

June 2020

## Final Report

# Paths to Clean Vehicle Technologies and Alternative Fuels

## in **San Bernardino County**

Prepared for the Southern California Association of Governments (SCAG)  
and the San Bernardino County Transportation Authority (SBCTA)



Prepared by



# Table of Contents

<b>Executive Summary .....</b>	<b>1</b>
Introduction .....	1
Clean Fuels Overview .....	1
Scenario Analysis and Results .....	3
Barriers to Clean Vehicle Technologies .....	6
Implementation Strategies for Clean Vehicles .....	7
Summary of Opportunities and Risks .....	13
<b>1 Introduction .....</b>	<b>20</b>
1.1 Study Overview .....	20
1.2 Air Pollution and Climate Change Challenges .....	20
<b>2 Options for Clean Vehicle Technologies and Fuels .....</b>	<b>23</b>
2.1 Electric Vehicles .....	24
2.2 Fuel Cell Vehicles .....	34
2.3 Natural Gas Vehicles .....	38
2.4 Renewable Natural Gas .....	41
2.5 Ethanol .....	42
2.6 Renewable Gasoline .....	43
2.7 Biodiesel .....	43
2.8 Renewable Diesel .....	44
2.9 Vehicle Efficiency Improvements .....	45
<b>3 Existing Conditions .....</b>	<b>54</b>
3.1 Economic Data and Plans .....	54
3.2 Vehicle Population and Activity .....	58
3.3 Alternative Fueling Infrastructure .....	59
<b>4 Scenario Analysis Methodology .....</b>	<b>66</b>
4.1 Analysis Framework .....	66
4.2 Baseline Results .....	86
4.3 Scenario Development Process .....	98
<b>5 Analysis Results .....</b>	<b>103</b>
5.1 Scenario A: Electrification .....	103
5.2 Scenario B: Natural Gas as a Bridge to Electrification .....	109
5.3 Scenario C: Liquid Biofuels .....	115
5.4 Scenario D: Biofuels and Low-NOx Diesel Engines .....	119
5.5 Summary of Scenario Analysis Results .....	123
<b>6 Barriers to Implementation .....</b>	<b>129</b>
6.1 Light-Duty Vehicles .....	129
6.2 Medium- and Heavy-Duty Vehicles .....	142
6.3 Regulatory Authority .....	154
<b>7 Implementation Strategies .....</b>	<b>156</b>
7.1 Introduction .....	156

7.2 Municipal Fleet Vehicles ..... 158

7.3 Private Vehicles..... 165

7.4 Commercial Fleet Vehicles..... 173

**8 Conclusion – Discussion of Opportunities and Risks ..... 178**

**Appendix A. Regulations and Incentive Programs ..... 184**

## Table of Tables

Table 1. List of Clean Vehicle Technologies and Fuels .....	1
Table 2. Summary of Benefits, Risks, and Uncertainties .....	19
Table 3. Summary of Major Vehicle Types .....	24
Table 4: Natural Gas Fueling Infrastructure Costs .....	40
Table 5: Population and Employment by County, 2016 .....	54
Table 6. Vehicle Population and VMT in Study Area, 2016 .....	59
Table 7. HDV VMT by Truck Type in Study Area, 2016 .....	59
Table 8. EVs as a Percent of Total Vehicle Registrations, as of January 1, 2019 .....	59
Table 9. County EVSE Charging Stations .....	62
Table 10. EMFAC Vehicle Categories .....	70
Table 11. Assumed PHEV Utility Factor by Model Year .....	71
Table 12. Redistribution of ZEV.....	72
Table 13. Energy Economy Ratios.....	72
Table 14. Carbon Intensity of Fossil Fuels.....	74
Table 15. CAMX Region Projected Grid Carbon Intensity by Year .....	75
Table 16. Carbon Intensity Values for Various Biofuels.....	75
Table 17. Biofuel Emissions Factors and Percent of Total Volume.....	76
Table 18: NOx Emission Factors for Representative Vehicle Types, aggregated model years.....	77
Table 19: PM2.5 Emission Factors for Representative Vehicle Types, aggregated all model years.....	78
Table 20. Fueling Infrastructure Installation and Equipment Costs .....	85
Table 21. Maintenance Cost per VMT .....	85
Table 22. Summary of Vehicle Population and Emissions, 2016, 2031, and 2040 .....	87
Table 23. Baseline Scenario Cumulative Costs, 2016 – 2040.....	97
Table 24. Zero Emission Sales Requirements for Proposed Advanced Clean Trucks Regulation .....	98
Table 25. EV Sales Fractions by Vehicle Type – Electrification Scenario .....	99
Table 26. NGV and EV Sales Fractions by Vehicle Type – Natural Gas as a Bridge Scenario .....	100
Table 27. Changes in Blend Percentages and Carbon Intensity – Biofuels Scenario .....	101
Table 28. Electrification Scenario Vehicle Population by Vehicle Type, 2016, 2031, and 2040 .....	103
Table 29. Electrification Scenario CO2e Emissions Impacts (MMT), 2040 .....	104
Table 30. Electrification Scenario NOx Emissions Impacts (thousand MT), 2040.....	105
Table 31. EV Sales Fractions for Aggressive Electrification Scenario .....	108
Table 32. Emissions Impacts of Aggressive Electrification Scenario (thousand MT), 2040 .....	109
Table 33. Natural Gas as a Bridge Scenario Vehicle Population by Vehicle Type, 2016, 2031, and 2040 .....	110
Table 34. Natural Gas as a Bridge Scenario CO2e Emissions Impacts (MMT), 2040 .....	112
Table 35. Natural Gas as a Bridge Scenario NOx Emissions Impacts (thousand MT), 2040 .....	112
Table 36. Biofuels Scenario CO2e Emissions Impacts (MMT), 2040.....	116
Table 37. Low NOx Diesel & Biofuels Scenario NOx Emissions Impacts (thousand MT), 2040 .....	121
Table 38. Price Comparison Between ICE Vehicle and EV Models .....	130
Table 39. Light-Duty Vehicle Model Availability by Body Type.....	133
Table 40. Estimated EV Charger Needs in San Bernardino County to Meet 2025 ZEV Goal .....	136
Table 41. EV Models Eligible for HVIP Incentives .....	143
Table 42. Per-Charger DCFC Make-Ready and Installation Costs .....	144

Table 43. SCE TOU-EV-8 Electricity Rate for Commercial EV Customers..... 145

Table 44. Natural Gas Fueling Infrastructure Costs ..... 148

Table 45. List of Clean Vehicle and Fuel Options ..... 156

Table 46. Commercialization Stages of Medium and Heavy-Duty EV Technologies ..... 162

Table 47. State Agency MD/HD EV Incentive Programs ..... 163

Table 48. Potential DCFC Sites in San Bernardino County ..... 167

Table 49. AB 1236 Requirements..... 167

Table 50. CALGreen 2020 EV Ready Requirements ..... 169

Table 51. State Agency Light Duty EV Incentive Programs ..... 172

Table 52. SCE TOU-EV-8 Electricity Rate for Commercial EV Customers..... 175

Table 53. Summary of Benefits, Risks, and Uncertainties ..... 183

Table 54. Advanced Clean Truck Regulation ZEV Sales Percentage Schedule..... 188

Table 55: ZANZEFF Project Awarded Fiscal Year 2017-18 ..... 192

Table 56: Funding for 2019-2020 Low Carbon Transportation & Air Quality Improvement Programs ... 193

Table 57: Per Capita GHG Reductions Reported in SCAG’s 2020 RTP/SCS ..... 195

## Table of Figures

Figure 1. Comparison of GHG Emissions by Scenario .....	4
Figure 2. Comparison of NOx Emissions by Scenario.....	5
Figure 3. Incremental Cumulative Costs (Relative to the Baseline), 2016-2030 .....	6
Figure 4. Incremental Cumulative Costs (Relative to the Baseline), 2016-2040 .....	6
Figure 5. CVRP Rebates by Geography: San Bernardino County .....	10
Figure 6. Relative Emission Rates of Sample Vehicles, 2018 .....	14
Figure 7. CEC Forecast Vehicle Purchase Costs for a Typical Light Duty Automobile.....	15
Figure 8. South Coast Air Basin NOx Emissions (tons per day) .....	21
Figure 9. California GHG Emissions Target.....	22
Figure 10. List of Clean Vehicle Technologies and Fuels.....	23
Figure 11. Medium and Heavy-Duty Zero Emission Vehicle Models Available .....	28
Figure 12. Real-World U.S. Vehicle Fuel Economy and GHG Emission Rates Through 2018.....	47
Figure 13. Forecast Growth Rate of Population and Employment, 2016-2040.....	54
Figure 14. Distribution of Job by Economic Sector, 2016 .....	55
Figure 15. Forecast Change in San Bernardino County Employment by Sector, 2016 – 2040 .....	56
Figure 16. Total Occupied Space of Industrial Warehouse Buildings in Square Feet, 2014 .....	57
Figure 17. Blue Collar Job Growth in the Inland Empire by Economic Sector, 2007-2018 .....	58
Figure 18. Biodiesel and Ethanol Fueling Stations in Study Area.....	61
Figure 19. Public Electric Vehicle Charging Locations in Study Area .....	62
Figure 20. Private Electric Vehicle Charging Locations in Study Area.....	63
Figure 21. Natural Gas Fueling Stations in Study Area .....	64
Figure 22. Propane Fueling Stations in Study Area.....	65
Figure 23. Flow Chart Overview of Analysis Framework .....	66
Figure 24. Analysis Area .....	67
Figure 25. Types of Vehicles by Weight Class .....	69
Figure 26. New Light Duty Vehicle Fuel Economy (miles per gge).....	73
Figure 27. New Heavy Duty Vehicle Fuel Economy (miles per dge) .....	73
Figure 28. Projected resource mix for the CAMX region based on RPS targets .....	74
Figure 29. Vehicle Purchase Costs by Fuel Type (LDA, or typical LDV) .....	79
Figure 30. Vehicle Purchase Costs by Fuel Type (T6 Small Instate, or typical MDV) .....	80
Figure 31. Vehicle Purchase Costs by Fuel Type (T7 Tractor, or typical HDV) .....	81
Figure 32. Fuel Cost Assumptions: Gasoline, Diesel, and Natural Gas Prices per Gallon Equivalent .....	82
Figure 33. VMT-Weighted Cost per Mile of HDVs by Technology .....	83
Figure 34. Baseline GHG and NOx Emissions in Study Area, 2016 – 2040.....	86
Figure 35. Baseline Vehicle Sales by Fuel Type .....	88
Figure 36. Baseline Vehicle Population by Fuel Type .....	88
Figure 37. Baseline VMT by Fuel Type .....	89
Figure 38. Baseline GHG Emissions by Vehicle Type.....	90
Figure 39. Baseline GHG Emissions by Vehicle Fuel Type .....	90
Figure 40. Baseline NOx Emissions by Vehicle Type .....	91
Figure 41. Baseline NOx Emissions by Vehicle Fuel Type .....	92
Figure 42. Baseline Light Duty Vehicle Purchase Costs.....	93

Figure 43. Baseline Medium Duty Vehicle Purchase Costs..... 94

Figure 44. Baseline Heavy Duty Vehicle Purchase Costs ..... 94

Figure 45. Baseline Light Duty Vehicle Fueling Costs..... 95

Figure 46. Baseline Medium Duty Vehicle Fueling Costs..... 95

Figure 47. Baseline Heavy Duty Vehicle Fueling Costs..... 96

Figure 48. Baseline Fueling Infrastructure Costs ..... 96

Figure 49. Baseline Vehicle Maintenance Costs ..... 97

Figure 50. Electrification Scenario Vehicle Population by Fuel Type..... 103

Figure 51. Electrification Scenario CO<sub>2</sub>e Emissions by Vehicle Type..... 104

Figure 52. Electrification Scenario NO<sub>x</sub> Emissions by Vehicle Type..... 105

Figure 53. Electrification Scenario Vehicle Purchase Costs ..... 106

Figure 54. Electrification Scenario Fueling Costs ..... 106

Figure 55. Electrification Scenario Infrastructure Costs ..... 107

Figure 56. Electrification Scenario Maintenance Costs ..... 108

Figure 57. Natural Gas as a Bridge Scenario Vehicle Population by Fuel Type..... 110

Figure 58. Natural Gas as a Bridge Scenario Vehicle Population by Fuel Type, MDV and HDV only..... 111

Figure 59. Natural Gas as a Bridge Scenario CO<sub>2</sub>e Emissions by Vehicle Type..... 111

Figure 60. Natural Gas as a Bridge Scenario NO<sub>x</sub> Emissions by Vehicle Type ..... 112

Figure 61. Natural Gas as a Bridge Scenario Vehicle Purchase Costs ..... 113

Figure 62. Natural Gas as a Bridge Scenario Fueling Costs ..... 114

Figure 63. Natural Gas as a Bridge Scenario Infrastructure Costs ..... 114

Figure 64. Natural Gas as a Bridge Scenario Maintenance Costs ..... 115

Figure 65. Biofuels Scenario Vehicle Population by Fuel Type ..... 115

Figure 66. Biofuels Scenario CO<sub>2</sub>e Emissions by Vehicle Type ..... 116

Figure 67. Biofuels Scenario NO<sub>x</sub> Emissions by Vehicle Type..... 117

Figure 68. Biofuels Scenario Vehicle Purchase Costs..... 117

Figure 69. Biofuels Scenario Fueling Costs..... 118

Figure 70. Biofuels Scenario Infrastructure Costs..... 118

Figure 71. Biofuels Scenario Maintenance Costs..... 119

Figure 72. Low NO<sub>x</sub> Diesel & Biofuels Scenario Vehicle Population by Fuel Type..... 119

Figure 73. Low NO<sub>x</sub> Diesel & Biofuels Scenario CO<sub>2</sub>e Emissions by Vehicle Type ..... 120

Figure 74. Low NO<sub>x</sub> Diesel & Biofuels Scenario NO<sub>x</sub> Emissions by Vehicle Type ..... 120

Figure 75. Low NO<sub>x</sub> Diesel & Biofuels Scenario Vehicle Purchase Costs ..... 121

Figure 76. Low NO<sub>x</sub> Diesel & Biofuels Scenario Fueling Costs..... 122

Figure 77. Low NO<sub>x</sub> Diesel & Biofuels Scenario Infrastructure Costs ..... 122

Figure 78. Low NO<sub>x</sub> Diesel & Biofuels Scenario Maintenance Costs ..... 123

Figure 79. Comparison of CO<sub>2</sub>e Emissions by Scenario..... 124

Figure 80. Comparison of NO<sub>x</sub> Emissions by Scenario..... 125

Figure 81. Comparison of Total Cost by Scenario ..... 126

Figure 82. Comparison of Fueling Infrastructure Costs by Scenario..... 126

Figure 83. Incremental Cumulative Costs (Relative to the Baseline), 2016-2030 ..... 127

Figure 84. Incremental Cumulative Costs (Relative to the Baseline), 2016-2040 ..... 128

Figure 85. Leading Automaker Domestic EV Sales and the Federal EV Tax Credit Sales Threshold..... 131

Figure 86. 2018 General Motors Ad Spend: Chevy Silverado and Chevy Bolt..... 134

Figure 87. Hydrogen Fueling Stations in Southern California ..... 138

Figure 88. Ownership of U.S. Convenience Stores Selling Fuel ..... 140

Figure 89. Heavy-Duty Fast Fill NGV Fueling Infrastructure Locations ..... 149

Figure 90. Illustrative Graphic of LCFS Declining CI Curve ..... 150

Figure 91. RNG and Fossil Natural Gas LCFS Annual Fuel Volumes ..... 151

Figure 92. B20 Fueling Station Locations in Southern California ..... 153

Figure 93. Example of Total Cost of Ownership Analysis ..... 158

Figure 94. CVRP Rebates by Geography: San Bernardino County ..... 166

Figure 96. Relative Emission Rates of Sample Vehicles, 2018 ..... 178

Figure 97. CEC Forecast Vehicle Purchase Costs for a Typical Light Duty Automobile ..... 179

Figure 98. Changes in Federal HDV NOx and PM Emission Standards ..... 185

Figure 99. Impact of CARB Truck & Bus Rule on Truck Age Distribution ..... 187



# Executive Summary

## Introduction

San Bernardino County is an economically dynamic region with over 2.2 million residents and 700,000 jobs. It is also a major transportation hub that supports goods movement across California and the United States. At the same time, the region faces urgent challenges associated with air quality and climate change. The most populated areas of the County in the South Coast Air Basin are in “extreme nonattainment” for federal ozone standards, which is exacerbated by the combustion of fossil fuels for transportation and emissions of nitrogen oxides (NOx). To meet federal ozone standards, the South Coast Air Basin must reduce nitrogen oxide emissions 45 percent by 2023 and 55 percent by 2031 relative to baseline levels. The combustion of fossil fuels also generates greenhouse gas (GHG) emissions that contribute to climate change, and San Bernardino County is already experiencing its impacts. In response, State and local governments have established aggressive goals to cut GHG emissions and mitigate the worsening effects of climate change. On-road vehicles are responsible for about one-third of GHG emissions in San Bernardino County; any comprehensive approach to addressing climate change must therefore address emissions in the transportation sector. One core strategy to reduce air pollutant and GHG emissions from this sector is the transition toward clean fuel and vehicle technologies.

## Clean Fuels Overview

There are a range of clean vehicle and fuel options that local governments, residents, and fleets can pursue to mitigate on-road transportation emissions. Light, medium, and heavy-duty vehicle types each have viable alternatives to petroleum fuels that can reduce their environmental footprint.

**Table 1. List of Clean Vehicle Technologies and Fuels**

Vehicle or Fuel Type	Most Relevant for:	
	Light Duty Vehicles	Medium and Heavy-Duty Vehicles
Electric Vehicles	●	●
Fuel Cell Vehicles	●	●
Natural Gas Vehicles		●
Renewable Natural Gas		●
Ethanol	●	
Renewable Gasoline	●	
Biodiesel		●
Renewable Diesel		●
Fuel Efficiency Improvements	●	●

**Plug-in electric vehicles (EVs)** are now have wide commercial availability and offer a promising alternative to both gasoline and diesel-powered vehicles. EVs are typically broken out into two distinct architectures: plug-in hybrid electric vehicles (PHEVs) use a battery and internal combustion engine for propulsion while battery electric vehicles (BEVs) rely solely on a battery. Supported by complementary policies and incentives, light-duty EV sales have surpassed 700,000 units in California and continue to grow as more models become available to consumers. Many EVs do not have driving ranges comparable to their internal combustion engine counterparts; however, the ability to charge EVs when parked for long periods of time (e.g., home, workplace) makes them well-suited to handling the daily driving needs of most consumers. The electrification of medium and heavy-duty vehicles is underway with varying degrees of commercialization among vehicle segments. Transit buses are currently the most mature segment for heavy-duty EVs. California’s public transit agencies have already deployed over 150 zero-emissions buses – the overwhelming majority of which are all-electric – and based on bus orders and planned purchases, the California Air Resources Board (CARB) expects that figure to rise to 1,000 by the end of 2020. In comparison, the electrification of heavy-duty regional and long-haul trucks is still limited. However, many electric truck demonstrations are in progress across Southern California and several models are already commercially available today. Adoption of the California Advanced Clean Trucks Regulation on June 25, 2020 will accelerate this process. EVs in all market segments typically exhibit a higher upfront cost than comparable internal combustion engine vehicles. However, EVs are energy efficient and produce zero tailpipe emissions, battery costs continue to decline, fuel costs can be very competitive with alternatives, and the ubiquity of the electric grid makes electric fuel accessible in most cases.

Similar to EVs, **fuel cell vehicles (FCVs)** use electricity to power an electric motor. However, the electricity instead comes from stored hydrogen gas that passes through a fuel cell that generates an electric current by splitting hydrogen molecules into electrons and protons. Light-duty FCVs are commercially available, but have not been deployed to the same degree as light-duty EVs and have far fewer models available. Commercial deployment of FCVs has been relatively limited to date. Like medium and heavy-duty EVs, transit buses are the most mature application for medium- and heavy-duty FCVs; 30 fuel cell buses are currently in operation in California. Beyond transit buses, medium- and heavy-duty FCV deployment and demonstration projects have been primarily focused at ports and in parcel delivery applications in California. The challenge with widespread deployment of FCVs is related less to the vehicles and more to the infrastructure needed to fuel them. There are about 40 public hydrogen fueling stations available in California today in part due to the high levels of investment needed to develop them. FCV advantages include quick fueling, relatively low-emissions, efficiency, and long ranges, which may make them suited for longer-haul and drayage applications. However, cost of fuel cell technology and hydrogen as well as the availability of hydrogen fueling infrastructure prove to be significant barriers to the widespread commercialization of this technology in the near-term.

**Natural gas vehicles (NGVs)** are predominately found among heavy-duty vehicle segments including transit buses, refuse haulers, and on-road trucks. According to the Port of Los Angeles and Port of Long Beach’s *2018 Feasibility Assessment for Drayage Trucks*, NGVs comprise 3 percent of the Ports’ drayage fleet and are the most dominant alternative fuel vehicle drayage truck platform with demonstrable model availability from major original equipment manufacturers (OEMs), dealership engagement, production capabilities, and customer interest. Natural gas from fossil sources offers modest GHG emission reductions relative to diesel, although renewable natural gas can significantly reduce GHG

emissions and provides a drop-in alternative to fossil natural gas. NGVs can reduce nitrogen oxides by 50-90 percent, and new low-NOx engines meet a voluntary emissions standard that is 90 percent below the current NOx standard. NGVs may have an incremental upfront price premium of \$50,000 above comparable diesel vehicles, though State and regional incentives can reduce costs for qualified vehicles.

**Ethanol** is a fuel produced from corn or cellulosic feedstocks, such as crop residues and wood. All gasoline in California consists of a blend of 10 percent ethanol and 90 percent gasoline. E85, known as flex fuel, is an ethanol blend containing 51-83 percent ethanol and is only for use in flex fuel vehicles. On a life cycle basis, ethanol produced from corn reduces GHG emissions by about 30 percent compared to gasoline. Ethanol produced with cellulosic feedstocks can reduce GHG emissions from 50-90 percent when land-use change emissions are considered. Although flex fuel vehicles are priced comparably to other internal combustion engine alternatives, there is limited commercial availability among smaller vehicles. The costs to retrofit a gas station for the sale of E85 can vary widely.

**Renewable Diesel** is a drop-in replacement for diesel fuel made from biomass and can be blended with diesel fuel without limitation. Due in part to incentives that result from the Low Carbon Fuel Standard, use of renewable diesel has been increasing rapidly in California. In 2019, renewable diesel accounted for approximately 16 percent of all diesel sold in the state, based on reporting for the Low Carbon Fuel Standard. Lifecycle emissions of renewable diesel depends on the fuel feedstock, but renewable diesel offers similar GHG emissions reductions to biodiesel. RD5 reduces GHG emissions by about 3 percent and RD100 reduces GHG emissions by about 66 percent.

## Scenario Analysis and Results

To assess how advanced vehicle technologies could support San Bernardino County's air quality and climate goals, ICF developed an analysis tool to quantify the emissions and cost impacts of alternative paths to clean vehicle and fuels implementation for the vehicle fleet in the region through 2040. The tool characterizes a baseline scenario that reflects the vehicle population, travel activity, emissions, and costs assuming expected technology changes and implementation of all adopted rules and regulations, but no additional rules, regulations, or significant incentive programs. The tool then allows characterization of alternative scenarios that modify the baseline vehicle and fuel assumptions in order to explore the emissions and cost impacts of these scenarios. The analysis framework breaks out the on-road vehicle population into 35 vehicle types and includes five primary fuel types (gasoline, diesel, natural gas, electricity, and hydrogen). The outputs of the model include vehicle populations, fuel use, emissions of key pollutants, and costs associated with vehicle purchase and operation.

ICF developed four alternative scenarios that represent alternatives paths to addressing air quality and change goals in San Bernardino County. To illustrate the trade-offs among the path options, these scenarios are designed to focus heavily on a single fuel type or technology:

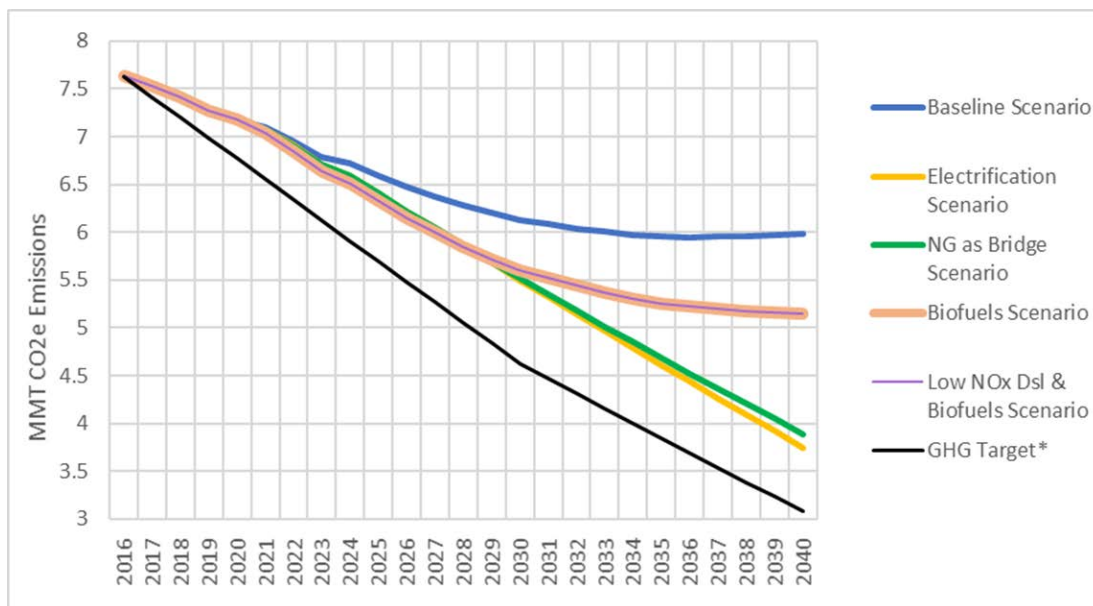
- **Electrification.** This scenario reflects a future with a faster-than-expected transition towards electrification among all vehicle types.
- **Natural Gas as a Bridge to Electrification.** This scenario relies primarily on natural gas for heavy-duty vehicle emission reductions through the South Coast Air Basin ozone attainment period. NGVs essentially serve as a bridge technology until electric truck costs decline sufficiently to

warrant significant deployment in medium and heavy-duty sectors. For light-duty vehicles, the scenario assumes widespread electrification.

- **Liquid Biofuels.** This scenario reflects a future with aggressive reductions across the spectrum linked to liquid biofuel consumption—including reduced carbon intensity of existing ethanol, higher consumption of ethanol in light-duty vehicles, and renewable diesel in heavy-duty vehicles. Accelerated turnover of the vehicle fleet is not needed.
- **Biofuels and Low NOx Diesel Engines.** This scenario reflects a future with low NOx diesel engines for heavy duty trucks in addition to the potential reductions linked to liquid biofuel consumption. Accelerated turnover of the vehicle fleet is not needed.

The results of the scenario analyses reinforce the aggressive nature of San Bernardino County’s climate and air quality goals. The figure below shows the GHG emissions under the Baseline and four analysis scenarios. The Electrification and Natural Gas as a Bridge Scenarios provide the largest reductions and are quite similar in terms of their GHG impacts. The Biofuels and Low NOx Diesel & Biofuels Scenarios are identical in terms of their GHG impacts, since the low NOx diesel engines do not affect GHG emissions. These two scenarios follow a similar emissions trajectory as Electrification and Natural Gas as a Bridge through 2030, but provide only modest additional reductions after 2030. None of the four scenarios achieve GHG emissions levels necessary to achieve reductions proportional to California’s statewide GHG targets.

**Figure 1. Comparison of GHG Emissions by Scenario**

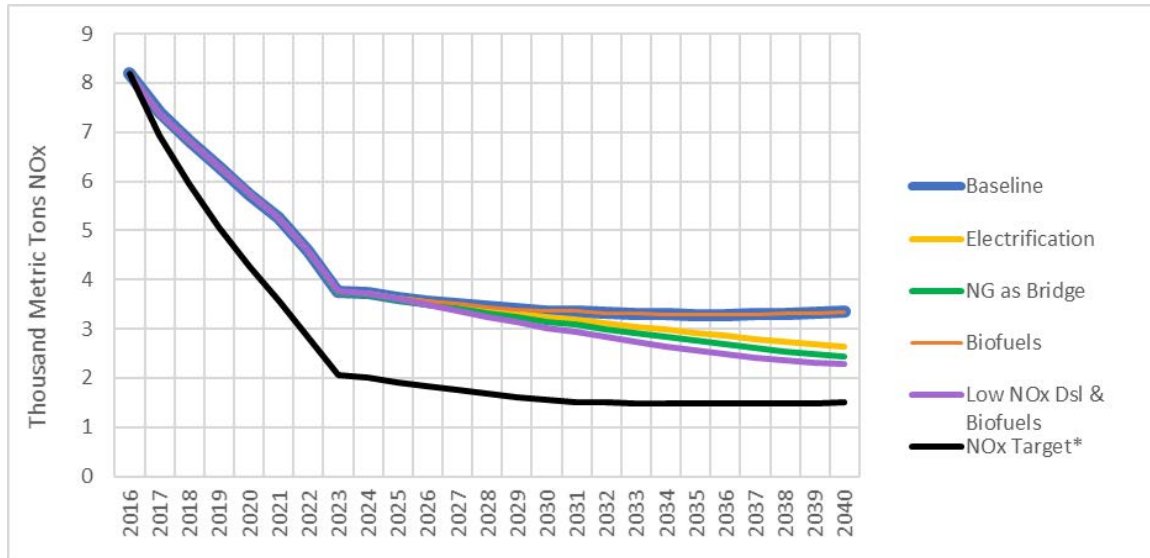


\* GHG target reflects the percent reductions needed statewide from all sources to achieve California’s 2030 and 2050 emissions targets.

The figure below illustrates the annual NOx emissions of the scenarios over the analysis period and their relationship to the NOx emissions target identified for the study area. NOx emissions under all scenarios rapidly decline until 2023 – driven by CARB’s Truck and Bus Regulation. Beyond 2023, all scenarios gradually reduce NOx emissions, with the Low NOx Diesel & Biofuels Scenario achieving the best performance in terms of NOx reductions over the remainder of the analysis period. Given that diesel

HGVs are the largest contributor to on-road NOx emissions, the adoption of low NOx diesel engines can have an outsized impact on reducing these emissions as other alternative fuels achieve scale in the market. The Natural Gas as a Bridge and Electrification Scenarios also achieve significant NOx reductions, albeit at a slightly more gradual rate. The Biofuels Scenario has no impact on NOx emissions and thus mirrors the Baseline Scenario emissions. None of the scenarios evaluated achieve the percent reduction in NOx emission identified in the South Coast Air Quality Management District’s 2016 Air Quality Management Plan for all emissions sources.

**Figure 2. Comparison of NOx Emissions by Scenario**



\* NOx target reflects the percent reduction in NOx emissions in the South Coast Air Basin from all sources necessary to achieve attainment with the federal ozone standard, as presented in the 2016 Air Quality Management Plan

The two figures below illustrate how each scenario compares to the Baseline Scenario in terms of cumulative costs between 2016-2030 and 2016-2040. These charts show only the difference between the Baseline and each scenario (i.e., the Baseline is zero in these charts). Overall, the Biofuels and Low NOx Diesel & Biofuels Scenarios generally track the Baseline costs throughout the analysis period. These scenarios require a minor incremental investment in infrastructure (\$6 million over the analysis period) – an amount that is much smaller than the other two scenarios.

The Electrification and Natural Gas as a Bridge Scenarios differ significantly from the Baseline Scenario. Both require significant incremental vehicle purchase costs (or incentives), particularly in the early years of analysis. However, both scenarios also illustrate substantial fuel cost savings relative to the baseline due to the relatively low cost to operate EVs and NGVs. Overall, considering the full analysis period out to 2040, the Electrification and Bridge Scenarios offer the greatest potential cumulative cost savings relative to the Baseline Scenario.

**Figure 3. Incremental Cumulative Costs (Relative to the Baseline), 2016-2030**



**Figure 4. Incremental Cumulative Costs (Relative to the Baseline), 2016-2040**



## Barriers to Clean Vehicle Technologies

As shown in the scenario analyses, clean vehicles and fuels provide numerous opportunities to reduce GHG and air pollutant emissions from the on-road transportation sector. However, scaling the transition to cleaner vehicles and fuels requires a paradigm shift in the manner that public and private organizations approach transportation. To better understand the strategies needed to accelerate clean transportation, we identified economic, technological, and policy barriers associated with alternative fuel vehicles, with a specific focus on San Bernardino County.

Light-duty EVs face a range of barriers that may limit their near-term adoption, including high upfront vehicle costs, limited model diversity relative to gasoline vehicles, lack of education and awareness among consumers and dealerships, and dearth of accessible charging infrastructure. Light-duty FCVs face many similar issues to EVs, though the magnitude of the hurdles are even greater. Accessible

fueling infrastructure is perhaps the greatest challenge for the expansion of FCVs due to high costs and long development timelines. Ethanol fuels are already widely used in the form of E10, but it is challenging to increase the ethanol content of blended gasoline. Uncertain regulatory processes, compatibility issues with current vehicles and fueling infrastructure, the fragmented nature of the fuel retailer market, relatively limited emissions benefits, and limited driver awareness all pose challenges to increasing ethanol fuel use in San Bernardino County.

EVs also face challenges to commercialization in medium and heavy-duty sectors. High upfront vehicle costs, lack of model availability, customer concerns of vehicle performance, and lack of publicly available charging can all inhibit near-term adoption. Heavy-duty FCVs encounter similar high-level challenges to heavy-duty EVs; however, these vehicles are not as mature as EVs in many cases and may require more time to achieve commercialization. NGVs experience somewhat higher vehicle costs than diesel alternatives, customer concerns regarding performance, and potentially significant infrastructure costs. Natural gas also faces greater regulatory risks as CARB and other State agencies move to develop regulations and incentives that prioritize the adoption of zero-emission fuels. Supply risks may also constrain the renewable natural gas market in the mid to long-term. Biofuels may suffer from potentially higher emissions than diesel alternatives, relatively limited public fueling infrastructure, and regulatory risks similar to natural gas.

## Implementation Strategies for Clean Vehicles

Local governments alone cannot achieve the transportation sector emissions reductions necessary to meet San Bernardino County's air quality and climate goals. However, these jurisdictions can pursue a range of strategies to accelerate the use of clean vehicles and fuels across municipal, private, and commercial fleets. For light-duty vehicles, it is clear that EVs are poised to play a significant role in reducing emissions and should be a core focus of local government's clean vehicle efforts. For medium and heavy-duty vehicles, the outlook is less certain. In the long-run, electric powertrains are expected to dominate the marketplace, and State regulations are driving manufacturers to sell more EVs across all vehicle classes. But for at least the next decade, a number of different technologies and fuels can offer solutions for medium and heavy-duty vehicles; the optimal clean vehicle option will depend heavily on the vehicle's duty cycle, range, payload, fueling requirements, and other factors. This phenomenon, sometimes described as the "messy middle", will require public agencies to stay informed about various vehicle options and support those that are most feasible and beneficial to County residents and businesses.<sup>1</sup> In spite of this uncertain outlook for some clean vehicles and fuels, local governments can still pursue a portfolio of low-risk strategies to complement the efforts of other regional stakeholders and prepare for future clean transportation investments.

