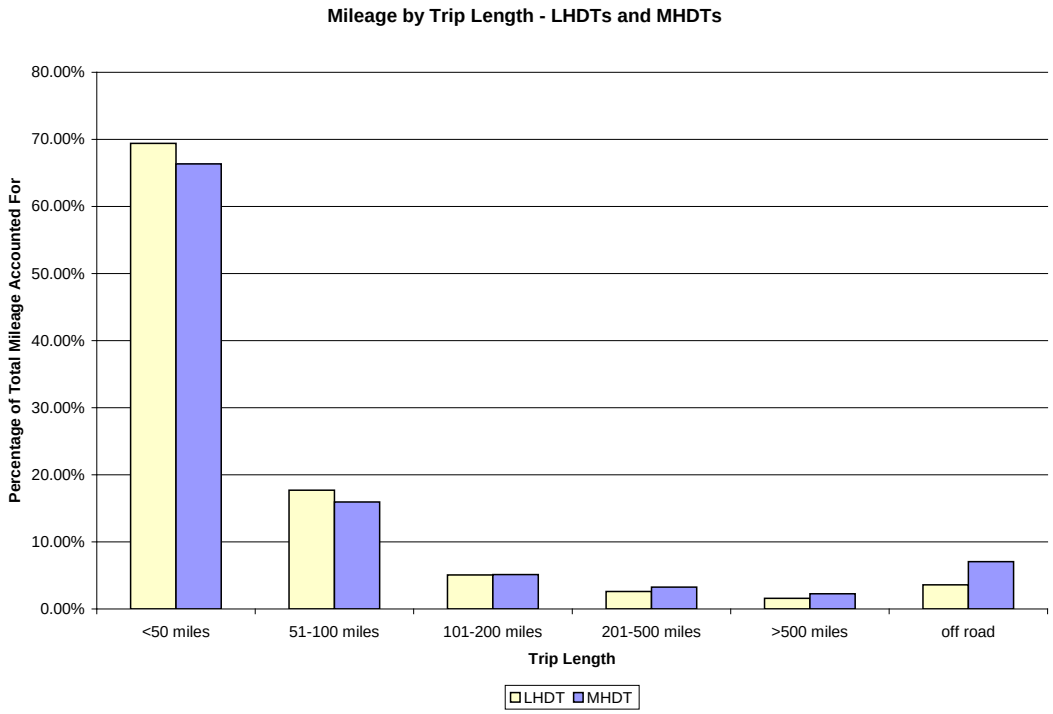


Figure 2-10 Mileage by Trip Length

Fuel economy has trended upwards over time, fairly consistently for the years delineated in the VIUS dataset, as shown in Figure 2-8. Average fuel economy for LHDT and MHDT vehicles, as of 2002 when the VIUS data was collected, is 11.2 and 7.9 mpg, respectively. For vehicles five years old and younger the values are 12.3 mpg for LHDT and 7.9 mpg for MHDT. The newest model year vehicles show fuel economy levels of 11.5 and 8.1 mpg respectively and fuel economy growth rates have been consistently in the 0.8 to 1.0 percent per year range over the time period examined. Fuel economy in the LHDT class grew very rapidly in the early 1990s when existing naturally aspirated and indirect injection engines were replaced by turbocharged direct injection engines with fuel economy jumping from 9.8 to 11+ mpg in that short period.

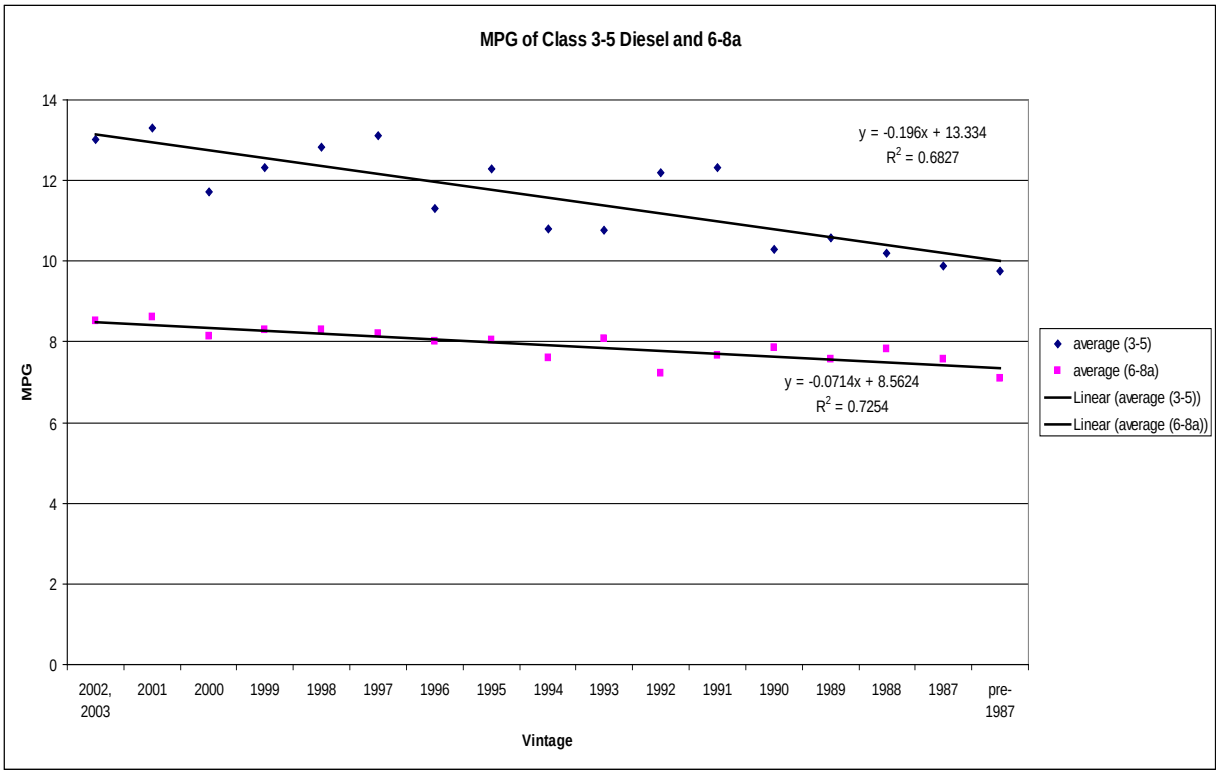


Figure 2-11 LHDT and MHDT Fuel Economy by Vintage

2.4 ENERGY CONSUMPTION ALLOCATION

The energy use by trucks has not been intensively studied as for light vehicles because there is no specific test cycle or driving cycle that is used as a reference. Since long haul trucks accumulate most of their mileage on the highway, some analyses have used a 65 mph constant speed case as a reference condition to allocate energy use to the different components, using analysis based on the first law of thermodynamics. In these analyses, the conversion of fuel energy by the diesel engine to shaft work is always the biggest user since the engine efficiency during driving is about 40%, implying that 60% of the energy is lost in this step. Other components of loss are much smaller, but this is misleading since it is the efficiency of the diesel engine which is approximately constant, not the absolute energy loss in fuel conversion, and a 10% reduction in shaft work results in a 10% reduction in fuel use. Figure 2-12 below is derived from DOE's 21st Century Truck Program for a constant speed 65 mph case.

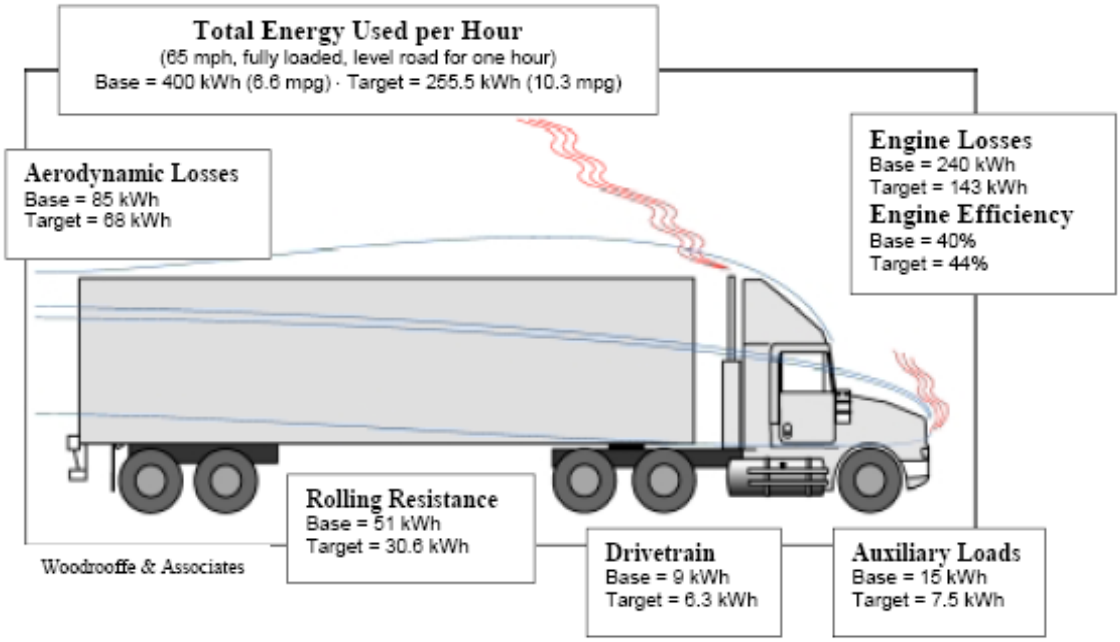


Figure 2-11: Allocation of Class 8B Truck Fuel Consumption at 65 mph.

In this case, base case engine output is 160 kW, with aerodynamic losses accounting for 85 kW or 53% of shaft work, tire rolling resistance for 51 kW or 32% of shaft work and the drive train friction loss and accessory drives accounting for 5.6% and 9.4% of shaft work. However, the constant speed condition is very unrealistic since rolling hills, road curves and traffic generally result in continuous speed and load variations as well as losses to the brakes. Steeper grades on mountainous geography have a very large effect but also affect the speed that trucks can maintain. Cummins provided a breakdown of shaft work on a “typical” long haul cycle in the Mid-west (i.e., modest road congestion and terrain effects) as shown in Figure 2-13, and this cycle uses 173 hp (129 kW) at an approximate average speed of 48 mph for class 8B truck.

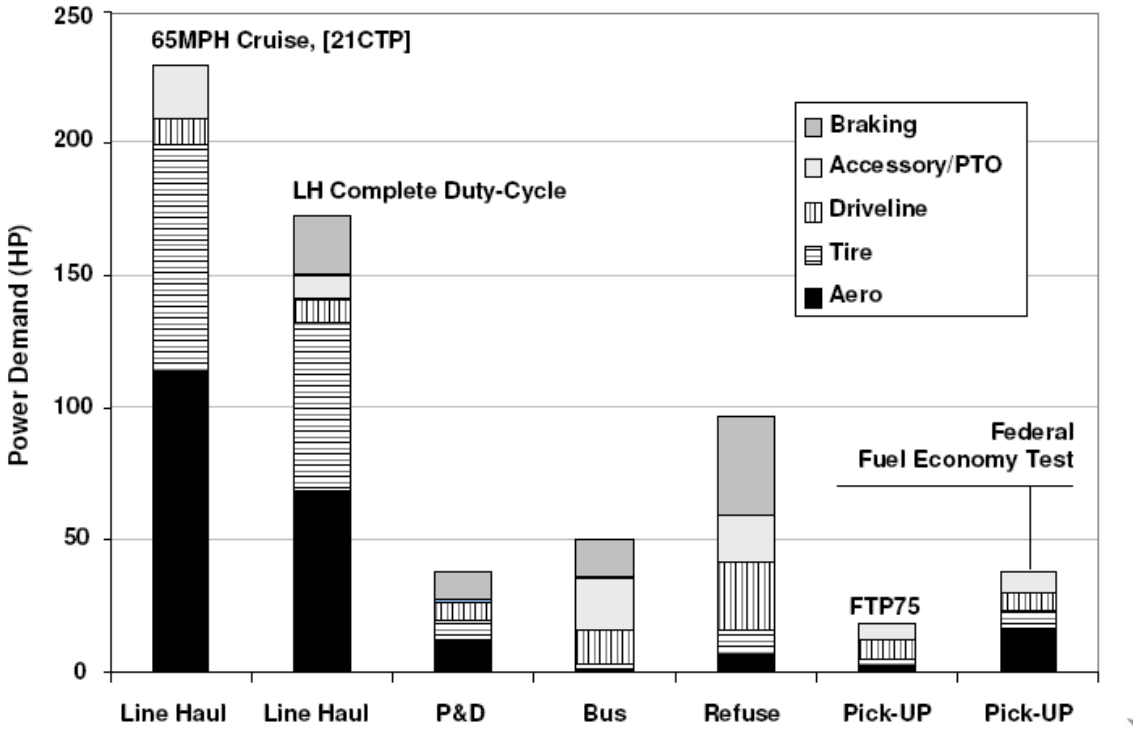


Figure 2-13: Power Demand for Typical Cycles on Heavy- Duty Trucks

The Cummins cycle shows a loss of 13 to 14% of shaft work to the brakes, with aerodynamic drag accounting for about 40% of shaft work, and rolling resistance accounting for about 37% of shaft work. Accessory drives account for 5% while driveline loss accounts for the remaining 4%. In this case, energy use is about 2.69 kWhr per mile as compared to 2.46 kWhr per mile in the constant speed 65mph case, which is 9% higher. In addition, idle fuel consumption is not accounted for in shaft work related analyses and is around 4 to 7 percent of total fuel for long haul trucks based on expert opinion (no hard data is available to estimate the idle fraction in real life). In vehicles with sleeper cabs, idle fuel consumption may be much higher if the engine runs all night to provide HVAC power for the cab. The Cummins cycle may underestimate actual brake losses since traffic congestion is much higher in the East and West Coast, while the topography in the mountain states may also result in larger braking energy loss.

In addition, fuel use at idle is not directly accounted for in analysis of tractive energy use and idle fuel use is not well documented or known. In some analyses of savings associated with idle reduction devices, EPA assumed that trucks idle 8 hours a day, 300 days a year for a total of 2400 hours per year. With fuel consumption at idle estimated at 0.8 to 0.9 gallons per hour, annual fuel use is about 2000 gallons which is 8 to 10 percent of total fuel use. These numbers appear very high from anecdotal information, and may be applicable only to the subset of trucks with sleeper cabs. In other HHDT applications, anecdotal information suggests that fuel use at idle may be only 2 to 4 percent of consumption, so that on aggregate, it is 4 to 6 percent of total fuel use as sleeper cab equipped vehicles account for about a third of all Class 8B trucks. Based on these estimates, we constructed energy and fuel use allocations as follows, to the nearest half percent

		Traction Energy	Fuel Use
Idle		0	5 ± 0.5
Inertia (lost to brakes)		13 ± 1	12.5 ± 1
Aerodynamics		40 ± 2	38 ± 2
Tire Rolling Resistance		37 ± 2	35 ± 2
Accessory Drives		6 ± 1	5.5 ± 0.5
Drive-train Loss		4 ± 1	4 ± 0.5

These allocations are utilized in the following sections to estimate Class 8B long haul truck related technology benefits. Allocations for other classes of trucks are more difficult because of the large variances in duty cycles. MHDT are used in suburban and short haul routes (less than 200 miles radius) for freight delivery, while many are used in urban pick-up and delivery, or by utilities (gas, electric, water, garbage). The “refuse” cycle shown in Figure 2-13 above shows average power of 95 hp (71kW) with 38% in inertia loss, 19% in accessory loads, 27% in driveline losses, 9% in tire loss and only 7% in aerodynamic drag loss. In general, MHDT have higher drive-train loss due to the relatively widespread use of automatic transmissions.

The Federal Test procedure for light duty vehicles has two drive cycles, one at 19 mph (city) and one at 48 mph (highway) with a weighted composite representing typical urban/suburban driving. The energy use for that cycle has been solved by numerical integration as a function of the drag to weight ratio and rolling resistance to weight ratio, and based on that solution we have derived the following values for fuel use fractions shown in Table 2-1:

		Line Haul (Manual Trans)	Regional Haul (Man. Trans.)	Urban/ Suburb. (Auto Trans)	Refuse/ Bus (Auto Trans)
Idle/ Decel.		5 ± 0.5	7 ± 0.5	8 ± 0.5	15 ± 1
Inertia (lost to brakes)		12.5 ± 1	31.5 ± 2	26.5 ± 2	32 ± 2
Aerodynamics		38 ± 2	25 ± 2	20 ± 2	6 ± 0.5
Tire Rolling Resistance		35 ± 2	25 ± 2	21.5 ± 2	8 ± 0.5
Accessory Drives		5.5 ± 0.5	7 ± 0.5	9 ± 0.5	16 ± 1
Drive-train Loss		4 ± 0.5	5.5 ± 1	15 ± 1	23 ± 1

2.5 REGULATORY CYCLES

The new regulations for HDT fuel economy announced in August 2011 incorporate drive cycles for fuel economy evaluation. However, the cycles incorporated appear to be relatively simplistic and quite general. The regulation requires separate testing of engines on the standard FTP and a simulation model approach for the entire vehicle.

The engine FTP cycle consists of 2 low speed cycles, the New York and Los Angeles non-freeway cycles, and one medium speed cycle called the Los Angeles freeway cycle. The cycle results are weighted to produce a near equal mileage on freeway and non-freeway operation which EPA recognized as not being representative of either

"vocational" trucks or long haul trucks. Instead, three new cycles were selected. One was a new Transient cycle with an average speed of 15.3 mph and a distance of 2.84 miles, and includes almost 17% of the time at idle. The other 2 cycles are simply two constant speed modes at 55 mph and 65 mph, with no gradients or transients. The same three modes are applied to all trucks with different weightings. For sleeper cab equipped long haul trucks, the 65 mph constant speed mode is VMT weighted at 86% of operation while the 55 mph mode is weighted at 9%, with only the remaining 5% weighing for the transient cycle. For day cab equipped tractors, the weightings are 64%, 17% and 19% respectively. Even for vocational vehicles, the EPA assumes 37% of the VMT at 65 mph and 21% at 55 mph, with only 42% on the transient mode.

The analysis presented in Sections 2.3 and 2.4 show that the EPA assumptions of constant speed cruise at 55/65 mph are quite unrealistic, and essentially remove the role of inertia, while over-emphasizing the role of aerodynamic drag and tire rolling resistance. In addition, it is not clear if engine technology improvements will be fairly represented in the selected cycles as the benefit of some technologies such as turbo-compounding are better at constant high speed high load points on the engine map, and would provide a larger benefit on the test than in the real world.

3 ENGINE AND DRIVELINE TECHNOLOGY

3.1 BASELINE

Engines used in most heavy duty trucks over 10,000 pounds. GVW are powered by diesel engines, with all gasoline engines have essentially been phased out and only a few gasoline engines sold in the 10K to 14K GVW class trucks. Diesel engines have been historically classified as light heavy, medium heavy and heavy-heavy by the EPA with different durability requirements. In the light heavy class, engines were typically in the 6L to 9L displacement range; in the medium heavy class, the were in the 7L to 11L range and heavy-heavy trucks used engines over 11L. With the advent of common rail fuel injection systems and high pressure turbo-charging, engine specific output has increased significantly and the lines of distinction between classes are not as well defined.

In the light heavy class, the Cummins B-series 6.7L, the Navistar 6.4L and the GM 6.6L engines account for the vast majority of engines sold, with the Cummins 6 cylinder engine sold on Dodge trucks, the Navistar V8 engine on Ford trucks, and the GM V8 engine on Chevy/GMC trucks. In the medium duty sector, the Navistar DT 466 engine, the Cummins C series 8.3L engine and the Detroit Series 50 (now replaced by a Mercedes engine) are the most popular models. In the heavy-heavy category, the Cummins M series engine and the N series engine, the Caterpillar C13 and the DDC series 60 engine were the most popular. These engines have been updated or replaced for 2010 by the ISX13 and 15 engines from Cummins and the Mercedes 13L and 15L engines, while Caterpillar's on-highway engines have been discontinued and replaced by the "Maxxforce" 11 and 13 engines. The Mercedes 15L engines are the first turbo-compound engines sold in North America. In addition, many light heavy engines are used in medium duty applications, while the medium duty engines are now used in many of the lighter weight heavy-heavy applications.

In class 8 trucks, the vast majority (about 75%) use the 10 speed manual transmission, while only about 8% (mostly vocational trucks) use automatic transmissions. The

remainder used manual transmissions with higher number of speeds, typically 12 or 16. This is consistent with the information in the VIUS which shows the heavy-heavy segment having 92.3% manual transmissions, 6 percent automatics and 1.7% automated manual transmissions. In medium duty trucks, the numbers are almost reversed with about 75 percent using six-speed automatic transmissions and 5 to 8 percent using the automated manual transmission (AMT). The VUIS data shows automatic penetration at 78.2% but has automated manual transmissions at only 0.7%, but AMT models have been newly introduced since 2002 and the information from manufacturers seems defensible. The remainder use 6 or 8 speed manual transmissions. At the light heavy end, almost 70 percent use automatic transmissions which were largely 4 –speed units in 2008 but are now transitioning to 6-speed units. The remaining 30 percent use 5 or 6 speed manual transmissions, and these numbers are confirmed in the VUIS data.

The efficiency of diesel engines over time has improved at slightly under 0.4% per year over the 1975 to 2003 period but has since decreased due to the imposition of strict Nox emission standards in 2004 of 2.5 g/bhp-hr, followed by the PM standards and the further tightening of the NOx standards in 2007 and 2010.

As shown in the figure 3-1 above, the peak efficiency point (right scale) of advanced heavy-duty diesels reached a maximum of about 44% but then declined to about 40%. In 2010, most heavy-heavy duty diesels will use exhaust after-treatment to control NOx that will allow engine-out emissions to increase relative to the 2007-2009 engines with efficiency increasing to 42%. The figure above also shows Volvo's hypothetical projection of efficiency at constant NOx emissions standards suggesting that fuel consumption has increased by 11% relative to this hypothetical level, but other manufacturers suggest that the loss may be only 5 to 6 percent, suggesting a peak efficiency of close to 45% at engine out NOx levels of 6g/ bhp-hr, a standard that has been in force since 1990. The historical rate of improvement estimated from the 38% efficiency level in 1980 to 44% in 2000 suggests engine thermal efficiency improvements on the order of 0.3% per year or a fuel economy improvement of 0.73% per year.

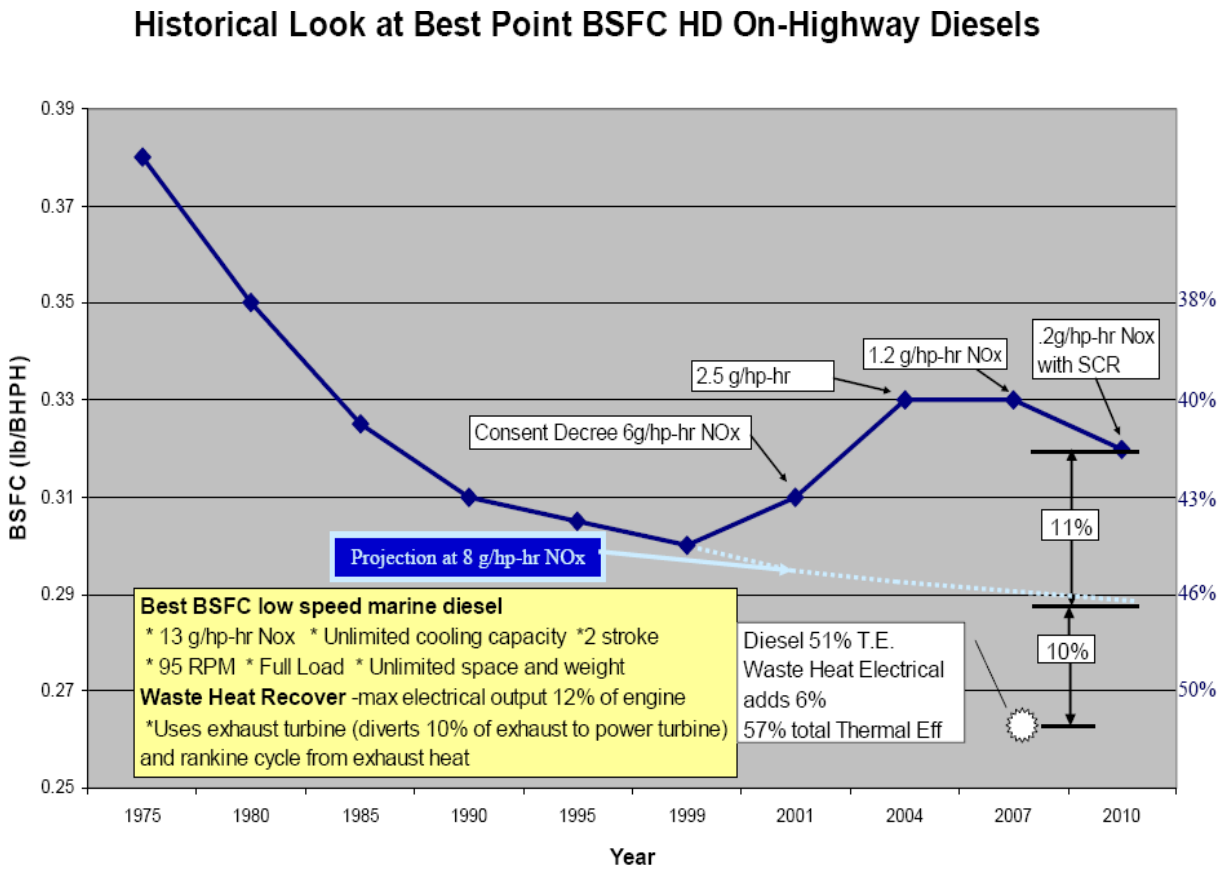


Figure 3-1

Source: Volvo

The 0.73% improvement per year is much higher than the 0.4 % to 0.45 % observed in the VIUS data described in Section 2 of this report, suggesting that some of the efficiency gains have been lost also to higher power ratings, and to time lags in the best technology being introduced in all engines. Another possible explanation is that peak efficiency attained in 2002 was on the order of 42 %, not the 45% shown in the figure, which would be consistent with an improvement of 0.45 % a year for 22 years. The rate of improvement is also not linear since the thermodynamic second law efficiency limit is an asymptote. Also, the above efficiency values are for heavy-heavy diesels and typically, the peak efficiency of the medium heavy diesels have been lower by about 1.5 to 2 %, and those of light-heavy diesels lower by about 2% to 3%, due partly to the smaller bore size which results in higher heat loss, and partly to the higher operating RPM which results in higher friction.

3.2 ENGINE IMPROVEMENT TARGETS AND ACTUAL POTENTIAL

Cummins provided a detailed map of energy flows for a recent model engine with a brake efficiency of 42%, as shown in Figure 3-2. Indicated efficiency of 50% is the current combustion duration limited diesel cycle efficiency, but with high EGR flow, there is more heat rejection to the coolant and EGR coolers than to exhaust. Heat rejection to exhaust has decreased from about 30 percent before the use of EGR (pre-2004) to 26 percent now, which has ramifications for the efficiency of heat recovery from turbo-compounding. Caterpillar data for a C15 engine with 42 percent efficiency shows exhaust gas heat rejection at 22 percent, but also shows heat loss from low pressure EGR (post Turbo) to be 5% for a total of 27% heat available after the turbo- charger. The heat loss values in figure 3-3 form the basis for Cummins' analysis of improving the brake efficiency to 52.5% in the future.

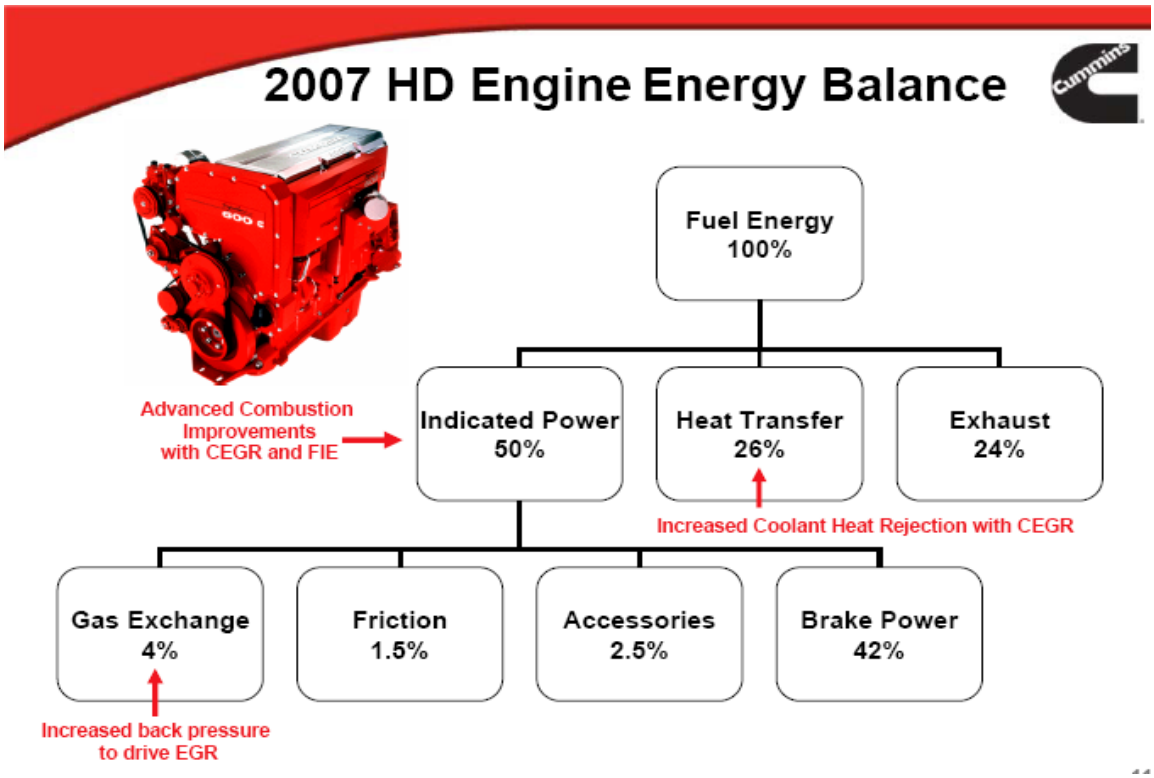


Figure 3-2: Distribution of Energy Losses in Current Engine

Figure 3-3 shows the energy flows modeled by Cummins to achieve the 52.5% efficiency target. This would require increasing indicated efficiency to 58%, while significantly reducing gas exchange losses indicating a fuel economy (FE) benefit of 25% (52.5/42-1). This would be the benefit for the base engine, and exhaust heat recovery could add another 6 to 8 percent fuel efficiency with advanced heat recovery systems, leading to a potential target figure of 31 to 33 percent FE improvement from the engine alone (engine total efficiency would be around 55%). Of course, the entire benefits of the target may not be attained in practice. If the historical FE improvement rate of about 0.45 % per year were to continue to 2030, engines would be 9.5% more fuel efficient by 2030 relative to 2010. Hence, there is a potential margin of 21% to 23% additional FE available from additional technology to meet the DOE engine efficiency targets. However, most manufacturers believe that such a large increase will not be possible and reaching 49% to 50% brake efficiency itself will be a major challenge,

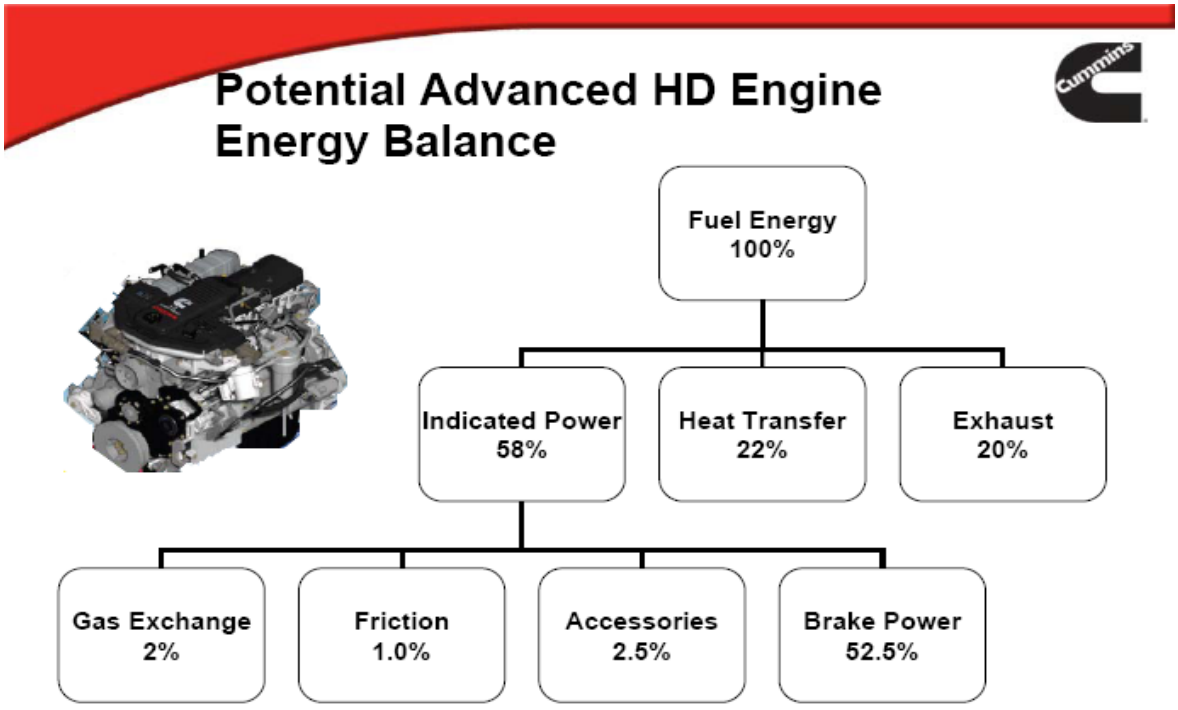


Figure 3-3: Estimated Distribution of Energy Loss in Advanced Engine

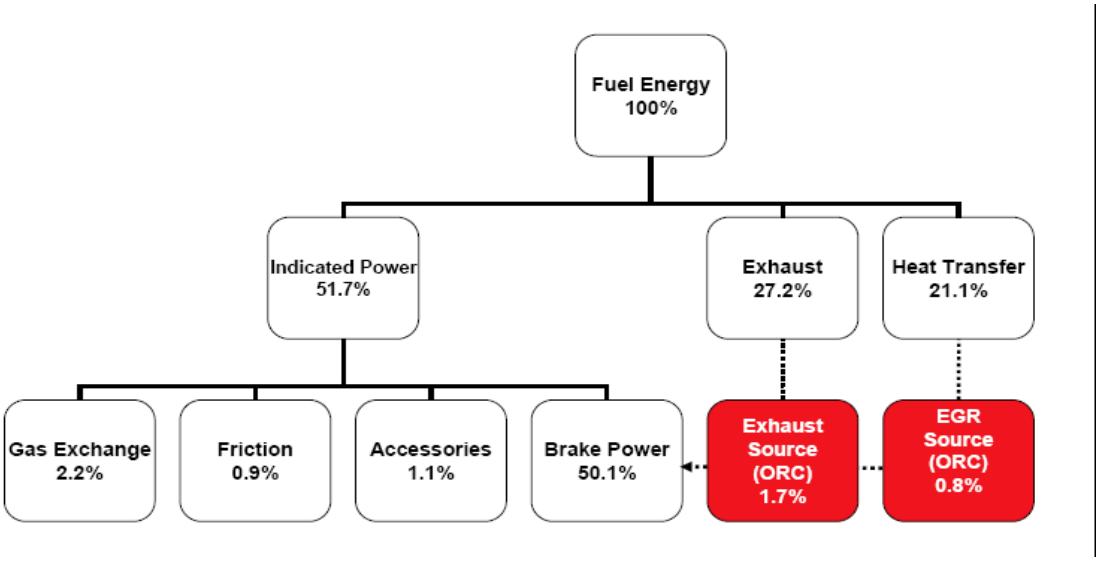


Figure 3-4: Actual potential by 2020 time frame

Source: Cummins

The DOE goals are to increase engine indicated efficiency to 58% by reducing heat transfer and exhaust heat energy loss. Brake efficiency is further enhanced by a 50% reduction in gas exchange losses, and a 33% percent reduction in friction loss, with accessory energy loss reduced by electrical drives included as a separate possibility with hybridization. Exhaust energy recovery through turbo-compounding and/or organic Rankine cycles can increase the overall brake thermal efficiency to about 55 % in constant high speed operation. Note that each 1% increase in efficiency increases FE by about 2.4%. The 55% efficiency path is a goal or target, and Cummins also provided a likely path towards a 50% goal that could be achieved over the next decade. As shown in Figure 3-4, the indicated efficiency increase is much more modest, and the 50% brake efficiency could be attained with an indicated efficiency of about 52%, with exhaust heat recovery. This path is consistent with the statements of other manufacturers about the potential to 2020 or 2025, implying a total increase of about 20 percent in fuel efficiency.

The specific technologies to improve indicated power to 50% include

- advanced common rail injection systems with very high injection pressure (2200 bar+)

- advanced injectors with multiple injections per stroke capability,
- advanced EGR cooling systems,
- closed loop injection control and
- improved air handling with an advanced twin sequential turbochargers or electrically assisted turbochargers.

3.3 COMBUSTION IMPROVEMENTS

Advanced injection systems and advanced injectors are likely to have a significant contribution to the overall improvement of efficiency at low engine-out Nox emissions. A very comprehensive analysis by Bosch shows the dependence of the injection pressure benefit to be a strong function of engine out Nox level. The 2010 emission standards require urea-SCR emission control systems that allow engine out Nox levels of 1.0 to 1.1 g/bhp-hr to attain the tailpipe standard of 0.2 g/ bhp-hr implying a catalyst system efficiency of around 85%. The engine out level translates to about 1.3 to 1.4 g/ kWh in European terms. As shown in the figure from Bosch below, the benefit of 2400 bar system over the typical 1800 bar system at this engine output is 3% at the “B50” operating point corresponding to 50 mph cruise on a highway. Increasing further to 3000 bar could enable an additional 1.5% fuel consumption benefit according to Bosch. These benefits continue to increase at even lower engine out Nox levels. In this context, engines operating at lighter average loads (as in trucks used for regional haul at lower speeds) will see smaller benefits from advanced injection systems.

It should be noted that the new Mercedes engine with turbo-compounding also features a hydraulically amplified CRS system from Bosch that currently operates at 2300 bar but is capable of 2500 bar. The next generation 3000 bar pressure systems would likely not enter the market until late in the next decade, possibly around 2018. Manufacturers confirm the benefits of increased pressure but suggest that a 2 percent benefit may be more reasonable as an average. The 2010 Navistar “Maxxforce” engines are being certified to a 0.5 g/ bhp-hr Nox standard without the use of urea-SCR catalyst systems.

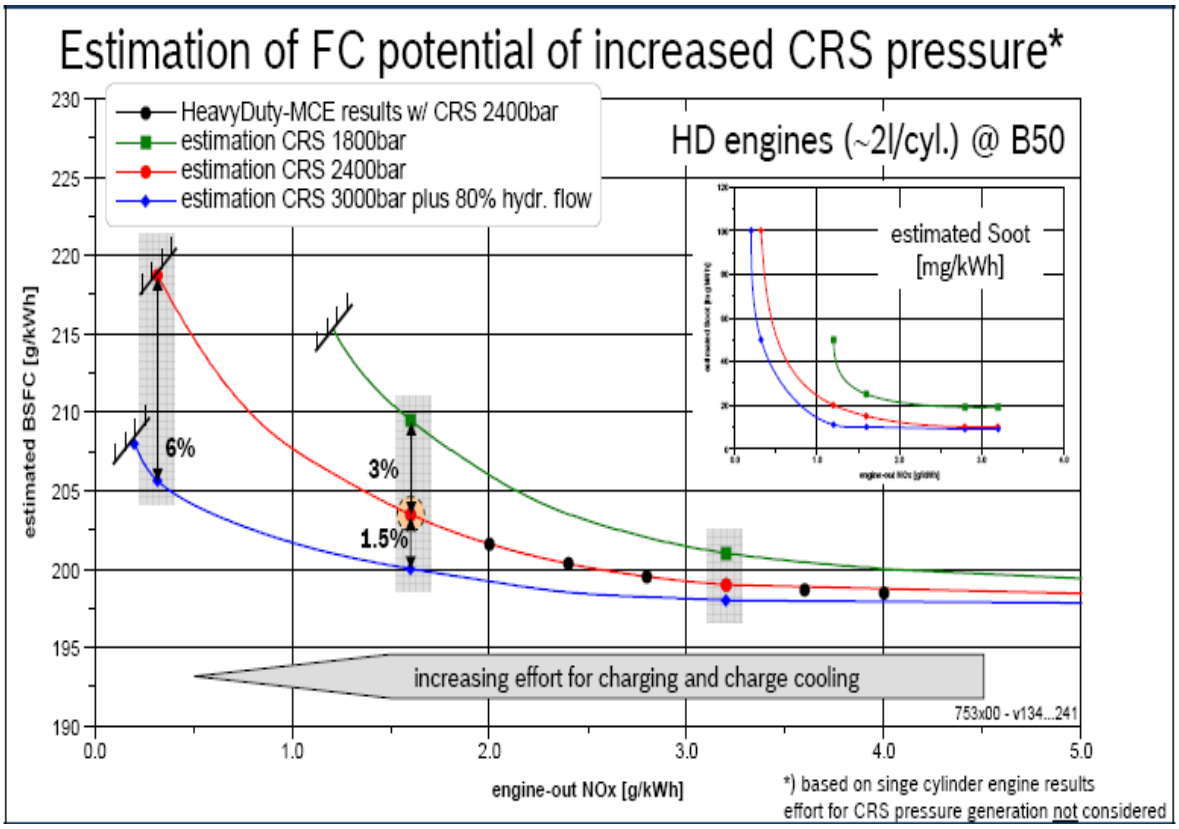
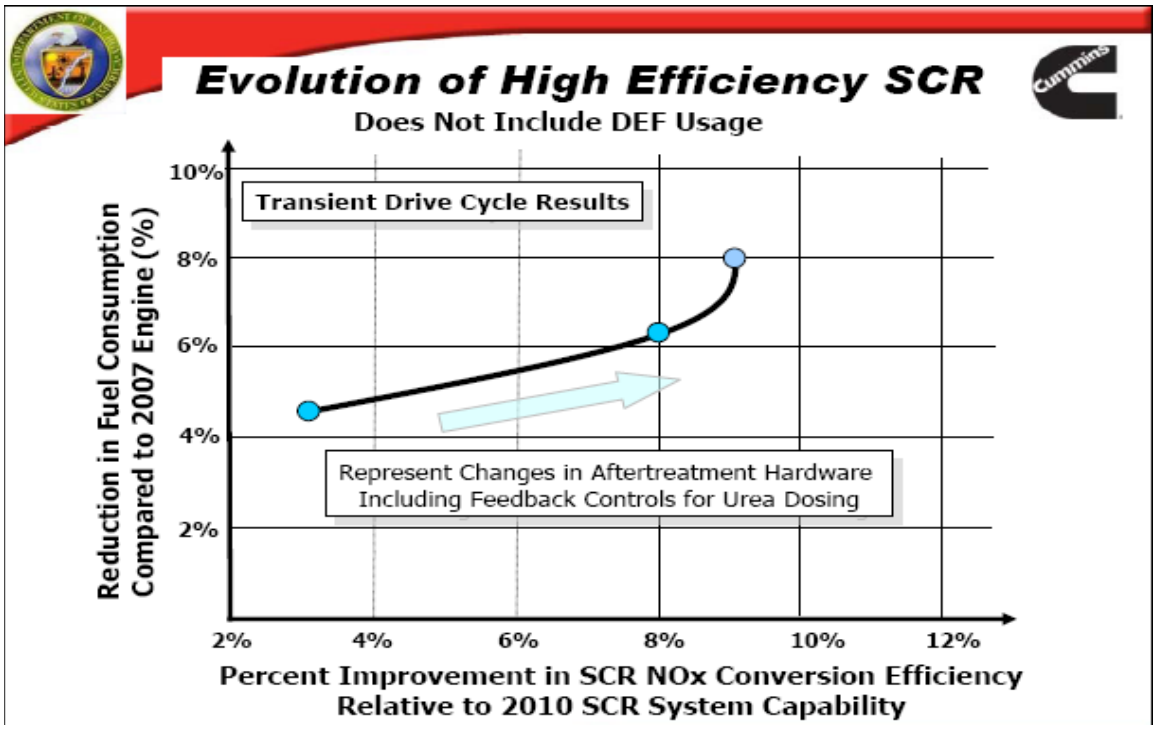


Figure 3-5: Effect of Common Rail System Pressure on BSFC

They utilize a 2200 bar system, and at this very low engine-out Nox level, the benefit of a 3000 bar system is assessed by Bosch at almost 6%. Manufacturers believe that the benefits could be around 4% to 5% after subtracting the energy used to increase rail pressure, but it is not clear if Navistar will continue to use a non-catalytic approach to meet the 0.2 standard. Moving to the urea- SCR system allows some recovery of efficiency to a level of 43% to 43.5%, which would improve fuel economy by 2.5% to 3%. However, the systems need to be filled with urea (sometimes referred to diesel exhaust fluid) which is consumed at a rate equivalent to 2 to 3 percent of fuel consumption. This level of FE improvement in 2010 has been confirmed by several engine manufacturers, while Cummins shows an improvement of 4+ % below. However, the cost of urea is a major concern, and the higher fuel cost of an in-cylinder Nox control system may be more than offset by the reduction in cost from not having to refill the urea system. The 2500 bar fuel injection system cost adds about $1500 to retail price over a 2000 bar system, while the 3000 bar system may add $2500 relative to current systems.



The current **urea SCR systems** operate at about 80 to 85% cycle efficiency and further improvement to 90+% is possible over the next five to eight years. This would allow engine out Nox levels to increase to almost 2 g/bhp-hr at constant tailpipe standards allowing another 1% efficiency increase or a 2.5% fuel economy increase, corresponding to a urea-SCR system efficiency increase of about 6 percent in the Figure 3-6. We anticipate that this improvement will be due to learning and incremental technology improvements but will not add additional cost to the system.

The **sequential twin turbocharger** concept has been introduced by several manufacturers such as Navistar for 2010, and constitutes one form of waste heat recovery. The twin turbo concept with inter-cooling between stages allows faster throttle response and more uniform boost capability over the RPM range. The twin turbo concept allows the engine to be downsized by 10 to 12 percent and still provide adequate low RPM torque and drivability at low speeds. This level of engine downsizing has occurred over the last 15 years, with the typical engine size for a 80,000 pounds. GVW vehicle and a 425 HP rating decreasing from around 15L to 12.5L to 13L. It is not clear if further downsizing will occur in the market in the near term, but additional downsizing to 11L to

11.5L is likely in the 2017 to 2025 time frame. DDC reported that improvement in turbocharger compressor and turbine efficiencies could provide a 1% to 1.5% FE benefit in the near term. The twin turbo approach has been used with engines certifying at very low engine-out Nox levels, with the high EGR rate making high boost a requirement to provide enough air for combustion. We estimate that the twin turbo concept with further downsizing to provide a 2.5 % to 3 % benefit in fuel economy by 2025. The twin turbo system adds about $1200 to engine price relative to a single turbo system with the same HP rating (i.e. a larger displacement engine)

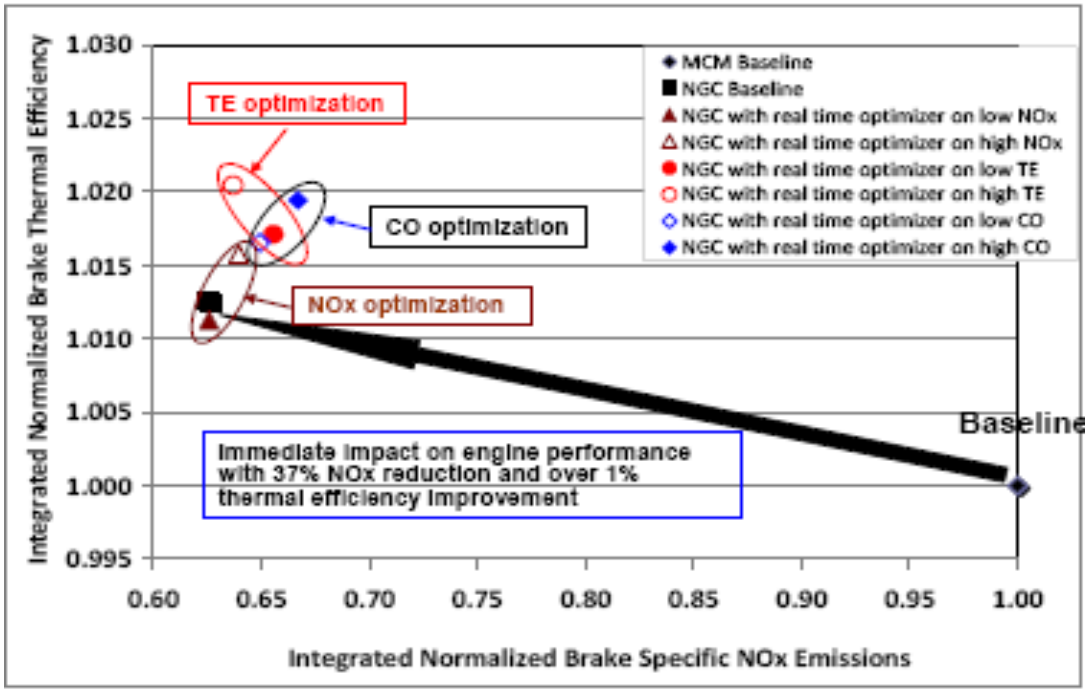


Figure 3-7: Benefits of Closed Loop Combustion Control

Closed loop combustion control has always been seen as a major goal to simultaneously improve emission and fuel economy performance. The new flexible fuel injection systems with amplified common rail and advanced injectors capable of multiple injections can allow PCCI combustion especially at lighter loads up to 10 bar BMEP. This would be more helpful on medium duty diesel engines, but can provide significant benefits for the heavy-heavy class as well. Real time combustion control with cylinder pressure sensing is now possible as sensors are available commercially at reasonable prices, and cylinder pressure sensing is already being used in some light duty diesels.

DDC has estimated a thermal efficiency gain of 1 to 2 percent with advanced controllers with a 37% NOx reduction as shown in Figure 3-7 above, indicating the potential for a FE gain of up to 5% with reduced emissions. It is possible that the NOx reduction could be traded for additional efficiency gains. Cylinder pressure sensors for light duty diesel engines have been commercialized at a cost of about $50 per cylinder. Even if heavy duty sensors were twice the price, the sensors and wiring should add about $700 to the cost (or $1100 to RPE) of an in-line 6 cylinder engine.

Gas exchange losses are also helped by the electrically assisted turbo and/or sequential turbo, but the other technologies to attain this goal include an **EGR pump** and variable valve actuation. The EGR pump is a positive contributor to fuel economy only at very high EGR flow rates that may be required to meet the NOx standards without the use of urea-SCR. As engines planning to use in-cylinder control technology appear to be moving to a sequential turbo, low and high pressure loop EGR system, the potential for the EGR pump appears small and no manufacturer has embraced this technology.

Variable Valve Timing (VVT) can be used to reduce gas exchange loss by increasing valve overlap to increase internal EGR but this would require a DOHC system, which is used in some but not all heavy-duty engines. In addition, it can be used to increase exhaust temperature if needed. Such a system could increase FE by 0.5% to 1.0%, but performance data on prototype systems have not been released publicly. The timing could be changed using hydraulic cam phasers similar to those that have been employed in light duty SI engines. Variable valve actuation is expensive for HHDT engines and has a payback of about 3 to 4 years, with a cost of about $800.

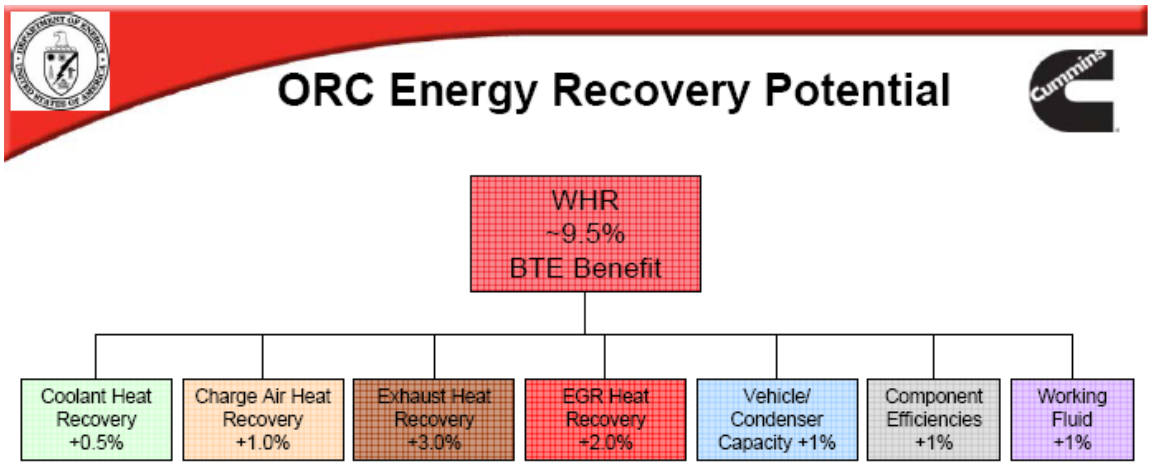
3.4 WASTE HEAT RECOVERY

Waste heat recovery is a major requirement for meeting the 50% thermal efficiency goal for the 2020+ time frame. As noted, mechanical turbo-compounding has been introduced by Daimler (DCC) in the new 2010 DD15L engine. Daimler claims a fuel economy benefit of about 3 percent for this feature, which is consistent with estimates of 2.5 to 3 percent in the literature, with a net RPE impact of $2500 to 3000. These new engines feature a high efficiency non-VGT turbo and a new low friction design, with urea-SCR

after-treatment. DDC has claimed a fuel economy benefit of 5% for the urea-SCR/ new engine combination relative to the 2007 Series 60 engines that certified at 1.2 g/bhp-hr.

The electrically assisted turbo extracts power from the waste heat and many manufacturers have looked into this technology as an alternative to mechanical turbo-compounding. The case where the turbocharger is directly connected to the motor generator is conceptually attractive as the electric system can drive the turbo at low engine RPM to provide more boost and extract electric power at high RPM and load, while avoiding waste-gating. This system has been difficult to execute in the high temperature environment of the turbocharger, and simpler systems have been studied. John Deere has investigated a concept which is similar to the mechanical turbo-compound in its setup of a single turbocharger with an additional turbine operating independently to recover exhaust waste heat. In the electric turbo-compound case, the turbine drives a generator, rather than being coupled to the engine output shaft. This permits very flexible operation of the turbine and the recovered electrical power can be stored in a battery and used as required. However, costs are high (estimated at around $9000) as the system requires a generator, power storage and a motor to convert the power back to shaft work. Deere has demonstrated a fuel economy potential of 7 to 10 percent at full power over a broad speed range, but efficiency over a driving cycle is estimated at 5 to 6 percent, which also accounts for power storage and re-conversion losses. The electric turbo-compound is potentially more attractive as part of a hybrid system described in the following sub-section of this report.

The highest potential for waste heat recovery is through the Organic Rankine Cycle which uses a Rankine bottoming cycle to recover waste heat lost in the exhaust, EGR and water coolers. Cummins has identified a potential of almost 10 percent benefit, but the most potential is in the Exhaust and EGR heat recovery. A simpler system focused on



Nearly a 10% performance improvement is possible – though with high additional cost and system complexity

Future development must focus on the most promising and realistic potentials energy recovery sources -

these sources could yield a 6 to 7 percent benefit according to Cummins and could potentially be lower cost than a electric turbo-compound system, implying a cost of about $6000 to 7000 . However, such a system is unlikely to be commercially available until about 2020.

3.5 FRICTION LOSS

Friction losses can be reduced through redesign of moving components and through the use of low friction coatings. Figure 3-8 shows the contribution to friction of the different components. The effect of friction reduction on diesel engines is estimated at about 0.4 percent per 10 percent reduction in friction for a highly turbocharged engine on the highway cycle, but can be as large as 0.8% per 10 percent on a medium duty engine running at an average load of 35 to 40 percent of peak torque, excluding idle.

As can be seen from the figure, the basic piston skirt, rings, rod bearings and crankshaft account for about 50% of total friction loss (the figure also shows gas pumping loss across the valves, and in the turbo and intake manifold, which is not included in this estimate). Friction reduction is an evolutionary process involving coatings, component redesign and the use of new materials in contact surfaces. Manufacturers agree that

friction reduction of 5 to 10 percent will occur in the near term and 15 to 20 percent is possible by 2025. In addition, the downsizing and increased BMEP of engines reduces friction as a percent of engine output, so that the total decrease in friction as a percent of engine output can be in the 25 to 30 percent range by 2025. This value is somewhat lower than the Cummins estimate of 33 percent friction reduction required to meet the DOE 55 percent efficiency goal. We have used this estimate to derive the net efficiency improvement.

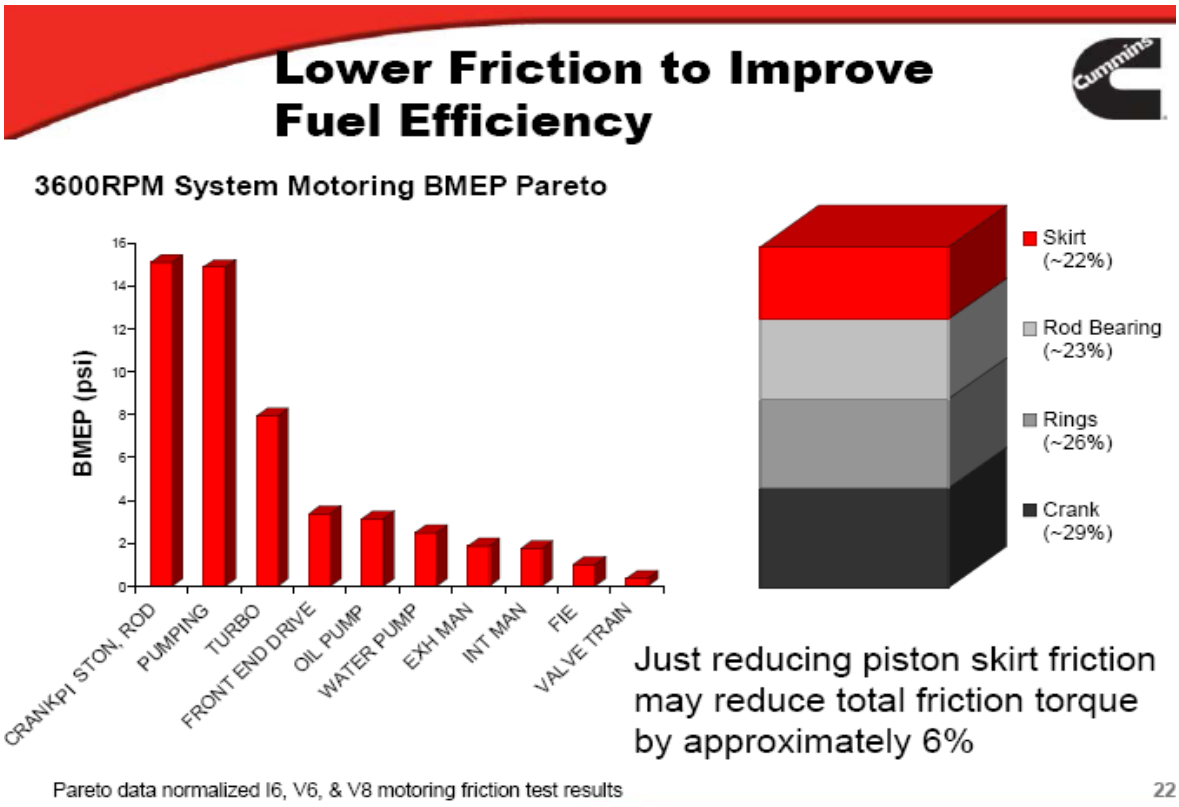


Figure 3-8: Friction Loss Allocation to Components in Engine

The use of friction reducing cylinder and piston coatings is expected to be very cost effective with a cost of about $250 and a payback of about 0.5 year. Friction reduction in the front end drives, crank journal bearings, and engine accessories are only somewhat less cost effective with a cost of about $500 at a payback of about 1 year.

3.6 ACCESSORY POWER LOSS REDUCTION

Accessory drive power for power steering, the cooling fan, water pump, oil pump and the HVAC unit can be supplied electrically, but the power requirements can be very large to meet peak demand as opposed to average power demand. Figure 3-5 shows estimates from IVECO (an Italian truck manufacturer) on the peak and average power demand of various accessory drives for a heavy truck. In total, there is a 9:1 ratio between peak and average demand but the high peak demand makes it difficult to electrically power all accessories. Typically, the cooling fan can be powered by a clutch drive to eliminate the largest peak power demand but even the remaining accessories cannot be easily electrified unless substantially more electrical power is available on-board, implying the need for hybridization.

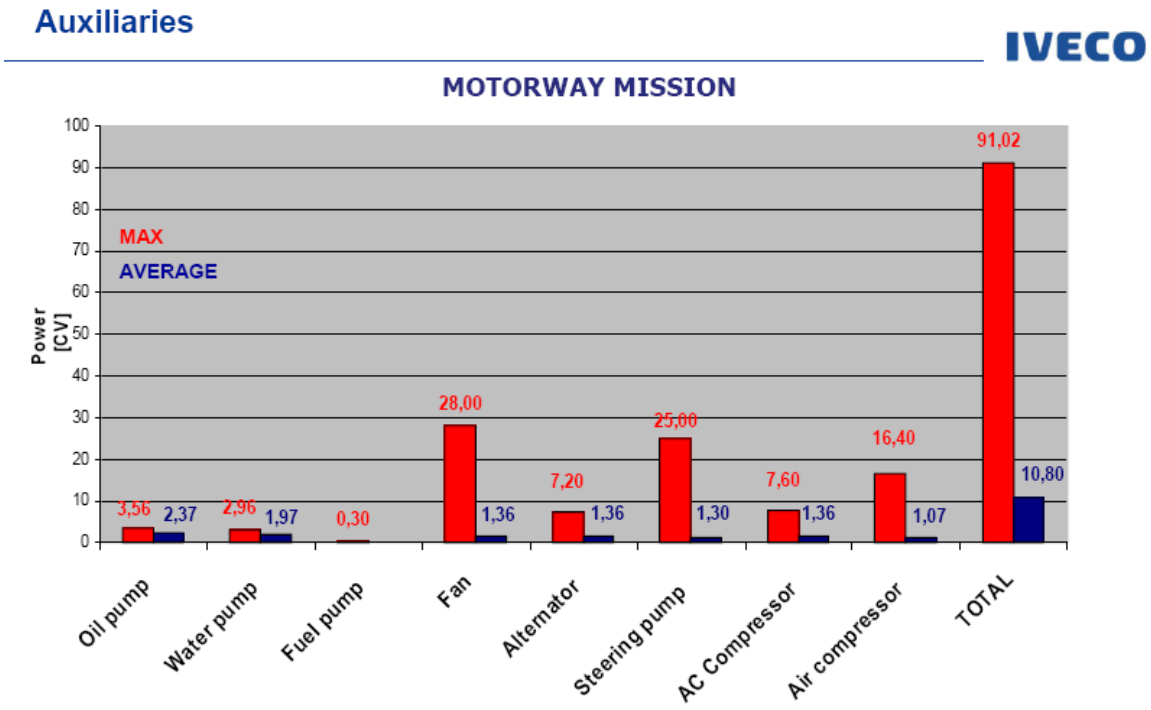


Figure 3-5: Peak and Average Power Demand for Accessory Drives in a HHDT

The 10.8 HP average demand indicated is approximately consistent with the estimate by Cummins of 6 percent of energy for accessories on the line haul cycle that requires 173 HP average power. In terms of average demand, the oil and water pump are the two highest and have a modest peak to average ratio of power so that electrification is not very expensive since the drive motor size is limited. Fuel savings from electrification is

not due to electric drive (since the electricity is derived from the engine driving the alternator) but from reduced use as electric drive permits tailoring to demand. From this perspective, the water pump, power steering pump, air conditioner compressor and air compressor offer savings since they need not be running or be running at reduced speed much of the time. The oil pump electrification may not provide significant fuel economy benefit but may allow lubrication improvements to allow some friction reduction and is also a candidate for electrification.

3.7 TRANSMISSION IMPROVEMENTS

The oil pump and water pump can be electrified with some strengthening of current vehicle electrical systems and battery capacity, but the other accessories will need significant amounts of power to meet peak demand, and cannot be easily included unless it is part of hybrid system where there is ample electric power on board. Estimates form manufacturers suggest that the oil and water pump may provide 0.6 to 1.0 percent benefit at a cost of about $1000, while electrification of all candidates could provide 2 to 2.5 percent benefit in fuel economy at a cost of about $2500 for line haul trucks. In medium duty trucks the same accessories could provide about twice the gain from electrification since accessory loads are a much larger part of total fuel use. In addition, vocational use MDT have power take off driven external accessories like a mobile crane or a refuse crusher, where there are significant prospects for fuel use reduction that are very application specific.

As noted, most heavy-heavy duty trucks use the 10 speed manual transmission and most do not feature direct drive in top gear. In Europe, there has been a significant shift to 12 speed transmissions with many featuring the “I-shift” AMT design. Experts at ZF indicated that the 12 speed transmission with direct drive in top gear offers a 1 to 1.5 percent in fuel economy over the standard 10 speed overdrive transmission, as shown in Figure 3-6.

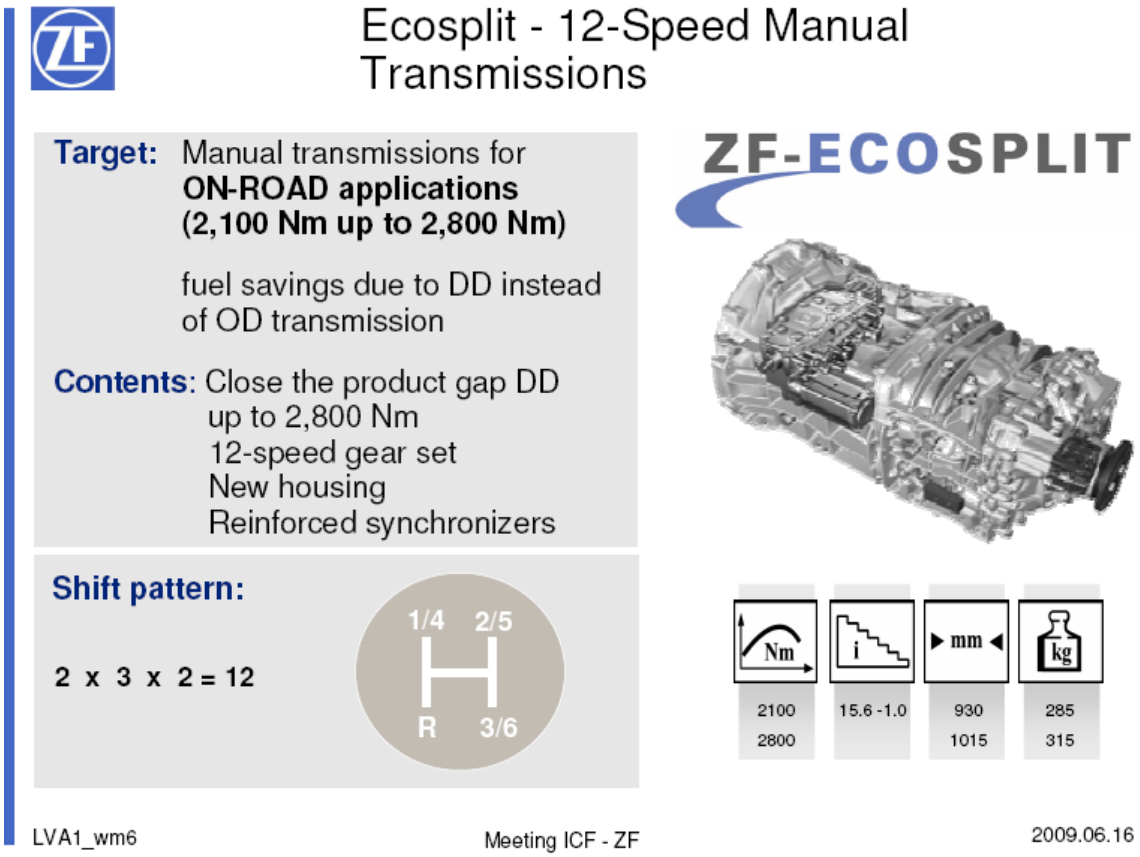


Figure 3-6: ZF Transmission Details

"I-shift" is a brand name given by Volvo for its 12 speed automated manual transmission (AMT), and this type of AMT has also been introduced by ZF in Europe (the shift pattern for these transmissions is in the form of an I as shown in Figure 3-6). These second generation AMT models introduced in 2008/9 are substantially superior to the first generation models introduced around 2000, and this has been made possible by closer integration of transmission and engine controls. For example, the current AMT models automatically disengage the clutch on downhill sections of rolling hills, and provide faster and smoother shifts than is possible from a conventional manual due to the control integration. AMT manufacturers concede that the best drivers can equal the performance of an AMT but state that on average, fleets see a gain of 3 to 4 percent in fuel economy. Even larger gains are observed with poor drivers, and the lack of experienced drivers could be a major market force for the AMT. The new AMT models also claim to offer improved clutch and brake wear, so that fuel savings are only a part of the total savings realized. In Europe, ZF estimates that the payback period for these transmissions is under

3 years. Given the lower fuel price in the US, payback will be longer. Currently, an AMT for a Class 8 tractor is a $9,000 to 10,000 option relative to a manual transmission, and even at a 4% fuel economy gain on average, payback on fuel savings at $3 per gallon is around 4 years, and could be close to 3 years if clutch and break wear benefits are considered. Manufacturers report that AMT penetration has increased in 2008/9 to about 15 percent of sales when fuel prices increased sharply.

As noted in Section 2, about three quarters of all medium duty trucks use automatic transmissions and the use of an AMT can provide fuel savings in the 7 to 9 percent range by eliminating the torque converter loss and by the use of more efficient gear sets. However, the shift quality of the AMT is not as good as that of an automatic, while the torque at launch is also lower since there is no torque multiplication in the torque converter. Hence, acceleration will be inferior to that of an automatic and some believe that the AMT reduces truck productivity in typical urban driving cycles. Newer generations of the six speed AMT for medium duty trucks have addressed some of these problems and will likely be more competitive in the future. In addition, the AMT may require more maintenance relative to a conventional automatic transmission, so that fuel savings alone may not provide a correct indication of payback. However, the AMT is cost competitive with an automatic transmission in terms of first cost and the value of fuel savings is on the order of $800 to $1000 per year. Hence, even with a large negative hedonic valuation of $2000 to $3000 for drivability and maintenance effects, payback on the order of 3 years is possible.

3.8 HYBRID DRIVETRAINS

Hybridization of the truck drivetrain is in principle, similar to the hybridization of passenger cars and many of the same design types under consideration: series, parallel and two-mode. One interesting addition to the available hybridization technologies is the hydraulic hybrid, which stores power in the form of a compressed fluid rather than in a battery. However, the series hybrid appears too expensive and heavy for most truck applications (it may be suitable for buses). The two-mode hybrid may also be too complex and expensive for most truck applications and the manufacturers appear to be

considering only the parallel hybrid for most applications and the hydraulic hybrid for selected applications.

The most popular parallel hybrid configuration is similar in both the EU and the US is the use of a electric motor sandwiched between the engine and transmission. Either a single clutch (between motor and transmission) or two clutches (also between engine and transmission) is employed, with the single clutch system being more dominant, since motor sizes do not permit pure electric drive at present. Physically, this system closely resembles the Honda integrated motor assist (IMA) system used in passenger cars, although the motor size and battery are three to four times larger for truck application. Typically motor sizes are in the 50 + 10 kW (peak) range, and the vast majority of systems have been used on medium duty Class 6 and 7 vehicles operating on city duty cycles ranging in speed from 4 to 20 mph. The Eaton system used by Kenworth and Navistar on their vehicles has a motor rated at 44 kW peak and a battery with energy storage capacity of 1.8 kWh, as an example The system is mated to a six speed AMT. ZF in Europe has very similar design with the motor rated at 60 kW. Current system strategy is to provide launch and acceleration assist to the engine and recover braking energy, but many systems do not provide idle stop, and do not downsize the engine to preserve full load continuous operating performance.

A comprehensive analysis of hybrid potential for trucks is outside the scope of this study and only some general parameters relating to hybrid benefits are examined. Most of the available data for trucks (as opposed to buses) from on road testing in the US is on the Eaton system and the following results have been reported:

- Hybrid class 4 vans operating in city pickup and delivery service (for UPS) showed an average fuel economy improvement of 29% for a cycle speed of about 20 mph
- Hybrid class 6 trucks tested by Navistar on the dynamometer over the city cycle showed a benefit of 24% in fuel economy, and about 20% on road cycles in California with speeds in the 20 to 30 mph range
- Hybrid class 6 trucks tested in New York over duty cycles with an average speed of about 5 mph showed a fuel economy benefit of 40%

In general, hybrid benefits increase with decreasing speeds and increasing number of stop-and –go operations. It should be noted that the UPS van comparison was an AMT hybrid compared to a diesel van with an automatic transmission tested by Navistar, so that the hybridization benefit was in the low 20% range consistent with Navistar data from California.

Although there have not been any detailed testing of class 8 hybrids in the US operating on long haul routes, Volvo testing in Europe has shown that typical long haul operation (potentially similar to the long haul cycle discussed in section 2) has enough acceleration and braking events to provide a 3 to 4 percent improvement in this application with a 25 kW motor. Simulations by the Southwest Research Institute (SwRI) with a 55 kW motor showed a hybrid benefit of 5.7% in fuel economy, although the cycle specifics were not provided. Volvo also claimed that hybridization made accessory electrification easier, so that they were able to attain 5 to 6 percent fuel economy benefit in European testing even with the smaller motor size.

Current hybrid systems with a 50 kW motor and about 2 kWh of energy storage add about $40 to $50 thousand to the price but this is at very low annual sales volumes, probably less than 1000 units per year. Manufacturers are contemplating using essentially the same system across a wide range of truck weights and applications, with different benefits. Near term (2014-2015) target prices assuming volumes of about 10 to 20 thousand per year are in the $20,000 range, and it appears possible that an additional 25 to 35 percent reduction in costs could occur from 2015 levels by 2025 if expected battery and motor price reductions occur from both scale and technology. Plug-in hybrids are also being contemplated although a 40 mile range would require a battery of 50 kWh or more for a medium duty class 6 truck with attendant very high costs.

Hydraulic hybrids have the capability of absorbing high power spikes due to the mechanical nature of energy storage, but total energy storage capacity is very limited. In addition, the system is quite bulky and space and weight requirements for the hydraulic tanks limit its applicability. Truck manufacturers believed that hydraulic hybrids are well suited for some applications with extreme stop and go cycles like garbage trucks. At the same time, they did not believe that these market niches could support adequate sales

volume to attain scale and scope economies, unlike an electrical hybrid powertrain, suggesting that markets for such hybrids would not develop to commercial scale.

3.9 SUMMARY

Engine benefits are summarized in Table 4 below for two of the three cycles defined in section 2: the long haul cycle (highway), and the city/highway cycle (regional). The low speed cycle is not well characterized for engine improvements as the effects of engine technology on idle consumption have not been reported, and idle and very low speed use are major components of the cycle. However, the benefits at low speed should be comparable to but slightly lower than the benefits on the regional cycle as some improvements like friction reduction and accessory improvements will have larger benefits while others such as urea-SCR and turbo-compounding have lower benefits.

Table 4: Engine and transmission related fuel consumption reduction (%)

Relative to MY 2008 engine/ 10-speed manual at constant 2010 emission standards for Class 8B truck

Technology		**2009 -2017**		**2009 – 2025**	
		Highway	Regional	Highway	Regional
Urea SCR		3.0*	2.0*	5.0	4.0
Closed loop combustion control		1.5	1.0	3.0	2.0
2500/3000 bar fuel injection		0*	0*	1.0	1.0
Sequential turbo/ down-sizing		0*	0*	0.5	0.8
Cooled EGR		1.0	1.0	1.5	1.5
Variable valve actuation		-		1.0	1.0
Mechanical turbo-compound		2.5	1.3	3.0	1.5
Electric turbo-compound		5.0	2.5	6.5	3.3
Organic Rankine cycle		-		6.5	3.3
Friction reduction		1.0	1.5	1.5	2.2
Improved accessories		0.5	0.8	0.7	1.0
Electric accessory drive (oil/water/steering/air compressor)		2.0	3.0	2.0	3.0
Maximum Engine total		**13 to 15**	**12 to 14**	**23 to 27**	**21 to 23**
Hybrid (50 $\pm$ 10 kw motor)		3 to 4	6 to 7	4 to 5	8 to 9
Transmission 12 speed with DD		1.5	1.0	1.5	1.0
AMT compared to average driver		3	5	3	5
Engine and Transmission Lubricants		1.0	1.5	1.5	2.2

Note: Technology benefits are not additive, and some technologies cannot be used together with others on the list

* Technology required for 2010 standard

4 AERODYNAMIC DRAG, ROLLING RESISTANCE AND WEIGHT REDUCTION

4.1 AERODYNAMIC DRAG REDUCTION TECHNOLOGIES

In basic terms, an aerodynamic drag force can be expressed as:

$$F_D = C_d * \rho * A * V^2/2,$$

where:

- F_D is the drag force,
- C_d – drag coefficient,
- ρ – air density,
- A – vehicle cross-sectional reference area, and
- V – effective speed (compounded from vehicle speed and a wind directional speed component).

While a truck cross-sectional effective area is dictated by its size requirements, the drag coefficient and vehicle effective speed are the two most significant components in determining the force required to overcome air resistance.

Since the drag force varies as the square of wind speed, its contribution to fuel consumption is significantly higher at highway speeds. Peterbilt has shown that (assuming steady state driving in undisturbed air) the aerodynamic drag component becomes the largest demand for power at speeds above about 50mpg, overtaking

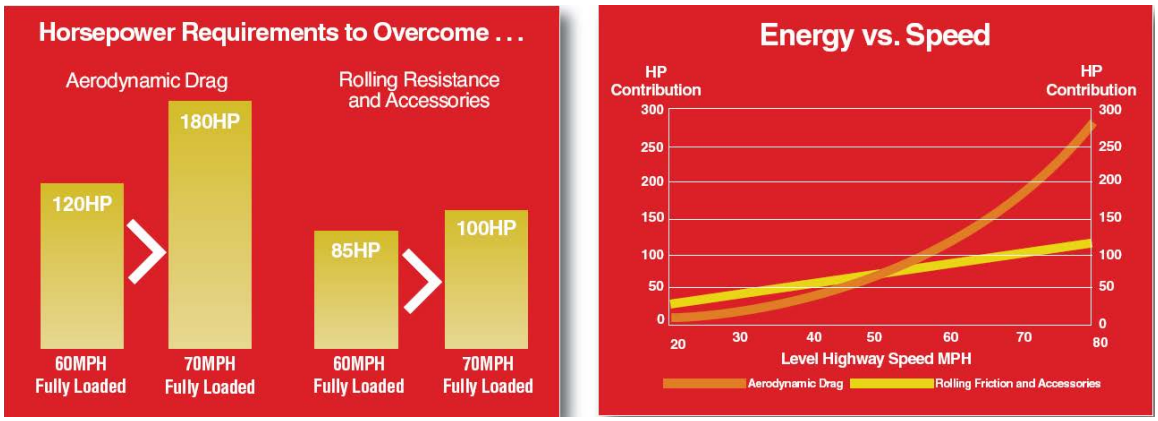


Figure 4-1: Steady-state Tractor/trailer Aerodynamic Drag vs. Speed, Compared to Rolling Resistance. Source: Peterbilt.

rolling resistance as the leading component for fuel consumption. The power requirement becomes especially large at highway speeds. For example, as indicated in Figure 4-1, when speed changes from 60mph to 70mph, the power requirement to overcome drag increases by 50%, assuming a fully loaded truck.

For a fully loaded Class 8B tractor/trailer system (80,000 pounds GVW), the energy distribution diagram, as provided in the US DOE's 21st Century Truck Program publications, lists the base energy consumption (assuming steady cruising at 65mph on level road) as 255.5 kilowatt-hours (kWh). Also, as a reference, the target energy level, according to DOE goals, is listed for the truck as 161 kWh. Assuming the energy use target for aerodynamic drag of 68 kWh is achievable, the reduction corresponds to 20% figure from the base drag energy consumption of 85 kWh. Since the base aerodynamic drag consumes 52.8% of an engine output of 161 kWh (85/161), 20% drag energy reduction would result in about 10.6% energy and fuel consumption reduction (0.528*0.2). This figure should be discounted for real world conditions such as rolling hills or traffic, even under the assumption of highway-type driving. Therefore, if aero drag is 38% of fuel use in the line haul cycle as specified by Cummins, the expected fuel savings from 20% reduction in aerodynamic drag is only about 7.6%.

It should be noted that, while air pressure on frontal truck surfaces is a large contributor to aerodynamic drag, studies have shown that for a typical tractor/trailer system, very large drag occurs in low pressure zones created in the gap behind the tractor, under the

vehicle and behind the trailer. Figure 4-2 provides a pictorial illustration of how these turbulent low pressure zones are created. In general, aerodynamic treatments of these large problem areas are designed to minimize pressure differentials by either preventing high speed air circulation and/or providing a surface to which the separated air flows can be redirected and "reattach" with minimal turbulence.

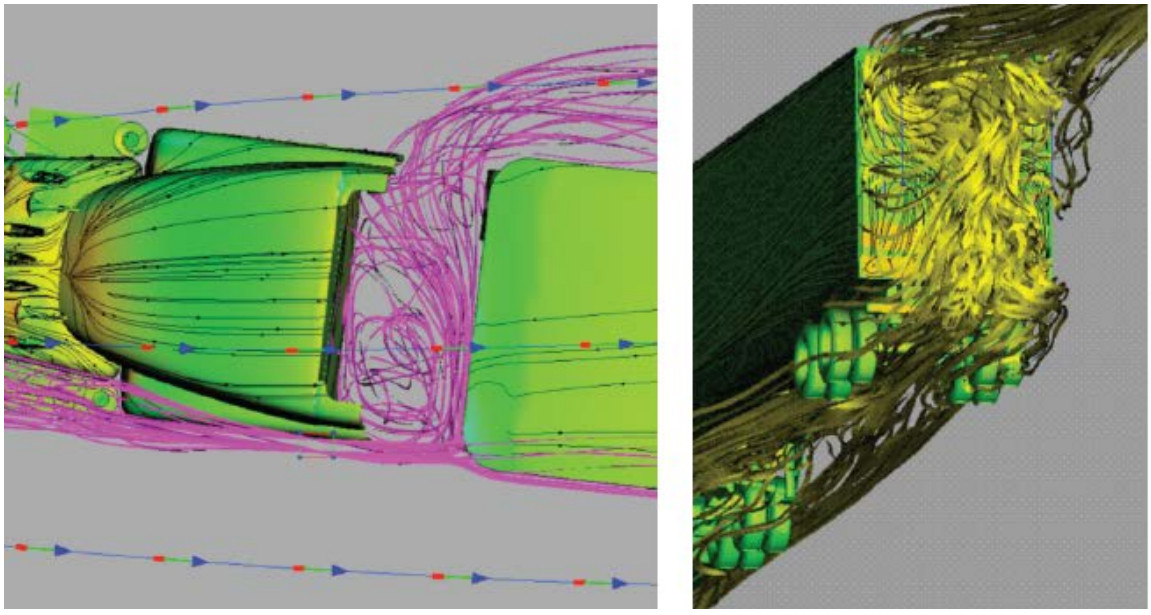


Figure 4-2: Simulation analysis of air flow around the tractor/trailer system.

Turbulent areas represent low pressure zones, large contributors to overall aerodynamic drag. Source: Peterbilt.

The rest of this section focuses on a literature review of aerodynamic drag reduction technologies and our interpretation of published fuel consumption reduction results. For the purposes of this discussion, all estimates for fuel consumption improvement assume the line haul cycle, unless otherwise noted.

4.1.1 Tractor Aerodynamic Improvement Technologies

Truck OEMs have claimed significant progress over past two decades in reducing drag coefficient of a typical Class 8 tractor with a smooth-sided 53-foot trailer from about 0.8 to 0.6 to 0.65, an improvement of 19 to 25%.[22] This level of drag reduction was achieved

[22] Rose McCallen, et. al., Aerodynamic Drag of Heavy Vehicles (Class 7-8): Simulation and Benchmarking", SAE Technical Paper 2000-01-2209

by aerodynamic refinements such as roof fairings, cab/trailer gap devices, side fairings and a tractor front body streamlining. US EPA's SmartWay[SM] guidance[23], states that this level of tractor aerodynamic drag reduction improves fuel consumption 13 to 17 percent as compared to "classic" style trucks with no drag optimization steps taken. These figures are supported by manufacturers such as Kenworth, which claims that their newest generation tractors T600 or T2000 can get up to 17% better fuel consumption compared to traditional "long nose" trucks with no aerodynamic devices[24]. However, this is almost double the effect computed from the line haul cycle approach discussed in section 2.

Figure 4-3 provides a comparison of technologies available on most tractors today with aerodynamic improvements that include sloped hood, air dam, covered intake, side fairings and an aerodynamic roof fairing. Many of these devices can be obtained from aftermarket manufacturers as bolt-on additions so the cost of these basic technologies is widely quoted and range from zero dollars (aerodynamic design incorporated into truck bodies during regular product redesign cycle) to thousands of dollars for devices such as glass fiber side skirts or roof fairings sold in relatively low volume.



Figure 4-3. Aerodynamically Refined Tractor Geometry vs. Non-Optimized Tractor.

[23] The US EPA, "A Glance at Clean Freight Strategies, Improved Aerodynamics", the SmartWay[SM] Facts Sheet, February 2004
[24] Kenworth Truck Company, "Push Less Air, Pull More Profit", a Guide to Increasing Fuel Economy, 2008

Most aerodynamics studies in the US focus on typical “front-engine” truck bodies. However, similar aerodynamic solutions are also applicable to “cab over engine” bodies as illustrated by Figure 4-4, which shows an innovative inflatable gap seal pioneered by IVECO in Europe.

Table 4-1 provides a compiled list of currently available aerodynamic drag reduction technologies most often quoted in the literature. Fuel consumption improvement ranges, as well as the baseline technology identification are also provided together with some of the main roadblocks for market implementation, as commonly identified by truck

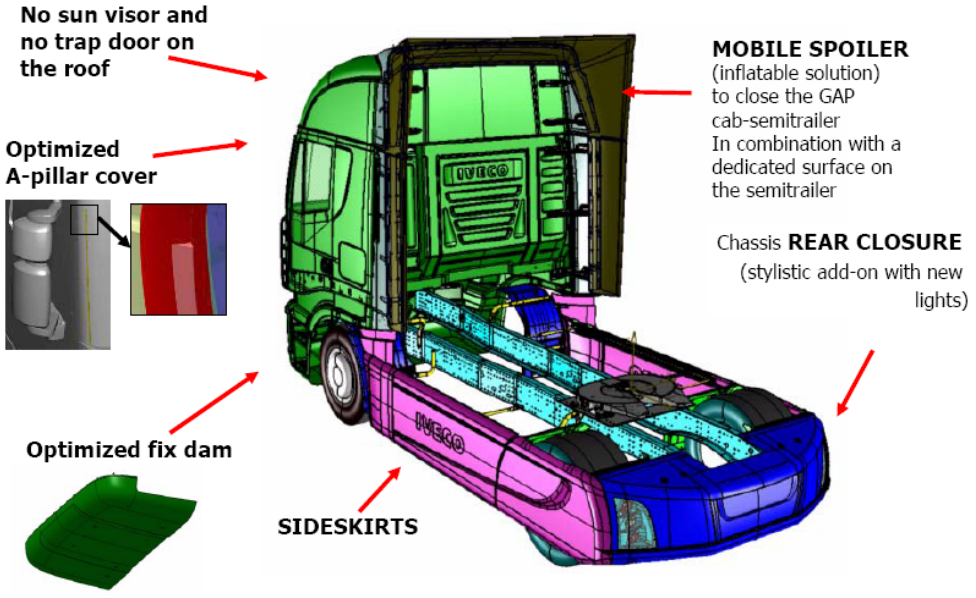


Figure 4-4: Cab-Over-Engine Aerodynamic Improvement Technologies.
Source: Iveco.

Operators. The roof fairing designed to shield an upper face of a trailer is claimed to be the most significant fuel efficiency technology available for tractors with no major implementation issues beyond add on costs.

We believe that historical 25% reduction in aerodynamic drag (from about 0.82 to 0.62) with the streamlined tractors and gap treatment is a defensible estimate. The best in class solutions in 2009 claim a drag co-efficient of 0.55 to 0.57, and anecdotal information from manufacturers suggests that about 35 to 40 percent of Class 8 tractors sold in 2009 are at or close to that level (many do not include the tractor side skirts and aerodynamic

mirrors and may be at a 0.58/0.59 drag coefficient). Another 35 to 40 percent of the market do not purchase the "full' aero package but have only the full roof fairing (possibly those used in regional haul) and may be at drag coefficients of 0.62 to 0.65, while 15 to 20 percent opt for the "classic" look at a drag coefficient of 0.71 to 0.75 with a roof deflector . This distribution yields an average drag coefficient of 0.62 for the 2009 fleet of tractors used to haul van trailers. However, the estimates of up to 17% fuel consumption improvement from the 25% level of drag reduction is highly optimistic and potentially reflects idealized driving scenarios. The line haul cycle based computation would yield a 9.5% fuel economy benefit in real-world operation.

Table 4-1: Tractor Aerodynamic Improvements and Fuel Consumption Estimates.

Technology	**Fuel Consumption Improvement [%]**	**Compared to base configuration…**	**Implementation Issues**
Trailer Gap 38 inches	1.2 ± 0.3	Gap 46 inches	Turn radius reduction
Trailer Gap 25 inches	0.7 ± 0.2 1.6 ± 0.3 3.0 ± 1.0	Gap 35 inches Gap 46 inches Gap 65 inches	Turn radius reduction
Cab Roof Deflector	4.0 ± 1.0	No deflector	
Full Roof Fairing	6.0 ± 2.0	No deflector or fairing	
Full Roof Fairing (with roof cap and rubber trim)	7.0 ± 2.0	Raised roof sleeper	
Cab Gap Extender (with rubber trim)	2.0 ± 0.5	No gap treatment	Turn radius reduction, compatibility with trailer
Improved Air Dam Front Bumper	1.5 ± 0.3	Standard bumper	
Tractor Side Skirts	2.0 ± 1.0	Exposed fuel tanks	Brake cooling, snow/ice buildup, ground clearance
Remove Bug Deflector	1.0 ± 0.5	Bug deflector	Bug accumulation
Radiator Shutters	0.5 to 2 1 to 3	No shutters – summer No shutters – winter	Engine Cooling Issues
Under-hood air cleaners	1.5 ± 0.5	Cowl mounted air cleaner	Packaging issues
Aerodynamic mirrors	1.2 ± 0.3	Regular mirrors	Visibility

Estimates for steady-state level driving at 65mph

Furthermore, the literature tends to report combined fuel consumption improvement figures of discrete aerodynamic devices as additive. For example, adding together all

possible devices that can be combined on a single truck from Table 4-1 yields a fuel economy improvement of about 17%, but the non-additive nature of benefits yields an actual combined benefit of around 10 to 12 percent at a continuous 65 mph and only 7 to 9 percent on the line haul cycle. Fuel consumption benefits of discrete technologies cannot be added together, since any single aerodynamic device will alter overall system air flow and, therefore, benefits from other "downstream" devices will be different. Using the line haul cycle effect as described above, the defensible figure associated with 25% drag reduction should be about 8%, as the nominal historical fuel consumption improvement estimate over 25 years compared to a base tractor/trailer with no aerodynamic enhancements. This value implies an annual fuel economy improvement from aerodynamics alone at 0.38%, which is still well above the fuel economy survey data based estimate of 0.2% to 0.25% per year for the combined effect of aerodynamic and rolling resistance improvements. This implies that as aerodynamics becomes a smaller part of engine load, the net benefits decrease from about 4% per 10 percent drag reduction to 3.5% or less.

Future tractor aerodynamic improvements will require more comprehensive streamlining of the truck exterior; these technologies are already being demonstrated by manufacturers. Peterbilt has performed wind tunnel testing and determined that even with today's aerodynamically refined tractor geometries, opportunities exist in drag "hot spots" such as tractor/trailer gap, windshield, and radiator grille/bumper system (see Figure 4-5)[25]. Freightliner's Innovation Truck program is another example that has shown a similar approach. The Freightliner designs build upon their Cascadia model 2007-level technology package and include rear wheel fairings, underbody panels and front bumper air splitter to smooth air flow in the corresponding areas. Also the program has demonstrated side view cameras in place of traditional mirrors.[26]

The total feasible drag reduction from current levels obviously depends on the base vehicle geometry. For example, lighter "straight" trucks (i.e., unarticulated single units, with truck and cargo container build on the same chassis, mostly falling into Classes 6

[25] Peterbilt, "Truck Aerodynamics and Fuel Efficiency", White Paper, 2008
[26] Daimler Press Release, "Daimler Trucks North America Previews Latest Technologies on New Innovation Truck at Mid-American Trucking Show", March 19, 2009.

and 7) will not have a gap between the truck body and container so the overall drag improvement potential will be smaller. Once again, the major applicability issue is how the trucks are used, i.e., primarily in city or suburban driving, or primarily interstate-type high speed driving patterns. All trucks have the potential to adopt technologies such as aerodynamic mirrors, bumpers and fuel tank fairings.

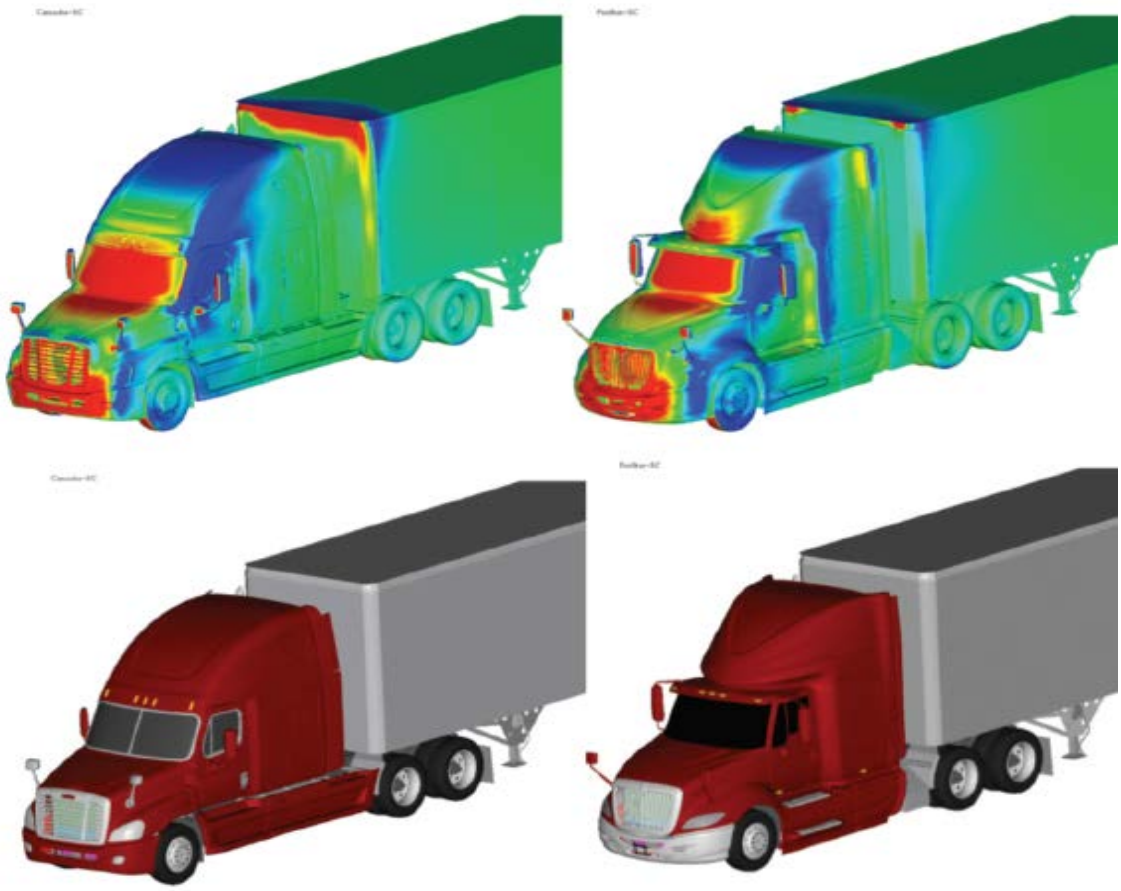


Figure 4-5. Peterbilt truck drag hotspots and resulting aerodynamic design improvements.
In general, aerodynamic drag reduction technologies are applicable to any truck class but

4.1.2 Trailer Aerodynamic Improvements

The basic rectangular shape of a van trailer offers significant opportunities for improving the aerodynamics and fuel efficiency of the tractor-trailer system. Existing trailer technologies are primarily designed to reduce turbulent air flow in the front (in the tractor-trailer gap), the underside (between the rear tractor tires and the rear trailer tires),

and the rear (behind the rear doors). Solus-Solutions has shown that these areas contribute about 75% of the total drag created by the trailer, which can be further divided as 30, 35 and 35 percent for each of these locations, respectively. Figure 4-6 provides examples of practical solutions for these problem areas. Trucks with other trailer types such as flat beds, auto carriers, or stake beds, therefore, can have only relatively small improvement to aerodynamics from items such as side skirts or diffusers.



Figure 4-6: Trailer Aerodynamic Devices

Photos above, from left to right, Side Skirts, Front Fairing, Tail Fairing. Sources: Layton Composites, Nose Cone Manufacturing, ATDynamics and Iveco.

Solus-Solutions claims that addressing the three trailer problem areas, a combined 10% fuel consumption improvement can be achieved at highway speeds[27]. Other literature sources we have examined provide further indication concerning claimed fuel consumption improvement that the discrete trailer devices can achieve and Table 4-2 provides a list of these estimates as well as the implementation issues as reported by truck operators.

[27] R.M. Wood, Solus-Solutions and Technologies, "Operationally-Practical and Aerodynamically-Robust Heavy Truck Trailer Drag Reduction Technology", SAE Technical Paper 2008-01-2603

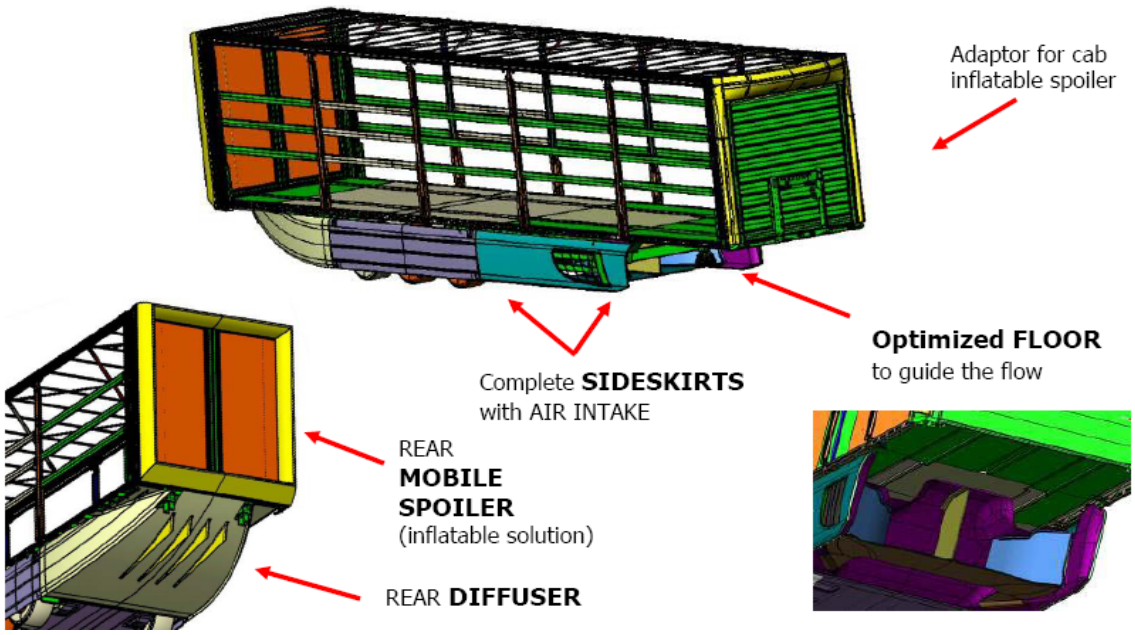


Figure 4 -7. Trailer Aerodynamic Drag Reduction Technologies.

This data appear to confirm that 10% fuel consumption improvement is possible at 65 mph with the smooth sides, trailer side skirts and boat tail. However, it is likely that some portion of this benefit can be attributed to the gap treatment technologies built onto tractor bodies and likely include the contribution from the tractor roof fairing.

Table 4-3 itemizes RPE ranges for the trailer aerodynamic devices as reported by various aftermarket manufacturers[28]. When these estimates are used to compute nominal cost effectiveness, it can be observed that the market values these devices in a range from $228 to $495 per each percent of claimed fuel efficiency gain. The average cost effectiveness for this data sample is $360 per 1% improvement.

[28] CK Salter, Presentation Before NAS Committee, June 18-19, 2009

Table 4-2. Trailer Aerodynamic Drag Improvement Technologies and Claimed Fuel Consumption Improvements

Technology	**Fuel Consumption Improvement [%]**	**Compared to base configuration…**	**Implementation Issues**
Smooth trailer sides	2 to 4	Trailer with exterior posts, no side curtains	
Side skirts	Up to 7	No skirts	Ground clearance issues, snow/ice accumulation, brake cooling
Boat tail	3 to 5	Regular base	Trailer length restrictions, door accessibility, docking issues
Inflatable tail	Up to 3	Regular base	Trailer length restrictions, door accessibility, docking issues
Trailer base vortex generators	Up to 3	Regular base	Trailer length restrictions, door accessibility, docking issues
Trailer face fairings	1 to 3	Regular face	Turn radius reduction
Nose cone	Up to 4	Regular face	Turn radius reduction, compatibility with tractor

Estimates for steady-state level driving at 65mph(?)

Table 4-3. Trailer Aerodynamic Device Manufacturer Responses Concerning their Product Costs and Fuel Consumptions Benefits

Technology	**Claimed Fuel Consumption Reduction %**	**Incremental RPE [$]**	**Nominal Cost Effectiveness [$RPE/%FC]**
Trailer Skirts	6 7 7	1,900 1,599 2,400	317 228 343
Trailer face devices: Stabilized Nose Fairing Gap Fairing Nose cone	 1 2 2 4	 495 795 849 1,264	 495 398 425 316

4.1.3 Tractor/Trailer as a System

Since the fuel consumption benefits are difficult to segregate into trailer and tractor portions, especially because the gap treatment device benefits can overlap between the trailer and tractor technologies, we have focused on the tractor/trailer system analysis as more appropriate approach to determine overall benefit potential.

Rocky Mountain Institute (RMI) has published a report claiming that advanced truck streamlining efforts should yield C_d of 0.45 for a tractor/trailer system or even lower[29]. Their claims were substantiated by results from Canadian Prevost articulated bus (size comparable to a typical Class 8 tractor/trailer system) wind testing program which demonstrated C_d result of 0.384 (with full gap seal, low sides and flat streamlined front end). RMI does indicate that Cd of this level would be more difficult to achieve for a typical front engine/large radiator trucks with several horizontal geometry separations but they believe that C_d of 0.45 is achievable.

The U. S. National Academy of Sciences (NAS) is currently evaluating and compiling fuel efficiency improvement technology information and early results are available in public domain. The estimates include RPE figures compiled by TIAX and others although these estimates are still to be reconciled[30]. For class 8 truck aerodynamic devices, the NAS data includes estimated system level improvement in order to achieve various C_d targets. Table 4-4 summarizes these estimates as compared to a baseline 53-foot tractor-box trailer combination with total C_d of 0.63. The data illustrates that 0.45-level of C_d is achievable although it will require inclusion of advanced trailer enhancements.

When nominal cost effectiveness is calculated using data provide for the NAS committee, it can be observed that basic aerodynamic tractor devices, such as fairings and deflectors, and other aerodynamically redesigned components, such as mirrors, can be implemented in the market place at RPE per 1% improvement ranging from $400 to $500. More advanced next generation advancements, that includes “active” drag mitigation devices

[29] Rocky Mountain Institute, “Transformational Trucks: Determining the Energy Efficiency Limits of a Class-8 Tractor Trailer”, July 2008.
[30] The National Academies, “Technologies Performance and Cost – Class 8 Truck and Trailer”, Presentation by Committee Workgroup During April 7, 2009 Meeting.

(for example, inflatable gap reducers or retractable flaps), will require RPE per 1% improvement ranging from $500 to $900 or higher.

Table 4-4: NAS Estimates of Drag Reduction Technology

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Technology/Package	**Fuel Consumption Reduction [%]**	**Incremental Cost [$RPE]**	**Nominal Cost Effectiveness [$RPE/%FC]**
Cab top deflector, sloping hood, cab side flares	1.0 to 2.0	750	500
Aggressive aero cab: streamlined mirrors, cab side extenders, integrated sleeper cab roof fairings, aero bumper, full fuel tank fairings (**C_d~0.55**)	3.0 to 3.6	0 to 2,750	417
Trailer streamlining: side skirts, aggressive trailer gap fairing (**C_d~0.5**)	3.8 to 5.9	2400	494
Advanced trailer aero package: flow treatment devices and dynamic boat tail, side skirts and aggressive gap fairings (**C_d~0.45**)	6 to 8.5	5,000	689
Pneumatic aero drag reduction devices	3.9 to 4.4	2,500 to 5,250	933

Baseline vehicle: 53-foot tractor-box trailer, 80,000pounds GVW, C_d=0.63

TIAX has shown that for lighter class 6 and 7 straight trucks the fuel consumption benefits of basic streamlining steps such as redesigned bumper or fuel tank wraps, would be similar, 1.0 to 2.0 % at an RPE of $750, which also translates to about $500 RPE per 1% improvement nominal cost effectiveness. More aggressive steps with additional technology, such as roof fairing and rear-mounted frame extensions for straight trucks, would achieve larger benefits, estimated at 5 to 8%, when compared to basic un-streamlined truck.

4.1.4 Aerodynamic Device Analysis and Summary

Significant aerodynamic refinements have been implemented by the heavy duty transport industry, but improvements were mostly integrated into tractor bodies, since no trailer owners were required to contribute. Most of the future potential for aerodynamic improvement is due to further refinement of the gap between tractor and trailer, underbodies, trailers, and to a much lesser extent improvements in tractor aerodynamics. Trailer improvements can be achieved at lower cost but are difficult to implement since trailers and tractors are often owned by different entities. The major institutional roadblock for trailer improvements is that their owners have no incentive to spend up-front capital with no direct benefit to them from fuel savings. Also aerodynamic trailer add-on technology was traditionally resisted by operators due such issues as cooling problems, ground clearance, durability and length limitations imposed on highway trucks. The use of devices such as inflatable adjustable gap seals, retractable skirts, or active devices should reduce incompatibility issues but will be more difficult to justify due to add-on costs and reliability concerns. The institutional trailer issues must be addressed before all of the benefits of the aerodynamic devices shown will be actually implemented widely in the market.

The potential for further aerodynamic drag reduction is highly dependent on base line truck configuration and duty cycle. Substantiating claims of fuel efficiency improvement by manufacturers, especially the aftermarket, is problematic, for two reasons. First, full scale independent wind-tunnel testing is costly and rarely available, and second, typical coast-down tests are hard to verify for marginal efficiency improvement technologies. Many researchers rely on truck scale model testing (typically 1:10 or 1:20 models) but OEMs such as Peterbilt believe that the scaled-down testing cannot be accurately translated into real-world performance, due to on-road variables such as wake interaction or the effect of rotating tires.

The EPA/DOT rulemaking has very similar data and has identified aerodynamic “packages” that combine discrete technologies. Its Bin 1 is the baseline with a C_d of 0.79, consistent with our data for the “classic” tractor-trailer. It has defined Bin 2, 3 and 4 packages with values of 0.72, 0.63, and 0.56 for C_d . The technologies are generally

defined but not specific as manufacturers have to evaluate the actual aerodynamic performance to compute the C_d, which must fall within predefined values. EPA has also defined a Bin 5 with a C_d value of 0.51 for unspecified future improvements.

The literature we have examined indicates that the best tractor and regular trailer class 8 systems today (with aggressive gap treatment) achieve a total C_d of 0.56, which can be estimated to result in about 11% fuel consumption improvement on the highway route cycle when compared to old-style tractor/trailer with no aerodynamic streamlining at a C_d level of 0.79. Our estimates for the marginal (additive) benefits of technology, starting from a classic high roof tractor trailer with a drag coefficient of 0.79 is as follows:

Technology	EPA Bin	Drag Co-efficient.	% Drag Reduction*	%FC Reduction*	Cumulative FC %
Classic Cab & Trailer	1	0.790	Base	Base	100
Aero Cab I	2	0.742	6	2.3	97.7
Full Roof Fairing		0.668	10	3.8	94.0
Aero Cab II	3	0.628	6	2.3	91.8
Cab Gap Extender		0.609	3	1.1	90.8
Tractor Fairing/ Skirts		0.585	4	1.5	89.4
Aero Cab III	4	0.561	4	1.5	88.1
Additional gap/ mirror treatment		0.544	3	1.1	87.1
Trailer Side skirts	5?	0.501	8	3.0	84.5
Trailer Smooth underbody		0.481	4	1.5	83.3
Trailer Boat tail		0.457	5	1.85	81.7

* from previous step

Our analysis does suggest that, assuming the institutional tractor/trailer issues are addressed and there is adequate lead time, the advanced aerodynamic streamlining efforts should result in an additional 18.3 % reduction in drag coefficient (0.56 to 0.46) for new

Class 8B tractor-trailers with aggressive trailer enhancements. This level of C_d reduction would provide up to 6.4% additional fuel consumption improvement relative to the base classic tractor trailer. The FC consumption reductions are for the long haul cycle, and will be much smaller for the regional cycle due to its lower speed. The two levels identified in yellow high lights correspond to the average and best levels in 2008/9. Note that the fuel consumption reduction from the best level available today is 7.3 % (1-81.7/88.1) and is 11% relative to the average. EPA however, assumes that 10% of sleeper cabs are in Bin 1 and 70% in Bin 2, with the remainder in Bin 3 so that their baseline is higher, permitting a larger reduction in drag coefficient.

For low and mid-roof tractors, the frontal area is lower by 25% to 30% for the tractor which leads to much lower drag at the same drag coefficient. If the base classic tractor has a similar drag coefficient, the aero drag related fraction of fuel consumption would be reduced to 26% for a low roof tractor and 28.5% for mid-roof tractor. The tractor aerodynamic drag co-efficient reductions would be similar but the full roof fairing would not apply. Hence for the long haul cycle, the estimates of aero drag benefits for a low roof and mid-roof tractor without a van trailer would be as follows:

Technology	EPA Bin	Drag Co-efficient.	% Drag Reduction	%FC Reduction*	Cumulative FC %
Classic Cab & Trailer	1	0.790	Base	Base	100
Aero Cab I		0.742	6	1.56/ 1.70	98.44/ 98.3
Aero Cab II	2	0.698	6	1.56/1.70	96.9/ 96.6
Cab Gap Extender		0.650	3	0.78/ 0.85	96.1/ 95.8
Tractor Fairing/ Skirts		0.624	4	1.05/1.15	95.1/ 94.7
Aero Cab III		0.599	4	1.05/ 1.15	94.1/93.6

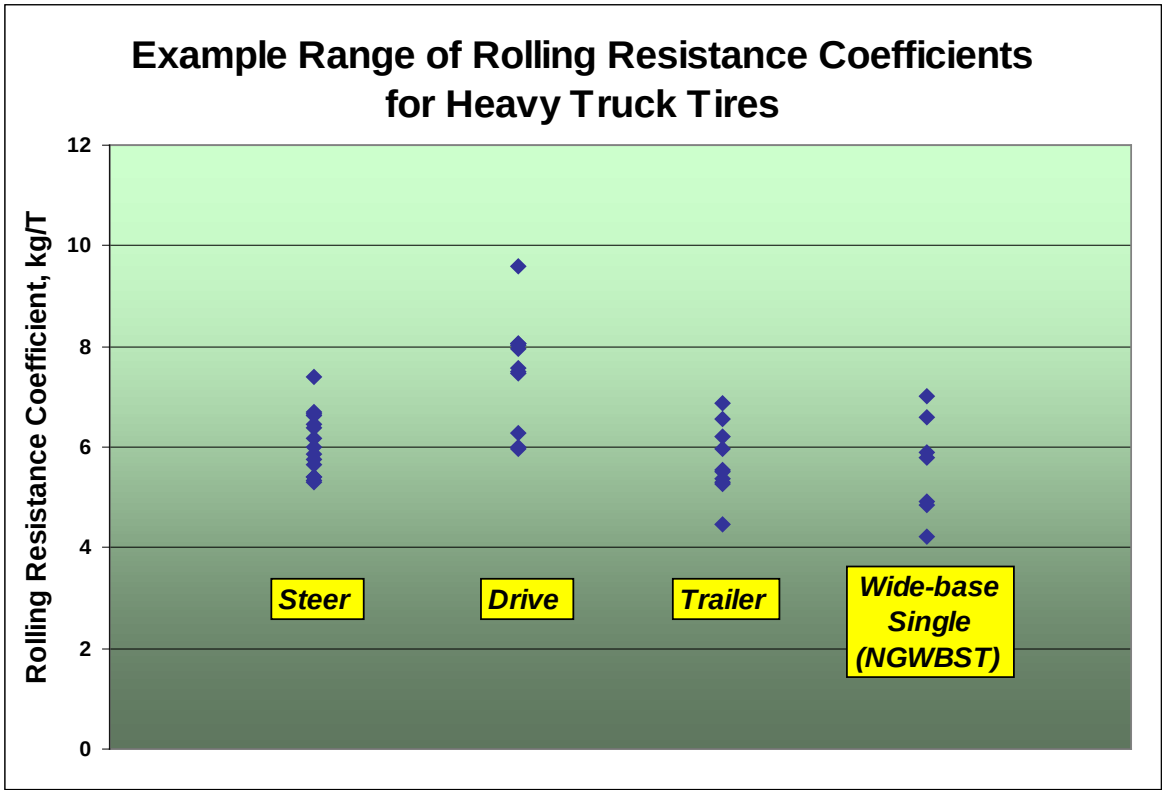
*Low roof/ mid-roof

Hence, for a non-van body tractor trailer on the same long haul cycle, the maximum benefits are only on the order of 6% from the tractor. Aerodynamic benefits for devices for flatbed trailers and tankers have not received much attention but some modest

benefits may be available. EPA assumes that 40% of day cab tractors are in Bin 1 while 60% are in Bin 2. We use this data since we do not have independent data on the baseline for these vehicles.

4.2 ROLLING RESISTANCE REDUCTION

The deformation of the tire as it rolls results in rolling resistance losses, and rolling resistance is proportional to the load on the tire. The rolling resistance coefficient (RRC) is the energy dissipated by the tire per unit distance normalized by the load on the tire, and is currently about 7 kg/ton, or 0.007. Information from tire manufacturers suggests that the RRC has declined by about 1.4 percent per year since the introduction of truck radial tires around 1960 with an RRC of about 0.14, although the rate of decline has not been uniform through the period. Unfortunately, little data on actual tire RRC values are publicly available to obtain the exact average and distribution, but sample data provided by Michelin is shown below in Figure 4-8. The figure suggests that steer and trailer tires have an approximate RRC of about 0.006 while drive tires are higher at about 0.008. More importantly, the figure shows that actual in-use tires show wide disparities in RRC, up to 40 percent between the best and worst, but there is little information on other tire variables which may be compromised by reduced RRC such as traction or durability.



The use of higher RRC tires on the drive axle does suggest that some compromise between traction and RRC is possible for a given level of technology. For example “rib” tires with straight tread grooves have lower RRC than “block” or “lug” tread designs but also have lower traction and are typically used on trailer axles. However, there is significant variation in RRC even within specific axle groups and tire tread designs; for example, some newer drive tires with continuous shoulder ribs can have lower RRC than trailer tires. In addition, the weight loads on the axle groups are different, and this leads to different sensitivity to RRC reduction. For example a properly loaded 5-axle tractor trailer will have 42 $\pm$ 2% of the load on each dual axle group and 16 $\pm$ 1 % on the front axle, but because of the higher RRC tires used on drive axles, they can account for about 50% of tire energy loss with the trailer axles accounting for 35% and the front axle accounting for 15%.

The EPA SmartWay program certifies tires that meet a maximum RRC level, which are currently specified as 5.8, 7.3 and 5.2 kg/ton for the steer, drive and trailer axles, respectively. Anecdotal information from truck manufacturers suggests that about half of all trucks are using tires that meet or exceed these specifications as of 2009, but the picture on trailer tires is less clear. These values may be close to the averages for Class 8B vehicles (tractors). If the averages decline at the historic rate of 1.4% per year, then the 2020 values will be 5 and 6.25 kg/ton respectively, which are equal to the lowest values shown in Figure 4-8. There appears to be no specific lower limit for 2025 proposed by tire manufacturers by axle type but the historical rate suggests a reduction of 20% to 4.64 and 5.84 kg/ton, though some studies such as those by NESSCAF and TIAX have asserted a lower value of 4 to 4.5 as feasible before 2020 for all axles.

The “Wide Base Single” tire has been offered by Michelin since the 1980s, and a New Generation version has been offered since 2000. Michelin has claimed that this tire can replace the dual tires employed on drive and trailer axles and their Single tire has 20 percent lower RRC than the best dual tire option. Current data shows some super single tires near the 4.0 kg/ton value, but it is not completely clear if the test methods to determine rolling resistance are identical across manufacturers. In addition, the lower tire

and rim weight can save 700 pounds with Aluminum rims, and possibly more with steel rims, and net cost on a new truck is lower due to the savings on the rims. In spite of these claimed advantages, the wide base single tire technology has achieved a market penetration of under 10% in 2009 according to truck manufacturers. One reason is that these tires do not offer “limp home” capability in the event of a tire failure while dual tire system could provide such capability in emergencies. Specific truck manufacturers also stated that some fleet owners experienced very little fuel savings when switching from low rolling resistance dual tries to wide base single tires. Finally, some states do not allow such tires on oversize/ overweight loads, so truck owners are cautious about using these tires. However, the wide base singles appear to reduce RRC by an additional 20 percent over a similar technology regular tire.

The effect of a 10 percent RRC reduction is readily derived from the sensitivity coefficients shown in Table 2-1. For a long haul truck, a 10 percent RRC reduction results in 3.5% reduction in fuel consumption at constant engine efficiency, but engine efficiency decreases slightly due to the lower average load so that a slightly lower number is expected. On a regional route, the same 10 percent RRC reduction results in a 2.15 percent fuel consumption decrease at constant engine efficiency. Michelin also provided data on the measured values from reducing RRC by 20 percent as shown here:

Heavy Truck (40t) 12.0l Diesel engine	Fuel Consumption		Fuel Savings	Percent
	CRR=5.5kg/t	CRR=4.5kg/t		
Sub Urban Use – half loaded	16.53 gal/100mi	15.98 gal/100mi	0.55 gal/100mi	3.3%
Regional Use – half loaded	15.13 gal/100mi	14.53 gal/100mi	0.59 gal/100mi	3.9%
Long Haul Use – half loaded	12.62 gal/100mi	11.94 gal/100mi	0.68 gal/100mi	5.4%
Sub Urban Use – full loaded	21.29 gal/100mi	20.57 gal/100mi	0.72 gal/100mi	3.4%
Regional Use – full loaded	19.76 gal/100mi	19.04 gal/100mi	0.72 gal/100mi	3.7%
Long Haul Use – full loaded	14.92 gal/100mi	14.02 gal/100mi	0.89 gal/100mi	6.0%

The regional cycle full loaded data shows a 3.7% decrease as opposed to the expected 4.3% and the long haul cycle shows a 6 percent decrease in fuel consumption as opposed to the 7% predicted, indicating that efficiency losses in the engine reduce the expected value by 15% in both cases (from 7 to 6 and 4.3 to 3.7). Hence, the anticipated 20% reduction in RRC between 2009 and 2025 should result in a 6% decrease in fuel consumption on the long haul cycle and a 3.7% decrease on the regional cycle. The

Michelin data also shows the reduced effect of RRC when the truck is not fully loaded, and the benefit of RRC reduction is reduced by 10 to 15 percent when moving from full load to half load. On the vocational truck cycle, the benefits of RRC reduction are quite small, with a 10 percent reduction yielding a maximum 0.8% fuel consumption benefit and an expected 0.68% benefit.

Costs of reduced rolling resistance are difficult to estimate since many tire attributes vary simultaneously. Cost increments estimated by TIAX are based on super single tires but appear to include the cost of aluminum rims (which reduce weight but not rolling resistance). According to manufacturers, the tires with Smart-Way specification typically cost $50 to 100 more per tire on average than uncertified tires and we have utilized this number ($75 $\pm$ 25) for a 10% RRC reduction, and $150 for a 20% RRC reduction per tire. Costs of the Single Wide Base Tire are small to negative if the cost of the rims are included and hence all of the cost is associated with the hedonic cost of uncertainty about limp home potential and resale value.

4.3 WEIGHT REDUCTION

The reduction in truck empty weight can have a beneficial effect on fuel economy or on the payload specific economy (payload ton miles per gallon) if the weight reduction is offset by increased payload. However, only a small fraction of trucks operate at the GVW limit at any given time and it appears likely that about 90 percent of trucks will have a fuel economy benefit from weight reduction. Weight affects both the inertial energy lost to the brakes and tire rolling resistance. With increasing speeds, the inertial loss component goes down as the tire component increases so that the sum of the two is near constant between 20 and 50 mph at 45 to 48%. At very low speeds (~5mph) the inertial component is dominant, but at speeds higher than 50 mph, the aerodynamic component becomes the largest single source of energy loss.

For a typical tractor trailer unit, the tractor (day cab) weighs about 14,000 pounds and the 53 foot steel trailer weighs about 13,000 pounds. Sleeper cab units are about 3000 to 4000 pounds heavier, so that the tractor-trailer combination weighs 27,000 to 31,000 pounds. Typical operating weight is about 75,000 pounds, so that a 1000 pound weight reduction is a 1.33% decrease of total weight but a 3.4% decrease of empty weight. As

noted, weight accounts for 47.5% of energy use on the long haul cycle and on the regional cycle, so that a 1000 pound weight reduction corresponds to a 0.64% fuel economy increase at constant engine efficiency or a 0.54% increase with a 15% efficiency loss factor as for tires. This number corresponds well with data reported from SmartWay (which reports impacts from 0.4 to1.0 percent) and the NESCCAF simulation study which reports 0.5%. The Aluminum Association also reported that a 10 percent empty weight reduction corresponds to a 1.6% fuel economy benefit which is proportional to the benefits we derived for the 3.5% reduction.

Medium-duty trucks in Class 6 and 7 weigh about 14,000 $\pm$ 1000 pounds for a van body unit and operate at 24,000 pounds (class 6) to 30,000 pounds (class 7) loaded weight. Hence, a 500 pounds. weight reduction corresponds to a 2.1% weight decrease for a Class 6 truck to a 1.7% reduction for a class 7 truck, with fuel economy impact of about 1% and 0.8% respectively. Data from manufacturers suggest that the 0.8 to 1 percent range is appropriate for this level of weight reduction.

Weight Reduction Through Material Substitution

Weight reduction is possible both through improved design and through the use of alternative materials, notably composites and/or aluminum. It is now common for cabs to have composite fenders, hood and aerodynamic aids such as the roof deflector and side flares. (Of course, the aerodynamic add-on devices add weight). However, most structural parts are still made of steel. Widespread use of high strength steel and weight efficient design can reduce weight; for example, MAN has introduced the new TGX series that saves 200 to 270 pounds relative to the older TGA series through improved design and use of high strength steel. The replacement of the twin leaf springs for the front axle with a single parabolic leaf alone resulted in a 100 to 120 pounds. weight saving. The use of HSLA in suspension components in the rear axle saves about 50 to 60 pounds

In addition, the 12L engines now common in most long haul trucks save about 300 to 400 pounds relative to the older 15L engines. The newest generation of trailers uses composites and high strength low alloy (HSLA) steel and are 1000 to 1500 pounds lighter

than older all steel trailers. At the same time, we note that many of these improvements are now incorporated into the majority of new trucks and are hence in the baseline.

For analysis purposes, we have separated truck empty weight reduction into four steps:

- A 5% weight reduction from weight efficient design and extensive use of HSLA steels as well as a smaller displacement engine. Most trucks introduced in the 2007+ time frame already incorporate these improvements although the state of the trailer market is less well understood.
- A 10% weight reduction from the use of composites for body closures, floor panels and exterior panels, as well as aluminum in some castings and forgings. Some Class 8B trucks that emphasize weight reduction already offer these improvements in new models
- A 15% weight reduction from aluminum or composite use in structural members such as the frame rails. Aluminum frame rails can save 900 to 1000 pounds if used on both tractor and trailer in a Class 8B truck, for example, and are offered in specific applications like a fuel tanker which operates at maximum allowable GVW.
- A maximum 20% weight reduction with a highly intensive weight reduction design employing both aluminum and composites. This is based on inputs from manufacturers, who see this level as technically achievable but not cost-effective now.

Each step in the weight reduction ladder corresponds to 600 to 700 pounds weight reduction for a Class 6/7 van body truck and a similar level of weight reduction for the tractor and trailer (each). In a recent analysis of light duty vehicle weight reduction, we have estimated the cost of material substitution per pound saved as $0.75. $1.50, $2.50 and $4 per incremental pound saved in each step. For a class 8 tractor, this would amount to $490, $1470, $3100 and $5700 respectively with similar amounts for the trailer.

5 FUEL SAVINGS FROM OPERATIONAL IMPROVEMENTS

5.1 OVERVIEW

Unlike light-duty vehicles, there is significant potential to reduce fuel consumption by increasing the operational efficiency of moving goods. These improvements can be summarized as follows

- reducing empty backhaul
- preventing over-speeding on the highway
- use of adaptive and predictive control
- improved driver training to drive in a fuel efficient manner
- maintaining proper tire pressure
- using double trailer combinations or longer trailers
- mode shifting from road to rail (inter-modal transport)
- Idle reduction

These operational items and their potential benefits are **not** the focus of this report but are mentioned here, as many analyses of fuel savings from heavy-duty trucks have combined operational savings with technology based savings. Only idle reduction can be facilitated with technology and considered in more detail in Section 5.3, but all other issues are summarized below.

5.2 SUMMARY OF POTENTIAL SAVINGS FROM OPERATIONAL IMPROVEMENTS

Reducing empty backhaul for heavy-heavy duty trucks can be achieved by better load and route matching but there is obviously an irreducible minimum since some amount of empty mileage is necessary as the delivery point and pickup of new loads will never occur at the same location. The 2002 VIUS data shows that empty backhaul accounts for

33 percent of VMT and about half that percentage of fuel consumption since trucks are substantially more fuel efficient when empty. Since 2002, there has been a proliferation of private load matching services and route optimization services based on the internet and on GPS based truck position sensing. Anecdotal evidence suggests that empty backhaul has declined since 2002 to less than 25%, and that load clearing market is already quite efficient. Hence, further fuel savings from reducing empty backhaul may be quite small and probably account for less than 5 percent fuel saving potential.

Preventing **over-speeding** on the highway has been shown to provide significant fuel savings. Reducing the speed from 70 mph to 65 mph (or 7.1%) results in a 6 percent fuel economy improvement. For a vehicle operating 100,000 miles per year at a base fuel economy of 6 mpg, fuel cost with diesel at $3 per gallon is $50,000 annually. Hence, a six percent fuel economy improvement saves about $2830 annually. Unfortunately truck productivity is also reduced since the distance traveled per day is reduced. Trucks do not operate at 70 mph all the time and assuming a peak to average speed ratio of 1.75, the reduction of peak speed by 7.1% will reduce truck productivity by 4.1%. A HHDT typically produces revenues of $180,000 to $250,000 per year implying a productivity loss of $7350 to $10,200, substantially higher than the fuel savings. This is the major reason why truckers speed; the economic incentives are too strong even at higher fuel prices. We do not anticipate any fuel savings from voluntary speed reductions. However, the EPA has proposed providing credits for hardwired speed limiters set at 63 mph or 60 mph. The credit provided for sleeper cab equipped trucks is quite large due to the EPA assumption that 85% of their VMT, these trucks operate at 65mph constant speed.

Driver training can have a significant impact on fuel economy on-road. The American Trucking Association (ATA) Maintenance Council estimates that the best drivers compared to the worst drivers can improve fuel economy by up to 35% but this is an extreme comparison; other studies have estimated impacts in the 5% to 15% range. In addition to limiting speed and idling time, drivers can improve fuel economy by improved gear shifting, acceleration practices, route choice and use of accessories. Due to the overlap with speed and idling issues considered separately (which accounts for much of the fuel economy benefit), we selected 4% as a possible maximum benefit from driver training, and have assumed that about 50% of drivers (mostly employed by large fleets)

have already had the training. Costs of driver training programs are estimated at $1400 based on data from ATA.

Maintaining proper tire pressure improves fuel economy since under-inflation by 10psi increases rolling resistance by 7% which reduces fuel economy by about 1.5 to 2% if all tires are under-inflated by this amount. Of course, under-inflation may vary across tires on a given truck, and EPA has estimated from limited survey data that the net average of proper inflation is to increase fuel economy by 0.6% for the fleet as a whole. New tire pressure monitoring systems are available for the approximate cost of $40 per tire + $100 for the monitoring system.

Shifting to larger trailers or using combinations of trailers called long combination vehicles (LCV) is always more efficient in terms of fuel use per ton-mile of payload transported. While this is widely recognized, many states and local areas restrict the use of multiple trailers that involve the use of two or three trailers of differing lengths (depending on state) that are currently used in some states. Indeed, the trucking community refers to these as “Turnpike doubles” or “Rocky Mountain doubles” and “triples”. LCV use is governed by federal law. Prior to 1991, states could set their own laws with regard to trailer length maximums and combination maximums. After a handful of (western) states starting increasing the maximum trailer limits the federal government stepped in and has governed the maximums for the interstate highway system, effectively governing all use. However states that had already increased their maximums were grandfathered into the new system and the old maximums are still allowed in those states. An allowed double is a combination of two 28-foot trailers, but this has limited application since it isn’t much bigger than a single 53-foot trailer that is standard. It is used for specific operational requirements where an operator will need to drop one trailer and carry the next to another destination (for example, Fed-Ex or UPS).

The use of many double combinations increases payload based efficiency by 12 to 25% based on measured values, but are often opposed based on safety grounds as it makes passing on narrow roads much more hazardous, and on access due to maneuverability issues. However, a change in federal law can widen usage to major routes, and assuming that the shortest double trailer combination (the Rocky Mountain double) is allowed, fuel

usage can be cut by 15% on approximately 60% of HHDT. This is a “zero cost” option if social and safety issues are not considered

Inter-modal freight has received wide attention in recent times. It is widely known that goods movement by rail or barge is much more energy efficient and rail can use one-tenth of the energy of trucks if the routes are identical and delivery is not time constrained. It is very difficult to generalize this to any specific load and route, since the route circuity on rail and the distance of the rail head from the pick up and delivery points strongly affect these comparisons of energy use. Increased use of barges is, of course, limited by available waterways. Road-to-rail has been increasing significantly for goods (typically commodities such as grain, ores, fertilizer, cement, etc.) where the market forces do not place a premium on time sensitivity, and the 2002 VIUS shows that bulk goods and commodities account for only 4% of trucking payloads. Hence, it appears that the market for road-to-rail is quite efficient and further significant movement in this direction may not result in large fuel savings.

5.3 IDLE REDUCTION

Idle reduction has received considerable attention form EPA and CARB with reference to criteria pollutants, but is also an energy issue. Surprisingly little data exists on the actual extent of long idles in practice; the EPA estimate of 8 hours a day for 300 days a year for all HHDT appears to be very much higher than any trucking industry estimate. Many long distance trucks do keep their engines on at night when the trucks feature a sleeper cab to provide space conditioning, but some trucks are kept running under very cold winter conditions because of problems starting a large diesel engine in very cold weather (typically below -10 C).

There are several technology options to reduce fuel use during idling including

- Direct-Fire Heaters, which heat the cab and engine using a small flame and a heat exchanger. This technology has only around 5% market penetration in US vs. 55% in Europe.
- Auxiliary Power Units (APU), which are a secondary combustion engine connected to a generator to power electrical systems and provide heat. They have

near zero market penetration due to concern about overloading existing wiring systems and retrofits rendering void the truck's warranty.

- Automatic Engine Idle Systems, which run the engine only to maintain set cabin temperature and battery voltage, and can automatically shut off and restart the engine to minimize fuel use. They are offered as an option of new truck purchases from some manufacturers but some drivers can find engine restarts disruptive while sleeping. They are currently installed in trucks that account for 7-8% of VMT.
- Truck Stop Electrification, which taps the electrical power grid to power the truck's auxiliary units while at overnight stops. This technology requires a properly equipped station with a "shore power" port as well as additional wiring and equipment on the truck. Stations are rare with implementation suffering from a 'chicken or the egg' problem as stations don't see a market until enough trucks are equipped, while the added cost of the equipment for trucks does not pay back without a sufficient station network.
- Advanced Truck Stop Electrification which provides cabin heating and cooling from an external source via air supply and return pipes as well as power outlets for driver accessories. A pilot project (IdleAire Technologies) charges $1.20 per hour to truckers and installs at stations at no fee to the station operators.

Based on the cost-benefit analysis shown below in Table 3-1, we have considered engine idle systems, direct fire heaters and APU power as possibilities for fuel conservation. Truck Stop Electrification is very cost effective but could require significant market intervention to make it widely available.

Table 3-1: Costs and Benefits of Idle Reduction Strategies

Technology	Initial Cost	Fuel Reduction		Emission Reduction (kg)			Maint. Savings	Operating Charge	Payback Period (months)
		Gallons	percent	CO2	Nox	PM-10			
Direct-Fire Heater	-$2,000	690	4.3%	7,000	121	N/A	$210	$0	19
Auxiliary Power Unit	-$7,000	1,320	8.1%	13,392	166	2.5	$336	$0	36
Automatic Engine Idle	-$1,250	900	5.6%	9,131	97	2.1	$168	$0	10
Plug-in TSE	-$2,800	1,800	11.1%	11,613	179	4.1	$336	-$745	15
Advanced TSE	-$25	1,800	11.1%	11,613	179	4.1	$336	-$2,880	2

Note: All costs reflect the perspective of the truck owner. Advanced TSE can provide services that may have to be paid
for separately, such as Internet access. The value/savings of such non-fuel related services is not reflected here.

From ICF draft report – January 2002

Most of the operational improvements are also not relevant for these classes of trucks except for the automatic engine idle and driver training related benefits. Of course, cost effectiveness for all technologies are quite different due to the different annual miles of travel and different use patterns but these are accounted for in the calculations shown in Section 6.

6 FUEL ECONOMY POTENTIAL AND COST EFFECTIVENESS ANALYSIS

6.1 OVERVIEW

This Section provides an integrated view of the fuel savings and costs possible from an analysis of scenarios of all truck technologies operating together on various truck weight classes, and different duty cycles. However, our detailed discussion of truck operating characteristics and technologies in the previous sections show that

- every weight class of trucks has a range of different truck types operating different duty cycles
- the current technology and fuel economy baseline for 2008/9 is not well understood
- costs of truck technology vary over broad ranges and by vehicle type.

Hence, the analysis presented in this section targets some specific functional areas where there are significant truck populations based on the VIUS survey data and allocates them to one of three duty cycles that are based largely on manufacturer inputs. In addition, baseline technology levels are based on manufacturer comments on sales in 2008/9. The cost issue was tackled by allocating technologies into broad payback categories that were more easy to determine than specific costs. The data and methodology employed to make these distinctions are described below.

6.2 NEW TRUCK SALES ALLOCATIONS BY CLASS AND APPLICATION

New heavy-duty truck sales have varied significantly over the last 5 years with the medium trucks in classes 5 through 7 varying form as much as 180,000 units to as low as 100,000 units. class 8 trucks sales have also varied form a high of 275 thousand units to a low of 128 thousand units during the period. These large variations were in part due to a “pre-buying” rush to beat the emission requirements for 2007 and exacerbated by the

recession in 2008. We anticipate future sales of about 140,000 units in the 2012 to 2015 period for medium duty trucks and sales of 225,000 Class 8 trucks. About 30% of Class 8 units are straight trucks (class 8A) in the 40,000 to 60,000 pound GVW category primarily used in rough-duty applications like refuse haulers, agricultural goods carrier and construction support (all 3 axle trucks are over 33,000 pounds GVW). The remaining 70 percent of class 8 vehicles are tractor-trailer units with GVW over 60,000 pounds or class 8B, and these are typically the focus of most analyses due to their high annual VMT Such trucks are used in long haul and regional haul applications, with a relatively small percentage in rough duty and short haul applications. About 60% of these feature sleeper cabs and 70% have enclosed van bodies. The splits between cab type and body type for new trucks, based on industry information, is as follows as a percent of entire Class 8B fleet:

Cab Type		Sleeper	Day cab
Van body		50%	20%
Tanker		2%	4%
Flatbed/Dump		8%	16%

The VIUS survey data lists the typical radius of operation in steps of 0 to 50 miles, 50 to 200 miles and over 200 miles, and the percentage of Class 8B trucks in the longest radius of operation is only 17.1% but the 50 to 200 miles segment is at 34.1%, and the average annual VMT for the van body tractor trailer is 112,500 miles and 82,000 miles for each segment suggesting that the mid-range operations also may entail some sleeper cab use. Moreover, the percentages of the fleet are different from the percentages of new trucks in this class since trucks are used intensively in the first 4 to 6 years and then sold to second owners who use the more in regional and short haul applications. According to industry sources, the average VMT of sleeper cab equipped trucks is in the 95,000 $\pm$ 10,000 miles per year range while the annual VMT for day cab trucks is about 50,000 $\pm$ 10,000 miles across different body types. However, new vehicles less than 5 years old average 120,000 miles a year for the van body tractor trailer according to Vehicle Inventory and Use

Survey (VIUS) data, and this is relevant for many of the calculations of cost effectiveness.

Medium duty trucks (classes 6, 7 and 8A) have much lower annual VMT and van body trucks account for about 30 percent of all trucks according to both manufacturers and the VIUS data. About 70 percent of all trucks are used short haul applications while about 20 percent are used in regional haul, with the remainder in rough duty or vocational applications. In general the trucks used in regional applications average 20,000 miles a year while the trucks in short haul applications average only 12,000 miles per year. Vocational trucks average even lower annual VMT between 5000 and 10,000 miles per year. Trucks under 5 years old have somewhat higher average VMT at 28,000 miles per year for regional applications and 18.000 miles per year for short haul. These values are used to compute cost effectiveness to the buyer.

6.3 EVALUATIONS OF COST EFFECTIVENESS

The technology discussion in sections 3 and 4 pointed to the fact that technology costs were not well defined except in isolated instances, and also varied considerably in many cases by truck size and application. Hence, the development of a traditional supply curve of technology improvement to fuel economy versus cost is difficult to establish in a manner similar to that for cars. However, it is widely recognized that most long haul truck buyers demand a that costs of technology be paid back from fuel savings in 3 years or less so that full cost recovery is guaranteed within the period of first ownership which is usually 4 to 5 years before resale. It is not clear if the same payback requirement exists for medium duty trucks but manufacturers believed that this would be a useful approximation of market demand to examine payback periods of five years as being more representative. In addition, manufacturers were more willing to provide inputs on payback period in a general sense than to discuss specific cost data and industry discounting practices. Hence, we classified technologies by “payback period” where the payback was determined by the **undiscounted** value of fuel saved (at $3/ gallon) relative to the incremental price of technology into three categories:

- a period of 3 years or less implying that normal market forces would be sufficient for technology introduction

- a period of 4 to 6 years, implying marginal cost-effectiveness at current conditions, but some of these technologies could be adopted by the market if fuel prices increase or standards would require such technology
- a period greater than or equal to 7 years, implying technologies unlikely to be adopted by the consumer absent subsidies or severe market forcing conditions.

These payback periods correspond to the following approximate price limits per percent fuel savings for the three categories in different applications, and should be treated as indicators rather than as exact numbers:

Value of 1% Fuel Consumption reduction		Total VMT 3/6 years	3 year payback	6 year payback
Long haul tractor trailer		360K/600K	$1800	$3000
Regional Haul tractor trailer		180K/300K	$900	$1500
Regional haul medium duty		84K/125K	$280	$420
Short haul medium duty		60K/100K	$225	$375
Vocational trucks		30K/48K	$120	$190

As can be seen, there is almost a 15 to 1 range in allowable price increase per percent fuel savings depending on application, illustrating the difficulty of commenting on cost and feasibility without specific reference to a baseline and usage type. In addition, the same technology can be classified at very different levels of cost-effectiveness depending on application. These issues are addressed for the heavy –heavy and medium heavy segments separately in the following sections.

6.4 CLASS 8B HEAVY-HEAVY DUTY POTENTIAL

As noted in Section 6.2, the long-haul and regional haul segments of the Class 8B fleet account for most of the population and over 95% of fuel use in this segment.

Technologies have been organized into four categories: those necessary for emission control, those likely to be adopted by the free market (3 years or less payback), marginally cost effective technologies (4 to 6 year payback) and cost-ineffective technologies. Drive train and body technologies are shown in the two tables below.

Table 6-1 shows the drive train technology improvements over the 2008 – 2017 and 2008 – 2025 time frames. The 2010 introduction of urea/SCR has a very significant effect in the short term with emission control related technology providing a 5.4% reduction in consumption by 2017 and a 9.2% related reduction by 2025 assuming constant emission standards. The non urea emission control system is expected to result in a fuel efficiency loss of about 2.5 to 3 percent relative to the urea/SCR system and the route also precludes mechanical turbo-compounding due to the sequential turbo requirement, although organic Rankine cycle based heat recovery will be possible Urea consumption is at about 2 to 2.5 percent the diesel consumption rate. Hence, our analysis shows that the non-urea route could be competitive in regional haul category where mechanical turbo-compounding produces very small benefits, as long as urea prices are higher than diesel fuel prices (they were almost $6 per gallon recently). However, it is less competitive in the long haul category, at least for the short term when mechanical turbo-compounding is widely introduced, but may be competitive if the Rankine bottoming cycle is introduced. It is also notable that the free market forces will likely bring about half to two thirds of the total drive train improvements possible.

The benefits of reducing truck tractive energy requirements from drag, weight and rolling resistance reduction are more complex in terms of cost effectiveness. Classification of many improvements into payback categories is very problematic due to three issues. First, there are many more trailers than tractors, and the registered population ratio is about 2.8, but this masks a lot of variability around the average for individual fleets. In addition, there are reportedly a large number of lightly used old trailers, so that newer trailers may have a much larger fraction of miles traveled. We have assumed an “active trailer” to tractor ratio of 2 to estimate costs and effectiveness of technology applicable to trailers. Second, many devices have operational issues and concerns that has prevented significant market penetration, and we can associate this with a hedonic cost that must be added to the real cost. Third, the effectiveness of some aerodynamic aids on trucks with

Table 6-1: Potential Class 8B Fuel Consumption Reduction (%) from Drive Train Technology

		2017		2025	
		Long haul	Regional	Long haul	Regional
2500/3000 bar FI		0	0	1.0	1.0
Seq. Turbo +downsize		0	0	0.5	1.0
Urea/SCR		3.0	2.0	5.0	4.0
Cooled EGR		1.0	1.0	1.5	1.5
Closed Loop FI		1.5	1.0	3.0	2.0
Emission Control Total with/ without urea		**5.4/ 2.5**	**4.0/ 2.0**	**9.2 / 5.9**	**7.3/ 5.4**
Variable valve actuation		-	-	1.0	1.0
Mech. Turbo-compound		2.5	-	3.0	-
Engine Friction		1.0	1.5	1.5	2.2
12-speed + Direct drive		1.5	1.0	1.5	1.0
Engine+ axle lubricants		0.7	1.0	1.0	1.5
Improved Accessories		0.5	0.8	0.7	1.0
3 year payback tech.		**6.05/ 3.65**	**4.25**	**8.4/ 5.6**	**6.55**
Mech. Turbo-compound		-	1.3	-	1.5
Electric Acc. Drive		1.5	2.2	1.3	2.0
Automated Manual Tran.		3.0	5.0	3.0	5.0
Electric Turbo-compound or Organic Rankine		2.5	-	3.5 or 6.5 w/o urea	3.3 w/o urea
4 – 6 year payback tech,		**6.85/4.45**	**8.3**	**7.6 / 10.5**	**8.2 /11.05**
Electric Turbo-compound		-	1.2	-	1.8 w/ urea
Hybrid 50kW drive		3.5	7.0	4.5	9.0
>6 year payback tech		**3.5**	**8.1**	**4.5**	**10.65/ 9.0**
Total Potential With/ without urea		**20 / 13.3**	**22.5 / 18.9**	**26.6 / 24.1**	**29.0 / 28.45**

non-van body trailers is not well understood and we have the used same benefits or aerodynamic cabs and trailer skirts for both body types as a first approximation. The estimation of hedonic cost is simply based on the classification by payback and current market share. For example, the use of trailer skirts at a cost of $1500 to 2000 to produce a 3 percent fuel consumption reduction is cost effective in a 3 year time frame for long haul trucks (after accounting for 2 trailers per tractor) but actual market penetration is low at around 5%. This would correspond to a 5+ year payback so that the hedonic cost is approximately equal to the actual cost and total cost is double actual cost. The available technologies and payback classifications are shown in Table 6-2.

There are several major findings related to the data shown in Table 6-2. Unlike the fact that drivetrain technology benefits are comparable for the long haul and regional cycles, the benefits of body technologies are significantly higher for the long haul case than the regional haul case, and in the van body case relative to the non van body case. This is due to the fact that aerodynamic aids and reduced tire rolling resistance have a much larger effect at highway speeds than at city/suburban speeds, and many aerodynamic aids like the gap treatment and boat tail are applicable only to van body trailers. Second, the negative hedonic aspects of some technologies distort the standard computations of cost-effectiveness and many technologies that are relatively inexpensive have market penetrations that suggest high hedonic cost. Determining market resistance to these technologies in the future is still a challenge. Third, only about 40 to 45 percent of the total available benefit is in the 3 year payback category, suggesting that a majority of the benefits available will not be used in a free market scenario.

Idle reduction benefits outside of short term idle reduction from hybridization are not directly considered in the tables, since it applies only to the subset of long haul Class 8B vehicles with sleeper cabs where the HVAC is provided by engine power. As noted, anecdotal information has been used to estimate that idle fuel consumption for these vehicles can account for 8 to 10 percent of total fuel use, and the use of auxiliary power units or externally supplied air can reduce the fuel use by 50 to 100 percent. This finding is independent of engine energy used to overcome tractive force during driving and can be accounted for separately.

Table 6-2; Fuel Consumption Reduction from Class 8B Body Related Improvements (%)
(Van body/ Non van body)

		2017		2025	
		Long haul	Regional	Long haul	Regional
Full roof fairing (50%)		1.9	1.25	1.9	1.25
Aero Cab II		2.3	1.50	2.3	1.50
Cab gap Extender		1.1	-	1.1	-
Aero Cab III		-	-	1.1	0.70
Rolling Resistance I		0.7	0.45	0.7	0.45
Weight Reduction I		0.8	1.0	0.8	1,0
Weight Reduction II		0.8	-	0.8	-
Rolling Resistance II		-	-	0.7	0.5
3 year payback tech.		**7.4 / 4.6**	**4.1 / 3.0**	**9.3 / 6.3**	**5.3 /4.0**
Weight Reduction II		-	1.0	-	1.0
Weight Reduction III		0.8	-	0.8	-
Cab gap Extender		-	0.7	-	0.7
Tractor Fairings		1.1	0.7	1.1	0.7
Additional Gap treatment		1.1	0.7	1.1	0.7
Trailer Side skirts		3.0	-	3.0	-
Wide base Single Tire		1.4	1.0	1.4	1.0
4 - 6 year payback tech,		**7.2 / 6.1**	**4.0 / 2.6**	**7.2 / 6.1**	**4.0 / 2.6**
Weight Reduction III		-	1.0	-	1.0
Weight Reduction IV		-	-	0.8	1.0
Trailer Side skirts		-	2.0	-	2.0
Trailer underbody		1.1	0.7	1.1	0.7
Boat Tail		1.9	1.25	1.9	1.25
>6 year payback tech		**3.0 / 0**	**4.8 / 3.0**	**3.7 / 0.8**	**5.7 / 4.0**
Total Potential		**16.7 / 10.6**	**12.4 / 8.5**	**19.0 / 12.7**	**14.3 / 10.3**

6.5 MEDIUM DUTY TRUCK TECHNOLOGY POTENTIAL

Almost all medium duty trucks in Classes 5 through 8A are straight trucks, with 2 axles (classes 5, 6 and 7) or 3 axles (class 8A). As noted in section 2, very few are used in long haul, and only a modest fraction, about 20 percent, are used in regional haul. The vast majority are used in urban locations or as vocational trucks in utility and municipal fleets or as buses. Due to the majority of such vehicles being used in low speed applications, it is likely that technologies better suited for high speed full load situations such as turbo-compounding or waste heat recovery may not be commercialized in the smaller displacement engines (6 to 10 liters), although there may be some models offering an optional turbo-compound versions.

Table 6-3 shows the benefits of drive-train technologies for vehicles operated on a regional cycle or city/ vocational cycle. The engine technology benefits are assumed to be similar for the city and vocational cycles as little data exists to accurately define the differences in engine technology benefits over a 15 to 20 mph cycle versus a 5 to 10 mph cycle with occasional high external power take off loads. However, the differences in hybridization benefits between the two cycles are recognized in this analysis. Although the benefits from engine technology alone are smaller for MDTs relative to the Class 8B vehicles, the net benefits from all drive-train technologies are higher than for Class 8B trucks due to the larger impacts of transmission and hybridization technology on the lower speed cycles.

Table 6-4 shows the benefits of body technologies for MDTs and the benefits on the regional cycle are comparable to those for Class 8B trucks, even though the aerodynamic benefits are smaller. However, the impact of body technologies is very small for trucks used in urban cycles or on vocational cycles since aerodynamics and rolling resistance are smaller parts of overall fuel consumption. This also minimizes the issues related to hedonic costs for trucks used in these applications.

Table 6-3: Potential MDT Fuel Consumption Reduction (%) from Drive Train Technology

		2017		2025	
		Regional	City/Voc	Regional	City/Voc
Seq. Turbo +downsize		0	0	1.0	1.5
Urea/SCR		2.0	1.5	3.0	2.0
Cooled EGR		1.0	1.0	1.5	1.5
Closed Loop FI		1.0	1.0	2.0	2.0
Emission Control Total with/ without urea		**4.0/ 2.0**	**3.5/ 2.0**	**7.3/ 4.4**	**6.3/ 4.9**
Variable valve actuation		-	-	1.0	1.0
Engine Friction		1.5	2.0	2.2	3.0
AMT (70% pen)		4.9	7.0	4.9	7.0
Engine+ axle lubricants		1.0	1.0	1.5	1.5
Improved Accessories		0.8	1.2	1.0	1.5
3 year payback tech.		**8.0**	**10.8**	**10.2**	**13.35**
Mech. Turbo-compound		1.3	0	1.5	0
Electric Acc. Drive		2.2	2.8	2.5	3.0
4 – 6 year payback tech,		**3.5**	**2.8**	**3.9**	**3.0**
Electric Turbo-compound		1.2	1.2	1.8	1.8
Hybrid 50kW drive*		12.0	20/30	15.0	24/35
>6 year payback tech		**13.1**	**21 / 31**	**16.5**	**26.35 / 36.1**
Total Potential Hybrid without urea		**25.2**	**32.9 / 40.3**	**29.5**	**41.1/ 48.9**

*Additional work is required to better characterize hybrid benefits and duty cycle dependence for trucks

Table 6-4: Fuel Consumption Reduction from Body Related Improvements (%) to Medium Duty Trucks

(Van body/ Non van body for Regional Trucks)

		2017		2025	
		Regional	City/Voc	Regional	City/Voc
Full roof fairing (50%)		1.25	-	1.25	-
Aero Cab II		1.5	0.4	1.5	0.4
Aero Cab III		-	-	0.7	0.2
Rolling Resistance I		0.45	0.15	0.45	0.15
Weight Reduction I		1.0	0.85	1.0	0.85
Weight Reduction II		1.0		1.0	-
Rolling Resistance II		-	-	0.45	0.15
3 year payback tech.		**5.1 / 3.9**	**1.4**	**6.2 / 5.0**	**1.7**
Weight Reduction II		-	0.8	-	0.8
Weight Reduction III		1.0	-	0.8	-
Wide base Single Tire		0.9	-	1.4	-
6 year payback tech,		**1.9**	**0.8**	**2.2**	**0.8**
Weight Reduction III		-	0.8	-	0.8
Weight Reduction IV		-	-	0.8	0.8
Side skirts		2.0	0.6	2.0	0.6
Boat Tail		1.25	-	1.25	-
>6 year payback tech		**3.2 / 2.0**	**1.4**	**4.0 / 2.8**	**2.2**
Total Potential		**9.9 / 7.8**	**3.6**	**12.0 / 9.7**	**4.6**

6.6 ABILITY TO MEET THE 2014/2017 STANDARDS

EPA has promulgated regulations for fuel economy and GHG emissions for heavy-duty trucks, with a voluntary standard for 2014 and a requirement for 2017. The standards are unusual in structure in that there is a separate standard for engines based on actual measured BSFC on an engine dynamometer, and a vehicle standard that assumes a "compliant" engine and models the effect of vehicle technologies using a simulation model. The effect of transmissions cannot be accounted for in the current set-up and hence EPA does not provide credits for transmission improvements. Vehicle technologies are accounted for in a discrete manner in which specific improvement types are bundled into "bins". The test cycles over which fuel economy compliance is evaluated is described in Section 2.5, and we noted the over-emphasis on the constant speed 55/65 mph modes for all trucks, and especially for sleeper cab equipped Class 8 trucks.

The engine standards are modeled in the regulatory analysis for the FTP and Steady State (SET) modes, and the required improvement for heavy-heavy duty engines to 2017 is 5% on the FTP cycle and 6.1% on the SET cycle, relative to 2010 baseline. In comparison, this analysis in Table 6-1 shows that a 6.05% improvement is possible within a 3 year payback(assuming that the 5% improvement related to urea/SCR implementation is included in the 2010 baseline) but this includes some transmission benefits equal to 1.7%. However, the benefits of turbo-compounding are much larger on the EPA cycle than our 2.5% estimate due to the high level of steady state operation, and we anticipate that technologies with 3 year payback will be adequate or nearly adequate to meet the 2017 standard. For medium duty engines, the standard requires an 8.6% reduction relative to 2010. Table 6-3 shows that up to 10.8% is possible for city/ vocational cycles, with 3 year payback but 7% is transmission related so that only 3.8% is possible form engine technology. In addition, we anticipate some improvements from emission control technology and adoption of a downsized sequential turbo engine that was not in the 2010 baseline for some engines that could provide an additional 1to 1.5% benefit. The shortfall would have to be made up with more expensive electric accessory drives, so that our estimate of cost of compliance for the medium duty engines would be higher than EPA's estimate.

On the vehicle side, the medium duty vocational trucks are offered only one option for improvement – tire rolling resistance reduction. The regulation allows credits for other technologies such as hybrids, but requires the manufacturer to demonstrate the benefits through actual testing. It is important to note that weight reduction and the use of the AMT, which figure very prominently in Table 6-4 for improvements are not considered in the EPA analysis.

In the case of long haul tractors, the regulations have several compliance options with aerodynamic and tire improvements, idle limiters and speed control. The benefits for these technologies are significantly higher than in our analysis due to the choice of the long haul cycle at steady state. Figure 6-1 shows the different compliance options for the long haul sleeper cab truck relative to the improvement required for 2017.