**Municipal Fleet Vehicles.** If local governments in San Bernardino County seek to maximize the use of clean fuels and technologies for vehicles operating in the region, it is important that they lead by example. Local governments can play an important role in maximizing the deployment of cleaner transportation alternatives; although government fleets contain a small fraction of the total vehicle population operating in the County, these fleets have historically been leaders in the use of low-

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<sup>1</sup> North American Council for Freight Efficiency, Guidance Report: Viable Class 7/8 Electric, Hybrid and Alternative Fuel Tractors, 2019. <https://nacfe.org/report-library/guidance-reports/>



emission vehicles and fuels. With direct control over the municipal fleets, local governments can help reduce emissions, increase adoption of cleaner technologies, and demonstrate their environmental stewardship to the private sector and the communities they serve. The following implementation strategies can be used to reduce emissions from municipal fleets:

- **Conduct a fleet assessment:** A first step in greening local government fleets is conducting a fleet assessment to identify the best opportunities to replace gasoline and diesel vehicles that are being retired with alternative fuel vehicles. Cities can start by documenting the current municipal fleet, including the number of vehicles, fuel type, annual mileage, fuel consumption, and fueling locations. Establishing a baseline for fuel use and fuel expenditures will help a city identify opportunities for improvement and allow the city to track progress over time. If municipal vehicles do not re-fuel at a centralized location, the city might need to implement record-keeping procedures to track fuel purchasing.
- **Establish light-duty EV procurement goals:** EVs have demonstrated significant potential to reduce emissions from the light-duty transportation sector, and local governments can accelerate the adoption of EVs through procurement of EVs for their own fleets. Establishment of formal procurement targets is directly within local governments' control, provides municipal fleets with firsthand experience owning and operating EVs, and potentially allows for significant fuel and maintenance cost savings over the life of the vehicles.
- **Establish clean medium and heavy-duty procurement goals:** Several options for alternative fuel medium and heavy-duty vehicles exist today across virtually all vehicle types. Local governments should explore these options, identify appropriate choices, and integrate these vehicles into fleet purchasing decisions via flexible procurement goals. Like targets for light-duty vehicles, targets can focus on near-term procurement while extending to 2030. However, given the diversity of medium and heavy-duty vehicle vocations and evolving commercialization status of different alternative fuel vehicle options, targets can be made flexible to account for uncertainty in future clean vehicle options. For example, targets may vary across vocations and may be inclusive of all viable alternative fuel vehicle options without specifying a particular technology.
- **Expand light-duty charging infrastructure investment:** Cities must accommodate additional EVs with corresponding investments in fleet charging infrastructure. Fleet managers should seek to deploy charging stations that meet the performance requirements and duty cycles of the EV fleet while minimizing costs. As fleets deploy charging infrastructure to meet their near-term needs, fleet managers may consider "futureproofing" their parking sites by making electrical upgrades necessary to support future charging station deployments. This approach to fleet planning could generate long-term savings when higher penetrations of EVs are incorporated into city fleets.
- **Leverage vehicle master purchase contracts:** Local governments can often buy alternative fuel vehicles at lower prices by using a state or county master contract. By leveraging these procurement programs, a city can take advantage of the larger state or county purchase contracts to gain more favorable vehicle pricing. Cities have used the State Department of General Services (DGS) contracts to purchase cars, SUVs, and trucks. DGS awards master vehicle contracts to individual dealerships for specific models of vehicles within a general class of



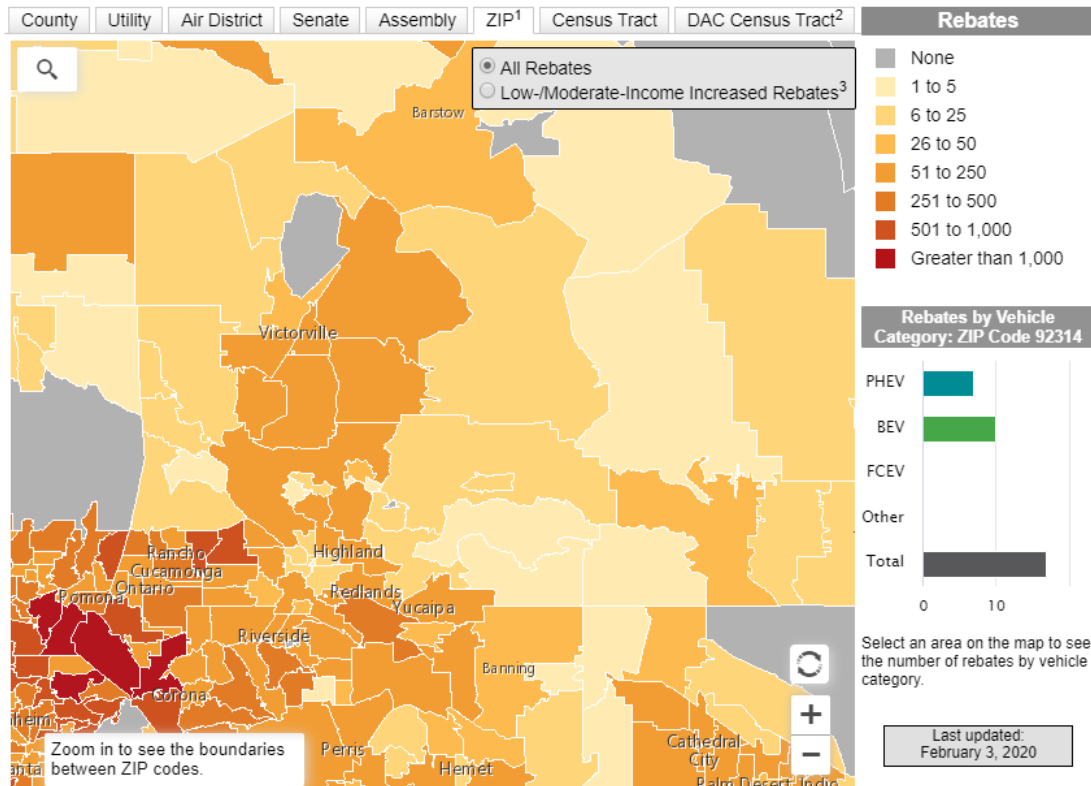
vehicles. Local agencies can order vehicles directly from the selected dealerships under the DGS master contracts.

- **Establish renewable natural gas goals for NGVs:** If a city is operating natural gas vehicles, the GHG emissions from these vehicles can be significantly reduced by using renewable natural gas (RNG). Some state incentive programs, such as the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), already require vehicles purchased through the program to secure RNG contracts to cover all of the planned vehicle fuel use. However, local governments can build on this requirement by procuring renewable natural gas to cover the fuel use of all NGV fleet vehicles—reducing the emissions associated with fleet vehicle operations.
- **Establish renewable diesel procurement goals for remaining diesel vehicles:** For diesel vehicles in municipal fleets that cannot readily transition to alternative fuels, local governments can establish renewable diesel procurement goals to lower GHG emissions associated with their operation. Renewable diesel is a drop-in replacement for fossil diesel at all blend levels, and cities can contract with fuel suppliers to supply renewable diesel to support their fleet operations at prices comparable to fossil diesel.
- **Participate in the Low Carbon Fuel Standard:** The Low Carbon Fuel Standard (LCFS) is a market-based regulation designed to reduce the carbon intensity of transportation fuel in California and can provide municipal fleets with a revenue stream to offset costs associated with alternative fuels and infrastructure. Qualified fleets can generate credits based on the tons of GHGs reduced from the use of alternative fuels, including electricity, renewable natural gas, and renewable diesel. These credits must be reported quarterly to CARB and can be sold to obligated parties to generate a new revenue stream to offset fueling costs. The lower the carbon intensity of the fuel, the more credits a fleet can generate per unit of fuel.

**Private Vehicles.** Most residents who live, work in, or visit San Bernardino County drive light-duty passenger vehicles. Light-duty vehicles comprise the majority of on-road GHG emissions in the County and a significant portion of on-road NOx emissions that cause ozone pollution. The following strategies outline how local governments can encourage the adoption of EVs and associated charging infrastructure in the San Bernardino region. More information on San Bernardino County’s light-duty EV landscape is also available in SBCTA’s 2019 “Zero-Emission Vehicle Readiness and Implementation Plan.”

- **Assess EV registrations in local jurisdictions:** Cities can plan more effectively for the transition to alternative fuel vehicles by completing a detailed assessment of vehicle registrations in their jurisdiction. The California Department of Motor Vehicles compiles and reports data on vehicle registrations by fuel type, by county, city, or zip code. This data source can be used to determine the number and percent of battery electric, plug-in hybrid, fuel cell, ethanol, and natural gas vehicles are registered at the city level. Officials can also develop more accurate estimates of EVs and FCVs in their jurisdiction by using Clean Vehicle Rebate Project (CVRP) data. According to the Zero-Emission Vehicle Readiness and Implementation Plan, 52 percent of CVRP rebates were for PHEVs, 46 percent for BEVs, and 2 percent for FCVs. The CVRP also maintains a rebate map that provides zip code and census tract-level information that cities can use. The figure below shows CVRP participation by zip code across a portion of San Bernardino County.

**Figure 5. CVRP Rebates by Geography: San Bernardino County**



Source: Center for Sustainable Energy

- **Identify EV charging infrastructure gaps:** Similar to assessing local EV registrations, cities can also identify gaps in local EV charging infrastructure networks by developing a greater understanding of current public charging investments. The U.S. Department of Energy’s Alternative Fuels Data Center Station Locator tool provides detailed information on publicly available charging infrastructure, including: station address, contact number, charging station type, plug type, number of outlets, and hours of accessibility. Station Locator maps can provide cities with a comprehensive view of where public charging infrastructure exists and where gaps remain.
- **Streamline EV charger permitting processes:** Streamlining EV charger permitting can improve the efficiency and cost-effectiveness of charging infrastructure deployment. Assembly Bill (AB) 1236 requires California cities to develop ordinances to streamline EV charging station permitting processes and provide clarity for EV charging service providers, site hosts, and local governments on permit review requirements. To help cities comply with the law, the California Governor’s Office of Business and Economic Development (GO-Biz) has developed several key resources on charging infrastructure permitting and installation, including the Electric Vehicle Charging Station Permitting Guidebook, the Permitting Electric Vehicle Charging Station Scorecard and Map, and a compilation of permitting best practices. Without streamlined, easy-to-follow permitting processes, cities risk losing opportunities for private EV charging infrastructure investment to jurisdictions with AB 1236-compliant procedures.

- **Strengthen EV-ready building codes:** Cities can help accelerate EV charger installation timelines and reduce costs by strengthening their local building codes. Several studies show that retrofitting electrical infrastructure to support EV charger installations can be 2-8 times more expensive than if the infrastructure is included during building construction. The state’s green building code (CALGreen) sets requirements for the construction of new buildings in California and has recently developed minimum requirements for the installation of electrical infrastructure (e.g. conduit, panels) that supports the deployment of EV charging stations. CALGreen has also developed “reach codes” that outline how local jurisdictions can exceed the requirements specified in the building code. These reach codes typically require higher percentages of parking spaces to be equipped with conduit and panel capacity necessary for additional Level 2 charging station deployments. Cities can also demonstrate leadership by strengthening EV readiness requirements beyond the furnishing of conduits and panels to include the installation circuits and wiring to support EV charging stations—further reducing the cost and complexity of deploying EV charging stations at the building site.
- **Deploy public EV charging infrastructure:** To expand access to electricity as a transportation fuel, local jurisdictions can make strategic investments to deploy EV charging stations in their communities. Cities own property that could be ideal to support community charging needs: municipally-owned parking lots at parks, libraries, other recreational areas, parking garages, and street parking may all provide valuable recharging opportunities for residents. Both State agency and utility EV programs offer potential avenues to receive incentives for the deployment of publicly accessible EV charging stations. Cities should also ensure that appropriate networking and maintenance contracts are in place to support the reliable and safe operation of EV charging stations in the long-term. In short, cities can stretch local resources further by seeking out additional funding to deploy charging stations that support their communities.
- **Explore EV shared mobility services:** Cities have begun promoting alternatives to vehicle ownership via EV carsharing and other shared mobility services; local jurisdictions can continue to assess the potential for these services in partnership with state agencies, non-profit and community-based organizations, and EV industry stakeholders. Car sharing services could provide access to e-mobility for residents that may not drive personal vehicles and could serve as a complement to public transit. Charging infrastructure deployment at designated car sharing parking spaces may also be necessary to refuel EVs in a timely manner and maintain utilization. Several state agencies have complementary programs and initiatives to support funding of zero-emission shared mobility services.
- **Support State EV programs:** Local governments can engage the State Legislature and relevant state agencies to encourage the expansion of programs that would accelerate EV adoption in the County. Participation in public hearings and comment periods can help demonstrate San Bernardino County’s leadership and commitment to advance transportation electrification.
- **Develop or update a Climate Action Plan (CAP):** Cities and county governments can develop and regularly update CAPs in accordance with local and state climate goals. CAPs leverage existing information from GHG inventories to establish GHG mitigation targets, identify cost-effective strategies to achieve these targets, and develop monitoring mechanisms to evaluate progress.

**Commercial Fleet Vehicles.** Most of the commercial vehicles in San Bernardino County are medium and heavy-duty trucks used for goods movement. The region’s economy is heavily concentrated in logistics and freight sectors, which contribute to the County’s air quality challenges. Although San Bernardino County may have little control over vehicle fleets based outside the region, local governments can implement measures to encourage the adoption of cleaner vehicles in commercial fleets.

- **Support knowledge maintenance on emerging technologies:** The medium and heavy-duty transportation sector is undergoing rapid change with the emergence of zero-emission alternatives to traditional diesel vehicles across an array of vehicle platforms. Many new models are expected to be commercially available in 2021 or shortly thereafter. However, vehicle demonstration projects are underway now to assess the performance of these emerging technologies; some of these pilots are taking place in or adjacent to San Bernardino County as part of a continued effort to reduce local emissions. Local governments can reach out to CARB and other state or regional agencies to gather more information on pilot parameters and gain preliminary insights into the viability of various zero-emission vehicle options that may influence local clean transportation policy in the near-term.
- **Streamline hydrogen fueling station permitting processes:** Although it may be premature for local governments to make investments in hydrogen fueling infrastructure, FCVs may become commercially viable options for select heavy-duty applications and cities can enable private sector infrastructure investment by streamlining hydrogen fueling station permitting processes. Currently, permitting and deployment of hydrogen fueling stations is a time-intensive process: for hydrogen fueling stations completed via a 2015 California Energy Commission (CEC) grant funding opportunity, it took 386 days on average to advance from an initial permit application to approval to begin construction. Cities can pursue a menu of options to streamline permitting processes and ultimately increase the availability of hydrogen fueling infrastructure.
- **Streamline natural gas fueling station permitting processes:** NGVs powered by renewable natural gas will likely remain part of a comprehensive strategy to reduce emissions from medium and heavy-duty vehicles in San Bernardino County, and expanding natural gas fueling infrastructure will be critical for supporting the adoption of new NGVs. Inefficient permit review processes can cause infrastructure project delays that hinder the adoption of alternatives to diesel fuel. Similar to hydrogen fueling infrastructure, cities can facilitate private investment in infrastructure by ensuring that permitting of natural gas fueling stations is streamlined and efficient. Zoning ordinances can clarify the use of natural gas as a transportation fuel, and permitting officials could review applications solely based on health and safety criteria—reducing the risk of delays from aesthetic or other discretionary reviews. Permitting requirements can be made accessible via online checklist for station developers and fleet managers seeking to deploy compressed natural gas (CNG) fueling stations.
- **Streamline EV charger permitting processes:** Like private vehicles, commercial fleets may also benefit from streamlined EV charger permitting processes. Fleet owners may install EV charging equipment to coincide with the procurement of medium and heavy-duty EVs, elevating the importance of a straightforward, consistent permitting process.

- **Strengthen EV-ready building codes:** Similar to private vehicles, strengthening EV-Ready building codes for commercial and industrial facilities can also reduce the costs of deploying EV charging infrastructure for commercial fleets.
- **Support State clean vehicle programs:** Similar to light-duty vehicles, California has implemented a variety of programs aimed to accelerate the adoption of cleaner medium and heavy-duty vehicles. San Bernardino County can demonstrate its commitment to air quality and climate change goals by leveraging public hearings, solicitations for comment, and other forums to expand or improve programs for alternative fuel medium and heavy-duty vehicles.

## Summary of Opportunities and Risks

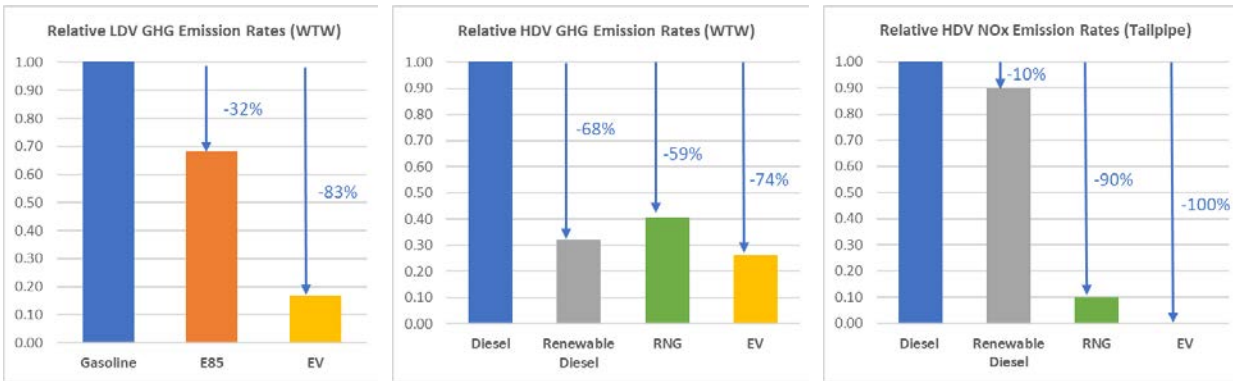
The information presented in this report shows the complexity involved in reducing emissions from the transportation sector. Each clean vehicle technology and alternative fuel option differs in terms of emissions benefits, vehicle and fuel costs, infrastructure requirements, technology readiness, and other factors. Some of the options are evolving rapidly, which adds to the uncertainty regarding future conditions. Given the complexities and uncertainties, it is impossible to identify, with a high degree of precision, a single set of actions for public and private sector entities seeking to advance clean transportation. The best approach is to understand the opportunities and risks associated with each clean transportation option, and to use this understanding to guide actions, with the recognition that shifts in direction may be needed over time. This section summarizes these opportunities and risks.

### Emissions Benefits

Tackling the dual challenge of climate change and ozone air pollution requires reducing emissions of two key pollutants: GHGs and NO<sub>x</sub>. Both EVs and natural gas vehicles using RNG will result in large reductions of these two pollutants. There are slight differences in the emissions benefits of these two options. GHG impacts depend on the electricity generation sources (which are becoming cleaner over time) and the source of RNG feedstock. EVs emit zero tailpipe emission of NO<sub>x</sub>, while NGVs emit small levels of NO<sub>x</sub>. Nonetheless, these differences are minor relative to the magnitude of emission reductions from both EVs and NGVs. In other words, emissions benefits alone should not be used to make a choice between EVs and NGVs – both options are highly beneficial.

Liquid biofuels, in contrast, can achieve large GHG reductions but only small NO<sub>x</sub> reductions. For this reason, biofuels such as ethanol, biodiesel, and renewable diesel can play an important role but should not be the centerpiece of the emission reduction strategy for San Bernardino County. The figure below illustrates the differences in emission rates for a typical light-duty vehicle (LDV) and heavy-duty vehicle (HDV) in 2018.

**Figure 6. Relative Emission Rates of Sample Vehicles, 2018**



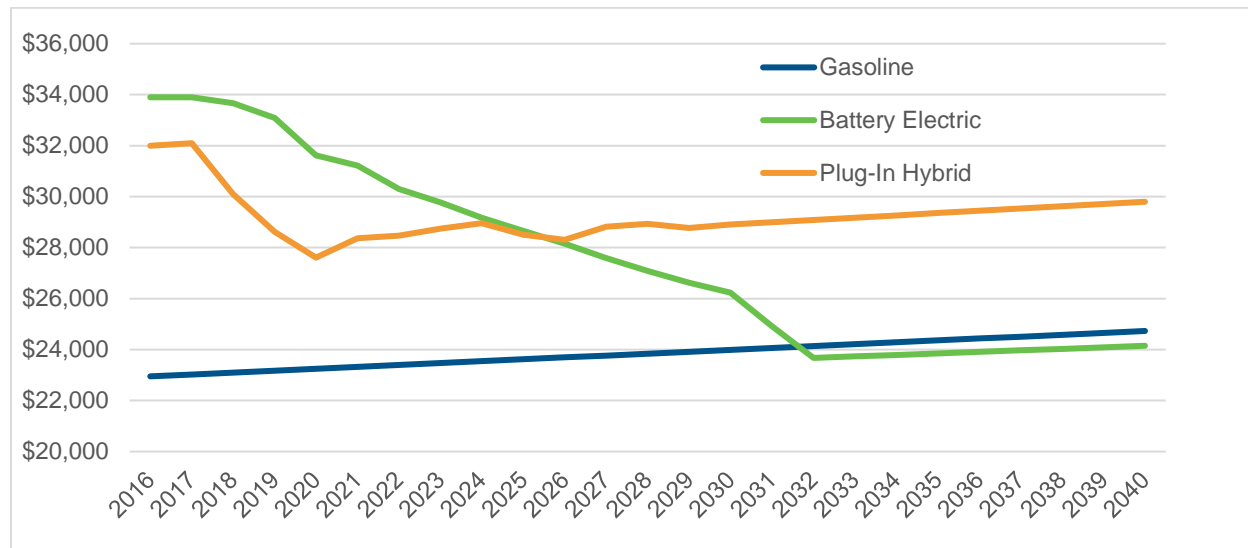
## Vehicle Costs and Incentives

One of the primary barriers to mass adoption of EVs and NGVs is the higher purchase price of these vehicles as compared to conventional gasoline and diesel vehicles. A light duty automobile EV currently costs 20 to 50 percent more than a similar gasoline vehicle; the price premium for an EV truck is even greater. A heavy-duty natural gas truck currently costs 20 to 50 percent more than a comparable diesel truck. EVs and NGVs benefit from lower fueling and operating costs (discussed below), so the total cost of ownership for EVs and NGVs can be lower, especially for vehicles with high annual mileage. But the current price premium prevents many buyers from considering these cleaner options, particularly given today’s low gasoline and diesel fuel prices. A major benefit of biofuels like renewable diesel is that they can be used in existing vehicles with little or no modification.

Government incentives can help overcome clean vehicle purchase costs, but existing incentive programs are inadequate to achieve significant market transformation. The federal tax credit of up to \$7,500 has helped spur EV sales, but it is now being phased out as leading manufacturers reach the statutory sales threshold. State incentive programs like HVIP have encouraged early adoption of heavy-duty EVs, but grant funding from these programs is regularly oversubscribed. Moreover, it is challenging to design and implement vehicle purchase incentives in a way that achieves the desired outcomes – enabling sales of clean vehicles that would not have otherwise occurred.

Looking ahead, it is widely expected that the price premium for EVs will decline, due largely to a drop in battery prices. CEC forecasts that battery electric automobiles will achieve price parity with gasoline vehicles by 2032, as illustrated in the figure below; other forecasters expect EV price parity even sooner. These price changes will reduce the need for government purchase incentives. However, the timing of the EV price changes is uncertain, which makes it hard for government agencies to plan and implement effective incentive programs.

**Figure 7. CEC Forecast Vehicle Purchase Costs for a Typical Light Duty Automobile**



Source: California Energy Commission

## Fueling and Operating Costs

One of the most attractive features of alternative fuel vehicles is the potential for lower fueling and operating costs. Fuel cost savings for EVs can be significant, particularly when drivers can take advantage of off-peak electricity rates. In California, the average price of an eGallon (gallon of gasoline equivalent for EVs) was \$1.74 compared to \$3.22 a gallon for regular gasoline as of March 2020.<sup>2</sup> EVs are also cheaper to maintain than conventional vehicles due greater reliability of batteries and electric motors as well as fewer fluids and moving parts. Automobile drivers who switch to an EV will typically save \$3,000 to \$4,000 over the first five years of vehicle ownership. Operators of medium and heavy-duty EVs can also see significant operating cost savings, with the magnitude of savings depending heavily on annual mileage.

Natural gas trucks benefit from fueling costs that are approximately 25 percent lower than comparable diesel trucks. Natural gas prices have also historically been more stable than diesel, allowing fleet owners to better predict their operating costs. Natural gas vehicle maintenance costs are comparable to diesel, according to Argonne National Laboratory’s AFLEET Tool.

Fuel cell vehicles currently face higher fueling costs. At an average hydrogen price of \$14 per kilogram, the price per energy equivalent to gasoline translates to \$5.60 per gallon. Some industry experts predict that hydrogen fuel prices could drop to \$8-\$10 per kilogram within the next five to ten years, at which point FCVs would approach fuel cost parity with gasoline and diesel vehicle vehicles.

Retail prices of liquid biofuels such as ethanol, biodiesel, and renewable diesel are similar to gasoline and diesel. Although biofuels may be more expensive to produce, their lower carbon intensity can

<sup>2</sup> U.S. Department of Energy, “Saving on Fuel and Vehicle Costs,” [www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs](http://www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs)



generate credits under California’s low carbon fuel standard, which are typically used to offset any purchase price premium.

## Technology Readiness

Gasoline and diesel internal combustion engines have been manufactured and continually improved for more than a century. These technologies have been optimized for the performance and reliability demanded by customers. While clean vehicle technologies like EVs, NGVs, and FCVs all show promise, they remain relatively new, and therefore face questions about how ready these technologies are to replace conventional vehicles across the full spectrum of vehicle types and applications.

EVs are rapidly growing in sales and commercial availability. EV sales in California have doubled in the last three years and accounted for 7.7 percent of all California light duty vehicle registrations in 2019. More than 100 models of light duty EVs are expected by 2022. Most current EVs are sedans or small SUVs; while there have been several recent manufacturer announcements of EV pickups, EVs are not expected to make significant inroads in the light truck market for at least five to ten years.

EV technology for medium- and heavy-duty vehicles has been slower to gain market share, although technology is now developing at a rapid pace. Transit buses are the most widely deployed heavy-duty EV. In contrast, only a small number of medium- and heavy-duty EV trucks have been deployed. Long-haul tractor-trailer trucks currently face challenges to electrification due to limited electric range relative to their diesel counterparts. This market is evolving, and several major manufacturers have recently announced planned new offerings.

NGVs are an established alternative to diesel among segments of the heavy-duty vehicle sector. Cummins Westport currently produces three certified CNG engines (6.7, 9, and 12 liter), which can be used in a variety of heavy-duty trucks. Southern California has a significant number of natural gas vehicles in service for port drayage, regional freight hauling, refuse fleets, and transit buses. For example, NGVs make up about 3 percent of the drayage fleet at the Ports of Los Angeles and Long Beach. However, many truck owners and operators remain skeptical about NGVs due to concerns about maintenance issues, power, fuel availability, and other issues.

FCVs are commercially available but lag far behind EVs in terms of manufacturer offerings and new sales. Approximately 2,000 FCVs were sold nationally in 2019, or less than 1 percent of EV sales. For heavier vehicles, transit buses are the most mature application of fuel cell technology; approximately 40 fuel cell buses currently operate in California. Beyond transit buses, medium- and heavy-duty FCV demonstration projects have been primarily focused at ports.

## Fuel Supply

Operating a significant number of alternative fuel vehicles will require an adequate fuel supply. There may be risks with investment in vehicles and infrastructure if the supply of fuel cannot meet demand. These concerns are expressed most often for low-carbon fuels. However, domestic investment in biofuel production has been growing, due in part to the demand created by California’s LCFS, and fuel supply does not appear to be a serious concern in terms of the scenarios explored for San Bernardino County.



Under the Natural Gas as a Bridge scenario analyzed as part of this study, vehicle natural gas fuel consumption would be 13 million diesel-gallon equivalent (DGE) in 2030 and 32 million DGE in 2040. All this fuel would need to be RNG to achieve the GHG benefits calculated for the scenario. For comparison, the total RNG used for transportation in California was 139 million DGE in 2019, and CARB projects significant increases by 2030.<sup>3</sup> So the state's RNG supply would be more than 20 times the projected maximum use in San Bernardino County. This appears to be an adequate supply given that trucks in the study area account for only about four percent of the California total truck population and vehicle miles of travel (VMT).

Under the Biofuels scenario, diesel fuel would contain a 60 percent renewable diesel blend by 2040, which equates to 70 million gallons of renewable diesel (RD). For comparison, there were 618 million gallons of renewable diesel used statewide in 2019, based on reporting for the LCFS.<sup>4</sup> CARB projects renewable diesel production to more than double by 2030. So similar to RNG, the state's renewable diesel supply would be more than 20 times the maximum volume projected for use in San Bernardino County under the Biofuels scenario. Again, this appears to be an adequate supply given that trucks in the study area account for only about four percent of the California total truck population and VMT.

## Infrastructure Requirements

Another potential barrier to large-scale deployment of alternative fuel vehicles is the infrastructure necessary to provide fueling or charging. Public agencies have an opportunity to support clean vehicles and fuels by streamlining infrastructure permitting processes, mandating fueling or charging infrastructure as part of permit approvals, or investing directly in the development of infrastructure. However, public agencies may be concerned about investing in infrastructure for fuels or technologies that later fall out of favor, leading to stranded assets and suboptimal use of public resources.

There are a variety of types of EV charging infrastructure depending on the location and power. The vast majority of passenger vehicle EV charging is expected to occur at home, with infrastructure costs borne by the homeowner. However, most apartment dwellers lack access to home charging, as property owners are not incentivized to install charging infrastructure. For medium and heavy-duty trucks, most charging infrastructure is expected to be installed at truck yards and garaging locations, although there are still many uncertainties about where and how EV trucks will charge.

Although there is consensus among experts that large-scale electrification of the vehicle fleet is inevitable, there are still risks of stranded assets for public agencies seeking to invest in charging infrastructure. For example, the types and locations of charging preferred by EV drivers may shift over time; a strong preference for DC fast charging could leave some level 2 chargers unused, for example. A major investment in infrastructure will be needed to support electrification of the fleet. As illustrated in Figure 4, the Electrification Scenario would involve more than \$1 billion in cumulative infrastructure costs through 2040 just for San Bernardino County, more than any other scenario analyzed.

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<sup>3</sup> California Air Resources Board, LCFS Quarterly Data Spreadsheet. Available at <https://ww3.arb.ca.gov/fuels/lcfs/lrtgsummaries.htm>

<sup>4</sup> California Air Resources Board, LCFS Quarterly Data Spreadsheet. Available at <https://ww3.arb.ca.gov/fuels/lcfs/lrtgsummaries.htm>

Infrastructure for natural gas vehicle fueling can also be substantial; the cost of a single large CNG fueling station can be more than \$1 million. But the total investment needed in NGV fueling stations is far less than the investment needed in EV charging infrastructure. This is in part because natural gas would be used only by medium and heavy-duty vehicles, and the population and aggregate fuel consumption of these vehicle is far less than LDVs. In addition, many medium and heavy-duty vehicles belong to fleets that can fuel centrally, which can be more efficient in terms of the number of vehicles served per station.

As noted above, if public agencies are helping to fund alternative fuel stations such as natural gas or hydrogen, they may be concerned about stranded assets if long term demand for the fuel does not materialize. If so, it may be an option to contract with a private developer to build, own, and operate the station. Examples of private natural gas station developers are Trillium CNG and Clean Energy. This option does not require public capital expenditure for the station but usually requires a long-term fueling agreement that guarantees a minimum fuel throughput for the operator. The fuel costs for this station option are usually higher than if the public agency were to build the station itself.

For fleets that are considering a transition to natural gas or possible hydrogen, the transition requires a significant “all-in” commitment to guarantee that the fleet can recoup any necessary infrastructure and vehicles costs. In other words, natural gas and hydrogen differ from most other alternative fuels in that fleets cannot simply “try out” the fuel with a few vehicles, unless the fleet is able to use public fueling station or one owned by another fleet. Infrastructure requirements are a major challenge to widespread deployment of FCVs. Currently, there are only 42 public hydrogen fueling stations available in the U.S., nearly all of them in California. CEC estimates a development cost of about \$2 million per station.

## Summary Table

The table below summarizes the key benefits, risks, and uncertainties highlighted in this section.

**Table 2. Summary of Benefits, Risks, and Uncertainties**

	EVs	FCVs	NGVs (with RNG)	Liquid Biofuels
<b>Emissions Benefits</b>	<ul style="list-style-type: none"> <li>• 100% NOx reduction</li> <li>• 70-80% GHG reduction</li> </ul>	<ul style="list-style-type: none"> <li>• 100% NOx reduction</li> <li>• 30-50% GHG reduction (depends on fuel source)</li> </ul>	<ul style="list-style-type: none"> <li>• 90% NOx reduction</li> <li>• 50-80% GHG reduction (depends on feedstock)</li> </ul>	<ul style="list-style-type: none"> <li>• Small NOx reduction</li> <li>• 20-60% GHG reduction (E85)</li> <li>• 60-80% GHG reduction (RD)</li> </ul>
<b>Vehicle Costs</b>	<ul style="list-style-type: none"> <li>• 20-50% higher cost (LDV)</li> <li>• 100-200% higher cost (HDV)</li> <li>• Costs declining rapidly</li> </ul>	<ul style="list-style-type: none"> <li>• Currently 2-3 times higher</li> <li>• Uncertain due to low production volumes</li> </ul>	<ul style="list-style-type: none"> <li>• 20-50% higher cost (HDV)</li> </ul>	<ul style="list-style-type: none"> <li>• No cost increment</li> </ul>
<b>Fueling and Operating Costs</b>	<ul style="list-style-type: none"> <li>• 50% lower fueling costs</li> <li>• Lower maintenance costs</li> </ul>	<ul style="list-style-type: none"> <li>• 80-90% higher fueling costs, although future decline expected</li> </ul>	<ul style="list-style-type: none"> <li>• 25% lower fueling costs</li> <li>• Comparable maintenance costs</li> </ul>	<ul style="list-style-type: none"> <li>• Fueling costs similar to gasoline and diesel</li> </ul>
<b>Technology Readiness</b>	<ul style="list-style-type: none"> <li>• Numerous commercial models available and rapid expansion</li> <li>• Range is a limiting factor for some applications</li> </ul>	<ul style="list-style-type: none"> <li>• Small number of LD and HD models available</li> <li>• Limited sales (less than 1% EV sales)</li> </ul>	<ul style="list-style-type: none"> <li>• Established technology for HDVs; 3 certified CNG engines</li> <li>• Widespread use among refuse trucks and buses</li> </ul>	<ul style="list-style-type: none"> <li>• E85 FFVs – proven technology, but declining consumer and manufacturer interest</li> <li>• RD – drop-in fuel</li> </ul>
<b>Fuel Supply</b>	<ul style="list-style-type: none"> <li>• Some distribution system upgrades needed</li> </ul>	<ul style="list-style-type: none"> <li>• Hydrogen supply uncertain</li> </ul>	<ul style="list-style-type: none"> <li>• Adequate RNG supply expected</li> </ul>	<ul style="list-style-type: none"> <li>• Adequate RD supply expected</li> </ul>
<b>Infrastructure Requirements</b>	<ul style="list-style-type: none"> <li>• More than 400 public charging outlets in SB County</li> <li>• Total cost for all future EVSE in SB County is \$1B+</li> </ul>	<ul style="list-style-type: none"> <li>• Very limited currently (42 in entire US)</li> <li>• Very high cost</li> </ul>	<ul style="list-style-type: none"> <li>• Approx. 20 NG stations in SB County</li> <li>• New CNG stations can cost \$1M+</li> </ul>	<ul style="list-style-type: none"> <li>• E85: 11 stations in SB County</li> <li>• RD: Fuel can be blended w/ conventional diesel</li> </ul>

# 1 Introduction

## 1.1 Study Overview

The purpose of this study is to explore feasible pathways that will enable San Bernardino County to improve air quality and reduce greenhouse gas emissions, while also supporting local and regional economic goals. San Bernardino County faces twin challenges of air pollution and climate change. Home to more than 2.2 million resident and 700,000 jobs, the County plays a vital role in the economy of Southern California and the nation. The transportation sector plays an outsized role in the economy of San Bernardino County and the challenges it faces in reducing emissions, as on-road vehicles are a major contributor to emissions that cause both air pollution and climate change.

A variety of advanced vehicle technologies and alternative fuels are available, or will soon be available, that reduce emissions as compared to conventional gasoline and diesel vehicles. These include electric vehicles, fuel cell vehicles, natural gas vehicles, and alternative fuels such as ethanol, renewable diesel, and renewable natural gas. These options differ in terms of their emissions benefits, costs, commercial availability, performance characteristics, and infrastructure requirements. The differences can make it difficult for public agencies who may be eager to support the transition to clean vehicles and fuels but are uncertain which options will provide the most benefits and fewest risks.

This study seeks to address the information needs of local and regional agencies in San Bernardino County and the broader Southern California area involved in clean vehicle and transportation emission reduction plans and programs. The report includes:

- A detailed review of the options for clean vehicle technologies and fuels (Chapter 2)
- A review of existing economic conditions, vehicle activity, and alternative fueling infrastructure (Chapter 3)
- Development and analysis of alternative scenarios for the deployment of clean vehicles and fuels to achieve emission reductions (Chapters 4 and 5)
- Identification of barriers to greater use of clean vehicles and fuels and development of strategies for local governments to address these barriers (Chapters 6 and 7)
- A conclusion that summarizes opportunities and risks (Chapter 8)
- A summary of relevant regulations (Appendix A)

A separate Action Plan serves as a companion to this Final Report, succinctly describing steps that local governments in San Bernardino County and their partners can take to increase the deployment and use of clean vehicles and fuels.

## 1.2 Air Pollution and Climate Change Challenges

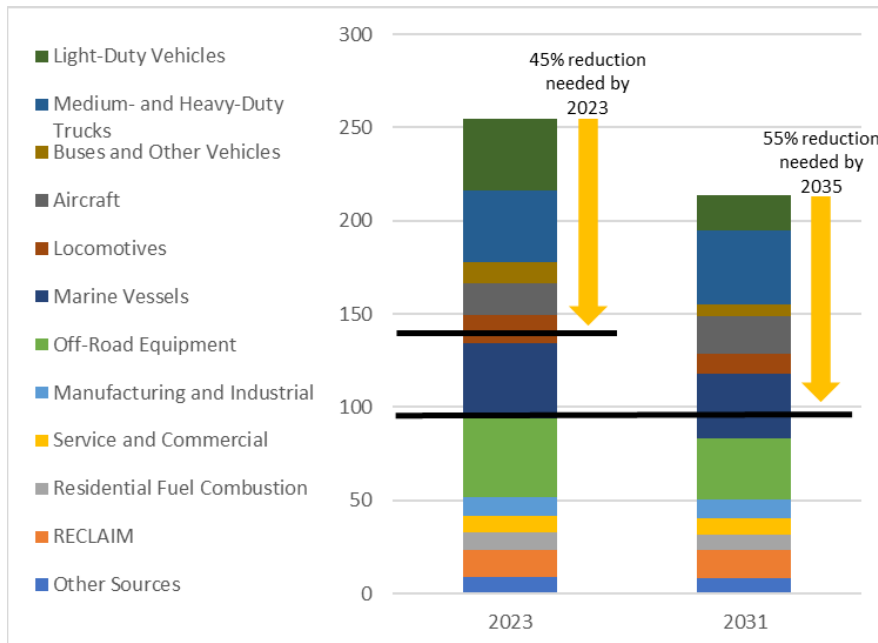
### Air Quality

Most of San Bernardino County does not meet federal air quality standards designed to protect human health. In particular, the southwest portion of the County lies in the South Coast Air Basin, which is classified as an Extreme nonattainment area for the federal ozone standard. Ground-level ozone (commonly called smog) can trigger a variety of health problems including aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses like pneumonia and bronchitis. The

ozone pollution problem in the Basin results from a combination of emissions, meteorological conditions, and the mountains that surround the region.