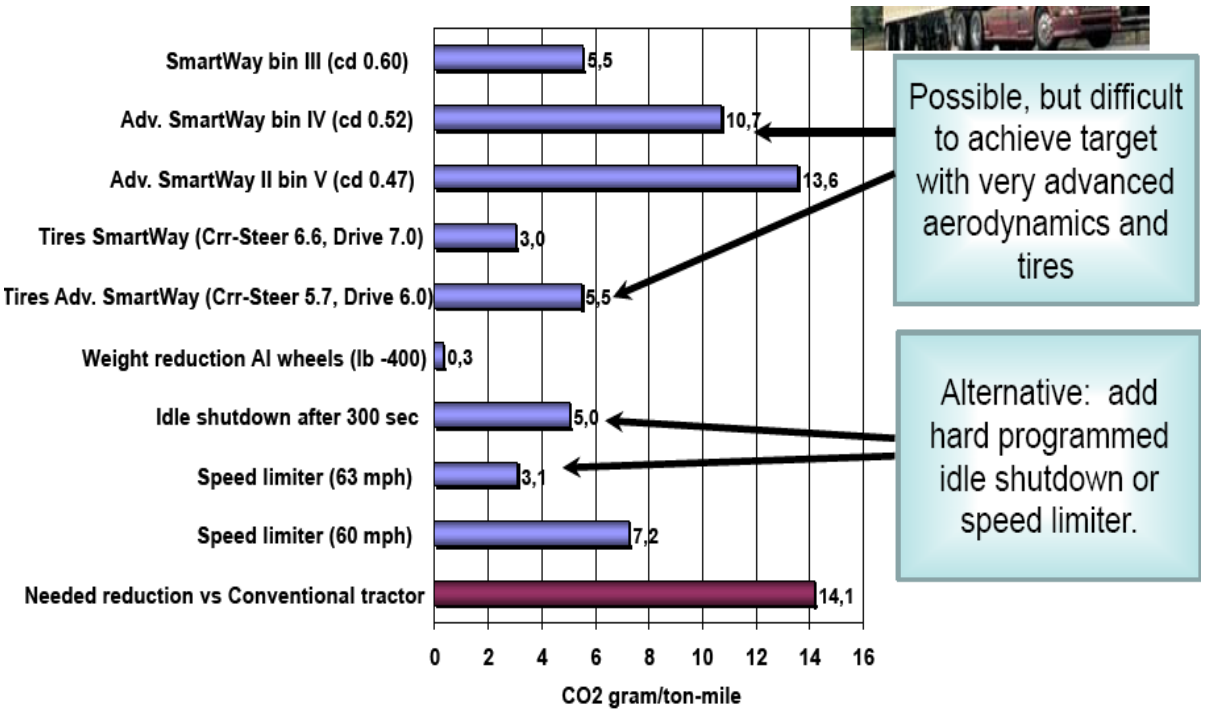


Figure 6-1: Technology Improvements for Class 8 Sleeper Cab Trucks for Compliance

The percentage reductions are very nearly similar to the CO2 g/ton-mile reduction required since the baseline is 96 g/ ton-mile. The lowest drag aerodynamic tractor available today coupled with the lowest rolling resistance tires is enough for compliance but must be implemented across 100% of the fleet. Alternatives can include a 63 mph

speed limiter which provides a 3.2% benefit, or idle shutdown after 5 minutes which provides a 5.2% benefit but these technologies carry substantial negative hedonic value that is not considered by EPA. Using the more realistic cycles, obtaining the required 14.7% improvement would require use of all technologies with a payback of up to 6 years from our calculations shown in Table 6-2. However, the overstatement of the benefit of the technologies shown in Figure 6-1 is a major factor allowing compliance.

6.6 SUMMARY AND CONCLUSIONS

The information in Tables 6-1 to 6-4 has been aggregated to provide forecasts of fuel consumption reduction by Class, Body Style and type of operation for the Class 8B trucks and the Classes 5 to 8A trucks in tables 6-5 and 6-6 for 2017 and 2025, respectively. The tables also show the cumulative technology benefit for fuel consumption reduction as a function of the payback period, with the column labeled ECT for emission control technology being independent of payback period as it is required by regulation. One of the unexpected findings from the analysis is that the total available benefit from technology is quite similar across all vehicle types (except vocational use trucks) at 30 $\pm$ 5 percent in 2017 and 39 $\pm$ 5 percent in 2025. However, the distribution of the benefits across payback period is quite different across the different combinations of weight class, body style, and use type.

The relative importance of hybrid technology, which is quite expensive, is also dramatically different, with hybrid technology accounting only for 11 percent of the total available benefit (not 11% absolute) in the Class 8B Long-haul Van body Truck to almost 70 percent of the total available benefit in vocational use trucks. Hybrid technology or trucks is still in its early development stages and refinement of this estimate is needed to better estimate the future potential especially to the 2025 period. Note that these estimates include the benefits of idle reduction in its definition of hybrid technology when the idle is part of the drive cycle, but does **not** include benefits of idle reduction associated with overnight use for sleeper cab trucks. The use of an auxiliary power supply unit or external HVAC supply can reduce fuel consumption by another 4 to 6 percent based on anecdotal estimates of annual use for overnight power.

The comparison of our results to those from the National Academy of Science's recent study of truck fuel economy is made difficult by the fact that the NAS study does not provide an explicit baseline or drive cycle associated with its percent consumption reduction estimates. In general, the NAS report includes the benefits of improved operational strategies and idle reduction; when their estimates are adjusted for the two effects, many of the numbers seem comparable. For example, the total benefit for tractor trailers is listed as 51 percent reduction in consumption with 6 percent from operational improvements another 4 to 6 percent from idle reduction (presumably overnight idle). This suggests technology benefits of about 40 percent on a comparable basis, which is very similar to our estimate. We are also less optimistic than the NAS on the pace of technology introduction and believe that these reductions may be feasible in 2025 rather than 2020, but even our estimate is an unprecedented rate of change for the truck industry.

In terms of the newly promulgated standards, the study shows the following:

- The use of 65/ 55 mph steady state cycles without any gradient to quantify fuel economy provides an incorrect picture of the real world benefits.
- The engine improvements required by EPA are those we consider likely to happen under free market forces for the heavy-heavy segment, but are aggressive for the medium duty segment
- Vehicle related improvements required for tractors in long haul operation emphasize drag and rolling resistance reduction, as well as speed limiters but their benefits are significantly overstated as a result of cycle choice.
- The benefits of weight reduction , transmission improvements and substitution of the AMT for an automatic are largely ignored by the regulation but are very relevant to the real world benefits, especially for medium-heavy trucks

APPENDIX A: DETAILED LISTING OF TECHNOLOGY IMPROVEMENT PROJECTIONS BY PAYBACK PERIOD

Regional

Wt. Class	Operating Range	Body Type		2008 MPG	ECT Benefit %	3 yr, Payback	6 year payback	Maximum Tech	Hybrid as % of max	Max. 2017 MPG
8B	Long Haul	Van (with urea)		6.00	5.40%	17.70%	28.86%	33.41%	10.48%	9.01
		Van (w/o urea)		6.00	2.50%	15.18%	26.68%	31.37%	11.16%	8.74
8B	Long Haul	Non-Van (with urea)		5.72	5.40%	15.21%	25.84%	28.43%	12.31%	7.99
		Non Van (w/o urea)		5.72	2.50%	12.61%	23.56%	26.24%	13.34%	7.75
8B	Regional	Van (with urea)		6.12	4.00%	11.85%	22.40%	32.11%	21.80%	9.01
		Van (w/o urea)		6.12	2.00%	10.01%	20.78%	30.69%	22.81%	8.83
8B	Regional	Non-Van (with urea)		5.66	4.00%	10.84%	20.36%	29.01%	24.13%	7.97
		Non Van (w/o urea)		5.66	2.00%	8.98%	18.70%	27.53%	25.43%	7.81
Medium	Regional	Van (with urea)		8.66	4.00%	16.18%	20.65%	33.26%	36.08%	12.97
		Van (w/o urea)		8.66	2.00%	14.44%	19.00%	31.86%	37.66%	12.71
		Non-Van (with urea)		8.82	4.00%	15.12%	19.65%	31.57%	38.01%	12.89
		Non Van (w/o urea)		8.82	2.00%	13.36%	17.98%	30.15%	39.80%	12.63
Medium	City	All (w/o urea)		8.00	2.00%	13.81%	16.89%	35.26%	56.72%	12.36
	Vocational	All (w/o urea)		6.70	2.00%	13.81%	16.89%	43.46%	69.03%	11.85

Table 6-5 2017 Projections by Vehicle Class and Application

Wt. Class	Operating Rang	Body Type		2008 MPG	ECT Benefit %	3 yr, Payback	6 yr. payback	Max. Tech	Hybrid % of max	Max. 2025 MPG
8B	Long Haul	Van (with urea)		6.00	9.20%	24.56%	35.31%	40.51%	11.11%	10.09
		Van (w/o urea)		6.00	5.90%	19.43%	33.08%	38.46%	11.70%	9.75
8B	Long Haul	Non-Van (with urea)		5.72	9.20%	22.07%	32.38%	35.94%	12.52%	8.93
		Non Van (w/o urea)		5.72	5.90%	16.77%	30.05%	33.73%	13.34%	8.63
8B	Regional	Van (with urea)		6.12	7.30%	17.96%	29.08%	40.25%	22.36%	10.24
		Van (w/o urea)		6.12	5.40%	16.28%	28.51%	39.77%	22.63%	10.16
8B	Regional	Non-Van (with urea)		5.66	7.30%	16.84%	27.06%	37.43%	24.04%	9.05
		Non Van (w/o urea)		5.66	5.40%	15.13%	26.47%	36.93%	24.37%	8.97
Medium	Regional	Van (with urea)		8.66	7.30%	21.92%	26.61%	41.17%	36.43%	14.72
		Van (w/o urea)		8.66	4.40%	19.47%	23.21%	38.45%	39.01%	14.07
		Non-Van (with urea)		8.82	7.30%	20.92%	25.67%	39.68%	37.81%	14.62
		Non Van (w/o urea)		8.82	4.40%	18.44%	22.23%	36.88%	40.67%	13.97
Medium	City	All (w/o urea)		8.00	4.90%	19.00%	22.06%	43.86%	54.72%	14.25
	Vocational	All (w/o urea)		6.70	4.90%	19.00%	22.06%	51.29%	68.24%	13.75

Table 6-6 2025 Projections be Vehicle Class and Application

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State-Variable and Representativeness Errors Conceal "Clean Diesel" Harm: Methodologically Fallacious ACES Research

Kristin Shrader-Frechette*

Department of Biological Sciences and Department of Philosophy, University of Notre Dame, Notre Dame, IN

***Corresponding Author:** Kristin Shrader-Frechette, O'Neill Family Endowed Professor, Department of Biological Sciences and Department of Philosophy; Director, Center for Environmental Justice and Children's Health, 100 Malloy Hall, University of Notre Dame, Notre Dame, IN 46556; E-mail: kshrader@nd.edu

Abstract

In 2015 authors of four joint US-government and auto-and-oil-industry studies, ACES, claimed to have done the first comprehensive evaluation of lifetime exposure to new-technology-diesel exhaust (NTDE-2007), so-called "clean diesel" required by US emissions standards for year-2007 and later heavy-duty trucks. ACES claimed to have found no evidence that NTDE-2007 causes lung cancer. However, since at least 2012, the World Health Organization (WHO), International Agency for Research on Cancer, American Public Health Association, and many other scientists say any diesel exhaust, especially diesel particulate matter, causes lung-cancer, cardiovascular, and neurological problems. Who is right about diesel exhaust, ACES or WHO? This question is important both because the US and other governments cite ACES research in their diesel-exhaust standard-setting, and because the auto and oil industries use ACES conclusions to claim new diesel exhaust is virtually harmless. This article (1) begins the task of assessing the ACES-versus-WHO scientific debate. It (2) argues that the ACES research is fatally flawed because it neither studies what it claims nor does so in an unbiased way. Instead the article (3) shows that ACES research (3.1) relies on state-variable biases (in focusing mainly on NO_2 and mass, not also on DPM and particle size/number), and (3.2) exhibits representativeness errors (in using only the healthiest animals, too-small sample sizes, and non-lifetime exposures). Despite some ACES strengths, the article (4) concludes that because ACES fails to fully assess the worst NTDE-2007 harm and typical exposures to typical subjects, therefore it draws no valid conclusions about NTDE-2007 harm.

Keywords: ACES; Bias; Clean Diesel; Conflict of Interest; Diesel Particulate Matter; IARC; New Technology Diesel Exhaust; NO_2; Particulate Matter; Representativeness Errors; WHO

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Introduction

Burning fossil fuels has driven much of the economic progress and military dominance of the past few centuries. Without oil and coal, the Industrial Revolution and its massive increase in incomes, manufacturing outputs, and standards of living probably would not have occurred. And as Hitler learned in World War II, Germany's small oil reserves were a factor in "its military defeat" (Becker, 1981).

Yet oil- and coal-created prosperity has been bought at a price, one that is especially high for diesel fuels. Apart from the many carcinogens such as benzene and formaldehyde in typical diesel exhaust, its particulate-matter (DPM) emissions are deadly; they are carcinogenic, have no safe dose, and thus exhibit a no-threshold, linear concentration-response relationship (Pope and Dockery, 2006; Dominici et al., 2003; Laden, 2006). In the US alone, tens of millions of diesel engines, mostly heavy-duty trucks, emit pollutants that cause 21,000 avoidable, premature deaths annually; the cancer risks from diesel vehicles are 7 times greater than the combined risk of all 187 other air toxics that the US Environmental Protection Agency (US-EPA) regulates (CATF, 2005a; see EPA, 2014; SCAQMD, 2008). In the UK, DPM alone causes 29,000 preventable premature deaths each year (COMEAP et al., 2010). Diesel-related threats are even worse in developing nations.

In 2015 the diesel debate came to a head when authors of four joint US-government and auto-and-oil-industry studies, ACES, said that apart from older, dirtier diesel engines, the latest-technology diesel was virtually harmless. ACES authors claimed to have done the first comprehensive evaluation of lifetime exposure to new-technolo-

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gy-diesel exhaust (NTDE-2007), so-called "clean diesel" based on US requirements for 2007-and-later-models of heavy-duty diesel trucks. ACES claimed to have found no evidence that NTDE-2007 causes lung cancer (McDonald et al., 2015; Bemis et al., 2015; Hallberg et al., 2015; Conklin and Kong, 2015; Greenbaum et al., 2015). However, groups such as the World Health Organization (WHO), International Agency for Research on Cancer (e.g., IARC, 2012a; IARC 2012b), American Public Health Association (APHA), and government agencies say NTDE-2007 merely reduces but does not eliminate diesel harm, especially harm from DPM. Because diesel exhaust has no safe dose, they say it still causes avoidable lung-cancer, cardiovascular, and neurological problems (APHA, 2014).

Importance of the ACES-versus-WHO/ IARC/APHA Debate

Who is right, the 2005-2015 ACES researchers or WHO-IARC-APHA? This question is important for at least four reasons. One reason is that the leading physicians and scientists agree that diesel exhaust is a major public-health problem (APHA, 2014). A second reason for the importance of the debate is that both top medical and scientific research associations say politics has interfered with diesel-related medical science. For well over two decades, they say the freight and oil industries repeatedly have used the courts to try to block clean-air, diesel, and particulate matter (PM) standards and health studies; yet they say these industries have argued, at the same time, that these very studies (that they have been blocking) are needed prior to any additional diesel regulation (Monforton, 2006; see Crump and Landingham, 2012). "From early days" of diesel research, says a prominent scientific-journal editor, DPM studies have "been subject to a series of legal actions initiated by industry bodies…which has delayed the publication of these [DPM] papers" (Ogden, 2010, p. 727).

A third reason for the importance of the ACES-versus-WHO/IARC debate is regulation. Because the US government cites the ACES research in its rulemaking about diesel-exhaust standards, it is important to determine whether these alleged grounds for not strengthening diesel regulations are scientifically defensible (EPA, 2012). After all, industry groups claim that because NTDE-2007 harm is unknown, thus controversial, the controversy should be resolved before imposing any new diesel regulations (Carter, 2014). Yet leading government and university scientists say diesel harm is well known and that industry is merely trying to delay regulations by claiming the harm is controversial (Michaels, 2008).

A fourth reason for the importance of the diesel debate is its scientific implications for clean-energy research. On one hand, government groups, physicians, environmentalists, and medical scientists say "clean diesel" is an oxymoron, as diesel has no safe dose (Monforton, 2006). On the other hand, oil and auto industries say the ACES studies show "clean diesel" is virtually harmless and should not be confused with the dirtier "old diesel" studied by IARC/WHO. Indeed, diesel-industry spokespeople suggest that "the new diesel engines are now so clean that the findings from this [WHO/IARC] monograph [that condemns diesel as carcinogenic]…are no longer relevant to today's situation" (Carter, 2014). Who is right about NTDE-2007?

One way to begin to access the important ACES-versus-WHO/IARC debate is to ask whether, in challenging scientific consensus about diesel-exhaust harm, ACES has actually studied what it claims--and done so accurately. This article shows that the 2005-2015 ACES research is fatally flawed, both because it does not do what it claims to do, and because it exhibits several well-known scientific biases. Instead of including full assessment of the most harmful components of NTDE-2007, ACES researchers make at least two state-variable errors--in focusing mainly on NO_2 and mass, not also on particle size/number, the main determinants of DPM harm. Likewise they exhibit two major representativeness biases in using only the healthiest animals over a short term, and in using too-small sample sizes. As a result, they fail to consider typical, genuinely representative exposures. Consider each of these four problems in order.

The NO_2 State-Variable Error

ACES research does not address what it claims, in part because it does not fully and correctly evaluate the most hazardous part of diesel exhaust, namely DPM. Government scientists say that in many areas of the US, mobile sources of pollution and especially diesel engines cause 90 percent of the total cancer risk, as in Los-Angeles County (SCAQMD, 2008, 2005; CAL-EPA, 2008a). On average across the US, DPM from diesel engines causes 78 percent of total premature, avoidable US cancers more cancer fatalities than any other pollutant (SCAQMD, 2005; SCAQMD, 2008; CAL-EPA, 2008a,b). As already mentioned, of all 188 regulated US air toxins, DPM causes 7 times more preventable, premature cancer deaths than all the other 187 air toxins combined (CATF, 2005a; see EPA, 2014; SCAQMD, 2008).

Yet ACES studies did not assess the total diesel-exhaust risk, especially DPM, because they did not fully and correctly determine DPM exposures. Instead ACES researchers exposed rats to one of three target dilutions of nitrogen dioxide, NO_2, or to filtered air as a control. As ACES editors admit, "Exposure levels were set based on NO_2 rather than PM…because… calibrating exposures based on PM would have been problematic" (Greenbaum et al., 2015, p.2), that is, too difficult for the ACES researchers to do, although many scientists have done such measurements.

The ACES authors and editors admitted that classic studies of diesel exhaust are based on direct DPM measures, the most hazardous component of diesel exhaust (Greenbaum et al., 2015, p. 2). Because the ACES researchers assessed effects of NO_2 rather than full and correct DPM risks--when DPM is responsible for 78 percent of the total diesel-vehicle cancer risk, they may have addressed no more than 22 percent of the relevant diesel risk. This means that their claims, to have done a groundbreaking, "comprehensive" study of diesel exhaust, are misplaced (McDonald et al., 2015; Bemis et al., 2015; Hallberg et al., 2015; Conklin and Kong, 2015; Greenbaum et al., 2015, p. 2). They have avoided evaluating much of the diesel-exhaust risk, then claimed this exhaust causes no cancer.

To this charge, ACES researchers would respond that because NTDE-2007 supposedly has little DPM, there is little reason to fully assess DPM (Greenbaum et al., 2015, p. 2). However, at least four reasons suggest ACES errs and should fully assess DPM.

First, ACES errs because it admits (Greenbaum et al, 2015, p. xi), as do government and the latest scientific researchers (e.g., CATF 2015), that the NTDE-2007, assessed by ACES, eliminates only 90 percent of DPM from traditional diesel ex-

haust and leaves roughly 10 percent. Yet government and university scientists say that diesel exhaust, mostly DPM, annually kills 21,000 people prematurely--4,500 just in California (CATF, 2008a; CAL-EPA, 2008b). Even if 90 percent of these deaths were prevented, NTDE-2007 would likely kill roughly 2,100 people/year, all prematurely.

Second, ACES errs because most diesel-exhaust deaths are from DPM, and confirmed scientific consensus is that there is *no safe dose* of any type of PM (Pope and Dockery, 2006; Dominici et al., 2003; Laden, 2006), as already mentioned. Consequently even 10 percent of a large-volume, no-safe-dose pollutant, obviously can be deadly. Even in economic terms, NTDE 2007 risks, largely DPM risks, are significant. Government and university scientists say that diesel exhaust, mostly DPM, annually costs $ 139 billion in avoidable, preventable health harm, $ 40 billion just in California (CATF, 2005a; CAL-EPA, 2008b). If NTDE-2007 avoided 90 percent of this annual health harm, it would still cause $ 14 billion in avoidable health damages/year. A trivial amount of pollution (as industry says of DPM from NTDE-2007) does not cause $14 billion in avoidable annual health harms.

Third, ACES errs because it admits that it tested NTDE-2007 that met *only year-2007 US standards* for heavy-duty diesel vehicles, not the latest technology. Yet under NTDE-2007 US standards, each heavy-duty diesel truck is allowed to release more than one pound of DPM, every 8 hours (Integer, 2014; EPA/NCDC, 2013), so that even a single NTDE-2007 truck would release about 3,000 pounds--a ton and a half-of DPM that has no safe dose. If all 15 million heavy-duty diesel trucks in the US were NTDE-2007, together they would release about 23 million tons/year of DPM, even with NTDE-2007 requirements (Integer, 2014; EPA/NCDC, 2013). Of course, DPM is blown by the wind, and not all of it would be released to every part of the US. Hence not everyone would be exposed to all US DPM, although it travels for miles because the PM is so small. Yet in industrial areas of hundreds of US towns, every day people are exposed to DPM from 10 or more diesel trucks. Even if all 10 trucks were NTDE-2007, people easily are exposed to substantial DPM. Besides, as already mentioned, although NTDE-2007 can reduce DPM by 90 percent, federal regulations require these filters only on trucks manufactured since 2007, not on the 80 percent of pre-2007 diesel trucks in the US that will operate for decades. NTDE-2007 is hardly relevant if government does not require it--and if only 20 percent of registered commercial trucks must use it (EPA, 2011; CATF, 2015; DTF, 2014; OEHHA, 2007).

Fourth, ACES errs in dismissing the DPM risks from NTDE-2007 because NTDE-2007 engines, that have low DPM (mass) emissions--appear to emit both much smaller particles and higher particle-number concentrations than pre-2007 diesel engines. As a result, NTDE-2007 includes a higher percentage of more dangerous particles than typical diesel exhaust (Karthikeyan et al., 2013; Khalek et al., 2011; Kittelson et al., 2008). This is because DPM in NTDE-2007 has more of the deadly ultrafine and fine PM than does traditional diesel PM, and because it is 50-90 percent metals, which are known neurotoxins (Ana et al., 2013; Bellinger, 2004; Bellinger, 2008; Lanphear et al., 2005, Zahran et al., 2009; Zahran et al., 2001; Williams, 2013).

To understand the ultrafine/fine PM threat from NTDE-2007, recall that according to scientific consensus, PM--an air-suspended mixture of solid or liquid particles has no safe dose and exhibits a linear concentration-response relationship (Pope and Dockery, 2006; Schwartz and Zanobetti, 2000; Daniels et al., 2000; Dominici et al., 2002; Dominici et al., 2003; Pope, 2002; Laden, 2006). Even the smallest doses of PM are associated with carcinogenic, neurological, reproductive, cardiovascular, and respiratory health harm (Pope and Dockery, 2006; Block and Calderón-Garcidueñas, 2009; Wilhelm et al., 2012; Nelin et al., 2012; Valavanidis et al., 2013), although the precise harm depends on the number, size, shape, surface area, chemical composition, solubility, and origin of the PM (Pope and Dockery, 2006). According to size, PM is classified into three main categories, coarse, fine, and ultrafine. PM of 2.5 to 10 μm (PM_{10}) is inhalable coarse particles. PM of 2.5 to 0.1 μm ($PM_{2.5}$) is inhalable fine particles, and PM of 0.1μM or less ($PM_{0.1}$) is inhalable ultrafine particles.

Ultrafine is the most dangerous of all types of PM because it can easily pass into the nose, through the blood-brain barrier, and directly into the brain, where it causes disease and brain dysfunction (Oberdörster et al., 2004; Cassee et al., 2013). Ultrafine PM also is much more potent than fine and coarse PM, in inducing oxidative stress, reactive oxidative species, and inflammation (Li et al., 2003; Rückerl et al., 2007; Delfino et al., 2009; Li et al., 2009; Song et al., 2011), all of which can cause cardiovascular, neurological, immune, and other problems (e.g., Franck et al., 2011; Kleinman et al., 2008). Because DPM or soot is mostly ultrafine, DPM is the most dangerous type of PM, and there is a lot of it; two-thirds of all PM emissions come from diesel-powered vehicles and equipment (IARC, 2012; UCS, 2008).

Because most DPM is ultrafine, it has four ultrafine characteristics that make it especially deadly. These include having small size; a large surface area, and thus worse inflammatory properties; being a Trojan-Horse pollutant; and having ability to travel great distances. Its small size enables DPM to enter either the nose and then the brain, or the lungs, bloodstream, and all bodily organs, where it can cause chronic inflammation and organ degeneration (CATF, 2005b; Peters et al., 2006; Terzano et al., 2010). Its small size also means it has relatively larger surface areas. For the same mass, smaller ultrafine or fine particles like DPM are far greater in number and have much greater surface areas than do coarse particles. As a result, DPM has much greater opportunity to interact with cell surfaces and cause inflammatory damage (EPA, 2013).

A third ultrafine and DPM characteristic, being a Trojan Horse pollutant, means that the DPM attracts other diesel-exhaust carcinogens, toxins, and metals such as arsenic, cadmium, formaldehyde, polyaromatic hydrocarbons or PAHs, and zinc. They adhere to the ultrafine PM, form fine PM, enter the brain or lungs and can travel to all bodily organs, where they can cause chronic inflammation leading to diseases such Alzheimer's, autism, birth defects, cancer, Parkinson's, and even death (Costa et al., 2014; Deng et al., 2009; Bush et al., 1994; Rivera-Mancia et al., 2006; Szewczyk, 2013; Aizenman et al., 2000; Dineley et al., 2002; James et al., 2011; Kleinewietfield et al., 2013; Pentyala et al., 2010; Trumbo et al., 2001; Vyshkinaet al., 2008; Yang et al., 2013; CATF, 2005b; Araujo, 2011; Terzano et al., 2010; Krivoshto et al., 2008; Pope and Dockery, 2006; Block and Calderón-Garcidueñas, 2009).

A fourth ultrafine and DPM characteristic is its ability

to linger in the air, travel great distances, and thus harm people far away from the emissions source. When other particles are adsorbed onto ultrafine PM, it can persist much longer and travel farther, up to thousands of kilometers from its emissions source (Amann et al., 2006; EPA, 2009).

Given the four preceding reasons that ACES errs in minimizing DPM risk from NTDE-2007, and the four characteristics of DPM that make it so dangerous, it is clear that ACES errs and massively underestimates the DPM risk of NTDE-2007. It underestimates this risk because instead of assessing the dominant diesel-exhaust threats, including DPM, it focuses on the misleading and incomplete state variable, NO_2. ACES ignores the facts that NTDE-2007 reduces only 90 percent of the no-safe-dose DPM released by older diesel engines; that NTDE-2007 contains much more ultrafine DPM, far more hazardous than traditional DPM; that measuring NO_2 is no guarantee of accurate DPM measures; that DPM harm is determined by particle size and surface area; and that scientific consensus about DPM threats is based on hundreds of studies that have no such errors. In other words, the ACES conclusions about NTDE-2007 are invalid because ACES research and methods employ misleading, erroneous, or incomplete state variables, such as NO_2, when they should be determining DPM levels directly and experimentally.

The Mass State-Variable Error

ACES researchers also erroneously minimize NTDE-2007 harm because they use another flawed state variable--mass -- as an indicator of diesel-exhaust exposure and hazard. Yet recall (from the preceding section) that for the same total mass, smaller ultrafine or fine particles like DPM have much larger numbers and surface areas, therefore pose much greater health harm than larger particles. Recall also that the larger DPM surface areas mean they have much greater opportunity to interact with cell surfaces and cause inflammatory and other damage that is much worse than larger particles having the same total mass (EPA, 2013). For instance, scientists know that, per unit of mass, ultrafine PM can be about 65 times more hazardous than coarse or fine PM (e.g., Sager and Castranova, 2009).

How did ACES researchers erroneously attempt to use mass, as a state variable, to supposedly assess DPM harm? Consider two examples of ACES errors in this regard. One instance concerns ACES attempts to measure DPM mass concentrations at the inlet and middle of the animal diesel-exhaust-exposure chambers. They claimed the different DPM-mass concentrations at these two spots would distinguish DPM from PM from the animals themselves; based on the mass differences, they claimed that the "major portion" of PM mass and hazard was from the animals themselves, not DPM (McDonald et al., 2015, p. 21). Yet for reasons already given in the previous section, one cannot distinguish DPM from animal PM, based on mass, as the ACES researchers attempt to do; instead one also must use particle number and surface area (EPA, 2013; Sager and Castranova, 2009), given that most DPM is ultrafine and fine PM, therefore much more hazardous than animal PM, which is mostly coarse PM.

For ACES researchers to use PM-mass differences as a way to distinguish DPM from experimental-animal PM such as feces or manure is erroneous and incomplete for at least three reasons. One reason is that metals tend to be toxic and carcinogenic, and DPM is mostly metals, whereas animal PM is not. Another reason is that animal PM is typically directly emitted, coarse PM, whereas DPM is not the less hazardous, coarse PM, but the more hazardous ultrafine and fine PM, as just mentioned. Moreover, animal PM does not appear to become smaller or more hazardous because during decomposition, particle size of animal PM remains the same, typically coarse, and thus less hazardous. Finally, because animal PM is not a Trojan-horse pollutant, as DPM is, it does not carry PM hazards such as formaldehyde and PAHs (Copeland, 2014; Hansen et al., 1976).

In other words, largely because the ACES researchers made many false factual assumptions already outlined... such as that animal and diesel PM can be distinguished from each other on the basis of mass, or that particle number and surface area are not necessary to separate DPM from animal PM levels--they erroneously underestimated DPM exposure and harm. They invalidly trimmed the data on DPM harm, just as they did when they invalidly assumed they could measure DPM by measuring mainly NO_2 levels. In using the state variable of mass to measure DPM levels and harm, ACES researchers made at least two scientific errors, against which a US National Academy of Sciences committee warned. They falsely assumed that urban or DPM air pollution is not different from rural or animal-waste PM. Their other error is ignoring the fact that less hazardous, coarse PM--not the more hazardous fine and ultrafine PM of DPM-- is what is "often encountered" in animal wastes (US-NRC, 2003).

Another way, in which ACES researchers erroneously used the state variable of mass to assess DPM exposure levels and harm, occurred when they evaluated the most hazardous NTDE-2007 pollutants by mass. As result, they invalidly assumed that mass indicates degree of hazard, something that is obviously false for nanomaterials and for fine and ultrafine PM, as already argued. After making this false assumption, ACES authors erroneously inferred that because mass-based particle concentrations were low, DPM harm was low. ACES authors likewise assumed that because their "calculated" ratio of mass: NO_2 was much lower, by a factor of 30, than in earlier studies, therefore they could conclude that DPM was mostly removed (Bemis et al., 2015, p. 150). Yet as already argued, the PM of NTDE-2007 typically has less mass but far greater numbers and surface areas of particles and therefore up to 65 times the typical DPM hazard. In other words, because the ACES researchers used an invalid state variable, mass, they erroneously concluded that DPM was mostly removed. They ignored the fact that their results are consistent with NTDE-2007 particles being smaller is size, greater in surface area, and therefore far more hazardous than traditional DPM. Thus, as already noted, although government says NTDE-2007 has 10 percent less PM by mass than traditional PM, NTDE-2007 does not remove 90 percent of DPM hazards because the much smaller PM of NTDE-2007 is far more hazardous, once one considers particle size and surface area (EPA, 2013; Sager and Castranova, 2009). ACES researchers, however, ignore this scientific consensus about relevant state variables for DPM. Instead, they erroneously claim that "the steep drop in particle mass…significantly decreased the overall toxicity of NTDE-2007 compared with the toxicity" of traditional diesel exhaust (Bemis et al., 2015, pp. 154-5).

Interestingly, reviewers of the ACES research also noticed these ACES state-variable problems namely, ACES assuming that NTDE-2007 toxicity is a function of NO_2 rather than DPM levels, and assuming that NTDE-2007 toxicity is reduced

because of reduced DPM mass in NTDE-2007, as compared to DPM in traditional diesel. The reviewers warned that "although engine-generated PM mass was greatly reduced [in NTDE-2007], substantial numbers of particles…in the [far more hazardous] ultrafine range…were detected. These levels are in the range of (or somewhat higher than) those found on or near major roads in urban areas and in environments in which diesel-powered traffic dominates…[Therefore] it is possible that components of NTDE-2007 other than NO_2 may have contributed to the effects reported" (Bemis et al., 2015, p. 156). However, ACES researchers ignored these reviewer comments, instead continued to use flawed state variables of NO_2 and mass, and thus drew the invalid conclusion that "observed" NTDE-2007 harm is minimal or nonexistent. ACES authors minimized NTDE-2007 harm because they ignored the fact that NTDE-2007 filters produce far greater numbers of far more hazardous ultrafine particles. Thus the ACES researchers do not fully assess the most relevant and largest contributors to NTDE-2007 harm: DPM number and surface area rather than merely NO_2 and particle mass.

The Life-Span Representativeness Error

ACES researchers likewise underestimate and minimize diesel-exhaust harm in a third main way: They use test subjects whose NTDE-2007 exposures trim the magnitude of actual DPM doses. That is, although the ACES researchers claim to have done "lifetime cancer and non-cancer assessment" in rats exposed to NTDE-2007, the exposures were not lifetime but partial-lifetime. As a result, although the title of the 2015 ACES report itself claims it does "lifetime assessment" of NTDE-2007 exposures, it does not.

How did ACES authors "trim the data" on supposed "lifetime" exposures to NTDE-2007? The authors say they received their experimental rats when they were 6 weeks of age, then quarantined them for at least another 2 weeks (McDonald et al., 2015, p. 11). This means that all ACES rats were 2 months of age or older. Yet researchers agree that when using rat studies to calculate effects on humans, each rat month of age is equivalent to 3 years of human age (Sengupta, 2013). This means that the ACES studies were equivalent to human studies whose subjects were already 6 years of age and older--far beyond the period of greatest vulnerability to pollutants.

Moreover, studies of humans 6 years of age and older are not "lifetime" exposure studies, contrary to what the ACES researchers repeatedly claim. Indeed, because the ACES researchers failed to use subjects, equivalent to those 6 years of age and younger, for at least two reasons they failed to test the most sensitive members of the population.

First, human subjects under 6 years of age can be 40 to 50 times more sensitive than adults when both are subjected to the same levels of pollutants (Makhijani, 2006).This is why scientists can predict rates of autism and IQ losses, based on young children's exposures to diesel exhaust, especially PM (e.g., Volk, 2010; Volk et al., 2013b; Becerra et al., 2013a; Roberts et al., 2013; Jung et al., 2013; Volk et al., 2013a; Morgan et al., 2011; Andrea et al., 2013; Hallymayerand Cleveland, 2011; Genc and Zadeoglulari, 2012). Thus by ignoring young subjects, ACES researchers falsely report less harm from diesel exhaust than actually occurs.

Second, given the latest understanding of epigenetic effects, scientists now believe that because very young humans under age 6 are so plastic, their early environmental-pollution exposures typically "program" them for various diseases later in life (e.g., Grandjean, 2013; Rassoulzadegan et al., 2006; Tollefsbol, 2014). Epigenetics research thus indicates that if subjects under age 6 receive fewer environmentally-harmful exposures, they will be far less likely to have any sort of disease in later life. By pre-selecting as their experimental subjects, those who have not had this typical, below-age-6, exposure, ACES researchers have biased their studies against finding any diesel harm from NTDE-2007 and trimmed the data on diesel harm. Contrary to their own explicit claims, ACES authors clearly have not considered lifetime NTDE-2007 exposures, but only NTDE-2007 exposures during the least-sensitive portion of life.

The Small-Sample Representativeness Error

In a fourth way, ACES researchers have not studied what they claim to have studied, and therefore draw invalid conclusions that deny NTDE-2007 harm. Not only did they did not study lifetime human exposure to NTDE-2007, as they falsely claimed, but they did not study representative samples of subjects. Instead, they used very small samples of rats, theoretically 140 male rats and 140 female rats at each of four exposure levels, for a total of 280 rats maximum at a single exposure level (Greenbaum et al., 2015,p. 2). Likely as a result, they drew false-negative conclusions about NTDE-2007 harm. Scientists agree that any sample size below several thousand is typically too low to detect even very large harmful effects. As a result, they typically use sample sizes at least in the thousands (e.g., Ein-Dor et al., 2006). Thus the ACES research used sample sizes that were at least 8-10 times too small to detect most significant effects. Standard error is larger with smaller samples, partly because the variation in a smaller sample is less than the variation in a larger sample.

For instance, recall that each 10 ug/m^3 increase in NO_2 causes those exposed to have a 4 percent increase in premature lung cancer (Hamra et al., 2015). That is, each 10 ug/m^3 increase causes 4 in every 100 people, or 40 in every 1000 people, who are exposed to have premature cancer, when they each otherwise would not have had it. But this, in turn, suggests that each 1 ug/m^3 increase in NO_2 might cause 1 in every 1000 exposed people to contract premature cancer. But because of genetic and inter individual variability, to adequately test whether some exposure causes 1 in every 1000 people to have premature cancer, obviously one would need a sample size much larger than 1000. Hence it is puzzling that the ACES researchers did not use samples of thousands of rats, at each exposure level, given that rat generations are quite short, that lifetime effects on rats are easy to test, and that animal testing is relatively inexpensive, compared to human testing.

Moreover, for several reasons, the ACES false-negative bias is even worse than is apparent. This is because ACES sample sizes were really much smaller than the authors claim. For one thing, because the ACES scientists sacrificed 10 animals at the end of each of four time periods (1, 3, 12, 24 months), at each of 4 exposure levels, the number of rats tested at each exposure level theoretically could not be 140 females and 140 males, but 100 males and 100 females. Yet because many rats died during the studies, ACES (159) researchers admitted "some groups in the 12 and 24-month exposures had between 3 and 5 animals." But if so, the ACES sample sizes at least for some exposure lev-

els actually were much smaller than 100 females and 100 males. Thus, both the initial ACES sample size and the final sample sizes were too small, by at least 800 to 1000 percent to detect most harm, even if the studies had been designed correctly with respect to state variables, sampling biopoints, and so on. Given the too-small, non representative samples, ACES studies exhibit a false-negative bias that makes it impossible to draw conclusions about NTDE-2007 harm.

An additional representativeness error in the ACES research may be that most US experimenters use Sprague-Dawley and not Wistar-Han strains of rats, as ACES did. Most researchers seem to view the ACES Wister-Han rats as experimentally unacceptable, in part because Wistar-Han rats areless susceptible to cancer and naturally have longer lifetimes (e.g., Hayakawa et al., 2013; Zmarowski et al., 2012; Kacew and Festing, 1996). Indeed, even the ACES researchers noted that the Wistar-Han rat is less susceptible to cancer, has a "relatively low incidence of background lung tumors" (McDonald et al., 2015); even the ACES authors say their Wistar-Han rats are "less sensitive to chemically induced neoplastic and non-neoplastic outcomes," compared with F344 and other rats such as Sprague-Dawley. But if so, how can the ACES authors justify their conclusions that NTDE-2007 is safe, if they used less sensitive experimental animals. Again, the flawed ACES methods appear to lead to false-negative conclusions, false conclusions that NTDE-2007 does not cause cancer. ACES did not do representative testing, thus underestimated NTDE-2007 harm.

Conclusions

ACES authors fail to rationally justify their conclusions that NTDE-2007 does not cause cancer because (A) they did not correctly and completely study the main components of the *pollutant* that they claimed to have studied, diesel exhaust; (B) they did not use correct *methods*, likely able to detect most of the harmful NTDE-2007 effects, and (C) they did not study representative *exposure subjects* during representative, lifetime *exposure periods*. The ACES authors err regarding (A) because they attempted to evaluate levels of DPM exposures, the most hazardous part of NTDE-2007, by erroneously studying different NO_2 levels, instead of measuring DPM levels themselves. They also erroneously studied only total PM mass, instead of also assessing PM number and surface area. As a result, they studied incomplete, therefore erroneous NTDE-2007 state variables. The ACES authors err regarding (B) because they attempted to evaluate DPM hazards by erroneously using only low-powered, small-sample studies. As a result, they used statistical methods that were 8-10 times too small to detect most of the NTDE-2007 harmful effects. The ACES authors likewise err regarding (C) because they studied a less-sensitive type of experimental rat during the least-sensitive periods of the rats' lives, rather than representative, lifetime exposures, as they claimed. As a result, at best the ACES authors' conclusions hold only for less-sensitive types of rats, only for shorter time periods, and only for NO_2 exposures and not DPM, the most hazardous component of NTDE-2007.

Together, all these biases and errors of the ACES authors studying the wrong or incomplete pollutants, exposures, experimental subjects, sample sizes, and time frames mean that in all these ways, the ACES results exhibit strong false-negative biases. In other words, even before hearing the supposed ACES conclusions, the ACES errors mean that they were certain to underestimate harm caused by NTDE-2007. Moreover, the errors that the ACES authors made are not sophisticated ones. They are textbook examples of how to bias science, how to purportedly show that a harmful pollutant is not harmful. Both ethics and science demand better.

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CALIFORNIA
AIR RESOURCES BOARD

California's 2017 Climate Change Scoping Plan

The strategy for achieving California's 2030 greenhouse gas target

arb.ca.gov

November 2017

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Decades of Leadership

From the first law to protect rivers from the impact of gold mining in 1884, to decades of work to fight smog, the Golden State has set the national – and international – standard for environmental protection. California pushes old boundaries, encounters new ones, and figures out ways to break through those as well. This is part of the reason why California has grown to become both the 6th largest economy in the world, and home to some of the world's strongest environmental protections. And, we have seen our programs and policies adopted by others as they seek to protect public health and the environment.



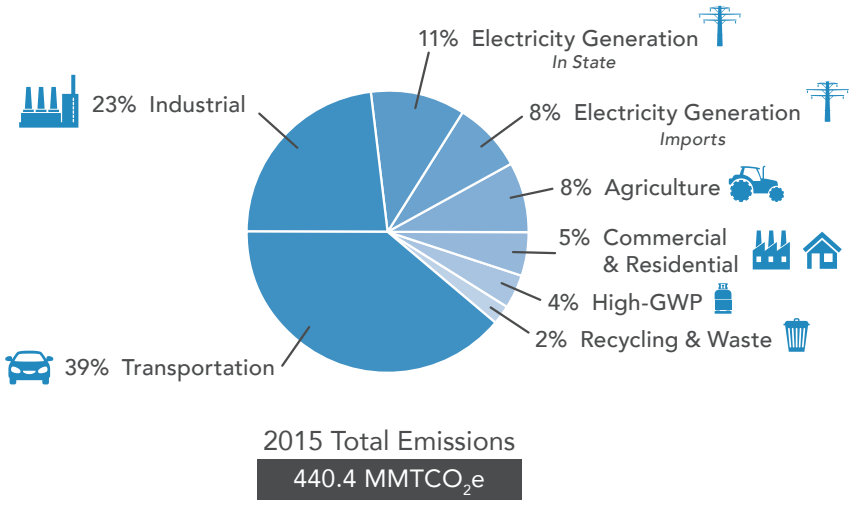
Governor Brown signs SB 32 recommitting California's efforts to curb climate change.

California's approach to climate change channels and continues this spirit of innovation, inclusion, and success. The 2030 target of 40 percent emissions reductions below 1990 levels guides this Scoping Plan, as the economy evolves to reduce greenhouse gas (GHG) emissions in every sector. It also demonstrates that we are doing our part in the global effort under the Paris Agreement to reduce GHGs and limit global temperature rise below 2 degrees Celsius in this century.

California's 2017 Climate Change Scoping Plan: The Strategy for Achieving California's 2030 Greenhouse Gas Target (Plan) builds on the state's successes to date, proposing to strengthen major programs that have been a hallmark of success, while further integrating efforts to reduce both GHGs and air pollution. California's climate efforts will:

- Lower GHG emissions on a trajectory to avoid the worst impacts of climate change;
- Support a clean energy economy which provides more opportunities for all Californians;
- Provide a more equitable future with good jobs and less pollution for all communities;
- Improve the health of all Californians by reducing air and water pollution and making it easier to bike and walk; and
- Make California an even better place to live, work, and play by improving our natural and working lands.

California Carbon Emissions



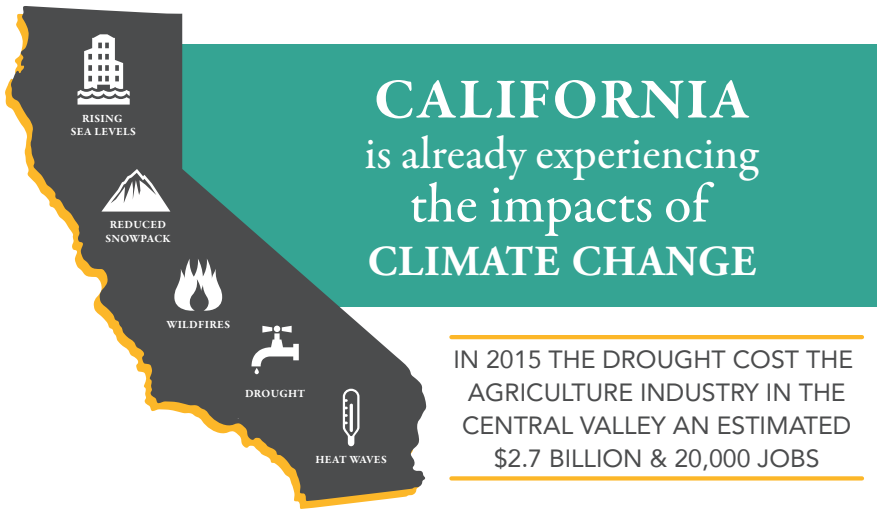
2015 Total Emissions

440.4 $MMTCO_2e$

The Climate Imperative – We Must Act

The evidence that the climate is changing is undeniable. As evidence mounts, the scientific record only becomes more definitive – and makes clear the need to take additional action now.

In California, as in the rest of the world, climate change is contributing to an escalation of serious problems, including raging wildfires, coastal erosion, disruption of water supply, threats to agriculture, spread of insect-borne diseases, and continuing health threats from air pollution. The drought that plagued California for years devastated the state's agricultural and rural communities, leaving some of them with no drinking water at all. In 2015 alone, the drought cost agriculture in the Central Valley an estimated $2.7 billion, and more than 20,000 jobs. Last winter, the drought was broken by record-breaking rains, which led to flooding that tore through freeways, threatened rural communities, and isolated coastal areas. This year, California experienced the deadliest wildfires in its history. Climate change is making events like these more frequent, more catastrophic and more costly. Climate change impacts all Californians, and the impacts are often disproportionately borne by the state's most vulnerable and disadvantaged populations.



CALIFORNIA is already experiencing the impacts of **CLIMATE CHANGE**

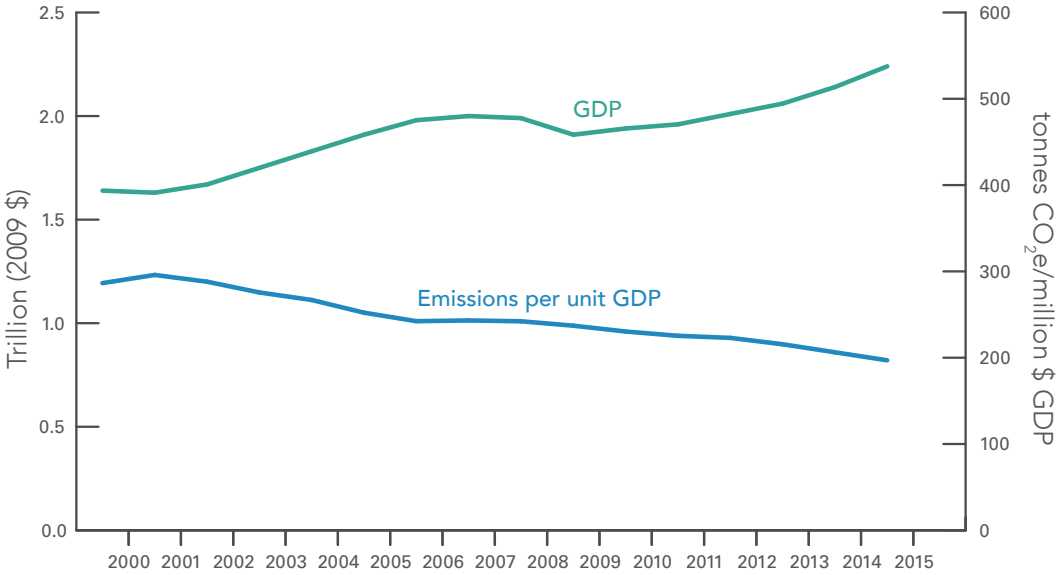
IN 2015 THE DROUGHT COST THE AGRICULTURE INDUSTRY IN THE CENTRAL VALLEY AN ESTIMATED $2.7 BILLION & 20,000 JOBS



California is on Track – But There is More to Do

Although the California Global Warming Solutions Act of 2006 – also known as AB 32 – marked the beginning of an integrated climate change program, California has had programs to reduce GHG emissions for decades. The state's energy efficiency requirements, Renewable Portfolio Standard, and clean car standards have reduced air pollution and saved consumers money, while also lowering GHG emissions.

Environmental Progress and a Resilient Economy

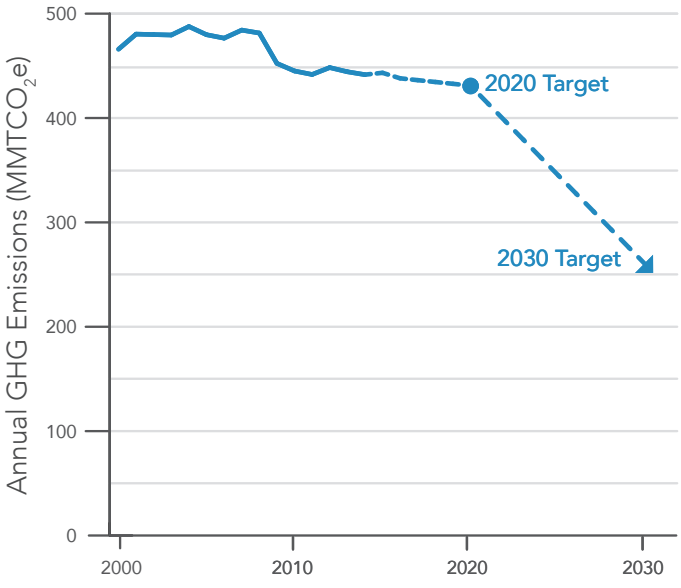


The California economy has grown while becoming less carbon intensive.

AB 32 set California's first GHG target called on the state to reduce emissions to 1990 levels by 2020. California is on track to exceed its 2020 climate target, while the economy continues to grow. Since the launch of many of the state's major climate programs, including Cap-and-Trade, economic growth in California has consistently outpaced economic growth in the rest of the country. The state's average annual growth rate has been double the national average – and ranks second in the country since Cap-and-Trade took effect in 2012. In short, California has succeeded in reducing GHG emissions while also developing a cleaner, resilient economy that uses less energy and generates less pollution.

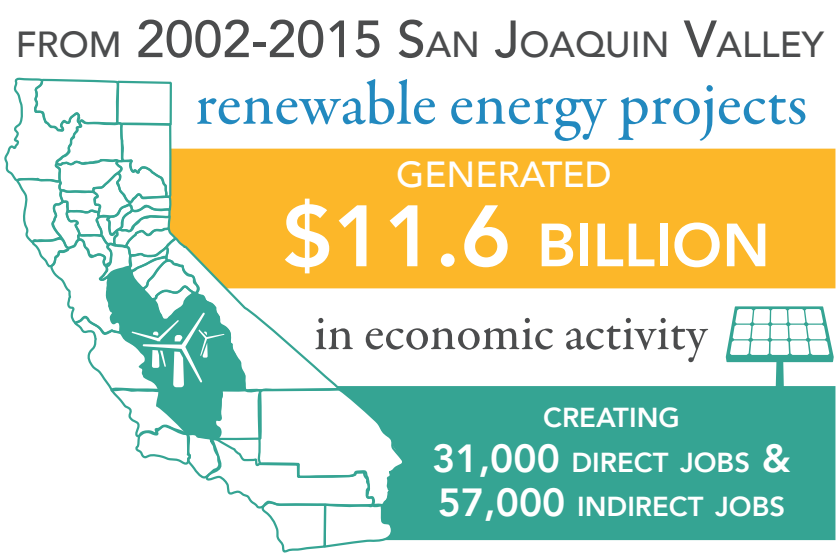
Importantly, the State's 2020 and 2030 targets have not been set in isolation. They represent benchmarks, consistent with prevailing climate science, charting an appropriate trajectory forward that is in line with California's role in stabilizing global warming below dangerous thresholds. As we consider efforts to reduce emissions to meet the State's near-term requirements, we must do so with an eye toward reductions needed beyond 2030. The Paris Agreement – which calls for limiting global warming to well below 2 degrees Celsius and pursuing efforts to limit it to 1.5 degrees Celsius – frames our path forward.

California's Path Forward



California's Path to 2030

Executive Order B-30-15 and SB 32 extended the goals of AB 32 and set a 2030 goal of reducing emissions 40 percent from 2020 levels. This action keeps California on target to achieve the level of reductions scientists say is necessary to meet the Paris Agreement goals. This is an ambitious goal – calling on the State to double the rate of emissions reductions. Nevertheless, it is an achievable goal.



This Plan establishes a path that will get California to its 2030 target. Given our ambitious goals, this Plan is built on unprecedented outreach and coordination. Over 20 state agencies collaborated to produce the Plan, informed by 15 state agency-sponsored workshops and more than 500 public comments. The broad range of state agencies involved reflects the complex nature of addressing climate change, and the need to work across institutional boundaries and traditional economic sectors to effectively reduce GHG emissions. As part of the Plan development, alternative strategies were considered and evaluated, ranging from carbon taxes to individual facility caps to relying solely on sector-specific regulations. In addition, efforts were made to ensure that the Plan would benefit all Californians. To this end, the Environmental Justice Advisory Committee (EJAC), a Legislatively created advisory body, convened almost 20 community meetings throughout California to discuss the climate strategy, and held 19 meetings of its own to provide recommendations on the Plan.

This Plan draws from the experiences in developing and implementing previous plans to present a path to reaching California's 2030 GHG reduction target. The Plan is a package of economically viable and technologically feasible actions to not just keep California on track to achieve its 2030 target, but stay on track for a low- to zero-carbon economy by involving every part of the state. Every sector, every local government, every region, every resident is part of the solution. The Plan underscores that there is no single solution but rather a balanced mix of strategies to achieve the GHG target. This Plan highlights the fact that a balanced mix of strategies provides California with the greatest level of certainty in meeting the target at a low cost while also improving public health, investing in disadvantaged and low-income communities, protecting consumers, and supporting economic growth, jobs and energy diversity. Successful implementation of this Plan relies, in part, on long-term funding plans to inform future appropriations necessary to achieve California's long-term targets.

California's Climate Policy Portfolio

- Double building efficiency
- 50% renewable power
- More clean, renewable fuels
- Cleaner zero or near-zero emission cars, trucks, and buses
- Walkable/Bikeable communities with transit
- Cleaner freight and goods movement
- Slash potent "super-pollutants" from dairies, landfills and refrigerants
- Cap emissions from transportation, industry, natural gas, and electricity
- Invest in communities to reduce emissions

California's Climate Vision

Create Inclusive Policies and Broad Support for Clean Technologies

Remarkable progress over the past 10 years has put the global energy and transportation sector on a transformative path to cleaner energy. Far outpacing previous predictions, today solar and wind power are often less expensive than coal or natural gas, and they now comprise the majority of global investment in the power sector. Electric vehicle battery costs have tumbled even more quickly than solar costs, while performance has improved dramatically, and the auto industry is committed to an electric future.

California's policies have created markets for energy efficiency, energy storage, low carbon fuels, renewable power – including utility-scale and residential-scale solar – and zero-emission vehicles. Our companies are thriving, making those markets grow. California is home to nearly half of the zero-emission vehicles in the U.S., 40 percent of North American clean fuels investments, the world's best known electric car manufacturer, and the world's leading ride-sharing services. California is further advancing efficient land use policies that reduce auto dependency. Altogether, we're unleashing nonlinear transitions to clean energy and clean transportation technologies that will put California on the path to meeting our 2030 target and the goals of the Paris Agreement.

California is home to

NEARLY 50% OF THE ZEVs IN THE U.S.

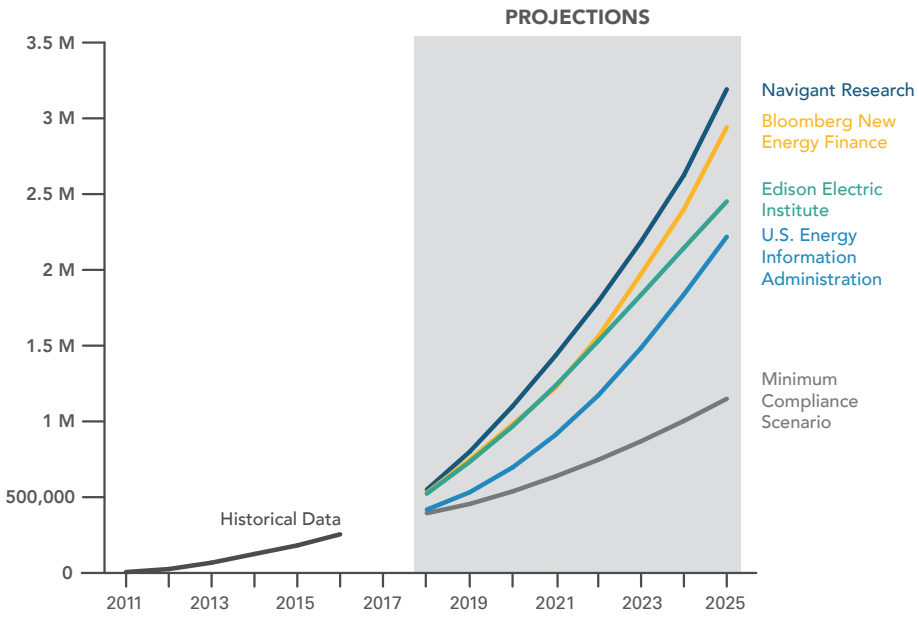
40% OF NORTH AMERICAN CLEAN FUEL INVESTMENTS

&

90% OF TOTAL U.S. INVESTMENT IN CLEAN TRANSPORTATION

California policymaking has succeeded through thoughtful planning, bolstered by an open public process that solicits the best ideas from a wide array of sources, and by integrating effective regulation with targeted investments to provide broad market support for clean technologies. A key element of California's approach continues to be careful monitoring and reporting on the results of our programs and a willingness to make mid-course adjustments. As the State looks to 2030 and beyond, all sectors of the economy must benefit from these ideas to create a new and better future.

Cumulative California ZEV Sales Projections



Experience has shown clean technology and markets continue to outpace expectations.

Legislative Leadership on Climate

The California Legislature has shaped the State's climate change program, setting out clear policy objectives over the next decade:

- 40% reduction in GHG emissions by 2030;
- 50% renewable electricity;
- Double energy efficiency savings;
- Support for clean cars;
- Integrate land use, transit, and affordable housing to curb auto trips;
- Prioritize direct reductions;
- Identify air pollution, health, and social benefits of climate policies;
- Slash "super pollutants";
- Protect and manage natural and working lands;
- Invest in disadvantaged communities; and
- Strong support for Cap-and-Trade.

The benefits of innovative technologies need to reach all residents and businesses. Air pollution reductions and the associated health benefits should be targeted to communities where they are needed most. All Californians need access to clean transportation options that enable healthy communities to develop and thrive, including walking, cycling, transit, rail, and clean vehicle options.

Although GHG reductions can help to reduce harmful air pollution, California must concurrently employ other strategies to accelerate reductions of pollutants from large industrial sources that adversely impact communities. Newly passed AB 617 strengthens existing criteria and toxic air pollutant programs and our partnerships with local air districts to further reduce harmful air pollutants and protect communities. More fundamentally, AB 617 establishes a comprehensive statewide program – the first of its kind – to address air pollution where it matters most: in neighborhoods with the most heavily polluted air.

California's Goals



California's environmental justice and equity movement is establishing a blueprint for the nation and world. The State is pioneering targeted environmental and economic development programs to help those most in need. So far, half of all California Climate Investments, stemming from the State's Cap-and-Trade-Program, have been used to provide benefits in the 25 percent of California communities that are most disadvantaged by environmental and socio-economic burdens. By increasingly engaging with, and investing in, these communities – investing in technical assistance resources, holding listening sessions, improving our programs, and accelerating our efforts to bring the cleanest technologies to mass market – all California residents can have clean air to breathe, clean water to drink, and opportunities to participate in the cleaner economy.

Achieving Success in Equity and Access

- Continue to engage local organizations and invest in disadvantaged communities to ensure broad access to clean technologies;
- Ensure air pollution reductions happen where they are needed the most;
- Integrate across programs and agencies to ensure complementary policies provide maximum benefits to disadvantaged communities;
- Implement California Energy Commission and CARB recommendations to overcome barriers to clean energy and clean transportation options for low-income residents;
- Provide energy-efficient affordable housing near job centers and transit; and
- Implement AB 617 to dramatically improve air quality in local communities through targeted action plans.



Enhance Industrial Efficiency & Competitiveness

California leads the country in manufacturing and industrial efficiency. For every dollar spent on electricity, our manufacturers produce 55 percent more value than the national average. And the efficiency of California industry continues to grow at rates faster than the national average. High efficiency rates, coupled with the Cap-and-Trade Program's firm emission cap, allow economic activity to increase without corresponding increases in GHG emissions. In other words, the more California produces, the better it is for the planet. Maintaining and extending our successful programs – from the Cap-and-Trade Program and Low Carbon Fuel Standard to zero-emission, renewable energy and energy efficiency programs – will reduce GHGs, increase energy cost savings, offer businesses flexibility to reduce emissions at low cost and provide clear policy and market direction, and certainty, for business planning and investment. This will encourage continued research, evaluation, and deployment of innovative strategies and technology to further reduce emissions in the industrial sector through advances in energy efficiency and productivity, increased access to cleaner fuels, and carbon capture, utilization and storage.

Action on HFCs

Hydrofluorocarbons (HFCs) represent one of the biggest opportunities to reduce GHGs in the State through 2030 due to their high climate impacts, and in many cases, offer energy efficiency and financial savings, as well. The world recently agreed to phase down their use, but California has committed to move more quickly, in line with the scope of the opportunity for cost-effective emissions reductions in the State.

Achieving Success in Industrial Efficiency and Competitiveness

- Evaluate and implement policies and measures to continue reducing GHG, criteria, and toxic air contaminant emissions from sources such as refineries;
- Improve productivity and strengthen economic competitiveness by further improving energy efficiency and diversifying fuel supplies with low carbon alternatives;
- Prioritize procurement of goods that have lower carbon footprints
- Support and attract industry that produces goods needed to reduce GHGs; and
- Cut energy costs and GHG emissions by quickly transitioning to efficient HFC alternatives.

Prioritize Transportation Sustainability

California's transportation system underpins our economy. The extensive freight system moves trillions of dollars of goods each year and supports nearly one-third of the state economy and more than 5 million jobs. The way we plan our communities impacts everything from household budgets to infrastructure needs, productivity lost to congestion, protection of natural and working landscapes, and our overall health and well-being. And transportation is the largest source of GHG, criteria, and toxic diesel particulate matter emissions in the state.

RENEWABLE BIO DIESEL USE

has increased 7000% since 2011

California's ability to remain an economic powerhouse and environmental leader requires additional efforts to improve transportation sustainability with a comprehensive approach that includes regulation, incentives, and investment. This approach addresses a full range of transportation system improvements relating to efficient land use, affordable housing, infrastructure for cyclists and pedestrians, public transit, new vehicle technologies, fuels and freight. One example is the deployment of the nation's first high-speed rail system, which will include seamless connections to local transit.

The approach is working: California is home to nearly half of the country's zero-emission vehicles. Innovative alternative fuel producers and oil companies are bringing more low carbon fuels to market than required by the Low Carbon Fuel Standard. And, the State has committed to investing billions in zero-emission vehicles and infrastructure, land use planning, and active transportation options such as walking and biking. In fact, renewable fuels in the heavy-duty vehicle sector are displacing diesel fossil fuel as quickly as renewable power is replacing fossil fuels on the electricity grid. California's climate policies will also reduce fossil fuel use and decouple the state from volatile global oil prices. CARB's analyses show fossil fuel demand will decrease by more than 45 percent by 2030, which means Californians will be using less gasoline and diesel resulting in healthier air and cost-savings on transportation fuels. These benefits will be further amplified as we move away from light-duty combustion vehicles.

By re-doubling our efforts, California can make sure that markets tip quickly and definitively in the favor of electric cars, trucks, buses, and equipment, while increasing the use of clean, low carbon fuels where zero-emissions options are not yet available. Local transportation planning can make communities become healthier and more vibrant and connected – encouraging housing, walking, biking and transit policies that reduce GHGs and promote good quality of life. And, we can work to ensure that an efficient sustainable freight system continues to power our ever-growing economy.





Achieving Success in Transportation Sustainability

- Connect California's communities with a state-of-the-art high-speed rail system;
- Promote vibrant communities and landscapes through better planning efforts to curb vehicle-miles-traveled and increase walking, biking and transit;
- Build on the State's successful regulatory and incentive-based policies to quickly make clean cars, trucks, buses, and fuels definitive market winners;
- Coordinate agency activities to ensure that emerging automated and connected vehicle technologies reduce emissions; and
- Improve freight and goods movement efficiency and sustainability to enable California's continued economic growth.

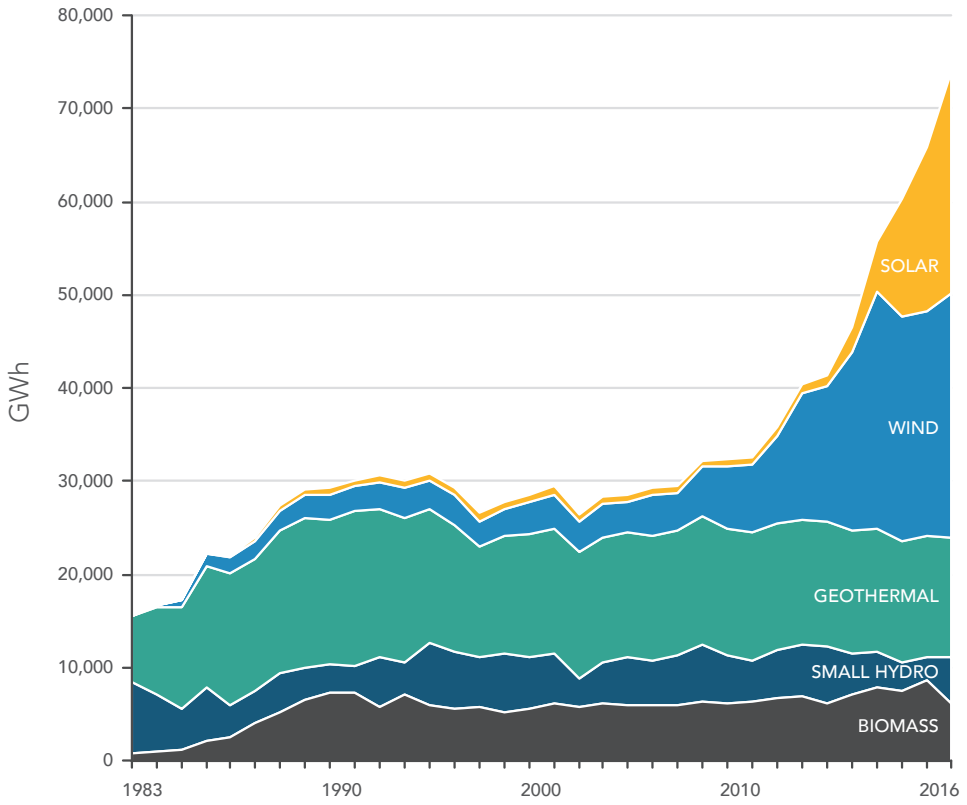


Continue Leading on Clean Energy

California is well ahead of schedule in meeting its renewable energy targets. Wind and solar generation have grown exponentially in recent years, while hydroelectric, geothermal, and biomass have consistently contributed renewable power to our energy supply. Californians are the ones who will take action to meet energy efficiency targets, integrate renewable power through demand response, and drive demand for net zero energy buildings. This includes self-generation which also grew exponentially in recent years with installed solar totaling 2,000 megawatts (MW) in 2014 and 5,100 MW of the total statewide self-generation installed solar in 2015. By June 2017, solar installed in California was about 5,800 MW, far exceeding the State's goals.

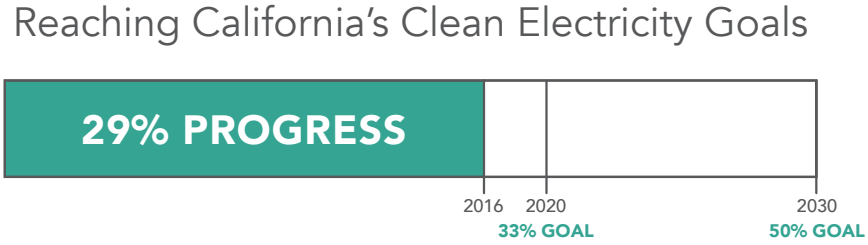
The Renewable Portfolio Standard, Carbon Pricing, and lower costs for renewable technology are delivering real environmental benefits.

Increasing Renewable Electricity Generation (in & out of state)





While at this time natural gas is an important energy source, we must move toward cleaner heating fuels and replicate the progress underway for electricity. As with electricity, this starts with efficiency and demand reduction, including building and appliance electrification where these advancements make sense. It calls for minimizing fugitive methane leaks throughout the system, including beyond California's borders where 90 percent of the natural gas used here originates. And, it includes using more renewable gas – a valuable in-state resource made from waste products – especially in the transportation sector. Replacing fossil fuels with renewable gas can reduce potent short-lived climate pollutants, and state policies should support this effort. Reducing demand for natural gas, and moving toward renewable natural gas, will help California achieve its 2030 climate target. However, switching from natural gas to electricity – where feasible and demonstrated to reduce GHGs – is needed to stay on track to achieve our long-term goals.



The State's 3 largest investor-owned utilities are on track to achieve a 50% RPS by 2020.

Achieving Success in Clean Energy

- Effectively integrate at least 50 percent renewables as the primary source of power in the State through coordinated planning, additional deployments of energy storage, and grid regionalization;
- Utilize distributed resources and engage customers by making net zero energy buildings standard, implement Existing Buildings Energy Efficiency Action Plan to double existing building efficiency, and increase access to energy efficiency, renewable energy, and energy use data; and
- Reduce the use of heating fuels while concurrently making what is used cleaner by minimizing fugitive methane leaks, prioritizing natural gas efficiency and demand reduction, and enabling cost-effective access to renewable gas.



Put Waste Resources to Beneficial Use

Effectively managing waste streams is perhaps the most basic of environmental tenets. "Reduce, re-use, and recycle" is a mantra known even to elementary school students. For decades California law has reduced waste reaching landfills and recaptured value from waste streams through recycling and composting. California law requires reducing, recycling, or composting 75 percent of solid waste generated by 2020. The State also has specific goals for diverting organic waste, which decomposes in landfills to produce the super pollutant methane. State law also directs edible food to hungry families rather than having it discarded.

Capturing value from waste makes sense. As described in the Healthy Soils Initiative, compost from organic matter provides soil amendments to revitalize farmland, reduces irrigation and landscaping water demand, and potentially increases long-term carbon storage in rangelands. Organic matter can also provide a clean, renewable energy source in the form of bioenergy, biofuels, or renewable natural gas.

California should take ownership of its waste and adhere to a waste "loading order" that prioritizes waste reduction, re-use, and material recovery over landfilling. The State can take steps to reduce waste from packaging, which constitutes about one-quarter of California's waste stream. It can invest in and streamline in-state infrastructure development to support recycling, remanufacturing, composting, anaerobic digestion, and other beneficial uses of organic waste. And, it can help communities in their efforts to recover food for those in need.

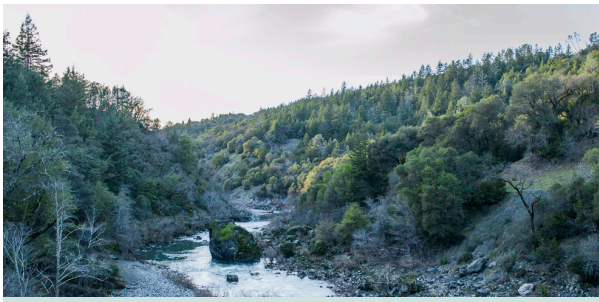
Achieving Success in Putting Waste Resources to Beneficial Use

- Develop and implement programs, including edible food waste recovery, to divert organics from landfills and reduce methane emissions;
- Develop and implement a packaging reduction program; and
- Identify a sustainable funding mechanism to support waste management programs, including infrastructure development to support organics diversion.

Support Resilient Agricultural and Rural Economies and Natural and Working Lands

California's natural and working landscapes, like forests and farms, are home to the most diverse sources of food, fiber, and renewable energy in the country. They underpin the state's water supply and support clean air, wildlife habitat, and local and regional economies. They are also the frontiers of climate change. They are often the first to experience the impacts of climate change, and they hold the ultimate solution to addressing climate change and its impacts. In order to stabilize the climate, natural and working lands must play a key role.

Work to better quantify the carbon stored in natural and working lands is continuing, but given the long timelines to change landscapes, action must begin now to restore and conserve these lands. We should aim to manage our natural and working lands in California to reduce GHG emissions from business-as-usual by at least 15-20 million metric tons in 2030, to complement the measures described in this Plan.



Improved forest management on tribal lands has preserved almost 3 million metric tons of carbon in California and the revenues from the carbon offsets have been used to secure ownership of ancestral lands.

Natural and working lands can be better incorporated into California's climate change mitigation efforts by encouraging collaboration with local and regional organizations and increasing investment to protect, enhance, and innovate in our rural landscapes and communities. The State is partnering with tribes to preserve carbon, protect tribal forest lands and increase their land base. Transportation and land use planning should minimize the footprint of the built environment, while supporting and investing in efforts to restore, conserve and strengthen natural and working lands. California's forests should be healthy carbon sinks that minimize black carbon emissions where appropriate, supply new markets for woody waste and non-merchantable timber, and provide multiple ecosystem benefits. Rehabilitating and strengthening wetlands and tidal environments, and incorporating natural landscapes into urban environments will also help make natural and working lands part of the state's climate solution. Finally, California farmers can be a powerful force in the fight against climate change, in how they manage their lands, tend their crops, and husband their livestock.

Achieving Success in Supporting Resilient Agricultural and Rural Economies and Natural and Working Lands

- Protect, enhance and innovate on California's natural and working lands to ensure natural and working lands become a net carbon sink over the long-term;
- Develop and implement the Natural and Working Lands Implementation Plan to maintain these lands as a net carbon sink and avoid at least 15-20 metric tons of GHG emissions by 2030;
- Measure and monitor progress by completing CARB's Natural and Working Lands Inventory and implementing tracking and performance monitoring systems; and
- Unleash opportunity in the agricultural sector by improving manure management, boosting soil health, generating renewable power, electrifying operations, utilizing waste biomass, and increasing water, fertilizer, and energy use efficiency to reduce super pollutants.



Secure California's Water Supplies

Water is California's lifeblood. It sustains communities and drives the economy. An elaborate network of storage and delivery systems has enabled the state to prosper and grow. But this aging system was built for a previous time and is increasingly challenged by the realities of climate change and population growth.

The Water-Energy Nexus

- About 12% of the total energy used in the state is related to water, with 2% for conveyance, treatment and distribution, and 10% for end-customer uses like heating and cooling.
- The water-energy nexus provides opportunities for conservation of these natural resources as well as reduction of GHGs.

Producing, moving, heating and treating water demands significant energy and produces commensurately significant emissions. As California looks to the future, meeting new demands and sustaining prosperity requires increased water conservation and efficiency, improved coordination and management of various water supplies, greater understanding of the water-energy nexus, and deployment of new technologies in drinking water treatment, groundwater remediation and recharge, and potentially brackish and seawater desalination. State efforts must support systemic shifts toward conservation, efficiency, and renewable energy in the water sector.

Achieving Success in Securing California's Water Supplies

- Increase water savings by certifying innovative technologies for water conservation and developing and implementing new conservation targets, updated agricultural water management plans, and long term conservation regulations;
- Develop a voluntary registry for GHG emissions from energy use associated with water; and
- Continue to increase the use of renewable energy to operate the State Water Project.

Cleaning the Air and Public Health

The benefits of this Plan are broader than just climate change – implementation of the Plan will also help improve public health. The Plan incorporates freight and mobile source strategies which will deliver reductions in criteria and toxic air pollutants to improve air quality.

Climate Plan Provides Health Benefits in 2030

AVOIDED PREMATURE DEATHS	VALUE OF AVOIDED HEALTH IMPACTS	VALUE OF AVOIDED DAMAGES USING SOCIAL COST OF CARBON
~ 3,300	$1.2-1.8 billion	$1.9-11.2 billion

California continues to seek ways to improve implementation of its climate program and its ability to address the unique set of impacts facing the state's most pollution burdened communities. In addition, CARB's environmental justice efforts are intended to reach far beyond climate change. While this Plan provides a path for reducing GHG emissions in disadvantaged communities, it also includes new tools that will complement the Plan and lead to further air quality improvements.

In particular, implementation of AB 617 will improve air quality in local communities, in partnership with local air districts, using targeted investments in neighborhood-level air monitoring and the development of air pollution reduction action plans with strong enforcement programs. These plans will require pollution reductions from both mobile and stationary sources. Through these efforts, CARB anticipates, and will work for, increased data transparency and the adoption of new statewide air pollutant emission controls that will not only confer short-term benefits to those most in need of improvement, but which will ultimately benefit all Californians.

Under the leadership of CARB's first executive-level environmental justice liaison, the agency is also laying a roadmap to better serve California's environmental justice communities in the design and implementation across its broader programs.



Successful Example of Carbon Pricing and Investment

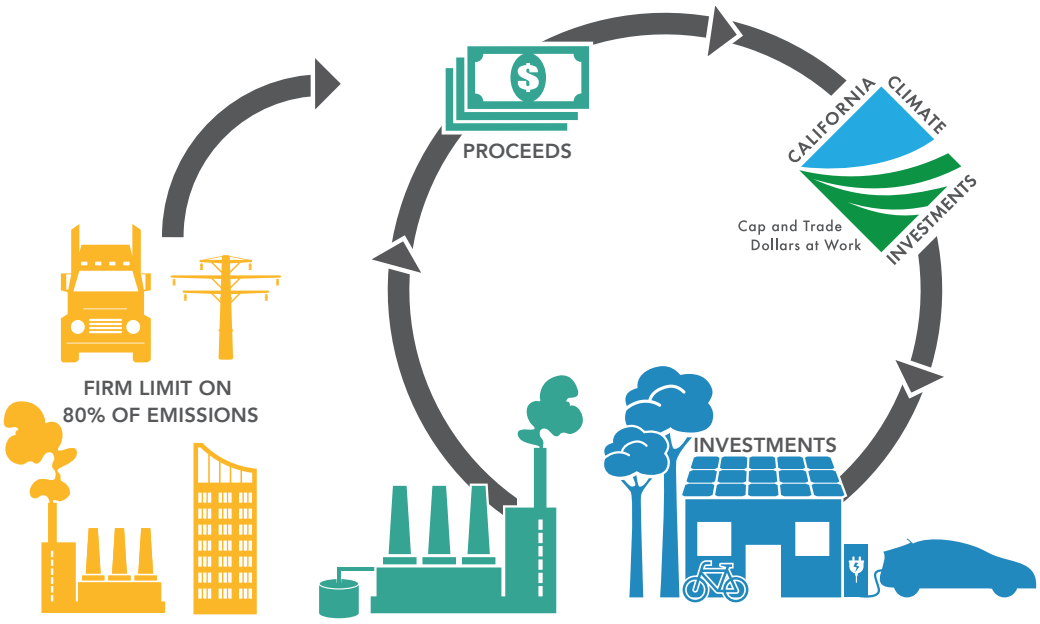
The Cap-and-Trade Program is fundamental to meeting California's long-range climate targets at low cost. The Cap-and-Trade Program includes GHG emissions from transportation, electricity, industrial, agricultural, waste, residential and commercial sources, and caps them while complementing the other measures needed to meet the 2030 GHG target. Altogether, the emissions covered by the Cap-and-Trade program total 80 percent of all GHG emissions in California. California's response to climate change has led to many innovative programs designed to reduce GHG emissions, including the Renewable Portfolio and Low Carbon Transportation Standards, but the Cap-and-Trade Program guarantees GHG emissions reductions through a strict overall emissions limit that decreases each year, while trading provides businesses with flexibility in their approach to reducing emissions. The Cap-and-Trade Program also generates revenue when the allowances to emit pollution are auctioned. Some of the revenue is returned directly to electricity ratepayers, and the rest is dedicated to reducing GHG emissions by making Legislatively directed investments in California with an emphasis on programs or projects that benefit disadvantaged and low-income communities.

Cap-and-Trade Program

- Firm, declining cap provides highest certainty to achieve 2030 target.
- Low cost GHG emission reductions minimize impact on consumers and economy.
- Flexibility for businesses
- Can be linked with similar programs worldwide.

Including the latest budget, approximately $5 billion has been appropriated to reduce GHG emissions, reduce air pollutant emissions where reductions are needed most, grow markets for clean technologies, and spur emissions reductions in sectors not covered by Cap-and-Trade. These investments are strengthening the economy and improving public health – especially in the areas of the state most burdened by pollution. So far, half of the $1.2 billion spent provides benefits to disadvantaged communities, and one-third of those investments were made directly in those communities.

California's Carbon Pricing & Investments Overview



Cap-and-Trade Dollars at Work (2017)

California's Cap-and-Trade Program is the most comprehensive, effective, and well-designed carbon market on the planet. Today, the Program is linked with a similar program in Quebec and will link with a similar program in Ontario beginning in 2018. Nearly 40 countries and over 20 subnational entities – altogether representing nearly a quarter of global emissions – have developed, or are developing, emissions trading programs. Each of them looks to California and our linked Western Climate Initiative Partners as they design, implement, and refine their own programs.

- Nearly 30,000 projects installing efficiency measures in homes
- 105,000+ rebates issued for zero-emission and plug-in hybrid vehicles
- 16,000+ acres of land preserved or restored
- 200+ transit agency projects funded, adding or expanding transit options
- 6,200+ trees planted in urban areas
- 1,100+ new affordable housing units under contract
- 50% of projects benefiting Disadvantaged Communities ($614M)
- 140,000+ total projects implemented

Fostering Global Action

Through the State's leadership in the Cap-and-Trade Program, innovative sector-specific policies that are reducing technology costs and GHG emissions, and community-scale engagement and investments to reduce GHGs and promote equity, California is playing a significant role in addressing global climate change.



Governor Brown has stated that climate change is the most important issue of our lifetime, and has promoted scientifically sound approaches to address climate change in California and beyond. He has participated in international climate discussions at the United Nations headquarters in New York, the United Nations Climate Change Conference in Paris, the Vatican, and the Climate Summit of the Americas in Canada – calling on other subnational and national leaders to join California in the fight against climate change. He has signed climate change agreements with leaders from Chile, China, the Czech Republic, Israel, Japan, Mexico, the Netherlands, other North American states and provinces, and Peru. He has joined an unprecedented alliance of heads of state, city and state leaders – convened by the World Bank Group and International Monetary Fund – to urge countries and companies around the globe to put a price on carbon. And California is a founding member of the International Zero Emission Vehicle (ZEV) Alliance, a coalition of national and subnational governments working to accelerate the adoption of ZEVs and make all new

cars zero emissions. Delegations from around the world travel to Sacramento to meet with the architects and implementers of California's climate policies to learn how to successfully combine strong greenhouse gas policies with a strong economy.

Perhaps most significant is the Under2Coalition. It is a global climate pact – spearheaded by Governor Brown – among states, provinces, countries, and cities all committing to do their part to limit the increase in global average temperatures below the dangerous levels. Signatories commit to either reducing greenhouse gas emissions 80 to 95 percent below 1990 levels by 2050 or achieving a per capita annual emission target of less than 2 metric tons by 2050. More than 200 jurisdictions from 38 countries and six continents have now signed or endorsed the agreement. Together, members of the Under2Coalition represent more than 1.2 billion people and $28.8 trillion in GDP, equivalent to 39 percent of the global economy.

Unleashing the California Spirit

This Plan is a declaration of California's path forward. It builds on the State's successful approach to addressing climate change and harnesses the California spirit to propel a cleaner economy, while serving as an example for others.

But this Plan will not be successful on its own. Our collective, and individual, efforts must reach every sector of California's economy, and every community in the state. As California faces the challenge of climate change, it will succeed as it always has – through open, inclusive processes, through support of clean technology markets, and through a relentless pursuit of a healthy California for all.

There should be no doubt that California is united in understanding the need to act, and in the will to act. Investments in clean, low-carbon options will pay off – for the environment and the economy. Investments and training in education and workforce development for a lower carbon economy are a critical part of this transition.

This Plan is only the beginning. All of the measures in the Plan will be developed in their own public process, shaped not just by the vision of this Plan, but also by the best understanding of the technology, costs and impacts on communities – and by input from a broad range of stakeholders and perspectives with the recognition that achieving the 2030 target is a milestone on our way to the deeper GHG reductions needed to protect the environment and our way of life. The Plan also proposes developing a long-term funding plan to inform future appropriations necessary to achieve our long-term targets, which will send clear market and workforce development signals.

Climate change presents unprecedented challenges, but just as we have always done, Californians will tackle them with innovation, inclusion and ultimately, success.

Chapter 1

Introduction

Background

In November 2016, California Governor Edmund G. Brown affirmed California's role in the fight against climate change in the United States, noting, "We will protect the precious rights of our people and continue to confront the existential threat of our time–devastating climate change." By working to reduce the threat facing the State and setting an example, California continues to lead in the climate arena. This Scoping Plan for Achieving California's 2030 Greenhouse Gas Target (Scoping Plan or 2017 Scoping Plan) identifies how the State can reach our 2030 climate target to reduce greenhouse gas (GHG) emissions by 40 percent from 1990 levels, and substantially advance toward our 2050 climate goal to reduce GHG emissions by 80 percent below 1990 levels. By selecting and pursuing a sustainable and clean economy path for 2030, the State will continue to successfully execute existing programs, demonstrate the coupling of economic growth and environmental progress, and enhance new opportunities for engagement within the State to address and prepare for climate change.

This Scoping Plan builds on and integrates efforts already underway to reduce the State's GHG, criteria pollutant, and toxic air contaminant emissions. Successful implementation of existing programs has put California on track to achieve the 2020 target. Programs such as the Low Carbon Fuel Standard and Renewables Portfolio Standard are delivering cleaner fuels and energy, the Advanced Clean Cars Program has put more than a quarter million clean vehicles on the road, and the Sustainable Freight Action Plan will result in efficient and cleaner systems to move goods throughout the State. Enhancing and implementing these ongoing efforts puts California on the path to achieving the 2030 target. This Scoping Plan relies on these, and other, foundational programs paired with an extended, more stringent Cap-and-Trade Program, to deliver climate, air quality, and other benefits.

In developing this Scoping Plan, it is paramount that we continue to build on California's success by taking effective actions. We must rapidly produce real results to avoid the most catastrophic impacts of climate change. The Scoping Plan identifies policies based on solid science and identifies additional research needs, while also recognizing the need for flexibility in the face of a changing climate. Ongoing research to better understand systems where our knowledge is weaker will allow for additional opportunities to set targets and identify actionable policies. Further, a long-term funding plan to inform future appropriations is critical to achieve our long-term targets, which will send clear market and workforce development signals.

Climate Legislation and Directives

California has made progress on addressing climate change during periods of both Republican and Democratic national and State administrations. California's governors and legislature prioritize public health and the environment. A series of executive orders and laws have generated policies and actions across State government, among local and regional governments, and within industry. These policies also have encouraged collaboration with federal agencies and spurred partnerships with many jurisdictions beyond California's borders. Moving forward, California will continue its pursuit of collaborations and advocacy for action to address climate change. The following list provides a summary of major climate legislation and executive orders that have shaped California's climate programs.

Assembly Bill 32 (AB 32) (Nuñez, Chapter 488, Statutes of 2006), the California Global Warming Solutions Act of 2006.

- Cut the State's GHG emissions to 1990 levels by 2020 with maintained and continued reductions post 2020.
- First comprehensive climate bill in California, a defining moment in the State's long history of environmental stewardship.

- Secured the State's role as a national and global leader in reducing GHGs.

Pursuant to AB 32, the California Air Resources Board (CARB or Board) prepared and adopted the initial Scoping Plan to "*identify and make recommendations on direct emissions reductions measures, alternative compliance mechanisms, market-based compliance mechanisms, and potential monetary and non-monetary incentives*" in order to achieve the 2020 goal, and to achieve "*the maximum technologically feasible and cost-effective GHG emissions reductions*" by 2020 and maintain and continue reductions beyond 2020. AB 32 requires CARB to update the Scoping Plan at least every five years.

Executive Order B-30-15

In his January 2015 inaugural address, Governor Brown identified actions in five key climate change strategy "pillars" necessary to meet California's ambitious climate change goals. These five pillars are:

- Reducing today's petroleum use in cars and trucks by up to 50 percent.
- Increasing from one-third to 50 percent our electricity derived from renewable sources.
- Doubling the efficiency savings achieved at existing buildings and making heating fuels cleaner.
- Reducing the release of methane, black carbon, and other short-lived climate pollutants.
- Managing farm and rangelands, forests, and wetlands so they can store carbon.

Consistent with these goals, Governor Brown signed Executive Order B-30-15 in April 2015:

- Establishing a California GHG reduction target of 40 percent below 1990 levels by 2030.
- Calling on CARB, in coordination with sister agencies, to update the AB 32 Climate Change Scoping Plan to incorporate the 2030 target.
- Building out the "sixth pillar" of the Governor's strategy–to safeguard California in the face of a changing climate–highlighting the need to prioritize actions to reduce GHG emissions and build resilience in the face of a changing climate.

Senate Bill 350 (SB 350) (De Leon, Chapter 547, Statutes of 2015), Golden State Standards

- Required the State to set GHG reduction planning targets through Integrated Resource Planning in the electricity sector as a whole and among individual utilities and other electricity providers (collectively known as load serving entities).
- Codified an increase in the Renewables Portfolio Standard (RPS) to 50 percent by 2030[1] and doubled the energy savings required in electricity and natural gas end uses as discussed in the Governor's inaugural address.

Senate Bill 32 (SB 32) (Pavley, Chapter 249, Statutes of 2016), California Global Warming Solutions Act of 2016: emissions limit and Assembly Bill 197 (AB 197) (E. Garcia, Chapter 250, Statutes of 2016), State Air Resources Board: greenhouse gases: regulations.

SB 32 affirms the importance of addressing climate change by codifying into statute the GHG emissions reductions target of at least 40 percent below 1990 levels by 2030 contained in Governor Brown's Executive Order B-30-15. The 2030 target reflects the same science that informs the agreement reached in Paris by the 2015 Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC), aimed at keeping the global temperature increase below 2 degrees Celsius (°C). The California 2030 target represents the most ambitious GHG reduction goal for North America. Based on the emissions reductions directed by SB 32, the annual 2030 statewide target emissions level for California is 260 million metric tons of carbon dioxide equivalent ($MMTCO_2e$).

The companion bill to SB 32, AB 197, provides additional direction to CARB on the following areas related to the adoption of strategies to reduce GHG emissions.

- Requires annual posting of GHG, criteria, and toxic air contaminant data throughout the State, organized by local and sub-county level for stationary sources and by at least a county level for mobile sources.
- Requires CARB, when adopting rules and regulations to achieve emissions reductions

1 *http://www.cpuc.ca.gov/renewables/*

and to protect the State's most affected and disadvantaged communities, to consider the social costs of GHG emissions and prioritize both of the following:
  - Emissions reductions rules and regulations that result in direct GHG emissions reductions at large stationary sources of GHG emissions and direct emissions reductions from mobile sources.
  - Emissions reductions rules and regulations that result in direct GHG emissions reductions from sources other than those listed above.
- Directs CARB, in the development of each scoping plan, to identify for each emissions reduction measure:
  - The range of projected GHG emissions reductions that result from the measure.
  - The range of projected air pollution reductions that result from the measure.
  - The cost-effectiveness, including avoided social costs, of the measure.

CARB has begun the process to implement the provisions of AB 197. For instance, CARB is already posting GHG, criteria pollutant and toxic air contaminant data. CARB also incorporated air emissions data into a visualization tool in December 2016 in response to direction in AB 197 to provide easier access to this data.[2]

Senate Bill 1383 (SB 1383) (Lara, Chapter 395, Statutes of 2016), Short-lived climate pollutants: methane emissions: dairy and livestock: organic waste: landfills

- Requires the development, adoption, and implementation of a Short-Lived Climate Pollutant Strategy.[3, 4]
- Includes the following specific goals for 2030 from 2013 levels:
  - 40 percent reduction in methane.
  - 40 percent reduction in hydrofluorocarbon gases.
  - 50 percent reduction in anthropogenic black carbon.[5]

Short-lived climate pollutants (SLCPs), such as black carbon, fluorinated gases, and methane, are powerful climate forcers that have a dramatic and detrimental effect on air quality, public health, and climate change. These pollutants create a warming influence on the climate that is many times more potent than that of carbon dioxide. In March 2017, the Board adopted the Short-Lived Climate Pollutant Reduction Strategy (SLCP Strategy) establishing a path to decrease GHG emissions and displace fossil-based natural gas use. Strategies include avoiding landfill methane emissions by reducing the disposal of organics through edible food recovery, composting, in-vessel digestion, and other processes; and recovering methane from wastewater treatment facilities, and manure methane at dairies, and using the methane as a renewable source of natural gas to fuel vehicles or generate electricity. The SLCP Strategy also identifies steps to reduce natural gas leaks from oil and gas wells, pipelines, valves, and pumps to improve safety, avoid energy losses, and reduce methane emissions associated with natural gas use. Lastly, the SLCP Strategy also identifies measures that can reduce hydrofluorocarbon (HFC) emissions at national and international levels, in addition to State-level action that includes an incentive program to encourage the use of low-Global Warming Potential (GWP) refrigerants, and limitations on the use of high-GWP refrigerants in new refrigeration and air-conditioning equipment.

Assembly Bill 1504 (AB 1504) (Skinner, Chapter 534, Statutes of 2010): Forest resources: carbon sequestration

- Requires the Board of Forestry and Fire Protection to adopt district forest practice rules and regulations in accordance with specified policies to, among other things, assure the continuous growing and harvesting of commercial forest tree species.
- Requires the Board of Forestry and Fire Protection to ensure that its rules and regulations that govern the harvesting of commercial forest tree species consider the capacity of forest resources to sequester carbon dioxide emissions sufficient to meet or exceed the sequestration target of 5 million metric tons of carbon dioxide annually, as established in the first AB 32 Climate Change Scoping Plan.

2 CARB. 2016. CARB's Emission Inventory Activities. *www.arb.ca.gov/ei/ei.htm*
3 CARB. Reducing Short-Lived Climate Pollutants in California. *www.arb.ca.gov/cc/shortlived/shortlived.htm*
4 Senate Bill No. 605. *leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB605*
5 Senate Bill No.1383. *leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383*

Senate Bill 1386 (SB 1386) (Wolk, Chapter 545, Statutes of 2016): Resource conservation, natural and working lands

- Declares it the policy of the State that protection and management of natural and working lands, as defined, is an important strategy in meeting the State's GHG reduction goals.
- Requires State agencies to consider protection and management of natural and working lands in establishing policies and grant criteria, and in making expenditures, and "implement this requirement in conjunction with the State's other strategies to meet its greenhouse gas emissions reduction goals."

Assembly Bill 398 (AB 398) (E. Garcia, Chapter 135, Statutes of 2017): California Global Warming Solutions Act of 2006: market-based compliance mechanisms: fire prevention fees: sales and use tax manufacturing exemption

- Clarifies the role of the State's Cap-and-Trade Program from January 1, 2021, through December 31, 2030, continuing elements of the current program, but requiring CARB to make some post-2020 refinements.
- Establishes a Compliance Offsets Protocol Task Force to provide guidance to CARB in approving new offset protocols that increase projects with direct, in-state environmental benefits.
- Establishes the Independent Emissions Market Advisory Committee to report annually on the environmental and economic performance of the Cap-and-Trade Program and other climate policies.
- Identifies legislative priorities for allocating auction revenue proceeds, to include but not be limited to: air toxic and criteria air pollutants from stationary and mobile sources; low- and zero-carbon transportation alternatives; sustainable agricultural practices that promote transition to clean technology, water efficiency, and improved air quality; healthy forests and urban greening; short-lived climate pollutants; climate adaptation and resiliency; and climate and clean energy research.

In addition, AB 398 requires CARB to designate the Cap-and-Trade Program as the mechanism for reducing GHG emissions from petroleum refineries and oil and gas production facilities in this update to the Scoping Plan. With respect to local air districts, AB 398 states that it does not limit or expand the district's existing authority, including the authority to regulate criteria pollutants and toxic air contaminants, except that it prohibits an air district from adopting or implementing a rule for the specific purpose of reducing emissions of carbon dioxide from stationary sources that are subject to the Cap-and-Trade Program.

Assembly Bill 617 (AB 617) (C. Garcia, Chapter 136, Statutes of 2017): Nonvehicular air pollution: criteria air pollutants and toxic air contaminants.

This bill was passed as a companion to AB 398 (E. Garcia, 2017) to strengthen air quality monitoring and reduce air pollution at a community level, in communities affected by a high cumulative burden of exposure to pollution. CARB is required to prepare a monitoring plan by October 1, 2018, that assesses the State's current air monitoring network with recommendations for a set of high-priority locations around the State to deploy community focused air monitoring systems. Local air districts must deploy air monitoring systems in the selected high priority locations by July 1, 2019. Thereafter, CARB will evaluate and select additional locations for community air monitoring on an annual basis. The air districts must also deploy air monitoring systems within one year of CARB's selection of the high-priority locations. In addition to the monitoring plan, the bill requires CARB to develop a statewide strategy to reduce criteria pollutants and toxic air contaminants (TACs) in communities affected by high cumulative exposure burdens through approved community emissions reduction programs developed by local air districts, in partnership with residents in the affected communities; requires CARB to establish a uniform system of annual reporting of criteria pollutants and TACs for the existing statewide air monitoring network; and expedites implementation of best available retrofit control technology in non-attainment areas.

Tables summarizing the legislation described in this section, along with other climate related legislation and programs are included in Appendix H and organized by sector.

Initial Scoping Plan and First Update to the Scoping Plan

The Initial Scoping Plan[6] in 2008 presented the first economy-wide approach to reducing emissions and highlighted the value of combining both carbon pricing with other complementary programs to meet California's 2020 GHG emissions target while ensuring progress in all sectors. The coordinated set of policies in the Initial Scoping Plan employed strategies tailored to specific needs, including market-based compliance mechanisms, performance standards, technology requirements, and voluntary reductions. The Initial Scoping Plan also described a conceptual design for a cap-and-trade program that included eventual linkage to other cap-and-trade programs to form a larger regional trading program.

AB 32 requires CARB to update the scoping plan at least every five years. The First Update to the Scoping Plan[7] (First Update), approved in 2014, presented an update on the program and its progress toward meeting the 2020 limit. It also developed the first vision for long-term progress beyond 2020. In doing so, the First Update laid the groundwork for the goals set forth in Executive Orders S-3-05[8] and B-16-2012[9]. It also identified the need for a 2030 mid-term target to establish a continuum of actions to maintain and continue reductions, rather than only focusing on targets for 2020 or 2050.

Building on California's Environmental Legacy

California's successful climate policies and programs have already delivered emissions reductions resulting from cleaner, more fuel-efficient cars and zero emission vehicles (ZEVs), low carbon fuels, increased renewable energy, and greater waste diversion from landfills; water conservation; improved forest management; and improved energy efficiency of homes and businesses. Beyond GHG reductions, these policies and programs also provide an array of benefits including improved public health, green jobs, and more clean energy choices. The 2030 GHG emissions reduction target in SB 32 will ensure that the State maintains this momentum beyond 2020, mindful of the State's population growth and needs. This Scoping Plan identifies a path to simultaneously make progress on the State's climate goals as well as complement other efforts such as the State Implementation Plans (SIPs) and community emissions reduction programs to help improve air quality in all parts of the State.

California's future climate strategy will require continued contributions from all sectors of the economy, including enhanced focus on zero- and near-zero emission (ZE/NZE) vehicle technologies; continued investment in renewables, such as solar roofs, wind, and other types of distributed generation; greater use of low carbon fuels; integrated land conservation and development strategies; coordinated efforts to reduce emissions of short-lived climate pollutants (methane, black carbon, and fluorinated gases); and an increased focus on integrated land use planning to support livable, transit-connected communities and conservation of agricultural and other lands. Requirements for GHG reductions at stationary sources complement efforts of local air pollution control and air quality management districts (air districts) to tighten criteria and toxics air pollution emission limits on a broad spectrum of industrial sources, including in disadvantaged communities historically located adjacent to large stationary sources. Finally, meeting the State's climate, public health, and environmental goals will entail understanding, quantifying, and addressing emissions impacts from land use decisions at all governmental levels.

Purpose of the 2017 Scoping Plan

This Scoping Plan incorporates, coordinates, and leverages many existing and ongoing efforts and identifies new policies and actions to accomplish the State's climate goals. Chapter 2 of this document includes a description of a suite of specific actions to meet the State's 2030 GHG limit. In addition, Chapter 4 provides a broader description of the many actions and proposals being explored across the sectors, including the natural resources sector, to achieve the State's mid and long-term climate goals.

Guided by legislative direction, the actions identified in this Scoping Plan reduce overall GHG emissions in California and deliver policy signals that will continue to drive investment and certainty in a low carbon

6 CARB. Initial AB 32 Climate Change Scoping Plan. Available at: *www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf*
7 CARB. First Update to the AB 32 Scoping Plan. Available at: *www.arb.ca.gov/cc/scopingplan/document/updatedscopingplan2013.htm*
8 *www.gov.ca.gov/news.php?id=1861*
9 *www.gov.ca.gov/news.php?id=17472*

economy. This Scoping Plan builds upon the successful framework established by the Initial Scoping Plan and First Update, while identifying new, technologically feasible, and cost-effective strategies to ensure that California meets its GHG reduction targets in a way that promotes and rewards innovation, continues to foster economic growth, and delivers improvements to the environment and public health, including in disadvantaged communities. The Plan includes policies to require direct GHG reductions at some of the State's largest stationary sources and mobile sources. These policies include the use of lower GHG fuels, efficiency regulations, and the Cap-and-Trade Program, which constrains and reduces emissions at covered sources.

Process for Developing the 2017 Scoping Plan

This Scoping Plan was developed in coordination with State agencies, through engagement with the Legislature, and with open and transparent opportunities for stakeholders and the public to engage in workshops and other meetings. Development also included careful consideration of, and coordination with, other State agency plans and regulations, including the Cap-and-Trade Program, Low Carbon Fuel Standard (LCFS), State Implementation Plan, California Sustainable Freight Action Plan, California Transportation Plan 2040, Forest Carbon Plan, and the Short-Lived Climate Pollutant Strategy, among others.

To inform this Scoping Plan, CARB, in collaboration with the Governor's Office and other State agencies, solicited comments and feedback from affected stakeholders, including the public, and the Environmental Justice Advisory Committee (EJAC or Committee). The process to update the 2017 Scoping Plan began with the Governor's Office Pillar Symposia, which included over a dozen public workshops, and featured a series of Committee and environmental justice community meetings.[10]

One key message conveyed to CARB during engagement with the legislature, EJAC, and environmental justice communities was the need to emphasize reductions at large stationary sources, with a particular focus on multi-pollutant strategies for these sources to reduce GHGs and harmful criteria and toxic air pollutants that result in localized health impacts, especially in disadvantaged communities. Other consistent feedback for CARB included the need for built and natural infrastructure improvements that enhance quality of life, increase access to safe and viable transportation options, and improve physical activity and related health outcomes.

Updated Climate Science Supports the Need for More Action

Climate scientists agree that global warming and other shifts in the climate system observed over the past century are caused by human activities. These recorded changes are occurring at an unprecedented rate.[11] According to new research, unabated GHG emissions could allow sea levels to rise up to ten feet by the end of this century–an outcome that could devastate coastal communities in California and around the world.[12]

California is already feeling the effects of climate change, and projections show that these effects will continue and worsen over the coming centuries. The impacts of climate change have been documented by the Office of Environmental Health Hazard Assessment (OEHHA) in the Indicators of Climate Change Report, which details the following changes that are occurring already:[13]

- A recorded increase in annual average temperatures, as well as increases in daily minimum and maximum temperatures.
- An increase in the occurrence of extreme events, including wildfire and heat waves.
- A reduction in spring runoff volumes, as a result of declining snowpack.
- A decrease in winter chill hours, necessary for the production of high-value fruit and nut crops.
- Changes in the timing and location of species sightings, including migration upslope of flora and fauna, and earlier appearance of Central Valley butterflies.

10 *www.arb.ca.gov/cc/scopingplan/scopingplan.htm*
11 Cook, J., et al. 2016. Consensus on consensus: A synthesis of consensus estimates on human-caused global warming. Environmental Research Letters 11:048002 doi:10.1088/1748-9326/11/4/048002. *iopscience.iop.org/article/10.1088/1748-9326/11/4/048002*.
12 California Ocean Protection Council. 2017. Rising Seas in California: An Update On Sea-Level Rise Science. *www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf*
13 Office of Environmental Health Hazard Assessment, Indicators of Climate Change (website): *oehha.ca.gov/climate-change/document/indicators-climate-change-california*

In addition to these trends, the State's current conditions point to a changing climate. California's recent historic drought incited land subsidence, pest invasions that killed over 100 million trees, and water shortages throughout the State. Recent scientific studies show that such extreme drought conditions are more likely to occur under a changing climate.[14,15] The total statewide economic cost of the 2013–2014 drought was estimated at $2.2 billion, with a total loss of 17,100 jobs.[16] In the Central Valley, the drought cost California agriculture about $2.7 billion and more than 20,000 jobs in 2015, which highlights the critical need for developing drought resilience.[17] Drought affects other sectors as well. An analysis of the amount of water consumed in meeting California's energy needs between 1990 and 2012 shows that while California's energy policies have supported climate mitigation efforts, the performance of these policies have increased vulnerability to climate impacts, especially greater hydrologic uncertainty.[18]

Several publications carefully examined the potential role of climate change in the recent California drought. One study examined both precipitation and runoff in the Sacramento and San Joaquin River basins, and found that 10 of the past 14 years between 2000 and 2014 have been below normal, and recent years have been the driest and hottest in the full instrumental record from 1895 through November 2014.[19] In another study, the authors show that the increasing co-occurrence of dry years with warm years raises the risk of drought, highlighting the critical role of elevated temperatures in altering water availability and increasing overall drought intensity and impact.[20] Generally, there is growing risk of unprecedented drought in the western United States driven primarily by rising temperatures, regardless of whether or not there is a clear precipitation trend.[21]

According to the U.S. Forest Service report, National Insect and Disease Forest Risk Assessment, 2013–2027,[22] California is at risk of losing 12 percent of the total area of forests and woodlands in the State due to insects and disease, or over 5.7 million acres. Some species are expected to lose significant amounts of their total basal area (e.g., whitebark pine is projected to lose 60 percent of its basal area; and lodgepole pine is projected to lose 40 percent). While future climate change is not modeled within the risk assessment, and current drought conditions are not accounted for in these estimates, the projected climate changes over a 15 year period (2013-2027) are expected to significantly increase the number of acres at risk, and will increase the risk from already highly destructive pests such as the mountain pine beetle. Extensive tree mortality is already prevalent in California. The western pine beetle and other bark beetles have killed a majority of the ponderosa pine in the foothills of the central and southern Sierra Nevada Mountains. A recent aerial survey by the U.S. Forest Service identified more than 100 million dead trees in California.[23] As there is usually a lag time between drought years and tree mortality, we are now beginning to see a sharp rise in mortality from the past four years of drought. In response to the very high levels of tree mortality, Governor Brown issued an Emergency Proclamation on October 30, 2015, that directed state agencies to identify and take action to reduce wildfire risk through the removal and use of the dead trees.

14 Diffenbaugh, N., D. L. Swain, and D. Touma. 2015. Anthropogenic Warming has Increased Drought Risk in California. Proceedings of the National Academy of Sciences 112(13): 3931–3936.

15 Cayan, D., T. Das, D. W. Pierce, T. P. Barnett, M. Tyree, and A. Gershunov. 2010. Future Dryness in the Southwest US and Hydrology of the Early 21st Century Drought. Proceedings of the National Academy of Sciences 107(50): 21272–21276.

16 Howitt, R., J. Medellin-Azuara, D. MacEwan, J. Lund, and D. Summer. 2014. Economic Impacts of 2014 Drought on California Agriculture. *watershed.ucdavis.edu/files/biblio/DroughtReport_23July2014_0.pdf*.

17 Williams, A. P., et al. 2015. Contribution of anthropogenic warming to California drought during 2012–2014. Geophysical Research Letters *http://onlinelibrary.wiley.com/doi/10.1002/2015GL064924/abstract*.

18 Fulton, J., and H. Cooley. 2015. The water footprint of California's energy system, 1990–2012 Environmental Science & Technology 49(6):3314–3321. *pubs.acs.org/doi/abs/10.1021/es505034x*.

19 Mann, M. E., and P. H. Gleick. 2015. Climate change and California drought in the 21st century. Proceedings of the National Academy of Sciences of the United States of America, 112(13):3858–3859. *doi.org/10.1073/pnas.1503667112*.

20 Diffenbaugh, N. S., D. L. Swain, and D. Touma. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences of the United States of America. 10.1073/pnas.1422385112. *www.pnas.org/content/112/13/3931.full.pdf*

21 Cook, B. I., T. R. Ault, and J. E. Smerdon. 2015. Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances 1(1), e1400082, doi:10.1126/sciadv.1400082.

22 Krist, F.J. Jr., J.R. Ellenwood, M.E. Woods, A.J. McMahan, J.P. Cowardin, D.E. Ryerson, F.J. Sapio, M.O. Zweifler, S.A. Romero. 2014. FHTET 2013 – 2027 National Insect & and Disease Forest Risk Assessment. FHTET-14-01 January 2014. Available at: *http://www.fs.fed.us/foresthealth/technology/pdfs/2012_RiskMap_Report_web.pdf*

23 USDA. 2016. New Aerial Survey Identifies More Than 100 Million Dead Trees in California. *www.usda.gov/wps/portal/usda/usdahome?contentid=2016/11/0246.xml&contentidonly=true*



Climate Impacts at the Community Level

The California Energy Commission Cal-Adapt tool provides information about future climate conditions to help better understand how climate will impact local communities.

cal-adapt.org

A warming climate also causes sea level to rise; first, by warming the oceans which causes the water to expand, and second, by melting land ice which transfers water to the ocean. Even if storms do not become more intense or frequent, sea level rise itself will magnify the adverse impact of any storm surge and high waves on the California coast. Some observational studies report that the largest waves are already getting higher and winds are getting stronger.[24] Further, as temperatures warm and GHG concentrations increase more carbon dioxide dissolves in the ocean, making it more acidic. More acidic ocean water affects a wide variety of marine species, including species that people rely on for food. Recent projections indicate that if no significant GHG mitigation efforts are taken, the San Francisco Bay Area may experience sea level rise between 1.6 to 3.4 feet, and in an extreme scenario involving the rapid loss of the Antarctic ice sheet, sea levels along California's coastline could rise up to 10 feet by 2100.[25] This change is likely to have substantial ecological and economic consequences in California and worldwide.[26]

While more intense dry periods are anticipated under warmer conditions, extremes on the wet end of the spectrum are also expected to increase due to more frequent warm, wet atmospheric river events and a higher proportion of precipitation falling as rain instead of snow. In recent years, atmospheric rivers have also been recognized as the cause of the large majority of major floods in rivers all along the U.S. West Coast and as the source of 30-50 percent of all precipitation in the same region.[27] These extreme precipitation events, together with the rising snowline, often cause devastating floods in major river basins (e.g., California's Russian River). It was estimated that the top 50 observed floods in the U.S. Pacific Northwest were due to atmospheric rivers.[28] Looking ahead, the frequency and severity of atmospheric rivers on the U.S. West Coast will increase due to higher atmospheric water vapor that occurs with rising temperature, leading to more frequent flooding.[29, 30]

Climate change can drive extreme weather events such as coastal storm surges, drought, wildfires, floods, and heat waves, and disrupt environmental systems including our forests and oceans. As GHG emissions continue to accumulate and climate disruption grows, such destructive events will become more frequent. Several recent studies project increased precipitation within hurricanes over ocean regions.[31, 32] The primary physical mechanism for this increase is higher water vapor in the warmer atmosphere, which enhances moisture convergence in a storm for a given circulation strength. Since hurricanes are responsible for many of the most extreme precipitation events, such events are likely to become more extreme. Anthropogenic warming by

24 National Research Council of the National Academy of Sciences. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. National Academies Press.

25 California Ocean Protection Council. 2017. Rising Seas in California: An Update On Sea-Level Rise Science. *www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf*

26 Chan, F., et al. 2016. The West Coast Ocean Acidification and Hypoxia Science Panel: Major Findings, Recommendations, and Actions. California Ocean Science Trust, Oakland, California, USA.

27 Dettinger, M. D. 2013. Atmospheric rivers as drought busters on the U.S. West Coast. Journal of Hydrometeorology 14:1721 1732, doi:10.1175/JHM-D-13-02.1. *journals.ametsoc.org/doi/abs/10.1175/JHM-D-13-02.1*.

28 Warner, M. D., C. F. Mass, and E. P. Salath´e. 2012. Wintertime extreme precipitation events along the Pacific Northwest coast: Climatology and synoptic evolution. Monthly Weather Review 140:2021–43. *http://journals.ametsoc.org/doi/abs/10.1175/MWR-D-11-00197.1*.

29 Hagos, S. M., L. R. Leung, J.-H. Yoon, J. Lu, and Y. Gao, 2016: A projection of changes in landfalling atmospheric river frequency and extreme precipitation over western North America from the Large Ensemble CESM simulations. Geophysical Research Letters, 43 (3), 357-1363, *http://onlinelibrary.wiley.com/doi/10.1002/2015GL067392/epdf*.

30 Payne, A. E., and G. Magnusdottir, 2015: An evaluation of atmospheric rivers over the North Pacific in CMIP5 and their response to warming under RCP 8.5. Journal of Geophysical Research: Atmospheres, 120 (21), 11,173-111,190, *http://onlinelibrary.wiley.com/doi/10.1002/2015JD023586/epdf*.

31 Easterling, D.R., K.E. Kunkel, M.F. Wehner, and L. Sun, 2016: Detection and attribution of climate extremes in the observed record. Weather and Climate Extremes, 11, 17-27. *http://dx.doi.org/10.1016/j.wace.2016.01.001*.

32 NAS, 2016: Attribution of Extreme Weather Events in the Context of Climate Change. The National Academies Press, Washington, DC, 186 pp. *http://dx.doi.org/10.17226/21852*.

the end of the 21st century will likely cause tropical cyclones globally to become more intense on average. This change implies an even larger percentage increase in the destructive potential per storm, assuming no changes in storm size.[33,34] Thus, the historical record, which once set our expectations for the traditional range of weather and other natural events, is becoming an increasingly unreliable predictor of the conditions we will face in the future. Consequently, the best available science must drive effective climate policy.

California is committed to further supporting new research on ways to mitigate climate change and how to understand its ongoing and projected impacts. California's Fourth Climate Change Assessment and Indicators of Change Report will further update our understanding of the many impacts from climate change in a way that directly informs State agencies' efforts to safeguard the State's people, economy, and environment.[35, 36]

Together, historical data, current conditions, and future projections provide a picture of California's changing climate, with two important messages:

- Change is already being experienced and documented across California, and some of these changes have been directly linked to changing climatic conditions.
- Even with the uncertainty in future climate conditions, every scenario estimates further change in future conditions.

It is critical that California continue to take steps to reduce GHG emissions in order to avoid the worst of the projected impacts of climate change. At the same time, the State is taking steps to make the State more resilient to ongoing and projected climate impacts as laid out by the Safeguarding California Plan.[37] The Safeguarding California Plan is being updated in 2017 to present new policy recommendations and provide a roadmap of all the actions and next steps that state government is taking to adapt to the ongoing and inevitable effects of climate change. The Draft Safeguarding California Plan[38] is available and will be finalized after workshops and public comments. California's continuing efforts are vital steps toward minimizing the impact of GHG emissions and a three-pronged approach of reducing emissions, preparing for impacts, and conducting cutting-edge research can serve as a model for action.

California's Greenhouse Gas Emissions and the 2030 Target

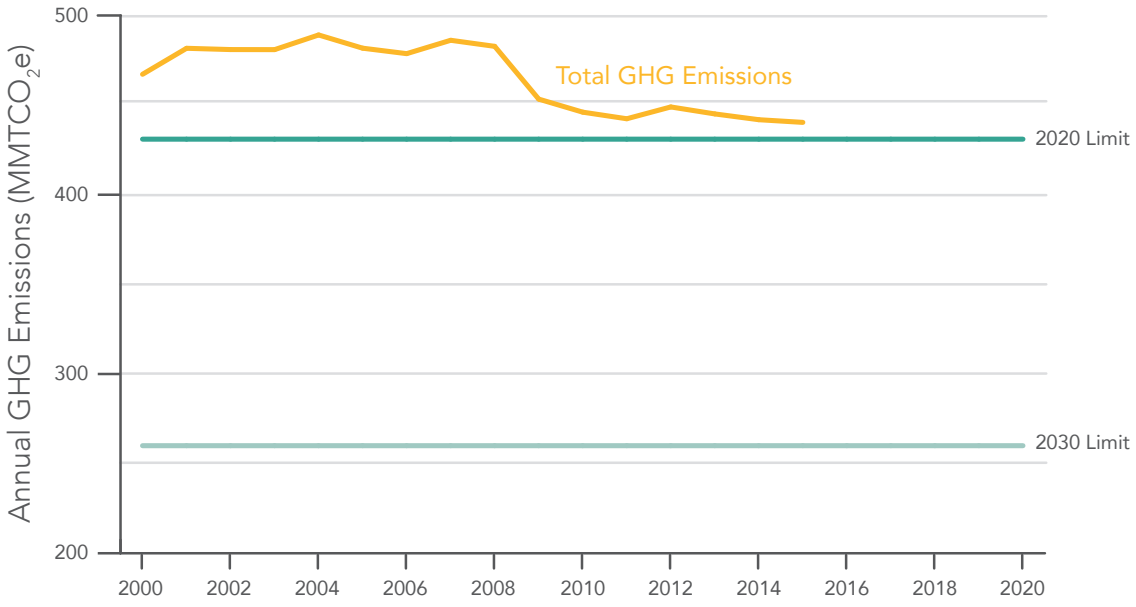
Progress Toward Achieving the 2020 Limit

AB 32 directs CARB to develop and track GHG emissions and progress toward the 2020 statewide GHG target. California is on track to achieve the target while also reducing criteria pollutants and toxic air contaminants and supporting economic growth. As shown in Figure 1, in 2015, total GHG emissions decreased by 1.5 MMTCO$_2$e compared to 2014, representing an overall decrease of 10 percent since peak levels in 2004. The 2015 GHG Emission Inventory and a description of the methodology updates can be accessed at: *www.arb.ca.gov/cc/inventory/inventory.htm*.

Per California Health and Safety Code section 38505, CARB monitors and regulates seven GHGs to reduce emissions: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and nitrogen trifluoride (NF_3). The fluorinated gases are also referred to as "high global warming potential gases" (high-GWP gases). California's annual statewide GHG emission inventory has historically been the primary tool for tracking GHG emissions trends. Figure 1 provides the GHG inventory trend. Additional information on the methodology for the GHG inventory can also be found at: *www.arb.ca.gov/cc/inventory/data/data.htm*.

33 Sobel, A.H., S.J. Camargo, T.M. Hall, C.-Y. Lee, M.K. Tippett, and A.A. Wing, 2016: Human influence on tropical cyclone intensity. Science, 353, 242-246.
34 Kossin, J. P., K. A. Emanuel, and S. J. Camargo, 2016: Past and projected changes in western North Pacific tropical cyclone exposure. Journal of Climate, 29 (16), 5725-5739, *https://doi.org/10.1175/JCLI-D-16-0076.1*.
35 California's Fourth Climate Change Assessment. *http://resources.ca.gov/climate/safeguarding/research/*
36 Office of Environmental Health Hazard Assessment, Indicators of Climate Change (website): *https://oehha.ca.gov/climate-change/document/indicators-climate-change-california*
37 California Natural Resources Agency. 2017. Safeguarding California. *http://resources.ca.gov/climate/safeguarding/*
38 *http://resources.ca.gov/climate/safeguarding/*

Figure 1: California GHG Inventory Trend



Carbon dioxide is the primary GHG emitted in California, accounting for 84 percent of total GHG emissions in 2015, as shown in Figure 2 below. Figure 3 illustrates that transportation, primarily on-road travel, is the single largest source of CO_2 emissions in the State. Upstream transportation emissions from the refinery and oil and gas sectors are categorized as CO_2 emissions from industrial sources and constitute about 50 percent of the industrial source emissions. When these emissions sources are attributed to the transportation sector, the emissions from that sector amount to approximately half of statewide GHG emissions. In addition to transportation, electricity production, and industrial and residential sources also are important contributors to CO_2 emissions.

Figures 2 and 3 show State GHG emission contributions by GHG and sector based on the 2015 GHG Emission Inventory.

Figure 2: Emissions by GHG

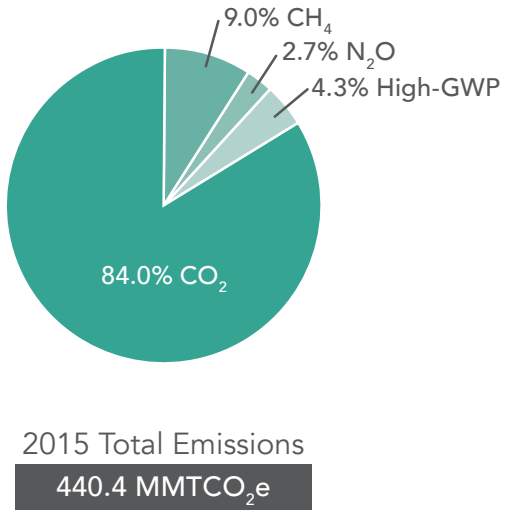
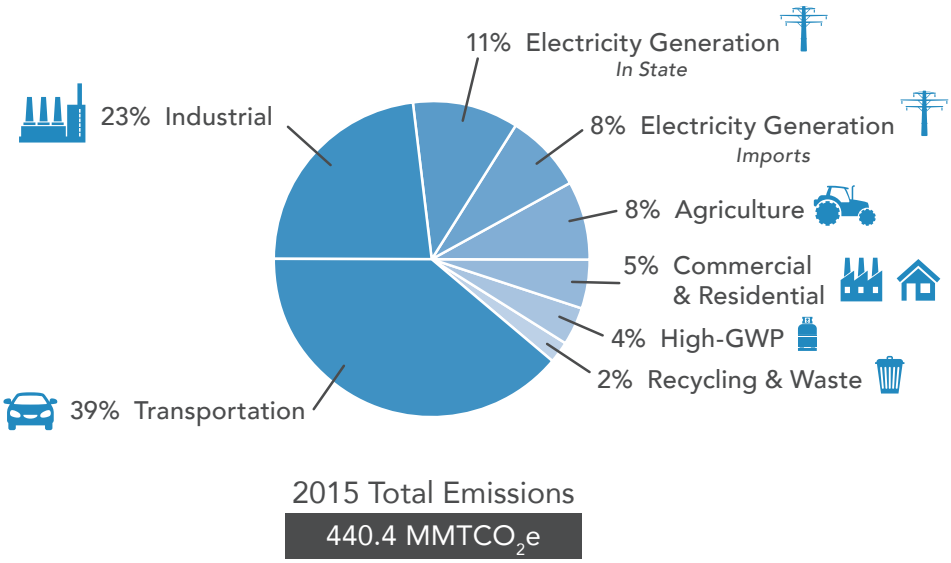
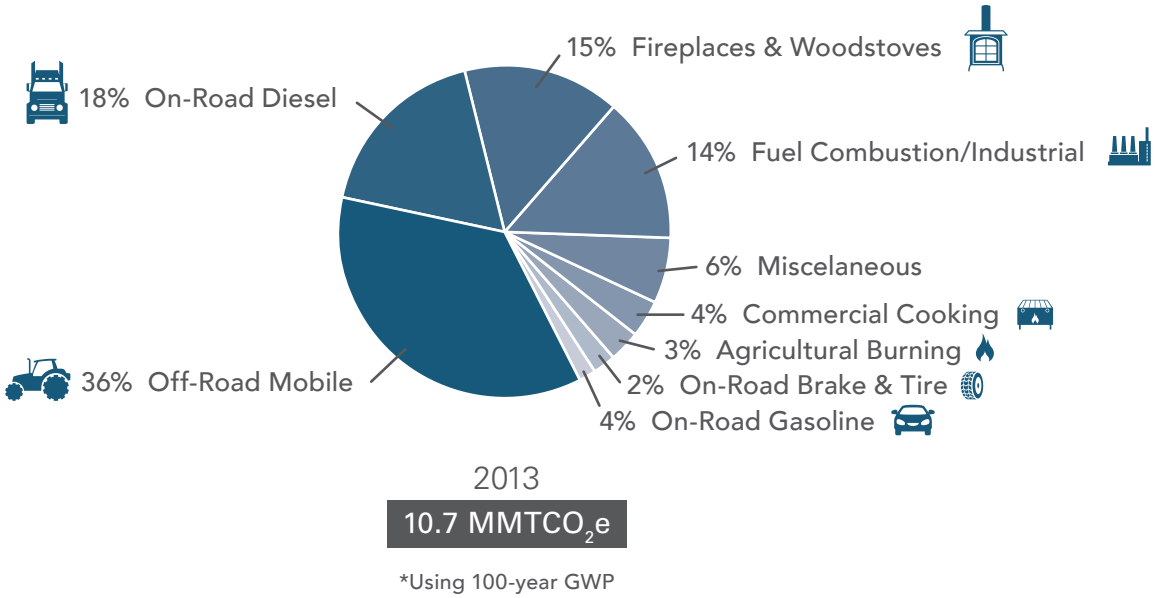


Figure 3: Emissions by Sector



In addition, CARB has developed a statewide emission inventory for black carbon in support of the SLCP Strategy, which is reported in two categories: non-forestry (anthropogenic) sources and forestry sources.[39] The black carbon inventory will help support implementation of the SLCP Strategy, but is not part of the State's GHG Inventory that tracks progress towards the State's climate targets. The State's major anthropogenic sources of black carbon include off-road transportation, on-road transportation, residential wood burning, fuel combustion, and industrial processes (Figure 4). The forestry category includes non-agricultural prescribed burning and wildfire emissions.

Figure 4: California 2013 Anthropogenic Black Carbon Emission Sources*



*Using 100-year GWP

The exchange of CO_2 between the atmosphere and California's natural and working lands sector is currently unquantified and therefore, excluded from the State's GHG Inventory. A natural and working lands carbon inventory is essential for monitoring land-based activities that may increase or decrease carbon sequestration over time. CARB staff is working to develop a comprehensive inventory of GHG fluxes from all of California's

39 Per SB 1383, the SLCP Strategy only addresses anthropogenic black carbon.

natural and working lands using the Intergovernmental Panel on Climate Change (IPCC) design principles. CARB released the Natural and Working Lands Inventory with the 2030 Target Scoping Plan Update Discussion Draft.[40] This inventory provides an estimate of GHG emissions reductions and changes in carbon stock from some carbon pools in agricultural and natural and working lands. The CARB Natural and Working Lands Inventory includes an inventory of carbon stocks, stock-change (and by extension GHG flux associated with stock-change) with some attribution by disturbance process for the analysis period 2001-2010. Disturbance processes include activities such as conversion from one land category to a different category, fire, and harvest. The CARB Natural and Working Lands Inventory covers varieties of forests and woodlands, grasslands, and wetlands (biomass-stock-change only). The Inventory includes default carbon densities for croplands and urban/developed lands to facilitate stock-change estimation for natural lands that convert to cropland, natural lands that convert to developed lands, and for croplands that convert to developed lands.

Greenhouse Gas Emissions Tracking

As described above, California maintains an economy-wide GHG inventory for the State that is consistent with IPCC practices to allow for comparison of statewide GHG emissions with those at the national level and with other international GHG inventories. Statewide GHG emissions calculations use many data sources, including data from other State and federal agencies. However, the primary source of data comes from reports submitted to CARB through the Regulation for the Mandatory Reporting of GHG Emissions (MRR). MRR requires facilities and entities with more than 10,000 metric tons of carbon dioxide equivalent ($MTCO_2e$) of combustion and process emissions, all facilities belonging to certain industries, and all electric power entities to submit an annual GHG emissions data report directly to CARB. Reports from facilities and entities that emit more than 25,000 $MTCO_2e$ are verified by a CARB-accredited third-party verification body. More information on MRR emissions reports can be found at: *www.arb.ca.gov/cc/reporti\ng/ghg-rep/reported-data/ghg-reports.htm.*

All data sources used to develop the GHG Emission Inventory are listed in inventory supporting documentation at: *www.arb.ca.gov/cc/inventory/data/data.htm.*

Other State agencies, nonprofit organizations, and research institutions are developing and testing methodologies and models to quantify GHG fluxes from California's natural and working lands. CARB's ongoing work on the Natural and Working Lands Inventory will serve as one source of data to gauge the scope of GHG reduction potential from California's natural and working lands and monitor progress over time. CARB will evaluate other data sources and methodologies to validate or support the CARB inventory or project-scale tracking. Interagency work is also underway to integrate and account for the land use and management impacts of development, transportation, housing, and energy policies.

Greenhouse gas mitigation action may cross geographic borders as part of international and subnational collaboration, or as a natural result of implementation of regional policies. In addition to the State's existing GHG inventory, CARB has begun exploring how to build an accounting framework that also utilizes existing program data to better reflect the broader benefits of our policies that may be happening outside of the State. For GHG reductions outside of the State to be attributed to our programs, those reductions must be real and quantifiable, without any double counting, including claims to those reductions by other jurisdictions. CARB is collaborating with other jurisdictions to ensure GHG accounting rules are consistent with international best practices. Robust accounting rules will instill confidence in the reductions claimed and maintain support for joint action across jurisdictions. Consistency and transparency are critical as we work together with other jurisdictions on our parallel paths to achieve our GHG targets.

California's Approach to Addressing Climate Change

Integrated Systems

The State's climate goals require a comprehensive approach that integrates and builds upon multiple ongoing State efforts. As we address future mobility, we identify how existing efforts – such as the California Sustainable Freight Action Plan, Mobile Source Strategy, California Transportation Plan 2040, High-Speed

40 CARB. 2016. California Greenhouse Gas Inventory - Forests and Other Lands. *www.arb.ca.gov/cc/inventory/sectors/forest/forest.htm*

Rail,[41] urban planning, housing, and goals for enhancement of the natural environment – can complement each other while providing multiple environmental benefits, including air quality and climate benefits. The collective consideration of these efforts illuminates the synergies and conflicts between policies. For example, land disturbance due to increased renewables through utility scale wind and solar and transmission can release GHGs from soil and disturb grasslands and rangelands that have the potential to sequester carbon. Further, policies that support sustainable land use not only reduce vehicle miles traveled (VMT) and its related emissions, but may also avoid land disturbance that could result in GHG emissions or loss of sequestration potential in the natural environment. Identifying these types of trade-offs, and designing policies and implementation strategies to support goals across all sectors, will require ongoing efforts at the local, regional, and State level to ensure that sustainable action across both the built and natural environments help to achieve the State's long-term climate goals.

Promoting Resilient Economic Growth

California's strategic vision for achieving at least a 40 percent reduction in GHG emissions by 2030 is based on the principle that economic prosperity and environmental sustainability can be achieved together. Policies, strategies, plans and regulations to reduce GHG emissions help California businesses compete in a global economy and spur new investments, business creation, and jobs to support a clean energy economy. California's portfolio-based climate strategy can achieve great success when accompanied by consistent and rigorous GHG monitoring and reporting, a robust public process, and an effective enforcement program for the few that attempt to evade rules. The transition to a low-carbon future can strengthen California's economy and infrastructure and produce other important environmental benefits such as reductions in criteria pollutants and toxic air contaminants, especially in California's most vulnerable communities.

Actions that are presented in this Scoping Plan provide economic opportunities for the future, but progress toward our goals is already evident today. For example, in 2015, California added more than 20,000 new jobs in the solar sector. This was more than half of the new jobs in this industry across the nation. Employment in the clean economy grew by 20 percent between 2002 and 2012, which included the period of economic recession around 2008.[42] Shifting to clean, local, and efficient uses of energy reinvests our energy expenditures in our local economies and reduces risks to our statewide economy associated with exposure to volatile global and national oil and gas commodity prices. Indeed, a clean economy is a resilient economy.

Successfully driving economic transition will require cleaner and more efficient technologies, policies and incentives that recognize and reward innovation, and prioritizing low carbon investments. Enacting policies and incentives at multiple jurisdictional levels further ensures the advancement of land use and natural resource management objectives for GHG mitigation, climate adaptation, and other co-benefits. Intentional synergistic linkages between technological advances and resource stewardship can result in sustainable development. The development and implementation of Sustainable Communities Strategies (SCSs) pursuant to Senate Bill (SB) 375, which link transportation, housing, and climate policy, are designed to reduce per capita GHG emissions while improving air quality and expanding transportation and housing options. This Scoping Plan identifies additional ways, beyond SB 375, to promote the technologies and infrastructure required to meet our collective climate goals, while also presenting the vision for California's continuing efforts to foster a sustainable, clean energy economy.

Increasing Carbon Sequestration in Natural and Working Lands

California's natural and working lands make the State a global leader in agriculture, a U.S. leader in forest products, and a global biodiversity hotspot. These lands support clean air, wildlife and pollinator habitat, rural economies, and are critical components of California's water infrastructure. Keeping these lands and waters intact and at high levels of ecological function (including resilient carbon sequestration) is necessary for the well-being and security of Californians in 2030, 2050, and beyond. Forests, rangelands, farms,

41 California's High-Speed Rail is part of the International Union of Railways (UIC) and California signed the Railway Climate Responsibility Pledge, which was commended by the Secretary of the UN Framework Convention on Climate Change as part of achieving global 2050 targets.

42 California Business Alliance for a Clean Economy. 2015. Clean Energy and Climate Change Summary of Recent Analyses for California. *clean-economy.org/wp-content/uploads/2015/01/Clean-Energy-Climate-Change-Analyses_January2015.pdf*

wetlands, riparian areas, deserts, coastal areas, and the ocean store substantial carbon in biomass and soils.

Natural and working lands are a key sector in the State's climate change strategy. Storing carbon in trees, other vegetation, soils, and aquatic sediment is an effective way to remove carbon dioxide from the atmosphere. This Scoping Plan describes policies and programs that prioritize protection and enhancement of California's landscapes, including urban landscapes, and identifies next steps to ensure management actions are taken to increase the sequestration potential of those resources. We cannot ignore the relationships between energy, transportation, and natural working lands sectors or the adverse impacts that climate change is having on the environment itself. We must consider important trade-offs in developing the State's climate strategy by understanding the near and long-term impacts of various policy scenarios and actions on our State and local communities.

Improving Public Health

The State's drive to improve air quality and promote community health and well-being as we address climate change remains a priority, as it has for almost 50 years. The State is committed to addressing public health issues, including addressing chronic and infectious diseases, promoting mental health, and protecting communities from exposure to harmful air pollutants and toxins. Several of the strategies included in this Plan were primarily developed to help California achieve federal and State ambient air quality standards for air pollutants with direct health impacts, but they will also deliver GHG reductions. Likewise, some climate strategies, such as GHG reduction measures that decrease diesel combustion from mobile sources, produce air quality co-benefits in the form of concurrent reductions in criteria pollutants and toxic air contaminants.

Climate change itself is already affecting the health of our communities and is exacerbating existing health inequities. Those facing the greatest health burdens include low-income individuals and households, the very young and the very old, communities of color, and those who have been marginalized or discriminated against based on gender or race/ethnicity.[43] Economic factors, such as income, poverty, and wealth, are among the strongest determinants of health. Addressing climate change presents an important opportunity to improve public health for all of California's residents and to further our work toward making our State the healthiest in the nation.

The major provisions of AB 617 (C. Garcia, 2017), to be completed by 2020, will ensure that as the State seeks to advance climate policy to meet the 2030 target, we will also act locally to improve neighborhood air quality. AB 617 requires strengthening and expanding community level air monitoring; expediting equipment retrofits at large industrial sources that are located in areas that are in nonattainment for the federal and State ambient air quality standards; requiring development of a statewide strategy to further reduce criteria pollutants and toxic air contaminants in communities faced with high cumulative exposure levels; and local air district-developed community emissions reductions plans that identify emissions reductions targets, measures, implementation schedules, and enforcement plans for these affected communities. By identifying and addressing the disproportionate impacts felt today and by planning, designing, and implementing actions for a sustainable future that considers both climate and air quality objectives, we can be part of the solution to make public health inequities an issue of the past.

Environmental Justice

Fair and equitable climate action requires addressing the inequities that create and intensify community vulnerabilities. The capacity for resilience in the face of climate change is driven by living conditions and the forces that shape them. These include, but are not limited to, access to services such as health care, healthy foods, air and water, and safe spaces for physical activity; income; education; housing; transportation; environmental quality; and good health status. Strategies to alleviate poverty, increase access to economic opportunities, improve living conditions, and reduce health and social inequities will result in more climate-resilient communities. The transition to a low carbon California economy provides an opportunity to not only reduce GHG emissions, but also to reduce emissions of criteria pollutants and air toxins, and to create a healthier environment for all of California's residents, especially those living in the State's most disadvantaged communities. Policies designed to facilitate this transition and state-wide, regional, and local reductions,

43 California Department of Public Health (CDPH). 2015. The Portrait of Promise: The California Statewide Draft Plan to Promote Health and Mental Health Equity. A Report to the Legislature and the People of California by the Office of Health Equity. Sacramento, CA: California Department of Public Health, Office of Health Equity.

must also be appropriately tailored to address the unique characteristics of economically distressed communities throughout the State's diverse geographic regions, including both rural and highly-urbanized areas. Equity considerations must likewise be part of the deliberate and thoughtful process in the design and implementation of all policies and measures included in the Scoping Plan. And CARB must ensure that its ongoing engagement with environmental justice communities will continue beyond the development of the Scoping Plan and be included in all aspects of its various air pollution programs. Additional detail on CARB's efforts to achieve these goals is provided in Chapter 5.

It is critical that communities of color, low-income communities, or both, receive the benefits of the cleaner economy growing in California, including its environmental and economic benefits. Currently, low-income customers enrolled in the California Alternate Rates for Energy (CARE) Program or the Family Electric Rate Assistance (FERA) Program are also eligible to receive a rebate under the California Climate Credit, or a credit on residential and small business electricity bills resulting from the sale of allowances received by investor-owned utilities as part of the Cap-and-Trade Program. SB 1018 (Committee on Budget and Fiscal Review, Chapter 39, Statutes of 2012) and other implementing legislation requires that Cap-and-Trade Program auction monies deposited into the Greenhouse Gas Reduction Fund (GGRF) be used to further the purposes of AB 32 and facilitate reduction of GHG emissions. Investments made with these funds not only reduce GHG emissions, but also provide other environmental, health, and economic benefits including, fostering job creation by promoting in-state GHG emissions reduction projects carried out by California workers and businesses.

Environmental Justice Advisory Committee

Martha Dina Argüello	Physicians for Social Responsibility	Los Angeles
Colin Bailey	The Environmental Justice Coalition for Water	Sacramento
Gisele Fong	End Oil	Los Angeles
Tom Frantz	Association of Irritated Residents	Central Valley
Katie Valenzuela Garcia (Served until May 2017)	Oak Park Neighborhood Association	Sacramento
Sekita Grant (Served until June 2017)	The Greenlining Institute	Statewide
Kevin Hamilton	Central California Asthma Collaborative	Central Valley
Rey León	Valley LEAP	Central Valley
Luis Olmedo	Comité Civico Del Valle	Salton Sea Region
Kemba Shakur	Urban Releaf	Bay Area
Mari Rose Taruc	Asian Pacific Environmental Network	Bay Area
Eleanor Torres	The Incredible Edible Community Garden	Inland Empire
Monica Wilson	Global Alliance for Incinerator Alternatives	Bay Area

Further, SB 535 (De Leon, Chapter 830, Statutes of 2012) and AB 1550 (Gomez, Chapter 369, Statutes of 2016) direct State and local agencies to make significant investments using GGRF monies to assist California's most vulnerable communities. Under SB 535 (de León, Chapter 830, Statutes of 2012), a minimum of 25 percent of the total investments were required to benefit disadvantaged communities; of that, a minimum of 10 percent were required to be located within and provide benefits to those communities. Based on cumulative data reported by agencies as of March 2016, the State is exceeding these targets. Indeed, 50 percent of the $1.2 billion dollars spent on California Climate Investments projects provided benefits to disadvantaged communities; and 34 percent of this funding was used on projects located directly in disadvantaged communities.[44]

Environmental Justice Advisory Committee

AB 32 calls for CARB to convene an Environmental Justice Advisory Committee (EJAC), to advise the Board in developing the Scoping Plan, and any other pertinent matter in implementing AB 32. It requires that the Committee be comprised of representatives from communities in the State with the most significant exposure to air pollution, including, but not limited to, communities with minority populations or low-income

44 www.arb.ca.gov/cc/capandtrade/auctionproceeds/cci_annual_report_2017.pdf

populations, or both. CARB consulted 13 environmental justice and disadvantaged community representatives for the 2017 Scoping Plan process, starting with the first Committee meeting in December 2015. In February and April 2017, members of the California Air Resources Board held joint public meetings with the EJAC to discuss options for addressing environmental justice and disadvantaged community concerns in the Scoping Plan. The full schedule of Committee meetings and meeting materials is available on CARB's website.[45]

Starting in July 2016, the Committee hosted a robust community engagement process, conducting 19 community meetings throughout the State. To enhance this community engagement, CARB staff coordinated with staff from local government agencies and sister State agencies. At the community meetings, staff from State and local agencies participated in extensive, topic-specific "world café" discussions with local groups and individuals. The extensive dialogue between the EJAC, State agencies, and local agencies provided community residents the opportunity to share concerns and provide input on ways California can meet its 2030 GHG target while addressing a number of environmental and equity issues.

Environmental Justice Advisory Committee Recommendations

The Committee's recommendations for the Scoping Plan were informed by comments received at community meetings described above and Committee member expertise. Recommendations were provided for the sector focus areas, overarching environmental justice policy, and California Climate Investments. The Committee also sorted their recommendations into five themes: partnership with environmental justice communities, equity, economic opportunity, coordination, and long-term vision. Finally, the Committee provided direction that their recommendations are intended "to be read and implemented holistically and not independently of each other." The EJAC's recommendations, in their entirety, are included in Appendix A and available at *www.arb.ca.gov/cc/ejac/meetings/04262017/ejac-sp-recommendations033017.pdf*.

The Committee's overarching recommendations for partnership with environmental justice communities, equity, coordination, economic opportunity, and long-term vision include the following recommendations:

- Encourage long-term community engagement, a culture shift in California, and neighborhood-level solutions to promote the implementation of the State's climate plans, using strategies identified by the Committee.
- Improve the balance of reducing GHGs and compliance costs with other AB 32 goals of improving air quality in environmental justice communities while maximizing benefits for all Californians.
- Consider public health impacts and equity when examining issues in any sector and have CARB conduct an equity analysis on the Scoping Plan and each sector, with guidance from the Committee.
- Develop metrics to ensure actions are meeting targets and develop contingency plans for mitigation and adjustment if emissions increases occur as programs are implemented.
- Develop a statewide community-based air monitoring network to support regulatory efforts and monitor neighborhood scale pollution in disadvantaged communities.
- Coordinate strategies between State, federal, and local agencies for strong, enforceable, evidence-based policies to prevent and address sprawl with equity at the center.
- Maximize the accessibility of safe jobs, incentives, and economic benefits for Californians and the development of a just transition for workers and communities in and around polluting industries.
- Prioritize improving air quality in environmental justice communities and analyze scenarios at a neighborhood scale for all California communities.
- Ensure that AB 32 economic reviewers come from various areas around the State to represent insights on economic challenges and opportunities from those regions.
- Do not limit the Scoping Plan to examining interventions and impacts until 2030, or even 2050. Plan and analyze on a longer-term scale to prevent short-sighted mistakes and reach the long-term vision, as actions today and for the next 30 years will have impacts for seven generations.
- The Scoping Plan must prioritize GHG reductions and investments in California environmental justice communities first, before other California communities; and the innovation of new technologies or strategies to reach even deeper emissions cuts, whenever possible.
- Convene the Committee beyond the Scoping Plan development process.

The Committee's key Energy sector recommendations include:

- Developing aggressive energy goals toward 100 percent renewable energy by 2030, including a vision for a clean energy economy, and prioritizing actions in disadvantaged communities.

45 *www.arb.ca.gov/cc/ejac/ejac.htm*

- Setting goals for green buildings.
- Enforcing GHG reduction targets for existing buildings, and providing upgrades that enable buildings to use renewable energy technologies and water capture.
- Prioritizing and supporting community-owned technologies, such as community-owned solar, for environmental justice communities.

Key Water sector recommendations include:

- Encouraging water conservation and recycling.
- Prioritizing safe drinking water for all.

The Committee's key Industry sector recommendations include:

- Prioritizing direct emissions reductions in environmental justice communities.
- Replacing the Cap-and-Trade Program with a carbon tax or fee and dividend program.
- Eliminating offsets and the allocation of free allowances if the Cap-and-Trade Program continues.
- Analyze where GHG emissions are increasing and identify strategies to prevent and reduce such emissions in environmental justice communities.
- Committing to reductions in petroleum use.

The Committee's key Transportation sector recommendations include:

- Increasing access to affordable, reliable, clean, and safe mobility options in disadvantaged communities.
- Community-engaged land use planning.
- Maximizing electrification.
- Restricting sprawl and examining transportation regionally.
- Considering the development of green transportation hubs that integrate urban greening with transportation options and implement the recommendations of the SB 350 studies.

The Committee's key Natural and Working Lands, Agriculture, and Waste sector recommendations include:

- Reducing waste and mandating that local jurisdictions manage the waste they create.
- Returning carbon to the soil.
- Not burning biomass or considering it a renewable resource.
- Supporting healthy soils as a critical element to land and waste management.
- Integrating urban forestry within local communities.
- Exploring ways to allow and streamline the process for cultural and prescribed burning for land management and to prevent large-scale wildfires.
- Including an annual reduction of 5 million metric tons of CO_2e from natural and working lands.

The Committee's recommendations for California Climate Investments include:

- Ensuring near-term technologies do not adversely impact communities and long-term investments move toward zero emissions.
- Requiring GGRF projects to be transformative for disadvantaged communities as defined by each community.
- Eliminating funding for AB 32 regulated entities.
- Providing technical assistance to environmental justice communities so they can better access funding and resources.
- Prioritizing projects identified by communities and ensuring all applicants have policies to protect against displacement or gentrification.

In April 2017, EJAC members provided a refined list of priority changes for the Scoping Plan from the full list of EJAC recommendations. CARB staff responded to each priority recommendation, describing additions to the Scoping Plan or suggested next steps for recommendations beyond the level of detail in the Plan. Appendix A includes the Priority EJAC Recommendations with CARB Responses and full list of EJAC Recommendations.

More information about the Committee and its recommendations on the previous Scoping Plans and this Scoping Plan is located at: *www.arb.ca.gov/ejac*.

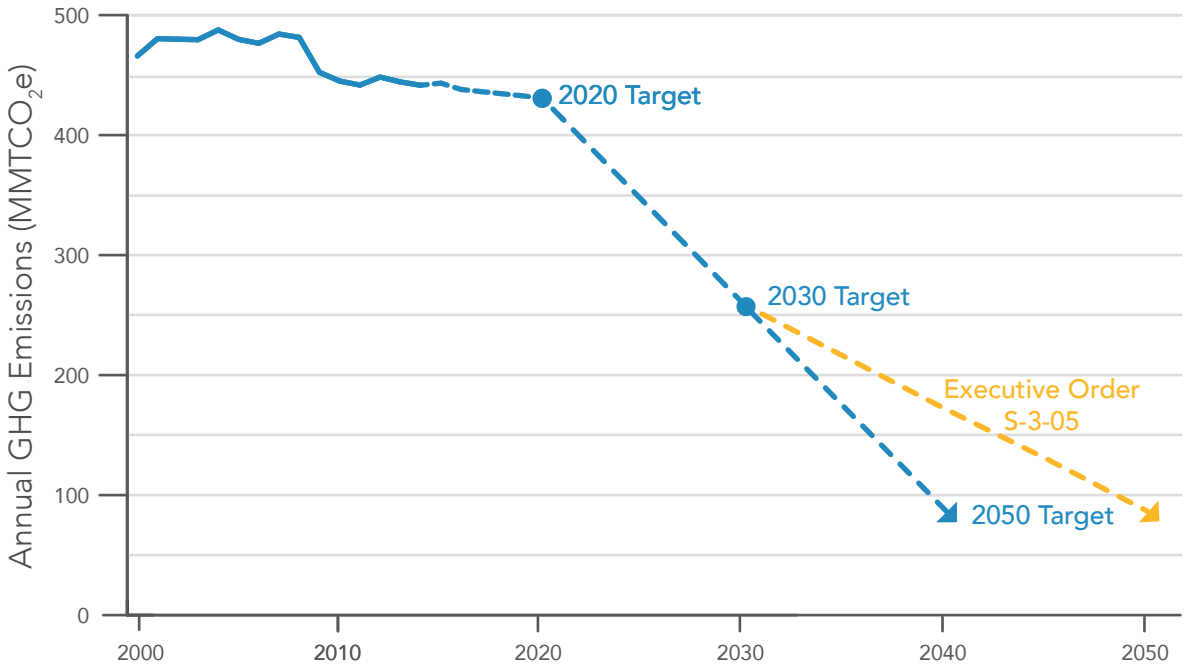
Setting the Path to 2050

The State's 2020 and 2030 targets have not been set in isolation. They represent benchmarks, consistent with prevailing climate science, charting an appropriate trajectory forward that is in-line with California's role in stabilizing global warming below dangerous thresholds. As we consider efforts to reduce emissions to meet the State's near-term requirements, we must do so with an eye toward reductions needed beyond 2030, as well. The Paris Agreement – which calls for limiting global warming to well below 2 degrees Celsius and aiming to limit it below a 1.5 degrees Celsius – frames our path forward.

While the Scoping Plan charts the path to achieving the 2030 GHG emissions reduction target, we also need momentum to propel us to the 2050 statewide GHG target (80 percent below 1990 levels). In developing this Scoping Plan, we considered what policies are needed to meet our mid-term and long-term goals. For example, though Zero Net Carbon Buildings are not feasible at this time and more work needs to be done in this area, they will be necessary to achieve the 2050 target. To that end, work must begin now to review and evaluate research in this area, establish a planning horizon for targets, and identify implementation mechanisms. Concurrently, we must consider and implement policies that not only deliver critical reductions in 2030 and continue to help support the State's long-term climate objectives, but that also deliver other health, environmental and economic benefits. We should not just be planning to put 1.5 million ZEVs on the road by 2025 or 4.2 million on the road by 2030 – but rather, we should be comprehensively facilitating the market-wide transition to electric drive that we need to see materialize as soon as possible. This means that we need to be working towards making all fuels low carbon as quickly as possible, even as we incrementally ramp up volume requirements through the Low Carbon Fuel Standard. And it means that we need to support the broad array of actions and strategies identified in Chapter 4, and new ones that may emerge – to keep us on track to achieve deeper GHG reductions to protect the environment and our way of life. As with all investments, the approach taken must balance risk, reward, longevity, and timing.

Figure 5 illustrates the potential GHG reductions that are possible by making consistent progress between 2020 and 2050, versus an approach that begins with the 2030 target and then makes progress toward the 2050 level included in Executive Order S-3-05. Depending on our success in achieving the 2030 target, taking a consistent approach may be possible. It would achieve the 2050 target earlier, and together with similar actions globally, would have a greater chance of preventing global warming of 2°C. The strategy for achieving the 2050 target should leave open the possibility for both paths. Note that Figure 5 does not include emissions or sequestration potential from the natural and working lands sector or black carbon.

Figure 5: Plotting California's Path Forward



Intergovernmental Collaboration

Federal, state, Tribal, and local action can be complementary. We have seen federal action through the Clean Air Act, regulations for GHG emissions from passenger cars and trucks, development of the Clean Power Plan to limit GHGs from power plants, and the advancement of methane rules for oil and gas production. We have also seen recent federal efforts to delay or reverse some of these actions. As we have done in the past, California, working with other climate leaders, can take steps to advance more ambitious federal action and protect the ability of states to move forward to address climate change. Both collaboration and advocacy will mark the road ahead. However, to the extent that California cannot implement policies or measures included in the Scoping Plan because of the lack of federal action, we will develop alternative measures to achieve the reductions from the same sectors to ensure we meet our GHG reduction targets.

Regional, Tribal, and local governments and agencies are critical leaders in reducing emissions through actions that reduce demand for electricity, transportation fuels, and natural gas, and improved natural and working lands management. Many local governments already employ efforts to reduce GHG emissions beyond those required by the State. For example, many cities and counties improve their municipal operations by upgrading vehicle fleets, retrofitting government buildings and streetlights, purchasing greener products, and implementing waste-reduction policies. In addition, they may adopt more sustainable codes, standards, and general plan improvements to reduce their community's footprints and emissions. Many Tribes within and outside of California have engaged in consultations with CARB to develop robust carbon offset projects under California's Cap-and-Trade Program, in particular forest projects. In fact, Tribal forest projects represent a significant percentage of offset credits issued under the Program. These consultations and carbon sequestration projects are in addition to other Tribal climate-related efforts. The State will provide a supportive framework to advance these and other local efforts, while also recognizing the need to build on, and export, this success to other regional, Tribal, and local governments throughout California and beyond.

Local actions are critical for implementation of California's ambitious climate agenda. State policies, programs, and actions–such as many of those identified throughout this Scoping Plan–can help to support, incentivize, and accelerate local actions to achieve mutual goals for more sustainable and resilient communities. Local municipal code changes, zoning changes, or policy directions that apply broadly to the community within the general plan or climate action plan area can promote the deployment of renewable, zero emission, and low carbon technologies such as zero net energy buildings, renewable fuel production facilities, and zero emission charging stations. Local decision-making has an especially important role in achieving reductions of GHG emissions generated from transportation. Over the last 60 years, development patterns have led to sprawling suburban neighborhoods, a vast highway system, growth in automobile ownership, and under-prioritization of infrastructure for public transit and active transportation. Local decisions about these policies today can establish a more sustainable built environment for the future.

International Efforts

California is not alone in its efforts to address climate change at the international level to reduce global GHG emissions. The agreement reached in Paris by the 2015 Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC), aimed at keeping the global temperature rise below 2°C, is spurring worldwide action to reduce GHGs and support decarbonization across the global economy. In recent years, subnational governments have emerged to take on a prominent role. With the establishment of the Under 2 Memorandum of Understanding (MOU),[46,47] the Governors' Climate and Forests Task Force,[48] and the Western Climate Initiative,[49] among other partnership initiatives, subnational jurisdictions from the around the world are collaborating and leading on how best to address climate change.

46 Under 2 MOU website: *under2mou.org/*

47 One of the Brown Administration's priorities is to highlight California's climate leadership on the subnational level, and to ensure that subnational activity is recognized at the international level. In the year preceding the Paris negotiations, the Governor's Office recruited subnational jurisdictions to sign onto the Memorandum of Understanding on Subnational Global Climate Leadership (Under 2 MOU), which brings together states and regions willing to commit to reducing their GHG emissions by 80 to 95 percent, or to limit emissions to 2 metric tons CO_2-equivalent per capita, by 2050. The governor led a California delegation to the Paris negotiations to highlight our successful climate programs and to champion subnational action and international cooperation on meeting the challenge of reducing GHG emissions. As of October 2017, 188 jurisdictions representing more than 1.2 billion people and more than one-third of the global economy had joined California in the Under 2 MOU.

48 Governors' Climate and Forests Task Force website: *www.gcftaskforce.org/*

49 Western Climate Initiative website: *www.wci-inc.org/*

From its inception, AB 32 recognized the importance of California's climate leadership and engagement with other jurisdictions, and directed CARB to consult with the federal government and other nations to identify the most effective strategies and methods to reduce GHGs, manage GHG control programs, and facilitate the development of integrated and cost-effective regional, national, and international GHG reduction programs. California undertook a two-pronged approach: first, we assessed our State-specific circumstances to develop measures that would apply specifically in California; and second, we assessed which measures might lend themselves, through careful design and collaboration with other interested jurisdictions, toward linked or collaborative GHG reduction programs. Under the Clean Air Act, California has a special role as an innovator and leader in the area of motor vehicle emission regulations, which allows our State to adopt motor vehicle emission standards that are stricter than federal requirements. Partners around the country and the world emulate these motor vehicle standards, leading to widespread health benefits. Similarly, by enacting a comprehensive climate strategy that appeals to national and international partners, California can help lead the world in tackling climate change.

Today, the State's Cap-and-Trade Program is linked with Québec's program and scheduled to link with Ontario's emissions trading system on January 1, 2018. Low carbon fuel mandates similar to California's LCFS have been adopted by the United States Environmental Protection Agency (U.S. EPA) and by other jurisdictions including Oregon, British Columbia, the European Union, and the United Kingdom. Over two-dozen states have a renewables portfolio standard. California is a member of the Pacific Coast Collaborative with British Columbia, Oregon, and Washington, who collaborate on issues such as energy and sustainable resource management, among others.[50] California continues to discuss carbon pricing through a cap-and-trade program with international delegations. We have seen design features of the State's Cap-and-Trade Program incorporated into other emerging and existing programs, such as the European Union Emissions Trading System, the Regional Greenhouse Gas Initiative, China's emerging national trading program, and Mexico's emerging pilot emission trading program.