Emissions of nitrogen oxides (NOx) are the greatest contributor to ozone formation in Southern California. NOx emissions are a product of fuel combustion, and most of these emissions come from diesel engines. The Clean Air Act requires that the South Coast Air Basin achieve attainment with federal standards; if not, the region will continue to experience air pollution-related health problems and also risks losing federal transportation funding. As shown in Figure 1, achieving the targets will require a 45 percent reduction in NOx emissions by 2023 and a 55 percent reduction by 2031, relative to the expected “business as usual” levels.<sup>5</sup>

**Figure 8. South Coast Air Basin NOx Emissions (tons per day)**



Source: South Coast Air Quality Management District, *Final 2016 Air Quality Management Plan*, March 2017

Air pollution from particulate matter is also a concern. Many scientific studies have linked breathing particulate matter to significant health problems, including aggravated asthma, chronic bronchitis, and heart attacks. New research suggests that an increase in PM2.5 levels is associated with higher a COVID-19 death rate.<sup>6</sup> The South Coast Air Basin is designated as nonattainment for the federal fine particulate matter (PM2.5) standard. Fine particulate matter is directly emitted from vehicle engines, and also forms in the atmosphere when NOx or sulfur oxides (SOx) react with other compounds to form particles. Diesel particulate matter is of particular concern because it is widely believed to be a human carcinogen when inhaled.

<sup>5</sup> South Coast Air Quality Management District, *Final 2016 Air Quality Management Plan*, March 2017.

[www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan/final-2016-aqmp](http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan/final-2016-aqmp)

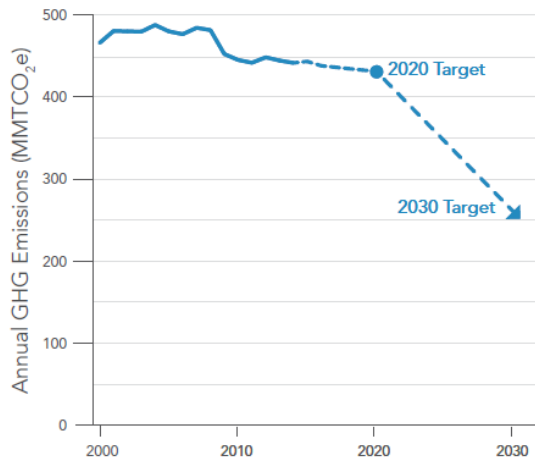
<sup>6</sup> Xiao Wu MS, Rachel C. Nethery PhD, M. Benjamin Sabath MA, Danielle Braun PhD, Francesca Dominici PhD, “Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study,” unpublished manuscript, April 24, 2020. <https://projects.iq.harvard.edu/covid-pm>

## Climate Change

Greenhouse gas (GHG) emissions are causing global climate change, with potentially catastrophic effects on California and the planet. San Bernardino County and the rest of the state are already feeling the effects of climate change. Evidence is mounting that climate change has contributed to a variety of recent problems plaguing California including drought, wildfires, pest invasions, heat waves, heavy rains, and mudslides. Projections show these effects will continue and worsen in the coming years, with major implications for our economy, environment, and quality of life.<sup>7</sup>

In response to the threat of climate change, the State of California and many local governments have adopted policies to reduce GHG emissions. The initial policies have largely succeeded – California achieved the 2020 GHG emissions target four years ahead of schedule. But more significant reductions will be needed going forward to avoid catastrophic impacts. Senate Bill 32, passed in 2016, requires the state to cut GHG emissions to 40 percent below 1990 levels by 2030, as shown in Figure 2.

**Figure 9. California GHG Emissions Target**



Source: California Air Resources Board, *California’s 2017 Climate Change Scoping Plan*, November 2017.

On-road vehicles are responsible for about one-third of GHG emissions in San Bernardino County. In addition to state-led efforts, programs and projects to reduce transportation GHG emissions are occurring at the regional and local level. The Regional Transportation Plan, developed by the Southern California Association of Governments, demonstrates how the region will reduce per-capita GHG emissions from passenger vehicles in accordance with the requirements of SB 375.<sup>8</sup> An effort led by the San Bernardino Council of Governments (SBCOG) has compiled an inventory of GHG emissions and an evaluation of reduction measures that could be adopted by 25 partnership cities in the County.<sup>9</sup>

<sup>7</sup> California Air Resources Board, *California’s 2017 Climate Change Scoping Plan*, November 2017.

[https://ww3.arb.ca.gov/cc/scopingplan/scoping\\_plan\\_2017.pdf](https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf)

<sup>8</sup> Southern California Association of Government, Connect SoCal - The 2020-2045 Regional Transportation Plan/Sustainable Communities Strategy, May 2020. [www.connectsocial.org/Pages/Connect-SoCal-Final-Plan.aspx](http://www.connectsocial.org/Pages/Connect-SoCal-Final-Plan.aspx)

<sup>9</sup> San Bernardino County Regional Greenhouse Gas Reduction Plan, 2020.

## 2 Options for Clean Vehicle Technologies and Fuels

There are many options for vehicle technologies and alternative fuels that can reduce emissions as compared to conventional gasoline and diesel vehicles. As shown in the figure below, these options may be particularly relevant for only some vehicle types, or can apply to all on-road vehicles. This section reviews the most promising of these options, discussing with level of technology readiness, emission impacts, vehicle costs, and fueling infrastructure.

**Figure 10. List of Clean Vehicle Technologies and Fuels**

Vehicle or Fuel Type	Most Relevant for:	
	Light Duty Vehicles	Medium and Heavy-Duty Vehicles
Electric Vehicles	●	●
Fuel Cell Vehicles	●	●
Natural Gas Vehicles		●
Renewable Natural Gas		●
Ethanol	●	
Renewable Gasoline	●	
Biodiesel		●
Renewable Diesel		●
Fuel Efficiency Improvements	●	●

Note: for simplification purposes, this figure assumes that all light duty vehicles operate on gasoline and all medium and heavy-duty vehicles operate on diesel.

This report refers to the three main categories of vehicles: Light-Duty, Medium-Duty, and Heavy-Duty. These three major types, based on gross vehicle weight rating (GVWR), are commonly used by transportation agencies and the trucking industry, and are based on the eight vehicle classes developed by the Federal Highway Administration (FHWA). The table below summarizes these vehicle types; Chapter 3 contains a more detailed description of the vehicle types. In this chapter, we often combine medium and heavy-duty vehicles when discussing vehicle technology and fuel options since the options are typically similar for the two vehicle types.

**Table 3. Summary of Major Vehicle Types**

Type	Description	FHWA Class	Gross Vehicle Weight Rating
<b>Light Duty</b>	Automobiles and light trucks. Nearly all fueled by gasoline	1, 2	Up to 10,000 lbs
<b>Medium Duty</b>	Single-unit trucks with two axles. Fueled by gasoline or diesel.	3, 4, 5, 6	10,000 lbs – 26,000 lbs
<b>Heavy Duty</b>	Tractor-trailer combination vehicles and some single-unit trucks, most with three axles. Nearly all fueled by diesel.	7, 8	More than 26,000 lbs

## 2.1 Electric Vehicles

### Technology Readiness

Plug-in electric vehicles (EVs) are now widely commercially available and offer a promising alternative to both gasoline and diesel-powered vehicles. EVs are typically broken out into two distinct architectures: plug-in hybrid electric vehicles (PHEVs) use a battery and internal combustion engine for propulsion while battery electric vehicles (BEVs) rely solely on a battery. Over 1.4 million EVs have been sold in the U.S., with nearly half of those sales occurring in California.<sup>10</sup>

#### *Light Duty Vehicles*

Although EVs were initially limited to smaller vehicle body types, electric SUVs and trucks are either already being sold or are under development: Kia, Hyundai, Subaru, Volvo, Tesla, and Jaguar have recently introduced all-electric SUVs and crossover vehicles in California while automakers like Ford, Tesla, and Rivian are developing electric pick-up trucks for sale in the next several years.<sup>11,12</sup> There are approximately 60 light duty EV models available today in the U.S. and that number is expected to increase to over 100 by 2022, giving consumers more choice and flexibility in EV purchase decisions.<sup>13</sup> Over 360,000 EVs were sold nationally in 2018 (about 2 percent of total light-duty sales) and that figure is expected to grow.<sup>14</sup> Edison Electric Institute recently developed a forecast, based on five independent forecasts, that predicts annual EV sales will reach 3.5 million and cumulative sales will surpass 18 million vehicles in the U.S. by 2030.<sup>15</sup> Bloomberg New Energy Finance anticipates EVs will comprise 55 percent

<sup>10</sup> <https://www.veloz.org/sales-dashboard/>

<sup>11</sup> <https://cleanvehiclerebate.org/eng/eligible-vehicles>

<sup>12</sup> <http://fortune.com/2019/04/25/ford-is-making-its-own-electric-truck-so-why-is-it-investing-in-rivian/>

<sup>13</sup> <http://eprijournal.com/electric-vehicle-market-revs-up/>

<sup>14</sup> <https://www.greentechmedia.com/articles/read/us-electric-vehicle-sales-increase-by-81-in-2018#gs.b6s9ku>

<sup>15</sup> [http://www.edisonfoundation.net/iei/publications/Documents/IEI\\_EEI%20EV%20Forecast%20Report\\_Nov2018.pdf](http://www.edisonfoundation.net/iei/publications/Documents/IEI_EEI%20EV%20Forecast%20Report_Nov2018.pdf)



of new car sales and a third of the vehicle fleet globally by 2040.<sup>16</sup> California and nine other states that have adopted California’s Zero Emissions Vehicle (ZEV) program have been coordinating to reach a cumulative 3.3 million ZEV sales goal by 2025, which will primarily be met with EVs.<sup>17</sup> California, via executive order B-48-18, has targets that put the state on the path toward 1.5 million EVs by 2025 and 5 million EVs by 2030.<sup>18</sup>

Most BEVs today do not have ranges comparable to their internal combustion engine counterparts. However, improvements in battery technology are increasing vehicle range: the Department of Energy found that the median range of new BEVs increased from 73 to 125 miles from 2011 to 2018.<sup>19</sup> Moreover, many new BEVs have ranges exceeding 200 miles, including but not limited to: the Chevrolet Bolt (248 miles), Nissan LEAF PLUS (226 miles), Hyundai Kona (258 miles), and Tesla Model 3 (220+ miles). Given that motorists drive, on average, approximately 12,000 to 15,000 miles



Source: Denver Metro Clean Cities

per year, EVs are well-suited to handling daily driving needs of most drivers between charges. Less frequent and longer-distance trips are still feasible in some situations, though concerns persist about the availability of public charging infrastructure – particularly fast-charging infrastructure.<sup>20</sup> About 80 percent of EV charging takes place at home, typically overnight when the vehicle is parked.<sup>21</sup> However, lack of charging infrastructure is one of the key challenges associated with the widespread use of EVs; as the EV market continues to grow, more public and workplace charging infrastructure will be needed to support EV adoption for drivers without dedicated access to residential charging.

### ***Medium and Heavy-Duty Vehicles***

EV battery technology continues to advance at a rapid pace, providing new opportunities for the electrification of a broad suite of medium- and heavy-duty fleets. Nearly 80 zero-emission electric medium- and heavy-duty vehicle models are currently eligible for CARB’s Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP).<sup>22</sup> However, given the diversity in the specifications, duty cycles, and ultimate function of these vehicles, there exists some diversity in the commercialization status of different medium- and heavy-duty vehicle types. In general, transit buses and vehicles that travel short distances on a day-to-day basis are ripe for transportation electrification. Vehicles that travel greater distances (i.e. long-haul semi-truck) are still in development, but a growing number of manufacturers and customers are driving greater investment in longer-range EV deployments.

<sup>16</sup> <https://about.bnef.com/electric-vehicle-outlook/#toc-download>

<sup>17</sup> <https://www.zevstates.us/>

<sup>18</sup> <http://www.opr.ca.gov/planning/transportation/zev.html>

<sup>19</sup> <https://www.energy.gov/eere/vehicles/articles/fotw-1064-january-14-2019-median-all-electric-vehicle-range-grew-73-miles>

<sup>20</sup> <https://www.fhwa.dot.gov/ohim/onh00/bar8.htm>

<sup>21</sup> <https://www.energy.gov/eere/electricvehicles/charging-home>

<sup>22</sup> <https://www.californiahvip.org/eligible-technologies/#your-clean-vehicles>

### *Transit Buses*

Transit buses are the most widely deployed heavy-duty EV. California’s public transit agencies have already deployed over 150 zero-emissions buses – the overwhelming majority of which are all-electric – and based on bus orders and planned purchases, CARB expects that figure to rise to 1,000 by 2020.<sup>23</sup> Transit bus electrification is also buoyed by CARB’s Innovative Clean Transit regulation, which establishes a statewide goal for the state’s transit agencies to transition to 100 percent zero-emission bus fleets by 2040.<sup>24</sup> There are currently 27 zero-emission electric transit bus models eligible for HVIP incentives with battery packs ranging from 94 kWh to 660 kWh.

Transit buses are well-suited to electrification for several reasons. They experience longer idle times than other medium- and heavy-duty vehicles, where diesel vehicles would typically waste more fuel.<sup>25</sup> Transit buses also run predictable routes in a defined geographic area, allowing fleet operators to more easily assess how buses may perform under routine conditions. Fleets are also typically housed in centralized depots where charging infrastructure can be accessed and managed. In addition, transit buses usually operate in urban areas where vehicle emissions and related human health concerns are greatest.



Source: Robert Prohaska / NREL

The National Renewable Energy Laboratory (NREL) gave Proterra’s battery electric buses a “Technology Readiness Level” of seven out of nine in 2017, indicating an ability for the buses to perform their essential functions and potential to scale commercially.<sup>26</sup> In terms of reliability, transit bus battery packs are expected to last throughout the useful life of the vehicle. BYD 40’ and 60’ model battery packs are intended to last 20 to 25 years, which includes a 12 year warranty for the life of the bus as well as second-life energy storage applications.<sup>27</sup>

### *Shuttle and School Buses*

Shuttle buses are similar to transit buses in that they travel short distances on fixed routes and may be subjected to longer idle times than other vehicles. CARB also expects shuttle bus electrification to

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<sup>23</sup> <https://ww2.arb.ca.gov/news/california-transitioning-all-electric-public-bus-fleet-2040>

<sup>24</sup> *Id.* The Innovative Clean Transit regulation does not specify that transit bus be electric, although it is expected that electric buses will play a large role in meeting the zero-emission requirements of the regulation.

<sup>25</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

<sup>26</sup> <https://www.nrel.gov/docs/fy17osti/67698.pdf>

<sup>27</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

increase substantially over the next decade.<sup>28</sup> There are currently seven electric, zero-emission shuttle bus models eligible for HVIP incentives with battery packs ranging from 52 kWh to 106 kWh.

School buses also generally fit the ideal electrification profile, running short, predictable routes in regular morning and afternoon cycles. They remain stationary most of the day, providing ample time for recharging and opportunity to provide valuable grid services. However, there are challenges to scaling school bus electrification, including rigorous safety standards for all school bus technologies, lack of available models in the market, upfront costs, and slowness of legacy school bus manufacturers to develop electric bus models – although Thomas Built now has a commercially available school bus.<sup>29</sup> There are eleven school bus models eligible for HVIP incentives, with battery packs ranging from 88 kWh to 220 kWh.

#### *Class 4-6 Vehicles*

Electrification has not significantly transformed medium-duty electrification to date, and it is estimated that there are about 300 medium-duty EVs in the United States.<sup>30</sup> However, given their short daily ranges and last-mile applications, local delivery and utility vehicles are prime candidates for electrification and they are beginning to experience greater deployment. Companies such as Frito Lay, Staples, Coca-Cola, Goodwill, FedEx, and UPS are beginning to incorporate medium-duty EVs into their fleets.<sup>31</sup> FedEx recently announced that it would purchase 100 V8100 electric delivery vehicles from Chanje, and lease 900 from Ryder.<sup>32</sup> UPS recently announced advances in charging station management would enable it to electrify all of its 170 delivery trucks operating in London.<sup>33</sup> Moreover, the California Hybrid, Efficiency, and Advanced Truck Research Center predicts that medium-duty delivery EVs will reach a widespread commercialization phase starting in 2020.<sup>34</sup> Currently, six electric delivery truck and panel van models are eligible for HVIP incentives, with battery packs ranging from 96 kWh to 128 kWh.

The number of announced commercial models of medium-duty EV trucks has grown rapidly in just the year. According to Calstart's recently released Zero-Emission Technology Inventory, more than 60 models of zero-emission medium duty vehicles will be available this year, as illustrated below.

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<sup>28</sup> *Id.*

<sup>29</sup> *Id.*

<sup>30</sup> *Id.*

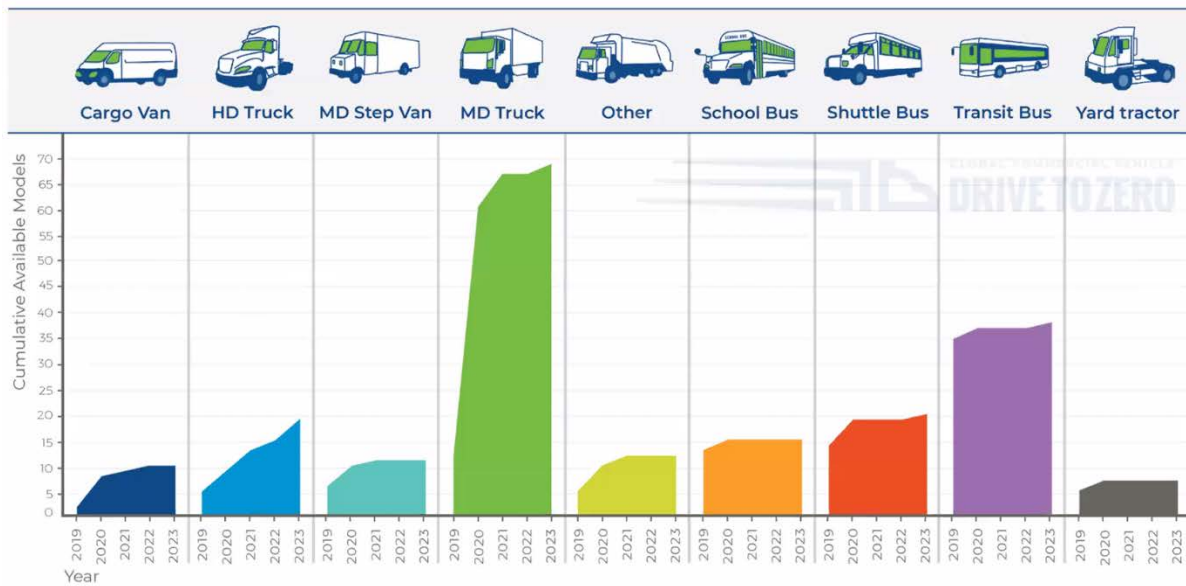
<sup>31</sup> *Id.*

<sup>32</sup> <https://about.van.fedex.com/newsroom/fedex-acquires-1000-chanje-electric-vehicles/>

<sup>33</sup> <https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1521473412769-768>

<sup>34</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

**Figure 11. Medium and Heavy-Duty Zero Emission Vehicle Models Available**



Source: Calstart, Zero-Emission Technology Inventory. <https://globaldrivetozero.org/tools/zero-emission-technology-inventory/>

### Class 7-8 Vehicles

Electrification of heavy-duty vehicles is still limited, although long-haul vehicles are beginning to enter the demonstration phase. Drayage and refuse trucks are somewhat more mature and have travel requirements that create advantages for electrification, though few models exist in the market today. Over 40 all-electric drayage trucks have been deployed in California and have helped reduce emissions from port operations.<sup>35</sup> Long-haul semi-trucks currently face clear challenges to electrification due to limited electric range relative to their diesel counterparts.<sup>36</sup> Energy density and weight of large battery packs are partially responsible for this challenge. However, the semi-truck space is evolving and several major manufacturers and suppliers, including Tesla, BYD, TransPower, Daimler/Freightliner, Volvo, Cummins, and others have either deployed or planning to deploy electric trucks or battery packs soon. The much-anticipated 300-500 mile Tesla Semi is expected to begin production in 2020 and Tesla plans to scale production to support production of 100,000 trucks per year.<sup>37</sup> Daimler’s Freightliner intends to begin production of its 250-mile eCascadia model by 2021 and has already delivered its first medium-duty electric delivery model.<sup>38</sup> Navistar also announced its intent to develop and sell electric Class 8 truck models by 2025. As of 2018, two OEMs offered a total of 2 electric drayage truck (day cab) models and 12 models are expected to be available by 2021.<sup>39</sup> Moreover, 65 electric drayage trucks are

<sup>35</sup> *Id.*

<sup>36</sup> *Id.*

<sup>37</sup> <https://electrek.co/2019/04/25/tesla-semi-delay-electric-truck-production-next-year/>

<sup>38</sup> <https://www.trucks.com/2018/06/06/daimler-unveils-electric-freightliner-cascadia/>

<sup>39</sup> Couch et al., *2018 Feasibility Assessment for Drayage Trucks*, prepared for The Port of Los Angeles and Port of Long Beach, April 2019, available at: <http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/>

currently or will soon be undergoing testing at the Ports of Los Angeles and Long Beach – including many models from the OEMs identified in this section.<sup>40</sup>

In short, increased energy density in batteries is needed to reduce overall vehicle weight and increase electric range. The most common battery chemistry used in EVs today is lithium-ion, and there are several variations of lithium-ion chemistries to consider in medium- and heavy-duty applications.<sup>41</sup> However, different chemistries often create trade-offs between vehicle range and life span of the battery (charge cycles): for example, lithium manganese oxide batteries have relatively high energy density (Wh/kg) but relatively low lifespan (1500+ cycles).<sup>42</sup> More research is being conducted to continue the development of lighter, more efficient batteries for use in medium- and heavy-duty applications.



Source: Dennis Schroeder / NREL

Overall, medium- and heavy-duty EVs are a quickly maturing alternative fuel vehicle type with significant opportunity for growth in California, although challenges remain. EVs are energy efficient and zero-emission, battery costs are continuing to decline, fuel costs can be very competitive with alternatives, and the ubiquity of the electric grid makes access to electricity straightforward in most cases. However, vehicle range, refueling time, and if left unmanaged, electricity costs, can prove to be challenging for medium- and heavy-duty EVs in certain applications in the near-term – particularly in the long-haul heavy-duty segment.<sup>43</sup>

## Emissions Impacts

BEVs and PHEVs produce zero tailpipe emissions when running on electricity. PHEVs produce emissions when using their gasoline or diesel engines, but are generally more fuel-efficient than the average internal combustion engine vehicle. Well-to-wheels emissions, which include emissions from fuel production and fuel use, are dependent on the regional electric generation mix. California's grid is one of the cleanest in the nation: 29 percent of California's power mix came from renewable generation in 2017 – not including large hydro.<sup>44</sup> On this generation mix, EVs produce 81 percent less GHG emissions

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<sup>40</sup> *Id.*

<sup>41</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

<sup>42</sup> *Id.*

<sup>43</sup> Couch et al., *2018 Feasibility Assessment for Drayage Trucks*, prepared for The Port of Los Angeles and Port of Long Beach, April 2019, available at: <http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/>

<sup>44</sup> [https://www.energy.ca.gov/almanac/electricity\\_data/total\\_system\\_power.html](https://www.energy.ca.gov/almanac/electricity_data/total_system_power.html)



than a comparable gasoline vehicle.<sup>45</sup> Moreover, Governor Brown signed Senate Bill 100 in 2018, which ramps up the state’s Renewable Portfolio Standard requirements to 60 percent by 2030 and 100 percent by 2045.<sup>46</sup> Therefore, as the state and regional electricity systems get cleaner, EV well-to-wheels emissions will continue to decline.

Based on 2018 data, Union of Concerned Scientists (UCS) found that EVs on California’s electric grid produce GHG emissions equivalent to a car with a fuel economy rating of 109 MPG, up from 78 MPG in 2009.<sup>47</sup> Natural Resources Defense Council (NRDC) and Electric Power Research Institute (EPRI) found that in a scenario with a significantly decarbonized power system and widespread EV adoption (including some medium- and heavy-duty electrification), national transportation sector emissions were reduced by 550 million tons annually in 2050.<sup>48</sup>

UCS and the Greenlining Institute estimated that an electric transit bus on California’s current grid mix would produce approximately 74 percent less GHG emissions per mile relative to a conventional diesel bus.<sup>49</sup> Moreover, CARB found that even if an electric transit bus ran on electricity generated completely from natural gas, it travelled twice as far as comparable compressed natural gas (CNG) bus.<sup>50</sup> This is primarily due to the superior efficiency of EVs: NREL’s Foothill Transit demonstration study found that Proterra buses achieved a MPGe of 17.35, whereas the typical fuel economy of a transit bus is 3.26 MPG.<sup>51</sup>

EVs are also a key part of reducing transportation sector emissions consistent with reaching California climate goals of reducing economy-wide emissions 80 percent by 2050 from 1990 levels. The California Energy Commission (CEC) estimates that in order to meet state decarbonization targets in 2030 and 2050, 60 percent of new light-duty vehicle sales need to be EVs in 2030.<sup>52</sup> CEC also finds that EVs will be the dominant medium-duty alternative fuel vehicle (approximately 60 percent of sales) and that EVs will play a non-trivial role in decarbonizing heavy-duty fleets (approximately 20 percent of sales) by 2050.<sup>53</sup> However, sales for both vehicle classes will need to increase rapidly over the next decade to reach the growth figures estimated in the report.

## Vehicle Costs

Light duty EVs are still more expensive than their gasoline counterparts on an upfront cost basis before incentives, which is largely due to the cost of the battery. However, battery costs are continuing to decline: in 2015, a battery represented roughly 57 percent of an EV’s total cost, and that figure has

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<sup>45</sup> [https://afdc.energy.gov/vehicles/electric\\_emissions.html](https://afdc.energy.gov/vehicles/electric_emissions.html)

<sup>46</sup> <https://www.energy.ca.gov/renewables/>

<sup>47</sup> <https://blog.ucsusa.org/dave-reichmuth/new-data-show-electric-vehicles-continue-to-get-cleaner>

<sup>48</sup> <http://epri.co/3002006881>

<sup>49</sup> <https://www.ucsusa.org/sites/default/files/attach/2016/10/UCS-Electric-Buses-Report.pdf>

<sup>50</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

<sup>51</sup> <https://www.nrel.gov/docs/fy17osti/67698.pdf>; <https://afdc.energy.gov/data/10310>

<sup>52</sup> <https://www.ethree.com/wp-content/uploads/2018/06/Deep-Decarbonization-in-a-High-Renewables-Future-CEC-500-2018-012-1.pdf>

<sup>53</sup> <https://www.ethree.com/wp-content/uploads/2018/06/Deep-Decarbonization-in-a-High-Renewables-Future-CEC-500-2018-012-1.pdf>

dropped to 36 percent in 2018.<sup>54</sup> Put differently, average EV battery costs declined from \$373/kilowatt-hour (kWh) in 2015 to \$176/kWh in 2018 and are expected to decline to \$94/kWh in 2024, at which point some analysts believe EVs will largely achieve upfront cost parity with internal combustion engine (ICE) vehicles.<sup>55</sup> Other reports have generally suggested more conservative costs by the middle of next decade (\$120-\$140/kWh).<sup>56</sup> Other EV powertrain equipment beyond the battery will continue to decline in cost by approximately 10 percent between 2017 and 2025.<sup>57</sup> On a total cost of ownership basis, some EVs may already be competitive with similar ICE models given the superior battery efficiency and low maintenance costs of EVs. Fuel cost savings can be significant, particularly when drivers can take advantage of time-varying electricity rates that lower the cost of fuel during off-peak times when the grid is not stressed. In California, the average price of an eGallon (gallon of gasoline equivalent for EVs) is \$1.80 compared to \$3.95 a gallon for regular gasoline.<sup>58</sup> ICCT estimates that EV owners could expect to realize fuel savings of \$3,500 for cars, \$3,900 for crossovers, and \$4,200 for SUVs over the first 5 years of ownership, and when comparing the first 5 years of ownership costs, many EVs will be more attractive than ICE models as early as 2022 and even earlier on a 10-year ownership basis.<sup>59</sup>

For medium and heavy-duty vehicles, upfront costs exceed those of comparable fossil fuel vehicles. However, increasing economies of scale and battery technology improvements are continuing to lower the total upfront cost of EVs. Based on recent literature, ICF estimates the average upfront cost of a new electric transit bus is \$820,000, while the average cost of a new, comparable diesel bus is around \$435,000.<sup>60</sup> However, it's important to note that costs have declined substantially in a relatively short period of time: for example, 40' Proterra buses were introduced in 2010 at \$1.2 million, decreasing to \$900,000 several years later and approximately \$750,000 today.

Electric medium-duty vans and trucks were estimated to cost approximately \$130,000-\$170,000 whereas the conventional diesel vehicle costs approximately \$80,000 in 2015. However, the specific cost differentials will depend on the vocation and model of the vehicle. Estimates for heavy-duty trucks are more speculative given the current limited availability of electric models. ICF estimates that Class 6-8 short-haul electric trucks are priced around \$200,000-\$300,000 relative to \$145,000 for a comparable diesel truck; given that many electric trucks in the U.S. are imported from China, the electric truck prices include estimated tariffs levied on the import of these vehicles.<sup>61</sup> Electric drayage trucks were estimated to cost \$208,000 relative to \$108,000 conventional drayage trucks in 2020. Thor and Tesla estimate their

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<sup>54</sup> <https://www.bloomberg.com/opinion/articles/2019-04-12/electric-vehicle-battery-shrinks-and-so-does-the-total-cost>

<sup>55</sup> <https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/>

<sup>56</sup> [https://www.theicct.org/sites/default/files/publications/EV\\_cost\\_2020\\_2030\\_20190401.pdf](https://www.theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf)

<sup>57</sup> [https://www.theicct.org/sites/default/files/publications/EV\\_cost\\_2020\\_2030\\_20190401.pdf](https://www.theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf)

<sup>58</sup> Accessed May 13, 2019. <https://www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs>

<sup>59</sup> [https://www.theicct.org/sites/default/files/publications/EV\\_cost\\_2020\\_2030\\_20190401.pdf](https://www.theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf)

<sup>60</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

<sup>61</sup> The tariffs are estimated to add 20% to the overall price of the vehicle. ICF Resources, LLC, *Economic Impacts of the Accelerated Deployment of Zero- and Near-Zero NOx Emissions Technologies in the Heavy-Duty Vehicle Sector Task 2: Implementation Scenarios Technical Memorandum*, May, 1, 2019

long-haul Class 8 semi-trucks will cost approximately \$150,000-\$250,000 depending on model's range, compared to \$125,000 for a diesel equivalent.<sup>62</sup>

Although upfront cost is an important factor in vehicle fleet purchase decisions, total cost of ownership (TCO) is generally paramount. TCO is dependent on a number of factors that may vary by geography and specific fleet operational conditions, including fuel costs, maintenance costs, charging infrastructure costs, access to incentives, duty cycles, and regulations, among other elements. As a general principle, it is acknowledged that EVs are cheaper to maintain than conventional vehicles due greater reliability of batteries and electric motors as well as fewer fluids and moving parts. CARB estimates TCO savings of \$150,000-\$250,000 per electric bus relative to diesel. Estimates for heavy-duty trucks are less competitive: National Center for Sustainable Transportation estimates that the total cost of ownership of an electric truck in 2030 is estimated at approximately \$430,000, compared to \$250,000 for a diesel truck.<sup>63</sup>

### Infrastructure Costs

EVs can refuel with different types of charging infrastructure at a diverse array of sites. Level 1 charging stations use a standard 120V outlet and provide about 1.1 kilowatts (kW) of power, refueling a light duty EV at a rate of 2-5 miles per hour of charging. Level 1 stations are typically deployed at locations where vehicles are parked for long periods of time, such as homes, workplaces, and airports. A simple Level 1 cord-set can cost as low as \$300 and is suitable for home use, but pedestal units that are more appropriate for parking lots can cost up to \$1,500 per unit.<sup>64</sup> Level 1 stations are typically non-networked, meaning that they cannot send data to a network operator.

Level 2 stations use a 208V/240V outlet and typically provide 3.3-6.6 kW of power, providing 10-20 miles of range per hour of charging for light duty vehicles. Level 2 stations are also deployed at locations where vehicles dwell for longer periods of time, including homes, workplaces, and other overnight locations. Level 2 units may cost as low as \$400 for basic, non-networked stations that may be appropriate for home use. However, for workplace and public networked Level 2 stations that require a pedestal, units can cost up to \$6,000.<sup>65</sup>

Direct Current Fast Charging (DCFC) stations require 480V service and current stations provide power at 25 kW up to 350 kW, although most installed DCFC stations provide 50 kW of power.<sup>66</sup> These 50 kW plugs can add over 3 miles of range per minute for light duty vehicles, while 350 kW connectors can add 20 mile per minute. DCFC stations are installed in public locations where cars may only be parked a short while or where electric shared mobility (i.e. car-sharing, ride-hailing, etc.) fleets can easily access them.<sup>67</sup> DCFC station costs are significant: 50 kW units cost roughly \$50,000 and 150-350 kW units can be

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<sup>62</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

<sup>63</sup> Miller, M. Q. Wang, and L. Fulton, Truck Choice Modeling: Understanding California's Transition to Zero-Emission Vehicle Trucks Taking into Account Truck Technologies, Costs, and Fleet Decision Behavior, University of California at Davis and the National Center for Sustainable Transportation, 2017.

<sup>64</sup> [https://afdc.energy.gov/files/u/publication/evse\\_cost\\_report\\_2015.pdf](https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf)

<sup>65</sup> [https://afdc.energy.gov/files/u/publication/evse\\_cost\\_report\\_2015.pdf](https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf)

<sup>66</sup> Only BEVs can charge at DCFC stations.

<sup>67</sup> These stations are also critical for enabling long distance EV travel on highway corridors



significantly more expensive.<sup>68</sup> Although some medium- and heavy-duty EVs may utilize Level 2 charging equipment, the battery capacities and duty cycles of these vehicles may require much faster charging in depot charging configurations. DCFC would be able to charge a 400 kWh bus battery overnight.

Installation costs for all three types of EV infrastructure vary widely and are dependent on charging station power levels and site specific conditions. Installation cost drivers include but are not limited to: permitting, electricity metering, electrical supply conduit, trenching and boring to lay conduit, and upgrading electrical panels. Level 1 installation costs are relatively modest, with wall-mounted Level 1 costs around \$300-\$1,000 and pedestal-mounted units costing \$1,000-\$3,000.<sup>69</sup> Level 2 installation costs vary widely: average costs hover around \$3,000 per station but have been as high as \$12,000.<sup>70</sup> DCFC installation costs also exhibit variability, with 50 kW stations averaging roughly \$25,000 per installation but often surpassing \$40,000 per installation in areas that require significant electrical upgrades. Higher capacity DCFC station installations will likely drive costs upward; a 450 kW charging may cost roughly \$350,000 per station.



Source: Dennis Schroeder / NREL

Beyond, depot charging, fast on-route charging may be available for EVs that travel in fixed, predictable routes (e.g. transit buses) and may cost around \$300,000-\$350,000 per station.<sup>71</sup> Vehicle duty cycles will likely govern decision-making on charging infrastructure investments – particularly for heavy-duty drayage trucks: single shift trucks with 10-14 hours of downtime daily may only need up to 50 kW of charging capacity, but double shift trucks may require upwards of 150 kW on average to complete daily routes.<sup>72</sup> Inductive charging provides opportunities for refueling without the use of a plug, but are typically more expensive and less commercially available than conductive charging: a 250 kW WAVE wireless charger costs \$286,000, and in-road and catenary charging may cost \$1.3 million to \$6 million per mile.<sup>73</sup> These route-based charging configurations may allow for EVs with smaller batteries to complete duty cycles of longer-range EVs and may be appropriate for short-distance, high-frequency travel corridors.

<sup>68</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

<sup>69</sup> [https://afdc.energy.gov/files/u/publication/WPCC\\_L1ChargingAtTheWorkplace\\_0716.pdf](https://afdc.energy.gov/files/u/publication/WPCC_L1ChargingAtTheWorkplace_0716.pdf)

<sup>70</sup> [https://afdc.energy.gov/files/u/publication/evse\\_cost\\_report\\_2015.pdf](https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf)

<sup>71</sup> [https://afdc.energy.gov/files/u/publication/evse\\_cost\\_report\\_2015.pdf](https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf)

<sup>72</sup> Couch et al., *2018 Feasibility Assessment for Drayage Trucks*, prepared for The Port of Los Angeles and Port of Long Beach, April 2019, available at: <http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/>

<sup>73</sup> Couch et al., *2018 Feasibility Assessment for Drayage Trucks*, prepared for The Port of Los Angeles and Port of Long Beach, April 2019, available at: <http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/>

Charging stations also incur operations and maintenance (O&M) costs that vary by charger type and location. On top of hardware component replacements and electricity costs (which may be passed on to EV drivers in some cases), networked stations also carry networking fees that can range from \$100-\$900 annually. Routine maintenance is typically more crucial for DCFC stations, which have more components than Level 1 or 2 stations and are relied upon in key refueling situations (e.g. highway corridor charging). Make-ready costs also vary widely and are dependent on the capacity of the charging equipment installed, distance from electrical panels, labor costs, and more: make-ready costs for a depot DC Fast Charging station may range from \$20,000-\$70,000 while installation of the 250 kW WAVE wireless charger may exceed \$200,000.

At current levels of EV adoption and in most cases, it is extremely challenging to make a compelling economic case to deploy EV charging solely based on charging fees for EV charging services (“charging for charging”). For that reason, many charging stations have been deployed with government or utility incentives or deployed as an amenity. As EV adoption and demand for charging stations increase, more private capital may be leveraged to deploy EV charging stations.

## 2.2 Fuel Cell Vehicles

### Technology Readiness

Similar to EVs, fuel cell vehicles (FCVs) use electricity to power an electric motor. However, the electricity instead comes from stored hydrogen gas that passes through a fuel cell that generates an electric current by splitting hydrogen molecules into electrons and protons.<sup>74</sup> Light-duty FCVs are commercially available but have not been deployed to the same degree as light-duty EVs. To date, about 8,000 FCVs were sold or leased in the U.S. (versus 1.4 million EVs).<sup>75</sup> Given that California has the most operational hydrogen fueling stations in the nation, it can be inferred that the bulk of FCVs reside in California.<sup>76</sup> The CEC also expects the number of FCVs in the state to increase to 13,400 in 2020 and 37,400 by 2023.<sup>77</sup> There are currently 4 light-duty FCV models eligible for California’s Clean Vehicle Rebate, including two SUV models from Hyundai.<sup>78</sup> These vehicles have ranges and refueling times comparable to ICE vehicles, meaning that the technology does not require significant consumer adaptation for their use.

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<sup>74</sup> <http://www.fchea.org/fuelcells>

<sup>75</sup> <https://cafcp.org/sites/default/files/FCEV-Sales-Tracking.pdf>

<sup>76</sup> <https://afdc.energy.gov/stations/#/find/nearest>

<sup>77</sup> <https://www.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf>

<sup>78</sup> <https://cleanvehiclerebate.org/eng/eligible-vehicles>

Commercial deployment of FCVs has been relatively limited to date. Similar to medium- and heavy-duty EVs, transit buses are the most mature application for medium- and heavy-duty FCVs. A 2018 NREL study scored hydrogen fuel cell electric buses (FCEBs) with a Technological Readiness Level (TRL) of 7 to 8 out of 9, meaning that the buses have achieved full-scale validation in a relevant environment.<sup>79</sup> However, the report identifies lingering performance and administrative challenges related to fuel cell technology, including: balance of plant (e.g. compressors, fans, pumps) maintenance and supply issues, refueling issues related to compressor failure, lack of access to affordable hydrogen, and need for transit agency training.<sup>80</sup> According to the California Fuel Cell Partnership, 30 hydrogen buses are currently in operation and 22 hydrogen buses are in development in California.<sup>81</sup> There are two FCEB models currently eligible for HVIP incentives, both of which are manufactured by El Dorado National.<sup>82</sup>



Source: Leslie Eudy / NREL

Beyond transit buses, medium- and heavy-duty FCV deployment and demonstration projects have been primarily focused at ports and in parcel delivery applications in California.<sup>83</sup> Toyota, in partnership with Kenworth, is testing fuel cell powertrains for Class 8 drayage trucks in the Los Angeles region: 10 Kenworth T680 models outfitted with Toyota fuel cell technology will transport cargo from Ports of Los Angeles and Long Beach throughout the region and are expected to drive more than 300 miles per fill.<sup>84</sup> US Hybrid fuel cell drayage trucks were also piloted at the Port of Houston for three years with \$6.4 million in funding.<sup>85</sup> Nikola Motors is currently in the demonstration phase of producing two fuel cell tractor models that are expected to reach mass production around 2025 with ranges upwards of 500 miles per fill.<sup>86</sup> NREL places hydrogen drayage trucks at a TRL level of 5 to 6 with the potential to move up to TRL 7 by 2021; however, TRL 8 – or commencing commercial production – does not seem likely

<sup>79</sup> <https://www.nrel.gov/docs/fy19osti/72208.pdf>

<sup>80</sup> <https://www.nrel.gov/docs/fy19osti/72208.pdf>

<sup>81</sup> <https://cafcp.org/by-the-numbers>

<sup>82</sup> <https://www.californiahvip.org/eligible-technologies/#your-clean-vehicles>

<sup>83</sup> [https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks\\_ICCT-white-paper\\_26092017\\_vF.pdf](https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf)

<sup>84</sup> <https://www.truckinginfo.com/330270/toyota-and-kenworth-unveil-jointly-developed-hydrogen-fuel-cell-truck>

<sup>85</sup> [https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks\\_ICCT-white-paper\\_26092017\\_vF.pdf](https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf)

<sup>86</sup> Couch et al., *2018 Feasibility Assessment for Drayage Trucks*, prepared for The Port of Los Angeles and Port of Long Beach, April 2019, available at: <http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/>

before 2025.<sup>87</sup> This timeline may change as progress continues to be made for development of fuel cells for transit bus applications and fleet operators gain more experience deploying fueling stations.

The challenge with widespread deployment of FCVs is related less to the vehicles and more to the infrastructure needed to fuel them. Currently, there are about 40 public hydrogen fueling stations available in the U.S., and all of them are in California; moreover, DOE’s Alternative Fuels Data Center identifies 24 planned (yet to be operational) stations nationwide, which includes a small Northeastern corridor from New York to Massachusetts.<sup>88</sup> California has a goal to deploy 100 hydrogen refueling stations statewide by 2022, and upon completing the deployment of 65 operational stations, some of which are currently in development, CEC estimates that California will have the hydrogen capacity to support 21,000 light-duty FCVs.<sup>89</sup> However, without sustained investments in refueling infrastructure, it is unlikely that the FCV will reach a scale needed to displace significant numbers of light duty ICE vehicles.

For heavy vehicles, Shell (via Equilon) has announced plans to increase hydrogen station deployment at the Port of Long Beach with CEC funding to support its truck demonstration pilot.<sup>90</sup> Nikola recently announced plans to develop a network of 700 hydrogen stations across the U.S. and Canada by 2028 to support its vehicles;<sup>91</sup> for scale, only 65 public and private stations are operational today across the two countries.<sup>92</sup>

Overall, medium- and heavy-duty FCVs have the potential to be an important component of an alternative fuel vehicle strategy. However, the technology is still in a demonstration phase across a wide swath of vehicle applications, and more needs to be understood about the scalability of FCVs and associated hydrogen infrastructure. FCV advantages include quick fueling, efficiency, and long ranges, which may make them suited for longer-haul and drayage applications.<sup>93</sup> However, cost of fuel cell technology and hydrogen as well as the availability of hydrogen fueling infrastructure prove to be significant barriers to the widespread commercialization of this technology in the near-term.<sup>94</sup>

## Emissions Impacts

FCVs produce zero tailpipe emissions. Like electricity for EVs, hydrogen for FCVs can be produced from a number of processes and sources which impacts FCVs’ well-to-wheels emissions. The most common

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<sup>87</sup> Couch et al., *2018 Feasibility Assessment for Drayage Trucks*, prepared for The Port of Los Angeles and Port of Long Beach, April 2019, available at: <http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf>

<sup>88</sup> <https://afdc.energy.gov/stations/#/find/nearest>

<sup>89</sup> *Id.*

<sup>90</sup> <https://www.bizjournals.com/losangeles/news/2018/04/20/toyota-shell-move-forward-with-hydrogen-facility.html>

<sup>91</sup> <https://www.forbes.com/sites/alanohnsman/2019/04/14/can-a-15-billion-bet-on-fuel-cell-big-rigs-be-a-game-changer-for-hydrogen/#27a373cfe4ce>

<sup>92</sup> <https://afdc.energy.gov/stations/#/find/nearest>

<sup>93</sup> [https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks\\_ICCT-white-paper\\_26092017\\_vF.pdf](https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf)

<sup>94</sup> [https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks\\_ICCT-white-paper\\_26092017\\_vF.pdf](https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf)

process is natural gas reforming, which involves the use methane and thermal processes to create hydrogen gas. This process dilutes some of the emissions reductions benefits of FCVs, but generally makes FCVs attractive relative to ICE vehicles: UCS found that the Hyundai Tucson FCV on hydrogen from natural gas reduced GHG emissions per mile by 34 percent compared to its gasoline-powered counterpart.<sup>95</sup> Hydrogen is increasingly being produced by electrolysis, which uses electricity to split water into hydrogen and oxygen; in California, that electricity is produced with increasingly cleaner generating resources, and state law requires that at least 33 percent of hydrogen produced at state-supported hydrogen stations must be produced with low-carbon resources.<sup>96</sup> Under this production method, the Hyundai Tucson FCV would produce 54 percent less GHG emissions than its ICE counterpart.<sup>97</sup> Renewable liquid reforming and fermentation are other production methods that use biomass to produce hydrogen and may provide emissions reductions benefits relative to gas reforming methods.<sup>98</sup>

Because of FCVs’ zero emission attributes and a focus on increasingly cleaner forms of hydrogen production, FCVs are also expected to play a role in achieving California’s GHG emission reduction targets. A CEC analysis finds that in a pathway to achieving 80 percent GHG reductions by 2050 from 1990 levels, FCVs may comprise as much as 10 percent of light-duty sales in 2030.<sup>99</sup>

### Vehicle Costs

FCVs are significantly more expensive than ICE vehicles on an upfront basis. The Toyota Mirai, comparable to a Toyota Prius in size and appearance, has a MSRP of \$58,500. The Hyundai Nexo, comparable to the Hyundai Kona, has a MSRP of \$58,300. Leasing options may provide a monthly payment that is costly yet more comparable to ICE vehicle leases. Automakers generally include 3 years of complementary fuel up to \$13,000-\$15,000 in their leases.



Source: Dennis Schroeder / NREL

For medium- and heavy-duty FCVs, concrete vehicle cost data is scarce due to limited deployment. In general, upfront FCV costs are still quite high, although they are beginning to decrease. In 2016, CARB estimated that FCEBs cost approximately \$1.235 million.<sup>100</sup> The NREL FCEB assessment from 2018 reveals that recent bus orders cost \$1.27 million, down from \$2.5 million in 2010.<sup>101</sup> An order of 40

<sup>95</sup> <https://www.ucsusa.org/sites/default/files/attach/2014/10/How-Clean-Are-Hydrogen-Fuel-Cells-Fact-Sheet.pdf>

<sup>96</sup> *Id.*

<sup>97</sup> *Id.*

<sup>98</sup> [https://afdc.energy.gov/fuels/hydrogen\\_production.html](https://afdc.energy.gov/fuels/hydrogen_production.html)

<sup>99</sup> <https://www.ethree.com/wp-content/uploads/2018/06/Deep-Decarbonization-in-a-High-Renewables-Future-CEC-500-2018-012-1.pdf>

<sup>100</sup> <http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review-Final-December-2018.pdf>

<sup>101</sup> <https://www.nrel.gov/docs/fy19osti/72208.pdf>



buses could push costs closer to \$1 million per FCEB.<sup>102</sup> Truck cost data is difficult to obtain. Nikola anticipates offering an all-in truck cost, fueling, and maintenance package for around \$900,000 over the million-mile life of the vehicle.<sup>103</sup> ICCT predicts that the TCO for heavy-duty FCVs may be 5-30 percent less than diesel vehicles in 2030, but these assumptions are dependent on hydrogen fuel and infrastructure costs declining over time.<sup>104</sup>

According to the California Fuel Cell Partnership, hydrogen prices range from \$12.85 to upwards of \$16 per kilogram (kg).<sup>105</sup> At \$14 per kg, the price per energy equivalent to gasoline translates to \$5.60 per gallon. NREL estimates that fuel prices could drop to \$8-\$10 per kg within the 2020-2025 period, at which point FCVs would approach fuel cost parity with ICE vehicles, but it may still be more costly depending on gasoline prices.<sup>106</sup>

### Infrastructure Costs

Hydrogen fueling infrastructure cost is perhaps the most significant barrier to the development of the light-duty FCV market. The CEC estimates that the total cost of reaching its 100 station goal will approach \$201.6 million, or over \$2 million per station.<sup>107</sup> All-in costs, including installation and overhead, are around \$2.5 million for 180 kg/day stations, and up to \$4 million for 360 kg/day stations. CEC provided the majority of funding to support station deployment costs, with some matching funds secured from other agencies and private sector stakeholders.<sup>108</sup> As the DOE notes, it is difficult to develop a comprehensive infrastructure network for distribution of hydrogen to hundreds or thousands of fueling stations.<sup>109</sup> Producing hydrogen on site may reduce distribution costs, but raises production costs if on-site production facilities are not already available. In short, the hydrogen station market has relied on government support to grow, and the CEC identifies a strong need for private investment to achieve economies of scale and reduce costs in a manner that ultimately supports the self-sufficiency of the technology.

## 2.3 Natural Gas Vehicles

### Technology Readiness

Natural gas is a fossil fuel primarily used in transit buses, refuse hauling, and over-the-road trucks. Natural gas is consumed either as compressed natural gas (CNG) or liquefied natural gas (LNG). About 200 million gasoline gallon equivalents of natural gas are consumed in California annually, with most of that currently being via CNG (77 percent).

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<sup>102</sup> <https://www.nrel.gov/docs/fy19osti/72208.pdf>

<sup>103</sup> <https://www.trucks.com/2019/04/17/nikola-unveils-trucks-launches-1-5-billion-investment-drive/>

<sup>104</sup> [https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks\\_ICCT-white-paper\\_26092017\\_vF.pdf](https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf)

<sup>105</sup> <https://cafcp.org/content/cost-refill>

<sup>106</sup> *Id.*

<sup>107</sup> <https://www.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf>

<sup>108</sup> *Id.*

<sup>109</sup> [https://afdc.energy.gov/fuels/hydrogen\\_production.html](https://afdc.energy.gov/fuels/hydrogen_production.html)

There is modest natural gas vehicle (NGV) commercial availability in medium-duty vehicles. In Class 4-5 vocations, NGVs are well suited for shuttles and urban delivery trucks, and in Class 6 vocations they are used in regional haul applications. There are some natural gas engines available in the Class 4-5 segment that are available at scale, but there is limitation to NGVs in this segment because the compressed storage tanks of CNG require special consideration in the design of the chassis. For example, the CNG fuel tank may need to be placed in such a way that reduces cargo space for delivery vans, which makes an NGV a less appealing alternative to a conventionally fueled vehicle.

Natural gas has more potential in heavy-duty vehicles, and there is good availability of NGVs in vocations like drayage, regional haul, refuse, and transit. According to the Port of Los Angeles and Port of Long Beach's *2018 Feasibility Assessment for Drayage Trucks*, NGVs comprise 3 percent of the Ports' drayage fleet and are the most dominant alternative fuel vehicle drayage truck platform with demonstrable model availability from major original equipment manufacturers (OEMs), dealership engagement, production capabilities, and customer interest.<sup>110</sup> Unlike medium-duty vehicles, the heavy-duty truck manufacturing industry is rarely vertically integrated, and the tractor, engine, powertrain, and trailer are typically manufactured separately. For heavy-duty vehicles (class 7 and 8), there is only one certified CNG engine in California (Cummins Westport's CWI line which includes a 6.7 liter engine, a 9 liter engine, and a 12 liter engine). These engines cover a wide array of performance requirements, and are good options for transit buses and refuse truck fleets. Natural gas is particularly popular in refuse trucks, and all of the major bus manufacturers have a CNG option.



Source: Lancer Automotive Group

## Emissions Impacts

Natural gas offers modest emissions benefits over diesel, with a roughly 12 percent GHG emission reduction on a lifecycle basis.

Natural gas also offers NO<sub>x</sub> and PM<sub>2.5</sub> benefits over diesel. NGVs can reduce PM<sub>2.5</sub> up to 70 percent, as compared to diesel vehicles, and NGVs reduce NO<sub>x</sub> by 50-90 percent. NO<sub>x</sub> reductions vary based on the NGV engine technology; new low-NO<sub>x</sub> engines meet a voluntary emissions standard that is 90 percent below the current NO<sub>x</sub> standard.

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<sup>110</sup> Couch et al., *2018 Feasibility Assessment for Drayage Trucks*, prepared for The Port of Los Angeles and Port of Long Beach, April 2019, available at: <http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/>

## Vehicle Costs

Class 4-6 NGVs have an incremental cost of between \$25,000 to \$50,000, as compared to diesel vehicles. This is a 50 percent to 80 percent price increment over the cost of a convention Class 4-6 diesel truck (\$48,000 to \$63,000). Class 7-8 have an incremental cost of \$40,000 to \$60,000 over conventional diesel vehicles. This is a 37 percent price increment over the cost of a conventional Class 7-8 diesel truck (\$110,000 to \$160,000). Total cost of ownership of the vehicle, which includes fuel costs, can be slightly less for certain vocations of NGV, particularly as vehicle miles traveled increases. Vehicle costs can also be defrayed by incentives; the HVIP program, for instance, provides vehicle incentives, and the RFS and LCFS programs both provide incentives that are typically passed on to the fleet or end user in some way.

## Infrastructure Costs

The costs for natural gas fueling infrastructure varies by the size of the fueling station. Assuming medium-duty fleet vehicles return to a base, they can be fueled at a centralized location using a fast fill or time fill station. Fast fill stations are best suited for retail situations and use a compressor on site to compress the gas to a high pressure and store the gas in storage vessels so it is available for quick fueling. Fast fill stations mimic the experience of a traditional gasoline fueling station and allow drivers to fill a 20 gallon tank in less than 5 minutes. Time fill stations are used by fleets and fill vehicles with gas directly from the compressor. Depending on the number of vehicles to be fueled and the compressor size, time-fill stations can take between a few minutes to several hours to fuel vehicles. The table below summarizes these costs. As shown below, time fill stations are generally less expensive to deploy and operate than fast fill stations due to smaller compressors and lower energy consumption.<sup>111</sup>

**Table 4: Natural Gas Fueling Infrastructure Costs**

Size	Type	Serving	Total Cost
<b>Small Station</b> 85-170 DGE/day	Fast Fill	10-15 work trucks	\$400-600k
	Time Fill	10-15 work trucks	\$250-500k
<b>Medium Station</b> 425-680 DGE/day	Fast Fill	50-80 shuttles/vans	\$700-900k
	Time Fill	25-40 trucks	\$550-\$850k
<b>Large Station</b> 1,275-1,700 DGE/day	Fast fill, retail	Refuse trucks, tractors, etc.	\$1.2-\$2.0 million

<sup>111</sup> *Id.*



## 2.4 Renewable Natural Gas

### Technology Readiness

Renewable natural gas (RNG) is derived from biomass or other renewable resources, and is a pipeline-quality gas that is fully interchangeable with conventional natural gas. RNG can be produced from a variety of feedstocks by three methods: anaerobic digestion, thermal gasification, and power to grid technology. Most RNG that is currently dispensed in California is derived from landfills.

Renewable natural gas is a drop-in fuel that can be used in NGVs. About 67 percent of California’s natural gas consumption in 2017 was RNG, and RNG accounted for more than 60 percent of California’s market for natural gas as a transportation fuel. This percentage will increase as major natural gas consumers (e.g., Los Angeles County Metropolitan Transportation Authority) expand their RNG demand significantly.

For more information about the availability of NGVs, see the Natural Gas section above.

### Emissions Impacts

RNG reduces GHG emissions about 54 to 92 percent, depending on the feedstock. Most RNG in California is made from landfill gas, which reduces GHG emissions by 56 percent. Production will likely shift over time to lower carbon intensity RNG made from feedstocks such as the anaerobic digestion of animal manure and digesters deployed at waste water treatment plants.



Source: Dennis Schroeder / NREL

RNG provides similar tailpipe emissions reductions to conventional natural gas, with PM2.5 reductions of 70 percent and NOx reductions between 50 and 90 percent, depending on engine technology.

### Vehicle Costs

RNG is used in NGVs. Class 4-6 NGVs have an incremental cost of between \$25,000 to \$50,000, as compared to diesel vehicles. Class 7-8 have an incremental cost of \$40,000 to \$60,000 over conventional diesel vehicles. Because of lower fuel costs than diesel (and similar costs to conventional natural gas), total cost of ownership of the vehicle can be slightly less for certain vocations of NGV, particularly as vehicle miles traveled increases.

### Infrastructure Costs

Because RNG is a drop-in fuel, it can use existing conventional natural gas fueling infrastructure. For more information about natural gas fueling infrastructure costs, see the table above.

## 2.5 Ethanol

### Technology Readiness

Ethanol is produced from corn or cellulosic feedstocks, such as crop residues and wood. Starch- and sugar-based ethanol is produced via dry-milling or wet-milling, and cellulosic production can be achieved through biochemical or thermochemical pathways. E10, a blend of 10 percent ethanol and 90 percent gasoline, is required for light-duty vehicles in California (E10 is referred to as reformulated gasoline; the gasoline and ethanol formulation helps to reduce harmful criteria pollutant emissions). E15 is a blend of 0.5-15 percent ethanol with gasoline and is approved for use in model year 2001 and newer light-duty conventional gas vehicles. E85, sometimes known as flex fuel, is an ethanol blend containing 51-83 percent ethanol and is only for use in flex fuel vehicles. Ethanol is produced at facilities across the Midwest, Southern US, and Western states, and there are 6 ethanol production facilities in California. Most ethanol consumed in California is via E10, although there has been growth in E85 consumption as well, with E85 retail stations increasing from 30 to more than 150 between 2009 and 2018. Ethanol consumption has shifted to ethanol with lower carbon intensity rather than increased as a whole.



Source: John De La Rosa / NREL

Flex fuel vehicles (FFVs), which can operate on E85, gasoline, or a blend of the two, are widely available as a standard option for many light-duty vehicle models. FFVs are very similar to conventional gasoline vehicles, and have improved acceleration performance when operating on higher ethanol blends.

### Emissions Impacts

On a life cycle basis, ethanol produced from corn reduces GHG emissions by about 30 percent. Ethanol produced with cellulosic feedstocks can reduce GHG emissions from 50-90 percent when land-use change emissions are considered.

Ethanol is predominantly produced using corn. However, ethanol producers are now seeking to reduce their carbon intensity, and the carbon intensity of ethanol has decreased steadily over time. Older facilities with high carbon intensity were nearly phased out by the end of 2017; ethanol with carbon intensity higher than 75 g/MJ was reduced from nearly 90 percent of the ethanol low carbon fuel standard (LCFS) credits in 2011 to less than 5 percent in 2018.

### Vehicle Costs

Flex fuel vehicles are available at comparable prices to gasoline vehicles, and there is not an incremental cost associated with flex fuel vehicles, though manufacturers likely face a per vehicle cost of roughly \$50-100.

## Infrastructure Costs

E85 fueling infrastructure costs vary widely by project. Stations can add E85 equipment by converting an existing tank or adding a new tank and retrofitting or adding new dispensers. A 2008 survey of 120 E85 stations by the National Renewable Energy Laboratory found that costs ranged from \$7,599-\$247,600 for a new tank and \$1,736-\$68,000 for an existing tank.<sup>112</sup>

## 2.6 Renewable Gasoline

### Technology Readiness

Renewable gasoline is a drop-in fuel that meets the ASTM D484 specification. (ASTM International, formerly known as American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. ASTM establishes standards for fuels used in motor vehicles that are widely recognized by manufacturers and fuel suppliers.) Renewable gasoline is made from biomass feedstocks.

Renewable gasoline is not commercially available at this time.

### Emissions Impacts

The emissions impacts of renewable gasoline are still being studied.

### Vehicle Costs

Because renewable gasoline is a drop-in fuel, there is no vehicle incremental cost associated with the use of renewable gasoline.

### Infrastructure Costs

Because renewable gasoline is a drop-in fuel, it can use existing gasoline fueling infrastructure.

## 2.7 Biodiesel

### Technology Readiness

Biodiesel is produced via the processing of virgin oils (e.g., soy or canola), byproducts of other processes (e.g., corn oil extracted via corn ethanol production), and waste products (e.g., used cooking oil). Biodiesel can be blended up to 5 percent with no labeling required at the pump; however, anything above 20 percent requires special labeling at retail fuel pumps. Most new medium- and heavy-duty engines on the road today have warranties that accommodate up to 20 percent blend of biodiesel with conventional diesel.

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<sup>112</sup> National Renewable Energy Laboratory. Cost of Adding E85 Fueling Capability to Existing Gasoline Stations: NREL Survey and Literature Search. <https://afdc.energy.gov/files/pdfs/42390.pdf>.

Statewide, biodiesel accounts for approximately 6 percent of diesel fuel sold, based on data reported for the Low Carbon Fuel Standard. However, biodiesel use has been discouraged in the South Coast Air Basin due to concerns about potential increased NOx emissions, as discussed below.

### **Emissions Impacts**

Depending on feedstock, B20 can reduce GHG emissions by 10-18 percent. B20 reduces emissions of volatile organic compounds (VOCs) by about 18 percent and reduces PM by an average of 17 percent in heavy duty engine model years 2006 and older. Biodiesel has been found to slightly increase NOx emissions, at least in some instances. The impact is uncertain and appears to vary depending on the biodiesel feedstock (soy vs. animal fats) and the engine age. Researchers at UC Riverside tested model year 2006 and 1991 truck engines running on B5 and B10 blends of both soy and animal-based biodiesel. The tests found statistically significant increases in NOx emissions of 0.7 percent to 3.6 percent in some cases, although other cases did not show statistically significant differences in NOx emissions due to B5 and B10. Because of the potential for NOx increases, has not been promoted as an alternative fuel in the South Coast Air Basin.

### **Vehicle Costs**

B20 can be used in conventional diesel vehicles, and in California, B20 is competitively priced with conventional diesel. Vehicles using biodiesel may have minor increased maintenance costs, since biodiesel can loosen accumulated deposits in fuel injectors and fuel lines, which may clog the fuel filter. As a result, users may need to replace the fuel filters after the first couple of tanks of biodiesel. While not necessarily maintenance related, biodiesel gels at cooler temperatures, which prevents the fuel from passing through fuel lines and injectors. B20 has a gel point of -15° F, so fleet managers using biodiesel need to monitor the fuel in colder temperatures and adjust blend levels based on the season.

### **Infrastructure Costs**

Biodiesel fueling can often use existing diesel fueling equipment, so biodiesel fueling infrastructure is relatively inexpensive. All existing tanks and associated underground equipment (e.g., tanks and pipes) are compatible with B20, and most are compatible with biodiesel blends up to B100. However, existing equipment must be cleaned prior to using a new fuel, which typically costs under \$2,000. As noted above, due to concerns about NOx emissions increases as noted above, biodiesel use has been discouraged in the South Coast Air Basin, since ozone formation in the region is primarily driven by NOx. There is currently only one retail fueling station selling biodiesel in the County – a 76 station in Ontario. Biodiesel is more commonly used in northern California and the rest of the country.

## **2.8 Renewable Diesel**

### **Technology Readiness**

Renewable diesel is a liquid fuel produced from biomass. It meets the fuel specification requirements of ASTM D975 for petroleum diesel fuel, meaning that although it is produced from biomass, it has the properties of conventional diesel. Renewable diesel is produced from the same biomass used to make biodiesel via different processes.

Renewable diesel is a drop-in replacement and can be blended into the conventional diesel supply without limitations. There are labeling requirements when the fuel is blended above 5 percent, and there are multiple retailers that have started to sell renewable diesel at higher level blends. Due in part to incentives that result from the Low Carbon Fuel Standard, use of renewable diesel has been increasingly rapidly in California. In 2019, renewable diesel accounted for approximately 16 percent of all diesel sold in the state, based on reporting for the Low Carbon Fuel Standard. This is up from approximately 4 percent in 2015. Most of this renewable diesel is blended with conventional diesel and thus largely unknown to truck owner and operators.

### **Emissions Impacts**

Lifecycle emissions of renewable diesel depends on the fuel feedstock, but renewable diesel offers similar GHG emissions reductions to biodiesel. RD5 reduces GHG emissions by about 3 percent and RD100 reduces GHG by about 66 percent. Renewable diesel also reduces criteria pollutant emissions, and can provide PM<sub>2.5</sub> reductions of up to 35 percent.

### **Vehicle Costs**

Because renewable diesel is a drop-in fuel, it can be used in existing diesel vehicles and does not have any incremental cost. Renewable diesel is priced competitively with conventional diesel, and does not have any additional operations and maintenance costs as compared to conventional diesel.

### **Infrastructure Costs**

Because renewable diesel is blended into conventional diesel, it does not need separate fueling infrastructure. As noted above, diesel sold in California currently contains approximately 16 percent renewable diesel on average.

## **2.9 Vehicle Efficiency Improvements**

Another approach to reduce emissions is to improve vehicle fuel efficiency. GHG emissions are directly correlated with fuel consumption, so improving vehicle fuel economy will lead to lower GHG emissions, and may also reduce criteria pollutant emissions such as NO<sub>x</sub> and PM.

## **Expand Fuel Economy Regulations for Light Duty Vehicles**

### **Technology Readiness**

Fuel economy standards have been around since the 1970s for light-duty vehicles and have contributed to significant reductions in petroleum use and fuel costs for consumers. California, under the Clean Air Act, has unique authority to set emissions standards for vehicles that are more stringent than national standards, which 13 states and the District of Columbia currently follow. In 2010, the U.S. Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) harmonized their emissions and fuel economy standards with California's program to create a new, two-phase National Program. Phase 1 covered vehicle model years 2012-2016 with an average fuel economy target of 34.1 mpg for model year 2016, and Phase 2 covered model years 2017-2025 with an average fuel economy target of 54.5 mpg for model year 2025 if standards were met solely with fuel efficiency

improvements.<sup>113</sup> The standards were subject to a mid-term evaluation in 2016, which concluded in a Final Determination that the original standards developed for model years 2022-2025 were feasible and appropriate.<sup>114</sup> In April 2018, the U.S. EPA declared it would reconsider the findings of the mid-term evaluation and in August, 2018, U.S. EPA and NHTSA issued the Safe Affordable Fuel Efficient Vehicles Proposed Rule for model years 2021-2026, which notably weakens the standards established under the original Phase 2 program.<sup>115</sup> The new Proposed Rule has not been adopted and would likely face litigation upon finalization, resulting in potential further regulatory uncertainty for automakers.

In its Final Determination of the mid-term evaluation on the appropriateness of fuel economy and greenhouse gas (GHG) emission standards for the later years of the Phase 2 program, U.S. EPA found that automakers had largely over-complied with the standards during the first four years of Phase 1, and that the industry had amassed a significant number of banked credits from these early years.<sup>116</sup> This finding demonstrates that automakers have the capability to deploy technologies at scale that lower emissions and exceed fuel economy standards. Moreover, the Phase 2 standards provide the flexibility for automakers to pursue multiple technology pathways to achieve compliance as the standards gradually tighten. For example, the Final Determination outlines a number of engine, transmission, and vehicle technologies and their estimated model year 2025 penetration rates (expressed as percentages below) that can be employed to achieve the standards, including turbocharged engines (31-41 percent), naturally aspirated gasoline engines (5-41 percent), advanced transmissions (92-94 percent), mass reduction (2-10 percent), stop-start idling technology (12-39 percent), and mild hybrids (16-27 percent).<sup>117</sup> All of these technologies are readily available today at commercial scale.

U.S. EPA and the California Air Resources Board (CARB) also regulate other vehicle emissions beyond GHGs. In 2014, US finalized “Tier 3” fuel and vehicle standards that would come into effect in 2017 to reduce criteria pollutant emissions.<sup>118</sup> The standards follow the implementation of Tier 2 standards, which were finalized in 2000, and cover evaporative and tailpipe emissions from nitrogen oxides, volatile organic compounds, particulate matter, carbon monoxide, and air toxics. The standards also lower the sulfur content in gasoline. In order to meet the standards, automakers need to improve emission control technologies such as catalytic converters. The Tier 3 Final Rule clearly states that the standards are feasible across all regulated fleets, and the standards are harmonized with CARB Low Emission Vehicle (LEV III) standards.<sup>119</sup>

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<sup>113</sup> According to Union of Concerned Scientists, given the compliance flexibility built into the standards, average fuel economy of new cars in 2025 is expected to be closer to 37 mpg. For comparison, on-road fleet fuel economy was 21 mpg in 2017. <https://www.ucsusa.org/clean-vehicles/fuel-efficiency/fuel-economy-basics.html>

<sup>114</sup> <https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-greenhouse-gas>

<sup>115</sup> <https://www.epa.gov/regulations-emissions-vehicles-and-engines/safer-affordable-fuel-efficient-safe-vehicles-proposed>

<sup>116</sup> <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockkey=P100QQ91.pdf>

<sup>117</sup> <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockkey=P100QQ91.pdf>

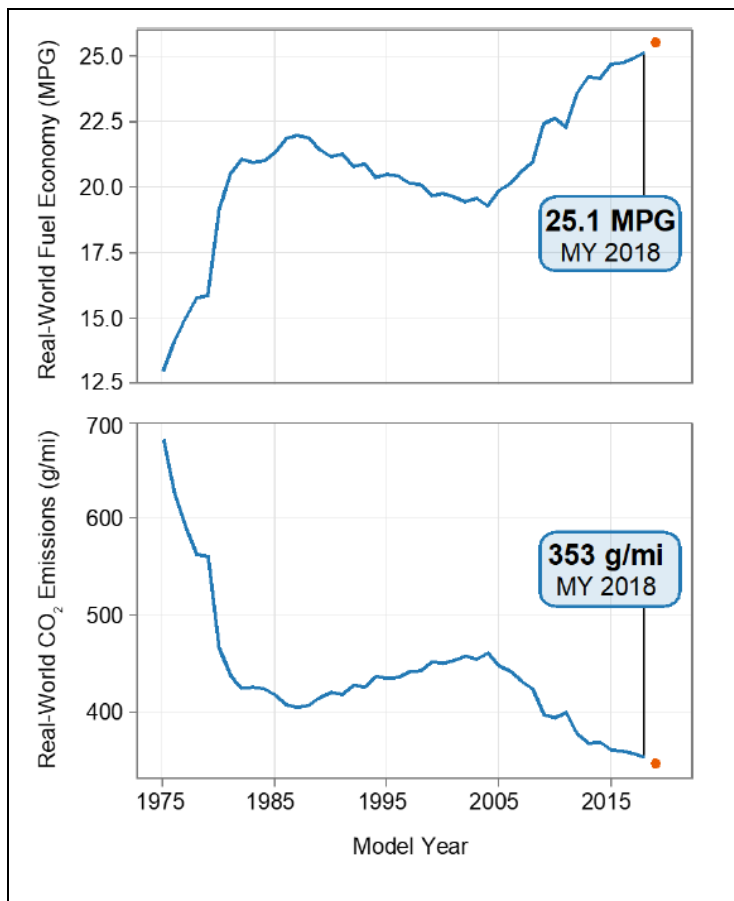
<sup>118</sup> <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100HVZV.PDF?Dockkey=P100HVZV.PDF>

<sup>119</sup> <https://www.govinfo.gov/content/pkg/FR-2014-04-28/pdf/2014-06954.pdf>

## Emissions Impacts

Emissions reductions attributable to light-duty fuel economy and GHG standards have been significant. The National Program (Phase 1 and Phase 2) were projected to avoid 6 billion metric tons of carbon dioxide pollution and cut oil consumption by 12 billion barrels over the lifetime of model year 2012-2025 vehicles.<sup>120</sup> Measures of actual emission reductions attributable to this program are not readily available, in part due to EPA’s recent decision to roll back the Phase 2 standards. EPA’s most recent Automotive Trends report shows that real-world fuel economy reached a new high in 2018 while fleet-average GHG emission rates reached a new low, as shown in the figure below.

**Figure 12. Real-World U.S. Vehicle Fuel Economy and GHG Emission Rates Through 2018**



Source: U.S. EPA, *The 2019 EPA Automotive Trends Report*, EPA-420-R-20-006, March 2020.