Recognizing the need to address the substantial GHG emissions caused by the deforestation and degradation of tropical and other forests, California worked with a group of subnational governments to form the Governors' Climate and Forests Task Force (GCF) in 2008.[51] The GCF is currently comprised of 38 different subnational jurisdictions– including states and provinces in Brazil, Colombia, Ecuador, Indonesia, Ivory Coast, Mexico, Nigeria, Peru, Spain, and the United States–that are contemplating or enacting programs for low-emissions rural development and reduced emissions from deforestation and land use. GCF members continue to engage in discussions to share information and experiences about the design of such programs and how the programs could potentially interact with carbon markets. Ongoing engagement between California and its GCF partners, as well as ongoing discussions with other stakeholders, continues to provide lessons on how such programs could complement California's climate programs.[52]

Further, California's High-Speed Rail is part of the International Union of Railways (UIC), and California has signed the Railway Climate Responsibility Pledge, which was commended by the Secretary of the UNFCCC as part of achieving the global 2050 targets. This initiative is to demonstrate that rail transport is part of the solution for sustainable and carbon free mobility.

California will continue to engage in multi-lateral forums that develop the policy foundation and technical infrastructure for GHG regulations in multiple jurisdictions through entities such as the International Carbon Action Partnership (ICAP), established by California and other partners in 2007. Members of the ICAP that have already implemented or are actively pursuing market-based GHG programs[53] share experiences and knowledge. California also participates in the Partnership for Market Readiness (PMR), a multilateral World Bank initiative that brings together more than 30 developed and developing countries to share experiences and build capacity for climate change mitigation efforts, particularly those implemented using market instruments.[54] In November 2014, CARB became a Technical Partner of the PMR, and CARB staff members have provided technical information on the design and implementation of the Cap-and-Trade Program at several PMR meetings.

50 Pacific Coast Collaborative website: *pacificcoastcollaborative.org/*
51 Governors' Climate and Forests Task Force Website: *www.gcftaskforce.org/*
52 Continued collaboration on efforts to reduce emissions from tropical deforestation and to evaluate sector-based offset programs, such as the jurisdictional program in Acre, Brazil, further demonstrates California's ongoing climate leadership and fosters partnerships on mutually beneficial low emissions development initiatives, including measures to encourage sustainable supply chain efforts by public and private entities.
53 International Carbon Action Partnership website: *icapcarbonaction.com/*
54 Partnership for Market Readiness website: *www.thepmr.org/*

Many foreign jurisdictions seek out California's expertise because of our history of success in addressing air pollution and climate change. California also benefits from these interactions. Expanding global action to fight air pollution and climate change expands markets for clean technology. This can bolster business for companies in California developing clean energy products and services and help to bring down the cost of those products globally and in California. Additionally, innovative policies and lessons learned from our partners' jurisdictions can help to inform future climate policies in California.

Governor Brown's focus on subnational collaborations on climate change and air quality has strengthened and deepened California's existing international relationships and forged new ones. These relationships are a critical component of reducing emissions of GHGs and other pollutants worldwide. As we move forward, CARB and other State agencies will continue to communicate and collaborate with international partners to find the most cost-effective ways to improve air quality, fight climate change, and share California's experience and expertise in reducing air pollution and GHGs while growing a strong economy. To highlight the State's resolve and support of other governments committed to action and tackling the threat of the global warming, on July 6, 2017, Governor Brown announced a major initiative to host world leaders at a Global Climate Action Summit planned for September 2018 in San Francisco.

Chapter 2

The Scoping Plan Scenario

This chapter describes the State strategy for meeting the 2030 GHG target (also called the Scoping Plan Scenario), along with a short description of the four alternative scenarios, which were evaluated but ultimately rejected when compared against statutory and policy criteria and priorities that the State's comprehensive climate action must deliver. All scenarios are set against the business-as-usual (BAU or Reference Scenario) scenario–what would GHG emissions look like if we did nothing beyond the existing policies that are required and already in place to achieve the 2020 limit. BAU includes the existing renewables requirements, advanced clean cars, the 10 percent reduction in carbon intensity Low Carbon Fuel Standard, and the SB 375 program for sustainable communities, among others. However, it does not include a range of new policies or measures that have been developed or put into statute over the past two years.

The Reference Scenario (BAU) shows continuing, but modest, reductions followed by a later rise of GHG emissions as the economy and population grow. The comprehensive analysis of all five alternatives indicates that the Scoping Plan Scenario–continuing the Cap-and-Trade Program–is the best choice to achieve the State's climate and clean air goals. It also protects public health, provides a solid foundation for continued economic growth, and supports California's quality of life.

All of the alternative scenarios briefly described in this chapter are the product of the Scoping Plan development process and were informed by public input, including that from EJAC, as well as Board and legislative direction over the course of two years. The scenarios all include a range of additional measures developed or required by legislation over the past two years with 2030 as their target date and include: extending the LCFS to an 18 percent reduction in carbon intensity beyond 2020, and the requirements of SB 350 to increase renewables to 50 percent and to double energy efficiency savings. They also all include the Mobile Source Strategy targets for more zero emission vehicles and much cleaner trucks and transit, the Sustainable Freight Action Plan to improve freight efficiency and transition to zero emission freight handling technologies, and the requirements under SB 1383 to reduce anthropogenic black carbon 50 percent and hydrofluorocarbon and methane emissions by 40 percent below 2013 levels by 2030. The recent adoption of AB 398 into State law on July 25, 2017, clarifies the role of the Cap-and-Trade Program through December 31, 2030.

Work is still underway on how to quantify the GHG emissions within the natural and working lands sector. As such, the analyses in this chapter do not include any estimates from this sector. Additional information on the current efforts to better understand GHG emissions fluxes and model the actions needed to support the goal of net carbon sequestration in natural and working lands can be found in Chapter 4. Even absent quantification data, the importance of this sector in achieving the State's climate goals should be considered in conjunction with any efforts to reduce GHG emissions in the energy and industrial sectors.

During the development of the Scoping Plan, stakeholders suggested alternative scenarios to achieve the 2030 target. While countless scenarios could potentially be developed and evaluated, the four below were considered, as they were most often included in comments by stakeholders and they bracket the range of potential scenarios. Several of these alternative scenarios were also evaluated in the Initial AB 32 Scoping Plan in 2008 (All Regulations, Carbon Tax).[55] Since the adoption of the Initial AB 32 Scoping Plan, some of the alternative scenarios have been implemented or contemplated by other jurisdictions, which has helped in the analysis and the development of this Scoping Plan. This section provides a brief description of the alternatives. A full description of the alternatives and staff's AB 197 and policy analyses are included in Appendix G.

55 CARB. 2009. Initial AB 32 Climate Change Scoping Plan Document. *www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm*

Scoping Plan Scenario: Ongoing and statutorily required programs and continuing the Cap-and-Trade Program. This scenario was modified from the January 2017 Proposed Scoping Plan to reflect AB 398, including removal of the 20 percent refinery measure.

Alternative 1: No Cap-and-Trade. Includes additional activities in a wide variety of sectors, such as specific required reductions for all large GHG sources, and more extensive requirements for renewable energy. Industrial sources would be regulated through command and control strategies.

Alternative 2: Carbon Tax. A carbon tax to put a price, but not limit, on carbon, instead of the Cap-and-Trade Program.

Alternative 3: All Cap-and-Trade. This alternative is the same as the Scoping Plan Scenario, while maintaining the LCFS at a 10 percent reduction in carbon intensity past 2020.

Alternative 4: Cap-and-Tax. This would place a declining cap on individual industrial facilities, and individual natural gas and fuel suppliers, while also requiring them to pay a tax on each metric ton of GHGs emitted.

Since the statutory direction on meeting a 2030 GHG target is clear, the issue of certainty of reductions is paramount. These alternatives vary greatly as to the certainty of meeting the target. The declining mass emissions cap under a cap-and-trade program provides certain and measurable reductions over time; a carbon tax, meanwhile, establishes some carbon price certainty, but does not provide an assurance on reductions and instead assumes that some degree of reductions will occur if costs are high enough to alter behavior.

There are also other considerations: to what extent does an alternative meet the target, but also deliver clean air benefits, prioritize reductions at large stationary sources, and allow for continued investment in disadvantaged communities? What is the cost of an alternative and what will be the impact on California consumers? Does an alternative allow for California to link with other jurisdictions, and support the Clean Power Plan[56] and other federal and international climate programs? Does an alternative provide for flexibility for regulated entities, and a cost-effective approach to reduce greenhouse gases?

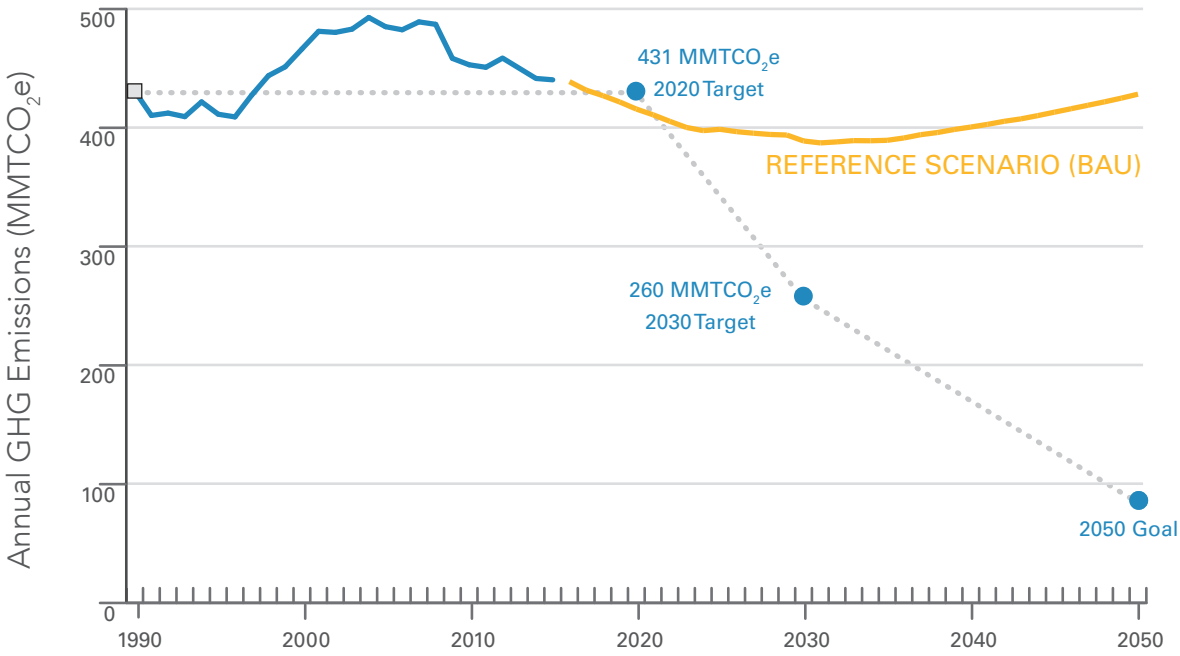
The Scoping Plan Scenario provides a portfolio of policies and measures that balances this combination of objectives, including the highest certainty to achieve the 2030 target, while protecting the California economy and consumers. A more detailed analyses of the alternatives is provided in Appendix G.

Scoping Plan Scenario

The development of the Scoping Plan began by first modeling a Reference Scenario (BAU). The Reference Scenario is the forecasted statewide GHG emissions through 2030 with existing policies and programs, but without any further action to reduce GHGs. Figure 6 provides the modeling results for a Reference Scenario for this Scoping Plan. The graph shows the State is expected to reduce emissions below the 2020 statewide GHG target, but additional effort will be needed to maintain and continue GHG reductions to meet the mid- (2030) and long-term (2050) targets. Figure 6 depicts a linear, straight-line path to the 2030 target. It should be noted that in any year, GHG emissions may be higher or lower than the straight line. That is to be expected as periods of economic recession or increased economic activity, annual variations in hydropower, and many other factors may influence a single or several years of GHG emissions in the State. CARB's annual GHG reporting and inventory will provide data on progress towards achieving the 2030 target. More details about the modeling for the Reference Scenario can be found in Appendix D.

56 Although the Clean Power Plan is being challenged in legal and administrative processes, its requirements reflect U.S. EPA's statutory obligation to regulate greenhouse gases from the power sector. Thus it, and other federal programs, are a key consideration for Scoping Plan development.

Figure 6: 2017 Scoping Plan Reference Scenario



The Scoping Plan Scenario is summarized in Table 1. As shown in the table, most of the measures are identified as "known commitments" (marked with "*"), meaning that they are existing programs or required by statute. These commitments are not part of the Reference Scenario (BAU) in Figure 6 since their passage and implementation is related to meeting the Governor's climate pillars, the 2030 climate target, or other long-term climate and air quality objectives. In addition to the known commitments, the Scoping Plan Scenario includes a post-2020 Cap-and-Trade Program.

Table 1: Scoping Plan Scenario

Policy	Primary Objective	Highlights	Implementation Time Frame
SB 350[57]*	Reduce GHG emissions in the electricity sector through the implementation of the 50 percent RPS, doubling of energy savings, and other actions as appropriate to achieve GHG emissions reductions planning targets in the Integrated Resource Plan (IRP) process.	• Load-serving entities file plans to achieve GHG emissions reductions planning targets while ensuring reliability and meeting the State's other policy goals cost-effectively. • 50 percent RPS. • Doubling of energy efficiency savings in natural gas and electricity end uses statewide.	2030
Low Carbon Fuel Standard (LCFS)*	Transition to cleaner/less-polluting fuels that have a lower carbon footprint.	• At least 18 percent reduction in carbon intensity, as included in the Mobile Source Strategy.	2030
Mobile Source Strategy (Cleaner Technology and Fuels [CTF] Scenario)[58]*	Reduce GHGs and other pollutants from the transportation sector through transition to zero-emission and low-emission vehicles, cleaner transit systems and reduction of vehicle miles traveled.	• 1.5 million zero emission vehicles (ZEV), including plug-in hybrid electric, battery-electric, and hydrogen fuel cell vehicles by 2025 and 4.2 million ZEVs by 2030. • Continue ramp up of GHG stringency for all light-duty vehicles beyond 2025. • Reductions in GHGs from medium-duty and heavy-duty vehicles via the Phase 2 Medium and Heavy-Duty GHG Standards. • Innovative Clean Transit: Transition to a suite of innovative clean transit options. Assumed 20 percent of new urban buses purchased beginning in 2018 will be zero emission buses with the penetration of zero-emission technology ramped up to 100 percent of new bus sales in 2030. Also, new natural gas buses, starting in 2018, and diesel buses, starting in 2020, meet the optional heavy-duty low-NO_X standard. • Last Mile Delivery: New regulation that would result in the use of low NO_X or cleaner engines and the deployment of increasing numbers of zero-emission trucks primarily for class 3-7 last mile delivery trucks in California. This measure assumes ZEVs comprise 2.5 percent of new Class 3–7 truck sales in local fleets starting in 2020, increasing to 10 percent in 2025. • Reduction in vehicle miles traveled (VMT), to be achieved in part by continued implementation of SB 375 and regional Sustainable Community Strategies; forthcoming statewide implementation of SB 743; and potential additional VMT reduction strategies not specified in the Mobile Source Strategy, but included in the document "Potential VMT Reduction Strategies for Discussion" in Appendix C.[59]	Various
SB 1383*	Approve and Implement Short-Lived Climate Pollutant strategy[60] to reduce highly potent GHGs	• 40 percent reduction in methane and hydrofluorocarbon (HFC) emissions below 2013 levels by 2030. • 50 percent reduction in anthropogenic black carbon emissions below 2013 levels by 2030.	2030
California Sustainable Freight Action Plan[61]*	Improve freight efficiency, transition to zero emission technologies, and increase competitiveness of California's freight system.	• Improve freight system efficiency by 25 percent by 2030. • Deploy over 100,000 freight vehicles and equipment capable of zero emission operation and maximize both zero and near-zero emission freight vehicles and equipment powered by renewable energy by 2030.	2030
Post-2020 Cap-and-Trade Program	Reduce GHGs across largest GHG emissions sources	• Continue the existing Cap-and-Trade Program with declining caps to ensure the State's 2030 target is achieved.	

* These measures and policies are referred to as "known commitments."

57 SB 350 Clean Energy and Pollution Reduction Act of 2015 (De León, Chapter 547, Statutes of 2015). *leginfo.legislature.ca.gov/faces/billNavClient.xhtml?billid=201520160SB350* This policy also includes increased demand response and PV.
58 CARB. 2016. 2016 Mobile Source Strategy. *www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf*
59 CARB. Potential State-Level Strategies to Advance Sustainable, Equitable Communities and Reduce Vehicle Miles of Travel (VMT)--for Discussion. *www.arb.ca.gov/cc/scopingplan/meetings/091316/Potential%20VMT%20Measures%20For%20Discussion_9.13.16.pdf*
60 CARB. 2016. Reducing Short-Lived Climate Pollutants in California. *www.arb.ca.gov/cc/shortlived/shortlived.htm*
61 State of California. California Sustainable Freight Action Plan website. *www.casustainablefreight.org/*

Table 2 summarizes the results of the modeling for the Reference Scenario and known commitments. Per SB 32, the 2030 limit is 260 $MMTCO_2e$. That is a limit on total GHG emissions in a single year. At approximately 389 $MMTCO_2e$, the Reference Scenario is expected to exceed the 2030 limit by about 129 $MMTCO_2e$.

Table 2 also compares the Reference Scenario 2030 emissions estimate of 389 $MMTCO_2e$ to the 2030 target of 260 $MMTCO_2e$ and the level of 2030 emissions with the known commitments, estimated to be 320 $MMTCO_2e$. And, in the context of a linear path to achieve the 2030 target, there is also a need to achieve cumulative emissions reductions of 621 $MMTCO_2e$ from 2021 to 2030 to reach the 2030 limit. While there is no statutory limit on cumulative emissions, the analysis considers and presents some results in cumulative form for several reasons. It should be recognized that policies and measures may perform differently over time. For example, in early years, a policy or measure may be slow to be deployed, but over time it has greater impact. If you were to look at its performance in 2021 versus 2030, you would see that it may not seem important and may not deliver significant reductions in the early years, but is critical for later years as it results in greater reductions over time. Further, once GHGs are emitted into the atmosphere, they can have long lifetimes that contribute to global warming for decades. Policies that reduce both cumulative GHG emissions and achieve the single-year 2030 target provide the most effective path to reducing climate change impacts. A cumulative construct provides a more complete way to evaluate the effectiveness of any measure over time, instead of just considering a snapshot for a single year.

Table 2: 2030 Modeling GHG Results for the Reference Scenario and Known Commitments

Modeling Scenario	2030 GHG Emissions ($MMTCO_2e$)	Cumulative GHG Reductions 2021–2030 ($MMTCO_2e$)	Cumulative Gap to 2030 Target ($MMTCO_2e$)
Reference Scenario (Business-as-Usual)	389	n/a	621
Known Commitments	320	385	236

As noted above, the known commitments are expected to result in emissions that are 60 $MMTCO_2e$ above the target in 2030, and have a cumulative emissions reduction gap of about 236 $MMTCO_2e$. This means the known commitments do not decline fast enough to achieve the 2030 target. The remaining 236 $MMTCO_2e$ of estimated GHG emissions reductions would not be achieved unless further action is taken to reduce GHGs. Consequently, for the Scoping Plan Scenario, the Post-2020 Cap-and-Trade Program would need to deliver 236 $MMTCO_2e$ cumulative GHG emissions reductions from 2021 through 2030. If the estimated GHG reductions from the known commitments are not realized due to delays in implementation or technology deployment, the post-2020 Cap-and-Trade Program would deliver the additional GHG reductions in the sectors it covers to ensure the 2030 target is achieved. Figure 7 illustrates the cumulative emissions reductions contributions of the known commitments and the Cap-and-Trade Program from 2021 to 2030.

Post-2020 Cap-and-Trade Program with Declining Caps

This measure would continue the Cap-and-Trade Program post-2020 pursuant to legislative direction in AB 398. The program is up and running and has a five-year-long record of auctions and successful compliance. In the face of a growing economy, dry winters, and the closing of a nuclear plant, it is delivering GHG reductions. This is not to say that California should continue on this road simply because the Cap-and-Trade Program is already in place. The analyses in this chapter, and the economic analysis in Chapter 3, clearly demonstrate that continuing the Cap-and-Trade Program through 2030 will provide the most secure, reliable, and feasible clean energy future for California–one that will continue to deliver crucial investments to improve the quality of life and the environment in disadvantaged communities.

Under this measure, funds would also continue to be deposited into the Greenhouse Gas Reduction Fund (GGRF) to support projects that fulfill the goals of AB 32, with AB 398 identifying a list of priorities for the Legislature to consider for future appropriations from GGRF. Investment of the Cap-and-Trade Program proceeds furthers the goals of AB 32 by reducing GHG emissions, providing net GHG sequestration, providing co-benefits, investing in disadvantaged communities and low-income communities, and supporting the long-term, transformative efforts needed to improve public and environmental health and

develop a clean energy economy. These investments support programs and projects that deliver major economic, environmental, and public health benefits for Californians. Importantly, prioritized investments in disadvantaged communities are providing a multitude of meaningful benefits to these communities some of which include increased affordable housing opportunities, reduced transit and transportation costs, access to cleaner vehicles, improved mobility options and air quality, job creation, energy cost savings, and greener and more vibrant communities.

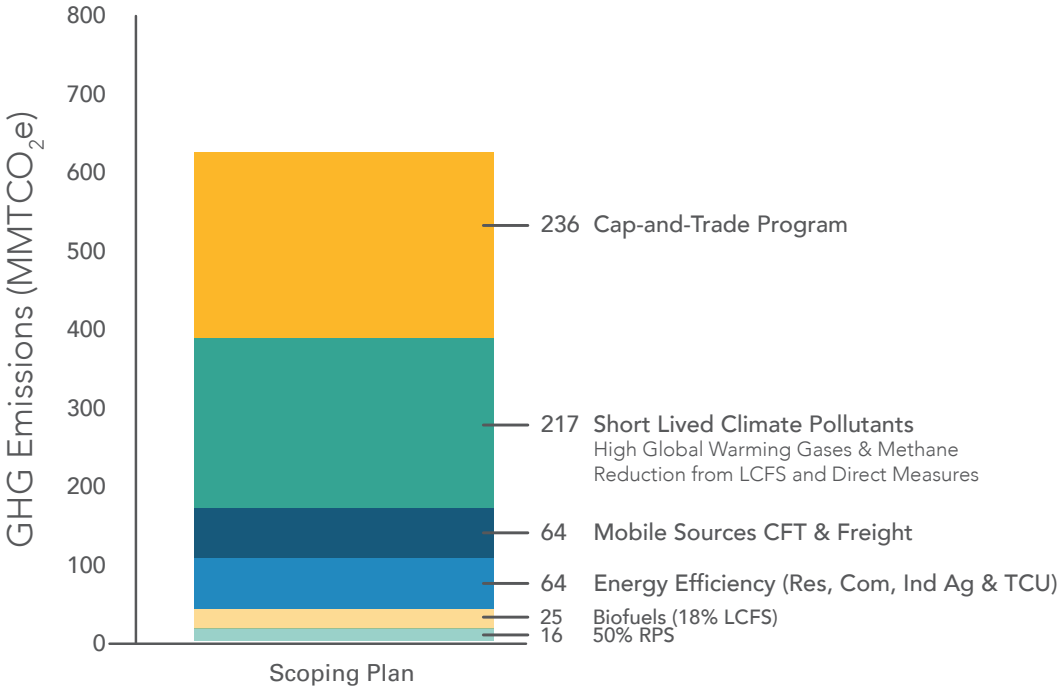
Further, the Cap-and-Trade Program is designed to protect electricity and natural gas residential ratepayers from higher energy prices. The program includes a mechanism for electricity and natural gas utilities to auction their freely allocated allowances, with the auction proceeds benefiting ratepayers. The Climate Credit is a twice-annual bill credit given to investor-owned utility electricity residential customers. The total value of the Climate Credit for vintage 2013 auction allowances alone was over $400 million. The first of these credits appeared on customer bills in April 2014.[62] Currently, natural gas utilities are permitted to use a portion of their freely allocated allowances to meet their own compliance obligations; however, over time, they must consign a larger percentage of allowances and continue to provide the value back to customers.

Additionally, under this measure, the State would preserve its current linkages with its Canadian partners and support future linkages with other jurisdictions, thus facilitating international action to address climate change. The high compliance rates with the Cap-and-Trade Program also demonstrate that the infrastructure and implementation features of the program are effective and understood by the regulated community. This measure also lends itself to integration with the Clean Power Plan requirements and is flexible to allow expansion to other sectors or regions.

In late 2017, CARB began evaluating changes to program design features for post-2020 in accordance with AB 398.[63] This includes changes to the offset usage limit, direction on allocation, two price containment points, and a price ceiling – which, if in the unlikely event were to be accessed, must result in GHG reductions by compensating for any GHG emissions above the cap, ensuring the environmental integrity of the program. Changes to conform to the requirements of AB 398 will be subject to a public process, coordinated with linked partners, and be part of a future rulemaking that would take effect by January 1, 2021.

62 *www.arb.ca.gov/cc/capandtrade/allowanceallocation/edu-v2013-allowance-value-report.pdf*
63 *www.arb.ca.gov/cc/capandtrade/meetings/20171012/ct_presentation_11oct2017.pdf*

Figure 7: Scoping Plan Scenario – Estimated Cumulative GHG Reductions by Measure (2021–2030)[64]



The Scoping Plan Scenario in Figure 7 represents an expected case where current and proposed GHG reduction policies and measures begin as expected and perform as expected, and technology is readily available and deployed on schedule. An Uncertainty Analysis was performed to examine the range of outcomes that could occur under the Scoping Plan policies and measures. The uncertainty in the following factors was characterized and evaluated:

- Economic growth through 2030;
- Emission intensity of the California economy;
- Cumulative emissions reductions (2021 to 2030) achieved by the prescriptive measures, including the known commitments; and
- Cumulative emissions reductions (2021 to 2030) that can be motivated by emission prices under the Cap-and-Trade Program.

The combined effects of these uncertainties are summarized in Figure 8. As shown in Figure 7, the Scoping Plan analysis estimates that the prescriptive measures will achieve cumulative emissions reductions of 385 $MMTCO_2e$, the Cap-and-Trade Program will achieve 236 $MMTCO_2e$, resulting in total cumulative emissions reductions of 621 $MMTCO_2e$. These values are again reflected in the bar on the left of Figure 8. The results of the Uncertainty Analysis are summarized in the three bars on the right of the figure as follows:

- The cumulative emissions reductions required to achieve the 2030 emission limit has the potential to be higher or lower than the Scoping Plan estimate. The uncertainty analysis simulates an average required emissions reductions of about 660 $MMTCO_2e$ with a range of +130 $MMTCO_2e$.[65] This estimate and the range are shown in Figure 8 as the bar on the right. Notably, the estimate of the average required emissions reductions is 40 $MMTCO_2e$ greater than the estimate in the Scoping Plan analysis.
- The prescriptive measures have the potential to underperform relative to expectations. Based on CARB staff assessments of the potential risk of underperformance of each measure, the average emissions reductions simulated to be achieved was 335 $MMTCO_2e$, or about 13 percent below the Scoping Plan estimate. The range for the performance of the measures was about +50 $MMTCO_2e$.

64 The whole number values displayed in Figure 7 do not mathematically sum to 621 $MMTCO_2e$, consistent with the modeling results summary in Table 2. This is a result of embedded significant figures and rounding for graphic display purposes. Please refer to the corresponding PATHWAYS modeling data spreadsheets for details.

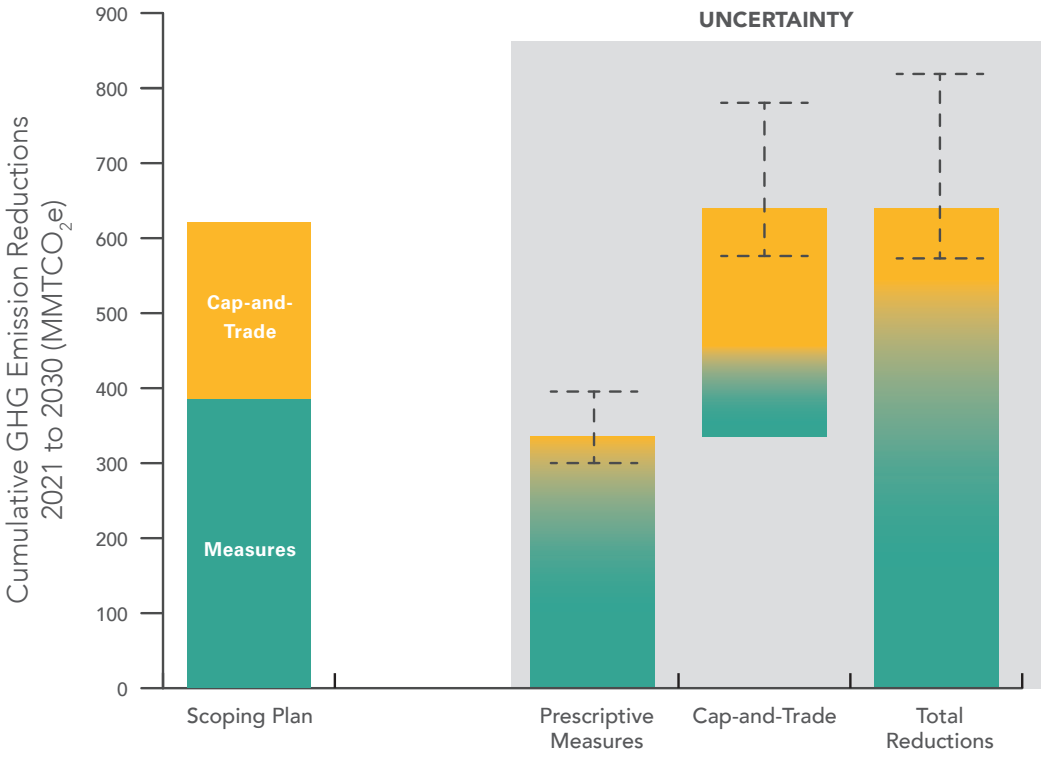
65 The ranges presented are the 5th and 95th percentile observations in the Uncertainty Analysis. See Appendix E for details.

These values for the potential reductions achieved by the measures are shown in the figure.

- The Cap-and-Trade program is designed to fill the gap in the required emissions reductions over and above what is achieved by the prescriptive measures. Because the total required emissions reductions are uncertain, and the emissions reductions achieved by the prescriptive measures are uncertain, the required emissions reductions from the Cap-and-Trade Program are also uncertain. The Uncertainty Analysis simulated the average emissions reductions achieved by the Cap-and-Trade Program at about 305 $MMTCO_2e$, or about 30 percent higher than the Scoping Plan estimate. The range was simulated to be about +120 $MMTCO_2e$. These values for the potential reductions achieved by the Cap-and-Trade Program are shown in the figure.

The Uncertainty Analysis provides insight into the range of potential emissions outcomes that may occur, and demonstrates that the Scoping Plan, with the Cap-and-Trade Program, is extremely effective in the face of uncertainty, assuring that the required emissions reductions are achieved (see Appendix E for more detail). The Uncertainty Analysis also indicates that the Cap-and-Trade Program could contribute a larger or smaller share of the total required cumulative emissions reductions than expected in the Scoping Plan analysis.

Figure 8: Uncertainty Analysis



While the modeling results provide estimates of the GHG reductions that could be achieved by the measures, the results also provide other insights and highlight the need to ensure successful implementation of each measure. The SLCP Strategy will provide significant reductions with a focus on methane and hydrofluorocarbon gases. To ensure the SLCP Strategy implementation is successful, it will be critical to ensure programs such as LCFS maintain incentives to finance the capture and use of methane as a transportation fuel–further reducing the State's dependence on fossil fuels. The modeling also shows that actions on energy efficiency could provide the same magnitude of GHG emissions reductions as the mobile source measures, but each effort will provide different magnitudes of air quality improvements and cost-effectiveness as discussed in Chapter 3.

Another way to look at this scenario is to understand the trajectory of GHG reductions over time, relative to the 2030 target. Figure 9 provides the trajectory of GHG emissions modeled for the Scoping Plan Scenario. Again, this depicts a straight-line path to the 2030 target for discussion purposes, but in reality GHG emissions may be above or below the line in any given year(s).

Figure 9: Scoping Plan Scenario GHG Reductions

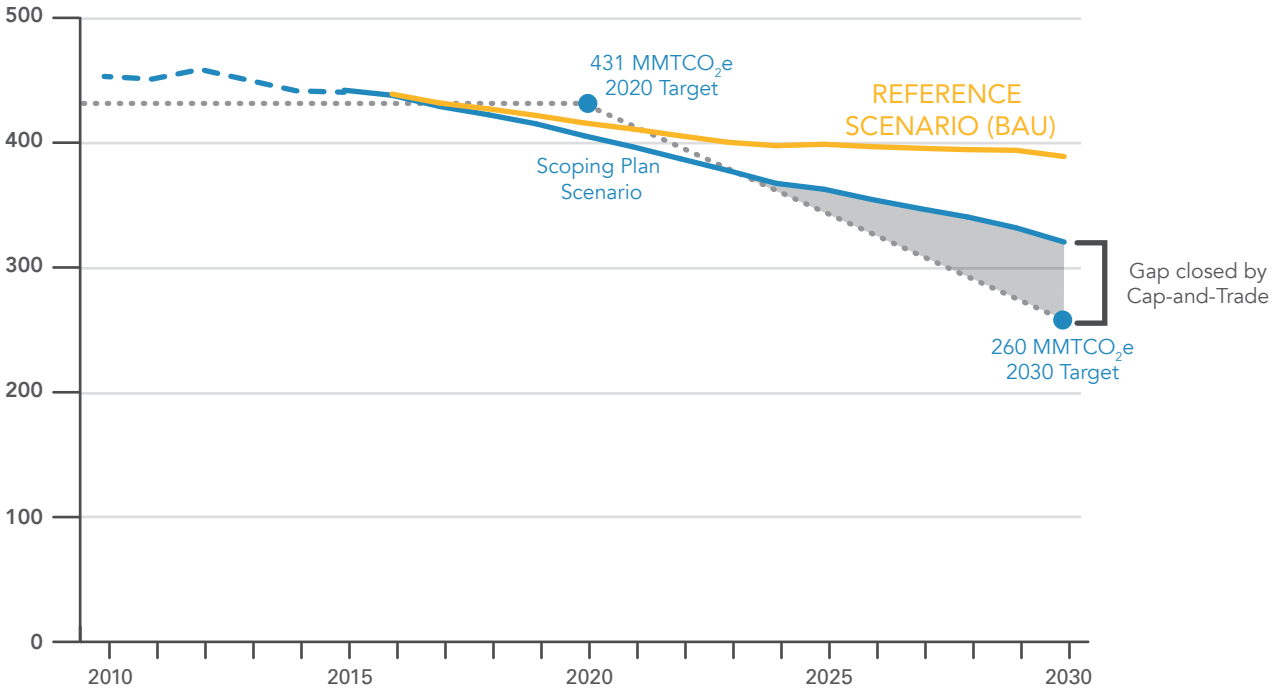


Figure 9 shows the Reference Scenario (yellow) and the version of the Scoping Plan Scenario that excludes the Cap-and-Trade Program (blue). Until 2023, the measures in the Scoping Plan Scenario constrain GHG emissions below the dotted straight line. After 2023, GHG emissions continue to fall, but at a slower rate than needed to meet the 2030 target. It is the Cap-and-Trade Program that will reduce emissions to the necessary levels to achieve the 2030 target. In this scenario, it is estimated that the known commitments will result in an emissions level of about 320 $MMTCO_2e$ in 2030. Thus, for the Scoping Plan Scenario, the Cap-and-Trade Program would deliver about 60 $MMTCO_2e$ in 2030 and ensure the 2030 target is achieved.

To understand how the Scoping Plan affects the main economic sectors, Table 3 provides estimated GHG emissions by sector, compared to 1990 levels, and the range of GHG emissions for each sector estimated for 2030. This comparison helps to illustrate which sectors are reducing emissions more than others and where to focus additional actions to reduce GHGs across the entire economy.

Table 3: Estimated Change in GHG Emissions by Sector ($MMTCO_2E$)

	1990	2030 Scoping Plan Ranges[66]	% change from 1990
Agriculture	26	24–25	-8 to -4
Residential and Commercial	44	38–40	-14 to -9
Electric Power	108	30–53[67]	-72 to -51
High GWP	3	8–11[68]	267 to 367
Industrial	98	83–90[69]	-15 to -8
Recycling and Waste	7	8–9[70]	14 to 29**
Transportation (Including TCU)	152	103–111	-32 to -27
Natural Working Lands Net Sink*	-7***	TBD	TBD
Sub Total	431	294–339	-32 to -21
Cap-and-Trade Program	n/a	34–79	n/a
Total	**431**	**260**	**-40**

* Work is underway through 2017 to estimate the range of potential sequestration benefits from the natural and working lands sector.
** The SLCP will reduce emissions in this sector by 40 percent from 2013 levels. However, the 2030 levels are still higher than the 1990 levels as emissions in this sector have grown between 1990 and 2013.
*** This number reflects net results and is different than the intervention targets discussed in Chapter 4.

The sector ranges may change in response to how the sectors respond to the Cap-and-Trade Program. While the known commitments will deliver some reductions in each sector, the Cap-and-Trade Program will deliver additional reductions in the sectors it covers. Annual GHG reporting and the GHG inventory will track annual changes in emissions, and those will provide ongoing assessments of how each sector is reducing emissions due to the full complement of known commitments and the Cap-and-Trade Program, as applicable.

Scenario Modeling

There are a variety of models that can be used to model GHG emissions. For this Plan, the State is using the PATHWAYS model.[70] PATHWAYS is structured to model GHG emissions while recognizing the integrated nature of the industrial economic and energy sectors. For example, if the transportation sector adds more electric vehicles, PATHWAYS responds to reflect an energy demand increase in the electricity sector. However, PATHWAYS does not reflect any change in transportation infrastructure and land use demand associated with additional ZEVs on the road. The ability to capture a subset of interactive effects of policies and measures helps to provide a representation of the interconnected nature of the system and impacts to GHGs.

66 Unless otherwise noted, the low end of the sector range is the estimated emissions from the Scoping Plan Scenario and the high end adjusts the expected emissions by a risk factor that represents sector underperformance.
67 The high end of the electric power sector range is represented by the Scoping Plan Scenario, and the low end by enhancements and additional electricity sector measures such as deployment of additional renewable power, greater behind-the-meter solar PV, and additional energy efficiency. The electric power sector range provided in Table 3 will be used to help inform CARB's setting of the SB 350 Integrated Resource Plan greenhouse gas emissions reduction planning targets for the sector. CARB, CPUC, and CEC will continue to coordinate on this effort before final IRP targets are established for the sector, load-serving entities, and publicly-owned utilities. State agencies will investigate the potential for and appropriateness of deeper electric sector reductions in light of the overall needs of the Scoping Plan to cost-effectively achieve the statewide GHG goals. Concurrently, CEC and CPUC are proceeding with their respective IRP processes using this range.
68 The sector emissions are anticipated to increase by 2030. As such, the high end of the sector range is the estimated emissions from the Scoping Plan Scenario and the low end adjusts the expected emissions by a risk factor that represents sector over performance.
69 This estimate does not account for the reductions expected in this sector from the Cap-and-Trade Program. The Cap-and-Trade line item includes reductions that will occur in the industrial sector.
70 CARB. 2016. AB 32 Scoping Plan Public Workshops. *www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm*

At this time, PATHWAYS does not include a module for natural and working lands. As such, PATHWAYS cannot be used to model the natural and working lands sector, the interactive effects of polices aimed at the economic and energy sectors and their effect on land use or conditions, or the interactive effects of polices aimed at the natural environment and their impact on the economic and energy sectors. For this Plan, external inputs had to be developed for PATHWAYS to supply biofuel volumes. The natural and working lands sector is also being modeled separately as described in Chapter 4. Moving forward, CARB and other State agencies will work to integrate all the sectors into one model to fully capture interactive effects across both the natural and built environments.

Lastly, the PATHWAYS assumptions and results in this Plan show the significant action that the State must take to reach its GHG reduction goals. It is important to note that the modeling assumptions may differ from other models used by other State agencies. Modeling exercises undertaken in future regulatory proceedings may result in different measures, programs, and program results than those used in the modeling for this Scoping Plan. State agencies will engage on their specific policies and measure development processes separately from CARB Scoping Plan activities, in public forums to engage all stakeholders.

Uncertainty

Several types of uncertainty are important to understand in both forecasting future emissions and estimating the benefits of emissions reductions scenarios. In developing the Scoping Plan, we have forecast a Reference Scenario and estimated the GHG emissions outcome of the Scoping Plan using PATHWAYS. Inherent in the Reference Scenario modeling is the expectation that many of the existing programs will continue in their current form, and the expected drivers for GHG emissions such as energy demand, population growth, and economic growth will match our current projections. However, it is unlikely that the future will precisely match our projections, leading to uncertainty in the forecast. Thus, the single "reference" line should be understood to represent one possible future in a range of possible predictions. For the Scoping Plan Scenario, PATHWAYS utilized inputs that are assumptions external to the model. PATHWAYS was provided plausible inputs such as energy demand over time, the start years for specific policies, and the penetration rates of associated technologies. Each of the assumptions provided to PATHWAYS has some uncertainty, which is also reflected in the results. Thus, while the results presented in the Scoping Plan may seem precise due to the need for precision in model inputs, these results are estimates, and the use of ranges in some of the results is meant to capture that uncertainty.

Further, as noted in the November 7, 2016, 2030 Target Scoping Plan Workshop, "All policies have a degree of uncertainty associated with them."[71] As this Scoping Plan is meant to chart a path to achieving the 2030 target, additional work will be required to fully design and implement any policies identified in this Scoping Plan. During the subsequent development of policies, CARB and other State agencies will learn more about technologies, cost, and how each industry works as a more comprehensive evaluation is conducted in coordination with stakeholders. Given the uncertainty around assumptions used in modeling, and in performance once specific policies are fully designed and implemented, estimates associated with the Scoping Plan Scenario are likely to differ from what actually occurs when the Scoping Plan is implemented. One way to mitigate for this risk is to develop policies that can adapt and increase certainty in GHG emissions reductions. Periodic reviews of progress toward achieving the 2030 target and the performance of specific policies will also provide opportunities for the State to consider any changes to ensure we remain on course to achieve the 2030 target. The need for this periodic review process was anticipated in AB 32, as it calls for updates to the Scoping Plan at least once every five years. Additional information on the uncertainty analyses conducted in the development of this Scoping Plan is located in Appendix E.

71 Bushnell, James. Economic Modeling and Environmental Policy Choice. PowerPoint. Department of Economics, University of California, Davis. *www.arb.ca.gov/cc/scopingplan/meetings/110716/bushnellpresentation.pdf*

Policy Analysis of Scoping Plan Scenario

The following key criteria were considered while evaluating potential policies beyond the known commitments. The results of the economic analysis (presented in Chapter 3) were also important in the design of this Scoping Plan.

- **Ensure the State achieves the 2030 target.** The strategy must ensure that GHG emissions reductions occur and are sufficient to achieve the 2030 target.
- **Provide air quality co-benefits.** An important concern for environmental justice communities is for any Scoping Plan to provide air quality co-benefits.
- **Prioritize rules and regulations for direct GHG reductions.** AB 197 requires CARB in developing this Scoping Plan to prioritize emissions reductions rules and regulations that result in direct emissions reductions at large stationary sources of GHG emissions sources and direct emissions reductions from mobile sources.
- **Provide protection against emissions leakage.** Require any policies to achieve the statewide limits to minimize emissions leakage to the extent possible. Emissions leakage can occur when production moves out-of-state, so there appears to be a reduction in California's emissions, but the production and emissions have just moved elsewhere. This loss in production may be associated with loss in jobs and decreases in the State's gross domestic product (GDP) and could potentially increase global GHG emissions if the production moves to a less efficient facility outside of California.
- **Develop greenhouse gas reduction programs that can be readily exported to other jurisdictions.** Currently, California's Cap-and-Trade Program is linked with Québec's program and is scheduled to link with Ontario's cap-and-trade program beginning in 2018. At the same time, California's ambitious policies such as the RPS, LCFS, and Advanced Clean Cars have resulted in other regions adopting similar programs.
- **Minimize costs and increase investment in disadvantaged and low-income communities, and low-income households.** Currently, Cap-and-Trade auction proceeds from the sale of State-owned allowances are appropriated for a variety of programs to reduce GHGs, and provide other environmental, health and economic benefits including job creation and economic development. Under AB 1550, a minimum of 25 percent of the proceeds are to be invested in projects located in and benefiting disadvantaged communities, with an additional minimum 10 percent to projects in low-income communities, and low-income households. It is important to understand if the strategy will require or result in funding to support these GHG reductions and associated benefits.
- **Avoid or minimize the impacts of climate change on public health by continuing reductions in GHGs.** Climate change has the potential to significantly impact public health, including increases in heat illness and death, air pollution-related exacerbation of cardiovascular and respiratory diseases, injury and loss of life due to severe storms and flooding, increased vector-borne and water-borne diseases, and stress and mental trauma due to extreme weather-related catastrophes.
- **Provide compliance flexibility.** Flexibility is important as it allows each regulated entity the ability to pursue its own path toward compliance in a way that works best for its business model. Flexibility also acknowledges that regulatory agencies may not have a complete picture of all available low-cost compliance mechanisms or opportunities even across the same sector. In addition, under AB 32 and AB 197, the strategy to reduce GHGs requires consideration of cost-effectiveness, which compliance flexibility provides.
- **Support the Clean Power Plan and other federal climate programs.** California will continue to support aggressive federal action, as well as to defend existing programs like the Clean Power Plan, which is the most prominent federal climate regulation applicable to stationary sources. The U.S. Supreme Court has repeatedly confirmed that federal greenhouse gas regulation must move forward under the federal Clean Air Act, so it is important to ensure that California's programs can support federal compliance as well. Although continuing litigation has stayed certain Clean Power Plan deadlines in the near term, and U.S. EPA has proposed to reconsider aspects of the rule as issued, the Clean Power Plan remains the law of the land. California is vigorously defending this important program, and is continuing to support federal climate regulation as is required by law. U.S EPA also has a legal obligation to implement GHG controls for power plants, even if it proposes to alter the form of those controls in the future. Therefore, the Clean Power Plan and other federal efforts are important considerations for this Scoping Plan. With regard to the

Clean Power Plan, California power plants are expected to be within their limits as set forth by the State's compliance plan, which was approved by CARB on July 27, 2017. However, the State still needs a mechanism to ensure the emissions for the covered electricity generating plants do not exceed the federal limits. This mechanism must be federally enforceable with regard to the affected power plants, and limit their emissions in accordance with the federal limit.

Table 4 uses the criteria listed above to assess the Scoping Plan Scenario. This assessment is based on CARB staff evaluation as well as the analyses described in Chapter 3.

Table 4: Policy Assessment of the Scoping Plan

Criteria	Details
Ensure the State Achieves the 2030 Target	• Incorporates existing and new commitments to reduce emissions from all sectors • The Cap-and-Trade Program scales to ensure reductions are achieved, even if other policies do not achieve them. This is particularly critical given the uncertainty inherent in both CARB's emission forecast and its estimate of future regulations.
Provide Air Quality Co-Benefits	• Reduced fossil fuel use and increased electrification (including plug-in hybrid electric, battery-electric, and hydrogen fuel cell vehicles) from policies such as the Mobile Source Strategy, enhanced LCFS and RPS, energy efficiency, and land conservation will likely reduce criteria pollutants and toxic air contaminants. • The Cap-and-Trade Program will ensure GHG emissions reductions within California that may reduce criteria pollutants and toxic air contaminants.
Prioritize Rules and Regulations for Direct GHG Reductions	• Advanced Clean Cars regulations require reduction in the light-duty vehicle sector. • Enhanced LCFS requires reductions in light-duty and heavy-duty transportation. • SB 350, RPS, and energy efficiency will reduce the need for fossil power generation. • The Cap-and-Trade Program constrains and reduces emissions across approximately 80 percent of California GHG emissions. • SB 1383 and the Short-lived Climate Pollutant Reduction Strategy require reductions in the agricultural, commercial, residential, industrial, and energy sectors.
Protect Against Emissions Leakage	• Free allowance allocation to minimize leakage, where supported by research.
Develop GHG Reduction Programs that can be Readily Exported to Other Jurisdictions	• Supports existing and future linkages, allows for larger GHG emissions reductions worldwide through collaborative regional efforts. • Provides leadership on how to integrate short-lived climate pollutants into the broader climate mitigation program.
Minimize Costs and Invest in Disadvantaged and Low-Income Communities, and Low-Income Households	• Continue to fund programs and projects that reduce GHGs and meaningfully benefit disadvantaged and low-income communities and low-income households through the Greenhouse Gas Reduction Fund.
Avoid or Minimize the Impacts of Climate Change on Public Health	• Reduces GHGs and provides leadership nationally and internationally for climate action. • Provides funding for programs such as home weatherization focused on disadvantaged communities, to mitigate potential cost impacts.
Compliance Flexibility	• Regulated sources self-identify and implement some GHG emissions reductions actions, beyond those already required to comply with additional prescriptive measures.
Support the Clean Power Plan and other Federal Climate Programs	• Post-2020 Cap-and-Trade Program can be used to comply with the Clean Power Plan.

Chapter 3

Evaluations

Programs for Air Quality Improvement in California

For half a century, CARB has been a leader in measuring, evaluating, and reducing sources of air pollution that impact public health. Its air pollution programs have been adapted for national programs and emulated in other countries. Significant progress has been made in reducing diesel particulate matter (PM), which is a designated toxic air contaminant, and many other hazardous air pollutants. CARB partners with local air districts to address stationary source emissions and adopts and implements State-level regulations to address sources of criteria and toxic air pollution, including mobile sources. The key air quality strategies being implemented by CARB include the following:

- **State Implementation Plans (SIPs).**[72] These comprehensive plans describe how an area will attain national ambient air quality standards by deadlines established by the federal Clean Air Act. SIPs are a compilation of new and previously submitted plans, programs, air district rules, State regulations, and federal controls designed to achieve the emissions reductions needed from mobile sources, fuels, stationary sources, and consumer products. On March 23, 2017, CARB adopted the Revised Proposed 2016 State Strategy for the SIP, describing the commitments necessary to meet federal ozone and $PM_{2.5}$ standards over the next 15 years.
- **Diesel Risk Reduction Plan.**[73] The plan, adopted by CARB in September 2000, outlined 14 recommended control measures to reduce the risks associated with diesel PM and achieve a goal of 75 percent PM reduction by 2010 and 85 percent by 2020. Since 2000, CARB has adopted regulations to reduce smog-forming pollutants and diesel PM from mobile vehicles and equipment (e.g., trucks, buses, locomotives, tractors, cargo handling equipment, construction equipment, marine vessels, transport refrigeration units); stationary engines and portable equipment (e.g., emergency standby generators, prime generators, agricultural irrigation pumps, portable generators); and diesel fuels. Diesel PM accounts for approximately 60 percent of the current estimated inhalation cancer risk for background ambient air.[74] CARB staff continues to work to improve implementation and enforcement efforts and examine needed amendments to increase the community health benefits of these control measures.
- **Sustainable Freight Action Plan.**[75] This joint agency strategy was developed in response to Governor's Executive Order B-32-15 to improve freight efficiency, transition to zero emission technologies, and increase the competitiveness of California's freight system. The transition of the freight transport system is essential to support the State's economic development in the coming decades and reduce air pollution affecting many California communities.
- **AB 32 Scoping Plan.**[76] This comprehensive strategy is updated at least every five years and is designed to achieve the State's climate goals, which includes measures that achieve air pollutant reduction co-benefits.
- **AB 1807.**[77] AB 1807 (Tanner, 1983) created California's program to reduce exposure to air toxics. CARB uses a comprehensive process to prioritize the identification of substances that pose the greatest health threat and to develop airborne toxic control measures to reduce those exposures. CARB has reduced public exposure to toxic air contaminants (TACs) through control of motor vehicles, fuels, consumer products, and stationary sources, including adopting control measures for

72 CARB. 2016. California State Implementation Plans. *www.arb.ca.gov/planning/sip/sip.htm*
73 CARB. 2000. Final Diesel Risk Reduction Plan with Appendices. *www.arb.ca.gov/diesel/documents/rrpapp.htm*
74 CARB and California Air Pollution Control Officers Association. 2015. Risk Management Guidance for Stationary Sources of Air Toxics. July 23. *www.arb.ca.gov/toxics/rma/rmgssat.pdf*
75 CARB. 2016. Sustainable Freight Transport. *www.arb.ca.gov/gmp/sfti/sfti.htm*
76 CARB. 2016. AB 32 Scoping Plan. *www.arb.ca.gov/cc/scopingplan/scopingplan.htm*
77 CARB. 2014. California Air Toxics Program – Background. *www.arb.ca.gov/toxics/background.htm*

industrial sources (e.g., perchloroethylene in automotive products; hexavalent chromium from cooling towers, automotive coatings and plating; ethylene oxide from sterilizers and aerators; dioxins from medical waste incinerators; perchloroethylene from dry cleaners; cadmium from metal melting).

- **AB 2588 Air Toxics "Hot Spots" Program.**[78] The Hot Spots Program supplements the AB 1807 program by requiring a statewide air toxics inventory, identification of facilities having localized impacts, notification of nearby residents exposed to a significant health risk, and facility risk management plans to reduce those significant risks to acceptable levels.
- **AB 617 Community Air Protection Program.** Together with the extension of the Cap-and-Trade Program and in recognition of ongoing air quality challenges, California has committed to expand its criteria and toxic emissions reductions efforts through the pursuit of a multipronged approach to reduce localized air pollution and address community exposure, framed by recently-signed new legislation, AB 617 (C. Garcia, 2017). AB 617 outlines actions in five core areas, to be completed in the 2018 to 2020 timeframe, to reduce criteria and toxic emissions in the most heavily impacted areas of the State:
  - **Community-scale air monitoring.** Ambient air monitoring is needed to evaluate the status of the atmosphere compared to clean air standards and historical data. Monitoring helps identify and profile air pollution sources, assess emerging measurement methods, characterize the degree and extent of air pollution, and track progress of emissions reductions activities. AB 617 requires a statewide assessment of the current air monitoring network and identification of priority locations where community-level air monitoring will be deployed.
  - **Statewide Strategy to reduce air pollutants impacting communities.** CARB will identify locations with high cumulative exposure to criteria and toxic pollutants, the sources contributing to those exposures, and select locations that will be required to develop a community action plan to reduce pollutants to acceptable levels.
  - **Community Action Plans to reduce emissions in identified communities.** High priority locations identified in the Statewide Strategy will need to prepare a community action plan that includes emissions reductions targets, measures, and an implementation timeline. The plan will be submitted to CARB for review and approval.
  - **Accelerated retrofits and technology clearinghouse.** This effort will focus on stationary source equipment at Cap-and-Trade facilities that, as of 2007, have not been retrofitted with BARCT-level emission controls for nonattainment pollutants. In addition, creation of a statewide clearinghouse that identifies BACT and BARCT technologies and emission levels for criteria pollutants and TACs will be developed to assist the air districts with the BARCT evaluation and identify available emission controls for the Statewide Strategy.
  - **Direct reporting of facility emissions data to CARB.** An improved, standardized emission inventory promotes a better understanding of actual emissions and helps identify major emission sources, priorities for emissions reduction, and data gaps requiring further work. AB 617 requires CARB to establish a uniform emission inventory system for stationary sources of criteria pollutants and TACs. Data integration and transparency-related efforts are already required by AB 197 (E. Garcia, 2016) and underway at CARB, so this new task will build on these efforts. Moreover, it is clear that better data reporting is necessary to identify localized exposure risk to harmful criteria and toxic pollutants and actions to address any localized impacts must be taken as quickly as possible.

To support efforts to advance the State's toxics program, the Office of Environmental Health Hazard Assessment (OEHHA) finalized a new health risk assessment methodology, *Air Toxics Hot Spots Program Risk Assessment Guidelines: Guidance Manual for Preparation of Health Risk Assessments*, on March 6, 2015, which updates the previous version of the guidance manual and reflects advances in the field of risk assessment along with explicit consideration of infants and children.[79] Subsequently, CARB, in collaboration with the California Air Pollution Control Officers Association (CAPCOA), finalized a *Risk Management Guidance for Stationary Sources of Air Toxics* for the air districts to use to incorporate OEHHA's new health risk assessment methodology into their stationary source permitting and AB 2588 Air Toxics Hot Spots programs.[80]

Together, all of these efforts will reduce criteria and toxics emissions in the State, with a focus on the most burdened communities. In particular, AB 617 responds to environmental justice concerns that the Cap-and-

78 CARB. 2016. AB 2588 Air Toxics "Hot Spots" Program. *www.arb.ca.gov/ab2588/ab2588.htm*

79 OEHHA. 2015. Notice of Adoption of Air Toxics Hot Spots Program Guidance Manual for the Preparation of Health Risk Assessments 2015. *http://oehha.ca.gov/air/crnr/notice-adoption-air-toxics-hot-spots-program-guidance-manual-preparation-health-risk-0*

80 *www.arb.ca.gov/toxics/rma/rmgssat.pdf*

Trade Program does not force large GHG emitters to reduce air pollution which results in localized health impacts. Prior to the passage of AB 617, in February 2017, OEHHA published the first in a series of reports tasked with evaluating the impacts of California's climate change programs on disadvantaged communities. The initial report focused on the Cap-and-Trade Program.[81] Future reports will focus on the impacts of other climate programs on disadvantaged communities. The report confirms disadvantaged communities are frequently located close to large stationary and mobile sources of emissions. It also notes there are complexities in trying to correlate GHGs with criteria and toxics emissions across industry and within sectors, although preliminary data review shows there may be some poor to moderate correlations in specific instances. Lastly, the report noted, "…the emissions data available at this time do not allow for a conclusive analysis."

Two additional reports were released during this same period of time: a California Environmental Justice Alliance (CEJA) report focused on identifying equity issues for disadvantaged communities resulting from the implementation of the Cap-and-Trade Program[82] and a research paper examining the question of whether the Cap-and-Trade Program is causing more GHG emissions in disadvantaged communities when compared to other regions.[83] Both of these reports also confirmed that disadvantaged communities are disproportionately located close to large stationary and mobile sources of emissions. While the CEJA report noted, "Further research is needed before firm policy conclusions can be drawn from this preliminary analysis," the research paper, in reference to GHGs, states, "By and large, the annual change in emissions across disadvantaged and non-disadvantaged communities look similar."

While the reports do not provide evidence that implementation of the Cap-and-Trade Program is contributing to increased local air pollution, they do underscore the need to use all of the tools (e.g., enhanced enforcement, new regulations, tighter permit limits) available to the State and local agencies to achieve further emissions reductions of toxic and criteria pollutants that are impacting community health. Importantly, AB 617 provides a new framework and tools for CARB, in collaboration with local air districts, to deploy focused monitoring and ensure criteria and toxics emissions reductions at the State's largest GHG emitters.

AB 197 Measure Analyses

This section provides the required AB 197 estimates for the measures evaluated in this Scoping Plan. These estimates provide information on the relative impacts of the evaluated measures when compared to each other. To support the design of a suite of policies that result in GHG reductions, air quality co-benefits, and cost-effective measures, it is important to understand if a measure will increase or reduce criteria pollutants or toxic air contaminant emissions, or if increasing stringency at additional costs yields few additional GHG reductions. To this end, AB 197 (E. Garcia, Chapter 250, Statutes of 2016) requires the following for each potential reduction measure evaluated in any Scoping Plan update:

- The range of projected GHG emissions reductions that result from the measure.
- The range of projected air pollution reductions that result from the measure.
- The cost-effectiveness, including avoided social costs, of the measure.

As the Scoping Plan was developed, it was important to understand if any of the proposed policies or measures would increase criteria pollutant or toxic air contaminant emissions. Note the important caveats around some of the estimates; they must be considered when using the information in the tables below for purposes other than as intended.

Estimated Emissions Reductions for Evaluated Measures

For many of the existing programs with known commitments, such as the Mobile Source Strategy, previous analyses provide emission factors or other methods for estimating the impacts required by AB 197. Where available, these values were used. In some cases, estimates are based on data from other sources, such as the California Public Utilities Commission (CPUC) Renewables Portfolio Standard Calculator. For newly proposed measures, assumptions were required to estimate the values. Consequently, the estimates for the newly proposed measures have substantial uncertainty. The uncertainty in the impacts of these measures would be reduced as the measures are defined in greater detail during the regulatory processes that are undertaken to

81 *https://oehha.ca.gov/media/downloads/environmental-justice/report/oehhaab32report020217.pdf*
82 *http://dornsife.usc.edu/PERE/enviro-equity-CA-cap-trade*
83 *https://www.dropbox.com/s/se3ibxkv8t4at8g/Meng_CA_EJ.pdf?dl=1*

define and adopt the programs. For example, as a measure is developed in detail, ways to obtain additional co-pollutant reductions or avoid co-pollutant increases may be identified and evaluated.

Table 5 provides the estimates for the measures evaluated during the development of the Scoping Plan. Based on the estimates below, these measures are expected to provide air quality benefits. The table also provides important context, limitations, and caveats about the values. As shown, the table includes criteria pollutant and diesel PM estimates. As mentioned in the Diesel Risk Reduction Plan, diesel PM accounts for 60 percent of the current estimated inhalation cancer risk for background ambient air. As we do not have direct modeling results for criteria and toxic pollutant estimates from PATHWAYS, we are estimating air quality benefits by using reductions in GHGs to assign similar reductions for criteria and toxic pollutants. By assigning an arbitrary 1:1 relationship in changes between GHGs and criteria and toxic pollutants, the air quality reductions likely overestimate the actual reductions from implementation of the measures. As noted in the OEHHA report, the exact relationship between GHGs and air pollutants is not clearly understood at this time. Moving forward, CARB will continue to assess the nature of the exact relationship between GHGs and criteria and toxics emissions. All estimates in Table 5 have some inherent uncertainty. The table allows for assessing measures against each other and should not be used for other purposes without understanding the limitations on the how the air quality values are derived.

Table 6 provides a summary of the total estimated emissions reductions for the Scoping Plan Scenario as outlined in Table 1. Table 6 was developed by adding the estimated emissions reductions for all of the measures included within the Scoping Plan Scenario in Table 1. More detail on the estimates for the Scoping Plan Scenario, as well as the specific measures included in each of the other four alternative scenarios can be found in Appendix G. In 2030, the Scoping Plan scenario and alternatives will provide comparable GHG and air quality reductions. When there is a range, the measure or policy should be designed to maximize the benefit to the extent possible.

Table 5: Ranges of Estimated Air Pollution Reductions by Policy or Measure in 2030

Measure	Range of NO_X Reductions (Tons/Day)	Range of VOC Reductions (Tons/Day)	Range of $PM_{2.5}$ Reductions (Tons/Day)	Range of Diesel PM Reductions (Tons/Day)
50 percent RPS	~0.5	<0.1	~0.4	< 0.01
Mobile Sources CTF and Freight	51–60	4.6–5.5	~1.1	~0.2
18 percent Carbon Intensity Reduction Target for LCFS - Liquid Biofuels*	3.5–4.4	0.5–0.6	0.4–0.6	~0.5
Short-Lived Climate Pollutant Strategy	–	–	–	–
2x additional achievable energy efficiency in the 2015 Integrated Energy Policy Report (IEPR)	0.4–0.5	0.5–0.7	< 0.1	< 0.01
Cap-and-Trade Program	A	A	A	4–9

* LCFS estimates include estimates of the NO_X and $PM_{2.5}$ tailpipe benefits limited to renewable diesel consumed in the off-road sector.

– CARB is evaluating how to best estimate these values. Criteria and toxic values are shown in tons per day, as they are episodic emissions events with residence times of a few hours to days, unlike GHGs, which have atmospheric residence times of decades.

A Due to the inherent flexibility of the Cap-and-Trade Program, as well as the overlay of other complementary GHG reduction measures, the mix of compliance strategies that individual facilities may use is not known. However, based on current law and policies that control industrial and electricity generating sources of air pollution, and expected compliance responses, CARB believes that emissions increases at the statewide, regional, or local level due to the regulation are not likely. A more stringent post-2020 Cap-and-Trade Program will provide an incentive for covered facilities to decrease GHG emissions and any related emissions of criteria and toxic pollutants. Please see CARB's Co-Pollutant Emissions Assessment for a more detailed evaluation of a cap-and-trade program and associated air emissions impacts: *www.arb.ca.gov/regact/2010/capandtrade10/capv6appp.pdf*

NO_X = nitrogen oxides; VOC = volatile organic compound

Important: These estimates assume a 1:1 relationship between changes in GHGs, criteria pollutants, and toxic air contaminant emissions, and it is unclear whether that is ever the case. The values should not be considered estimates of absolute changes for other analytical purposes and only allow for comparison across measures in the table. The values are estimates that represent current assumptions of how programs may be implemented; actual impacts may vary depending on the design, implementation, and performance of the policies and measures. The table does not show interactions between measures, such as the relationship with increased transportation

electrification and associated increase in energy demand for the electricity sector. The measures in the Scoping Plan Scenario are shown in bold font in the table below. Additional details, including GHG reductions, are available in Appendix G.

Table 6: Summary of Ranges of Estimated Air Pollution Reductions for the Scoping Plan Scenario in 2030

Scenario	Range of NO_x Reductions (Tons/Day)	Range of VOC Reductions (Tons/Day)	Range of $PM_{2.5}$ Reductions (Tons/Day)	Range of Diesel PM Reductions (Tons/Day)
Scoping Plan Scenario	48–73	5.1–7.3	1.4–2.4	5–10

The total estimates for air pollution reductions provided in this table for the Scoping Plan Scenario are estimated by adding the air pollution benefits for the subset of individual measures examined in Table 5 and included in the Scoping Plan Scenario described in Table 1, and scaled by a risk adjustment factor to capture interactive effects and risks of under/over achieving on air pollution reductions. Appendix G includes details of the specific measures in the Scoping Plan Scenario and Alternatives. **All caveats in Table 5 apply to air quality estimates in this table.**

Estimated Social Costs of Evaluated Measures

Consideration of the social costs of GHG emissions is a requirement in AB 197, including evaluation of the avoided social costs for measures within this Scoping Plan.[84] Social costs are generally defined as the cost of an action on people, the environment, or society and are widely used to evaluate the impact of regulatory actions. Social costs do not represent the cost of abatement or the cost of GHG reductions, rather social costs estimate the harm that is avoided by reducing GHGs.

Since 2008, federal agencies have been incorporating the social costs of GHGs, including carbon dioxide, methane, and nitrous oxide into the analysis of their regulatory actions. Agencies including the U.S. Environmental Protection Agency (U.S. EPA), Department of Transportation (DOT), and Department of Energy (DOE) are subject to Executive Order 12866, which directs agencies "to assess both the costs and benefits of the intended regulation…".[85] In 2007, the National Highway Transportation Safety Administration (NHTSA) was directed by the U.S. 9th Circuit Court of Appeals to include the social cost of carbon in a regulatory impact analysis for a vehicle fuel economy rule. The Court stated that "[w]hile the record shows that there is a range of values, the value of carbon emissions reduction is certainly not zero."[86]

In 2009, the Council of Economic Advisors and the Office of Management and Budget convened the Interagency Working Group on the Social Cost of Greenhouse Gases[87] (IWG) to develop a methodology for estimating the social cost of carbon (SC-CO_2). This methodology relied on a standardized range of assumptions and could be used consistently when estimating the benefits of regulations across agencies and around the world. The IWG, comprised of scientific and economic experts, recommended the use of SC-CO_2 values based on three integrated assessment models (IAMs) developed over decades of global peer-reviewed research.[88]

In this Scoping Plan, CARB utilizes the current IWG supported SC-CO_2 values to consider the social costs of actions to reduce GHG emissions. This approach is in line with Executive Orders including 12866 and the OMB Circular A-4 of September 17, 2003, and reflects the best available science in the estimation of the socio-economic impacts of carbon.[89] CARB is aware that the current federal administration has recently withdrawn certain social cost of carbon reports as no longer representative of federal governmental policy.[90] However, this determination does not call into question the validity and scientific integrity of federal social

84 AB 197 text available at: *https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB197*.
85 *https://www.reginfo.gov/public/jsp/Utilities/EO_12866.pdf*
86 Center for Biological Diversity v National Highway Traffic Safety Administration 06-71891 (9th Cir, November 15 2007)
87 Originally titled the Interagency Working Group on the Social Cost of Carbon, the IWG was renamed in 2016.
88 Additional technical detail on the IWG process is available in the Technical Updates of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866. Iterations of the Updates are available at: *https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf*, *https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf*, and *https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf*.
89 OMB circular A-4 is available at: *https://www.transportation.gov/sites/dot.gov/files/docs/OMB%20Circular%20No.%20A-4.pdf*.
90 See Presidential Executive Order, March 28, 2017, sec. 5(b).

cost of carbon work, or the merit of independent scientific work. Indeed, the IWG's work remains relevant, reliable, and appropriate for use for these purposes.

The IWG describes the social costs of carbon as follows:

> *The social cost of carbon ($SC\text{-}CO_2$) for a given year is an estimate, in dollars, of the present discounted value of the future damage caused by a 1-metric ton increase in carbon dioxide (CO_2) emissions into the atmosphere in that year, or equivalently, the benefits of reducing CO_2 emissions by the same amount in that year. The $SC\text{-}CO_2$ is intended to provide a comprehensive measure of the net damages – that is, the monetized value of the net impacts – from global climate change that result from an additional ton of CO_2.*
>
> *These damages include, but are not limited to, changes in net agricultural productivity, energy use, human health, property damage from increased flood risk, as well as nonmarket damages, such as the services that natural ecosystems provide to society. Many of these damages from CO_2 emissions today will affect economic outcomes throughout the next several centuries.*[91]

Table 7. presents the range of IWG $SC\text{-}CO_2$ values used in regulatory assessments including this Scoping Plan.[92]

Table 7: $SC\text{-}CO_2$, 2015-2030 (in 2007 $ per Metric Ton)

Year	5 Percent Discount Rate	3 Percent Discount Rate	2.5 Percent Discount Rate
2015	$11	$36	$56
2020	$12	$42	$62
2025	$14	$46	$68
2030	$16	$50	$73

The $SC\text{-}CO_2$ is year specific, that is, the IAMs estimate the environmental damages from a given year in the future and discount the value of the damages back to the present. For example, the $SC\text{-}CO_2$ for the year 2030 represents the value of climate change damages from a release of CO_2 in 2030 discounted back to today. The $SC\text{-}CO_2$ increases over time as systems become stressed from the aggregate impacts of climate change and future emissions cause incrementally larger damages. Table 7 presents the $SC\text{-}CO_2$ across a range of discount rates – or the value today of preventing environmental damages in the future. A higher discount rate decreases the value placed on future environmental damages. This Scoping Plan utilizes the IWG standardized range of discount rates, from 2.5 to 5 percent to represent varying valuation of future damages.

The $SC\text{-}CO_2$ is highly sensitive to the discount rate. Higher discount rates decrease the value today of future environmental damages. This Scoping Plan utilizes the IWG standardized range of discount rates, from 2.5 to 5 percent to represent varying valuation of future damages. The value today of environmental damages in 2030 is higher under the 2.5 percent discount rate compared to the 3 or 5 percent discount rate, reflecting the trade-off of consumption today and future damages. The IWG estimates the $SC\text{-}CO_2$ across a range of discount rates that encompass a variety of assumptions regarding the correlation between climate damages and consumption of goods and is consistent with OMB's Circular A-4 guidance.[93]

There is an active discussion within government and academia about the role of $SC\text{-}CO_2$ in assessing regulations, quantifying avoided climate damages, and the values themselves. In January 2017, the National Academies of Sciences, Engineering, and Medicine (NAS) released a report examining potential approaches for a comprehensive update to the $SC\text{-}CO_2$ methodology to ensure resulting cost estimates reflect the best available science. The NAS review did not modify the estimated values of the $SC\text{-}CO_2$, but evaluated the models, assumptions, handling of uncertainty, and discounting used in the estimating of the $SC\text{-}CO_2$. The report titled, "Valuating Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide," recommends near-term improvements to the existing IWG $SC\text{-}CO_2$ as well as a long-term strategy to more comprehensive updates.[94] The State will continue to follow updates to the IWG $SC\text{-}CO_2$, including changes

91 From The National Academies, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, 2017, available at: *http://www.nap.edu/24651*

92 The $SC\text{-}CO_2$ values as of July 2015 are available at: *https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf*

93 The National Academies, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, 2017, available at: *http://www.nap.edu/24651.*

94 The National Academies, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, 2017, available at:

outlined in the NAS report, and incorporate appropriate peer-reviewed modifications to estimates based on the latest available data and science.

It is important to note that the SC-CO_2, while intended to be a comprehensive estimate of the damages caused by carbon globally, does not represent the cumulative cost of climate change and air pollution to society. There are additional costs to society outside of the SC-CO_2, including costs associated with changes in co-pollutants, the social cost of other GHGs including methane and nitrous oxide, and costs that cannot be included due to modeling and data limitations. The IPCC has stated that the IWG SC-CO_2 estimates are likely underestimated due to the omission of significant impacts that cannot be accurately monetized, including important physical, ecological, and economic impacts.[95] CARB will continue engaging with experts to evaluate the comprehensive California-specific impacts of climate change and air pollution.

The Social Cost of GHG Emissions

Social costs for methane (SC-CH_4) and nitrous oxide (SC-N_2O) have also been developed using methodology consistent with that used in estimating the IWG SC-CO_2. These social costs have also been endorsed by the IWG and have been used in federal regulatory analyses.[96] Along with the SC-CO_2, the State also supports the use of the SC-CH_4 and SC-N_2O in monetizing the impacts of GHG emissions.

While the SC-CO_2, SC-CH_4, and SC-N_2O provide metrics to account for the social costs of climate change, California will continue to analyze ways to more comprehensively identify the costs of climate change and air pollution to all Californians. This will include following updates to the IWG methodology and social costs of GHGs and incorporating the SC-CO_2, SC-CH_4, and SC-N_2O into regulatory analyses.

Table 9 presents the estimated social cost for each policy or measure considered in the development of the Scoping Plan in 2030. For each measure or policy, Table 9 includes the range of the IWG SC-CO_2 values that result from the anticipated range of GHG reductions in 2030 presented in Appendix G. The SC-CO_2 range is obtained using the IWG SC-CO_2 values in 2030 at the 2.5, 3, and 5 percent discount rates. These values (of $16 using the 5 percent discount rate, $50 using the 3 percent discount rate, and $73 using the 2.5 percent discount rate) are translated into 2015 dollars and multiplied across the range of estimated reductions by measure in 2030 to estimate the value of avoided social costs from each measure in that year.[97]

Implementation of the SLCP Strategy will result in reduction of a variety of GHGs, including methane and HFCs, which reported in carbon dioxide equivalent (CO_2e). While there is no social cost of CO_2e, the avoided damages associated with the methane reductions outlined in the SLCP Strategy are estimated in Table 9 using the IWG SC-CH_4 as presented in Table 8.[98]

Table 8: SC-CH_4, 2015-2030 (in 2007$ per Metric Ton)

Year	5 Percent Discount Rate	3 Percent Discount Rate	2.5 Percent Discount Rate
2015	$450	$1000	$1400
2020	$540	$1200	$1600
2025	$650	$1400	$1800
2030	$760	$1600	$2000

The range of SC-CH_4 is obtained using the IWG SC-CH_4 values in 2030 at the 2.5, 3, and 5 percent discount rates. The SC-CH_4 values (e.g., $760 using the 5 percent discount rate, $1,600 using the 3 percent discount rate, and $2,000 using the 2.5 percent discount rate) are translated into 2015 dollars and multiplied across the range of estimated methane reductions in 2030 to estimate the value of climate benefits from the SLCP

http://www.nap.edu/24651

95 *https://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3s3-5-3-3.html*

96 More information is available at: *https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf*

97 The IWG.SC-CO_2 values are in 2007 dollars. In 2015 dollars, $16, $50, and $73 in 2007 translates to about $18, $57, and $83, respectively, based on the Bureau of Labor Statistics GDP Series Table 1.1.4.

98 *https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf*

Strategy.[99] As the social cost associated with the SLCP Strategy does not include the impact associated with non-methane reductions, Table 9 underestimates the avoided social costs of this Scoping Plan as calculated using the IWG valuations.

As this Scoping Plan is a suite of policies developed to reduce GHGs to a specific level in 2030, any alternative scenario that also achieves the 2030 target (with the same proportion of carbon dioxide and methane reductions) will have the same avoided social cost, as estimated using the IWG social cost of GHGs, for the single year 2030. The social costs of alternatives could vary if the 2030 target is achieved with vastly different ratios of carbon dioxide to methane reductions. However, all alternatives in this Scoping Plan are anticipated to achieve the same proportion of carbon dioxide and methane reductions and will therefore all have the same estimated avoided social damage or social cost. This social cost, as estimated in 2030 using the IWG SC-CO_2 and SC-CH_4, ranges from $1.9 to $11.2 billion using the 2.5 to 5 percent discount rates, and is estimated at $5.0 to $7.8 billion using the 3 percent discount rate. For example, in Table 9 the CH_4 reductions for the SCLP strategy are about 1 MMTCH_4. That value is multiplied by the 2030 SC-CH_4 values in Table 8 for the 2030 values at the 2.5 and 5 percent discount rates to get a range of $860 to $2,260 in 2015 dollars.

99 The IWG.SC-CH_4 values are in 2007 dollars. In 2015 dollars, the range of SC-CH_4 translates to about $858, $1,807, and $2,259, for the 5 percent, 3 percent, and 2.5 percent discount rates, respectively. These values are based on the Bureau of Labor Statistics GDP Series Table 1.1.4.

Table 9: Estimated Social Cost (Avoided Economic Damages) of Policies or Measures Considered in the 2017 Scoping Plan Development#

Measure (Measures in bold are included in the Scoping Plan)	Range of Social Cost of Carbon $ million USD (2015 dollars)**
50 percent Renewables Portfolio Standard (RPS)	$55–$250
Mobile Sources CTF and Freight	$200–$1,080
18 percent Carbon Intensity Reduction Target for LCFS -Liquid Biofuels	$70–$330
Short-Lived Climate Pollutant Strategy	$860-$2,260 ($SC\text{-}CH_4$)
2x additional achievable energy efficiency in the 2015 IEPR	$125–$750
Cap-and-Trade Program	$610–$6,560
10 percent incremental RPS and additional 10 GW behind-the-meter solar PV*	$250–$1,160
25 percent Carbon Intensity Reduction Target for LCFS and a Low-Emission Diesel Standard - Liquid Biofuels*	$90–$415
20 percent Refinery	$55–$500
30 percent Refinery	$20–$250
25 percent Industry	$20–$415
25 percent Oil and Gas	$35–$330
5 percent Increased Utilization of RNG (core and non-core)	$35–$165
Mobile Source Strategy (CTF) with Increased ZEVs in South Coast and early retirement of LDVs with more efficient LDVs*	$55–$500
2.5x additional achievable energy efficiency in the 2015 IEPR, electrification of buildings (heat pumps and res. electric stoves) and early retirement of HVAC*	$70–$580
Carbon Tax	$775–$8,300
All Cap-and-Trade	$700–$6,890
Cap-and-Tax	$775–$8,300
Scoping Plan Scenario $SC\text{-}CO_2$ Scoping Plan Scenario $SC\text{-}CH_4$ **Scoping Plan Scenario (Total)**	$1,060–$8,970 $860–$2,260 **$1,920–$11,230**

Note: All values are rounded. The values for $SC\text{-}CO_2$ and $SC\text{-}CH_4$ in 2030 are presented in Tables 7 and 8.

* Where enhancements have been made to a measure or policy, the ranges in emissions reductions are incremental to the original measure. For example, the ranges for the 25 percent LCFS are incremental to the emissions ranges for the 18 percent LCFS.

\# Measures included in the Scoping Plan and the All Cap-and-Trade measure reflect emissions reductions from modeling changes after passage of AB 398. Emissions reductions from all other measures reflect modeling completed prior to passage of AB 398. See Appendix G for additional details.

** All values have been rounded to the nearest 0 or 5.

~ Some measures do not show a significant change in 2030 when there is an incremental increase in measure stringency or when modeling uncertainty was factored.

Social Costs of GHGs in Relation to Cost-Effectiveness

AB 32 includes a requirement that "rules and regulations achieve the maximum technologically feasible and cost-effective greenhouse gas emissions reductions."[100] Under AB 32, cost-effectiveness means the relative cost per metric ton of various GHG reduction strategies, which is the traditional cost metric associated with emission control. In contrast, the SC-CO_2, SC-CH_4, and SC-N_2O are estimates of the economic benefits, and not the cost of reducing GHG emissions.

There may be technologies or policies that do not appear to be cost-effective when compared to the SC-CO_2, SC-CH_4, and SC-N_2O associated with GHG reductions. However, these technologies or policies may result in other benefits that are not reflected in the IWG social costs. For instance, the evaluation of social costs might include health impacts due to changes in local air pollution that result from reductions in GHGs, diversification of the portfolio of transportation fuels (a goal outlined in the LCFS) and reductions in criteria pollutant emissions from power plants (as in the RPS).

Estimated Cost Per Metric Ton by Measure

AB 197 also requires an estimation of the cost-effectiveness of the potential measures evaluated for the Scoping Plan. The values provided in Table 10 are estimates of the cost per metric ton of estimated reductions for each measure in 2030. To capture the fuel and GHG impacts of investments made from 2021 through 2030 to meet the 2030 GHG goal, the table also includes an evaluation of the cost per metric ton based on the cumulative GHG emissions reductions and cumulative costs or savings for each potential measure from 2021 through 2030. While it is important to understand the relative cost effectiveness of measures, the economic analysis presented in Appendix E provides a more comprehensive analysis of how the Scoping Plan and alternative scenarios affect the State's economy and jobs.

The cost (or savings) per metric ton of CO_2e reduced for each of the measures is one metric for comparing the performance of the measures. Additional factors beyond the cost per metric ton that could be considered include continuity with existing laws and policies, implementation feasibility, contribution to fuel diversity and technology transformation goals, as well as health and other benefits to California. These considerations are not reflected in the cost per ton metric below.

Because many of the measures interact with each other, isolating the cost and GHG savings of an individual measures is analytically challenging. For example, the performance of the renewable electricity measure impacts the GHG savings and cost per ton associated with increasing the use of electric vehicles. Likewise, the increased use of electric vehicles may increase flexible loads on the electric system, enabling increased levels of renewable electricity to be achieved more cost effectively. Both the renewable electricity measure and the increased use of electric vehicles affect the cost of meeting the Low-Carbon Fuel Standard.

For most of the measures shown in Table 10, the 2030 cost per metric ton is isolated from the other measures by performing a series of sensitivity model runs in the California PATHWAYS model. This cost per metric ton is calculated as the difference in the 2030 annualized cost (or savings) with and without the measure. For the measures in the Scoping Plan Scenario, the analysis starts with the Scoping Plan Scenario PATHWAYS estimates, and then costs and emissions are recalculated with each measure removed individually. For measures included in the No Cap-and-Trade Scenario, the approach starts with the No Cap-and-Trade Scenario PATHWAYS estimates and then each measure is removed. Using this approach, the incremental impact on GHG emissions and costs for each measure is calculated. The incremental cost in 2030 is divided by the incremental GHG emission impact to calculate the cost per ton in 2030.

The same approach of removing each measure individually is used to estimate the incremental cost and emission impacts of each measure for the period 2021 to 2030. For each measure, its annual incremental costs from 2021 to 2030 are calculated and then discounted to 2021 using the discount rate used in PATHWAYS to levelize capital costs over the life of equipment. As a result, the discounted incremental cost of each measure is the total investment required from 2021 to 2030 to achieve each measure's emissions reductions from 2021 to 2030 (including both incremental capital costs and incremental fuel savings/expenditures). This discounted cost for each measure was divided by its cumulative emissions reductions from 2021 to 2030 to calculate a cost per ton for the measure for the period. A second calculation was also made that divides each measure's discounted cost by its discounted emissions reductions from 2021 to 2030. The

100 *www.arb.ca.gov/cc/docs/ab32text.pdf*

same discount rate is used to discount both incremental costs and emissions in this approach. The estimates are presented in the table below.

Costs that represent transfers within the state, such as incentive payments for early retirement of equipment, are not included in this California total cost metric. The cost ranges shown below represent some of the uncertainty inherent in estimating this metric. The details of how the ranges for each measure were estimated are described in the footnotes below. All cost estimates have been rounded representing further uncertainty in individual values.

It is important to note that this cost per metric ton does not represent an expected market price value for carbon mitigation associated with these measures. In addition, the single year (2030) values and the estimates that encompass 2021 to 2030 do not capture the fuel savings or GHG reductions associated with the full economic lifetime of measures that have been implemented by 2030, but whose impacts extend beyond 2030. The estimates also do not capture the climate or health benefits of the GHG mitigation measures. Table 10 also notes the measures for which sources other than the PATHWAYS model were used to develop estimates of the cost per metric ton. The estimates in the table indicate that the relative cost of the measures is reasonably consistent across the different measures of cost per metric ton. Measures that are relatively less costly using the 2030 cost per metric ton are also less costly using the cost per metric ton based on the period 2021 to 2030. However, for several measures the sign of the estimate differs, such that in 2030 the measure has a positive cost while there is a negative cost for the period 2021 to 2030. This difference in sign occurs because the measure includes increasingly costly investments toward the end of the period examined. By examining only 2030, the lower cost components of the measure that occur in earlier years are omitted, resulting in a higher cost estimate for 2030 alone.

Table 10: Estimated Cost Per Metric Ton of Measures Considered in the 2017 Scoping Plan Development and Averaged from 2021 through 2030

Important: As individual measures are designed and implemented they will be subject to further evaluation and refinement and public review, which may result in different findings than presented below. The ranges are estimates that represent current assumptions of how programs may be implemented and may vary greatly depending on the design, implementation, and performance of the policies and measures. Measures in bold text are included in the Scoping Plan.

Measure	Cost/metric ton in 2030*	Cost/metric ton 2021-2030**
50 percent Renewables Portfolio Standard (RPS) [a]	**$175**	**$100 to $200**
Mobile Sources CFT and Freight [b]	**<$50**	**<$50**
Liquid Biofuels (18 percent Carbon Intensity Reduction Target for LCFS) [c]	**$150**	**$100 to $200**
Short-Lived Climate Pollutant Strategy [d]	**$25**	**$25**
2x additional achievable energy efficiency in the 2015 IEPR [f]	**-$350**	**-$300 to -$200**
10 percent incremental RPS and additional 10 GW behind-the-meter solar PV [a]	$350	$250 to $450
Liquid Biofuels (25 percent Carbon Intensity Reduction Target for LCFS and a Low-Emission Diesel Standard) [b]	$900	$550 to $975
20 percent Refinery [d]	$100	$50 to $100
30 percent Refinery [d]	$300	$175 to $325
25 percent Industry [d]	$200	$150 to $275
25 percent Oil and Gas [d]	$125	$100 to $175
5 percent Increased Utilization of renewable natural gas - core and non-core [e]	$1500	$1350 to $3000
Mobile Source Strategy (CFT) with Increased ZEVs in South Coast & additional reductions in VMT and energy demand & early retirement of LDVs with more efficient LDVs [b]	$100	<$50
2.5x additional achievable energy efficiency in the 2015 IEPR, electrification of buildings (heat pumps & res. electric stoves) and early retirement of HVAC [f]	$75	-$120 to -$70

* Where enhancements have been made to a measure or policy, the cost per metric ton are incremental to the original measure. For example, the cost per metric ton for the 25 percent LCFS are incremental to the cost per metric ton for the 18 percent LCFS.

** The lower values use a cost discount rate of 10 percent and cumulative emissions for the period 2021 to 2030. The higher values discount both costs and emissions using a discount rate of 10 percent.

a Cost estimate is based on PATHWAYS sensitivity analysis as described in the main text.

b Cost estimate is based on PATHWAYS sensitivity analysis as described in the main text.

c Liquid biofuel values are calculated as the average unsubsidized cost of biofuels supplied above that of an equivalent volume of fossil fuels. These values do not reflect impacts from other biofuel policies, such as the Renewable Fuel Standard or production tax credits, that are partially supported by fuel purchasers/taxpayers outside of California. Therefore, these values do not represent LCFS program costs or potential LCFS credit prices.

d See Appendix D

e Cost estimate is based on PATHWAYS sensitivity analysis as described in the main text.

f Cost estimate is based on PATHWAYS sensitivity analysis as described in the main text. The cost per metric ton does not represent the results of the CPUC's or CEC's standard cost-effectiveness evaluation tests

Health Analyses

Climate mitigation will result in both environmental and health benefits. This section presents information about the potential health benefits of the Scoping Plan. The impacts are primarily from reduced particulate matter pollution, reduced toxics pollution (both diesel combustion particles and other toxic pollutants), and the health benefits of increased physical activity that will result from more active modes of transportation such as walking and biking in lieu of driving. CARB is using the AB 197 air quality estimates in Table 5 as a proxy to understand the potential health impacts from the Scoping Plan. There is uncertainty in the air quality estimates and that is carried through to the health impacts evaluation presented here. In the future, CARB will be working to explore how to better integrate health analysis and health considerations in the design and implementation of climate programs.

Because the health endpoints of each of these benefits is different (e.g., fewer incidences of premature mortality, lower cancer risk, and fewer incidences of heart disease), the methodologies for estimating the benefits differ. Further, the methodologies are statistical estimates of adverse health outcomes aggregated to the statewide level. Therefore, this information should only be used to understand the relative health benefits of the various strategies and should not be taken as an absolute estimate of the health outcomes of the Scoping Plan statewide, or within a specific community. The latter is a function of the unique exposure to air pollutants within each community and each individual's choice of more active transport modes that increase physical activity.

The estimates of health benefits in this section do not include any potential avoided adverse health impacts associated with a reduction in global climate change. While we recognize that mitigating climate change will, for example, prevent atmospheric temperature rise, thereby preventing increases in ozone in California, which will result in fewer breathing problems, the connection is difficult to estimate or model. Since it takes collective global action to mitigate climate change, the following analyses do not attempt to quantify the improved health outcomes from reducing or stopping the rise in global temperatures.

The estimated statewide health benefits of the Scoping Plan are dominated by reductions in particulate matter from mobile sources and wood burning and a switch to more active transport modes. In particular, the focus on the impacts of exposure to particulate matter from mobile sources is expected because this is a major cause of air pollution statewide. For this reason, the actions concerning mobile sources in the Scoping Plan were specifically developed with the goal of achieving health-based air quality standards by reducing criteria and toxics emissions as well as GHG emissions simultaneously. In addition, actions that support walkable communities not only result in reduced VMT and related GHG emissions, but promote active transport and increased physical activity that is strongly related to improved health.

Table 11 provides a summary of the total estimated health benefits from the relevant metrics for the Scoping Plan. The sections below summarize the methodologies used to estimate these benefits. More detail on how these estimates were calculated can be found in Appendix G. The air pollutant values used in estimating the health impacts are from Table 5 and all caveats in the estimation of the air quality impacts must be considered when reviewing the health impacts discussed below as the air pollutant values are likely overestimates based on assigned relationships to GHGs that may not be real.

Potential Health Impacts of Reductions in Particulate Matter Air Pollution

CARB relied on an U.S. EPA-approved methodology to estimate the health impacts of reducing air pollution by actions in the Scoping Plan. This methodology relies on an incidents-per-ton factor to quantify the health benefits of directly emitted (diesel particles and wood smoke) and secondary $PM_{2.5}$ formed from oxides of nitrogen from reductions due to regulatory controls. It is similar in concept to the methodology developed by the U.S. EPA for comparable estimations[101], but uses California air basin specific relationships between emissions and air quality. The basis of the methodology is an approximately linear relationship between changes in $PM_{2.5}$ emissions and estimated changes in health outcomes. In this methodology, the number of premature deaths is estimated by multiplying emissions by the incidents-per-ton scaling factor. The factors are derived from studies that correlate the number of incidents (premature deaths, hospitalizations, emergency room visits) associated with exposure to $PM_{2.5}$.

101 Fann, N., Fulcher, C.M, & Hubbell, B.J. (2009) The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution. (2009)Air Quality, Atmosphere & Health 2(3), 169–176

Potential Health Impacts of Reductions in Toxic Air Pollution

A number of factors complicate any attempt to evaluate the health benefits of reducing exposure to toxic air pollution. First, there are hundreds of individual chemicals of concern with widely varying health effects and potencies. Therefore, a single metric is of limited value in capturing the range of potential toxics benefits. Furthermore, unlike the criteria pollutants whose impacts are generally measured on regional scales, toxics pose concern for both near-source impacts and larger-scale photochemical transformations and transport. Finally, the accepted scientific understanding for cancer risk is that there is usually no safe threshold for exposures to carcinogens. Therefore, cancer risks are usually expressed as "chances per million" of contracting cancer over a (70-year) lifetime exposure (in Table 11 lifetime exposure is provided in the far right column).

In light of these complexities, CARB relied on the most recent National Air Toxics Assessment (NATA) conducted by the U.S. EPA.[102] The NATA 2011 models the potential risks from breathing emissions of approximately 180 toxic air pollutants across the country. Modeled cancer risk results are available by census tract. The NATA data cover industrial facilities, mobile sources (on-road and off-road), small area-wide sources, and more. CARB multiplied the NATA "cancer risk-per-million" values by census tract by the census tract's population, in order to estimate a population-weighted metric that could be aggregated to the statewide level. This statistic should not be construed as actual real-world cancers (due to the many uncertainties in estimating the real-world levels of risk). Next, CARB applied the percent reductions in emissions due to Scoping Plan actions, in order to obtain an estimate of the "avoided incidence" of statistical lifetime cancers attributable to implementation of the Scoping Plan. Again, the "avoided incidence" is a construct designed to provide a useful statistical metric for comparative purposes among scenarios. It should not be construed to be a real-world parameter.

Potential Health Impacts of Active Transportation

High levels of active transportation have been linked to improved health and reduced premature mortality by increasing daily physical activity, representing a major direct co-benefit of using active transportation as a strategy to reduce GHG emissions. The benefits of physical activity can be very large. Individuals who are active for approximately 12 minutes a day have a 20 percent lower risk of dying early than those who are active for just 5 minutes a day and those who are active an hour a day, have close to a 40 percent lower risk of premature death.[103]

The Scoping Plan includes reductions in VMT, which can be achieved in a number of ways, including increased active transportation. To estimate the potential health benefits of active transport, CARB staff reviewed work done by the California Department of Public Health (CDPH) concerning the potential health benefits associated with the Caltrans Strategic Management Plan. In this Management Plan, Caltrans set a target for increasing the adoption of active transportation, aiming for a doubling of walking and a tripling of bicycle trips by 2020 compared to 2010. While this plan itself is not part of the Scoping Plan, it helps provide a sense of the magnitude of health benefits associated with increased active transportation.

CDPH performed a risk assessment to compare the number of premature deaths due to physical inactivity and traffic injuries in the baseline year of 2010 to the year 2020, assuming that Caltrans' walking and bicycling mode share targets were met.[104] CPDH's methodology has been documented in a publicly available technical manual[105] and the model has appeared in many peer-reviewed research articles.[106] It has been in development

102 U.S. Environmental Protection Agency (2011), National Air Toxics Assessment (NATA) 2011, *https://www.epa.gov/national-air-toxics-assessment/2011-nata-assessment-results*

103 U.S. Department of Health and Human Services (2008) Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, Washington, DC

104 Maizlish, N. (2016a) Increasing Walking, Cycling, and Transit: Improving Californians' Health, Saving costs, and Reducing Greenhouse Gases. Office of Health Equity, California Department of Public Health. *https://www.cdph.ca.gov/Programs/OHE/CDPH%20Document%20Library/Maizlish-2016-Increasing-Walking-Cycling-Transit-Technical-Report-rev8-17-ADA.pdf*

105 Maizlish, N. (2016b) Integrated Transport and Health Impact Model (ITHIM): A Guide to Operation, Calibration and Integration with Travel Demand Models. California Spreadsheet Version December 12, 2016.

106 Gotschi, T., Tainio, M., Maizlish, N., Schwanen, T., Goodman, A., & Woodcock, J. (2015). Contrasts in active transport behaviour across four countries: how do they translate into public health benefits? Preventative Medicine, 74, 42-48. doi:10.1016/j.ypmed.2015.02.009
Maizlish, N., Woodcock, J., Co, S., Ostro, B., Fanai, A., & Fairley, D. (2013). Health cobenefits and transportation-related reductions in greenhouse gas emissions in the San Francisco Bay area. American journal of public health, 103(4), 703-709. doi:10.2105/ajph.2012.300939
Whitfield, G. P., Meehan, L. A., Maizlish, N., & Wendel, A. M. (2016). The Integrated Transport and Health Impact Modeling

since 2009, and a California-specific version was released with a recent update in November 2016.[107]

CDPH estimated that 2,100 premature deaths annually would be avoided if Californians met the Management Plan's 2020 targets were met by Californians compared to 2010 travel patterns. A recent paper by Dr. Maizlish et al[108] quantified the health co-benefits of the preferred Sustainable Communities Strategies scenarios (compared to the 2010 baseline travel pattern) for the major Metropolitan Planning Organizations using the same methodology and found that 940 deaths annually would be avoided. For both analyses, there were significant reductions in cause-specific premature mortality due to increased physical activity, which was slightly counteracted by a much smaller increase in fatal traffic injuries due to the increased walking and bicycling. When taken together, the health benefit of increasing active transportation greatly outweighed the increased mortality from road traffic collisions. The Scoping Plan goals related to active transportation are more aggressive than those in both the Maizlish et al. 2017 publication and the analysis by CDPH for the Management Plan. Therefore, CARB staff used the CDPH estimate of approximately 2,100 fewer premature deaths from the Management Plan as a lower bound of what could be realized through implementation of the VMT reductions and active transport goals called for in the Scoping Plan Scenario.

Table 11: Summary of Ranges of Estimated Health Impacts for the Scoping Plan Scenario in 2030

	Fewer Premature Deaths	Fewer Hospitalizations (all)	Fewer ER visits	Fewer cancers *
Diesel PM	~60-91	~9-14	~25-38	
Secondary PM	~76-120	~11-17	~33-50	
Toxics				~21-61
Wood smoke	~1000	~ 148	~ 418	
Active Transport**	>2100			
Total	~3300	~180	~500	~21-61

* This metric should not be construed as actual real-world cancer cases. It is intended to be a comparative metric, based on the NATA estimates of lifetime cancer risk (chances-per-million over a 70 year life-time exposure) by census tract multiplied by the tract population.

** Reduction in premature death assumes meeting the CSMP 2020 mode shift target.

Note: The numbers in the table represent individual avoided incidences.

Tool in Nashville, Tennessee, USA: Implementation Steps and Lessons Learned. Journal of transport & health, 3. doi:10.1016/j.jth.2016.06.009

Woodcock, J. (2015). Integrated Transport and Health Impact Modelling Tool (ITHIM). Retrieved from http://www.cedar.iph.cam.ac.uk/research/modelling/ithim/

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B. G., Ashiru, O., Banister, D., & Roberts, I. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. Lancet, 374(9705), 1930-1943. doi:10.1016/s0140-6736(09)61714-1

Woodcock, J., Givoni, M., & Morgan, A. S. (2013). Health impact modelling of active travel visions for England and Wales using an Integrated Transport and Health Impact Modelling Tool (ITHIM). PLoS One, 8(1), e51462. doi:10.1371/journal.pone.0051462

Woodcock, J., Tainio, M., Cheshire, J., O'Brien, O., & Goodman, A. (2014). Health effects of the London bicycle sharing system: health impact modelling study. BMJ (Clinical research ed.), 348, g425. doi:10.1136/bmj.g425

107 Woodcock, J. Maizlish, N. (2016). ITHIM: Integrated Transport & Health Impact Modelling, California Version, November 11, 2016. Original citation: Woodcock J, Givoni M, Morgan AS. Health Impact Modelling of Active Travel Visions for England and Wales Using an Integrated Transport and Health Impact Modelling Tool (ITHIM). PLoS One. 2013;8(1):e51462.

108 Maizlish N, Linesch N,& Woodcock J.(2017) Health and greenhouse gas mitigation benefits of ambitious expansion of cycling, walking, and transit in California. Journal of Transport and Health. ; doi: 10.1016/j.jth.2017.04.011

Future Health Activities

As Table 11 shows, the Scoping Plan measures would have significant potential positive health outcomes. The integrated nature of the strategies to reduce emissions of GHGs and criteria and toxics emissions could provide multiple benefits. Actions to reduce black carbon from wood smoke are reducing the same particles that lead to premature mortality. Reductions in fossil combustion will not only reduce GHG emissions, but also toxics emissions. Finally, reducing VMT with strategies that provide opportunities for people to switch to active transport modes can have very large health benefits resulting from increased physical activity.

In recognition of the potential for significant positive health benefits of the Scoping Plan, CARB is initiating a process to better understand how to integrate health analysis broadly into the design and implementation of our climate change programs with the goal of maximizing the health benefits. Although health impact assessments have been used to inform CARB's policymaking, these analyses have not been consistently integrated into the general up-front design of CARB programs. To begin the effort to increase health benefits from climate change mitigation policies, CARB will convene a public meeting in Spring 2018 to solicit input on how best to incorporate health analyses into our policy development. CARB staff will seek appropriate tools for these analyses and will assemble a team of academic advisors to provide input on the latest developments in methods and data sources.

Economic Analyses

The following section outlines the economic impact of the Scoping Plan relative to the business-as-usual Reference Scenario. Additional detail on the economic analysis, including modeling details and the estimated economic impact of alternative scenarios is presented in Appendix E.

The Scoping Plan outlines a path to achieve the SB 32 target that requires less reliance on fossil fuels and increased investment in low carbon fuels and clean energy technologies. Through this shift, California can lead the world in developing the technologies needed to reduce the global risks of climate change. This builds on California's current successes of reducing GHG emissions while also developing a cleaner, resilient economy that uses less energy and generates less pollution. Innovation in low-carbon technologies will continue to open growth opportunities for investors and businesses in California. As modeled, the analysis in this Scoping Plan suggests that the costs of transitioning to this lower carbon economy are small, even without counting the potential opportunities for new industries and innovation in California. Under the Scoping Plan, the California economy, employment, and personal income will continue to grow as California businesses and consumers make clean energy investments and improve efficiency and productivity to reduce energy costs.

In 2030, the California economy is projected to grow to $3.4 trillion, an average growth rate of 2.2 percent per year from 2021 to 2030. It is not anticipated that implementation of the Scoping Plan will change the growth of annual State Gross Domestic Product (GDP). Further, this growth in GDP will occur under the entire projected range of Cap-and-Trade Program allowance prices. Based on this analysis, in 2030 the California economy will take only three months longer to grow to the GDP estimated in the absence of the Scoping Plan–referred to as the Reference Scenario. The impact of the Scoping Plan on job growth is also negligible, with employment less than one half of one percent smaller in 2030 compared to the Reference Scenario.

Additionally, reducing GHG emissions 40 percent below 1990 levels under the Scoping Plan will lead to avoided social damages from climate change on the order of $1.9 to $11.2 billion, as estimated using the SC-CO_2 and SC-CH_4, as well as additional potential savings from reductions in air pollution and petroleum dependence. These impacts are not accounted for in this economic analysis. The estimated impact to California households is also modest in 2030. In 2030, the average annual household impact of the Scoping Plan ranges from $115 to $280, depending on the price of reductions under the Cap-and-Trade Program.[109] Estimated personal income in California is also relatively unchanged by the implementation of the Scoping Plan.

109 Household projections are obtained from the California Department of Finance and were access on March 16, 2017 at: *http://www.dof.ca.gov/Forecasting/Demographics/projections/*.

Overview of Economic Modeling

Two models are used to estimate the economic impact of the Scoping Plan and California's continued clean energy transition: (1) the California PATHWAYS model, and (2) the Regional Economic Models, Inc. (REMI) Policy Insight Plus model. The California PATHWAYS model estimates the direct costs and GHG emissions reductions of implementing the prescriptive (or non-Cap-and-Trade) measures in the Scoping Plan relative to the BAU scenario.[110] Direct costs are the sum of the incremental changes in capital expenditures and fuel expenditures, including fuel savings for reduced energy use from efficiency measures. In most cases, reducing GHG emissions requires the use of more expensive equipment that can be operated using less fuel. In the Scoping Plan, the prescriptive measures modeled in PATHWAYS account for a portion of the GHG reductions required to meet the 2030 target. The remaining reductions are delivered through the Cap-and-Trade Program. The direct costs associated with the Cap-and-Trade Program are calculated outside of PATHWAYS based on an assumed range of Cap-and-Trade allowance prices from 2021 through 2030.

To estimate the future costs of the Scoping Plan, this economic analysis necessarily creates a hypothetical future California that is essentially identical to today, adjusted for currently existing climate policy as well as projected economic and population growth through 2030. The analysis cannot predict the types of innovation that will create efficiencies nor can it fully account for the significant economic benefits associated with reducing emissions. Rather, the economic modeling is conducted by estimating incremental capital and clean fuel costs of measures and assigning those costs to certain sectors within this hypothetical future.

The macroeconomic impacts of the Scoping Plan on the California economy are modeled using the REMI model with output from California PATHWAYS and estimated Cap-and-Trade Program costs as inputs. Additional methodological detail is presented in Appendix E.[111]

Estimated Cost of Prescriptive Measures

As described above, the Scoping Plan combines new measures addressing legislative mandates and the extension of existing measures, including a comprehensive cap on overall GHG emissions from the State's largest sources of pollution. The PATHWAYS model calculates costs and GHG emissions reductions associated with the prescriptive measures in the Scoping Plan. Changes in energy use and capital investment are calculated in PATHWAYS and represent the estimated cost of achieving an estimated 50 to 70 percent of the cumulative GHG reductions required to reach the SB 32 target between 2021 and 2030. The Cap-and-Trade Program delivers any remaining reductions, as shown in Figure 8.

Table 12 outlines the cost of prescriptive measures by sector in 2030, compared to the Reference Scenario, as calculated in PATHWAYS. Estimated capital costs of equipment are levelized over the life of the equipment using a 10 percent discount rate and fuel costs are calculated on an annual basis.[112] The costs in Table 12 are disaggregated into capital costs and fuel costs, which includes the varying costs of gasoline, diesel, biofuels, natural gas, electricity and other fuels.[113] Table 12 assumes that all prescriptive measures deliver anticipated GHG reductions, and does not include any uncertainty in GHG reductions or cost.[114] The impact of uncertainty in GHG reductions is explored in more detail in Appendices E, which include additional detail on measure, cost, and Reference Scenario uncertainty.

The prescriptive measures result in incremental capital investments of $6.7 billion per year in 2030, but these annual capital costs are nearly offset by annual fuel savings of $6.6 billion in 2030. The incremental net cost of prescriptive measures in the Scoping Plan is estimated at $100 million in 2030, which represents 0.03 percent of the projected California economy in 2030. The residential and transportation sectors are anticipated to see net savings in 2030 as fuel savings for these areas vastly outweigh annual capital investment. Several sectors will see a net cost increase from implementation of the prescriptive measures. The industrial sector sees higher fuel costs relative to the Reference Scenario. In the agriculture sector, capital expenditures are due to investments in more efficient lighting and the mitigation of agricultural methane and nitrogen oxides. Agricultural fuel costs increase due to higher electricity and liquid biofuel costs.

110 The PATHWAYS modeling is described in Chapter 2, and additional detail is presented in Appendix D.
111 Additional modeling details are available at the REMI PI+ webpage: *http://www.remi.com/products/pi*.
112 PATHWAYS costs are calculated in real $2012. For this analysis, all costs are reported in $2015. The PATHWAYS costs are inflated using Bureau of Economic Analysis (BEA) data available at: *https://www.bea.gov/iTable/iTable.cfm?ReqID=9#reqid=9&step=1&isuri=1&903=4*.
113 Additional information on the fuels included in PATHWAYS is available at: *www.arb.ca.gov/cc/scopingplan/meetings/1142016/e3pathways.pdf*.
114 More information on the inputs to the California PATHWAYS model is available at: *www.arb.ca.gov/cc/scopingplan/scoping_plan_scenario_description2016-12-01.pdf*.

Table 12: Change in PATHWAYS Sector Costs in 2030 Relative to the Reference Scenario (Billion $2015)[115]

End Use Sector[116]	Levelized Capital Cost	Fuel Cost	Total Annual Cost
Residential	$0.1	-$1.2	-$1.1
Commercial	$1.8	-$1.8	$0.1
Transportation	$3.5	-$3.8	-$0.3
Industrial	$0.8	$0.3	$0.5
Oil and Gas Extraction	$0.0	$0.0	$0.1
Petroleum Refining	$0.0	$0.0	$0.0
Agriculture	$0.3	$0.2	$0.5
TCU (Transportation Communications and Utilities)	$0.1	$0.1	$0.2
Total	$6.7	-$6.6	$0.1

Note: Table values may not add due to rounding.

Estimated Cost of the Cap-and-Trade Program

The direct cost of achieving GHG reductions through the Cap-and-Trade Program is estimated outside of PATHWAYS. The Cap-and-Trade Program sets an economy-wide GHG emissions cap and gives firms the flexibility to choose the lowest-cost approach to reduce emissions. As with the prescriptive measures, the direct costs of any single specific GHG reduction activity under the Cap-and-Trade Program is subject to a large degree of uncertainty. However, as Cap-and-Trade allows covered entities to pursue the reduction options that emerge as the most efficient, overall abatement costs can be bounded by the allowance price. Covered entities should pursue reduction actions with costs less than or equal to the allowance price. An upper bound on the compliance costs under the Cap-and-Trade Program can therefore be estimated by multiplying the range of anticipated allowance prices by the anticipated GHG reductions needed (in conjunction with the reductions achieved through the prescriptive measures) to achieve the SB 32 target.

A large number of factors influence the allowance price, including the ease of substituting lower carbon production methods, consumer price response, the pace of technological progress, and impacts to the price of fuel. Other policy factors that also affect the allowance price include the use of auction proceeds from the sale of State-owned allowances and linkage with other jurisdictions.

Flexibility allows the Cap-and-Trade allowance price to adjust to changes in supply and demand while a firm cap ensures GHG reductions are achieved. This analysis includes a range of allowance prices bounded at the low end by the Cap-and-Trade auction floor price (C+T Floor Price) which represents the minimum sales price for allowances sold at auction and the Allowance Price Containment Reserve Price (C+T Reserve Price), which represents the price at which an additional pool of allowances will be made available to ensure entities can comply with the Cap-and-Trade Program and is the highest anticipated price under the Program. Table 13 outlines the projected allowance prices used in this analysis.[117]

115 PATHWAYS costs reported in $2012 are inflated to $2015 using the Bureau of Economic Analysis (BEA) data available at: *https://www.bea.gov/iTable/iTable.cfm?ReqID=9#reqid=9&step=1&isuri=1&903=4*.

116 Information on the end use sectors are available in the California PATHWAYS documentation available at: *www.arb.ca.gov/cc/scopingplan/scopingplan.htm*.

117 The Cap-and-Trade allowance price range is based on the Cap-and-Trade Regulation approved by the Office of Administrative

Table 13: Estimated Range of Cap-and-Trade Allowance Price 2021–2030*

($2015)	2021	2025	2030
C+T Floor Price	$16.2	$19.7	$25.2
C+T Reserve Price	$72.9	$76.4	$81.9

* Based on current regulation in effect October 1, 2017

Uncertainty in the GHG reduction potential of prescriptive measures in the Scoping Plan can affect the cost of achieving the 2030 target. The aggregate emissions cap of the Cap-and-Trade Program ensures that the 2030 target will be met–irrespective of the GHG emissions realized through prescriptive measures. If GHG reductions anticipated under prescriptive measures do not materialize, the Cap-and-Trade Program will be responsible for a larger share of emissions reductions. Under that scenario, the demand for Cap-and-Trade allowances may rise, resulting in an increase in allowance price. While the Cap-and-Trade allowance price may rise, it is highly unlikely that it will rise above the C+T Reserve price, given the program design. If prescriptive measures deliver anticipated GHG reductions, demand for allowances will be low, depressing the price of allowances. However, the C+T Floor Price represents the lowest price at which allowances can be sold at auction.

Table 14 presents the estimated direct cost estimates for GHG reductions achieved through the Cap-and-Trade Program in 2030. These costs represent the lower and upper bounds of the cost of reducing GHG emissions to achieve the SB 32 target under the Scoping Plan. The estimated direct costs range from $1.6 to $5.1 billion dollars (in $2015), depending on the allowance price in 2030. This range highlights the allowance price uncertainty that is a trade-off to the GHG reduction certainty provided by the Cap-and-Trade Program. The estimated cost of GHG reductions is calculated by multiplying the allowance price by the GHG emissions reductions required to achieve the SB 32 target.

Sensitivity Analysis

In addition to uncertainty in the Cap-and-Trade allowance price and uncertainty in the GHG reductions achieved through the prescriptive measures, there is uncertainty in the GHG emissions that will occur under the Reference Scenario, as presented in Figure 6. There is also uncertainty in costs embedded within the Reference Scenario including the price of oil, other energy costs, and technology costs.

The PATHWAYS incremental cost results are also sensitive to the fossil fuel price assumptions. Altering the fuel price trajectory in the Reference Scenario directly impacts the incremental cost of achieving GHG reductions in the Scoping Plan, as the costs of the Scoping Plan are relative to the Reference Scenario.[118]

The PATHWAYS scenarios use fossil fuel price projections from the Annual Energy Outlook (AEO) 2015 reference case.[119] To estimate the impact of changes in future fuel prices on the estimated incremental cost of the Scoping Plan two sensitivities were conducted. In the low fuel price sensitivity, the AEO low oil and natural gas price case is used to project the future cost of fuels in the Reference Scenario. The cost of the Scoping Plan, relative to the Reference Scenario, increases under these conditions, since fuel savings are less valuable when fuel prices are low. A second sensitivity shows that high future oil and natural gas prices (as projected in the AEO high oil price case) reduce the net cost of the Scoping Plan, relative to the Reference Scenario. This is because avoided fuel savings are more valuable when fuel prices are high. Table 14 outlines the costs and savings from the Scoping Plan (both prescriptive measures and cap-and-trade) under the high and low fuel price sensitivities.

The price of oil and natural gas affects the value of fuel savings (as presented in Table 12), which are estimated to be significant using AEO reference oil and natural gas prices. Under the low fuel price sensitivity,

Law on September 18, 2017. Documentation is available at: *www.arb.ca.gov/regact/2016/capandtrade16/capandtrade16.htm*

118 In addition to the fuel cost sensitivities presented in this section, Appendix E includes an uncertainty analysis of the Scoping Plan Scenario and alternatives. This analysis addresses uncertainty in the Reference Scenario emissions, GHG reductions from each measure, as well as capital and fuel costs.

119 The high and low fuel price sensitivity ranges are derived from differences between the AEO 2016 High Oil Price or Low Oil Price forecast and the AEO 2016 reference case, and are applied as ratios to the base case fuel price assumptions (which are based on the AEO 2015 report). The AEO 2015 report is available at: *http://www.eia.gov/outlooks/aeo/pdf/0383(2015).pdf* and the AEO 2016 report is available for download at: *http://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf*.

the net incremental cost of prescriptive measures is $2.9 billion in 2030. Under the high fuel price sensitivity, the prescriptive measures result in net *savings of* $4.9 billion in 2030. Table 14 also shows that these price uncertainties are captured within the analyzed range of allowance prices. As described above, changes in fuel prices may affect the price of Cap-and-Trade allowances, but the price is highly unlikely to go outside the range of prices bounded by the C+T Floor Price and C+T Reserve Price. The final column in Table 14 presents the estimated direct cost of the Scoping Plan, including both the prescriptive measures and a range of estimated costs to achieve GHG reductions under the Cap-and-Trade Program for varying projections of future fuel prices. The total cost, reflecting fuel and allowance price uncertainty, ranges from an annual savings to California of $3.3 billion to an annual cost of $8.0 billion in 2030. The net climate benefits, as estimated by the SC-CO_2 and SC-CH_4, outweigh these direct costs.[120]

Table 14: Estimates of Direct Cost and Climate Benefits in 2030 Relative to the Reference Scenario and Including Fuel Price Sensitivity (Billion $2015)

Scenario	Prescriptive Measures	C+T Floor Price	C+T Reserve Price	2030 Total Cost
Scoping Plan	$0.1	$1.6	$5.1	$1.7 to $5.2
Low Fuel Price Sensitivity	$2.9	$1.6	$5.1	$4.5 to $8.0
High Fuel Price Sensitivity	-$4.9	$1.6	$5.1	-$3.3 to -$0.2

Fuel price sensitivity is directly modeled in PATHWAYS, resulting in a range of impacts from prescriptive measures. The range of costs labeled "2030 Total Cost" includes the cost of prescriptive measures estimated in PATHWAYS and the impact of the Cap and-Trade Program calculated at the C+T Floor Price (the lower bounds) and the C+T Reserve Price (the upper bounds).
The social cost of GHGs estimated range in 2030 is $1.9 to $11.2 billion.

Macroeconomic Impacts

The macroeconomic impacts of the Scoping Plan are estimated using the REMI model. Annual capital and fuel costs (for example, the costs in Table 12) are estimated using PATHWAYS and input into the REMI model to estimate the impact of the Scoping Plan on the California economy each year relative to GDP, which is often used as a proxy for economic growth, as well as employment, personal income, and changes in output by sector and consumer spending. Table 15 presents key macroeconomic impacts of implementing the Scoping Plan, based on the range of anticipated allowance prices. In 2030, under the Scoping Plan, growth across the indicators is about one-half of one percent less than the Reference Scenario. The results in Table 15 include not only the estimated direct cost of the Cap-and-Trade Program, but also distribution of allowance value from the auction of Cap-and-Trade allowances to California and consumers. See Appendix E for more detail on the modeling of the return of allowance value under the Cap-and-Trade Program in REMI.

The Cap-and-Trade Program is modeled in REMI as an increase in production cost to sectors based on estimated future GHG emissions and anticipated free allowance allocation. If a sector is expected to receive free allocation of allowances, the value of those free allowances is not modeled as a cost in REMI. The analysis does include the estimated benefit to sectors due to the proceeds from the auction of cap-and-trade allowances and assumes that each year $2 billion of proceeds from the auction of State-owned cap-and-trade allowances are distributed to the economic sectors currently receiving GGRF appropriations. These funds work to achieve further GHG reductions in California, lower the cost to businesses of reducing GHG emissions and protect disadvantaged communities. Any auction proceeds remaining after the distribution of $2 billion through GGRF sectors are distributed evenly to consumers in California as a dividend. The estimated costs in Table 15 include the cost of the GHG reductions to sectors, as well as the benefit to those sectors when allowance proceeds are returned through the GGRF and as a dividend to consumers, as detailed in Appendix E.

120 Climate benefits are estimated using the Social Cost of Carbon in 2030 across the range of discount rates from 2.5 to 5 percent. All values are reported in $2015. Additional information on the Social Cost of Carbon is available from the National Academies of Sciences, Engineering, and Medicine at: *https://www.nap.edu/catalog/24651/valuing-climate-damages-updating-estimation-of-the-social-cost-of*.

Table 15: Macroeconomic Indicators in 2030 Under Base Fuel Price Assumptions

	Reference Scenario (2030)	Scoping Plan (2030)	Percentage Change Relative to Reference Scenario
California GDP (Billion $2015)	$3,439	$3,430 to $3,420	-0.3 percent to -0.6 percent
Employment (Thousand Jobs)	23,522	23,478 to 23,441	-0.2 percent to -0.3 percent
Personal Income (Billion $2015)	$3,010	$3,006 to $3,008	-0.1 percent to -0.1 percent

Table 15 was estimated using the REMI model. The range of costs for the Scoping Plan represents the impact of achieving the SB 32 target through prescriptive measures and the Cap-and-Trade Program at the C+T Floor Price (the lower bounds) and the C+T Reserve Price (the upper bounds).

It is important to put the results of Table 15 into context of the growing $3.4 trillion California economy in 2030. As noted earlier, the economic analysis does not include avoided social damages and other potential savings from reductions in air pollution and petroleum dependency.

Determining employment changes as a result of policies is challenging to model, due to a range of uncertainties and global trends that will influence the California economy, regardless of implementation of the Scoping Plan. The global economy is seeing a shift toward automation and mechanization, which may lead to slowing of employment across some industries globally, irrespective of California's energy and low carbon investments. In California, employment is projected to reach 23.5 million jobs in 2030. In this analysis, implementing the Scoping Plan would slow the growth of employment by less than one-half of one percent in 2030.

Estimated personal income in California is relatively unchanged under the Scoping Plan relative to the Reference Scenario. Considering the uncertainty in the modeling, modest changes in the growth of personal income are not different from zero, which suggests that meeting the SB 32 target will not change the growth of personal income relative to the Reference Scenario.

When analyzing the estimated macroeconomic impacts, it is important to remember that a major substitution of electricity and capital away from fossil fuels is anticipated to have a very small effect on California GDP, employment, and personal income–less than one percent relative to the Reference Scenario in 2030. The economic impacts indicate that shifting money and investment away from fossil fuels and to clean energy is likely to have a negligible effect on the California economy. Additionally, it is certain that innovation will continue as new technologies are developed and implemented. While this analysis projects the costs and GHG reductions of current technologies over time, it does not capture the impact of new technologies that may shift the economy and California in unanticipated ways or benefits related to changes in air pollution and improvements to human health, avoided environmental damages, and positive impacts to natural and working lands. Thus, the results of this analysis very likely underestimate the benefits of shifting to a clean energy economy.

Consumer spending also shifts in response to implementation of the Scoping Plan relative to the Reference Scenario. As presented in Table 15, there is a negligible impact to consumer income, but small changes in income can alter the distribution of consumer spending among categories. In 2030, consumer spending is lower under the Scoping Plan than in the Reference Scenario across all analyzed allowance prices. Consumers spend less on fuels, electricity, natural gas, and capital as a result of measures in the Scoping Plan that reduce demand, increase efficiency, and drive technological innovations. The estimated impact to California households is also modest in 2030. The estimated cost to California households in 2030 ranges from $115 to $280, depending on the price of reductions under the Cap-and-Trade Program.[121]

The household impact is estimated using the per-household change in personal income as modeled in REMI and utilizing household estimates from the California Department of Finance. The household impact does not account for benefits from reduced climate impacts, health savings from reduced air pollution impacts, or lower petroleum dependence costs that might impact households. Additional details are presented in Appendix E.

As modeled, the household impact of the Scoping Plan comprises approximately one percent of average household expenditures in 2030. To ensure that vulnerable populations and low-income households are not

121 Household projections are obtained from the California Department of Finance and are available at: *http://www.dof.ca.gov/Forecasting/Demographics/projections/*.

disproportionately affected by California's climate policy, CARB is taking steps to better quantify localized economic impacts and ensure that low-income households see tangible benefits from the Scoping Plan. Researchers at the University of California, Los Angeles (UCLA) are currently working on a retrospective analysis that will estimate the impacts across California communities of the implementation of AB 32, which will help identify areas of focus as 2030 measures are developed. The Cap-and-Trade Program will also continue to provide benefit to disadvantaged communities through the disbursement of GGRF funds.

The investments made in implementing the Scoping Plan will have long-term benefits and present significant opportunities for California investors and businesses, as upfront capital investments will result in long-term fuel and energy efficiency savings, the benefits of which will continue into the future. The California economy will continue to grow under the Scoping Plan, but it will grow more resilient, more sustainable, and will be well positioned to reap the long-term benefits of lower carbon investments.

Economic Modeling of Health Impacts

Health benefits associated with reductions in diesel particulate matter (DPM) and nitrogen oxides (NO_x) are monetized for inclusion in the macroeconomic modeling. The health benefits are estimated by quantifying the harmful future health effects that will be avoided by reducing human exposure to DPM and NO_x, as detailed in Appendix G, and monetized by estimating a health effect's economic value to society. As previously noted the health impacts are based on air quality benefits estimated in Table 6, which have important limitations and likely overestimate the impacts of the Scoping Plan. Additional detail on the economic modeling of health impacts, including the monetization methodology and modeling results for all Scoping Plan scenarios, is presented in Appendix E. Including the monetized health impacts in the REMI modeling has no discernible impact on the overall results. The impact of including the monetized health impacts is indiscernible relative to the impact of the Scoping Plan.

Estimating the Economic Impact on Disadvantaged Communities (DACs)

Implementing the Scoping Plan is estimated to have a small impact on the Statewide California economy through 2030. However, shifting from fossil fuels can disproportionately affect specific geographic regions whose local economies rely on fossil fuel intensive industries. These regions can also include vulnerable populations and disadvantaged communities who may be disproportionately impacted by poor air quality and climate.

The regional impacts of the Scoping Plan, including the impact to disadvantaged communities, are estimated using the REMI California County model, which represents the 58 counties and 160 sectors of the California economy. Utilizing the same inputs used for modeling the statewide impact of the Scoping Plan relative to the Reference Scenario, the California County model estimates how measures will affect employment, value added, and other economic indicators at the county level across the state.

The county-level REMI output is also used to estimate impacts on disadvantaged communities affected by the Scoping Plan by allocating county impacts proportional to their share of economic indicators unique to each census tract.[122] These indicators include industry output, industry consumption by fuel category, personal consumption, and population. The overall impact on employment across regions is not significant and there is no discernible difference in the impact to employment in disadvantaged communities. There is also no discernible impact to wages in disadvantaged communities across regions in California. Additional details on the regional modeling, including the results for the Scoping Plan and alternatives, is presented in Appendix E.

In addition to the regional modeling conducted in this analysis, there are currently three research contracts underway at CARB to quantify the impact of California's climate policy on regions and disadvantaged communities throughout California. As mentioned above, researchers from UCLA are estimating the improvements in health outcomes associated with AB 32, with a focus on disadvantaged communities. This research will be informed by input from technical advisory committees including a group focused on environmental justice.

122 Census tracts are small geographic areas within greater metropolitan areas that usually have a population between 2,500 and 8,000 persons. More information on the composition of census tracts available here: *https://www.census.gov/geo/reference/gtc/gtc_ct.html*. Disadvantaged census tracts are identified using CalEnviroScreen 2.0. Additional information is available at: *https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-version-20*.

There are also two studies currently underway to quantify the impact of GGRF funds. A UCLA contract focuses on quantifying jobs supported by GGRF funds in California, while a University of California, Berkeley contract is constructing methodologies to assess the co-benefits of GGRF projects across California. These research efforts will provide a regional analysis of the impact of and benefits to specific communities and sectors to ensure that all Californians see economic benefits, in addition to clean air benefits, from the implementing the Scoping Plan.

Public Health

Many measures to reduce GHG emissions also have significant health co-benefits that can address climate change *and* improve the health and well-being of all populations across the State. Climate change is already affecting the health of communities.[123] Climate-related health impacts can include increased heat illness and death, increases in air pollution-related exacerbation of cardiovascular and respiratory diseases, injury and loss of life due to severe storms and flooding, increased vector-borne and water-borne diseases, and stress and mental trauma due to extreme weather-related catastrophes.[124] The urgency of action to address the impacts already being felt from a changing climate and the threats in coming decades provides a unique opportunity for California's leadership in climate action to reduce GHG emissions and create healthy, equitable, and resilient communities where all people thrive. This section discusses the link between climate change and public health. It does not analyze the specific measures included in the strategy but provides context for assessing the potential measures and scenarios.

Achieving Health Equity through Climate Action

Many populations in California face *health inequities,* or unfair and unjust health differences between population groups that are systemic and avoidable.[125] Differences in environmental and socioeconomic determinants of health result in these health inequities. Those facing the greatest health inequities include low-income individuals and households, the very young and the very old, communities of color, and those who have been marginalized or discriminated against based on gender or race/ethnicity.[126] It is these very same populations, along with those suffering existing health conditions and certain populations of workers (e.g., outdoor workers), that climate change will most disproportionately impact.[127] The inequitable distribution of social, political, and economic power results in health inequities, while perpetuating systems (e.g., economic, transportation, land use, etc.) that drive GHG emissions. As a result, communities face inequitable living conditions. For example, low-income communities of color tend to live in more polluted areas and face climate change impacts that can compound and exacerbate existing sensitivities and vulnerabilities.[128,129] Fair and healthy climate action requires that the inequities creating and intensifying community vulnerabilities be addressed. Living conditions and the forces that shape them, such as income, education, housing, transportation, environmental quality, and access to services, significantly drive the capacity for climate resilience. Thus, strategies such as alleviating poverty, increasing access to opportunity, improving living conditions, and reducing health and social inequities will result in more climate-resilient communities. In fact, there are already many "no-regret" climate mitigation and adaptation measures available (discussed below) that can reduce health burdens, increase community resilience, and address social inequities.[130] Focusing efforts to achieve health equity can thus lead to significant progress in addressing human-caused climate change.

123 USGCRP. 2016. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Crimmins, A., J. Balbus, J. L. Gamble, C. B. Beard, J. E. Bell, D. Dodgen, R. J. Eisen, N. Fann, M. D. Hawkins, S. C. Herring, L. Jantarasami, D. M. Mills, S. Saha, M. C. Sarofim, J. Trtanj, and L. Ziska, Eds. U.S. Global Change Research Program, Washington, D.C., 312 pp.
124 Ibid.
125 Whitehead, M. 1992. "The concepts and principles of equity and health." International Journal of Health Services 22(3), 429–445.
126 California Department of Public Health (CDPH). 2015. The Portrait of Promise: The California Statewide Plan to Promote Health and Mental Health Equity. A Report to the Legislature and the People of California by the Office of Health Equity. Sacramento, CA: California Department of Public Health, Office of Health Equity.
127 Shonkoff, S., R. Morello-Frosch, M. Pastor, and J. Sadd. 2011. "The climate gap: Environmental health and equity implications of climate change and mitigation policies in California–a review of the literature." Climatic Change 109 (Suppl 1):S485–S503.
128 Ibid.
129 Rudolph, L. and S. Gould. 2015. "Climate change and health inequities: A framework for action." Annals of Global Health 81:3, 432–444.
130 Watts N, Adger WN, Agnolucci P, et al. 2015. Health and climate change: policy responses to protect public health. Lancet: 386, 1861-1914

Potential Health Impacts of Climate Change Mitigation Measures

Socioeconomic Factors: Income, Poverty, and Wealth

Economic factors, such as income, poverty, and wealth, are collectively one of the largest determinants of health. As such, climate mitigation measures that yield economic benefits can improve population health significantly, especially if the economic benefits are directed to those most vulnerable and disadvantaged (including those living in poverty) who often face the most health challenges. From the poorest to richest ends of the income spectrum, higher income is associated with greater longevity in the United States.[131,132,133] The gap in life expectancy between the richest 1 percent and poorest 1 percent of Americans was almost 15 years for men in 2014, and about 10 years for women.[134] Early death among those living in poverty is not a result of those with higher incomes having better access to quality health care.[135] Only about 10-20 percent of a person's health status is accounted for by health care (and 20-30 percent attributed to genetics), while the remainder is attributed to the social determinants of health. These include environmental quality, social and economic circumstances, and the social, media, policy, economic, retail, and built environments– all of which in turn shape stress levels and behaviors, including smoking, diet, and exercise.[136,137,138,139,140,141,142,143,144,145,146] In fact, where people live, work, learn, and play is often a stronger predictor of life expectancy than their genetic and biological makeup.[147] The World Health Organization's Commission on the Social Determinants of Health concluded that the poor health of poor people, and the social gradient in health, are caused by the unequal distribution of power, income, goods, and services resulting from poor social policies and programs, unfair economic arrangements, and bad politics.[148] Thus, improving the conditions of daily life and tackling the inequitable distribution of power, money, and resources can remedy inequitable health outcomes.[149] Simply put, the more evenly distributed the wealth, the healthier a society is.[150]

The wealth-health gradient has significant implications for this Scoping Plan. State climate legislation and policies require prioritizing GHG reduction strategies that serve vulnerable populations and improve well-being for disadvantaged communities. As such, strategies that improve the financial security of communities facing disadvantages while reducing GHG emissions are win-win strategies. These include providing funds or services for GHG reduction programs (e.g., weatherization, energy efficiency, renewable energy, ZEVs, transit, housing, and others) to low-income individuals and households to help them reduce costs. Among the poorest 25 percent of people, per capita government expenditures are strongly associated with longer

131 Chetty, R., M. Stepner, S. Abraham, et al. 2016. "The Association Between Income and Life Expectancy in the United States, 2001–2014." JAMA Published online April 10, 2016. doi:10.1001/jama.2016.4226.
132 Marmot, M., S. Friel, R. Bell, et al. 2008. "Closing the gap in a generation: Health equity through action on the social determinants of health." The Lancet 372, 9650: 1661–1669.
133 Woolf, S. H., and P. Braveman. 2011. "Where health disparities begin: The role of social and economic determinants–and why current policies may make matters worse." Health Affairs (Millwood) 30(10), 1852–1859.
134 Chetty R, Stepner M, Abraham S, et al. 2016. The Association between Income and Life Expectancy in the United States, 2001-2014. JAMA. Published online April 10, 2016. doi:10.1001/jama.2016.4226
135 Ibid.
136 DHHS, Public Health Service. 1980. Ten leading causes of death in the United States. Atlanta, GA: Bureau of State Services.
137 McGinnis, J., and W. Foege. 1993. "Actual causes of death in the United States." JAMA 270(18), 2207–2212.
138 Lantz, P. et al. 1998. "Socioeconomic factors, health behaviors, and mortality: Results from a nationally representative prospective study of US adults." JAMA 279(21), 1703–1708.
139 McGinnis, J. et al. 2002. "The case for more active policy attention to health promotion." Health Affairs 21(2), 78–93.
140 Mokdad, A. et al. 2004. "Actual causes of death in the United States, 2000." JAMA 291(10), 1238–1245.
141 Danaei, G. et al. 2009. "The preventable causes of death in the United States: Comparative risk assessment of dietary, lifestyle, and metabolic risk factors." PLoS Medicine 6(4), e1000058.
142 World Health Organization (WHO). 2009. Global health risks: Mortality and burden of disease attributable to selected major risks. Geneva: WHO.
143 Booske, B. et al. 2010. Different perspectives for assigning weights to determinants of health. County Health Rankings Working Paper. Madison, WI: University of Wisconsin Population Health Institute.
144 Stringhini, S. et al. 2010. "Association of socioeconomic position with health behaviors and mortality." JAMA 303(12), 1159–1166.
145 Thoits, P. 2010. "Stress and health: Major findings and policy implications." *Journal of Health and Social Behavior* 51 Suppl, S41–53.
146 McGovern, L., G. Miller and P. Highes-Cromwick. 2014. "Health policy brief: The relative contribution of multiple determinants to health outcomes." Health Affairs
147 Iton, A. 2006. Tackling the root causes of health disparities through community capacity building. In: Hofrichter R, ed. Tackling Health Inequities Through Public Health Practice: A Handbook for Action. Washington, D.C., and Lansing, MI: National Association of County and City Health Officials and Ingham County Health Department; 116–136.
148 Marmot M, Friel S, Bell R, et al. 2008. Closing the gap in a generation: health equity through action on the social determinants of health. The Lancet , Volume 372 , Issue 9650, 1661 – 1669
149 Ibid.
150 Smith, R. 1996. "The big idea." British Medical Journal 312:April 20th, Editor's choice.

life spans.[151] Successful strategies California has already implemented to assure the poor do not pay higher costs for societal GHG reductions include low-income energy discount programs, in combination with direct climate credits, and policies and programs that help Californians reduce electricity, natural gas, and gasoline consumption.[152] More such strategies could be pursued. To tackle the inequitable distribution of power that leads to disparate health outcomes, agencies can first assure their hearing and decision-making processes provide opportunities for civic engagement so people facing health inequities can themselves participate in decision-making about solutions. Whether it is absolute poverty or relative deprivation that leads to poor health, investments and policies that both lift up the poor and reduce wealth disparities will address the multiple problems of climate change mitigation, adaptation, and health inequities.

Employment

Employment status impacts human health in many ways. Poor health outcomes of unemployment include premature death, self-rated ill-health (a strong predictor of poor health outcomes), and mental illness.[153,154,155,156] Economic strain related to unemployment can impact mental health and trigger stress that is linked to other health conditions.[157,158] Populations of color are overrepresented in the unemployment and under-employment ranks, which likely contributes to racial health inequities. In 2014, 14.7 percent of African-Americans, 12.1 percent of American Indians and Alaska Natives, and 9.8 percent of Latinos were unemployed, compared to 7.9 percent of Whites.[159] In addition to providing income, the work experience has health consequences. There is a *work status–health gradient* similar to the wealth–health gradient. Workers with lower occupational status have a higher risk of death,[160] increased blood pressure,[161] and more heart attacks.[162,163] Higher status workers often have a greater sense of autonomy, control over their work, and predictability, compared to lower status workers, whose lack of control and predictability translates to stress that shortens their lives.[164] Nonstandard working arrangements such as part-time, seasonal, shift, contract, or informal sector work have been linked to greater psychological distress and poorer physical health.[165,166] Women are heavily overrepresented in nonstandard work, as are people of color and people with low levels of education.[167,168]

The implementation of California's climate change goals provides great opportunity to not only improve the habitability of the planet, but also to increase economic vitality, employ historically disadvantaged people

151 Chetty R, Stepner M, Abraham S, et al. 2016. The Association between Income and Life Expectancy in the United States, 2001-2014. JAMA. Published online April 10, 2016. doi:10.1001/jama.2016.4226

152 Gattaciecca, J., C. Callahan, and J. R. DeShazo. 2016. Protecting the most vulnerable: A financial analysis of Cap-and-Trade's impact on households in disadvantaged communities across California. UCLA Luskin School of Public Affairs: Los Angeles, CA. *http://innovation.luskin.ucla.edu/content/protecting-most-vulnerable*. Accessed April 22, 2016.

153 Krueger, P., and S. Burgard. 2011. Income, occupations and work. In: Rogers R, Crimmins E, eds. International Handbook of Adult Mortality. New York: Springer: 263–288.

154 Rogers, R., R. Hummer, and C. Nam. 2000. Living and Dying in the USA. Behavioral, health, and social differentials of adult mortality. New York, NY: Academic.

155 Ross, C. and J. Mirowsky. 1995. "Does employment affect health?" Journal of Health and Social Behavior 36(3):230–243.

156 Burgard, S., and K. Lin. 2013. "Bad jobs, bad health? How work and working conditions contribute to health disparities." Am Behav Sci 57(8).

157 Price, R., D. Friedland, J. Choi, and R. Caplan. 1998. Job-loss and work transitions in a time of global economic change.

158 Price, R., J. Choi, and A. Vinokur. 2002. "Links in the chain of adversity following job loss: How financial strain and loss of personal control lead to depression, impaired functioning, and poor health." Journal of Occupational Health Psychology 7(4), 302.

159 U.S. Census Bureau. 2014. American Community Survey 1-Year Estimates. *http://www2.census.gov/programs-surveys/acs/summary_file/2014/data/*. Last updated August 31, 2015. Accessed April 20, 2016.

160 Rogers R, Hummer R, and Nam C. 2000. Living and Dying in the USA. Behavioral, health, and social differentials of adult mortality. New York, NY: Academic

161 Colhoun, H., H. Hemingway, and N. Poulter. 1998. "Socio-economic status and blood pressure: An overview analysis." Journal of Human Hypertension 12(2).

162 Möller, J., T. Theorell, U. De Faire, A. Ahlbom, and J. Hallqvist. 2005. "Work related stressful life events and the risk of myocardial infarction. Case-control and case-crossover analyses within the Stockholm heart epidemiology programme (SHEEP)." Journal of Epidemiology and Community Health 59(1), 23–30.

163 Burgard S, Lin K. 2013. Bad jobs, bad health? How work and working conditions contribute to health disparities. Am Behav Sci: 57(8).

164 Marmot, M., G. Rose, M. Shipley, and P. Hamilton. 1978. "Employment grade and coronary heart disease in British civil servants." Journal of Epidemiology and Community Health 32(4), 244–249.

165 Dooley, D., and J. Prause. 2004. Settling down: Psychological depression and underemployment. The social costs of underemployment, 134-157. In: Dooley, D. and J. Prause. The Social Costs of Underemployment: Inadequate Employment as Disguised Unemployment.

166 Virtanen, M., M. Kivimäki, M. Joensuu, P. Virtanen, M. Elovainio, and J. Vahtera. 2005. "Temporary employment and health: A review." International Journal of Epidemiology 34(3): 610–622.

167 Nollen, S. 1996. "Negative aspects of temporary employment." Journal of Labor Research 17(4): 567–582.

168 Burgard S, Lin K. 2013. Bad jobs, bad health? How work and working conditions contribute to health disparities. Am Behav Sci: 57(8)

in secure jobs, and improve the health of the population. Measures in the Scoping Plan that aim to reduce GHGs can simultaneously improve health and social equity by prioritizing or requiring that: (1) infrastructure projects using public funds pay living wages, provide quality benefits to all employees, and minimize nonstandard work; (2) locals are hired as much as is feasible; (3) preference is given for women-owned and minority-owned businesses; (4) employers receiving public funds assess and reduce work stress and lack of workplace control; (5) projects benefiting from State climate investments prioritize hiring from historically hard-to-employ groups, such as youth (especially youth of color), formerly incarcerated people, and people with physical or mental illness; and (6) training is provided to these same groups to work in jobs in sectors that will support a sustainable economy.

Communications Supporting Climate Change Behaviors and Policies

California's leadership on GHG reductions is exceptional. However, climate mitigation goals are often treated independently by sector, and the public does not see a unified message that changes must take place on every level in every sector to preserve human health and well-being. Climate strategy could be supported by public communications campaigns that link sectors and present a message of the need for bold action, along with the benefits that action can yield. Mass media communications and social marketing campaigns can help shift social and cultural norms toward sustainable and healthy practices. Messaging about the co-benefits of climate change policies in improving health and well-being can lead to increased community and decision-maker support among vulnerable groups for policies and measures outlined in the Scoping Plan.

Community Engagement Leads to Robust, Lasting, and Effective Climate Policies

For California's climate change policies to be supported by the public and be implemented with enthusiasm, they must be developed through ample, genuine opportunities for community members to discuss and provide input. Californians' contributions to the policy arena strengthen the end products and assist in their implementation and enforcement.

Efforts to mitigate climate change through policy, environmental, and systems change present considerable opportunities to promote sustainable, healthy, resilient, and equitable communities. The measures in the Scoping Plan, and the way they are implemented, can help create living conditions that facilitate physical activity; encourage public transit use; provide access to affordable, fresh, and nutritious foods; protect the natural systems on which human health depends; spur economic development; provide safe, affordable, and energy-efficient housing; enable access to jobs; and increase social cohesion and civic engagement. These climate change mitigation measures can improve overall population health, as well as material conditions, access to opportunity, and health and well-being in communities facing health inequities. Approaching the policy solutions outlined in the Scoping Plan with a health and equity lens can ultimately help lead to a California in which all current and future generations of Californians can benefit and thrive.

Environmental Analysis

CARB, as the lead agency, prepared a Draft Environmental Analysis (Draft EA) in accordance with the requirements of the California Environmental Quality Act (CEQA) and CARB's regulatory program (CARB's program has been certified as complying with CEQA by the Secretary of Natural Resources; see California Code of Regulation, title 17, sections 60006-60008; California Code of Regulation, title 14, section 15251, subdivision (d)). The resource areas from the CEQA Guidelines Environmental Checklist were used as a framework for a programmatic environmental analysis of the reasonably foreseeable compliance responses resulting from implementation of the measures proposed in the Scoping Plan to achieve the 2030 target. Following circulation of the Draft EA for an 80-day public review and comment period (January 20, 2017 through April 10, 2017), CARB prepared the Final Environmental Analysis Prepared for the Proposed Strategy for Achieving California's 2030 Greenhouse Gas Target (Final EA), which includes minor revisions to the Draft EA, and the Response to Comments on the Draft Environmental Analysis prepared for the Proposed Strategy for Achieving California's 2030 Greenhouse Gas Target (RTC). The Final EA is included as Appendix F to the 2017 Scoping Plan. The Final EA and RTC were posted on CARB's Scoping Plan webpage before the Board hearing in December 2017.

The Final EA provides a programmatic level of analysis of the adverse environmental impacts that are reasonably foreseeable as resulting from implementation of the proposed Scoping Plan measures; feasible mitigation measures; a cumulative impacts analysis and an alternatives analysis.

Collectively, the Final EA concluded that implementation of these actions could result in the following short-term and long-term beneficial and adverse environmental impacts:

- Beneficial long-term impacts to air quality, energy demand and greenhouse gas emissions.
- Less than significant impacts to energy demand, resources related to land use planning, mineral resources, population and housing, public services, and recreational services.
- Potentially significant and unavoidable adverse impacts to aesthetics, agriculture and forest resources, air quality, biological resources, cultural resources, geology and soils, hazards and hazardous materials, hydrology and water quality, resources related to land use planning, noise, recreational services, transportation/traffic, and utilities and service systems.

The potentially significant and unavoidable adverse impacts are disclosed for both short-term construction-related activities and long-term operational activities, which explains why some resource areas are identified above as having both less-than-significant impacts and potentially significant impacts. For a summary of impacts, please refer to the table in Attachment B to the Final EA.

Chapter 4

Key Sectors

Climate change mitigation policies must be considered in the context of the sector's contribution to the State's total GHGs, while also considering any co-benefits for criteria pollutant and toxic air contaminant reductions. The transportation, electricity (in-state and imported), and industrial sectors are the largest contributors to the GHG inventory and present the largest opportunities for GHG reductions. However, to ensure decarbonization across the entire economy and to meet our 2030 GHG target, policies must be considered for all sectors. Policies that support energy efficiency, alternative fuels, and renewable power also can provide co-benefits for both criteria and toxic air pollutants.

The specific policies identified in this Scoping Plan are subject to additional analytical and public processes to refine the requirements and methods of implementation. For example, a change in the LCFS Carbon Intensity (CI) target would only take effect after a subsequent rulemaking for that regulation, which would include its own public process and environmental, economic, and public health analyses. As described in Chapter 2, many policies for reducing emissions toward the 2030 target are already known. This Scoping Plan identifies these and additional policies or program enhancements needed to achieve the remaining GHG reductions in a complementary, flexible, and cost-effective manner to meet the 2030 target. These policies should continue to encourage reductions beyond 2030 to keep us on track to stabilize the climate. Policies that ensure economy-wide investment decisions that incorporate consideration of GHG emissions are particularly important.

As we pursue GHG reduction targets, we must acknowledge the integrated nature of our built and natural environments, and cross-sector impacts of policy choices. The State's Green Buildings Strategy is one such example of this type of integrated approach. Buildings have tremendous cross-sector interactions that influence our health and well-being and affect land use and transportation patterns, energy use, water use, communities, and the indoor and outdoor environment. Green building regulations and programs offer complementary opportunities to address the direct and indirect effects of buildings on the environment by incorporating strategies to minimize overall energy use, water use, waste generation, and transportation impacts. The Governor's Green Buildings Executive Order B-18-12 for State buildings and the California Green Building Standards (CALGreen) Code[169] are key state initiatives supporting emissions reductions associated with buildings. Local governments are taking action by adopting "beyond code" green building standards. Additional efforts to maintain and operate existing buildings as third-party certified green buildings provides a significant opportunity to reduce GHG emissions associated with buildings. These foundational regulations and programs for reducing building-related emissions are described in more detail in Appendix H. Looking forward, there is a need to establish a path toward transitioning to zero net carbon buildings[170], which will be the next generation of buildings that can contribute significantly to achieving long-term climate goals. A discussion of how the green buildings strategy can support GHG reductions to help meet the 2030 target is provided in Appendix I. Recent research activities have provided results to better quantify GHG emissions reductions of green buildings, and additional research activities need to continue to expand their focus to support technical feasibility evaluations and implementation. Research needs related to green buildings are included in Appendix I.

Further, each of the policies directed at the built environment must be considered in the broader context of the high-level goals for other sectors, including the natural and working lands sector. For example, policies that support natural and working lands can reduce emissions and sequester carbon, while also providing ecosystem benefits such as better water quality, increased water yield, soil health, reduced erosion, and

169 The authority to update and implement the CALGreen Code is the responsibility of several State agencies identified in California Building Standards Law.

170 A zero carbon building generates zero or near zero GHG emissions over the course of a year from all GHG emission sources associated, directly and indirectly, with the use and occupancy of the building (initial definition included in the May 2014 *First Update to the Climate Change Scoping Plan*).

habitat connectivity. These policies and co-benefits will be considered as part of the integrated strategy outlined above. Table 16 provides examples of the cross-sector interactions between and among the main sectors analyzed for the Scoping Plan that are discussed in this chapter (Energy, Transportation, Industry, Water, Waste Management, and Natural and Working Lands, including agricultural lands).

This chapter recognizes these interactions and relates these broad strategic options to the specific additional programs recommended in Chapter 2 of this document. Accordingly, Chapter 4 provides an overview of each sector's contributions to the State's GHG emissions, a description of both ongoing and proposed programs and policies to meet the 2030 target, and additional climate policy or actions that could be considered in the future. The wide array of complementary and supporting measures being contemplated or undertaken across State government are detailed here. The broad view of State action described in this chapter thus provides context for the narrower set of measures discussed in detail in Chapter 2 of this Scoping Plan. It is these measures in Chapter 2 that CARB staff has identified as specific actions to meet the 2030 target in SB 32.

The following phrases have specific meanings in this discussion of the policy landscape: "Ongoing and Proposed Measures" refers to programs and policies that are either ongoing existing efforts, or efforts required by statute, or which are otherwise underway or about to begin. These measures include, but are not limited to, those identified as necessary specific actions to meet the 2030 GHG target, and which are set apart and described in greater detail in Chapter 2. "Sector Measures" listed also include cross-cutting measures that affect many entities in the sector; some of these are also identified in Chapter 2. "Potential Additional Actions" are not being proposed as part of the specific strategy to achieve the 2030 target in this Scoping Plan. This Scoping Plan includes this broader, comprehensive, review of these measures because it aims to spur thinking and exploration of innovative new technologies and polices that may help the State achieve its long-term climate goals. Some of these items may not ever be formally proposed, but they are included here because CARB, other agencies, and stakeholders believe their potential should be explored with stakeholders in coming years.

Table 16: Cross-Sector Relationships

Sector	Example Interactions with Other Sectors
 Energy	• Hydroelectric power, cooling, cleaning, waste water treatment plant (WWTP) bioenergy • Vehicle-to-grid power; electricity supply to vehicle charging infrastructure • Biomass feedstock for bioenergy, land for utility-scale renewable energy (solar, wind) • Agricultural waste and manure feedstocks for bioenergy/biofuels • Organic waste for bioenergy
 Transportation	• Electric vehicles, natural gas vehicles, transit/rail; more compact development patterns that reduce vehicle miles traveled (VMT) also demand less energy per capita • More compact development patterns that reduce VMT also demand less water per capita and reduce conversion of natural and working lands • Reducing VMT also reduces energy demands necessary for producing and distributing fuels and vehicles and construction and maintenance of roads • Biomass feedstock for biofuels • Agricultural waste and manure feedstocks for biofuels • Organic waste for biofuels • Greenfield suburban development on natural and working lands leads to increased VMT
 Industry	• Potential to electrify fossil natural gas equipment, substitution of fossil-based energy with renewable energy • Greenfield urban development impacts
 Water	• Energy consumption for water pumping, treatment, heating; resource for cooling, cleaning; WWTP bioenergy • Use of compost to help with water retention / conservation / drought mitigation • Land conservation results in healthier watersheds by reducing polluted runoff, allowing groundwater recharge, and maintaining properly functioning ecosystems
 Waste Management	• Composting, anaerobic digestion, and wastewater treatment plant capacity to help process organic waste diverted from landfills • Compost for carbon sequestration, erosion control in fire-ravaged lands, water conservation, and healthy soils • Replacing virgin materials with recycled materials associated with goods production; enhanced producer responsibility reduces energy impacts of consumption • Efficient packaging materials reduces energy consumption and transportation fuel use
 Agriculture	• Crop production, manure management; WWTP biosolids for soil amendments • Agricultural waste and manure feedstocks for bioenergy • Compost production in support of Healthy Soils Initiative
 Natural and Working Lands	• Healthy forestlands provide wood and other forest products • Restoring coastal and sub-tidal areas improves habitat for commercial and other fisheries • Sustainable management can provide biomass for electricity • Sustainable management can provide biomass for biofuels • Resilient natural and working lands provide habitat for species and functions to store water, recharge groundwater, naturally purify water, and moderate flooding. Forests are also a source of compost and other soil amendments. • Conservation and land protections help reduce VMT and increase stable carbon pools in soils and above-ground biomass

Low Carbon Energy

The energy sector in California is composed of electricity and natural gas infrastructure, which brings electricity and natural gas to homes, businesses, and industry. This vast system is critical to California's economy and public well-being, and pivotal to reducing its GHG emissions.

Historically, power plants generated electricity largely by combusting fossil fuels. In the 1970s and early 1980s, a significant portion of California's power supply came from coal and petroleum resources. To reduce air pollution and promote fuel diversity, the State has shifted away from these resources to natural gas, renewable energy, and energy efficiency programs, resulting in significant GHG emissions reductions. Emissions from the electricity sector are currently approximately 20 percent below 1990 levels and are well on their way to achieving deeper emissions cuts by 2030. Since 2008, renewable generation has almost doubled, coal generation has been reduced by more than half, and GHG emissions have been reduced by a quarter.

Carbon dioxide is the primary GHG associated with electricity and natural gas systems. The electricity sector, which is composed of in-State generation and imported power to serve California load, has made great strides to help California achieve its climate change objectives. Renewable energy has shown tremendous growth, with capacity from solar, wind, geothermal, small hydropower, and biomass power plants growing from 6,600 megawatts (MW) in 2010 to 27,500 MW as of June 2017.[171]

Renewable energy adoption in California has been promoted through the RPS and several funding mechanisms, such as the California Solar Initiative (CSI) programs, Self-Generation Incentive Program (SGIP), Net-Energy Metering (NEM), and federal tax credits. These mandates and incentives have spurred both utility-scale and small-scale customer-developed renewable energy projects. SB 350 increased the RPS requirement from 33 percent by 2020 to 50 percent by 2030.

SB 350 requires publicly-owned utilities under the jurisdiction of the California Energy Commission (CEC) and all load-serving entities under the jurisdiction of the California Public Utilities Commission (CPUC) to file integrated resource plans (IRPs) with the CEC and CPUC, respectively. Through their IRPs, filing entities will demonstrate how they will plan to meet the electricity sector's share of the State's 2030 GHG reduction target while ensuring reliability in a cost-effective manner. The CEC and CPUC have developed the guidelines that publicly-owned utilities and load-serving entities will follow to prepare and submit IRPs, and CARB is working collaboratively with CEC and CPUC to set the sector and utility and load-serving entity planning targets. The Scoping Plan provides information to help establish the range of GHG reductions required for the electricity sector, and those numbers will be translated into planning target ranges in the IRP process. The IRP processes as currently proposed by CEC and CPUC staff will grant publicly-owned utilities flexibility to determine the optimal way to reduce GHG emissions, and load serving entities some flexibility to achieve the electricity sector's share of the 2030 goal. The CPUC has developed a Reference System Plan to help guide investment, resource acquisition, and programmatic decisions to reach the State's policy goals, in addition to informing the development of individual load serving entities' IRPs.

Energy efficiency is another key component to reducing energy sector GHG emissions, and is another consideration in each agency's IRP process. Utilities have been offering energy efficiency programs, such as incentives, to California customers for decades, and CEC has continually updated building and appliance standards. In the context of IRPs, utility-ratepayer-funded energy efficiency programs will likely continue to play an important role in reducing GHG emissions in the electricity sector.

SB 350 requires CEC and CPUC to establish annual targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings in electricity and natural gas end uses by 2030. These targets can be achieved through appliance and building energy efficiency standards; utility incentive, rebate, and technical assistance programs; third-party delivered energy efficiency programs; and other programs. Achieving greater efficiency savings in existing buildings, as directed by Governor Brown in his 2015 inaugural speech, will be essential to meet the goal of doubling energy efficiency savings. In September 2015, CEC adopted the Existing Buildings Energy Efficiency Action Draft Plan, which is designed to provide foundational support and strategies to enable scaling of energy efficiency in the built environment. Pursuant to SB 350, CEC published an updated Existing Buildings Energy Efficiency Action Plan prior to January 2017. More than $10 billion in private capital investment will be needed

171 California Energy Commission. August, 2017. Tracking Progress. Renewable Energy – Overview. *http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf*

to double statewide efficiency savings in California.[172] Energy efficiency programs are one part of the broader green buildings strategy, which incorporates additional measures to minimize water use, waste generation, and transportation impacts. The green buildings strategy is described in further detail in Appendix I.

Heating fuels used for activities such as space and water heating in the residential, commercial, and industrial sectors represent a significant source of GHG emissions. Transitioning to cleaner heating fuels is part of the solution of achieving greater efficiency savings in existing buildings and has significant GHG emissions reductions potential. Examples of this transition can include use of renewable gas and solar thermal, as well as electrification of end uses in residential, commercial, and industrial sectors. However, achieving significant GHG emissions reductions can only be achieved by decarbonizing the electricity sector – switching from natural gas end uses to electricity generated by burning natural gas would not be effective. Electrification can complement renewables and energy storage if implemented in an integrated, optimized manner. Other hurdles that will have to be overcome include electric equipment performance across all California climate regions, seasonal variations of renewable generation, cost-effectiveness, and consumer acceptance of different heating fuel options.

Fossil-fuel-based natural gas is a significant fuel source for both in-State electricity generation and electricity imported into California. It is also used in transportation applications and in residential, commercial, industrial, and agricultural sector end uses. Greenhouse gas emissions from combustion of fossil natural gas decreased from 134.71 $MMTCO_2e$ in 2000 to 126.98 $MMTCO_2e$ in 2015, while natural gas pipeline fugitive emissions were estimated to be 4.0 $MMTCO_2e$ in 2015 and have been nearly unchanged since 2000.[173] Greenhouse gas-reduction strategies should focus on efficiency, reducing leakage from wells and pipelines, implementing the SLCP strategy, and studying the potential for renewable gas fuel switching (e.g., renewable hydrogen blended with methane or biomethane).