The Tier 3 emissions standards are also expected to significantly reduce criteria pollutant emissions from on-road vehicles. By 2030, annual emissions reductions would amount to: 328,509 tons of Nitrogen Oxide (NOx), 167,591 tons of volatile organic compounds, 3,458,041 tons of carbon monoxide, 7,892

<sup>120</sup> <https://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Draft-TAR-Final-Executive-Summary.pdf>



tons of particulate matter (2.5), and 12,399 tons of sulfur dioxide, among other pollutants and air toxics.<sup>121</sup>

### Vehicle Costs

In its Final Determination, U.S. EPA found that the incremental per vehicle costs of meeting model year 2022-2025 standards were approximately \$1,100, or \$36 billion in aggregate across the industry.<sup>122</sup> However, the net consumer fuel cost savings realized as a result of fuel economy improvements were projected to be \$1,500 per vehicle, with total projected consumer pre-tax fuel savings amounting to \$89 billion.<sup>123</sup>

U.S. EPA estimates the cost of the Tier 3 standards will cost less than a penny per gallon of gasoline, or about \$72 per vehicle.<sup>124</sup> This translates to an annual overall program cost of \$1.5 billion in 2030, with annual monetized health benefits amounting to \$6.7-\$19 billion.

Although increasingly-stringent fuel economy and emissions standards require investment and commercialization of new technologies with short-term costs, standards have proven to help reduce petroleum consumption, lower GHG and other air pollutant emissions, save drivers money on fuel costs, and provide ancillary health benefits.

### Infrastructure Costs

While there may be some incremental infrastructure costs associated with achieving compliance with Tier 3 fuel sulfur standards for refiners, fuel economy standards do not require the deployment of additional infrastructure.

## Expand Fuel Economy Regulations for Medium and Heavy-Duty Vehicles

### Technology Readiness

Fuel economy improvements can also be achieved among medium- and heavy-duty vehicles. Fuel economy and GHG standards have applied to light-duty vehicles since the 1970s, but they are relatively new for heavier vehicles: Phase 1 standards were finalized by U.S. EPA and the National Highway Traffic Safety Authority (NHTSA) in 2011 and applied to model years 2014-2018.<sup>125</sup> Phase 2 standards were finalized in 2016 and apply to model years 2019-2027.<sup>126</sup> Although medium- and heavy-duty vehicles comprise only 7 percent of the vehicles on the road, they consume roughly a quarter of the fuel used for on-road transportation; for that reason, targeted fuel economy and GHG standards can yield significant

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<sup>121</sup> It's important to note that these standards also regulate some medium- and heavy-duty vehicles, so not all emissions reductions from Tier 3 standards are attributable to light-duty vehicles.

<sup>122</sup> <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100HVZV.PDF?Dockkey=P100HVZV.PDF>

<sup>123</sup> <https://fas.org/sgp/crs/misc/R45204.pdf>

<sup>124</sup> <https://fas.org/sgp/crs/misc/R45204.pdf>

<sup>125</sup> <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100HVZV.PDF?Dockkey=P100HVZV.PDF>

<sup>126</sup> [https://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean\\_vehicles/HDV-emissions-fuel-economy-factsheet.pdf](https://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/HDV-emissions-fuel-economy-factsheet.pdf)

<sup>127</sup> <https://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm>

fuel savings and emissions reductions.<sup>127</sup> The implementation of the federal medium- and heavy-duty vehicle fuel economy and GHG standards is uncertain at this time. Portions of the regulation have been delayed and are currently subject to litigation.

There is a suite of readily-available technological improvements that fleet operators can take advantage of to improve the efficiency of their vehicles and reduce fuel costs – particularly for heavy-duty long-haul combination vehicles. Additional tractor and trailer equipment can be installed to improve aerodynamics and fuel economy between 2-7 percent.<sup>128</sup> Long-haul combination trucks can also take advantage of low rolling resistance and wide-base single tires, which can also improve fuel economy 2-5 percent; applications for Class 3-6 vehicles are limited. Tire pressure devices can monitor and even adjust pressure to reduce energy losses from tire underinflation and decrease tire maintenance costs. Idle reduction technologies such as fuel operated heaters/coolers, auxiliary power units, and auto start/stop systems, and vehicle electrification for in-truck appliances can reduce reliance on the main engine for heating and cooling; these technologies can reduce idling time by 50 percent and are for the most part applicable to all medium- and heavy-duty vehicles.<sup>129</sup> Engine governors can set limits on highway vehicle speeds, and as a general rule, each 1 mph reduction over 55 mph can improve fuel economy by 0.1 MPG. Trucks that travel at highway speeds often are mostly to benefit, and most fleet operators have governors set to 68 mph or lower. Truck refrigeration units (TRUs), which are typically powered by diesel independent of the truck's engine, can benefit from increased efficiency of hybrid electric technologies that allow for TRUs to be plugged in when stationary. These technologies can reduce TRU diesel consumption by 16 percent. Finally, similar to idle reduction, truck stop electrification (TSE) can improve vehicle efficiency by using external electric power to provide heating, cooling, and other services; TSE can reduce energy use by 74 percent compared to idling a truck engine. However, trucks may need additional internal wiring installed to support TSE.

## Emissions Impacts

The emissions impacts of individual measures to improve fuel economy of trucks and fleets will depend on several factors, including duty cycle, vehicle (weight) loads, and driving conditions. Idle reduction technologies such as auxiliary power units can reduce NOx, particulate matter, and carbon dioxide emissions by 12 percent, 11 percent, and 3 percent respectively.<sup>130</sup> TSE can dramatically reduce these same pollutants by 98 percent, 93 percent, and 80 percent respectively relative to an idling diesel engine.

If implemented as adopted, the overall impact of fuel economy and GHG standards on national trucking emissions will be significant. Phase 1 standards were estimated to reduce GHG emissions by 270 million metric tons – equivalent to the lifetime emissions of 4 million light-duty cars and trucks.<sup>131</sup> Phase 2 standards are estimated reduce GHG emissions by approximately 1 billion metric tons over the life of

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<sup>127</sup> <https://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm>

<sup>128</sup> <http://www.trb.org/Publications/Blurbs/176904.aspx>

<sup>129</sup> The American Trucking Association estimates that long-haul truckers idle for an average of six hours per day.

<sup>130</sup> <http://www.trb.org/Publications/Blurbs/176904.aspx>

<sup>131</sup> <https://www.govinfo.gov/content/pkg/FR-2016-10-25/pdf/2016-21203.pdf>

the vehicles regulated by the standards.<sup>132</sup> The Union of Concerned Scientists found that while Phase 2 standards are expected to reduce fuel consumption by 36 percent in 2027 from 2010 levels, 40 percent reductions are achievable by 2025 with technology that is already being deployed or piloted; this improvement would reduce GHG emissions by an additional 40 million metric tons annually.<sup>133</sup> Unfortunately, there is currently no reliable information to depict how these standards have affected fuel consumption and GHG emissions to date.

Overall, standards are critical tools for reducing transportation sector emissions while saving fleet operators billions in fuel costs and providing regulatory certainty for manufacturers. However, emissions reductions from improved medium- and heavy-duty fuel economy for diesel vehicles are being offset by increases in vehicle miles traveled in the trucking industry. Demand for diesel fuel increased by 3.1 percent in 2018, likely in response to e-commerce and broader economic trends.<sup>134</sup> In sum, fuel economy and GHG standards are an important pathway for reducing emissions from medium- and heavy-duty vehicles, but these emissions reductions are not immune to increased demand for trucking so long as diesel vehicles comprise the bulk of the truck fleet.

## Vehicle Costs

Costs to retrofit or install efficient equipment to diesel trucks are relatively inexpensive but can yield significant fuel cost savings. Aerodynamic improvements can cost between \$300-\$3,100 per device.<sup>135</sup> Low rolling resistance tires cost up to \$50 per tire and wide-base tires save \$130 on average when trucks are equipped with them. Tire pressure monitoring systems cost approximately \$750 while automatic tire inflation systems cost \$1,000 before installation and maintenance. Fuel-operated heaters typically cost \$800-\$1,500, auto start/stop systems can cost between \$1,500-\$2,500, and auxiliary power units may cost \$8,000-\$12,000 before installation and maintenance. Engine governor costs are marginal. Hybrid electric TRUs cost roughly 10 percent more than a comparable diesel model. TSE may require additional wiring and equipment that costs roughly \$3,000.

Most of the nation's large trucking companies, and many smaller companies, invest in at least some of these fuel saving technologies. Fueling costs are typically the second largest component of truck operating cost (after driver wages), so there is a strong incentive for motor carriers to adopt fuel saving technologies that are cost effective. EPA's SmartWay program helps to encourage these technologies by providing information about effectiveness, providing tools for fuel use benchmarking, and rewarding those who voluntarily adopt fuel saving measures by allowing use of SmartWay branding. However, a large portion of heavy-duty trucks are owned by independent owner-operators or small fleets; these entities may lack the resources to invest in fuel saving technologies or may lack knowledge of the benefits.

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<sup>132</sup> <https://www.govinfo.gov/content/pkg/FR-2016-10-25/pdf/2016-21203.pdf>

<sup>133</sup> <https://www.ucsusa.org/sites/default/files/attach/2015/07/proposed-heavy-duty-vehicles-standards.pdf>

<sup>134</sup> <https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/>

<sup>135</sup> <http://www.trb.org/Publications/Blurbs/176904.aspx>

## Infrastructure Costs

Most efficiency improvements do not require the installation of infrastructure, except for TSE. Adding electrical capacity to truck parking spots may add \$1,700-\$2,500 per space. Some TSE operators provide heating and cooling through ventilators that connect to the side of the long-haul truck tractor and charge a time-based fee for service. These systems may cost \$5,000-\$10,000 per space.

## Fleet Turnover Incentives

### Technology Readiness

Fleet turnover incentives can help encourage consumers and fleet operators to retire fuel-inefficient vehicles in favor of newer, more efficient ones. These incentives can be monetary or non-monetary and include purchase rebates, scrappage rebates, income tax credits, HOV lane access, and parking fee exemptions.<sup>136</sup> At the federal level, the Car Allowance Rebate System (also known as CARS or ‘Cash-for-Clunkers’) was signed into law in 2009 and ran from July to August of 2009.<sup>137</sup> California implements its own vehicle retirement program, the Consumer Assistance Program, which is administered by the Bureau of Automotive Repair.<sup>138</sup>

Turnover incentives do not require any technological readiness, though the impact of these incentives will depend on difference in performance of the vehicles retired compared to the performance of new vehicles incentivized as a result of the program. Therefore, it’s inferred that technological improvements have occurred between vehicles that are retired early and vehicles that are eligible for incentives.

### Emissions Impacts

Estimating emissions impacts of turnover incentives is challenging because it requires the establishment of a counterfactual or baseline from which reductions are measured. Two different studies from 2013 estimate that the 2009 CARS program reduced carbon dioxide emissions by 4.4 million tons and 25-27 million tons.<sup>139</sup> California’s Consumer Assistance Program reduced emissions an estimated 7,000 tons during fiscal year 2016-2017.<sup>140</sup>

### Vehicle Costs & Infrastructure Costs

There are no direct vehicle or infrastructure costs associated with fleet turnover incentives.

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<sup>136</sup> [https://www.arb.ca.gov/cc/sb375/policies/fltrnvr/fleet\\_turnover\\_brief.pdf](https://www.arb.ca.gov/cc/sb375/policies/fltrnvr/fleet_turnover_brief.pdf)

<sup>137</sup> <https://obamawhitehouse.archives.gov/blog/2010/04/05/did-cash-clunkers-work-intended>

<sup>138</sup> [https://www.bar.ca.gov/Consumer/Consumer\\_Assistance\\_Program/CAP\\_Vehicle\\_Retirement\\_Program.html](https://www.bar.ca.gov/Consumer/Consumer_Assistance_Program/CAP_Vehicle_Retirement_Program.html)

<sup>139</sup> [https://www.arb.ca.gov/cc/sb375/policies/fltrnvr/fleet\\_turnover\\_brief.pdf](https://www.arb.ca.gov/cc/sb375/policies/fltrnvr/fleet_turnover_brief.pdf)

<sup>140</sup> [https://www.bar.ca.gov/Consumer/Consumer\\_Assistance\\_Program/CAP\\_Vehicle\\_Retirement\\_Program.html](https://www.bar.ca.gov/Consumer/Consumer_Assistance_Program/CAP_Vehicle_Retirement_Program.html)

## Fuel Efficient Tires

### Technology Readiness

Approximately 4-11 percent of light-duty vehicle fuel consumption is attributed to overcoming rolling resistance, which can be expressed as a dimensionless coefficient.<sup>141</sup> Low rolling resistance tires reduce the amount of energy lost from drag and friction, and a 10 percent reduction in rolling resistance could improve fuel economy by 1-2 percent.<sup>142</sup> Most new vehicles are already equipped with low rolling resistance tires; however, there are no requirements in place to ensure the efficiency of replacement tires and consumers have limited access to information on rolling resistance when making tire purchase decisions.<sup>143</sup> Replacement tires vary widely in terms of rolling resistance performances, with the least efficient tires producing 25 percent more rolling resistance than the most efficient ones.<sup>144</sup>

Improvements to tires' rolling resistance should not compromise other aspects of tire performance. Despite concerns that lower rolling resistance would sacrifice tire traction, the U.S. National Research Council has not found significant differences in rolling resistance of tires with similar traction grades.<sup>145</sup> Silica can also be used to improve rolling resistance without sacrificing traction. Studies have also found no robust correlation between tire rolling resistance and tire wear. Ensuring tires are properly inflated can improve both efficiency and durability.

Overall, while fuel-efficient replacement tires are commercially available, there are still consumer information and marketing gaps that must be overcome to increase adoption of low rolling resistance tires.

### Emissions Impacts

In aggregate, the emissions impacts of low rolling resistance tires can be significant. According to a 2010 International Council on Clean Transportation (ICCT) report, modest and technically feasible tire improvements could reduce fuel consumption by 3-5 percent and reduce GHG emissions by an estimated 100 million metric tons per year globally in 2020.<sup>146</sup> These improvements would also mitigate 45,000 metric tons of nitrogen oxides and 10,000 metric tons of particulate matter emissions annually. A University of Michigan study found that based on average light-duty vehicle miles traveled data, switching from the worst- to best-performing tires could save approximately 32 gallons annually – equivalent to roughly 750 pounds of GHG emissions per vehicle.

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<sup>141</sup> [https://afdc.energy.gov/conserve/fuel\\_economy\\_tires\\_light.html](https://afdc.energy.gov/conserve/fuel_economy_tires_light.html)

<sup>142</sup> [https://www.theicct.org/sites/default/files/publications/ICCT\\_tireefficiency\\_jun2011.pdf](https://www.theicct.org/sites/default/files/publications/ICCT_tireefficiency_jun2011.pdf)

<sup>143</sup> Consumer Reports offers ratings that compare tires based on rolling resistance and overall performance, but this information is only accessible to Consumer Reports members.

<https://www.consumerreports.org/cro/2012/12/low-rolling-resistance-tires/index.htm>

<sup>144</sup> <https://www.edmunds.com/fuel-economy/resistance-movement.html>

<sup>145</sup> [https://www.theicct.org/sites/default/files/publications/ICCT\\_tireefficiency\\_jun2011.pdf](https://www.theicct.org/sites/default/files/publications/ICCT_tireefficiency_jun2011.pdf)

<sup>146</sup> [https://www.theicct.org/sites/default/files/publications/ICCT\\_tireefficiency\\_jun2011.pdf](https://www.theicct.org/sites/default/files/publications/ICCT_tireefficiency_jun2011.pdf)

## Vehicle Costs

Producing tires that achieve noticeable fuel economy improvements require relatively modest cost increases. U.S. EPA estimated that improving rolling resistance in tires by 10 percent would cost \$6 per vehicle, while the National Research Council estimated that similar improvements would cost \$2-\$5 per tire for new cars.<sup>147</sup> Fuel cost savings from tire improvements will depend on the price of gasoline and the distance the vehicles are traveled; switching from high to low rolling resistance tires could save approximately \$78 annually in fuel costs, based on gasoline prices at \$2.43 per gallon.<sup>148</sup> Savings will increase as gasoline costs rise.

## Infrastructure Costs

There are no infrastructure costs directly related to low-rolling resistance tires.

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<sup>147</sup> [https://www.theicct.org/sites/default/files/publications/ICCT\\_tireefficiency\\_jun2011.pdf](https://www.theicct.org/sites/default/files/publications/ICCT_tireefficiency_jun2011.pdf)

<sup>148</sup> <https://www.consumerreports.org/fuel-economy/low-rolling-resistance-tires-can-save-fuel/>

### 3 Existing Conditions

#### 3.1 Economic Data and Plans

This section presents a high-level overview of the economy of San Bernardino County and the importance of the logistics sector to the region’s economy.

#### Employment Data

San Bernardino County had approximately 720,000 jobs in 2016, or 9 percent of the SCAG region’s total, as shown in the table below.

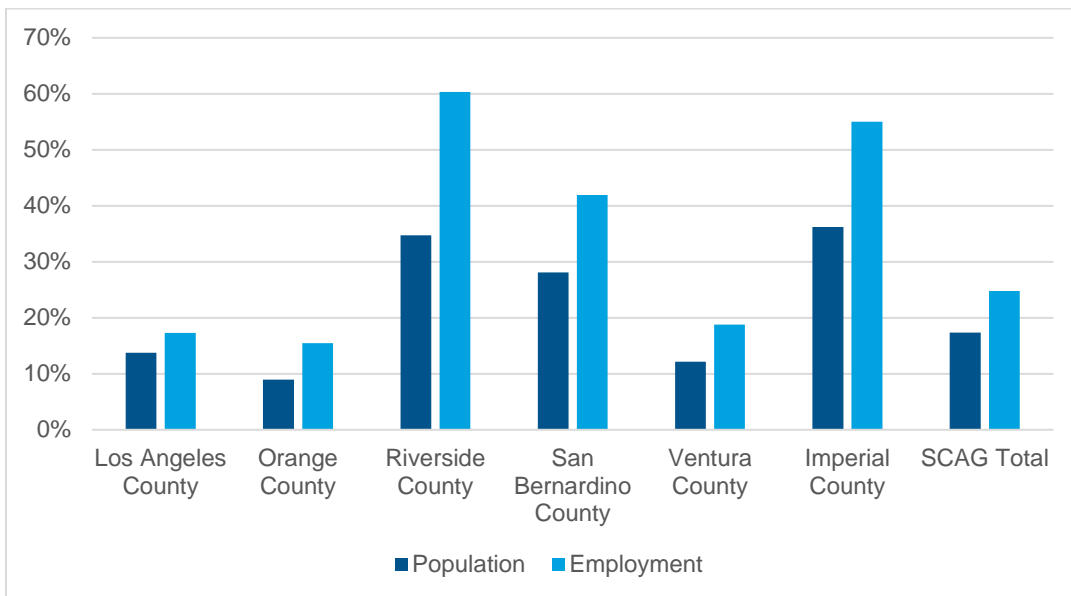
**Table 5: Population and Employment by County, 2016**

County	Population, 2016		Employment, 2016	
Los Angeles	10,124,537	54%	4,454,302	56%
Orange	3,176,666	17%	1,644,967	21%
Riverside	2,362,502	13%	732,617	9%
San Bernardino	2,132,574	11%	724,450	9%
Ventura	860,950	5%	353,386	4%
Imperial	207,037	1%	80,394	1%
<b>SCAG Total</b>	<b>18,864,266</b>	<b>100%</b>	<b>7,909,722</b>	<b>100%</b>

Source: SCAG

Over the next 20 years, population and employment are forecast to grow in San Bernardino County at a significantly higher rate than SCAG region overall, as shown below. San Bernardino County employment is expected to increase by 42 percent between 2016 and 2040.

**Figure 13. Forecast Growth Rate of Population and Employment, 2016-2040**

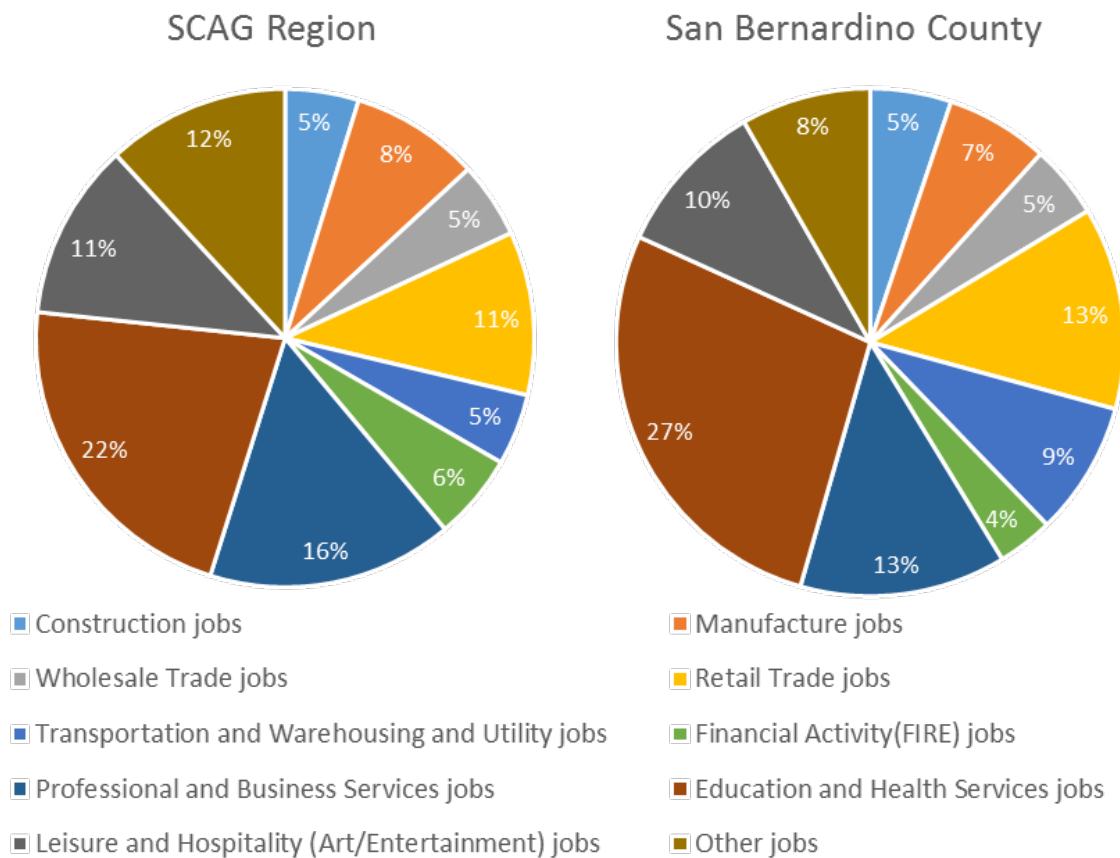


Source: SCAG



Like most of Southern California, San Bernardino County has a diversified economy, with significant employment in all major economic sectors. The figure below shows the distribution of jobs by sector in the entire SCAG region and in San Bernardino County. The County has a significantly larger share of jobs in the Transportation, Warehousing, and Utility sector – 9 percent of all jobs in the County as compared to 5 percent in the entire SCAG region.

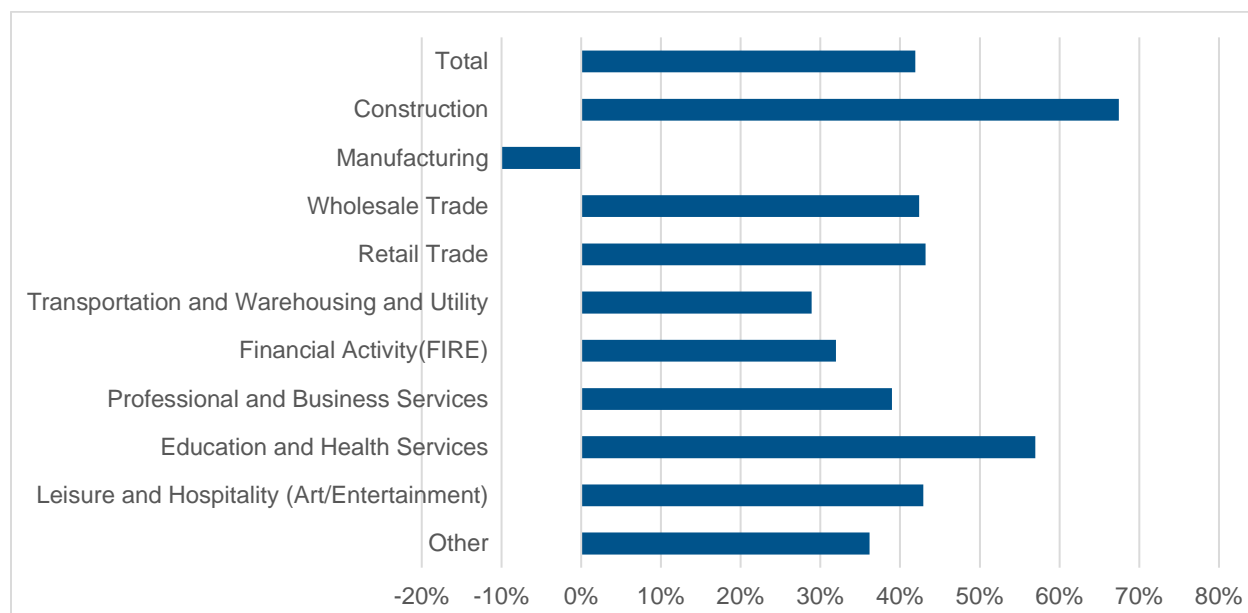
**Figure 14. Distribution of Job by Economic Sector, 2016**



Source: SCAG

Looking ahead, all major economic sectors will see significant growth with the exception of manufacturing, which is forecast to decline by 10 percent. Jobs in the “Transportation and Warehousing and Utility” sector will increase by 29 percent – representing healthy growth although lower than other major sectors, as shown below. Note that these forecasts were developed before the COVID-19 pandemic.

**Figure 15. Forecast Change in San Bernardino County Employment by Sector, 2016 – 2040**



Source: SCAG

## Significance of Logistics to the Region’s Economy

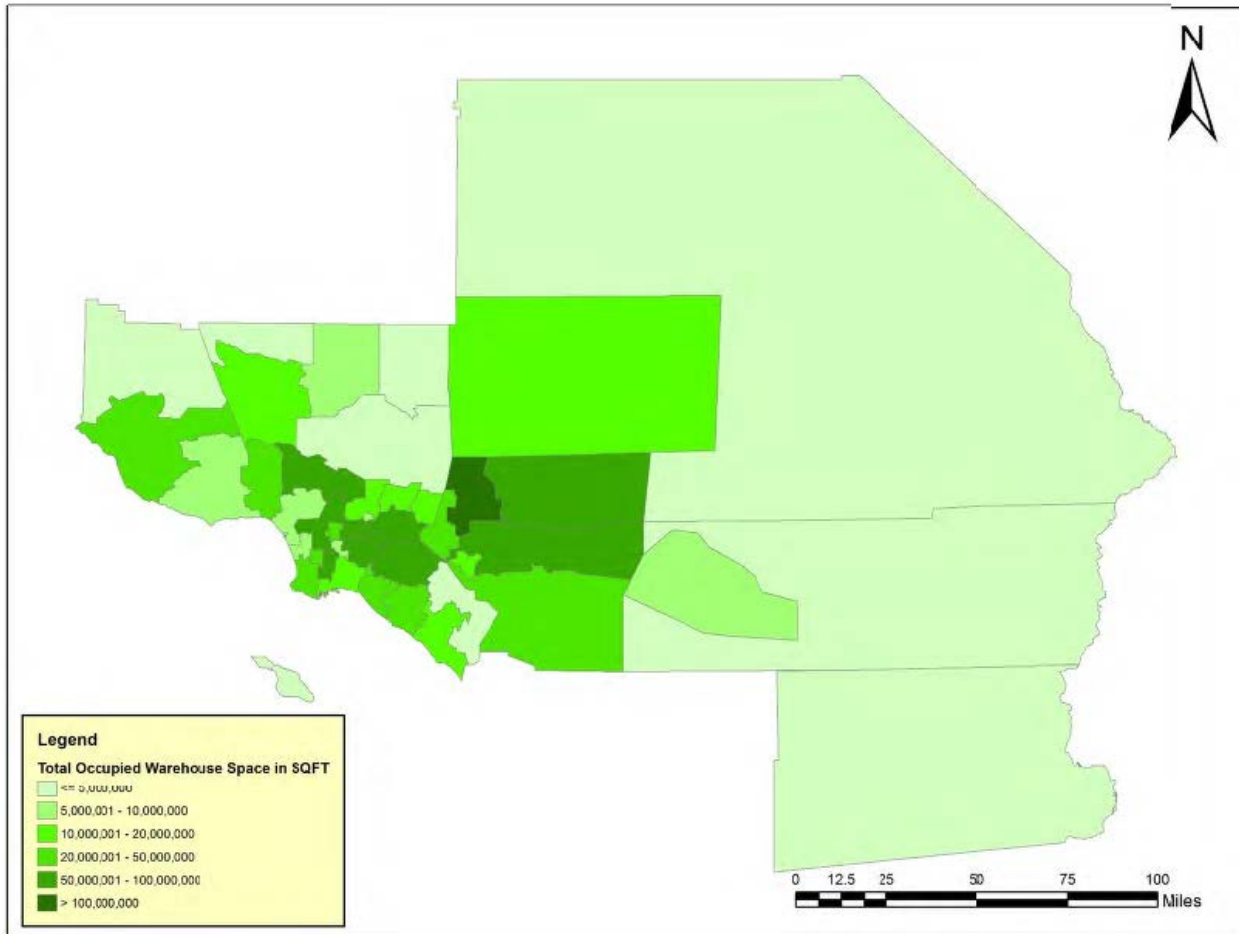
The logistics sector is a major economic driver in the Inland Empire. The logistics sector includes transportation companies (trucking and other modes), third-party logistics providers, warehousing, and wholesale trade. This sector provides a large base of jobs that generally do not require a college degree, which is important in the Inland Empire where 46 percent of adults age 25 and over have a high school degree or less.<sup>149</sup> Among logistics sector workers in the Inland Empire, 78 percent have occupations that require only a high school degree or less.<sup>150</sup> Salaries in the logistics sector are relatively high as compared to other jobs that do not require a college degree; the median annual pay for logistics sector workers in the Inland Empire was \$48,708 in 2017. Thus, the logistics sector is an important driver of upward mobility in the region, particularly for Inland Empire residents with lower education levels who may be unqualified for jobs in other growth industries like information technology and health care, and given the decline in traditional blue-collar manufacturing jobs.

Growth in the logistics sector has been driven by several factors, including international trade through the Ports of Los Angeles and Long Beach, international and domestic air cargo through the Los Angeles International Airport and Ontario International Airport, and the rise of e-commerce. On-line purchasing and the desire for rapid delivery is creating demand for fulfillment centers located in close proximity to population centers. Available land in the Inland Empire coupled with essential transportation infrastructure has led to rapid expansion of warehouse space and associated businesses. The figure below illustrates the concentration of warehouse space in the Inland Empire and western San Bernardino County in particular.

<sup>149</sup> Husing, John. (2017). 2017 Detailed Status of the Inland Empire Economy.

<sup>150</sup> Husing, John. (2017). 2017 Detailed Status of the Inland Empire Economy.

**Figure 16. Total Occupied Space of Industrial Warehouse Buildings in Square Feet, 2014**



Source: Southern California Association of Governments, Industrial Warehousing Study, Task 2 Inventory of Warehouse Facilities, 2018.

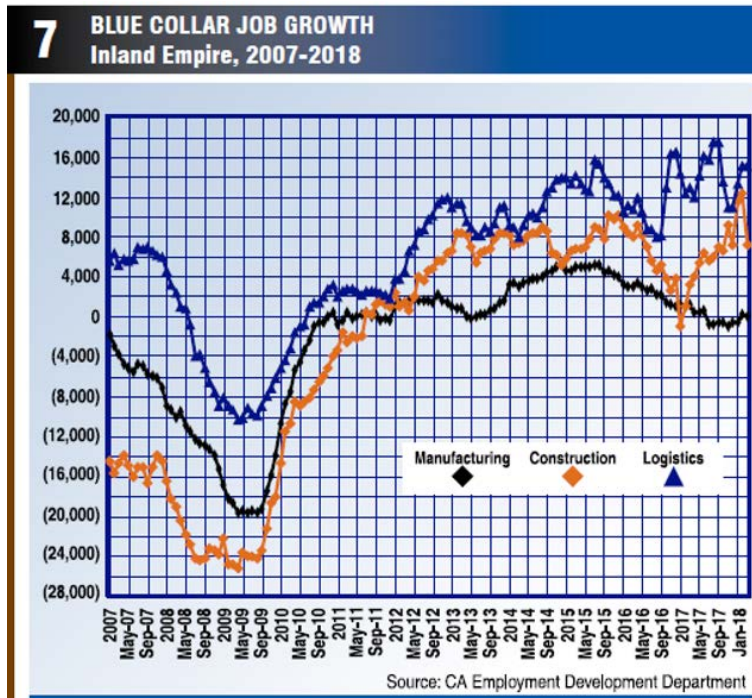
The importance of the logistic sector is increasing, as post-recession job growth in the sector is moving at an even faster pace than the economy as a whole. Much of this information has been reported by the Inland Empire Economic Partnership (IEEP). Over the last decade, the total number of logistics jobs has nearly doubled.<sup>151</sup> The Inland Empire gained over 300,000 jobs from 2011-2017, 20.5 percent of which were from the logistics sector, making it the fastest-growing component of the regional economy over that period.<sup>152</sup> This trend appears to be accelerating, with the logistics sector accounting for 28.4 percent of total job growth in the region in 2017.<sup>153</sup> This job growth in the logistics sector stands in contrast to the manufacturing sector, which has seen less job growth since the 2008-10 recession.

<sup>151</sup> California News Wire Services, Report: Inland Empire Economy Going Strong, No Recession in Sight. ThePatch.com.

<sup>152</sup> Husing, John, 2018 Forecast... Continued Strong Growth! *Inland Empire Quarterly Economic Report* 30(2): 1-7. April 2018.

<sup>153</sup> Husing, John, 2018 Forecast... Continued Strong Growth! *Inland Empire Quarterly Economic Report* 30(2): 1-7. April 2018.

**Figure 17. Blue Collar Job Growth in the Inland Empire by Economic Sector, 2007-2018**



Source: Husing, John, 2018 Forecast... Continued Strong Growth! Inland Empire Quarterly Economic Report 30(2): 1-7. April 2018.

Macroeconomic forces will likely support long-term growth of logistics sector, although the COVID-19 pandemic has added major uncertainty to any economic forecasts. Most importantly, e-commerce is growing rapidly, and many of the facilities supporting Southern California e-commerce are in the Inland Empire.<sup>154</sup> New fulfillment centers continue to be built in the Inland Empire. For example, Amazon already has six fulfillment centers in the region and recently announced a 7<sup>th</sup> to be built in Beaumont, estimated to create 1,000 jobs.<sup>155</sup> Sales tax revenue from these centers is also a large potential source of municipal revenue, with a single facility potentially able to generate \$5 million in annual revenue.<sup>156</sup> Since the industry is largely fueled by imports of foreign products, changes in inflation, exchange rates, and trade policy could affect the logistics market in Southern California (positively or negatively).

### 3.2 Vehicle Population and Activity

As discussed in the next section of this report, the vehicle and emissions analysis for this study focuses on the southwestern portion of San Bernardino County that lies within the South Coast Air Basin. Within this study area, approximately 850,000 light duty vehicles were registered in 2016, according to the EMFAC model. Light duty vehicles account for 93 percent of the 39 million daily VMT in the study area, with heavy duty trucks responsible for another 5 percent.

<sup>154</sup> Husing, John, 2018 Forecast... Continued Strong Growth! *Inland Empire Quarterly Economic Report* 30(2): 1-7. April 2018.

<sup>155</sup> Steiner, Ina, "Amazon to Open Another Fulfillment Center in California," *eCommerce Bytes*. Nov 2, 2018.

<sup>156</sup> Husing, John, 2017 Detailed Status of the Inland Empire Economy.

**Table 6. Vehicle Population and VMT in Study Area, 2016**

Vehicle Type	Vehicle Population		VMT per day	
	Number	Percent	Number	Percent
<i>Light Duty Autos</i>	476,559	54%	21,664,271	55%
<i>Light Duty Trucks</i>	375,984	42%	14,765,706	38%
Light Duty Vehicles	852,542	96%	36,429,976	93%
Medium Duty Trucks	17,100	2%	761,350	2%
Heavy Duty Trucks	17,726	2%	1,930,174	5%
<b>Total</b>	<b>887,368</b>	<b>100%</b>	<b>39,121,501</b>	<b>100%</b>

Source: EMFAC2017

Because of San Bernardino County’s role in trade and logistics, many of the heavy trucks operating in the county are not based in the county. According to the EMFA model, 20 percent of heavy-duty truck VMT in the study area is from out-of-state trucks. Another 14 percent comes from California trucks registered under the International Registration Plan (IRP), which indicates trucks that often travel across state lines. And 10 percent of HDV VMT in the study area is trucks that serve the Ports of Los Angeles and Long Beach. Together, these three types of “non-local” trucks account for nearly half of the HDV VMT in the study area, as shown in the table below.

**Table 7. HDV VMT by Truck Type in Study Area, 2016**

HDV Type	VMT per day	Percent
Out of-State Trucks	379,379	20%
CA IRP Trucks	267,242	14%
Port Trucks	195,947	10%
Other In-State HDV	1,087,606	56%
<b>Total HDV</b>	<b>1,930,174</b>	<b>100%</b>

Source: EMFAC2017

The table below shows EV registrations in the County as a percent of total vehicle registrations. San Bernardino County lags behind the state average, with EVs accounting for just 0.7 percent of county registrations versus 1.5 percent statewide.