Moving forward, reducing use of fossil natural gas wherever possible will be critical to achieving the State's long-term climate goals. For end uses that must continue to rely on natural gas, renewable natural gas could play an important role. Renewable natural gas volume has been increasing from approximately 1.5 million diesel gallon equivalent (dge) in 2011 to more than 68.5 million dge in 2015, and continued substitution of renewable gas for fossil natural gas would help California reduce its dependence on fossil fuels. In addition, renewable gas can be sourced by in-vessel waste digestion (e.g., anaerobic digestion of food and other organics) and recovering methane from landfills, livestock operations, and wastewater treatment facilities through the use of existing technologies, thereby also reducing methane emissions. The capture and productive use of renewable methane from these and other sources is consistent with requirements of SB 1383.

Collectively, renewable energy and energy efficiency measures can result in significant public health and climate benefits by displacing air pollution and GHG emissions from fossil-fuel based energy sources, as well as by reducing the health and environmental risks associated with the drilling, extraction, transportation, and storage of fossil fuels, especially for communities living near fossil-fuel based energy operations.

As the energy sector continues to evolve and decarbonize, both the behavior of individual facilities and the design of the grid itself will change, with important distributional effects. Some power plants may operate more flexibly to balance renewables, emerging technologies (examples include storage, smart inverters, renewably-fueled fuel cells, and others) will become more prevalent, and aging facilities may retire and be replaced. In turn, this may shift patterns of criteria pollutant emissions at these facilities. Because many existing power plants are in, or near, disadvantaged communities, it is of particular importance to ensure that this transition to a cleaner grid does not result in unintended negative impacts to these communities.

Appendix H highlights the more significant existing policies, programs, measures, regulations, and initiatives that provide a framework for helping achieve GHG emissions reductions in this sector.

172 California Energy Commission. 2016. Existing Building Energy Efficiency Action Plan. page 61. Available at: *http://docketpublic.energy.ca.gov/PublicDocuments/16-EBP-01/TN214801_20161214T155117_Existing_Building_Energy_Efficency_Plan_Update_Deceber_2016_Thi.pdf*

173 CARB. 2017. CARB's Emission Inventory Activities. *www.arb.ca.gov/ei/ei.htm*

Looking to the Future

This section outlines the high-level objectives and goals to reduce GHGs in this sector.

Electricity Goals

- Achieve sector-wide, publicly-owned utility, and load-serving entity specific GHG reduction planning targets set by the State through Integrated Resource Planning.
- Reduce fossil fuel use.
- Reduce energy demand.

Natural Gas Goals

- Ensure safety of the natural gas system.
- Decrease fugitive methane emissions.
- Reduce dependence on fossil natural gas.

Cross-Sector Interactions

The energy sector interacts with nearly all sectors of the economy. Siting of power plants (including solar and wind facilities) and transmission and distribution lines have impacts on land use in California–be it conversion of agricultural or natural and working lands, impacts to sensitive species and habitats, or implications to disadvantaged, vulnerable, and environmental justice communities. Additionally, more compact development patterns reduce per capita energy demands, while less-compact sprawl increases them. Further, efforts to reduce GHG emissions in the transportation sector include electrification, such as PHEVs, BEVs, and FCEVs. Some industrial sources also use electricity as a primary or auxiliary source of power for manufacturing. In the future, industrial facilities may electrify their systems instead of relying on natural gas. These activities will increase demand in this sector. In addition, water is used in various applications in the energy sector, ranging in intensity from cooling of turbines and other equipment at power plants to cleaning solar photovoltaic panels. Given California's recent historic drought, water use for the electricity sector is an important consideration for operation, maintenance, and construction activities.

Continued planning and coordination with federal, State, and local agencies, governments, Tribes, and stakeholders will be crucial to minimizing environmental and health impacts from the energy sector, deploying new technologies, and identifying feedstocks.

Efforts to Reduce Greenhouse Gases

The measures below include some required and new potential measures to help achieve the State's 2030 target and to support the high-level objectives for this sector. Some measures may be designed to directly address GHG reductions, while others may result in GHG reductions as a co-benefit.

Ongoing and Proposed Measures – Electricity

- Per SB 350, with respect to Integrated Resource Plans, establish GHG planning targets for the electricity sector, publicly-owned utilities, and load-serving entities.
- Per SB 350, ensure meaningful GHG emissions reductions by publicly-owned utilities and load-serving entities through Integrated Resource Planning.
- Per AB 197, prioritize direct reductions at large stationary sources, including power-generating facilities.
- Per SB 350, increase the RPS to 50 percent of retail sales by 2030 and ensure grid reliability.
- Per Governor Brown's Clean Energy Jobs Plan, AB 327 (Perea, Chapter 611, Statutes of 2013), and AB 693 (Eggman, Chapter 582, Statutes of 2015), increase development of distributed renewable generation, including for low income households.
- Continue to increase use of distributed renewable generation at State facilities where space allows.
- Increase retail customers' use of renewable energy through optional utility 100 percent renewable energy tariffs.
- Continue GHG reductions through participation in the California Independent System Operator (CAISO) Energy Imbalance Market.

- Per SB 350, efforts to evaluate, develop, and deploy regionalization of the grid and integration of renewables via regionalization of the CAISO should continue while maintaining the accounting accuracy and rigor of California's GHG policies.
- Per SB 350, establish annual targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings in electricity and natural gas end uses by 2030.
- Per SB 350, implement the recommendations of the Barriers Study for increasing access to renewable energy generation for low-income customers, energy efficiency and weatherization investments for low-income customers, and contracting opportunities for local small business in disadvantaged communities.[174] And, track progress towards these actions over time to ensure disadvantaged communities are getting equal access and benefits relative to other parts of the State.
- Continue implementation of the Regulations Establishing and Implementing a Greenhouse Gases Emission Performance Standard for Local Publicly Owned Electric Utilities as required by SB 1368 (Perata, Chapter 598, Statutes of 2006), which effectively prohibits electric utilities from making new long-term investments in high-GHG emitting resources such as coal power.
- Per AB 802 (Williams, Chapter 590, Statutes of 2015), adopt the forthcoming CEC regulations governing building energy use data access, benchmarking, and public disclosure.
- Per AB 2868 (Gatto, Chapter 681, Statutes of 2016), encourage development of additional energy storage capacity on the transmission and distribution system.
- Per AB 758 (Skinner, Chapter 470, Statutes of 2009),[175] implement recommendations under State jurisdiction included in the AB 758 Action Plan developed by CEC.

Ongoing and Proposed Measures – Natural Gas

- Implement the CARB Regulation for Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities to reduce fugitive methane emissions from storage and distribution infrastructure.
- Per SB 1371 (Leno, Chapter 525, Statutes of 2014), adopt improvements in investor-owned utility (IOU) natural gas systems to address methane leaks.
- Implement the SLCP Strategy to reduce natural gas leaks from oil and gas wells, pipelines, valves, and pumps to improve safety, avoid energy losses, and reduce methane emissions associated with natural gas use.
- Per SB 1383, CEC will develop recommendations for the development and use of renewable gas as part of its 2017 Integrated Energy Policy Report (IEPR).
- Per SB 1383, adopt regulations to reduce methane emissions from livestock manure and dairy manure management operations by up to 40 percent below the dairy sector's and livestock sector's 2013 levels by 2030, including establishing energy infrastructure development and procurement policies needed to encourage dairy biomethane projects. The regulations will take effect on or after January 1, 2024.
- Per SB 1383, reduce methane emissions at landfills by reducing landfill disposal of organic waste 75 percent below 2014 levels by 2025, including establishing energy infrastructure development and procurement policies needed to encourage in-vessel digestion projects and increase the production and use of renewable gas.
- Per SB 887 (Pavley, Chapter 673, Statutes of 2016), initiate continuous monitoring at natural gas storage facilities and (by January 1, 2018) mechanical integrity testing regimes at gas storage wells, develop regulations for leak reporting, and require risk assessments of potential leaks for proposed new underground gas storage facilities.
- Per Public Utilities (PU) Code 454.56, CPUC, in consultation with CEC, (1) identifies all potentially achievable cost-effective natural gas efficiency savings and establishes gas efficiency targets for the gas corporation to achieve, and (2) requires gas corporations to first meet unmet resource needs through available natural gas efficiency and demand reduction resources that are cost-effective, reliable, and feasible (PU Codes 890–

174 CEC. 2016. Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities. *http://docketpublic.energy.ca.gov/PublicDocuments/16-OIR-02/TN214830_20161215T184655_SB_350_LowIncome_Barriers_Study_Part_A__Commission_Final_Report.pdf*

175 AB 758 requires CEC, in collaboration with CPUC, to develop a comprehensive program to achieve greater energy efficiency in the State's existing buildings.

900 provide public goods charge funding authorization for these programs).
- Per SB 185 (De Leon, Chapter 605, Statutes of 2015), implement the requirement for the California Public Employees' Retirement System (CalPERS) and the California State Teachers' Retirement System (CalSTRS) to sell their holdings in coal-producing companies by June 1, 2017, and explore extending divestiture requirements for additional fossil-fuel assets.

Sector Measures

- Implement the post-2020 Cap-and-Trade Program.

Potential Additional Actions

The actions below have the potential to reduce GHGs and complement the measures and policies identified in Chapter 2. These are included to spur thinking and exploration of innovation that may help the State achieve its long-term climate goals. It is anticipated that there will be workshops and other stakeholder forums in the years following finalization of the Scoping Plan to explore these potential actions.

- Further deploy fuel cells that use renewable fuels or those that generate electricity that is less carbon intensive than the grid.
- Increase use of renewable energy through long-term agreements between customers and utilities (such as Sacramento Municipal Utility District Solar Shares).
- Develop rules needed for the development of electricity storage technologies.
- Adopt a zero net energy (ZNE) standard for residential buildings by 2018/2019, and for commercial buildings by 2030.
- Through a public process, evaluate and set targets for the electrification of space and water heating in residential and commercial buildings and cleaner heating fuels that will result in GHG reductions, and identify actions that can be taken to spur market transformation in the 2021-2030 period.
- Expand the State Low-Income Weatherization Program (LIWP) to continue to improve energy efficiency and weatherize existing residential buildings, particularly for low-income individuals and households.
- Decrease usage of fossil natural gas through a combination of energy efficiency programs, fuel switching, and the development and use of renewable gas in the residential, commercial, and industrial sectors.
- Accelerate the deployment of heat pumps and the replacement of diesel generators.
- Consider enhanced energy efficiency (high efficiency air conditioners, light-emitting diode (LED) lamps, efficiency improvements in industrial process cooling and refrigeration, efficient street lighting).
- Promote programs to support third-party delivered energy efficiency projects.
- Per AB 33 (Quirk, Chapter 680, Statutes of 2016), consider large-scale electricity storage.
- Support more compact development patterns to promote reduced per capita energy demand (see the Transportation sector for specific policy recommendations).

Industry

California's robust economy, with the largest manufacturing sector in the United States, is supported by a variety of sub-industrial sectors, some of which include cement plants, refineries, food processors, paper products, wineries, steel plants, and industrial gas, entertainment, technology and software, aerospace, and defense companies. Together, industrial sources account for approximately 21 percent of the State's GHG emissions–almost equal to the amount of GHG emissions from the energy sector. Emissions in this sector are mainly due to fuel combustion and, in some industries, process-related emissions. Changes in this sector strongly correlate with changes in the overall economy. For example, housing and construction growth usually increases demand for cement. Moving toward a cleaner economy and ensuring we meet the statewide targets requires us to address GHG emissions in this sector, which has the potential to provide local co-benefits in criteria pollutant and toxic air contaminant reductions in immediate surrounding locations, especially in vulnerable communities. At the same time, we must ensure there is a smooth path to a cleaner future to support a resilient and robust economy with a strong job force, including training opportunities for workers in disadvantaged communities, while continuing to support economic growth in existing and new industries.

Greenhouse gas emissions in the Industrial sector have remained relatively flat for the last few years while the State's economy has continued to grow, meaning the GHG emissions to produce each dollar of gross standard product is decreasing. Manufacturing accounts for approximately 10 percent of the gross state product.[176] In 2016, California industry exported $163.6 billion in merchandise.[177]
Policies to address GHG emissions reductions must continue to balance the State's economic well-being with making progress toward achievement of the statewide limits.

As this sector is dominated by combustion-related emissions, policies and measures to supply cleaner fuels and more efficient technology are the key to reducing GHG emissions. Some sectors, such as cement and glass, also have significant process emissions, and it may be more challenging to address those process emissions, as they are related to chemical reactions and processes to meet safety, product-specific, or regulatory standards for the final products. Another important aspect for this sector is its role as the State transitions to a cleaner future. Infrastructure, including existing facilities and new facilities, can support the production of new technology to bolster the State's efforts to address GHGs. For example, existing refineries have an opportunity to move away from fossil fuel production and switch to the production of biofuels and clean technology. As the State works to double energy efficiency in existing buildings, there will be an increased demand for efficient lighting fixtures, building insulation, low-e[178] coatings for existing windows, or new windows–goods which could be produced in California. The predominant paths to reducing GHG emissions for the Industrial sector are: fuel switching, energy efficiency improvements, and process modifications. Carbon capture and sequestration also offers a potential new, long-term path for reducing GHGs for large stationary sources.

Relocation of production to outside the State would also reduce emissions, but this is disadvantageous for a couple of reasons and efforts are needed to avoid this outcome. First, AB 32 requires the State's climate policies to minimize emissions leakage, and relocation would shift GHG emissions outside of the State without the benefit of reducing pollutants that contribute to overall global warming impacts. Second, it could also reduce the availability of associated jobs and could impact a local tax base that supports local services such as public transportation, emergency response, and social services, as well as funding sources critical to protecting the natural environment and keeping it available for current and future generations.

Even while we continue to seek further GHG reductions in the sector, it is important to recognize the State has a long history of addressing health-based air pollutants in this sector. Many of the actions for addressing criteria pollutants and toxic air contaminants in the industrial sector are driven by California's local air district stationary source requirements to ensure progress toward achieving State and national ambient air quality standards. Some of those actions, such as use of Best Available Control Technology, have resulted in co-benefits in the form of GHG reductions. The State must continue to strengthen its existing criteria and toxic air pollutant programs and relationships with local air districts to ensure all Californians have healthy, clean air. This is especially true in disadvantaged communities.

AB 32 directed CARB to take several actions to address GHG emissions, such as early action measures, GHG reporting requirements for the largest GHG sources, and other measures. In response, the State adopted multiple measures and regulations, including regulations for high global warming potential (high-GWP) gases used in refrigeration systems and the semiconductor industry.[179] These regulations apply to specific GHGs and types of equipment that can be found across the economy. For example, high-GWP gases are found in refrigeration systems in large food processing plants and chemical and petrochemical facilities, among others.[180]

The State has also adopted the first in the world economy-wide cap-and-trade program that applies to all large industrial GHG emitters, imported electricity, and fuel and natural gas suppliers. As discussed in Chapters 2 and 3, the Cap-and-Trade Program is a key element of California's GHG reduction strategy. The

176 *http://www.investopedia.com/articles/investing/011416/californias-economy-9-industries-driving-gdp-growth.asp*
177 U.S. Department of Commerce. International Trade Administration. 2017. California Exports, Jobs, & Foreign Investment. *www.trade.gov/mas/ian/statereports/states/ca.pdf*
178 Low-e coatings reduce the emissivity, or heat transfer, from a window to improve its insulating properties.
179 CARB. Refrigerant Management Program. *www.arb.ca.gov/cc/rmp/rmp.htm*
180 The U.S. Environmental Protection Agency (U.S. EPA) has also enacted regulations to reduce hydrofluorocarbon (HFC) emissions by prohibiting high-GWP refrigerants in new retail food refrigeration equipment and in chillers used for large air-conditioning applications. On the international level, the European Union F-gas regulations went into effect January 1, 2015. Those regulations prohibit high-GWP HFCs in new equipment and require a gradual phasedown in the production and import of HFCs. A similar HFC phasedown that would take place globally was the subject of international negotiations during the Montreal Protocol meeting in Rwanda in October, 2016. Those negotiations resulted in an agreement that will phase down the use of HFCs and put the world on track to avoid nearly 0.5°C of warming by 2100.

Cap-and-Trade Program establishes a declining limit on major sources of GHG emissions, and it creates a powerful economic incentive for major investment in cleaner, more efficient technologies. The Cap-and-Trade Program applies to emissions that cover about 85 percent of the State's GHG emissions. CARB creates allowances equal to the total amount of permissible emissions (i.e., the "cap") over a given compliance period. One allowance equals one metric ton of GHG emissions. Fewer allowances are created each year, thus the annual cap declines and statewide emissions are reduced over time. An increasing annual auction reserve (or floor) price for allowances and the reduction in annual allowance budgets creates a steady and sustained pressure for covered entities to reduce their GHGs. All covered entities in the Cap-and-Trade Program are still subject to the air quality permit limits for criteria and toxic air pollutants.

The Cap-and-Trade Program is designed to achieve the most cost-effective statewide GHG emissions reductions; there are no individual or facility-specific GHG emissions reductions requirements. Each entity covered by the Cap-and-Trade Program has a compliance obligation that is set by its GHG emissions over a compliance period, and entities are required to meet that compliance obligation by acquiring and surrendering allowances in an amount equal to their compliance obligation. Companies can also meet a limited portion of their compliance obligation by acquiring and surrendering offset credits, which are compliance instruments that are based on rigorously verified emissions reductions that occur from projects outside the scope of the Cap-and-Trade Program. Like allowances, each offset credit is equal to one metric ton of GHG emissions. The program began in January 2013 and achieved a near 100 percent compliance rate for the first compliance period (2013–2014). Reported and verified emissions covered by the Cap-and-Trade Program have been below the cap throughout the first years of the Program.[181]

Allowances are issued by CARB and distributed by free allocation and by sale at auctions. CARB also provides for free allocation to some entities covered by the Program to address potential trade exposure due to the cost of compliance with the Program and address concerns of relocation of production out-of-state and resulting emissions leakage. Offset credits are issued by CARB to qualifying offset projects. Secondary markets exist where allowances and offset credits may be sold and traded among Cap-and-Trade Program participants. Facilities must submit allowances and offsets to match their annual GHG emissions. Facilities that emit more GHG emissions must surrender more allowances or offset credits, and facilities that can cut their emissions need to surrender fewer compliance instruments. Entities have flexibility to choose the lowest-cost approach to achieving program compliance; they may purchase allowances at auction, trade allowances and offset credits with others, take steps to reduce emissions at their own facilities, or utilize a combination of these approaches. Proceeds from the sale of State-owned allowances at auction are placed into the Greenhouse Gas Reduction Fund.

It is important to note that while the Cap-and-Trade Program is designed to reduce GHGs for the industrial sector, there are recommendations from the EJAC (or Committee) for the State to pursue more facility-specific GHG reduction measures to achieve potential local air quality co-benefits, and AB 197 directs CARB to prioritize direct reductions at large stationary sources. The Committee has expressed a strong preference to forgo the existing Cap-and-Trade Program and rely on prescriptive facility level regulations.

We agree with the EJAC that more can and should be done to reduce emissions of criteria pollutants and toxic air contaminants. These pollutants pose air quality and related health issues to the communities adjacent to the sources of industrial emissions. Further, many of these communities are already disadvantaged and burdened by a variety of other environmental stresses. As described in Chapter 3, however, there is not always a direct correlation between emissions of GHGs, criteria pollutants, and toxic air contaminants. Also, relationships between these pollutants are complex within and across industrial sectors. The solution, therefore, is not to do away with or change the regulation of GHGs through the Cap-and-Trade Program to address these legitimate concerns; instead, consistent with the direction in AB 197 and AB 617, State and local agencies must evaluate and implement additional measures that directly regulate and reduce emissions of criteria and toxic air pollutants through other programs.

181 CARB. 2016. Mandatory Greenhouse Gas Emissions Reporting. *www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep.htm*

Looking to the Future

This section outlines the high-level objectives and goals to reduce GHGs in this sector.

Goals

- Increase energy efficiency.
- Reduce fossil fuel use.
- Promote and support industry that provides products and clean technology needed to achieve the State's climate goals.
- Create market signals for low carbon intensity products.
- Maximize air quality co-benefits.
- Support a resilient low carbon economy and strong job force.
- Make California the epicenter for research, development, and deployment of technology needed to achieve a near-zero carbon future.
- Increase in-State recycling manufacturing.

Cross-Sector Interactions

There are clear, direct relationships between the industrial sector and other sectors that go beyond the economic support that a strong economy provides. For instance, this sector could increase its use of renewable fuels such as biomethane, which would be sourced from landfills or dairies. Additionally, some industries could shift from raw materials to recycled materials to reduce waste and reduce GHG emissions associated with processing of raw materials. Further, addressing energy efficiency could reduce onsite heating, water, and fuel demand. Moreover, supporting mass-transit or ride share programs for employees would reduce VMT. Finally, upgrading existing facilities or repurposing existing infrastructure instead of constructing new facilities or infrastructure would support land conservation and smart growth goals.

Efforts to Reduce Greenhouse Gases

The measures below include some required and new potential measures to help achieve the State's 2030 target and to support the high-level objectives for this sector. Some measures may be designed to directly address GHG reductions, while others may result in GHG reductions as a co-benefit.

Ongoing and Proposed Measures

- At the October 2016 annual Montreal Protocol Meeting of Parties in Kigali, Rwanda, an international amendment to globally phase down HFC production was agreed upon by more than 150 countries. Depending on the level of future HFC emissions reductions expected for California from the Kigali Agreement, California may also: (1) consider placing restrictions on the sale or distribution of refrigerants with a GWP > 2,500, and (2) consider prohibiting refrigerants with a GWP >= 150 in new stationary refrigeration equipment and refrigerants with a GWP >= 750 for new stationary air-conditioning equipment. At the time the SLCP Strategy was finalized, U.S. EPA was expected to continue implementing certain HFC reductions under its Significant New Alternatives Policy (SNAP). Recent litigation may result in CARB implementing similar measures as state law instead.
- Develop a regulatory monitoring, reporting, verification, and implementation methodology for the implementation of carbon capture and sequestration projects.
- Implement the CARB Regulation for Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities to reduce fugitive methane emissions from storage and distribution infrastructure.

Sector Measures

- Implement the post-2020 Cap-and-Trade Program.
- Continue and strategically expand research and development efforts to identify, evaluate, and help deploy innovative strategies that reduce GHG emissions in the industrial sector.
- Promote procurement policies that prioritize low carbon production to delivery options, including at the State and local government levels.
- Identify and remove barriers to existing grant funding for onsite clean technology or efficiency upgrades.

Potential Additional Actions

The actions below have the potential to reduce GHGs and complement the measures and policies identified in Chapter 2. These are included to spur thinking and exploration of innovation that may help the State achieve its long-term climate goals. It is anticipated that there will be workshops and other stakeholder forums in the years following finalization of the Scoping Plan to explore these potential actions.

- Further deploy fuel cells that use renewable fuels or those that generate electricity that is less carbon intensive than the grid.
- Decrease usage of fossil natural gas through a combination of efficiency, fuel switching, and the development and use of renewable gas.
- Partner with California's local air districts to effectively use BARCT to achieve air quality and GHG reduction co-benefits at large industrial sources.
- Evaluate the potential for and promote electrification for industrial stationary sources whose main emissions are onsite natural gas combustion.
- Identify new funding for grants and tariff opportunities for onsite clean technology, efficiency upgrades, diesel generator replacement, or recycling manufacturing technology.
- Develop an incentive program to install low-GWP refrigeration systems in retail food stores.
- Evaluate and design additional mechanisms to further minimize emissions leakage in the Cap-and-Trade Program (e.g., border carbon adjustment).

Transportation Sustainability

California's population is projected to grow to 50 million people by 2050. How and where the State grows will have important implications for all sectors of the economy, especially the transportation sector. Supporting this growth while continuing to protect the environment, developing livable and vibrant communities, and growing the economy is dependent on transitioning the State's transportation system to one powered by ZEVs (including PHEVs, BEVs, and FCEVs) and low carbon fuels. It must also offer other attractive and convenient low carbon transportation choices, including safe walking and bicycling, as well as quality public transportation. Investments should consider California's diverse communities and provide accessible and clean travel options to all while drastically reducing reliance on light-duty combustion vehicles.

The transportation system in California moves people between home, work, school, shopping, recreation, and other destinations, and connects ports, industry, residential communities, commercial centers, educational facilities, and natural wonders.[182] California's vast transportation system includes roads and highways totaling more than 175,000 miles and valued at approximately $1.2 trillion, 500 transit agencies, 245 public-use airports, 12 major ports, and the nation's first high-speed rail system, now under construction.[183] Transportation infrastructure also includes sidewalks, bicycle paths, parking, transit stations and shelters, street trees and landscaping, signage, lighting, and other elements that affect the convenience, safety, and accessibility of transportation choices. Increasingly, technologies such as real-time, web- and mobile-enabled trip planning and ride-sourcing services are changing how people travel. In the near future, automated and connected vehicles, and unmanned aerial systems (e.g., drones) are expected to be part of our transportation landscape and to transform the way that people and freight are transported. Responsibility for the transportation system is spread across State, regional, and local levels.

Through effective policy design, the State has an opportunity to guide technology transformation and influence investment decisions with a view to mitigate climate and environmental impacts while promoting economic opportunities and community health and safety. The network of transportation technology and infrastructure, in turn, shapes and is shaped by development and land use patterns that can either support or detract from a more sustainable, low carbon, multi-modal transportation future. Strategies to reduce GHG emissions from the transportation sector, therefore, must actively address not only infrastructure and technology, but also coordinated strategies to achieve development, conservation, and land use patterns that align with the State's GHG and other policy goals.

Transportation also enables the movement of freight such as food, building materials, and other consumable products, as well as waste and recyclables. The California freight system includes myriad equipment and

182 Caltrans. California Transportation Plan 2040, February 2016.
183 Ibid.

facilities,[184] and is the most extensive, complex, and interconnected system in the country, with approximately 1.5 billion tons of freight valued at $2.8 trillion shipped in 2015 to, through, and within California.[185] Freight-dependent industries accounted for over $740 billion of California's GDP and over 5 million California jobs in 2014.[186, 187]

Transportation has a profound and varied impact on individuals and communities, including benefits such as economic growth, greater accessibility, and transport-related physical activity, and adverse consequences such as GHG emissions, smog-forming and toxic air pollutants, traffic congestion, and sedentary behaviors. The sector is the largest emitter of GHG emissions in California. Air pollution from tailpipe emissions contributes to respiratory ailments, cardiovascular disease, and early death, with disproportionate impacts on vulnerable populations such as children, the elderly, those with existing health conditions (e.g., chronic obstructive pulmonary disease, or COPD), low-income communities, and communities of color.[188, 189, 190, 191, 192] Importantly, transportation costs are also a major portion of most Californian's household budgets.[193] Additionally, dependence on cars has a direct impact on levels of physical activity, which is closely linked to multiple adverse health outcomes.

Fortunately, many measures that reduce transportation sector GHG emissions simultaneously present opportunities to bolster the economy, enhance public health, revitalize disadvantaged communities, strengthen resilience to disasters and changing climate, and improve Californians' ability to conveniently access daily destinations and nature. These opportunities are particularly important for those who are not able to, or cannot afford to, drive. In addition, a growing market demand for walkable, bikeable, and transit-accessible communities presents a significant opportunity to shift California's transportation systems toward a lower-carbon future while realizing significant public health benefits through increased levels of physical activity (e.g., walking and bicycling). In fact, transport-related physical activity could result in reducing risks from chronic diseases such as cardiovascular disease, diabetes, certain cancers, and more, to such an extent that it would rank among the top public health accomplishments in modern history, and help to reduce the billions of dollars California spends each year to treat chronic diseases. Just as California was the first to mitigate the contribution of cars and trucks to urban smog, it is leading the way toward a clean, low carbon, healthy, interconnected, and equitable transportation system.

Continuing to advance the significant progress already underway in the areas of vehicle and fuel technology is critical to the transportation sector strategy and to reducing GHG emissions in the transportation sector. The rapid technological and behavioral changes underway with automated and connected vehicles, unmanned aerial systems, and ride-sourcing services are redefining the transportation sector, and should be part of the solution for a lower carbon transportation sector. It is critical to support and accelerate progress on transitioning to a zero carbon transportation system, while ensuring VMT reductions are still achieved. The growing severity of climate impacts, persistent public health impacts and costs from air pollution,[194] and rapid technology progress that supports the expectation that cost parity between some ZEVs and comparable internal combustion vehicles will be attained in a few years, underscores the need for further

184 The freight system includes trucks, ocean-going vessels, locomotives, aircraft, transport refrigeration units, commercial harborcraft and cargo handling, industrial and ground service equipment used to move freight at seaports, airports, border crossings, railyards, warehouses, and distribution centers.

185 U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration. Freight Analysis Framework, V 4.1, 2016.

186 U.S. Department of Commerce, Bureau of Economic Analysis. Regional Economic Accounts. Available at: *www.bea.gov/regional/index.htm*, accessed March 11, 2016.

187 State of California Employment Development Department. Labor Market Information by California Geographic Areas. Available at: *www.labormarketinfo.edd.ca.gov/geography/lmi-by-geography.html*, accessed March 21, 2016.

188 CARB. May 2016. Mobile Source Strategy. Available at: *www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf*

189 Hoek, G., Krishnan, R. M., Beelen, R., Peters, A., Ostro, B., Brunekreef, B., and Kaufman, J. D. 2013. Long-term air pollution exposure and cardio-respiratory mortality: a review. Environmental Health, 12(1), 1.

190 Friedman, M. S., K. E. Powell, L. Hutwagner, L. M. Graham, and W. G. Teague. 2001. "Impact of changes in transportation and commuting behaviors during the 1996 Summer Olympic Games in Atlanta on air quality and childhood asthma." JAMA 285(7), 897–905.

191 Bell, M. L., and K. Ebisu. 2012. "Environmental inequality in exposures to airborne particulate matter components in the United States." Environmental Health Perspectives 120(12), 1699.

192 Morello-Frosch, R., M. Zuk, M. Jerrett, B. Shamasunder, and A. D. Kyle. 2011. "Understanding the cumulative impacts of inequalities in environmental health: implications for policy." Health Affairs 30(5), 879–887.

193 H + T® Index website. *htaindex.cnt.org/*

194 For example, a recent report by the American Lung Association estimates the costs of climate and air pollution from passenger vehicles in California to be $15 billion annually. Holmes-Gen, B. and W. Barrett. 2016. Clean Air Future – Health and Climate Benefits of Zero Emission Vehicles. American Lung Association in California, October.

action on ZEVs. Therefore, CARB is signaling the need for additional policy and technical support on strategies to move toward a goal of achieving 100 percent ZEV sales in the light-duty vehicle sector. Austria, Germany, India, Netherlands, and Norway are all taking steps to, or have indicated a desire to, move to 100 percent ZEV sales in the 2020–2030 time frame.

In addition, policies that maximize the integration of electrified rail and transit to improve reliability and travel times, increase active transportation such as walking and bicycling, encourage use of streets for multiple modes of transportation, improve freight efficiency and infrastructure development, and shift demand to low carbon modes will need to play a greater role as California strives to achieve its 2030 and 2050 climate targets.[195]

The State's rail modernization program has identified critical elements of the rail network where improvements, either in timing of service or infrastructure, provide benefits across the entire statewide network, furthering the attractiveness of rail for a range of trip distances.[196] The State also uses the Transit and Intercity Rail Capital Program (TIRCP) and Low Carbon Transit Operations Program (LCTOP) to provide grants from GGRF to fund transformative improvements modernizing California's intercity, commuter, and urban rail systems, as well as bus and ferry transit systems, to reduce emissions of GHGs by reducing congestion and VMT throughout California. As the backbone of an electrified mass-transportation network for the State, the high-speed rail system catalyzes and relies on focused, compact, and walkable development well-served by local transit to funnel riders onto the system and provide alternative options to airplanes and automobiles for interregional travel. Concentrated development, such as that incentivized by the Affordable Housing and Sustainable Communities (AHSC) grant program, can improve ridership and revenue for the system while providing vibrant communities for all.

At the same time, more needs to be done to fully exploit synergies with emerging mobility solutions like ride-sourcing and more effective infrastructure planning to anticipate and guide the necessary changes in travel behavior, especially among millennials. Uniquely, high-speed rail affects air-miles traveled, diverting, at minimum, 30 percent of the intrastate air travel market in 2040.[197]

While most of the GHG reductions from the transportation sector in this Scoping Plan will come from technologies and low carbon fuels, a reduction in the growth of VMT is also needed. VMT reductions are necessary to achieve the 2030 target and must be part of any strategy evaluated in this Plan. Stronger SB 375 GHG reduction targets will enable the State to make significant progress toward this goal, but alone will not provide all of the VMT growth reductions that will be needed. There is a gap between what SB 375 can provide and what is needed to meet the State's 2030 and 2050 goals.

At the time of this writing, adoption of the first round of SCSs by MPOs is complete, and the second round of SCS planning is underway. Three MPO regions are in the very early stages of developing their third SCSs. To date, CARB staff reviewed the final determinations of 16 MPOs, and concluded that all 16 of those SCSs would achieve their targets, if implemented, with many of the MPOs indicating that they expect to exceed their targets. CARB staff recognizes the very strong performance in this first round of SCSs as a major success. Currently adopted sustainable communities strategies achieve, in aggregate, a 17 percent reduction in statewide per capita GHG emissions relative to 2005 by 2035.

Since 2014, CARB has been working with MPOs and other stakeholders to update regional SB 375 targets. At the same time, CARB has also conducted analysis for development of the Mobile Source Strategy and Scoping Plan that identifies the need for statewide per capita greenhouse gas emissions reductions on the order of 25 percent by 2035, to meet our climate goals. Many MPOs have identified challenges to incorporating additional strategies and reducing emissions further in their plans, principally tied to the need for additional and more flexible revenue sources. MPOs have submitted target update recommendations to CARB that in aggregate maintains a 17 percent reduction statewide, which includes commitments of 18 percent reduction by 2035 from each of the four largest MPOs in the State.

CARB is currently reviewing each MPOs target update recommendations alongside new State policies. State agencies have been working on new State-level VMT-related Policies and Measures (see Table 17) as part of this Scoping Plan intended to provide the State, MPOs, and local agencies with additional funding resources and tools to successfully meet the State's climate goals. CARB's preliminary review indicates that new State-level policies and measures will help support updated SB 375 targets that achieve up to 20 percent of the

195 Morello-Frosch, R., M. Zuk, M. Jerrett, B. Shamasunder, and A. D. Kyle. 2011. "Understanding the cumulative impacts of inequalities in environmental health: Implications for policy." Health Affairs 30(5), 879–887.
196 California State Transportation Agency. 2016. 2018 California State Rail Plan factsheet and TIRCP fact sheet.
197 California High-Speed Rail Authority. 2016. 2016 Business Plan. Ridership and Revenue Forecast.

needed statewide reduction, as well as help bridge the remaining VMT growth reduction gap.

Discussions among a broad suite of stakeholders from transportation, the building community, financial institutions, housing advocates, environmental organizations, and community groups are needed to begin the process to pursue and develop the needed set of strategies to ensure that we can achieve necessary VMT reductions, and that the associated benefits are shared by all Californians. Appendix C further details potential actions for discussion that can be taken by State government, regional planning agencies, and local governments, to achieve a broad, statewide vision for more sustainable land use and close the VMT gap.[198]

At the State level, a number of important policies are being developed. Governor Brown signed Senate Bill 743 (Steinberg, Chapter 386, Statutes of 2013), which called for an update to the metric of transportation impact in CEQA. That update to the CEQA Guidelines is currently underway. Employing VMT as the metric of transportation impact statewide will help to ensure GHG reductions planned under SB 375 will be achieved through on-the-ground development, and will also play an important role in creating the additional GHG reductions needed beyond SB 375 across the State. Implementation of this change will rely, in part, on local land use decisions to reduce GHG emissions associated with the transportation sector, both at the project level, and in long-term plans (including general plans, climate action plans, specific plans, and transportation plans) and supporting sustainable community strategies developed under SB 375. The State can provide guidance and tools to assist local governments in achieving those objectives.

Appendix H highlights the more significant existing policies, programs, measures, regulations, and initiatives that provide a framework for helping achieve GHG emissions reductions in this sector.

Looking to the Future

This section outlines the high-level objectives and goals to reduce GHGs in this sector.

Vibrant Communities and Landscapes / VMT Reduction Goals

- Implement and support the use of VMT as the metric for determining transportation impacts under CEQA, in place of level of service (LOS).
- Promote all feasible policies to reduce VMT, including:
  - Land use and community design that reduce VMT,
  - Transit oriented development,
  - Complete street design policies that prioritize transit, biking, and walking, and
  - Increasing low carbon mobility choices, including improved access to viable and affordable public transportation and active transportation opportunities.
- Complete the construction of high-speed rail integrated with enhanced rail and transit systems throughout the State.
- Promote transportation fuel system infrastructure for electric, fuel-cell, and other emerging clean technologies that is accessible to the public where possible, and especially in underserved communities, including environmental justice communities.
- Increase the number, safety, connectivity, and attractiveness of biking and walking facilities to increase use.
- Promote potential efficiency gains from automated transportation systems and identify policy priorities to maximize sustainable outcomes from automated and connected vehicles (preferably ZEVs), including VMT reduction, coordination with transit, and shared mobility, and minimize any increase in VMT, fossil fuel use, and emissions from using automated transportation systems.
- Promote shared-use mobility, such as bike sharing, car sharing and ride-sourcing services to bridge the "first mile, last mile" gap between commuters' transit stops and their destinations.
- Continue research and development on transportation system infrastructure, including:
  - Integrate frameworks for lifecycle analysis of GHG emissions with life-cycle costs for pavement and large infrastructure projects, and
  - Health benefits and costs savings from shifting from driving to walking, bicycling, and transit use.
- Quadruple the proportion of trips taken by foot by 2030 (from a baseline

198 CARB. Potential State - Level Strategies to Advance Sustainable, Equitable Communities and Reduce Vehicle Miles of Travel (VMT) -- for Discussion. *www.arb.ca.gov/cc/scopingplan/meetings/091316/Potential%20VMT%20Measures%20For%20Discussion_9.13.16.pdf*

of the 2010–2012 California Household Travel Survey).
- Strive for a nine-fold increase in the proportion of trips taken by bicycle by 2030 (from a baseline of the 2010–2012 California Household Travel Survey).
- Strive, in passenger rail hubs, for a transit mode share of between 10 percent and 50 percent, and for a walk and bike mode share of between 10 percent and 15 percent.

Vehicle Technology Goals

- Through a strong set of complementary policies–including reliable incentives, significant infrastructure investment, broad education and outreach, and potential regulation–aim to reach 100 percent ZEV sales in the light-duty sector (PHEVs, BEVs, and FCEVs) by 2050.
- Make significant progress in ZEV penetrations in non-light-duty sectors.
- Deploy low-emission and electrified rail vehicles.

Clean Fuels Goals

- Electrify the transportation sector using both electricity and hydrogen.
- Promote research development and deployment of low carbon fuels such as renewable gas, including renewable hydrogen.
- Rapidly reduce carbon intensity of existing liquid and gaseous transportation fuels.

Sustainable Freight Goals

- Increase freight system efficiency of freight operations at specific facilities and along freight corridors such that more cargo can be moved with fewer emissions.
- Accelerate use of clean vehicle and equipment technologies and fuels of freight through targeted introduction of zero emission or near-zero emission (ZE/NZE) technologies, and continued development of renewable fuels.
- Encourage State and federal incentive programs to continue supporting zero and near-zero pilot and demonstration projects in the freight sector.
- Accelerate use of clean vehicle, equipment, and fuels in freight sector through targeted introduction of ZE/NZE technologies, and continued development of renewable fuels. This includes developing policy options that encourage ZE/NZE vehicles on primary freight corridors (e.g., Interstate-710); examples of such policy options include a separated ZE/NZE freight lane, employing market mechanisms such as favorable road pricing for ZE/NZE vehicles, and developing fuel storage and distribution infrastructure along those corridors.

Cross-Sector Interactions

The transportation sector has considerable influence on other sectors and industries in the State. California's transportation sector is still primarily powered by petroleum, and to reduce statewide emissions, California must reduce demand for driving; continue to reduce its gasoline and diesel fuel consumption; diversify its transportation fuel sources by increasing the adoption of low- and zero-carbon fuels; increase the ease and integration of the rail and transit networks to shift travel mode; and deploy ZE/NZE vehicles.

As California's population continues to increase, land use patterns will directly impact GHG emissions from the transportation sector, as well as those associated with the conversion and development of previously undeveloped land. Specifically, where and how the State population grows will have implications on distances traveled and tailpipe emissions; as well as on secondary emissions from the transportation sector, including emissions from vehicle manufacturing and distribution, fuel refining and distribution, demand for new infrastructure (including roads, transit, and active transportation infrastructure), demand for maintenance and upkeep of existing infrastructure. Conversion of natural and working lands further affects emissions, with the attendant impacts to food security, watershed health, and ecosystems. Less dense development also demands higher energy and water use. With the exception of VMT reductions, none of these secondary emissions are currently accounted for in the GHG models used in this Scoping Plan, but are nonetheless important considerations. Additionally, compact, lower-VMT future development patterns are essential to achieving public health, equity, economic, and conservation goals, which are also not modeled but are important co-benefits of the overall transportation sector strategy. For example, high-speed rail station locations were identified in downtown areas to reinforce existing city centers.

Achieving LCFS targets and shifting from petroleum dependence toward greater reliance on low carbon fuels also has the potential to affect land use in multiple ways. For example, increased demand for conventional biofuels could require greater use of land and water for purpose-grown crops, which includes interactions with the agricultural and natural and working lands sectors. On the other hand, continuing growth in fuels from urban organic waste, as well as waste biomass such as composting residues, by-processing residues and agricultural waste and excess forest biomass acts to alleviate the pressure on croplands to meet the need for food, feed, and fuel. Likewise, captured methane from in-vessel digestion, landfills or dairy farms for use in vehicles requires close interaction with the waste and farming sectors.

Also, as more electric vehicles and charging stations are deployed, drivers' charging behavior will affect the extent to which additional electric generation capacity and ancillary services are needed to maintain a reliable grid and accommodate a portfolio of 50 percent renewable electricity by 2030. Charging control and optimization technologies will determine how well integrated the electric and transportation sectors can become, including, for instance, the widespread use of electric vehicles as storage for excess renewable generation, vehicle to grid, smart charging, and/or smart grid. The GHG emissions intensity of electricity affects the GHG savings of fuel switching from petroleum-based fuels to electricity; the cleaner the electric grid, the greater the benefits of switching to electricity as a fuel. Similar to electric vehicles, hydrogen fuel cell electric vehicles have zero-tailpipe emissions and can mitigate GHGs and criteria pollutants. Greenhouse gas emissions could be further reduced with the use of renewable hydrogen, which can be produced using renewable electricity or renewable natural gas.

Efforts to Reduce Greenhouse Gases

The measures below include some required and new potential measures to help achieve the State's 2030 target and to support the high-level objectives for the transportation sector. Some measures may be designed to directly address GHG reductions, while others may result in GHG reductions as a co-benefit.

Ongoing and Proposed Measures – Vibrant Communities and Landscapes / VMT Reduction Goals

- Mobile Source Strategy – 15 percent reduction in total light-duty VMT from the BAU in 2050 (with measures to achieve this goal not specified; potential measures identified in Appendix C).
- Work with regions to update SB 375 Sustainable Communities Strategies targets for 2035 to better align with the 2030 GHG target and take advantage of State rail investments.
- Stronger SB 375 GHG reduction targets will enable the State to make significant progress toward the goal of reducing total light-duty VMT by 15 percent from expected levels in 2050, but alone will not provide all of the VMT reductions that will be needed. The gap between what SB 375 can provide and what is needed to meet the State's 2030 and 2050 goals needs to be addressed through additional VMT reduction measures such as those mentioned in Appendix C.
- Implement and support the adoption and use of VMT as the CEQA metric of transportation impact, such that it promotes GHG reduction, the development of multimodal transportation networks, and a diversity of land uses.
- Continue to develop and explore pathways to implement State-level VMT reduction strategies, such as those outlined in the document "Potential State-Level Strategies to Advance Sustainable, Equitable Communities and Reduce Vehicle Miles of Travel (VMT) – for Discussion"[199] – included in Appendix C – through a transparent and inclusive interagency policy development process to evaluate and identify implementation pathways for additional policies to reduce VMT and promote sustainable communities, with a focus on:
  - Accelerating equitable and affordable transit-oriented and infill development through new and enhanced financing and policy incentives and mechanisms,
  - Promoting stronger boundaries to suburban growth through enhanced support for sprawl containment mechanisms such as urban growth boundaries and transfer of development rights programs,
  - Identifying performance criteria for transportation and other infrastructure investments

199 Refers to the document discussed at the September 2016 Public Workshop on the Transportation Sector to Inform Development of the 2030 Target Scoping Plan Update, also available at: *www.arb.ca.gov/cc/scopingplan/meetings/091316/Potential%20VMT%20Measures%20For%20Discussion_9.13.16.pdf*

  - to ensure alignment with GHG reduction goals and other State policy priorities and expand access to transit, shared mobility, and active transportation choices,
  - Promoting efficient development patterns that maximize protection of natural and working lands,
  - Developing pricing mechanisms such as road user/VMT-based pricing, congestion pricing, and parking pricing strategies,
  - Reducing congestion and related GHG emissions through commute trip reduction strategies, and
  - Programs to maximize the use of alternatives to single-occupant vehicles, including bicycling, walking, transit use, and shared mobility options.
- Finalize analysis of the results of the pilot road usage charge program, implemented pursuant to SB 1077 (DeSaulnier, Chapter 835, Statues of 2014), and evaluate deployment of a statewide program.
- Continue promoting active transportation pursuant to SB 99 (Committee on Budget and Fiscal Review, Chapter 359, Statutes of 2013) – The Active Transportation Program and beyond.
- Continue to build high-speed rail and broader statewide rail modernization pursuant to the funding program in SB 862 (Committee on Budget and Fiscal Review, Chapter 36, Statutes of 2014) and other sources.
- Encourage use of streets for multiple modes of transportation (including public transit and active transportation, such as walking and bicycling), and for all users, including the elderly, young, and less able bodied, pursuant to AB 1358 (Leno, Chapter 657, Statutes of 2008) – Complete Streets policies.
- Support and assist local and regional governments, through technical assistance, and grant and other local assistance programs, to develop and implement plans that are consistent with the goals and concepts in The Second Investment Plan for Fiscal Years 2016-2017 through 2018-2019[200] and its subsequent updates, and Appendix C: Vibrant Communities and Landscapes, including the following:
  - California Climate Investment programs such as Transformative Climate Communities Program, ensuring promotion of GHG reductions from neighborhood-level community plans in disadvantaged communities.
  - AB 2087 (Levine, Chapter 455, Statutes of 2016) – Help local and State agencies apply core investment principles when planning conservation or mitigation projects.
  - High speed rail station area plans.
  - Implementation of updated General Plan Guidelines.
- Per SB 350, implement the recommendations identified in the Barriers Study to accessing ZE/NZE transportation options for low-income customers and recommendations on how to increase access.[201] And, track progress towards these actions over time to ensure disadvantaged communities are getting equal access and benefits relative to other parts of the State.
- Take into account the current and future impacts of climate change when planning, designing, building, operating, maintaining, and investing in State infrastructure, as required under Executive Order B-30-15.

Ongoing and Proposed Measures – Vehicle Technology

- Implement the Cleaner Technology and Fuels Scenario of CARB's Mobile Source Strategy, which includes:
  - An expansion of the Advanced Clean Cars program, which further increases the stringency of GHG emissions for all light-duty vehicles, and 4.2 million zero emission and plug-in hybrid light-duty electric vehicles by 2030,
  - Phase 1 and 2 GHG regulations for medium- and heavy-duty trucks, and
  - Innovative Clean Transit.
- Periodically assess and promote cleaner fleet standards.
- Deploy ZEVs across all vehicle classes, including rail vehicles, along with the necessary charging infrastructure.
- Encourage State and federal incentive programs to continue supporting zero and near-zero pilot and demonstration projects.
- Collaborate with the U.S. Environmental Protection Agency to promulgate more

200 CARB. January 2016. Cap-and-Trade Auction Proceeds Second Investment Plan: Fiscal Years 2016-17 through 2018-19. Available at: *www.arb.ca.gov/cc/capandtrade/auctionproceeds/16-17-updated-final-second-investment-planii.pdf*

201 CARB. 2017. Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low Income Residents. *www.arb.ca.gov/msprog/transoptions/draft_sb350_clean_transportation_access_guidance_document.pdf*

stringent locomotives requirements,[202] work with California seaports, ocean carriers, and other stakeholders to develop the criteria to incentivize introduction of Super-Low Emission Efficient Ships, and investigate potential energy efficiency improvements for transport refrigeration units and insulated truck and trailer cargo vans.
- Promote research, development, and deployment of new technology to reduce GHGs, criteria pollutants, and toxics.
- Implement a process for intra-state agency and regional and local transportation coordination on automated vehicles to ensure shared policy goals in achieving safe, energy efficient, and low carbon autonomous vehicle deployment that also contribute to VMT reductions.

Ongoing and Proposed Measures – Clean Fuels

- Continue LCFS activities, with increasing stringency of at least 18 percent reduction in carbon intensity (CI).
- Continue to develop and commercialize clean transportation fuels through renewable energy integration goals, tax incentives, research investments, support for project demonstration, public outreach, setting procurement standards, including updating State and local procurement contracts.
- Per SB 1383 and the SLCP Strategy, adopt regulations to reduce and recover methane from landfills, wastewater treatment facilities, and manure at dairies; use the methane as a source of renewable gas to fuel vehicles and generate electricity; and establish infrastructure development and procurement policies to deliver renewable gas to the market.
- Accelerate deployment of alternative fueling infrastructure pursuant to the following:
  - SB 350 – CPUC to accelerate widespread transportation electrification.
  - Executive Order B-16-2012 and 2016 ZEV Action Plan – call for infrastructure to support 1 million ZEVs by 2020.
  - CEC's Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP).
  - CPUC's NRG settlement.
  - CALGreen Code provisions mandate installation of PEV charging infrastructure in new residential and commercial buildings.[203]
  - IOU electric vehicle charging infrastructure pilot programs.

Ongoing and Proposed Measures – Sustainable Freight

- Implement the California Sustainable Freight Action Plan:
  - 25 percent improvement of freight system efficiency by 2030.
  - Deployment of over 100,000 freight vehicles and equipment capable of zero emission operation, and maximize near-zero emission freight vehicles and equipment powered by renewable energy by 2030.

Ongoing and Proposed Measures – California and Transportation Plan

- Update every five years and implement California Transportation Plan.

Sector Measures

- Implement the post-2020 Cap-and-Trade Program

Potential Additional Actions

The actions below have the potential to reduce GHGs and complement the measures and policies identified in Chapter 2. These are included to spur thinking and exploration of innovation that may help the State achieve its long-term climate goals.

- Develop a set of complementary policies to make light-duty ZEVs clear market winners, with a goal of reaching 100 percent light-duty ZEV sales. This could include the following:
  - Reliable purchase/trade-in incentives for at least 10 years.
  - Dealer incentives for ZEV sales.
  - Policies to ensure operating cost savings for ZEVs relative to internal

202 *www.arb.ca.gov/railyard/docs/final_locomotive_petition_and_cover_letter_4_13_17.pdf*
203 Such as raceway and panel capacity to support future installation of electrical vehicle charging stations.

combustion engines, including low cost electricity.
    - Additional investments in charging and ZEV refueling infrastructure.
    - A broad and effective marketing and outreach campaign.
    - Collaborations with cities to develop complementary incentive and use policies for ZEVs.
    - Targeted policies to support ZEV sales and use in low income and disadvantaged communities.
- Develop a Low-Emission Diesel Standard to diversify the fuel pool by incentivizing increased production of low-emission diesel fuels. This standard is anticipated to both displace consumption of conventional diesel with increased use of low-emission diesel fuels, and to reduce emissions from conventional fuels.
- Continue to develop and explore pathways to implement State-level VMT reduction strategies, such as those outlined in Appendix C through a transparent and inclusive interagency policy development process to evaluate and identify implementation pathways for additional policies to reduce VMT and promote sustainable communities, with a focus on the following:
    - Accelerating equitable and affordable transit-oriented and infill development through new and enhanced financing and policy incentives and mechanisms.
    - Promote infrastructure necessary for residential development in existing communities, and ensure any urban growth boundaries are paired with significant infill promotion strategies and removal of infill development barriers.
    - Identifying performance criteria for transportation and other infrastructure investments, to ensure alignment with GHG reduction goals and other State policy priorities, and improve proximity, expanded access to transit, shared mobility, and active transportation choices.
    - Promoting efficient development patterns that maximize protection of natural and working lands.
    - Developing pricing mechanisms such as road user/VMT-based pricing, congestion pricing, and parking pricing strategies.
    - Reducing congestion and related GHG emissions through programs to maximize the use of alternatives to single-occupant vehicles, including bicycling, walking, transit use, and shared mobility options for commute trips.
- Continue to promote research and standards for new and existing technologies to reduce GHGs, including but not limited to:
    - Low rolling resistance tires in the replacement tire market, subject to certification standards that identify tires as low rolling resistance tires or verify emissions reductions and potential fuel savings.
    - Impacts on VMT of car sharing, ride-sourcing, and other emerging mobility options.
    - Driving behaviors that reduce GHG emissions, such as ecodriving training and real-time feedback mechanisms.

Natural and Working Lands Including Agricultural Lands

In his 2015 State of the State address, Governor Brown established 2030 targets for GHG emissions reductions and called for policies and actions to reduce GHG emissions from natural and working lands, including forests, rangelands, farms, wetlands, and soils. The passage of SB 1386 (Wolk, Chapter 535, Statutes of 2015-16) codified this policy and emphasized the important role natural and working lands play in the State's climate strategy. This Scoping Plan focuses renewed attention on California's natural and working lands and the contribution they make to meet the State's goals for carbon sequestration, GHG reduction, and climate change adaptation.

California's natural and working lands encompass a range of land types and uses, including farms, ranches, forests, grasslands, deserts, wetlands, riparian areas, coastal areas and the ocean-- as well as the green spaces in urban and built environments. These resources can be both a source and sink for GHG emissions. Policy in this sector must balance GHG emissions reductions and carbon sequestration with other co-benefits, such as clean air, wildlife and pollinator habitat, strong economies, food, fiber and renewable energy production, and water supply.[204]

Recent trends indicate that significant pools of carbon from these landscapes risk reversal: over the period 2001–2010 disturbance caused an estimated 150 MMT C loss, with the majority– approximately 120 MMT C–

204 *www.sierranevada.ca.gov/our-region/ca-primary-watershed*

lost through wildland fire.[205] At the same time, energy use, methane, and N_2O emissions from the agricultural sector accounts for eight percent of the emissions in the statewide GHG inventory.

California's climate objective for natural and working lands is to maintain them as a carbon sink (i.e., net zero or negative GHG emissions) and, where appropriate, minimize the net GHG and black carbon emissions associated with management, biomass utilization, and wildfire events. In order to achieve this objective, this Plan directs the continued development of the broad and growing understanding of carbon dynamics on California's landscapes, statewide emission trends, and their responses to different land management scenarios. Further, in order to build a programmatic framework for achieving this long-term objective to maintain California's natural and working lands as a carbon sink, this Plan directs the State to quantify the carbon impacts of both publicly funded (e.g., bonds, special taxes, general fund) climate intervention activities on California's natural and working lands made through existing programs as well as potential regulatory actions on land management. This Plan proposes an intervention based reduction goal of at least 15-20 million metric tons by 2030 as a reasonable beginning point for further discussion and development based on the State's current preliminary understanding of what might be feasible. This Plan recognizes that achieving an initial statewide goal of sequestering and avoiding emissions in this sector by at least 15-20 million metric tons by 2030 through existing pathways and new incentives would provide a crucial complement to the measures described in this Scoping Plan and will inform the development of longer-term natural and working lands goals. Achieving this ambitious climate goal will require collaboration and support from State and local agencies, which must improve their capacity to participate and benefit from State climate programs, and set the path for natural and working lands to help the State meet its long-range climate goals.

Looking to the Future

This section outlines how the State will achieve California's climate objectives to: (1) maintain them as a resilient carbon sink (i.e., net zero or negative GHG emissions), and (2) minimize the net GHG and black carbon emissions associated with management, biomass disposal, and wildfire events to 2030 and beyond.

Implementation will include policy and program pathways, with activities related to land protection; enhanced carbon sequestration; and innovative biomass utilization. The framework for this section is to:

- **Protect** land from conversion to more intensified uses by increasing conservation opportunities and pursuing local planning processes in urban and infrastructure development patterns that avoid greenfield development.
- **Enhance** the resilience of and potential for carbon sequestration on lands through management and restoration, and reduce GHG and black carbon emissions from wildfire and management activities. This enhancement includes expansion and management of green space in urban areas.
- **Innovate** biomass utilization such that harvested wood and excess agricultural and forest biomass can be used to advance statewide objectives for renewable energy and fuels, wood product manufacturing, agricultural markets, and soil health, resulting in avoided GHG emissions relative to traditional utilization pathways. Associated activities should increase the resilience of rural communities and economies.

To accomplish these objectives, the State, led by California Natural Resources Agency (CNRA), California Department of Food and Agriculture (CDFA), California Environmental Protection Agency (CalEPA) and CARB will complete a Natural and Working Lands (NWL) Climate Change Implementation Plan (Implementation Plan) in 2018 to evaluate a range of implementation scenarios for natural and working lands and identify long-term (2050 or 2100) sequestration goals that can be incorporated into future climate policy. The Implementation Plan will:

- Include a projection of statewide emissions under business-as-usual land use and management conditions and alternative scenarios, as well as a listing and quantitative assessment of conservation and management activities the state may pursue to achieve the NWL climate objectives and the statewide goals of at least 15-20 $MMTCO_2e$ emissions sequestering and avoidance from the NWL sector by 2030;
- Identify state departments, boards, conservancies, and CNRA and CDFA programs responsible for meeting the 15-20 $MMTCO_2e$ goal by 2030; and
- Identify methodologies to be used by State programs to account for the

205 *www.arb.ca.gov/cc/inventory/sectors/forest/forest.htm*

GHG impacts of prior state funded land use and management interventions, and to be used to estimate the GHG impacts of future interventions.

While growing trees and other vegetation, as well as soil carbon sequestration, reduce some of the carbon losses measured, climate change itself further stresses many of these systems and affects the ability of California's landscapes to maintain its carbon sink. The State will continue to rely on best available science to support actions and incentives to slow and reverse these trends, in concert with other production and ecological objectives of land use. The Forest Climate Action Team, Healthy Soils Initiative, State Coastal Conservancy's Climate Ready Program, various California Climate Investment programs, and CARB's compliance offset program already undertake portions of this work. As we move towards and maximize the ability of our land base to serve as a carbon sink, it will also be important to strengthen these individual activities through the coordination and aggregation of ecoregional plans that inform these interventions. These and future additional efforts can not only protect California's natural carbon stocks, they can also improve quality of life in urban and rural communities alike and increase the climate resilience of agricultural, forestry, and recreational industries and the rural communities they support; the State's water supply; biodiversity; and the safety and environmental health of all who call California home.

Research and Policy Needs

Research is ongoing across agencies to advance the state of the science on NWL carbon dynamics, including a number of projects within the Fourth Climate Change Assessment, and a compendium of climate research being managed by the CNRA that will be completed in 2018. Additionally, California needs a well-defined reference case, or "business as usual" scenario to set a comprehensive and strategic path forward for California's lands and ocean environments to contribute to the State's climate goals. Finally, efforts must increase to gather, interpret, and unify best available science on the GHG and carbon sequestration impacts of land use and management practices applied across forests, cultivated agricultural lands, rangelands and grasslands, wetlands, coastal and ocean systems, desert ecosystems, and urban and other settled lands.

The Implementation Plan, as summarized above, will utilize the Protect-Enhance-Innovate framework and employ projections for carbon sequestration and GHG emissions from California's land base under reference case and increased management scenarios. The quantitative outputs of these projections, expressed as carbon dioxide equivalents will drive acreage needs for implementation using CO_2e/acre results from multiple modeling efforts. The Implementation Plan will also identify GHG emissions quantification within and across programs and agencies and describe implementation monitoring and emissions inventories.

Natural and Working Lands Inventory

In order to understand how carbon is released and sequestered by natural and working landscapes, CARB has worked extensively with other State agencies, academic researchers and the public to develop a Natural and Working Lands inventory that will guide this process. As with other sectors, the CARB Natural and Working Lands inventory represents a snapshot of emissions in recent years, using a combination of reported and measured data. A time lag exists between the last year of available data and the completion of the inventory to allow time for reporting and processing the data. For emission sources that are hard to individually measure, the CARB inventory estimates emissions based on "surrogates," such as the typical amount of travel on unpaved roads to estimate particulate matter emissions at the county level. The most recent inventory can also be "forecast" to project prevailing conditions in a future year based on rules and programs currently in place – known as a "business as usual projection" - along with scenarios to explore the benefits of further strategies to reduce emissions. Forecasts of business-as-usual and policy scenarios guide planning efforts.

As discussed below, ongoing research into forecasting emissions from Natural and Working Lands includes a project at Lawrence Berkeley National Laboratory funded by CNRA. CARB is monitoring this and other research activities and will incorporate results into a proposed inventory and forecasting methodology for Natural and Working Lands. CARB will solicit public feedback and review on the resulting product prior to completing the first full Natural and Working Lands Inventory by the end of 2018, as called for in SB 859. The Natural and Working Lands Inventory is spatially-resolved, so it can be segmented by county, watershed, or other regional planning areas. This spatial resolution allows local governments and regional organizations to use the inventory, along with more granular location-specific information, to track progress from projects in their jurisdictions.

CARB plans to update the forest component of the Natural and Working Lands inventory to include 2012 GHG emissions estimates, followed by emissions estimates for soil carbon, urban forestry, and croplands by mid-2018. Work currently in progress applies airborne and space-based technologies to monitor forest health and quantify emissions associated with land-based carbon. California and federal agencies are working with researchers and funding studies to enhance our understanding of the roles of forests and other lands in climate change using rapidly advancing remote sensing technology.[206, 207]

CALAND Carbon Emissions Model

CNRA is managing the development of a CALAND model through Lawrence Berkeley National Laboratory, which will include a projection of business-as-usual emissions as well as a listing and quantitative assessment of conservation and management activities the State may pursue to achieve at least 15-20 MMT sequestration and GHG avoided emissions from the NWL sector by 2030.

CNRA, along with CARB and CDFA, will establish a formal public engagement process to gather external scientific expertise to inform development and finalization of the CALAND model for use in the Implementation Plan. Development of the Implementation Plan itself will also include a formal public process.

Cross-Sector Interactions

Strategies that reduce GHG emissions or increase sequestration in the natural and working lands sector often overlap and result in synergies with other sectors, most notably at intersections with land use, biomass and waste utilization, energy and water. It will be important for the sector to make critical linkages to other sectors, including energy, transportation fuels, and waste, and develop plans to integrate the natural and working lands sector into existing models, such as PATHWAYS and REMI.

Landowner, local, and regional decisions affect land use development patterns and natural and working land conversion rates; conversely, conservation activities can support infill-oriented regional development and related transportation needs. As discussed earlier in the Transportation Sustainability section, under SB 375, Sustainable Communities Strategies (SCSs) aim to link transportation, housing, and climate policy to reduce per capita GHG emissions while providing a range of other important benefits for Californians. Some SCSs include policies, objectives or implementation measures relating to conservation and land protections, and to urban greening.[208] Protecting natural and working lands that are under threat of conversion can promote infill development, reduce VMT, limit infrastructure expansion, and curb associated GHG emissions. An integrated vision for community development, land conservation and management, and transportation is a key component of meeting our transportation and natural and working lands goals.[209]

Agricultural and commercial forestry operations produce biomass as both an objective (i.e., food and fiber production) and a waste by-product. How this material is utilized can either increase or decrease emissions associated with management and restoration activities, turn waste into usable products, displace fossil fuels used in energy and transportation, and increase carbon stored in durable wood products in the built environment. Finding productive ways to use this material offers new opportunities to reduce GHG emissions, promote carbon sequestration, and generate economic resources for forest, agricultural, and waste sectors and communities. California is investigating ways to transform how organic waste from the agricultural and municipal sectors is managed to meet SLCP emissions reductions targets required by SB 1383,[210] and to protect public health. Cross-sector synergies and complete waste inter-cycles, discussed further in the Waste Management section, result from conscientious treatment of these resources, including opportunities to improve soil health, increase renewable energy generation, and enhance market support for non-commercial products and waste. Productive utilization of dead and dying trees is a significant focus of the Governor's Tree Mortality Task Force, and efforts to resolve the current shortfall in utilization capacity is addressed in that State of Emergency Declaration as well as in SB 859.

Natural and working lands stewardship is essential to securing the State's water supply along the entire

206 Asner, G. et al. (2015) Progressive forest canopy water loss during the 2012–2015 California drought. PNAS 113.2: E249-E255

207 Battles, J. et al. (in progress) Innovations in measuring and managing forest carbon stocks in California. Project 2C: 4th California Climate Change Assessment. Natural Resources Agency. resources.ca.gov/climate/fourth/

208 Livingston, Adam. Sustainable Communities Strategies and Conservation. January 2016. Available at: *www.nature.org/ourinitiatives/regions/northamerica/unitedstates/california/sustainable-communities-strategies-and-conservation.pdf*

209 *www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm*

210 SB1383 (Lara, Chapter 396, Statutes of 2016) requires a 50 percent reduction in anthropogenic black carbon emissions by 2030.

supply chain, from protection and management of the forested headwaters to preserving the ability of mountain meadows to retain and filter water ensuring flows and habitat in the Delta and its tributaries, end use efficiencies in agricultural and urban uses, and groundwater infiltration and utilization statewide. For example, more efficient water and energy use in farming operations could support GHG emissions reductions goals in the energy sectors. And improving forest health in the Sierra Nevada, Cascades, and other headwaters protects water quality and availability, in alignment with the California Water Action Plan.

Potential Actions to Enhance Carbon Sequestration and Reduce Greenhouse Gases in NWL

While agricultural and forest lands comprise the greatest acreage of NWL statewide, representing significant opportunity for achieving the State's NWL climate goals, actions on all NWL remain critical. The land management strategies and targets included in these sections are illustrative of the types of actions that will be necessary to maintain all of California's NWL and urban green space as a net sink of carbon, and are being used to aid in development of scenario modeling. The Implementation Plan will use this scenario modeling to scope the scale of action needed to ensure resilient future landscapes and identify key areas for advancement.

Agriculture's Role in Emissions Reductions and Carbon Sequestration

In 2030 and 2050, the agricultural sector must remain vibrant and strong. California's agricultural production is critical to global food security. It is also vulnerable to climate change. A study[211] by the University of California concluded that the drought in 2015 cost the state economy $2.7 billion and 21,000 full time jobs. These losses are expected to ripple through rural communities for another several years. This illustrates the importance of strengthening agriculture while protecting resources and mitigating climate change.

As the State works to meet emissions reductions goals, the agricultural sector can reduce emissions from production, sequester carbon and build soil carbon stocks, and play a role in cross-sectoral efforts to maximize the benefits of natural and working lands.

Climate-smart agriculture is an integrated approach to achieving GHG reductions while also ensuring food security and promoting agricultural adaptation in the face of climate change. Conserving agricultural land, sequestering carbon in agricultural soils, employing a variety of techniques to manage manure on dairies, and increasing the efficiency of on-farm water and energy use are examples of practices that can achieve climate and food production goals across diverse agricultural systems. Climate-smart agriculture can support the Protect, Enhance, and Innovate goals.

Approximately 60 percent of agricultural emissions are methane emissions from the dairy and livestock sectors. Emissions come from the animals themselves, through enteric fermentation, as well as from manure management–especially at dairies. SB 1383 and the resultant SLCP Strategy identify a mix of voluntary, incentive-based, and potential regulatory actions to achieve significant emissions reductions from these sources. A variety of techniques can attain the best results for each specific farming operation; effectively implementing a broad mix of strategies will reduce the GHG emissions from the agricultural sector significantly. CARB and CDFA and other agencies are working together to solicit input from industry, environmental, and community groups to encourage early and meaningful action to reduce emissions from the livestock sector.

Over the last several years, farms have begun to optimize fertilizer applications to protect water quality, maintain high yields, and reduce emissions of N_2O, a greenhouse gas. Farmers are required through the Irrigated Lands Regulatory Program to manage nitrogen fertilizers to protect water quality through the use of nitrogen management plans. Nitrogen management plans are a tool designed to prevent over-applications of nitrogen through an approach that accounts for the nitrogen inputs from water, soil amendments and other sources, and also accounts for nitrogen removed from the field. CDFA's Fertilizer Research and Education Program, in coordination with university researchers and others, has developed fertilization guidelines to optimize the rate, timing and placement of fertilizers for crops that represent more than half of the irrigated agriculture in California. Similarly, innovations in water management and the expansion of high efficiency irrigation methods also are contributing to N_2O reductions.

211 Howitt, Richard E., Duncan MacEwan, Josué Medellín-Azuara, Jay R. Lund, Daniel A. Sumner. 2015. Economic Analysis of the 2015 Drought for California. Davis, CA: Center for Watershed Sciences, University of California – Davis.

California's farms and ranches have the ability to remove carbon from the atmosphere through management practices that build and retain soil organic matter. Adequate soil organic matter ensures the continued soil capacity to function as a vital living ecosystem with multiple benefits, producing food for plants, animals, and humans. The Healthy Soils Initiative, announced by Governor Brown in 2015, offers an opportunity to incentivize the management of farmland for increased carbon sequestration in soil, also augmenting co-benefits including improved plant health and yields, increased water infiltration and retention, reduced sediment erosion and dust, improved water and air quality, and improved biological diversity and wildlife habitat.

SB 859, signed into law in 2016, establishes the Healthy Soils Program at CDFA to provide incentives to farmers. It enables financial support for on-farm demonstration projects that "result in greenhouse gas benefits across all farming types with the intent to establish or promote healthy soils". It defines healthy soils as "soils that enhance their continuing capacity to function as a biological system, increase soil organic matter, improve soil structure and water-and nutrient-holding capacity, and result in net long-term greenhouse gas benefits."

As noted in the Cross-Sector Interactions section, State and local efforts to manage land for carbon sequestration must work in conjunction with existing plans, incentives, and programs protecting California's water supply, agricultural lands, and wildlife habitat. This Scoping Plan fits within a wide range of ongoing planning efforts throughout the State to advance economic and environmental priorities associated with natural and working lands.

The Role of Forests in Emissions Reductions and Carbon Sequestration

Decades of fire exclusion, coupled with an extended drought and the impacts of climate change, have increased the size and intensity of wildfires and bark beetle infestations; exposed millions of urban and rural residents to unhealthy smoke-laden air from wildfires; and threatened progress toward meeting the state's long-term climate goals. Managing forests in California to be healthy, resilient net sinks of carbon is a vital part of California's climate change policy.

More than 100 million trees are dead, and recent wildfires have been among the most destructive and expensive in state history. As many as 15 million acres of California forests are estimated to be unhealthy and in need of some form of restoration, including more than 9 million acres managed by federal land management agencies and 6 million acres of State and privately managed forests.

California's urban forests also face multiple challenges, including drought and invasive exotic insects. Urban forests require maintenance to preserve the multiple values they provide and merit expansion to sequester carbon and secure other benefits to urban dwellers and the State.

The California Forest Carbon Plan (FCP), being developed by the Forest Climate Action Team (FCAT), seeks to establish California's forests as a more resilient and reliable long-term carbon sink, rather than a GHG and black carbon emission source, and confer additional ecosystem benefits through a range of management strategies.[212] The FCP emphasizes working collaboratively at the watershed or landscape scale to restore resilience to all forestlands in the state.

The current draft of the FCP places carbon sequestration and reducing black carbon and GHG emissions as one set of management objectives in the broader context of forest health and a range of other important forest co-benefits. California will manage for carbon alongside wildlife habitat, watershed protection, recreational access, traditional tribal uses, public health and safety, forest products, and local and regional economic development.

212 *http://www.fire.ca.gov/fcat/*

Federally managed lands play an important role in the achievement of the California climate goals established in AB 32 and subsequent related legislation and plans. Over half of the forestland in California is managed by the federal government, primarily by the USDA Forest Service Pacific Southwest Region, and these lands comprise the largest potential forest carbon sink under one ownership in the state. Several regulatory, policy, and financial challenges have hindered the ability of the Forest Service and Department of Interior agencies (Bureau of Land Management and National Park Service) to increase the pace and scale of restoration needed, such as the current budget structure to fund wildland fire suppression and the procedural requirements of a number of federal environmental and planning statutes. The State of California must continue to work closely and in parallel to the federal government's efforts to resolve these obstacles and achieve forest health and resilience on the lands that federal agencies manage.

Protection of Land and Land Use

California will continue to pursue development and new infrastructure construction patterns that avoid greenfield development, limit conflicts with neighboring land uses, and increase conservation opportunities for NWL to reduce conversion to intensified uses. Success will depend on working through local and regional land use planning and permitting, as well as developing incentives for participation by local governments and individual landowners.

Enhance Carbon Sequestration and Resilience through Management and Restoration

California will increase efforts to manage and restore land to secure and increase carbon storage and minimize GHG and black carbon emissions in a sustainable manner so that the carbon bank is resilient and provides other benefits such as water quality, habitat and recreation.

One tool to demonstrate the potential for greater management and restoration on NWL is the CALAND model. As detailed in the Discussion Draft[213] and discussed above, it considers a variety of management and restoration activities employed across the State. Version 1 of the CALAND model considered two potential scenarios, a "low" and a "high" rate of implementation to 2030, with resulting carbon sequestration outcomes to 2050. The acreages given in the "low" scenario all represent feasible implementation on public and private lands beyond current rates for the listed activity, given availability of additional funding and other supporting resources. The "high" scenario represents a more ambitious approach, requiring new programs and policies, including collaboration with federal partners, to support implementation.

The activities presented in the Discussion Draft and Version 2 of CALAND are not inclusive of all activities under this strategy. Modeling will continue beyond finalization of the Scoping Plan. Agencies and modelers will continue to identify and analyze land management and restoration activities to advance the State's climate goals and improvements in modeling projections or other quantification protocols.

Management and restoration activities under consideration to help reduce GHG emissions beyond those identified in initial modeling include, but are not limited to the following:

- Forest fuel reduction treatments, reforestation, other restoration activities, prescribed fire and managed ignition.
- Restoration of mountain meadows, managed wetlands in the Sacramento San Joaquin Delta, coastal wetlands and desert habitat.
- Increasing the extent of eelgrass beds.
- Creation and management of parks and other greenspace in urban areas, including expansion of the existing urban tree canopy.
- Implementation of U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) management practices suitable for California agriculture including those practices identified in the Healthy Soils Incentive Program.
- Compost application to irrigated cropland.

Additional potential tools to encourage these activities include working with the federal government to fund more management on federal lands, mitigating for land conversion (as modeled by the High Speed Rail Authority), and revisiting the Forest Practices Act to enhance carbon sequestration benefits associated with timber production activities.

213 *www.arb.ca.gov/cc/scopingplan/2030target_sp_dd120216.pdf*

Innovate NWL Waste Utilization Pathways

Excess materials generated by commercial agricultural and forestry operations, biomass and wood harvested through forest health and restoration treatments, and material that is generated in response to Tree Mortality Emergency activities, should be used in a manner that minimizes GHG and black carbon emissions and promotes public and environmental health. The Legislature and Governor Brown set an ambitious goal of 75 percent recycling, composting or source reduction of solid waste in landfills by 2020. The State and stakeholders must develop targeted policies or incentives to support durable markets for all of this diverted material. Market opportunities include production of renewable electricity and biofuels, durable wood products, compost and other soil amendments, animal feed and bedding, and other uses. Research, development, and implementation activities in energy, wood products, waste, and soil amendment fields should be spatially-scaled to better link waste generation with infrastructure development.

The goals of this sector, with the potential to reduce GHGs and complement the measures and policies identified in Chapter 2, are described in Looking to the Future. The development of the Implementation Plan will spur thinking and exploration of innovation that may help the State achieve its long-term climate goals.

Waste Management

The Waste Management sector covers all aspects of solid waste[214] and materials management including reduction/reuse; recycling, and remanufacturing of recovered material; composting and in-vessel (anaerobic and aerobic) digestion; biomass management (chip and grind, composting, biomass conversion); municipal solid waste transformation; and landfilling. This sector also includes market development programs, such as the State's recycled-content product procurement program and a range of grant and loan programs. Data from CalRecycle's report, *2014 Disposal Facility-Based Characterization of Solid Waste in California*, shows that materials, such as organics, that decompose in landfills and generate methane comprise a significant portion of the waste stream. Methane is a potent SLCP with a global warming potential 25 times greater than that of carbon dioxide on a 100-year time horizon and more than 70 times greater than that of carbon dioxide on a 20-year time horizon.[215]

Within CARB's greenhouse gas inventory, emissions from the waste management sector consist of methane and nitrous oxide emissions from landfills and from commercial-scale composting, with methane being the primary contributor to the sector's emissions. The sector emitted 8.85 MMTCO$_2$e in 2014, comprising approximately 2 percent of the State's GHG emissions.

Emissions from recycling and waste have grown by 19 percent since 2000. The majority of those emissions are attributed to landfills, despite the majority of landfills having gas collection systems in place.[216] Landfill emissions account for 94 percent of the emissions in this sector, while compost production facilities make up a small fraction of emissions.[217] The annual amount of solid waste deposited in California landfills grew from 37 million tons in 2000 to its peak of 46 million tons in 2005, followed by a declining trend until 2009 when landfilled solid waste stabilized to relatively constant levels. Landfill emissions are driven by the total waste-in-place, rather than year-to-year fluctuation in annual deposition of solid waste, as the rate and volume of gas produced during decomposition depends on the characteristics of the waste and a number of environmental factors. As a result, waste disposed in a given year contributes to emissions that year and in subsequent years.

In addition to direct emissions, the reduction, reuse, and recycling of waste materials decreases upstream GHG emissions associated with the extraction and processing of virgin materials and their use in production and transport of products. Although many of these upstream GHG emissions happen outside of California, California's waste policies can reduce both local and global GHG emissions and create jobs within the State.

214 In general, the term solid waste refers to garbage, refuse, sludges, and other discarded solid materials resulting from residential activities, and industrial and commercial operations. This term generally does not include solids or dissolved material in domestic sewage or other significant pollutants in water such as silt, dissolved or suspended solids in industrial wastewater effluents, dissolved materials in irrigation return flows or other common water pollutants.

215 Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: Working Group I: The Physical Science Basis. 2.10.2 Direct Global Warming Potentials. Fourth Assessment Report. *www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html*

216 CARB. 2013. California Greenhouse Gas Inventory for 2000–2013 – by Category as Defined in the 2008 Scoping Draft Plan (based upon IPCC Fourth Assessment Report's Global Warming Potentials).

217 CARB. 2016. 2016 Edition California GHG Emission Inventory. California Greenhouse Gas Emission Inventory: 2000–2014. Version June 17, 2016.

While landfills are an effective and relatively safe way to manage some waste, disposal-centric activities result in squandering valuable resources and generate landfill gases as well as other risks. A large fraction of the organics in the waste stream can be diverted from landfills to composting or digestion facilities to produce beneficial products. Moreover, food waste is the largest component of organics disposed in landfills; a portion of this is edible and should be captured at its source and, for example, provided to food banks to feed people in need. A State waste management sector "loading order" should focus more attention on reducing how much waste we generate and recovering and recycling whatever resources we can, using landfills as a last resort.

Landmark initiatives like the Integrated Waste Management Act of 1989 (AB 939) demonstrate California's efforts to build communities that consume less, recycle more, and take resource conservation to higher and higher levels. Statewide, Californians achieved a 49 percent recycling rate in 2014, and recycling programs support an estimated 75,000 to 115,000 green jobs in California. If California were to achieve a 75 percent statewide solid waste recycling rate by 2020–a goal set out by the Legislature in AB 341 (Chesboro, Chapter 476, Statutes of 2011)–by recycling and remanufacturing at in-state facilities, the State could potentially generate an additional 100,000 green jobs.[218] In addition to employment contributions, diversion of organic waste from landfills can generate positive environmental impacts. Compost from organic matter provides soil amendments to revitalize farmland, reduces irrigation and landscaping water demands, contributes to erosion control in fire-ravaged landscapes, and potentially increase long-term carbon storage in rangelands. Production and use of bioenergy in the form of biofuels and renewable natural gas has the potential to reduce dependency on fossil fuels for the transportation sector. For the energy sector, however, renewable natural gas faces safety, feasibility, and cost issues.

The State has a robust waste management system in place, with established programs that reduce air emissions through activities such as gas collection systems from landfills[219] and stringent recycling mandates. AB 939 required cities and counties to reduce the amount of waste going to landfills by 50 percent in 2000, and municipalities have nearly universally met this mandate. Californians dispose about 30 million tons of solid waste in landfills each year. To further reduce landfilled solid waste, the Legislature adopted AB 341 to achieve more significant waste reductions by setting a goal that 75 percent of solid waste generated be reduced, recycled, or composted by 2020, and by mandating commercial recycling. AB 1826 (Chesboro, Chapter 727, Statutes of 2014) added requirements regarding mandatory commercial organics recycling.

Although solid waste management has evolved over the last 27 years and diversion rates (which include more than recycling) have increased more than six-fold since 1989, if no further changes in policy are made, the State's growing population and economy will lead to higher amounts of overall disposal along with associated increases in GHG emissions. The pathway to reducing disposal and associated GHG emissions will require significant expansion of the composting, anaerobic digestion, and recycling manufacturing infrastructure in the State.

To help reduce GHG emissions by 40 percent below 1990 levels by 2030 and meet California's waste reduction goals, California's waste management sector strives to achieve in-state processing and management of waste generated in California. To carry out this vision, we must work with residents and producers to reduce the volume of waste generated overall and capitalize on technology and social changes that might enable waste reduction. Packaging comprises approximately 8 million tons of waste landfilled in California annually, or about one quarter of the State's total disposal stream. To reduce the climate change footprint of packaging, the State is promoting the inclusion of source reduction principles in packaging and product design; fostering recycling and recyclability as a front end design parameter for packaging and products that cannot be reduced; and encouraging recycling markets and market development for recycled-content products and packaging. CalRecycle is developing a packaging policy model containing components necessary for a mandatory comprehensive, statewide packaging program in California; this would need to be legislatively enacted to achieve a packaging reduction goal, such as 50 percent by 2030. CalRecycle is also continuing to work with stakeholder organizations and industry to explore complementary voluntary activities that have the potential to significantly decrease packaging disposal in California. In addition, large-scale shifts in materials management will be necessary, including steps to maximize recycling and diversion from landfills

218 CalRecycle. 2013. AB 341's 75 Percent Goal and Potential New Recycling Jobs in California by 2020. July. *www.calrecycle.ca.gov/Publications/Documents/1463/20131463.pdf*

219 CARB approved a regulation to reduce methane from municipal solid waste landfills as a discrete early action measure under AB 32. The regulation became effective June 17, 2010. Additional information is available at: *www.arb.ca.gov/regact/2009/landfills09/landfillfinalfro.pdf*

and build the necessary infrastructure to support a sustainable, low carbon waste management system within California. Working together, State and local agencies will identify ways to increase the use of waste diversion alternatives and expand potential markets, obtain funds and incentives for building the infrastructure and strengthening markets, and evaluate the need for additional research to achieve California's GHG reduction and waste management goals.

Additional legislation codified since the First Scoping Plan Update outlines new opportunities and requirements to reduce GHG emissions from the waste sector, with a focus on reducing organic waste sent to landfills. SB 605 (Lara, Chapter 523, Statutes of 2014) requires that CARB develop a strategy to reduce SLCPs and SB 1383 requires the strategy to be implemented by January 1, 2018. CARB's recently adopted SLCP Reduction Strategy includes organic waste diversion targets for 2020 and 2025 consistent with SB 1383 to reduce methane emissions from landfills. It requires CalRecycle, in consultation with CARB, to adopt regulations to achieve statewide disposal targets to reduce landfilling of organic waste by: (1) 50 percent from the 2014 level by 2020, and (2) 75 percent from the 2014 level by 2025. Under SB 1383, of the edible food destined for the organic waste stream, not less than 20 percent is to be recovered to feed people in need by 2025. The regulations are to take effect on or after January 1, 2022, and CalRecycle, in consultation with CARB, must analyze the progress that the waste management sector, State government, and local government have made in achieving the 2020 and 2025 goals by July 1, 2020. It is estimated that the combined effect of the food waste prevention and rescue programs and organics diversion from landfills will reduce 4 $MMTCO_2e$ of methane in 2030 (using a 20-year GWP), but one year of waste diversion in 2030 is expected to result in a reduction of 14 $MMTCO_2e$ of emissions over the lifetime of waste decomposition.

Looking to the Future

This section outlines the high-level objectives and goals to reduce GHGs in this sector.

Goals

- Take full ownership of the waste generated in California.
- View waste as a resource and convert waste from all sectors to beneficial uses.
- Develop a sustainable, low carbon waste management system that processes collected waste within California and generates jobs, especially in disadvantaged communities.
- Maximize recycling and diversion from landfills.
- Reduce direct emissions from composting and digestion operations through improved technologies.
- Build the infrastructure needed to support a sustainable, low carbon waste management system within California.
- Increase organics markets which complement and support other sectors.[220]
- Capture edible food before it enters the waste stream and provide to people in need.
- Increase production of renewable transportation fuels from anaerobic digestion of waste.
- Recognize the co-benefits of compost application.

Cross-Sector Interactions

The waste management sector interacts with all of the other sectors of the State's economy. Reducing waste, including food waste, is key to reducing the State's overall carbon footprint. Additionally, replacing virgin materials with recycled materials reduces the energy and GHGs associated with the goods we produce and consume.

California leads the United States in agricultural production in terms of value and crop diversity. Soil carbon is the main source of energy for important soil microbes and is key for making nutrients available to plants. Waste-derived compost and other organic soil amendments support the State's Healthy Soils Initiative being implemented by CDFA. In addition, the use of compost to increase soil organic matter in the agricultural sector provides other benefits, including reduced GHG emissions, conserved water, reduced synthetic (petroleum-based) fertilizer and herbicide use, and sequestered carbon.

220 Examples may include renewable energy (biogas to renewable transportation fuels or electricity); soils (application of organics to agricultural soils for building soil organic matter and conserving water; application of organics to mulch for erosion control; application of organics to rangelands for increased carbon sequestration); and forests (support use of forest residues for erosion control; stabilization of fire-ravaged lands).

Efforts to Reduce Greenhouse Gases

The measures below include some required and new potential measures to help achieve the State's 2030 target and to support the high-level objectives for this sector. Some measures may be designed to directly address GHG reductions, while others may result in GHG reductions as a co-benefit. In addition, to move forward with the goals of the waste management sector and achieve the 2030 target, certain actions are recommended to help set the groundwork. These actions affect several broad areas and are necessary for reducing the challenges facing this sector, and they are listed below as supporting actions.

Ongoing and Proposed Measures

- Continue implementation of the Landfill Methane Control Measure.
- Continue implementation of the Mandatory Commercial Recycling Regulation and the Mandatory Commercial Organics Recycling requirements.
- As required by SB 1383:
  - By 2018, CARB will implement the SLCP Strategy.
  - CalRecycle will develop regulations to require 50 percent organic waste diversion from landfills from 2014 levels by 2020 and 75 percent by 2025, including programs to achieve an edible food waste recovery goal of 20 percent below 2016 levels by 2025. The regulations shall take effect on or after January 1, 2022. By July 1, 2020, analyze the progress that the waste sector, State government, and local governments have made in achieving these goals.
  - CEC will develop recommendations for the development and use of renewable gas as part of the 2017 Integrated Energy Policy Report. Based on these recommendations, adopt policies and incentives to significantly increase sustainable production and use of renewable gas.

Potential Additional or Supporting Actions

The actions below have the potential to reduce GHGs and complement the measures and policies identified in Chapter 2. These are included to spur thinking and exploration of innovation that may help the State achieve its long-term climate goals.

- Establishing a sustainable State funding source (such as an increased landfill tip fee and new generator charge) for development of waste management infrastructure, programs, and incentives.
- Working with residents and producers to reduce the volume of waste generated overall and capitalize on technology and social changes that might enable waste reduction.
- Increasing organics diversion from landfills, building on established mandates (AB 341's 75 percent by 2020 solid waste diversion goal, AB 1594,[221] AB 1826,[222] AB 876[223]) and new short-lived climate pollutant targets for 2025 (SB 605, SB 1383) to be accomplished via prevention (including food rescue), recycling, composting/digestion, and biomass options.
- Addressing challenges and issues associated with significant expansion and construction of organics and recycling infrastructure in California that is needed to achieve recycling and diversion goals. Challenges and issues include permitting, grid/pipeline connection, funding, local siting, markets, and research.
- Developing programmatic Environmental Impact Reports (EIRs) and model permit and guidance documents to assist in environmental review and CEQA for new facilities.
- Providing incentives for expanded and new facilities to handle organics and recyclables to meet 2020 and 2030 goals.
- Providing incentives to develop and expand food rescue programs to reduce the amount of edible food being sent to landfills.
- Further quantifying co-benefits of compost products and addressing regulatory barriers that do not provide for consideration of co-benefits.
- Supporting existing and new clean technologies and markets for excess woody biomass from urban areas, forests, and agriculture.
- Supporting the development of transportation fuel production at digestion facilities to generate renewable transportation fuels.

221 Assembly Bill 1594, Waste Management (Williams, Chapter 719, Statutes of 2014).
222 Assembly Bill 1826, Solid Waste: Organic Waste (Chesbro, Chapter 727, Statutes of 2014).
223 Assembly Bill 876, Compostable Organics (McCarty, Chapter 593, Statutes of 2015).

- Resolving issues of pipeline injection and grid connection to make renewable energy projects competitive.
- Supporting the use of available capacity at wastewater treatment plants that have digesters to process food waste.
- Working with local entities to provide a supportive framework to advance community-wide efforts that are consistent with, or exceed, statewide goals.
- Supporting research and development and pathways to market for dairy and codigestion digesters, including pipeline injection and interconnection.
- Supporting research on digestate characterization and end products.

Water

Water is essential to all life, and is vital to our overall health and well-being. A reliable, clean, and abundant supply of water is also a critical component of California's economy and has particularly important connections to energy, food, and the environment. California's water system includes a complex infrastructure that has been developed to support the capture, use, conveyance, storage, conservation, and treatment of water and wastewater. This elaborate network of storage and delivery systems enables the State to prosper and support populations, amidst wide variability in annual precipitation rates and concentration of rain north of Sacramento, through storing and moving water when and where it is needed.

Local water agencies play an important role in delivering water to communities, farms, and businesses. Some purchase water from the major State and federal projects, treat the water as needed, and deliver it to their customers; others act as wholesale agencies that buy or import water and sell it to retail water suppliers. Some agencies operate their own local water supply systems, including reservoirs and canals that store and move water as needed. Many agencies rely on groundwater exclusively, and operate local wells and distribution systems. In recent decades, local agencies have developed more diversified sources of water supplies. Many agencies use a combination of imported surface water and local groundwater, and also produce or purchase recycled water for end uses such as landscape irrigation.[224]

The State's developed surface and groundwater resources support a variety of residential, commercial, industrial, and agricultural activities. California's rapidly growing population–estimated to reach 44 million by 2030[225] – is putting mounting pressure on the water supply system. In the future, the ability to meet most new demand for water will come from a combination of increased conservation and water use efficiency, improved coordination of management of surface and groundwater, recycled water, new technologies in drinking water treatment, groundwater remediation, and brackish and seawater desalination.[226]

One of the State's largest uses of energy is attributed to several aspects of the water life cycle, including end uses such as heating and cooling, and water treatment and conveyance. Ten percent of the State's energy use is associated with water-related end uses, while water and wastewater systems account for 2 percent of the State's energy use.[227] Therefore, as water demand grows, energy demand may increase concurrently. Population growth drives demand for both water and energy resources, so both grow at about the same rates and in many of the same geographic areas.[228] This dynamic is further exacerbated by the precipitation-population mismatch between Northern and Southern California. Since the greatest energy consumption related to water is from delivery to end uses, the potential for energy savings also resides with water end users, where water conservation and efficiency play an important role.

The principal source of GHG emissions from the water sector comes from the fossil fuel-based energy consumed for water end uses (e.g., heating, cooling, pressurizing, and industrial processes), and the fossil fuel-based energy used to "produce" water (e.g., pump, convey, treat). Therefore, emissions reductions strategies are primarily associated with reducing the energy intensity of the water sector. Energy intensity is a measure of the amount of energy required to take a unit of water from its origin (such as a river or aquifer)

224 California Department of Water Resources. Regional Energy Intensity of Water Supplies. *www.water.ca.gov/climatechange/RegionalEnergyIntensity.cfm*
225 *http://www.dof.ca.gov/Forecasting/Demographics/projections/*
226 California Natural Resources Agency, California Department of Food and Agriculture, and California Environmental Protection Agency. California Water Action Plan.
227 California Department of Water Resources. Water-Energy Nexus: Statewide. Web page accessed November 2016 at: *www.water.ca.gov/climatechange/WaterEnergyStatewide.cfm*.
228 Ibid

and extract and convey it to its end use.[229] Within California, the energy intensity of water varies greatly depending on the geography, water source, and end use. The California Department of Water Resources (DWR) subdivides the State into 10 regions corresponding to the State's major drainage basins. An interactive map on the DWR website allows users to see a summary of the energy intensity of regional water supplies, ignoring end-use factors.[230] As the energy sector is decarbonized through measures such as increased renewable energy and improved efficiency, energy intensities will also be reduced. It is also important to note that end user actions to reduce water consumption or replace fresh water with recycled water do not automatically translate into GHG reductions. The integrated nature of the water supply system means that a reduction by one end user can be offset by an increase in consumption by another user. Likewise, use of recycled water has the potential to reduce GHGs if it replaces, and not merely serves as an alternative to, an existing, higher-carbon water supply.

The State is currently implementing several targeted, agricultural, urban, and industrial-based water conservation, recycling, and water use efficiency programs as part of an integrated water management effort that will help achieve GHG reductions through reduced energy demand within the water sector. Appendix H highlights the more significant existing policies, programs, measures, regulations, and initiatives that provide a framework for helping achieve GHG emissions reductions in this sector.

While it is important for every sector to contribute to the State's climate goals, ensuring universal access to clean water as outlined in AB 685 (Eng, Chapter 524, Statutes of 2012), also known as the "human right to water" bill, should take precedence over achieving GHG emissions reductions from water sector activities where a potential conflict exists. AB 685 states that it is the policy of the State that "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes." As described in this section, water supplies vary in energy intensity and resulting GHGs, depending on the source of the water, treatment requirements, and location of the end user.

Looking to the Future

This section outlines the high-level objectives and goals to reduce GHGs in this sector.

Goals

- Develop and support more reliable water supplies for people, agriculture, and the environment, provided by a more resilient, diversified, sustainably managed water resources system with a focus on actions that provide direct GHG reductions.
- Make conservation a California way of life by using and reusing water more efficiently through greater water conservation, drought tolerant landscaping, stormwater capture, water recycling, and reuse to help meet future water demands and adapt to climate change.
- Develop and support programs and projects that increase water sector energy efficiency and reduce GHG emissions through reduced water and energy use.
- Increase the use of renewable energy to pump, convey, treat, and utilize water.
- Reduce the carbon footprint of water systems and water uses for both surface and groundwater supplies through integrated strategies that reduce GHG emissions while meeting the needs of a growing population, improving public safety, fostering environmental stewardship, aiding in adaptation to climate change, and supporting a stable economy.

Cross-Sector Interactions

Water, energy, food, and ecosystems are inextricably linked, and meeting future climate challenges will require an integrated approach to managing the resources in these sectors.

Water is used in various applications in the energy sector, ranging in intensity from cooling of turbines and other equipment at power plants to cleaning solar photovoltaic panels. In 2003, CEC adopted a water conservation policy for power plants to limit the use of freshwater for power plant cooling, and has since encouraged project

229 A broader definition of energy intensity could consider the "downstream" energy (i.e., wastewater treatment) as well as the upstream components. More robust data are needed, and the State is working to better quantify these upstream and downstream emissions.

230 California Department of Water Resources. Regional Energy Intensity of Water Supplies. *www.water.ca.gov/climatechange/RegionalEnergyIntensity.cfm*

owners proposing to build new power plants in California to reduce water consumption with water-efficiency technologies such as dry cooling and to conserve fresh water by using recycled water. Likewise, energy is used in multiple ways and at multiple steps in water delivery and treatment systems, including energy for heating and chilling water; treating and delivering drinking water; conveying water; extracting groundwater; desalination; pressurizing water for irrigation; and wastewater collection, treatment, and disposal.

Although GHG reduction strategies for the water sector have the closest ties to energy, the water sector also interacts with the natural and working lands, agricultural, waste management, and transportation sectors. Water flows from mountains to downstream regions through natural and working lands, which provide habitat for many species and function to store water, recharge groundwater, naturally purify water, and moderate flooding. Protection of key lands from conversion results in healthier watersheds by reducing polluted runoff and maintaining a properly functioning ecosystem. California is the United States' leading agricultural production state in terms of value and crop diversity. Approximately nine million acres of farmland in California are irrigated.[231] In addition, water use is associated with livestock watering, feedlots, dairy operations, and other on-farm needs. Altogether, agriculture uses about 40 percent of the State's managed water supply.[232] In the end, agricultural products produced in California are consumed by humans throughout the world as food, fiber, and fuel. Wastewater treatment plants provide a complementary opportunity for the waste management sector to help process organic waste diversion from landfills. Treatment plants with spare capacity can potentially accommodate organic waste for anaerobic co-digestion of materials such as food waste and fats, oil, and grease from residential, commercial, or industrial facilities to create useful by-products such as electricity, hydrogen, biofuels, and soil amendments.[233] The water sector is also essential to our community health and long-term well-being, and measures must ensure that we continue to have access to clean and reliable sources of drinking water. Climate change threatens to impact our water supplies, for example, with long-term droughts leading to wells and other sources of water running dry. This can have devastating consequences, especially on communities already vulnerable and sensitive to changes in their water supply and natural hydrological systems, including rural communities who have limited options for water supplies. Water conservation and management strategies that are energy efficient can also ensure a continued supply of water for our health and well-being.

Efforts to Reduce Greenhouse Gases

The measures below include some required and new potential measures to help achieve the State's 2030 target and to support the high-level objectives for this sector. Some measures may be designed to directly address GHG reductions, while others may result in GHG reductions as a co-benefit. In addition, several recommended actions are identified to help the water sector move forward with the identified goals and measures to achieve the 2030 target; these are listed as supporting actions.

Ongoing and Proposed Measures

- As directed by Governor Brown's Executive Order B-37-16, DWR and State Water Resources Control Board (SWRCB) will develop and implement new water use targets to generate more statewide water conservation than existing targets (the existing State law requires a 20 percent reduction in urban per capita water use by 2020 [SBx7-7, Steinberg, Chapter 4, Statutes of 2009]). The new water use targets will be based on strengthened standards for indoor use, outdoor irrigation, commercial, industrial, and institutional water use.
- SWRCB will develop long-term water conservation regulation, and permanently prohibit practices that waste potable water.
- DWR and SWRCB will develop and implement actions to minimize water system leaks, and to set performance standards for water loss, as required by SB 555 (Wolk, Chapter 679, Statutes of 2015).
- DWR and CDFA will update existing requirements for agricultural water management plans to increase water system efficiency.

231 Hanson, Blaine. No date. Irrigation of Agricultural Crops in California. PowerPoint. Department of Land, Air and Water Resources University of California, Davis. *www.arb.ca.gov/fuels/lcfs/workgroups/lcfssustain/hanson.pdf*

232 Applied water use is the official terminology used by DWR. "Applied water refers to the total amount of water that is diverted from any source to meet the demands of water users without adjusting for water that is used up, returned to the developed supply, or considered irrecoverable."

233 An example of a resource recovering project that can help achieve methane reductions includes fuel cells that are integrated into wastewater treatment plants for both onsite heat and power generation and the production of renewable hydrogen.

- CEC will certify innovative technologies for water conservation and water loss detection and control.
- CEC will continue to update the State's Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601–1608) for appliances offered for sale in California to establish standards that reduce energy consumption for devices that use electricity, gas, and/or water.
- California Environmental Protection Agency (CalEPA) will oversee development of a voluntary registry for GHG emissions resulting from the water-energy nexus, as required by SB 1425 (Pavley, Chapter 596, Statutes of 2016).
- The State Water Project has entered long-term contracts to procure renewable electricity from 140 MW solar installations in California.
- As described in its Climate Action Plan, DWR will continue to increase the use of renewable energy to operate the State Water Project.

Overall, these actions will contribute to the broader energy efficiency goals discussed in the Low Carbon Energy section of this chapter.

Potential Additional or Supporting Actions

The actions below have the potential to reduce GHGs and complement the measures and policies identified in Chapter 2. These are included to spur thinking and exploration of innovation that may help the State achieve its long-term climate goals.

- Where technically feasible and cost-effective, local water and wastewater utilities should adopt a long-term goal to reduce GHGs by 80 percent below 1990 levels by 2050 (consistent with DWR's Climate Action Plan), and thereafter move toward low carbon or net-zero carbon water management systems.
- Local water and wastewater utilities should develop distributed renewable energy where feasible, using the expanded Local Government Renewable Energy Bill Credit (RES-BCT) tariff and new Net Energy Metering (which allow for installation without system size limit).
- In support of the Short-Lived Climate Pollutant Strategy, encourage resource recovering wastewater treatment projects to help achieve the goal of reducing fugitive methane by 40 percent by 2030, to include:
  - Determining opportunities to support co-digestion of food-related waste streams at wastewater treatment plants.
  - Incentivizing methane capture systems at wastewater treatment plants to produce renewable electricity, transportation fuel, or pipeline biomethane.
- Support compact development and land use patterns, and associated conservation and management strategies for natural and working lands that reduce per capita water consumption through more water-efficient built environments.

Chapter 5

Achieving Success

Meeting, and exceeding, our mandated GHG reduction goals in 2020 and through 2030 requires building on California's decade of success in implementing effective climate policies. State agencies are increasingly coordinating planning activities to align with overarching climate, clean air, social equity, and broader economic objectives.

However, to definitely tip the scales in favor of rapidly declining emissions, we also need to reach beyond State policy-making and engage all Californians. Further progress can be made by supporting innovative actions at the local level–among governments, small businesses, schools, and individual households. Ultimately, success depends on a mix of regulatory program development, incentives, institutional support, and education and outreach to ensure that clean energy and other climate strategies are clear, winning alternatives in the marketplace–to drive business development and consumer adoption.

Ongoing Engagement with Environmental Justice Communities

CARB continues seek ways to improve implementation of AB 32 and the unique set of impacts facing environmental justice communities. However, CARB's environmental justice efforts reach far beyond climate change. In 2001, the Board approved CARB's "Policies and Actions for Environmental Action,"[234] which expresses a broad commitment to environmental justice and makes it integral to all of CARB's programs, consistent with State directives at the time. Though over the years CARB has taken on a wide array of activities aimed at reducing environmental burdens on environmental justice communities, it has not knitted its various efforts together in a coherent narrative or maximized the impact of these activities by leveraging them off of each other.

This year, CARB appointed its first executive-level environmental justice liaison. Under her leadership, CARB will lay a roadmap for better serving California's environmental justice communities in the design and implementation of its programs, and identifying new actions CARB can take to advance environmental justice and social equity in all of its functions.

The extensive legislative framework addressing climate change, air quality, and environmental justice that has emerged since the passage of AB 32 has prompted CARB to step up its environmental justice efforts and articulate a vision that reflects the current context. CARB will initiate a public process, seeking advice and input from environmental justice advocates and other key stakeholders to inform the development of a new strategic plan for further institutionalizing environmental justice and social equity.

CARB understands that in addition to our programs to address climate change and reduce emissions of GHGs, more needs to be done to reduce exposure to toxic air and criteria pollutants and improve the quality of life in communities surrounding our largest emissions sources. To this end, and consistent with AB 617, AB 197, AB 1071, SB 535 and AB 1550, we will actively engage EJ advocates, communities, and relevant air districts in the development of programs that improve air quality and quantify the burdens placed on air quality in local communities. Measuring and monitoring air quality conditions over time and ongoing community engagement are integral to the success of CARB's efforts. This engagement will include substantive discussions with EJ stakeholders, gathering their input and providing adequate time for review before matters are taken to the Board for decision.

234 *www.arb.ca.gov/ch/programs/ej/ejpolicies.pdf*

CARB's approach to environmental justice will be grounded in five primary pillars: transparency, integration, monitoring, research, and enforcement.

- **Transparency:** CARB must improve communication and engagement with environmental justice stakeholders and deepen partnerships with local communities impacted by air pollution. CARB will continue to prioritize transparency in its decision-making processes and provide better access to the air quality, toxics, and GHG data CARB collects and stewards.
- **Integration:** Besides integrating environmental justice throughout all of CARB's programs, those programs must complement each other. To that end, CARB will endeavor to break down programmatic silos so that it is able to leverage its work and achieve more effective and timely results. Focused resources in individual communities can accelerate reduction in emissions, proliferation of clean vehicles and creation of jobs in the clean energy economy, while concurrently improving public health.
- **Monitoring:** Communities should be engaged in CARB's monitoring work. They can play a critical role in collecting their own data and adding to the coverage of other air monitoring efforts (e.g., CARB, local air districts). CARB has already invested in research on low-cost monitors that are accessible by communities, and it will continue to evaluate how community monitoring can make CARB more nimble in identifying and addressing "hotspots." Mobile monitoring projects similarly will allow CARB to better serve and protect residents of disadvantaged communities. CARB will continue to build partnerships with local communities and help build local capacity through funding and technical assistance.
- **Research:** CARB's research agenda is core to achieving its mission. To ensure that the research done by CARB responds to environmental justice concerns and has the greatest potential to improve air quality and public health in disadvantaged communities, CARB will engage communities groups early in the development of its research agenda and the projects that flow out from that agenda.
- **Enforcement:** Disadvantaged communities are often impacted by many sources of pollution. In order to improve air quality and protect public health, CARB will prioritize compliance with legal requirements, including enforcement actions if necessary, in environmental justice communities to ensure emissions of toxic and criteria pollutants in these communities are as low as possible.

Our inclusive approaches to further environmental justice in California's local communities may include an array of direct regulation, funding, and community capacity-building. CARB will continue to actively implement the provisions of AB 617, AB 197, AB 1071, SB 535, AB 1550, and other laws to better ensure that environmental justice communities see additional benefits from our clean air and climate policies. Our inclusive approaches to further environmental justice in California's local communities may include an array of direct regulation, funding, and community capacity-building.

Enabling Local Action

Local governments are essential partners in achieving California's goals to reduce GHG emissions. Local governments can implement GHG emissions reduction strategies to address local conditions and issues and can effectively engage citizens at the local level. Local governments also have broad jurisdiction, and sometimes unique authorities, through their community-scale planning and permitting processes, discretionary actions, local codes and ordinances, outreach and education efforts, and municipal operations. Further, local jurisdictions can develop new and innovative approaches to reduce GHG emissions that can then be adopted elsewhere. For example, local governments can develop land use plans with more efficient development patterns that bring people and destinations closer together in more mixed-use, compact communities that facilitate walking, biking, and use of transit. Local governments can also incentivize locally generated renewable energy and infrastructure for alternative fuels and electric vehicles, implement water efficiency measures, and develop waste-to-energy and waste-to-fuel projects. These local actions complement statewide measures and are critical to supporting the State's efforts to reduce emissions. Local efforts can deliver substantial additional GHG and criteria emissions reductions beyond what State policy can alone, and these efforts will sometimes be more cost-effective and provide more cobenefits than relying exclusively on top-down statewide regulations to achieve the State's climate stabilization goals. To ensure local and regional engagement, it is also recommended local jurisdictions make readily available information regarding ongoing and proposed actions to reduce GHGs within their region.

Many cities and counties are already setting GHG reduction targets, developing local plans, and making progress toward reducing emissions. The Statewide Energy Efficiency Collaborative recently released a report, *The State of Local Climate Action: California 2016*,[235] which highlights local government efforts, including:

- In California, 60 percent of cities and over 70 percent of counties have completed a GHG inventory, and 42 percent of local governments have completed a climate, energy, or sustainability plan that directly addresses GHG emissions. Many other community-scale local plans, such as general plans, have emissions reduction measures incorporated as well (see Governor's Office of Planning and Research [OPR] Survey questions 23 and 24).[236]
- Over one hundred California local governments have developed emissions reduction targets that, if achieved, would result in annual reductions that total 45 $MMTCO_2e$ by 2020 and 83 $MMTCO_2e$ by 2050.[237]

Local air quality management and air pollution control districts also play a key role in reducing regional and local sources of GHG emissions by actively integrating climate protection into air quality programs. Air districts also support local climate protection programs by providing technical assistance and data, quantification tools, and even funding.[238] Local metropolitan planning organizations (MPOs) also support the State's climate action goals via sustainable communities strategies (SCSs), required by the Sustainable Communities and Climate Protection Act of 2008 (SB 375, Chapter 728, Statutes of 2008). Under SB 375, MPOs must prepare SCSs as part of their regional transportation plan to meet regional GHG reduction targets set by CARB for passenger vehicles in 2020 and 2035. The SCSs contain land use, housing, and transportation strategies that allow regions to meet their GHG emissions reductions targets.

energy upgrade CALIFORNIA
COOLCALIFORNIA CHALLENGE

To engage communities in efforts to reduce GHG emissions, CARB has partnered with Energy Upgrade California on the CoolCalifornia Challenge. It is a competition among California cities to reduce their carbon footprints and build more vibrant and sustainable communities. Three challenges have been completed. Most recently, the 2015–2016 Challenge included 22 cities and engaged nearly 3,200 households, each of which took actions to reduce energy use and carbon GHG emissions. In total, the participants reported savings of 5,638 MTCO2 from completed actions, equivalent to emissions from more than 1,000 cars or from electricity used by more than 2,500 California homes in a year.

State agencies support these local government actions in several ways:

- *CoolCalifornia.org* is an informational website that provides resources that assist local governments, small businesses, schools, and households to reduce GHG emissions. The local government webpage includes carbon calculators, a climate planning resource guide, a Funding Wizard that outlines grant and loan programs, and success stories. It also features ClearPath California, a no-cost GHG inventory, climate action plan development, and tracking tool developed through the Statewide Energy Efficiency Collaborative in coordination with CARB and the Governor's Office of Planning and Research (OPR).
- Chapter 8 of OPR's General Plan Guidelines[239] provides guidance for climate action plans and

235 Statewide Energy Efficiency Collaborative. 2016. State of Local Climate Action: California 2016. *californiaseec.org/wp-content/uploads/2016/10/State-of-Local-Climate-Action-California-2016_Screen.pdf*

236 Governor's Office of Planning and Research. 2016. 2016 Annual Planning Survey Results. November. *www.opr.ca.gov/docs/2016_APS_final.pdf*

237 These reductions include reductions from both state and local measures.

238 Examples include: (1) Bay Area Air Quality Management District (BAAQMD). 2016 Clean Air Plan and Regional Climate Protection Strategy. Available at: *www.baaqmd.gov/plans-and-climate/air-quality-plans/plans-under-development*; (2) California Air Pollution Control Officers Association. California Emissions Estimator Model (CalEEMod). Available at: *www.caleemod.com/*; (3) San Joaquin Valley Air Pollution Control District. Grants and Incentives. Available at: *valleyair.org/grants/*; (4) BAAQMD. Grant Funding. Available at: *www.baaqmd.gov/grant-funding*; (5) South Coast Air Quality Management District. Funding. Available at: *www.aqmd.gov/grants-bids/funding*; (6) Sacramento Metropolitan Air Quality Management District. Incentive Programs. Available at: *www.airquality.org/Residents/Incentive-Programs*.

239 *http://opr.ca.gov/planning/general-plan/*

other plans linked to general plans, which address the community scale approach outlined in CEQA Guidelines Section 15183.5(b), Plans for the Reduction of Greenhouse Gas Emissions.

- OPR hosts the Integrated Climate Adaptation and Resiliency Program, which is developing resources and case studies that outline the co-benefits of implementing emissions reduction strategies and addressing the impacts of climate change.
- CARB is developing a centralized database and interactive map that will display the current statewide status of local government climate action planning. Users can view and compare the details of emission inventories, planned GHG reduction targets and strategies, and other climate action details specific to each local government. This information will help jurisdictions around California identify what climate action strategies are working in other, similar jurisdictions across the State, and will facilitate collaboration among local governments pursuing GHG reduction strategies and goals. This database and map will be featured on the *CoolCalifornia.org* website and are anticipated to be available in 2017.
- Additional information on local government activities is available on Cal-Adapt (*www.cal-adapt.org*) and OPR (*www.opr.ca.gov*)

Further, a significant portion of the $3.4 billion in cap-and-trade expenditures has either directly or indirectly supported local government efforts to reduce emissions, including, for example, the Affordable Housing and Sustainable Communities (AHSC) program and approximately $142 million for project implementation and planning grants awarded under the Transformative Climate Communities program.

Climate Action through Local Planning and Permitting

Local government efforts to reduce emissions within their jurisdiction are critical to achieving the State's long-term GHG goals, and can also provide important co-benefits, such as improved air quality, local economic benefits, more sustainable communities, and an improved quality of life. To support local governments in their efforts to reduce GHG emissions, the following guidance is provided. This guidance should be used in coordination with OPR's General Plan Guidelines guidance in Chapter 8, Climate Change.[240] While this guidance is provided out of the recognition that local policy makers are critical in reducing the carbon footprint of cities and counties, the decision to follow this guidance is voluntary and should not be interpreted as a directive or mandate to local governments.

Recommended Local Plan-Level Greenhouse Gas Emissions Reduction Goals

CARB recommends statewide targets of no more than six metric tons CO_2e per capita by 2030 and no more than two metric tons CO_2e per capita by 2050.[241] The statewide per capita targets account for all emissions sectors in the State, statewide population forecasts, and the statewide reductions necessary to achieve the 2030 statewide target under SB 32 and the longer term State emissions reduction goal of 80 percent below 1990 levels by 2050.[242] The statewide per capita targets are also consistent with Executive Order S-3-05, B-30-15, and the Under 2 MOU that California originated with Baden-Württemberg and has now been signed or endorsed by 188 jurisdictions representing 39 countries and six continents.[243,244] Central to the Under 2 MOU is that all signatories agree to reduce their GHG emissions to two metric tons CO_2e per capita by 2050. This limit represents California's and these other governments' recognition of their "fair share" to reduce GHG emissions to the scientifically based levels to limit global warming below two degrees Celsius. This limit is also consistent with the Paris Agreement, which sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to below 2°C.[245]

CARB recommends that local governments evaluate and adopt robust and quantitative locally-appropriate

240 *http://opr.ca.gov/planning/general-plan/* .
241 These goals are appropriate for the plan level (city, county, subregional, or regional level, as appropriate), but not for specific individual projects because they include all emissions sectors in the State.
242 This number represents the 2030 and 2050 targets divided by total population projections from California Department of Finance.
243 *http://under2mou.org/* California signed the Under 2 MOU on May 19, 2015. See *under2mou.org/wp-content/uploads/2015/05/California-appendix-English.pdf* and *under2mou.org/wp-content/uploads/2015/05/California-Signature-Page.pdf*.
244 The Under 2 MOU signatories include jurisdictions ranging from cities to countries to multiple-country partnerships. Therefore, like the goals set forth above for local and regional climate planning, the Under 2 MOU is scalable to various types of jurisdictions.
245 UNFCCC. The Paris Agreement. *unfccc.int/paris_agreement/items/9485.php*

goals that align with the statewide per capita targets and the State's sustainable development objectives and develop plans to achieve the local goals. The statewide per capita goals were developed by applying the percent reductions necessary to reach the 2030 and 2050 climate goals (i.e., 40 percent and 80 percent, respectively) to the State's 1990 emissions limit established under AB 32.

Numerous local governments in California have already adopted GHG emissions reduction goals for year 2020 consistent with AB 32. CARB advises that local governments also develop community-wide GHG emissions reduction goals necessary to reach 2030 and 2050 climate goals. Emissions inventories and reduction goals should be expressed in mass emissions, per capita emissions, and service population emissions. To do this, local governments can start by developing a community-wide GHG emissions target consistent with the accepted protocols as outlined in OPR's General Plan Guidelines Chapter 8: Climate Change. They can then calculate GHG emissions thresholds by applying the percent reductions necessary to reach 2030 and 2050 climate goals (i.e., 40 percent and 80 percent, respectively) to their community-wide GHG emissions target. Since the statewide per capita targets are based on the statewide GHG emissions inventory that includes all emissions sectors in the State, it is appropriate for local jurisdictions to derive evidence-based local per capita[246] goals based on local emissions sectors and population projections that are consistent with the framework used to develop the statewide per capita targets. The resulting GHG emissions trajectory should show a downward trend consistent with the statewide objectives. The recommendation for a community-wide goal expands upon the reduction of 15 percent from "current" (2005-2008) levels by 2020 as recommended in the 2008 Scoping Plan.[247]

In developing local plans, local governments should refer to "The U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions,"[248] (community protocol) which provides detailed guidance on completing a GHG emissions inventory at the community scale in the United States – including emissions from businesses, residents, and transportation. Quantification tools such as ClearPath California, which was developed with California agencies, also support the analysis of community-scale GHG emissions. Per the community protocol, these plans should disclose all emissions within the defined geographical boundary, even those over which the local government has no regulatory authority to control, and then focus the strategies on those emissions that the jurisdiction controls. For emissions from transportation, the community protocol recommends including emissions from trips that extend beyond the community's boundaries. Local plans should also include the carbon sequestration values associated with natural and working lands, and the importance of jurisdictional lands for water, habitat, agricultural, and recreational resources. Strategies developed to achieve the local goals should prioritize mandatory measures that support the Governor's "Five Pillars" and other key state climate action goals.[249] Examples of plan-level GHG reduction actions that could be implemented by local governments are listed in Appendix B. Additional information and tools on how to develop GHG emissions inventories and reduction plans tied to general plans can be found in OPR's General Plan Guidelines and at *CoolCalifornia.org*.

These local government recommendations are based on the recognition that California must accommodate population and economic growth in a far more sustainable manner than in the past. While state-level investments, policies, and actions play an important role in shaping growth and development patterns, regional and local governments and agencies are uniquely positioned to influence the future of the built environment and its associated GHG emissions. Greenhouse gas emissions reduction strategies in Climate Action Plans (CAPs) and other local plans can also lead to important co-benefits, such as improved air quality, local economic benefits such as green jobs, more mobility choices, improved public health and quality of life, protection of locally, statewide, and globally important natural resources, and more equitable sharing of these benefits across communities.

Contributions from policies and programs, such as renewable energy and energy efficiency, are helping to achieve the near-term 2020 target, but longer-term targets cannot be achieved without land use decisions that allow more efficient use and management of land and infrastructure. Local governments have primary authority to plan, zone, approve, and permit how and where land is developed to accommodate population growth, economic growth, and the changing needs of their jurisdictions. Land use decisions affect GHG emissions associated with transportation, water use, wastewater treatment, waste generation and treatment, energy consumption, and conversion of natural and working lands. Local land use decisions play a particularly

246 Or some other metric that the local jurisdiction deems appropriate (e.g., mass emissions, per service population)
247 2008 Scoping Plan, page 27, *www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm*
248 *http://icleiusa.org/publications/us-community-protocol/*
249 *www.arb.ca.gov/cc/pillars/pillars.htm*

critical role in reducing GHG emissions associated with the transportation sector, both at the project level, and in long-term plans, including general plans, local and regional climate action plans, specific plans, transportation plans, and supporting sustainable community strategies developed under SB 375.

While the State can do more to accelerate and incentivize these local decisions, local actions that reduce VMT are also necessary to meet transportation sector-specific goals and achieve the 2030 target under SB 32. Through developing the Scoping Plan, CARB staff is more convinced than ever that, in addition to achieving GHG reductions from cleaner fuels and vehicles, California must also reduce VMT. Stronger SB 375 GHG reduction targets will enable the State to make significant progress toward needed reductions, but alone will not provide the VMT growth reductions needed; there is a gap between what SB 375 can provide and what is needed to meet the State's 2030 and 2050 goals. In its evaluation of the role of the transportation system in meeting the statewide emissions targets, CARB determined that VMT reductions of 7 percent below projected VMT levels in 2030 (which includes currently adopted SB 375 SCSs) are necessary. In 2050, reductions of 15 percent below projected VMT levels are needed. A 7 percent VMT reduction translates to a reduction, on average, of 1.5 miles/person/day from projected levels in 2030. It is recommended that local governments consider policies to reduce VMT to help achieve these reductions, including: land use and community design that reduces VMT; transit oriented development; street design policies that prioritize transit, biking, and walking; and increasing low carbon mobility choices, including improved access to viable and affordable public transportation and active transportation opportunities. It is important that VMT reducing strategies are implemented early because more time is necessary to achieve the full climate, health, social, equity, and economic benefits from these strategies.

Once adopted, the plans and policies designed to achieve a locally-set GHG goal can serve as a performance metric for later projects. Sufficiently detailed and adequately supported GHG reduction plans (including CAPs) also provide local governments with a valuable tool for streamlining project-level environmental review. Under CEQA, individual projects that comply with the strategies and actions within an adequate local CAP can streamline the project-specific GHG analysis.[250] The California Supreme Court recently called out this provision in CEQA as allowing tiering from a geographically specific GHG reduction plan.[251] The Court also recognized that GHG determinations in CEQA should be consistent with the statewide Scoping Plan goals, and that CEQA documents taking a goal-consistency approach may soon need to consider a project's effects on meeting the State's longer term post-2020 goals.[252] The recommendation above that local governments develop local goals tied to the statewide per capita goals of six metric tons CO_2e by 2030 and no more than two metric tons CO_2e per capita by 2050 provides guidance on CARB's view on what would be consistent with the 2017 Scoping Plan and the State's long-term goals.

Production based inventories and emissions reduction programs are appropriate for local communities wanting to mitigate their emissions pursuant to CEQA Section 15183.5(b). Consumption based inventories are complementary to production based inventories and are appropriate as a background setting, disclosure, and as an outreach tool to show how personal decisions may change a person's or household's contribution to climate change. For additional information, see the OPR General Plan Guidelines.[253]

Project-Level Greenhouse Gas Emissions Reduction Actions and Thresholds

Beyond plan-level goals and actions, local governments can also support climate action when considering discretionary approvals and entitlements of individual projects through CEQA. Absent conformity with an adequate geographically-specific GHG reduction plan as described in the preceding section above, CARB recommends that projects incorporate design features and GHG reduction measures, to the degree feasible, to minimize GHG emissions. Achieving no net additional increase in GHG emissions, resulting in no contribution to GHG impacts, is an appropriate overall objective for new development. There are recent examples of land use development projects in California that have demonstrated that it is feasible to design projects that achieve zero net additional GHG emissions. Several projects have received certification from the Governor under AB 900, the Jobs and Economic Improvement through Environmental Leadership Act (Buchanan, Chapter 354, Statutes of 2011), demonstrating an ability to design economically viable projects that create jobs while contributing no net additional GHG emissions. [254] Another example is the Newhall

250 CEQA Guidelines, § 15183.5, sub. (b).
251 Center for Biological Diversity v. California Dept. of Fish and Wildlife (2015) 62 Cal.4th 204, 229–230.
252 Id. at pp. 223–224.
253 *http://opr.ca.gov/planning/general-plan/*.
254 Governor's Office of Planning and Research. California Jobs. *http://www.opr.ca.gov/ceqa/california-jobs.html*

Ranch Resource Management and Development Plan and Spineflower Conservation Plan,[255] in which the applicant, Newhall Land and Farming Company, proposed a commitment to achieve net zero GHG emissions for a very large-scale residential and commercial specific planned development in Santa Clarita Valley.

Achieving net zero increases in GHG emissions, resulting in no contribution to GHG impacts, may not be feasible or appropriate for every project, however, and the inability of a project to mitigate its GHG emissions to net zero does not imply the project results in a substantial contribution to the cumulatively significant environmental impact of climate change under CEQA. Lead agencies have the discretion to develop evidence-based numeric thresholds (mass emissions, per capita, or per service population) consistent with this Scoping Plan, the State's long-term GHG goals, and climate change science.[256]

To the degree a project relies on GHG mitigation measures, CARB recommends that lead agencies prioritize on-site design features that reduce emissions, especially from VMT, and direct investments in GHG reductions within the project's region that contribute potential air quality, health, and economic co-benefits locally. For example, on-site design features to be considered at the planning stage include land use and community design options that reduce VMT, promote transit oriented development, promote street design policies that prioritize transit, biking, and walking, and increase low carbon mobility choices, including improved access to viable and affordable public transportation, and active transportation opportunities. Regionally, additional GHG reductions can be achieved through direct investment in local building retrofit programs that can pay for cool roofs, solar panels, solar water heaters, smart meters, energy efficient lighting, energy efficient appliances, energy efficient windows, insulation, and water conservation measures for homes within the geographic area of the project. These investments generate real demand side benefits and local jobs, while creating the market signals for energy efficient products, some of which are produced in California. Other examples of local direct investments include financing installation of regional electric vehicle (EV) charging stations, paying for electrification of public school buses, and investing in local urban forests.

Local direct investments in actions to reduce GHG emissions should be supported by quantification methodologies that show the reductions are real, verifiable, quantifiable, permanent, and enforceable. Where further project design or regional investments are infeasible or not proven to be effective, it may be appropriate and feasible to mitigate project emissions through purchasing and retiring carbon credits. CAPCOA has developed the GHG Reduction Exchange (GHG Rx) for CEQA mitigation, which could provide credits to achieve additional reductions. It may also be appropriate to utilize credits issued by a recognized and reputable voluntary carbon registry. Appendix B includes examples of on-site project design features, mitigation measures, and direct regional investments that may be feasible to minimize GHG emissions from land use development projects.

California's future climate strategy will require increased focus on integrated land use planning to support livable, transit-connected communities, and conservation of agricultural and other lands. Accommodating population and economic growth through travel- and energy-efficient land use provides GHG-efficient growth, reducing GHGs from both transportation and building energy use.[257] GHGs can be further reduced at the project level through implementing energy-efficient construction and travel demand management approaches.[258] Further, the State's understanding of transportation impacts continues to evolve. The CEQA Guidelines are being updated to focus the analysis of transportation impacts on VMT. OPR's Technical Advisory includes methods of analysis of transportation impacts, approaches to setting significance thresholds, and includes examples of VMT mitigation under CEQA.[259]

255 *https://nrm.dfg.ca.gov/documents/ContextDocs.aspx?cat=NewhallRanchFinal*

256 CARB provided some guidance on development project thresholds in a paper issued in October 2008, which included a concept utilizing a bright-line mass numeric threshold based on capturing approximately 90 percent of emissions in that sector and a concept of minimum performance based standards. Some districts built upon that work to develop thresholds. For example, Santa Barbara County adopted a bright-line numeric threshold of 1,000 $MTCO_2e/yr$ for industrial stationary-source projects, and Sacramento Metropolitan Air Quality Management District adopted a 10,000 $MTCO_2e/yr$ threshold for stationary source projects and a 1,100 $MTCO_2e/yr$ threshold for construction activities and land development projects in their operational phase. CARB is not endorsing any one of these approaches, but noting them for informational purposes.

257 Robert Cervero, Jim Murakami; Effects of Built Environment on Vehicle Miles Traveled: Evidence from 370 US Urbanized Areas. Environment and Planning A, Vol 42, Issue 2, pp. 400-418, February-01-2010; Ewing, R., & Rong, F. (2008). The impact of urban form on U.S. residential energy use. Housing Policy Debagte, 19 (1), 1-30.).

258 CAPCOA, Quantifying Greenhouse Gas Mitigation Measures: A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures, August, 2010.

259 *http://www.opr.ca.gov/ceqa/updates/sb-743/*

Implementing the Scoping Plan

This Scoping Plan outlines the regulations, programs, and other mechanisms needed to reduce GHG emissions in California. CARB and other State agencies will work closely with State and local agencies, stakeholders, Tribes, and the public to develop regulatory measures and other programs to implement the Scoping Plan. CARB and other State agencies will develop regulations in accordance with established rulemaking guidelines. Per Executive Order B-30-15, as these regulatory measures and other programs are developed, building programs for climate resiliency must also be a consideration. Additionally, agencies will further collaborate and work to provide the institutional support needed to overcome barriers that may currently hinder certain efforts to reduce GHG emissions and to support the goals, actions, and measures identified for key sectors in Chapter 4. Table 17 provides a high-level summary of the Climate Change Policies and Measures discussed in the Scoping Plan, including, but not limited to, those identified specifically to achieve the 2030 target.

Table 17: Climate Change Policies and Measures

Recommended Action	Lead Agency
Implement SB 350 by 2030: • Increase the Renewables Portfolio Standard to 50 percent of retail sales by 2030 and ensure grid reliability. • Establish annual targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings in electricity and natural gas end uses by 2030. • Reduce GHG emissions in the electricity sector through the implementation of the above measures and other actions as modeled in IRPs to meet GHG emissions reductions planning targets in the IRP process. Load-serving entities and publicly-owned utilities meet GHG emissions reductions planning targets through a combination of measures as described in IRPs.	CPUC, CEC, CARB
Implement Mobile Source Strategy (Cleaner Technology and Fuels): • At least 1.5 million zero emission and plug-in hybrid light-duty electric vehicles by 2025. • At least 4.2 million zero emission and plug-in hybrid light-duty electric vehicles by 2030. • Further increase GHG stringency on all light-duty vehicles beyond existing Advanced Clean Cars regulations. • Medium- and heavy-duty GHG Phase 2. • Innovative Clean Transit: Transition to a suite of to-be-determined innovative clean transit options. Assumed 20 percent of new urban buses purchased beginning in 2018 will be zero emission buses with the penetration of zero-emission technology ramped up to 100 percent of new sales in 2030. Also, new natural gas buses, starting in 2018, and diesel buses, starting in 2020, meet the optional heavy-duty low-NO_X standard. • Last Mile Delivery: New regulation that would result in the use of low NO_X or cleaner engines and the deployment of increasing numbers of zero-emission trucks primarily for class 3-7 last mile delivery trucks in California. This measure assumes ZEVs comprise 2.5 percent of new Class 3–7 truck sales in local fleets starting in 2020, increasing to 10 percent in 2025 and remaining flat through 2030. • Further reduce VMT through continued implementation of SB 375 and regional Sustainable Communities Strategies; forthcoming statewide implementation of SB 743; and potential additional VMT reduction strategies not specified in the Mobile Source Strategy but included in the document "Potential VMT Reduction Strategies for Discussion."	CARB, CalSTA, SGC, CalTrans CEC, OPR, Local agencies
Increase stringency of SB 375 Sustainable Communities Strategy (2035 targets).	CARB
By 2019, adjust performance measures used to select and design transportation facilities. • Harmonize project performance with emissions reductions, and increase competitiveness of transit and active transportation modes (e.g. via guideline documents, funding programs, project selection, etc.).	CalSTA and SGC, OPR, CARB, GoBiz, IBank, DOF, CTC, Caltrans
By 2019, develop pricing policies to support low-GHG transportation (e.g. low-emission vehicle zones for heavy duty, road user, parking pricing, transit discounts).	CalSTA, Caltrans, CTC, OPR/SGC, CARB

Recommended Action	Lead Agency
Implement California Sustainable Freight Action Plan: • Improve freight system efficiency. • Deploy over 100,000 freight vehicles and equipment capable of zero emission operation and maximize both zero and near-zero emission freight vehicles and equipment powered by renewable energy by 2030.	CalSTA, CalEPA, CNRA, CARB, CalTrans, CEC, GoBiz
Adopt a Low Carbon Fuel Standard with a CI reduction of 18 percent.	CARB
Implement the Short-Lived Climate Pollutant Strategy by 2030: • 40 percent reduction in methane and hydrofluorocarbon emissions below 2013 levels. • 50 percent reduction in black carbon emissions below 2013 levels.	CARB, CalRecycle, CDFA, SWRCB, Local air districts
By 2019, develop regulations and programs to support organic waste landfill reduction goals in the SLCP and SB 1383.	CARB, CalRecycle, CDFA, SWRCB, Local air districts
Implement the post-2020 Cap-and-Trade Program with declining annual caps.	CARB
By 2018, develop Integrated Natural and Working Lands Implementation Plan to secure California's land base as a net carbon sink: • Protect land from conversion through conservation easements and other incentives. • Increase the long-term resilience of carbon storage in the land base and enhance sequestration capacity • Utilize wood and agricultural products to increase the amount of carbon stored in the natural and built environments • Establish scenario projections to serve as the foundation for the Implementation Plan	CNRA and departments within, CDFA, CalEPA, CARB
Establish a carbon accounting framework for natural and working lands as described in SB 859 by 2018	CARB
Implement Forest Carbon Plan	CNRA, CAL FIRE, CalEPA and departments within
Identify and expand funding and financing mechanisms to support GHG reductions across all sectors.	State Agencies & Local Agencies

A Comprehensive Approach to Support Climate Action

Ultimately, successfully tipping the scales in the fight against climate change relies on our ability to incentivize clean technologies in the marketplace and to make other climate strategies clearly understood and easily accessible. We must support and guide our businesses as they continue to innovate and make clean technologies ever more attractive to ever more savvy consumers. Until the point that clean technologies become the best and lowest cost option–which is clearly on the horizon for many technologies, including renewable energy and electric cars–we must continue to support emerging markets through incentives and outreach efforts. More than just coordinating among agencies and providing institutional support as described above, we will succeed if we tackle climate change from all angles–through regulatory and policy development, targeted incentives, and education and outreach.

Regulations and Programmatic Development

Our decade of climate leadership has demonstrated that developing mitigation strategies through a public process, where all stakeholders have a voice, leads to effective actions that address climate change and yield a series of additional economic and environmental co-benefits to the State. As we implement this Scoping Plan, State agencies will continue to develop and implement new and existing programs, as described herein. During any rulemaking process, there are many opportunities for both informal interaction with technical staff in meetings and workshops, and formal interaction at Board meetings, Commission business meetings, monthly public meetings, and others. Each State agency will consider all information and stakeholder input during the rulemaking process. Based on this information, the agency may modify proposed measures to reflect the status of technological development, the cost of the measure, the cost-effectiveness of the measures, and other factors before presenting them for consideration and adoption.

Further, to achieve cost-effective GHG reductions, California State agencies must consider the environmental impact of small businesses and provide mechanisms to assist businesses as GHG reduction measures are

implemented. CARB provides resources and tips for small businesses to prevent pollution, minimize waste, and save energy and water on *CoolCalifornia.org*. California's small businesses and their employees represent a valuable economic resource in the State and "greening" existing businesses is not only achievable, but sets an example for new businesses which will prove significant as California transitions to a low carbon state.

State agencies conduct environmental and environmental justice assessments of our regulatory actions. Many of the requirements in AB 32 overlap with traditional agency evaluations. In adopting regulations to implement the measures recommended in the Scoping Plan, or including in the regulations the use of market-based compliance mechanisms to comply with the regulations, agencies will ensure that the measures have undergone the aforementioned screenings and meet the requirements established in California Health and Safety Code Section 38562(b)(1-9) and Section 38570(b)(1-3).

Incentive Programs

Financial incentives and direct funding are critical components of the State's climate framework. In particular, incentives and funding are necessary to support GHG emissions reductions strategies for priority sectors, sources, and technologies. Although California has a number of existing incentive programs, available funding is limited. It is critical to target public investments efficiently and in ways that encourage integrated, system wide solutions to produce deep and lasting public benefits. Significant investments of private capital, supported by targeted, priority investments of public funding, are necessary to scale deployment and to maximize benefits. Public investments, including through decisions related to State pension fund portfolios, can help incentivize early action to accelerate market transition to cleaner technologies and cleaner practices, which can also be supported by regulatory measures.

Many existing State funding programs work in tandem to reduce emissions from GHGs, criteria pollutants, and toxic air contaminants, and are helping to foster the transition to a clean energy economy and protect and manage land for carbon sequestration. State law, including Senate Bill 535 (De León, Chapter 830, Statutes of 2012) and Assembly Bill 1550 (Gomez, Chapter 369, Statutes of 2016) also requires focused investment in low income and disadvantaged communities.

The State will need to continue to coordinate and utilize funding sources, such as the Greenhouse Gas Reduction Fund (cap-and-trade auction proceeds), the Alternative and Renewable Fuel and Vehicle Technology Program (AB 118), Electric Program Investment Charge (EPIC) Program, Carl Moyer Program, Air Quality Improvement Program, and Proposition 39 to expand clean energy investments in California and further reduce GHG and criteria emissions. Additionally, programs including the Bioenergy Feed-In Tariff, created by Senate Bill 1122 (Rubio, Chapter 612, Statutes of 2012), Low Carbon Fuel Standard, Cap-and-Trade, Self-Generation Incentive Program, Federal Renewable Fuel Standard, utility incentives pursuant to Assembly Bill 1900 (Gatto, Chapter 602, Statutes of 2012), and others provide important market signals and potential revenue streams to support projects to reduce GHG emissions.

These programs represent just a portion of the opportunities that exist at the federal, State, and local levels to incentivize GHG emissions reductions. The availability of dedicated and long-lasting funding sources is critical to help meet the State's climate objectives and help provide certainty and additional partnership opportunities at the national, State, Tribal, regional, and local levels for further investing in projects that have the potential to expand investments in California's clean economy and further reductions in GHG emissions.

Public Education and Outreach Efforts

California State agencies are committed to meaningful opportunities for public input and effective engagement with stakeholders and the public through the development of the Scoping Plan, and as measures are implemented through workshops, other meetings, and through the formal rulemaking process. Additionally, the State has broad public education and outreach campaigns to support markets for key technologies, like ZEVs and energy efficiency, as well as resources to support local and voluntary actions, such as *CoolCalifornia.org*.

In developing this Scoping Plan, there has been extensive outreach with environmental justice organizations and disadvantaged communities. The EJAC launched a community engagement process starting in July 2016, conducting 19 community meetings throughout the State and collecting hundreds of individual comments. To enhance the engagement opportunity, CARB coordinated with local government agencies and sister State agencies to hold collaborative discussions with local residents about specific climate issues that impact their

lives. This effort was well received and attended by local community residents and initiated a new community engagement endeavor for CARB. Recognizing the value of the input received and the opportunity to present California's climate strategy to communities across the State, CARB intends to continue this community involvement to generate awareness about California's climate strategy and be responsive to specific community needs as climate programs are implemented.

Education and Environment Initiative

The California Environmental Protection Agency (CalEPA), the California Department of Education, and the California Natural Resources Agency have developed an environmental curriculum that is being taught in more than half of California's school districts. The Education and Environment Initiative (EEI) provides California's teachers with tools to educate students about the natural environment and how everyday choices can improve our planet and save money.

Conclusion

This Scoping Plan continues more than a half-century of California's nation-leading efforts to clean our air, our water and improve the environment. But, climate change poses a challenge of unprecedented proportions that will, in one way or another, impact all Californians whether they are city dwellers in Los Angeles, San Diego or San Francisco, farmers in Salinas or the Central Valley, or the millions of Californians who live in the Sierra or in the desert areas.

This is the State's climate action plan, and in a very real sense it belongs to all those Californians who are feeling, and will continue to feel, the impacts of climate change. Californians want to see continued effective action that addresses climate change and benefits California – this Plan responds to both of these goals. The Plan was developed by the coordinated consensus of State agencies, but it is really California's Plan, because over the coming decades the approaches in this document will be carried out by all of us.

In this Scoping Plan, every sector in our thriving economy plays a crucial role. Tribes, cities, and local governments are already rising to the challenge, and will play increasingly important roles with everything from low-carbon and cleaner transit, to more walkable streets and the development of vibrant urban communities.

We will see a remarkable transformation of how we move throughout the state, away from cars that burn fossil fuels to cleaner, electric cars that will, in some cases, even drive themselves. Freight will be moved around the state by trucks that are vastly cleaner than those on the road now, with our ports moving towards zero- and near-zero emissions technologies. The heavily traveled Los Angeles-San Francisco corridor will be serviced by comfortable, clean and affordable high speed rail.

In addition to reducing GHGs, these efforts will slash pollution now created from using gasoline and diesel fuel statewide, with the greatest benefits going to the disadvantaged communities of our state which are so often located adjacent to ports, railyards, freight distribution centers and freeways. And, thanks to the continued investment of proceeds from the Cap-and-Trade Program in these same communities, we can continue to work on bringing the benefits of clean technology – whether electric cars or solar roofs – to those in our state who need them the most.

Climate change presents us with unprecedented challenges – challenges that cannot be met with traditional ways of thinking or conventional solutions. As Governor Brown has recognized, meeting these challenges will require "courage, creativity and boldness." The last ten years proved to ourselves, and the world, that Californians recognize the danger of climate change. It has also demonstrated that developing mitigation strategies through a public process where all stakeholders have a voice leads to effective actions that address climate change while yielding a series of co-benefits to the state. This Scoping Plan builds on those early steps and moves into a new chapter that will deliver a thriving economy and a clean environment to our children and grandchildren. It is a commitment to the future, but it begins today by moving forward with the policies in this Plan.

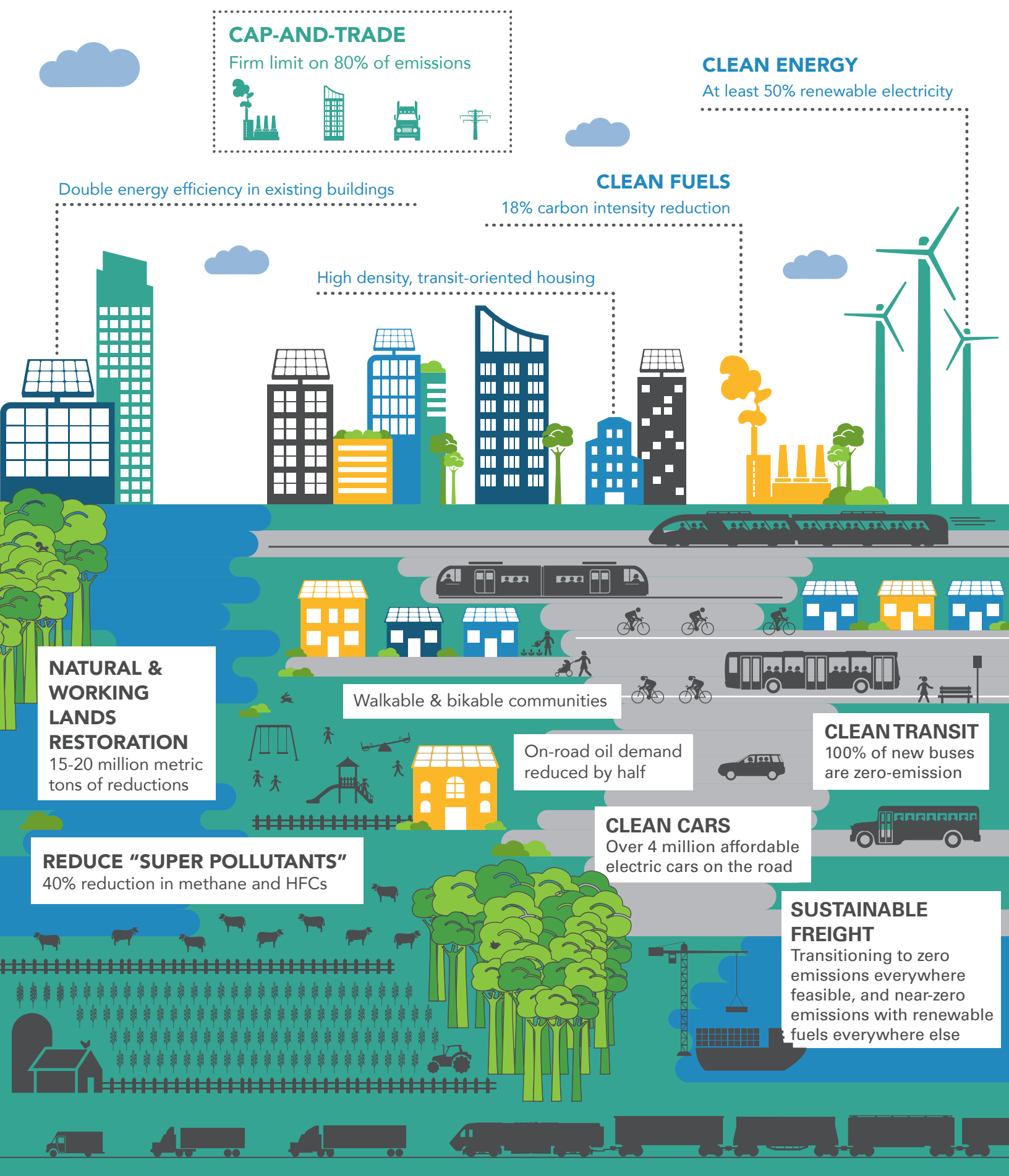
Abbreviations

AB	Assembly Bill
AC	air conditioning
AEO	Annual Energy Outlook
AHSC	Affordable Housing and Sustainable Communities
ARFVTP	Alternative and Renewable Fuel and Vehicle Technology Program
BARCT	best available retrofit control technology
BAU	business-as-usual
BC	British Columbia
BEV	Battery-electric vehicle
CARB	California Air Resources Board
CAISO	California Independent System Operator
CalEPA	California Environmental Protection Agency
CALGreen	California Green Building Standards
CalPERS	California Public Employees' Retirement System
CalSTA	California State Transportation Agency
CalSTRS	California State Teachers' Retirement System
CAP	Climate Action Plan
CARE	California Alternate Rates for Energy Program
CDFA	California Department of Food and Agriculture
CDPH	California Department of Public Health
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CFT	Clean Fuels and Technology
CH_4	Methane
CI	carbon intensity
CNRA	California Natural Resources Agency
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COPD	chronic obstructive pulmonary disease
CPUC	California Public Utilities Commission
CSI	California Solar Initiative
dge	diesel gallon equivalent
DWR	California Department of Water Resources
EA	Environmental Analysis
EEI	Education and Environment Initiative
EIR	Environmental Impact Report
EJAC	Environmental Justice Advisory Committee

EO	Executive Order
EPIC	Electric Program Investment Charge Program
F-gases	fluorinated gases
FCEV	Fuel-cell electric vehicle
FERA	Family Electric Rate Assistance
GCF	Governors' Climate and Forests Task Force
GDP	gross domestic product
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
GoBiz	Governor's Office of Business and Economic Development
GWP	global warming potential
HCD	California Department of Housing and Community Development
HFC	Hydrofluorocarbon
HVAC	heating, ventilation and air conditioning
ICAP	International Carbon Action Partnership
IEPR	Integrated Energy Policy Report
IOU	investor-owned utility
IPCC	United Nations Intergovernmental Panel on Climate Change
IRP	integrated resource plan
IWG	Interagency Working Group on the Social Cost of Greenhouse Gases
LCFS	Low Carbon Fuel Standard
LCTOP	Low Carbon Transit Operations Program
LDV	light-duty vehicle
LED	light-emitting diode
LIWP	Low-Income Weatherization Program
LOS	level of service
$MMTCO_2e$	million metric tons of carbon dioxide equivalent
MOU	memorandum of understanding
MPO	metropolitan planning organization
MRR	Regulation for the Mandatory Reporting of GHG Emissions
$MTCO_2$	metric tons of carbon dioxide
MW	Megawatt
N_2O	nitrous oxide
NAICS	North American Industry Classification System
NEM	Net-Energy Metering
NF_3	nitrogen trifluoride
NO_X	nitrogen oxide
NZE	near-zero emission
OEHHA	Office of Environmental Health Hazard Assessment
OPR	Governor's Office of Planning and Research

PEV	plug-in electric vehicle
PHEV	Plug-in hybrid electric vehicle
PFC	Perfluorocarbon
PM	particulate matter
$PM_{2.5}$	fine particulate matter
PMR	Partnership for Market Readiness
REMI	Regional Economic Models, Inc.
RES-BCT	Renewable Energy Bill Credit
RNG	renewable natural gas
RPS	renewable portfolio standard
RTP	regional transportation plan
SB	Senate bill
SCS	Sustainable Communities Strategies
SC-CO_2	social cost of carbon
SF_6	sulfur hexafluoride
SGC	Strategic Growth Council
SGIP	Self-Generation Incentive Program
SLCP	Short-lived climate pollutant
SWRCB	State Water Resources Control Board
TBD	to be determined
TCU	Transportation Communications and Utilities
TIRCP	Transit and Intercity Rail Capital Program
UCLA	University of California, Los Angeles
UHI	urban heat island
UIC	International Union of Railways
UNFCCC	United Nations Framework Convention on Climate Change
USDA	U.S. Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
VMT	vehicle miles traveled
WWTP	waste water treatment plant
ZE	zero emission
ZEV	zero emission vehicles

California's 2030 Vision



AB-398 California Global Warming Solutions Act of 2006: market-based compliance mechanisms: fire prevention fees: sales and use tax manufacturing exemption. (2017-2018)

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Assembly Bill No. 398

CHAPTER 135

An act to amend, repeal, and add Sections 38501, 38562, and 38594 of, and to add and repeal Sections 38505.5, 38590.1, 38591.1, 38591.2, 38591.3, 38592.5, and 38592.6 of, the Health and Safety Code, to add Section 4213.05 to, to add Article 3 (commencing with Section 4229) to Chapter 1.5 of Part 2 of Division 4 of, and to repeal Chapter 1.5 (commencing with Section 4210) of Part 2 of Division 4 of, the Public Resources Code, and to amend Section 6377.1 of the Revenue and Taxation Code, relating to public resources, and declaring the urgency thereof, to take effect immediately.

[Approved by Governor July 25, 2017. Filed with Secretary of State July 25, 2017.]

LEGISLATIVE COUNSEL'S DIGEST

AB 398, Eduardo Garcia. California Global Warming Solutions Act of 2006: market-based compliance mechanisms: fire prevention fees: sales and use tax manufacturing exemption.

(1) The California Global Warming Solutions Act of 2006 establishes the State Air Resources Board as the state agency responsible for monitoring and regulating sources emitting greenhouse gases. The act requires the state board to approve a statewide greenhouse gas emissions limit equivalent to the statewide greenhouse gas emissions level in 1990 to be achieved by 2020 and to ensure that statewide greenhouse gas emissions are reduced to at least 40% below the 1990 level by 2030. The act authorizes the state board to include the use of market-based compliance mechanisms.

The act requires the state board to prepare and approve a scoping plan for achieving the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions and to update the scoping plan at least once every 5 years.

The act authorizes the state board to adopt a regulation that establishes a system of market-based declining annual aggregate emissions limits for sources or categories of sources that emit greenhouse gases, applicable from January 1, 2012, to December 31, 2020, inclusive, as specified.

This bill would require the state board, no later than January 1, 2018, to update the scoping plan, as specified. The bill would require all greenhouse gas rules and regulations adopted by the state board to be consistent with the scoping plan.

This bill would, until January 1, 2031, extend the applicability of a regulation that establishes a system of market-based declining annual aggregate emissions limits for sources or categories of sources that emit greenhouse gases to December 31, 2030.

This bill would, until January 1, 2031, require the state board to include specified price ceilings, price containment points, offset credit compliance limits, and industry assistance factors for allowance allocation as part of a regulation that establishes a system of market-based declining annual aggregate emissions limits for

sources or categories of sources that emit greenhouse gases from January 1, 2021, to December 31, 2030, inclusive. The bill, until January 1, 2031, additionally would require the state board to develop approaches to increase offset projects in the state and to make specified reports to the Legislature as part of that regulation.

This bill would, until January 1, 2031, establish the Compliance Offsets Protocol Task Force, with a specified membership, to provide guidance to the state board in approving new offset protocols for a market-based compliance mechanism for the purposes of increasing offset projects with direct environmental benefits in the state while prioritizing disadvantaged communities, Native American or tribal lands, and rural and agricultural regions.

This bill would, until January 1, 2031, establish the Independent Emissions Market Advisory Committee with a specified membership and would require the advisory committee to at least annually hold a public meeting and report to both the state board and the Joint Legislative Committee on Climate Change Policies on the environmental and economic performance of a specified market-based compliance mechanism and other relevant climate policies.

This bill would, until January 1, 2031, require the California Workforce Development Board, in consultation with the state board, to submit a specified report to the Legislature, no later than January 1, 2019, on the need for increased education, career technical education, job training, and workforce development resources or capacity to help industry, workers, and communities transition to economic and labor-market changes related to specified statewide greenhouse gas emissions reduction goals.

This bill would, until January 1, 2031, require the Legislative Analyst's Office to annually report to the Legislature on the economic impacts and benefits of specified greenhouse gas emissions targets.

(2) Existing law requires all moneys, except for fines and penalties, collected by the state board as part of a market-based compliance mechanism to be deposited in the Greenhouse Gas Reduction Fund and to be available upon appropriation. Existing law continuously appropriates 60% of the annual proceeds of the fund for transit, affordable housing, sustainable communities, and high-speed rail purposes.

This bill would declare the intent of the Legislature that moneys collected pursuant to the market-based compliance mechanism be appropriated in accordance with a specified order of priorities.

(3) Existing law provides that the California Global Warming Solutions Act of 2006 does not limit or expand the existing authority of air pollution control and air quality management districts.

This bill instead would, until January 1, 2031, prohibit an air district from adopting or implementing an emission reduction rule for carbon dioxide from stationary sources that are also subject to a specified market-based compliance mechanism.

(4) Existing law provides that the state has the primary financial responsibility for preventing and suppressing fires in areas that the State Board of Forestry and Fire Protection has determined are state responsibility areas, as defined. Existing law requires that a fire prevention fee be charged on each habitable structure on a parcel that is within a state responsibility area, to be used for specified fire prevention activities.

This bill, until January 1, 2031, would suspend the fire prevention fee. The bill would declare that it is the intent of the Legislature that moneys derived from the auction or sale of allowances pursuant to the market-based compliance mechanism described under (1) replace the fire prevention fee to continue the funding of the fire prevention activities. The bill would repeal those provisions requiring the payment of the fire prevention fee on January 1, 2031.

(5) Existing law, commencing July 1, 2017, provides that the California Department of Tax and Fee Administration is responsible for the administration of the Sales and Use Tax Law, which was previously administered by the State Board of Equalization.

Existing sales and use tax laws impose taxes on retailers measured by the gross receipts from the sale of tangible personal property sold at retail in this state, or on the storage, use, or other consumption in this state of tangible personal property purchased from a retailer for storage, use, or other consumption in this state, and provide various exemptions from those taxes.

Existing law exempts from those taxes, on and after July 1, 2014, and before July 1, 2022, the gross receipts from the sale of, and the storage, use, or other consumption of, qualified tangible personal property purchased by a qualified person for use primarily in manufacturing, processing, refining, fabricating, or recycling of tangible personal property, as specified; qualified tangible personal property purchased for use by a qualified person to

be used primarily in research and development, as provided; qualified tangible personal property purchased for use by a qualified person to be used primarily to maintain, repair, measure, or test any qualified tangible personal property, as provided; and qualified tangible personal property purchased by a contractor purchasing that property for use in the performance of a construction contract for the qualified person, that will use that property as an integral part of specified processes.

This bill would, on and after July 1, 2014, and before July 1, 2030, additionally exempt from those taxes qualified tangible personal property purchased for use by a qualified person to be used primarily in the generation or production, as defined, or storage and distribution, as defined, of electric power or purchased for use by a contractor for the qualified person, as specified. The bill, on and after January 1, 2018, and until July 1, 2030, would also exempt from those taxes special purpose buildings and foundations used for the generation or production or storage and distribution of electric power. The bill, on and after January 1, 2018, and until July 1, 2030, would expand the definition of qualified person to include, among others, a person primarily engaged in the business of electric power generation.

Under existing law, no later than each March 1 next following a calendar year for which these provisions provide an exemption, the California Department of Tax and Fee Administration is required to provide to the Joint Legislative Budget Committee a report of the total dollar amount of exemptions taken for the immediately preceding calendar year.

This bill would require the department to also provide that exemption report to the Department of Finance. The bill would require the total dollar amount, as reported by the department, with the concurrence of the Department of Finance, to be transferred from the Greenhouse Gas Reduction Fund to the General Fund, as provided.

This bill would also make various nonsubstantive and conforming changes and would repeal this exemption on January 1, 2031.

(6) This bill would declare that it is to take effect immediately as an urgency statute.

Vote: 2/3 Appropriation: no Fiscal Committee: yes Local Program: no

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

SECTION 1. Section 38501 of the Health and Safety Code is amended to read:

38501. The Legislature finds and declares all of the following:

(a) Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems.

(b) Global warming will have detrimental effects on some of California's largest industries, including agriculture, wine, tourism, skiing, recreational and commercial fishing, and forestry. It will also increase the strain on electricity supplies necessary to meet the demand for summer air-conditioning in the hottest parts of the state.

(c) California has long been a national and international leader on energy conservation and environmental stewardship efforts, including the areas of air quality protections, energy efficiency requirements, renewable energy standards, natural resource conservation, and greenhouse gas emission standards for passenger vehicles. The program established by this division will continue this tradition of environmental leadership by placing California at the forefront of national and international efforts to reduce emissions of greenhouse gases.

(d) National and international actions are necessary to fully address the issue of global warming. However, action taken by California to reduce emissions of greenhouse gases will have far-reaching effects by encouraging other states, the federal government, and other countries to act.

(e) By exercising a global leadership role, California will also position its economy, technology centers, financial institutions, and businesses to benefit from national and international efforts to reduce emissions of greenhouse gases. More importantly, investing in the development of innovative and pioneering technologies will assist California in achieving statewide greenhouse gas emissions targets established by this division and will provide

an opportunity for the state to take a global economic and technological leadership role in reducing emissions of greenhouse gases.

(f) It is the intent of the Legislature that the State Air Resources Board coordinate with state agencies, as well as consult with the environmental justice community, industry sectors, business groups, academic institutions, environmental organizations, and other stakeholders in implementing this division.

(g) It is the intent of the Legislature that the State Air Resources Board consult with the Public Utilities Commission in the development of emissions reduction measures, including limits on emissions of greenhouse gases applied to electricity and natural gas providers regulated by the Public Utilities Commission in order to ensure that electricity and natural gas providers are not required to meet duplicative or inconsistent regulatory requirements.