**Table 8. EVs as a Percent of Total Vehicle Registrations, as of January 1, 2019**

	BEV	PHEV	EV Total
San Bernardino County	0.3%	0.4%	0.7%
All California	0.8%	0.7%	1.5%

Source: Department of Motor Vehicles

### 3.3 Alternative Fueling Infrastructure

This section provides an overview of existing public and private alternative fueling locations within the portion of San Bernardino County in the South Coast Air Basin. Information in this section is compiled primarily from the U.S. Department of Energy’s Station Locator database (Station Locator).<sup>157</sup> Alternative

<sup>157</sup> <https://afdc.energy.gov/stations/#/find/nearest>.

fuels in the Station Locator include biodiesel, compressed natural gas (CNG), ethanol (E85), electric vehicle supply equipment (EVSE), hydrogen, liquefied natural gas (LNG), and propane. Due to the absence of existing hydrogen fueling infrastructure in the county, hydrogen is not included in the discussion below. Data in the Station Locator is gathered and verified through a variety of methods, and existing stations in the database are contacted at least once a year on an established schedule to verify they are still operational and providing the fuel specified. The Station Locator defines private stations as stations that are not accessible to the public. The sections below provide a summary of each fuel type and the existing fueling locations within the search area of San Bernardino County as of December 2018.

## Biodiesel and Ethanol

Biodiesel and ethanol (collectively referred to as biofuels) are domestically produced fuels that are manufactured from renewable materials and can be used in many diesel and gasoline vehicles without engine modification, including in light-, medium-, and heavy-duty commercial and fleet applications. Biofuels saw an increase in fuel production and use in 2007 with the introduction of the Renewable Fuel Standard (RFS)<sup>158</sup>, a federal program that requires transportation fuel sold in the United States to contain a minimum volume of renewable fuels. Major biofuel providers include Kwik Trip, National Grid, Pearson Fuels, and Propel.

Biodiesel is manufactured from vegetable oils, animal fats, or recycled restaurant grease, and is most often used as a blend with diesel fuel. The Station Locator includes biodiesel fueling locations with a blend of B20 or higher. (B20 means a blend of 20 percent biodiesel and 80 percent conventional diesel.). According to the National Biodiesel Board<sup>159</sup>, the biodiesel industry association in the U.S., biodiesel has been used in the United States for decades, with commercial production ramping up in the early 2000's. Biodiesel production reached its peak in 2016, and has slowly declined in recent years. The number of fueling stations offering B20 or higher has also declined, with a 14% decrease in the number of biodiesel stations in the Station Locator in 2018. The decrease in biodiesel can be attributed, in part, to stations opting to switch to renewable diesel or to stop selling biodiesel altogether.

Ethanol is made from corn and other plant materials. The Station Locator includes ethanol fueling locations containing 51% to 83% ethanol (known as E85 or flex fuel), as well as any E85 stations that also carry lower level ethanol blends of E15 or higher. Ethanol has been used as a transportation fuel since the 1970's. According to the Renewable Fuels Association<sup>160</sup>, the ethanol industry association in the U.S., ethanol production reached its highest level ever in 2018. However, fuel use declined, with a four-year low of just 9.5 percent in April, 2018<sup>161</sup>. Despite the decline in fuel use, the number of E85 stations in the Station Locator increased by 7 percent in 2018.

The map below shows the locations of biodiesel and E85 fueling locations within the county.

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<sup>158</sup> <https://afdc.energy.gov/laws/RFS.html>.

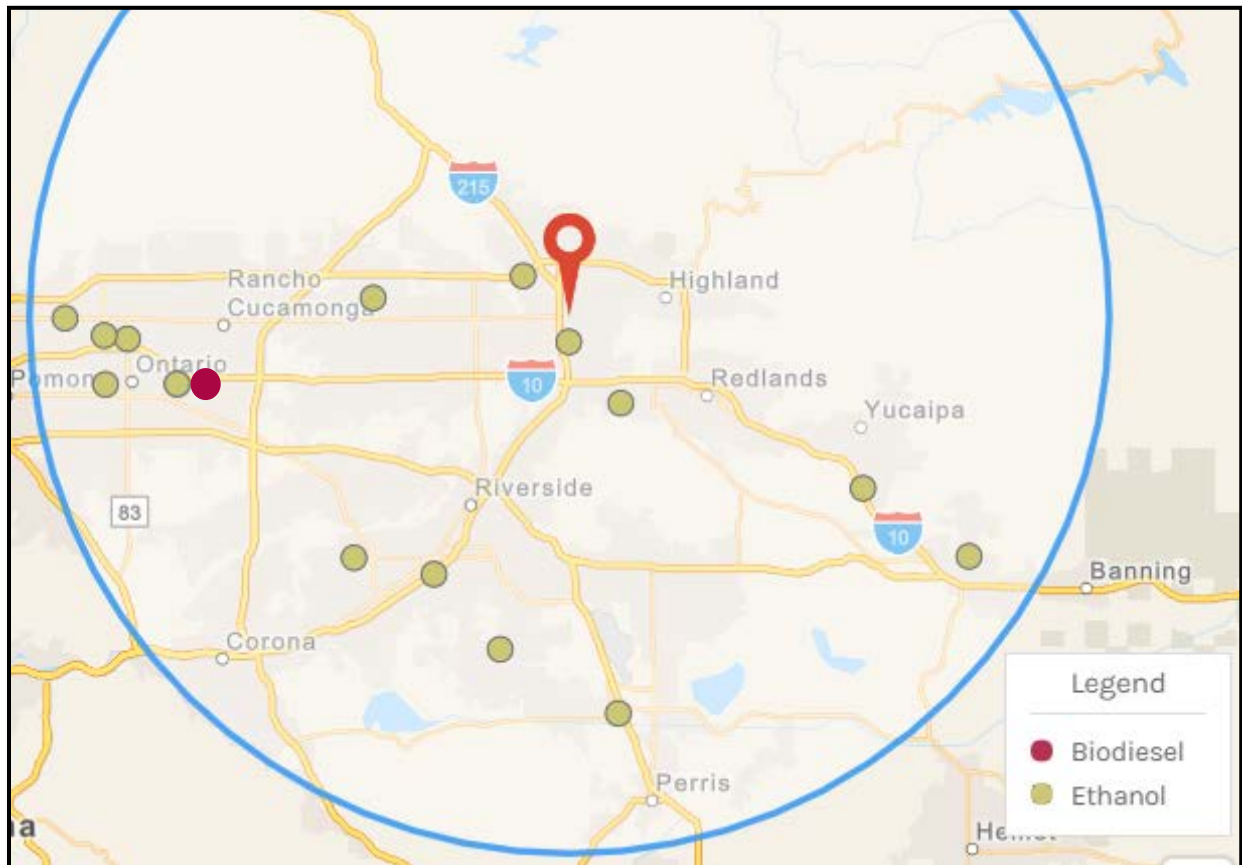
<sup>159</sup> <https://www.biodiesel.org/>.

<sup>160</sup> <https://ethanolrfa.org/>.

<sup>161</sup> Renewable Fuels Association, *2019 Ethanol Industry Outlook* (2019), available at <https://ethanolrfa.org/wp-content/uploads/2019/02/RFA2019Outlook.pdf>.



**Figure 18. Biodiesel and Ethanol Fueling Stations in Study Area**



### Plug-In Electric Vehicle Charging

Electricity is used to power EVs, including all-electric vehicles and plug-in hybrid electric vehicles, which can also operate on conventional fuels. Use of electricity as a vehicle fuel started increasing rapidly in 2010 along with the introduction of EVs by major original equipment manufacturers (OEMs) such as Toyota and Chevrolet. EVs are primarily used in light-duty fleet and commercial applications, but are becoming more prevalent in medium- and heavy-duty fleet applications, as OEMs begin offering more vehicle models.

Electric vehicle supply equipment (EVSE) is used to charge EVs and is classified by the rate at which the EV batteries are charged. Level 1 charging provides two to five miles of range per hour of charging through a 120 volt (V) outlet. Level 2 charging provides 10-20 miles of range per hour of charging through a 240V outlet or EVSE. Finally, DC fast charging provides 60 to over 80 miles of range per 20 minutes of charging through a 480V or higher EVSE. The table below provides a summary of public and private EVSE charging levels in the county.



**Table 9. County EVSE Charging Stations**

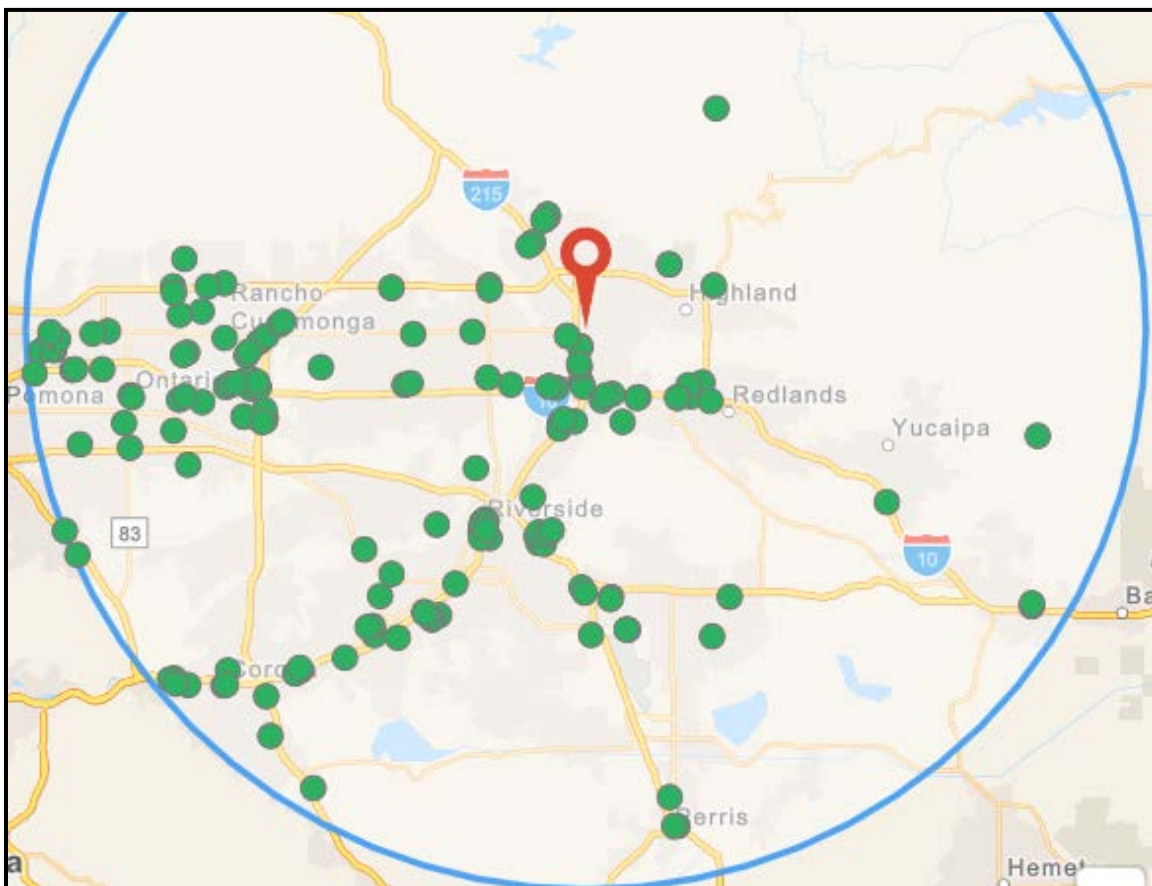
	Level 1 Outlets	Level 2 Outlets	DC Fast Outlets
<b>Public</b>	3	297	64
<b>Private*</b>	2	137	0

\*Note that private electric vehicle charging infrastructure does not include residential or multi-unit dwelling charging.

The number of EVSE is currently growing at a pace much faster than any other alternative fuel in the U.S., with significant increases in the number of EVSE each year since 2012. In particular, the number of EVSE in the Station Locator grew by 21 percent in 2018, which can be attributed to the growing industry as well as to EVSE installations completed by Electrify America as part of the 2017 Volkswagen Clean Air Act Civil Settlement.<sup>162</sup> Other major EVSE fuel providers include Blink, ChargePoint, EVgo, Greenlots, and SemaConnect. The number of EVSE is expected to continue to increase in 2019 and beyond.

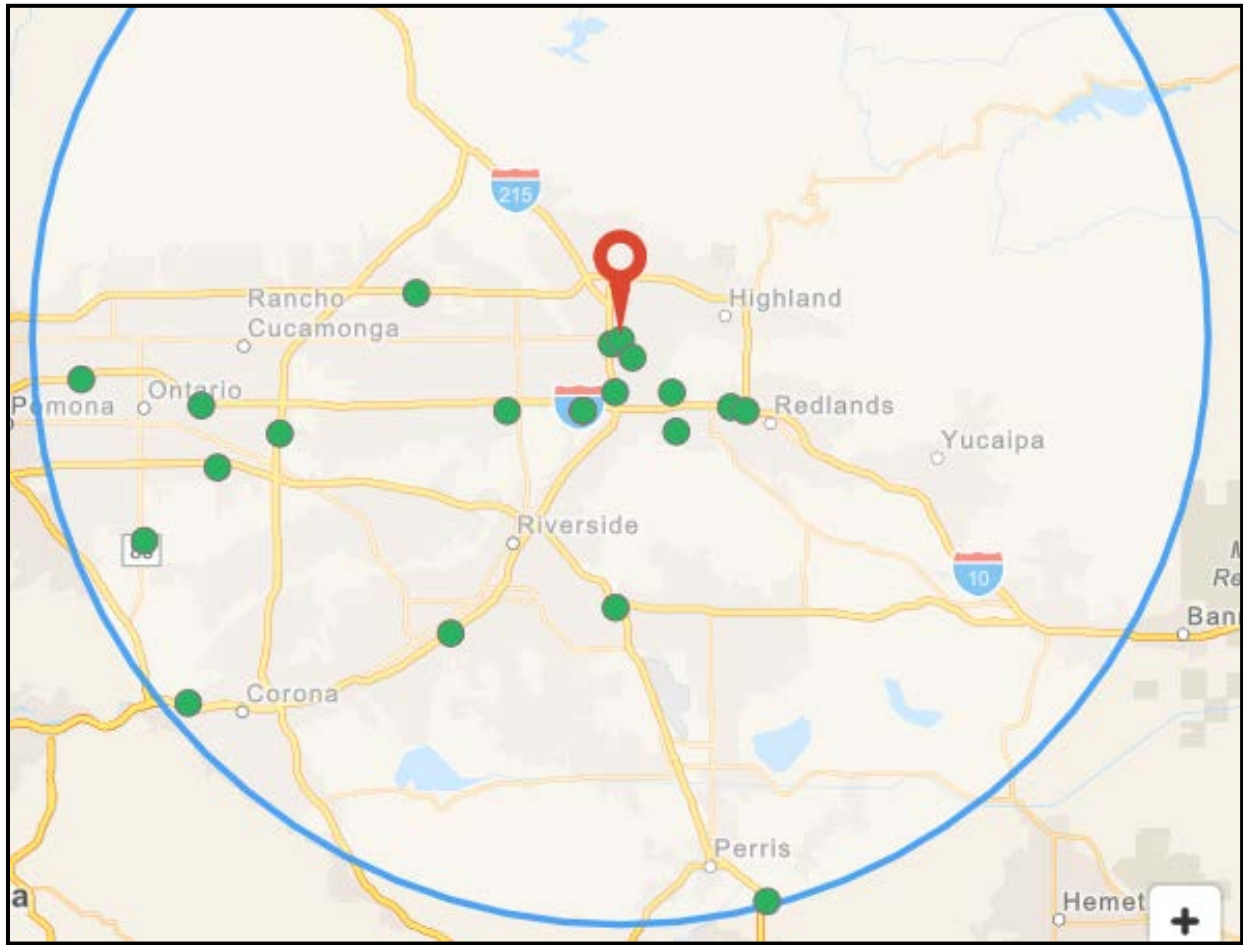
The maps below show the locations and access of EVSE within the county.

**Figure 19. Public Electric Vehicle Charging Locations in Study Area**



<sup>162</sup> <https://www.epa.gov/enforcement/volkswagen-clean-air-act-civil-settlement>

**Figure 20. Private Electric Vehicle Charging Locations in Study Area**



## Natural Gas

Natural gas is a clean-burning alternative fuel that must be compressed (CNG) or liquefied (LNG) for use in natural gas vehicles (NGVs). Natural gas can be used in light-, medium-, and heavy-duty commercial and fleet NGVs that are either dedicated, bi-fuel (vehicles that can run on either natural gas or gasoline), or dual fuel (mainly heavy-duty vehicles that run on natural gas but use diesel fuel for assistance). Natural gas has been used as a vehicle fuel in the U.S. since the 1990's, with annual vehicle fuel consumption increasing slightly each year<sup>163</sup>.

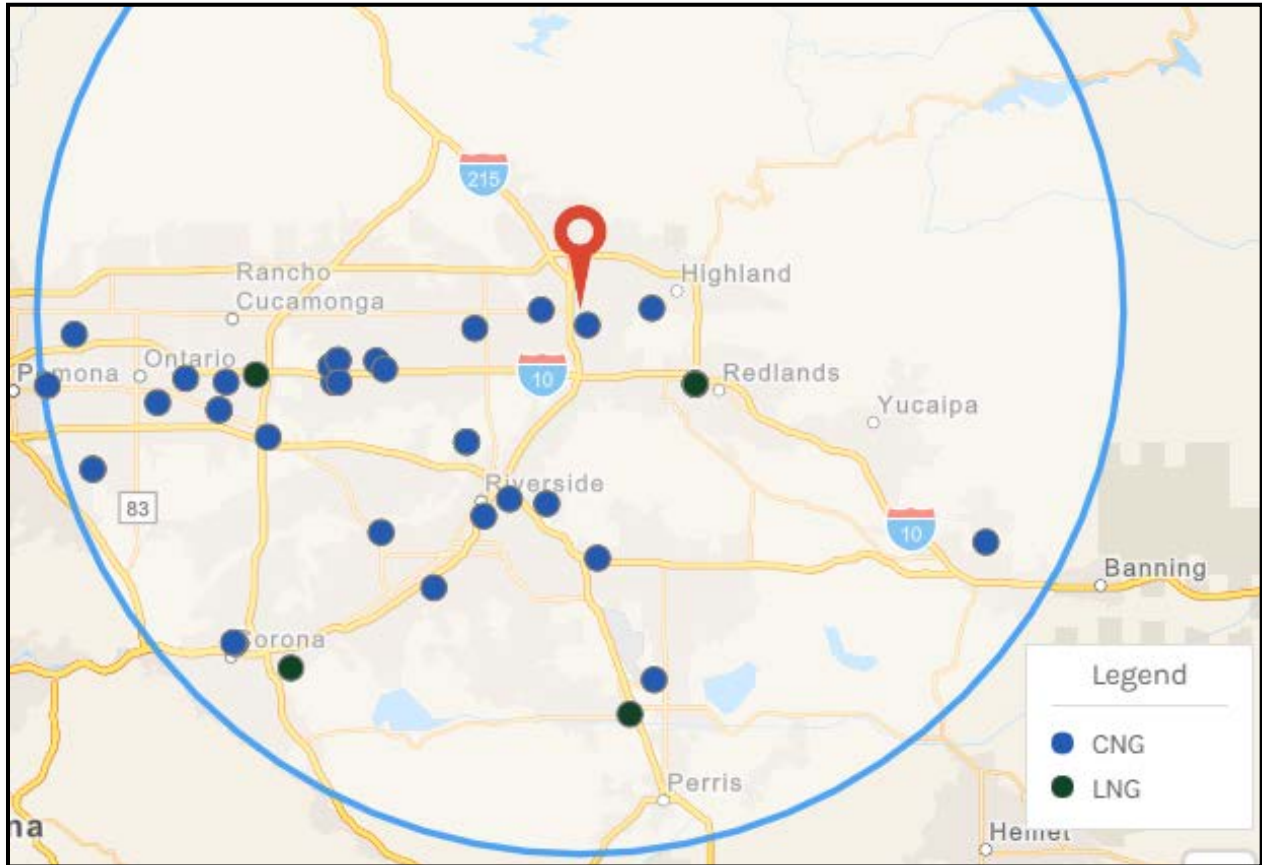
Despite fuel consumption increases, the number of natural gas fueling stations in the Station Locator declined in 2018 by 7 percent for CNG and 16 percent for LNG, respectively. The decrease in natural gas stations is partially due to low gasoline prices and public station closures resulting from low demand. Natural gas stations are also beginning to consolidate by closing smaller stations and opening larger stations with increased fueling capacities. Major fuel providers for natural gas in the U.S. include Clean

<sup>163</sup> <https://www.eia.gov/dnav/ng/hist/n3025us2m.htm>

Energy, Kwik Trip, and Trillium. The industry association for natural gas in the U.S. is Natural Gas Vehicles for America (NGVA).

The map below shows public and private natural gas fueling locations in the study area.

**Figure 21. Natural Gas Fueling Stations in Study Area**



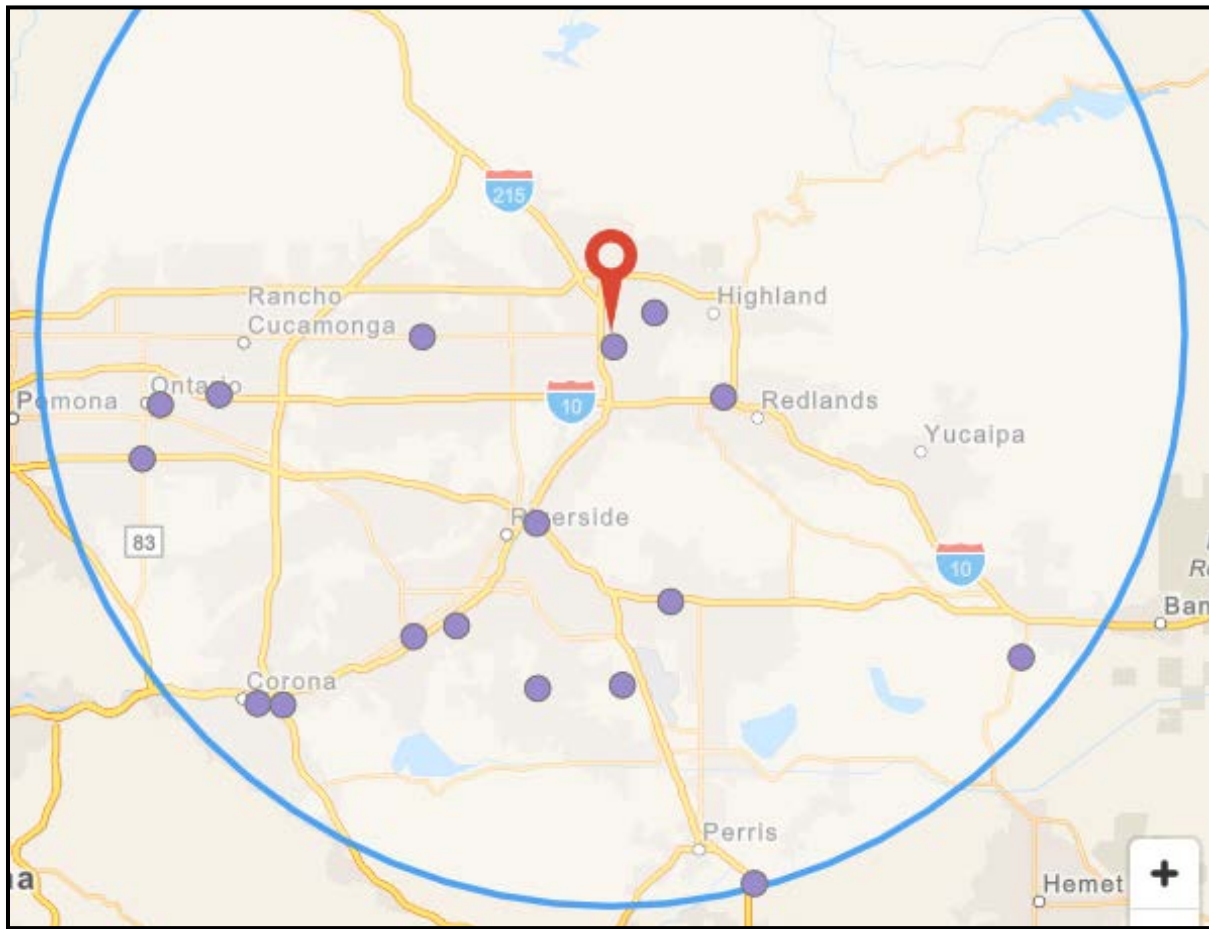
## Propane

Propane, also known as liquefied petroleum gas (LPG) or propane autogas, is a by-product of natural gas processing and crude oil refining, and is stored as a liquid. Propane has been used as a vehicle fuel in the U.S. since the 1970's for light-, medium-, and heavy-duty fleet and commercial applications. There are two types of propane vehicles: dedicated and bi-fuel. Dedicated propane vehicles are designed to run only on propane, while bi-fuel propane vehicles have two separate fueling systems that enable the vehicle to use either propane or gasoline.

Propane demand has decreased slightly in recent years, contributing to a decrease in the number of propane fueling stations in the Station Locator. Specifically, the number of propane fueling stations decreased by 6 percent in 2018, and can be attributed to stations beginning to only offer bottle fueling, likely due to lack of demand or a lapse in licensing for vehicle fueling. Major propane fuel providers in the U.S. include AmeriGas, Blossman Gas, Ferrellgas, Suburban Propane, and U-Haul. The industry association for propane in the U.S. is the Propane Education & Research Council (PERC).

The map below shows public and private propane fueling locations in the study area.

**Figure 22. Propane Fueling Stations in Study Area**



## 4 Scenario Analysis Methodology

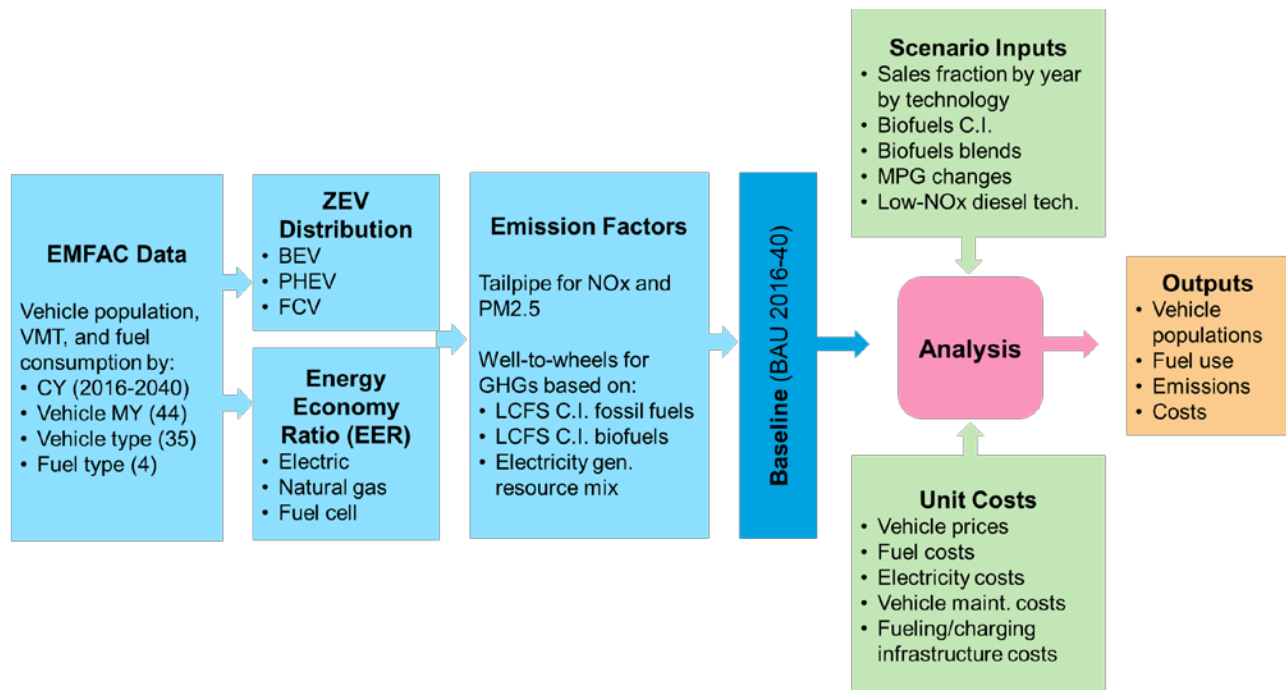
This section describes the methodology for developing and analyzing alternative paths to clean vehicle and fuels implementation. The baseline (business as usual) and alternative paths are referred to as “scenarios”. This section describes the development of the analysis framework; the assumptions for fuel economy, emission factors, and costs; the emissions and costs results for the baseline scenario, and the process for creating the alternative scenarios.

### 4.1 Analysis Framework

ICF developed an analysis tool for the purpose of quantifying the emissions and cost impacts of alternative paths to clean vehicle and fuels implementation. The tool characterizes a baseline scenario that reflects the vehicle population, travel activity, emissions, and costs assuming expected technology changes and implementation of all adopted rules and regulations, but no additional rules, regulations, or significant incentive programs. The tool then allows characterization of alternative scenarios that modify the baseline vehicle and fuel assumptions in order to explore the emissions and cost impacts of these scenarios. This section describes the development of the analysis framework.

The figure below shows an overview of the analysis framework as a flow chart.

**Figure 23. Flow Chart Overview of Analysis Framework**



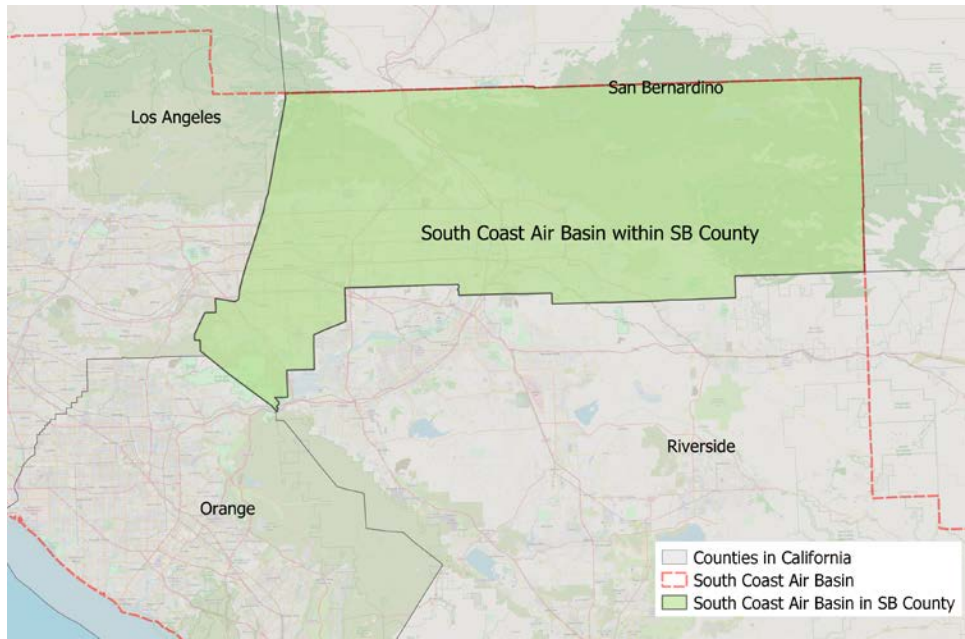
### Scope and Analysis Years

The analysis covers all on-road vehicles, including light, medium, and heavy-duty vehicles. No off-road vehicles or equipment are included in the analysis.



The focus of interest for this study is the portion of San Bernardino County that is within the South Coast Air Basin, illustrated as the green shaded area in the figure below. The EMFAC model can provide vehicle population and activity data for this same geographic area. So all VMT and emissions data presented in this report reflect only the portion of San Bernardino County within the South Coast Air Basin.

**Figure 24. Analysis Area**



The “base year” is the first calendar year included in the analysis, and is typically selected to be the most recent year for which observed (as opposed to projected) vehicle population and activity data exists. The base year for this analysis is 2016. This year was selected primarily because it is the base year in the California Air Resources Board’s (ARB) latest emissions model, EMFAC2017 – the primary source for vehicle population and activity data as described below.

## Baseline Vehicle Categories and Populations

We obtained vehicle population and activity data from the EMFAC model. EMFAC is the model approved by the U.S. EPA for air quality planning purposes in California and is widely used for emissions analyses in the state. EMFAC is based on an extensive database of current and forecast vehicle information. Specifically, the model contains vehicle miles of travel (VMT) and emissions by:

- Geographic area
- Calendar year
- Vehicle type
- Fuel type
- Vehicle model year

Note that both the South Coast Air Quality Management District’s Final 2016 Air Quality Management Plan (AQMP) and SCAG’s Final 2016 Regional Transportation Plan and Sustainable Communities Strategy (RTP/SCS) relied on EMFAC2014, which was the model version available at the time of the plan analyses.

Thus, these plans have a base year of 2012. EMFAC2017 was released on March 1, 2018, and it is therefore feasible to use this updated version of the model and a more recent base year. EMFAC2017 contains a number of updates and improvements compared to EMFAC2014, including:

- While vehicle population in EMFAC2014 was based on 2000-2012 vehicle registration data from California Department of Motor Vehicles (DMV), EMFAC2017 uses DMV populations for years 2000 through 2016. The additional 4 years of DMV registration data (2013-2016) reflects the most recent changes to California motor vehicle fleet characteristics.
- EMFAC2017 uses the most recent International Registration Plan (IRP) data for characterizing out-of-state trucks and buses. Trucks that regularly travel in multiple states typically register with the IRP to facilitate payment of apportionable fees in multiple jurisdictions. ARB uses IRP data to help estimate the population and age distribution of out-of-state trucks that travel in California.
- EMFAC2017 updates the assumptions regarding how fleets are complying with the state Truck and Bus Rule requirements.
- For EMFAC2017, the Port of Los Angeles/Long Beach and the Port of Oakland provided lists of vehicle identification numbers (VINs) for vehicles that actually visited the ports, which has improved the model's characterization of port trucks.
- Emission factors have been updated for both light and heavy-duty vehicles.
- Updated socioeconomic factors are used to predict new vehicle sales and VMT growth trends.
- EMFAC2017 reflects the federal Phase 2 GHG standards, which were enacted in 2016.
- EMFAC2017 incorporates updates to assumptions regarding the state's Advanced Clean Cars (ACC) regulation based on the 2017 Midterm review of ACC. These include updates to Zero Emission Vehicle (ZEV) sales forecasts and updated carbon dioxide (CO<sub>2</sub>) emission rate and fuel efficiency forecasts.

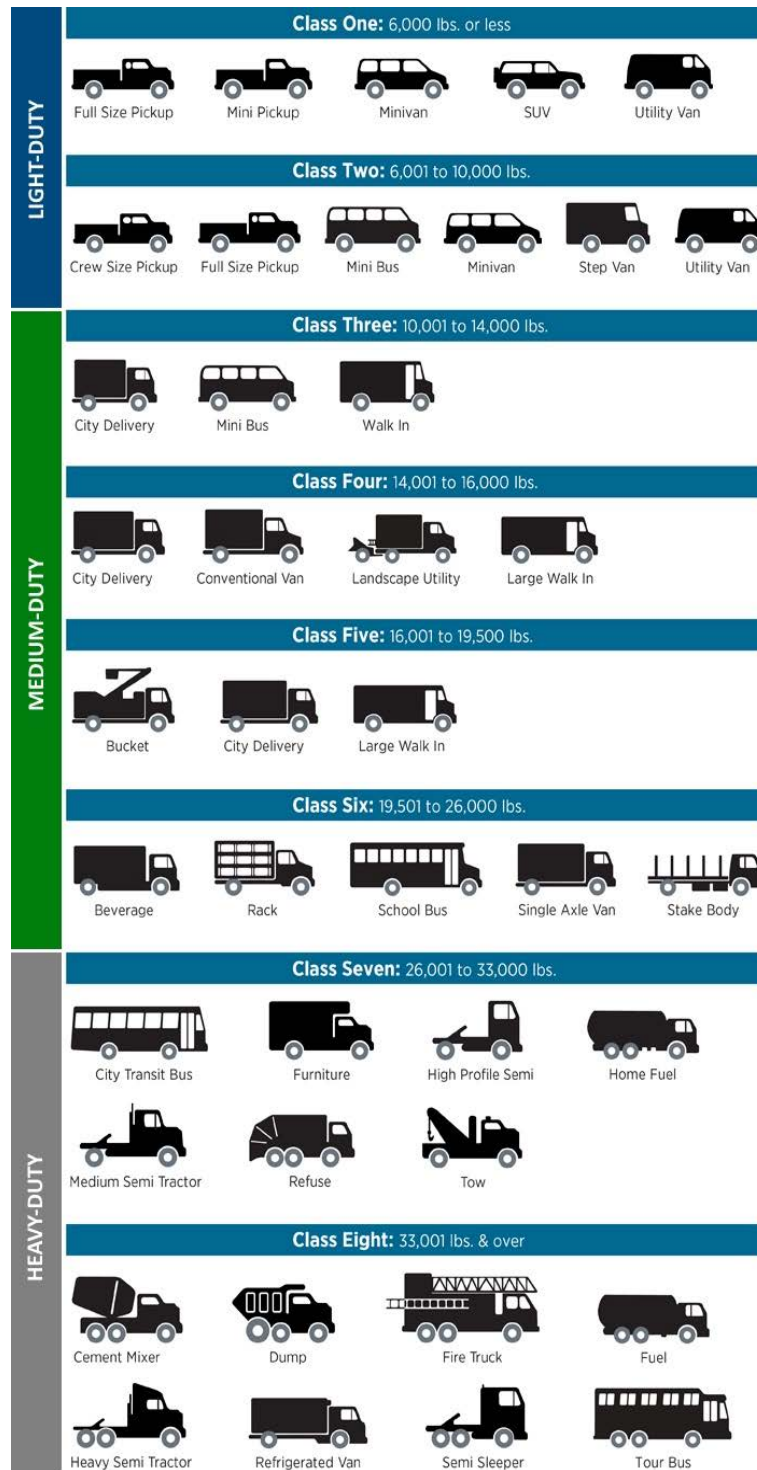
Use of EMFAC2017 means that the base year emissions for this study are not exactly consistent with the existing AQMP or RTP/SCS. However, since the purpose of this study is primarily to identify effective emission reduction strategies and not directly for compliance or regulatory purposes, minor inconsistencies with the AQMP and RTP/SCS do not affect the study conclusions. Moreover, if we were to use EMFAC2014, the analysis would require that we make additional adjustments to EMFAC output to reflect the more recent regulations listed above.

## Vehicle Categories

For the purpose of reporting results, we group vehicles into three major types – Light-Duty, Medium-Duty, and Heavy-Duty. These three major types, based on gross vehicle weight rating (GVWR), are commonly used by transportation agencies and the trucking industry, and are based on the eight vehicle classes developed by the Federal Highway Administration (FHWA). The figure below illustrates the three major vehicle types and the correspondence with the eight FHWA vehicle classes.



Figure 25. Types of Vehicles by Weight Class



Source: U.S. Department of Energy, Alternative Fuel Data Center, <https://afdc.energy.gov/data/>

EMFAC categorizes vehicles using a different system. The table below shows how we mapped by EMFAC vehicle categories to FHWA classes and major vehicle types.

**Table 10. EMFAC Vehicle Categories**

EMFAC Vehicle Category	EMFAC Description	FHWA Class	Vehicle Type
<b>LDA</b>	Passenger Cars	1	Light-Duty
<b>LDT1</b>	Light-Duty Trucks (GVWR <6000 lbs and ETW <= 3750 lbs)	1	Light-Duty
<b>LDT2</b>	Light-Duty Trucks (GVWR <6000 lbs and ETW 3751-5750 lbs)	1	Light-Duty
<b>MDV</b>	Medium-Duty Trucks (GVWR 6000-8500 lbs)	2	Light-Duty
<b>LHD1</b>	Light-Heavy-Duty Trucks (GVWR 8501-10000 lbs)	2	Light-Duty
<b>LHD2</b>	Light-Heavy-Duty Trucks (GVWR 10001-14000 lbs)	3	Medium-Duty
<b>T6TS</b>	Medium-Heavy Duty Gasoline Truck	4	Medium-Duty
<b>T6 Public</b>	Medium-Heavy Duty Diesel Public Fleet Truck	5	Medium-Duty
<b>T6 utility</b>	Medium-Heavy Duty Diesel Utility Fleet Truck	5	Medium-Duty
<b>T6 Ag</b>	Medium-Heavy Duty Diesel Agriculture Truck	6	Medium-Duty
<b>T6 CAIRP small</b>	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR<=26000 lbs	6	Medium-Duty
<b>T6 instate construction small</b>	Medium-Heavy Duty Diesel instate construction Truck with GVWR<=26000 lbs	6	Medium-Duty
<b>T6 instate small</b>	Medium-Heavy Duty Diesel instate Truck with GVWR<=26000 lbs	6	Medium-Duty
<b>T6 OOS small</b>	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR<=26000 lbs	6	Medium-Duty
<b>T6 CAIRP heavy</b>	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>26000 lbs	7	Heavy-Duty
<b>T6 instate construction heavy</b>	Medium-Heavy Duty Diesel instate construction Truck with GVWR>26000 lbs	7	Heavy-Duty
<b>T6 instate heavy</b>	Medium-Heavy Duty Diesel instate Truck with GVWR>26000 lbs	7	Heavy-Duty
<b>T6 OOS heavy</b>	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR>26000 lbs	7	Heavy-Duty
<b>PTO</b>	Power Take Off	8	Heavy-Duty
<b>T7 Ag</b>	Heavy-Heavy Duty Diesel Agriculture Truck	8	Heavy-Duty
<b>T7 CAIRP</b>	Heavy-Heavy Duty Diesel CA International Registration Plan Truck	8	Heavy-Duty
<b>T7 CAIRP construction</b>	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck	8	Heavy-Duty
<b>T7 NNOOS</b>	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-state Truck	8	Heavy-Duty
<b>T7 NOOS</b>	Heavy-Heavy Duty Diesel Neighboring Out-of-state Truck	8	Heavy-Duty
<b>T7 other port</b>	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities	8	Heavy-Duty
<b>T7 POAK</b>	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area	8	Heavy-Duty
<b>T7 Public</b>	Heavy-Heavy Duty Diesel Public Fleet Truck	8	Heavy-Duty
<b>T7 Single</b>	Heavy-Heavy Duty Diesel Single Unit Truck	8	Heavy-Duty
<b>T7 single construction</b>	Heavy-Heavy Duty Diesel Single Unit Construction Truck	8	Heavy-Duty
<b>T7 SWCV</b>	Heavy-Heavy Duty Diesel Solid Waste Collection Truck	8	Heavy-Duty
<b>T7 tractor</b>	Heavy-Heavy Duty Diesel Tractor Truck	8	Heavy-Duty
<b>T7 tractor construction</b>	Heavy-Heavy Duty Diesel Tractor Construction Truck	8	Heavy-Duty
<b>T7 utility</b>	Heavy-Heavy Duty Diesel Utility Fleet Truck	8	Heavy-Duty
<b>T7IS</b>	Heavy-Heavy Duty Gasoline Truck	8	Heavy-Duty
<b>T7 POLA</b>	Heavy-Heavy Duty Diesel Drayage Truck near South Coast	8	Heavy-Duty

The following EMFAC vehicle types were excluded from the analysis: Motor Coach, Other Buses, School Buses, Urban Buses, All Other Buses, Motor Homes, and Motorcycles. Because EMFAC breaks out VMT for out-of-state trucks that operate in the San Bernardino County study area, the analysis scenarios that focus on accelerated purchase of clean vehicle technologies (electric and natural gas) assume that these

out-of-state trucks are unaffected, on the assumption that state and local stakeholders have less ability to influence these fleets. This is discussed below in the scenario analysis sections.

### Vehicle Populations by Fuel Type

EMFAC presents data categorized by four fuel types:

- Gasoline
- Diesel
- Natural Gas
- Electric

The vehicles defined as “electric” are actually the portion of the fleet that will operate similar to pure zero emission vehicles (ZEVs). The electric portion is the sum of the populations of Battery Electric Vehicle (BEVs), Fuel Cell Electric Vehicles (FCVs) and the fraction of Plug-In Hybrid Electric Vehicles (PHEVs) that operate like pure ZEVs.<sup>164</sup> We separated the combined total into its individual components using a few key assumptions. The table below displays the assumed PHEV utility factor, defined by CARB as the fraction of VMT the PHEV obtains from the electrical grid.<sup>165</sup>

**Table 11. Assumed PHEV Utility Factor by Model Year**

Model Year	Utility Factor
<2018	0.46
2019	0.48
2020	0.50
2021	0.52
2022	0.54
2023	0.56
2024	0.58
2025+	0.60

The projected population of electric vehicles reflects compliance with the CARB ZEV mandate, based on the CARB Mid-Range Scenario of Advanced Clean Cars Midterm Review (Appendix A).<sup>166, 167</sup> We used the outputs of the Advanced Clean Cars modeling to calculate the percent of each vehicle type in the ZEV total. The table below presents the proportion of ZEVs attributed to each vehicle type, after accounting for the utility factor of PHEVs. The fossil fuel portion of PHEV was subtracted from the gasoline

<sup>164</sup> <https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf>

<sup>165</sup> <https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf>

<sup>166</sup> [https://www.arb.ca.gov/msprog/acc/mtr/appendix\\_a.pdf](https://www.arb.ca.gov/msprog/acc/mtr/appendix_a.pdf)

<sup>167</sup> [https://www.arb.ca.gov/msprog/zevprog/zevcalculator/zevcalculator\\_2017.xlsx](https://www.arb.ca.gov/msprog/zevprog/zevcalculator/zevcalculator_2017.xlsx)

population and VMT data, making PHEVs a category of its own.

**Table 12. Redistribution of ZEV**

Calendar Year	PHEV	BEV	FCV
<2018	62.3%	29.8%	7.9%
2019	52.1%	37.1%	10.7%
2020	50.4%	38.2%	11.4%
2021	48.2%	39.4%	12.4%
2022	45.3%	36.8%	17.8%
2023	44.6%	36.8%	18.6%
2024	44.2%	36.5%	19.3%
2025+	44.0%	36.0%	20.0%

## Fuel Economy

The assumed gasoline and diesel fuel economy for each vehicle type was calculated directly from EMFAC data by dividing fuel consumption by VMT. The fuel economy for natural gas, electric, and fuel cell vehicles were calculated by applying the energy economy ratio (EER) to the fuel economy of the gasoline or diesel vehicle of the same vehicle category. The EER is a dimensionless ratio that accounts for the differing energy efficiency of powertrains that use various fuels. For example, the electric vehicle fuel economy in DGE is equal to the diesel fuel economy multiplied by the electric EER. EER assumptions are shown in the table below.

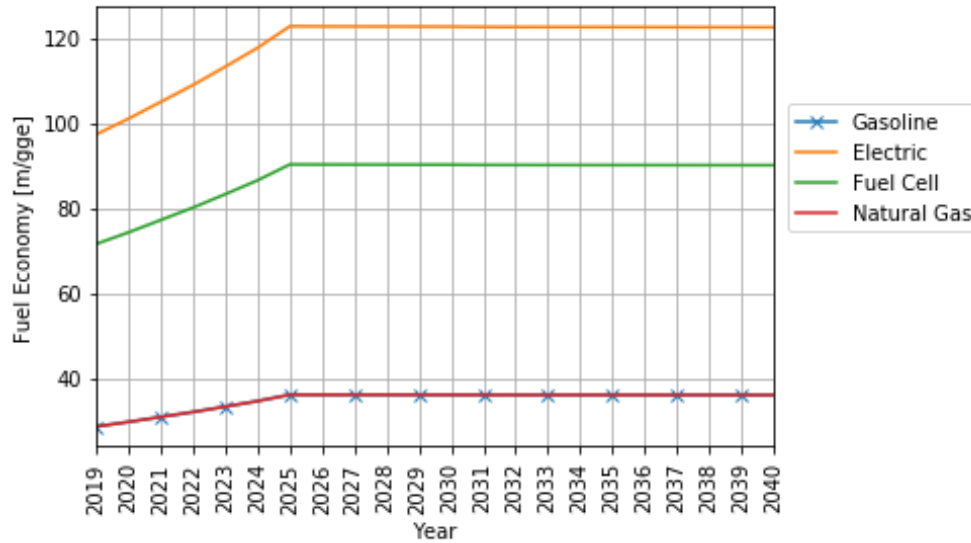
**Table 13. Energy Economy Ratios**

Fuel	Light/Medium-Duty EER Relative to Gasoline	Heavy Duty EER Relative to Diesel
Gasoline	1.0	N/A
Diesel	N/A	1.0
Natural Gas	1.0	0.9
Electricity	3.4	5.0
Hydrogen	2.5	1.9

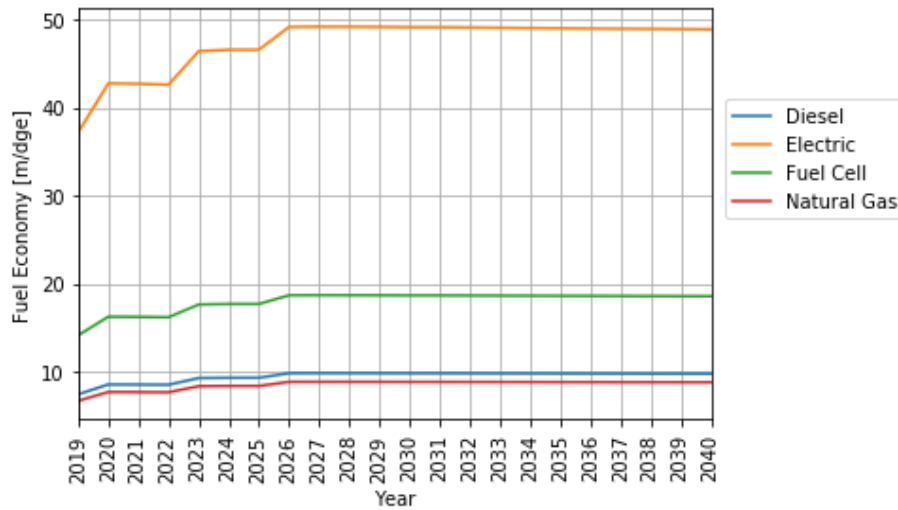
Source: CARB, *Analyses Supporting the Addition or Revision of Energy Economy Ratio Values for the Proposed LCFS Amendments*, 2018a. Available online at: <https://www.arb.ca.gov/regact/2018/lcfs18/apph.pdf>

The figures below display the weighted average fuel economy for new light and heavy duty vehicles over time, respectively.

**Figure 26. New Light Duty Vehicle Fuel Economy (miles per gge)**



**Figure 27. New Heavy Duty Vehicle Fuel Economy (miles per dge)**



## Emission Factors

### Greenhouse Gas Emission Factors

Greenhouse gas emissions are calculated on a lifecycle basis using the carbon intensity (CI) values for each fuel type.

#### Fossil Fuels

The CI and energy density values for fossil fuels are displayed in the table below. These are default values from the Low Carbon Fuel Standard Final Regulation Order.

**Table 14. Carbon Intensity of Fossil Fuels**

Fuel	Description	Carbon Intensity (g CO <sub>2</sub> e/MJ)	Energy Density
Gasoline	CARBOB-California Reformulated Gasoline Blendstock for Oxygenate Blending	100.82	119.53 MJ/gallon
Diesel	ULSD-Ultra Low Sulfur Diesel	100.45	134.47 MJ/gallon
Natural Gas	CNG- from Pipeline Average North American Fossil Natural Gas	79.21	105.5 MJ/Therm
Hydrogen	Compressed H <sub>2</sub> from central SMR of North American fossil-based NG	117.67	120.00 MJ/kg

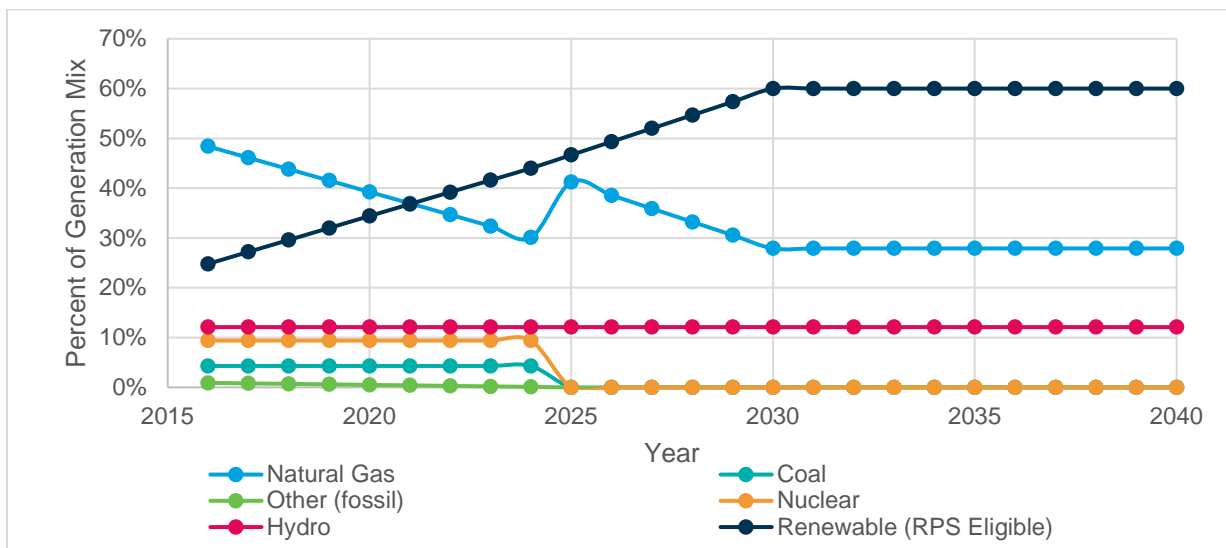
Source: CA LCFS Final Regulation Order, <https://ww3.arb.ca.gov/fuels/lcfs/cleanfinalregorder112612.pdf>

**Electricity**

For GHG emissions from electrified transport, we determined the current and future electrical grid carbon intensity values that take into consideration regional Renewable Portfolio Standard (RPS) requirements. The California-Mexico Power Area (CAMX) covers the San Bernardino County study area. The figure below shows the electricity generation resource mix by year, which is based on the following assumptions:

- Diablo Canyon nuclear facility to retire in 2025
- Coal power is retired by 2025 to meet RPS targets
- Oil and 'other' fossil fuels evenly decrease to 0 percent by 2025 to meet RPS targets
- Renewable RPS increase according to SB100 remaining constant at 60 percent from 2030 onward
- Renewable sources increase proportionally

**Figure 28. Projected resource mix for the CAMX region based on RPS targets**



The table below presents the results of the electricity emissions factor analysis, which is calculated using CA-GREET3.0 and based on the 2016 eGRID resource mix for the CAMX region and future RPS requirements. We assume energy density of electricity is 3.6 MJ/kWh.

**Table 15. CAMX Region Projected Grid Carbon Intensity by Year**

2016	2020	2025	2030	2035	2040
92.04	77.76	67.19	47.51	47.51	47.51

**Biofuels**

The lifecycle emission factors for biofuels vary greatly based on the feedstock and process used during production. The table below shows the wide variation in carbon intensity values for biofuels depending on the feedstock and production process.

**Table 16. Carbon Intensity Values for Various Biofuels**

Fuel	Feedstock	Emissions Factors (gCO <sub>2</sub> e/MJ)	
		Low	High
<b>Ethanol</b>		20.00	72.04
	Corn	63.90	75.97
	Sorghum	63.90	83.49
	Sugarcane	35.50	56.66
	Corn stover	41.05	41.05
	Cellulosic	20.00	20.00
<b>Renewable Gasoline</b>		15.00	35.00
<b>Biodiesel</b>		10.00	39.32
	Soybean oil	42.03	51.85
	Corn oil	5.00	10.00
	Canola oil	40.19	57.87
	Animal fats	15.00	37.54
<b>Renewable Diesel</b>		20.00	40.00
<b>Renewable Natural Gas</b>		7.85	55.53
	LFG, CNG	15.00	46.42
	LFG, LNG	20.00	64.63
	High solids anaerobic digestion (HSAD)		-22.93
	Waste water treatment		19.34

Source: Fuel pathways submitted for California’s Low Carbon Fuel Standard



The baseline emission factors for biofuels used in the analysis are based on the average CI in 2018 as published by the Low Carbon Fuel Standard quarterly reporting.<sup>168</sup> Similarly, the percent of the Baseline Scenario total fuel consumption replaced with biofuels was calculated based on the fuel volumes reported.

**Table 17. Biofuel Emissions Factors and Percent of Total Volume**

Renewable Fuel	2018 Average Carbon Intensity (g CO <sub>2</sub> e/MJ)	Fuel Replaced	Percent of Total Demand
Ethanol	68.60	Gasoline	10%
Biodiesel	31.05	Diesel	5%
Renewable Diesel	32.17	Diesel	10%
Renewable Natural Gas	40.94	CNG	71%
Renewable Hydrogen	99.48	Compressed H <sub>2</sub>	0%

Note: Default CI value for compressed hydrogen produced in California from central SMR of biomethane (renewable feedstock) from North American landfills.

## NOx Emission Factors

### *Diesel & Gasoline Vehicles*

For gasoline and diesel vehicles, tailpipe emission factors were taken directly from EMFAC2017. The emission factors are unique to each vehicle class, fuel type, model year, and calendar year. The tailpipe emission factors for NOx used in this model include:

- Running Exhaust Emissions (RUNEX) that come out of the vehicle tailpipe while traveling on the road.
- Idle Exhaust Emissions (IDLEX) that come out of the vehicle tailpipe while it is operating but not traveling any significant distance (for example, heavy-duty vehicles that idle while loading or unloading goods).
- Start Exhaust Tailpipe Emissions (STREX) that occur when starting a vehicle

The table below shows NOx emission factors for select vehicle types for 2019, 2030, and 2040. The analysis includes emission factors for each vehicle category in EMFAC, listed in Table 2. Rather than show emission factors for all vehicle categories and fuel types (more than 50), this report shows three representative vehicle types from the EMFAC model: LDA (light duty automobile, a typical light-duty vehicle), T6 Small Instate (a typical medium-duty vehicle), and T7 Tractor (a typical heavy-duty vehicle). These vehicle types were selected because they comprise a significant share of the vehicles within their given weight class.

<sup>168</sup> <https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm>

NOx emission rates are much higher for diesel vehicles. Running NOx emission rates drop significantly between 2019 and 2030 as older vehicles (those that do not meet with 2010 emission standards) are retired from the fleet. There is little change in Baseline NOx emission rates between 2030 and 2040.

**Table 18: NOx Emission Factors for Representative Vehicle Types, aggregated model years**

Vehicle Type	Fuel	Idle (g/trip)			Running (g/mile)			Start (g/trip)		
		2019	2030	2040	2019	2030	2040	2019	2030	2040
LDA	Gasoline	0.000	0.000	0.000	0.057	0.021	0.018	0.025	0.015	0.014
T6 instate small	Diesel	0.139	0.060	0.063	3.148	1.096	1.110	0.264	0.522	0.544
T7 tractor	Diesel	0.202	0.192	0.179	5.438	2.248	2.115	0.099	0.205	0.192

### CNG Vehicles

For the scenario calculations, all new CNG vehicles are assumed to have a Low-NOx natural gas engine. These engines are certified at 0.02 grams per brake horsepower-hour (g/bhp-hr), which is a 90 percent reduction from the current heavy-duty vehicle standard of 0.2 g/bhp-hr. In our analysis framework, the NOx emissions factors for new CNG vehicles are assumed to be 10 percent of the emissions factor of the diesel vehicle it is replacing.

### Electric & Fuel Cell Vehicles

Electric and fuel cell vehicles are assumed modeled to have zero tailpipe NOx emissions.

## PM2.5 Emission Factors

### Diesel & Gasoline Vehicles

For fine particular matter (PM2.5), gasoline and diesel vehicle tailpipe emission factors were taken directly from EMFAC2017. The emission factors are unique to each vehicle class, fuel type, model year, and calendar year. The tailpipe emission factors for PM2.5 used in this model include:

- Running Exhaust Emissions (RUNEX) that come out of the vehicle tailpipe while traveling on the road.
- Idle Exhaust Emissions (IDLEX) that come out of the vehicle tailpipe while it is operating but not traveling any significant distance (for example, heavy-duty vehicles that idle while loading or unloading goods).
- Start Exhaust Tailpipe Emissions (STREX) that occur when starting a vehicle.
- Tire Wear Particulate Matter Emissions (PMTW) that originate from tires as a result of wear.
- Brake Wear Particulate Matter Emissions (PMBW) that originate from brake usage.

The table below shows PM2.5 emission factors for select vehicle types for 2019, 2030, and 2040. As with NOx emission factors, the table shows only three representative vehicle types, although the analysis includes PM2.5 emission factors specific to each EMFAC vehicle category and fuel. Like NOx emission factors, PM2.5 emission rates are much higher for diesel trucks than gasoline automobiles. For gasoline autos, PM2.5 emissions come primarily from brake wear, not exhaust. PM2.5 emission rates are expected to decline significantly between 2019 and 2030 as older vehicles are retired, then change little

between 2030 and 2040. In the later years of the analysis, exhaust PM emission rates become lower than brake wear emission rates.

**Table 19: PM2.5 Emission Factors for Representative Vehicle Types, aggregated all model years**

Vehicle Type	Fuel	Brake Wear (g/mile)			Exhaust (g/mile)			Tire Wear (g/mile)		
		2019	2030	2040	2019	2030	2040	2019	2030	2040
LDA	Gasoline	0.016	0.016	0.016	0.002	0.001	0.001	0.002	0.002	0.002
T6 instate small	Diesel	0.056	0.056	0.056	0.111	0.007	0.007	0.003	0.003	0.003
T7 tractor	Diesel	0.026	0.026	0.026	0.102	0.020	0.018	0.009	0.009	0.009

### CNG Vehicles

For the scenario calculations, all new CNG vehicles are assumed to have a Low- NOx certified engine. All new CNG vehicles were assumed to have a PM2.5 running exhaust emission factor of 0.0005 g/mile based on a previous study prepared by ICF for NextGen Climate America and the Union of Concerned Scientists.<sup>169</sup> The tire and brake wear emissions factors for CNG vehicles were assumed to be equivalent to the diesel vehicle they are replacing.

### Electric & Fuel Cell Vehicles

Electric and fuel cell vehicles were modeled to have zero running, idling, and starting tailpipe PM2.5 emissions factors. Electric vehicles still have PM emissions from tire and brake wear. EVs have lower brake wear emissions than comparable gasoline and diesel vehicles because the use of regenerative braking reduces brake use. For this analysis, we assume electric vehicles emissions for brake wear to be 50 percent of the vehicle emissions they are replacing.

## Cost Assumptions

To evaluate the total costs associated with each scenario modeled, ICF developed estimates for the following cost categories:

- Vehicle purchase costs
- Fuel costs
- Fueling infrastructure costs
- Maintenance costs (for vehicles and infrastructure)

These categories reflect the capital, operations, and maintenance costs associated with incorporating alternative fuel vehicles into the on-road fleet, providing a means to compare the costs and savings associated with the adoption of various vehicle technologies. Cost assumptions are primarily adopted from publicly available government datasets, tools, and publications. These cost per unit assumptions are held constant across all the scenarios evaluated.

<sup>169</sup> ICF International, *Half the Oil: Pathways to Reduce Petroleum Use on the West Coast*, Prepared for NextGen Climate America and the Union of Concerned Scientists, 2016.

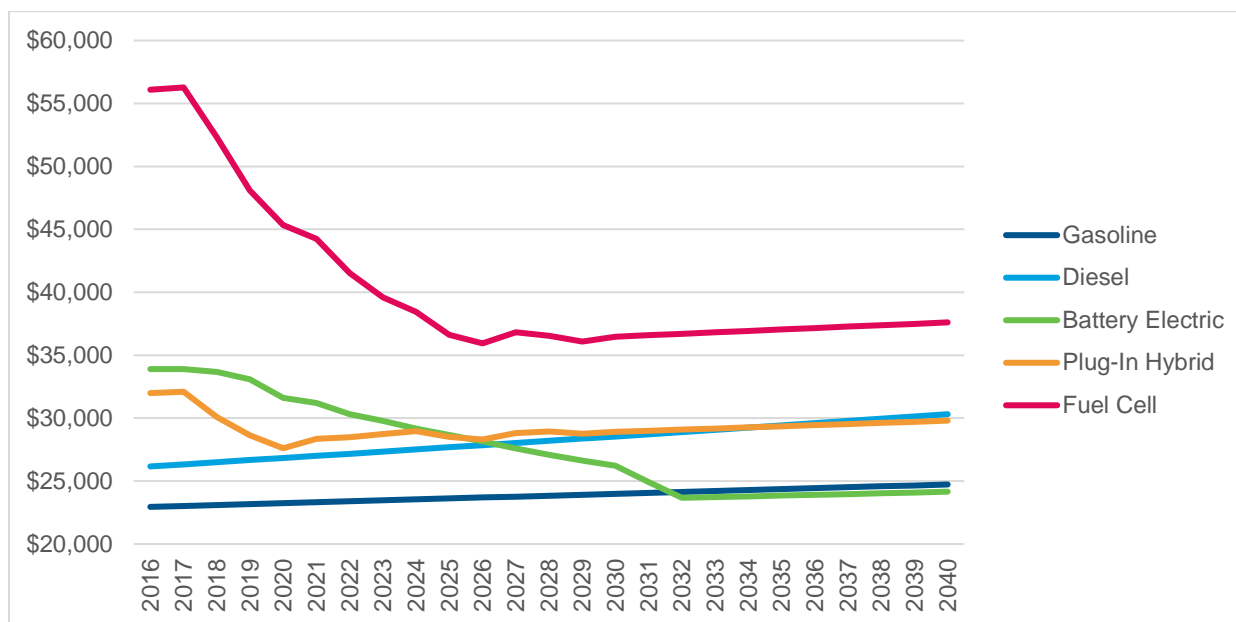
## Vehicle Purchase Costs

Vehicle purchase costs can vary significantly across and within vehicle weight classes. Vehicles within the weight same class may also exhibit diverse costs depending on their fuel types. We developed estimates of current and future vehicle purchase prices primarily from CEC’s *Transportation Energy Demand Forecast, 2018-2030*<sup>170</sup> and ICF’s analysis for the California Electric Transportation Coalition (CaETC).<sup>171</sup> The CaETC analysis relies on estimates of price curves for truck battery packs produced by Bloomberg New Energy Finance, a literature review, and interviews with current battery electric truck manufacturers. Purchase price assumptions vary by weight class and fuel type. As with the emission rates above, to illustrate these assumptions, below we show the assumptions for three representative vehicle types from the EMFAC model: LDA (a typical light-duty vehicle), T6 Small Instate (a typical medium-duty vehicle), and T7 Tractor (a typical heavy-duty vehicle). These vehicle types were selected because they comprise a significant share of the vehicles within their given weight class.

### Light-Duty Vehicles

LDA vehicle costs are broken out by fuel type in the figure below and derived from the CEC’s *Transportation Energy Demand Forecast, 2018-2030*. The forecast provides key data on vehicle and fuel trends in California, which are used to support the CEC’s Integrated Energy Policy Reports and inform the State’s approach to energy policymaking.

**Figure 29. Vehicle Purchase Costs by Fuel Type (LDA, or typical LDV)**



Gasoline light duty auto vehicle prices increase gradually from \$23,000 in 2016 to \$25,000 in 2040. LDA BEVs start at approximately \$34,000 in 2016 but drop steadily due primarily to the expected decline in battery costs. By 2032, LDA BEVs are assumed to have a slightly lower purchase price than gasoline

<sup>170</sup> <https://efiling.energy.ca.gov/getdocument.aspx?tn=221893>

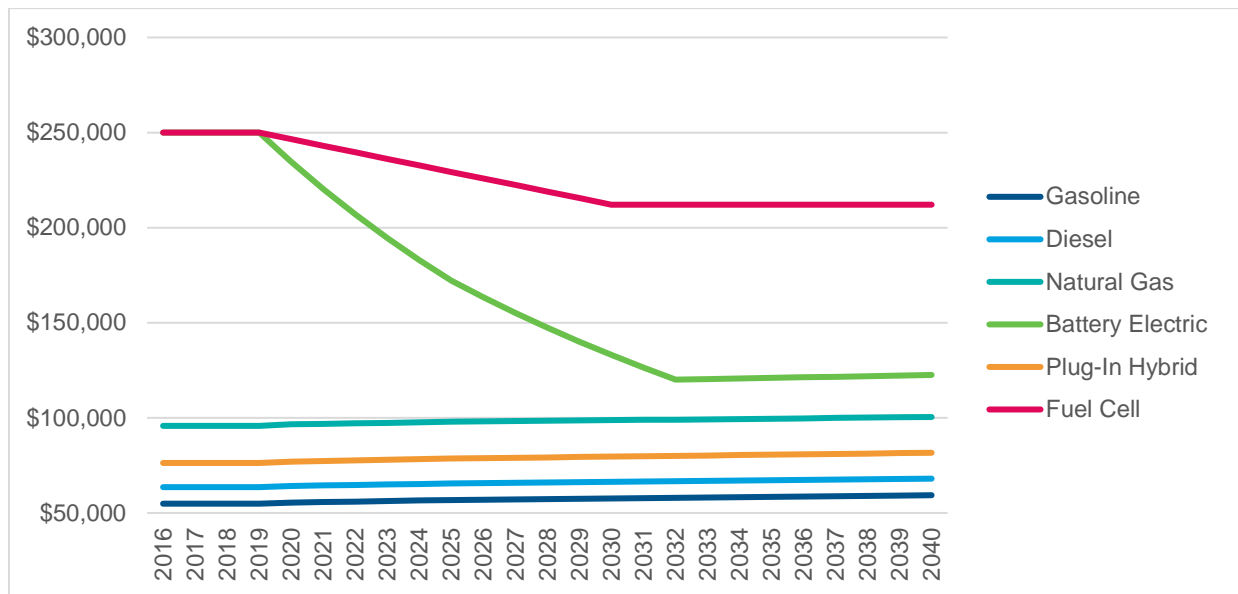
<sup>171</sup> ICF, Total Cost of Ownership Assessment for Medium and Heavy Duty Technologies in California, prepared for California Electric Transportation Coalition (CaETC), 2019.

vehicles. PHEVs start off modestly cheaper than BEVs, but then cross over by the mid-2020s and increase moderately to \$30,000 in 2040. LDA FCVs remain the most expensive vehicle type throughout the analysis period, despite significant cost declines in throughout the 2020s. Overall, gasoline LDA vehicles remain the most competitive vehicle type on an upfront cost basis until the early 2030s when BEVs become the lowest-cost vehicle type.

### Medium-Duty Vehicles

Purchase price assumptions for MDVs were adapted from ICF’s analysis for CalETC.<sup>172</sup> The figure below shows the purchase price assumptions for a representative MDV. Diesel vehicles in this class cost approximately \$63,000 in 2016, increasing marginally to \$68,000 in 2040. NGVs start at \$95,000 in 2016 and experience similar cost escalation through 2040. EVs costs are expected to decline 50 percent between 2016 and 2040 as battery technologies improve. Similarly, FCV costs are projected to decrease from a \$250,000 peak in 2016 and reach \$180,000 in 2040. Throughout the analysis period, gasoline and diesel remain the lowest MDV in terms of vehicle cost.

**Figure 30. Vehicle Purchase Costs by Fuel Type (T6 Small Instate, or typical MDV)**

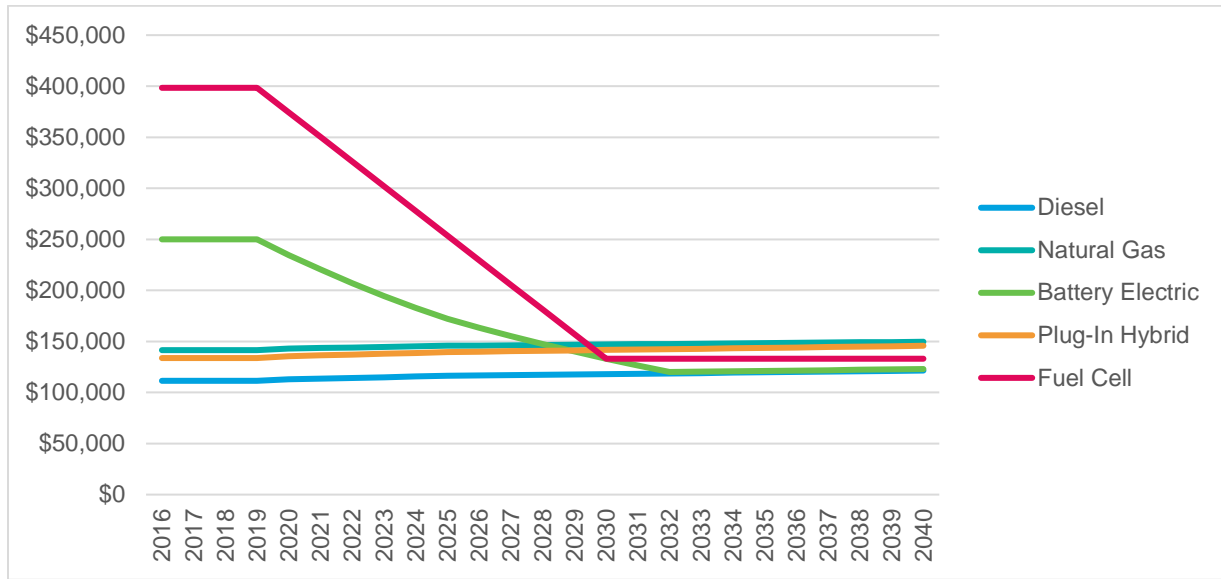


### Heavy-Duty Vehicles

HDV costs are also adopted from ICF’s analysis for CalETC. Diesel T7 tractor trucks are assumed to cost \$110,000 in 2016 and escalate steadily to \$120,000 in 2040. Natural gas and plug-in hybrid trucks experience similar cost increases – albeit from a higher initial purchase price. Battery electric truck costs start at \$250,000 in 2016, but significant cost decreases through the 2020s bring vehicle costs to levels comparable to diesel trucks. Fuel cell trucks also experience notable cost declines and are estimated to reach approximately \$130,000 in 2040.

<sup>172</sup> ICF, Total Cost of Ownership Assessment for Medium and Heavy Duty Technologies in California, prepared for California Electric Transportation Coalition (CalETC), 2019.