(h) It is the intent of the Legislature that the State Air Resources Board design emissions reduction measures to meet the statewide emissions limits for greenhouse gases established pursuant to this division in a manner that minimizes costs and maximizes benefits for California's economy, improves and modernizes California's energy infrastructure and maintains electric system reliability, maximizes additional environmental and economic cobenefits for California, and complements the state's efforts to improve air quality.

(i) It is the intent of the Legislature that the State Air Resources Board extend the market-based compliance mechanism adopted pursuant to subdivision (c) of Section 38562 from January 1, 2021, to December 31, 2030, inclusive, in a manner that effectively reduces greenhouse gas emissions; minimizes any adverse impacts on state consumers, businesses, and the economy; and continues elements of the current program that protect state utility ratepayers.

(j) It is the intent of the Legislature that the Climate Action Team established by the Governor to coordinate the efforts set forth under Executive Order S-3-05 continue its role in coordinating overall climate policy.

(k) This section shall remain in effect only until January 1, 2031, and as of that date is repealed.

SEC. 2. Section 38501 is added to the Health and Safety Code, to read:

38501. (a) Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems.

(b) Global warming will have detrimental effects on some of California's largest industries, including agriculture, wine, tourism, skiing, recreational and commercial fishing, and forestry. It will also increase the strain on electricity supplies necessary to meet the demand for summer air-conditioning in the hottest parts of the state.

(c) California has long been a national and international leader on energy conservation and environmental stewardship efforts, including the areas of air quality protections, energy efficiency requirements, renewable energy standards, natural resource conservation, and greenhouse gas emission standards for passenger vehicles. The program established by this division will continue this tradition of environmental leadership by placing California at the forefront of national and international efforts to reduce emissions of greenhouse gases.

(d) National and international actions are necessary to fully address the issue of global warming. However, action taken by California to reduce emissions of greenhouse gases will have far-reaching effects by encouraging other states, the federal government, and other countries to act.

(e) By exercising a global leadership role, California will also position its economy, technology centers, financial institutions, and businesses to benefit from national and international efforts to reduce emissions of greenhouse gases. More importantly, investing in the development of innovative and pioneering technologies will assist California in achieving the 2020 statewide limit on emissions of greenhouse gases established by this division and will provide an opportunity for the state to take a global economic and technological leadership role in reducing emissions of greenhouse gases.

(f) It is the intent of the Legislature that the State Air Resources Board coordinate with state agencies, as well as consult with the environmental justice community, industry sectors, business groups, academic institutions, environmental organizations, and other stakeholders in implementing this division.

(g) It is the intent of the Legislature that the State Air Resources Board consult with the Public Utilities Commission in the development of emissions reduction measures, including limits on emissions of greenhouse gases applied to electricity and natural gas providers regulated by the Public Utilities Commission in order to ensure that electricity and natural gas providers are not required to meet duplicative or inconsistent regulatory requirements.

(h) It is the intent of the Legislature that the State Air Resources Board design emissions reduction measures to meet the statewide emissions limits for greenhouse gases established pursuant to this division in a manner that minimizes costs and maximizes benefits for California's economy, improves and modernizes California's energy infrastructure and maintains electric system reliability, maximizes additional environmental and economic cobenefits for California, and complements the state's efforts to improve air quality.

(i) It is the intent of the Legislature that the Climate Action Team established by the Governor to coordinate the efforts set forth under Executive Order S-3-05 continue its role in coordinating overall climate policy.

(j) This section shall become operative on January 1, 2031.

SEC. 3. Section 38505.5 is added to the Health and Safety Code, to read:

38505.5. (a) "District" has the same meaning as in Section 39025.

(b) This section shall remain in effect only until January 1, 2031, and as of that date is repealed.

SEC. 4. Section 38562 of the Health and Safety Code is amended to read:

38562. (a) On or before January 1, 2011, the state board shall adopt greenhouse gas emissions limits and emissions reduction measures by regulation to achieve the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions in furtherance of achieving the statewide greenhouse gas emissions limit, to become operative beginning on January 1, 2012.

(b) In adopting regulations pursuant to this section and Part 5 (commencing with Section 38570), to the extent feasible and in furtherance of achieving the statewide greenhouse gas emissions limit, the state board shall do all of the following:

(1) Design the regulations, including distribution of emissions allowances where appropriate, in a manner that is equitable, seeks to minimize costs and maximize the total benefits to California, and encourages early action to reduce greenhouse gas emissions.

(2) Ensure that activities undertaken to comply with the regulations do not disproportionately impact low-income communities.

(3) Ensure that entities that have voluntarily reduced their greenhouse gas emissions prior to the implementation of this section receive appropriate credit for early voluntary reductions.

(4) Ensure that activities undertaken pursuant to the regulations complement, and do not interfere with, efforts to achieve and maintain federal and state ambient air quality standards and to reduce toxic air contaminant emissions.

(5) Consider cost-effectiveness of these regulations.

(6) Consider overall societal benefits, including reductions in other air pollutants, diversification of energy sources, and other benefits to the economy, environment, and public health.

(7) Minimize the administrative burden of implementing and complying with these regulations.

(8) Minimize leakage.

(9) Consider the significance of the contribution of each source or category of sources to statewide emissions of greenhouse gases.

(c) (1) Unless otherwise required by context, terms in this subdivision shall have the definitions that apply pursuant to Section 95802 of Title 17 of the California Code of Regulations, as they read on January 1, 2017.

(2) The state board may adopt a regulation that establishes a system of market-based declining annual aggregate emissions limits for sources or categories of sources that emit greenhouse gases, applicable from January 1, 2012, to December 31, 2030, inclusive, that the state board determines will achieve the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions, in the aggregate, from those sources or categories of sources. In adopting a regulation applicable from January 1, 2021, to December 31, 2030, inclusive, pursuant to this subdivision, the state board shall do all of the following:

(A) (i) Establish a price ceiling. In establishing the price ceiling, the state board shall consider, using the best available science, all of the following:

(I) The need to avoid adverse impacts on resident households, businesses, and the state's economy.

(II) The 2020 tier prices of the allowance price containment reserve.

(III) The full social cost associated with emitting a metric ton of greenhouse gases.

(IV) The auction reserve price.

(V) The potential for environmental and economic leakage.

(VI) The cost per metric ton of greenhouse gas emissions reductions to achieve the statewide emissions targets established in Sections 38550 and 38566.

(ii) To implement the price ceiling, the state board shall develop a mechanism that consists of both of the following:

(I) Allowances remaining in the allowance price containment reserve as of December 31, 2020, shall be utilized solely for the purpose of sale at the price ceiling established by this section.

(II) If the allowances from the allowance price containment reserve are exhausted, the state board shall offer covered entities additional metric tons at the price ceiling if needed for compliance. All moneys generated pursuant to this clause shall be expended by the state board to achieve emissions reductions, on at least a metric ton for metric ton basis, that are real, permanent, quantifiable, verifiable, enforceable by the state board and in addition to any greenhouse gas emission reduction otherwise required by law or regulation and any other greenhouse gas emission reduction that otherwise would occur.

(B) Establish two price containment points at levels below the price ceiling. The state board shall offer to covered entities nontradable allowances for sale at these price containment points. The price containment points shall be established using two-thirds, divided equally, of the allowances in the allowance price containment reserve as of December 31, 2017.

(C) Require that current vintage allowances designated by the state board for auction that remain unsold in the auction holding account for more than 24 months to be transferred to the allowance price containment reserve.

(D) Evaluate and address concerns related to overallocation in the state board's determination of the number of available allowances for years 2021 to 2030, inclusive, as appropriate.

(E) (i) Establish offset credit limits according to the following:

(I) From January 1, 2021, to December 31, 2025, inclusive, a total of 4 percent of a covered entity's compliance obligation may be met by surrendering offset credits of which no more than one-half may be sourced from projects that do not provide direct environmental benefits in state.

(II) From January 1, 2026, to December 31, 2030, inclusive, a total of 6 percent of a covered entity's compliance obligation may be met by surrendering offset credits of which no more than one-half may be sourced from projects that do not provide direct environmental benefits in the state.

(ii) For purposes of this subparagraph, "direct environmental benefits in the state" are the reduction or avoidance of emissions of any air pollutant in the state or the reduction or avoidance of any pollutant that could have an adverse impact on waters of the state.

(F) Develop approaches to increase offset projects in the state considering guidance provided by the Compliance Offsets Protocol Task Force, established pursuant to Section 38591.1.

(G) Set industry assistance factors for allowance allocation commencing in 2021 at the levels applicable in the compliance period of 2015 to 2017, inclusive. The state board shall apply a declining cap adjustment factor to the industry allocation equivalent to the overall statewide emissions declining cap using the methodology from the compliance period of 2015 to 2017, inclusive.

(H) Establish allowance banking rules that discourage speculation, avoid financial windfalls, and consider the impact on complying entities and volatility in the market.

(I) Report to the Legislature, by December 31, 2025, on the progress toward meeting the greenhouse gas emissions reduction targets established pursuant to Sections 38550 and 38566 and the leakage risk posed by the regulation. The state board shall include recommendations to the Legislature on necessary statutory changes to the program to reduce leakage, including the potential for a border carbon adjustment, while maintaining the state's ability to reach its targets.

(J) (i) Report to the Legislature, in consultation with the Independent Emissions Market Advisory Committee, established pursuant to Section 38591.2, if two consecutive auctions exceed the lower of the price containment levels established pursuant to subparagraph (B). The report shall assess the potential for allowance prices to reach the price ceiling for multiple auctions.

(ii) A report submitted to the Legislature pursuant to this section shall be submitted in compliance with Section 9795 of the Government Code.

(K) Report to the relevant fiscal and policy committees of the Legislature, including the Joint Committee on Climate Change Policies, on all of the following:

(i) Updates to the scoping plan prepared pursuant to Section 38561 prior to adopting the update.

(ii) Updates on the implementation of the scoping plan prepared pursuant to Section 38561.

(iii) Updates on the implementation of the market-based compliance mechanism adopted pursuant to this subdivision.

(d) Any regulation adopted by the state board pursuant to this part or Part 5 (commencing with Section 38570) shall ensure all of the following:

(1) The greenhouse gas emission reductions achieved are real, permanent, quantifiable, verifiable, and enforceable by the state board.

(2) For regulations pursuant to Part 5 (commencing with Section 38570), the reduction is in addition to any greenhouse gas emission reduction otherwise required by law or regulation, and any other greenhouse gas emission reduction that otherwise would occur.

(3) If applicable, the greenhouse gas emission reduction occurs over the same time period and is equivalent in amount to any direct emission reduction required pursuant to this division.

(e) The state board shall rely upon the best available economic and scientific information and its assessment of existing and projected technological capabilities when adopting the regulations required by this section.

(f) The state board shall consult with the Public Utilities Commission in the development of the regulations as they affect electricity and natural gas providers in order to minimize duplicative or inconsistent regulatory requirements.

(g) The state board may revise regulations adopted pursuant to this section and adopt additional regulations to further the provisions of this division.

(h) This section shall remain in effect only until January 1, 2031, and as of that date is repealed, unless a later enacted statute which is enacted before that date, deletes or extends that date.

SEC. 5. Section 38562 is added to the Health and Safety Code, to read:

38562. (a) On or before January 1, 2011, the state board shall adopt greenhouse gas emissions limits and emissions reduction measures by regulation to achieve the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions in furtherance of achieving the statewide greenhouse gas emissions limit, to become operative beginning on January 1, 2012.

(b) In adopting regulations pursuant to this section and Part 5 (commencing with Section 38570), to the extent feasible and in furtherance of achieving the statewide greenhouse gas emissions limit, the state board shall do all of the following:

(1) Design the regulations, including distribution of emissions allowances where appropriate, in a manner that is equitable, seeks to minimize costs and maximize the total benefits to California, and encourages early action to reduce greenhouse gas emissions.

(2) Ensure that activities undertaken to comply with the regulations do not disproportionately impact low-income communities.

(3) Ensure that entities that have voluntarily reduced their greenhouse gas emissions prior to the implementation of this section receive appropriate credit for early voluntary reductions.

(4) Ensure that activities undertaken pursuant to the regulations complement, and do not interfere with, efforts to achieve and maintain federal and state ambient air quality standards and to reduce toxic air contaminant emissions.

(5) Consider cost-effectiveness of these regulations.

(6) Consider overall societal benefits, including reductions in other air pollutants, diversification of energy sources, and other benefits to the economy, environment, and public health.

(7) Minimize the administrative burden of implementing and complying with these regulations.

(8) Minimize leakage.

(9) Consider the significance of the contribution of each source or category of sources to statewide emissions of greenhouse gases.

(c) In furtherance of achieving the statewide greenhouse gas emissions limit, the state board may adopt a regulation that establishes a system of market-based declining annual aggregate emissions limits for sources or categories of sources that emit greenhouse gases, applicable from January 1, 2012, to December 31, 2020, inclusive, that the state board determines will achieve the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions, in the aggregate, from those sources or categories of sources.

(d) Any regulation adopted by the state board pursuant to this part or Part 5 (commencing with Section 38570) shall ensure all of the following:

(1) The greenhouse gas emission reductions achieved are real, permanent, quantifiable, verifiable, and enforceable by the state board.

(2) For regulations pursuant to Part 5 (commencing with Section 38570), the reduction is in addition to any greenhouse gas emission reduction otherwise required by law or regulation, and any other greenhouse gas emission reduction that otherwise would occur.

(3) If applicable, the greenhouse gas emission reduction occurs over the same time period and is equivalent in amount to any direct emission reduction required pursuant to this division.

(e) The state board shall rely upon the best available economic and scientific information and its assessment of existing and projected technological capabilities when adopting the regulations required by this section.

(f) The state board shall consult with the Public Utilities Commission in the development of the regulations as they affect electricity and natural gas providers in order to minimize duplicative or inconsistent regulatory requirements.

(g) The state board may revise regulations adopted pursuant to this section and adopt additional regulations to further the provisions of this division.

(h) This section shall become operative on January 1, 2031.

SEC. 6. Section 38590.1 is added to the Health and Safety Code, to read:

38590.1. (a) It is the intent of the Legislature that moneys collected from the auction or sale of allowances pursuant to a market-based compliance mechanism established pursuant to the California Global Warming

Solutions Act of 2006 (Division 25.5 (commencing with Section 38500)) shall be appropriated to include, but need not be limited to, the following priorities at the time an expenditure plan is adopted:

(1) Air toxic and criteria air pollutants from stationary and mobile sources.

(2) Low- and zero-carbon transportation alternatives.

(3) Sustainable agricultural practices that promote the transitions to clean technology, water efficiency, and improved air quality.

(4) Healthy forests and urban greening.

(5) Short-lived climate pollutants.

(6) Climate adaptation and resiliency.

(7) Climate and clean energy research.

(b) This section shall remain in effect only until January 1, 2031, and as of that date is repealed unless a later enacted statute that is enacted on or before that date deletes or extends that date.

SEC. 7. Section 38591.1 is added to the Health and Safety Code, to read:

38591.1. (a) The Compliance Offsets Protocol Task Force is hereby established to provide guidance to the state board in approving new offset protocols for a market-based compliance mechanism for the purposes of increasing offset projects with direct environmental benefits in the state while prioritizing disadvantaged communities, Native American or tribal lands, and rural and agricultural regions. The state board shall appoint members to the Compliance Offsets Protocol Task Force to include a representative from each stakeholder group, including, but not limited to, all of the following:

(1) Scientists.

(2) Air pollution control and air quality management districts.

(3) Carbon market experts.

(4) Tribal representatives.

(5) Environmental Justice advocates.

(6) Labor and Workforce representatives.

(7) Forestry experts.

(8) Agriculture experts.

(9) Environmental advocates.

(10) Conservation advocates.

(11) Dairy experts.

(b) This section shall remain in effect only until January 1, 2031, and as of that date is repealed.

SEC. 8. Section 38591.2 is added to the Health and Safety Code, to read:

38591.2. (a) The Independent Emissions Market Advisory Committee is hereby established within the California Environmental Protection Agency.

(b) (1) (A) The committee shall be composed of at least five experts on emissions trading market design appointed according to the following:

(i) Three members appointed by the Governor.

(ii) One member appointed by the Senate Committee on Rules.

(iii) One member appointed by the Speaker of the Assembly.

(B) The committee shall include a representative from the Legislative Analyst's Office.

(2) The committee members shall meet all of the following requirements:

(A) Have academic, nonprofit, and other relevant backgrounds.

(B) Lack financial conflicts of interest with entities subject to the regulation adopted by the state board pursuant to subdivision (c) of Section 38562.

(c) The committee, at least annually, shall hold a public meeting and report to both the state board and the Joint Legislative Committee on Climate Change Policies on the environmental and economic performance of the regulation adopted by the state board pursuant to subdivision (c) of Section 38562 and other relevant climate policies.

(d) This section shall remain in effect only until January 1, 2031, and as of that date is repealed.

SEC. 9. Section 38591.3 is added to the Health and Safety Code, to read:

38591.3. (a) No later than January 1, 2019, the California Workforce Development Board, in consultation with the state board, shall report to the Legislature on the need for increased education, career technical education, job training, and workforce development resources or capacity to help industry, workers, and communities transition to economic and labor-market changes related to statewide greenhouse gas emissions reduction goals, pursuant to Sections 38550 and 38566, and the scoping plan, adopted pursuant to Section 38561. The California Workforce Development Board shall ensure that the report aligns, as appropriate, with California's Unified Strategic Workforce Development Plan, developed by the California Workforce Development Board. The California Workforce Development Board and the state board shall work in consultation with all of the following:

(1) State Department of Education.

(2) California Community Colleges.

(3) Trustees of the California State University.

(4) Regents of the University of California.

(5) Governor's Office of Business and Economic Development.

(6) Interested stakeholders.

(b) The report to the Legislature shall address all of the following:

(1) Creating and retaining jobs and stimulating economic activity in the state.

(2) Imbedding workforce training and employment services in infrastructure investments so that services more directly connect to the jobs created.

(3) The use of community benefits agreements, community workforce agreements, and project labor agreements that connect workforce services and job training directly to jobs impacted or jobs created.

(4) Preparing the state's students with relevant career technical education that responds to business and industry demands.

(5) Developing worker retraining programs to assist the existing workforce with the necessary tools to upgrade their skills.

(6) Responding to the job creation and workforce needs of the state's new and emerging industries, including emerging technologies that will result in greater greenhouse gas emissions reductions.

(7) Developing job training programs to assist specific populations, such as at-risk youth, displaced workers, veterans, the formerly incarcerated, and others facing barriers to employment.

(8) Opportunities for community-based organizations to partner with local workforce agencies to improve the labor-market outcomes of targeted disadvantaged populations.

(9) Targeting workforce development programs and activities in disadvantaged communities, as identified pursuant to Section 39711, and communities that are located near entities regulated by the state board pursuant

to this division.

(10) Identifying and leveraging state and federal funding resources to implement the recommendations made in the report consistent with the regulatory purposes of this division.

(c) This section shall remain in effect only until January 1, 2031, and as of that date is repealed.

SEC. 10. Section 38592.5 is added to the Health and Safety Code, to read:

38592.5. (a) (1) No later than January 1, 2018, the state board shall update the scoping plan, prepared pursuant to Section 38561, to achieve the greenhouse gas emissions reductions required pursuant to Section 38566. The state board shall designate the market-based compliance mechanism adopted pursuant to subdivision (c) of Section 38562 as the rule for petroleum refineries and oil and gas production facilities to achieve their greenhouse gas emissions reductions.

(2) All greenhouse gas rules and regulations adopted by the state board shall be consistent with the updated scoping plan.

(3) Nothing in this section shall limit the state board's authority to adopt, maintain, or revise any other measure, including, but not limited to, any of the following:

(A) Measures governing methane and fugitive emissions at refineries and oil and gas facilities.

(B) Advanced clean cars program adopted by the state board.

(C) Low-Carbon Fuel Standard regulations (Subarticle 7 (commencing with Section 95480) of Article 4 of Subchapter 10 of Chapter 1 of Division 3 of Title 17 of the California Code of Regulations).

(D) Regulations addressing short-lived climate pollutants.

(E) Implementation of the sustainable freight action plan released in July 2015 pursuant to Executive Order B-32-15.

(b) This section shall remain in effect only until January 1, 2031, and as of that date is repealed, unless a later enacted statute, which is enacted before January 1, 2031, deletes or extends that date.

SEC. 11. Section 38592.6 is added to the Health and Safety Code, to read:

38592.6. (a) The Legislative Analyst's Office shall, until January 1, 2030, annually report to the Legislature on the economic impacts and benefits of the greenhouse gas emissions targets established pursuant to Sections 38550 and 38566.

(b) This section shall remain in effect only until January 1, 2031, and as of that date is repealed, unless a later enacted statute, which is enacted before January 1, 2031, deletes or extends that date.

SEC. 12. Section 38594 of the Health and Safety Code is amended to read:

38594. (a) Except as provided in subdivision (b), nothing in this division shall limit or expand the existing authority of any district.

(b) A district shall not adopt or implement an emission reduction rule for carbon dioxide from stationary sources that are also subject to a market-based compliance mechanism adopted by the state board pursuant to subdivision (c) of Section 38562.

(c) Nothing in this section affects in any manner the authority of a district to adopt or implement, as applicable, any of the following:

(1) A rule, regulation, standard, or requirement authorized or required for a district to adopt under Division 26 (commencing with Section 39000) for purposes other than to reduce carbon dioxide from sources subject to a market-based compliance mechanism adopted by the state board pursuant to subdivision (c) of Section 38562.

(2) A rule, regulation, standard, or requirement authorized pursuant to a law affecting emissions associated with landfills, refrigerants, natural gas or methane, volatile organic compounds, or a rule required to comply with the federal Clean Air Act (42 U.S.C. Sec. 7401 et seq.) or regulations implementing that act.

(3) A rule, regulation, standard, or requirement authorized pursuant to a law to reduce vehicle trips, vehicle miles traveled, parking, or vehicular air emissions, including, but not limited to, a rule adopted pursuant to Chapter 728 of the Statutes of 2008.

(4) A rule, regulation, standard, or requirement established pursuant to the California Environmental Quality Act (Division 13 (commencing with Section 21000) of the Public Resources Code).

(5) A rule, regulation, standard, or requirement adopted by any state agency.

(d) This section shall become inoperative if the state board repeals the market-based compliance mechanism adopted by the state board pursuant to subdivision (c) of Section 38562. The state board shall notify the Secretary of State if this section becomes inoperative.

(e) This section shall remain in effect only until January 1, 2031, and as of that date is repealed.

SEC. 13. Section 38594 is added to the Health and Safety Code, to read:

38594. (a) Nothing in this division shall limit or expand the existing authority of any district, as defined in Section 39025.

(b) This section shall become operative on January 1, 2031.

SEC. 14. Section 4213.05 is added to the Public Resources Code, to read:

4213.05. (a) Commencing with the 2017–18 fiscal year, the fire prevention fee imposed pursuant to Section 4212 shall be suspended, effective July 1, 2017. Any moneys held in reserve in the State Responsibility Area Fire Responsibility Fund shall be appropriated by the Legislature in a manner consistent with subdivision (d) of Section 4214.

(b) It is the intent of the Legislature that moneys derived from the auction or sale of allowances pursuant to a market-based compliance mechanism established pursuant to Division 25.5 (commencing with Section 38500) of the Health and Safety Code shall be used to replace the moneys that would have otherwise been collected under Section 4212 to continue fire prevention activities.

(c) This section shall become inoperative on January 1, 2031.

SEC. 15. Article 3 (commencing with Section 4229) is added to Chapter 1.5 of Part 2 of Division 4 of the Public Resources Code, to read:

Article 3. Repeal

4229. This chapter shall remain in effect only until January 1, 2031, and as of that date is repealed, unless a later enacted statute that is enacted on or before January 1, 2031, deletes or extends that date.

SEC. 16. Section 6377.1 of the Revenue and Taxation Code is amended to read:

6377.1. (a) Except as provided in subdivision (e), on or after July 1, 2014, and before July 1, 2030, there are exempted from the taxes imposed by this part the gross receipts from the sale of, and the storage, use, or other consumption in this state of, any of the following:

(1) Qualified tangible personal property purchased for use by a qualified person to be used primarily in any stage of the manufacturing, processing, refining, fabricating, or recycling of tangible personal property, beginning at the point any raw materials are received by the qualified person and introduced into the process and ending at the point at which the manufacturing, processing, refining, fabricating, or recycling has altered tangible personal property to its completed form, including packaging, if required.

(2) Qualified tangible personal property purchased for use by a qualified person to be used primarily in research and development.

(3) Qualified tangible personal property purchased for use by a qualified person to be used primarily to maintain, repair, measure, or test any qualified tangible personal property described in paragraph (1) or (2).

(4) Qualified tangible personal property purchased for use by a contractor purchasing that property for use in the performance of a construction contract for the qualified person, that will use that property as an integral part of the manufacturing, processing, refining, fabricating, or recycling process, the generation or production, or storage and distribution, of electric power, or as a research or storage facility for use in connection with those processes.

(5) Qualified tangible personal property purchased for use by a qualified person to be used primarily in the generation or production, or storage and distribution, of electric power.

(b) For purposes of this section:

(1) "Department" means the California Department of Tax and Fee Administration.

(2) "Fabricating" means to make, build, create, produce, or assemble components or tangible personal property to work in a new or different manner.

(3) "Generation or production" means the activity of making, producing, creating, or converting electric power from sources other than a conventional power source, as defined in Section 2805 of the Public Utilities Code.

(4) "Manufacturing" means the activity of converting or conditioning tangible personal property by changing the form, composition, quality, or character of the property for ultimate sale at retail or use in the manufacturing of a product to be ultimately sold at retail. Manufacturing includes any improvements to tangible personal property that result in a greater service life or greater functionality than that of the original property.

(5) "Primarily" means 50 percent or more of the time.

(6) "Process" means the period beginning at the point at which any raw materials are received by the qualified person and introduced into the manufacturing, processing, refining, fabricating, or recycling activity of the qualified person and ending at the point at which the manufacturing, processing, refining, fabricating, or recycling activity of the qualified person has altered tangible personal property to its completed form, including packaging, if required. Raw materials shall be considered to have been introduced into the process when the raw materials are stored on the same premises where the qualified person's manufacturing, processing, refining, fabricating, or recycling activity is conducted. Raw materials that are stored on premises other than where the qualified person's manufacturing, processing, refining, fabricating, or recycling activity is conducted shall not be considered to have been introduced into the manufacturing, processing, refining, fabricating, or recycling process.

(7) "Processing" means the physical application of the materials and labor necessary to modify or change the characteristics of tangible personal property.

(8) (A) "Qualified person" means:

(i) Prior to January 1, 2018, a person that is primarily engaged in those lines of business described in Codes 3111 to 3399, inclusive, 541711, or 541712 of the North American Industry Classification System (NAICS) published by the United States Office of Management and Budget (OMB), 2012 edition.

(ii) On and after January 1, 2018, and before July 1, 2030, a person that is primarily engaged in those lines of business described in Codes 3111 to 3399, inclusive, 22111 to 221118, inclusive, 221122, 541711, or 541712 of the North American Industry Classification System (NAICS) published by the United States Office of Management and Budget (OMB), 2012 edition.

(B) Notwithstanding subparagraph (A), "qualified person" shall not include either of the following:

(i) Prior to January 1, 2018, an apportioning trade or business that is required to apportion its business income pursuant to subdivision (b) of Section 25128 or a trade or business conducted wholly within this state that would be required to apportion its business income pursuant to subdivision (b) of Section 25128 if it were subject to apportionment pursuant to Section 25101.

(ii) On and after January 1, 2018, and before July 1, 2030, an apportioning trade or business, other than a trade or business described in paragraph (1) of subdivision (c) of Section 25128, that is required to apportion its business income pursuant to subdivision (b) of Section 25128, or a trade or business, other than a trade or business described in paragraph (1) of subdivision (c) of Section 25128, conducted wholly within this state that would be required to apportion its business income pursuant to subdivision (b) of Section 25128 if it were subject to apportionment pursuant to Section 25101.

(9) (A) "Qualified tangible personal property" includes, but is not limited to, all of the following:

(i) Machinery and equipment, including component parts and contrivances such as belts, shafts, moving parts, and operating structures.

(ii) Equipment or devices used or required to operate, control, regulate, or maintain the machinery, including, but not limited to, computers, data-processing equipment, and computer software, together with all repair and replacement parts with a useful life of one or more years therefor, whether purchased separately or in conjunction with a complete machine and regardless of whether the machine or component parts are assembled by the qualified person or another party.

(iii) Tangible personal property used in pollution control that meets standards established by this state or any local or regional governmental agency within this state.

(iv) (I) Prior to January 1, 2018, special purpose buildings and foundations used as an integral part of the manufacturing, processing, refining, fabricating, or recycling process, or that constitute a research or storage facility used during those processes. Buildings used solely for warehousing purposes after completion of those processes are not included.

(II) On and after January 1, 2018, and before July 1, 2030, special purpose buildings and foundations used as an integral part of the manufacturing, processing, refining, fabricating, or recycling process, or that constitute a research or storage facility used during those processes, or the generation or production or storage and distribution of electric power. Buildings used solely for warehousing purposes after completion of those processes are not included.

(B) "Qualified tangible personal property" shall not include any of the following:

(i) Consumables with a useful life of less than one year.

(ii) Furniture, inventory, and equipment used in the extraction process, or equipment used to store finished products that have completed the manufacturing, processing, refining, fabricating, or recycling process.

(iii) Tangible personal property used primarily in administration, general management, or marketing.

(10) "Refining" means the process of converting a natural resource to an intermediate or finished product.

(11) "Research and development" means those activities that are described in Section 174 of the Internal Revenue Code or in any regulations thereunder.

(12) "Storage and distribution" means storing or distributing through the electric grid, but not transmission of, electric power to consumers regardless of source.

(13) (A) "Useful life" for tangible personal property that is treated as having a useful life of one or more years for state income or franchise tax purposes shall be deemed to have a useful life of one or more years for purposes of this section. "Useful life" for tangible personal property that is treated as having a useful life of less than one year for state income or franchise tax purposes shall be deemed to have a useful life of less than one year for purposes of this section. For the purposes of this paragraph, tangible personal property that is deducted under Sections 17201 and 17255 or Section 24356 shall be deemed to have a useful life of one or more years.

(B) The board shall cancel any outstanding and unpaid deficiency determination and any related penalties and interest and shall not issue any deficiency determination or notice of determination, with respect to unpaid sales and use tax on qualified property with a useful life, as defined in subparagraph (A), that was purchased or leased on or after July 1, 2014, and before January 1, 2018. Any amounts paid by a qualified person pursuant to such determination shall be refunded by the department to the qualified person. Any cancellation or refund described in this subparagraph is contingent upon a qualified person making a request to the department, in a manner prescribed by the department, by June 30, 2018.

(c) An exemption shall not be allowed under this section unless the purchaser furnishes the retailer with an exemption certificate, completed in accordance with any instructions or regulations as the department may prescribe, and the retailer retains the exemption certificate in its records and furnishes it to the department upon request.

(d) (1) Notwithstanding the Bradley-Burns Uniform Local Sales and Use Tax Law (Part 1.5 (commencing with Section 7200)) and the Transactions and Use Tax Law (Part 1.6 (commencing with Section 7251)), the

exemption established by this section shall not apply with respect to any tax levied by a county, city, or district pursuant to, or in accordance with, either of those laws.

(2) Notwithstanding subdivision (a), the exemption established by this section shall not apply with respect to any tax levied pursuant to Section 6051.2, 6051.5, 6201.2, or 6201.5, pursuant to Section 35 of Article XIII of the California Constitution, or any tax levied pursuant to Section 6051 or 6201 that is deposited in the State Treasury to the credit of the Local Revenue Fund 2011 pursuant to Section 6051.15 or 6201.15.

(e) (1) The exemption provided by this section shall not apply to either of the following:

(A) Any tangible personal property purchased during any calendar year that exceeds two hundred million dollars ($200,000,000) of purchases of qualified tangible personal property for which an exemption is claimed by a qualified person under this section. For purposes of this subparagraph, in the case of a qualified person that is required to be included in a combined report under Section 25101 or authorized to be included in a combined report under Section 25101.15, the aggregate of all purchases of qualified personal property for which an exemption is claimed pursuant to this section by all persons that are required or authorized to be included in a combined report shall not exceed two hundred million dollars ($200,000,000) in any calendar year.

(B) The sale or storage, use, or other consumption of property that, within one year from the date of purchase, is removed from California, converted from an exempt use under subdivision (a) to some other use not qualifying for exemption, or used in a manner not qualifying for exemption.

(2) If a purchaser certifies in writing to the seller that the tangible personal property purchased without payment of the tax will be used in a manner entitling the seller to regard the gross receipts from the sale as exempt from the sales tax, and the purchase exceeds the two-hundred-million-dollar ($200,000,000) limitation described in subparagraph (A) of paragraph (1), or within one year from the date of purchase, the purchaser removes that property from California, converts that property for use in a manner not qualifying for the exemption, or uses that property in a manner not qualifying for the exemption, the purchaser shall be liable for payment of sales tax, with applicable interest, as if the purchaser were a retailer making a retail sale of the tangible personal property at the time the tangible personal property is so purchased, removed, converted, or used, and the cost of the tangible personal property to the purchaser shall be deemed the gross receipts from that retail sale.

(f) This section shall apply to leases of qualified tangible personal property classified as "continuing sales" and "continuing purchases" in accordance with Sections 6006.1 and 6010.1. The exemption established by this section shall apply to the rentals payable pursuant to the lease, provided the lessee is a qualified person and the tangible personal property is used in an activity described in subdivision (a).

(g) (1) Upon the effective date of this section, the Department of Finance shall estimate the total dollar amount of exemptions that will be taken for each calendar year, or any portion thereof, for which this section provides an exemption.

(2) (A) No later than each March 1 next following a calendar year for which this section provides an exemption, the department shall provide to the Joint Legislative Budget Committee and to the Department of Finance a report of the total dollar amount of exemptions taken under this section for the immediately preceding calendar year. The report shall compare the total dollar amount of exemptions taken under this section for that calendar year with the department's estimate for that same calendar year. If that total dollar amount taken is less than the estimate for that calendar year, the report shall identify options for increasing exemptions taken so as to meet estimated amounts.

(B) No later than June 30 of that same calendar year, that total dollar amount, notwithstanding subparagraph (A) of paragraph (13) of subdivision (b), as reported by the department, with the concurrence of the Department of Finance, shall be transferred from the Greenhouse Gas Reduction Fund to the General Fund.

(h) This section is repealed on January 1, 2031.

SEC. 17. This act is an urgency statute necessary for the immediate preservation of the public peace, health, or safety within the meaning of Article IV of the California Constitution and shall go into immediate effect. The facts constituting the necessity are:

To secure a greater reduction in greenhouse gas emissions to prevent catastrophic climate change, it is necessary for this act to take effect immediately.

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EXECUTIVE ORDER B-16-2012

Published: Mar 23, 2012

EXECUTIVE ORDER B-16-2012

WHEREAS California is the nation’s largest market for cars and light-duty trucks; and

WHEREAS the transportation sector is the biggest contributor to California’s greenhouse gas emissions and accounts for approximately 40 percent of these emissions; and

WHEREAS California should encourage the development and success of zero-emission vehicles to protect the environment, stimulate economic growth and improve the quality of life in the State; and

WHEREAS California is a leader of technological innovation, including the innovation necessary to produce commercially successful zero-emission vehicles; and

WHEREAS California attracts over half of the nation’s venture capital for clean technology and ranks high among the states in the number of workers and facilities supporting the clean-car industry; and

WHEREAS California is leading the nation in enacting laws and establishing policies and programs that are reducing greenhouse gases, protecting air and water quality, promoting energy diversity and supporting low-carbon alternative fuel technologies; and

WHEREAS zero-emission vehicles provide multiple benefits in addition to reducing greenhouse gas emissions, such as reducing conventional pollutants, operating quietly and cleanly, allowing home refueling and lowering operating and fuel costs; and

WHEREAS California should support and encourage car manufacturers’ plans to build and sell tens of thousands of zero-emission vehicles in California in the coming years.

NOW, THEREFORE, I, Edmund G. Brown Jr., Governor of the State of California, do hereby issue the following orders to become effective immediately:

IT IS HEREBY ORDERED that all State entities under my direction and control support and facilitate the rapid commercialization of zero-emission vehicles.

IT IS FURTHER ORDERED that the California Air Resources Board, the California Energy Commission, the Public Utilities Commission and other relevant agencies work with the Plug-in Electric Vehicle Collaborative and the California Fuel Cell Partnership to establish benchmarks to help achieve by 2015:

- The State’s major metropolitan areas will be able to accommodate zero-emission vehicles, each with

infrastructure plans and streamlined permitting; and
• The State's manufacturing sector will be expanding zero-emission vehicle and component manufacturing; and
• The private sector's investment in zero-emission vehicle infrastructure will be growing; and
• The State's academic and research institutions will be contributing to zero-emission vehicle research, innovation and education.

IT IS FURTHER ORDERED that these entities establish benchmarks to help achieve by 2020:
• The State's zero-emission vehicle infrastructure will be able to support up to one million vehicles; and
• The costs of zero-emission vehicles will be competitive with conventional combustion vehicles; and
• Zero-emission vehicles will be accessible to mainstream consumers; and
• There will be widespread use of zero-emission vehicles for public transportation and freight transport; and
• Transportation sector greenhouse gas emissions will be falling as a result of the switch to zero-emission vehicles; and
• Electric vehicle charging will be integrated into the electricity grid; and
• The private sector's role in the supply chain for zero-emission vehicle component development and manufacturing State will be expanding.

IT IS FURTHER ORDERED that these entities establish benchmarks to help achieve by 2025:
• Over 1.5 million zero-emission vehicles will be on California roads and their market share will be expanding; and
• Californians will have easy access to zero-emission vehicle infrastructure; and
• The zero-emission vehicle industry will be a strong and sustainable part of California's economy; and
• California's clean, efficient vehicles will annually displace at least 1.5 billion gallons of petroleum fuels.

IT IS FURTHER ORDERED that California target for 2050 a reduction of greenhouse gas emissions from the transportation sector equaling 80 percent less than 1990 levels.

IT IS FURTHER ORDERED that California's state vehicle fleet increase the number of its zero-emission vehicles through the normal course of fleet replacement so that at least 10 percent of fleet purchases of light-duty vehicles be zero-emission by 2015 and at least 25 percent of fleet purchases of light-duty vehicles be zero-emission by 2020. This directive shall not apply to vehicles that have special performance requirements necessary for the protection of the public safety and welfare.

This Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Order.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 23rd day of March 2012.

_____

EDMUND G. BROWN JR.
Governor of California

ATTEST:

_____
DEBRA BOWEN
Secretary of State

###

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TRANSPORTATION SYSTEM

GOODS MOVEMENT

SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS

2016 2040 RTPSCS

APPENDIX

ADOPTED | APRIL 2016

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APPENDIX

TRANSPORTATION SYSTEM | GOODS MOVEMENT

ADOPTED | APRIL 2016

GOODS MOVEMENT

SYSTEM VISION

Our region's transportation network for moving goods, referred to as our "goods movement" system, relies on a complex infrastructure that supports multiple modes of transportation. This system includes deep-water marine ports, international border crossings, Class I rail lines, interstate highways, state routes and local connector roads, air cargo facilities, intermodal facilities and distribution and warehousing centers.

With rising consumer demand for multiple shopping options, faster order replenishment and inexpensive or free two-way shipping costs, holistic supply chain strategies supported by a reliable transportation network are critical. Supply chain strategies are becoming increasingly complex and imposing greater demands on our transportation system. Collaborative planning is critical in this emerging environment and to this end, the Southern California Association of Governments (SCAG) continues to support the vision for the region's goods movement system established in coordination with our public and private sector industry partners.

> SCAG supports a world-class, coordinated Southern California goods movement system that accommodates growth in the throughput of freight to the region and nation in ways that support the region's economic vitality, attainment of clean air standards and the quality of life for our communities.

This vision continues to promote the improvement of the goods movement system in order to:

- Maintain the long-term economic competitiveness of the region
- Promote local and regional job creation and retention
- Increase freight and passenger mobility
- Improve the safety of goods movement activities
- Mitigate environmental impacts of goods movement operations

In support of this vision, the 2016 RTP/SCS describes a goods movement system with regional initiatives and projects totaling about $71 billion through 2040. This Plan includes key initiatives identified in past RTPs, namely a comprehensive system of zero- and near zero-emission freight corridors, alleviation of major bottlenecks, a rail corridor improvement package and an environmental strategy to address emissions through both near-term initiatives and a long-term action plan for technology advancement.

This Goods Movement Appendix provides an overview of our regional goods movement system, describing key components and how they work together to support commerce and our economy. The following section describes critical markets served, and how these markets depend on our transportation infrastructure. The final section identifies regional strategies and initiatives, including an action plan to support the development and commercialization of technologies necessary for a zero and near-zero emissions goods movement system.

THE REGIONAL GOODS MOVEMENT SYSTEM

The goods movement system in the SCAG region is comprised interconnected infrastructure components designed to serve commercial activities spurred by regional, national and global demand. This goods movement system provides the backbone for the flow of goods between businesses and consumers. Numerous demand factors (e.g., types of products, destinations, urgency, costs, etc.) create unique markets that must be accommodated by varying types of goods movement activities. Markets in the SCAG region range from origins like local manufacturing companies and the San Pedro Bay Ports to business and customers across the U.S. These markets depend on an extensive regional transportation network that provides the mobility and speed necessary to support economic growth. These mobility needs, coupled with air quality, environmental and community challenges posed by regional goods movement activities, serve as the rationale for developing a comprehensive plan to enhance the regional freight system.

COMPONENTS OF THE REGIONAL GOODS MOVEMENT SYSTEM

EXHIBIT 1 depicts the region's multimodal goods movement system, which is comprised of the following major elements:

- **Seaports (Ports of Los Angeles, Long Beach and Hueneme):** Serving as the largest container port complex in the U.S., the Ports of Los Angeles and Long Beach (together called the San Pedro Bay Ports) handled about 117 million metric tons of imports and exports in 2014 – for a total value of goods at about $395.7 billion.[1] The Port of Hueneme, in Ventura County, specializes in the import and export of automobiles and produce, and serves as the primary support facility for the offshore oil industry. In 2014, two-way trade activities through the Port of Hueneme were valued at nearly $9.2 billion and generated $1.1 billion in economic activities in the immediate region.[2]

- **Land Ports:** The international border crossings in Imperial County are busy commercial land ports; they were responsible for more than $8 billion in imports and $6 billion in exports in 2014. This cross-border commerce was driven by the maquiladora trade, as well as the movement of agricultural products.
- **Air Cargo Facilities:** The region is home to numerous air cargo facilities, including Los Angeles International Airport (LAX) and Ontario International Airport (ONT). Together they handled more than 99 percent of the region's air cargo, valued at more than $96 billion[3], in 2014.
- **Class I Railroads:** Critical to the growth of the region's economy, the Burlington Northern Santa Fe Railway (BNSF) and Union Pacific (UP) carry international and domestic cargo to and from distant parts of the country. The BNSF mainline operates on the Transcontinental Line (Cajon and San Bernardino Subdivisions). The UP operates on the Coast Line, Saugus Line through Santa Clarita, Alhambra and LA Subdivisions, and Yuma Subdivision to El Paso. Both railroads operate on the Alameda Corridor that connects directly to the San Pedro Bay Ports. The San Pedro Bay Ports also provide several on-dock rail terminals along with the six major intermodal terminals operated by the BNSF and UP. The SCAG region also has Class III railroads (Pacific Harbor Line, Los Angeles Junction Railway and the Ventura County Railway) that provide short-haul services.
- **Warehouse and Distribution Centers:** In 2014, the region had close to 1.2 billion square feet of facility space for warehousing, distribution, cold storage and truck terminals.[4] Nearly 750 million square feet of this space, or 4,900 buildings, were facilities that are larger than 50,000 square feet. An estimated ten percent of the occupied warehouse space served port-related uses, while the remaining 90 percent supported domestic shippers.[5] Many of these warehouses are clustered along key goods movement corridors (**EXHIBIT 1**). Port-related warehousing is concentrated in the Gateway Cities subregion, while national and regional distribution facilities tend to be located in the Inland Empire.
- **Interstate, Highways and Local Roads:** Our region has about 70,000 lane miles of roadways.[6] Sections of I-710, I-605, SR-60 and SR-91, which carry the highest volumes of truck traffic in the region, averaged more than 25,000 trucks per day in 2013. Other major components of the regional highway network also serve significant numbers of trucks. These include I-5, I-10, I-15 and I-210. More than 20,000 trucks per day travel on some sections. These roads carry a mix of cargo loads, including local, domestic and international. The arterial roadway system also plays a critical role in goods movement, providing first and last-mile connections to regional ports, manufacturing facilities, intermodal terminals, warehousing and distribution centers and retail outlets.
- **Primary Highway Freight System:** With the recent passage of the Fixing America's Surface Transportation (FAST) Act, the Primary Highway Freight System (PHFS) is designated, using a 41,000 mile highway network. Within the SCAG region, about 1,477.33 miles of highways are designated as a part of the PHFS, with Los Angeles and San Bernardino Counties accounting for about 60 percent of the total coverage. **TABLE 1** shows the breakdown of the miles by county within the SCAG region.

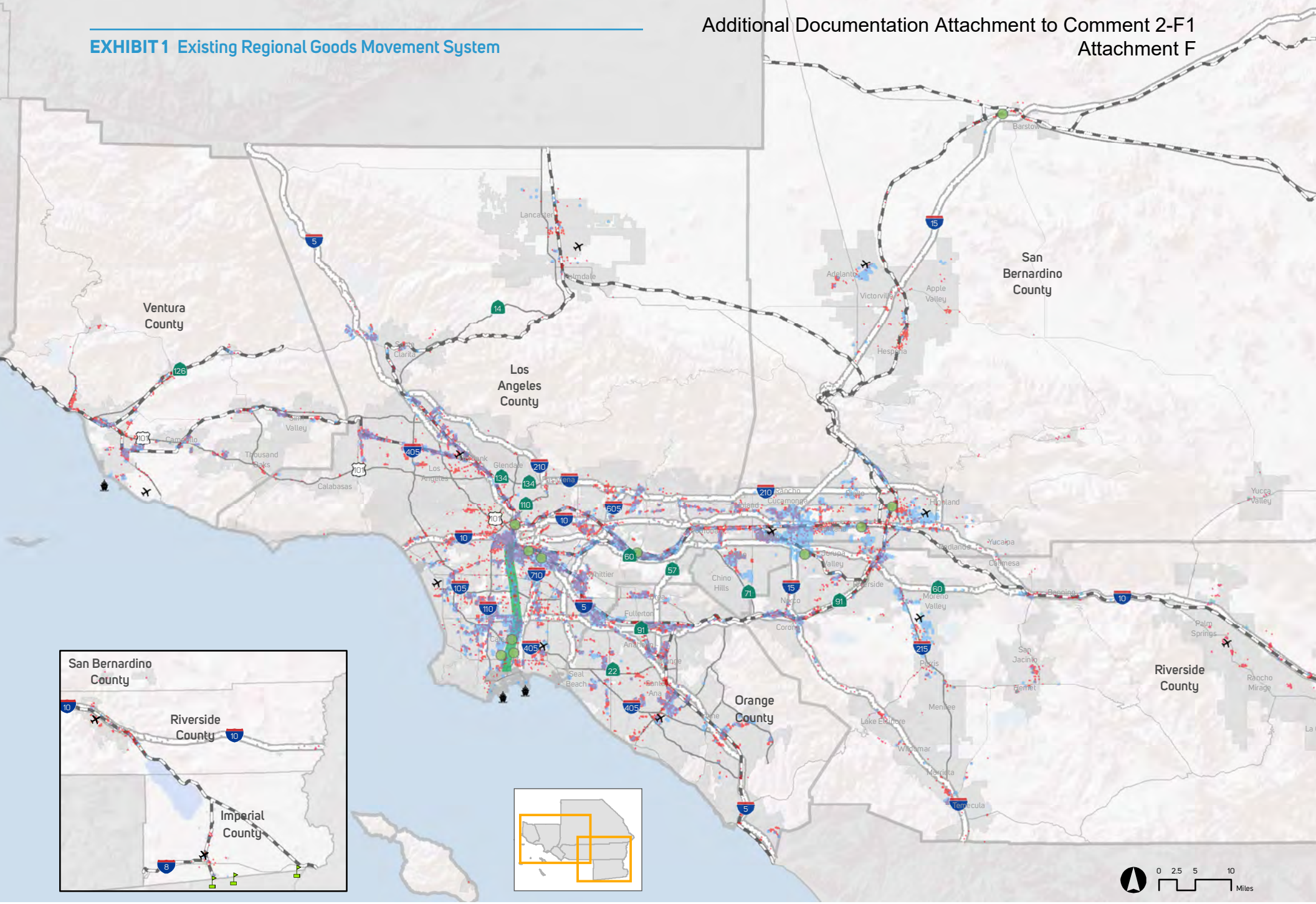
EXHIBIT 2 shows the location of both the PHFS coverage within the SCAG region.

TABLE 1 Primary Highway Freight System-Southern California Summary

County	Total Miles of Primary Freight Network	% Share
Imperial	77.74	5.3%
Los Angeles	460.81	31.2%
Orange	126.21	8.5%
Riverside	312.72	21.2%
San Bernardino	446.88	30.2%
Ventura	52.97	3.6%
Total	1,477.33	100.0%

Source: U.S. Department of Transportation
Note: Does not include "Other Interstate" portions not on the PHFS, Critical Rural Freight Corridors (CRFCs), nor Critical Urban Freight Corridors (CUFCs).

EXHIBIT 1 Existing Regional Goods Movement System



Ports
Ports of Entry
Major Airports
Intermodal Facilities

Routes
Major Freight Highway Corridors
Main Line Rail Network
Alameda Corridor

Warehouses
>= 50,000 sq ft
< 50,000 sq ft

(Source: SCAG, CoStar Realty Information Inc.)

EXHIBIT 2 Primary Highway Freight System



Primary Highway Freight System

Source: U.S. Department of Transportation *Note: Does not include "Other Interstate" portions not on the PHFS, Critical Rural Freight Corridors (CRFCs), nor Critical Urban Freight Corridors (CUFCs).*

THE SUPPLY CHAIN SYSTEM AND SOUTHERN CALIFORNIA

Supply chains generally refer to end-to-end processes, starting from product demand forecasting and production planning, material sourcing, manufacturing and product delivery to intermediate nodes such as distribution centers and warehouses to consumption nodes such as stores. While supply chains encompass end-to-end processes, logistics involves the management of inventory, whether goods are in transit or stored in warehouses. The simplest definition of logistics is the flow of funds, goods and information between source and consumer. If logistics doesn't flow, then the supply chain does not function.[7]

Businesses are continuously evaluating their supply chain strategies. Generally, functional products with steady demand, long product life and low profit margins (e.g., daily items such as toilet paper, canned foods, general purpose nails and screws) require efficient supply chains to minimize inventory and transportation cost. Innovative products with high demand uncertainties, high inventory cost, high seasonality and high profit margins (e.g., latest model of digital printers, high fashion items, seasonal furniture) require responsive supply chains to ensure that the products are available at the right time and in the right quantities. Further, businesses factor in supply chain trade-offs (i.e., making choices to accept less of one thing in order to receive more of something else).

There are several prominent forces that have facilitated the rapid globalization of supply chains in the last couple of decades. These include national GDP growth rates of foreign countries, the availability of skilled labor in different parts of the world, advanced technology, trade policies, and political and economic factors. The force of rapid globalization and information technology have raised the importance of international gateways as consumers demand faster order fulfillment and companies promise to deliver through their sophisticated global supply chains. Southern California is a key global trade gateway as many trade routes are connected through SCAG's regional transportation system to the rest of the nation and the world.

GOODS MOVEMENT-DEPENDENT INDUSTRIES

All industries depend on reliable and efficient transportation services to meet their business objectives. Understanding the impacts and linkages between improvements in the transportation system and supply chains for key goods movement-dependent businesses is critical for making decisions to support the regional economy. Goods movement-dependent industries are defined as industries that operate frequent inbound and outbound freight vehicle trips and costs associated with goods movement have sizable impact on their business expenses. Key industries include construction, manufacturing, wholesale trade, retail trade, and transportation and warehousing.

As a premier global trade gateway to the U.S., Southern California boasts high concentrations of goods movement-dependent industries, with each industry contributing considerably to the overall regional GDP and employment (TABLE 2). In 2014, the SCAG region's goods movement-dependent industries collectively generated close to three million jobs, which is 33 percent of the region's total number of jobs. These industries also contributed $291 billion, or 35 percent of the regional GDP in the same year. Among all goods movement-dependent industries, retail trade generated the highest number of jobs at 985,000, or 11 percent of the regional total, followed by manufacturing at 702,000 jobs or eight percent of the regional total. In terms of GDP, manufacturing contributed the most at $107 billion, or 13 percent, of the regional total, followed by the wholesale trade at $58 billion, or seven percent of the regional total.

TABLE 2 Regional Employment and GDP Contribution of Key Goods Movement-Dependent Industries (2014)

Key Industries	Jobs (in Thousands)	% Share of Total	GDP (in Billions)	% Share of Total
Construction	437	5%	$29	3%
Manufacturing	702	8%	$107	13%
Wholesale Trade	461	5%	$58	7%
Retail Trade	985	11%	$54	7%
Transportation and Warehousing	332	4%	$23	3%
Other Goods Producing	82	1%	$21	3%
All Goods Movement Dependent Industries	2,999	33%	$291	35%
All Sectors	9,069		$820	

Source: Regional Economic Models, Inc. TranSight SCAG, CA, US v3.6.5
Note: Numbers may not sum to total due to rounding.

MANUFACTURING SECTOR IN THE SCAG REGION

While the overall national trend in the number of manufacturing establishments has been declining, the SCAG region remains the second largest manufacturing center in the nation, after the state of California (**FIGURE 1**).[8]

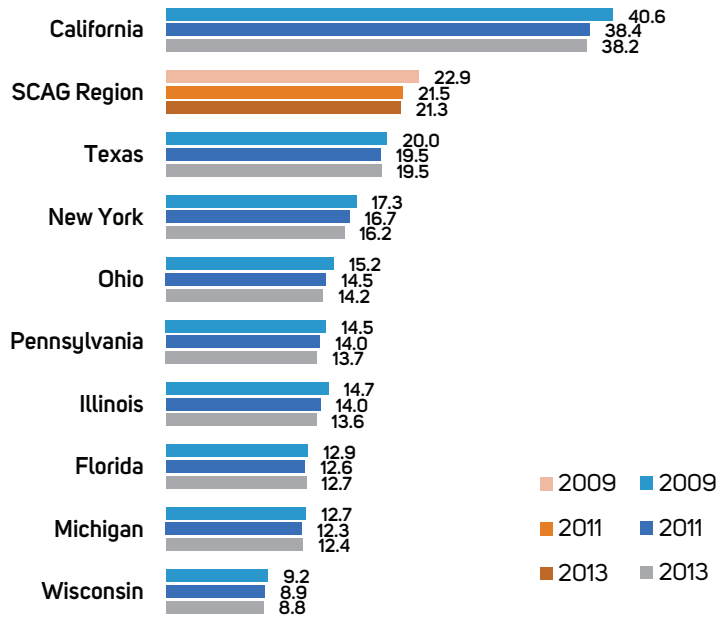
The top five manufacturing sectors in the SCAG region in terms of the number of establishments include fabricated metal product manufacturing, apparel manufacturing, food manufacturing[9] and printing and related support activities.[10] In 2013, the manufacturing sector generated over $34 billion in payroll. Contributing 13 percent to the regional GDP and generating eight percent of the region's employment, manufacturing still plays an important role in the SCAG region's economy.

The regional manufacturing sector relies heavily on truck transportation, followed by rail transportation. In 2014, the manufacturing sector spent over $2.25 billion on truck transportation, a 68 percent share of total direct transportation expenditures (**TABLE 3**). This is evident as many of the manufacturing facilities in the SCAG region are strategically located near major transportation corridors (**EXHIBIT 3**). This is a highly specialized and segmented industry, where a number of manufacturers individually handle various stages of production before products become finished goods. As a result, semi-finished goods are moved between plants via trucks, especially if the plants are located within or near the SCAG region. As discussed in the next section, the SCAG region's manufacturing industries have complementary relationships with a number of manufacturers in Mexico, including maquiladoras along the Baja California border. The distance between the SCAG region and Mexico makes truck transportation the most desirable mode of transportation.

MANUFACTURING, NEAR-SHORING AND RE-SHORING

Manufacturing is expected to remain critical to the regional economy for the foreseeable future. This is largely due to the synergy created by increasing manufacturing activities in Mexico, especially in Baja California. Since 2007, Mexico has invested nearly $40 billion on transportation infrastructure to significantly improve the quality and increase the capacity of its multi-modal transportation system. The country generates approximately three times more engineering graduates each year as compared to the U.S. Mexico's strategic decision to shift its manufacturing sector make-up two decades ago has resulted in a major shift from commodity manufacturing to high-tech manufacturing. As a result, Mexico's industry cluster today includes manufacturing of vehicles, automotive parts, aerospace components, white goods (washers, dryers, refrigerators, etc.), electronics (cell phones and other small electronic devices), medical devices and pharmaceuticals.[11]

FIGURE 1 Total Number of Manufacturing Establishments (in Thousands)



Source: U.S. Census County Business Patterns

TABLE 3 Expenditures on Transportation by Manufacturing Industries (2014) (Direct inputs)

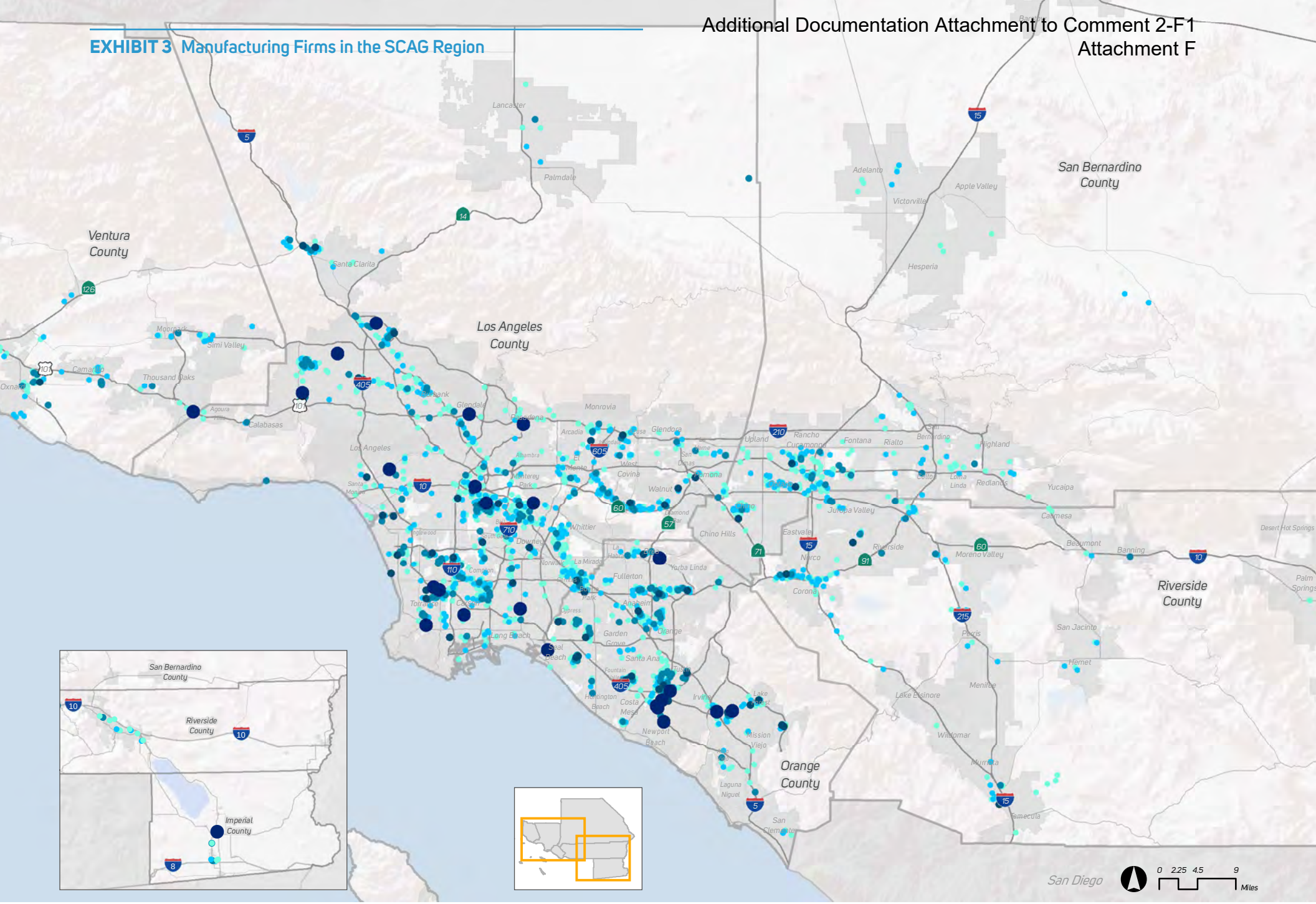
Transportation Mode	Spending on Different Transportation Modes	
	Millions of Dollars	Percent of Total
Air transportation	$211	6%
Rail transportation	$424	13%
Water transportation	$125	4%
Truck transportation	$2,252	68%
Warehousing and storage	$166	5%
Other*	$113	3%
Total	$3,291	100%

** Other includes "Transit and ground passenger transportation", "Pipeline Transportation", "Other transportation and support activities" and "Household production of transportation services"*

Source: REMI TranSight for SCAG v3.7.6 and the Transportation Satellite Accounts Commodity-by-Industry Direct Requirements (2012)

Note: Numbers may not sum to total due to rounding.

EXHIBIT 3 Manufacturing Firms in the SCAG Region



Manufacturing Firms by Total Employment

- *<=50*
- *51 - 100*
- *101 - 250*
- *251 - 500*
- *501 - 1,000*
- *1,001 - 3,000*

Source: InfoGroup 2011

Many of the goods manufactured at plants in the SCAG region and Mexico are semi-finished goods that receive further modifications and refinements before being transported to warehouses and distribution centers. Similarities in manufacturing commodities are observed in the types of manufacturing establishments that exist in the SCAG region and Mexico. These include transportation equipment, computer and electronic products, electrical equipment, appliances, and components and machinery.[12] The similarities in commodities indicate that complementary manufacturing processes take place with Mexico. Often, semi-finished products are moved across the border several times, each time getting closer to finished products, before being shipped to final destinations in the U.S. for consumption. This synthesized manufacturing system is expected to continue as more businesses observe the benefits of near-shoring.

While outsourcing and off-shoring of manufacturing still dominate the current industry practice, some multi-national corporations such as General Electric and Caterpillar are re-shoring jobs to the U.S. The types of products that lend themselves to re-shoring, however, are relatively limited. These include electrical equipment, appliances, transportation equipment, computers and electronics, plastics and rubber products, fabricated metal products and machinery. Top decision drivers for companies to re-shore include [13]:

- Reduce time-to-market (73.7 percent);
- Reduce cost (63.9 percent);
- Improve product quality (62.2 percent);
- Gain more control (56.8 percent);
- Reduce hidden supply chain management costs (51.4 percent); and
- Protect intellectual property (48.5 percent).

RETAIL SUPPLY CHAINS

Retail trade includes a wide variety of subsectors including motor vehicles, furniture, electronics and appliances, building materials, health and personal care products, clothing, sporting goods and books. The retail industry supported nearly $30 billion in wages and salaries in 2014.[14] In general, retail industries are heavily dependent on international trade to receive materials and products, usually through containerized cargo imported through the San Pedro Bay Ports. This industry is also heavily reliant on Southern California's freight transportation systems to ensure products are available at stores as well as for the delivery of goods via online shopping.

Similar to the manufacturing sector, the direct transportation expenditures by the SCAG region's retail industry exhibit the industry's heavy reliance on truck transportation. Compared to the manufacturing sector, however, the retail industry spends significantly more on transportation services. In 2014, the regional GDP was almost $107 billion for manufacturing and $54 billion for retail (**TABLE 2**). While total direct transportation expenditure for manufacturing sector was $3.3 billion (three percent of the SCAG region manufacturing GDP), the retail sector's direct expenditure was $5.6 billion (ten percent of the SCAG region retail GDP) (**TABLE 3 & 4**). This indicates that a reliable transportation system is critical to the SCAG region's retail industry.

KEY FUNCTIONS AND MARKETS

The freight transportation system in the SCAG region serves a wide range of user markets with unique performance needs that dictate the components of the system that they will use. The following provides a summary of international, domestic and local trade markets and associated transportation system needs.

INTERNATIONAL TRADE

The SCAG region is the largest international trade gateway in the U.S. with trade moving through the San Pedro Bay Ports, international land border crossings with Mexico and regional airports. This international trade is supported by an extensive transportation system that includes a highly developed network of roadways and railways, air cargo facilities, intermodal facilities and an abundance of regional distribution and warehousing clusters. While the SCAG region has made great strides in building infrastructure and planning for the future, continued investment is needed to support commerce and economic growth.

TABLE 4 Transportation Expenditures by Retail Industry (2014) (Direct inputs)

Transportation Mode	Transportation Spending	
	In Millions	Percent of Total
Air transportation	$65.1	1%
Rail transportation	$7.8	0%
Water transportation	$2.8	0%
Truck transportation	$3,290.8	59%
Warehousing and storage	$1,524.0	27%
Other*	$709.2	13%
Total	$5,599.6	100%

** Other includes "Transit and ground passenger transportation", "Pipeline Transportation", "Other transportation and support activities" and "Household production of transportation services"*

Source: REMI TranSight for SCAG v3.7.6 and the Transportation Satellite Accounts Commodity-by-Industry Direct Requirements (2012)

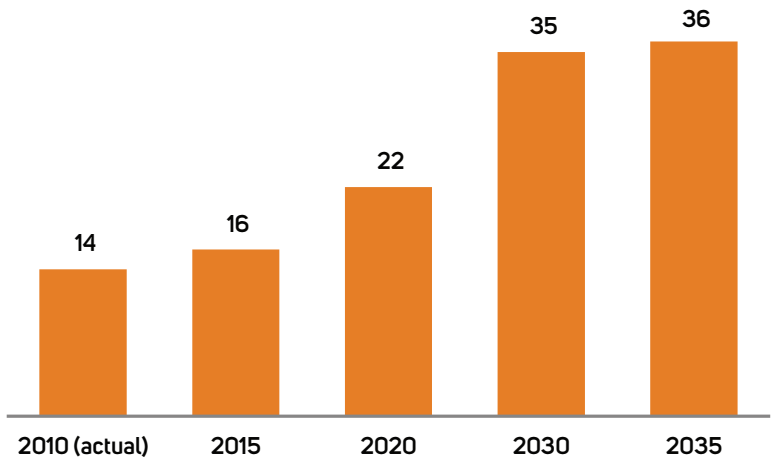
SAN PEDRO BAY PORTS

Containerized trade between the U.S. and Asia constitutes the majority of international cargo transiting the SCAG region, with over 32.5 percent of all containers in the U.S. moving through the San Pedro Bay Ports.[15] Despite some modest shifts recently in container volumes to other U.S., Canadian and Mexican ports, total container volume for the San Pedro Bay Ports is still expected to grow to 36 million by 2035, a 225 percent increase over the next two decades (**FIGURE 2**).

Imports, which constitute most of the containers that move through the San Pedro Bay Ports, may be categorized as local or discretionary. Local containerized traffic is that which is ultimately consumed in a geographical area local to the San Pedro Bay Ports (Southern California, Southern Nevada, Arizona and New Mexico and southern portions of Utah and Colorado). Discretionary containerized traffic is that which terminates outside this region. Recent analysis indicates that local traffic carrying containerized imports accounts for approximately 22-29 percent of San Pedro Bay Ports' total import-related traffic. The other 71-78 percent is assumed to be discretionary traffic, routed through the San Pedro Bay Ports for economic reasons.[16]

Beyond local or discretionary (outside of the region), imports can be further categorized as Direct, Transloaded, or Rail. When containers arrive at the San Pedro Bay Ports, the way they move is largely determined by final consumption points, inventory needs and transportation costs (see **FIGURE 3**).

FIGURE 2 San Pedro Bay Ports Container Volume Trend and Projections (Millions of TEUs)



Source: Port of Long Beach and Port of Los Angeles, based on thier Feb. 2015 forecats:

Transloading is broadly defined as activities that involve the deconsolidation of the contents of marine containers, which are usually 40-foot equivalent units (FEUs) and reloading of their contents into 53-foot domestic trailers that can be transported by trucks. Transloading allows for the movement of increased amounts of goods while utilizing less equipment, resulting in significant cost savings through economies of scale and other transportation-related savings. Transloading sometimes provides value-added services as well. Existing infrastructure, equipment and trade flows in the SCAG region provide a substantial competitive advantage and serve as a major economic incentive for importers to move freight requiring transloading through Southern California.

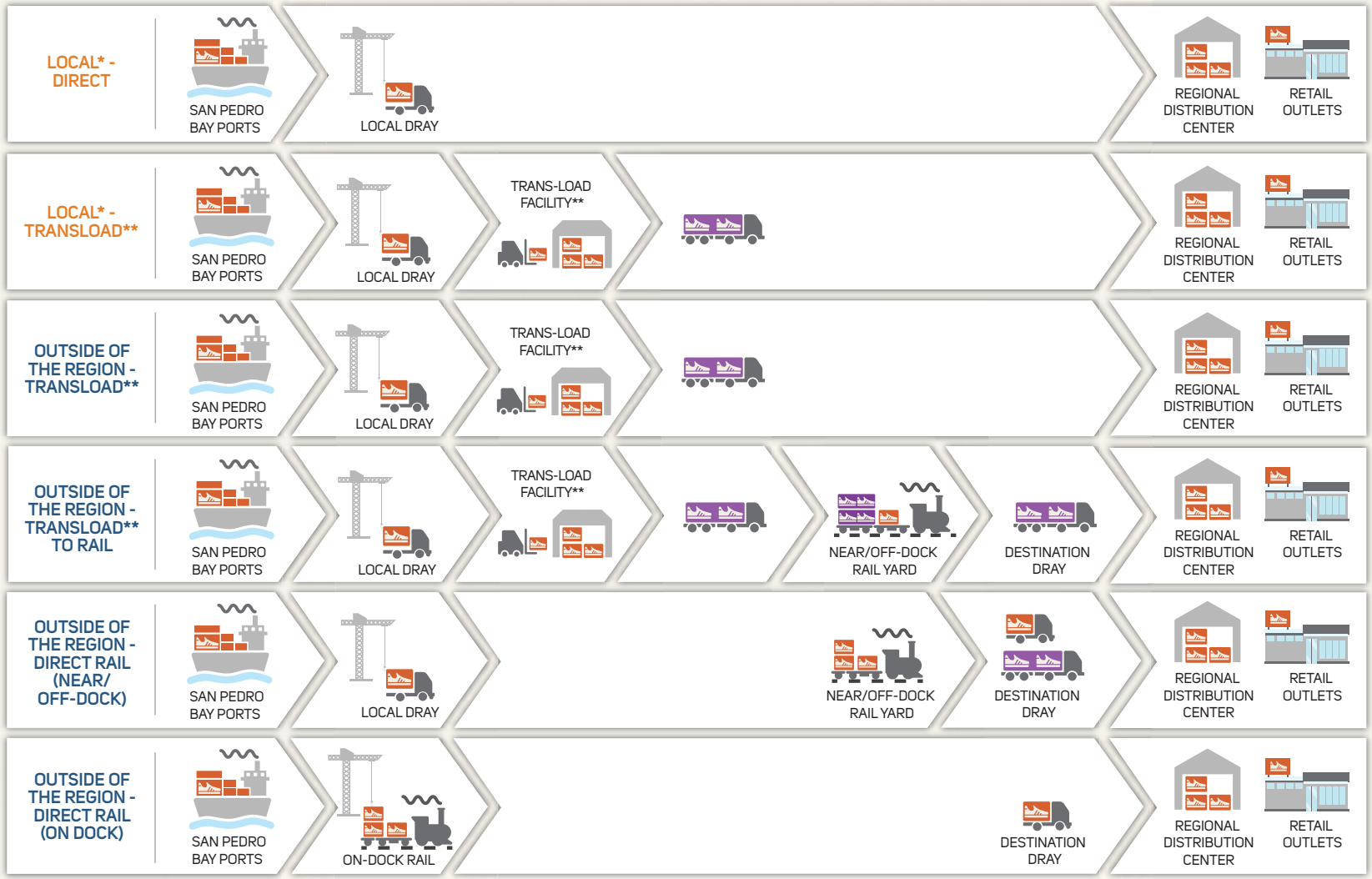
INTERNATIONAL BORDER CROSSINGS

International border crossings between the U.S. and Mexico are critical components of the freight transportation system in Southern California. Mexico remains the third-largest trading partner of the U.S. behind Canada and China, with a $534.5 billion trade volume in 2014, accounting for 13.5 percent of total U.S. foreign trade. It is also the largest market for exports of goods made in California, accounting for approximately $25.4 billion (or 12.4 percent) of California's overall exports in 2014. Most of the merchandise flows in the California-Baja California region are made by truck, supporting manufacturing and maquiladora industries that lie on the Mexican side of the international border.

Increased trade across the border has been bolstered by the existence of multiple free trade zones (FTZs). As a result of the associated tax savings and lower wages in Mexico, FTZs have been used by U.S. companies to export raw materials into Mexican manufacturing firms (maquiladoras), where goods are processed or assembled and then exported back in their finished state to the U.S.[17] The ability to transfer goods from one FTZ to another within Mexican territory without losing any of the fiscal incentives (tax savings) is slowly creating a logistics and manufacturing network of FTZs that is expected to boost Mexican foreign trade with the U.S.

As more businesses try to capitalize on the benefits of sourcing and manufacturing in Mexico, substantial impacts are expected on the transportation systems that service the border region and provide network connections to the trade nodes that have strong relationships with the border region i.e., the Inland Empire and the San Pedro Bay Ports. In order to assess the mobility of commerce at the Imperial County-Mexicali border and to develop freight planning strategies that address long term trade and transportation infrastructure needs in this border region, SCAG is analyzing the patterns and the efficiency of goods that move across the border. Although analysis is still underway, some key findings include the following: (i) projected cross-border goods movement volumes in future years suggest that roadway congestion levels will increase, partly due to cross-border activities; (ii) transportation infrastructure in the greater Los Angeles area (intermodal rail, ports, roadway

FIGURE 3 Import Container Flow by Mode, Handling Process, and Destination



* Geographical areas included in Local Market are Southern California, Southern Nevada, Arizona, New Mexico, and southern portions of Utah and Colorado for which the San Pedro Bay Ports serve as the closest container ports with the lowest land-side transportation costs.
** Transloading is broadly defined as activities that involve the deconsolidation of the contents of marine containers, which are usually forty-foot equivalent units (FEUs), and reloading of their contents into 53-foot domestic trailers. Transloading allows for the movement of increased amounts of goods while utilizing less equipment, resulting in transportation cost savings through economies of scale. Transloading sometimes provides value-added services as well.

LEGEND
MARINE (40 Feet in Length)
DOMESTIC (53 Feet in Length)

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network, air cargo facilities) and distribution facilities in the Inland Empire will continue to be critical in supporting the growth of manufacturing activities in Tijuana; (iii) the magnitude of the near-shoring trend and associated impacts on overall cross-border activities is yet to be determined; (iv) delays associated with land port of entry, especially for northbound finished goods, continue to be major concerns for companies on both sides of the border; and, (v) research & development, value engineering in certain manufacturing sectors like medical devices and components is providing additional opportunities for growth.

INTERNATIONAL AIR CARGO

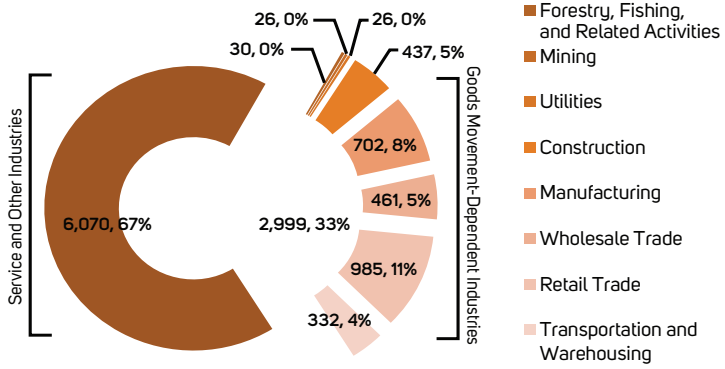
Los Angeles International Airport (LAX) handled over 897,000 metric tons of cargo in 2014, making it the seventh-busiest cargo airport in the United States and the 14th busiest in the world. Most often used for time-sensitive and higher-value goods, international air cargo plays a significant role in the regional economy, representing $96 billion in trade. Over 82 percent of the international air cargo at LAX is handled by scheduled passenger airlines or their cargo divisions that operate freighter aircraft. According to SCAG's recent air cargo forecast, air cargo activity has been declining over the past decade, with most of this decline confined to domestic air cargo. International air cargo, representing nearly 60 percent of tonnage handled, peaked in 2007, declined during the recession between 2007 through 2009 and is slowly recovering to pre-recession levels. As the regional economy continues its recovery from the recession, international air cargo at LAX is expected to grow by 1.9 percent annually within the next twenty years, totaling 3.0 million metric tons by 2040. Preparing for this growth will be a major challenge for LAX over the coming decades as the existing urban footprint may limit the ability to address warehousing and office requirements, aeronautical infrastructure needs, auto parking demands and other landside operational issues.

DOMESTIC AND LOCAL GOODS MOVEMENT

While the region is a major gateway for international containers, local and domestic freight is dominant. An overwhelming majority of goods movement activity in the SCAG region is generated by local businesses moving goods to local customers and serving national domestic trade systems. These local goods movement-dependent industries rely on transportation as a key part of their business model and generally utilize a more geographically dispersed transportation network than the international container market. About 85 percent of truck trips are associated with intra-regional goods movement. Domestic manufacturers, wholesalers and retailers also use the rail system and the air cargo system, though to a much more limited extent than international shippers.

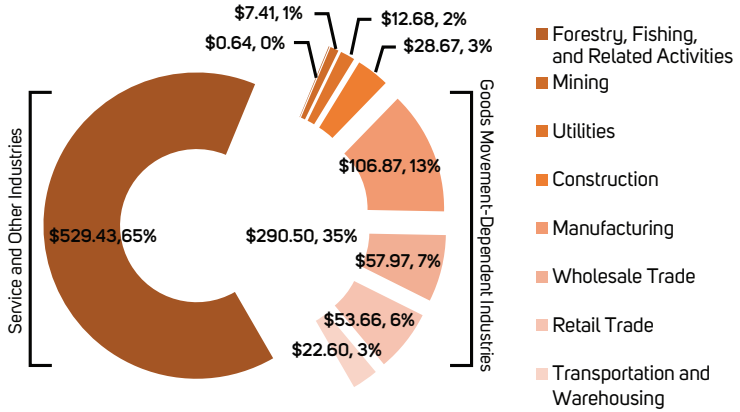
The regional transportation system provides the infrastructure to allow these businesses to ship and receive the materials necessary to perform daily operations. Examples include shipments of raw material to support manufacturing processes and the delivery of refined or finished products to market. Major goods movement-dependent industries include those related to the manufacturing, wholesale trade, construction, transportation and warehousing, and mining sectors.

FIGURE 4 2014 Employment Contribution of Goods Movement-Dependent Industries (in Thousands)



Source: REMI TranSight SCAG, CA, USv3.6.5.

FIGURE 5 2014 Economic Contribution of Goods Movement-Dependent Industries (in Billions)



Source: REMI TranSight SCAG, CA, USv3.6.5.

In 2014, local goods movement-dependent industries employed over 2.9 million people throughout the region (**FIGURE 4**) and contributed $291 billion to the regional GDP. (**FIGURE 5**). As shown in **FIGURE 6** these industries are projected to grow steadily through 2040.

Regional GDP is a broad indicator of the level and strength of economic activity in a region. In the long term, the region's GDP is projected to grow steadily through 2040 at a rate slightly faster than the U.S. economy as a whole. The region's total GDP was $820 billion in 2014 and is projected to top $1.45 trillion in 2040, growing at an average rate of 2.3 percent between these years. In comparison, the U.S. economy (U.S. GDP) is expected to grow at 2.4 percent annually during the same period.[18]

Mirroring national trends, this GDP growth is anticipated to be accompanied by an increasing transition toward a higher value-added manufacturing and service economy. The predicted highest-growth industry sectors from 2014 to 2040 include the manufacturing, wholesale trade and construction sectors—all of which are highly dependent on the regional freight transportation system. All three of these sectors will more than double in size over the next two decades and will contribute a combined $545 billion to regional GDP by 2040.

FIGURE 6 2014-2040 Average Real Annual Growth Rates by Major Goods Movement-Dependent Sectors



Source: REMI TranSight SCAG, CA, USv3.6.5.

TECHNOLOGY AND CONSUMER BEHAVIOR IMPACTING GOODS MOVEMENT

In 2014, the retail industry provided nearly $30 billion in wages and salaries for the region.[19] This industry includes a wide variety of subsectors including motor vehicles, furniture, electronics and appliances, building materials, health and personal care products, clothing, sporting goods, and books. In general, retail industries are heavily dependent on international trade to receive materials and products, usually through containerized cargo imported through the San Pedro Bay Ports.

One of the most notable changes in the retail industry is the strong growth in e-commerce. E-commerce sales for U.S. retailers were $261 billion in 2013, an increase of 13.6 percent from 2012, while total sales increased by 3.8 percent at $4.5 trillion in 2013. Within the e-commerce sales merchandise category, clothing and clothing accessories had the largest sales at $40 billion, followed by electronics and appliances at nearly $23 billion. E-commerce provides consumers with a broad range of shopping options as they compare product prices instantaneously from their mobile devices and decide how the purchased products will be acquired (e.g., home delivery or store pick-up), known as omni-channel retailing (**TABLE 5**). Omni-channel retailing offers shoppers multiple purchasing and receiving options. Simultaneously, e-commerce has generated a considerable force of change in terms of how traditional distribution centers and retail outlets are operating to meet customer demands.

Distribution centers in the past delivered bulk size goods to their customers or single vendors. Because e-commerce orders tend to be smaller in size than the traditional distribution center orders (i.e., a single item order as compared to a bulk-case order), many retailers and distribution center/warehouse operators are upgrading their facilities, or developing new facilities to meet surging e-commerce orders.

TABLE 5 Omni-Channel Retailing Options

Shopping Mode	Fulfillment Options	Return Options
• In store • Online or catalog • Via phone or other mobile device	• Pick up in store • Online or catalog • Ship from warehouse/distribution center • Direct shipping from manufacturer	• In store • Online • Via phone or other mobile device

Source: Industrial Warehousing in the SCAG Region Study, Task 3 Trend Report, SCAG, 2015

Further, consumers are increasingly demanding quicker fulfillment of their orders and same-day delivery options. To meet the same-day delivery promise, distribution or fulfillment center proximity to population centers becomes critical. This is exemplified by large-scale e-commerce fulfillment center developments in the periphery of urban population centers. At the same time, small to medium size buildings that are narrow, but with ample loading doors and docks in urban cores, have also been attractive as they provide even quicker access to dense population centers than those in the outskirts. Additionally, retailers are increasingly using products available at their stores to fulfill e-commerce orders. This has increased their reliance on parcel delivery services such as UPS, FedEx and the U.S. Postal Service, making parcel hubs, delivery centers, as well as local streets and highways in urban environments critical to e-commerce.[20,21,22]

GOODS MOVEMENT TRENDS AND DRIVERS

A number of key trends and drivers are expected to impact our region's goods movement system. Some of these are highlighted below:

- **Population and Employment Growth:** The regional population and rate of employment in our region are key indicators of economic health, and both are projected to grow rapidly over the next two decades. By 2040, the region's population is expected to grow by about 21 percent and employment is expected to grow by about 32 percent. This growth is expected to fuel consumer demand for products and in turn, the goods movement services that provide them. This increased demand will drive stronger growth in freight traffic on already constrained highways and rail lines.
- **Unemployment rates:** The rates have declined in more recent years for the region. The latest data reflects a 6.6 percent unemployment rate for the region—a decline from 7.5 percent a year ago.[23] The Inland Empire, in particular, is experiencing steady job growth with a 6.9 percent unemployment rate—2.1 percentage points lower than it was one year ago. Employment growth in the Inland Empire is being led by the Transportation, Warehousing and Utilities sectors.[24]
- **Continued Growth in International Trade:** The San Pedro Bay Ports anticipate cargo volumes to grow to 36 million containers by 2035[25]—despite increasing competition with other North American ports, the expansion of the Panama Canal and more recent delays at the port terminals due to labor contract negotiations. Port of Hueneme in Ventura County is also positioned to grow as a preferred port for specialized cargo such as automobiles, break bulk fruit and military cargo. This growth will place further demands on marine terminal facilities, highway connections, and rail intermodal terminals. If port-related rail traffic and commuter demands are to be met, main line rail capacity improvements also will be required. Meanwhile, mitigating the impacts of increased train traffic in communities will continue to be a challenge.
- **Logistics Epicenter:** Southern California continues to be the nation's epicenter for distribution and logistics activity despite challenges that were observed in recent years, including increasing land prices, labor cost and transportation cost for moving goods through Southern California. The geographical proximity to the nation's largest container ports and accessibility to the rest of the country via the region's extensive transportation network make Southern California an ideal location for many logistics activities. With continued growth in international trade and regional and national population, Southern California is poised to continue serving as a global trade node.
- **Air Quality Issues:** Much of our region does not meet federal air quality standards for ozone and fine particulate matter ($PM_{2.5}$). Ships, trucks, trains and other goods movement equipment are among the largest contributors to regional air pollution. Criteria pollutants such as NO_x and $PM_{2.5}$ can have significant public health impacts. Freight transportation is also a major producer of greenhouse gas emissions. Emissions generated by the movement of goods are being reduced through efforts such as the San Pedro Bay Ports Celan Air Action Plan, as well as regulations such as the statewide Heavy Duty Truck and Bus Rule. But these reductions are unlikely to be sufficient to meet regional air quality goals.
- Emissions generated by the movement of goods are being reduced through efforts such as the San Pedro Bay Ports Clean Air Action Plan, as well as regulations such as the statewide Heavy Duty Truck and Bus Rule. But these reductions are unlikely to be sufficient to meet regional air quality goals.

HIGHWAY STRATEGIES

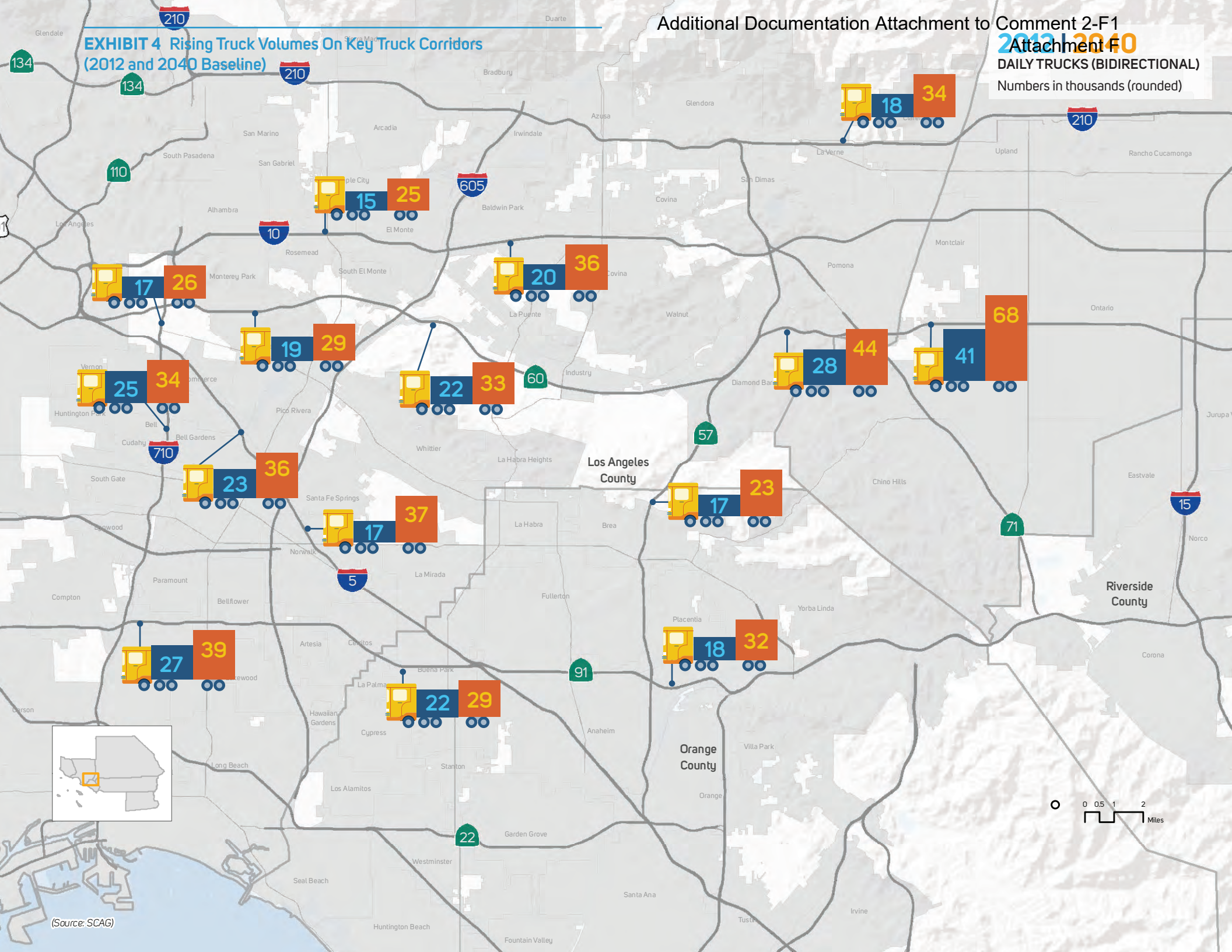
Our strategies will now be described, however, for information on individual regional goods movement projects, refer to Regional Goods Movement Project List (**TABLE 19**) at the end of this appendix.

EXISTING AND PROJECTED HIGHWAY CONDITIONS

With continued growth in freight demands, regional truck-related activities will increase over the 2016 RTP/SCS time horizon. SCAG's Heavy Duty Truck (HDT) model is the primary analysis tool to evaluate the impacts of truck traffic and highway goods movement strategies on the regional transportation network. Major sources of truck traffic are grouped into the following categories in SCAG's HDT model:

EXHIBIT 4 Rising Truck Volumes On Key Truck Corridors (2012 and 2040 Baseline)

2012 | 2040
DAILY TRUCKS (BIDIRECTIONAL)
Numbers in thousands (rounded)



(Source: SCAG)

- **Internal Truck Trips:** These are truck trips that have both an origin and a destination within the SCAG region and are generated by local industries, construction sites, domestic warehouses, truck terminals and residences.
- **External Truck Trips:** These are interregional truck trips that reflect trade between the SCAG region and the rest of the U.S.
- **Port Truck Trips:** These are truck trips with an origin or destination at the San Pedro Bay Ports.
- **Secondary Port Truck Trips:** These are truck trips with an initial origin or destination at the San Pedro Bay Ports that are moved a second time after the first trip to or from the San Pedro Bay Ports. Transloading trips are in this category.
- **Intermodal (IMX) Truck Trips:** These are domestic intermodal truck trips that have origins or destinations at regional intermodal rail terminals. These truck trips do not include those that have either an origin or destination at the San Pedro Bay Ports.

TABLE 6 shows the number of regional truck trips in 2012 by category and county.

In 2012, the San Pedro Bay Ports were responsible for approximately 55,000 direct daily regional truck trips. As shown in **TABLE 6**, this constitutes only five percent of regional truck trips. That number is expected to grow to approximately 87,000 daily regional truck trips, an increase of nearly 58 percent, by 2040.

All key regional highway corridors used to move goods are expected to see an increase in overall truck volumes by 2040 (**EXHIBIT 4** reflects 2040 baseline conditions). **EXHIBIT 5** and **EXHIBIT 6** illustrate existing truck speeds on the regional highway network during the AM and PM Peak periods, respectively. **EXHIBIT 7** illustrates the expected speeds on the regional highway network during the PM Peak period in 2040 if no action is taken.

HIGHWAY TRUCK COLLISIONS

Truck-involved collisions are of critical concern as the region's highways carry high volumes of trucks daily. Between 2010 and 2012, truck-involved collisions on the region's highway network totaled 5,013, predominately along heavily truck traveled corridors in Los Angeles County and the Inland Empire.

EXHIBIT 8 shows truck involved crashes on the major highways in the region on a per-mile basis. Some of the key locations with the highest truck involved crashes are located along the following highways within our region:

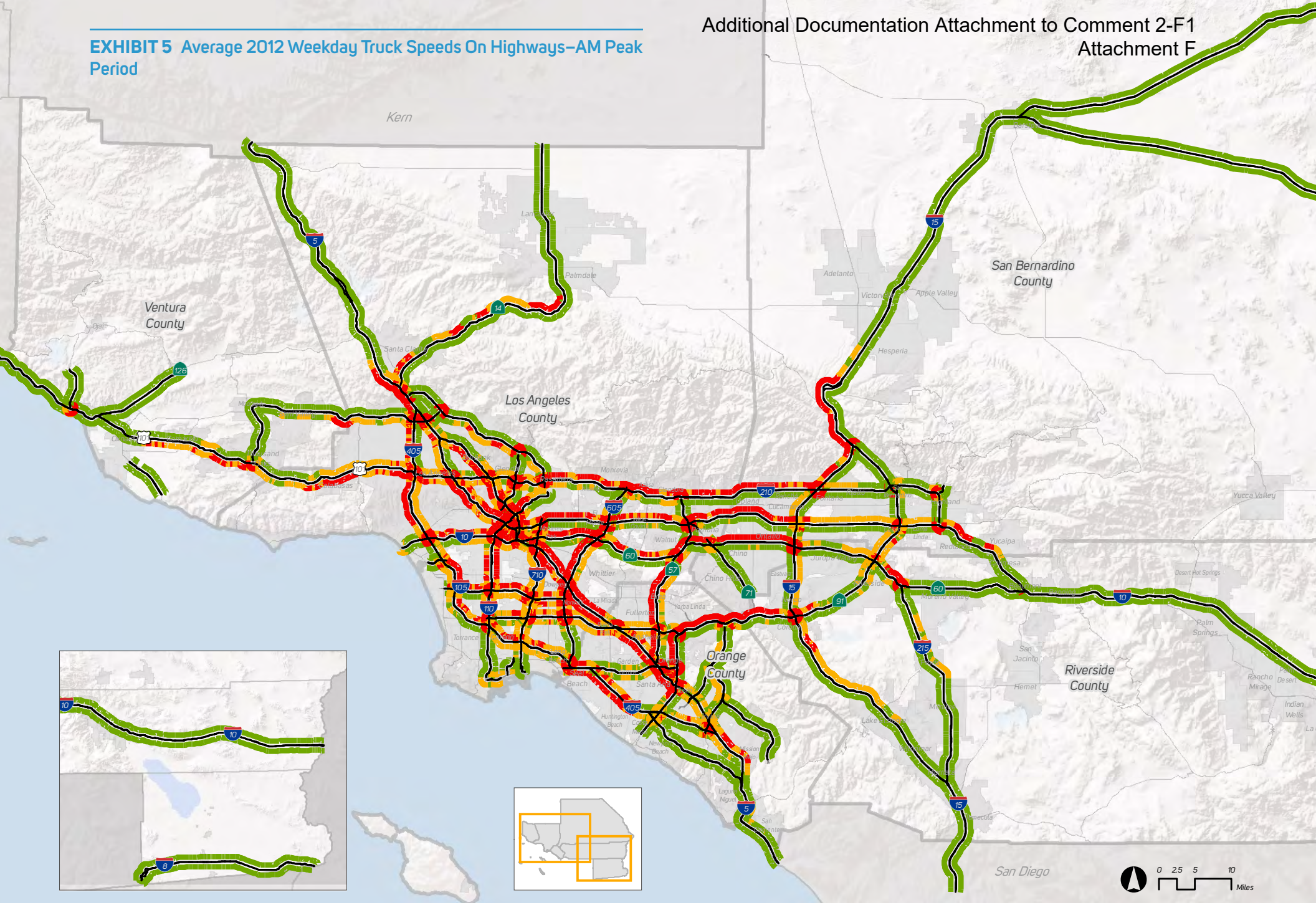
- I-5 between SR-60 and I-10
- SR-60 east of SR-57 to Euclid Ave
- I-710 North of I-5
- I-710 between I-105 and SR-91
- I-10 between SR-57 and I-215

TABLE 6 Daily Regional Truck Trips by Category by County

	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total	Percent
Internal	10,002	550,207	174,631	89,910	112,434	45,781	982,965	84.8%
External *	2,061	47,992	8,046	4,231	7,601	2,347	72,278	6.2%
Port	14	50,585	1,460	659	1,897	104	54,719	4.7%
Intermodal (IMX)	6	5,430	284	197	1,610	44	7,571	0.7%
Secondary	2	5,986	307	128	1,206	20	7,648	0.7%
Total	12,085	660,200	184,728	95,124	124,748	48,295	1,125,181	
Percent	1.0%	56.9%	15.9%	8.2%	10.8%	4.2%		

** Does not include the trips between external to external SCAG zones (about 10,000 trips)*
Source: SCAG

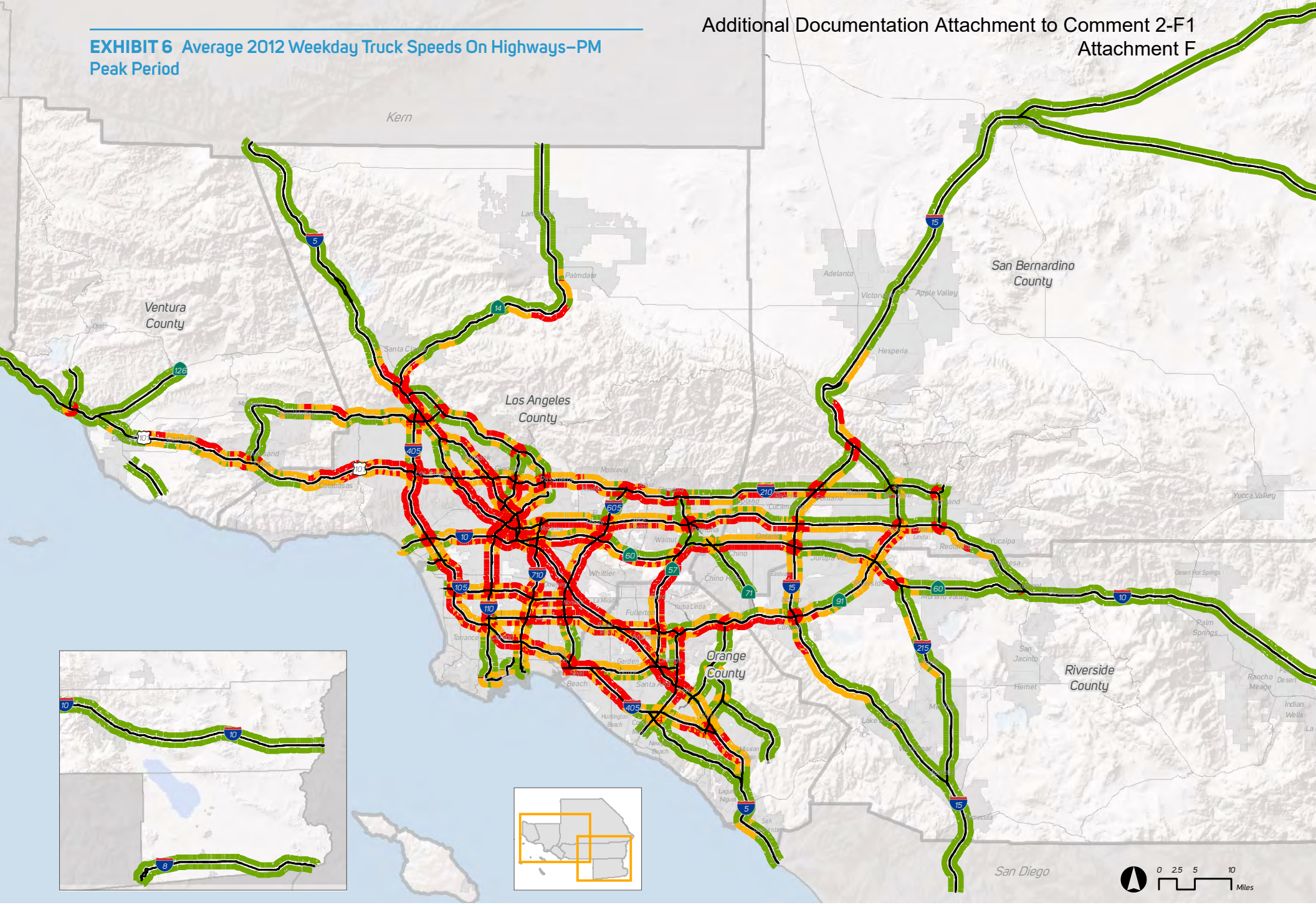
EXHIBIT 5 Average 2012 Weekday Truck Speeds On Highways–AM Peak Period



AM Peak Speed (mph) 2012 Less than 35 36 to 50 Greater than 50

Source: SCAG

EXHIBIT 6 Average 2012 Weekday Truck Speeds On Highways–PM Peak Period



PM Peak Speed (mph) 2012 — Less than 35 — 36 to 50 — Greater than 50

Source: SCAG

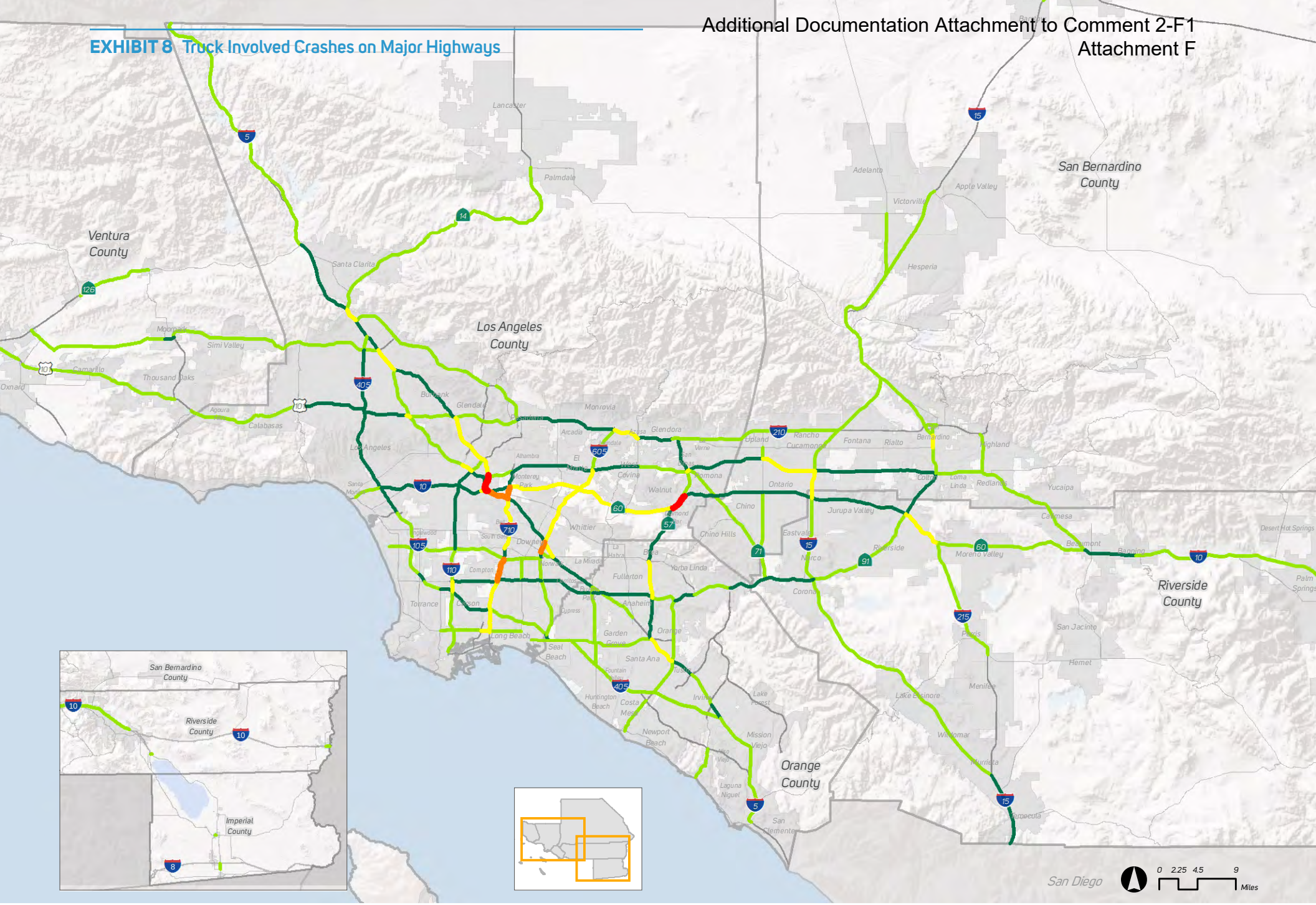
EXHIBIT 7 Baseline 2040 Weekday Truck Speeds on Highways–PM Peak Period



PM Peak Speed (mph) 2040 — Less than 35 — 36 to 50 — Greater than 50

Source: SCAG

EXHIBIT 8 Truck Involved Crashes on Major Highways



Avg Truck Involved Crashes per mile <= 3 | 4 to 7 | 8 to 12 | 13 to 15 | > 15

Source: Californa Statewide Integrated Traffic Records System (SWITRS), Safe Transportation Research & Education Center at University of California, Berkeley (2010, 2011, & 2012)

REGIONAL CLEAN FREIGHT CORRIDOR SYSTEM

The 2016 RTP/SCS continues to envision a system of truck-only lanes extending from the San Pedro Bay Ports to downtown Los Angeles along I-710, connecting to the SR-60 corridor and finally reaching I-15 in San Bernardino County. Such a system would address the growing truck traffic and safety issues on core highways through the region and serve key goods movement industries. Truck-only lanes add capacity in congested corridors, improve truck operations and safety by separating trucks and autos and provide a platform for the introduction and adoption of zero- and near zero-emission technologies. Ongoing evaluation of a regional freight corridor system is underway, including recent work on an environmental impact report (expected to be recirculated in Winter 2016) for the I-710 segment. Additionally, as a part of the 2016 RTP/SCS, SCAG continues to refine the east-west corridor component of the system along the SR-60 corridor. Current efforts have focused on working to identify an initial operating segment. Additional study is underway to evaluate the East-West Freight Corridor (EWFC) project concept.

EAST-WEST FREIGHT CORRIDOR

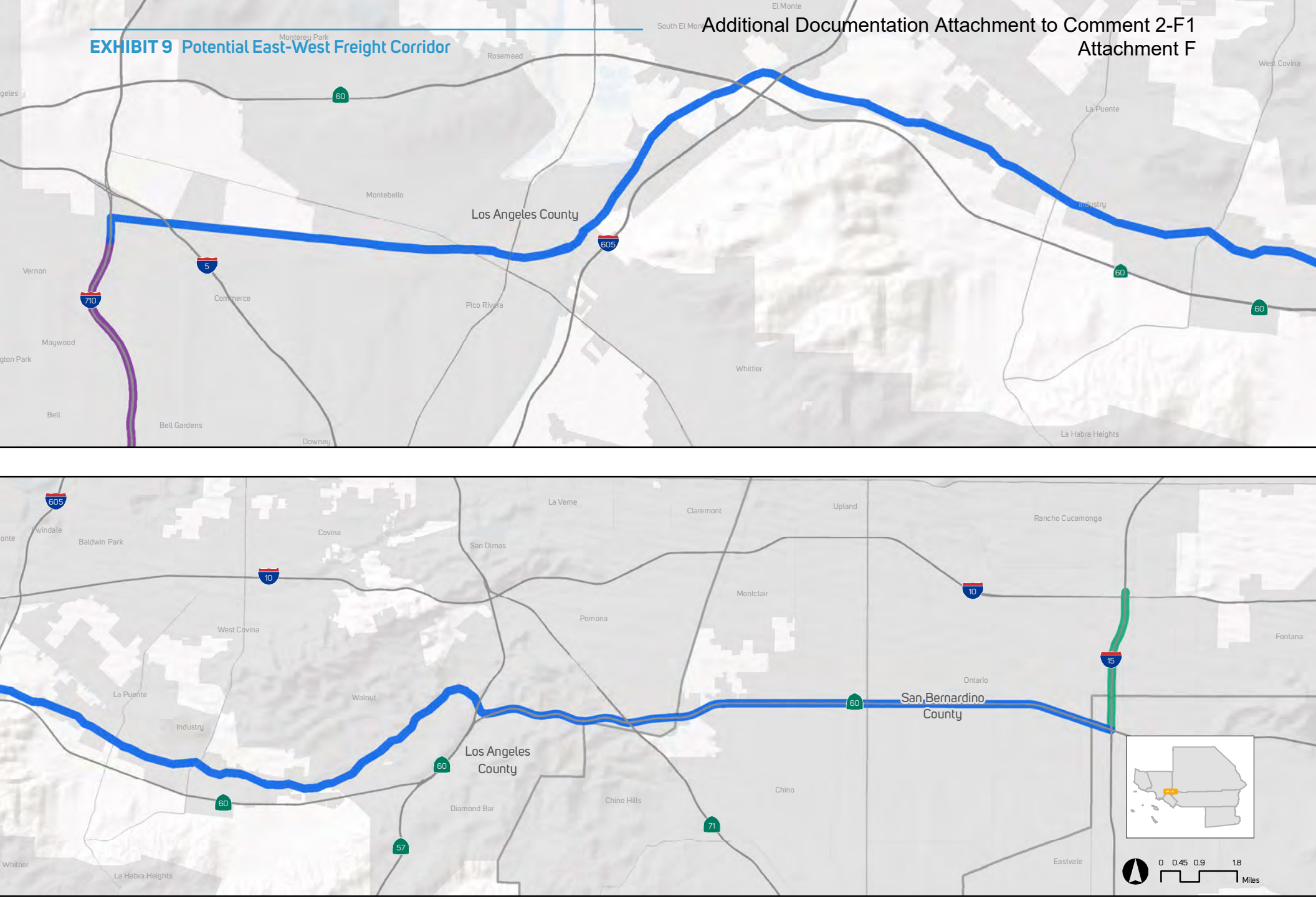
The 2016 RTP/SCS continues to identify a corridor concept along the SR-60 (**EXHIBIT 9**). While numerous EWFC options were examined, the Plan identifies a corridor concept to be explored further. Utilizing a right-of-way of approximately 100 feet, the bi-directional corridor would be restricted to truck traffic and have limited ingress/egress points. The EWFC would be a catalyst for the use of zero- and near zero-emission truck technologies, improving air quality for communities near the corridor and throughout the region.

BENEFITS OF THE EAST-WEST FREIGHT CORRIDOR

Continuing to move freight efficiently is critical to retain Southern California's trade competitiveness. The EWFC offers the opportunity to address many goods movement challenges, including congestion, air quality and safety concerns. The EWFC will support mobility for key industries, serve goods movement markets in an efficient manner, promote the region's environmental goals and contribute to alleviating the region's congestion. Analysis completed as part of the SCAG Comprehensive Regional Goods Movement Plan and Implementation Strategy indicates that major benefits of the potential East-West Freight Corridor include:

- **Mitigation of Future Truck Traffic:** Truck traffic is projected to grow significantly on all existing key east-west freeway segments. These dramatic increases in truck traffic on east-west corridors will cause increased congestion and longer delays to both trucks and general traffic on existing routes. The construction of the EWFC would increase capacity to accommodate the projected growth in truck activity. The corridor's traffic mitigation impacts would be significant, especially considering that some segments of the EWFC are forecast to carry between 58,000 and 78,000 trucks per day in 2040.
- **Reduction in Regional Delay:** The EWFC is projected to result in substantial delay reduction for both trucks and autos. Within the identified project influence area, all traffic is expected to experience a reduction of approximately 4.3 percent, with heavy-duty trucks seeing a nearly ten percent decrease. This reduced delay would provide demonstrable travel time savings as well as reduce emissions from idling vehicles on congested roadways.
- **Impact on Parallel Routes:** The EWFC is projected to draw significant volumes of truck traffic away from parallel routes, easing congestion and creating capacity for other vehicles on general purpose lanes. Estimates indicate that the EWFC could reduce daily traffic on portions of SR-60 (between 42-82 percent), I-10 (up to 33 percent), SR-91 (up to 19 percent), I-210 (up to 17 percent) and major regional arterials (up to 21 percent).
- **Mobility Benefits for Critical Markets:** The EWFC would offer considerable benefits to regional businesses and industries served by the numerous clusters of warehousing and manufacturing facilities near the route. Portions of the recommended potential route lie within a five-mile radius of 52 percent of the region's warehousing square footage and 27 percent of regional manufacturing employment.
- **Reduction of Truck-Involved Accidents:** The East-West Freight Corridor offers the potential to reduce truck-involved crashes as a result of the separation between trucks and other vehicles. Safety analysis revealed that several existing east-west corridors have high rates of truck-involved crashes, including segments of SR-60, SR-91 and I-10. The EWFC designed specifically for use by heavy duty trucks has the potential to improve safety and decrease the number of accidents for trucks and autos on parallel routes.
- **Preservation of Jobs and Income:** Increasing congestion is making Southern California a less attractive place to do business, threatening jobs and the positive economic impacts of the goods movement sector. An EWFC delivers a transportation system with greater capacity and less congestion in support of industries that depend on efficient freight movement throughout the SCAG region.
- **Reduction of Harmful Emissions:** The EWFC provides an opportunity to reduce harmful pollutants through the use of zero and near-zero emission technologies for freight transportation, although the technology to be used will be determined as the market evolves.

EXHIBIT 9 Potential East-West Freight Corridor



I-15 Freight Corridor Potential East West Freight Corridor Alignment I-710 Freight Corridor

(Note: Actual alignment is being evaluated)

Source: SCAG

Additional Documentation Attachment to Comment 2-F1
Attachment F

TRUCK BOTTLENECK RELIEF STRATEGY

As driver wages and fuel costs represent over 50 percent of total motor carrier costs, truck congestion has major impacts on the bottom line of the trucking industry. In a 2013 analysis conducted by the American Transportation Research Institute (ATRI), the Los Angeles metropolitan area was identified as leading the nation in costs to the trucking industry caused by traffic congestion, with nearly $1.1 billion in added operational costs to truckers.[26] Further, the SCAG region had five of the top 100 truck bottlenecks in the U.S. in 2014 and 2015 as identified by ATRI. The 2015 ranking for the SCAG region is as follows:

- #9 SR-60 at SR-57 in Los Angeles County
- #18 I-710 at I-105 in Los Angeles County
- #36 I-10 at I-15 in San Bernardino County
- #43 I-15 at SR-91 in Riverside County
- #61 I-110 at I-105 in Los Angeles County.[27]

In 2013, SCAG's Comprehensive Regional Goods Movement Plan identified the top-priority truck bottlenecks through a process that included both a quantitative analysis of congestion in the region along with stakeholder outreach and input from other sources such as Caltrans' Corridor System Management Plans (CSMPs). This analysis resulted in a list of the top 50 regional priority bottlenecks (**TABLE 7**). Top priority bottlenecks include those that had the highest truck-related annual delay according to the quantitative bottleneck assessment as well as others identified by key stakeholders and CSMPs.

For the 2016 RTP/SCS, these bottlenecks were updated using a two-step approach. The first step was to update the congestion levels for the previously identified bottlenecks to verify if any major changes had occurred between 2008 and the 2012 base year for the 2016 RTP/SCS. The second step used readily available data to identify potential emerging truck bottlenecks that may have developed since the last analysis. The existing bottleneck "refresh" was performed by estimating the percent change in truck delay on a corridor between 2009 and 2012. To facilitate this analysis using the Caltrans Performance Measurement System (PeMS), a corridor was defined as a directional freeway at the county level (e.g., I-5 northbound in Orange County). The percent change was calculated by taking PeMS corridor delays for 2008 and 2012, adjusting those total delays to represent truck congestion by using Caltrans estimated truck volumes and calculating the percent change in corridor delay for the two years.

Using this approach, all truck bottlenecks on a corridor will have the same percent change applied to them. Potential emerging bottlenecks were identified by utilizing the PeMS "Top Bottlenecks" feature to measure queue lengths, time periods and estimated delays for recurring regional bottlenecks. These delays were adjusted by using Caltrans truck volumes since PeMS estimates total delay, but not truck delay. This recent analysis also identifies potential new truck bottleneck locations as shown in **TABLE 7** and **EXHIBIT 10**.

These priority truck bottleneck locations, combined, contribute over 1 million hours of truck delay annually to SCAG regional roadways during congested time periods. Addressing these bottlenecks would contribute to reduction in delay as well as emissions "hot spots."

One of the most congested truck bottleneck locations in the SCAG region is at the intersection of the SR-57 and SR-60 freeways in Los Angeles County. In 2014, the City of Industry, along with the Los Angeles County Metropolitan Transportation Authority (LACMTA), was awarded a TIGER Grant to construct the 57/60 Confluence Freight Corridor Project. This $37.3 million project will improve both directions of travel to/from the Grand Avenue interchange by constructing an eastbound on- and off-ramp bypass, add an eastbound mainline lane, re-align all on- and off-ramps, replace the Grand Avenue Overcrossing and reconstruct the Grand Avenue & Golden Springs Drive intersection. The multi-phase effort is expected to reduce congestion, eliminate the hazards associated with a high accident rate at that location, and will facilitate more efficient freight movement.

There are a number of major highway projects that were recently completed or are currently under construction as shown in **TABLE 8**. These projects are expected to provide significant improvements at or near the identified truck bottleneck locations. SCAG is currently developing a supplemental truck bottleneck report, and with access to the latest real time data, bottleneck issues are anticipated to be monitored on a continuous basis.

Some of the truck bottleneck locations also have a higher number of truck related crashes in the region with a crash rate of more than eight on a per mile basis. These locations are listed below:

- **I-5:** At I-210, between SR-2 and I-710, South of I-605, between SR-22 and SR-55;
- **I-605:** Between I-105 and I-10;
- **I-15:** Between I-10 and SR-60;
- **I-210:** East of SR-134;
- **I-10:** East of I-605 and east of I-15;
- **SR-60:** Between I-10 and east of I-710, between I-605 and SR-57;
- **SR-91:** West of SR-57.

TABLE 7 Priority Truck Bottlenecks in the SCAG Region

Identification Methodology	Route	Direction	Absolute Postmile/Limits	County
SCAG Analysis*	605	SB	13.8	Los Angeles
	5	NB	117.8	Los Angeles
	405	NB	46.5	Los Angeles
	101	SB	4.1	Los Angeles
	5	NB	124.9	Los Angeles
	605	NB	17.5	Los Angeles
	60	EB	18.3	Los Angeles
	110	NB	16.1	Los Angeles
	10	EB	25.6	Los Angeles
	91	WB	3.9	Los Angeles
	60	EB	21.6	Los Angeles
	110	SB	17.8	Los Angeles
	60	EB	19.3	Los Angeles
	10	WB	32.0	Los Angeles
	405	NB	50.8	Los Angeles
	60	EB	5.1	Los Angeles
	60	EB	8.2	Los Angeles
	91	WB	42.7	Los Angeles
	101	NB	132.4	Los Angeles
	5	SB	128.5	Los Angeles
	5	NB	101.5	Orange
	605	NB	19.2	Los Angeles
	5	SB	132.3	Los Angeles
	210	WB	31.0	Los Angeles
	60	WB	13.0	Los Angeles

Note: Not listed in the order of priority.
*Sources:*Comprehensive Regional Goods Movement Plan and Implementation Strategy. ** 2016-2040 Regional Transportation Plan/ Sustainable Communities Strategy (RTP/SCS).*

TABLE 7 Priority Truck Bottlenecks in the SCAG Region Continued

Identification Methodology	Route	Direction	Absolute Postmile/Limits	County
SCAG Analysis*	91	WB	40.9	Riverside
	5	NB	160.8	Los Angeles
	10	WB	30.1	Los Angeles
	10	EB	6.6	Los Angeles
	105	WB	12.9	Los Angeles
	5	NB	119.2	Los Angeles
	60	WB	16.4	Los Angeles
	710	SB	17.5	Los Angeles
	91	WB	23.6	Orange
Corridor System Management Plan (CSMP)*	5	SB	144.3	Los Angeles
	10	EB	70.5	San Bernardino
	57	SB	12.3	Orange
	91	WB	46.9	Riverside
	210	WB	28.8	Los Angeles
Stakeholder Identified*	215	NB/SB	NA	San Bernardino
	10	EB	57.5	San Bernardino
	101	NB	53.2	Ventura
	101	NB	42.1	Ventura
	57	NB	24.4	Los Angeles
	710	NB	0.5	Los Angeles
	98	EB/WB	Dogwood Rd to SR111	Imperial
	Forrestor Rd	NB/SB	SR-78/86 to CA-98	Imperial
	8	EB/WB	Imperial Ave	Imperial
Potential New Bottlenecks Identified SCAG Analysis**	5	NB	137.7	Los Angeles
	57	NB	15.2	Los Angeles

Note: Not listed in the order of priority.
*Sources:*Comprehensive Regional Goods Movement Plan and Implementation Strategy. ** 2016-2040 Regional Transportation Plan/ Sustainable Communities Strategy (RTP/SCS).*

TABLE 7 Priority Truck Bottlenecks in the SCAG Region Continued

Identification Methodology	Route	Direction	Absolute Postmile/Limits	County
Potential New Bottlenecks Identified SCAG Analysis**	60	EB	23.5	Los Angeles
	105	EB	11.9	Los Angeles
	210	EB	33.4	Los Angeles
	605	NB	11.4	Los Angeles
	5	NB	104.6	Orange
	5	NB	108.7	Orange
	91	EB	42.9	Riverside
	91	EB	46.6	Riverside
	15	SB	107.7	San Bernardino
	101	SB	45.7	Ventura

Note: Not listed in the order of priority.
*Sources:*Comprehensive Regional Goods Movement Plan and Implementation Strategy. ** 2016-2040 Regional Transportation Plan/ Sustainable Communities Strategy (RTP/SCS).*

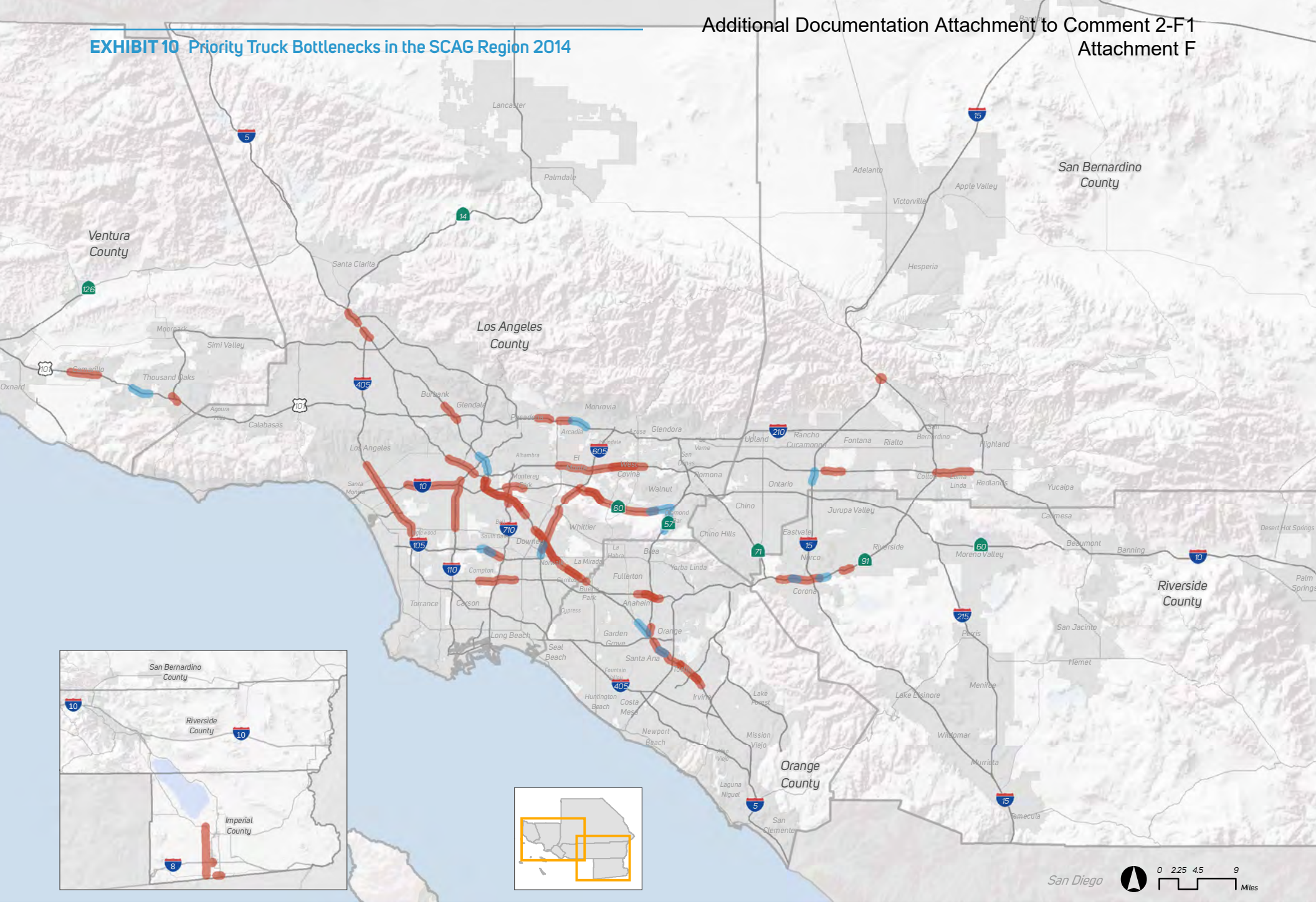
TABLE 8 Major Highway Projects within SCAG Region at Bottleneck Locations

Major Highway Projects	Status
I-5/SR-14 Direct HOV Connector	Completed
I-405 Sepulveda Pass Project	Completed
I-5 South Los Angeles County Projects	Under Construction
I-10/I-605 Interchange Improvements	Under Construction
I-15/I-215 Interchange Improvements at Devore	Under Construction
SR-91 Fast Forward Project (Riverside County)	Under Construction
SR-91 Westbound General Purpose (Between SR-57 and I-5)	Under Construction
US 101/SR-23 Interchange Improvements Projects	Under Construction
I-710/Firestone Blvd/Atlantic Interchange SR-2 Terminus Project (3 phases)	Under Construction

Source: SCAG

The 2016 RTP/SCS allocates an estimated $5 billion toward goods movement bottleneck relief strategies. Some bottleneck relief concepts have been identified through the CSMP process, and others are currently programmed for implementation. Major capital-intensive goods movement infrastructure investments must be supplemented with a comprehensive strategy to mitigate the most pressing bottlenecks in the region. Examples of bottleneck relief strategies include ramp metering, extension of merging lanes, ramp and interchange improvements, capacity improvements and auxiliary lane additions. Although some bottleneck relief projects, such as auxiliary lanes, can be capital-intensive. Others like ramp metering are less complex and would therefore be relatively easier to implement.

EXHIBIT 10 Priority Truck Bottlenecks in the SCAG Region 2014



High Priority Bottlenecks/ Congested Areas

Recently Identified Bottlenecks

Source: SCAG

RAIL STRATEGIES

EXISTING AND PROJECTED RAIL CONDITIONS

Southern California is served by two Class I railroads:[28] Union Pacific Railroad (UP) and the Burlington Northern Santa Fe Railway (BNSF). Pacific Harbor Line, Inc. (PHL), a Class III railroad, provides rail transportation, maintenance and dispatching services within the San Pedro Bay Ports area. The Port of Hueneme is served by the Ventura County Railway (VCR), a Class III railroad, which connects to the UP Coast main line in Oxnard. Another Class III line, the Los Angeles Junction Railway (LAJ), provides industrial switching services in the Cities of Vernon, Maywood, Bell and Commerce. The LAJ provides connections to both UP and BNSF. **EXHIBIT 11** shows key segments of the rail system described in more detail below.

North of the Ports of Los Angeles and Long Beach, UP and BNSF trains operate on the Alameda Corridor, which was completed in 2002. All harbor-related trains of the UP and BNSF use the Alameda Corridor to access the rail mainlines that originate near downtown Los Angeles. East of downtown Los Angeles, freight trains operate on the BNSF San Bernardino Subdivision, the UP Los Angeles Subdivision, or the UP Alhambra Subdivision. North and west of Los Angeles, freight trains operate on the UP Coast line toward Santa Barbara, the Antelope Valley line from the San Fernando Valley to Palmdale, or the UP Mojave Subdivision from West Colton to Palmdale.

To transition from the Alameda Corridor to the Alhambra Subdivision, the UP utilizes trackage rights over Metrolink's East Bank Line, which runs parallel to the Los Angeles River on the east side of downtown Los Angeles. The UP Los Angeles Subdivision terminates at West Riverside Junction, where it joins the BNSF San Bernardino Subdivision. The BNSF San Bernardino Subdivision continues north of Colton Crossing and transitions to the BNSF Cajon Subdivision. The Cajon line continues north to Barstow and Daggett and then east toward Needles, CA and beyond. UP trains exercise trackage rights over the BNSF San Bernardino Subdivision from West Riverside Junction to San Bernardino and over the Cajon Subdivision from San Bernardino to Daggett, which is a short distance east of Barstow. UP trains continue north of Daggett on the UP Cima Subdivision to Las Vegas.

The UP Alhambra Subdivision and the BNSF San Bernardino Subdivision cross at Colton Crossing in San Bernardino County. East of Colton Crossing, the UP operates its transcontinental Sunset Corridor main line, also known as the UP Yuma Subdivision. The Yuma Subdivision passes through the Palm Springs area, Indio and continues to Arizona and beyond.

The UP Yuma Subdivision has two main tracks from Colton to Indio. East of Indio, double-tracking of more than 80 percent of the Sunset Corridor has been completed to date.

The BNSF San Bernardino Subdivision has at least two main tracks with segments of triple track between Hobart and Fullerton. On the Cajon Subdivision, the BNSF completed a third main track from San Bernardino to the summit of Cajon Pass.

While a majority of the UP Alhambra Subdivision is single track, since the 2012 RTP/SCS 5.8 miles between South Fontana and Reservoir has been double-tracked and three new run-through tracks at Montclair have been constructed. Combined, these projects addressed more than one-third of the entire project that is envisioned for the segment between South Fontana and Reservoir on the Alhambra subdivision. The UP Los Angeles Subdivision has two main tracks west of Pomona and a mixture of one and two tracks east of Pomona.

North from West Colton, the single-track UP Mojave Subdivision closely parallels the BNSF Cajon Subdivision as the two lines climb the south slope of Cajon Pass. There are connections at Keenbrook and Silverwood to enable UP trains to enter/exit the main tracks of the BNSF Cajon Subdivision. Beyond Silverwood to Palmdale, the UP Mojave Subdivision has very little train traffic. UP uses this line to reach points in Northern California and the Pacific Northwest.

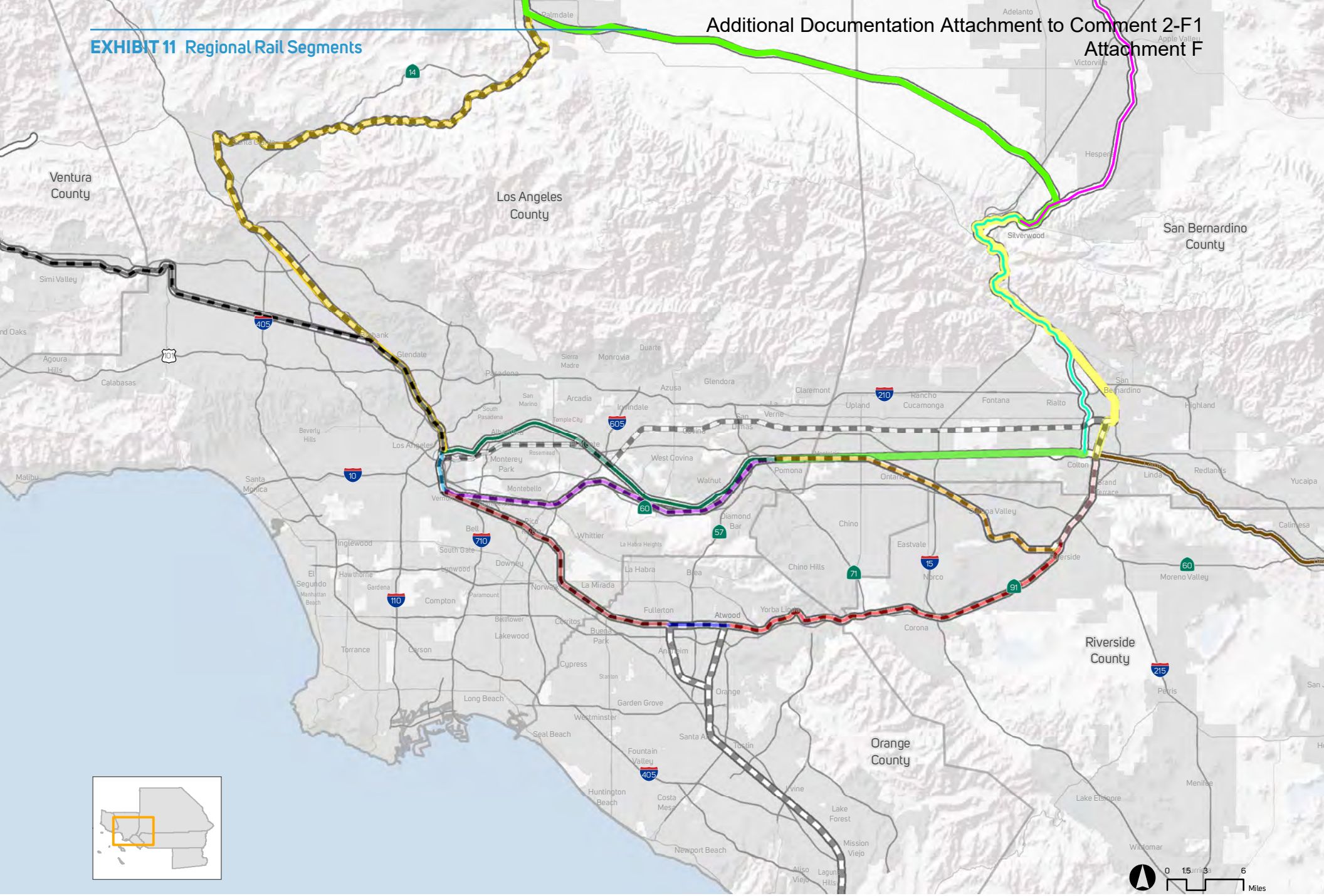
The BNSF operates intermodal terminals for containers and trailers at Hobart Yard (in the City of Commerce) and at San Bernardino. UP operates intermodal terminals at:

- East Los Angeles Yard at the west end of the UP Los Angeles Subdivision;
- Los Angeles Transportation Center (LATC) at the west end of the UP Alhambra Subdivision;
- City of Industry on the UP Alhambra Subdivision; and the
- Intermodal Container Transfer Facility (ICTF) near the south end of the Alameda Corridor.

In addition, both UP and BNSF operate trains hauling marine containers that originate or terminate at on-dock terminals within the Ports of Los Angeles and Long Beach.

UP also has a large carload freight classification yard at West Colton (at the east end of the Alhambra Subdivision). A large automobile unloading terminal is located at Mira Loma (mid-way between Pomona and West Riverside on the Los Angeles Subdivision).

EXHIBIT 11 Regional Rail Segments



BNSF San Bernardino Subdivision:
- Hobart to Fullerton
- Fullerton to Atwood
- Atwood to W Riverside
- W Riverside to Colton

BNSF Cajon Subdivision:
- Colton to Silverwood
- Silverwood to Barstow

UP Alhambra Subdivision:
- Yuma Junction to Pomona
- Pomona to W Colton

UP LA Subdivision:
- East LA to Pomona
- Pomona to W Riverside

UP Mojave Subdivision:
- W Colton to Silverwood
- Silverwood to Mojave

UP Yuma Subdivision:
- UP Yuma Subdivision

- UP East Bank
- UP Coast Line
- UP Santa Clarita Line

- Main Line Rail
- Commuter Rail Network

Source: SCAG

CURRENT AND FUTURE VOLUMES AND POTENTIAL CAPACITY CONSTRAINTS

Significant growth in passenger and freight rail traffic is expected on most segments of the SCAG regional rail system by 2040. This anticipated growth is highlighted in **TABLE 9**, which shows 2012 and projected 2040 peak day train volumes on key segments. Freight train volumes include container trains, also called intermodal trains (marine and domestic) and non-intermodal trains (unit automobile trains, unit oil trains, unit bulk and carload trains). Passenger trains include Amtrak and Metrolink service. Increases in railroad traffic will require ongoing infrastructure investment to maintain current levels of service. Increased rail traffic also has an impact on roadway traffic and congestion, as more trains will result in increased wait times for vehicles at at-grade crossings - as much as 5,500 vehicle hours of delay per day at the regional level by year 2040.

REGIONAL RAIL STRATEGIES

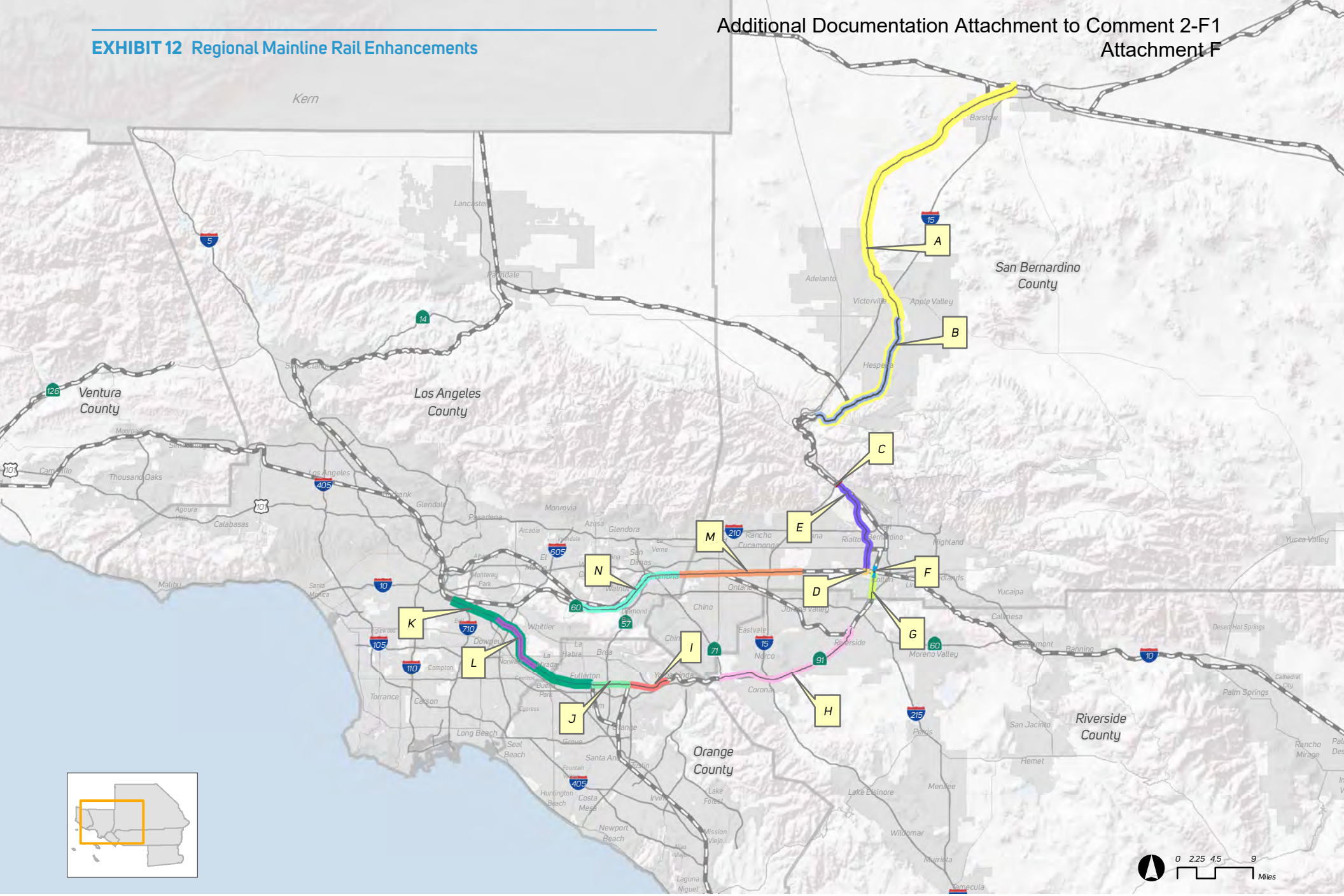
The proposed regional rail package has several components. These include mainline rail improvements (rail-to-rail grade separations, double or triple tracking, new signal systems, universal crossovers, new sidings, etc.) that would benefit both freight rail and passenger rail service depending on their location; rail yard improvements (upgrades to existing yards as well as construction of new yards); rail operation safety improvements such as Positive Train Control (PTC) that could greatly reduce the risk of rail collisions and increase capacity; grade separations; and emissions reduction strategies.

TABLE 9 Peak Day Train Volume (Metrolink Volumes in Parentheses)

Line Segments	Type	2012	2040
BNSF San Bernardino Sub Hobart-Fullerton	Passenger	49 (25)	110 (72)
	Freight	36	80
BNSF San Bernardino Sub Atwood-W. Riverside	Passenger	27 (25)	62 (60)
	Freight	40	91
BNSF San Bernardino Sub W. Riverside-Colton	Passenger	39 (37)	108 (106)
	Freight	60	139
BNSF Cajon San Bernardino-Silverwood + UPRR Mojave W. Colton-Silverwood	Passenger	2	2
	Freight	89	167
UPRR LA Sub East LA-Pomona + UP Alhambra Sub Yuma Jct. - Pomona	Passenger	54 (53)	98 (96)
	Freight	37	100
UP LA Sub Pomona-W. Riverside + UPRR Alhambra Sub Pomona-W. Colton	Passenger	13 (12)	48 (46)
	Freight	43	112
UPRR Yuma	Passenger	1	2
	Freight	40	95

Note: A "peak day" experiences the 90th percentile of the distribution of daily train movements. SCAG's freight rail volume forecast was originally developed by Dr. Robert Leachman, Leachman and Associates, LLC, and was recently updated using the Train Builder model by Cambridge Systematics. These numbers do not represent forecasts made by BNFS Railway or UP Railroad. Passenger volume totals include Amtrak and Metrolink. Passenger volumes reflect input provided by Metrolink, LOSSAN Rail Corridor Agency, Riverside County Transportation Commission, and San Bernardino Associated Governments.

EXHIBIT 12 Regional Mainline Rail Enhancements



A - Fourth Main Track from Silverwood to Frost
B - Third Main Track Martinez to Barstow
C - Devore Rd Crossovers
D - Flying Junction at Rancho
E - Second Main Track Devore to Rancho
F - Colton Crossing Grade Separation
G - Third Main Track MP 2.9 to Highgrove MP 6.1
H - Third Main Track West Riverside to Prado Dam
I - Third Main Track Esperanza to Atwood
J - Third Main Track Atwood to Fullerton
K - Fourth Main Track Fullerton to Hobart
L - Third Main Track Valley View to Serapis
M - Second Main Track South Fontana to Reservoir
N - Second Main Track Pomona to City of Industry
Main Line Rail Network

Source: SCAG

TABLE 10 Estimated Cost of Mainline Rail Improvements (in Nominal Dollars)

Mainline Rain Improvements	"Estimated Cost ($ YOE, Thousands)"
Rail package — mainline rail capacity expansion: Colton rail-to-rail grade separation–BNSF Cajon Subdivision (Complete not included in the total); Barstow to Keenbrook–BNSF San Bernardino Subdivision; Colton Crossing to Redondo Junction–UP Mojave Subdivision; Devore Road to West Colton (inc. Rancho Flying Junction)–UP Alhambra Subdivision; West Colton to City of Industry–UP Los Angeles Subdivision; UP Yuma Subdivision.	$3,092,400

MAINLINE ENHANCEMENTS

The most notable change since the 2012 RTP/SCS is the completion of the Colton rail-to-rail grade separation project in the City of Colton, San Bernardino County. Completed in August 2013, this project physically separated two Class I railroads that crossed perpendicularly. An elevated 1.4-mile-long overpass that lifts UP trains traveling east-west removed the chokepoint that existed where BNSF and UP mainlines crossed tracks in Colton. Physically separating this crossing has numerous economic benefits to the region as well as the nation as the majority of imported cargo through the San Pedro Bay Ports are moved by freight rail via this crossing. The project completion was widely celebrated by the surrounding community, San Bernardino Associated Governments, Caltrans and both UP and BNSF as the project was delivered eight months ahead of schedule with $109 million in project cost savings.[29]

Positive Train Control (PTC) is a radio or GPS-based system designed to automatically prevent train-to-train collisions, derailments caused by excessive speeds, unauthorized train movements in work zones, and the movement of trains through switches left in the wrong position. Congress mandated the installation of PTC through the Rail Safety Improvement Act of 2008 on lines where certain hazardous materials are carried and any line on which passenger or commuter rail services operate.[30,31]

While information on individual railroads implementation status is not available, recent documentation through the Federal Rail Administration reports that, nationally, 32 out of 38 railroads have completed installation of approximately 50 percent of the locomotives that require PTC equipment, deployed approximately 50 percent of wayside units, replaced approximately 505 signals that need replacement and completed most of the required mapping for PTC tracks. With projected volume increases on both freight and passenger rail, ensuring railroad safety is of paramount importance to the region's growth and quality of life.

The 2016 RTP/SCS assumes that no changes have been made to the Class I Railroads routing operations and includes mainline rail improvements that were estimated based on the Modified Status Quo routing along the UP Lines.[32]

Location of regional mainline rail enhancements are shown in **EXHIBIT 12** and estimated costs of the recommended mainline track improvements are shown in **TABLE 10**.

Improvements to the BNSF Cajon Subdivision include installing a third main track and a fourth main track on specific segments, exceptional earthmoving, crossovers and bridges across multiple culverts.

Improvements to the BNSF San Bernardino Subdivision include a third main track, as well as a fourth main track along the Hobart to Fullerton segment. Caltrans has provided $121.8 million for the triple tracking from Serapis (MP 151.1) to Valley View (MP 158.7).

TABLE 11 San Pedro Bay Ports Direct Intermodal Volumes as a Percentage of Total Port Container Throughput (2003–2014)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
% On-Dock	15.9%	18.1%	20.7%	24.1%	23.0%	23.7%	24.6%	23.5%	24.2%	25.0%	24.8%	26.9%
% Near-/Off-Dock	23.4%	21.2%	19.5%	18.7%	18.4%	18.5%	15.3%	11.7%	9.9%	11.2%	10.5%	9.7%
Total % Direct Intermodal	39.3%	39.3%	40.2%	42.8%	41.4%	42.2%	39.9%	35.2%	34.1%	36.2%	35.3%	36.6%
Total Throughput (POLA +POLB) Millions of TEUs	11.8	13.1	14.2	15.8	15.7	14.3	11.8	14.1	14	14.1	14.6	15.1

Source: Ports of Los Angeles and Long Beach

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Improvements to the UP Mojave Subdivision include a second main track over a key segment and a "flying junction" at Rancho (West Colton).

Improvements to the UP Alhambra Subdivision include double tracking key segments and route connections in Pomona.

ON-DOCK/NEAR-DOCK RAIL CAPACITY ENHANCEMENTS

In 2014, approximately 36.6 percent of the San Pedro Bay Ports' containers were shipped by rail "intact" (direct intermodal), meaning the cargo was moved by rail in marine containers without being transloaded or deconsolidated first (TABLE 11). In addition to direct intermodal movement, containers can be transloaded into 53-foot domestic containers or trailers at deconsolidation facilities in the region. The larger containers are then trucked to off-dock rail yards for loading onto trains and transported out of the region. The 53-foot wheeled trailers are also typically transported out of the region. Containers that are neither shipped by rail intact (direct intermodal) nor transloaded are trucked directly to/from local warehouses or distribution facilities.

TABLE 11 shows the percentage of direct intermodal cargo handled at on-dock and near-dock rail yards. Containers moved using on-dock rail do not have to be trucked to/from more distant rail yards. In 2014, 26.9 percent of direct intermodal cargo was handled using on-dock rail. In that same year, 9.7 percent of containers were handled at off-dock yards (e.g., Hobart, East Los Angeles) or existing near-dock yards (i.e., ICTF). These containers must be trucked between port terminals and these yards.

TABLE 12 Estimated Cost of Port-Area Rail Improvement (Millions of Nominal Dollars)

Port Area Rail Improvements (Excluding SCIG and ICTF)	Estimated Costs
Port of Long Beach	
On-Dock Railyards	$186.20
Rail Infrastructure Outside Marine Terminals	$704.80
Subtotal Port of Long Beach	$891.00
Port of Los Angeles	
On-Dock Railyards	$806.02
Rail Infrastructure Outside Marine Terminals	$297.01
Subtotal Port of Los Angeles	$1,103.03
Total Port Area	$1,994.03

Source: Ports of Los Angeles and Long Beach

ON DOCK RAIL SUPPORT FACILITY AT PIER B STREET (PIER B ODRSF)

Pier B ODRSF is a $310 million project that will expand the existing Pier B Rail Yard. Creation of an expanded rail support facility at the Pier B Rail Yard site would provide comprehensive rail support that currently does not exist within the port complex. The Pier B ODRSF project will provide the following functions: (1) arrival or departure of an entire container train internal to the site, (2) sufficient yard track storage capacity to facilitate train assembly and disassembly and (3) ancillary yard functions, such as locomotive layover and refueling capability. Carrying containers by rail is the most efficient method for cargo destined to points well beyond the Southern California region. Utilizing rail has the added benefit of potentially reducing the number of truck trips on regional roadways and freeways, which would otherwise be needed to carry cargo containers to near-dock or off-dock yards. The expanded facility will ease congestion and reduce air pollution. An Environmental Impact Report (EIR) is currently being prepared for this project.

PORT AREA RAIL INFRASTRUCTURE IMPROVEMENTS

The Ports of Los Angeles and Long Beach have proposed neraly $2.0 billion in rail improvements within the harbor area (TABLE 12). These projects are designed to support increased on-dock rail service, to reduce railroad delay associated with train meets and passes and to reduce conflicts with highway traffic. By allowing more on-dock rail, truck traffic between the San Pedro Bay Ports and distant rail yards can be reduced. Use of on-dock rail eliminates truck vehicle miles of travel (VMT) and associated emissions by allowing trains to be loaded and unloaded inside marine terminals.

With continued investments in on-dock infrastructure as proposed, on-dock rail is estimated to account for the movement of approximately 35 percent of all port TEUs by 2035. This projected share is sizeable as on-dock rail will not be able to accommodate 100 percent of direct intermodal moves. It is limited by factors such as shipper/steamship line logistics (transloading, transportation costs, etc.), railroad operations (equipment availability, the need to generate destination-specific unit trains, train schedules and steamship line contracts/arrangements) and terminal operation and congestion.

The "On-Dock Railyards" category in TABLE 12 includes the following projects (see EXHIBIT 23 for project locations):

- Port of Long Beach

- Pier G South Working Yard Rehabilitation
- Pier G Metro Track Improvements
- Middle Harbor Terminal Rail Yard (Three Phases)

- Port of Los Angeles
  - **West Basin Container Terminal (WBCT) On-Dock Rail :** Addition of two new loading tracks
  - **YTI On-Dock Rail:** Addition of one new loading track
  - **Pier 400 Rail Expansion:** Phase 1
  - **Pier 300 Rail Expansion:** Addition of two new loading tracks
  - **Seaside Yard:** Dedicated on-dock rail yard for Berth 226-236 terminal (Evergreen)
  - Terminal Island Support Yard
  - **Berth 200 Railyard Expansion:** Additional Storage/working tracks
  - **Evergreen/TICTF:** Adding one new loading track
  - **Port of LA Container Movement Enhancement Program:** WBCT wharf improvements, YTI wharf improvements and Pier 300 wharf improvements
  - Pier 400 Second Lead Track.

The "Rail Infrastructure Outside Marine Terminals" category in **TABLE 12** includes the following projects (see Exhibit 23 for project locations):

- Port of Long Beach
  - Pier B Street Realignment
  - Pier F Support Yard (currently under construction)
  - Track Realignment at Ocean Boulevard (currently under operation)
  - Terminal Island Wye Track Realignment
  - Reconfiguration of Control Point (CP) Mole
  - Navy Mole Road Storage Yard
  - Pier B Rail Yard (Phase III–12th Street Alternative)
- Port of Los Angeles
  - Port Truck Traffic Reduction Program: West Basin Railyard
  - Port of Los Angeles Rail Efficiency Program (Alameda Corridor - West Basin Area Gap Closures)
- Port of Los Angeles and Port of Long Beach Joint Projects
  - New Cerritos Channel Rail Bridge[33]
  - Third Track at Thenard Junction.[34]

EXPANSION OF NEAR-DOCK RAIL

Additional lift capacity at near-dock yards is needed to accommodate projected demand and to reduce the number of truck trips to off-dock yards. Near-dock rail terminals provide rail accessibility to import and export cargo, using drayage trucks for the connection to and from port terminals. Expansion of near-dock rail will reduce truck VMT and emissions by eliminating the need to access more distant off-dock rail facilities.

Two near-dock rail projects are currently undergoing environmental review: BNSF's Southern California International Gateway (SCIG) and modernization of UP's Intermodal Container Transfer Facility (ICTF). Without the SCIG and ICTF expansion projects, it is estimated that the growth in direct intermodal container volumes would require that at least

TABLE 13 List of Recently Completed Grade Separation

County	Locations
Los Angeles	Valley View Ave
Los Angeles	S. Wilmington
Los Angeles	Baldwin Ave
Los Angeles	Del Amo Blvd
Los Angeles	Passons Blvd
Orange	Kraemer Blvd
Orange	Placentia Ave Undercrossing
Orange	Jeffery Rd
Riverside	Iowa Ave
Riverside	Streeter Ave
Riverside	Auto Center Drive
Riverside	Riverside Ave
Riverside	Avenue 52
San Bernardino	Hunts Ln
San Bernardino	Glen Helen Pkwy
San Bernardino	N. Milliken
San Bernardino	Ramona Ave at State Ave

Source: SCAG

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1.5 million container lifts would have to be handled at different yards throughout the SCAG region. While the number of truck trips would not change significantly, vehicle miles traveled would be reduced due to the shorter distance from the Ports to the SCIG terminal (about 3 to four miles), compared to the distance to Hobart and East Los Angeles yards terminal (about 20 miles). The Alameda Corridor has sufficient capacity to handle the projected increase in railroad traffic from the ICTF and SCIG.

INTERMODAL TRANSFER CONTAINER FACILITY (ICTF)

The UP has proposed to invest $500 million in a modernization project that will increase the capacity at the ICTF, from the current maximum of 725,000 containers (1.4 million TEUs) to 1.5 million containers (2.8 million TEUs). The project will include the replacement of diesel cranes and yard hostlers with electric ones as well as the addition of six new railroad tracks totaling 50,000 ft. Clean technologies will be utilized to cut facility emissions by 74 percent. An EIR is currently being prepared for this project.

SOUTHERN CALIFORNIA INTERNATIONAL GATEWAY (SCIG)

SCIG is a $500 million project that will create a new near-dock facility for the BNSF adjacent to the San Pedro Bay Ports with direct access to the Alameda Corridor. BNSF forecasts that the new facility will take millions of truck-miles off regional freeways, easing congestion and reducing air pollution. The SCIG will include the use of electric and low-emission equipment and will have requirements that only lower emission trucks serve the facility. The Project was approved by Los Angeles City Council in May 2013.

RAIL GRADE SEPARATIONS

With increasing railroad and highway traffic, vehicle delays at grade crossings are expected to increase substantially by the year 2040. Allowing two intersecting axes of traffic to move concurrently, grade separations of at-grade crossings reduce traffic congestion and delays, as well as emissions from idling vehicles and address other critical rail crossing related concerns such as noise and safety.

TABLE 14 Estimated Cost of the Proposed Package of Rail Projects, by Major Category (Millions of Nominal Dollars)

Category	Estimated Costs
Mainline Rail Improvements	$3,092.40
Port Area Rail Improvements	$1,994.03
Near-Dock Railyard Improvements	$1,000.00
Rail-Highway Grade Separations	$4,870.20
Total	$10,956.63

Source: SCAG

Seventy-one grade crossings throughout the SCAG region were identified for inclusion in the financially constrained 2012 RTP/SCS. To date, seventeen grade separations were completed and opened to traffic as shown in **TABLE 13**.

Twenty-one grade separation projects are currently under construction and are anticipated to be complete and open to traffic in late 2015 to 2016. Further, additional grade separation projects have been identified for inclusion in the financially constrained 2016 RTP/SCS, for a total of forty-two grade separation projects (excluding complete and under construction projects). The forty-two grade separation locations are shown in **EXHIBIT 13.**

Financially Constrained and Strategic Plan (unfunded) grade separation projects are included at the end of this Technical Appendix (**TABLE 17 &18**), along with grade separation maps by county (**EXHIBITS 14, EXHIBIT 15, EXHIBIT 16, EXHIBIT 17, EXHIBIT 18 AND EXHIBIT 19**). The estimated costs of the grade separation projects in the financially constrained plan total approximately $4.8 billion.

RAIL PACKAGE SUMMARY

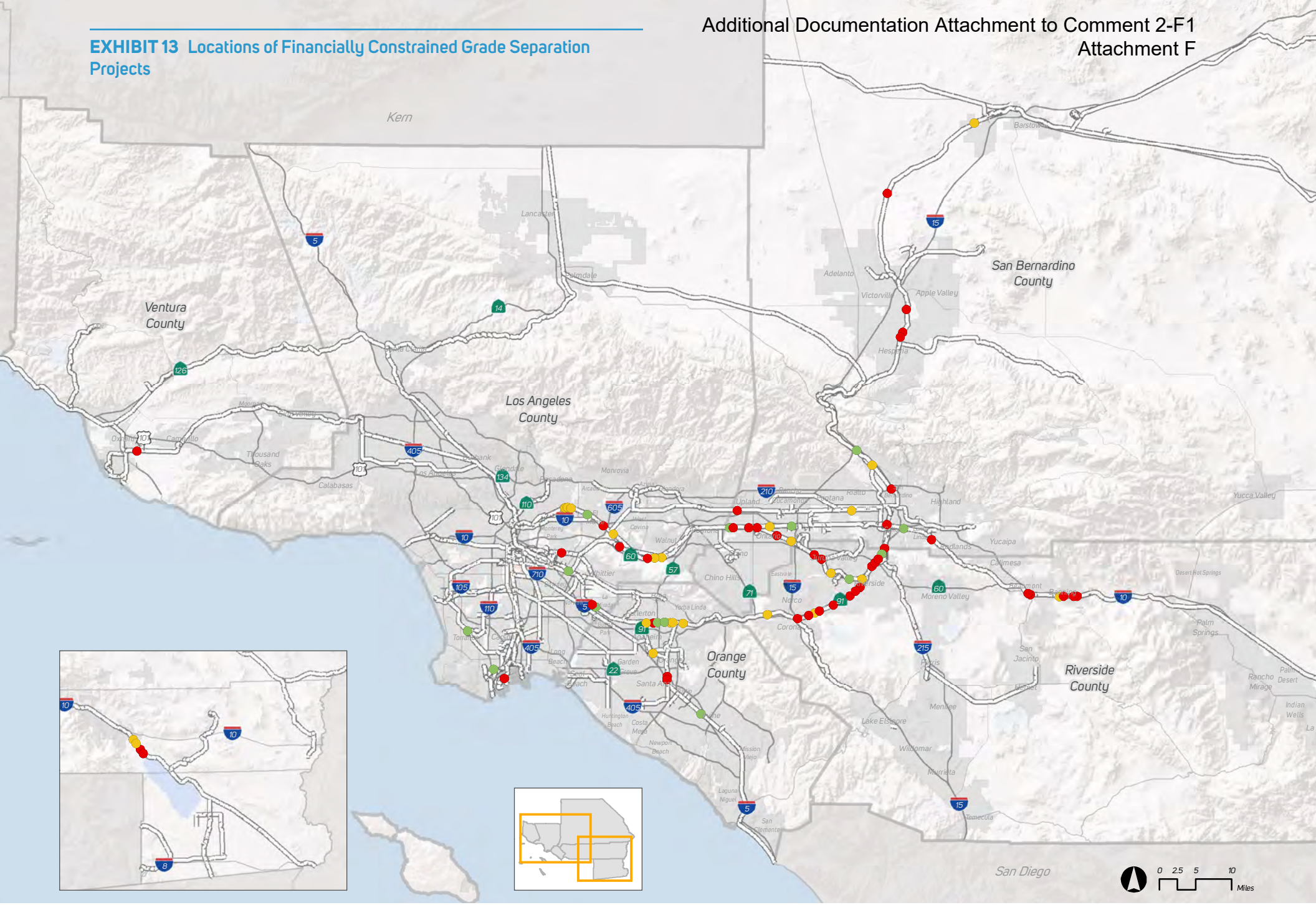
As shown in **TABLE 15**, the combined rail package has been estimated to cost approximately $11 billion, including mainline rail improvements, port area rail improvements, near-dock railyard improvements and rail-highway grade separations.

FIGURE 7 Rendering of Gerald Desmond Bridge–Expected 2018



Source: Port of Long Beach

EXHIBIT 13 Locations of Financially Constrained Grade Separation Projects



Constrained Plan Status (as of November 2015): Complete (14) Planned (40) Under Construction (22) Regional Rail Lines

Source: SCAG

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OTHER STRATEGIES

SAN PEDRO BAY PORTS ACCESS PROJECTS

Landside access to the San Pedro Bay Ports is provided by highway facilities, including I-110 and I-710 and the Vincent Thomas (SR-47), Commodore Schuyler Heim (SR-103) and the Gerald Desmond Bridges. The San Pedro Bay Ports have long worked with regional and state transportation planning organizations to identify and promote projects that will alleviate congestion to and from port areas and improve air quality in the region (**EXHIBIT 23**).

Some key projects to improve direct access to the San Pedro Bay Ports are already underway, including:

- **The Gerald Desmond Bridge replacement (FIGURE 7):** This bridge, which has been designated as a National Highway System Intermodal Connector Route and part of the Strategic Highway Network, carries nearly 15 percent of the nation's waterborne cargo and is a critical access route for the Port of Long Beach, the Port of Los Angeles, downtown Long Beach and surrounding communities. The new bridge will provide three travel lanes in each direction for improved traffic flow including the emergency lanes on both inner and outer shoulders. The bridge also includes a Class I bicycle facility and pedestrian path along the south side of the bridge, connecting Pico Avenue and Terminal Island. A 205-foot vertical clearance would accommodate some of the largest vessels in the world. The new bridge will be built with a cable-stayed design and will be high enough to accommodate the newest generation of the most efficient cargo ships. In addition, the new bridge will be wider and better able to accommodate existing and future traffic volumes. Currently, the bridge is under construction and is expected to generate about 3,000 jobs. It is expected to be completed between late 2017 and mid-2018.
- **The Pier B Street Freight Corridor Reconstruction Project:** This project is a crucial component to the success and full utilization of the Pier B On-Dock Rail Support Facility, a capital project that is intended to transport more containers by rail. The project involves realigning the roadway, which will facilitate future enhancement of the Pier B On-Dock Rail Support Facility, a critical link between the Port's container terminals and the Alameda Corridor. In addition to the realignment of Pier B Street and Pico Avenue, the project will also enhance the capacity of the roadway by adding additional lanes to the Pier B Street, which would accommodate projected future cargo demand. This "stand-alone" project will also provide safety enhancements for both motorists and pedestrians by increasing its capacity and constructing a new sidewalk on the south side (eastbound) of Pier B Street for pedestrian travel. Upon eventual completion of the Pier B On-Dock Rail Support Facility (which involves the removal of 9th street at-grade railroad crossing), the realigned Pier B Street & Pico Avenue will be designated as a National Highway System Intermodal Connector Route. An EIR is currently being prepared for this project.
- **The Schuyler Heim Bridge Replacement and SR-47 Expressway Project:** Includes replacement of the seismically deficient bridge and development of a truck expressway that will transport port truck traffic on an elevated structure from the new bridge 1.7 miles northwest to Alameda Street. This project is already in the design phase. This project will improve safety (by bypassing three signalized intersections and five rail at-grade crossings) and reduce congestion and delay at many of the Port of Los Angeles' terminals.
- **South Wilmington Grade Separation:** This project was completed in spring 2015 and eliminates the conflict between vehicular traffic and two existing at-grade railroad crossings. The project provides unimpeded grade-separated vehicular access to the South Wilmington area (including for emergency vehicles), eliminates truck queues on surrounding streets, reduces accidents and improves safety in the area.
- **C Street/I-110 Access Ramp Improvements:** This will consolidate two closely spaced intersections and improve connectivity to Figueroa Street and Harry Bridges Boulevard and access to several shipping terminals. This project is currently under construction and is scheduled to be completed in January 2017.
- **I-110/SR-47 Interchange & John S. Gibson Intersection/NB I-110 Ramp Access:** This project will provide an additional lane from the SR-47 connector to NB I-110 and extend the existing off-ramp at John S. Gibson Boulevard. It will eliminate weaving between the slow-moving, on-ramp traffic from San Pedro and the fast-moving bridge traffic from Long Beach to improve the connection between SR-47 and the I-110 Freeway. This project is currently under construction and is scheduled to be completed in June 2016.
- **SR 47 (Seaside Avenue)/Navy Way Interchange:** Construction of interchange at the intersection of SR-47/Navy Way to eliminate the existing traffic signal and movement conflicts. This project removes the last signal on SR 47 between the I-710and the I-110. SR 47 is an NHS Intermodal Connector Route.
- **SR 47/V. Thomas Bridge/Front St Interchange:** This project entails removal of the existing westbound (WB) SR 47/Vincent Thomas Bridge off-ramp (south of the Vincent Thomas Bridge) with Harbor Boulevard and construction of new WB SR 47/Vincent Thomas Bridge off-ramp (north of the Vincent Thomas Bridge) with Front Street. These improvements eliminate the existing non-standard ramp connection to the Harbor Boulevard off-ramp. Front Street is an NHS Intermodal Connector Route and the Vincent Thomas Bridge is a state-owned bridge that is on the U.S. DOT Primary Freight Network. This project also includes realigned eastbound and westbound SR 47 on-ramps.

- **Harbor Boulevard. & 7th Street Intersection:** The project includes a reconfigured intersection at the junction of Harbor Boulevard, Sampson Way and 7th Street. The project improves motorized/non-motorized mobility to/from regional highways (I-110 and SR-47) and the following major regional destinations: community of San Pedro, downtown San Pedro, Catalina Ferry/Freight facility, World Cruise Center, Battleship USS Iowa Museum, Ports O' Call (POC) Village, Alta Sea facility and Cabrillo Beach/Marina. The project entails the elimination of Sampson Way/6th Street intersection, incorporation of synchronized signals into the LADOT Advanced Traffic Control System, the widening of sidewalks from six to 12 feet, the building of textured concrete crosswalks, and Class II bike lanes.
- **Sampson Way to 22nd Street & Miner Street:** Sampson Way would be realigned and expanded to two lanes in each direction and would curve near the Municipal Fish Markets to meet 22nd Street in its westward alignment east of Miner Street. In the proposed project, Harbor Boulevard would remain in place at its current capacity with two lanes in each direction. Proposed enhancements would be consistent with design standards for the Community Redevelopment Agency (CRA) Pacific Corridor and the City of Los Angeles Planning Department Community Design Overlay.
- **Harbor Boulevard Improvements:** As part of the San Pedro Waterfront Development Project, Harbor Boulevard will be restriped and the median removed/reconstructed as needed to provide three northbound through and southbound through lanes between the reconstructed Sampson Way/Harbor Boulevard intersection and the Westbound SR 47 on-ramp/Front Street intersection. This will result in the removal of parking and the bike lane on the northbound side. The parking and five foot bike lane on the southbound side, south of O'Farrell Street, will be preserved. North of O'Farrell Street, the parking and the parking lane on the southbound side would need to be removed to accommodate the northbound dual left-turn lane. The innermost northbound through-lane at the Eastbound off-ramp intersection would become a forced left-turn lane at the SR 47 Westbound on-ramp. This improvement is projected to be needed by the year 2024.

PORT OF HUENEME ACCESS PROJECTS

In addition to the Ports of Los Angeles and Long Beach, the SCAG region is home to the Port of Hueneme in Ventura County. Although smaller, two-way trade activities through the Port of Hueneme were valued at nearly $9.2 billion and generated $1.1 billion in economic activities in the immediate region.[35] Unlike the San Pedro Bay Ports, the Port of Hueneme does not focus on containerized cargo. Instead, its primary imports and exports are refrigerated goods and produce, automobiles, bulk cargo and fuels.

On October 12, 2015, the Port of Hueneme Board of Harbor Commissioners formally adopted the 2020 Strategic Plan, which was developed through a comprehensive public outreach effort that included over 40 interviews with a diverse stakeholder base of port customers, local and regional agencies, Ventura County businesses and community stakeholders. The 2020 Strategic Plan highlights a number of key strategies including:

- Business Retention and Growth;
- New Business Opportunities;
- Waterside Investments;
- Project Funding and Fiscal Planning;
- Terminal Efficiency;
- Agency Coordination;
- Land Use and Logistical Efficiency; and
- Port Safety and Resiliency.

As part of the 2020 Strategic Plan, critical transportation project priorities along the Port Intermodal Corridor include:

- Grade Separation at Rice Avenue and East 5th Street;
- Port Hueneme Road Widening between Ventura Road and Rice Avenue; and
- Rice Avenue Paving (allowing for State Route designation).

In addition to the 2020 Strategic Plan, the following projects and strategies are among those anticipated to reduce truck congestion and other impacts:

- Rice Avenue UP Grade Separation;
- Rose Avenue UP Grade Separation;
- SR-118/Coast Line Grade Separation;
- Rice Avenue Reconstruction from Pacific Coast Highway (Route 1) to US Highway 101; and
- Maintain Port Hueneme Road/Hueneme Road and Rice Avenue as the primary truck access corridors to the Port of Hueneme and encourage trucks to use this route through additional signage.

The Port of Hueneme is also committed to protecting the environment and supporting a quality of life through numerous green initiatives. These include the use of clean energy at the Port, its Stormwater Improvement Plan, and shoreside power for vessels that will provide a 92 percent reduction in particulate matter, a 55 percent reduction in greenhouse gasses, and a 98 percent reduction in NO_x over the 30 year life of the project. For more information, go to http://www.portofhueneme.org/community/environment.

IMPERIAL COUNTY INTERNATIONAL PORTS OF ENTRY

International border crossings between the U.S. and Mexico in Imperial County are critical components of the freight transportation system in Southern California. Within Imperial County, the three ports of entry (POEs)–Calexico West-Mexicali I, Calexico East-Mexicali II and Andrade-Los Algodones–accounted for over $14 billion in international trade in 2014.

While most goods in Imperial County move by truck, the border areas also are served by the UP and Carrizo Gorge Railway (CGR). The Calexico East border crossing is the only international rail crossing in the SCAG region and provides the only rail connection from California into Central Mexico.

According to the Overall Economic Development Commission (OEDC), there are a number of challenges in Imperial County that could constrain future economic development. A lack of adequate transportation infrastructure, at the U.S. - Mexico border is a significant concern, but there are also operational issues that have to be addressed. Some of the most noticeable challenges include:

- The lack of direct freeway connections to railyards and intermodal facilities;
- The lack of dedicated truck lanes, passing lanes and truck bypass routes;
- High truck traffic through urban areas; and
- The impacts of empty trucks returning to Mexico after unloading their cargo in Calexico.

These statements are consistent with findings of recent SCAG goods movement border crossing studies, which found that costs of delays at the border are high. Other major findings were that:

- Border-crossing times in Imperial County's land port of entries (LPOEs) are among the highest along the U.S.-Mexico border;
- Southbound commercial border-crossing times are higher than commonly anticipated, occasionally attaining levels comparable to those of northbound commercial trips;
- Future volumes of goods crossing the border are anticipated to generate significant pressure on current LPOE infrastructure, potentially increasing commercial truck wait times at the border; and
- LPOE users are willing to pay to improve border-crossing times and reliability on northbound trips.

Key transportation strategies identified to improve the flow of goods in the area include:

- Improving interchanges and developing bypasses to appropriate regional roadways;
- Reconstruction of the I-8/Imperial Avenue interchange and Imperial Avenue Extension projects in the City of El Centro which expand to the Calexico East Port of Entry. The proposed projects would increase the number of commercial vehicle inspection lanes and booths from the existing three to six lanes and booths, while widening the bridge over the All-American Canal (Canal serves as U.S./Mexico Border);
- Construction of cold storage facilities in Imperial County to perform pre-inspections and allow streamlined crossing of trucks across the LPOEs; and
- Development at air cargo and intermodal capacity in the region.

HIGH DESERT CORRIDOR

The High Desert Corridor (HDC) project includes the construction of a new 63-mile east-west multi-purpose corridor between SR-18 and SR-14 in Los Angeles and San Bernardino counties. This multi-purpose corridor is composed of a range of alternatives including the possible incorporation of Transportation System Management/Travel Demand Management (TSM/TDM) strategies, expressway/tollway, high-speed rail, a bike route and green energy components. The exact elements that will be included as part of the project are dependent on the outcome of the final preferred alternative. The Draft EIR/EIS for the project was released in fall 2014, and the Final EIR/EIS is scheduled to be completed in spring 2016.

Caltrans and Los Angeles County Metropolitan Transportation Authority (LACMTA or Metro) are in the process of preparing the Draft EIR/EIS for the Northwest 138 Corridor project to analyze a range of alternatives along the 36-mile stretch of SR-138 between I-5 and SR-14. Proposed alternatives include a highway (six-lanes)/expressway (four-lanes), an expressway (six-lanes)/limited access conventional highway (four-lanes) and the TSM alternative to provide operational improvements to the existing SR-138 without adding capacity or access restrictions. Overall, the project will provide for improved connectivity and mobility between I-5 and SR-14.

TRUCK CLIMBING LANES

Additional highway projects that would facilitate goods movement activities in the region include truck climbing lanes. Examples of corridors identified as suitable for truck climbing lanes and currently programmed with funding and/or under construction include I-5, I-10, I-15, SR-57 and SR-60. Truck climbing lanes are additional lanes located outside mixed-flow lanes, which permit slower-moving trucks to operate at their own pace. This enables other vehicles to move at a faster pace, thereby reducing congestion. These lanes are typically placed where slow-moving trucks would cause an obstruction to other vehicles, such as hillsides or other areas with significant grade increases.

INTELLIGENT TRANSPORTATION SYSTEMS (ITS) AND FREIGHT

Under MAP-21, evidence of consideration of innovative technologies and operational strategies, including intelligent transportation systems (ITS), which improve the safety and efficiency of freight movement, is now required for project development. ITS technologies allow freight infrastructure to increase its efficiency and capacity by enabling the value and volume of freight and freight movement to increase while reducing demands on the system. ITS technologies are very flexible and can be applied to the vast transportation infrastructure of highways, streets, bridges, tunnels, railways, seaports and airports, as well as associated vehicles. ITS can also be applied to mobile freight handling equipment, such as cranes, forklifts and conveyor belts. Even the shipping containers used to transport goods can have ITS applications.

Both public agencies and the private sector have recognized the need for a coordinated, strategic approach to ITS deployment and have established direct links between ITS planning and other transportation and strategic planning efforts. It is expected that ITS and technology projects will be specifically identified and funded within every freight funding program and that nearly all freight projects will have an ITS or advanced technology component. Within the SCAG region, there are some key ITS projects that are currently ongoing and are summarized in the following paragraphs.

GATEWAY CITIES TECHNOLOGY PLAN FOR GOODS MOVEMENT

The Gateway Cities Technology Plan for Goods Movement represents the most significant fusion of ITS and freight operation technologies within the region. Through the integration of traditional highway, arterial and traveler information technologies with intermodal freight, port and truck technologies, this project evaluates the potential of providing an end-to-end information support system that can improve the efficiency of goods movement in Southern California. The plan identifies new and expanded technology applications for the Gateway Cities and also includes a concept of operations and business plan. It is being developed by the Gateway Cities Council of Governments and the LACMTA, with close involvement from the Ports of Long Beach and Los Angeles, Caltrans, the SCAG and other key stakeholders.

FREIGHT ADVANCED TRAVELER INFORMATION SYSTEM (FRATIS)

The United States Department of Transportation (US DOT), in conjunction with the Port of Los Angeles, a marine terminal and a drayage trucking company, is currently testing an advanced intermodal logistics information technology system designed to improve drayage and container handling. This system, termed the Freight Advanced Traveler Information System (FRATIS), is a demonstration project funded by the US DOT. The FRATIS project seeks to improve the efficiency of freight operations by using several levels of real-time information to guide adaptive and effective decision making.

The FRATIS project is focused on:

- Improving communications and sharing intermodal logistics information between the truck drayage industry and port terminals so that terminals are less congested during peak hours; and
- Improving traveler information available to intermodal truck drayage fleets so that they can more effectively plan around traffic and port congestion.

Together, these two areas of focus can result in significant improvements in intermodal efficiency, including reductions in truck trips, reductions in travel times and improved terminal gate and processing efficiency. Technologies that are being utilized during the demonstration test include advanced traveler information, port terminal truck-queue-time measurement, automated Estimated Time of Arrival (ETA) messaging to the terminals one day in advance of truck arrivals, direct messaging of trucks by terminals, and employment of an algorithm that will optimize truck deliveries and movements based on several key constraints (e.g., time of day, PIERPASS restrictions, terminal queue status, etc.).

The primary user interfaces for these technologies are a web application for drayage truck dispatchers, a mobile application for drayage truck drivers and messaging and alerts functionality for terminal operators. This demonstration project is currently in operational testing that began in December 2013. US DOT will be expanding the FRATIS project to more container terminals in the Ports of Los Angeles and Long Beach and involve more trucking companies as part of Phase 2.

I-710 AUTOMATED TRUCK RESEARCH

This project will implement a staged progression of commercial vehicle technologies in order to transition from current research-based, automated, commercial vehicle demonstration efforts to staged operational testing of a flow efficiency system of trucks along the planned I-710 truck lanes. The project will build upon the unique operational environment and potential partnerships of the Gateway Cities region to promote and enhance truck automated commercial vehicle research by bringing together the applications of automated commercial vehicle and automation technologies on one of the most heavily congested truck corridors in the country. The project will examine and test the specific design and operational concerns that impact the future development of I-710 and its approaches.

The Truck Platooning Demonstration Project is an intermediate step toward a long-term vision of trucks operating in closely coupled automated platoons on both long-haul and short-haul freight corridors. As part of the I-710 South Corridor project, one of the build alternatives considers dedicated truck lanes on a separate structure. Through the use of Vehicle-to-Vehicle (V2V) communication and suitable sensor technologies, the automated trucks will be able to follow each other in platoons at separations of just a few feet on a dedicated corridor. In addition, V2V and Cooperative Adaptive Cruise Control (CACC) will be

tested in mixed-flow traffic conditions on the highway system as a short-term solution, if dedicated truck lanes are not implemented in the near term.

Caltrans and Berkeley PATH received approximately $1.6 million to test Cooperative Adaptive Cruise Control (CACC) on heavy trucks, enabling them to electronically couple themselves so that they occupy less space and use less energy than if driven independently. The project was initiated in September 2014.

ADVANCED TRANSPORTATION MANAGEMENT INFORMATION SYSTEM (ATMIS)

The Ports of Los Angeles and Long Beach have deployed the ATMIS to monitor truck traffic within the Ports using vehicle detection devices and closed-circuit television cameras. A traffic management center operated jointly by the Ports provides traveler information, including real-time traffic conditions and incidents on changeable message signs in the vicinity of the Port area.

AUTONOMOUS COMMERCIAL VEHICLES

Autonomous vehicle technology is also being tested outside the SCAG region. For instance, on May 5, 2015, State of Nevada awarded the first license for an autonomous commercial truck to operate on a public highway to Daimler Trucks North America (DTNA). This autonomous vehicle technology is expected to help reduce accidents, improve fuel consumption, reduce highway congestion and in turn, address environmental impacts. This pilot project links together sophisticated camera and radar technology with systems providing lane stability, collision avoidance, speed control, braking, steering, and an advanced dash display to allow for safe autonomous operation on public highways.

Trucks such as the Daimler truck may have applications in the SCAG region once the technology becomes commercially available. The autonomous commercial truck is not a driverless truck; however, it provides a state-of-the-art dash interface and connectivity for a better driving experience. It is able to greatly improve the way data from the truck's performance is communicated to the driver. The highway pilot informs the driver visually on its status and also accepts commands from the driver. Taking connectivity to another level, video displays inside the truck are capable of replacing exterior mirrors. Not only does this boost fuel efficiency by up to 1.5 percent, but the use of tiny cameras on the exterior of the truck greatly reduces blind spots. With the safety features on the trucks, drivers can optimize their time on the road by handling other important logistical tasks, from logging to routing. The technology contributes to improved safety and efficiency, while allowing for improved communication through connectivity and integration.

GOODS MOVEMENT ENVIRONMENTAL STRATEGIES

EXISTING AND PROJECTED ENVIRONMENTAL CONDITIONS

Ships, trucks, trains and other goods movement equipment are among the largest contributors to regional air pollution, which must be reduced to comply with federal law and improve quality of life. Criteria pollutants such as NO_x, $PM_{2.5}$, SO_x and CO can have significant public health impacts, including contributing to asthma and other respiratory ailments, increased stress and increased cancer risk. In addition, noise, safety issues, aesthetic changes, vibrations and natural resource depletion associated with goods movement impact quality of life and may have health implications. Freight transport is also a major producer of greenhouse gas (GHG) emissions and a user of energy in the form of diesel fuel.

Currently, much of the SCAG region fails to meet federal ozone and fine particulate air quality standards as mandated by the federal Clean Air Act. The South Coast Air Basin (SCAB) which includes most of the SCAG region, has a deadline to reduce ozone concentrations to 80 parts per billion (ppb) by 2023 under the revoked 1997 eight-hour ozone standards and to 75 ppb by 2031 under the current 2008 8-hour ozone standards. Moreover, new federal ozone standards are expected to be finalized by the EPA in the 2015/2016 time frame. Currently, the proposed range is 65-70 ppb, with an expected new attainment deadline of 2037. This translates to a need to reduce NO_x emissions in the South Coast Air Quality Management District (SCAQMD) by 65 percent by 2023 and 75 percent beyond projected 2023 emissions by 2032 (beyond the benefits of all adopted programs) in order to attain federal ozone standards.[36]

In addition, both the South Coast Air Basin and the urbanized area of Imperial County have been designated as a "Moderate" nonattainment area under the new 2012 annual $PM_{2.5}$ standards. The statutory attainment deadline is 2020 and the new annual $PM_{2.5}$ standard is 12 micrograms per cubic meter (µg/m3) versus the previous standard of 15 µg/m3. If appropriate measures to meet federal standards are not adopted, federal transportation funds may be jeopardized and permitting of stationary facilities may be restricted. The federal government may also take over air regulation if state plans are not adequate to meet federal standards.

Goods movement sources include trucks, locomotives, cargo handling equipment, marine vessels and aircraft. These sources, combined with all mobile sources in the region, emit approximately 90 percent of regional NO_x.[37] In 2014, heavy-duty trucks contributed 71 percent of NO_x emissions and locomotives contributed nine percent, of NO_x emissions from

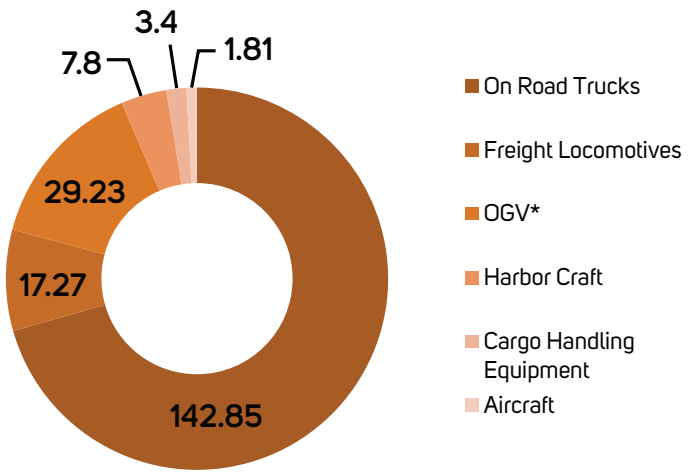
goods movement related sources. **FIGURE 8** shows the distribution of emissions from various goods movement sources.

Several regional and state efforts are intended to reduce criteria pollutants such as NO_x and $PM_{2.5}$. Many of the regulations and programs in place will likely have co-benefits for GHG reductions. The California Air Resources Board's (CARB) truck and bus regulation, as well as state and local incentive programs, were put into place to accelerate the introduction of cleaner technology. The Heavy Truck and Bus rule, passed in 2008, first implemented in 2012 and then amended in 2014, requires that by 2023 nearly all heavy duty vehicles (HDVs)will have engines that are model year 2010 or newer. Additionally, various incentive programs have since funded deployment of hybrid-electric and cleaner fueled trucks. Given existing programs and control measures, truck NO_x emissions are expected to decrease from 142.85 tons per day (tpd) in 2014 to 56.4 (tpd) in 2032.[38] This forecast is displayed **FIGURE 9**.

Additional state programs are under development as part of the California Sustainable Freight Strategy (SFS). Though not finalized, the SFS is intended to create a sustainable freight system that is primarily powered by zero-emission technologies and near zero-emissions technologies, when a zero emissions option is not a viable option. The plan defines sustainability broadly and is intended to meet environmental, economic, energy and transportation objectives. CARB is working closely with other state agencies including Caltrans and The Governor's Office of Business and Economic Development ("GO Biz") to make this a fully integrated plan. To date, the sustainable freight initiative has involved broad outreach statewide, technology assessments and identification of near-term and longer-term actions that include fleet turnover and improved system efficiency.

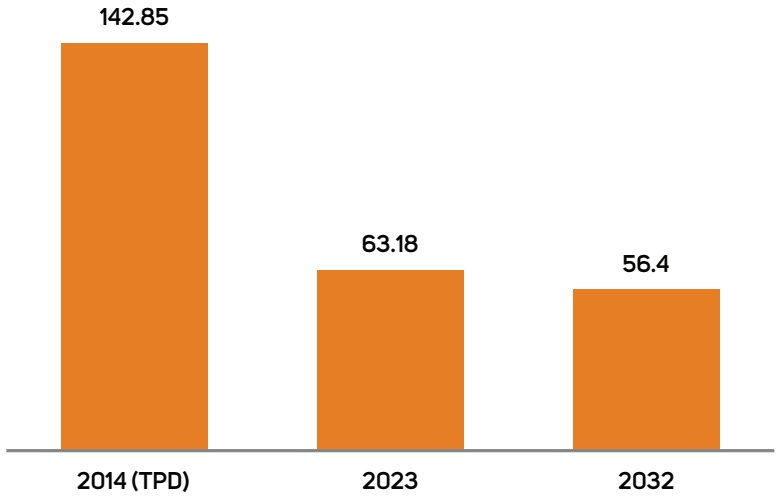
GHG emissions are also produced by goods movement sources. On a national scale, heavy-duty vehicles were only four percent of registered vehicles on the road in 2010, but they accounted for approximately 25 percent of on-road fuel use and greenhouse gas emissions in the transportation sector.[39] In September 2011, the EPA and the US DOT's National Highway Traffic Safety Administration (NHTSA) finalized the first round of standards for medium- and heavy-duty vehicles, creating fuel efficiency standards for model year 2014-2018 vehicles. Stricter Phase 2 standards are expected to be finalized in 2016. The proposed new standards would be for model year vehicles from 2021-2027 and are expected to cut national GHG emissions by approximately 1 billion metric tons and conserve about 1.8 billion barrels of oil over the lifetime of the vehicles sold under the program.[40] The U.S. Department of Energy has also started a Super Truck (2010) program to develop and demonstrate more fuel efficient trucks that will increase engine efficiency and overall fuel economy from about 6.5 miles per gallon to about 9.75 miles per gallon. To date, the four manufacturers involved in this program have improved engine efficiency and fuel economy. For instance, Cummins and PACCAR's Peterbilt Motors Company have reached over ten miles per gallon under real world driving conditions on a Class 8 tractor-trailer.[40]

FIGURE 8 2014 Distribution of NOx Emissions from Goods Movement Sources



*Source: SCAQMD (June 2015) "Preliminary Draft AQMP White Paper Goods Movement: * Ocean Going Vessels*

FIGURE 9 Truck Emissions Baseline and Forecast NO_x (Tons Per Day)



*Source: SCAQMD (June 2015) "Preliminary Draft AQMP White Paper Goods Movement: * Ocean Going Vessels*

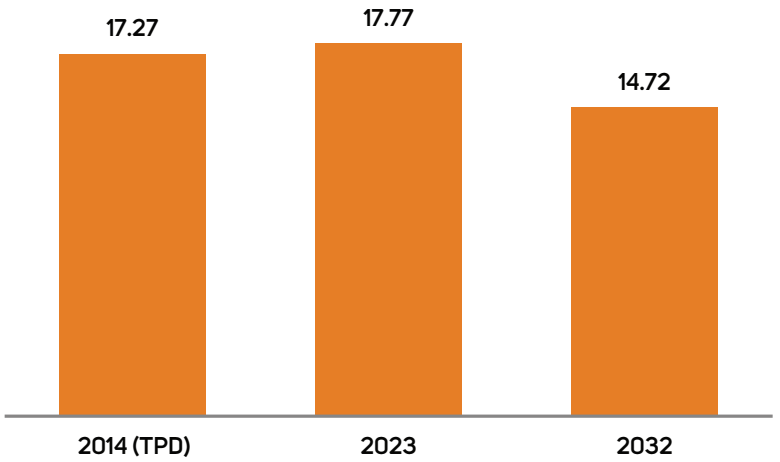
At the state level, reducing GHG emissions is a priority, as established by landmark legislation such as AB 32 and SB 375. In April 2015, Governor Brown signed Executive Order B-30-15, which calls for a reduction in GHG to 40 percent below 1990 levels by 2030 as a way of ensuring that the earlier targets of Executive Orders B-16-2012 and S-03-05, which require transportation GHG emissions to be reduced 80 percent below 1990 levels by 2050, are met. Between 2012 and 2016, the State of California has continued to implement GHG reduction measures to meet these goals, with some implications for freight. For instance, the Low Carbon Fuel Standard requires a minimum of ten percent reduction in carbon intensity of transportation fuels, based on a life cycle analysis of the fuel, by 2020. Beginning January 2015, GHG emissions from transportation fuels are included under the Cap-and-Trade Program. Additionally, in 2013, CARB adopted the Federal Phase 1 standards (passed in 2011) for heavy duty vehicles manufactured for use in California. This harmonization of standards is set to reduce new vehicle emissions by four to five percent per year from 2014-2018.[41] While a regional forecast is not available for GHG emissions, CARB reports that GHG emissions from goods movement sources statewide will continue to increase. For instance, GHG emissions from trucks increase from 20 million metric tons CO_2 in 2012 to just over 30 million metric tons of CO_2 in 2040.[42] Because most control measures to date focused on reducing criteria pollutants harmful to human health, CO_2 emissions show a different trend by increasing over time, rather than decreasing.[43]

It is also a regional priority to reduce rail pollutants and work toward the objective of a zero- and near zero-emission freight rail system. At the federal level, regulations are in place that will contribute to future reductions in rail emissions, including the U.S. EPA Locomotive Engine Standards, the 2008 EPA rulemaking to reduce locomotive idling and the EPA non-road locomotive and marine (NRLM) fuel sulfur rule. The EPA Tier 4 locomotive standards also become effective for all new engines in 2015, and Tier 4 are now available from General Electric (GE). GE was able to achieve the Tier 4 standard without using Selective Catalytic Reduction (SCR) for after-treatment, eliminating the need for an extra urea storage tank and reducing the complexity and cost of using a Tier 4 engine. GE estimates that these engines will reduce emissions by 70 percent as compared to a Tier 3 engine.[44] Given current regulations, NO_x emissions from rail are expected to decrease from 17.27 tpd in 2014 to 14.72 in 2032. The emissions forecast for rail emissions is shown in **FIGURE 10**.

In the South Coast Air Basin, attaining the national ozone standards will require reductions in emissions of NO_x well beyond reductions resulting from current rules, programs and commercially-available technologies. Previous regulations and incentive programs have improved vehicle emissions performance, but as the region grows, existing measures are not enough to realize attainment of the ozone standards in the 2023 and 2031 time frames. With the projected changes in both truck and rail emissions, greater advancements in technology are needed to meet regional attainment objectives. As such, the 2016 RTP/SCS includes an action plan to facilitate technology development and reduce emissions.

The 2016 RTP/SCS Goods Movement Environmental Strategy was developed to address community health concerns, federal attainment requirements and climate change issues, while contributing to our economic and energy security goals. Accordingly, the strategy emphasizes coordinated solutions for mobility, economy, energy and environment so that investments can provide multiple benefits. This 2016 RTP/SCS continues to focus on the long-term goal of a zero-emission goods movement system where technically feasible and economically viable, while also integrating near zero-emissions technologies that serve as bridging options to continue to reduce emissions below today's levels. It is important to note that the term "zero-emission" as used throughout this document refers to technologies that are zero tailpipe emissions, where emissions are not released at the location of the vehicle, but may still be produced off-site through the production of energy needed to power the vehicle. For instance, electric vehicles may be zero tailpipe emissions while in use, but emissions are still being generated at the location of the power plant that is producing energy to power or charge the vehicle. Similarly, emissions may be generated in the production and transportation of fuels used to power the vehicle. Though this plan supports immediate accelerated deployment of existing proven technologies that will serve to improve the region's air quality, this investment must be balanced with investment in our long-term goal of zero- and near zero-emission freight system. Continued innovation, partnerships with the private sector and building on lessons learned will help us achieve the goal of a robust zero- and near zero-emission freight system.

FIGURE 10 Rail Emissions Baseline and Forecast NOx (Tons Per Day)



SCAQMD (June 2015) "Preliminary Draft AQMP White Paper Goods Movement:

GOODS MOVEMENT ENVIRONMENTAL STRATEGY AND ACTION PLAN

ACTION PLAN FOR ADVANCEMENT OF ZERO-EMISSION TECHNOLOGY

In the 2008 RTP, recommendations for truck emissions reduction strategies included truck replacement, engine repowering, exhaust treatment device retrofits and alternative fuels. In 2012, the RTP/SCS included near-term measures similar to those in 2008, in addition to near zero-emission strategies. Further, the 2012 RTP/SCS included a Technology Advancement Plan to develop and deploy a fully zero-emission goods movement system in the 2035 time frame. Since the 2012 RTP/SCS, several key action steps have been taken. The 2016 RTP/SCS proposes an updated environmental action plan for the goods movement system that builds on regional progress to date. As the four phases of the updated action plan are reviewed below, the text also points to progress made related to specific action steps identified in 2012.

The technology development and deployment plan put forth in this Appendix is inclusive of all stages of technology development and deployment: beginning from an initial definition of key operational parameters, moving through prototype development, initial demonstration and evaluation, and eventually a staged roll-out. This start-to-finish framework is useful as there are many potential technologies available, each at different stages of readiness.

The four phases of the action plan applicable to technology solutions are (**FIGURE 11**):

- **Phase 1:** Project Scoping and Evaluation of Existing Work
- **Phase 2:** Evaluation, Development and Prototype Demonstrations
- **Phase 3:** Initial Deployment and Operational Demonstration
- **Phase 4:** Full-Scale Demonstrations and Commercial Deployment

PHASE 1: PROJECT SCOPING AND EVALUATION OF EXISTING WORK

The project scoping stage of technology development is intended to define the needs that the new technology must provide. In addition to meeting the overriding goal of zero emissions, new technologies must have adequate range, power and charging capability to serve business needs. This stage of exploring market needs and potential applications that could meet those needs has already begun.

Project scoping also includes an understanding of the best state of technologies. Zero-emission freight technologies are evolving and some technologies are moving closer to market readiness. It is important to stay aware of progress made in this area. In 2012, the Zero-Emission Freight Collaborative was formed to foster the regional development of zero-emission technologies and share information on progress made in technology advancement. The collaborative includes SCAG, LACMTA, the Gateway Cities Council of Governments, the Port of Los Angeles, the Port of Long Beach and the South Coast Air Quality Management District. The group shares knowledge and findings about ongoing testing efforts and works together to attract funding to the region for additional testing and development.

This project scoping stage began prior to 2012, and we have learned and tracked information about operational needs and technology readiness. However, ongoing work is needed in this area, particularly to learn how industry could best incorporate new technologies into their daily operations. As several companies have begun to implement energy saving and emissions reducing practices, it is important to determine if these are indeed "best practices" and to determine if these practices can be replicated for other companies operating throughout the region.

FIGURE 11 Phases of Technology Development and Deployment



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****PHASE 1 ACTION STEPS ACCOMPLISHED SINCE 2012:**

Continue to research goods movement user-markets and associated infrastructure needs while exploring a range of technologies as appropriate with equipment manufacturers.

In the past four years, many studies have been done to evaluate new technologies and the role that they may play in the SCAG region as well as to better understand market criteria and operational parameters. At least two studies were conducted that began to define operational criteria for trucks in the SCAG region. These studies analyzed performance parameters and operational needs for drayage and regional truck trips. One key finding was that flexibility is critical as trucks often rotate between routes and markets. Operators commonly reported that a vehicle must have sufficient power for operation (400 horsepower [HP], 1,200-1,800 foot pounds [ft-lbs] of torque) and be able to travel at least a 200 mile range. Additionally, vehicles generally refuel every 2-3 days and have a lifespan of approximately 600,000 miles. Please see the studies below for additional information:

- Characterization of Drayage Truck Duty Cycles at the POLB and POLA, (TIAX, LLC, prepared for POLA and POLB); March 2011.[45]
- Key Performance Parameters for Drayage Trucks Operating at the Ports of Los Angeles and Long Beach, (CALSTART, prepared for LACMTA and Gateway Cities COG); November, 2013.[46]

The studies listed below are a sampling of work that has been completed to date to evaluate technological readiness, emissions benefits and potential operational performance. This work continues to date as technologies evolve towards full commercialization. Please see the following studies for more information:

- Evaluation of Environmental Mitigation Strategies, (ICF on behalf of SCAG); April 2012
- Zero Emission Catenary Hybrid Truck Market Study (Gladstein Neandross & Associates (GNA) on behalf of SCAQMD); March 2012
- Moving California Forward, Zero and Low Emission Freight Pathways (GNA on behalf of the California Cleaner Freight Coalition); November, 2013
- Pathways to Near-Zero-Emission Natural Gas Heavy Duty Vehicles (GNA on behalf of Southern California Gas Company); May 2014
- DRAFT–Port of Los Angeles Zero Emission White Paper, (POLA), June 2015.

PHASE 2: EVALUATION, DEVELOPMENT AND PROTOTYPE DEMONSTRATIONS

As technology development progresses, Phase 2 includes the development, design validation and initial demonstration of several types of advanced prototype vehicles and testing of the initial prototype. Phase 2 includes performance assessment of new technologies, including addressing market risks/uncertainties. As prototypes are developed and demonstrated, significant evaluation will also occur.

Developing and testing zero-emission prototypes requires considerable investment from both public and private sector partners. It is the original equipment manufacturers (OEMs) that must invest in research and development, with the assurance that there will be a market for their product when it becomes commercially viable. Both large companies and smaller startups have invested in new technology development. Particularly for smaller companies, it is important to receive public financial support for prototype development. Several successful partnerships already exist where public funding combines with private sector investment to develop technology prototypes. Once prototypes are available, it is beneficial for them to be tested in operational service with industry operators. Existing partnerships allow for trucking companies and terminal operators to integrate and experiment with new technologies in their everyday business operations.

****PHASE 2 ACTION STEPS SINCE 2012:**

Convene Logistics Working Groups

Since 2012, the region has formed the Los Angeles County Zero Emission Truck Collaborative. This group includes LACMTA, the Gateway Cities COG, POLA, POLB, SCAQMD and SCAG. This group meets to coordinate on advanced technology initiatives including applying for advanced technology funding, evaluating new technology proposals and collaborating on technology demonstrations.

Determine a set of market criteria to move trucks forward to successful commercialization

See examples listed in Phase 1.

Secure funding commitments for the development of vehicle prototypes and infrastructure demonstrations

Since 2012, the region has secured several funding commitments to continue with zero-emission technology research and demonstration. For instance, the POLA and POLB Technology Advancement Program (TAP), provides funding to test new technologies in ongoing terminal operations. Ports partner with industry and provide $3 million annually to develop and test new clean air technologies. The TAP addresses clean air technologies for rail, truck, ship, cargo handling equipment and harbor craft. In addition, several grants have been secured including:

- Several funders (including the SCAQMD, the California Energy Commission (CEC), the U.S. EPA and several regional partners) have contributed roughly $13.5 million to construct and demonstrate a one-mile Overhead Catenary System (OCS) in the City of Carson and develop prototype trucks to assess compatibility with the OCS. In-kind contributions from OEMs increase the total value of this project.
- In 2012, the SCAQMD received a U.S. Department of Energy (DOE) grant of $4.2 million to develop and test 13 zero-emission drayage trucks using various technologies.
- In 2014, a second DOE grant of $9.5 million was granted to SCAQMD for the development and demonstration of zero-emission fuel cell range extended electric drayage trucks and hybrid electric drayage trucks.

Moreover, the state Cap-and-Trade Program's Greenhouse Gas Reduction Fund may also emerge as a funding source for the development of clean vehicle prototypes and infrastructure demonstrations. Regional partners have submitted applications in response to recent competitive grant solicitations for various categories of low carbon transportation initiatives.

Develop and demonstrate truck and truck wayside power prototypes

The 2012 RTP/SCS included a $35 million line item for a wayside power system to be demonstrated in two phases. Phase 1, a one-mile test track, has begun in the City of Carson.

Further study of operational impacts of zero-emission rail technologies/ Evaluate practicability of applying existing electrified rail technologies

Regional and state efforts such as the CARB Technology Assessments for rail and the SCAQMD Goods Movement White Paper have continued to explore operational impacts of zero-emission rail technologies. Additionally, several demonstration projects have been completed.

Select truck technologies for continued fleet evaluation under Phase 3/ Identify vehicle technologies and wayside power applications to be tested under operational demonstrations in Phase 3

Evaluation of technologies has begun throughout the course of several demonstration projects. As technologies evolve and more is learned about them, SCAG maintains a technology neutral position.

PHASE 3: INITIAL DEPLOYMENT AND OPERATIONAL DEMONSTRATION

Phase 3 is an opportunity to scale up research and development efforts to evaluate not just a prototype, but the performance of a larger fleet of vehicles. In this phase, industry partners are critical to test and evaluate larger vehicle fleets in everyday business operations. In addition, these tests may serve in part as initial deployment of cleaner vehicles. Assuming a successful demonstration, the industry partner may opt to continue to use these emergent technologies. Another opportunity for initial deployment is the use of incentive programs, where all, or a portion of, the incremental cost of the new technology is subsidized. For instance, the CARB Multi-Source Facility Demonstration Project, provides over $23 million to demonstrate technologies that are within three years of commercialization.[47] This type of program provides an opportunity to see how new technologies work in practice, while at the same time hastening their placement into service. In the initial deployment phase, incentive programs can continue to support industry in this transition.

PHASE 4: FULL SCALE DEMONSTRATIONS, COMMERCIAL DEPLOYMENT AND INFRASTRUCTURE CONSTRUCTION (IF WAYSIDE POWER IS NEEDED)

The prior stages of technology testing and demonstrations will have prepared the region for Phase 4 deployment using the commercialization, regulatory and market steps determined in prior phases. Any new technology deployment must be coordinated with infrastructure planning, and key decisions will be incorporated into RTP updates and future State Implementation Plan revisions. During Phase 4, technologies will be deployed as they meet the criteria for deployment established by regional stakeholders. As various technologies are currently in different stages of readiness, it is assumed that their deployment will be staggered throughout the 2020-2040 timeframe.

In this stage, there may be a greater role for planning agencies as it will be critical to provide infrastructure that supports the deployment of new technologies. If wayside power is deemed applicable, this may be incorporated into infrastructure planning. Additionally, the public sector must continue to use incentives, regulatory and market mechanisms to facilitate full commercialization and work with private sector users and developers to make sure that advanced technologies are integrated into regional transportation networks.

TIMELINE AND KEY ACTION STEPS

FIGURE 12 shows updated action steps and time frames to implement the phases outlined previously. Further details are provided in **TABLE 15** and **TABLE 16**. The time frames suggested in this plan are broad and will likely capture a majority of technologies that can serve the region's needs. However, as innovation is continuous, these time frames may not catch all technologies, and the development of particular technologies may either exceed or lag behind proposed time frames. The ability to create partnerships and procure funding for research and development efforts will also influence the timeline for technology

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development. As explained below, this plan of technology development, evaluation and eventual deployment will be undertaken in close cooperation with regional partners and industry stakeholders.

AGENCY AND PARTNER ROLES AND RESPONSIBILITIES FOR ACTION

In addition to the phases described above, significant regional actions will be needed in order to realize this vision of a zero- and near zero-emission freight transportation system that meets regional objectives for long-term sustainability and can also meet the performance objectives required by industry. SCAG may act together with key partner agencies such as the Port of Los Angeles, the Port of Long Beach, the SCAQMD and the region's county transportation commissions to update and implement this plan as needed. Stakeholders must work together to share and evaluate new information as it becomes available.

Important roles for these partners include:

- Identify funding to support technology evaluation and demonstration efforts in the financially constrained RTP.
- Advocate for additional federal funding to support technology evaluation and demonstration efforts.
- Advocate for additional state funding to support technology evaluation and demonstration efforts.
- Advocate for state funding to support deployment incentives to keep costs manageable for industry.
- Demonstrate the holistic importance of new technology development for co-benefits such as energy security, energy cost certainty, climate protection and green-sector job development.
- Evaluate mechanisms for advanced technology implementation such as incentives, differential tolls and public private partnerships.
- Continue to lead demonstration projects and evaluate and share the results with partner agencies and private sector partners.
- Continue to engage and collaborate with the private sector to continuously solicit feedback on operational parameters and real world operating conditions.
- Encourage private sector partners to participate in operational demonstrations. Partners are needed to evaluate the performance of technologies in a real world setting.
- Support partnerships with OEMS for technology development and send a consistent signal to OEMs that there will be market demand for the new technologies they are investing in and creating.

FIGURE 12 Timeline and Key Actions Steps

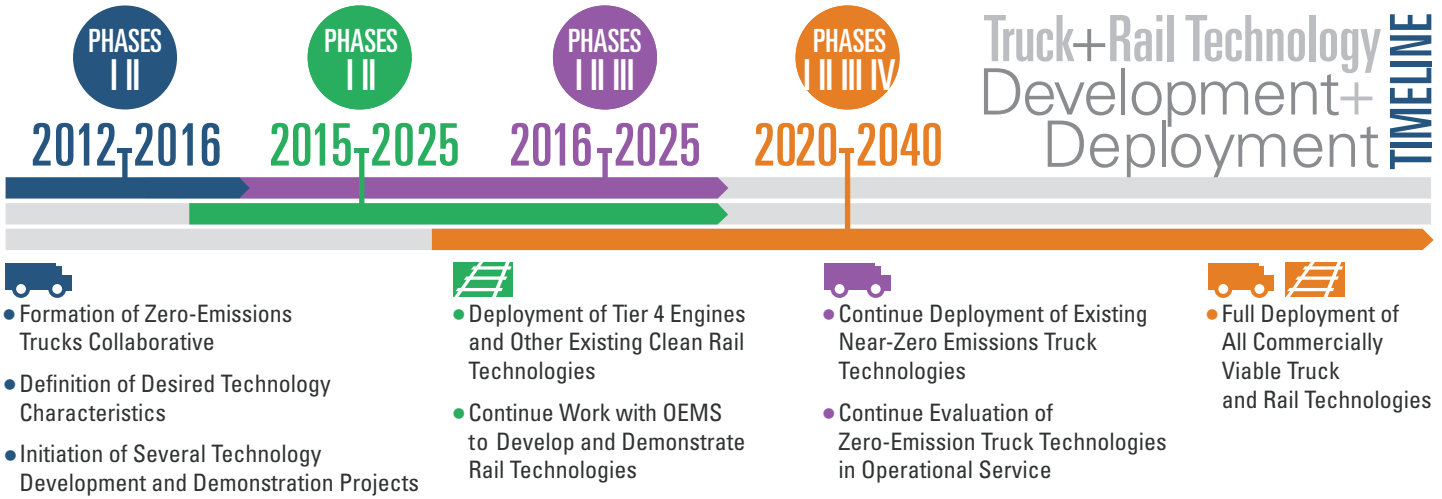


TABLE 15 Timeline for Zero-Emission Truck Deployment

Years	Phase	Trucks
2012-2016	1, 2	The 2012 RTP/SCS includes an environmental action plan for a zero- and near zero-emission freight transportation system, including a line item for a near-term demonstration of the Zero Emission Container Movement System project for $35 million. The Zero-Emission Trucks Collaborative comprising LACMTA, SCAQMD, Port of LA and Port of Long Beach, Gateway Cities Council of Governments, and SCAG is formed. Original Equipment Manufacturers (OEMs) continue development and testing of zero- and near zero-emission truck models, including battery electric and fuel cell models. Several technology development and demonstration projects are initiated. See "Phase 2" description above for more detail.
2016-2020	1, 2, 3	Continue deployment of existing near zero-emission truck technologies (described below under "Near-Term Truck Technologies") Continue development and evaluation of wayside power and other technologies. Continue to partner with federal, state and private funding partners to finance technology development. Continue to collect and evaluate information from ongoing zero-emission technology demonstrations. As feasibility is demonstrated, ensure that the "tests" remain in service and begin to scale up efforts. Begin initial deployment, with industry partners who can put test trucks into immediate service. Continue investigation of mechanisms (i.e., regulatory, market based, incentive based) to facilitate technology deployment.
2020-2040	1,2, 3, 4*	If applicable, plan for wayside power system. Begin deployment of appropriate zero- and near zero-emission trucks (see examples under "Long Term Truck Technologies" below) and continue operational demonstration.

**Stages 1 and 2 will likely be completed prior to this time frame. However, to allow for continuous innovation in new and improved products, we assume that project scoping and early phases of the development/deployment cycle will continue to occur as new products and technologies are considered.*

TABLE 16 Timeline for Zero Emission Rail Deployment

Years	Phase	Rail
2012-2016	1, 2	The 2012 RTP/SCS includes an environmental action plan for a zero- and near zero-emission freight transportation system, including near-term measures for genset and switcher engines and recommends further study of viable zero- and near zero-emission rail technologies. Original Equipment Manufacturers (OEMs) finalize development of Tier 4 engines and continue to build hybrid electric locomotive prototypes. Partner agencies continue demonstration projects.
2015-2025	1, 2	As old locomotives are replaced, Tier 4 will be deployed as required by the U.S. EPA. Encourage use of retrofit kits on existing engines as they are serviced or re-manufactured. Continue to work with OEMs to develop and demonstrate zero- and near zero-emission technologies.
2020-2040	1, 2, 3, 4*	As zero- and near zero-emission rail technologies can be practicably applied to the region, fully deploy such technologies.

**Stage 1 will likely be completed prior to this timeframe. However, to allow for continuous innovation in new and improved products, we assume that project scoping and early phases of the development/deployment cycle will continue to occur as new products and technologies are considered.*

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In addition to facilitation of development, demonstration and deployment, it is important that SCAG and other regional partners continue to advocate for additional funding for technology development efforts as well as the proper regulatory and market structure to deploy these technologies. In the past, the Southern California National Freight Gateway Collaboration has successfully advocated for additional technology investment with the National Freight Advisory Committee, FHWA and CALTRANS. In fact, the California Freight Mobility Plan includes a $3 billion line-item for the development of new technologies.

Regional partners may also facilitate a greater understanding of potential market and regulatory mechanisms to support and enable zero- and near zero-emission truck commercialization and widespread deployment. Models may include incentives, buy-down rebates, preferred or exclusive access to port service, exclusive or preferred access to corridors, etc. Truck manufacturers and technology developers will be included to determine a set of market criteria (i.e. the minimum market size and volumes of vehicles needed to move forward to successful commercialization.) Incentive structures may be financial, such as subsidies or financing of incremental capital costs of new clean technologies; or non-financial, such as reduced tolls for zero-emission vehicles, expedited access to freight facilities, dedicated lanes for advanced clean technology trucks, or public recognition programs for companies utilizing advanced clean technologies.

NEAR-TERM AND LONG-TERM TECHNOLOGIES FOR COMMERCIAL DEPLOYMENT

The 2016 RTP/SCS recommends a two-pronged environmental strategy to be implemented in the four phases outlined in the previous section. SCAG recognizes that not all technologies have advanced to the stage where they can be implemented immediately. As the region works to advance and deploy current prototype technologies (i.e., those that are currently in Phase 2), focus should be placed on commercializing and implementing existing solutions as well (i.e., implementing those that are currently in Phases 3 & 4). For trucks, several near-zero emission clean-fuel trucks and hybrid trucks are currently available but require a more aggressive deployment. Technological advancement also has increased efficiency and reduced emissions of the conventional combustion engine. Additional zero-emission vehicle types are in the prototype stage but need further testing to advance to full commercialization. It is worth pointing out that operational strategies discussed elsewhere in this Appendix can also reduce emissions by improving overall system efficiency. For instance, the bottleneck strategy described in earlier sections and the rail strategy, which proposes new grade separations, can reduce emissions by improving operating conditions and reducing congestion.

For rail, near -erm technologies for switcher locomotives can reduce emissions at railyards. With cleaner Tier 4 locomotive engines currently available, accelerated replacements of locomotives with Tier 4 engines are also needed to reduce emissions. A longer-term objective of a zero-emission rail system, or the ability to operate in zero-emissions mode while in the region, can be reached through further technology development. This section will briefly describe both near- and long-term technologies that have the potential to reduce emissions and help the region meet attainment deadlines. The technologies identified in this section serve as examples of potential near- and long-term options for further study and do not constitute specific technologies under the financially constrained RTP/SCS.

NEAR-TERM TRUCK TECHNOLOGIES

The trucking market offers unique challenges due to heavy weights, operational performance requirements and high incremental costs. However, several reduced-emissions trucks are currently commercially available and many zero- and near zero-emission trucks are under development for future deployment. Three categories of potential near-term improvements are trucks using a cleaner fuel, such as natural gas, hybrid-electric trucks and improvements to the existing combustion engine.

CLEANER FUEL TRUCKS

Alternative fuels include compressed and liquefied natural gas (CNG, LNG), liquefied petroleum gas (LPG, i.e., propane), ethanol, methanol, dimethyl ether (DME), hydrogen and nonpetroleum biodiesel fuels.[48] Natural gas trucks use compressed natural gas (CNG) or liquefied natural gas (LNG) to power an internal combustion engine. Natural gas trucks have already been deployed and may experience greater market penetration if more fueling infrastructure is provided. Range may be a concern due to limited on-board fuel storage and there are remaining concerns with vehicle cost and methane emissions.[49] Nevertheless, several efforts are underway to expand use of natural gas trucks in the region as a near-term solution and a few notable success stories have occurred within the SCAG region. For instance, Ryder trucks has secured over $20 million in grant funding from US DOE's American Recovery and Reinvestment Act, the California Energy Commission and the SCAQMD to deploy 200 natural gas trucks operating within the SCAG region. Additionally, two publicly available natural gas fueling stations were constructed.[50] Southern California Gas Company (SoCalGas) has also been involved in several technology development projects and has worked with OEMs to develop and test several engines and vehicles. These projects have been funded by partners including the CEC, DOE, SCAQMD, in addition to funding invested by SoCalGas.

Renewable natural gas, also known as biomethane, is another alternative fuel source and is widely used by United Parcel Service (UPS) in their fleet of compressed natural gas vehicles. RNG is produced as organic matter from landfills, wastewater treatment plants and

agricultural sources decomposes and is thus viewed by some as a more sustainable fuel.[51] As of 2013, AQMD reports 526 heavy duty natural gas public fleet vehicles in operation and an additional 3,692 medium and light duty public fleet vehicles.[52]

HYBRID-ELECTRIC TRUCKS

Hybrid-electric trucks contain an internal combustion engine as well as an electric motor, generator and energy storage device (e.g., a battery). The electric motor and generator absorb energy via regenerative braking and store that energy to offset acceleration and power demands of the vehicle. However, when battery power is insufficient, the truck draws power from a conventional engine. The incremental cost of this truck remains a barrier to market penetration, though some of this has been offset through incentive programs. In Southern California[53] there were 603 hybrid and 66 zero-emission vehicles deployed through the State Hybrid Truck and Bus Voucher Incentive Project (HVIP) since January 1, 2012.[54] CARB estimates that an additional 420 vehicles will be funded statewide in 2015. A full report of CARB's Technology Assessment for this category is not available. However a summary power point can be found at http://www.arb.ca.gov/msprog/tech/presentation/hybridtrucks.pdf.[55]

COMBUSTION ENGINE IMPROVEMENTS

While the majority of this Environmental Strategy seeks to develop and deploy a regional fleet of zero-emission trucks, it is important to recognize the value of near-term improvements to the existing combustion engine. Improvements to engine efficiency will reduce fuel used and emissions produced in the near-term and lessons learned will help in the design of more power efficient zero-emission vehicles as the fleet converts to full zero-emissions. Improvements to internal combustion engines are discussed at length in the CARB Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency, released June 2015. This report discusses the potential to obtain increased efficiency in the existing internal combustion engine through engine technologies (such as waste heat recovery) and vehicle efficiency technologies (such as automatically inflating tires and improved aerodynamics). For a complete list, please see the CARB report.[56] Technologies to improve engine efficiency have already been developed and advanced through the US DOE Supertruck program (see description above).

LONG-TERM TRUCK TECHNOLOGIES

The long-term goal is to develop and deploy a fleet of zero-emission trucks, or trucks that can operate in zero-emission range while in the region. Two broad categories of trucks are under development to meet this goal including battery-powered electric and fuel cell. Depending on the truck design and compatibility, wayside power solutions may be used to extend the range of these configurations. In addition to developing zero-emission vehicles, charging and fueling infrastructure is also a consideration that must be planned over the long term.

BATTERY-ELECTRIC TRUCKS

Battery-electric trucks replace the entire engine and drive train of a conventional vehicle with an electric motor and generator. The battery can provide all the power needed to power the truck and would ideally be recharged through normal operations; for instance, regenerative breaking could recharge the battery. However, this would likely not be enough power and therefore battery-powered electric trucks could allow for the battery to be recharged through plugging into the grid, using an on-board hydrogen fuel cell or connecting to a wayside power system. Several prototype models of battery-powered electric trucks exist but current obstacles include cost, charging time and range. Current battery charges are estimated to allow for a 100-mile range.[57]

FUEL-CELL TRUCKS

There are many applications for a fuel cell vehicle. For instance, a battery-powered electric vehicle may have an electric motor that is powered by a battery. In addition to charging the battery through the means described above, a fuel cell would draw hydrogen from an onboard storage tank and then generate the electricity needed to recharge the battery. Calstart estimates that by using a charged battery, then recharging the battery onboard via the fuel cell, this configuration could have a range of up to 400 miles. This would be limited only by the amount of on-board hydrogen storage.[58] While fuel cells offer greater range, the system is more complicated and adds infrastructure cost (i.e., hydrogen fueling in addition to charging equipment) and possibly additional maintenance costs. Fuel cells are also less efficient from a wells-to-wheels perspective, because of the electrolysis needed to make H_2 and the need to transport and distribute the fuel. A fuel cell truck will require 2.5 times the energy cost as a battery-powered electric truck.[59]

CHARGING INFRASTRUCTURE FOR ZERO-EMISSION TRUCK TECHNOLOGIES

The deployment of the technologies discussed above cannot be completed without supporting infrastructure to provide either fuel or power to the vehicle. For electric technologies, this implies a network of electric heavy-duty vehicle charging stations. Fuel cell vehicles, and alternative fuel near zero-emission vehicles, such as hydrogen and natural gas, would require their own unique refueling infrastructure. Alternatively, wayside power systems could allow a vehicle to charge or draw power during on-road operations.

Wayside power technologies allow a vehicle to charge while in operation, drawing power as it moves along the road. Ideally, these systems would allow for trucks to enter and exit seamlessly and change lanes, and they could be shared with standard trucks. They offer the potential to extend the range of a vehicle that is charged from a stationary power source by

providing additional power in motion. An example of this is the Overhead Catenary System (OCS) that is currently the subject of a demonstration project led by SCAQMD (see above for more detail on the demonstration project). This system allows vehicles to charge through use of an overhead pantograph that is connected to overhead wires drawing power from the electric grid. Catenary systems are well-established and efficient in light-rail applications, trolley cars and buses and even mining trucks. For in-road power, the roadway itself provides power to the vehicles, which must be equipped with pick-up devices. Examples include in-road power such as third rail or linear synchronous motor (LSM).

Both in-road or distributed charging systems draw power, which leads to emissions being produced during electricity generation. Therefore, the increased use of renewable energy sources will help move the vehicles described above which are designed to be zero tailpipe emissions closer to a truly zero-emissions vehicle.

NEAR-TERM RAIL EMISSION REDUCTION STRATEGIES

A fully zero-emission rail system offers unique challenges as freight rail operates as a national system and locomotives cannot remain captive to the region. For instance, CARB estimates that 8,400 of 10,000 interstate line-haul locomotives operated in the SCAB in 2013.[60] Any new technology will require an operational strategy to change out locomotive types, or will require compatible infrastructure nationwide to provide power and/or fuel to locomotives. Even near term improvements are difficult, as the normal life of a locomotive may be up to 50 years.[61] Even given these challenges, several near zero- and zero-emission rail technologies are under development and investigation. Near zero-emission opportunities include acceleration of Tier 4 engines, use of after-treatment technologies that can be compatible with Tier 4 and earlier engine types, and further development of liquid natural gas tender cars.

EXISTING TECHNOLOGIES

EPA standards for locomotives became effective in 2015, requiring that all new locomotives purchased after that date must meet Tier 4 standards. In addition, any re-manufactured locomotive must be retrofited with stricter emission controls. In 2015 General Electric released a commercially viable Tier 4 line-haul locomotive. Relative to Tier 2 engines, Tier 4 engines produce between 75-85 percent less NO_x and PM emissions[62]; they also offer combustion improvements, enhanced cooling and exhaust gas recirculation. While Tier 2 locomotives are estimated to cost $2.3 million per unit, Tier 4 locomotives are estimated to cost $3 million.[63] CARB anticipates full scale commercialization in 2017. SCAG encourages partnerships to accelerate the transition to these new engines.

Distributed power units are currently in use by Union Pacific Railroad (UP) on two thirds (2/3) of its gross ton miles. Distributed power units are spread throughout the train rather than all in the front, making the train less prone to derailments and facilitating more even braking. These units also provide a fuel savings of four to six (4-6) percent compared to standard locomotive power. [64]

TECHNOLOGIES IN DEVELOPMENT

To go beyond the Tier 4 standard, Selective Catalytic Reduction (SCR) for NO_x and Diesel Oxidation Catalysts (DOCs) and Diesel Particulate Filters (DPFs) for PM are estimated to reduce NO_x and PM emissions 70 percent beyond the Tier 4 standard at a cost of approximately $4 million per unit.[65] These units may require additional maintenance costs, but are otherwise compatible with the national fleet. These units, as applied to Tier 4 locomotives, are still in the conceptual phase. However, DOCs, DPFs and a third technology called Exhaust Gas Recirculation (EGR) have all been tested by UP in intermediate length halls of approximately 200 miles. The smaller size of this engine allowed for all after treatment to be applied simultaneously.[66]

Liquid natural gas has also been considered as a fuel for rail locomotives. It is estimated that use of LNG with a Tier 4 locomotive would lead to NO_x and PM reductions of 70 percent beyond the Tier 4 locomotive.[67] Tender car prototypes currently exist; however, there are operational considerations such as the need to carry an additional tender car to store the LNG fuel and the need for fueling infrastructure.

UP and BNSF are working with stakeholders such as locomotive and engine manufacturers, cryogenic fuel tank suppliers, natural gas/LNG suppliers, the Federal Railroad Administration and first responders to evaluate how natural gas could safely and economically be incorporated into their operations.

LONG TERM EMISSION REDUCTIONS STRATEGIES FOR RAIL

The longer term goal of a fully zero-emission system could potentially be accomplished with an electric catenary or linear synchronous motor system. A hybrid-electric engine or a battery tender car could also provide additional battery power to allow for locomotives to operate in zero-emissions mode where battery power is available. The CARB Sustainable Freight Strategy promotes a long-term vision of zero-emission rail as the technology permits. Without a full system conversion, this goal would allow for zero-emission track miles where possible as facilitated by battery or fuel cell tender cars to allow locomotives to operate in zero-emission mode when these tender cars can provide power. Similarly, LNG tender cars may allow for operation in near zero-emission mode.

ELECTRIFICATION TECHNOLOGIES

Electrification technologies require further evaluation to more precisely address questions about cost, funding and how to best implement such systems with minimal operational impacts. Because of the cost and potential operational challenges associated with mainline electrification, such a strategy should be considered a longer-term initiative, requiring further studies as well as proof of concept and prototype testing of zero-emission locomotive technologies that have the potential to minimize cost and operational impacts, as discussed under the phased implementation section of this Appendix. Construction of any electrified rail system in Southern California would be a large investment and would need the participation of the BNSF and UP railways.

ELECTRIC CATENARY RAIL SYSTEMS

These are perhaps the most technologically ready; however, construction of an electrified rail system in Southern California would be a major undertaking in terms of labor, timeline and cost for the SCAG region and would require a large investment as well as cooperation and investment by the BNSF and UP railways. Though electric catenary systems are widely used for passenger and light rail and electric freight rail has been used in other countries, locomotives would need to be re-engineered for use with trains of the size and length operated in the United States.[68]

DUAL-MODE LOCOMOTIVES

These have been deployed for passenger rail applications, but would need development for freight applications. They have the ability to operate on a catenary or with traditional diesel power. The ability to operate in both modes could potentially reduce operational difficulties associated with the need to remove the engine at the end of the electrified system. However, additional operational considerations remain to be addressed.

LINEAR SYNCHRONOUS MOTORS

This technology propels rail cars by creating an electromagnetic field from motors embedded in the railway. One advantage of LSM is that overhead electric lines would not be needed, allowing the electric rail system to extend further into ports and railyards. Because the propulsion comes from the track, locomotives would not need to be switched when leaving the electrified portion of the system. LSM technology is in its early stages and costs cannot be estimated, however demonstration projects are underway.

OPTIONS FOR ZERO-EMISSIONS OPERATION

While the scale of a fully electrified system may be challenging, opportunities may exist to supplement locomotive power with zero-emissions options. One option is the hybrid electric locomotive engine, where a battery is built into the frame of the engine and can recharge through regenerative braking. Prototypes of this model currently exist.[69] Battery tender cars could also supplement a main engine with zero-emission propulsion by using the battery power. In contrast with the hybrid electric locomotive, the tender car would need to be charged prior to use, likely at railyards. The number of tender cars required to move a train long distances is challenging as space is at a premium on interstate trains. Similarly, facilitating the change out of the tender car is a big operational challenge for this type of system. Conventional locomotives generally refuel every 1,000 miles[70], so a tender car system that offered less power would create operational challenges. Currently these are in the conceptual stage.

Hydrogen Fuel Cell locomotives would also allow for zero-emission miles, but would require a national fueling infrastructure and have similar challenges as described above. These are conceptual for line-haul locomotives but prototypes exist for a switcher and a green goat.

IMPLEMENTING THE ENVIRONMENTAL STRATEGY

Broad deployment of zero- and near zero-emission transportation technologies in the 2023 to 2040 time frame is a critical and significant undertaking with technological, cost and operational challenges. As outlined above, the 2016 RTP/SCS describes a process to develop and deploy needed technologies, along with key action steps for public sector agencies to help move the region to that objective. Industry stakeholder participation will be necessary, including the efforts of numerous state and federal resources agencies, transportation agencies, commercial technology developers/manufacturers, and logistics experts. The 2016 RTP/SCS reaffirms zero- and near zero-emission technologies as a priority, and establishes the regional path forward to such a goods movement system.

TABLE 17 Constrained Grade Separations (Not Listed in Priority Order)

County	Crossing Street	Under Construction	Complete	Planned
LOS ANGELES	VALLEY VIEW AVENUE		X	
LOS ANGELES	REEVES AVE			X
LOS ANGELES	S. WILMINGTON		X	
LOS ANGELES	MONTEBELLO/MAPLE			X
LOS ANGELES	BALDWIN AVENUE		X	
LOS ANGELES	RAMONA ST	X		
LOS ANGELES	MISSION RD	X		
LOS ANGELES	DEL MAR AVE	X		
LOS ANGELES	SAN GABRIEL BLVD	X		
LOS ANGELES	PUENTE AVENUE	X		
LOS ANGELES	NOGALES ST	X		
LOS ANGELES	TURNBULL CYN RD			X
LOS ANGELES	FAIRWAY DRIVE	X		
LOS ANGELES	FULLERTON RD			X
LOS ANGELES	DURFEE AVE			X
LOS ANGELES	DEL AMO BLVD		X	
LOS ANGELES	PASSONS BLVD		X	
LOS ANGELES	ROSECRANS AVE			X
ORANGE	KRAEMER BLVD		X	
ORANGE	LAKEVIEW AVENUE	X		
ORANGE	PLACENTIA AVENUE UNDERCROSSING		X	
ORANGE	RAYMOND AVENUE	X		
ORANGE	STATE COLLEGE	X		
ORANGE	TUSTIN AVENUE/ROSE DRIVE	X		
ORANGE	JEFFERY ROAD		X	
ORANGE	ORANGETHORPE AVENUE	X		
ORANGE	STATE COLLEGE BLVD			X
ORANGE	SANTA ANA BLVD			X
ORANGE	17TH STREET			X
RIVERSIDE	AUTO CENTER DRIVE		X	
RIVERSIDE	IOWA AVENUE		X	
RIVERSIDE	MAGNOLIA AVENUE	X		
RIVERSIDE	MARY STREET			X
RIVERSIDE	MCKINLEY ST			X

Source: SCAG

TABLE 17 Constrained Grade Separations (Not Listed in Priority Order) Continued

County	Crossing Street	Under Construction	Complete	Planned
RIVERSIDE	CLAY STREET	X		
RIVERSIDE	RIVERSIDE AVENUE		X	
RIVERSIDE	STREETER AVENUE		X	
RIVERSIDE	AVENUE 52		X	
RIVERSIDE	AVENUE 56	X		
RIVERSIDE	SUNSET AVENUE	X		
RIVERSIDE	CHICAGO AVE			X
RIVERSIDE	PIERCE ST			X
RIVERSIDE	BELLGRAVE AV			X
RIVERSIDE	MADISON ST			X
RIVERSIDE	SPRUCE ST			X
RIVERSIDE	JURUPA RD			X
RIVERSIDE	TYLER ST			X
RIVERSIDE	RADIO ST			X
RIVERSIDE	ADAMS ST			X
RIVERSIDE	VIELE AVE			X
RIVERSIDE	CALIFORNIA AVE			X
RIVERSIDE	22ND ST			X
RIVERSIDE	SAN GORGONIO AVE			X
RIVERSIDE	HARGRAVE ST			X
RIVERSIDE	AVENUE 62			X
RIVERSIDE	AVENUE 66			X
RIVERSIDE	3RD STREET			X
SAN BERNARDINO	GLEN HELEN PARKWAY		X	
SAN BERNARDINO	GREEN TREE BLVD EXTENSION			X
SAN BERNARDINO	LENWOOD ROAD	X		
SAN BERNARDINO	PALM AVE	X		
SAN BERNARDINO	LAUREL ST.	X		
SAN BERNARDINO	MT. VERNON			X
SAN BERNARDINO	MAIN ST			X
SAN BERNARDINO	N. VINEYARD AVE	X		
SAN BERNARDINO	S. MILLIKEN AVE	X		
SAN BERNARDINO	SOUTH ARCHIBALD AVE			X
SAN BERNARDINO	CAMPUS AVE			X

Source: SCAG

TABLE 17 Constrained Grade Separations (Not Listed in Priority Order) Continued

County	Crossing Street	Under Construction	Complete	Planned
SAN BERNARDINO	HUNTS LANE		X	
SAN BERNARDINO	SAN ANTONIO AVE			X
SAN BERNARDINO	RAMONA AV AT STATE AVE		X	
SAN BERNARDINO	CENTRAL AVENUE			X
SAN BERNARDINO	MONTE VISTA			X
SAN BERNARDINO	EUCALYPTUS ST			X
SAN BERNARDINO	VISTA ROAD			X
SAN BERNARDINO	LEMON ST/MAUNA LOA ST			X
SAN BERNARDINO	VALLEY BOULEVARD			X
SAN BERNARDINO	N. MILLIKEN AVE		X	
SAN BERNARDINO	BEAUMONT			X
VENTURA	RICE AVE/FIFTH STREET			X

Source: SCAG

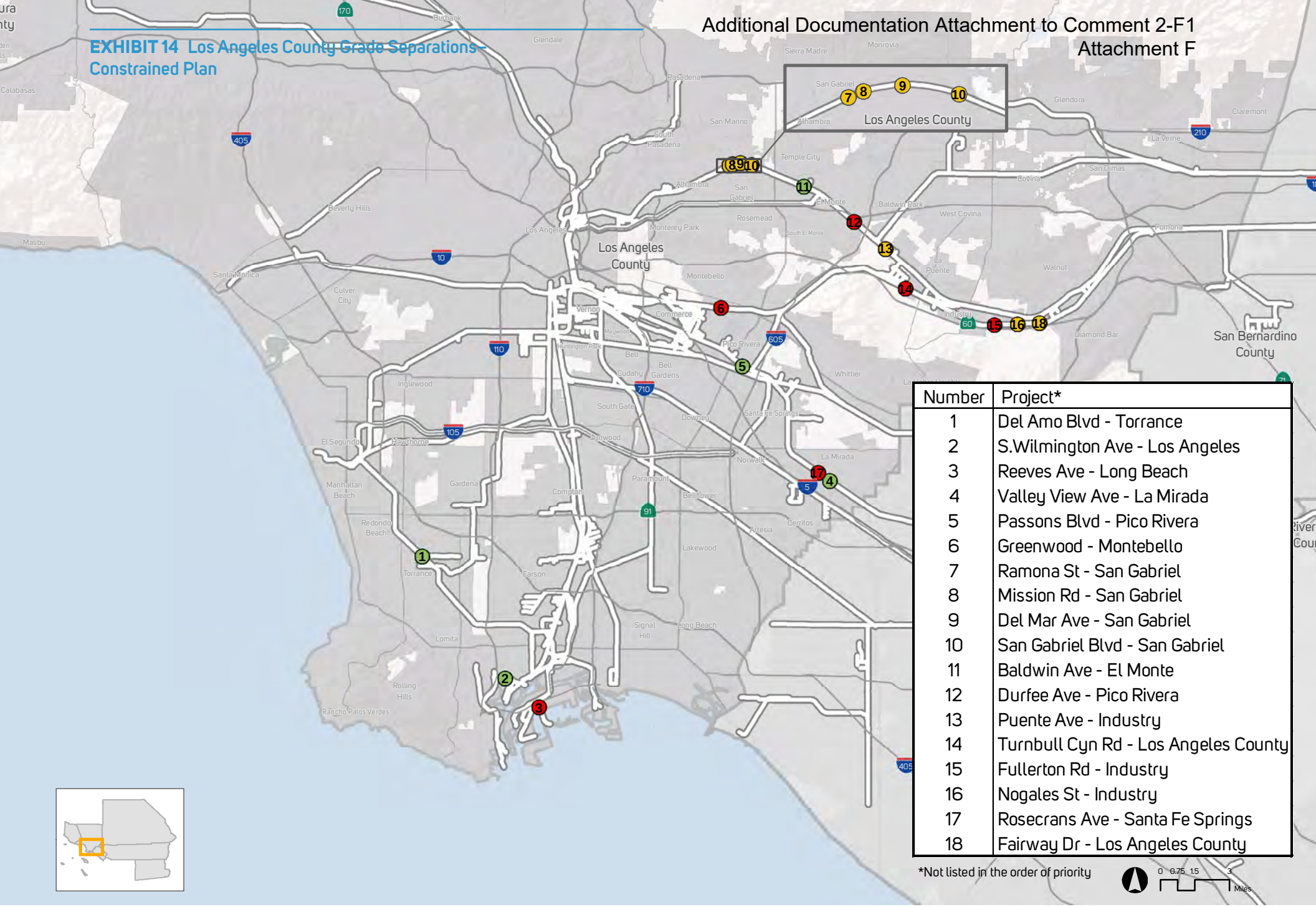
TABLE 18 Strategic Grade Separations (Not Listed in Priority Order)

County	Crossing Street
Imperial	Ward Rd (Imperial County)
Imperial	SR-78/SR-111 (Brawley)
Imperial	Malan St (Brawley)
Imperial	Mead Rd (Brawley)
Imperial	Keystone Rd (Imperial County)
Imperial	Aten Rd (Imperial)
Imperial	Evan Hewes Hwy (Imperial County)
Imperial	Dog Wood Rd (Imperial County)
Imperial	Herber Ave (Imperial County)
Imperial	West Cole Rd (Calexico)
Los Angeles	San Antonio Ave (Pomona)
Los Angeles	Lemon Ave (LA Subdivision)
Orange	Jefferson St (Anaheim)
Orange	Van Buren Ave (Placentia)
Orange	Richfield Rd (Placentia)
Orange	Kellogg Dr Undercrossing (Anaheim)
San Bernardino	Hinckley Ave (San Bernardino County)
San Bernardino	Shadow Mountain Rd (San Bernardino County)
San Bernardino	Phelan Rd (San Bernardino County)
San Bernardino	Archibald Ave (Rancho Cucamonga)
San Bernardino	Vine Ave (Ontario)
San Bernardino	Sultana Ave (Ontario)
San Bernardino	Bon View Ave (Ontario)
San Bernardino	Olive St (San Bernardino)
San Bernardino	Alessandro Rd (Redlands)
Ventura	Route 118 (Ventura County)

County	Crossing Street
Riverside	Smith Ave (Corona)
Riverside	Railroad St (Corona)
Riverside	Cota St (Corona)
Riverside	Buchanan St (Riverside)
Riverside	Rutile St (Jurupa Valley)
Riverside	Harrison St (Riverside)
Riverside	Gibson St (Riverside)
Riverside	Jackson St (Riverside)
Riverside	Washington St (Riverside)
Riverside	Brockton Ave (Riverside)
Riverside	Apache Trail (Riverside County)
Riverside	Panorama Rd (Riverside)
Riverside	Cridge St (Riverside)
Riverside	Palmyrita Ave (Riverside)
Riverside	Center St (Riverside County)
Riverside	Main St (Riverside County)
Riverside	San Timoteo Canyon (Calimesa)
Riverside	Shetidan St (Corona)
Riverside	Pennsylvania Ave (Beaumont)
Riverside	7th St (Riverside)
Riverside	Broadway (Riverside County)
Riverside	Tipton Rd (Palm Springs)
Riverside	Ave 54 (Coachella)
Riverside	Ave 58 (Riverside County)

Source: SCAG

EXHIBIT 14 Los Angeles County Grade Separations – Constrained Plan



Number	Project*
1	Del Amo Blvd - Torrance
2	S.Wilmington Ave - Los Angeles
3	Reeves Ave - Long Beach
4	Valley View Ave - La Mirada
5	Passons Blvd - Pico Rivera
6	Greenwood - Montebello
7	Ramona St - San Gabriel
8	Mission Rd - San Gabriel
9	Del Mar Ave - San Gabriel
10	San Gabriel Blvd - San Gabriel
11	Baldwin Ave - El Monte
12	Durfee Ave - Pico Rivera
13	Puente Ave - Industry
14	Turnbull Cyn Rd - Los Angeles County
15	Fullerton Rd - Industry
16	Nogales St - Industry
17	Rosecrans Ave - Santa Fe Springs
18	Fairway Dr - Los Angeles County

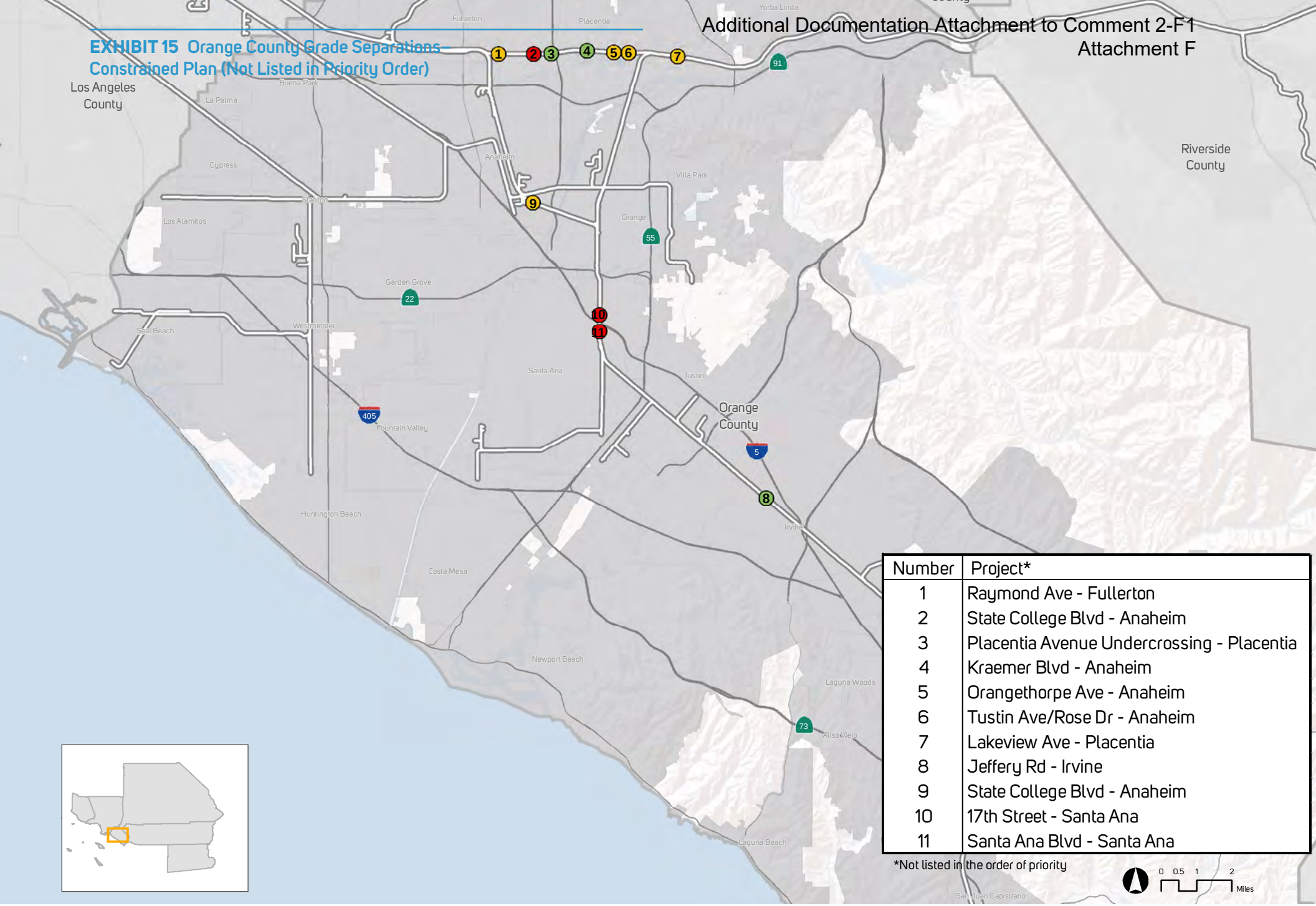
*Not listed in the order of priority

0 0.75 1.5 3 Miles

Constrained Plan Status (as of November 2015): Complete Under Construction Planned Regional Rail Lines

Source: SCAG

EXHIBIT 15 Orange County Grade Separations – Constrained Plan (Not Listed in Priority Order)



Number	Project*
1	Raymond Ave - Fullerton
2	State College Blvd - Anaheim
3	Placentia Avenue Undercrossing - Placentia
4	Kraemer Blvd - Anaheim
5	Orangethorpe Ave - Anaheim
6	Tustin Ave/Rose Dr - Anaheim
7	Lakeview Ave - Placentia
8	Jeffery Rd - Irvine
9	State College Blvd - Anaheim
10	17th Street - Santa Ana
11	Santa Ana Blvd - Santa Ana

*Not listed in the order of priority

0 0.5 1 2 Miles

Constrained Plan Status (as of November 2015): Complete · Under Construction · Planned · Regional Rail Lines

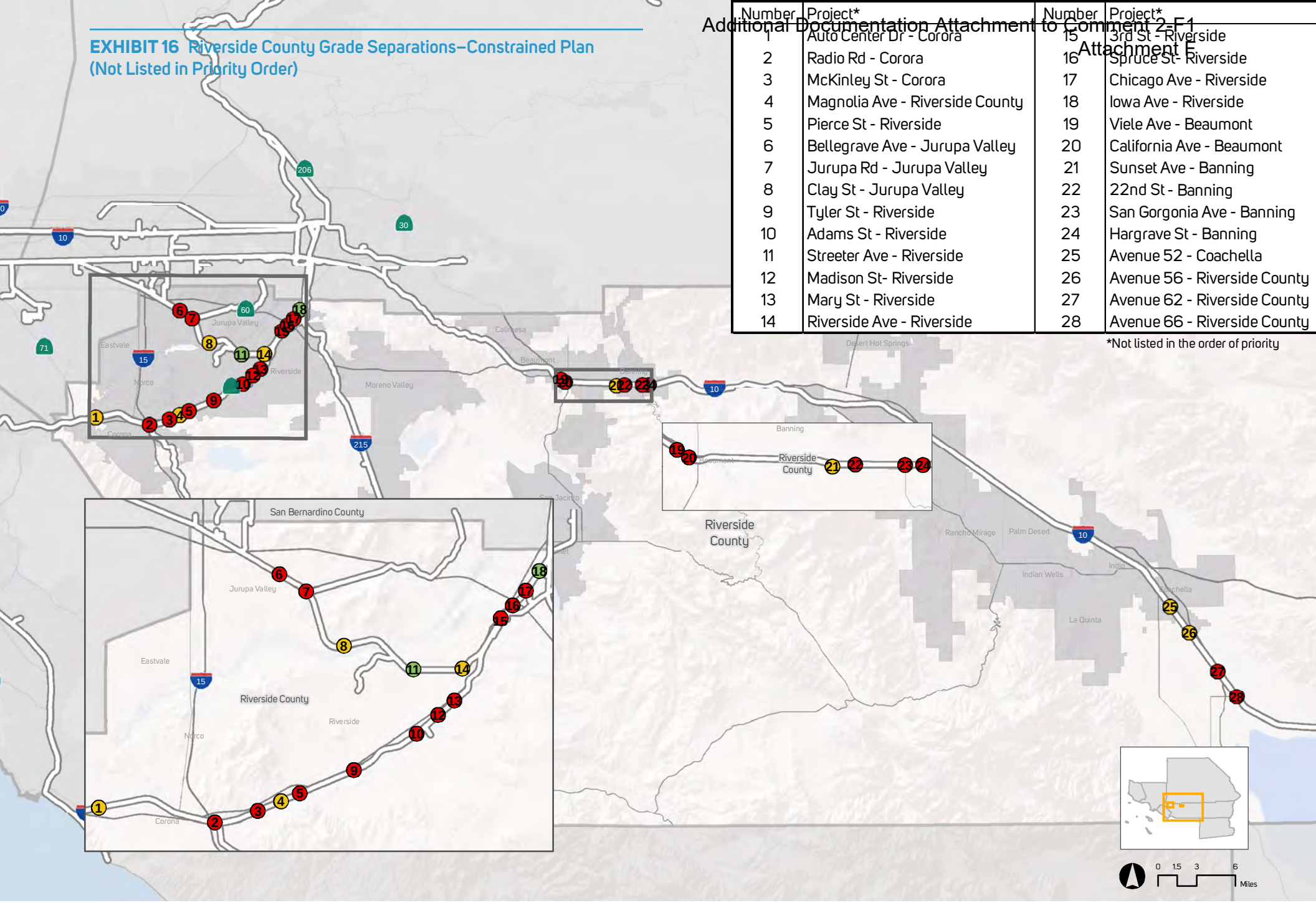
Source: SCAG

Additional Documentation Attachment to Comment 2-F1
Attachment F

EXHIBIT 16 Riverside County Grade Separations–Constrained Plan
(Not Listed in Priority Order)

Number	Project*	Number	Project*
1	Auto Center Dr - Corona	15	3rd St - Riverside
2	Radio Rd - Corona	16	Spruce St- Riverside
3	McKinley St - Corona	17	Chicago Ave - Riverside
4	Magnolia Ave - Riverside County	18	Iowa Ave - Riverside
5	Pierce St - Riverside	19	Viele Ave - Beaumont
6	Bellegrave Ave - Jurupa Valley	20	California Ave - Beaumont
7	Jurupa Rd - Jurupa Valley	21	Sunset Ave - Banning
8	Clay St - Jurupa Valley	22	22nd St - Banning
9	Tyler St - Riverside	23	San Gorgonia Ave - Banning
10	Adams St - Riverside	24	Hargrave St - Banning
11	Streeter Ave - Riverside	25	Avenue 52 - Coachella
12	Madison St- Riverside	26	Avenue 56 - Riverside County
13	Mary St - Riverside	27	Avenue 62 - Riverside County
14	Riverside Ave - Riverside	28	Avenue 66 - Riverside County

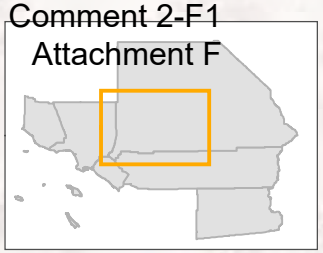
*Not listed in the order of priority



Constrained Plan Status (as of November 2015): Complete Under Construction Planned Regional Rail Lines

Source: SCAG

EXHIBIT 17 San Bernardino County Grade Separations–Constrained Plan (Not Listed in Priority Order)



Number	Project*
1	Lenwood Rd - San Bernardino County
2	Green Tree Blvd - San Bernardino County
3	Glen Helen Pkwy - San Bernardino County
4	Palm Ave - San Bernardino County
5	Mt. Vernon Ave - San Bernardino
6	Ramona Ave - Montclair
7	San Antonio Ave - Ontario
8	Campus Ave - Ontario
9	N. Vineyard Ave - Ontario
10	South Archibald Ave - Ontario
11	S. Milliken Ave - Ontario
12	Laurel St - Fontana
13	Main St - Grand Terrace
14	Hunts Ln - Colton
15	Central Ave - Montclair
16	Monte Vista Ave - Montclair
17	Eucalyptus St - Hesperia
18	Vista Rd - Hesperia
19	Lemon St/Mauna Loa St - San Bernardino County
20	Valley Blvd - Colton
21	N. Milliken Ave - Ontario
22	Beaumont Ave - Loma Linda

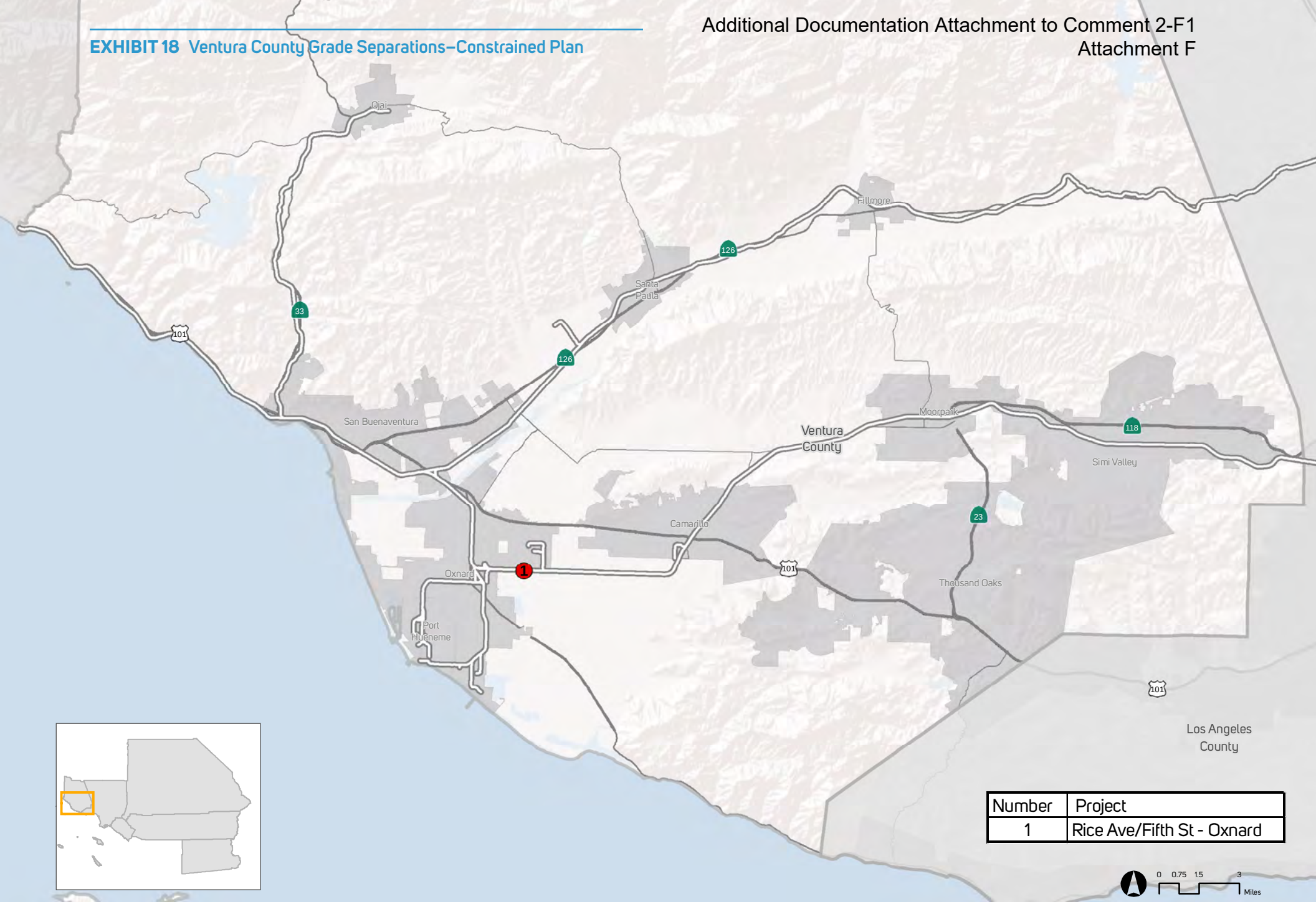
*not listed in the order of priority

0 1.5 3 6 Miles

Constrained Plan Status (as of November 2015): Complete | Under Construction | Planned | Regional Rail Lines

Source: SCAG

EXHIBIT 18 Ventura County Grade Separations–Constrained Plan



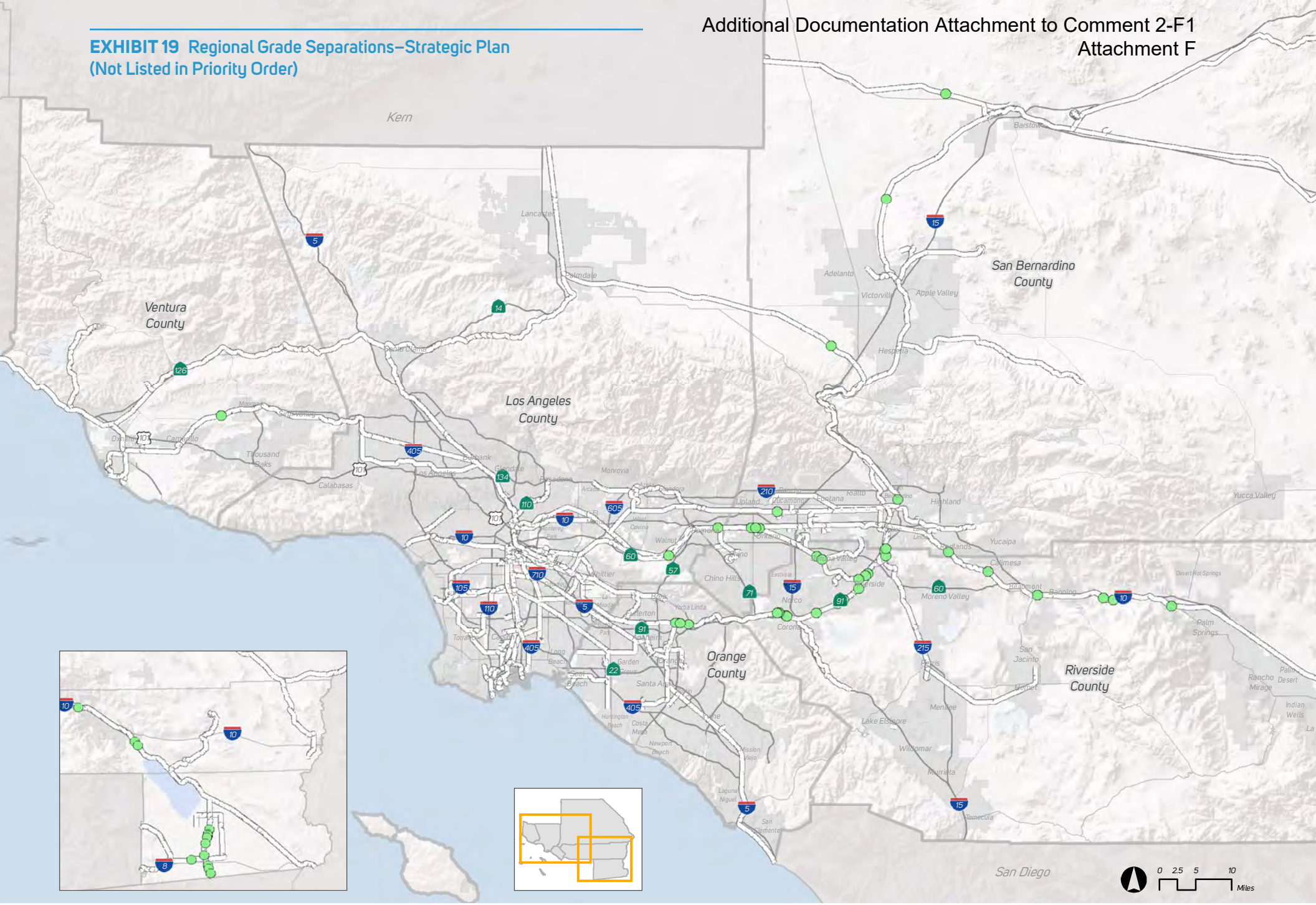
Number	Project
1	Rice Ave/Fifth St - Oxnard

0 0.75 1.5 3 Miles

Constrained Plan Status (as of November 2015): Planned Regional Rail Lines

Source: SCAG

EXHIBIT 19 Regional Grade Separations–Strategic Plan (Not Listed in Priority Order)



Regional Grade Seperations Identified under Strategic Plan (as of November 2015): ● *Grade Seperations* ∿ *Regional Rail Lines*

Source: SCAG

TABLE 19 Regional Goods Movement Project List

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
A. ROADWAY ACCESS TO MAJOR GOODS MOVEMENT FACILITIES				
A.1	Los Angeles	ROUTE 005: PHASE 1 OF 3-- IN SANTA CLARITA FROM ROUTE 14 TO PICO CANYON/LYONS AVENUE IN THE SOUTHBOUND DIRECTION AND FROM ROUTE 14 TO GAVIN CANYON ROAD IN THE NORTHBOUND DIRECTION. CONST TRUCK CLIMBING LANES. (EA 2332A, PPNO 3189), (SAFTETEA-LU#465 FUNDED PAED FOR THIS PHASE INCLUDED IN LA0G440).	$131,000	S
A.2	Los Angeles	ROUTE 005: PHASE 2,FROM SR-14 TO PARKER ROAD, CONSTRUCT HOV/ HOT, TRUCK & AUX LANES (EA 2332C, PPNO 3189A & EA 2332E PPNO 3189B), SAFTETEA-LU#465. PE & RW $ ARE PROGRAMMED FOR EA 2332E ONLY.	$46,877	S
A.3	Los Angeles	SR-47 EXPRESSWAY: REPLACEMENT OF SCHUYLER HEIM BRIDGE (Segment 1): ACTA completing PE, ROW, and Design Support during Construction; SAFETEA-LU #712 & #3797.	$91,583	S
A.3	Los Angeles	SR-47 EXPRESSWAY: CONSTRUCT 4 LANE EXPRESSWAY AND 2-LANE FLYOVER TO SCHUYLER HEIM BRIDGE	$420,000	L
A.4	Los Angeles	ROUTE 047: REPLACEMENT OF SCHUYLER HEIM BRIDGE TO INCLUDE 2 THRU LANES AND 1 AUX LANE NB; AND 3 THRU LANES AND 1 AUX LANE SB EA 13820, PPNO 0444E).	$278,993	S
A.5	Los Angeles	WIDEN AND RECONSTRUCT WASHINGTON BOULEVARD FROM WESTERN CITY BOUNDARY AT VERNON [350' WEST OF INDIANA STREET] TO I-5 FREEWAY AT TELEGRAPH RD., WIDEN FROM 2 LANES TO 3 LANES IN EACH DIRECTION, INCREASE TURN RADIUS AND MEDIANS, UPGRADE TRAFFIC SIGNALS AND STREET LIGHTING AND IMPROVE SIDEWALKS.	$32,000	S
A.6	Los Angeles	BRIDGE NO. 53C0065, OCEAN BLVD, OVER ENTRANCE CHANNEL, UP RR, 1.0 MI E STATE ROUTE 47. REPLACE EXISTING 5 LANE GERALD DESMOND BRIDGE (GDB) WITH NEW 6 LANE BRIDGE.	$1,288,101	S
A.7	Los Angeles	COMMERCE GOODS MOVEMENT ATLANTIC BOULEVARD: WASHINGTON BOULEVARD TO COMO STREET : (1) IMPLEMENTS SOUTHBOUND RIGHT-TURN OVERLAP SIGNAL PHASING FROM ATLANTIC BL ONTO WASHINGTON BL TO IMPROVE MOBILITY FOR TRUCKS AND VEHICLES. (2) STREETSCAPE IMPROVEMINTS, SUCH AS RAISED MEDIANS, CROSSING IMPROVEMENTS, AND SIDEWALK IMPROVEMENTS TO IMPROVE PEDESTRIAN SAFETY AND REDUCE PEDESTRIAN/VEHICLE CONFLICT.	$1,172	S
A.8	Los Angeles	OLYMPIC BL AND MATEO STREET GOODS MOVEMENT IMP-PHASE II. IMPROVEMENT OF FREEWAY ACCESS BY WIDENING WB OLYMPIC BL BET MATEO ST & SANTA FE AV FOR A RIGHT-TURN LANE, AND NB MATEO ST BET OLYMPIC BL & PORTER ST FOR INCREASED CURB RETURN.	$4,421	S

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TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
A.9	Los Angeles	AT I-110 NB AT JOHN S GIBSON BLVD NB RAMPS & NB SR-47/I-110 CONNECTOR. WIDEN SB 47 TO NB 110 CONNECTOR FROM 1 TO 2 LNS BEGIN AT SB 47 PM 0.72 (STATION 535+00) JUST W OF FRONT ST ON-RAMP. ADDL THROUGH LN CONTINUES ON NB 110 & ENDS JUST N OF THE J S GIBSON OFF-RAMP. WIDEN NB 110/J S GIBSON ON-RAMP TO IMPROVE ACCESS TO FWY & INTERSECTION OF J S GIBSON/110 NB RAMPS W/IMPROVED TURN RADII & RE-STRIPING.	$34,733	S
A. 10	Los Angeles	PROJECT WILL IMPROVE FLOW OF TRAFFIC FROM I-110 FWY ON/OFF-RAMPS AT C STREET BY CONSOLIDATING TWO CLOSELY SPACED INTERSECTIONS INTO ONE.	$23,980	S
A.11	Los Angeles	WB SR-60/SB SR-57 GRAND AVENUE OFF RAMP INTERCHANGE : ADD WB SR-60 AUXILIARY LANE FROM SB SR-57 TO GRAND AVENUE OFF-RAMP TO IMPROVE TRUCK MOBILITY AND REDUCE CONGESTION.	$21,303	M
	Los Angeles	RECONSTRUCT SR 60/GRAND AV INTERCHANGE - WIDEN GRAND AV: SB ADD 1THRU LN (2 EXSTNG); NB ADD 1 THRU LN (3 EXSTNG), REPLACE GRAND AV OC, ADD EB LOOP ON-RAMP, CONSTRUCT ADDITIONAL EB THRU LN FROM GRAND AVE TRAP LN TO SR57 ADD LN, ADD TWO BYPASS RAMP CONNECTORS, ADD AUX LANES EB AND WB FROM EAST TO WEST JUNCTION OF THE CONFLUENCE.	$257,900	S
A.12	Los Angeles	I-605 CORRIDOR "HOT SPOT" INTERCHANGES IN GATEWAY CITIES	$3,200,000	L
A.13	Los Angeles	I-710 EARLY ACTION PROJECTS	$711,600	M
A.14	Los Angeles	SR 47/NAVY WAY INTERCHANGE: CONSTRUCTION OF INTERCHANGE AT SR-47 / NAVY WAY TO ELIMINATE TRAFFIC SIGNAL AND MOVEMENT CONFLICTS; THIS PROJECT WAS A S.CA TRADE CORRIDOR TIER II TCIF PROJECT AS SUBMITTED TO THE CTC IN 2008; PROJECT REMOVES LAST SIGNAL ON SR 47 BETWEEN DESMOND AND V. THOMAS BRIDGES, NHS INTERMODEL CONNECTOR ROUTE	$57,593	M
A.15	Los Angeles	SR 47-V. THOMAS BRIDGE/FRONT ST INTERCHANGE: NEW WESTBOUND SR 47 ON- AND OFF-RAMPS AT FRONT STREET JUST WEST OF THE VINCENT THOMAS BRIDGE AND ELIMINATE THE EXISTING NON-STANDARD RAMP CONNECTION TO THE HARBOR BOULEVARD OFF-RAMP; FRONT STREET IS AN NHS CONNECTOR. THE PROJECT ALSO INCLUDES REALIGNED EASTBOUND AND WESTBOUND SR47 ON-RAMPS.	$37,285	M
A.16	Los Angeles	ALAMEDA STREET DOWNTOWN LA: GOODS MOVEMENT, PHASE I. THIS PROJECT WILL PROVIDE CONGESTION RELIEF, IMPROVE MOBILITY/REDUCE CONFLICTS, AND IMPROVE SAFETY FOR BOTH AUTOS AND TRUCKS BY PROVIDING INTERSECTION IMPROVEMENTS. PROJECT WILL ALSO REMOVE ABANDONED RAIL LINES, REPAIR PAVEMENT, ADD NEW STREET LIGHTING, AND CONSTRUCT PEDESTRIAN IMRPOVEMENTS.	$7,132	S

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TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
A.17	Los Angeles	ALAMEDA STREET WIDENING FROM ANAHEIM STREET TO 300 FT. SOUTH OF PCH : (1) WIDENS ALAMEDA ST BETWEEN ANAHEIM ST AND 300 FT SOUTH OF PACIFIC COAST HIGHWAY FROM 2 TO 3 LANES IN EACH DIRECTION FOR CONGESTION RELIEF AND IMPROVE GOODS MOVEMENT MOBILITY.	$9,709	S
A.18	Los Angeles	ANAHEIM STREET WIDENING - FARRAGUT AVENUE TO DOMINGUEZ CHANNEL : WIDEN ANAHEIM ST BETWEEN FARRAGUT AV AND DOMINGUEZ CHANNEL FROM 2 TO 3 LANES IN EACH DIRECTION FOR CONGESTION RELIEF AND IMPROVE GOODS MOVEMENT MOBILITY. THIS UPGRADES THE ARTERIAL TO MAJOR HIGHWAY STANDARDS.	$6,566	S
A.19	Los Angeles	PHASE 2 AND 3 OF 3: IN LA/SANTA CLARITA: PHASE 2: CONSTRUCT HOV LANE NORTHBOUND FROM ROUTE 14 TO WELDON CANYON RD; PHASE 3: CONSTRUCT HOV, TRUCK, & AUX LANES FROM SR-14 TO PARKER RD OC.	$410,000	S
A.20	Los Angeles	HARBOR BLVD IMPROVEMENTS - AS PART OF THE SAN PEDRO WATERFRONT DEVELOPMENT PROJECT, HARBOR BLVD WILL BE RESTRIPED, AND THE MEDIAN IS REMOVED/RECONSTRUCTED AS NEEDED TO PROVIDE THREE NBT AND SBT LANES BETWEEN THE RECONSTRUCTED SAMPSON WAY/HARBOR BLVD. INTERSECTION AND THE WB ON RAMP/FRONT STREET INTERSECTION. THIS WILL RESULT IN THE REMOVAL OF PARKING AND THE BIKE LANE ON THE NORTHBOUND SIDE. THE PARKING AND 5' BIKE LANE ON THE SOUTHBOUND SIDE, SOUTH OF O'FARRELL STREET WILL BE PRESERVED. NORTH OF O'FARRELL STREET, THE PARKING AND THE PARKING LANE ON THE SOUTHBOUND SIDE WOULD NEED TO BE REMOVED TO ACCOMMODATE THE NORTHBOUND DUAL LEFT-TURN LANE. THE INNERMOST NORTHBOUND THROUGH LANE AT THE EB OFF-RAMP INTERSECTION WOULD BECOME A FORCED LEFT-TURN LANE AT THE SR 47 WB ON-RAMP. THIS IMPROVEMENT IS PROJECTED TO BE NEEDED BY THE YEAR 2024.	$1,134	M
A.21	Los Angeles	HARBOR BLVD. & 7TH STREET INTERSECTION- THE PROJECT INCLUDES A RECONFIGURED INTERSECTION AT THE JUNCTION OF HARBOR BLVD, SAMPSON WAY, AND 7TH STREET. WORK INCLUDES RETAINING WALL, STREET WORK, GRADING, PAVING, LIGHTING, RESTRIPING AND A NEW SIGNALIZED INTERSECTION.	$15,905	S
A.22	Los Angeles	SAMPSON WAY TO 22ND STREET & MINER STREET - SAMPSON WAY WOULD BE REALIGNED AND EXPANDED TO TWO LANES IN EACH DIRECTION AND WOULD CURVE NEAR THE MUNICIPAL FISH MARKETS TO MEET WITH 22ND STREET IN ITS WESTWARD ALIGNMENT EAST OF MINER STREET. IN THE PROPOSED PROJECT, HARBOR BLVD. WOULD REMAIN IN PLACE AT ITS CURRENT CAPACITY WITH TWO LANES IN EACH DIRECTION. PROPOSED ENHANCEMENTS WOULD BE CONSISTENT WITH DESIGN STANDARDS FOR THE COMMUNITY REDEVELOPMENT AGENCY (CRA) PACIFIC CORRIDOR AND THE CITY OF LOS ANGELES PLANNING DEPARTMENT COMMUNITY DESIGN OVERLAY. ALIGNMENT EAST OF MINER STREET.	$34,614	M

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TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
A.23	Los Angeles	ALAMEDA CORRIDOR SOUTH TERMINUS/HENRY FORD AVE. RAIL CROSSING ADVANCED WARNING SYSTEM.	$5,000	M
A.24	Los Angeles	PIER B STREET FREIGHT CORRIDOR RECONSTRUCTION : (1) REALIGNS PIER B ST BETWEEN PICO AV AND PIER A WY AND WIDENS INTO 2 LANES IN EACH DIRECTION TO IMPROVE GOODS MOVEMENT MOBILITY AND ENHANCE PEDISTRIAN TRAVEL. (2) CONSTRUCTS NEW SIDEWALK ON THE SOUTH SIDE OF PIER B ST. (3) CONSTRUCTS J-HOOK FLYOVER TO CONNECT PIER B ST WITH ANAHEIM ST.	$105,791	S
A.25	Orange	SR-57 FROM LAMBERT TO LA COUNTY LINE - ADD 1 NB TRUCK CLIMBING LANE (PE ONLY)(PPNO 3847A)	$124,600	L
A.26	Orange	ADD ONE MF LANE ON N/B SR-57 FROM 0.4 MI N/O SR-91 TO 0.1 MI N/O LAMBERT RD (5.1 MILES) EA 0F0321 (YORBA LINDA TO LAMBERT SEGMENT) SPLIT PROJECT WITH ORA120332	$50,550	COMPLETE
A.27	Orange	ADD ONE MF LANE ON N/B SR-57 FROM 0.4 MI N/O SR-91 TO 0.1 MI N/O LAMBERT RD (5.1 MILES) EA 0F0311 (SR91/ORANGETHORPE TO YORBA LINDA SEGMENT) SPLIT PROJECT WITH ORA081901	$49,828	COMPLETE
A.28	Orange	CONNECT EXISTING AUXILIARY LANE THROUGH INTERCHANGES ON WB SR-91 BETWEEN SR-57 AND I-5 WITH ITS ELEMENTS PPNO 4516A EA 0C5700	$65,677	S
A.29	Orange	SR-91: ADD 1 MF LANE E/B BTWN 91/55 CONNECTOR & SR-241 -- W/B BTWN SR-241 & IMPERIAL HWY; MODIFY W/B ON RAMPS FROM LAKEVIEW AVE TO IMPRV MERGE (ADD AUX LANE BETWEEN NB 55 - TO - EB 91 ON-RAMP AND LAKEVIEW OFF RAMP). PROJECT SPLIT PARENT	$85,986	COMPLETE
A.30	Orange	ADD 1 ML LANE EACH DIRECTION (I5 FROM 57 TO 91)	$305,924	L
A.31	Orange	SR-91 WB (SR-55 THROUGH TUSTIN INTERCHANGE) EXTEND LANE AND RECONSTRUCT AUX. LANE. PPNO 4587A EA 0C560)	$46,270	S
A.32	Orange	EXIST 4 MF N/B; WIDEN TO 5 MF LANES N/B FROM 0.3 MI S/O KATELLA TO 0.3 MI N/O LINCOLN (2.92 MILES) -- 0F0400	$41,086	COMPLETE
A.33	Orange	ADD 1 MF LANE EACH DIRECTION FROM I-5 TO SR-55 AND ADD SB AUX LANES FROM 133 TO IRV CTR DR	$424,620	L
A.34	Orange	I-405 FROM SR-73 TO I-605 ADD 1 MF LANE IN EACH DIRECTION, AND ADDITIONAL CAPITAL IMPROVEMENTS. COMBINED WITH ORA045, ORA151, ORA100507 AND ORA120310. PHASE 1 PROJECT LISTED UNDER ORA030605.	$1,300,000	M

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TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
A.35	Orange	I-5 (I-405 TO SR-55) - IN THE CITIES OF IRVINE AND TUSTIN. ADD 1 MF LANE NB FROM TRUCK BYPASS ON RAMP TO SR-55, ADD 1 MF LANE SB FROM SR-55 TO ALTON AND 1 AUX LANE FROM ALTON TO TRUCK BYPASS. (PA&ED AND PS&E PHASE) PROJECT WILL UTILIZE $917,600 TOLL CREDIT MATCH.	$452,000	M
A.36	Orange	ADD 1 MF LANE EB FROM 55 TO 57, AND 1 MF LANE WB FROM KRAEMER TO STATE COLLEGE; IMPROVE INTERCHANGES; AND ADD AUX LANES.	$481,827	L
A.37	Orange	ADD 1 LANE EACH DIRECTION FROM SR 241 TO COUNTY LINE, AND OTHER OPERATIONAL IMPROVEMENTS. SEE RIVERSIDE COUNTY FOR ADDITIONAL DETAILS.	Included in RIV071250B	L
A.38	Riverside	ON I-10 NEAR BEAUMONT: ADD/CONSTRUCT NEW EASTBOUND TRUCK CLIMBING LANE FROM SAN BERNARDINO COUNTY LINE TO 1-10/SR60 JCT (EA: 35300)	$35,709	M
A.39	Riverside	ON SR-60 NEAR BEAUMONT: CONSTRUCT NEW EASTBOUND AND WESTBOUND TRUCK LANES FROM GILMAN SPRINGS RD TO 1.47 MILES WEST OF JACK RABBIT TRAIL AND UPGRADE EXISTING INSIDE AND OUTSIDE SHOULDERS TO STANDARD WIDTHS (10-FT INSIDE SHOULDER AND 10-FT OUTSIDE SHOULDER) (EA: 0N69U) - CMAQ PM2.5 BENEFITS PROJECT. $802.9 TC WILL BE UTILIZED FOR CMAQ ENG IN FY 14/15	$126,282	S
A.40	Riverside	CONSTRUCT NEW INTERCHANGE	$282,443	L
A.41	Riverside	ON VAN BUREN BLVD NEAR MARCH AIR RESERVE BASE: WIDEN FROM 4 TO 6 LANES FROM APPROXIMATELY 0.5 MILES WEST OF I-215 TO BARTON ST	$6,700	COMPLETE
A.42	Riverside	CONSTRUCT NEW IC AND RAMPS AND WIDEN OC FROM 2 TO 6 LANES	$67,863	L
A.43	Riverside	WIDEN FROM 2 TO 6 LANES	$68,423	L
A.44	Riverside	CONSTRUCT 4 LANE BRIDGE/INTERCHANGE AND RAMPS ACROSS SR-86S	$92,843	L
A.45	Riverside	RECONSTRUCT/WIDEN IC FROM 2 TO 4 LANES AND RECONSTRUCT/WIDEN RAMPS	$26,851	M
A.46	Riverside	ON SR-91/I-15: SR91 - ADD 1 MFL EA DIR (SR241-SR71)(I15-PIERCE); I15 - ADD TEL MED DIR CONNCT SB15 TO WB91 & EB91 TO NB15, 1 TEL EA DIR HIDDEN VALLEY-SR91 DIR CONNCT.	$404,847	M
A.47	Riverside	AT SR86S/AVENUE 52: WIDEN AND CONSTRUCT NEW 6 THROUGH LANE IC FROM E/O COACHELLA STORMWATER CHANNEL BRIDGE TO E/O TYLER ST. IMPROVEMENTS INCLUDE: REALIGN POLK ST AND RELOCATE AVE 52 AND POLK ST INTERSECTION, EXTENDED RAMP ACCELERATION/DECELERATION LANES, BIKE LANES, SIDEWALKS, AND RECONSTRUCT TRAFFIC SIGNALS (EA: OC960).	$33,000	M

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TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
A.48	Riverside	AT SR86S/AVENUE 50: WIDEN AND CONSTRUCT NEW 6THROUGH LANE IC FROM E/O COACHELLA STORMWATER CHANNEL BRIDGE TO E/O TYLER ST. IMPROVEMENTS INCLUDE: EXTENDED RAMP ACCELERATION/DECELERATION LANES, RELOCATE/REALIGN AVE 50 AND TYLER ST, BIKE LANES, SIDEWALKS, SIDEWALKS, AND RECONSTRUCT TRAFFIC SIGNALS (SAFETEA LU 1702, CA583, #2543)(EA:0C970)	$32,160	S
A.49	Riverside	IN WESTERN RIVERSIDE COUNTY IN THE CITY OF MORENO VALLEY ALONG SR 60 - WIDEN FROM TWO TO THREE LANES IN EACH DIRECTION IN THE EXISTING MEDIAN TO PROVIDE ONE ADDITIONAL GENERAL PURPOSE LANE IN EACH DIRECTION FROM REDLANDS BLVD. TO GILMAN SPRINGS RD.	$7,500	M
A.50	San Bernardino	I-10 AT CEDAR AVE. BETWEEN SLOVER AND VALLEY- RECONSTRUCT I/C-WIDEN FROM 4-6 LANES WITH LEFT AND RIGHT TURN LANES. ADD AUX LANE ON E/B ON AND OFF RAMPS	$62,930	S
A.51	San Bernardino	I-10 TIPPECANOE RECONFIGURE INTERCHANGE & LOCAL RD IMP/MOD (HP 1366)(WESTBOUND - PHASE II)(FORMERLY PART OF RTP ID 44810)	$57,358	COMPLETE
A.52	San Bernardino	SR210 LANE ADDITION - ADD 1 MIXED FLOW LANE IN EACH DIRECTION FROM HIGHLAND AVE(S/B). TO LUGONIA (REDLANDS) INCLUDES AUX. LANES BETWEEN BASE LINE AND 5TH STS AND AN ACCELERATION LANE AT 5TH ST. E/B ON RAMP AND DECELRATION LANE AT HIGHLAND AVE E/B OFF RAMP. (UNDER 1/4 MILES LENGTH)	$134,267	M
A.53	San Bernardino	I-10 AT GROVE INTERCHANGE AND GROVE AVE. CORRIDOR - RELOCATE I/10 & 4TH ST. I/C TO GROVE AVE. AND WIDEN GROVE AVE BETWEEN I-10 TO HOLT (4-6 LNS); WIDEN GROVE AVE FROM STATE ST TO 350 FT N OF HOLT BLVD INCLUDING RR BRDGE(4-6 LNS); LEFT TURN LANES AT HOLT.	$13,034	M
A.54	San Bernardino	I-10/CHERRY AVENUE INTERCHANGE - INTERCHANGE RECONSTRUCT - REPLACE O/C, WIDEN O/H AND WIDEN I/C FROM SLOVER TO VALLEY FROM 4-6 LANES WITH DOUBLE LEFT TURNS TO RAMPS	$76,114	COMPLETE
A.55	San Bernardino	I-15/I-215 I/C IMPROVMTS-DEVORE I/C S/O GLEN HELEN PARKWY TO N/O KENWOOD & I-215 FROM S/O DEVORE RD. I/C TO I-15 (16.0-17.8) ADD 1 M/F LN IN EA DIR TO EXISTG 3 M/F LNS FROM 3800 FT S/O GLEN HELEN PARKWY TO 3100 FT N/O I-215 I/C ADD 1 DECEL LN FROM 3200 FT S/O 15/216I/C OFFRMP TO S/B DEVORE ON I-215. CONSTRUCT TRUCK BYPASS LNS.	$324,669	S
A.56	San Bernardino	SR-60 AT ARCHIBALD AVENUE WIDEN ON AND OFF RAMPS (2-3 LANES EACH WAY)	$7,900	M
A.57	San Bernardino	WIDEN 5TH ST FROM CITY CRK TO SR210; RESTRIPE 5TH ST FROM 4-6LNS BTW CHURCH AVE & SR210; RESTRIPE 210 UNDERCROSSING 4-5LNS BTW RAMPS WITH ADD. TURN LN. CONSTRUCT TRUCK ACCL. LN ON SB SR210 ON-RAMP AND FWY MAINLINE INCLUDING WIDENING OF EXISTING FWY BRIDGE	$5,070	S

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TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
A.58	San Bernardino	I-10/PEPPER IC: WIDEN BRIDGE FROM FIVE TO SIX LANES TO PROVIDE FOR ONE ADDITIONAL SOUTHBOUND TURN LANE AND ADD AUXILIARY LANES TO FREEWAY	$39,815	S
A.59	San Bernardino	I-10 @ MT VERNON AVE INTERCHANGE IMPROVEMENTS	$37,125	M
A.60	San Bernardino	I-10/MOUNTAIN VIEW AVE INTERCHANGE IMPROVEMENTS	$82,889	L
A.61	San Bernardino	ON I-10 ADD/CONSTRUCT NEW EASBOUND TRUCK CLIMBING LANE FROM LIVE OAK CANYON ROAD TO SINGLETON RD INCLUDING TRANSITION BETWEEN COUNTY LINE AND CALIMESA BLVD	$50,024	M
A.62	San Bernardino	I-10 @ CALIFORNIA ST INTERCHANGE IMPROVEMENTS	$73,137	L
A.63	Ventura	GROUPED PROJECTS FOR PAVEMENT RESURFACING AND/OR REHABILITATION - LOCAL STREETS & ROADS SCOPE: PROJECTS ARE CONSISTENT WITH 40 CFR PART 93.126 EXEMPT TABLES 2 CATEGORIES - PAVEMENT RESURFACING AND/OR REHABILITATION, EMERGENCY RELIEF (23 U.S.C. 125), WIDENING NARROW PAVEMENTS OR RECONSTRUCTING BRIDGES (TO ADD TRAVEL LANES)	$31,167	S
A.64	Ventura	HUENEME RD FROM OXNARD CITY LIMITS TO RICE RD - WIDEN FROM 2 TO 4 LANES	$6,953	M
A.65	Ventura	IN OXNARD HUENEME RD SAVIERS TO ARCTURUS WIDEN AND CONSTRUCT FROM 2 TO 4 LANES (SAFETEA-LU PROJECT #735'TIP')	$2,924	S
A.66	Ventura	IN OXNARD AT RICE AVE (SANTA CLARA) RECONSTRUCT INTERCHANGE (T21-#664) (SAFETEA-LU #1565) (SAFETEA-LU #2639 AND 'TIP') (TCSP - 2010 APPROP EARMARK)	$83,997	COMPLETE
A.67	Imperial	WIDEN AND IMPROVE TO 6 LANE FREEWAY WITH INTERCHANGES AT HEBER, MCCABE, AND JASPER AND OVERPASS AT CHICK RD.	$999,136	L
A.68	Imperial	EXPANSION OF THE CALEXICO EAST PORT OF ENTRY - THE PROPOSED PROJECT IS TO INCREASE THE NUMBER OF COMMERCIAL VEHICLE INSPECTION LANES AND BOOTHS FROM EXISTING 3 TO 6 LANES AND BOOTHS; AND WIDEN BRIDGE OVER THE ALL-AMERICAN CANAL (CANAL SERVES AS U.S./MEXIC	$90,000	L
SUBTOTAL - ROADWAY ACCESS TO MAJOR GOODS MOVEMENT FACILITIES			$14,025,890	

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TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
B. FREIGHT CORRIDOR SYSTEM				
B.1	Los Angeles	I-710 CORRIDOR USER-FEE BACKED CAPACITY ENHANCEMENT - WIDEN TO 5 MIXED FLOW + 2 DEDICATED LANES FOR CLEAN TECHNOLOGY TRUCKS (EACH DIRECTION) AND INTERCHANGE IMPROVEMENTS, FROM OCEAN BLVD IN LONG BEACH TO THE INTERMODAL RAILROAD YARDS IN COMMERCE/VERNON	$5,110,000	M
B.2	Various	EAST-WEST FREIGHT CORRIDOR SEGMENT 1 (FROM I-710 TO JUST WEST OF I-605)	$2,413,086	L
B.3	Various	EAST-WEST FREIGHT CORRIDOR SEGMENT 2 (FROM JUST WEST OF I-605 TO JUST EAST OF SR-57)	$9,102,359	L
B.4	Various	EAST-WEST FREIGHT CORRIDOR SEGMENT 3 (FROM JUST EAST OF SR-57 TO I-15)	$3,777,816	L
B.5	Various	I-15 FREIGHT CORRIDOR (INITIAL SEGMENT) (SR-60 TO I-10)	$856,570	L
SUBTOTAL - FREIGHT CORRIDOR SYSTEM			$21,259,831	
C. ZERO-EMISSION TECHNOLOGY				
NA	Los Angeles	LOS ANGELES REGIONAL DIESEL EMISSIONS REDUCTION PROGRAM FOR ENGINE RETROFIT PROVIDES INCENTIVE GRANTS TO OWNER OPERATORS OLD DIESEL TRUCKS TO UPGRADE EQUIPMENT TO REDUCE EMISSIONS	$449	S
NA	Los Angeles	EXPAND DIESEL EMISSIONS REDUCTION PROGRAM OF GATEWAY CITIES COG	$2,676	S
NA	Various	ZERO-EMISSION GOODS MOVEMENT	$3,000,000	L
SUBTOTAL - ZERO EMISSION TECHNOLOGY			$3,003,125	
D. OFF DOCK AND NEAR DOCK INTERMODAL YARD PROJECTS				
D.1	San Bernardino	TRACK AND INTERMODAL YARD IMPROVEMENTS (PHASES 1 THROUGH 4)	$799,616	L
D.2		SCLA RAIL SERVICE FROM AIR EXPRESSWAY APPROX. 5 MILES NO TO COLUSA RD. BETWEEN PHANTOM EAST & MOJAVE RIVER-PUT IN NEW RAIL LINE FROM BNSF TO SCLA.(FOR FREIGHT)PROJECT IN CONNECTION WITH NEW INTERMODAL/MULTIMODAL FACILITY ON SCLA PROPERTY	$250,000	S
D.3	Los Angeles	INTERMODAL FACILITIES (SCIG/ICTF)	$1,000,000	S
SUBTOTAL - OFF DOCK AND NEAR DOCK INTERMODAL YARD PROJECTS			$2,049,616	

** Note: Map ID refers to maps in 2016 RTP/SCS Goods Movement Appendix (pgs. 74 to 77)*
*** Note: Short-term (S) (2012-2020); Medium-term (M) (2020-2030); Long-term (L) (2030-2040+)*

TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
E. MAINLINE RAIL				
"E.1-A to E.1-N"	Various	"Rail package — mainline rail capacity expansion: Barstow to Keenbrook–BNSF San Bernardino Subdivision; Colton Crossing to Redondo Junction–UP Mojave Subdivision; Devore Road to West Colton (inc. Rancho Flying Junction)–UP Alhambra Subdivision; West Colton to City of Industry–UP Los Angeles Subdivision; UP Yuma Subdivision."	$3,092,400	-
E.2	San Bernardino	· Colton Crossing: in Colton from 0.2 miles (0.3 KM) west of Rancho Avenue to 0.9 miles (1.5 KM) east of La Cadena Drive; construct railroad to railroad grade separation; (Cost included in the Rail package - mainline rail capacity expansion).	$201,994	COMPLETE
E.3	Orange	· BNSF Line - 10 miles of triple track from Fullerton to Orange/Riverside County line; (Same as Atwood to Fullerton and Esperanza to Fullerton); (Cost included in the Rail package - mainline rail capacity expansion).	$70,000	L
SUBTOTAL - MAINLINE RAIL			$3,364,394	

** Note: Map ID refers to maps in 2016 RTP/SCS Goods Movement Appendix (pgs. 74 to 77)*
*** Note: Short-term (S) (2012-2020); Medium-term (M) (2020-2030); Long-term (L) (2030-2040+)*

TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
F. ON-DOCK RAIL				
-	Los Angeles	**PORT OF LOS ANGELES**		
F.1 - LA		WBCT On-Dock Rail: Addition of 2 new loading tracks	$806,021	
F.2 - LA		YTI On-Dock Rail: Addition of 1 new loading track		
F.3 - LA		Pier 400 Rail Expansion-Phase 1		
F.4 - LA		Pier 300 Rail Expansion: Addition of 2 new loading tracks		
F.5 - LA		Seaside Yard: Dedicated on-dock rail yard for Berth 226-236 terminal (Evergreen)		
F.6 - LA		Terminal Island Support Yard		
F.7 - LA		Berth 200 Railyard Expansion: Additional Storage/working tracks		
F.8 - LA		Evergreen/TICTF - adding 1 new loading track		
F.9 - LA		Port of LA Container Movement Enhancement Program: WBCT wharf improvements, YTI wharf improvements, Pier 300 wharf improvements, and Evergreen/STS wharf improvements		
F.10 - LA		Pier 400 Second Lead Track		
-		**PORT OF LONG BEACH**		
F.1 - LB		Pier G South Working Yard Rehabilitation.	$316,500	
F.2 - LB		Middle Harbor Terminal Rail Yard (3 Phases).		
F.3 - LB		Pier A On-Dock Rail Yard Expansion To Carrack.		
F.4 - LB		Pier A On-Dock Rail Yard East of Carrack.		
F.5 - LB		Pier G Metro Track Improvements.		
SUBTOTAL - ON-DOCK RAIL			$1,122,521	

** Note: Map ID refers to maps in 2016 RTP/SCS Goods Movement Appendix (pgs. 74 to 77)*
*** Note: Short-term (S) (2012-2020); Medium-term (M) (2020-2030); Long-term (L) (2030-2040+)*

TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
G. RAIL ACCESS IMPROVEMENTS TO PORT OF LONG BEACH & PORT OF LOS ANGELES				
G.1 - LA	Los Angeles	PORT TRUCK TRAFFIC REDUCTION PROGRAM: WEST BASIN RAILYARD. INTERMODAL RAILYARD CONNECTING PORT OF LA WITH ALAMEDA CORRIDOR TO ACCOMMODATE INCREASED LOADING OF TRAINS AT THE PORT, THEREBY REDUCING TRUCK TRIPS TO OFF-DOCK RAILYARDS.(LAF5204)		S
	Los Angeles	PORT OF LOS ANGELES RAIL EFFICIENCY PROGRAM (ALAMEDA CORRIDOR-WEST BASIN AREA GAP CLOSURES) THIS PROJECT WILL ELIMINATE TWO SHORT GAPS IN TRACKAGE BETWEEN THE WEST BASIN AREA OF THE PORT OF LOS ANGELES AND THE ALAMEDA CORRIDOR (INCREASING THE NUMBER OF TRACKS FROM ONE TO TWO IN THIS AREA). THIS DOESN'T CHANGE ANY ON-DOCK RAILYARD CAPACITY ASSUMPTIONS, AND THUS DOESN'T CHANGE ANY PROJECTIONS OF TRAIN OR TRUCK VOLUMES IN THE RTP. THE PROJECT HOWEVER DOES REDUCE TRAIN DELAYS AND IDLING.		
G.2 - LB	Los Angeles	Pier B Street Realignment - Pier B Street Intermodal Railyard Expansion. Project will expand Pier B Street Intermodal Railyard to facilitate additional rail shipments and realign and widen Pier B Street.		M
G.3 - LB	Los Angeles	Pier F Support Yard - this project provides storage tracks on the Pier F Road cul-de-sac, which are useful for support functions such as set out of bad order rail cars and possibly engine tie-up.		S
G.4 - LB	Los Angeles	Track Realignment at Ocean Blvd - this project will create improved lead tracks to the Metropolitan Stevedoring Co. (Metro) rail yard and to Pier F on-dock rail yard.	$1,076,625	S
G.5 - LB	Los Angeles	Terminal Island Wye Track Realignment - this project will provide for double tracking the south leg of the Wye to accommodate simultaneous train switching moves from these various activities on Terminal Island.		S
G.6 - LB	Los Angeles	Reconfiguration of Control Point (CP) Mole - the new control point at the Mole will enable increased train speeds and reduced train delays caused by manual switch operations.		S
G.7 - LB	Los Angeles	Navy Mole Road Storage Yard - the proposed project includes three new tracks along the west side of Pier T. This project will also involve relocating the existing utilities.		S
G.8 - LB TO G.9 - LB	Los Angeles	Pier B Rail Yard (Phase III - 12th Street Alternative) expansion of Pier B Street intermodal railyard.		M
G.10 - LB	Los Angeles	New Cerritos Channel Rail Bridge		L
G.11 - LB	Los Angeles	TRIPLE TRACK S/O THENARD		L
SUBTOTAL - RAIL ACCESS IMPROVEMENTS TO PORT OF LONG BEACH & PORT OF LOS ANGELES			$1,076,625	

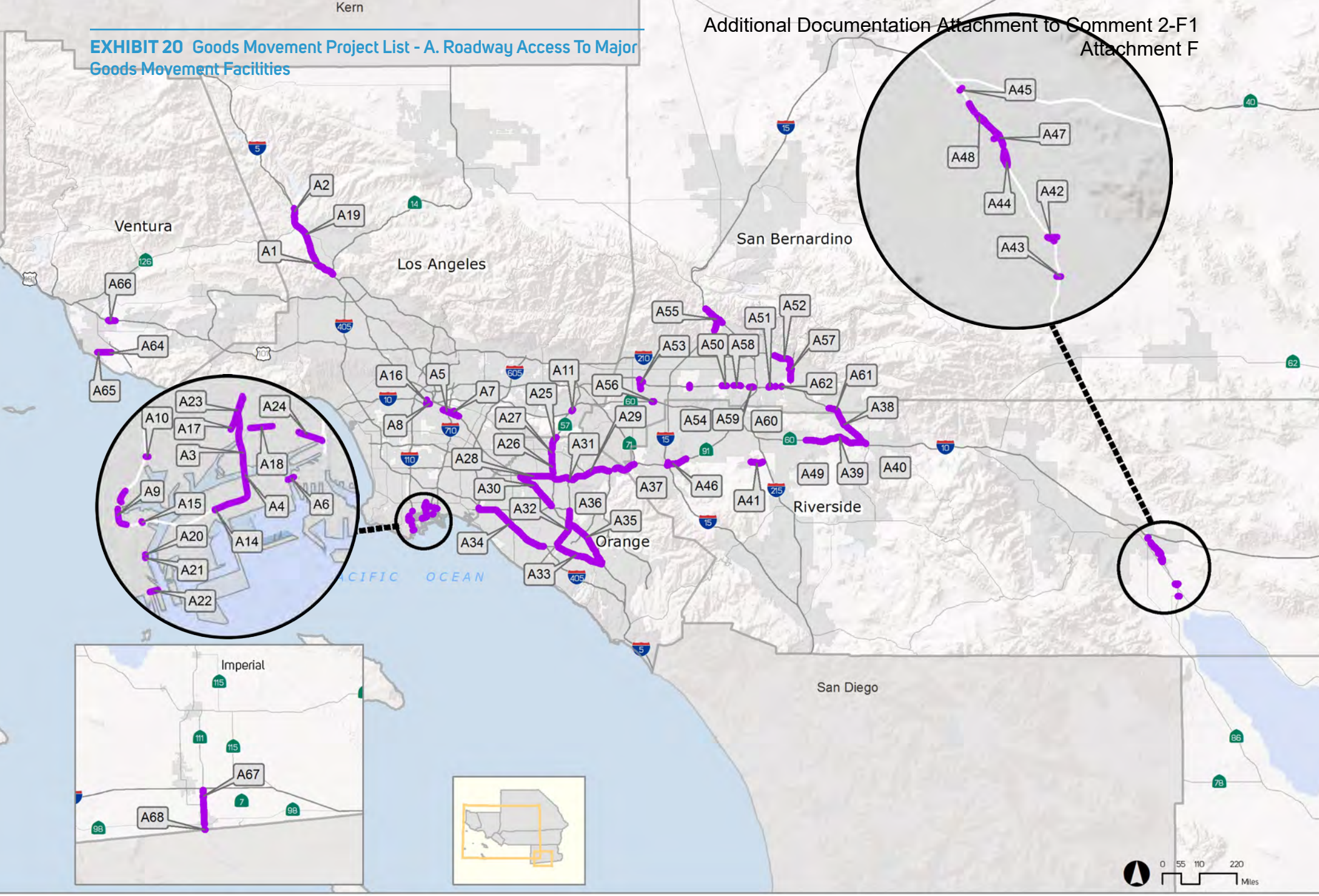
** Note: Map ID refers to maps in 2016 RTP/SCS Goods Movement Appendix (pgs. 74 to 77)*
*** Note: Short-term (S) (2012-2020); Medium-term (M) (2020-2030); Long-term (L) (2030-2040+)*

TABLE 19 Regional Goods Movement Project List Continued

Map ID	County	Project Description	Project Cost ($YOE, Thousands)	Timeframe (Short, Medium, Long)
H. RAIL-HIGHWAY GRADE SEPARATIONS				
SEE EXHIBITS B1 THROUGH B5	Various	RAIL PACKAGE- GRADE SEPARATIONS. (SEE DETAILED LIST) * Note: the total includes the non-goods movement grade separation total of $334,753,000	$4,795,109	S
SUBTOTAL - RAIL-HIGHWAY GRADE SEPARATIONS			$4,795,109	
I. BOTTLENECK RELIEF PROJECTS				
I.1-I.22	Various	GOODS MOVEMENT - BOTTLENECK RELIEF STRATEGY	$5,000,000	L
SUBTOTAL - BOTTLENECK RELIEF PROJECTS			$5,000,000	
J. FUTURE INITIATIVE THAT COULD SERVE GOODS MOVEMENT				
J.1	"Los Angeles/ San Bernardino"	HIGH DESERT CORRIDOR - CONSTRUCT NEW 4-6 LANE FACILITY: EAST-WEST FACILITY BETWEEN SR-14 AND US-395 (CONNECTING AT SAN BERNARDINO COUNTY); EAST-WEST FACILITY BETWEEN I-5 AND SR-14; AND NORTH-SOUTH FACILITY BETWEEN SR-14 AND SR-138. (INCLUDES Project IDs 1122004 & LA962212)	$5,000,000	L
NA	Various	GOODS MOVEMENT - ITS STRATEGY	$3,000,000	L
NA	Various	FREIGHT ARTERIAL O&M	$7,000,000	L
SUBTOTAL - FUTURE INITIATIVE THAT COULD SERVE GOODS MOVEMENT			$15,000,000	
TOTAL GOODS MOVEMENT PROJECTS			$70,697,111	

** Note: Map ID refers to maps in 2016 RTP/SCS Goods Movement Appendix (pgs. 74 to 77)*
*** Note: Short-term (S) (2012-2020); Medium-term (M) (2020-2030); Long-term (L) (2030-2040+)*

EXHIBIT 20 Goods Movement Project List - A. Roadway Access To Major Goods Movement Facilities

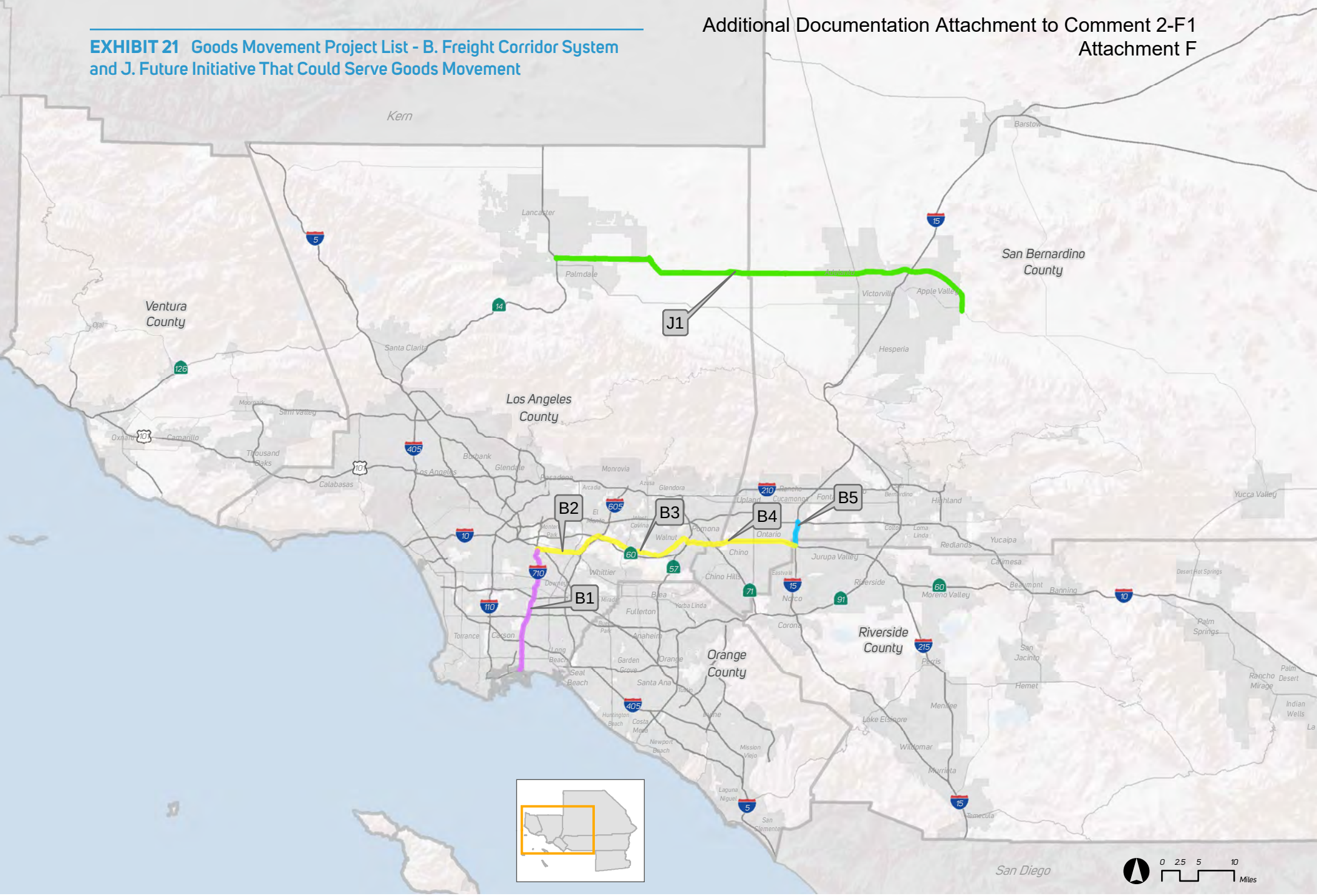


A - Raodway Access To Major Goods Movement Facilities

Note: Projects A12, A13, A63 are not mapped. See Project Listing

(Source: SCAG, 2015)

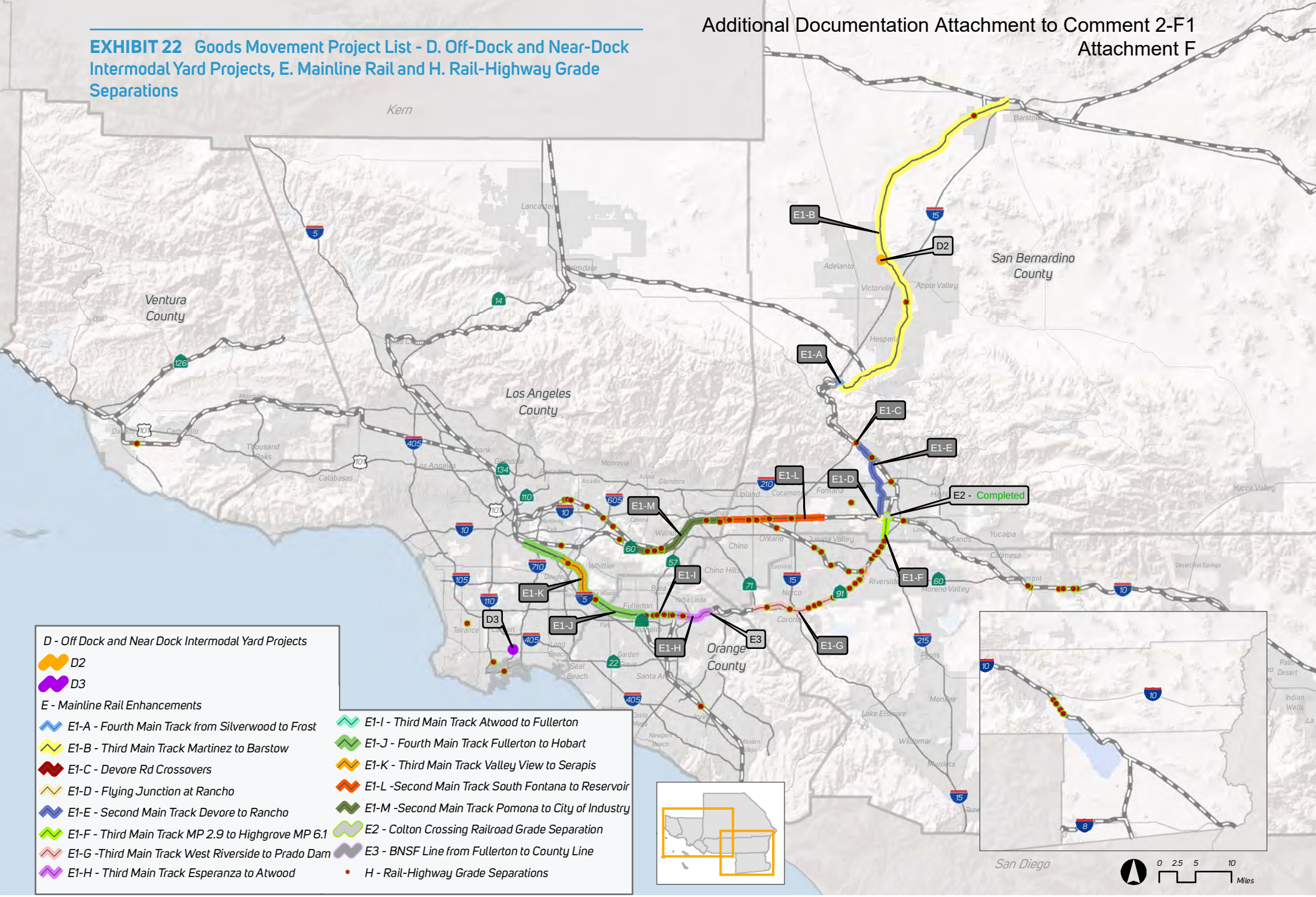
EXHIBIT 21 Goods Movement Project List - B. Freight Corridor System and J. Future Initiative That Could Serve Goods Movement



I-710 Freight Corridor | Potential East-West Freight Corridor | I-15 Freight Corridor | High Desert Corridor

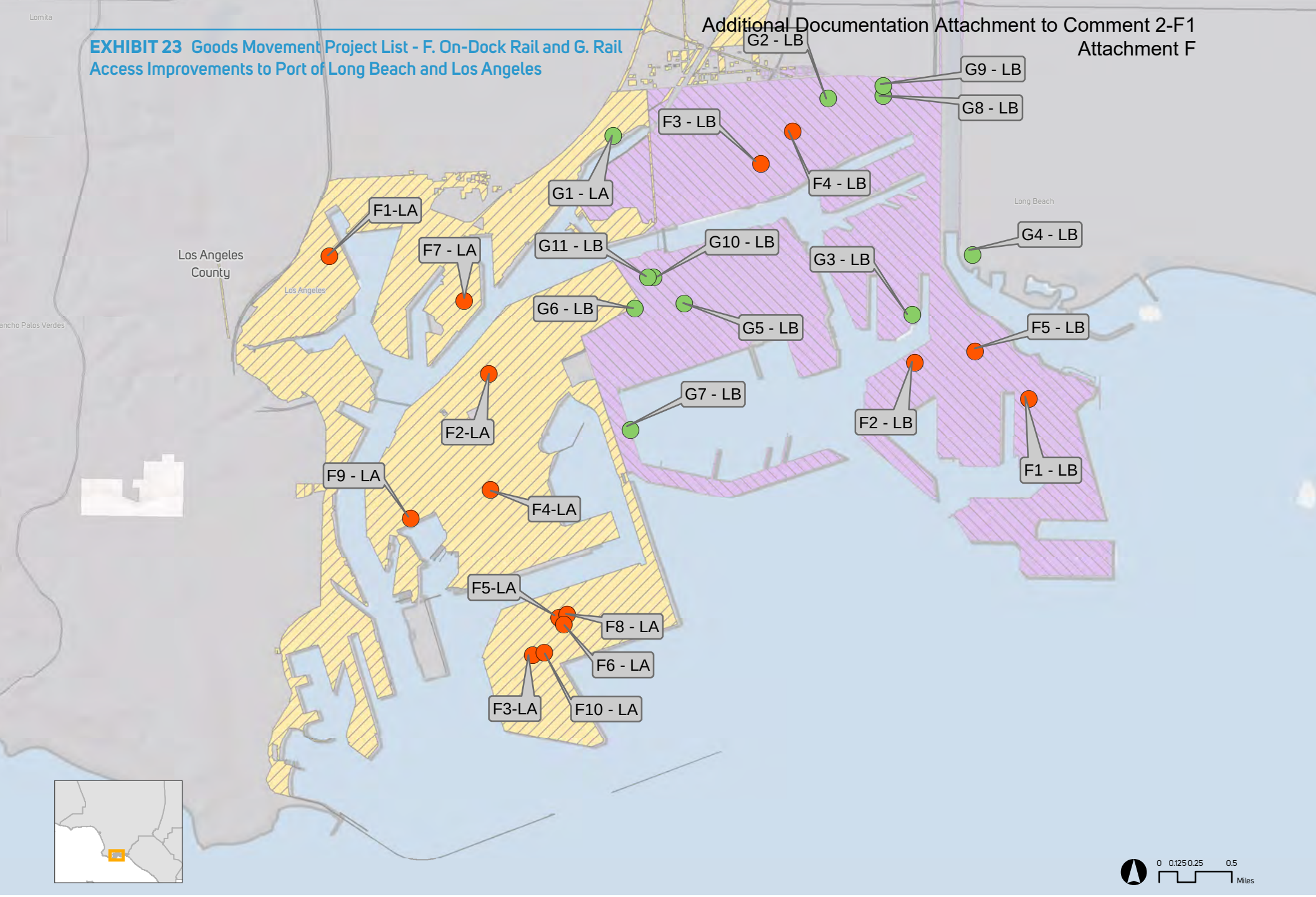
Source: SCAG

EXHIBIT 22 Goods Movement Project List - D. Off-Dock and Near-Dock Intermodal Yard Projects, E. Mainline Rail and H. Rail-Highway Grade Separations



Source: SCAG

EXHIBIT 23 Goods Movement Project List - F. On-Dock Rail and G. Rail Access Improvements to Port of Long Beach and Los Angeles



F - On Dock Rail

G - Rail Access Improvements to Port of Long Beach and Port of Los Angeles

Port of Los Angeles (LA)

Port of Long Beach (LB)

Source: SCAG

NOTES

1 American Association of Port Authorities and U.S. Trade Online, U.S. Census

2 U.S. Trade Online, U.S. Census and Port of Hueneme

3 U.S. Trade Online, U.S. Census

4 CoStar Reality Information, Inc. www.costar.com, based on November 2014 data downloads

5 Industrial Warehousing in the SCAG Region Study, SCAG, based on the Avison-Young methodology for port-related and non-port related warehousing needs

6 SCAG's Regional Travel Demand Model

7 UPS Solutions: Defining Logistics, How It Relates to Your Supply Chain—and Why It's Crucial for Your Company https://www.ups.com/content/us/en/bussol/browse/article/what-is-logistics.html

8 The U.S. Census, County Business Patterns, https://www.census.gov/econ/cbp/

9 Food manufacturing includes all sectors under the NAICS category for 311. This sector transforms livestock and agricultural products into products for intermediate or final consumption. It includes animal food manufacturing, cereal manufacturing, vegetable and fruit canning, etc

10 US Census County Business Patterns https://www.census.gov/econ/cbp/

11 The Industrial Warehousing in the SCAG Region Study, Task 3 Trend Report, SCAG, 2015

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13 2012 Annual Re-Shoring Report, MIT Forum.

14 Regional Economic Model Inc. TranSight SCAG, CA, US v3.6.5

15 Source: American Association of Port Authorities (AAPA).

16 The San Pedro Bay Ports QuickTrip–Train Builder, Oct 20, 2014, "By Lifts & TEUs Estimation" tab

17 Originally these FTZs were located primarily along the border, but recent changes to the Mexican Customs Law now allow them to operate anywhere in the Mexican territory and several FTZs have opened in mainland Mexico, creating logistic hubs such as San Luis Potosí and Guanajuato.

18 Regional Economic Model Inc. TranSight SCAG, CA US v3.6.5

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22 Same-day delivery is transforming the CRE industry, Kris Bjornson, JLL, June 2015, http://www.joneslanglasalleblog.com/investor/same-day-delivery-is-transforming-the-cre-industry/?utm_source=us-retail-ecom&utm_medium=jll-website&utm_campaign=featuredpost

23 Employment Development Department, Labor Force Data for May 2014 and May 2015

24 Ibid.

25 San Pedro Bay Ports Container Forecast, February, 2015

26 American Transportation Research Institute (ATRI). *Cost of Congestion to the Trucking Industry*. April 2014.

27 American Transportation Research Institute (ATRI). *Congestion Impact Analysis of Freight Significant Highway Locations* - 2015

28 For purposes of accounting and reporting, the Surface Transportation Board designates three classes of freight railroads based upon their operating revenues for three consecutive years using the following scale: Class I–$250 million or more; Class II–less than $250 million but more than $20 million; and Class III–$20 million or less. These operating revenue thresholds are stated in 1991 dollars and are adjusted annually for inflation using a Railroad Freight Price Index developed by the Bureau of Labor Statistics (BLS).

29 California Department of Transportation, http://www.dot.ca.gov/hq/paffairs/news/pressrel/13pr082.htm

30 Federal Communications Commission https://www.fcc.gov/encyclopedia/positive-train-control-ptc

31 Federal Railroad Administration

32 For further information on the Modified Status Quo Routing of UP Trains, see 2011 Regional Rail Study completed by Dr. Robert Leachman, Leachman and Associates, LLC for SCAG.

33 New Cerritos Channel Rail Bridge and Third Track at Thenard are joint port projects; however, the cost of these two projects are listed under the Port of Los Angeles.

34 See previous note.

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[49] http://www.arb.ca.gov/msprog/tech/presentation/trucksummary.pdf

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SOUTHERN CALIFORNIA
ASSOCIATION of GOVERNMENTS

MAIN OFFICE

818 West 7th Street, 12th Floor
Los Angeles, CA 90017
(213) 236-1800

www.scag.ca.gov

REGIONAL OFFICES

Imperial County
1405 North Imperial Avenue, Suite 1
El Centro, CA 92243
Phone: (760) 353-7800
Fax: (760) 353-1877

Orange County
OCTA Building
600 South Main Street, Suite 1233
Orange, CA 92868
Phone: (714) 542-3687
Fax: (714) 560-5089

Riverside County
3403 10th Street, Suite 805
Riverside, CA 92501
Phone: (951) 784-1513
Fax: (951) 784-3925

San Bernardino County
Santa Fe Depot
1170 West 3rd Street, Suite 140
San Bernardino, CA 92410
Phone: (909) 806-3556
Fax: (909) 806-3572

Ventura County
950 County Square Drive, Suite 101
Ventura, CA 93003
Phone: (805) 642-2800
Fax: (805) 642-2260

2016 2040 RTPSCS

APPENDIX

TRANSPORTATION SYSTEM | GOODS MOVEMENT

ADOPTED | APRIL 2016

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SB-100 California Renewables Portfolio Standard Program: emissions of greenhouse gases. (2017-2018)

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Date Published: 09/10/2018 09:00 PM

Senate Bill No. 100

CHAPTER 312

An act to amend Sections 399.11, 399.15, and 399.30 of, and to add Section 454.53 to, the Public Utilities Code, relating to energy.

[Approved by Governor September 10, 2018. Filed with Secretary of State September 10, 2018.]

LEGISLATIVE COUNSEL'S DIGEST

SB 100, De León. California Renewables Portfolio Standard Program: emissions of greenhouse gases.

(1) Under existing law, the Public Utilities Commission (PUC) has regulatory authority over public utilities, including electrical corporations, while local publicly owned electric utilities, as defined, are under the direction of their governing boards. The California Renewables Portfolio Standard Program requires the PUC to establish a renewables portfolio standard requiring all retail sellers, as defined, to procure a minimum quantity of electricity products from eligible renewable energy resources, as defined, so that the total kilowatthours of those products sold to their retail end-use customers achieve 25% of retail sales by December 31, 2016, 33% by December 31, 2020, 40% by December 31, 2024, 45% by December 31, 2027, and 50% by December 31, 2030. The program additionally requires each local publicly owned electric utility, as defined, to procure a minimum quantity of electricity products from eligible renewable energy resources to achieve the procurement requirements established by the program. The Legislature has found and declared that its intent in implementing the program is to attain, among other targets for sale of eligible renewable resources, the target of 50% of total retail sales of electricity by December 31, 2030.

This bill would revise the above-described legislative findings and declarations to state that the goal of the program is to achieve that 50% renewable resources target by December 31, 2026, and to achieve a 60% target by December 31, 2030. The bill would require that retail sellers and local publicly owned electric utilities procure a minimum quantity of electricity products from eligible renewable energy resources so that the total kilowatthours of those products sold to their retail end-use customers achieve 44% of retail sales by December 31, 2024, 52% by December 31, 2027, and 60% by December 31, 2030.

Under existing law, a local publicly owned electric utility is not required to procure more than a specified minimum quantity of eligible renewable energy resources under the program if it receives more than 50% of its retail sales from hydroelectric generation, as specified.

This bill would revise those provisions, limit the applicability of this exception to large hydroelectric generation, and reduce that threshold to 40%.

(2) Existing law establishes the California Environmental Protection Agency, establishes the State Air Resources Board within the agency as the entity with responsibility for control of emissions from motor vehicles, and designates the state board as the air pollution control agency for all purposes set forth in federal

law. The California Global Warming Solutions Act of 2006 establishes the state board as the state agency charged with monitoring and regulating sources of emissions of greenhouse gases that cause global warming.

The Warren-Alquist State Energy Resources Conservation and Development Act establishes the State Energy Resources Conservation and Development Commission (Energy Commission) and requires it to conduct an ongoing assessment of the opportunities and constraints presented by all forms of energy, to encourage the balanced use of all sources of energy to meet the state's needs, and to seek to avoid possible undesirable consequences of reliance on a single source of energy.

This bill would state that it is the policy of the state that eligible renewable energy resources and zero-carbon resources supply 100% of retail sales of electricity to California end-use customers and 100% of electricity procured to serve all state agencies by December 31, 2045. The bill would require that the achievement of this policy for California not increase carbon emissions elsewhere in the western grid and that the achievement not allow resource shuffling. The bill would require the PUC and the Energy Commission, in consultation with the state board, to take steps to ensure that a transition to a zero-carbon electric system for the State of California does not cause or contribute to greenhouse gas emissions increases elsewhere in the western grid. The bill would require the PUC, Energy Commission, state board, and all other state agencies to incorporate that policy into all relevant planning. The bill would require the PUC, Energy Commission, state board, and all other state agencies to ensure actions taken in furtherance of these purposes achieve specified objectives. The bill would require the PUC, Energy Commission, and state board to utilize programs authorized under existing statutes to achieve that policy and, as part of a public process, issue a joint report to the Legislature by January 1, 2021, and every 4 years thereafter, that includes specified information relating to the implementation of the policy.

(3) Under existing law, a violation of the Public Utilities Act or any order, decision, rule, direction, demand, or requirement of the PUC is a crime.

Because certain of the provisions of this bill would be a part of the act and because a violation of an order or decision of the PUC implementing its requirements would be a crime, the bill would impose a state-mandated local program. By expanding the requirements placed upon a local publicly owned electric utility, the bill would impose a state-mandated local program.

The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement.

This bill would provide that no reimbursement is required by this act for specified reasons.

Vote: majority Appropriation: no Fiscal Committee: yes Local Program: yes

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

SECTION 1. (a) This act shall be known as The 100 Percent Clean Energy Act of 2018.

(b) The Legislature finds and declares that the Public Utilities Commission, State Energy Resources Conservation and Development Commission, and State Air Resources Board should plan for 100 percent of total retail sales of electricity in California to come from eligible renewable energy resources and zero-carbon resources by December 31, 2045.

(c) It is the intent of the Legislature in enacting this act to extend and expand policies established pursuant to the California Renewables Portfolio Standard Program (Article 16 (commencing with Section 399.11) of Chapter 2.3 of Part 1 of Division 1 of the Public Utilities Code), and to codify the policies established pursuant to Section 454.53 of the Public Utilities Code, and that both be incorporated in long-term planning.

SEC. 2. Section 399.11 of the Public Utilities Code is amended to read:

399.11. The Legislature finds and declares all of the following:

(a) In order to attain a target of generating 20 percent of total retail sales of electricity in California from eligible renewable energy resources by December 31, 2013, 33 percent by December 31, 2020, 50 percent by December 31, 2026, and 60 percent by December 31, 2030, it is the intent of the Legislature that the commission and the Energy Commission implement the California Renewables Portfolio Standard Program described in this article.

(b) Achieving the renewables portfolio standard through the procurement of various electricity products from eligible renewable energy resources is intended to provide unique benefits to California, including all of the following, each of which independently justifies the program:

(1) Displacing fossil fuel consumption within the state.

(2) Adding new electrical generating facilities in the transmission network within the WECC service area.

(3) Reducing air pollution, particularly criteria pollutant emissions and toxic air contaminants, in the state.

(4) Meeting the state's climate change goals by reducing emissions of greenhouse gases associated with electrical generation.

(5) Promoting stable retail rates for electric service.

(6) Meeting the state's need for a diversified and balanced energy generation portfolio.

(7) Assisting with meeting the state's resource adequacy requirements.

(8) Contributing to the safe and reliable operation of the electrical grid, including providing predictable electrical supply, voltage support, lower line losses, and congestion relief.

(9) Implementing the state's transmission and land use planning activities related to development of eligible renewable energy resources.

(c) The California Renewables Portfolio Standard Program is intended to complement the Renewable Energy Resources Program administered by the Energy Commission and established pursuant to Chapter 8.6 (commencing with Section 25740) of Division 15 of the Public Resources Code.

(d) New and modified electric transmission facilities may be necessary to facilitate the state achieving its renewables portfolio standard targets.

(e) (1) Supplying electricity to California end-use customers that is generated by eligible renewable energy resources is necessary to improve California's air quality and public health, particularly in disadvantaged communities identified pursuant to Section 39711 of the Health and Safety Code, and the commission shall ensure rates are just and reasonable, and are not significantly affected by the procurement requirements of this article. This electricity may be generated anywhere in the interconnected grid that includes many states, and areas of both Canada and Mexico.

(2) This article requires generating resources located outside of California that are able to supply that electricity to California end-use customers to be treated identically to generating resources located within the state, without discrimination.

(3) California electrical corporations have already executed, and the commission has approved, power purchase agreements with eligible renewable energy resources located outside of California that will supply electricity to California end-use customers. These resources will fully count toward meeting the renewables portfolio standard procurement requirements.

SEC. 3. Section 399.15 of the Public Utilities Code is amended to read:

399.15. (a) In order to fulfill unmet long-term resource needs, the commission shall establish a renewables portfolio standard requiring all retail sellers to procure a minimum quantity of electricity products from eligible renewable energy resources as a specified percentage of total kilowatthours sold to their retail end-use customers each compliance period to achieve the targets established under this article. For any retail seller procuring at least 14 percent of retail sales from eligible renewable energy resources in 2010, the deficits associated with any previous renewables portfolio standard shall not be added to any procurement requirement pursuant to this article.

(b) The commission shall implement renewables portfolio standard procurement requirements only as follows:

(1) Each retail seller shall procure a minimum quantity of eligible renewable energy resources for each of the following compliance periods:

(A) January 1, 2011, to December 31, 2013, inclusive.

(B) January 1, 2014, to December 31, 2016, inclusive.

(C) January 1, 2017, to December 31, 2020, inclusive.

(D) January 1, 2021, to December 31, 2024, inclusive.

(E) January 1, 2025, to December 31, 2027, inclusive.

(F) January 1, 2028, to December 31, 2030, inclusive.

(2) (A) No later than January 1, 2017, the commission shall establish the quantity of electricity products from eligible renewable energy resources to be procured by the retail seller for each compliance period. These quantities shall be established in the same manner for all retail sellers and result in the same percentages used to establish compliance period quantities for all retail sellers.

(B) In establishing quantities for the compliance period from January 1, 2011, to December 31, 2013, inclusive, the commission shall require procurement for each retail seller equal to an average of 20 percent of retail sales. For the following compliance periods, the quantities shall reflect reasonable progress in each of the intervening years sufficient to ensure that the procurement of electricity products from eligible renewable energy resources achieves 25 percent of retail sales by December 31, 2016, 33 percent by December 31, 2020, 44 percent by December 31, 2024, 52 percent by December 31, 2027, and 60 percent by December 31, 2030. The commission shall establish appropriate three-year compliance periods for all subsequent years that require retail sellers to procure not less than 60 percent of retail sales of electricity products from eligible renewable energy resources.

(C) Retail sellers shall be obligated to procure no less than the quantities associated with all intervening years by the end of each compliance period. Retail sellers shall not be required to demonstrate a specific quantity of procurement for any individual intervening year.

(3) The commission may require the procurement of eligible renewable energy resources in excess of the quantities specified in paragraph (2).

(4) Only for purposes of establishing the renewables portfolio standard procurement requirements of paragraph (1) and determining the quantities pursuant to paragraph (2), the commission shall include all electricity sold to retail customers by the Department of Water Resources pursuant to Division 27 (commencing with Section 80000) of the Water Code in the calculation of retail sales by an electrical corporation.

(5) The commission shall waive enforcement of this section if it finds that the retail seller has demonstrated any of the following conditions are beyond the control of the retail seller and will prevent compliance:

(A) There is inadequate transmission capacity to allow for sufficient electricity to be delivered from proposed eligible renewable energy resource projects using the current operational protocols of the Independent System Operator. In making its findings relative to the existence of this condition with respect to a retail seller that owns transmission lines, the commission shall consider both of the following:

(i) Whether the retail seller has undertaken, in a timely fashion, reasonable measures under its control and consistent with its obligations under local, state, and federal laws and regulations, to develop and construct new transmission lines or upgrades to existing lines intended to transmit electricity generated by eligible renewable energy resources. In determining the reasonableness of a retail seller’s actions, the commission shall consider the retail seller’s expectations for full-cost recovery for these transmission lines and upgrades.

(ii) Whether the retail seller has taken all reasonable operational measures to maximize cost-effective deliveries of electricity from eligible renewable energy resources in advance of transmission availability.

(B) Permitting, interconnection, or other circumstances that delay procured eligible renewable energy resource projects, or there is an insufficient supply of eligible renewable energy resources available to the retail seller. In making a finding that this condition prevents timely compliance, the commission shall consider whether the retail seller has done all of the following:

(i) Prudently managed portfolio risks, including relying on a sufficient number of viable projects.

(ii) Sought to develop one of the following: its own eligible renewable energy resources, transmission to interconnect to eligible renewable energy resources, or energy storage used to integrate eligible renewable

energy resources. This clause shall not require an electrical corporation to pursue development of eligible renewable energy resources pursuant to Section 399.14.

(iii) Procured an appropriate minimum margin of procurement above the minimum procurement level necessary to comply with the renewables portfolio standard to compensate for foreseeable delays or insufficient supply.

(iv) Taken reasonable measures, under the control of the retail seller, to procure cost-effective distributed generation and allowable unbundled renewable energy credits.

(C) Unanticipated curtailment of eligible renewable energy resources if the waiver would not result in an increase in greenhouse gas emissions.

(D) Unanticipated increase in retail sales due to transportation electrification. In making a finding that this condition prevents timely compliance, the commission shall consider both of the following:

(i) Whether transportation electrification significantly exceeded forecasts in that retail seller's service territory based on the best and most recently available information filed with the State Air Resources Board, the Energy Commission, or another state agency.

(ii) Whether the retail seller has taken reasonable measures to procure sufficient resources to account for unanticipated increases in retail sales due to transportation electrification.

(6) If the commission waives the compliance requirements of this section, the commission shall establish additional reporting requirements on the retail seller to demonstrate that all reasonable actions under the control of the retail seller are taken in each of the intervening years sufficient to satisfy future procurement requirements.

(7) The commission shall not waive enforcement pursuant to this section, unless the retail seller demonstrates that it has taken all reasonable actions under its control, as set forth in paragraph (5), to achieve full compliance.

(8) If a retail seller fails to procure sufficient eligible renewable energy resources to comply with a procurement requirement pursuant to paragraphs (1) and (2) and fails to obtain an order from the commission waiving enforcement pursuant to paragraph (5), the commission shall assess penalties for noncompliance. A schedule of penalties shall be adopted by the commission that shall be comparable for electrical corporations and other retail sellers. For electrical corporations, the cost of any penalties shall not be collected in rates. Any penalties collected under this article shall be deposited into the Electric Program Investment Charge Fund and used for the purposes described in Chapter 8.1 (commencing with Section 25710) of Division 15 of the Public Resources Code.

(9) Deficits associated with the compliance period shall not be added to a future compliance period.

(c) The commission shall establish a limitation for each electrical corporation on the procurement expenditures for all eligible renewable energy resources used to comply with the renewables portfolio standard. This limitation shall be set at a level that prevents disproportionate rate impacts.

(d) If the cost limitation for an electrical corporation is insufficient to support the projected costs of meeting the renewables portfolio standard procurement requirements, the electrical corporation may refrain from entering into new contracts or constructing facilities beyond the quantity that can be procured within the limitation, unless eligible renewable energy resources can be procured without exceeding a de minimis increase in rates, consistent with the long-term procurement plan established for the electrical corporation pursuant to Section 454.5.

(e) (1) The commission shall monitor the status of the cost limitation for each electrical corporation in order to ensure compliance with this article.

(2) If the commission determines that an electrical corporation may exceed its cost limitation prior to achieving the renewables portfolio standard procurement requirements, the commission shall do both of the following within 60 days of making that determination:

(A) Investigate and identify the reasons why the electrical corporation may exceed its annual cost limitation.

(B) Notify the appropriate policy and fiscal committees of the Legislature that the electrical corporation may

exceed its cost limitation, and include the reasons why the electrical corporation may exceed its cost limitation.

(f) The establishment of a renewables portfolio standard shall not constitute implementation by the commission of the federal Public Utility Regulatory Policies Act of 1978 (Public Law 95-617).

SEC. 4. Section 399.30 of the Public Utilities Code is amended to read:

399.30. (a) (1) To fulfill unmet long-term generation resource needs, each local publicly owned electric utility shall adopt and implement a renewable energy resources procurement plan that requires the utility to procure a minimum quantity of electricity products from eligible renewable energy resources, including renewable energy credits, as a specified percentage of total kilowatthours sold to the utility's retail end-use customers, each compliance period, to achieve the targets of subdivision (c).

(2) Beginning January 1, 2019, a local publicly owned electric utility subject to Section 9621 shall incorporate the renewable energy resources procurement plan required by this section as part of a broader integrated resource plan developed and adopted pursuant to Section 9621.

(b) The governing board shall implement procurement targets for a local publicly owned electric utility that require the utility to procure a minimum quantity of eligible renewable energy resources for each of the following compliance periods:

(1) January 1, 2011, to December 31, 2013, inclusive.

(2) January 1, 2014, to December 31, 2016, inclusive.

(3) January 1, 2017, to December 31, 2020, inclusive.

(4) January 1, 2021, to December 31, 2024, inclusive.

(5) January 1, 2025, to December 31, 2027, inclusive.

(6) January 1, 2028, to December 31, 2030, inclusive.

(c) The governing board of a local publicly owned electric utility shall ensure all of the following:

(1) The quantities of eligible renewable energy resources to be procured for the compliance period from January 1, 2011, to December 31, 2013, inclusive, are equal to an average of 20 percent of retail sales.

(2) The quantities of eligible renewable energy resources to be procured for all other compliance periods reflect reasonable progress in each of the intervening years sufficient to ensure that the procurement of electricity products from eligible renewable energy resources achieves 25 percent of retail sales by December 31, 2016, 33 percent by December 31, 2020, 44 percent by December 31, 2024, 52 percent by December 31, 2027, and 60 percent by December 31, 2030. The Energy Commission shall establish appropriate multiyear compliance periods for all subsequent years that require the local publicly owned electric utility to procure not less than 60 percent of retail sales of electricity products from eligible renewable energy resources.

(3) A local publicly owned electric utility shall adopt procurement requirements consistent with Section 399.16.

(4) Beginning January 1, 2014, in calculating the procurement requirements under this article, a local publicly owned electric utility may exclude from its total retail sales the kilowatthours generated by an eligible renewable energy resource that is credited to a participating customer pursuant to a voluntary green pricing or shared renewable generation program. Any exclusion shall be limited to electricity products that do not meet the portfolio content criteria set forth in paragraph (2) or (3) of subdivision (b) of Section 399.16. Any renewable energy credits associated with electricity credited to a participating customer shall not be used for compliance with procurement requirements under this article, shall be retired on behalf of the participating customer, and shall not be further sold, transferred, or otherwise monetized for any purpose. To the extent possible for generation that is excluded from retail sales under this subdivision, a local publicly owned electric utility shall seek to procure those eligible renewable energy resources that are located in reasonable proximity to program participants.

(d) (1) The governing board of a local publicly owned electric utility shall adopt procurement requirements consistent with subparagraph (B) of paragraph (4) of subdivision (a) of, and subdivision (b) of, Section

(2) The governing board of a local publicly owned electric utility may adopt the following measures:

(A) Conditions that allow for delaying timely compliance consistent with subdivision (b) of Section 399.15.

(B) Cost limitations for procurement expenditures consistent with subdivision (c) of Section 399.15.

(e) The governing board of the local publicly owned electric utility shall adopt a program for the enforcement of this article. The program shall be adopted at a publicly noticed meeting offering all interested parties an opportunity to comment. Not less than 30 days' notice shall be given to the public of any meeting held for purposes of adopting the program. Not less than 10 days' notice shall be given to the public before any meeting is held to make a substantive change to the program.

(f) Each local publicly owned electric utility shall annually post notice, in accordance with the Ralph M. Brown Act (Chapter 9 (commencing with Section 54950) of Part 1 of Division 2 of Title 5 of the Government Code), whenever its governing body will deliberate in public on its renewable energy resources procurement plan.

(g) A public utility district that receives all of its electricity pursuant to a preference right adopted and authorized by the United States Congress pursuant to Section 4 of the Trinity River Division Act of August 12, 1955 (Public Law 84-386), shall be in compliance with the renewable energy procurement requirements of this article.

(h) For a local publicly owned electric utility that was in existence on or before January 1, 2009, that provides retail electric service to 15,000 or fewer customer accounts in California, and is interconnected to a balancing authority located outside this state but within the WECC, an eligible renewable energy resource includes a facility that is located outside California that is connected to the WECC transmission system, if all of the following conditions are met:

(1) The electricity generated by the facility is procured by the local publicly owned electric utility, is delivered to the balancing authority area in which the local publicly owned electric utility is located, and is not used to fulfill renewable energy procurement requirements of other states.

(2) The local publicly owned electric utility participates in, and complies with, the accounting system administered by the Energy Commission pursuant to this article.

(3) The Energy Commission verifies that the electricity generated by the facility is eligible to meet the renewables portfolio standard procurement requirements.

(i) Notwithstanding subdivision (a), for a local publicly owned electric utility that is a joint powers authority of districts established pursuant to state law on or before January 1, 2005, that furnishes electric services other than to residential customers, and is formed pursuant to the Irrigation District Law (Division 11 (commencing with Section 20500) of the Water Code), the percentage of total kilowatthours sold to the district's retail end-use customers, upon which the renewables portfolio standard procurement requirements in subdivision (b) are calculated, shall be based on the authority's average retail sales over the previous seven years. If the authority has not furnished electric service for seven years, then the calculation shall be based on average retail sales over the number of completed years during which the authority has provided electric service.

(j) A local publicly owned electric utility in a city and county that only receives greater than 67 percent of its electricity sources from hydroelectric generation located within the state that it owns and operates, and that does not meet the definition of a "renewable electrical generation facility" pursuant to Section 25741 of the Public Resources Code, shall be required to procure eligible renewable energy resources, including renewable energy credits, to meet only the electricity demands unsatisfied by its hydroelectric generation in any given year, in order to satisfy its renewable energy procurement requirements.

(k) (1) For purposes of this subdivision, "large hydroelectric generation" means electricity generated from an existing hydroelectric facility located within the state that does not qualify as an eligible renewable energy resource and, as of January 1, 2018, was owned by a local publicly owned electric utility, the federal government as a part of the federal Central Valley Project, or a joint powers agency formed and created pursuant to the Joint Exercise of Powers Act (Chapter 5 (commencing with Section 6500) of Division 7 of Title 1 of the Government Code).

(2) If, during a year within a compliance period set forth in subdivision (b), a local publicly owned electric

utility receives more than 40 percent of its retail sales from large hydroelectric generation under an ownership agreement or contract in effect as of January 1, 2018, it is not required to procure eligible renewable energy resources that exceed the lesser of the following for that year:

(A) The portion of the local publicly owned electric utility's retail sales unsatisfied by the local publicly owned electric utility's large hydroelectric generation.

(B) The soft target adopted by the Energy Commission for the intervening years of the relevant compliance period.

(3) An extension or renewal of a procurement agreement shall not be eligible to count towards the determination that the local publicly owned electric utility receives more than 40 percent of its retail sales from large hydroelectric generation in any year. This paragraph shall not apply to any agreement in effect on January 1, 2015, between a local publicly owned electric utility and the Western Area Power Administration or federal government as part of the federal Central Valley Project.

(4) The Energy Commission shall adjust the total quantities of eligible renewable energy resources to be procured by a local publicly owned electric utility for a compliance period to reflect any reductions required pursuant to paragraph (2).

(5) This subdivision does not modify the compliance obligation of a local publicly owned electric utility to satisfy the requirements of subdivision (c) of Section 399.16.

(l) (1) (A) For purposes of this subdivision, "unavoidable long-term contracts and ownership agreements" means commitments for electricity from a coal-fired powerplant, located outside the state, originally entered into by a local publicly owned electric utility before June 1, 2010, that is not subsequently modified to result in an extension of the duration of the agreement or result in an increase in total quantities of energy delivered during any compliance period set forth in subdivision (b).

(B) The governing board of a local publicly owned electric utility shall demonstrate in its renewable energy resources procurement plan required pursuant to subdivision (f) that any cancellation or divestment of the commitment would result in significant economic harm to its retail customers that cannot be substantially mitigated through resale, transfer to another entity, early closure of the facility, or other feasible measures.

(2) For the compliance period set forth in paragraph (4) of subdivision (b), a local publicly owned electric utility meeting the requirement of subparagraph (B) of paragraph (1) may adjust its renewable energy procurement targets to ensure that the procurement of additional electricity from eligible renewable energy resources, in combination with the procurement of electricity from unavoidable long-term contracts and ownership agreements, does not exceed the total retail sales of the local publicly owned electric utility during that compliance period. The local publicly owned electric utility may limit its procurement of eligible renewable energy resources for that compliance period to no less than an average of 33 percent of its retail sales.

(3) The Energy Commission shall approve any reductions in procurement targets proposed by a local publicly owned electric utility if it determines that the requirements of this subdivision are satisfied.

(m) A local publicly owned electric utility shall retain discretion over both of the following:

(1) The mix of eligible renewable energy resources procured by the utility and those additional generation resources procured by the utility for purposes of ensuring resource adequacy and reliability.

(2) The reasonable costs incurred by the utility for eligible renewable energy resources owned by the utility.

(n) The Energy Commission shall adopt regulations specifying procedures for enforcement of this article. The regulations shall include a public process under which the Energy Commission may issue a notice of violation and correction against a local publicly owned electric utility for failure to comply with this article, and for referral of violations to the State Air Resources Board for penalties pursuant to subdivision (o).

(o) (1) Upon a determination by the Energy Commission that a local publicly owned electric utility has failed to comply with this article, the Energy Commission shall refer the failure to comply with this article to the State Air Resources Board, which may impose penalties to enforce this article consistent with Part 6 (commencing with Section 38580) of Division 25.5 of the Health and Safety Code. Any penalties imposed shall be comparable to those adopted by the commission for noncompliance by retail sellers.

(2) Any penalties collected by the State Air Resources Board pursuant to this article shall be deposited in the Air Pollution Control Fund and, upon appropriation by the Legislature, shall be expended for reducing emissions of air pollution or greenhouse gases within the same geographic area as the local publicly owned electric utility.

SEC. 5. Section 454.53 is added to the Public Utilities Code, to read:

454.53. (a) It is the policy of the state that eligible renewable energy resources and zero-carbon resources supply 100 percent of all retail sales of electricity to California end-use customers and 100 percent of electricity procured to serve all state agencies by December 31, 2045. The achievement of this policy for California shall not increase carbon emissions elsewhere in the western grid and shall not allow resource shuffling. The commission and Energy Commission, in consultation with the State Air Resources Board, shall take steps to ensure that a transition to a zero-carbon electric system for the State of California does not cause or contribute to greenhouse gas emissions increases elsewhere in the western grid, and is undertaken in a manner consistent with clause 3 of Section 8 of Article I of the United States Constitution. The commission, the Energy Commission, the State Air Resources Board, and all other state agencies shall incorporate this policy into all relevant planning.

(b) The commission, Energy Commission, state board, and all other state agencies shall ensure that actions taken in furtherance of subdivision (a) do all of the following:

(1) Maintain and protect the safety, reliable operation, and balancing of the electric system.

(2) Prevent unreasonable impacts to electricity, gas, and water customer rates and bills resulting from implementation of this section, taking into full consideration the economic and environmental costs and benefits of renewable energy and zero-carbon resources.

(3) To the extent feasible and authorized under law, lead to the adoption of policies and taking of actions in other sectors to obtain greenhouse gas emission reductions that ensure equity between other sectors and the electricity sector.

(4) Not affect in any manner the rules and requirements for the oversight of, and enforcement against, retail sellers and local publicly owned utilities pursuant to the California Renewables Portfolio Standard Program (Article 16 (commencing with Section 399.11) of Chapter 2.3) and Sections 454.51, 454.52, 9621, and 9622.

(c) Nothing in this section shall affect a retail seller's obligation to comply with the federal Public Utility Regulatory Policies Act of 1978 (16 U.S.C. Sec. 2601 et seq.).

(d) The commission, Energy Commission, and state board shall do both of the following:

(1) Utilize programs authorized under existing statutes to achieve the policy described in subdivision (a).

(2) In consultation with all California balancing authorities, as defined in subdivision (d) of Section 399.12, as part of a public process, issue a joint report to the Legislature by January 1, 2021, and at least every four years thereafter. The joint report shall include all of the following:

(A) A review of the policy described in subdivision (a) focused on technologies, forecasts, then-existing transmission, and maintaining safety, environmental and public safety protection, affordability, and system and local reliability.

(B) An evaluation identifying the potential benefits and impacts on system and local reliability associated with achieving the policy described in subdivision (a).

(C) An evaluation identifying the nature of any anticipated financial costs and benefits to electric, gas, and water utilities, including customer rate impacts and benefits.

(D) The barriers to, and benefits of, achieving the policy described in subdivision (a).

(E) Alternative scenarios in which the policy described in subdivision (a) can be achieved and the estimated costs and benefits of each scenario.

(e) Nothing in this section authorizes the commission to establish any requirements on a nonmobile self-cogeneration or cogeneration facility that served onsite load, or that served load pursuant to an over-the-fence

arrangement if that arrangement existed on or before December 20, 1995.

SEC. 6. No reimbursement is required by this act pursuant to Section 6 of Article XIII B of the California Constitution because a local agency or school district has the authority to levy service charges, fees, or assessments sufficient to pay for the program or level of service mandated by this act or because costs that may be incurred by a local agency or school district will be incurred because this act creates a new crime or infraction, eliminates a crime or infraction, or changes the penalty for a crime or infraction, within the meaning of Section 17556 of the Government Code, or changes the definition of a crime within the meaning of Section 6 of Article XIII B of the California Constitution.









CA | Energy Efficiency Strategic Plan

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INTRODUCTION

In October 2007, the California Public Utilities Commission (CPUC) created a framework to make energy efficiency a way of life in California by refocusing ratepayer-funded energy efficiency programs on achieving long-term savings through structural changes in the way Californians use energy.[1]

The Commission recognized that California's very ambitious energy efficiency and greenhouse gas reduction goals require long-term strategic planning to eliminate persistent market barriers and effect lasting transformation in the market for energy efficiency across the economy. Accordingly, the Commission committed to prepare and adopt a long-term strategic plan for California energy efficiency through 2020 and beyond.

This Long Term Energy Efficiency Strategic Plan (Plan) was developed through a collaborative process involving the CPUC's regulated utilities – Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), San Diego Gas & Electric Company (SDG&E) and Southern California Gas Company (SoCalGas) (collectively, "IOUs") – and over 500 individuals and organizations working together over an eleven-month period.[2]

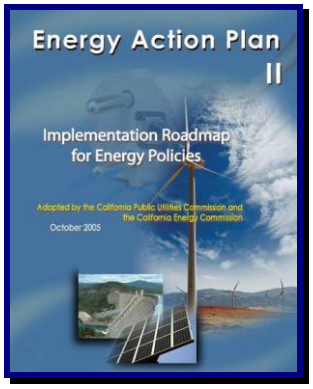
This Plan sets forth a roadmap for energy efficiency in California through the year 2020 and beyond. It articulates a long-term vision and goals for each economic sector and identifies specific near-term, mid-term and long-term strategies to assist in achieving those goals.[3]

With broad stakeholder input, the CPUC has continually refined the implementation strategies which are at the heart of this Plan. Every participant in this process recognizes the formidable task that lies ahead. Every participant also recognizes, however, that ever-increasing energy prices and the urgent threat of climate change require that California set the bar high and move forward quickly and purposefully to realize the full extent of efficiency opportunities statewide and achieve deep reductions in energy demand and usage.

1.1 PAST ACCOMPLISHMENTS AND FUTURE CHALLENGES

The 2005 CPUC and California Energy Commission's (Energy Commission) Energy Action Plan II,[4] declared:

"[The] goal is for California's energy to be adequate, affordable, technologically advanced, and environmentally-sound…[C]ost effective energy efficiency is the resource of first choice for meeting California's energy needs. Energy efficiency is the least cost, most reliable, and most environmentally-sensitive resource, and minimizes our contribution to climate change."

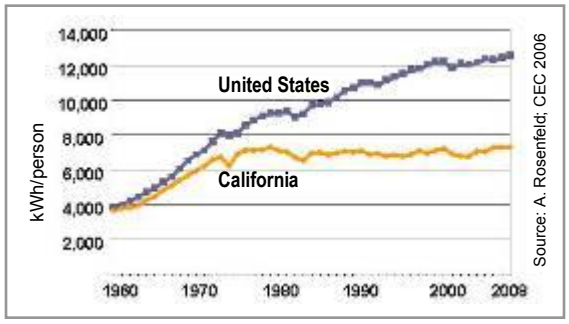


The state's "loading order" – first acknowledged in Energy Action Plan I[5] – identifies energy efficiency as California's top priority resource. Under Public Utilities Code Section 454.5(b)(9)(C) utilities are required to first meet their "unmet resource needs through all available energy efficiency and demand reduction resources that are cost effective, reliable, and feasible."

California has taken this principle to heart and with three decades of leadership and innovation in the public and private sectors, California leads the nation, and perhaps the world, in developing and implementing successful energy efficiency efforts.

As the Energy Commission notes in its 2007 Integrated Energy Policy Report (IEPR)[6]:

"Energy efficiency, which helped to flatten the state's per capita electricity use, will continue to be the keystone of California's energy strategy. California's building and appliance standards have saved consumers more than $56 billion in electricity and natural gas costs since 1978 and averted building 15 large power plants. It is estimated the current standards will save an additional $23 billion by 2013."



Over the years, successive CPUC decisions have created a policy framework to motivate IOUs to develop and continuously expand energy efficiency programs on behalf of their customers. This policy framework is composed of a number of elements including: the state's adopted loading order; aggressive goals set based upon up-to-date potential studies; decoupling of sales from revenues for electric and gas utilities; performance-based incentive mechanisms; and a robust dual funding stream comprised of a public goods charge and procurement funding.

The IOUs' 2006-2008 energy efficiency portfolio marks the single-largest energy efficiency campaign in U.S. history, with a $2 billion investment by California's energy ratepayers. In addition, individual and corporate energy consumers; state and local agencies; and publicly-owned utilities continue to make significant independent investments to increase the efficient use of energy across California.

However, with a growing population, increasing demand for energy, and the pressing need to reduce greenhouse gas (GHG) emissions in a rapid and low-cost manner, there has never been a more important time for energy efficiency in California. California is the second-largest GHG-emitting state in the U.S. and electricity production is the second largest source of carbon emissions in California, accounting for some 32 percent of its total, with gas use in businesses and homes another 9 percent.[7]

An Enabling Policy Framework

California's success to date has been enabled by a comprehensive policy framework supporting energy efficiency investment. The aggressive scale-up envisioned by this Plan hinges on a steady foundation composed of the following elements:

- ***Clear Policy Direction.*** The Energy Action Plan sets forth a bold policy vision establishing efficiency as the California's first priority energy resource. Specific savings goals, tied to supply procurement, implement that policy.
- ***Adequate Financial Incentives and Funding.*** The decoupling of sales from revenues for electric and gas utilities, along-side performance-based incentive mechanisms, address a fundamental bias against efficiency investment. Meanwhile, a public goods charge and procurement funding produce substantial funding resources for such investment.
- ***Robust Program Administration and Oversight.*** In California, efficiency programs are largely administered by utilities utilizing universal contact with homes and businesses throughout the state, while government maintains primary responsibility for program direction and oversight, including program evaluation and the measurement and verification of claimed energy savings.
- ***Firm Ratcheting Standards.*** The establishment of minimum efficiency standards for buildings and appliances that are updated on a regular basis have driven guaranteed progressive energy savings over the past three decades.

Meanwhile California demand for electricity and natural gas continues to grow, with statewide electricity consumption forecast to increase an average of 1.25 percent per year over the next decade.[8] In addition, the state faces rapidly-escalating fuel prices.

The combination of these pressures poses significant economic and social risks to California. As both an emissions-free and low-cost energy resource alternative, energy efficiency is uniquely-poised to play a central role in reconciling the current challenge. This fact is acknowledged in virtually every discussion of GHG abatement opportunities, including McKinsey & Company's comprehensive 2007 review.[9]

Capitalizing on this opportunity in California will require that we make energy efficiency investments an integral part of life and a "business as usual" choice for California market actors.

It will require that we overcome market barriers that have persisted over the course of California's 30-year history with energy efficiency policy, and it will demand the political will to continue making investments during times of economic stress to extend and to capture the full extent of energy efficiency potential obtainable across the state. However, in succeeding, this initiative will bring benefits not only for California but will allow the state to share its energy efficiency leadership, skills and experience in the national and international efforts to combat global warming through energy efficiency.

1.2 POLICY CONTEXT

The passage of the California Global Warming Solutions Act of 2006 (Assembly Bill 32)[10] has amplified the need for intensive energy efficiency efforts across California. The California Air Resources Board's (CARB) Draft Scoping Plan for Assembly Bill (AB) 32 implementation states that while "California has a long history of success in implementing regulations and programs to encourage energy efficiency… [it] will need to greatly expand those efforts to meet our greenhouse gas emission reduction goals." [11]

The Draft Scoping Plan, which offers preliminary indication of how the state plans to achieve its GHG reduction targets, establishes a statewide energy efficiency target of at least 32,000 gigawatt hours and 800 million therms by 2020.[12] If achieved, emission reductions from these efficiency savings would result in over 25 million metric tons of GHG emissions reductions, making them the second largest component in the state's overall emissions reduction program. The Draft Scoping Plan recognizes this, stating that efficiency provides an emission reduction opportunity for California "on a scale second only to the Pavley regulations."[13]

AB 32 and other pivotal legislation and policy in California — such as the Energy Action Plan II, AB 2021 (establishment of statewide energy efficiency goals), the Low-Income Energy Efficiency statutes, the Governor's Green Building Executive Order[14], and the 2007 IEPR — create an environment where energy efficiency efforts must not only continue to thrive but scale up unprecedented levels.

In July 2008, the CPUC redoubled its own energy savings efforts by establishing new targets for energy savings for the years 2012 through 2020 for its regulated utilities.[15] Within IOU service areas these goals are expected to save over 4,500 megawatts, the equivalent of over 9 major power plants, and over 16,000 GWh of electricity savings and 620 million therms. Combined with recent goal-setting by the state's publicly-owned utilities under AB 2021, these goals provide an aggressive contribution to statewide energy savings targeted under AB 32.

A number of recent policies, such as AB 1109, which requires defined reductions in energy usage for lighting, and the Federal Energy Independence and Security Act of 2007, which contains many provisions for new minimum efficiency standards and research, have dramatically altered the landscape for energy efficiency activities in California.[16] Ensuring the continued effectiveness of public purpose efficiency programs, for instance, will require

careful coordination with emerging mandates and market changes.

This Plan provides a strategic roadmap for integrating energy efficiency efforts to achieve the aggressive goals the state has set for itself. It aims to bring together key participants beyond the CPUC and the IOUs, including publicly-owned utilities, the financial and building industries, cities and counties, other state agencies, and businesses and consumers, to work together toward common energy efficiency goals. Therefore, the strategies and goals are not restricted by geographical, jurisdictional, regulatory, or political boundaries. To achieve these goals, all actors must work collaboratively over the long-term to fundamentally transform the way Californians use energy at home and at work.

1.3 TARGETING MARKET TRANSFORMATION

The CPUC's October 2007 decision (D.07-10-032) directed that "a key element of the Strategic Plan would be that it articulates how energy efficiency programs are or will be designed with the goal of transitioning to either the marketplace without ratepayer subsidies, or codes and standards."[17]

The CPUC also stated that the Plan would incorporate the market transformation goal described above and "develop milestones to measure progress towards that goal," including the development of a "targeted timeframe for such market transition and the process for tracking progress so that it is clear at what point a program has made a successful transition or conversely, is having problems."[18]

This Plan fulfills the Commission's goal by employing market transformation as its unifying objective. The Plan seeks to effect substantial and sustained progress towards more efficient technologies and practices in each of the customer end use sectors (e.g., Commercial, Industrial, Residential, Agricultural). Likewise, the Plan describes the market transformation efforts necessary in each of the cross-cutting areas discussed (e.g., Codes and Standards, Workforce Education and Training, Marketing Education and Outreach, and Research and Technology)

As early as 1998, the Commission defined market transformation as:

"Long-lasting sustainable changes in the structure or functioning of a market achieved by reducing barriers to the adoption of energy efficiency measures to the point where further publicly-funded intervention is no longer appropriate in that specific market."[19]

In theory, ratepayer-funded efficiency programs over the past thirty years have been designed either to encourage suppliers and manufacturers to sell efficiency products or services to "push" the market, or to encourage consumers to buy these products or services to "pull" the market. Typical utility rebate programs aim to increase the market penetration of energy-efficient products along a continuum until market acceptance reached sufficient levels for the measure to be incorporated into codes and standards or used in the marketplace without ratepayer subsidies.

In practice, however, utility programs in California have naturally tended towards measures which produce readily-quantified, low-cost, near-term savings which offer the opportunity to "buy" load reduction in easy, well-packaged measures with limited market impacts. There has been little incentive for utilities to engage in measures with a longer-term orientation – those very measures which produce meaningful market transformation.

This Plan seeks to move utilities, the CPUC, and other stakeholders beyond a focus on short-term energy efficiency activities into a more sustained long-term, market transformation strategic focus.

By re-emphasizing the market transformation goal, we do not discount the benefits of short-term measures for energy savings. Utility portfolios must contain an appropriate mix of short and longer term energy savings. However, short-term programs such as the replacement of incandescent light bulbs with compact fluorescent light bulbs must be accompanied by solutions which focus on multi-year and holistic lighting system strategies, improved conservation actions, and other means of market transformation.

Additionally, the Plan recognizes that the process of market transformation cannot and

should not be driven by ratepayer-funded utility programs alone. While utilities will play a continued role in stimulating market transformation across sectors, each of the cross-cutting areas described in this Plan represents an avenue where non-utility actors may well be better positioned to drive the "push" of new technologies to market, or the "pull" for customers and business to adopt available efficiency technologies or practices.

Transformation is an evolutionary process, as markets for a given end-use are not transformed just once, but continuously. Understanding when a technology promoted in utility programs has become established within the mainstream market or incorporated into codes and standards will help target when new programs are needed to encourage the next generation of energy efficiency technologies. Decision 07-10-032 recognized this in directing the utilities' proposed 2009-2011 portfolios to identify "an 'end game' for each technology or practice that transforms building, purchasing, and the use decisions to become either 'standard practice', or incorporated into minimum codes and standards."[20]

It is necessary to develop appropriate rules, metrics, and guidelines for determining when market-transformation has occurred and publicly-funded intervention is no longer appropriate, so as to define an end-point for strategies and set the course for new programs and goals. A key priority for the first update of this Plan will be the development of end-point definitions, rules, and progress metrics. The Plan's content, however, is oriented towards charting a programmatic course that embraces the goals and strategies of market transformation by seeking to achieve significant transformative progress in all sectors by 2020 or earlier.[21]

The CPUC also recognizes its responsibility to examine changes to the policy rules on counting savings from IOU programs to attribute gains from market transformation and long-term strategies resulting from IOU actions. In order to ensure utilities are motivated to devote portfolio dollars towards market transformation measures, associated savings must be fairly accounted for in attribution methodologies.

Policy Tools for Market Transformation

The market transformation strategies covered in the Plan are built upon one or more of the following policy tools employed to "push" or "pull" more efficient products or practices to market:

- ***Customer Incentives*** including rebates; innovative or discounted financing; and/or non-financial support to consumers are the "carrots" that help *pull* consumers into choosing the efficient option.
- ***Codes and Standards*** which mandate minimum efficiency thresholds for buildings, appliances and/or equipment, removing the less efficient choices from the marketplace are the "sticks" that *push* builders and manufacturers to provide efficient goods and services.
- ***Education and Information*** through marketing, education and outreach inform market actors about energy efficiency opportunities. These programs often include labeling; benchmarking; internet-based comparisons; professional and trade materials; school curricula; peer-to-peer exchanges; and other resources.
- ***Technical Assistance*** helps to ensure that knowledge barriers on the part of customers, installers or retailers are not unnecessarily hampering the progress of critical efficiency initiatives.
- ***Emerging Technologies*** rely on research, development, demonstration and/or deployment to move energy-efficient products and developments from the laboratory into the commercial marketplace.

1.4 STRATEGIC PLANNING PROCESS

Decision 07-10-032 outlined the key goals, content, and development process for this Plan. During November and December 2007 and January 2008, working groups for four "vertical" market sectors — residential, including low-income, commercial, industrial, and agricultural — and seven cross-cutting areas — Heating, Ventilation and Air Conditioning (HVAC) systems; Demand Side Management (DSM) Coordination and Integration; Workforce Education and Training (WET); Marketing Education and Outreach (ME&O); Research and Technology; Codes and Standards; and Local Governments — held 36 public stakeholder workshops.

The objective of these workshops was to facilitate information exchange and develop an action plan for each market sector and each cross-cutting sector. In January 2008, these plans ("Convener Reports") were provided to the IOUs to inform their strategic planning efforts.

Throughout this process, the CPUC acted as a centralized information hub via a specially built webportal, disseminating team updates and reports and providing models for teams to look to in recording their findings.

As required by the CPUC, the IOUs filed a draft Plan on February 8, 2008. On March 6, 2008, the IOUs filed a revised draft Plan, supplementing the February draft pursuant to Commission direction. Three stakeholder workshops were then held in San Diego, Los Angeles, and San Francisco.[22]

All public comments, workshop transcripts, IOU and CPUC staff materials, and convener reports have been archived and are available on the strategic planning website: www.californiaenergyefficiency.com.

"BIG BOLD" ENERGY EFFICIENCY STRATEGIES






In order to guide market transformation in a number of key sectors, this Plan embraces four specific programmatic goals, known as the "Big Bold Energy Efficiency Strategies" (BBEES), established by the CPUC in D.07-10-032 and D.07-12-051.These goals were selected not only for their potential impact, but also for their easy comprehension and their ability to galvanize market players.

1. All new residential construction in California will be zero net energy by 2020;
2. All new commercial construction in California will be zero net energy by 2030;
3. Heating, Ventilation and Air Conditioning (HVAC) will be transformed to ensure that its energy performance is optimal for California's climate; and
4. All eligible low-income customers will be given the opportunity to participate in the low income energy efficiency program by 2020.

1.5 LIMITATIONS OF THIS FIRST PLAN

Two limitations to this 2008 Plan should be noted:

1. Because it is the initial plan—and due to time and other constraints—this Plan has not undergone cost-benefit analysis. However, the efficiency activities envisioned in this Plan subject to the Commission's jurisdiction will only be funded by ratepayers as part of cost-effective portfolios. Similarly, the strategies and actions have not been fully evaluated for prioritization or for budget and resource-allocation decisions. Accordingly, the strategies and actions described in this Plan will be updated as conditions change and new experience and information is obtained.
2. This Plan does not specifically address three important elements of energy efficiency. These are the evaluation and measurement and verification of energy savings; transportation; and the water-energy "nexus." The reasons for these exclusions are two-fold: first, there was no specific input provided by the working groups on these topics; and, second, various state agencies are covering these issues in separate processes. Future strategic planning cycles are likely to address these issues.

Many of the strategies in the Plan do not require changes in state or federal law or the regulations of various agencies. Specifically, most of the activities to be implemented in the near term (approximately 2009-2011) are expected to be feasible under current law and the rules of the CPUC and other agencies. However, there are longer term elements of the Plan for which changes in law and/or agency rules and policies would be useful—or even essential—to achieve the desired cost-effective energy efficiency over the 2009-2020 period.

1.6 UPDATING THE PLAN

This Plan is a dynamic document that will be regularly updated to reflect past successes, failures, and lessons learned and to adjust the visions, goals and strategies accordingly. Given the urgency of the need to achieve the AB 32 goals, it is necessary to quickly and efficiently complete foundational activities such as studies, data collection and pilot programs and to move just as quickly to implement actual programs and deliver real results in the near term.

The process that started during the fall of 2007 was a tremendous and highly productive effort by the utilities, CPUC, and the Energy Commission working with a large number of stakeholders from all sectors of the California economy. This process must continue in order to continue the momentum and build the sustained velocity needed to achieve the goals expressed in this Plan.

In the short term, this process will be advanced through the establishment of goal and/or strategy-specific task forces, to be coordinated by the CPUC. Over the longer term, there is widespread stakeholder support for coordination at a statewide level by an entity with a membership and mandate better suited to the multi-jurisdictional scope of the strategies articulated in this Plan. Such an entity would build on the collaboration initiated by the strategic planning process thus far and allow for enhanced participation by all stakeholders.

The next planning cycle will include:

- Incorporating data collection efforts, including market assessment and market potential studies, more directly in this and other planning processes, such as the Energy Commission's IEPR and the utilities' long-term procurement planning processes.
- Aligning this planning effort with related statewide long-term resource plans, such as those associated with water, land use, and greenhouse gas mitigation.
- Evaluating performance with respect to the goals and strategies established in the current Plan, and market transformation criteria in particular.
- Engaging even more key stakeholders prior to initiating the planning cycle and cooperatively developing roles and a process that increases information exchange and participation of these stakeholders. Conducting more widespread public workshops to enable these stakeholders to provide planning input and to vet planning documents.
- Central to this expanded process will be participation by additional state agencies, which may wish to co-sponsor various task forces—for example, in Workforce Education and Training or the Agricultural Sector -- and obtaining commitments from key participants willing to fund, lead, or implement strategies.

2. RESIDENTIAL SECTOR INCLUDING LOW INCOME

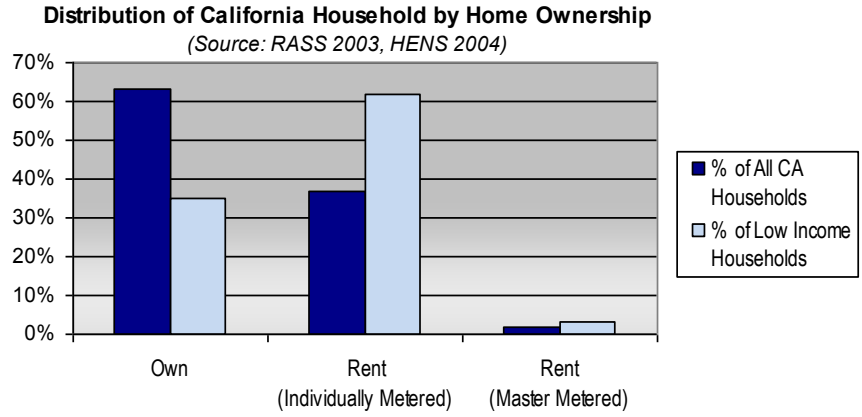
2.1 CORE RESIDENTIAL

2.1.1 VISION

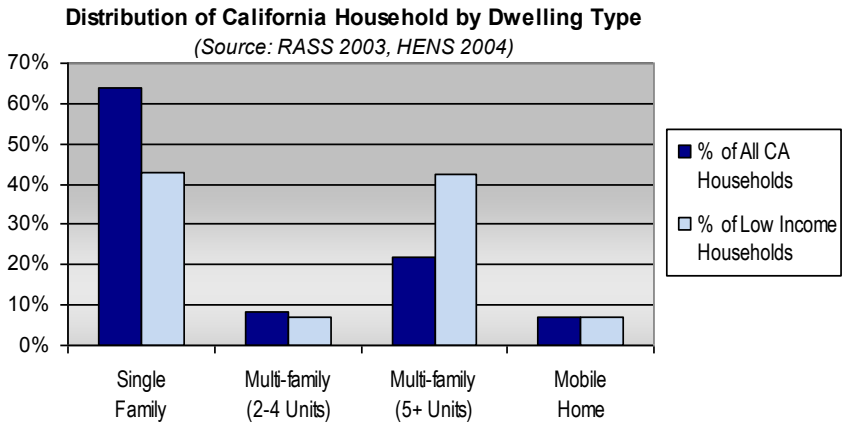
Residential energy use will be transformed to ultra-high levels of energy efficiency resulting in Zero Net Energy new buildings by 2020. All cost-effective potential for energy efficiency, demand response and clean energy production will be routinely realized for all dwellings on a fully integrated, site-specific basis.

2.1.2 PROFILE

In 2008, energy demand for California's 12.6 million households was over 25,000 MW. The residential sector represents approximately 32 percent of total state electricity consumption and 36 percent of its total natural gas consumption. Electricity demand is expected to grow to almost 31,000 MW by 2018.[23]

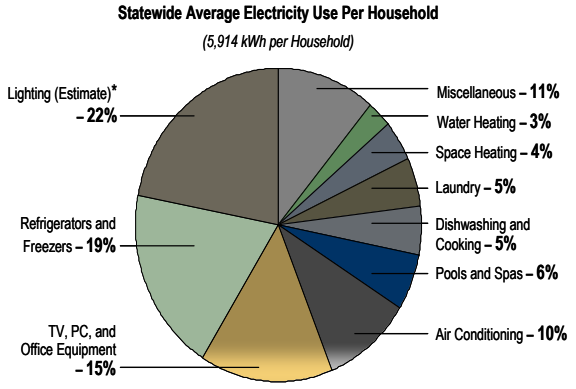


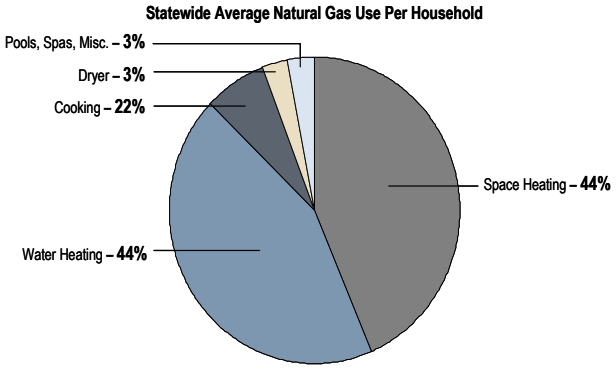
Approximately one-third of all households live in multi-family structures, and two-thirds in single family homes. The balance of renters to homeowners is about 42 percent to 58 percent, respectively. Most or all of these households qualify for utility energy efficiency programs targeting residential customers.[24] About one-third (approximately 4 million) of these households qualify for additional low income energy efficiency (LIEE) programs extended to households with annual incomes less than or equal to 200 percent of federal Poverty Guidelines.[25]



Pursuant to a legislative mandate to reduce energy usage in California, the Energy Commission adopted California's Appliance Efficiency Regulations in 1976 (Title 20) and Part 6 of Title 24 of the California Code of Regulations, the Energy Efficiency Standards for Residential and Nonresidential Buildings in 1978, (Title 24).[26] The Title 24 standards are updated triennially to incorporate new energy efficiency technologies and methods. The Title 20 standards are updated more frequently.

The utilities have responded to the diverse needs of California's residential sector by offering a wide range of energy efficiency programs that impact every level of the residential market, including rebates for efficient products, such as lighting, air conditioners, and refrigerators; training and education to architects, engineers, building managers and building inspectors; and work to enhance the Energy Commission's building and appliance codes and standards. The utilities also have introduced a number of innovative whole house or community-wide programs such as the SCE Sustainable Communities program which targets new residential developments and the Design for Comfort Program that provides efficiency assistance to affordable housing developments that are undergoing renovation.





VISION

Over the past two utility program cycles (2004/2005 and 2006/2008), the utilities have focused heavily on residential lighting, which accounts for the largest electricity end use in the residential sector. As a result, the bulk of residential efficiency savings has come from lighting programs such as measures that encourage the use of compact fluorescent light (CFL) bulbs. In the past few years, the CFL market has undergone a major transformation, as evidenced by the ubiquity of CFL products in the retail market and recent energy measurement and verification studies.

A major transformation of the lighting market will be completed through the passage and implementation of AB 1109, the 2007 California Lighting Efficiency and Toxics Reduction Act.[27] AB 1109 requires a 50 percent increase in efficiency for residential general service lighting by 2018 through phased increases in the Energy Commission's Title 20 regulations, with the first phase of the standards taking effect by January 1, 2010.[28] These changes in the lighting market provide will allow opportunities to redirect utilities' residential energy efficiency resources towards new lighting technologies and other innovative programs focused on whole-building efficiency measures.

Likewise, the strategies set forth in this Plan will create longer-term savings from the built environment with a goal of continual incorporation of advances into codes and standards or the private marketplace. The 2009-2011 IOU program cycle will lay the foundation for aggressive, long-term strategies to change the way residential buildings are constructed, used and maintained.

2.1.3 GOALS

Goal	Goal Results
1. New construction will reach "zero net energy" (ZNE) performance (including clean, onsite distributed generation) for all new single and multi-family homes by 2020.	By 2011, 50% of new homes will surpass 2005 Title 24 standards by 35%; 10% will surpass 2005 Title 24 standards by 55%. By 2015, 90% will surpass 2005 Title 24 standards by 35%. By 2020, all new homes are ZNE.
2. Home buyers, owners and renovators will implement a whole house approach to energy consumption that will guide their purchase and use of existing and new homes, home equipment (e.g., HVAC systems), household appliances, lighting, and "plug load" amenities.	Energy consumption in existing homes will be reduced by 20% by 2015 and 40% by 2020 through universal demand for highly efficient homes and products.
3. Plug loads will be managed by developing consumer electronics and appliances that use less energy and provide tools to enable customers to understand and manage their energy demand.	Plug loads will grow at a slower rate and then decline through technological innovation spurred by market transformation and customer demand for energy efficient products.
4. The residential lighting industry will undergo substantial transformation through the deployment of high-efficiency and high-performance lighting technologies, supported by state and national codes and standards.	Utilities will begin to phase traditional mass market CFL bulb promotions and giveaways out of program portfolios and shift focus toward new lighting technologies and other innovative programs that focus on lasting energy savings and improved consumer uptake.

Transformation of markets for new multi-family homes can be achieved through strategies targeting the Commercial or Residential sectors or a combination of both, since rental buildings are commercial enterprises as well as dwelling units. In this first Plan, with the exception of the approximately 50 percent of LIEE-eligible households living in multi-family housing, there is no specific focus on strategies to upgrade efficiency in existing multi-family dwellings. This is a recognized shortcoming and strategies for this market must be addressed in greater detail in the next iteration of this Plan.

The leadership and active participation of many organizations are also necessary to achieve the vision for the residential sector. The Energy Commission must continue to lead the efforts to continually enhance and expand the building and appliance codes with active technical support and expertise from the IOUs, national laboratories, and the building industry.

In addition, the United States Department of Energy (DOE) and the United States Environmental Protection Agency (EPA) play critical roles in residential energy efficiency efforts. Moreover, significant attention must be directed towards manufactured (or "prefabricated") housing, a substantial and growing component within new housing stock, which is built under federal code set by the United States Department of Housing and Urban Development.

Extensive R&D efforts and partnership programs will push the market further. For technological advances in buildings, appliances and plug loads, the IOU's Emerging Technologies program and the Energy Commission's ratepayer-funded Public Interest Energy Research (PIER) program must work cooperatively with the national laboratories and private industry to achieve the advances envisioned in this Plan.

2.1.4 STRATEGIES

The market transformation envisioned by the residential sector *Vision and Goals* involves changing both the supply chain of products and services and the behaviors that residential energy consumers rely on to use energy efficiently. The four interrelated residential Goals are designed to achieve this transformation through the following themes:

1. **Building Innovation**: Drive continual advances in technologies in the building envelope, including building materials and systems, construction methods, distributed generation, advanced metering infrastructure, and building design, and incorporate technology advances into codes and standards.
2. **Comprehensive Solutions**: Develop, offer and promote comprehensive solutions for single and multi-family buildings, including energy efficiency measures, demand management tools and real-time information, and clean distributed generation options in order to maximize economic decision-making and energy savings.
3. **Customer Demand**: Create high levels of customer demand for progressively more efficient homes through a coordinated statewide public education campaign and targeted incentive programs.
4. **Statewide Solutions**: Coordinate and collaborate with state agencies and private organizations to advance research and development and to align state efforts on buildings.
5. **Financing**: Work with the financial community to develop innovative and affordable financing options for energy efficient buildings and retrofits.
6. **Codes and Standards**: Adopt aggressive and progressive minimum energy codes and standards for buildings and plug loads, effective code compliance and enforcement, and parallel, tiered voluntary energy efficiency standards that pull the market along and set a higher bar for subsequent standards.

While the overall mission for the residential sector is ambitious, these goals and strategies are interrelated and many of the efforts to reach one goal will contribute to the achievement of a different goal; for example, success in Goal 3 (Plug Load) will contribute to the success of Goal 1 (ZNE Homes) and Goal 2 (Whole House Performance). Improvements in building standards resulting from improvements in technologies (Goal 1) will promote efficiencies from existing home renovations and improvements (Goal 2).

Certain strategies in the residential market (e.g., marketing, education and outreach) are part of larger, cross-cutting strategies. As a consequence, the strategies described below contain a certain amount of repetition and cross-referencing; however, each strategy will require refinements to accomplish the specific goal for target markets. This is consistent with our overall goal of encouraging integrated energy efficiency programs that recognize and leverage the benefits of related projects, while at the same time aligning specific strategies with the requirement of each goal.

2.1.5 IMPLEMENTATION PLAN

Goal 1: Deliver Zero Net Energy New Homes By 2020.

Goal 1 envisions a continual and dramatic increase in the demand for and supply of lower energy homes based on new technologies, new building principles, and policy support to achieve a statewide standard of zero net energy (ZNE) for all new homes built in 2020.

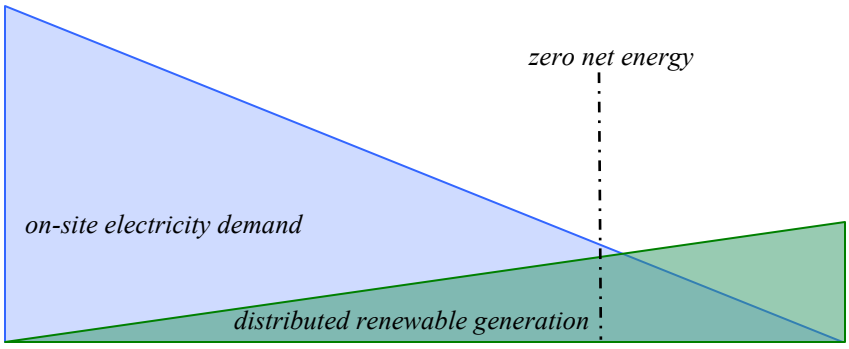
A ZNE home employs a combination of energy efficiency design features, efficient appliances, clean distributed generation, and advanced energy management systems to result in no net purchases of energy from the grid. The CPUC has defined "Zero Net Energy" at the level of a single "project" seeking development entitlements and building code permits in order to enable a wider range of technologies to be considered and deployed, including district heating and cooling systems and/or small-scale renewable energy projects that serve more than one home or business.

A wide range of design features may be considered to achieve zero net energy, including building orientation (relative to the daily and seasonal position of the sun), window and door type and placement, insulation type and values of the building elements, weatherization, the efficiency of heating, cooling, lighting and other equipment, as well as local climate.

Heating and cooling loads are lowered by using high-efficiency equipment, added insulation, high-efficiency windows, in addition to passive solar and other design elements; water heating loads can be alleviated by using heat recovery units and high-efficiency water heating equipment; lighting energy needs are reduced by daylighting and fluorescent and LED fixtures; while plug loads are managed by efficient appliances and minimized standby power.

WHAT IS ZERO NET ENERGY?

Zero net energy is a general term applied to a building with a net energy consumption of zero over a typical year. To cope with fluctuations in demand, zero energy buildings are typically envisioned as connected to the grid, exporting electricity to the grid when there is a surplus, and drawing electricity when not enough electricity is being produced.



- The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building.
- A ZNE building may also consider embodied energy – the quantity of energy required to manufacture and supply to the point of use, the materials utilized for its building.[29]

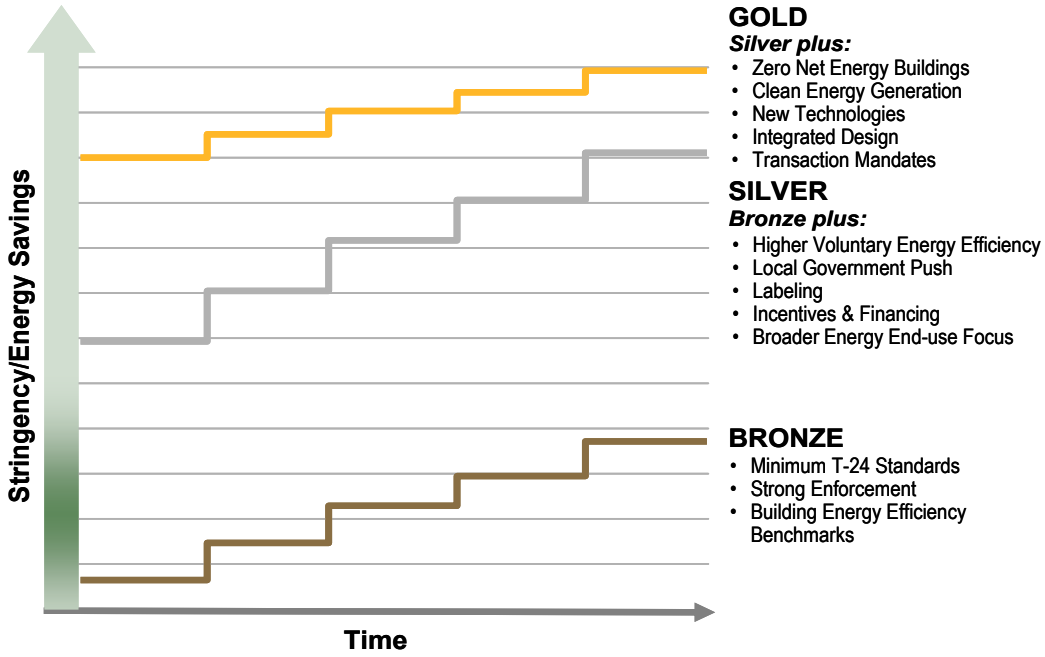
Interim milestones for this programmatic goal are that by 2011, 50 percent of new homes will be 35 percent more efficient than 2005 Title 24 standards (coincident with the Energy Commission's Tier II standard for incentives under the New Solar Homes Partnership[30]) and 10 percent will be 55 percent more efficient; and

that by 2015, 90 percent of homes will surpass 2005 Title 24 standards by 35 percent.

The "Big / Bold" goal of achieving ZNE for 100 percent of new residential construction and the supporting interim goals are extremely aggressive. Accordingly, we characterize them in this first Plan as "reach" and "programmatic" goals. They are intended to capture the imagination and spark the enthusiasm of all who participate in transforming residential new construction to ultra-high levels of energy efficiency.

As part of this effort, California will establish a "Path to Zero" campaign sponsored by the CPUC, state agencies, utilities, the building industry, and others. This campaign will feature real-world experience and data on emerging technologies, practices, and designs that deliver zero net and ultra-low energy buildings, coordinated with marketing tactics and financial incentives. A first step will be convening a task force of key stakeholders committed to zero net energy buildings.

California's Title 24 should continue to be progressively updated and tightened on a triennial basis along a planned trajectory leading to achievement of goals for the year 2020. Mandatory standards of Title 24 should be linked to one or two tiers of voluntary, beyond-code standards such that the single mandatory and one or two voluntary levels comprise a bronze-silver-gold approach to residential efficiency performance. Each Title 24 Code update will achieve a stepped pattern of tightening standards toward what had been the higher voluntary level, dropping the previous minimum mandatory (i.e., 2011's gold becomes 2014's silver and 2017's minimum mandatory). These voluntary silver-gold tiers could be used as



alongside mechanisms to demonstrate their effectiveness and create demand in the marketplace for high-performance buildings

In July 2008, California's Building Standards Commission (BSC) adopted a first-ever set of Green Building Standards that apply to commercial and residential construction

reference points for "reach" building policies and programs, local ordinances, and utility incentives.

statewide.[31] The standards will take effect on a voluntary basis in 2009, and will likely be adopted as mandatory standards by 2012. In addition, in August, the City and County of San

Francisco adopted a Green Building ordinance requiring newly constructed commercial buildings over 5,000 sq ft, residential buildings over 75 feet in height, and renovations on buildings over 25,000 sq ft to meet the United States Green Building Council's Leadership in Energy and Environmental Design standards (LEED) and other green building certifications. [32] Similarly, the City of Los Angeles enacted its own Green Building Ordinance in April 2008, which takes affect later in 2008 and 2009. It establishes a series of requirements and incentives for developers to meet LEED standards and is expected to affect at least 7.5 million square feet each year.[33]

The emergence of sustainable building policies and ordinances are an indication that many local governments desire building practices that go beyond state minimum building codes. As more local governments enact codes that are more stringent than state codes, a patchwork of different and potentially conflicting building requirements is arising. As requirements become more varied across geography, developers and particularly production home builders may have difficulty designing and building major developments consistent with both state and local codes.

Accordingly, Strategy 2 requires coordination of local government building codes and development policies to facilitate common approaches to the adoption and rapid evolution of highly energy efficient technologies and techniques in new construction statewide. Coordination also will advance testing of sustainable building technologies and techniques in different operating environments to provide a stronger basis for progressive increases in the stringency and coverage of energy efficiency standards within state building codes.

The Energy Commission is the logical candidate to lead the codes and standards effort along with the BSC and the Department of Housing and Community Development. Near-term, the Energy Commission could collaborate with these agencies to publish a provisional, performance-based "reach code" reference standard for "beyond code" residential construction in California. This would be advisory and create a reference from which to gauge further improvements.

The process could coordinate with the Energy Commission's Public Interest Energy Research (PIER) and other research organizations (Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Building Industry Research Alliance (BIRA) to assess and provide the foundation for recommendations, including monitoring and measurement approaches.

This Goal also requires a major transformation in the construction, design and usage of residences through a combination of mandates and voluntary actions. The technical feasibility of ZNE homes is in early stages of demonstration through the pioneering efforts of the Sacramento Municipal Utility District (SMUD), NREL, and home designers and builders. DOE's Building America effort, for instance, has put ZNE research to work in homes across 34 states. These demonstrations also provide a forum for continual research on optimizing performance of homes with ZNE elements.

Several ZNE residential projects, such as SMUD's project in Roseville, CA, are already underway and others are in the planning or conceptual phase. In the near term, the utilities will aggressively promote additional proof of concept pilots, including affordable housing elements in these pilots.

Significant additional resources will be required to scale these efforts up to for full-scale production and sale at affordable prices. In an effort to marshal private, public, academic, corporate, and entrepreneurial resources towards this objective, a prominent philanthropy organization will soon announce an Energy Free Home Challenge: to achieve zero net energy at zero net cost. Launching in fall 2008, the prize will award $20 million in cash prizes both for enabling technology innovation and whole-home innovation.

California will need new, cost-effective technologies for home building materials and fabrication techniques, and "smarter" home operating systems, such as visual displays of real-time (or near real-time) energy use. In addition, the energy efficiencies of household equipment and appliances must increase. (In this regard, see Strategies 2 and 3 below and the Heating, Ventilation & Air Conditioning

Chapter.) These innovations must be accompanied by a strong education, outreach and marketing effort to increase consumer demand for efficient homes, including the use of energy or carbon benchmarks and labels.

Affordability is a key consideration in California, where the cost of housing is a serious, long-term issue.[34] A key element of this Goal is to develop ZNE example homes across the spectrum of housing options, including multi-family affordable housing in urban infill areas with access to public transportation.

Finally, innovative financing solutions, such as loans that remain with the property through owner-occupant turnover and energy efficient mortgages, will be essential in allowing builders and owners to leverage the cost-savings inherent in ZNE buildings into investment costs.

Furthermore, finance mechanisms must fully reflect the savings in monthly operating costs from low energy homes. New programs must leverage and build upon financing options available from private markets and other government initiatives. To this end, the CPUC will establish a Finance Task Force for the commercial and residential sectors made up of members of the financial/investment industries; building and developer community; and, state, federal and local governments to identify existing and additional needed tools, instruments, and information necessary to attract greater participation of capital markets in funding efficiency transactions. The Task Force will identify actors to develop innovative and effective financing tools especially suited for ZNE and ultra low-energy buildings.

Goal 1: Zero Net Energy Homes

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid-Term 2012 – 2015**	**Long Term 2016 – 2020**
1-1: Drive continual advances in technologies in the building envelope, including building materials and systems, construction methods, distributed generation, and building design.	Energy Commission (PIER) Utilities DOE, national labs Production home builders and building industry organizations	• 50% of new homes exceed 2005 Title 24 standards by 35% • 10% of new homes exceed 2005 Title 24 standards by 55%	• 90% of new homes exceed Title 24 by 35% • 40% of new homes exceed Title 24 by 55%	• 100% of new homes exceed Title 24 by 35% • 90% of new homes exceed Title 24 by 55%
		• Develop and participate in pilot projects in specific climates to prove technologies for next generation of lower and zero energy homes, including affordable housing projects. • Continually monitor performance of pilot projects to provide feedback for next level of design and development of technologies.	• Develop and implement next generation of pilot projects; continually monitor performance of pilots to provide feedback for next level of design and development of technologies	• Develop and implement next generation of pilot projects; continually monitor performance of pilots to provide feedback for next level of design and development of technologies
		• Advance technological innovation through collaboration of Energy Commission PIER and Emerging Technologies Programs, LBNL, NREL, Utilities, CBIA, and other appropriate organizations.	• Ongoing	• Ongoing

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid-Term 2012 – 2015**	**Long Term 2016 – 2020**
		• Assess existing technologies and identify areas for strategic involvement in research and development	• Ongoing	• Ongoing
1-2: Continual coordination and cooperation between the Energy Commission and others to progressively increase Title 24 building standards and Title 20 appliance standards consistent with the interim and long-term goals set forth in this Plan	Energy Commission Utilities Local governments California Building Standards Commission	• Map a trajectory for Title 24 mandatory and voluntary standard(s) through 2020 • Progressively make energy efficiency advances permanent by raising Title 24 mandatory standards in 2011 consistent with the trajectory • Progressively advance Title 24 voluntary, "beyond code" standard(s) and ratings systems in step with changes to the mandatory standards	• Fine-tune and revise the trajectory based on the changing energy efficiency state-of-the-art • Progressively make energy efficiency advances permanent by raising Title 24 mandatory standards in 2014 consistent with the trajectory • Progressively advance Title 24 voluntary, "beyond code" standard(s) in step with mandatory standards in 2011 and 2014	• Fine-tune and revise the trajectory based on the changing energy efficiency state-of-the-art • Progressively make energy efficiency advances permanent by raising Title 24 mandatory standards in 2017 and to ZNE by 2020 consistent with the trajectory • Progressively advance Title 24 voluntary, "beyond code" standard(s) in step with mandatory standards in 2017 and 2020
1-3: Coordinate and Support "Reach" Building Standards	Energy Commission Utilities Local governments California Building Standards Commission Building Industry	• Identify and resolve conflicts or inconsistencies between Title 24 and local "green" building ordinances or other standards • Establish policies and procedures for statewide coordination of local building standards that are acceptable to local governments • Provide technical support for the development and implementation of reach standards through partnerships with local governments	• Monitor success of coordination and resolve new issues as they arise	• Monitor success of coordination and resolve new issues as they arise
1-4: Develop innovative financing programs for the construction of energy efficient homes	Finance Task Force Financial institutions Building Industry Utilities	• Convene a task force of financial experts to develop attractive financial products for energy efficiency homes. • Implement Options	• Ongoing expansion of these options.	• Ongoing expansion of these options.

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid-Term 2012 – 2015**	**Long Term 2016 – 2020**
1-5: Encourage local, regional, and statewide leadership groups to support pilots and foster communication among pioneering homeowners and builders	Local Governments Homeowner groups Leading Builders Utilities	• Develop network of building owners (home-owners associations) and builders to help support the dissemination of information and develop peer-to-peer relationships	• Ongoing	• Ongoing

Goal 2: Transform home improvement markets to apply whole house energy solutions to existing homes.

The overall objective of Goal 2 is to reach all existing homes and maximize their energy efficiency potential through delivery of a comprehensive package of cost-effective, whole house energy efficiency retrofit measures—including building shell upgrades, high-efficiency HVAC units, and emerging deep energy reduction initiatives— with comprehensive audits, installation services and attractive financing. This can be achieved through parallel and coordinated initiatives among utility programs, private market actors, and state and local government policies.

The IOUs currently offer a wide range of energy efficiency programs for existing homes, including audits, efficient appliance rebates, and consumer education. This Plan envisions a refocusing of these programs to move from a "widget" based approach to a "whole house" approach to program delivery to offer comprehensive packages of audits, demand side management options and tools, rebates and financing options, and installation services.

A similar approach must be developed for multi-family housing, both condominiums and rentals. The key to this effort will be defining workable financing mechanisms that allow energy bill savings from improvements occurring in the individual units to offset the up-front capital costs typically paid by building owners and homeowners associations. These mechanisms also must allow repayment of energy improvements from successor occupants so that turnover does not dissuade taking action. With such financing mechanisms, it should be possible for multi-family housing to take fuller advantage of both private energy services and utility programs and incentives. Since many lower-income households live in multi-family housing, they can be served via the strategies targeting low income households discussed later in this Chapter.

It is also essential that market actors, once aware of efficiency opportunities at hand, have access to suitable financing mechanisms for whole house measures. The Finance Task Force referenced in the ZNE discussion above, will focus on effective financing tools especially suited for whole house retrofit measures.

While many residential building retrofit measures have unacceptably long customer payback periods based on energy prices alone, they can find market acceptance and leverage private sector investment based on attributes other than energy savings (e.g. comfort and noise reduction). Financing mechanisms for whole house measures will also improve customer affordability and thus may increase market acceptance. In the future, the increased value of GHG reductions may also improve the economics of such measures. These issues should be considered in updating the methodology for calculating program or portfolio cost-effectiveness.

A key driver for the success of this Goal is to create market demand for efficient homes by increasing awareness of, and information on, energy efficiency. In the near term, the Energy Commission will adopt its Home Energy Rating

System (HERS) standards for existing homes by the end of 2008. In cooperation with the Energy Commission, the IOUs will begin voluntary pilot programs to implement the HERS system and to encourage local governments to adopt residential energy conservation ordinances for energy ratings at the time of sale. In the longer-term, additional mechanisms might include community initiatives to reduce the "carbon footprint" of homes or neighborhoods, or promoting inclusion of home energy ratings in real estate sales listing information.

To achieve both widespread and deep levels of energy efficiency throughout the existing housing stock will require local government leadership. Individual local governments can adopt residential energy conservation ordinances (RECOs) for energy ratings and possible improvements at the time of sale. Utility programs can partner with these governments to provide supporting information on ratings systems, cost-effective measures and related implementation issues.

In addition, many actors must work together to ensure building code compliance. Strengthening building codes without improving local on-the-ground compliance leads to illusory progress. Concerns have arisen regarding whether HVAC compliance issues already undermine the effectiveness of Title 24 standards, and increasing the stringency and coverage of state standards is likely to add to these issues. The reasons behind compliance issues vary with jurisdiction and may include conflicts between state and local priorities, local government budget limitations, and market disincentives for contractors to comply.

The CPUC and utilities should coordinate with the Energy Commission and local governments to identify barriers to aggressive enforcement of state building standards and to develop effective plans for overcoming these barriers. An objective of these plans should be to leverage state and local resources to improve compliance. City and county building officials, for instance, are responsible for the vast majority of Title 24 enforcement, and their statewide association, the California Association of Local Building Officials (CALBO) is one key source of perspective on what is and is not working as energy standards become more stringent.

In order to ensure progress in implementing this Goal, a task force of key stakeholders should be convened to refine and oversee the strategies identified here.

Goal 2: Existing Homes

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2-1: Deploy full-scale Whole house programs.	Utilities Home improvement industry	• Implement pilot home retrofit programs with effective integration and delivery of comprehensive demand-side options including energy efficiency, demand response and renewable energy measures in specific locations to prove technologies for next generation of lower energy homes in various climate zones	• Monitor performance of selected lower energy homes. Design implement, monitor and continuously improve full-scale programs for whole house energy efficiency and renewable energy retrofits	By 2020: • 25% of existing homes have a 70% decrease in purchased energy from 2008 levels • 75% of existing homes have a 30% decrease in purchased energy from 2008 levels • 100% of existing multi-family homes have a 40% decrease in purchased energy from 2008 levels
2-2: Promote effective decision-making to create widespread demand for energy efficiency measures	Utilities Home improvement industry Real estate industry assns Local governments	• Complete initial market research to determine homeowner "decision triggers" to improving home energy efficiency, including an assessment of the impact of EE or carbon labeling	• Follow-up market research	• Follow-up market research
		• Develop, launch, monitor and continuously improve campaigns to raise demand for lower energy homes, including home energy or carbon labeling programs • Actively support local governments considering RECOs to improve the energy performance of existing homes at time of sale or during major renovations • Develop and implement home rating system pilot projects based on the Energy Commission HERS program	• Continuously improve campaigns to raise demand for lower energy homes, including home labeling programs	• Continuously improve campaigns to raise demand for lower energy homes, including home labeling programs
2-3: Manage research into new/advanced cost-effective innovations to reduce energy use in existing homes	Energy Commission DOE/National labs Utilities	• Gather and disseminate information on advanced retrofits. • Advance technological innovation through collaboration of Energy Commission PIER and Emerging Technologies Programs, Utilities and other appropriate organizations. • Promote commercialization of home energy management tools including AMI-based monitoring and display tools	• Ongoing	• Ongoing

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2-4 Develop financial products and programs such as on-bill financing to encourage demand for energy efficiency building products, homes systems, and appliances	Finance Task Force Financial institutions Contractors Local Government Utilities	• Develop partnerships for innovative financing programs, such as performance contracts and City of Berkeley's solar and EE property loans • Investigate the feasibility of on-bill financing and other lending products. • Convene Task force on Financing with attention to issues of multi-family housing and paying for actions with longer-term paybacks	• Design implement, monitor and continuously improve financial products and programs for whole house energy efficiency and renewable energy retrofits	• Design implement, monitor and continuously improve financial products and programs for whole house energy efficiency and renewable energy retrofits
2-5: Increase Title 24 compliance through specific measures leading to aggressive statewide enforcement	Energy Commission State Contractor Licensing Board Utilities Local Governments CALBO California BSC	• Identify the barriers to compliance and develop a compliance plan to implement remedial measures, including legislation if necessary. • Leverage the compliance plan measures to support enforcement of local energy efficiency codes and standards. Identify opportunities for leveraging Title 24 and local codes enforcement • Develop program models that require proof of code compliance as a condition of receiving rebates or financing	• 80% of transactions that trigger Title 24 requirements will comply with all applicable requirements. • Monitor success or failure of leveraging and pursue additional actions to achieve success as necessary	• Monitor success or failure of leveraging and pursue additional actions to achieve success as necessary

Goal 3: Develop comprehensive, innovative initiatives to reverse the growth of plug load energy consumption through technological and behavioral solutions.

Plug loads are a complex, rapidly growing driver of electricity consumption, which currently account for at least 10-15 percent of overall household energy use.[35] The loads range from the ubiquitous energy thief transformers on almost every electronic appliance to home offices and the 1+ kW home entertainment centers growing in popularity. Potential savings from this plug load strategy could be 200 MW by 2011, with larger potential savings in the future.

Reduce plug loads will require changes in consumer purchasing patterns, research to develop smarter products, commercialization support for such products in terms of upstream rebates and incentives, and stimulation of customer demand through informational initiatives including unbiased and ubiquitous labeling. Ultimately, these savings will need to be locked in by raising state and federal standards.

Goal 3: Reduce Plug Loads

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
3-1 Drive continual advances in residential energy usage, including plug loads, home energy management systems, and appliances	Energy Commission (PIER) Utilities LBNL Appliance manufacturers Retailers	• Work with research organizations to develop smarter products with lower energy requirements. • Work with manufacturers to raise product energy efficiency, both when in use and when in standby mode	• 10% reduction in plug loads	• 25% reduction in plug loads
3-2 In coordination with Strategy 2-2 above, develop public awareness of and demand for highly efficient products	Utilities Manufacturers retailers Local Government Consumer information outlets	• Complete initial market research including identification of customer decision triggers for choosing highly energy efficient devices. • Implement public awareness and information campaign to promote purchase of more efficient products and create behavioral changes in the way products are perceived, used, and managed	• Follow-up market research	• Follow-up market research
3-3: Create demand for such products through market transformation activities	Utilities Industry partners	• Deploy package of rebates, incentives and voluntary industry agreements to bring significant numbers of the best current technologies for managing plug loads (e.g., smart power strips and informative visual displays) to market • Promote unbiased labels and Web sites (*Consumer Reports* approach)	• Ongoing	• Ongoing
3-4: Continuously strengthen standards, including the expansion of both Title 24 and 20 to codify advances in plug load management	Energy Commission Utilities	• Continuously incorporate gains in efficiency in the appliance standards	• Continuously incorporate gains in efficiency in the appliance standards	• Continuously incorporate gains in efficiency in the appliance standards

2.2 LOW INCOME RESIDENTIAL SEGMENT

2.2.1 VISION

By 2020, 100 percent of eligible and willing customers will have received all cost-effective Low Income Energy Efficiency measures.

2.2.2 PROFILE

California's Low Income Energy Efficiency (LIEE) programs provide no-cost energy efficiency and appliance testing and repair measures to qualified low income customers in rental and customer-owned residences. The complementary objectives of the LIEE programs are to provide an energy resource for California and to produce energy savings, while reducing low-income customer bills. Customers qualifying for LIEE programs represent up to 30 percent of the IOUs' residential customers—or about 3.8 million households. In the past ten years, LIEE programs have provided about 1.6 million low-income households a range of energy-related services including home weatherization, refrigerator replacement, repair and replacement of heating and air conditioning equipment, and CFL distribution.

Although a large number of homes have benefitted from measures under the LIEE programs over the past 10 years, more than 50 percent of low income residences have yet to receive energy efficiency upgrades. The Commission has called upon the IOUs for a fresh look at LIEE programs to provide an expanded role for LIEE programs as a California energy resource, working in concert with other efforts to address climate change and meeting the needs of more low-income customers. In particular, the Commission has adopted a Big/Bold Strategy to provide all eligible and willing low income customers the opportunity to participate in the LIEE programs and to offer cost-effective and quality-of-life improving energy efficiency measures in their residences by 2020.

During the initial years of this Plan, the IOUs will focus their efforts on developing a more effective outreach program using segmentation techniques to identify target groups within the low income populations. In order to serve these additional households, the IOUs will design programs to be more administratively and operationally efficient. In the near term, the IOUs will develop partnerships with community organizations and local governments to leverage existing services and tools.

2.2.3 GOALS

This Plan contains two goals to achieve the LIEE vision:

Goal	Goal Results
1. By 2020, all eligible customers will be given the opportunity to participate in the LIEE program.	Marketing, Education and Outreach programs will be highly successful and the number of eligible households in California receiving LIEE services will increase. LIEE customers will be educated on the benefits of energy efficiency and conservation behaviors. A trained LIEE workforce will accommodate future job

		demand and educate their communities.
2. The LIEE programs will be an energy resource by delivering increasingly cost-effective and longer-term savings.	➡	Other state, federal and local programs will be leveraged to streamline and improve customer identification and program delivery. LIEE programs will be integrated with core energy efficiency programs to achieve economies of scale. Participants will receive comprehensive energy efficiency services that produce long-term energy savings for the state, while reducing low-income customers' bills and improving their quality of life.

2.2.4 STRATEGIES

The market transformation envisioned for the LIEE sector involves changing both the delivery of products and services and the behaviors that low income energy consumers rely on to use energy efficiently.

The LIEE Goals require leadership from the Low Income Oversight Board and the IOUs working in partnership with community-based organizations, contractors, educational and training institutions, and local, state and federal agencies that also serve the low income community.

2.2.5 IMPLEMENTATION PLAN

Goal 1: By 2020, all eligible customers will be given the opportunity to participate in the LIEE program.

California and the IOUs will approach this Goal through two broad efforts: Marketing, Education, and Outreach (ME&O) and Workforce Education and Training (WE&T). These broader efforts will encompass current activities as a foundation, but will expand to newer, more creative efforts. ME&O efforts will be improved through the statewide collaborative and integrated approach as discussed in the ME&O Chapter. As part of the overall ME&O program, additional efforts specifically designed for the low income community will be implemented. The IOUs will target outreach efforts based on four customer profile segments: geography, demographic description (e.g., language preference), social networks; and level of energy use. Though this list of factors may expand over time, it represents an extension of current approaches and areas scheduled to be further developed in the IOUs' 2009-2011 programs.

Second, the IOUs will focus on improving delivery methods so that all willing and eligible customers can be reached by 2020. The segmentation approach discussed earlier will improve the efficiency of delivery by identifying geographic and social concentrations of customers to achieve economies in delivery, material purchasing and resources. It also promotes effective use of low-income service providers, including community-based organizations and other qualified agencies. The segmentation or tiered approach will enable the IOUs to offer more households measures more efficiently.

The expanded LIEE programs will require additional trained professionals. Training efforts for the LIEE program are addressed by the strategies described in the WE&T Chapter of the Plan, including incorporating the needs of the LIEE programs into the needs assessment. The needs assessment will include the development of LIEE job definitions, inform a LIEE Training Roadmap, and ensure trained resources are available to deliver LIEE services. To promote substantial growth in a trained LIEE workforce, the IOUs will integrate LIEE program installation training with other energy efficiency training. This integration will enable a wider network of providers to provide for LIEE services and provide those trained in LIEE access to other energy service opportunities.

Goal 1: Improve Customer Outreach

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
1.1: Strengthen LIEE outreach using segmentation analysis and social marketing tools	IOUs Low income customers LIOB Contractors Community Based Organizations (CBOs) ME&O Taskforce Local, state and federal agencies	• Identify, implement and evaluate effective marketing, education and outreach methods for targeting low-income customer segments • Use social marketing to effectively engage low income customers in program participation	• Implement energy education designed to help customers understand and change behaviors in ways that support LIEE savings	• Continue to assess and evaluate customer-behavior and energy savings; improve upon outreach to eligible communities
1.2: Develop a recognizable and trustworthy Brand/Tagline for the LIEE programs	IOUs Low Income customers LIOB Contractors (CBOs)	• Develop a statewide program name and description for LIEE which is coordinated with the ME&O efforts for energy efficiency, demand response and any other demand-side options • Implement branding.	• Launch integrated EE/LIEE/DSM brand	• Evaluate progress/refine strategy
1.3: Improve program delivery	IOUs LIOB Low Income Customers CBOs Contractors Local, state and federal agencies	• Use information from segmentation analysis to achieve efficiencies in program delivery. • Leverage with Local, state, and federal agencies as well as other organizations to increase seamless coordination, efficiency and enrollment	• Ongoing	• Ongoing
1.4: Promote the growth of a trained LIEE workforce	WE&T Task Force IOUs Low income customers LIOB Contractors CBOs Local Governments	• Incorporate LIEE training needs into the Workforce Training needs assessment • Develop Training Roadmap which includes funding requirements and sources other than IOUs • Implement LIEE workforce education and training	• Implement LIEE workforce education and training. • Coordinate resources for training related to LIEE program needs to ensure delivery of LIEE-trained resources to the program	• Implement LIEE workforce education and training. • Coordinate LIEE workforce and service providers with broader market

Goal 2. The LIEE programs will be an energy resource by delivering increasingly cost-effective and longer-term savings.

Significant opportunities exist for increased collaboration between the IOUs and the state and federal agencies providing services to the low-income community. In particular, data sharing with other state and federal agencies, and collaborating with community partners to leverage federal, state and local funds are critical in achieving this Goal.

The IOUs currently have successful partnerships with low-income population assistance agencies, community based organizations, county agencies, and water districts. Over the longer-term, utility efforts will increase the number of partnerships with additional resources and organizations.

In addition to working with other local, state and federal agencies, the IOUs will focus on providing LIEE program measures and services that are cost-effective and emphasize long-term and enduring energy savings—for example, refrigerators, attic insulation, and other major appliance replacements. The LIEE program may also include measures that improve customers' quality of life.

The LIEE programs will also incorporate the most recent strategies and programs in the core residential sector energy efficiency and Demand Side Management (DSM) programs, including the energy efficiency mandates of the California Solar Initiative (CSI). The IOUs will ensure that LIEE participants are made aware of core energy efficiency and demand response programs at the time of enrollment. LIEE messaging and outreach will be integrated into energy efficiency marketing to provide information on energy efficiency and demand response programs to low-income customers.

The LIEE programs will also receive the benefits of the core residential strategies on new and existing homes. As new technologies are commercialized for reduced plug loads, energy management tools, and building materials, they will be incorporated into the programs offered to low income customers. As advanced meters are deployed, the LIEE programs will ensure that low income customers receive the benefits of energy management tools. As discussed above, the ZNE new residential homes goal will include affordable housing components.

In some cases, strategies identified for the core residential sector will be modified for the LIEE context. For instance, while we have indicated a particular strategic direction for lighting programs in the core residential sector, it may be appropriate to take an alternative approach within LIEE programs, largely due to the high initial costs of CFLs and high-efficiency lighting technologies.

The IOUs will focus on improving delivery methods so that all of these homes can be reached by 2020. The segmentation outreach approach discussed earlier will improve the efficiency of delivery by identifying geographic and social concentrations of customers to achieve economies in delivery, material purchasing and resources. It also promotes effective use of low-income customer service providers, including community-based organizations and other qualified agencies. The segmentation or tiered approach will enable the IOUs to offer more households measures more efficiently.

Goal 2: LIEE is an Energy Resource

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2.1: Increase collaboration and leveraging of other low-income programs and services	IOUs LIOB CBOs Department of Community Services Local, state, and federal Government	• Identify key areas where data sharing would be advantageous and seek legislative changes to ease data sharing between agencies • Develop partnerships to leverage resources available from local governments, federal, state, and private project funding sources	• Continue to expand partnerships with stakeholders and seek new opportunities for data sharing	• Continue to expand partnerships with stakeholders and seek new opportunities for data sharing
2.2: Coordinate and communicate between LIEE, energy efficiency and DSM programs to achieve service offerings that are seamless for the customer	IOUs LIOB	• Ensure LIEE participants are aware of energy efficiency and DSM/EE programs • Coordinate with CSI programs to provide LIEE program services in qualified low income housing for both single family and multi-family CSI programs. • Coordinate AMI delivery and LIEE Programs	• Continually reevaluate and update programs to take advantage of new technologies • Explore in-home displays; home area networks and/or "pay-as-you-go" technology to assist low income customers manage their use	• Continually reevaluate and update programs to take advantage of new technologies
2.3: Provide low income customers with measures that result in the most savings in the LIEE program	IOUs LIOB	• Assess design of programs to ensure increasingly cost-effective measures, while reducing low-income customers' bills and improving quality of life • Continue to include measures that provide long term energy savings, such as refrigerators	• Assess opportunities to incorporate new energy efficiency measures into the LIEE program, e.g., plug-load reduction, new HVAC technology	• Continue to evaluate
2.4: Identifying segmented concentrations of customers to improve delivery	IOUs CBOs Local Governments	• Identify and develop segmented approach to deliver services to households • Improve use of CBOs in delivering services.	• Evaluate approach determine whether additional segments are needed	• Continue to evaluate

3. COMMERCIAL SECTOR

3.1 VISION

Commercial buildings will be put on a path to zero net energy by 2030 for all new and a substantial proportion of existing buildings. Innovative technologies and enhanced building design and operation practices will dramatically grow in use in the coming years through a combination of comprehensive whole building programs, technology development, market pull, professional education, targeted financing and incentives, and codes and standards.



3.2 PROFILE

Commercial buildings consume more electricity than any other end-use sector in California. The sector's 5 billion-plus square feet of space is very diverse—not only office buildings but stores, restaurants, warehouses, schools, hospitals, public buildings and facilities[36], and others—in aggregate accounting for 38 percent of the state's power use and over 25 percent of natural gas consumption. Four electric end uses (lighting, cooling, refrigeration, and ventilation) account for 75 percent of all commercial electric use, while just three (space heating, water heating, and cooking) account for over 90 percent of gas use. These end uses command attention for energy efficiency savings strategies.

In terms of the electricity use by the various commercial building types, office buildings are the largest, accounting for nearly 25 percent. Restaurants have a comparable share among gas consumers. Offices, restaurants, and schools and colleges are in the top five facility types for both fuel types.

The following chart provides a snapshot of dominant energy end uses for buildings in California by building type and energy end use category for 2006:

Table 1 - Profile of Consumption by End Use and Major Facility Type *

	Electric %	Cumulative Electric %		Gas %	Cumulative Gas %
End Use			**End Use**		
Lighting-inter & exter	34.5	34.5	Space Heating	36.4	36.4
Cooling	14.9	49.4	Water heating	31.8	68.2
Refrigeration	13.4	62.8	Cooking	22.6	90.8
Ventilation	11.9	74.7	Process	5.9	96.7
Office Equipment	7.1	81.8	Misc.	1.8	98.5
Facility Type			**Facility Type**		
Office	24.5	24.5	Restaurant	24.5	24.5
Retail	14.7	39.2	Health	13.7	38.2
Restaurant	8.9	48.1	Office	13.3	51.5
Food Store	8.8	56.9	School & College	11.1	62.6
School & College	8.8	65.7	Lodging	9.0	71.6
Health	6.8	72.5	Food Store	3.1	74.7
Lodging	4.9	77.4	Retail	2.5	77.2
Unrefrig warehouse	3.7	81.1	Unrefrig warehouse	1.3	78.5

** Source: California End Use Survey, 2006*

Commensurate with the energy demand from the commercial sector, the 2006-2008 IOU energy efficiency programs for commercial building retrofits is approximately one third of the total budget, exceeding $1 billion dollars over the three year period. The IOUs also offer a "Savings by Design" program for new construction, which provides incentives to owners and design teams to incorporate efficient systems into building design or to develop projects that go beyond Title 24 standards using a whole building approach.

For 2009-2011, this Plan envisions an increased emphasis on programs to exceed Title 24 standards with the ultimate goal of building codes and standards that require zero net energy (ZNE) new construction and retrofits by 2030.

Achieving the transformational vision and goals established for the commercial sector will involve changing energy user behaviors and the supply chain of services and products that commercial end-users rely on to efficiently use energy as well as continual updating of codes and standards.

3.3 GOALS

The following goals will spur actions to transform the energy patterns of California's largest energy-consuming sector—its commercial buildings.

Goal	Goal Results
1. New construction will increasingly embrace zero net energy performance (including clean, distributed generation), reaching 100% penetration of new starts in 2030.	An increasing percentage of the 50-120 million sq.ft. per year of new commercial construction will be progressively more efficient and all new construction will be zero net energy by 2030.
2. 50% of existing buildings will be equivalent to zero net energy buildings by 2030 through achievement of deep levels of energy efficiency and clean distributed generation.	250 million square feet (1/20th of existing space) per year through 2030 reach deep levels of energy efficiency improvements and clean, distributed generation through whole building approaches.

3.4 STRATEGIES

Three interrelated and comprehensive strategies will be employed to reach the goals for energy efficiency in new and existing commercial buildings:

1. Codes and Standards: Adopt aggressive and progressive minimum energy codes and standards for buildings and plug loads, effective code compliance and enforcement, and parallel, tiered voluntary energy efficiency standards.

2. Access to Information: Align commercial building benchmarking, advanced metering infrastructure, energy and carbon labeling, and operations and maintenance practices to increase energy efficiency.

3. Financing: Target financing and incentives to support meeting commercial sector goals. Meeting the challenge of reaching ZNE levels, for a substantial fraction of the new and existing commercial building stock, will likely require increased availability and use of innovative and expanded financing and financial incentives, especially approaches to resolve the "principal agent" problem, when economic motivation is split between owners and tenants.

These primary strategies will be supported by three enabling strategies:

1. Promote integrated design knowledge as the basis for commercial building design, construction, renovations and occupancy.
2. Support targeted research and development and promotion of emerging technologies.
3. Offer integrated program delivery of DSM retrofit solutions.

This Plan envisions that the building industry (including developers, construction firms, building owners, tenants, building managers, contractors and others), the CPUC, Energy Commission, architectural and engineering (A&E) firms, and utilities embrace the vision statement and goals as the basis for long-term strategic planning and actions, assuring other market participants of their commitments through 2030. As a result, demand within building space markets will provide demand "pull" alongside both codes and standards and market supply "push" for ZNE and ultra-low energy buildings.

One promising approach for commercial buildings is a progressive set of building codes and standards that steadily tightens over the coming years and is directly linked to one or two tiers of voluntary higher standards, in the "bronze-silver-gold" approach described in the Residential Sector Chapter. These voluntary higher standards (also known as "beyond" or "reach" codes) will be the leading edge that serves to prove and improve the efficacy and cost-effectiveness of advanced products and practices. This Plan anticipates that the IOUs, in cooperation with the building industry and local governments, will continue to play a critical role in providing technical support for developing these voluntary standards and the progressively higher mandatory standards.

Commercial building market actors tend to follow the industry leaders. Corporate champions and state and local government leaders can set the direction and pace using the voluntary higher standards. The voluntary tiers should be the common reference points for utility incentives, local government ordinances, recognition given to highly efficient buildings, and other policy and market-based drivers that go beyond the minimum code to pull up new construction and renovation.

A second key approach is to call upon building energy and carbon benchmarking and labeling to inform building owners, tenants, and prospective buyers about the relative efficiency, operating costs, and carbon footprint of buildings and leased space. This information can help drive a competitive market demand for greener, more efficient buildings – both new construction as well as improvements to existing structures.

The Finance Task Force mentioned in the Residential Chapter above, will be critical to identifying existing and additional means to attracting greater participation of capital markets in funding efficiency transactions and innovative and effective financing tools especially suited for ZNE and ultra low-energy commercial buildings. This effort comes at a critical period in the development of California's AB 32 implementation process, which has identified building efficiency as a sizeable source of GHG reductions. The Task Force should investigate methods to leverage the value of carbon reductions from energy efficiency to finance implementation of energy efficiency in buildings.

3.5 IMPLEMENTATION PLAN

Goal 1: New construction will increasingly embrace zero net energy performance (including clean, distributed generation), reaching 100 percent penetration of new starts in 2030.

The CPUC and the Energy Commission have adopted the goal of all new commercial buildings constructed to ZNE levels by 2030. This BBEES is based on the Architecture 2030's

2030° Challenge, a global initiative to have all new buildings and major renovations reduce their carbon emissions by 50 percent by 2010, and then increasing new buildings' performance to be carbon neutral by 2030. A consortium of groups including the AIA, the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), the US Green Buildings Council (USGBC), and the Alliance to Save Energy (ASE) have initiated the Commercial Building Initiative which is working to develop a framework and strategy for the 2030 Challenge goal.[37]

In August 2008, DOE launched the ZNE Commercial Building Initiative (CBI) which aims to develop marketable ZNE commercial buildings by 2025. To help with the CBI, DOE has formed the National Laboratory Collaborative on Building Technologies (NLCBT), which will allow DOE and five of its national laboratories to work closely on the research, validation, and commercialization priorities that are critical to the success of ZNE buildings.[38]

The follow actions are necessary to implement the ZNE goal:

- As with the Residential ZNE goal, new construction design, products, materials, and operations innovations must be developed and implemented. California's Title 24 should be broadened to address as many energy end uses as possible, especially plug loads; metering and data management; automated diagnostic systems; and sub-metering for tenant-occupied space. These innovations also can quickly transfer to the existing building market, especially for those undergoing occupancy turn-over renovations or improvements. This effort should be led by the Energy Commission with significant support from the utilities, the Building Standards Commission (BSC), the construction and building design industry, and manufacturers.
- The ZNE goal must promote an integrated design strategy. Integrated design brings together all relevant players at the start of a building project to comprehensively analyze and optimize energy strategies to deliver energy-efficient, high performance buildings and renovations, at little or no additional cost to the building owner. Integrated design can go beyond individual buildings and consider community-level energy and carbon impacts. Led by the utilities' energy efficiency programs, the Energy Commission and the BSC, in partnership with the AIA, ASHRAE, USGBC, the California Architects Board, and construction and development organizations, should promote the use of building commissioning, retro-commissioning, and ongoing building measurement and verification to validate the building performance goals of integrated design teams.



- California's "Path to Zero" campaign and associated task force described in the Residential Chapter will lend real-world experience and data on emerging technologies, practices, and designs to deliver zero net and ultra-low energy commercial buildings.
- Financial tools supporting Commercial ZNE investments will be essential. The Finance Task Force discussed in the Residential Chapter will also focus on solutions for the commercial sector. These include appraisal, insurance,

and operations pass-through mechanisms that reflect lower operating costs, higher property values, and substantial non-energy occupancy benefits from green buildings.

Goal 1: ZNE Commercial Buildings

Implementation Plan and Timeline					
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**	**2021 – 2030**
1-1: Establish a long-term progressive path of higher minimum codes and standards ending with ZNE codes and standards for all new buildings by 2030	Energy Commission Utilities BSC A&E firms Building industry	• Establish one- or two-tiered voluntary EE standards, coordinated with green building rating systems. • Align Title 24 targets with goals of AB 32 and carbon reduction	• Develop/adopt process to adjust the code on a triennial schedule on a "fixed" trajectory	• RD&D • Title 24 updates	• RD&D • Title 24 updates
1-2: Expand Titles 20 and 24 to address all significant energy end uses	Energy Commission Utilities Building industry BCS	• Develop and adopt broader codes and standards for plug loads, such as copy machines, printers, battery chargers, televisions • Expand Title 24 to include whole building approaches including metering and data management; automated diagnostic systems; and sub-metering for tenant-occupied space • Adopt progressive codes and standards for high performance commercial lighting applications.	• Develop and adopt broader codes and standards for plug loads and sub-metering and automated self diagnostic controls • Expand Title 20 and Title 24 to cover additional uses such as server farms, process loads and water use • Develop building standards to better integrate on-site clean distributed generation	• Develop and adopt broader codes and standards for other end uses and devices	• Develop and adopt broader codes and standards for other end uses and devices
1-3 Establish a "Path to Zero" Campaign to create demand for high-efficiency buildings	DOE and other ZNE efforts Building industries Building owners A&E firms Local and regional governments Utilities	• Convene leading building industry associations to plan and conduct campaign • Organize forums to develop and exchange experience and data on emerging technologies, practices and designs that deliver ultra-low and ZNE buildings	• Develop companion strategies to create demand in the marketplace for high-scoring buildings • Stimulate rapid innovation toward ZNE among design, engineering, and construction professionals via competitions or other recognition	• Continue and refine Campaign	• Conduct expanded Campaign
1-4: Develop innovative financial tools for ZNE and ultra-low energy *new* buildings	Finance Task Force Financial and Investment community, Commercial developers and Trade groups Utilities	• Develop and pilot innovative financial tools • Identify building performance metrics or documentation needed to inform building performance and valuation • Develop performance data	• Disseminate performance information on new financing, insurance, and property valuation instruments to increase awareness and utilization within financial and real estate markets including	• Expand Implementation of innovative financing mechanisms • Promote benefits via benchmarks, labeling, and case studies	• Ongoing expansion of most useful mechanisms

Implementation Plan and Timeline					
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**	**2021 – 2030**
			owners/investors. • Implement most effective funding mechanisms		
1-5: Create additional investment incentives and leverage other funding	Finance Task Force Utilities Financial and Investment community Building trade groups	• Investigate other funding support that might be offered such as local government "feebates" for EE/green construction, federal funding, federal or state tax incentives, GHG reduction benefits, e.g. via carbon offsets	• Secure governmental support for most promising supplemental funds or investment support	• Ongoing expansion of these options	• Ongoing expansion of these options
1-6: Develop a multi-pronged approach to advance the practice of integrated design	Integrated Design Working Group Utilities AIA CAB Architectural schools Building and Building products Industry ASHRAE USGBC	• Promote ID development via Title 24 codes/ standards and market activities • Identify/develop tools and protocols from building commissioning, retro-commissioning and building M&V to enable ID to be deployed. • Form partnerships with industry and architectural/engineering schools to promote the practice of and education in ID • Provide incentive credits for professionals who maintain their accreditation with ID training	• Promote widespread adoption of tools and resources that enable ID • Create market demand for ID as a key strategy to comply with a vastly enhanced Title 24 • Leverage competition between A/E firms to ramp up their ID expertise (similar to how LEED-AP has become de rigueur) • Implement an integrated design curricula	• Ongoing curriculum enhancements to promote ID • Professional boards establish minimum guidelines for A/E and construction firms to require ID skills as a core competency among personnel • Demonstrate how ID, Cx, RCx, and Bldg M&V can produce GHG benefits	• Ongoing expansion of these options

Goal 2: 50 percent of existing buildings will be retrofit to zero net energy by 2030 through achievement of deep levels of energy efficiency and with the addition of clean distributed generation.

As discussed above, the commercial building industry tends to respond to industry leaders to set the path for action. Therefore, it is critical to lead by example by making public, state-owned and leased buildings benchmarked, sub-metered, and retro-commissioned and energy efficient. In a 2004 Executive Order, Governor Schwarzenegger established the Green Buildings Initiative (GBI) which sets a goal of reducing energy use in state-owned buildings by 20 percent by 2015 (from a 2003 baseline) and encourages the private commercial sector to set the same goal. The Green Action Team (GAT), established by the Order, has carried out efforts over the past three years to promote energy efficiency in state and commercial buildings.[39] Both the University of California and the California State University System have committed to sustainable energy goals for their campuses.

Additionally, the state Architect in cooperation with the Office of Public School Construction is developing a "Grid Neutral by Design" program to encourage schools built and renovated with state funds to achieve higher levels of energy efficiency and produce as much energy as they use over the course of a year. The Grid Neutral schools program will further encourage energy efficient public schools while providing additional opportunities to implement clean on-site generation as new schools are built and the existing schools are renovated. [40]

A wide range of local governments, corporations, and institutions, likewise have committed to attaining certification for energy efficiency (via US EPA's EnergyStar building ratings) and/or the US Green Building Council's LEED system for green buildings. California has by far more qualifying facilities in these programs than any other state.

Goal 2 uses a combination of regulatory and market forces to enable owners and tenants to value the economic and environmental advantages of high-performing (existing) buildings, thereby creating a "market pull" for buildings that are energy efficient.

Goal 2 will also leverage the progress made in mandatory and voluntary codes and standards developed for Goal 1, by lowering the renovation threshold at which minimum codes and standards are applied to an entire existing structure. This effort must be accompanied by appropriate financing tools and robust actions to improve and enforce compliance with existing codes for renovations and by including training of building managers and operators to ensure maximum efficiency from building systems. As discussed in detail in Chapter 6, special attention must be placed on proper design and installation/repair of air conditioning systems.

In 2005, the Energy Commission issued a report titled, *Options for Energy Efficiency in Existing Buildings*,[41] which adopted two strategies for commercial buildings – benchmarking tools and retro-commissioning guidelines and implementation. Elements of the benchmarking strategy are being implemented through AB 1103 (Saldana, 2007) which requires benchmarking of the energy consumption of commercial buildings and disclosure to a prospective buyer, lessee, or lender.[42]

The Energy Commission's benchmarking and retro-commissioning strategies must be further implemented by actions to better align commercial building benchmarking, and operations and maintenance practices with labeling and financial incentives. The IOUs will link their rebate programs to benchmarking to spur market demand for steadily improving benchmarks. During the 2009-2011 periods, the goal is to attain a benchmark score for specified buildings; starting in 2012-2015, the goal is to attain a minimum Energy Star benchmark score. In concert with benchmarking, strategies to increase the role of asset value ratings, similar to the Home Energy Rating System (HERS), provide a potent means to

making energy efficiency a key determinant in driving the commercial real estate market.

The EPA Portfolio Manager's Energy Star benchmark rating system is a commonly-used and well-known benchmarking system well-suited to major commercial building types such as offices and schools. California or EPA will need to develop other or expanded tools to rate remaining building types including through the use of asset ratings. Also in the longer term, local governments could adopt ordinances to issue and renew building certificates of occupancy only for buildings meeting minimum energy benchmarks.

The benchmarking and labeling mandates must evolve to include carbon footprint information. Although the US Green Building Council's LEED rating system has become a de facto "green" label, it does not provide specific information on a building's energy or carbon performance. Annual energy and carbon labels are needed for populated buildings to send signals to market players that actual (not just designed) building energy performance is of value in commercial building markets. Protocols for low-carbon and high-efficiency commercial building attributes will be needed to encourage owners and tenants to demand—and, in turn, markets to deliver—highly efficient buildings.

The Energy Commission's 2005 Existing Buildings Report identified development of retro-commissioning guidelines by the Energy Commission as a key step in the strategy for existing buildings. The Energy Commission should develop such guidelines in the near future. The IOUs should strengthen their existing retro-commissioning efforts by using benchmarking information to strategically identify the best candidates for retro-commissioning and promote whole-building approaches and incentives. Collaboration must occur among the Energy Commission, CPUC, the building industry, and national laboratories to develop tools and strategies to further reduce energy consumption via information, behavioral strategies, commissioning and retro-commissioning, and operating practices. An effective communications strategy to make the business and environmental case for owners and tenants to demand high voluntary performance levels must also be delivered.

Achieving the energy savings identified from codes and standards, benchmarking, and commissioning requires further action on three fronts.

- First is to motivate owners and operators to undertake improvements. This will mean presenting compelling business cases to top decision-makers, while strengthening the skills and knowledge of building operators.

- Second is to ensure access to financing mechanisms that effectively surmount capital limitations and cash flow requirements. This means attracting the interest of banking and capital industries to the magnitude of investment and borrowing needs, and identifying finance mechanisms that properly balance recovery of owner costs through rents, operating cost pass-throughs, or sales price premiums as occupants experience reduced utility bills, higher worker productivity, and other benefits.

- Third is to facilitate the existence of knowledgeable energy management service providers that can conveniently arrange comprehensive improvements in buildings. This may require experimentation with incentives or new business model incubation to attract and reward those businesses willing to offer and arrange one-stop comprehensive energy management solutions that achieve deeper levels of savings than more typically obtained from the more specialized businesses primarily operating in energy service markets today.

Goal 2: Existing Buildings

Implementation Plan and Timeline					
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**	**2020-2030**
2-1: Lead by Example: state/local governments and major corporations commit to achieve energy efficiency, EE, (or green) targets in existing buildings	State of California Green Action Team Local governments Building industry Building owners Business Community	• Ensure all state-owned and leased buildings are benchmarked and retro-commissioned by 2012 • Conduct campaign to have 100 local governments commit to the same target • Conduct campaign to have 500 million sq. ft of commercial space where owners/tenants pledge to reach the same target by 2015	• Require all public buildings receiving significant financial support from the state are benchmarked and retro-commissioned by 2015 • All state-owned and leased buildings (on average) reach Energy Star equivalent rating by 2015 • 100 local governments reach the Energy Star target by 2015. • 500 million sq. ft of commercial space where owners/tenants reach the Energy Star target by 2015	• 250 local governments reach the Energy Star target by 2020 • 2 billion sq. ft. of commercial space reach the Energy Star target by 2020	• 400 local governments reach the Energy Star target by 2030 • 4 billion sq. ft. of commercial space reach the Energy Star target by 2030
2-2: Lower the threshold for applying codes to existing buildings	Energy Commission California Building Standards Commission Building industry Local governments	• Adopt regulations to lower threshold applied to existing building renovations	• Implement lower threshold for renovations	• If necessary, adopt regulations to further lower threshold applied to existing building renovations	
2-3: Ensure compliance with minimum Title 24 codes and standards for building renovations and expansion	Energy Commission BSC Contractors State Licensing Board Professional licensing/ Registration agencies Local governments	• Analyze and adopt best options to ensure compliance with minimum standards • Establish accepted certification methods for voluntary levels of high-performance buildings • 15% of HVAC sales by 2015 are for advanced air conditioning technologies optimized for climate variations	• 50% of HVAC installations comply with codes via permits by 2015 (See implementation details in Chapter 6, Goal 1)	• By 2020, 90% of HVAC systems are installed to code and optimally maintained for systems' useful life	
2-4: Establish mandatory energy and carbon labeling and benchmarks	Legislature Energy Commission Utilities Research institutions Building owners and operators Industry stakeholders state agencies	• Mandate benchmarking for all commercial buildings, triggered by changes in building ownership, financing or tenancy • Develop or approve protocols for benchmarking and compliance options • Incorporate carbon footprint into labeling • Link IOU and other incentives to benchmarks	• Implement mandatory energy and carbon labeling and benchmarks • Promote national labeling and benchmarking standards and protocols • Develop minimum levels of benchmarks to maintain future certificates of occupancy	• Require minimum levels of benchmarks to maintain future certificates of occupancy • Establish change of ownership as a trigger for updated benchmarking requirements	• Establish change in tenancy/lease as a trigger for updated benchmarking requirements

Implementation Plan and Timeline					
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**	**2020-2030**
2-5: Develop tools and strategies to use information and behavioral strategies, commissioning, and training to reduce energy consumption in commercial buildings	Building Industry Energy Commission Utilities Research Institutions	• Identify new or improved tools and strategies that apply information and behavioral strategies, including presentation of economic, comfort and productivity cases to owners, occupants, and appraisers • Strengthen tools and practices for building commissioning • Strengthen Building Operator Certification (BOC) training for commissioning	• Quantify and document business case for EE commissioning and operation and maintenance (O&M activities	• Use business case to expand BOC programs to an increased portion of commercial buildings	
2-6: Develop effective financial tools for EE improvements to *existing* buildings	Finance Task Force Utilities Financial and Investment community Building owners and operators Real estate trade organizations Local Governments	• Quantify magnitude of building investment needed in California to meet long-term EE goals, and identify business-types expected to benefit from EE investments • Build and quantify strong business case for DSM/GHG reduction. • Identify tools, instruments, and information necessary to attract capital to EE • Explore changes to standard lease terms to address perceived tenant/owner "split incentives" issue • Explore expanding on-bill financing offerings to other DSM programs	• Roll out new instruments • Evaluate instruments and cash flow of transactions. Promote success stories • Refine or develop most effective EE financial instruments and business capital investment paths	• Evaluate instruments and cash flow of transactions. Promote success stories	• Refine or develop most effective EE financing instruments and business capital investment paths
2-7: Develop business models and supplier infrastructure to deliver integrated and comprehensive "one-stop" energy management solutions	Utilities Energy Service Companies (ESCOs) DSM and solar service providers venture capital firms Local Governments	• Initiate utility incentive pilots that test the viability of integrated DSM service delivery models (ESCOs, aggregators, etc.) • Explore other mechanisms to more highly reward comprehensive energy management retrofits, e.g. premium incentives for measured performance, local government permits incentives, insurance discounts, etc.	• Identify and promote to venture capital and investment circles business model barriers and opportunities for scalable integrated business models	Apply branding, certification, marketing, or incentive strategies that best delivery one-stop comprehensive DSM services	• Refine most effective integrated onestop delivery models
2.8. Improve utilization of plug load technologies within the commercial sector	Utilities Industry Partners	• Test and deploy package of rebates, incentives and voluntary industry agreements to bring significant numbers of the best available technologies for managing plug loads within the commercial sector	• Incorporate most effective approaches and technologies into building codes and state/federal equipment standards	• Promote best practices and fully incorporate into benchmarking and labeling systems	• Refine and pursue most promising new approaches

4. INDUSTRIAL SECTOR

4.1 VISION

California industry will be vibrant, profitable and exceed national benchmarks for energy efficiency and resource management.



4.2 PROFILE

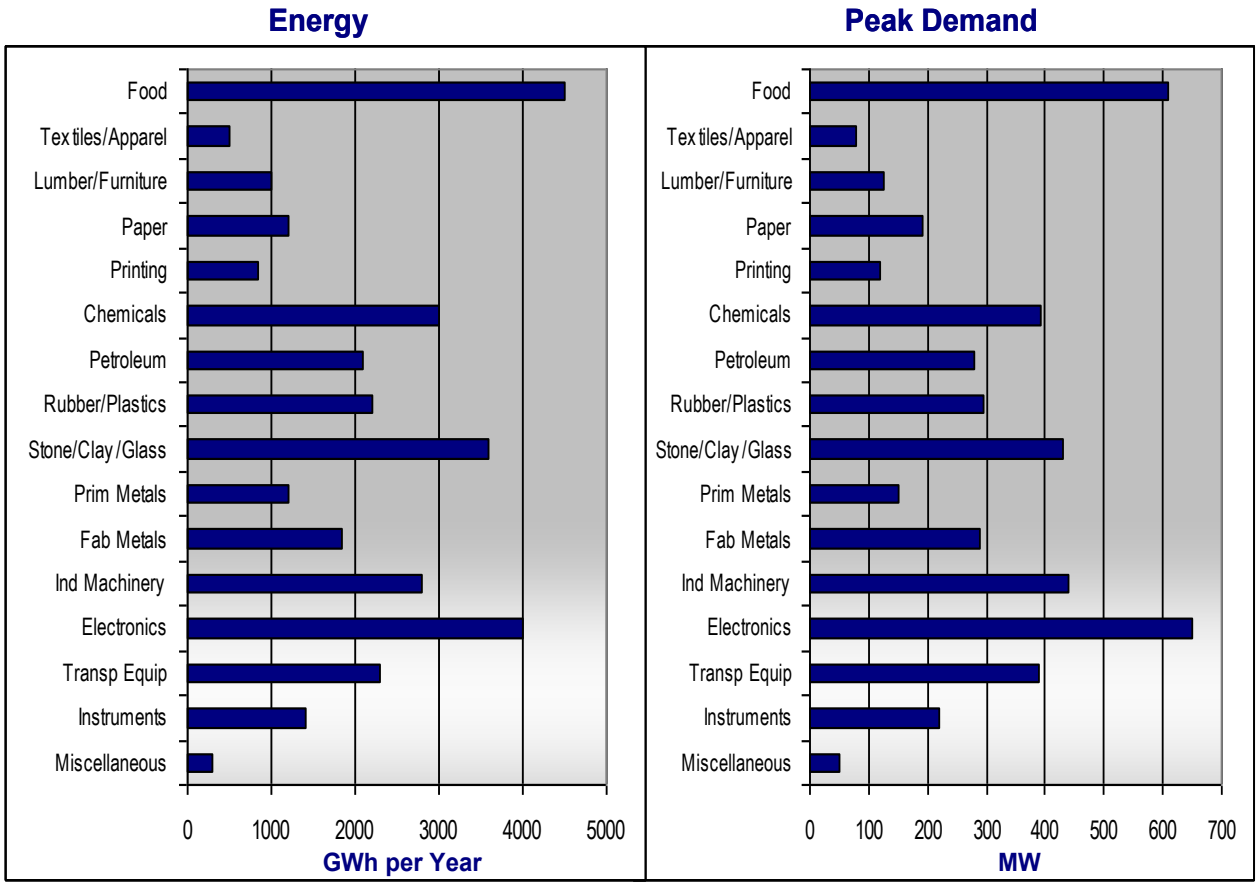
California's industrial sector is both a major driver of California's economy and a major consumer of energy:

Contribution of the Industrial Sector	(% of total in CA)
Electricity use	16
Natural gas use[43]	33
Energy use[44]	22
End use CO2 emissions[45]	20

The treatment, distribution, and use of water in California's industrial sector contributes an additional 3 percent of California's electricity use and 14 percent of its non-power plant natural gas.[46]

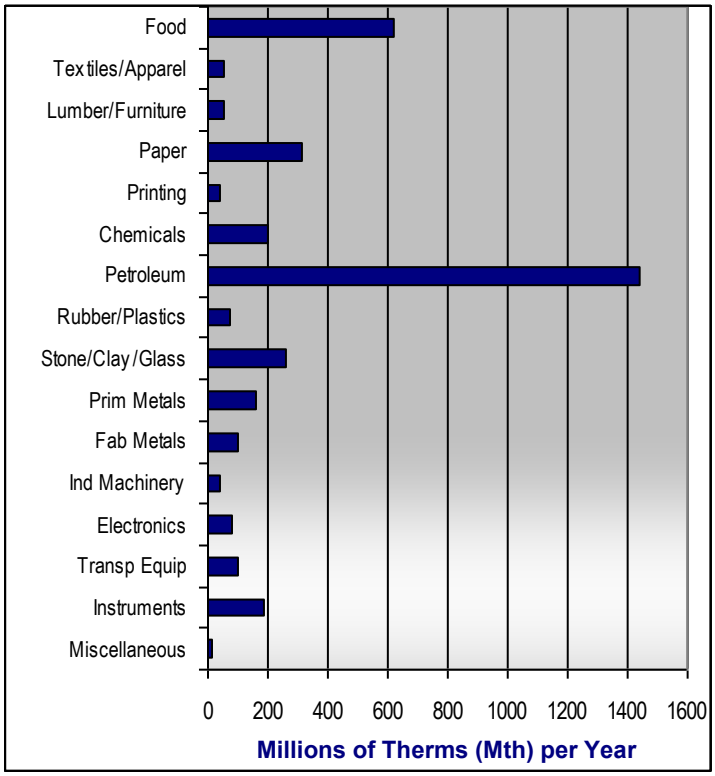
Energy consumption in the industrial sector is distributed across a variety of distinct industries and processes. As shown below, the largest industrial users of electricity in California are food processing and electronics, although a number of other sectors have also reached significant use levels.

Industrial Electricty Usage by Industry Type, 2003–Overall



The largest user of natural gas is petroleum sector, with about half going to feedstocks, followed by food processing.

Industrial Natural Gas Usage by Industry Type, 2003–Overall



Source: KEMA 2006, California Industrial Existing Construction Energy Efficiency Potential Study

Several factors unique to the industrial sector require an approach to California's energy efficiency and greenhouse gas (GHG) reduction goals different from that used in the commercial and residential sectors:

- Industry uses a large quantity of energy and other resources via complex and proprietary processes to create and bring products to market. Products, to varying degrees, have embedded energy that traditionally cannot be "zeroed out", although technology is changing (e.g., the developing technologies for "zero energy" cement, dry walls, etc.)
- Industrial facilities in California are increasingly managed by corporations that reside outside of the state or outside of the country and that view these facilities as mobile assets in a competitive global marketplace.
- California industry is highly diverse in type, size, and operation; uniform programs often will not match corporate or facility needs.
- Industries are subject to multiple policies and rules in resource areas (e.g. air quality, water quality, energy efficiency, GHG reductions, solid waste management), where compliance can raise competing objectives and outcomes.

4.3 GOALS

Goal	Goals Results
1. Support California industry's adoption of energy efficiency by integrating energy efficiency savings with achievement of GHG goals and other resource management objectives	By 2012, the goals, program designs and funding of industrial resource management programs are fully coordinated
2. Build market value of and demand for energy efficiency through branding and certification	Energy efficiency certification and benchmarking will become a standard industrial practice for businesses that are responsible for 80 percent of the sectoral energy usage by 2020 By 2020, Energy intensity (per gross dollar of production value) will be reduced at least 25 percent There will be a trained workforce in energy management and systems energy efficiency
3. Provide centralized technical and public policy guidance for resource efficiency and workforce training	Industrial consumers will use this knowledge base to inform energy efficiency actions and manage their energy and resource use by adopting best practices

4.4 STRATEGIES

Industry has the capacity to significantly improve its overall energy performance and help meet both private-sector and national goals for energy and the environment. There are a multitude of significant barriers, however, to achieving the full technical or economic potential for energy efficiency in the industrial sector. These barriers are predominantly institutional and behavioral, not technical. They include:

- Lack of awareness of energy efficiency opportunities by industry personnel consultants, and suppliers.
- Difficulty in accessing industry-relevant technical assistance.
- Inadequate availability of qualified personnel and consistent organizational structure oriented towards energy use management.
- Primary business focus on optimizing industrial output, not energy throughput.
- Risk aversion to investing in new technologies and processes which may impact industrial output or quality.
- Resource limitations of both time and capital for assessment and implementation of energy efficiency projects.
- Internal hurdle rates that often limit capital available for energy efficiency projects with paybacks longer than two years.
- Utility program parameters that can be at odds with industry practice (e.g. limitations due to "free-rider shop" rules, lack of recognition of savings from process or operational changes, limits on funding for large projects).

This Plan will use the following strategies to address these barriers:

1. **Integrated Solutions**: Provide integrated energy solutions and products through a "one-stop shop" approach.
2. **Education and Outreach**: Provide energy efficiency education and outreach to create awareness of and demand for continuous energy efficiency improvements.
3. **Branding and Certification**: Promote commonly accepted metrics to document corporate and facility attainment of resource management levels, gaining market recognition, spurring peer competition, and facilitating engagement in market trading mechanisms.
4. **Workforce Training**: Leverage existing training initiatives and technical exchange forums so that California industries have access to highly-skilled professionals who are fully knowledgeable in the areas of system energy efficiency and energy management

4.5 IMPLEMENTATION PLAN

Goal 1: Support California industry's adoption of energy efficiency by integrating energy efficiency savings with achievement of GHG goals and other resource goals.

Ideally, this Goal will be integrated with the CARB's AB 32 requirements so that industrial facilities use energy efficiency to meet or exceed regulatory requirements for GHG emission reductions (as well as water conservation, waste disposal, and air quality). Properly structured, a coordinated regulatory framework could be coupled with incentives to actively promote and reward measured performance improvements across energy, water, GHG emissions, waste disposal, and air quality.

A major strategy will be to directly engage industry in coordinated interagency planning for the energy efficiency portions of AB 32. This effort will include examining the potential benefits of negotiated, legally binding agreements with the chief operating officers of industrial corporations as a policy mechanism to promote energy efficiency in industry and corresponding reductions in GHG emissions. The United Kingdom, the Netherlands, Sweden, and a number of other countries have negotiated agreements programs in place, and such a strategy may work in California. DOE has begun development of national voluntary agreement programs as well. A multi-stakeholder alliance focused on knowledge sharing and capacity building could further aid in the adoption of changes in industrial operations and processes.

While the CPUC and IOU utilities could potentially develop such a program focused only on energy efficiency savings, a program approach covering all energy resource utilization, including energy efficiency, demand response, energy storage, combined heat and power, distributed generation, renewables and emerging technologies will provide the greatest benefit.

The food processing industry, with the leadership of the California League of Food Processors in partnerships with the Manufacturers Council of the Central Valley, has proposed such a pilot demonstration project that could be initiated in 2009.

This effort will also enable broadening utility program incentives from the current focus on energy efficient projects to include energy efficient processes (defined as documented, measurable evidence of energy management resulting in improved energy efficiency via projects, process, and operational improvements). The focus must move to delivered energy savings, either from hardware installations or documented permanent changes in operational processes. Utility program rules must become more flexible and find ways to work with the reality of industrial decision-making, particularly regarding early replacement of equipment.

Goal 1: Integration with Other Resource Strategies

Implementation Plan and Timeline				
Strategy	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
1-1: Develop coordinated energy and resource management program for CA's industrial sector, to enhance use of energy efficiency	CARB CEC state agencies for water, solid waste, and toxic substances Utilities Industry Reps.	• Establish CARB AB 32 Industry Team • Study feasibility of implementing negotiated agreements • Undertake pilot program with food processing sector	• Analyze results of pilot program. • If favorable, negotiate agreements with other key sectors	• Implement statewide

Goal 2: Build market value and demand for continuous improvement in industrial efficiency through branding and certification.

Goal 1 above focused on strategies that will support development of minimum regulatory energy efficiency requirements for either individual company or industrial sub-sectors as a whole, preferably integrated with the state's AB 32 program. Goal 2 is focused on companies that seek to exceed either minimum regulatory requirements or any negotiated bilateral agreement targets for industries as a whole, by actively managing their energy use over time.

In order for industry to make significant gains in energy efficiency, there must be greater awareness and knowledge sharing about programs, resources, and practical methods that can help industrial plants identify, develop, and document energy efficiency improvements and their economic benefits. Technologies common to many industries offer opportunities to increase efficiency. Significant knowledge sharing opportunities exist across firms and industries in the areas of combustion, industrial distributed energy, energy-intensive processes, fuel and feedstock flexibility, materials, sensors and automation, and combined heat and power.

The development of a national standard for industrial energy efficiency is currently under way. The Superior Energy Performance (SEP) partnership is a collaboration of industry, government, and non-profit organizations seeking to improve the energy intensity of U.S. manufacturing through a series of initiatives, most notably, by developing the standardized Plant Certification program.[47] The development of this American National Standards Institute (ANSI) accredited standard will help individual companies certify energy efficiency improvements, independently verify resulting energy savings, receive public recognition for achievements, and "raise the bar" for industrial energy efficiency overall.[48] Building on the ANSI standards, the SEP partnership is also helping to coordinate US participation in the development of an international ISO energy management standard. A representative from PG&E has been selected as the lead on the national ANSI effort, which positions California to play a critical role in the development of this important national and international standard. California's engagement in the partnership would ensure that the elements of the certification program, including the monitoring and verification methodology, are compatible with other California industrial energy efficiency and GHG emission reduction program regulations.

By participating in a recognized national effort to certify industrial facilities for energy efficiency, California will be assisting its industries to:

- More easily reach their GHG emission reductions targets via a supported, structured program based on proven best practices;
- Develop wide market recognition for their efforts through third-party certification, thus increasing global competitiveness

- Ensure corporate attention to a uniform national approach; and
- Provide a tangible way to encourage greater energy efficiency through their supply chain.

Programs such as those offered through DOE's Industrial Technologies Program (DOE/ITP) and EPA could provide substantial cost-share opportunities and in-kind assistance, especially if linked to certification.

To meet the near-term needs for a branding and certification program, California industries must have ready access to highly-skilled professionals who are trained in energy management and systems efficiency. Key areas include training industry professionals (consultants, plant engineers, and equipment suppliers) to provide energy management assistance, in-depth system assessment services, and in later phases, multi-resource utilization assistance, including waste reduction, water efficiency and air quality. California can leverage the workforce training element of the SEPP program to achieve this goal.

Goal 2: Certification Program for Continuous Improvement

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2-1: Participate in DOE/EPA's national Plant Energy Efficiency Certification Program (E^2)	DOE/EPA SEPP participants Utilities Industry	• Participate in planning process		
2-2: Implement certification	E^2 Program Utilities Industry	• Plan pilot and recruit host sites (8-10 facilities). • Implement and analyze pilots	• If successful, launch broader program for priority industry segments	• Refine and obtain widespread industrial enrollment and certifications
2-3: Develop and implement workforce training program (integrated with national training effort)	E^2 Program WE&T Task Force Utilities Industry Universities	• Adopt the national curriculum for certification • Consider curriculum enhancements for awareness-level training on integrating energy efficiency into the workplace and developing a new curriculum to fast track for future energy management professionals • Begin pilot courses with key industry segments	• Expand to wider industry segments	• Expand to industries statewide • Maintain and update curriculum
2-4: Create tracking and scoring systems to measure resource efficiency improvements (integrate w/ nat'l effort)	Utilities Industry	• Develop systems. • Implement on test basis.	• Modify and roll-out to industry segments on a phased schedule statewide • Coordinate with ME&O program	• Maintain and improve systems based on feedback
2-5: Implement ME&O program to educate industry and consumers	ME&O Task Force Utilities Industry	• Form industrial collaboration mechanisms • Develop plan	• Launch w/ priority industry segments	• Modify and roll-out statewide on a phased schedule • Maintain and improve systems based on feedback

Goal 3*:* Provide centralized technical and public policy guidance for California industrial energy and resource efficiency.

The purpose of this goal is to facilitate adoption of energy efficiency through centralized and easily accessed information and resources.

Industrial facilities are not just large buildings that can be effectively served by uniform programs designed for the commercial sector. The principal use of energy in industrial facilities is to create proprietary products or transform materials. Most industrial facilities have management systems in place for materials and labor but many are still lagging on optimizing energy or resource utilization. The goal is to provide a single clearinghouse of technical and resource management regulatory assistance that industries can use for more effective utilization of energy and environmental resources. Ideally, there would be a single source of knowledge that builds on and fills in the gaps in existing partnerships and relationships in the industrial sector. The goal is to provide access for industrial personnel and service businesses to technical information that can be applied in a practical way to industry needs.

The clearinghouse will also include information on emerging technologies, and industry-specific research. The clearinghouse will leverage knowledge developed through other organizations, including DOE and EPA. Both agencies have developed extensive expertise in industrial energy efficiency through a host of industry-specific programs and partnerships, including a Data Center Efficiency program under DOE's Save Energy Now initiative and Laboratories for the 21st Century (Labs21) a partnership program co-sponsored by DOE and EPA.[49]

Goal 3: Single Clearinghouse

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Short Term 2012 – 2015**	**Medium Term 2016 – 2020**
3-1: Compile technical and resource management regulatory materials into centralized assistance repository	Utilities Industry Associations	• Inventory existing sources for technical and regulatory assistance for industrial energy efficiency and other environmental resource targets • Identify and incorporate priority energy and other data • Develop clearinghouse or integration system	• Update and expand industry segment coverage as needed • Extend to GHG and water	• Extend info to include waste disposal and air quality
3-2: Conduct statewide marketing and education effort to create demand for Industrial Information clearinghouse	Utilities Industry Associations	• Develop ME&O Plan. • Implement plan	• Publicize results of pilots • Extend statewide	• Update and maintain

5. AGRICULTURAL SECTOR

5.1 VISION



Energy efficiency will support the long-term economic and environmental success of California agriculture.

5.2 PROFILE

The agricultural sector accounts for about 7 percent of California's overall energy,[50] a similar percentage of its private sector jobs, and around 1.5 percent of the gross state product. In terms of energy efficiency (and renewable energy), this sector has seven key end-use subsectors:

- Irrigated Agriculture
- Dairies
- Refrigerated Warehouses
- Vineyards & Wineries
- Greenhouses & Nurseries
- Post-Harvest Processing (on and near-frame)
- Confined Animal Feeding Operations (feedlots)

Energy consumption in the agricultural sector is concentrated in three end uses: irrigation, process heat applications, and refrigeration. Of these end uses, irrigation pumping accounts for 80 percent of electric energy use in the agricultural sector and has average pumping efficiencies of only about 53 percent.

Opportunities, barriers, and uncertainties that affect the success of energy efficiency in this sector include:

- Continuing consolidation of farming into agribusiness enterprises, concentrating decisions affecting energy consumption in the hands of fewer decision makers.
- Agricultural operators relying on commodity-specific and often local networks for information on technologies, practices and programs.
- Lack of up-to-date, statewide, segment-specific data on energy consumption and the potential for energy efficiency (and renewable generation) across the sector.
- Reluctance to accept higher first costs required to realize longer-term financial benefits, and to bear production risks associated with emerging or unproven technologies and practices.
- Continuing rapid evolution of regulations - including new requirements of the state Water Resources Control Board and Regional Water Quality Controls Boards, and the Air Resources Board and Regional Air Quality Control Boards, - that have no compliance coordination and which can slow the impetus to adopt energy efficiency technologies and practices, as well as the unknown structure of the AB 32 regulatory scheme.
- Expected reductions in surface water supplies due to climate change that will increase demand for energy-intensive groundwater pumping, making energy efficiency both critical and cost-compelling.

Beyond energy efficiency, agriculture offers a unique opportunity to integrate on-site renewable energy in the form of biomass from agricultural field crop residues and biogas from animal wastes from dairy, cattle,

and poultry farms. While this overall resource management opportunity is highly important, this first Plan has not been able to focus specific attention on renewable energy.

5.3 GOALS

Goals	Goal Results
1. Establish and maintain a knowledge base sufficient to support development of all available, cost-effective, reliable, and feasible energy efficiency, demand reduction (and renewable) energy resources.	By 2015 California agriculture will develop and implement action plans, best practices and educational infrastructure to support ongoing improvements in irrigation, refrigeration and process heating efficiency, demand response, and renewable energy production.
2. California regulations, financing mechanisms, and incentives programs affecting the management of energy, air and water resources, solid waste, and climate change will be coordinated to mutual advantage.	By 2010, key stakeholders will develop a roadmap for agricultural regulatory and incentives coordination. By 2012, the goals, program designs and funding of such programs for energy, air and water improvements will be fully coordinated.
3. Achieve significant increases in the efficiency of electricity and natural gas use and on-site renewable energy utilization.	California agriculture will reduce production energy intensity by 15 percent from 2008 levels by 2020 for non-renewable energy.

5.4 STRATEGIES

A central challenge to achieving broader energy efficiency in the agricultural sector is elevating energy as a business priority. Demonstrating how energy efficiency contributes to increased competitiveness or profitability and to compliance with environmental requirements (e.g., impending AB 32 regulations) will be essential.

The overall strategic approach will be to focus on the largest energy end users first, while also capitalizing on consolidating companies and entities that address energy decision making within the sector. The initial emphasis will be on the most energy intensive end uses—irrigation, process heating and refrigeration. However, this emphasis will be supported by an integrated "whole farm" approach that evaluates and addresses energy resource management comprehensively.

Strategies will expand to target progressively smaller energy consumers, especially early movers and opinion influencers. Success stories from both large- and smaller-scale agricultural enterprises will be widely disseminated throughout the sector to build both awareness of and enthusiasm for whole farm approaches targeting energy efficiency.

Success in carrying out these strategies will require the collaboration and active engagement of numerous stakeholders. Among state agencies, key players will be the Department of Food and Agriculture (DFA), Department of Water Resources (DWR), the Energy Commission, and others. At the federal level, the Department of Agriculture (USDA) and the Bureau of Reclamation are significant players. The agriculture industry associations obviously will be leaders in this effort, supported by educational institutions, the USDA Cooperative Extension service, and the investor-owned and publicly-owned utilities serving agricultural energy users. Local government agricultural commissioners' offices likely will drive some of the marketing education and outreach efforts in tandem with the statewide ME&O Task Force.

Agricultural sector stakeholders have identified the single highest priority is to conduct baseline studies to understand the energy usage patterns in California's agricultural sector, forecast likely changes in the future, determine the energy efficiency potential in the seven sub-energy sectors, and evaluate the cost-effectiveness of measures and programs, best practices, etc. Without this basic information, it is impossible to design a cohesive strategy to pursue all cost-effective energy efficiency in California.

Two additional items are central to the success of all three goals:

1. **Marketing, Education and Outreach**: There must be a defined, comprehensive, long-term marketing, education, and outreach program to inform the agricultural sector and consumers regarding the goal and key strategies.
2. **Workforce Training**: There must be a statewide focus on the workforce needs to achieve the goal, with adequate funding and support for development of the needed workforce.

5.5 IMPLEMENTATION PLAN

Goal 1: Establish and maintain a knowledge base sufficient to support development of all available, cost-effective, reliable, and feasible energy efficiency, demand reduction (and renewable) energy resources.

Absent a better understanding of the current and forecasted energy use in California's agricultural sector, energy efficiency potential, successes and failures to date, it will be impossible to implement significant energy efficiency in this sector, much less provide the cost-saving opportunities that energy efficiency offers. Therefore, the single most important step – which is needed immediately – is to conduct energy use and efficiency potential studies that will provide critical information on a statewide basis.

Once developed, this information must be accessible to agricultural professionals and operators through appropriate education, training, and field-based extension activities. This will require a needs assessment, followed by development of curricula, training modules, and supportive tools that can access and leverage the content of the newly created knowledge base. Trained and experienced advisors and farm operators can then be developed and recognized for their knowledge in how to apply efficiency and resource solutions to individual agri-business operations.

The search for solutions will not stop with existing technologies and practices. There will be a focused effort to develop new technologies and applications that can help achieve multiple resource management goals. For example, opportunities exist to leverage knowledge from the industrial sector to apply to key processes driving energy consumption in the agricultural sector – such as for pumping, boiler operations and refrigeration. Another strategy will be better coordination of knowledge being developed by the federal and state agricultural and energy research programs, agricultural equipment manufacturers, utility promotion of emerging technologies, and agricultural extension programs to individual farms and production facilities.

Goal 1: Energy Efficiency Knowledge Data Base

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
1-1: Develop knowledge base of efficiency solutions	Utilities CDFA DWR Agriculture Industry	• Conduct an energy use characterization and efficiency potential study for the statewide agricultural market. Include potential for waste streams to offset energy consumption. Study plan (6/2009) and study completed (12/2010) • Collect data on key programs and measures, best practices for energy efficiency in the agricultural sector. Study complete (6/10)	• Develop framework for common agricultural data base • Establish central clearinghouse for technical, program, regulatory, and incentive information	• Ongoing refinement and maintenance
1-2: Ensure workforce has information and training necessary to apply efficiency solutions	Utilities WE&T Task Force Educational Institutions Agricultural industry	• Conduct workforce training needs assessment and next steps (12/2010) • Develop training curricula and modules identified by needs assessment. (12/2011)	• Develop training and education tools for use of date base and benchmarking methods • Begin pilot training & education programs	• Training & education activities are fully rolled-out • Certification programs are in place
1-3: Conduct research & development of new technologies and practices for agricultural efficiency	Energy Commission Utilities National Labs Agriculture Industry	• Conduct an Energy Technologies/ RD&D gap analysis. Identify and prioritize needed RD&D/ET projects. (12/2011) • Coordinate research activities across government, utilities, agricultural extension and university programs, and equipment manufacturer proprietary efforts	• Ongoing identification, prioritization and execution of ET/RD&D projects	• Ongoing identification, prioritization and execution of ET/RD&D projects

Goal 2: California regulations, financing mechanisms, and incentives programs affecting the management of energy, air and water resources, solid waste, and climate change will be coordinated to mutual advantage.

The agricultural sector is subject to water use, water quality, air quality, solid waste, and soon global warming requirements. Energy efficiency, particularly when linked to water conservation, can be a key strategy to achieve goals in these other areas. Yet there is currently no coordination at the state, local or federal level to optimize the use of energy efficiency in meeting multiple resource objectives.

A multitude of programs – currently uncoordinated – operate in the agricultural sector that address the sector's use of energy, air and water. Better coordination of these programs would lead to enhanced use of energy efficiency as a successful strategy to implement the goals across all programs. Specific programs warranting coordination are: water conservation and quality improvement funding, Energy Commission PIER funds, local air quality improvement funds, federal tax credits, Rural Energy for America Program (REAP) under the Federal Food, Conservation and Energy Act of 2008 (Farm Bill) and utility energy efficiency and renewable energy incentives.

One of the most important goals for agriculture is to develop a forum or process involving multiple stakeholders to coordinate technical energy efficiency solutions and program designs (e.g., knowledge bases, technical assistance, financing, and financial incentives) across the range of environmental management policies and goals.

Strategies will include:

- **Integrated Resource Management**: Setting up a common framework for resource management that can better leverage and "piggyback" multiple resource management programs to support increased adoption of energy efficiency, demand response and onsite generation opportunities integrated with efforts to attain air, water, and solid waste objectives.
- **Financing**: Developing common technical and financial assistance energy efficiency strategies most appropriate in the agricultural sector for achieving specific program objectives (e.g. deciding among grants vs. loans vs. rebates; structuring financial programs sensitive to preferences between traditional financing vs. performance contracting; and utilizing technical assistance advisors and expertise to deliver integrated solutions across multiple objectives).

The ultimate goal of this Plan is to provide "one-stop-shopping" assistance to both program sponsors and the agricultural operators targeted by energy, air and water programs. This will assist program sponsors in tailoring their programs to the unique needs and preferences of agricultural operators, and prospective program participants in understanding opportunities, requirements and how to efficiently participate in programs.

A task force including representatives of all major sources of agricultural expertise, financing, and incentives targeting energy, air, water and solid waste concerns is envisioned as the mechanism for implementing the strategy. The task force will provide both a forum for alignment and leveraging of program goals, designs and funding, and a clearinghouse for program information and coordination. The California Department of Food and Agriculture (CDFA) is developing a California Agricultural Vision through 2030, which may provide a useful opportunity to launch this forum.[51]

The immediate focus of the task force will be on identifying and mitigating existing conflicts in programs operating across energy, air, water and solid waste concerns within the agricultural sector.

Goal 2: Coordination of Programs and Funding

Implementation Plan and Timeline				
Strategies	**Non-CPUC Parties**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2-1: Set objectives and framework for agriculture to attain multi-resource management goals	Utilities CDFA DWR Industry participants	• Establish a task force to coordinate resource management policies, action goals, and program designs targeting California's agricultural sector • Identify where goal conflicts arise and resolve these conflicts • Assess potential for integrated approaches	• Establish a central database to track and coordinate resource policies and initiatives • Undertake pilot integrated approaches • Refine program designs and support based on experience	• Continue to modify and refine approaches for integrated solutions

Implementation Plan and Timeline				
Strategies	**Non-CPUC Parties**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2-2 Coordinate technical assistance, funding, and incentive mechanisms	Financing Task Force Utilities Financial Institutions Agriculture Industry	• Identify the programs and major funding sources affecting the management of energy, air and water resources, and climate change • Create a collaborative forum to facilitate sharing of information and coordination of programs	Identify approaches to cross-market and leverage resource management goals across programs, funding, and technical assistance	Continue to modify and refine approaches for integrated solutions

Goal 3: Achieve significant increases in the efficiency of electricity and natural gas use and on-site renewable energy utilization, including setting a specific target for irrigation efficiency.

Because irrigation accounts for 80 percent of the electricity used in the agricultural sector and current pumping efficiencies are so low, a specific goal targeting improvement in this area is warranted. Two other areas that warrant specific focus are higher efficiency with refrigeration and process heating from natural gas.

Strategies needed to achieve this goal include identification and adoption of management best practices and highly efficiency equipment. Specific areas of focus will include targeting energy efficiency opportunities from:

- Onsite source-water reduction
- Retro-commissioning
- Precision agriculture
- Advanced irrigation systems
- Pressure reduction in irrigation
- Waste heat recovery and other gas-savings measures
- Improved industrial refrigeration practices and technologies.

One of the emerging energy efficiency practices to guide end users in their efficiency actions is the use of “benchmarking”. This requires developing a best practice standard and supporting systems that enables individual end users to analyze their energy usage compared to the benchmark. Development of benchmarking tools for each agricultural sub-sector – starting first with the irrigated agriculture subsector and then expanding to other subsectors – would be an important strategy in identifying profitable opportunities for efficiency improvements.

Achieving real savings in agriculture will be founded upon a compelling business case to decision-makers in agricultural sub-sectors and individual companies. The strategy will identify the most effective communication channels, partners, and messages to deliver to these decision-makers.

Recognizing that irrigation accounts for the predominant share of electricity, both on-farm and in the statewide delivery of water, pilot programs and evaluation will be used to identify the embodied energy savings associated with water efficiency gains. This will be a critical step in linking energy and water efficiency strategies.

Goal 3: Capturing Energy Efficiency

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Medium Term 2016 – 2020**
3-1 Make information on efficiency solutions readily available to motivate efficiency improvements	Utilities Agricultural Industry	• Develop benchmarking resources, tools and methods for the agricultural sub-sectors. • Design and launch focused program for irrigation efficiency, refrigeration, and process heating	• Apply feedback and refine benchmarking tools • Expand programs to wider audience and promising end uses	• Ongoing refinement and maintenance
3-2 Conduct marketing & outreach to stimulate efficiency actions	ME&O Task Force Utilities Agriculture Industry	• Develop ME&O strategy, addressing communication channels, partners, and effective messaging • Begin pilot implementation	• Launch statewide program	• Ongoing refinement and maintenance
3-3 Resolve metrics for embedded energy in water savings	State water agencies Agriculture Industry Energy and Water utilities	• Update evaluation measurement & verification protocols to define energy impacts of water efficiency actions • Design and conduct appropriate water/energy efficiency pilots for agriculture	• Measure and report all embedded energy savings associated with irrigation and process efficiency • Incorporate findings into business case messages and policies for water and energy efficiency	• Ongoing application to policies and programs

6. HEATING, VENTILATION AND AIR CONDITIONING

6.1 VISION

The residential and small commercial heating, ventilation, and air conditioning (HVAC) industry will be transformed to ensure that technology, equipment, installation, and maintenance are of the highest quality to promote energy efficiency and peak load reduction in California's climate.



6.2 PROFILE

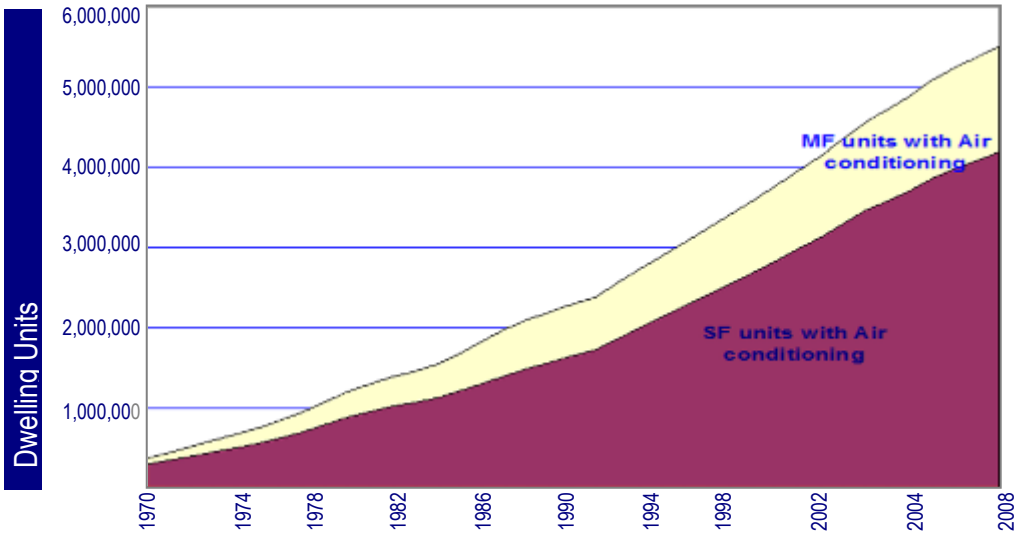
One of the BBEES adopted by the Commission in October 2007 is to "reshape residential and small commercial HVAC to ensure optimal equipment performance." [52] This initiative targets a 50 percent improvement in efficiency in the HVAC sector by 2020, and a 75 percent improvement by 2030.

The rapid growth in air conditioning in California's commercial buildings and homes has made it one of the state's largest energy-consuming end uses and the single largest contributor to peak demand—and a leading opportunity to improve energy efficiency and reduce peak power demand.

In 1976, 25 percent of new California homes had central air conditioning. Today, it is 95 percent: new home size has increased by more than 50 percent and new homes are concentrated in hot inland communities. These increases have resulted in a greater than seven-fold increase in the electricity capacity to meet this load.

By 2006, peak demand for residential air conditioning units was 14,316 MW. When small commercial air conditioning is added to the residential share, air conditioning loads cause over 30 percent of California's total peak power demand in the summer—with an enormous and costly impact on the need for generation, transmission, and distribution resources and a concurrent lowering of utility load factors.

Growth in Residential Dwellings with Central Air Conditioning - Single Family and Multi Family Units from 1970 to 2007



Unfortunately, as air conditioning was becoming nearly ubiquitous in new California buildings, installation and maintenance practices suffered substantially. The HVAC industry has struggled to provide qualified technicians, and market conditions rarely value quality installation and maintenance (QI/QM). Less than 10 percent of HVAC systems obtain legally required pre-installation local building permits and 30-50 percent of new central air conditioning systems are not being properly installed. As a result, Californians pay a large price for the lack of quality installation and maintenance, with commensurate poor performance. The factors that have led to a 20-30 percent increase in the peak energy needed to provide consumers with the cooling and comfort they demand on hot summer afternoons[53] has been accompanied by an estimated 30 percent increase in carbon emissions.

AB 2021 (Levine, 2006) required the Energy Commission to investigate options and develop a plan to improve the energy efficiency of, and to decrease the peak electricity demand of, air-conditioners." The Energy Commission's subsequent report, "Strategic Plan to Reduce the Energy Impact of Air Conditioners",[54] estimated potential cumulative savings from higher quality installation in the residential and small commercial markets at 1,216 GWh and 1,096 MW by 2020. The estimated cumulative savings from accelerated introduction of more efficient and properly installed cooling technologies is 1,272 MW and peak shifting technologies is 2,299 MW by 2020. The content of this chapter draws heavily from the CEC report, and the strategies set forth in this plan mirror those of the report's recommendations.

HVAC is regulated in California by the Energy Commission's Title 20 and Title 24 appliance and building codes and by federal appliance standards. These codes and standards have become increasingly stringent in recent years, along with related activities such as the promotion of Energy Star-compliant units. But numerous barriers reduce the effectiveness of the codes and standards including:

- The federal standards use a single, national air conditioning metric that does not robustly measure—never mind promote—the performance of air conditioners in hot, dry conditions such as California.
- Federal law pre-empts California's ability to set its own air conditioning efficiency standards.[55]
- Consumer markets focus on lowest first cost, and ignoring operating costs, making it difficult for quality contractors to compete.
- Installation and maintenance practices are inadequate, driven by cost competition and the "invisibility" of quality work to consumers.
- Building design practices do not take an integrated systems approach to lessen the size or need for HVAC.

6.3 GOALS

Goal	Goal Results
1. Consistent and effective compliance, enforcement, and verification of HVAC-related building and appliance standards.	HVAC-related permits are obtained for 50% of installations by 2015 and 90+% by 2020.
2. Quality installation and maintenance becomes the industry and market norm.	By 2020 100% of systems are installed to quality standards and optimally maintained throughout their useful life.
3. Whole building design and construction practices fully integrate building performance objectives to reduce cooling and heating loads.	Integrated design and construction practices are standard practice by 2020.
4. New climate-appropriate HVAC technologies (equipment and controls, including system diagnostics) are developed with accelerated market penetration.	At least 15% of equipment shipments are optimized for California's climate by 2015 and 70% by 2020.

6.4 STRATEGIES

To achieve the Commission's adopted Programmatic Initiative of transforming the HVAC market and the four specific goals identified above, broad-based and aggressive strategies are needed that involve many stakeholders beyond the Commission and IOUs. An HVAC Advisory Group should be chartered to involve high-level HVAC industry stakeholders—such as manufacturers, distributors, and contractors—to coordinate industry sponsorship of and participation in HVAC strategies. Membership should also include other key players, such as the CPUC, Energy Commission, utilities, local building officials, building owners/managers, consumers, and the federal government.

6.5 IMPLEMENTATION PLAN

Goal 1: Consistent and effective compliance, enforcement, and verification of applicable building and appliance standards.

California law requires contractors to obtain a permit for the installation of new HVAC equipment (including replacements of existing equipments) and to perform quality control checks. Yet fewer than 10 percent of contractors obtain such permits, perform quality control checks, or have their work verified by third-party raters. Failure to ensure quality at the time of cooling system installations results in a 20 to 30 percent increase in the peak energy needed by systems.

This problem is exacerbated by Title 24 provisions that allow optional compliance with HVAC quality control requirements; a contractor may install higher efficiency measures in a new building in lieu of the quality installation and control requirements, absent any performance verification. The Air Conditioning Contractors of America (ACCA) recently developed a quality installation (QI) specification for air conditioning equipment that has become an American National Standards Institute (ANSI) standard. It is comprehensive, addressing all aspects of HVAC quality installation, including equipment, installation and ducts. The Energy Commission's June 2008 HVAC report recommended that the Energy Commission consider making the ACCA or similar requirements mandatory for all HVAC installations, in lieu of Title 24's current optional requirement. Energy Commission action to change its optional standards to mandatory quality control provisions is critical.

Changing the status quo will require significant effort, since contractors who comply with HVAC code provisions incur higher costs that are difficult to pass onto customers in a highly competitive market. Such contractors may also experience delays due to local government permit timelines. Local building officials may not have the resources or knowledge to establish streamlined permitting systems to support quality HVAC installations or penalize contractors who do not comply.

Strategies to achieve significantly improved compliance include:

- **Permitting Reform.** Streamlining local government permitting and state licensing processes, beginning with pilot programs.
- **Mandatory Requirements**. Changing the building code by replacing the current optional quality control requirements with mandatory requirements.
- **Verification**. Improving the current processes for inspecting and verifying compliant system installations, such as tracking the installation of all new and replacement equipment to ensure they are installed in compliance with all applicable state energy codes, or developing lower-cost compliance verification mechanisms.
- **Enforcement.** Actively enforcing penalties for contractors who do not pull required permits or who operate without the appropriate licenses.

Goal 1: Improve Code Compliance

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
1-1: Develop streamlined local government HVAC permitting systems, including on-line HVAC replacement permitting	Local Governments CALBO Utilities Distributors Contractors	• Convene an industry/local government stakeholder group; develop proposed new system; pilot test with local governments	• Revise pilots and expand to other cities; develop framework for statewide program	• Expand statewide
1-2: Streamline process for obtaining and overseeing contractor business licenses	Local Governments CALBO Calif. Contractor State License Board	• Pilot test streamlined process with local building departments • Explore possible common business licenses for multiple jurisdictions	• Revise pilot and expand pilot testing to other cities; develop framework for statewide program	• Expand statewide
1-3: Replace Title 24's current optional quality control requirements with mandatory requirements (ACCA/ANSI QI/QM specification)	Energy Commission ACCA/ANSI Utilities Contractors	• Adopt ANSI standards into Title 24; integrate into existing utility program designs	• Explore steadily higher QI/QM standards as baseline becomes commonplace	• Ongoing
1-4: Develop affordable standards and quality compliance solutions	Utilities Local Governments CALBO Distributors Contractors	• Convene stakeholder group; develop details of proposed system and determine whether to proceed • Consider developing an internet-based system that tracks the status of equipment, from the initial sale to final quality check in the field	• If recommended for development; pilot test	• Expand statewide if pilot testing is successful
1-5: Enforce penalties for contractors who do not pull permits or operate without the appropriate license	Local Governments CA Contractor State License Board Contractors Utilities	• Pilot test local government fines in lieu of contractor license suspension; expand SMUD program to IOUs (proof of quality installation req'd for rebate); identify local govn't resources needed for enforcement; establish action plan to phase-in mandatory enforcement	• Expand pilot programs; Continue phase-in of mandatory enforcement activities	• Fully implement mandatory enforcement

Goal 2: Quality HVAC installation and maintenance becomes the norm. The marketplace understands and values the performance benefits of quality installation and maintenance.

Quality HVAC installation and maintenance (QI/QM) is currently the exception, not the norm. Achieving this goal will require a major transformation in both markets and behavior.

Consumers need education on the value of properly installed and maintained systems in order to demand quality installations, and the service industry needs proper education,

training, and certification to then meet consumer demand.

Beyond Strategy 1-3 under Goal 1 above, a logical next step is to develop a label that would be attached to residential or small commercial HVAC installations by a third-party rater.

Even before a change in the Title 24 requirements occurs, a statewide brand program could be developed to benchmark and recognize and/or certify quality installation and maintenance and high levels of HVAC technician competence. This effort could be conducted by California alone, with other southwestern states, or on a national basis. The brand would be used in at least two ways: (1) affixed to equipment to certify the equipment has been installed pursuant to QI/QM requirements and, (2) made available to contractors who voluntarily ensure a high proportion (perhaps 90 percent) of their workers have received high-quality certification from North American Technician Excellence or other industry groups. This branding effort could be tied to utility programs, such that only customers or contractors who use the brand receive incentives.

A consumer marketing and education campaign about the value of HVAC QI/QM can introduce and stimulate the demand for the new brand—communicating that quality work results in increased comfort, improved air quality and higher energy and cost savings. Development and launch of the quality brand should be supported with the appropriate level of behavioral studies to assess the market transformation impacts of the brand and ensure that utility incentives linked to use of a statewide brand are effective in changing consumer and contractor behavior.

A necessary concurrent strategy is the development of adequate workforce education and training for HVAC contractor/owners, service and installation technicians, sales representatives and building officials. This requires a comprehensive needs assessment to identify industry skill gaps and form the basis of an effective action plan to address these gaps. After this assessment is completed, support should be provided to certify new trainers and courses and provide incentives directly to technicians who complete training.

Goal 2: Quality HVAC Installation and Maintenance

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012-2015**	**Long Term 2016 – 2020**
2-1: Create a statewide Quality Installation and Maintenance (QI/QM) brand that will be attached to systems/installations/ contractors that meet quality standards	ME&O Task Force Utilities HVAC industry Retailers	• Create and launch statewide quality brand and/or align with national brand • Develop operating and lifecycle data on economic and comfort benefits	• Ongoing	• Ongoing
2-2: Launch a consumer marketing and education campaign to support the brand and stimulate market demand	Utilities HVAC industry Retailers Local Governments	• Develop and launch campaign	• Conduct ongoing behavioral studies to ensure strategies are effective	• Conduct ongoing behavioral studies to ensure strategies are effective

Implementation Plan and Timeline				
Strategies	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012-2015**	**Long Term 2016 – 2020**
2-3: Develop and provide expanded QI/QM training for contractors, technicians and sales agents	WE&T Task Force Utilities HVAC Industry Educational institutions Labor Unions CSLB NATE	• Conduct comprehensive training needs assessment to indentify industry skill gaps; begin expanded training programs	• Assess impact of training activities and update needs assessment as required • Expand training programs statewide, particularly at the vocational/technical and community college levels	• Ongoing
2-4: Develop and implement comprehensive contractor accreditation program	HVAC Industry Energy Commission Labor Unions CSLB WE&T Task Force Educational institutions NATE	• Develop accreditation program requirements; begin implementation	• Expand program	• Statewide certification program

Goal 3: Building industry design and construction practices that fully integrate building performance to reduce cooling and heating loads.

Both the Residential and Commercial Sector Chapters address the need for "whole building" design and implementation in California, in order to achieve truly aggressive energy efficiency savings. One key goal of this overall effort must be building performance that improves space conditioning, by dramatically reducing cooling and heating loads. Fundamental changes will be needed in current design and building practices.

Specific design and building changes addressing HVAC performance include:

- Placing more emphasis on the whole building as a complete interactive system and improving the thermal integrity of the building shell to reduce heating and cooling loads.
- Moving ducts and equipment off the roof and out of hot attics.
- Incorporating ductless systems, radiant heating and cooling, ground source heat pumps and thermal energy storage technologies with overall higher efficiencies.

The Residential and Commercial Sector Chapters address behavioral change strategies to promote whole building design and implementation. Those strategies must include a focus on the HVAC industry in particular.

Goal 3: Whole-Building Design

Implementation Plan and Timeline				
Strategy	**Non-CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
3-1: Aggressively promote whole building design concepts that improve the overall thermal integrity of new and existing structures	CEC HVAC industry Architects Builders and Contractors Utilities Local Governments	• Pilot targeted programs. • Incorporate radiant cooling, ductless systems, ground source heat pumps, etc. into 5% of new and existing construction by 2011 • Review priorities of PIER and Emerging Technologies program activities to more fully support newer HVAC technologies and systems	• Include standard program offerings that emphasize HVAC-related elements to whole building approaches. Incorporate radiant cooling, ductless systems, ground source heat pumps, etc. into 25% or more of new and existing construction by 2015	• Incorporate radiant cooling, ductless systems, ground source heat pumps, etc. into 50% or more of new and existing construction by 2020
3-2: Accelerate activities related to HVAC aspects of whole building industry design standards	ASHRAE Energy Commission Utilities Manufacturers AHRI	• Evaluate and update existing standards to include increased emphasis on HVAC aspects of whole building approaches.	• Ongoing	• Ongoing
3-3: Accelerate HVAC related aspects of whole building design in the educational and professional communities	Colleges/ Universities Utilities Department of Education	• Develop continuing education programs. Begin curriculum use	• Expand statewide. Develop university degree level programs	• Ongoing
3-4: Accelerate code-based solutions to improving the thermal structural integrity and incorporating alternative cooling methods into building designs	Energy Commission Local Governments Utilities	• Implement optional code improvements necessary to facilitate moves to whole building design approaches	• Establish mandatory whole building code-based solutions	• Ongoing
3-5. Sponsor design competitions to encourage builders to design and build homes with zero net peak demands	Utilities Foundations Industry Builders and Contractors	• Conduct first competition in 2010 and annually thereafter	• Annually	• Annually

Goal 4: New climate-appropriate HVAC technologies (equipment and controls, including system diagnostics) are developed with accelerated marketplace penetration.

Goal 4 requires coordinated development and use of new and improved HVAC technologies (equipment *and* controls, including two-way demand response and onboard diagnostics) that are adapted to California's climate zones.

The strategies to achieve this goal include:

- **Develop a regional (southwest) strategy**: Because advanced technology development and market penetration has a regional impact, it would be advantageous to draw participants from other states experiencing similar increasing air conditioning loads (e.g., Nevada, Arizona, New Mexico and perhaps Texas). The focus would be on working with DOE to develop new cooling systems with technology and designs that reflect California and similar hot/dry climate conditions.
- **Expand HVAC-related R&D**: Past improvements in HVAC energy efficiency have been the result of R&D by the HVAC manufacturers, utilities, government, and academia. There needs to be a new focus on hot dry climate solutions.
- **Support incremental improvements to HVAC equipment.** Because highly advanced cooling technologies will only penetrate small portions of the total market at a time, incremental improvements in standard HVAC equipment are also necessary, including continued upgrading of codes and standards. Any cost-benefit analysis for state or federal regulations must include on-peak energy resource values and resulting peak-specific standards.
- **Commercialize on-board diagnostic systems**: Such systems automatically collect data and alert consumers and/or contractors when a fault or negative performance trend is detected. These diagnostics will result in energy benefits by helping ensure that HVAC systems are maintained and operate within design specifications. While many manufacturers currently offer either "on board" systems or hand-held ones that work with all systems, none are widely used by consumers or contractors. Actions to accelerate the commercialization of such diagnostics include:

1. Prioritizing in-field diagnostic and maintenance approaches based on the anticipated size of savings, cost of repairs, and the frequency of faults occurring
2. Benchmarking of existing diagnostic, repair and maintenance protocols
3. Developing nationwide standards and/or guidelines for onboard diagnostic functionality and specifications for designated sensor mount locations.
4. Aggressive promotion of diagnostic systems as a standard offering on all HVAC equipment.

In addition to technology development, a key strategy to achieve this goal is education of contractors and consumers about the advanced technologies' availability and value, as well as education and training of service technicians, particularly on the use of diagnostic systems.

Goal 4: New HVAC Technologies and System Diagnostics

Implementation Plan and Timeline				
Strategies	**Non -CPUC Partners**	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
4-1: Pursue regional climate optimized equipment standards through DOE rulemaking process	DOE Utilities Nat'l Labs NBI HVAC industry	• Develop recommended standards and present to DOE	• Regional climate optimized standards adopted by DOE	• Ongoing
4-2: Update "Total Avoided Cost Model" and Title 24 "Time Dependent Valuation" calculations, including use of peak energy values	Energy Commission Utilities	• Evaluate, revise and update as needed in state and federal applications	• Ongoing	• Ongoing
4-3: Accelerate market penetration of advanced technologies by HVAC industry promotions and updating/expanding current utility programs to include the new technologies as appropriate	Utilities Energy Commission	• Conduct a comprehensive cost-benefit analysis of leading and prospective advanced technologies, and use to prioritize utility incentive offerings and HVAC industry deployment strategies • Establish an incubator program to accelerate commercialization of most promising technologies	• Provide necessary program incentives to ensure that advanced technologies represent 30% of the systems sold by 2015	• Continue to provide necessary program incentives to ensure that advanced technologies represent 50% of systems sold by 2020
4-4: Adopt a progressive set of building codes that support the deployment of peak efficient equipment	Energy Commission Utilities AHRI ASHRAE ACCA	• Enhance and accelerate the deployment of Title 20/24 codes	• Ongoing	• Ongoing
4-5: Develop nationwide standards and/or guidelines for onboard diagnostic functionality and specifications for designated sensor mount locations	Manufacturers Utilities Trade Associations AHRI ASHRAE	• Establish an industry-wide task force to develop national standard diagnostic protocols • Begin implementation. • Incorporate into HVAC industry and utility programs	• Incorporate diagnostic standards into equipment codes.	• Ongoing
4-6: Prioritize in-field diagnostic and maintenance approaches based on the anticipated size of savings, cost of repairs, and the frequency of faults occurring	Manufacturers Utilities Trade Associations AHRI ASHRAE	• Benchmark existing diagnostic, repair and maintenance protocols and develop appropriate products	• Commercialize on-board diagnostic systems	• Incorporate mandatory onboard diagnostic systems in California building codes

7. CODES AND STANDARDS

7.1 VISION

A broad range of aggressive and continually improving minimum and higher voluntary sets of energy codes and standards will be adopted to greatly accelerate the wide-spread deployment of zero-net energy and highly efficient buildings and equipment. The effectiveness of codes and standards will be enhanced by improved code compliance as well as coordinated voluntary efficiency activities.



The ambitious goals of this Plan as well as greenhouse gas imperatives place an unprecedented reliance on mandatory codes and standards—both on energy codes for new and renovated buildings and on efficiency standards for appliances and equipment—and pressure for them to perform.

PROFILE

There is no policy tool more essential for the widespread and persistent transformation of energy performance in California than energy codes and standards. For thirty years, California has aggressively and successfully used its two principal frameworks for regulating minimum energy performance—Title 24 building energy codes and Title 20 appliance standards[56]—to cost-effectively reduce the energy consumption of commercial buildings, homes, and appliances. The effectiveness of energy codes and standards is beyond debate—the Energy Commission's 2007 Integrated Energy Policy Report[57] finds that: "California's building and appliance standards have saved consumers more than $56 billion in electricity and natural gas costs since 1978 and averted building 15 large power plants. It is estimated the current standards will save an additional $23 billion by 2013."

The appeal of codes and standards for promoting energy efficiency is simple: they make better energy performance mandatory, and not just for early adopters or self-selected consumers but for all users of regulated products and structures.

Codes and standards' impact, while enormous, can be enhanced and made even more successful and cost-effective if they are:

- Capturing a wide range of economically viable technologies and building practices, including integrated DSM approaches.
- Coordinated with non-regulatory market transformation efforts, such as utility incentives and rebates, Energy Star and other benchmarking programs, and builder and consumer education efforts that pave the way for successive strengthening of codes and standards.
- Optimized with other regulations, especially federal efficiency standards, non-California state efficiency standards, AB 32, ambient air quality rules and local government development policies.

- Applied more comprehensively to end uses, including plug loads and building operations.
- Supported by better enforcement and compliance at local levels.
- Reliant on more sophisticated design principles and analytics regarding whole buildings and measures.
- Encouraging of building industry players to design or manufacture new energy solutions

7.3 GOALS

Goal	Goal Results
1. Continually strengthen and expand building and appliance codes and standards as market experience reveals greater efficiency opportunities and compelling economic benefits.	California's codes and standards will support this Plan's residential, commercial, and HVAC sector goals.
2. Dramatically improve code compliance and enforcement.	Energy savings from codes and standards will be fully realized.

7.4 STRATEGIES

The Energy Commission re-visits and tightens Title 24 energy efficiency codes on a triennial basis. However, the scale of the goals and challenges at hand—including that of putting all new commercial buildings on a path to zero net energy by 2030, and meeting AB 32's emission reduction targets—prompts an accelerated strategy to make the codes more stringent and cover more end uses and measures.

The strategies described below pursue both sides of the codes and standards coin: they develop enhanced regulations "on paper;" and they improve their real world effectiveness, cost-effectiveness, and compliance. Although the strategies place greater emphasis on building codes than on appliance/equipment standards—as the former are principally regulated at the state level and the latter principally at the federal level—there is nonetheless a tremendous opportunity for appliance regulation to increase energy savings.

The Energy Commission is a key leader in this effort, along with the California Building Standards Commission. The federal government, utilities, research organizations (Energy Commission-PIER, national labs), trade and professional licensing/registration agencies, the building/developer/contractor/ manufacturers industry and realtors must work cooperatively to develop common goals and provide the technical support for this effort.

These strategies are intentionally presented at a high level in this Chapter. The Residential, Commercial and HVAC Chapters provide greater detail on codes and standards goals and strategies applicable to those sectors

7.5 IMPLEMENTATION PLAN

There is a de facto symbiotic relationship between more stringent codes and standards and improvements in technology, products and practices (the former prods the latter, while the latter helps allow the former) that will need to strengthen and accelerate in the coming years.

More than most other efficiency policy areas, codes and standards demand coordination with other efforts and parties—from regulators to the regulated—to be optimal. Both the Energy Commission and the IOUs have played a major role in coordination, and must be committed to playing an even larger role in the future to support and/or facilitate future efforts. Such coordination has two major components: one, coordinating with other relevant governmental regulations; and two, coordinating with relevant

programs, incentives, market dynamics, research and other non-regulatory initiatives.

Many other governmental entities can impact the effectiveness of California's codes and standards. For example, the federal government (i.e., DOE) has primary responsibility for appliance/equipment standards. Local governments play an important role, both in the enforcement of Title 24 for building construction and renovation and in the development of local "reach" codes that can serve as pilots for statewide codes. California's newly-adopted Green Building Standards along with San Francisco and Los Angeles' recent Green Building Ordinances, referenced earlier, represent recent "beyond code" efforts. These important efforts serve to continually "raise the bar" for California's statewide standards. Coordination among such "reach" codes and the statewide efforts, as well as among non-governmental building rating and certification systems frequently embraced by local government development policies, is critical.

Coordination with other programs and laws is also critical. Codes and standards are more focused on eliminating inefficient products and practices than on developing or popularizing new highly efficient ones. Accordingly, codes and standards should be coordinated with public and private efficiency programs that develop and commercialize new products and building design solutions.

While efforts to leverage efficiency investments at times of sale and/or major retrofit labeling or other requirements provide important opportunities for efficiency gains, excessive "trigger" requirements can serve as a disincentive to undertaking beneficial investments. Interagency collaboration is needed to identify solutions to such challenges and develop and prioritize action paths towards California's energy and GHG goals.

Goal 1: Code Enhancement and Expansion

Implementation Plan and Timeline				
Strategies	**Near-Term (2009-2011)**	**Mid-Term (2012-2015)**	**Long-Term (2016-2020)**	**2021 – Beyond**
1.1: Develop a phased and accelerated approach to more stringent codes and standards	• Adopt a progressive set of building codes; including one or two voluntary "reach" code tiers for residential and commercial sectors • Lower the renovation threshold at which the code applies to an entire existing structure • Identify local code or ordinance opportunities as pilots or where local conditions may support accelerated action	• Develop road map for accelerating Title 20 standards and Title 24 codes in a "top-down" approach • Increase use of building commissioning requirements for new buildings and retrofits • Identify analysis, case study, R&D, and other activities necessary to support progressive strengthening of codes and standards	• Develop "reach" codes for buildings as "net producers" of energy (ZNE) • Codes and Standards require zero net residential buildings by 2020	• Codes and Standards require zero net commercial buildings by 2030

Implementation Plan and Timeline				
Strategies	**Near-Term (2009-2011)**	**Mid-Term (2012-2015)**	**Long-Term (2016-2020)**	**2021 – Beyond**
1.2: Expand Titles 24 and 20 to address all significant energy end uses	• Expand Title 20 to cover additional plug loads such as copy machines, printers, battery chargers, televisions. • Enhance Title 24 to include whole building approaches including metering and data management; automated diagnostic systems; and sub-metering for tenant-occupied space • Pursue greater alignment of national and localized green building codes with energy codes • Integrate AB 32 standards with energy efficiency goals	• Expand Title 20 and Title 24 to cover additional uses such as server farms, process loads and water use. • Develop building standards to better integrate on-site clean distributed generation • Investigate establishing energy and green building codes on a community and/or city level that may include infrastructure issues such as transportation, wastewater treatment, solid waste disposal	• Investigate expansion of Titles 24 and 20 to address all significant energy end uses (manufacturing, agricultural, healthcare, etc.) • Evaluate including land development in energy standards and regulations	• Continue to develop and refine approaches from experience
1-3: Improve code research and analysis	• Conduct analysis that will help the code move toward a zero-based approach • Analyze approaches for whole buildings, non-covered end uses and measures that are not currently credited by Title 24 • Conduct tests and evaluations of potential code change measures. • Increase research and analysis regarding how behavior affects use of buildings and code compliance • Evaluate and develop appropriate approaches to include DR standards in C&S • Continue exploration and adoption of improved building energy simulation and compliance tools	• Continue research to improve program impact and processes. • Conduct analysis of embedded energy savings with transportation, wastewater, and solid waste options for green building standards • Investigate the balance between mandatory, prescriptive, and beyond-code "reach" standards to achieve more effective codes, greater compliance rates, and more innovation in the marketplace	• Continue research. • Conduct research on revising and updating the cost-effectiveness, including the potential for using non-energy benefits as a component of cost effectiveness	• Continue research based on promising next steps
1-4: Improve coordination of state energy codes and standards with other state and federal regulations	• Continue to develop appliance standards to influence the market prior to preemption by DOE • Coordinate Title 24 goals with 1992 Energy Policy Act requirements for meeting/exceeding federal code • Coordinate development and adoption of California Green Building Standards with Title 20/24 and ASHRAE Standard 189, CHPS	• Coordinate development of related codes and standards such as the California Green Building Standards, ASHRAE 90.1 and 189.1, ICC, CHPS, etc. • Coordinate/support implementation of legislation impacting C&S program such as AB 32 • Coordinate development of codes and standards with state and voluntary programs such as Energy Star, LEED, Flex Your Power, etc.	• Pursue remaining priorities as identified	• Pursue remaining priorities as identified
1-5: Improve	• Develop and implement plan	• Investigate ways to integrate C&S	• Investigate a	• Investigate the integration

Implementation Plan and Timeline				
Strategies	**Near-Term (2009-2011)**	**Mid-Term (2012-2015)**	**Long-Term (2016-2020)**	**2021 – Beyond**
coordination of energy codes and standards with utility programs	for enhanced coordination and integration of codes and standards with full spectrum of EE market transformation, including Emerging Technologies promotion, deployment, incentives, consumer education, etc.	with other DSM by offering tiered incentives (financial and other) and technical assistance for more comprehensive and inclusive definitions of codes and standards	greater convergence of the C&S and other DSM through non-code mechanisms and utility program integration	of utility infrastructure planning with potential community-based codes

Goal 2*:* Improve code compliance and enforcement.

Compliance with California's efficiency codes and standards varies enormously, especially with respect to building codes. For example, fewer than 10 percent of HVAC systems installed have permits pulled and 30-50 percent of new central air conditioning systems are not being installed properly. This compliance failure comes at considerable cost to Californians—the HVAC compliance shortcomings have led to an estimated 20-30 percent increase in the peak energy needed on hot summer afternoons.[58] It has been estimated that at least 30 percent of the technical energy savings potential of energy codes is lost due to non-compliance—but in reality there is inadequate understanding of code compliance rates or the resulting degradation in performance.[59]

This strategy will require a strong, coordinated effort among federal, state and local entities, the utilities, California building officials (and their association, CALBO) and other code compliance organizations, trade and professional licensing/ registration agencies, and building/developer/ contractor/ manufacturers associations.

Goal 2: Compliance and Enforcement

Implementation Plan and Timeline				
Strategies	**Near-Term (2009-2011)**	**Mid-Term (2012-2015)**	**Long Term (2016-2020)**	**2021 – Beyond**
2-1: Improve code compliance and enforcement.	• Conduct research to determine high-priority tactical solutions for code compliance and focus efforts accordingly. • Increase training and support for local building code officials. • Investigate regulatory tools such as licensing/ registration enforcement. • Evaluate proposed changes to the code and compliance approaches to simplify and expedite compliance. • Work with local governments to improve code compliance, adopt above code ordinances, and provide training/education	• Continue to conduct further research relating to code compliance. Refocus efforts as needed • Pursue appropriate involvement of HERS raters. • Pursue trade associations to improve "self-policing" of membership • Investigate tools, software programs, "incentives", and policies to simplify and streamline permit process • Apply feasible mechanisms to prove code compliance as a pre-requisite for partnership funding or incentives from the IOUs	• Continue to conduct research • Investigate aggressive "stick" and "carrot" programs with monetary penalties and incentives • Investigate greatest opportunities of compliance improvement of appliances (Title 20) in the upstream and midstream markets, including working directly with manufacturers and distributors to improve appliance and equipment compliance	• Continue to conduct research. Investigate and pursue solutions to the perceived and real "penalties" associated with non-compliance • Investigate codes and standards that would regulate the operation of buildings that may include such things as maintenance requirements, regular updates to operating schedules, mandatory monitoring and controls points, system reporting requirements, etc.

8. DSM COORDINATION AND INTEGRATION

8.1 VISION

Energy efficiency, energy conservation, demand response, advanced metering, and distributed generation technologies are offered as elements of an integrated solution that supports energy and carbon reduction goals immediately, and eventually water and other resource conservation goals in the future.

8.2 PROFILE

Historically, demand side management (DSM) options for energy consumers have been ”siloed” activities within regulatory bodies, utilities, environmental organizations, and among private sector service providers. The programs are focused on mass delivery and promotion of individual products, for example efficient air conditioners, rather than on integrated packages of measures, for example, air conditioner rebates with duct sealing, weather-stripping, programmable thermostats, and advanced meters. This current narrow focus on a single product offering does not maximize energy savings nor minimize the costs of program delivery.

A narrow, single-product approach also results in customer confusion by requiring the customer to seek out information on a wide array of different programs with multiple points of contact in order to acquire a basic understanding of the DSM options available and the various benefits they offer. Most energy users across all economic sectors do not have the time or expertise to seek this information; as a result, many opportunities to accomplish DSM actions are lost.

At the CPUC, a number of individual proceedings relate to DSM, including energy efficiency, demand response, advanced metering, combined heat and power/distributed generation, and the California Solar Initiative (CSI), in addition to an upcoming Smart Grid rulemaking.[60] The CPUC should integrate the DSM programs within its jurisdiction – including the harmonization of cost-effectiveness methodologies and metrics – in order to enable offerings of integrated packages that will maximize savings and efficiencies of utility program overhead.

The development of Smart Grid technologies that enable active, real-time energy management in homes and businesses also will play a critical role in the packaging of integrated DSM services. A recent report by IBM, *Plugging in the Consumer*, demonstrates that we are poised for the uptake of advanced energy management systems.[61] Activities to plan for Smart Grid integration are underway in a number of venues, including ongoing R&D at the CEC[62], and the upcoming Smart Grid rulemaking at the CPUC. These efforts will lead to deployment of new grid and metering technologies. These, in turn, will help to optimize energy system performance, and encourage behavioral changes in energy use.

The goal of this Plan is to build on successes from initial efforts such as PG&E’s Market Integrated DSM Initiative and the SCE and Sempra Sustainable Communities Initiative to offer integrated DSM solutions to maximize energy savings. A related goal is to design policies and programs in research and development, commercialization, deployment, and codes and standards that reinforce each other and use feedback loops to constantly improve energy efficiency programs.

8.3 GOAL

Goal		Goal Results
Deliver integrated DSM options that include efficiency, demand response, energy management and self generation measures, through coordinated marketing and regulatory integration.	➡	Customers realize increased energy savings at lower cost through the implementation of a menu of DSM options.

There are three levels of integration for DSM options:

- **Comprehensive and Coordinated Marketing**: Outreach and consumer education, and DSM program options must be offered in a unified fashion so that energy users receive complete DSM information with minimum effort , preferably through single points of contact.
- **Program Delivery Coordination**: Combined DSM audits and recommendations across all relevant energy management opportunities will be offered to customers, including advice on energy efficiency, demand response, distributed generation, Permanent Load Shifting (PLS), solar rebates, and other applicable measures.
- **Technology and Systems Integration**: This includes equipment and information systems that enable achievement of multiple DSM options (energy efficiency, demand response, etc.) and synergies across DSM program types (e.g., addressable electronic ballasts that both save energy and manage demand during utility peak hours).

Integrated packages of DSM solutions are a consistent theme throughout each of the Chapters in this Plan. This Chapter describes augmented, not duplicate, strategies described elsewhere.

8.4 STRATEGIES

This Plan contains four overarching strategies for DSM integration:

1. **Pilot Programs**: The best short-term path to promote integration is to continue successful efforts by the IOUs and pursue an expanded series of pilot projects as part of the IOUs' efficiency and demand response 2009-2011 portfolios. These pilots will (a) be designed to inform future program and policy submissions regarding the value and best methods and targets of integration, (b) offer a bundled product that includes elements of energy efficiency and conservation, consumer generation, demand response, and the best available AMI technology and, (c) offer different forms of delivery (including third-party and local government platforms) and information access.
2. **Stakeholder Coordination**: For the longer term, the CPUC will work with key stakeholders to develop and implement a comprehensive, coordinated long-term approach to effective utilization of energy resources while also achieving GHG emissions reductions, water conservation, waste disposal, and air quality requirements.
3. **New Technology**: Technology is a fundamental element in achieving the CPUC's Big/ Bold Strategies and maximizing the contribution of energy efficiency in meeting the state's energy and environmental goals. A major effort is needed to develop new technologies and systems that enable multiple DSM options and provide synergy across DSM program types. The CPUC has already approved installation of AMI throughout IOU service areas and will soon initiate a Smart Grid proceeding which will likely spur development of new, integrated DSM technologies.

4. **Coordinated DSM Marketing**: Coordinated marketing will be an essential component in achieving greater up-take of integrated DSM programs. "Smart meter" systems and associated dynamic pricing tariffs also are important tools for customers to monitor and reduce their energy consumption. The majority of these systems will be deployed statewide during 2009-2011. This present a unique near-term opportunity to promote integrated demand-side management programs. Program administrators should streamline and integrate the marketing of DSM programs in conjunction with smart meter deployment.

8.5 IMPLEMENTATION PLAN

Historically, resource efficiency messages, programs, and initiatives have been promoted as separate and largely independent activities. Energy, air quality, water, and waste regulations are under the jurisdictions of separate agencies and commissions. It is critical to develop a shared vision and process for regulatory coordination in California to support the energy savings benefits of DSM coordination/integration and to ensure consistent and mutually supportive energy, water, air, and GHG policy and regulations. Enhancing utility programs, technology advancement and general education and training objectives depends on coordinated regulation and voluntary efforts across the spectrum of DSM activities. In addition, the implementation of AB 32 will require additional coordination by all agencies to achieve a common goal.

Achieving this vision will require new forms of government agency collaboration, mechanisms to quantify and value multiple resource benefits, and fundamental changes to the standard business and service delivery practices of utilities, energy service companies and building contractors.

Goal: Integrated DSM Programs, Messages, and Technologies

Implementation Plan and Timeline			
Strategies	**Near-Term (2009-2011)**	**Mid-Term (2012-2015)**	**Long Term (2016-2020)**
1.1: Carry out integrated marketing of DSM opportunities across all customer classes	• IOUs adopt marketing integration plans, by sector • Streamline and integrate EE, DR, and DG program outreach • Coordinate integrated marketing with AMI deployment • Offer audits and technical assistance that address combined DSM opportunities	• Continue integrated marketing through AMI full deployment • Leverage lessons learned to other general marketing materials	• Incorporate output of other integration strategies and pilot programs into marketing materials
1-2: Conduct integrated DSM delivery *pilots* in the Residential, Commercial, Industrial and Agricultural sectors	Propose and launch program delivery pilots testing capabilities and effectiveness in the marketplace, including EE, DR, AMI and DG	• Apply lessons from pilots to full scale implementation • Develop new pilots "smart buildings", building operator training, and solar PV and hot water	• Expand successful activities statewide
1.3: Develop *integrated* DSM programs across resources, including energy, water, and transportation	• Establish ongoing working group to develop and implement blueprint for integration	• Implement pilot programs that integrate solutions across resources	• Expand successful approaches
1.4: Promote development and support of new technologies that enable or facilitate DSM Coordination and Integration	• Assess the current state of integration-enabling technology and develop a guidance document detailing a technology development path for fuller integration. (2009) • Prioritize integration-enabling technologies in RD&D and ET programs based on the technology assessment	• Update biennially	• Update biennially

9. WORKFORCE EDUCATION AND TRAINING

9.1 VISION

By 2020, California's workforce is trained and fully engaged to provide the human capital necessary to achieve California's economic energy efficiency and demand-side management potential.



9.2 PROFILE

Workforce Education and Training (WE&T) focuses on educating and training people to perform the jobs needed to reach California's clean energy goals. The IOUs currently provide efficiency-specific training and education courses to fulfill needs associated with implementing IOU programs; efficiency-specific course materials; training for third-party program implementers; and energy efficiency and sustainability curricula at K-12 schools.

In order to accommodate the dramatic increase in energy efficiency activities envisioned by this Plan and required by AB 32, California must develop a trained workforce, including people qualified in energy-efficiency engineering, construction, maintenance, program design and implementation, and financial analysis. Meeting the goals established in the Plan will require at least two categories of personnel development: completely new types of jobs that do not exist today (e.g., corporate emissions manager) and supplemental training for existing positions (e.g., training engineers to enhance energy efficiency).

This cross-cutting sector demands a truly statewide coordination effort that integrates energy efficiency training into a wide range of public and private programs. This effort will include the California Department of Education, the Department of Employment Development, industry and labor associations, educational institutions at all levels, technical and vocational training organizations, community based non-profit organizations, and the business community.

9.3 GOALS

Goals	Goal Results
1. Establish energy efficiency education and training at all levels of California's educational systems.	Students develop careers and existing workers develop skills and knowledge that advance DSM businesses, policy, research and development, and education.
2. Ensure that minority, low income and disadvantaged communities fully participate in training and education programs at all levels of the DSM and energy efficiency industry.	Individuals from the targeted communities take advantage of programs that specialize in energy disciplines at all levels of the educational system and successfully advance themselves into rewarding careers in the energy services fields.

9.4 STRATEGIES

An effective, comprehensive WE&T program for a new energy efficient economy requires collaborative efforts by many entities. It is not the core mission of utilities to effectuate the level of change needed to

create a comprehensive WE&T program, nor can ratepayers fully fund the effort. In addition to the educational institutions themselves, participants in defining and/or providing energy efficiency WE&T resources include:

- **Government.** California Department of Education and the Department of Employment Development, federal government (e.g., Department of Labor), specialized state agencies (e.g., licensing boards) and local governments (e.g., building departments) to recruit train and prepare workforce candidates for technical and professional careers.
- **Educational Institutions.** The University of California, the California State University, community colleges, school districts and private colleges, universities, and technical schools.
- **Community-based and non-profit organizations.** Organizations funded to provide education, career development and workforce training programs (i.e., Greenlining Institute, Apollo Alliance).
- **Industry and labor organizations.** Trade unions, the Sheet Metal and Air Conditioning Contractors' National Association, the California Building Performance Contractors Association, home rating organizations, and energy efficiency associations.

Several strategies must be initiated or completed in the near term to more thoroughly define, initiate and drive long-term WE&T development and strategic planning.

1. **WE&T Needs Assessment**. An in-depth formal statewide training and education resource inventory and needs assessment is necessary for long-range strategic planning and delivery. The needs assessment and resource inventory will be structured to produce short-, near- and long-term workforce strategies to support each sector defined in the Plan. Information in the WE&T Convener Report[63] provides an excellent start for the assessment. The assessment will be completed by a third-party with its process managed by the CPUC and IOUs, in collaboration with the California Department of Education.
2. **WE&T Web Portal.** The web portal will include links to various demand-side management (DSM) related training programs and will allow for a single point of communication. The portal will also serve as a repository for all demand-side management and energy efficiency training, educational conferences, and career opportunities. This portal will be created and funded in collaboration with other appropriate entities, and linked to the statewide energy efficiency web portal.
3. **Energy Efficiency WE&T Task Force.** The Task Force, comprised of energy efficiency program administrators, the CPUC, and educational experts, will fulfill administrative functions including: developing a needs assessment RFP; selecting the third party to conduct the needs assessment; and managing the needs assessment evaluation. The Task Force members will continue to help implement the goals and strategies set forth in this Plan.
4. **Identify And Implement Specific Programs For Each Educational Sector.** WE&T needs are best organized and approached by identifying the enabling or supporting educational sectors. Thus, five educational sectors have been defined for addressing WE&T needs and opportunities: Kindergarten through high school, adult education and community colleges, technical training, colleges and universities, and minority, low income and disadvantaged communities.

These actions will also support development of funding streams other than ratepayer funding, identify market sector specific needs, and inform short-term actions to initiate longer-term strategies for each market and educational sector.

WE&T measures that are specific to particular industries or economic sectors are included in the appropriate chapters of this Plan. For example, the HVAC Chapter addresses training for technicians and installers and building code officials. Similarly, the Commercial Chapter contains a strategy for expanded building operator certification training and integrated training of architects and engineers for the design of zero net energy buildings. This Chapter focuses on cross-cutting workforce development measures.

9.5 IMPLEMENTATION PLAN

Goal 1. Establish energy efficiency education and training at all levels of California's educational system.

This Plan envisions that the IOUs will act as a catalyst to action by sponsoring several foundational activities that are necessary to accurately identify specific WE&T needs and recommendations for action. These activities will also enable the IOUs to review their existing programs and better align them within the context of a comprehensive WE&T strategy.

The most critical near term activity is a comprehensive needs assessment to evaluate energy efficiency workforce requirements through 2020 that are necessary to sustain a robust and effective industry to accomplish the goals set forth in this Plan. This needs assessment will solicit broad input from organizations identified above.

Goal 1: Energy Efficiency Education and Training

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
1-1: Define, initiate and drive long-term WE&T development and strategic planning, including identification of funding streams and market sector specific needs	• Conduct an in-depth formal statewide energy efficiency training and education resource inventory and needs assessment • Assess current and alternative funding mechanisms for WE&T activities • Create a WE&T-specific web portal and identify entities to co-fund and co-sponsor the web portal with utilities • Initiate ongoing dialogue with broad group of market participant and education stakeholders to inform the overall plan • Establish task force to oversee utility specific WE&T activities	• Update assessment as needed • Maintain and update web portal • Maintain ongoing dialogue with actors positioned to lead priority educational and workforce development initiatives • Continue to oversee utility specific WE&T activities	• Update assessment as needed • Maintain and update web portal • Maintain ongoing dialogue • Continue to oversee utility specific WE&T activities

1-2: Support the community college and adult education efforts to support students to develop their education based on visible career paths in energy efficiency and related fields	• Utilize community colleges to provide technical training such as HVAC maintenance and building operator certification • Develop appropriate linkages with K-12 programs • Coordinate with the community colleges and adult education sector to incorporate an energy component into their career laddering concept	• Implement programs. • Evaluate progress and refine strategy • Find opportunities to expand programs and funding and placement partnerships	• Implement programs. • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships
1-3: Incorporate energy efficiency and demand side energy management into traditional contractor and technician training, such as for plumbers and electricians, and expand training resources to produce target numbers of trained workers	• Expand or establish training curricula, and training and professional career development programs in building construction, services, building operator and other energy efficiency technical fields • Establish or expand key financial and placement partnerships that demonstrate employment prospects for trained personnel	• Implement programs • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships	• Implement programs • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships
1-4: Create or expand college and university programs with energy efficiency focus and foster green campus efforts to apply this knowledge in clear view of students and faculty	• Utilize existing UC/CSU extension programs to incorporate a continuing education curriculum component • Work with Universities and colleges to expand professional energy related degree offerings and contribute to tailored curriculum	• Implement programs • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships	• Implement programs • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships
1-5: Develop K-12 curriculum to include energy efficiency fundamentals (e.g. math, science, behavior) and identify career options in energy-related fields	• Identify opportunities to leverage governor's career technical initiative. • Identify opportunities to work with the California Department of Education to develop curricula with specific content for energy and GHG issues. • Support outreach into K-12 schools on energy, water and environmental issues.	• Implement programs • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships	• Implement programs • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships

Goal 2: Ensure that minority, low income and disadvantaged communities fully participate in training and education programs at all levels of the DSM and the energy efficiency industry.

Coordination of LIEE workforce training with other energy efficiency training programs is essential. This includes coordination with The Green Jobs Act of 2007 as well as with existing programs associated with state agencies such as the Employment Development Department (EDD) and the Department of Social Services (DSS). The Green Jobs Act of 2007, approved as part of the recent federal Energy Bill, authorizes funding up to $125 million annually for job training in the energy efficiency and renewable energy industries and facilitates economic development within minority, low-income, and economically disadvantaged communities. The IOUs will work to coordinate both the federally-supported training to be offered under this Act, as well as other state employment training resources, with the LIEE workforce training. Recruiting for trainees may be accomplished within the targeted communities served by LIEE contractors. This coordination should expand employment options for those in disadvantaged communities beyond the LIEE program itself. Finally, as new legislation is adopted and AB 32 begins implementation, additional funding and programs from those activities need to be leveraged to the advantage of the energy efficiency WE&T effort.

Goal 2: Disadvantaged Communities

Implementation Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2-1: Collaboratively identify appropriate goals and strategies to build California's energy efficiency workforce through 2020, focusing on training that increases participation from within minority, low-income and disadvantaged communities in achieving California's economic energy efficiency potential	• Leverage Marketing Education & Outreach and WE&T task forces to partner w/ community-based organizations and provide targeted outreach on employment opportunities with energy efficiency • Develop Low Income WE&T Plan • Train qualified diverse business enterprises from minority, low-income and disadvantaged communities to undertake or expand efficiency services	• Implement programs • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships	• Implement programs • Evaluate progress and refine strategy • Find opportunities to expand programs and partnerships

10. MARKETING, EDUCATION AND OUTREACH

10. 1 VISION

Californians will be engaged as partners in the state's energy efficiency, demand-side management and clean energy efforts by becoming fully informed of the importance of energy efficiency and their opportunities to act.



10.2 PROFILE

The purpose of Marketing, Education and Outreach (ME&O) is to increase consumer awareness and participation in demand side management activities and to encourage behavior changes that save energy, reduce greenhouse gas emissions, and support clean energy solutions. A highly successful ME&O program is a fundamental part of many of the strategies and programs presented in this Plan as well as the overarching goals of behavior and market transformation for energy efficiency. A successful ME&O must move consumers through a transitional process from awareness, to attitude change, to action.

Californians are currently engaged in a broad public discussion about energy use and its relationship to global warming and the environment. AB 32 set the stage for a statewide transition to a clean energy future by requiring the reduction of greenhouse gas emissions to 1990 levels by 2020. Across numerous studies, energy efficiency strategies consistently are identified as uniquely able to significantly reduce GHG emissions and do so with a net economic savings. As a result, there is increased awareness of the value of energy efficiency and interest among consumers and businesses to do their part. This discussion presents a strategic window of opportunity to use ratepayer-funded ME&O to leverage public and private messages on global warming to achieve greater impact on consumer awareness of, and demand for, energy efficiency actions.

Between 2006 and 2008, California IOU ratepayers will have funded approximately $300 million for public education, marketing, and outreach to support customer demand-side programs. Of this amount, $176 million funds public education and outreach for IOU energy efficiency programs.[64]

The majority of these outreach efforts have focused primarily on promoting isolated consumer actions, such as buying energy efficient clothes washers or compact fluorescent light bulbs, or reducing usage to prevent outages during peak periods. By and large, ME&O messages have lacked the comprehensive focus necessary to engage consumers in adopting energy efficiency broadly as a way of life. While messaging that differentiates program and service area issues will remain an important aspect of overall ME&O efforts, the launch of a coherent statewide campaign will be instrumental in bringing consumer awareness of the value of energy efficiency to the next level. Accordingly, it is a top-level priority for the next round of efficiency investment.

The CPUC's Decision 07-10-032 directed that the current approach be changed significantly, under Commission direction and oversight, beginning in 2009 in order to better leverage ratepayer ME&O funding for more effective results.

10.3 GOALS

Goal	Goal Results
Create and launch an integrated, statewide Marketing, Education and Outreach effort for energy efficiency, including an energy efficiency brand.	High levels of awareness statewide of the value of energy efficiency that leads to strong demand for energy efficient products, homes and services.

The ME&O effort will:

- Create instant brand recognition for energy efficiency in California, similar to the US EPA's EnergyStar label, and expanded to reflect GHG benefits.
- Utilize appropriate channels to create effective "demand pull" for efficiency actions that are necessary for achieving the goals set forth elsewhere in this Plan.
- Motivate consumers to reduce energy consumption on a daily basis.

10.4 STRATEGIES

The ME&O goal will be achieved through four strategies:

1. **An Energy Efficiency Brand:** Creation of an instantly recognized brand for "California Energy Efficiency" with clear delineation of what the brand encompasses, including reducing GHG.
2. **Integrated Marketing**: Development of marketing messages that offer bundles of DSM programs targeted to specific customer groups and delivery of effective messages using partnerships with a range of energy efficiency participants, including local governments, retailers and manufacturers.
3. **Social Marketing:** Use of social marketing techniques to create emotional and intellectual drivers for consumers to make a commitment to change and participate in energy efficiency.
4. **Internet-Based Networking:** Creation of a web portal that allows energy efficiency practitioners and consumers to exchange information and solutions on implementing energy efficiency programs and measures.

The key to the next generation of ME&O is to create a consumer experience that offers an integrated set of DSM information and program options that are clear, relevant to the consumer, and accessible to all Californians. By beginning with a systematic approach to branding energy efficiency that is rooted in effective message research, evaluation, social marketing, behavioral science, and targeted segmentation, California will lay a framework for successful integration of ME&O across all clean energy programs. Under Commission direction and oversight, a statewide brand will establish a clear, consistent message about the individual and social value of energy efficiency, and set a foundation for consumers to receive targeted information on efficiency programs, products, and incentives. Next, segmentation research will be used to develop a wide range of appropriate messages designed to build on the brand and connect with specific groups of consumers, including low income and other hard to reach populations. Additional highly-targeted program marketing efforts will be conducted that focus on consumer segments with the highest propensity to participate in clean energy programs in order to create a strong base of early adopters. These efforts will use multiple channels and leverage

strategic partners across the spectrum. All messages will be components of an integrated marketing strategy that will provide consumers with an increased understanding of the full array of energy efficiency and DSM options.

California's businesses and educational institutions (public and private) with excellent channels to further leverage energy efficiency messaging and create the next generation of energy ambassadors. The statewide ME&O effort will work with both sectors to leverage their resources and utilize them fully in the statewide campaigns.

The Internet offers powerful, cost-effective opportunities as a clearinghouse for energy efficiency programs and promoting behavior change. As required by D.07-10-032, the ME&O effort will include development of an interactive Energy Efficiency Web Portal that provides one integrated point of access to a multitude of energy efficiency information. The web portal will be a user-centered, interactive resource that allows users to easily navigate multiple points of data, applications, and information systems.[65]

The portal will have two development stages and functions. The first stage will be a website for energy efficiency professionals such as program designers, implementation practitioners, evaluators, marketers, and policy makers to share information and best practices on implementing energy efficiency measures, policies and programs. The second stage will be development of an online resource for individual consumers (and businesses) that provides easy access to information on products, programs, services, practices and tools to manage their energy usage. This consumer web platform will be designed to facilitate peer-to-peer information exchange.



Peer-to-peer and word-of-mouth contact are proven modes of information exchange that heighten motivation for action. The ME&O effort will maximize these and other social marketing techniques to motivate consumers and achieve goals for changes in energy use behaviors, attitudes and perceptions. The practice of energy efficiency requires a sustained effort on the part of the consumer, both in information acquisition (i.e., what are the most effective efficiency methods and techniques) and in implementation and ongoing practice. Therefore, an approach based on increased access to information and behavior-based marketing techniques will both educate *and* inspire consumers to make a long-term change in how they think about and use energy.

For all of these strategies to be effective, clear objectives and metrics for the statewide campaign will be established prior to its launch, including an appropriate evaluation mechanism to measure results. The ME&O Task Force will continue to function in an advisory capacity, leveraging inputs and expertise from key stakeholders whose contributions collectively are vital to the successful implementation of the goals and strategies envisioned in this Plan. The CPUC will guide the process for developing and implementing the ME&O effort and integrating strategic adjustments and improvements over time to ensure the achievement of goals and benchmarks.

The result of these efforts will be a coordinated, comprehensive system of communicating with Californians and delivering an array of effective messages and valuable information resources. This system will prove essential for engaging the public to help achieve California's aggressive energy efficiency goals and global warming solutions.

Goal 1: Comprehensive ME&O Effort

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid-Term 2012 – 2015**	**Long Term 2016 – 2020**
1-1: Establish a recognizable and trustworthy brand for California's Energy Efficiency and other DSM consumer products and services	• Research appropriate look and meaning of a California efficiency/ GHG reduction Brand • Launch integrated energy efficiency/DSM Brand • Evaluate progress and refine strategy	• Evaluate progress and refine strategy	• Evaluate progress and refine strategy
1-2: Develop an integrated marketing plan for all Californians	• Conduct statewide segmentation research, including LIEE and other hard to reach groups, on interests, awareness, and attitudes/perceptions related to energy efficiency and global warming messaging • Establish objectives and metrics for public campaign • Develop targeted and highly relevant energy efficiency and DSM marketing messages to incite behavior change/action • Create partnerships with private industry and businesses to help motivate consumer and business sector action • Define deliverables for each strategy	• Evaluate progress and refine segmentation research	• Evaluate progress and refine segmentation research
1-3: Use social marketing techniques to build awareness and change consumer attitudes and perceptions	• Develop a roadmap for a social marketing approach including exploration of behavioral science principles	• Implement social marketing approach • Establish partnerships with community, social, and other institutions and networks to convey the action messages	• Evaluate progress and refine strategy
1-4: Develop a California Energy Efficiency web portal with statewide Information on GHG reductions, efficiency and DSM awareness and options	• Develop initial website/portal for the energy efficiency/DSM industry • Begin pilot programs in using web portal	• Add consumer and business end use function to website/portal	• Evaluate progress and refine strategy
1-5: Conduct public communications campaigns, alongside longer-term supporting school education initiatives to deliver the efficiency message	• Implement integrated public communications and marketing campaigns • Identify or develop curriculum for K-12 education, and work with state Board of Education to integrate into state requirements	• Refine campaign based on ongoing research and evaluation insights (above) • Initiate K-12 curriculum in initial locations • Evaluate and refine, as appropriate	• Continue to refine and deliver public communication campaign to support targeted actions • Expand K-12 curriculum applications statewide and further integrate into state curriculum requirements

11. RESEARCH AND TECHNOLOGY

11. 1 VISION

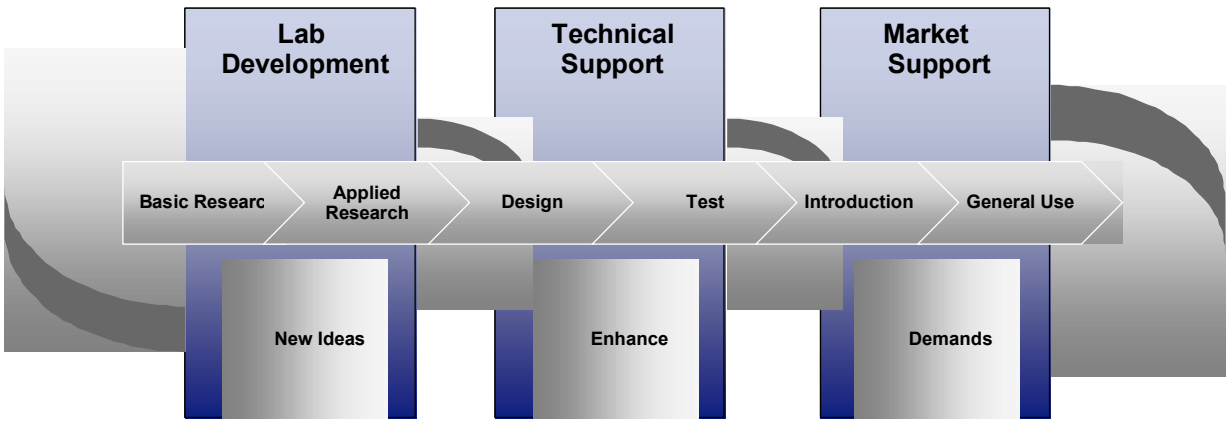
Technology advancement related to energy use and demand will match—or even eclipse— the consumer electronics industry in innovation, time to market, and consumer acceptance.

11.2 PROFILE

The development, enhancement, deployment, and operation of more and better energy efficiency related technology is fundamental to achieving California's energy efficiency vision and goals. The time frame of California's goals demands a targeted focus on moving innovative technologies more quickly into the marketplace. Since most demand-side technologies involve a human interface, increased knowledge of human behavior and social science is also necessary—as is the infusion of that knowledge into technology development, deployment, and integration. Finally, establishing a robust and vibrant evaluation and user feedback loop is crucial to advancing technology development.

Technology progresses along a continuum from basic research to general use, as suggested by the graphic below.[66] The advancement process comprises several stages and is not strictly linear. It also includes several feedback loops, restarts and early terminations.

Technology Advancement Continuum



Historically, the Energy Commission's Public Interest Energy Research (PIER) program has funded technology development primarily prior to market readiness, corresponding to the "Applied Research", "Design" and "Test" phases above. In 2000, the CPUC, utilities and the Energy Commission started the Emerging Technologies Coordinating Council (ETCC) to coordinate statewide market promotion of emerging technology efforts. That program's has been on supporting energy efficiency technologies that are market ready but not commonly accepted (moving technologies from the "Test" and "Introduction" phases toward "General Use", as displayed in the diagram above). To achieve the next level of energy efficiency, the Plan is looking beyond that historical focus.

Innovation in building design, materials, and construction practice emanates from national

laboratories, such as the National Renewable Energy Laboratory (NREL) and the Lawrence Berkeley National Laboratory (LBNL). Major portions of their work are funded by DOE, while LBNL receives substantial PIER funding. Further applied research occurs with proprietary funding from equipment and building materials manufacturers. Additionally, at the national level, leading edge energy efficiency initiatives are now often led by entities like the America Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE), the American Institute of Architects (AIA), Architecture 2030, the New Buildings Institute, other state organizations like the New York Energy Research and Development Authority (NYSERDA), and large municipalities like New York City. On an international level, the leadership of the United Kingdom and the European Commission is critical. Within California, agencies like the Sacramento Municipal Utility District (SMUD) and progressive municipalities are also often on the leading edge. California will benefit greatly from deliberate efforts to secure better integration and leverage across these activities.

While new buildings and industrial facilities offer good opportunities to adopt new advanced technologies, this construction replaces only 1-2percent of the existing stock each year. To make rapid progress with energy efficiency will also require making incremental technology improvements that can be inserted into California's existing buildings and industrial facilities. It will be important that research on advanced technologies pursue paths that target both breakthrough as well as incremental technologies and their performance gains.

11.3 GOALS

New technologies that use minimum energy as well as new energy efficiency enabling technologies (e.g., nanotechnology, wireless sensors, DC Power Architecture) are fundamental to a transformed energy market. However, neither utility-funded ETCC programs, nor PIER by themselves create technology or drive technology advancement; rather they support the commercialization process and create an element of market pull.

Utility and Energy Commission energy efficiency technology programs must be refocused to catalyze research, development and commercialization of technologies that support the BBEES and integrated energy solutions initiatives. As noted above, research and technology strategies must include the entire technology advancement continuum as well as the operational and behavioral factors that influence technology usage. This will require greater attention to, and prioritization of, DOE and privately-funded Research and Development (R&D) activities, and more explicit commercialization and utilization strategies.

Goal	Goal Results
1. Refocus utility and Energy Commission energy efficiency research and technology support to create demand pull and set the research agenda for both incremental and game-changing energy efficiency technology innovations.	Ratepayer-funded R&D programs will explicitly support widely applicable whole-building improvement, lighting, and plug load solutions envisioned in this Plan and will be used to leverage other private and public funds for the deployment of new technologies.
2. Conduct targeted emerging technologies R&D to support the Big, Bold Energy Efficiency Strategies and integrated energy solutions goals.	Profound improvement in equipment efficiency as well as new building materials and designs aimed at achieving more efficiency from new buildings than technically feasible today, and necessary to achieve Zero Net Energy and hot/dry climate HVAC outcomes

11.4 STRATEGIES

California's energy efficiency goals require substantial changes in all stages of the technology advancement cycle including technology research and development, marketing, and operations. Strategies must harness private market forces – as well as regulatory-directed efforts - to foster the development and deployment of technologies and methods that promote and support a comprehensive adoption of energy efficiency practices. Key research and technology strategies are:

1. Engage the full-range of participants – private entities, national labs, clean energy and environmental groups, green venture capital firms, federal, state and local governments, utilities and consumers.
2. Identify new technologies and enhance existing technologies to make them better and improve their uptake and use.
3. Employ a systems approach to establishing research priorities.
4. Facilitate paths-to-market for technologies and enabling/supporting practices through, directed research and technology investment, market push/pull techniques, and targeted product distribution methods.
5. Apply social and behavioral science theory to encourage the adoption and best use of resources and energy efficient technology.

11.5 IMPLEMENTATION PLAN

Goal 1: Create demand pull and set the research agenda to pursue both incremental and game-changing energy efficiency technology innovations.

To stimulate transformations in technology and related market dynamics, ratepayer-funded emerging technologies programs must be focused on creating demand pull for the emerging technologies that support the goals of this Plan. Key to this effort is a focused effort to leverage the R&D resources of both the public and private sectors.

Private industry's enormous investment in technology development and its ability to respond quickly to changing economic priorities and to capture opportunities is needed to realize the goals of the Plan. federal R&D funding, particularly its role in supporting for national laboratories, also plays a critical role in early-stage R&D activities for emerging technologies.

Academic research (both public and private) is a third major technology development and advancement force, while the efforts of other state or regional entities that utilize energy efficiency as a means to achieve their goals (e.g., CARB, South Coast Air Quality Management District) provide additional resources.

Better coordination among these activities will ensure both incremental and game-changing energy efficiency technologies, while at the same time creating sustained demand pull for the technologies that emerge.

Strategies to tap incremental technology gains will draw on collaboration with technology providers and the R&D community to promote performance enhancements of existing technologies. This work will include targeting leading opportunities for energy management, such as with plug-loads (e.g., High Definition Television), one of the major growth areas in demand. In addition, targeted R&D is required for commercial and residential lighting, as well as energy management control systems.

Goal 1: Create Demand Pull for New Technologies

Implementation Plan and Timeline			
Strategies	**Near-Term**	**Mid-Term**	**Long Term**
1-1 Apply systems approaches to establishing research priorities	• Collaborate with regional and national labs, manufacturers, universities to develop and enhance technologies that can help meet the statewide strategic EE/DR goals • Form Utility advisory group to formally provide input into PIER research strategies and programs and coordinate with ETCC promotion process • Target most promising opportunities for improving plug-loads, lighting, and integrated DSM information & control systems • Refine ET and PIER process to encourage more rapid evaluation of emerging technologies	• Maintain coordination and collaboration process • Apply findings and insights to steer research agendas of collaborating parties	• Ongoing
1-2: Leverage private industry and federally funded technology research and investment	• Expand federal government R&D support for and integration with California's efforts • Create an investor-ET network to share market information, technology assessment results, and expedited access to incentive programs • Pilot incubator program to fast-track ET deployment • Expand upstream relationships and channels to effectively target and generate support for energy-related technology	• Improve and evolve enabling mechanisms. Continuous improvement, including lessons learned • Create mechanisms for enabling technology development and support to technology incubators, inventors at the development stage • Deploy statewide EE-based technology incubation process	• Continuous improvement, including lessons learned • Create mechanisms for enabling technology development and support to technology incubators, inventors at the development stage • Ongoing
1-3: Enhance market intelligence and behavioral research activities related to energy efficient technologies	• Develop road map to identify and prioritize consumer needs, behavioral drivers and decision processes • Develop and launch behavior and market research agenda • Integrate customer influences in emerging technologies project screening • Assess technology specific market potential using secondary market research to obtain technical and economic potential on new and emerging technologies and market segments	• Integrate research and 2009-2011 M&V studies for continuous improvement • Ongoing research on customer choices, acceptance, experiences with new technologies • Where secondary research is lacking, perform primary market research on specific applications and technologies	• Integrate research and 2012-2014 M&V studies for continuous improvement • Ongoing research on customer choices, acceptance, experiences with new technologies • Where secondary research is lacking, perform primary market research on specific applications and technologies

Implementation Plan and Timeline			
Strategies	**Near-Term**	**Mid-Term**	**Long Term**
1-4: Expand activities to create market pull for energy-efficient technologies	• Plan and launch knowledge management systems • Explore customer/manufacturer targeted strategies for creating pull	Continuous improvement of knowledge system, including lessons learned. Increase scope of reference material where needed	Continuous improvement of knowledge system, including lessons learned Increase scope of reference material where needed

Goal 2: Conduct targeted emerging technologies R&D to support the Big, Bold Energy Efficiency Strategies/Programmatic Initiatives and integrated energy solutions goals.

While Goal 1 calls for reshaping the overall focus and direction of ratepayer-funded energy efficiency R&D programs, in the near term, it is critical that work progress rapidly on specific areas to support the BBEES for Zero Net Energy buildings and hot-dry climate-appropriate HVAC technologies described in this Plan.

To stimulate major breakthroughs in support of BBEES there must be an intensive focus on the technologies, products, and practices driving the majority of building energy use, as well as integrated building design approaches and dynamic diagnostic and energy management control systems that take a holistic view of building design, delivery and operations.

A focus of Goal 2 will be on ZNE homes, commercial buildings, and HVAC technology performance best suited to California's climate. This approach must extend beyond equipment components and building systems to encompass whole building, integrated approaches. Initial work may call upon pilot efforts, to be followed later my larger scale market transformation strategies. One example of this type of pilot is a DOE-led effort at UC Merced, being executed by a team composed of LBNL, United Technologies Research Center, UC Berkeley, and UC Merced, directed at the identification and maturation of key technologies for integrated building operation. This effort aims to reduce energy demand by nearly 30 percent by using systems technologies for real-time energy performance diagnostics.

Goal 2: Targeted R&D

Implementation Plan and Timeline			
Strategies	**Near-Term**	**Mid-Term**	**Long Term**
2-1: Develop general R&D community support for support BBEES	Convene collaboration among researchers and their funders to ensure alignment of activities with big, bold focus areas for ZNE buildings and hot-dry climate HVAC technologies and systems	• Continue involvement and collaboration with R&D community, including input to ensure alignment	• Continue involvement and collaboration with R&D community, including input to ensure alignment

2-2: Promote cost-effective near-term performance enhancements of existing technologies	• Target building shell, HVAC, lighting and supporting areas, such as real-time energy performance monitoring and automated building commissioning technologies • Collaborate with manufacturers to improve performance of existing technologies • Develop specifications to drive / guide improvement activities. Provide technology feedback through ET assessments • Explore longer term strategies to increase saturation of new big and bold measures and technologies	• Target additional big, bold focus areas • Continuous improvement, including lessons learned • Continue collaborations with designers, builders, and manufacturers to bring more efficient technologies into the market	• Continue previous efforts with higher levels of attention to zero net energy residential goals • Continuous improvement, including lessons learned • Continue collaborations with manufacturers to bring more efficient technologies into the market
2-3: Develop initiatives aimed at PIER to support larger gains in support of BBEES	• Provide stakeholder input to ensure alignment of PIER activities with BBEES • Collaborate with PIER to develop a formal process to roll PIER developed technologies into ET	• Continue collaboration with PIER, including input to ensure alignment	• Continue collaboration with PIER, including input to ensure alignment
2-4: Develop initiatives aimed at ET to support BBEES	• Initiate upstream technology program activities, including whole building integrated solutions. • Embark on plan to demonstrate big bold measures in customer sites and seed the market • Conduct "pilot" programs of new technology seeding and market uptake through subsidies and incentives • Collaborate with manufacturers in new ambitious pilot programs, including full-scale demonstration programs to mature innovative system technologies	• Continue to drive efforts aimed at non-mainstream technologies. Improve and evolve upstream programs • Continue to collaborate with manufacturers in new ambitious pilot programs	• Continue to drive efforts aimed at non-mainstream technologies

12. LOCAL GOVERNMENTS

12.1 VISION

By 2020, California's local governments will be leaders in using energy efficiency to reduce energy use and global warming emissions both in their own facilities and throughout their communities.



12.2 PROFILE

California's 600-plus local governments are remarkably diverse—they range from the largest county in the United States to small towns; from busy agricultural centers to residential suburbs to world-renowned cities.[67] This diversity includes energy efficiency: California's local governments and their communities face different circumstances and have different constituencies, and are at different levels of commitment and capacity. Many of them, however, are paying significant attention to energy efficiency and climate change and are interested in doing what they can, as quickly as they can, and in collaboration with their residents, other local governments, state government, utilities and other key participants.

Local governments share a broad array of energy-related authorities and opportunities:

Regulatory Authority. Local governments have significant powers that can improve the energy efficiency of new and existing buildings. These include:

- Ensuring compliance and enforcement of the Title 24 energy code for residential and commercial buildings.
- Adopting building codes beyond Title 24's energy requirements (and potentially other "green" requirements).
- Supporting highly efficient projects that voluntarily exceed minimum energy codes through favorable fee structures, fast-tracked permitting and other innovative and locally appropriate approaches.
- Enacting ordinances with point-of-sale or other approaches that spur efficiency actions in existing privately owned buildings.
- Applying efficiency-related "carrots" and "sticks" using local zoning and development authority.

Energy Use for Government Facilities. Local governments can be significant energy end users in their own buildings and facilities, from public schools to wastewater treatment plants to City Hall. These facilities provide an opportunity to "lead by example" by improving energy efficiency, reducing CO_2 emissions, and cutting government energy bills. They can also use these facilities to showcase the products and practices that will become commonplace in a "zero net energy" world.

Energy Leadership in Local Communities. Local governments often can play an important role in influencing the energy attitudes and actions of their citizens and businesses. This can take on many forms, from public education to adopting innovative policies and initiatives to integrating actions addressing energy efficiency, climate change and sustainability.

The CPUC has long-recognized the unique role of local governments in fostering innovation. Almost ten years ago, the CPUC directed utilities to consider programs that take advantage of the unique expertise, relationships with customers, and ability to coordinate among related activities offered by individual or groups of local government.[68] So too have there been local governments leading innovation with efficiency on their own, as well as through their associations – the League of California Cities, California State Association of Counties, Local Government Commission. More recently the state Attorney General's Office has called upon local governments to use their CEQA[69] compliance responsibilities to address greenhouse gas impacts and mitigation strategies of local development policies. Energy efficiency policies and initiatives are among the options available to communities.

12.3 GOALS

Goals	Goal Results
1. Local governments lead adoption and implementation of "reach" codes stronger than Title 24, on both mandatory basis and voluntary bases.	At least 5% of California's local governments (representing at least 5% of CA total population) each year adopt "reach" codes. By 2020, the majority of local governments have adopted incentives or mandates to achieve above-code levels of energy efficiency (or DSM) in their communities, or have led statewide adoption of these higher codes.
2. Strong support from local governments for energy code compliance enforcement.	The current rate of non-compliance with codes and standards is halved by 2012, halved again by 2016, and there is full compliance by 2020.
3. Local governments lead by example with their own facilities and energy usage practices.	The energy usage footprint of local government buildings is 20percent below 2003 levels by 2015 and 20% below 1990 levels by 2020.
4. Local governments lead their communities with innovative programs for energy efficiency, sustainability and climate change.	By 2015, 50% of local governments have adopted energy efficiency/sustainability/climate change action plans for their communities and 100% by 2020, with implementation and tracking of achievements.
5. Local government energy efficiency expertise becomes widespread and typical.	By 2020, 100% of local governments have in-house capabilities devoted to achieving all cost-effective energy efficiency in their facilities and stimulating the same throughout the communities.

12.4 STRATEGIES

The three key strategies for local government action are:

1. **Tap Local Government Authority:** Use local government authority over planning and development policy to maximize energy efficiency in privately owned new construction and existing buildings.
2. **Lead by Example:** Showcase with local governments' facilities achieving economic energy efficiency, reducing CO_2 emissions, and showcasing promising energy efficiency, DSM and renewables products and practices.
3. **Community Leadership:** Local governments lead their communities to support clean energy goals.

There are five important associations of local governments that are key to these strategies: the California State Association of Counties (CSAC), League of California Cities (League), Local Governments for Sustainability (ICLEI), the Institute for Local Government (Institute), and the Local Government Commission (LGC). A task force should be formed consisting of leaders from each of these organizations, the CPUC, the Energy Commission, and utilities to develop and implement the strategies listed for Local Government listed in this Plan.

12.5 IMPLEMENTATION PLAN

Goal 1: Local governments are leaders in adopting and implementing "reach" codes.

Local governments can adopt building standards more stringent than state and federal mandates. As mentioned in the residential ZNE discussion above, over the past year both the City of San Francisco and the City of Los Angeles have adopted Green Building Ordinances for new buildings in the respective cities. However, with over 400 cites and counties in the state, relatively few local governments have adopted local ordinances that exceed Title 24 requirements. Much more can, and should, be done at the local level.

In addition, local governments can adopt "point of sale" requirements. For example, the City of Berkeley for over two decades has had residential and commercial building ordinances requiring basic efficiency improvements, triggered at the time of property sale or significant renovations. Sacramento and San Francisco have applied similar requirements at various times.

Several foundational activities will assist local governments in this effort:

- Development of model (mandatory) local government codes, ordinances and programs that local governments can modify as needed, adopt, and implement. These would include tiers of codes beyond Title 24 (see the Residential and Commercial Chapters.)
- Development of sample local ordinances for point-of-sale and other point-of-transaction energy efficiency requirements and building energy ratings that must be disclosed at these points. (This strategy may require additional legal authorization.)
- Development of sample local government programs to reward projects that voluntarily exceed state and local minimum energy codes by expedited permitting, entitlement approval processes, favorable fee structures, and other favorable actions for qualifying green buildings and developments.
- Focused and sustained outreach support for local governments to inform them about the model standards and ordinances and provide assistance in developing, adopting, and implementing "reach" standards.
- Networking tools to allow local governments on a peer-to-peer basis to share information and experiences on adopting and implementing "reach" standards and programs.
- Policies that support utility efforts to assist local government development and implementation of "reach" standards or point of sale ordinances.
- Leadership recognition of elected officials and local governments that adopt and implement "reach" standards and other programs.
- Linkage of emission reductions from "reach" standards and programs to CARB's AB 32 implementation strategies.

Goal 1: "Reach" Codes

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
1-1: Develop, adopt and implement model building energy codes (and/or other green codes) more stringent than Title 24's requirements, on both a mandatory and voluntary basis; adopt one or two additional tiers of increasing stringency	• Develop model codes and tiers in conjunction with existing energy and green building rating systems • Gain consensus of leading designers and builders on "reach" levels • Launch statewide campaign for adoption	• Expand percent of cities and counties adopting codes; monitor effectiveness and upgrade model codes	• Expand to statewide program
1-2: Establish expedited permitting and entitlement approval processes, fee structures and other incentives for green buildings and other above-code developments	• Develop sample programs • Enact needed local laws • Put implementing processes, fee structures, and other incentives in place statewide by 12/2011	• Ongoing improvement and refinement	• Ongoing improvement and refinement
1-3: Develop, adopt and implement model point-of-sale and other point-of transactions relying on building ratings to increase efficiency in existing buildings	• Develop model codes and programs in 2009 • Launch pilot programs in 2010	• Implement statewide building energy ratings disclosure system by 6/2012	• Implement requirements beyond disclosure, such as ratings and/or energy upgrades at sale of properties by 1/2013
1-4: Create assessment districts or other mechanisms so property owners can fund EE through local bonds and pay back on property taxes; develop other local EE financing tools	• Develop model mechanisms for funding sources • Establish model loan mechanisms • Launch in pilot cities	• Expand percent of cities and counties adopting local financing mechanisms	• Expand statewide
1-5: Develop broad education program and peer-to-peer support to local govt's to adopt and implement model "reach" codes and/or point of sale policies	• Fund statewide energy efficiency liaison to local gov't associations • Develop information campaign on mechanics and benefits of model programs, targeting local gov't decision-makers and community leaders • Establish leadership recognition programs	• Expand content and geographical reach of information campaign	• Ongoing

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
1-6: Link emission reductions from "reach" codes and similar programs to CARB's AB 32 program and to local gov't CEQA responsibilities	• CARB adopts regulation providing local gov't emission reduction credit for "reach" standards • State Attorney General and Office of Planning & Research provide guidance on using CEQA authority to target energy and GHG savings in LG development authority	• Identify best practices and incorporate into local programs and policies	• Ongoing
1-7: Develop energy efficiency-related "carrots" and "sticks" using local zoning and development authority	• Plan approaches by 12/2009. Launch approaches by 12/2010 • Approach in place by 6/2009. Requirement in place by 12/2010	• Ongoing refinement of approaches based on feedback from implementation efforts	• Ongoing implementation

Goal 2: Strong support from local governments for energy code compliance enforcement.

Under state law, local governments, through their building permit and inspection processes, are responsible for enforcement of Titles 20 and 24. While there is inadequate understanding of code compliance rates and the resulting degradation in performance, more than 30 percent of the technical energy savings from California's statewide energy codes may be lost due to non-compliance. A 2007 study estimated noncompliance rates with the Energy Commission statewide building measures ranging from 28 to 100percent and with appliances standards from 0percent to 63 percent.[70]

Generally, the lack of financial resources (e.g., funds to send an inspector to training) is a barrier to enforcement. Inspections and enforcement are funded through local permit fees. However, local governments are often reluctant to raise fees to cover full costs of standards compliance if those fee levels would rise above neighboring jurisdictions.

A comprehensive, adequately funded statewide program for state building code compliance that strongly supports local government compliance responsibilities is key to obtaining full savings from California's aggressive building and appliance standards.

Goal 2: Code Compliance

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2-1: Statewide assessment of local government code enforcement and recommendations for change	• Develop and conduct assessment; develop set of recommended improvements (e.g. via compliance tools, information, training, modified standards, and/or funding)	• Ongoing	• Ongoing

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
2-2: Dramatically improve compliance with and enforcement of Title 24, including HVAC permitting and inspection requirements (including focus on peak load reductions in inland areas)	• Develop strategies • Test pilot programs in 2010 • Put initial improvements in place statewide by 12/2010	• Expand statewide • Strengthen compliance solutions	• Ongoing
2-3: Local inspectors and contractors hired by local governments shall meet the requirements of the energy component of their professional licensing (as such energy components are adopted)	• Update and/or incorporate energy components in licensing requirements • Adopt requirements	• Ongoing	• Ongoing

Goal 3: Local governments lead by example with their own facilities and energy usage practices.

Cities and counties can lead by example by embracing energy efficiency in their facilities. There are many examples of local governments undertaking major actions to reduce energy usage in their own facilities. Examples of specific goals that local governments can set for their buildings include:

- Requiring all local government owned and leased buildings to be benchmarked, sub-metered, commissioned by 2012, and upgraded to the next level of energy efficiency by 2015.
- Requiring LEED Certified and LEED Silver (or their equivalents) for all new local government facilities.
- Requiring LEED Existing Building Silver for existing facilities, by a specified date.
- Achieving all cost-effective or economic energy efficiency in their facilities (e.g. 20-40percent efficiency gains), by a specified date.
- Requiring commissioning for new buildings, and re-commissioning and retro-commissioning of existing buildings.

A sustained, comprehensive effort to extend these efforts statewide should be undertaken. In order to accomplish this goal, providing local government facility personnel with additional staff, expert assistance and/or technical resources is needed.

Goal 3: Lead by Example

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
3-1: Adopt specific goals for efficiency of local new and existing government buildings	• Showcase innovative EE and other DSM relevant to achieving ZNE buildings • Implement local policies for LEED new construction and existing buildings	• Complete benchmarking and LEED policy implementation • Launch statewide program	• Implement statewide
3-2: Require commissioning for new buildings, and re-commissioning and retro-commissioning of existing buildings	• Benchmark existing buildings against ratings such as Energy Star and its Portfolio Manager • Test commissioning programs on selected high-use buildings • Adopt mandatory benchmarking and commissioning requirements for local government facilities statewide by 12/2011	• Ongoing refinement and improvement	• Ongoing
3-3: Improve access to favorable financing terms that create positive cash flow from energy efficiency/DSM savings	• Identify various financing tools available to local governments. (e.g. such as expanding the Energy Commission's loan fund, seeking federal or state support for lower interest rate loans, third-party financing, and utility on-bill financing • Modify as appropriate to increase utilization	• Ongoing implementation	• Ongoing

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
3-4: Promote local gov't adoption of policies for a budget line item fir energy management or other options that allow energy efficiency cost savings to be returned to the host facility or department and/or as a revolving fund for additional energy projects	• Explore and document model policies and mechanisms complete by 12/2009 • Implementation plan in place by 6/2010 for mechanisms warranted	• Ongoing implementation	• Ongoing
3-5: Develop an innovation incubator that competitively selects energy design, technology, and system initiatives for local government pilot projects	• Coordinate this approach with Research & Technology activities • Develop and begin first projects by 12/2009	• Ongoing refinement and expansion	• Ongoing

Goal 4: Local governments lead their communities with innovative programs for energy efficiency, sustainability, and climate change.

Local governments are in a unique position to implement innovative, long-term, cross-cutting programs promoting energy efficiency, sustainability, and reduced carbon emissions. Their ability to interact with businesses and residents to work towards integrated sustainable communities is unique and needs to be engaged far beyond current efforts, to support California's aggressive energy efficiency and global warming goals.

There are various resources available to aid local governments. Non-profit associations, for-profits, state agencies, utilities and others can give technical assistance; offer targeted online and written tools; and share an over-arching vision and best practices in conferences and workshops. One example of an innovative local government initiative is the Cambridge Energy Alliance effort in Cambridge, MA. The Alliance is a city-sponsored non-profit group established to identify and arrange financing for unprecedented levels of gas, electricity and water savings by retrofitting buildings and installing renewable technologies across the community.[71] Another effort is California Sustainable Communities Initiative sponsored by the Department of Conservation (DOC) which seeks to expand the DOC's recycling experience with local governments into a more comprehensive statewide initiative that promotes innovative and coordinated programs for energy efficiency, sustainability, and climate change at the local level, using public-private partnerships.

Additionally, local governments can and do commit themselves and/or their communities to externally developed relevant commitments, such as the United Nation's Urban Environmental Accord or the Local Governments for Sustainability (ICLEI) Cities for Climate Protection campaign.

Local governments also have a number of regulatory carrots and sticks including: community design requirements; land use and zoning policies that promote energy efficiency and smart growth; requiring redevelopment agencies to address energy efficiency in development contracts, and; negotiating energy efficiency into developer agreements on major projects.

Recent legislation in CA has increased the role of local government in facilitating efficiency investments and ensuring sustainable planning. AB 811 (Levine, 2008) authorizes cities to provide low-interest loans to property owners with long-term repayments added to their annual property tax bills to help finance energy efficiency improvements and distributed

generation installations.[72] Similarly, SB 375 (Steinberg, 2008) requires metropolitan planning organizations to include "sustainable communities strategies" in their regional transportation plans and creates specified incentives for the implementation of such sustainable communities strategies.[73]

The success of this goal will require not only resources from the state, utilities, non-profits and the business community but the commitment of local governments and their leaders to use their leadership and legal authority in new and often challenging ways. A necessary step is to support organizations serving local governments at the state level (e.g., League of California Cities; California State Association of Counties; Institute for Local Government), regional levels (e.g., Association of Bay Area Governments, Association of Monterrey Bay Area Governments, San Diego Association of Governments, Southern California Association of Governments), and non-profits so they can leverage their activities with other local governments on energy and environmental issues. This includes: creating a statewide liaison resource by local government focused on energy efficiency programs; enhanced and expanded technical assistance; targeted online tools; information on best practices; and conference and workshop activities

.

Goal 4: Community Leadership

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Mid Term 2012 – 2015**	**Long Term 2016 – 2020**
4-1: Local governments commit to clean energy/climate change leadership	• Assist initial set of local governments in commitments; develop and communicate appropriate messages	• Expand local government participation statewide	• Ongoing implementation
4-2: Use local governments' general plan to promote energy efficiency, sustainability and climate change	• Develop model General Plan amendments • Leaders among local governments adopt policies in General Plan elements • Publicize to other local governments	• Expand inclusion in general plans. By 2015, inclusion in all local gov't plans	• Ongoing implementation
4-3: Statewide liaison to assist local governments in energy efficiency, sustainability, and climate change programs	• Provide energy efficiency liaison funded via IOU ratepayer funds. • Provide climate change liaison as part of ARB AB32 activities	• Ongoing implementation	• Ongoing implementation
4-4: Develop local projects that integrate energy efficiency, DSM, and water/wastewater end uses	• Identify opportunities and challenges for more energy/environmentally integrated development and infrastructure • Develop and implement pilot projects, such as the California Sustainable Communities Initiative	• Expand implementation	• Ongoing implementation

Goal 5: Local government energy efficiency expertise becomes widespread and typical.

Many local governments do not have adequate dedicated staff or resources to move proactively on energy efficiency in their own or community buildings. They also often lack capacity or awareness to promote building and zoning codes that would dramatically accelerate green, efficient buildings within their jurisdictions.

The workforce education and training strategies outlined elsewhere in this Plan are one vehicle for attacking these issues. Another is the standardization of tiered voluntary building codes across the state (as described in Strategy 1) which will be easier for local governments to embrace and promote than if codes are developed independently each time.

Even so, a focused effort on development of local government energy efficiency expertise is critical to the state's energy efficiency goals. Programs such as the regional technical assistance and education centers in Marin, Ventura, and Humboldt that work with local governments, schools, and special districts in their areas, are an example of effective training programs.

Goal 5: Local Government Energy Efficiency Expertise

Implementation Plan and Timeline			
Strategies	**Near Term 2009 – 2011**	**Short Term 2012 – 2015**	**Long Term 2016 – 2020**
5-1: Create a menu of products, services, approved technologies and implementation channels to guide local governments that currently lack deep expertise in energy efficiency	• Identify menu by 9/2009 • Plan for provision of menu in place by 12/2009 • Begin to provide menu content by 3/2010	• Ongoing implementation	• Ongoing implementation
5-2: Develop model approaches to assist local governments participating in regional coordinated efforts for energy efficiency, DSM, renewables, green buildings, and zoning	• Complete model approaches (e.g. joint powers authorities, memoranda of understanding, regional councils) by 2009 • Leader governments begin pilots. • Communicate information on a peer-to-peer basis	• Expand outreach on benefits of regional approaches to wider range of local governments • Identify funding sources to support wider utilization	• Ongoing implementation
5-3: Establish a statewide effort to facilitate peer-to-peer learning, such as a "local champions" program or a governor's invitation-only local government leaders' summit	• Identify the most suitable peer-to-peer learning vehicle by 6/2009. • Launch peer-to-peer learning vehicle by 12/2009	• Ongoing refinement and improvement	• Ongoing implementation
5-4: Create a statewide technical assistance program for local governments, including peer-to-peer expertise exchange	• Develop program in 2009	• Implement statewide in 2010	• Ongoing implementation

13. LIGHTING

13.1 VISION

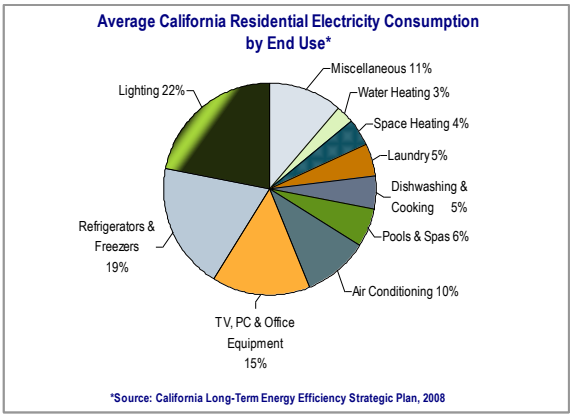
By 2020, advanced products and best practices will transform the California lighting market. This transformation will achieve a 60-80 percent reduction in statewide electrical lighting energy consumption by delivering advanced lighting systems to all buildings.

13.2 PROFILE

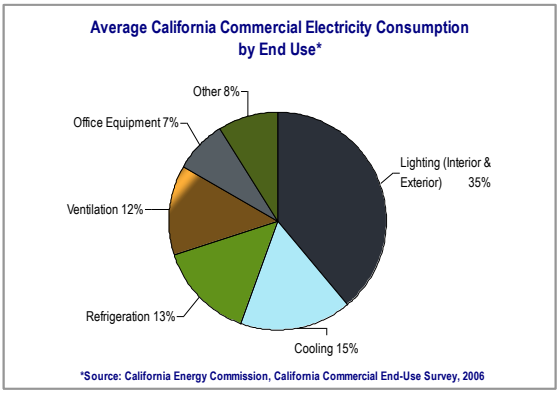
Lighting comprises approximately one-fourth of California's electricity use;[74] therefore, the widespread use of energy efficient lighting is a critical element in the Strategic Plan. California's AB 1109 (known as "the Huffman Bill"*) will phase-out traditional, low efficiency incandescent lamps by 2018 and help advance the Strategic Plan's goals. However, supporting strategies and implementation activities are needed to achieve the higher goal of a 60 to 80 percent reduction in energy usage for lighting.

Each goal in this chapter has elements relevant to three market sectors: residential, nonresidential and exterior lighting.

Residential. Lighting comprises 22 percent of electricity use in the average California home (see figure).[75] With more than 11 million homes and 500 million light sockets in California, there is substantial potential for energy savings and peak demand reduction.[76] For example, incandescent lamps in the 10-15 lumens per watt range are the predominant technology in residential applications. Switching all residential sector lighting to technologies using 40 lumens per watt would achieve a 50 percent reduction in energy use.[77]



Non-Residential. Nonresidential lighting covers a wide range of applications including task lights on office desks and overhead lighting in industrial warehouses.[78] In the commercial sector, lighting accounts for approximately 35 percent of electricity use (see figure below).



California has 1 billion square feet of commercial office space, most of which was built prior to the state's Title 24* regulations. Installing existing best practice* lighting retrofits in these applications (instead of simple ballast and lamp

* See Glossary at end of document for definitions of terms with asterisk.

replacements) will yield substantial savings[79] and can enhance worker productivity by improving the visual environment. Products for office task ambient lighting systems can save 40-60 percent over current practices — approximately twice the energy, peak demand and CO_2 emissions compared to current Title 24 codes of 0.9 watts per square foot.[80]

Exterior. Exterior lighting includes parking lot, area, walkway and security lighting. In the nonresidential sector, exterior lighting usage comprises 1.4 percent of California's total electricity use, much of which occurs during limited occupancy periods.[81] Through a combination of sensors, occupancy controls and other technologies, end users can save money by reducing energy usage by more than 50 percent.[82] Such retrofits are one of many relatively untapped opportunities to reduce lighting energy demand and deliver identical or improved service.[83]

Commercial office spaces typically rely on a standard practice lighting design approach known as "general lighting," where ceiling-mounted lights supply uniform lighting levels for an entire office interior. This approach results in wasted energy, increased cooling costs and sub-par lighting for human performance. Best practices include a high performance task lighting retrofit in worker specific areas, reducing lighting energy use and increasing the quality of light in the office space.*

Substantial reductions in lighting energy demand are contingent upon successfully addressing or navigating around barriers within the lighting market. These impediments include:

- **Policy Barriers** that conflict with the accelerated adoption of best practice lighting technologies and systems required to meet the state's ZNE goals;
- **Lack of knowledge** regarding best practice lighting technologies among specifiers, installers and other lighting professionals;
- **Proprietary protocols** that can limit innovation and interoperability of lighting systems and integration with other building and network systems;
- **Lack of retailer and consumer awareness** about lighting's invisible benefits, such as contributions to human performance, well-being and energy and cost savings;
- **Cost** constraints, including the challenge of encouraging end users to purchase and install best practice lighting technologies and systems;
- **Gaps in the Research, Development and Demonstration (RD&D)* infrastructure** that cause redundancies and unnecessary delays in rapid deployment of best practice technologies to the market.

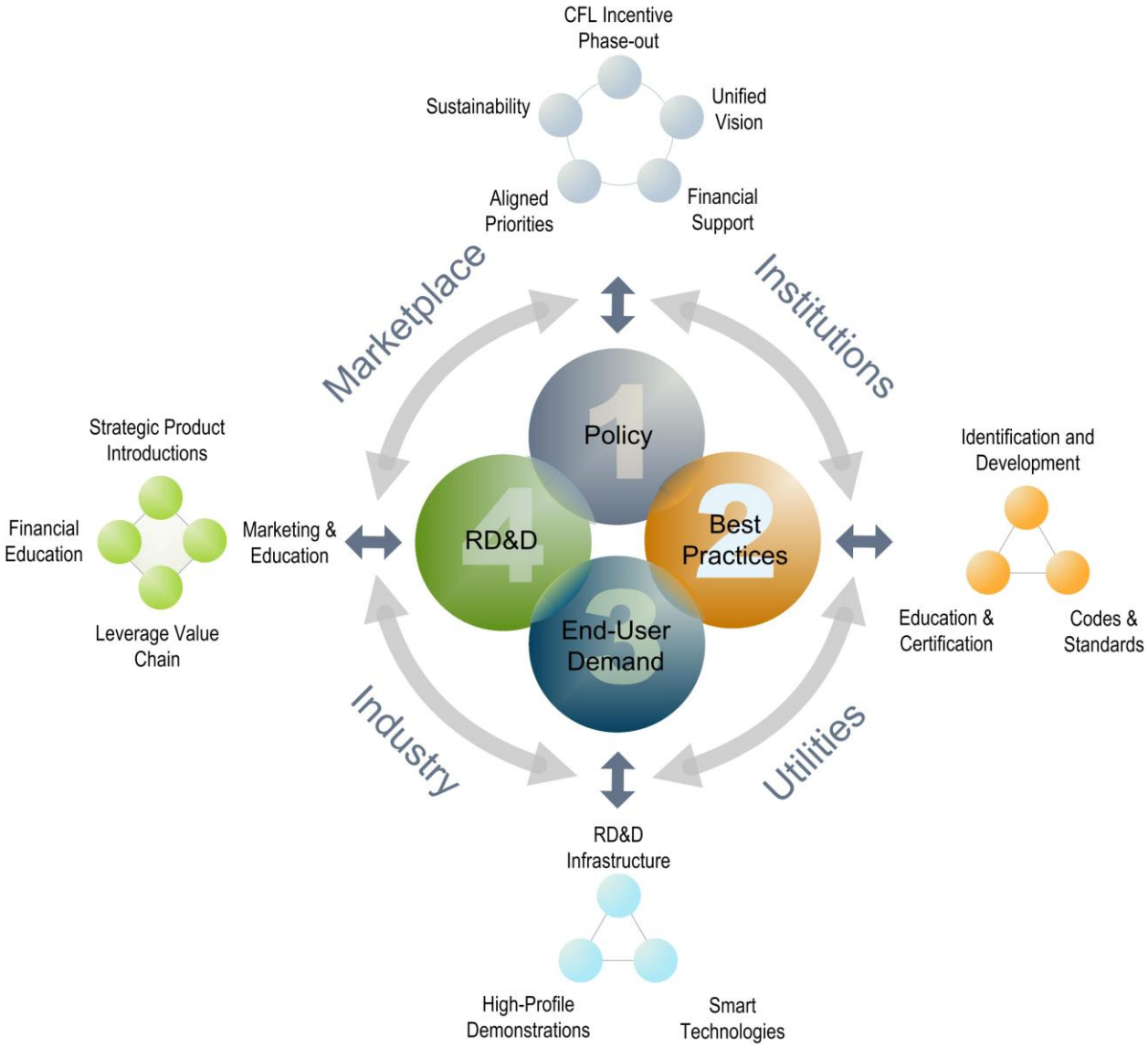
13.3 GOALS

Goal	Goal Result
1. Develop and implement coordinated policies, procedures, and other market interventions that eliminate barriers, accelerate lighting market transformation* in California and provide incentives for best practice lighting technologies and systems.	By 2020, existing policies and procedures in California will enable lighting technologies to contribute to zero net energy (ZNE)* consumption with negligible negative impacts on the environment.
2. Define and advance best practices for design, installation, operation and maintenance of integrated systems* to achieve sustainable* lighting solutions for all spaces.	By 2020, 100percent of new and retrofit lighting installations will meet best practices. End users will receive education and training to maintain optimal performance of installations throughout their useful lives.
3. Create widespread end user demand to purchase and use best practice lighting technologies and systems.	By 2020, transform consumers' lighting preferences to best practices as demonstrated by an 80% decrease in perceived barriers to adoption and a 50% decrease in sales of inefficient lighting products in key market segments (over 2010 baselines).
4. Develop research, development and demonstration (RD&D) networks to create, test, and deliver the lighting solutions needed to transform California's lighting market achieve ZNE goals.	Create a broad RD&D portfolio of technologies that will support a 60-80% statewide reduction in electrical lighting energy consumption by 2020.

The goals described in this chapter envision defining, creating, testing and delivering advanced lighting products and best practices to an educated pool of end users in a supportive policy environment. Best practices are defined as coordinated technologies, systems and design approaches that typically provide savings of 25-50 percent over standard practices while avoiding negative environmental impacts. Best practices may change over time as improved components, technologies and design approaches become available. The four goals in this chapter together provide the foundational support for best practices to make them the default lighting choice for California end users.

In California, lighting technology, design and installation is regulated primarily by the California Energy Commission's (CEC) Title 20* and Title 24 appliance and building codes (as well as by the federal Energy Policy Act*). Such command and control measures — including local government reach codes* — can advance lighting market transformation but cannot achieve the goals without interventions that bring advanced lighting technologies and best practices to the marketplace and support rapid adoption by end users.

As shown in the figure below, this chapter sets forth a comprehensive strategy to bring together all aspects of the lighting market in California: public policy and regulations, building designers, owners, managers and occupants, consumers and technology developers. This chapter will set the market on the path to achieve the targeted 60-80 percent reduction in statewide lighting electrical use thereby furthering the goal of ZNE buildings in California.



The figure above represents the interconnectedness of the four lighting goals. To achieve the vision for a transformed lighting market in California, all four goals have to work in synergy to continuously define, create, test and deliver advanced lighting products and best practices to an educated pool of end users in a supportive policy environment.

13.4 STRATEGIES

California can achieve a 60-80 percent reduction in statewide lighting energy use by 2020. The Huffman Bill requires California to "reduce average statewide electrical energy consumption by not less than 50 percent from the 2007 levels for indoor residential lighting and not less than 25 percent from the 2007 levels for indoor commercial and outdoor lighting by 2018." This critical piece of legislation will move California toward its goals but will not achieve the 60-80 percent reduction in lighting energy consumption necessary to truly transform the lighting market.

Advanced lighting technologies* and design solutions – such as integrated controls,

daylighting* and task/ambient lighting systems – can deliver the additional savings necessary to achieve this transformation.[84, 85] This will require shifting incentives to encourage best practices, enhancing coordination among regulatory agencies and creating more effective financing mechanisms for lighting retrofits.

To effect rapid change in California's lighting market, numerous stakeholders — beyond the CPUC and IOUs — will need to participate actively and collaborate effectively. With a vast array of players involved in the lighting market — such as the CEC's Public Interest Energy Research (PIER) Program*, manufacturers, distributors, retailers, Title 24 consultants, specifiers and contractors, lighting designers, architects, environmental groups, construction companies, building engineers, industry and professional groups, utilities, local building officials, building owners/managers, consumers and local, state and federal government agencies — it is essential that the industry's leaders continue their involvement past the development of these goals and strategies and help implement the actions needed for the next 10 years and that new leaders continue to become engaged as the process moves forward.

IMPLEMENTATION PLAN

Goal 1: Develop and implement coordinated policies, procedures, and other market interventions that eliminate barriers, accelerate lighting market transformation in California and provide incentives for best practice lighting technologies and systems.

There are many untapped lighting efficiency opportunities that could yield significant energy savings in California if comprehensive and innovative policies are implemented. Policy can both directly and indirectly affect availability and the use of best practice technologies. California's major policy-making institutions — including the CPUC, CEC, Air Resources Board (ARB)* and local governments* — must commit to integrated policies that transform California's lighting market away from standard practices to best practices at a rapid pace.

To date, the majority of the utilities' lighting programs have focused on widget swap-out strategies (such as replacing incandescent lamps with CFLs). With the new state and federal lighting standards, utility programs promoting basic CFLs will provide little incremental benefit.[86] Future efforts in lighting, including ratepayer funded programs, should focus on systems-based opportunities that achieve savings beyond standards. This may require reexamining the CPUC's current 3-year funding cycle to potentially allow longer-term funding and targets.

California's key regulatory agencies must coordinate on intermediate steps toward lighting market transformation and ZNE policies and for improvements to codes and standards. In addition, by creating economies of scale and emphasizing lighting in the state's ongoing greening efforts, governments at the state, regional and local levels can help reduce initial market barriers through leadership by example.

To transform the market, policymakers must help end users afford or finance best practice lighting solutions. Additional financial mechanisms to address market barriers must also be created to spur adoption. Related solutions — such as incorporating third-party funding into large scale on-bill financing programs and advancing statewide participation in AB 811*-authorized financing mechanisms - could enable a broader base of Californians to purchase and install best practice lighting technologies. California should examine ways to align incentives such that lighting efficiency is maximized prior to awarding incentives for onsite generation (e.g., California Solar Initiative).

Policies should be developed to ensure that best practice lighting systems avoid unintended negative environmental consequences by minimizing the ecological impacts of each technology throughout its lifecycle — from design through disposal. California must support a comprehensive view of energy efficient lighting systems that includes not only their energy savings and financial implications but also their environmental costs.

The strategies to achieve this goal include:

- **Aligned Priorities**: Match public policy and utility energy efficiency program priorities to statewide lighting goals.
- **Unified Vision:** Build a common vision among key state regulators and align codes and standards to advance California's lighting market transformation.
- **Financial Support:** Create financial incentives and supportive policies to avoid trapped lighting energy savings opportunities.
- **Sustainability**: Minimize environmental impacts of each lighting technology throughout its lifecycle (production, use and disposal).
- **Basic CFL Incentive Phase-out**: Prepare suppliers for a shift in program incentives away from CFLs and toward the next generation of high efficiency lighting.

Goal 1: Policy for Transformation

Implementation Plan and Timeline			
Strategies	**Near Term 2010 – 2012**	**Mid Term 2013 – 2015**	**Long Term 2016 – 2020**
1-1: Match state laws, policy and regulations with utility energy efficiency program priorities and statewide lighting goals	• Explore implications of current cost/benefit methodologies on IOUs' ability to incorporate advanced lighting products into their programs • Explore implications of IOU program cycles on ability to reach lighting goals • Monitor lighting legislation, regulations and industry developments with the aim of incorporating additional lighting technologies and best practices into the next utility program cycle (including residential low-income) • Design and test innovative program delivery strategies to accelerate market transformation • Incorporate 2010-2012 EM&V results into policies and programs for future EE program cycles	• Adjust methods as appropriate • Adjust cycles as appropriate • Continue monitoring legislation, regulations and industry developments; incorporate new technologies and best practices into the next utility program cycle • Incorporate cost-effective pilot programs from prior program period into core programs; continue pilot projects • Ongoing	• Adjust methods as appropriate • Adjust cycles as appropriate • Ongoing • Incorporate cost-effective pilot programs from prior program period into core programs; continue pilots • Ongoing

Implementation Plan and Timeline			
Strategies	**Near Term 2010 – 2012**	**Mid Term 2013 – 2015**	**Long Term 2016 – 2020**
1-2: Build a common vision for advancing lighting market transformation among key state agencies	• Engage statewide institutional stakeholders in collaborative efforts to agree on steps toward lighting market transformation and ZNE goals • Align lighting-related codes & standards, green building rating systems and industry norms and practices with ZNE policy • Develop standards for all public buildings to encourage leadership by example in support of ZNE goals	• Review and revise steps as needed • Identify and resolve next priorities • Implement ZNE standards in public buildings	• Review and revise steps as needed • Identify and resolve next priorities • Ongoing
1-3: Create financial incentives and supportive policies to avoid trapped lighting energy savings opportunities and make best practice lighting solutions affordable	• Identify and implement creative financing mechanisms, including those that reduce barriers to lifecycle investment strategies • Identify and eliminate barriers to on-bill financing and incorporate third-party financing into IOU program offerings • Target statewide participation in AB 811-authorized financing mechanisms (such as Property Assessed Clean Energy* [PACE] bonds) • Advocate to raise percentage above T24 (including lighting) required to receive funding from California Solar Initiative (CSI) to 30% • Increasingly integrate funding for demand response*, energy efficiency and renewable energy projects	• Increase the adoption rate of lifecycle investment strategies • Expand on-bill financing program • Ongoing • Advocate for 60% above T24 to obtain CSI incentives • Ongoing	• Increase the adoption rate of lifecycle investment strategies • Expand on-bill financing program • Ongoing • Advocate for 90% above T24 to obtain CSI incentives • Ongoing

Implementation Plan and Timeline			
Strategies	**Near Term 2010 – 2012**	**Mid Term 2013 – 2015**	**Long Term 2016 – 2020**
1-4: Minimize environmental impacts of each lighting technology throughout its lifecycle (production, use and disposal).	• Allocate RD&D funding to increase sustainability of best practice lighting systems and determine long range funding needs • Develop cost-effective, convenient methods to collect and recycle any end of life lamps and test as pilot programs • Establish hazardous materials content specifications for all lighting products in IOU programs • Develop and implement voluntary manufacturing and labeling standards that include sustainability indices • Incorporate measurement of avoided GHG emissions along with kW/kWh into EM&V activities/reports to encourage deeper energy savings	• Develop and implement funding plan • Continue successful recycling programs • Implement specifications • Develop and implement additional standards and continue recruiting manufacturers to participate • Refine and continue GHG efforts	• Expand funding, based on results of prior cycles • Ongoing • Ongoing • Continue implementing standards and recruiting lighting manufacturers to participate in standards • Refine and continue GHG efforts
1-5: Coordinate phase out of Utility incentives for purchase of CFLs.	• Ensure that big box and home improvement retailers such as Wal-Mart and Home Depot are ready to stock Energy star price discounted CFLs in CA as IOUs phase out CFL programs • Utilities engage in negotiations with manufacturers and retailers to buy-down prices and stock the next generation of high efficiency lighting	• Ongoing	• Complete

Goal 2: Define and advance best practices for design, installation, operation and maintenance of integrated systems to achieve sustainable lighting solutions for all spaces.

Whole building design is a key element of the Strategic Plan, and best practice lighting systems are a foundational component of whole building design strategy. Best practice lighting technologies, systems and solutions must become standard practice.

Sample Best Practices in Lighting (2010)

- *Task/Ambient Lighting with Controls in Commercial Offices*
- *Integrated Classroom Lighting Systems*
- *Interior Electronic High-Intensity Discharge (HID) lamps and ballasts*
- *Light-Emitting Diode (LED) Downlights for Residential Buildings*
- *Light-Emitting Diode (LED) Downlights for Commercial Buildings*
- *Smart Bi-level Exterior Lighting*

It is the nature of best practices to evolve; best practice lighting must be defined, updated frequently and promulgated to achieve the largest energy savings possible.[†] Identifying successive generations of lighting best practices must be part of RD&D efforts and pilot projects. These technologies and systems should be demonstrated and pilot tested, and post-occupancy data should be collected to optimize performance and improve energy savings estimates and ensure consumer acceptance. Incentives should be provided to California's major lighting end users should be to encourage benchmarking of energy lighting use over time to enable quantification and tracking of lifecycle impacts of these enhanced codes and building performance improvements.

Best practices should then be incorporated into utility programs and into pattern books* to assist lighting professionals in improving the quality and efficiency of lighting statewide.

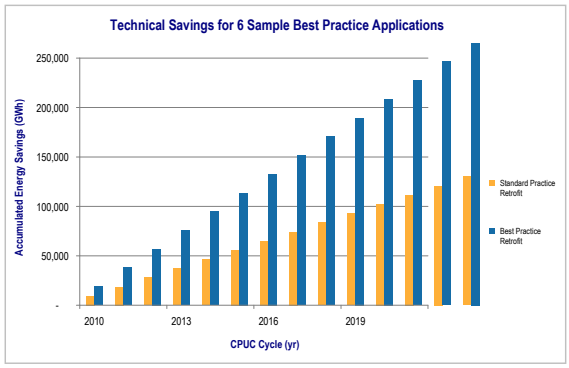
Lighting professionals must be trained and certified in the proper specification, installation and maintenance of the most up-to-date best practice technologies and systems. Certified lighting professionals must become the norm; contractors and electricians must be encouraged to obtain lighting certifications, trained to integrate efficient technologies and designs into lighting systems for both new construction and retrofit applications, and rewarded for doing so.

End users must be educated regarding the long-term benefits of best practice technologies to move the market away from decisions based upon first cost* and simple payback* (the amount of money spent on purchase/installation and amount of time to recover those costs) and toward lifecycle cost* assessments.

In parallel, best practices must also be incorporated into building codes and standards to ensure their widespread adoption. The current multi-year cycle for updating California's building codes (including Title 20 and Title 24) is too slow to enable the ongoing and rapid adoption of advanced lighting technologies and systems into code. The current process for changing these codes should be examined to identify opportunities to streamline and integrate best solutions on an ongoing basis.

Strategies to achieve best practices must be tailored to major space types and customer segments. For example, low-income customers in particular have cost constraints that may place some advanced technologies and best practices out of reach. While these customers may not be on the leading edge of market transformation, strategies must be developed to make advanced technologies and best practices available to all market segments -- and continually move the market forward.

[†] As will be discussed under Goal 4 (RD&D), the CPUC will convene an advisory body to coordinate research and related activities with stakeholders. This body will define best practices for lighting and update these definitions annually as lighting technologies and systems evolve.



This figure illustrates the technical potential energy savings achievable through the pursuit of six example best practices for lighting. The difference between the bars represents the "lost opportunity" inherent in the pursuit of standard practices in lighting efficiency. See Appendix A for the savings assumptions underlying these analyses.

The key strategies to identifying, promoting and ensuring best practices include:

- **Identification and Development:** Identify best practices and continually update in coordination with lighting market transformation activities.
- **Education and Certification:** Elevate the level of professional practice and performance by expanding access to high-quality new and existing education, training and certification programs.
- **Codes and Standards:** Include lighting system design improvements in codes and standards and local government reach codes.

Goal 2: Lighting Best Practices

Implementation Plan and Timeline			
Strategies	**Near Term 2010 – 2012**	**Mid Term 2013-2015**	**Long Term 2016 – 2020**
2-1: Identify best practices in coordination with RD&D and lighting market transformation programs to ensure use of high-performance lighting systems	• Identify top best practices for major space types and customer segments (including residential low income); achieve 50% of the potential savings identified • Develop online pattern books for market segments that represent at least 60% of the total lighting use • Develop pilot projects that support best practices • Initiate post-occupancy evaluation of 5% of permitted and/or incentivized lighting installations • Integrate best practices with core utility programs and ensure use in at least 50% of new projects • Incorporate open source lighting communications protocols into best practices, incentives and codes • Establish integration protocols for lighting systems with all building systems, smart grid, monitoring and commissioning systems used in the public sector	• Achieve at least 80% of the savings potential by switching to best practices • Add pattern books to cover at least 85% of total lighting use • Ongoing • Adjust the percent surveyed, based on 2010-2012 results • Ensure best practices are used in at least 80% of new projects • Include protocols for smart grid and building systems for lighting • Extend integration to 50% of private sector	• Achieve 95%+ of the potential savings identified by switching to best practices • Add pattern books to cover at least 95% of total lighting use • Ongoing • Confirm monitoring capability built into lighting systems • Ensure best practices are used in 95% of new projects • Include protocols for zero net energy systems for lighting integration • Extend integration to 100% of private sector
2-2: Elevate the level of professional practice and performance for designers, architectural consultants, electrical contractors, engineers and other lighting professionals.	• Develop specifications for 2020 lighting best practices by market sector for highest end-uses in coordination w/RD&D • Educate and train lighting professionals on evolving best practices and how best to explain their benefits to end users • Require Lighting Certification for designers and contractors who implement public agency installations/retrofits; encourage 30% of private sector projects to require certification • Ensure understanding and application of lighting system integration protocols among lighting professionals	• Expand 2020 specifications to 50% of all markets • Ongoing • Expand system to 50% of private sector projects • Ongoing	• Expand 2020 specifications to 100% of all markets • Ongoing • Expand system to 100% of private sector projects • Ongoing

Implementation Plan and Timeline			
Strategies	**Near Term 2010 – 2012**	**Mid Term 2013-2015**	**Long Term 2016 – 2020**
2-3: Continuously promote lighting system design improvements to codes and standards based on the best available field data and studies	• Explore opportunities to enhance and accelerate process for integrating best practices into codes (T20 and T24) and code enforcement • Develop an integrated benchmarking process that enables accounting of lighting savings and encourage 50% of California's major lighting end users to benchmark • Create a standard lifecycle evaluation for lighting impacts, including savings calculation template with kW; kWh, Therms, CO_2 and funding source	• Enhance process for integrating best practices into codes (including enforcement) • Optimize the integrated process to cover 80% of major markets • Ongoing	• Continue process for integrating best practices into codes (including enforcement) • Optimize integrated process for 100% of all markets • Ongoing

Goal 3: Create widespread end user demand to purchase and use best practice lighting technologies and systems.

Understanding the end user — e.g., CEOs, facility managers, individuals and apartment managers — is a prerequisite for effective product development and adoption of lighting best practices.

Influencing complex human choices (including product selection and use) for lighting is a significant challenge and cannot be accomplished simply by offering a better product. Recent studies published by the CPUC conclude that awareness of energy savings benefits alone does not lead to changes in attitudes, beliefs, habits and/or practices.[87] Barriers (perceived or actual) have an equal impact on adoption of energy efficient activity.

California has some successful lighting market transformation experiences. For example, in the commercial sector, a combination of codes and standards, education and aggressive utility program promotions reduced new construction office lighting power density by 70 percent between 1973 and 2005 (from 4 watts to 1.2 watts per square foot).[88] In the residential market, CFLs have achieved saturation in approximately 20 percent of sockets.[89]

The general public must be treated as a partner in lighting market transformation; consumers must understand, purchase, install and properly use energy efficient lighting. Consumer demand for advanced lighting will also change as end users develop lighting literacy (through education from schools or local governments) and understand how quality of light affects quality of life (health and performance).

Marketing to end users must leverage the most relevant outlets and influencers in the value chain to influence lighting decisions and purchases. This may include working with IOU customer service teams at points of change (i.e., lease renewals), manufacturers on improved labeling, trade unions on best installation practices, retailers on point-of-sale promotions or even corporate "green teams"* on bottom-up approaches to large scale corporate lighting upgrades. Relevant marketing messages should be developed for each market segment (including residential low income customers) based upon the specific barriers and motivations within each segment.

The higher first cost of best practice lighting technologies presents a challenge in consumer adoption. Communication strategies must be developed to encourage consumers to look past first cost through promotion of lifecycle costing and non-energy benefits such as reduced maintenance and improved comfort. For large scale installations, financing programs such as regional incentive guides, outreach partnerships with lenders and facilitating group purchases with public institutions must be explored. A transformed lighting market will require diverse financial options built upon understanding end users and the unique barriers facing each segment of the market.

Market transformation also requires the support of the lighting industry. In this highly competitive industry, data that can accelerate market transformation is not often shared. Annual baseline studies and market segmentation analyses should be conducted, widely shared among all market actors and utilized to create effective product introduction and marketing campaigns.

Strategic product introduction cannot be overemphasized. California must examine the success and failure of past market introductions (both inside and outside the lighting industry) to develop highly effective methods. Market introductions require the support of integrated communication strategies with market stakeholders (including advertising, marketing and public relations organizations) to convey how lighting affects the human environment and trigger end user desire for best practice lighting technologies and systems.

Specific activities to create widespread end user adoption of lighting best practices include:

- **Marketing and Education:** Transform thinking about lighting; teach Californians to equate quality of light with quality of life.
- **Leverage Value Chain:** Partner with key market actors to promote advanced lighting technologies and achieve maximum energy savings.
- **Financial Education:** Promote financing that enables a broad range of end users to purchase, install and maintain advanced lighting technologies.
- **Strategic Product Introductions:** Strategically introduce next generation products and technologies to the marketplace with progressive goals.

Goal 3: Drive End User Demand

Implementation Plan and Timeline			
Strategy	**Near Term 2010 – 2012**	**Mid Term 2013 –2015**	**Long Term 2016 –2020**
3-1: Educate Californians to equate quality of light with quality of life	• Institute a statewide baseline study to assess end user wants and needs related to lighting as well as their satisfaction with current lighting technologies and systems • Create relevant campaigns and messages for each market segment (including residential low income) • Initiate lighting literacy education to the public via local governments, schools, etc. • Explore options for marketing campaigns targeting key outlets (including social media, retail displays, lighting shows, etc.)	• Re-evaluate study; share results • Assess campaigns; use results to inform next phase • Coordinate with K-12 schools to introduce lighting literacy to curriculum • Assess and refine campaigns	• Re-evaluate study; share results • Assess campaigns; use results to inform next phase • Coordinate with elementary schools to introduce lighting literacy to curriculum • Assess and refine campaigns

Implementation Plan and Timeline			
Strategy	**Near Term 2010 – 2012**	**Mid Term 2013 –2015**	**Long Term 2016 –2020**
3-2: Leverage key market stakeholders along the entire lighting value chain to promote advanced lighting technologies, systems and best practices	• Develop partnerships with lighting influencers to coordinate promotion of priority technologies • Work with IOUs to leverage customer service teams and ensure efficient lamps are installed, not stored • Launch grassroots efforts with corporate green teams and local environmental groups to influence lighting leadership • Elevate the role of lighting in green building rating systems (e.g., LEED) Work with industry on tenant improvement packages (link to high-quality advanced lighting)	• Develop and distribute partnership case studies/demonstration projects • Leverage contractors to help educate public about advanced lighting • Ongoing • Institutionalize changes; maintain and ongoing feedback loops • Develop statewide initiatives to incorporate best practices into retrofit and new construction projects	• Ongoing • Develop lead sharing programs for all lighting influencers • Ongoing • Ongoing • Ongoing
3-3: Educate decision makers about creative financial mechanisms that enable purchase of advanced lighting technologies, systems and best practices	• Explore barriers to sale/purchase/installation of best practice lighting technologies • Create and publicize cooperative guides that inventory all financing options related to best practice lighting solutions • Create education and outreach partnerships with lenders focused on financing energy efficient lighting projects • Facilitate group purchasing orders for large institutions	• With RD&D and policy advisors, reassess financial barriers to sale/install and where/how used • Update all cooperative financing guides; publicize widely • Leverage system retrofits efforts (such as Whole House) to advance energy efficient lighting • Ongoing	• With RD&D and policy advisors, reassess financial barriers to sale/install • Update all cooperative financing guides; publicize widely • Ongoing • Ongoing
3-4: Introduce advanced lighting technologies, systems and best practices into the marketplace with progressive goals.	• Study product introductions from other industries to inform strategies for lighting technology introductions • Conduct a lighting transition/ intervention points study (segmented by building type); use results to accelerate best practice adoption • Research and propose business case for best practice lighting (including GHG offsets) to CFOs and key decision makers	• Continue to study, refine and promulgate best practices • Develop reward/awareness for old products and large scale change outs • Ongoing	• Continue to study, refine and promulgate best practices • Ongoing • Ongoing

Goal 4: Develop research, development and demonstration (RD&D) networks to create, test and deliver the lighting solutions needed to transform California's lighting market and achieve ZNE goals.

Major advances in lighting systems and best practices are necessary by 2015 for California to achieve the Strategic Plan's goals. Research, development and demonstration (RD&D) efforts must address a wide range of technological issues (such as retrofitting lighting applications to integrated systems with smart controls and demand response capabilities) and include large scale, high-profile demonstration projects that showcase these solutions.

Given the global nature and fast pace of the lighting industry, it is vital that California uses its position as a leader and innovator to transform the international lighting market in order to meet the aggressive timelines identified herein.

To create an effective movement toward lighting market transformation, California needs a collaborative lighting RD&D approach that coordinates research and related activities with stakeholders to develop a lighting RD&D roadmap for California. Through an associated advisory body, the coordinated approach would create a network of collaborative partnerships among lighting industry market actors (in the public and private sectors) to develop, refine and improve statewide best practices. These efforts would focus on rapid market transformation, instead of slow, incremental technological advances.

Changing the state of the lighting industry will require significant cooperation among all market actors. For example, stakeholders overseeing publicly funded emerging technologies programs could seek partnerships with lighting industry peers to identify opportunities for rapid deployment of best practice solutions. These players would help to establish support and funding and participate in ongoing RD&D forums, workshops and other activities to disseminate lighting solutions and demonstrated outcomes. The PIER program has already undertaken noteworthy efforts in this area; Californians should continue to develop and expand upon these endeavors.

Activities could include researching reducing lighting power density and hours of use through smart integrated controls and other solutions that will help create improved best practices in the marketplace.

Demonstration projects are also a critical element of RD&D efforts to develop, assess and confirm field performance, identify improvements, prevent failures, create case studies and best practices.

Demonstration results would be integrated with the IOUs' Emerging Technologies programs and shared with the lighting industry at large using the CPUC web portal* and other communications platforms.

The CEC's Public Interest Energy Research (PIER) Program, California Institute for Energy and Environment and California Lighting Technology Center* jointly demonstrate innovative interior and exterior lighting systems at sites throughout the state. Using a similar collaborative model, the RD&D strategies in this chapter will define best practices, develop the RD&D roadmap and demonstrate the lighting technologies and solutions needed to achieve California's ZNE goals.*

Strategies to develop a robust, integrated RD&D network include:

- **RD&D Infrastructure:** Establish and maintain a collaborative, multi-institutional statewide lighting RD&D approach.
- **Smart Technologies:** Develop smart lighting* technologies, systems and solutions that are optimized for energy savings, demand response, renewable energy and human performance.
- **High-Profile Demonstrations:** Design creative, high-profile demonstrations of best practice lighting solutions that are scalable, targeted and leverage regional, statewide and national projects.

Goal 4: Integrated RD&D Network

Implementation Plan and Timeline			
Strategies	**Near Term 2010 – 2012**	**Mid Term 2013 – 2015**	**Long Term 2016 – 2020**
4-1: Establish and maintain a research-based collaborative, multi-institutional statewide lighting RD&D approach	• Establish a lighting RD&D advisory group with relevant subgroups to provide long-term guidance to California in the lighting efficiency and sustainability arenas	• Host ongoing quarterly roundtables, provide annual reporting on advisory's findings	• Host ongoing quarterly roundtables, provide annual reporting on advisory's findings
	• Publish California's first statewide multi-institutional lighting RD&D roadmap	• Conduct annual roundtables to refine and update roadmap	• Conduct annual roundtables to refine and update roadmap
	• Establish an online resource (integrated with the CPUC web portal) to assist disseminating RD&D solutions and demonstration outcomes	• Create initiatives that support/fund manufacturer partnerships' development	• Ongoing
	• Develop ongoing RD&D forums and workshops to assist in disseminating solutions and demonstration outcomes	• Conduct ongoing RD&D forums and workshops	• Conduct ongoing RD&D forums and workshops
	• Establish broad support and funding for RD&D portfolio	• Pursue broad funding support for RD&D activities	• Ongoing
4-2: Develop smart lighting technologies, systems and solutions that are optimized for energy savings, demand response, renewable energy and human performance	• Research and develop solutions that lead to a 25% reduction in lighting power density and hours of use through smart integrated controls	• Target solutions that create a 50% reduction in lighting power density	• Extend power density reductions to 60 percent or greater
	• Experiment with novel programs to launch new technologies which help create improved best practices in the marketplace	• Continue development of new programs to launch new systems and technologies	• Continue development of new programs for new systems and technologies
	• Develop a research plan for exploring non-energy lighting performance, including economic, human factors, style, etc.	• Ongoing	• Ongoing
	• Develop and use market intelligence on energy use patterns, best practices and trends and behaviors with industry partners	• Share findings with market (ongoing)	• Share findings with market (ongoing)
	• Commission a study to assess best practices in RD&D programs (inside and outside of the energy efficiency industry)	• Establish links to other efficiency programs and agencies	• Establish links to other efficiency programs and agencies

Implementation Plan and Timeline			
Strategies	**Near Term 2010 – 2012**	**Mid Term 2013 – 2015**	**Long Term 2016 – 2020**
4-3: Design creative, high-profile demonstrations of advanced lighting technologies that are scalable, targeted and leverage regional, statewide and national projects	• Develop a standardized framework that identifies goals, objectives, field protocols and expected outcomes for demonstration projects • Establish a formal, universal process for data collection, analysis (evaluation and measurement) and technology handoff of RD&D demonstration projects • Design collaborative demonstration programs that are highly visible, scalable, targeted and leverage other demonstration efforts • Establish formal feedback program that leverages the CPUC web portal to disseminate results and lessons learned from demonstration projects	• Modify framework based on a review of goals and outcomes • Ongoing • Launch integrated demonstration collaborative • Modify efforts based on industry feedback	• Ongoing • Ongoing • Ongoing integrated demonstration collaborative • Ongoing

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California Public Utilities Commission

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Theresa Cho
Jeanne Clinton
Cathleen Fogel
Jamie Fordyce
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Kristina Skierka

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(Lists in alphabetical order by last name)

Kay Hardy
Peter Lai
Jean Lamming
Ayat Osman
Lisa Paulo
Anne Premo
Johanna Sevier
Ava Tran
Pam Wellner
Michael Wheeler

California Energy Commission

Ricardo Amon
Norm Bourassa
Martha Brook
Bill Pennington
Daryl Mills
Amy Morgan
Bill Pennington
John Sugar
John Wilson

Conveners

Karl Brown, California Institute for Energy and Environment
Pete Canessa, Center for Irrigation Technology, California State University Fresno
Karin Corfee, KEMA Inc.
Cyane Dandridge, Executive Director of Strategic Energy Innovations
Rick Diamond, Lawrence Berkeley National Laboratory
Bob Graves, Green Technology
Val Jensen, ICF, Inc.
Debbie McGhee, Project Performance Corporation
Aimee McKane, Lawrence Berkeley National Laboratory
Michael Messenger, California Energy Commission
Carl Smith, Green Technology
David Zoldoske, Center for Irrigation Technology, California State University Fresno

IOU Staff Leads

Don Arambula, SCE
Athena Besa, SDG&E/SCG
William Miller, PG&E

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Gregg Ander, SCE
Barbara Cronin, SDG&E/SCG
Tom DeCarlo, SDG&E/SCG
Patsy Dugger, PG&E
John Fasano, SCE
Rick Hobbs, SoCalGas
David Jacot, SCE
Paul Kyllo, SCE
Mary O'Drain, PG&E
Angie Ong-Carrillo, PG&E
Jack Parkhill, SCE
Carlos Ruiz, SCG
Charles Segerstrom, PG&E
Frank Spasaro, SDG&E/SCG
Frances Thompson, PG&E
Vinnie Tucker, SCE
Sandra Williams, SDG&E
Joy Yamagata, SDG&E/SCG

IOU Strategic Planning Consultants

Ziyad Awad, Awad & Company, Inc.
Dan Frederick, D. C. Frederick Consulting
David Nemtzow, Nemtzow & Associates
Steve Schiller, Schiller Consulting Inc.

Others

Accenture
Low Income Oversight Board Members
Vinita Thakkar, SDG&E

LIST OF ACRONYMS

AB 32	Assembly Bill 32/California Global Warming Solutions Act of 2006 *www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf*
ABAG	Association of Bay Area Governments *www.abag.ca.gov*
AC	Air Conditioning
ACCA	Air Conditioning Contractors of America *www.acca.org*
ACEEE	American Council for an Energy-Efficient Economy *www.aceee.org*
ACR	Assigned Commissioner Ruling
AHRI	Air Conditioning, Heating and Refrigeration Institute *www.ahridirectory.org/ahridirectory/pages/ariDirectoryMain.aspx*
AIA	American Institute of Architects *www.aia.org*
AMBAG	The Association of Monterey Bay Area Governments *www.ambag.org*
AMI	Advanced Metering Infrastructure
ANSI	American National Standards Institute *www.ansi.org*
ASAP	Appliance Standards Awareness Project *www.standardsasap.org*
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers *www.ashrae.org*
BBEES	Big Bold Energy Efficiency Strategies *Three programmatic initiatives identified by the California Public Utilities Commission in Decision 07-10-032*
BIRA	Building Industry Research Alliance *www.bira.ws*
BOC	Building Operator Certification
BTH	Business, Transportation and Housing Agency *www.bth.ca.gov*
BuRec	Bureau of Reclamation *www.usbr.gov*
C&S	Codes and Standards
CAB	California Architects Board *www.cab.ca.gov*
CAIA	California Agricultural Irrigation Association *www.caia-irrigation.org*
CAISO (or ISO)	California Independent System Operator *www.caiso.com*
CALBO	California Building Officials *www.calbo.org*
CalWORKS	California Work Opportunities and Responsibility to Kids *www.ladpss.org/dpss/calworks/default.cfm*
CARB (or ARB)	California Air Resources Board *www.arb.ca.gov*
CBO	Community-based Organization
CDFA	California Department of Food and Agriculture *www.cdfa.ca.gov*
CDE	California Department of Education *www.cde.ca.gov*

Energy Commission	California Energy Commission *www.energy.ca.gov*
CEE	Consortium for Energy Efficiency *www.cee1.org*
CEEA	California Energy Efficiency Alliance
CEESP	California Energy Efficiency Strategic Plan *www.californiaenergyefficiency.com*
CFL	Compact Fluorescent Lamp or Light
CO_2	Carbon Dioxide
CIEE	California Institute for Energy and Environment (CIEE) *www.uc-ciee.org*
CLTC	California Lighting Technology Center *www.cltc.ucdavis.edu*
CPUC	California Public Utilities Commission *www.cpuc.ca.gov/puc*
CSAC	California State Association of Counties
CSI	California Solar Initiative *www.gosolarcalifornia.ca.gov/csi/index.html*
CSLB	California State License Board *www.cslb.ca.gov*
CSU	California State University
Cx	Commissioning
DC	Direct Current
DCSD	Department of Community Services and Development *www.csd.ca.gov/default.aspx*
DEER	Database for Energy Efficient Resources *www.energy.ca.gov/deer*
DG	Distributed Generation
DOE	U.S. Department of Energy *www.energy.gov*
DR	Demand Response
DRA	Division of Ratepayer Advocates *www.dra.ca.gov*
DSM	Demand-Side Management
DSS	Department of Social Services *www.dss.cahwnet.gov/cdssweb/default.htm*
DWR	California Department of Water Resources *www.water.ca.gov*
EAP	California Energy Action Plan *www.energy.ca.gov/energy_action_plan/index.html*
ED	California Public Utilities Energy Division
EDD	Employment Development Department *www.edd.ca.gov*
EE	Energy Efficiency
EM&V	Evaluation, Measurement and Verification
EMS	Energy Management System
EPA	U.S. Environmental Protection Agency *www.epa.gov*
EPRI	Electric Power Research Institute *www.epri.com*
ESCO	Energy Service Company
ET	Emerging Technology or Emerging Technologies
ETAAC	Economic and Technology Advancement Advisory Committee *www.etaac.org/jsp/genericdoc.jsp*
ETCC	Emerging Technologies Coordinating Council *www.etcc-ca.com*

ETP	California Employment Training Panel *www.etp.ca.gov*
FSEC	Florida Solar Energy Center *www.fsec.ucf.edu/en*
GAIN	Greater Avenues for Independence *www.ladpss.org/dpss/gain/default.cfm*
GHG	Greenhouse Gas
GWh	Gigawatt Hour
HARDI	Heating, Air Conditioning and Refrigeration Distributors International *www.hardinet.org*
HDTV	High Definition Television
HERS	Home Energy Rating System *www.energy.ca.gov/HERS*
HVAC	Heating, Ventilation and Air Conditioning
ICLEI	International Council for Local Environmental Initiatives *www.iclei.org*
ID	Irrigation Districts or Integrated Design
IEPR	Integrated Energy Policy Report *www.energy.ca.gov/2007_energypolicy/index.html*
IOU	Investor-Owned Utility
ISO	See CAISO or International Organization for Standardization
ITP	U.S. Department of Energy's Industrial Technologies Program *www1.eere.energy.gov/industry*
kW	kilowatt
kWh	Kilowatt Hour
LBNL	Lawrence Berkeley National Laboratory *www.lbl.gov*
LCD	Liquid Crystal Display
LED	Light-emitting Diode (also used to describe lamps using LED technology)
LEED	Leadership in Energy and Environmental Design (green building rating system) *www.usgbc.org/leed*
LG	Local Government
LGC	Local Government Commission *www.lgc.org*
LIEE	Low Income Energy Efficiency
LIOB	Low Income Oversight Board *www.ligb.org*
LOC	League of California Cities *www.cacities.org/index.jsp?zone=locc*
ME&O	Marketing, Education and Outreach
Mth	Million Therms
MW	Megawatt
MWh	Megawatt Hour
NATE	North American Technician Excellence *www.natex.org*
NBI	New Buildings Institute *www.newbuildings.org*
NEMA	National Electrical Manufacturers Association *www.nema.org*
NIST	U.S. Department of Commerce's National Institute of Standards and Technology *www.nist.gov*
NRCS	Natural Resources Conservation Service *www.nrcs.usda.gov*
NREL	National Renewable Energy Laboratory *www.nrel.gov*

NWEEA	Northwest Energy Efficiency Alliance *www.nwalliance.org*
O&M	Operations and Maintenance
PA	Program Administrator
PACE	Property-Assessed Clean Energy
PDA	Personal Digital Assistant
PG&E	Pacific Gas and Electric Company *www.pge.com*
PIER	Public Interest Energy Research *www.energy.ca.gov/pier*
POU	Publicly Owned Utility
PV	Photovoltaic
QI/QM	Quality Improvement/Quality Management
R&D	Research and Development
RCx	Retrocommissioning
RD&D	Research, Development and Demonstration
RECO	Residential Energy Conservation Ordinances
RFP	Request for Proposals
RH	Relative Humidity
SanDAG	San Diego Association of Governments *www.sandag.cog.ca.us*
SCAG	Southern California Association of Governments *www.scag.ca.gov*
SCE	Southern California Edison *www.sce.com*
SCG (or SoCalGas)	Southern California Gas Company *www.socalgas.com*
SDG&E	San Diego Gas & Electric Company *www.sdge.com/index.shtm*
SFLI	Single Family Low Income
SGIP	Self-Generation Incentive Program *www.cpuc.ca.gov/PUC/energy/051005_sgip.htm*
SMJU	Small and Multijurisdictional Utility
SMUD	Sacramento Municipal Utility District *www.smud.org*
SWEEP	Southwest Energy Efficiency Project *www.swenergy.org*
TURN	The Utility Reform Network *www.turn.org*
TRC	Total Resource Cost
UC	University of California
USDA	U.S. Department of Agriculture *www.usda.gov*
USGBC	U.S. Green Building Council *www.usgbc.org*
WCEC	Western Cooling Efficiency Center *wcec.ucdavis.edu*
WE&T	Workforce Education and Training
WWD	Wind Wave Direction
ZNE	Zero Net Energy

LIGHTING CHAPTER GLOSSARY AND BEST PRACTICES

AB 811

California Assembly Bill 811 (authored by Assembly member Lloyd Levine and signed by Governor Arnold Schwarzenegger on July 21, 2008), which authorizes California cities and counties to designate areas within which willing property owners could enter into contractual assessments to finance the installation of energy efficiency improvements and/or distributed renewable energy generation. For more information, visit http://info.sen.ca.gov/pub/07-08/bill/asm/ab_0801-0850/ab_811_bill_20080721_chaptered.pdf.

AB 1109

California Assembly Bill 1109; see "Huffman Bill"

Advanced Lighting Technologies

Components and systems with improved performance attributes that contribute toward efficiency enhancement and best practices. Examples (in 2010) include specialty CFLs, LEDs, cold cathode and high-efficiency incandescents (HEI).

Air Resources Board (ARB)

A part of the California Environmental Protection Agency that reports directly to the Governor's Office in the Executive Branch of California State Government. The ARB's mission is to promote and protect public health, welfare and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state.

Best Practice

Coordinated technologies, systems and design approaches, which (through research and experience) demonstrate the ability to consistently achieve above standard results while avoiding negative environmental impacts. Best Practices change over time as improved components, technologies, systems and design approaches become available.

California Institute for Energy and Environment (CIEE)

A branch of the University of California Energy Institute, CIEE is a partnership of energy agencies, utilities, building industry, non-profits and research entities designed to advance energy efficiency science and technology for the benefit of California, other energy consumers and the environment. For more information, visit CIEE's website at http://uc-ciee.org.

California Lighting Technology Center (CLTC)

Established in 2003 at the University of California, Davis, the CLTC is an organization developed through a collaborative effort between the CEC, the California utilities, the U.S. Department of Energy (DOE) and the National Electrical Manufacturers Association (NEMA) to advance energy efficient lighting and daylighting technologies. For more information, visit the CLTC website at http://cltc.ucdavis.edu.

CPUC Web Portal

The CPUC's Energy Efficiency Web Portal, is a website currently under development by the CPUC designed to serve as an organizing and information vehicle to achieve the California Energy Efficiency Strategic Plan vision.

Daylighting

Building assemblies (such as use of windows, skylights, light tubes and reflective surfaces) designed to introduce daylight into a building for the purpose of illumination, view and to reduce a building's reliance on electric lighting.

Demand Response

Mechanism for managing end user electricity consumption in response to energy supply conditions. A demand responsive system is one that can be controlled (either directly or remotely) to reduce electricity consumption during times of increased energy demand and/or constrained energy availability.

Federal Energy Policy Act

A bill (Pub.L. 109-58) passed by the United States Congress and signed into law by President George W. Bush on August 8, 2005, which includes provisions for tax incentives for energy efficient equipment, requires the DOE to research demand response and other elements. For more information, visit the Federal Energy Regulatory Commission website at http://www.ferc.gov/legal/fed-sta/ene-pol-act.asp.

First Cost

Immediate purchase and installation cost. First costs do not include lifecycle or long-term operating costs, which may result in long-term cost savings from increased efficiency, reduced maintenance and other factors.

Green Teams

A formal or informal group of people in a company who are passionate about environmental issues. The groups brainstorm solutions and promote ways in which their company's practices can become more environmentally sustainable, often creating sustainability plans and approaching management for funding to meet plans.

Huffman Bill

California Assembly Bill 1109 (authored by Assembly member Jared Huffman and signed by Governor Arnold Schwarzenegger on October 12, 2007), which prohibits the manufacturing for sale or the sale of certain general purpose lights that contain hazardous substances and requires the California Energy Commission to adopt energy efficiency standards for general purpose lights. For more information visit http://www.leginfo.ca.gov/cgi-bin/postquery?bill_number=ab_1109&sess=CUR&house=B&author=huffman.

Integrated Systems

Lighting systems that include components, assemblies and controls designed to work together effectively.

Lifecycle Cost

Cost of a component, technology, or system over its entire lifespan, including not just first costs but also operating, maintenance and disposal costs.

Local governments

Entities including cities, counties, special districts and school districts.

Market Transformation

Long-lasting, sustainable changes in the structure or functioning of a market achieved by reducing barriers to the adoption of energy efficiency measures to the point where continuation of the same publicly-funded intervention is no longer appropriate in that specific market. Market transformation includes promoting one set of efficient technologies, processes or building design approaches until they are adopted into codes and standards (or otherwise substantially adopted by the market), while also moving forward to bring the next generation of even more efficient technologies, processes or design solutions to the market.[90]

Pattern Book

Prototype designs for energy efficient lighting suitable for typical building types. Information on lighting products and techniques enables the architect, interior designer, electrical contractor, building professional or do-it-yourself homeowner to design quality lighting for individual space types.

Property-Assessed Clean Energy (PACE)

A form of financing that creates municipal finance districts to provide loans to homeowners and businesses for energy-efficient retrofits and renewable energy system installations. Loans are repaid through an annual surcharge on property tax assessments. Governor Schwarzenegger signed the nation’s first law allowing PACE financing in 2008.

Public Interest Energy Research (PIER)

Program created by the CEC to conduct public interest energy research that seeks to improve the quality of life for California citizens by providing environmentally sound, safe, reliable and affordable energy services and products. It includes the full range of research, development and demonstration activities that will advance science or

technology not adequately provided by competitive and regulated markets. For more information, visit the PIER website at http://www.pierminigrid.org/.

Reach Codes

Codes that direct contractors to construct buildings significantly more energy efficient than required by conventional building codes.

Simple Payback

Amount of time required to recover an initial investment.

Smart Lighting

Lighting that is dynamically responsive to end user needs based on daylighting, occupancy, scheduling and demand response requirements.

Standard Practice

As opposed to best practices, standard practices include techniques, policies, methodologies, procedures, technologies and systems that are typically employed by practitioners and generally do not achieve optimal results (in terms of energy efficiency, demand-responsiveness, high quality, environmental sustainability, smart grid connectedness and integration with renewable energy generation sources). For lighting, standard practices may include efficiency "floors" required by building codes.

Sustainable

Describes a technique, policy, methodology, procedure, technology, or system designed or configured in such a way as to minimize (or entirely eliminate) negative impacts on natural ecosystems and public health.

Title 20

The Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 through 1608), which details current efficiency regulations for appliances sold or offered for sale in California, except those sold wholesale in California for final retail sale outside the state and those designed and sold exclusively for use in recreational vehicles or other mobile equipment. The standards are updated periodically to allow consideration and possible incorporation of new energy efficiency technologies and methods. http://www.energy.ca.gov/2006publications/CEC-400-2006-002/CEC-400-2006-002-REV2.PDF.

Title 24

California's Energy Efficiency Standards for Residential and Nonresidential Buildings (California Code of Regulations, Title 24, Section 6), which contain the regulations that govern the construction of buildings in California. The standards are updated periodically to allow consideration and possible incorporation of new energy efficiency technologies and methods. On April 23, 2008, the CEC adopted the most recent standard and the Building Standards Commission approved them for publication on September 11, 2008. These standards will go into effect for all building permit applications submitted on or after January 1, 2010. http://www.energy.ca.gov/title24/.

Research, Development and Demonstration

A process incorporating the discovery of new knowledge and understandings using experimental methodology. This includes translational activities of applying research to the evolving of new systems and projects and activities wherein new products and approaches are tested to develop applications based performance data.

Zero Net Energy

For buildings, use of no more energy over the course of a year than can be generated onsite through renewable resources such as solar, wind, or geothermal power.

LIGHTING BEST PRACTICES

Space Types	Best Practice Retrofits	Standard Practice Retrofits
Commercial Office	Task/Ambient lighting with occupancy and daylight controls with 73 percent energy savings or 0.5 Watts/sq ft	Retrofit of ambient lighting system with 37 percent energy savings or 1.1 Watts/sq ft
Educational Classrooms	Integrated Classroom Lighting System with occupancy controls with 65 percent energy savings or 0.7 Watts/sq ft	Recessed troffer fixtures with occupancy controls with 50 percent energy savings or 1.0 Watts/sq ft
Residential Downlights	High quality LEDs or SSL fixture system with 79 percent energy savings	Compact fluorescent (CFL) fixture system with 60 percent energy savings
Commercial Downlights	High quality LEDs or SSL fixture systems with 78 percent energy savings	Compact fluorescent (CFL) fixture system with 54 percent energy savings
Exterior Lighting (e.g. Parking lot ,pathway, not including parking garages)	Smart Bi-level lighting systems with occupancy and daylight controls with 40 percent energy savings	Standard lighting with photocell controls with 0 percent energy savings
Interior HID Applications (e.g. retail and industrial)	Electronic HID ballasts with 25 percent system energy savings or 0.75 Watts/sq ft	Magnetic HID ballasts with 0 percent energy savings or 1.0 Watts/sq ft

***PLEASE NOTE*: these best practice examples show the total technical savings potential and are primarily intended to illustrate the results from the using best practices versus standard practices over 10 years. Calculations are based on accepted estimates for total building stock, assumed hours of operations, demonstrations and verified savings results from both standard and best practice approaches. Detailed accounting including source and assumption data is in the 2010 Lighting Technology Overview.**

ENDNOTES

[1] California Public Utilities Commission Decision 07-10-032. (D.07-10-023) Available at: http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/74107.pdf

[2] Extensive documentation of the materials developed though the strategic planning process is available at: www.californiaenergyefficiency.com

[3] The last state effort of this nature was the California Conservation Collaborative, which in 1990 restored emphasis and funding to utility energy efficiency programs and established new design principles for programs and utility regulation, in response to a drop-off in utility energy efficiency efforts in the late 1980s.

[4] "Energy Action Plan II, Implementation Roadmap for Energy Policies", California Energy Commission and California Public Utilities Commission, September 21, 2005. Available at: http://docs.cpuc.ca.gov/word_pdf/REPORT/51604.pdf

[5] "Energy Action Plan I", California Energy Commission, California Public Utilities Commission and Consumer Power and Conservation Financing Authority. May 8, 2003. Available at: http://docs.cpuc.ca.gov/word_pdf/REPORT/28715.pdf

[6] California Energy Commission, 2007 Integrated Energy Policy Report (2007 IEPR), adopted December 5, 2007. CEC-100-2007-008-CMF. Available at: http://www.energy.ca.gov/2007_energypolicy/documents/index.html

[7] California Air Resources Board "Climate Change Draft Scoping Plan: A Framework for Change" June 2008 Discussion Draft. (CARB Scoping Plan) p. 7. Available at: http://www.arb.ca.gov/cc/scopingplan/document/draftscopingplan.pdf

[8] 2007 IEPR.

[9] McKinsey & Company. "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost? U.S. Greenhouse Gas Abatement Mapping Initiative" Executive Report, December 2007. Available at: http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf

[10] Assembly Bill No. 32 (Pavley, 2006) California Health and Safety Code, §§ 38500 et seq. Available at: http://www.climatechange.ca.gov/publications/legislation/ab_32_bill_20060927_chaptered.pdf

[11] CARB Scoping Plan p. 13.

[12] Ibid. pp 21-22. The Draft Plan Appendices also consider a more stringent target for energy savings of 40,000 GWh.

[13] Ibid. p.22. Assembly Bill 1493 (Pavley, 2002) directed ARB to adopt vehicle standards that lower greenhouse gas emissions to the maximum extent technologically feasible, beginning with the 2009 model year. ARB plans to adopt a second, more stringent, phase of the Pavley regulations. Over the 2020 timeframe these measures are expected to yield over 30 million metric tons of GHG reductions. ARB adopted regulations in 2004 and applied to the U.S. Environmental Protection Agency (U.S. EPA) for a waiver under the federal Clean Air Act to implement the regulation. While initially denied, it is likely that ARB will ultimately be permitted to implement the Pavley regulations. If not, they plan to pursue other avenues to realize the vast potential for GHG reductions in the transportation sector.

[14] http://www.green.ca.gov/GreenActionTeam/default.htm

[15] California Public Utilities Commission Decision 08-07-047. (D.08-07-047) Available at: http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/85995.pdf

[16] Energy Independence and Security Act of 2007. (EISA 2007) Public Law 110–140. Dec. 19, 2007. Available at: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ140.110.pdf

[17] D.07-10-032, p.33.

[18] Ibid. , p. 33

[19] California Public Utilities Commission Decision 98-04-063, Appendix A.

[20] D.07-10-032, p.150.

[21] As an example, the Northeast Energy Efficiency Partnership (NEEP) sets market transformation goals for its programs, and then measures progress towards the goals by determining the extent to which various barriers have been overcome in a given market. Such barrier criteria include: consumer awareness, product/service availability, pricing, purchasing behavior, customer satisfaction, and future customer actions. Measures and programs that have achieved their goals are phased out of utility energy efficiency portfolios to make room for new measures.

[22] Transcripts of the three stakeholder workshops—as well as the written comments submitted—are available on the strategic planning website: www.californiaenergyefficiency.com.

[23] 2007 IEPR

[24] California is served by well over 60 electricity and natural gas distribution companies. (Energy Commission at http://www.energy.ca.gov/electricity/utilities.html#300; and U.S. Census Bureau, 1997 Economic Census December 29, 1999, which counts over 200 utilities) Some smaller utilities may not offer residential customers opportunities to participate in energy efficiency programs. However, a large majority of California residents are served by utilities that do offer energy efficiency programs. (See also endnote 3 below.)

[25] Thirty percent (30%) is the proportion of IOU-served residential households qualifying for Low Income Energy Efficiency (LIEE) programs. IOUs serve about 10.5 million residential customers (CPUC at http://www.cpuc.ca.gov/PUC/energy/), or approximately 83% of California households. The proportion of LIEE-qualifying households served by publicly-owned utilities is assumed to be similar.

[26] Title 20, Cal. Code Regs., Sections 1601 – 1608, http://www.energy.ca.gov/appliances/; Title 24, Cal.Code Regs. Part 6, http://www.energy.ca.gov/title24/.

[27] Assembly Bill No. 1109 (Huffman, 2007) Public Resources Code §§ 25402 et seq. Available at: http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1101-1150/ab_1109_bill_20071012_chaptered.pdf

[28] 2007 IEPR, pp. 88.

[29] Several green building standards take embodied energy into account. See, for instance, US Green Building Council Leadership in Environmental and Environmental Design (LEED) (http://www.usgbc.org) or UK Code for Sustainable Homes (http://www.planningportal.gov.uk/england/professionals/en/1115314116927.html)

[30] In establishing the New Solar Homes Partnership (NSHP), the Energy Commission requires that new residential buildings granted an incentive under the NSHP exceed California's Title 24 Building Energy Efficiency Standards. This helps the combined energy efficiency and solar project to be as affordable as possible over the life of the home. To qualify for "Tier II" incentives, the home must exceed Title 24 standards by 35%. For more information regarding the Energy Commission's New Solar Homes Partnership and qualifying energy efficiency standards, go to: http://www.gosolarcalifornia.org

[31] BSC Green Building Standards. Available at: http://www.documents.dgs.ca.gov/bsc/prpsd_stds/2007/combined_approved_green_code_pt11.pdf

[32] San Francisco 2008 Green Building Ordinance, Available at: http://www.sfenvironment.org/downloads/library/sf_green_building_ordinance_2008.pdf

[33] Los Angeles 2008 Green Building Ordinance, Available at: http://cityplanning.lacity.org/Code_Studies/GreenLA/greenbuildingordinance.pdf

[34] At the end of 2007 (prior to the mortgage crisis), only one-in-three of the state's households could afford a conventional entry level home, an improvement from one-in-four a year earlier, but still challenging for prospective home buyers. See: "Housing Affordability Improves as Prices and Rates Decline", Robert A. Kleinhenz, California Association of Realtors, February 2008.

[35] United States Department of Energy. "Residential Energy Consumption Survey." 2001. Available at: http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html

[36] Federal, state and local governmental buildings and facilities are categorized as "commercial" and implicitly included in the strategies of this Chapter and periodically differentiated as warranted; additionally, local governmental buildings are discussed extensively in the Local Government Chapter of this Strategic Plan.

[37] For more information on the 2030 Challenge go to: http://www.zeroenergycbi.org/

[38] For more information on this Initiative go to: http://www.eere.energy.gov/news/daily.cfm/hp_news_id=129

[39] For more information on California's Green Buildings Initiative, go to: http://www.dgs.ca.gov/GB%20Program.htm

[40] For more information on California's Grid Neutral Schools Program, go to: http://www.green-technology.org/green_technology_magazine/images/grid_neutral.pdf

[41] California Energy Commission, *Options for Energy Efficiency in Existing Buildings.* December 2005. CEC-400-2005-039-CMF. Available at: http://www.energy.ca.gov/2005publications/CEC-400-2005-039/CEC-400-2005-039-CMF.PDF

[42] Assembly Bill 1103 (Saldana, 2007) Public Resourc eCode, §§ 25402 et seq. Available at: http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1101-1150/ab_1103_bill_20071012_chaptered.pdf

[43] California Energy Commission, http://www.energy.ca.gov/electricity/consumption_by_sector.html

[44] 2007 IEPR.

[45] CARB Scoping Plan, p.7.

[46] 2007 IEPR.

[47] For more information on the Superior Energy Performance Partnership, go to: http://www.superiorenergyperformance.net/

[48] For more information on the ANSI-accredited Plant Energy Efficiency Certification Program initiated through SEPP go to: http://www.superiorenergyperformance.net/pdfs/Plant-Certification-StrategicPlan-SEP-May-2008.pdf

[49] For more information on these programs, go to: http://www1.eere.energy.gov/industry/saveenergynow/ and http://www.labs21century.gov/

[50] 2007 IEPR, p. 13.

[51] For more information on CDFA's Vision, go to: http://www.cdfa.ca.gov/agvision/.

[52] This Plan examines residential and small commercial HVAC, and therefore implicitly assumes unitary equipment (packaged and split) that is 20 tons and below, rather than large, built-up HVAC. Large systems are an important energy efficiency and peak management issue but, pursuant to the Commission's big, bold Programmatic Initiative in D.07-10-032, are not directly examined in this Chapter as they have a very different marketplace dynamic than unitary systems. Many of the factors that influence efficiency of large systems are examined in the Commercial Chapter.

[53] Chris Neme, John Proctor, and Steve Nadel, National Energy Savings Potential from Addressing HVAC Installation Problems; (Prepared for the U.S. EPA, February 1999.) Available at: http://www.aceee.org/pubs/a992.htm

[54] "Strategic Plan to Reduce the Energy Impact of Air Conditioners" AB 2021 Report" June 2008. CEC-400-2008-010. Available at: http://www.energy.ca.gov/2008publications/CEC-400-2008-010/CEC-400-2008-010.PDF

[55] Section 306 of EISA 2007 allows, for the first time, for the U.S. Secretary of Energy to set regional standards for certain HVAC equipment.

[56] Appliances are, in fact, primarily regulated at the federal level; and for any product that is regulated at the federal level states are preempted from regulating. Buildings are primarily regulated at the state level; notable exceptions are manufactured housing (which is federally regulated) and hospitals.

[57] 2007 IEPR.

[58] Chris Neme, John Proctor, and Steve Nadel, National Energy Savings Potential from Addressing HVAC Installation Problems (Prepared for the U.S. EPA, February 1999). Available at: http://www.aceee.org/pubs/a992.htm

[59] See for example Quantec, Statewide Codes and Standards Market Adoption and Noncompliance Rates. Prepared for Southern California Edison May 10, 2007.

[60] EISA 2007 requires state to initiate smart grid proceedings by the end of 2008. All of the IOUs have already filed for recovery of infrastructure investments for smart grid.

[61] "Plugging in the Consume: Innovating Utility Business Models for the Future" IBM Institute for Business Value, 2007. Available at: http://www-03.ibm.com/industries/utilities/doc/content/landingdtw/3165578119.html

[62] California Energy Commission recently held on this emerging CEC Smart Grid research initiative, "Defining the Pathway to the California Smart Grid of 2020". Agenda available at: http://www.energy.ca.gov/research/notices/2008-08-05_RFP_smartgrid/2008-08-05_AGENDA.PDF

[63] The topical convener reports are summaries based on the input received at publicly-held workshops attended by stakeholders, experts, IOU staff and others to provide information and discussion in the development of the California Energy Efficiency Strategic Plan. The CPUC convened the workshops and enlisted leading subject matter experts to serve as conveners for each sector and crosscutting issue in this process. The HVAC Convener Report itself can be found on the California Energy Efficiency Strategic Plan site, http://www.californiaenergyefficiency.com

[64] D.07-10-032, p. 59.

[65] D.07-10-032, pp. 64-65.

[66] Johnson, K., N. Bourassa, and M. Seaman. 2008. "New California PIER R&D Product Introduction Process" Proceedings of the 2008 ACEEE Summer Study on Energy Efficiency in Buildings. 9:162-171. Washington D.C.: American Council for an Energy-Efficient Economy.

[67] "Local governments" primarily refers to cities and counties, which have land use authority. However, there are also important roles for regional government, metropolitan planning organizations, school and special districts and other local and regional government entities.

[68] California Public Utilities Commission Decision 99-08-021, Ordering Para. 11. See also D.01-01-060 directing the utilities to increase partnerships with local governments to achieve energy efficiency at the local level.

[69] California Environmental Quality Act

[70] Quantec, Statewide Codes and Standards Market Adoption and Noncompliance Rates. Prepared for Southern California Edison, May 10, 2007. Available at: http://www.californiaenergyefficiency.com/docs/hvac/references/Codes_and_Standards_Final_Report.pdf

[71] For more information on the Cambridge project, go to: http://www.cambridgeenergyalliance.org/

[72] Assembly Bill 811 (Levine, 2008) Streets and Highway Code, §§ 5898 et seq. Available at: http://info.sen.ca.gov/pub/07-08/bill/asm/ab_0801-0850/ab_811_bill_20080721_chaptered.pdf

[73] Senate Bill 375 (Steinberg, 2008) Available at: http://info.sen.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080902_enrolled.pdf

[74] California Energy Commission. *California Energy Demand 2003-2013 Forecast: Staff Report.* Prepared in Support of the Electricity and Natural Gas Report under the Integrated Energy Policy Report Proceeding (02-IEP-01). August 2003.

[75] California Lighting Technology Center (CLTC). *2010 Lighting Technology Overview*. Prepared for the CPUC, 2010.

[76] KEMA Inc. *Final Evaluation Report: Upstream Lighting Program (Volume* 1). Prepared for the CPUC Energy Division. February 8, 2010.

[77] California Lighting Technology Center. Preliminary results from ongoing CLTC study on Super CFLs. Prepared for the CPUC, 2009.

[78] California Lighting Technology Center. *2010 Lighting Technology Overview*.

[79] ibid.

[80] ibid, page 3.

[81] Gibbs, M. and J. Townsend. *The Role of Rebates in Market Transformation: Friend or Foe?* Published in the Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings, 6.121-6.132. Washington, D.C., 2000.

[82] CLTC. *2010 Lighting Technology Overview*. page 8.

[83] Pierce, S. *California Outdoor Lighting Baseline Assessment.* Prepared for the California Energy Commission, PIER Program. P500-03-082-A-18. 2003.

[84] Gauna, et al. “Developing Lighting Technologies: Integrated Office Lighting.” PIER Final Report, California Energy Commission. May 2008.

[85] CLTC. *2010 Lighting Technology Overview.* page 4.

[86] California Public Utilities Commission, California Long-Term Energy Efficiency Strategic Plan, Section 2-Page 22; See also, Decision 09-09-047 (D.09-09-047) September 24, 2009, pgs. 137-138 (Available at: http://docs.cpuc.ca.gov/proceedings/A0807021.htm#decisions)

[87] Opinion Dynamics Corporation. *Ethnographic Research Findings*. Presented to the CPUC on August 25, 2009. Available at http://www.cpuc.ca.gov/NR/rdonlyres/3D5AC333-D531-4734-AF9D-1A28AF7E5008/0/FinalEthnographicResearchPresentation.PDF

[88] Rosenfeld, Arthur H. (Commissioner, California Energy Commission). "From the Lab to the Market to Standards The Role of California Energy Policy." Digital presentation at California Lighting Technology Center. CEC-999-2006-023. November 2006.

[89] KEMA Inc. *Final Evaluation Report: Upstream Lighting Program (Volume* 1). Prepared for the CPUC Energy Division. February 8, 2010.

[90] California Public Utilities Commission, D.09-09-047.