**Figure 31. Vehicle Purchase Costs by Fuel Type (T7 Tractor, or typical HDV)**



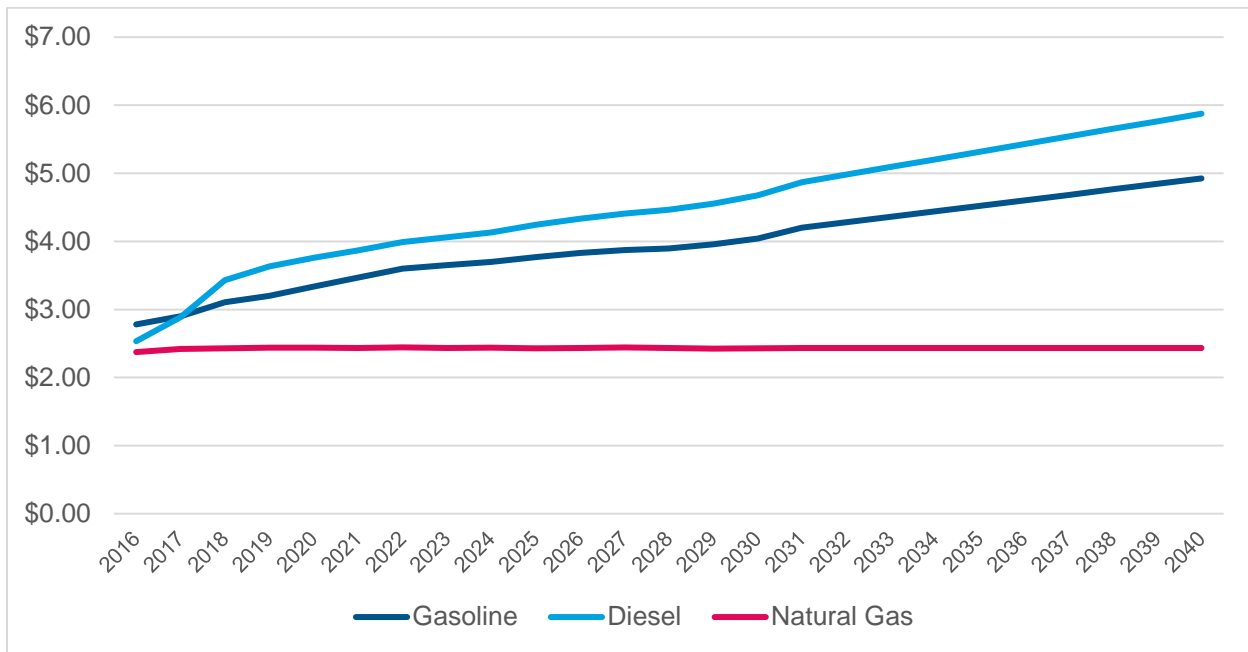
**Fuel Costs**

Fuel cost assumptions for gasoline, diesel, natural gas, and hydrogen are derived from CEC’s *Revised Transportation Energy Demand Forecast, 2018-2030*.<sup>173</sup> For years 2031-2040, ICF extrapolated CEC’s fuel cost estimates to follow DOE’s Annual Energy Outlook trends.<sup>174</sup> The figure below illustrates estimated fuel prices for gasoline, diesel, and natural gas on a gallon-equivalent basis from 2016-2040.

<sup>173</sup> <https://efiling.energy.ca.gov/GetDocument.aspx?tn=223241>

<sup>174</sup> <https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf>

**Figure 32. Fuel Cost Assumptions: Gasoline, Diesel, and Natural Gas Prices per Gallon Equivalent**



Gasoline and diesel prices start below \$3 per gallon in 2016 and gradually increase through 2040 to nearly \$6 per gallon and \$5 per gallon, respectively. Gasoline prices surpass \$4 per gallon in 2022 while diesel prices do not exceed \$4 per gallon until approximately 2030. Natural gas prices are assumed to remain flat near \$2.50 per gallon-equivalent throughout the analysis period.

The CEC finds that hydrogen prices were approximately \$15.50 per gallon of gasoline equivalent (GGE) in 2016. However, unlike other transportation fuels, hydrogen prices are expected to decline gradually through 2030 to approximately \$10 per GGE in CEC’s Mid Demand Scenario due to economies of scale resulting from increased hydrogen production.<sup>175</sup> Hydrogen costs are expected to decline an additional \$2 between 2031-2040 to \$8 per gallon of gasoline equivalent and are not projected to reach cost parity with gasoline on a GGE basis.

Electricity costs are derived from Southern California Edison’s (SCE) residential and commercial electricity tariffs: TOU-EV-1 and TOU-EV-8, respectively.<sup>176</sup> Both tariffs are time-of-use rates, which vary depending the time of day that an EV draws power and are based on electricity (per kilowatt-hour) consumption. Rates are higher during “on-peak” periods when the electricity system typically experiences high demand and lower during “off-peak” periods when spare capacity is more available on the grid. While “per gallon-equivalent” prices will vary depending on when EV charging occurs, electricity costs are generally lower than relative to gasoline and diesel. For example, a light-duty EV charging on off-peak on SCE’s TOU-EV-1 rate can experience fuel costs as low as \$1 per gallon.<sup>177</sup>

<sup>175</sup> <https://efiling.energy.ca.gov/GetDocument.aspx?tn=223241>

<sup>176</sup> <https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442457781>

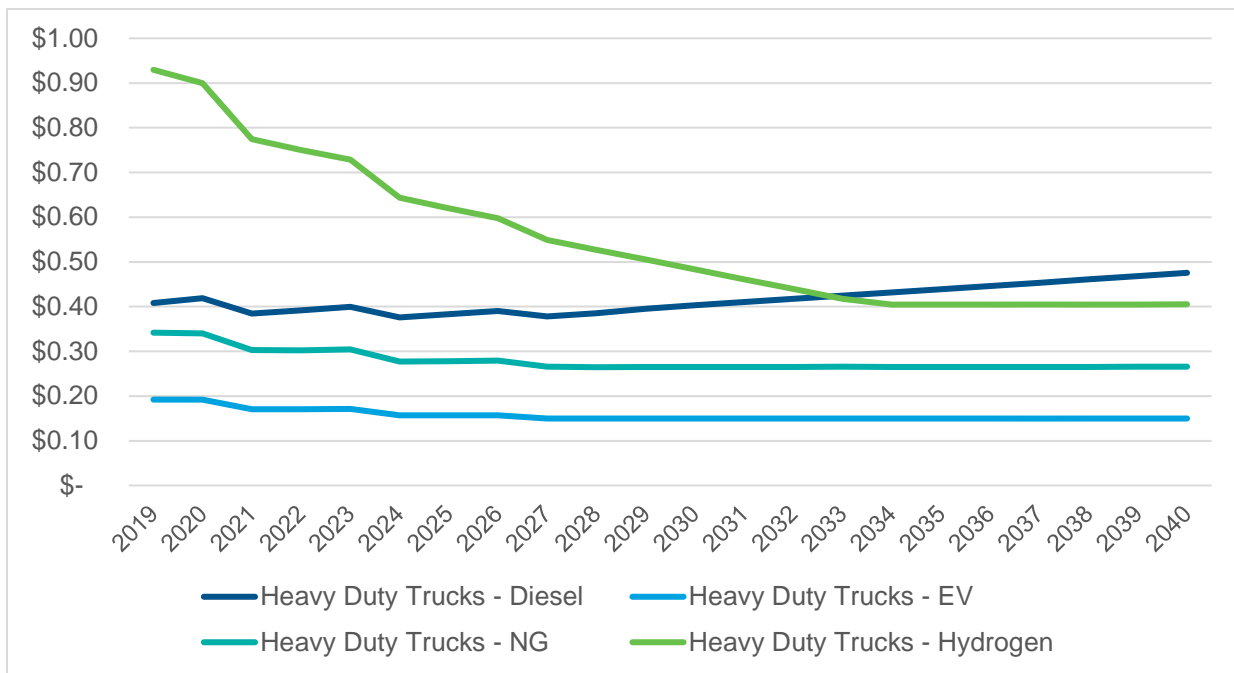
<sup>177</sup> Assumes the TOU-EV-1 off-peak rate of \$0.13 per kWh, EV efficiency of .27 kWh per mile, and comparable gasoline vehicle efficiency of 28.6 miles per gallon.



Commercial utility customers are also traditionally subject to demand charges, which are collected based on customers’ instantaneous electricity demand (per kilowatt) and often challenge the economics of DCFC station operations due to their high electricity *demand* but relatively low electricity *consumption*. In other words, DCFC station operators typically have little opportunity to recoup operational costs through revenue from EV charging at current station utilization rates. To encourage EV adoption while ensuring “just and reasonable” rates<sup>178</sup>, the California Public Utilities Commission-approved TOU-EV-8 rate temporarily substitutes demand charges for energy charges for five years and gradually re-introduces demand charges over an additional five years as EV adoption increases. This adjustment is expected to improve the economics of fueling EVs – including medium- and heavy-duty EVs that may rely almost exclusively on fast charging.

Fuel costs directly affect cost per vehicle mile traveled, a salient factor in fleet managers’ decisions to procure alternative fuel vehicles. The figure below illustrates the fueling cost per mile of all HDVs based on their VMT-weighted average fuel economy. Per mile electricity fueling costs remain lowest throughout the analysis period, starting at nearly \$0.20 per mile and declining to approximately \$0.15 per mile in 2040. Costs per mile for natural gas trucks were consistently second-lowest in the analysis, declining marginally through 2040. Cost per mile for diesel-fueled trucks remain near \$0.40 per mile through 2030, but due to increasing diesel costs and declining hydrogen fuel costs, hydrogen fuel becomes more competitive on a cost per mile basis relative to diesel around 2033 and remains near \$0.40 per mile through 2040.

**Figure 33. VMT-Weighted Cost per Mile of HDVs by Technology**



<sup>178</sup> Public Utilities Code section § 451 requires that the CPUC determine whether a utility’s proposed rates, services, and charges are just and reasonable.

## Fueling Infrastructure Costs

Alternative fuel vehicles rely on the deployment of diverse types of refueling infrastructure with varying levels of cost. These costs are typically broken out into equipment costs, installation costs, and operation costs.

For light-duty vehicles, gasoline blended with 15 percent ethanol (E15) provides a drop-in alternative to conventional gasoline with the provision of additional infrastructure. Signage, underground storage tanks (UST), and new or converted dispensers are needed to support E15 fueling. Converting a dispenser at a gas station to E15 without installing a new UST is approximately \$4,800; a new UST costs \$115,000. Diesel blended with 20 percent biofuel (B20) can similarly be used as a drop-in fuel for diesel engines and requires similar infrastructure upgrades at conventional diesel fueling stations. Total conversion costs for four dispensers are assumed to be approximately \$75,000.

New natural gas stations that are capable of dispensing one million diesel gallon equivalent (DGE) per year are estimated to cost \$1 million. On top of this \$1 million capital expenditure, these station installation costs are projected to be \$1 million per station with annual operation costs at \$115,000 per year. These figures are expected to remain constant throughout the analysis period and are derived from DOE's *Costs Associated With Compressed Natural Gas Vehicle Fueling Infrastructure*.<sup>179</sup>

Hydrogen fueling stations for light-duty vehicles cost an estimated \$2.8 million per station. Installation costs comprise an additional \$1 million and annual station operating expenses reach approximately \$150,000. These costs are expected to remain constant throughout the analysis period and are derived from CEC's staff report on Assembly Bill 8.<sup>180</sup>

EV charging station deployment costs can vary widely depending on the throughput of the station, amount of available electrical capacity at the site, charging station features and software, and other factors. Residential L2 charging station and installation costs are expected to be \$1,200 throughout the analysis period. Non-residential L2 station hardware and installation costs amount to approximately \$9,500, with operational costs reaching \$1,200. 50 kilowatt DCFC station hardware and installation costs are expected to remain near \$75,000 with an additional \$2,500 devoted to operational expenses. Comparable hardware and installation costs for 200 kW DCFC stations are expected to be \$105,000, with \$5,500 dedicated to operational costs. However, hardware costs are expected to decline from \$50,000 to \$25,000 in 2030 and remain unchanged through 2040, suggesting that production costs for fast charging will decrease as more DCFC stations are deployed. The table below summarizes the primary cost drivers for each fueling infrastructure type. Residential L2 chargers, non-residential L2 chargers, and non-residential DCFC stations are used by light-duty vehicles whereas 19 kW, 40 kW, 100 kW, and 200 kW chargers are used for medium- and heavy-duty vehicles.

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<sup>179</sup> [https://afdc.energy.gov/files/u/publication/cng\\_infrastructure\\_costs.pdf](https://afdc.energy.gov/files/u/publication/cng_infrastructure_costs.pdf)

<sup>180</sup> <https://ww2.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf>

**Table 20. Fueling Infrastructure Installation and Equipment Costs**

Fuel	Station Capacity	Amt. (AFDC)	Lifetime (AFLEET)	Installation Cost	Cost per Station
Natural Gas	1 million DGE/year	15-20	5-12	\$1,000,000	\$1,000,000
Hydrogen	230 kg/day	0	20	\$1,000,000	\$2,800,000
Residential L2 chargers	1 vehicle/ station	N/A	N/A	\$3,000	\$400-\$6,500
Non-residential L2 chargers	1 vehicle/station	103	7	\$3,000	\$400-\$6,500
Non-residential DCFC	2 vehicles/station	34	10	\$21,000	\$20,000-\$36,000
19 kW Charger	2 vehicle/station	0	20	\$20,000	\$5,000
40 kW Charger	2 vehicle/station	0	20	\$20,000	\$8,000
100 kW Charger	2 vehicle/station	0	20	\$50,000	\$20,000
200 kW Charger	2 vehicle/station	0	20	\$55,000	\$50,000
Conversion to E15 Station	4-6	2	20+	NA	\$119,800-\$146,000
Conversion to B20 Station	4-6	0	20+	NA	\$45,500

**Maintenance Costs**

Estimates of vehicle maintenance costs come from Argonne National Laboratory’s Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool’s default maintenance values. AFLEET is commonly used to assess the emissions from and costs of operating vehicles via payback calculators and total cost of ownership calculators.<sup>181</sup> Key inputs to the tool include vehicle location, type, fuel type, annual mileage, fuel economy, vehicle purchase price, and fuel prices. Maintenance costs include brake maintenance, oil changes, treatments or additives, scheduled inspections, and other repairs. The table below illustrates the total maintenance costs per mile by fuel type for the three representative vehicle classes: LDA, T6 Instate Small, and T7 Tractor. Maintenance costs per mile are assumed to remain constant over time.

**Table 21. Maintenance Cost per VMT**

Vehicle Type \ Fuel Type	Gasoline	Diesel	Natural Gas	BEV	PHEV	FCV
LDA (typical LDV)	\$0.14	\$0.19	N/A	\$0.13	\$0.13	\$0.13
T6 Instate small (typical MDV)	N/A	\$0.19	\$0.19	\$0.17	\$0.16	\$0.17
T7 Tractor (typical HDV)	N/A	\$0.19	\$0.19	\$0.17	\$0.16	\$0.17

Key: BEV = battery electric vehicle, PHEV = plug-in hybrid vehicle, FCV = fuel cell vehicle

<sup>181</sup> [https://greet.es.anl.gov/afleet\\_tool](https://greet.es.anl.gov/afleet_tool)

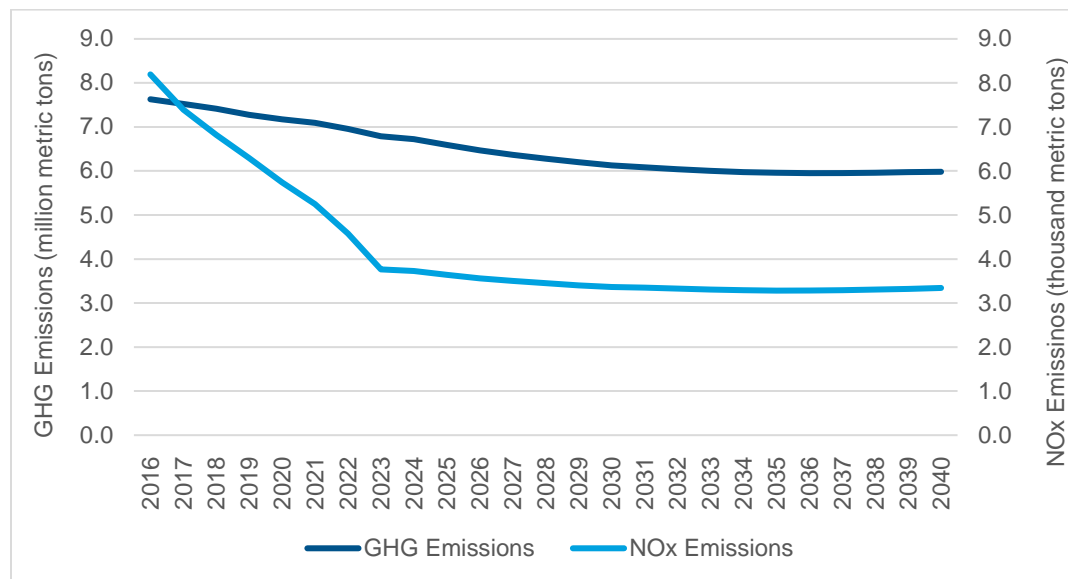
LDA vehicles exhibit the widest variation in maintenance cost between fuel types, with diesel and BEVs forming the upper and lower cost bounds for this vehicle class. Maintenance costs for T6 Instate Small and T7 Tractor vehicles do not vary significantly; however, BEV and FCV costs remain slightly less expensive on a per mile basis than comparable fossil-fuel vehicles.

## 4.2 Baseline Results

This section summarizes the Baseline Scenario, which serves as the reference scenario for comparison against the clean vehicle and fuels scenarios describe in the next section. As noted previously, the Baseline Scenario and all other scenarios reflect only the VMT and emissions within the South Coast Air Basin portion of San Bernardino County. The Baseline Scenario reflects the implementation of all rules and regulations that had been adopted at the time of the analysis (fall 2019), but not additional regulations or significant incentive programs. So, for example, the Baseline Scenario does not reflect CARB’s Advanced Clean Truck regulation, which was not yet adopted at the time of this analysis; many of the assumptions in that regulation are reflected in the Electrification Scenario discussed later.

As an overview of the Baseline Scenario, the figure below shows the baseline on-road vehicle GHG and NOx emissions in the study area. Over the analysis period, while the total vehicle population is expected to grow by 54 percent, NOx emissions will decline by 59 percent and GHG emissions will decline by 22 percent. The sharp decline in NOx emissions between 2016 and 2023 is primarily due to the retirement of older trucks that do not meet the latest emission standards, driven by the CARB Statewide Truck and Bus Rule. After 2023, NOx emissions are relatively flat, as the slow introduction of cleaner vehicles and fuels is offset by growth in the vehicle population and VMT. GHG emissions from on-road vehicles in the study area are projected to decline gradually until around 2030, due to natural fleet turnover and the introduction of more fuel efficient vehicles couple with growing use of low carbon fuels, After 2030, GHG emissions remain flat, as growth in vehicle population and VMT offsets the benefits of further fleet fuel economy improvements.

**Figure 34. Baseline GHG and NOx Emissions in Study Area, 2016 – 2040**



The table below shows further summary information on the baseline emission in the study area – vehicle population, NOx emissions, and GHG emissions by the three vehicle types for 2016, 2031 (the South Coast Air Basin ozone attainment date), and 2040. Looking at contributions by vehicle type, light duty vehicles dominate the vehicle population at 96 percent of all vehicles. Yet LDVs produce only 38 percent of NOx emission currently, declining to 17 percent in 2040. In contrast, heavy duty vehicles account for only 2 percent of the population but produce half of all on-road NOx emissions, rising to 71 percent in 2040. This is because, per vehicle, HDVs drive more and emit a much higher rate of NOx emissions per mile. In general, NOx emissions are much higher from diesel engines than gasoline engines, and nearly all HDVs are diesel.

In terms of GHG emissions, LDVs produce the bulk of on-road vehicle emissions – 81 percent currently and 77 percent in the future. HDVs produce 15 percent of on-road GHGs currently, rising to 18 percent in 2040. Thus, HDVs (and MDVs) account for a disproportionate share of GHG emissions because, per vehicle, they drive more and burn more fuel per miles than LDVs. But the differences are not as stark as with NOx emissions.

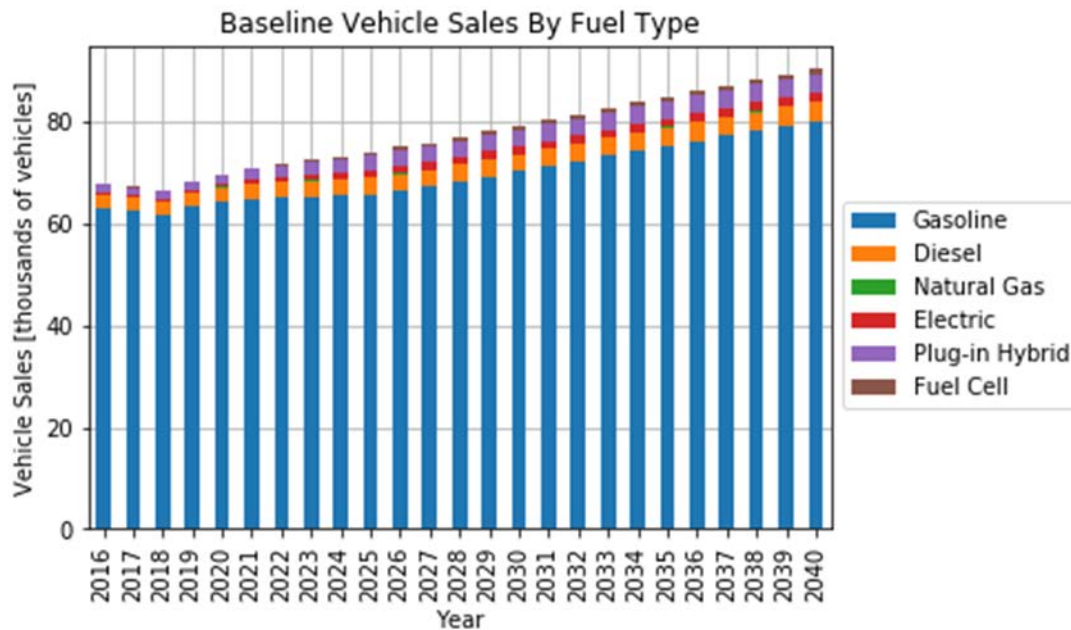
**Table 22. Summary of Vehicle Population and Emissions, 2016, 2031, and 2040**

	2016		2031		2040	
	<b>Vehicle Population (thousand)</b>					
Light Duty	852.5	96%	1140.3	96%	1314.8	96%
Medium Duty	17.1	2%	23.0	2%	25.7	2%
Heavy Duty	17.7	2%	22.9	2%	24.0	2%
Total	887.4	100%	1186.2	100%	1364.5	100%
	<b>NOx Emissions (thousand metric tons)</b>					
Light Duty	3.15	38%	0.76	23%	0.58	17%
Medium Duty	0.98	12%	0.39	12%	0.40	12%
Heavy Duty	4.06	50%	2.20	66%	2.37	71%
Total	8.19	100%	3.35	100%	3.34	100%
	<b>GHG Emissions (million metric tons)</b>					
Light Duty	6.17	81%	4.68	77%	4.60	77%
Medium Duty	0.31	4%	0.31	5%	0.31	5%
Heavy Duty	1.14	15%	1.09	18%	1.07	18%
Total	7.63	100%	6.09	100%	5.98	100%

## Vehicle Sales, Population, and VMT Details

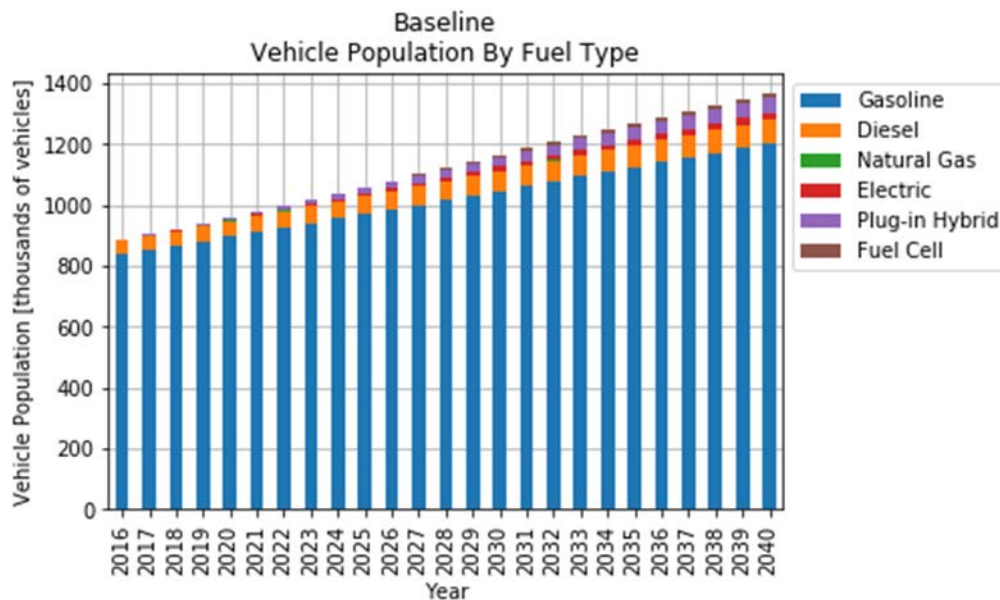
The figure below shows baseline vehicle sales by fuel type and calendar year. Gasoline vehicles dominate new vehicle sales in the study area, growing steadily from about 50,000 per year to nearly 70,000 per year in 2040. The Baseline includes only a small number of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). In 2040, BEVs and PHEVs account for 2 percent and 4 percent of total annual new vehicles sales in the study area, respectively.

**Figure 35. Baseline Vehicle Sales by Fuel Type**



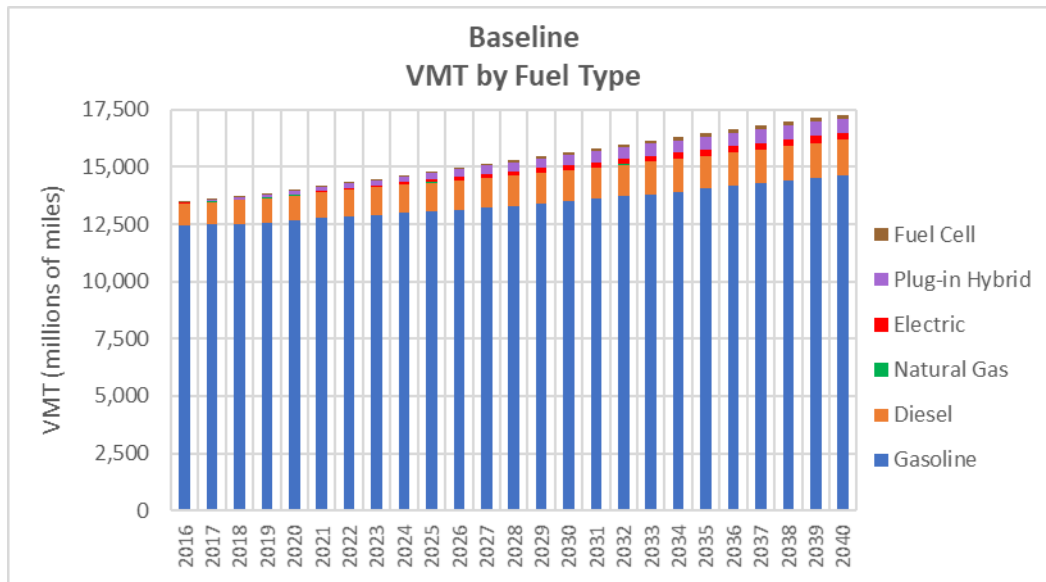
Like vehicle sales, the vehicle population is dominated by gasoline powered LDVs, which exceed 800,000 units in 2016; MDVs and HDVs comprise a relatively small portion of the vehicle population. Diesel vehicles of all classes remain the second largest category throughout the analysis period. When combined, battery electric and plug-in hybrid vehicles surpass 70,000 units in 2040 but comprise only 6 percent of the total vehicle fleet. Natural gas vehicles and FCVs make minor gains but remain a small percentage of the fleet.

**Figure 36. Baseline Vehicle Population by Fuel Type**



As shown in the figure below, the Baseline VMT follows a trend similar to vehicle population, rising gradually to nearly 17.5 billion VMT in 2040. Gasoline vehicles account for 93 percent of study area VMT in 2016 and 85 percent by 2040. Because heavy-duty vehicles (primarily diesel) are driven more per year than light-duty vehicles, the diesel VMT accounts for a larger fraction of VMT as compared to vehicle population. Electric, plug-in hybrid, and fuel cell vehicles account for 6 percent of all study area VMT in 2040.

**Figure 37. Baseline VMT by Fuel Type**



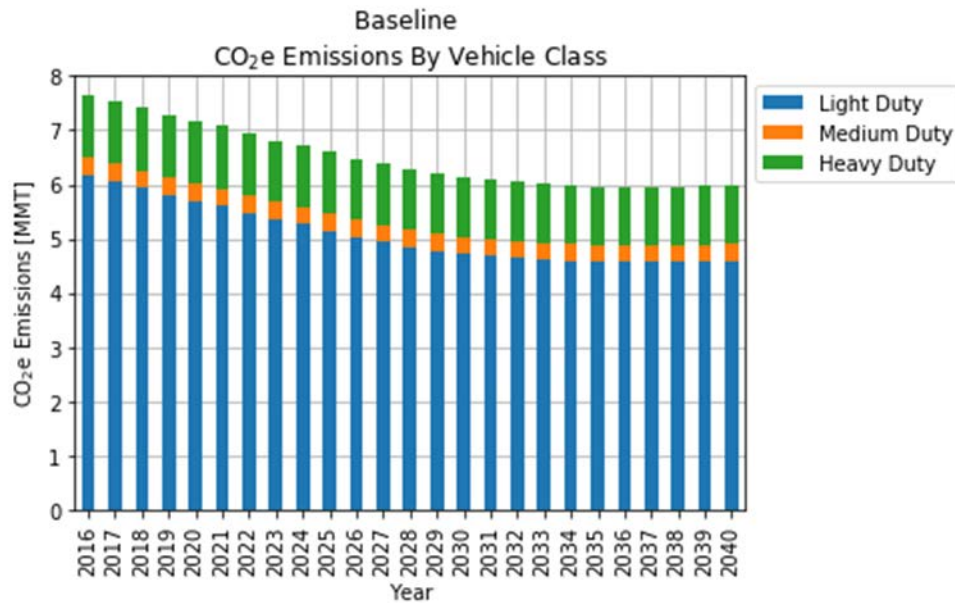
## Emissions

### GHG Emissions

Baseline GHG emissions by vehicle class are illustrated in the figure below. Total study area on-road vehicle GHG emissions are 7.7 MMT in 2016 and decline gradually to 6 MMT in 2040 – a 22 percent decrease primarily driven by reductions in LDV emissions. LDVs comprise the greatest share of GHG emissions, representing approximately 75-80 percent of annual emissions annually throughout the analysis period. The heavy-duty sector experiences only slight emissions reductions between 2016 and 2040, indicating the difficulty of decarbonizing HDVs under current policies and with business-as-usual technologies.

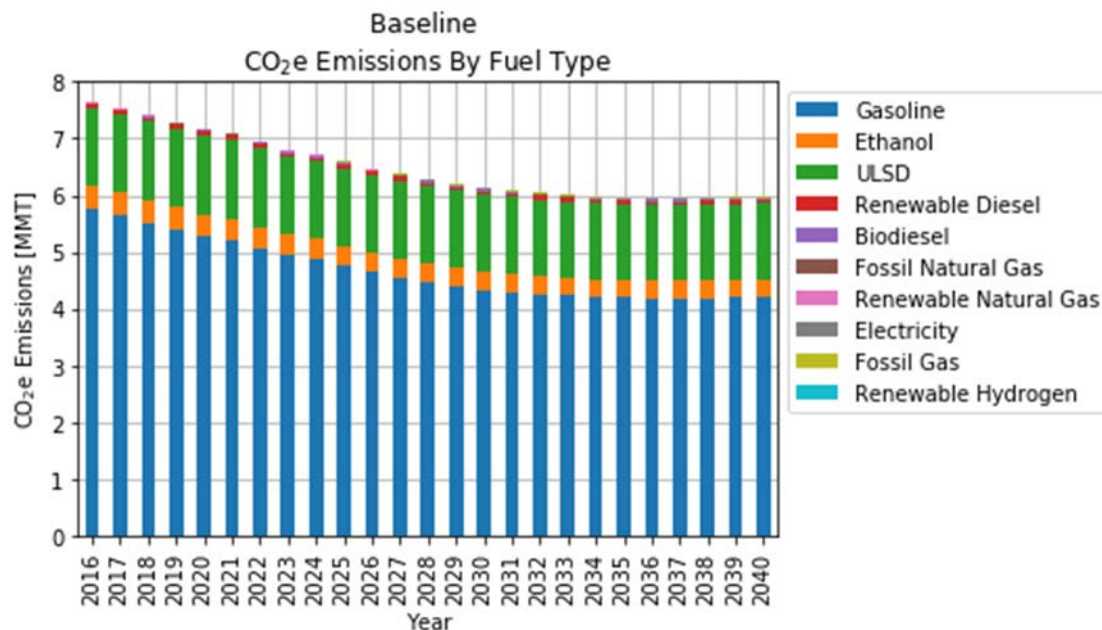


**Figure 38. Baseline GHG Emissions by Vehicle Type**



The figure below illustrates baseline GHG emissions by vehicle fuel type. Combustion of gasoline fuel, used in LDVs and some MDVs, represents 70-75 percent of on-road GHG emissions on an annual basis throughout the analysis period. Diesel, primarily used by HDVs, generates approximately 20 percent of GHG emissions annually. Emissions from other fuels – ethanol, renewable diesel, biodiesel, fossil natural gas, renewable natural gas, electricity, fossil gas, and renewable hydrogen – make up a minor percentage of emissions. They also generally produce less emissions per unit of energy than gasoline and diesel fuels and are consumed at lower volumes.

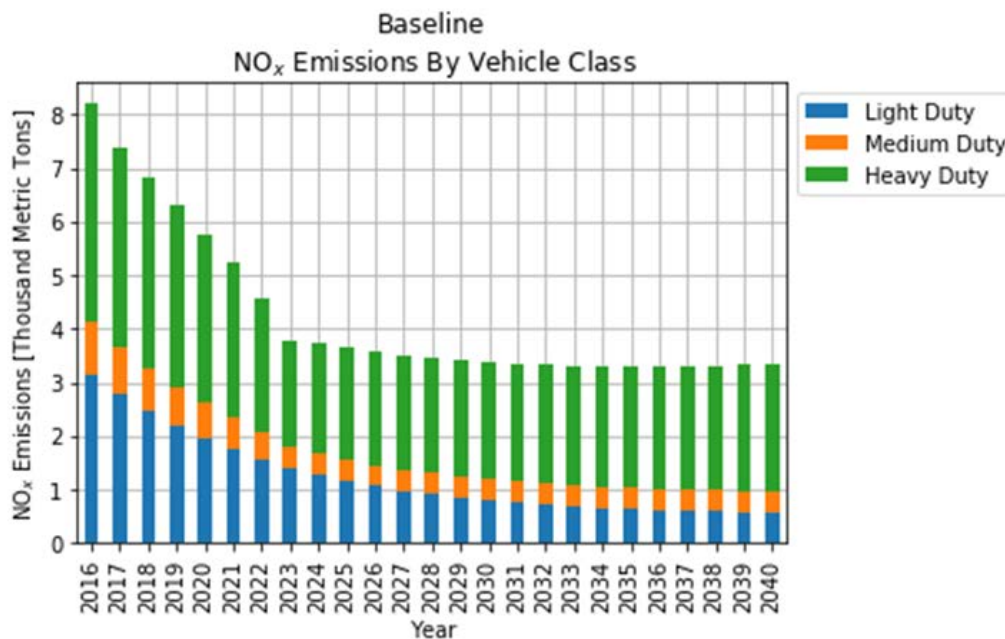
**Figure 39. Baseline GHG Emissions by Vehicle Fuel Type**



## Nitrogen Oxide Emissions

The figure below shows NO<sub>x</sub> emissions by vehicle class in the Baseline Scenario. Overall, on-road NO<sub>x</sub> emissions experience a much more significant decrease than GHG emissions under the Baseline Scenario – declining by over 50 percent between 2016 and 2040. In contrast to GHG emission sources, NO<sub>x</sub> emissions from the on-road transportation sector are primarily driven by HDVs. Although all vehicle classes produce less NO<sub>x</sub> emissions in 2040 than in 2016, HDVs emissions reach their lowest level in 2023 and gradually increase through the remainder of the analysis period. This rebound in emissions is driven by the conclusion of CARB’s Truck and Bus Rule in 2023 and the growth of VMT through 2040.<sup>182</sup> Moreover, the HDV share of NO<sub>x</sub> emissions increases from 60 percent in 2016 to over 80 percent in 2040 – indicating that the greatest opportunity for significant NO<sub>x</sub> reductions beyond the baseline scenario lies in the heavy-duty sector.

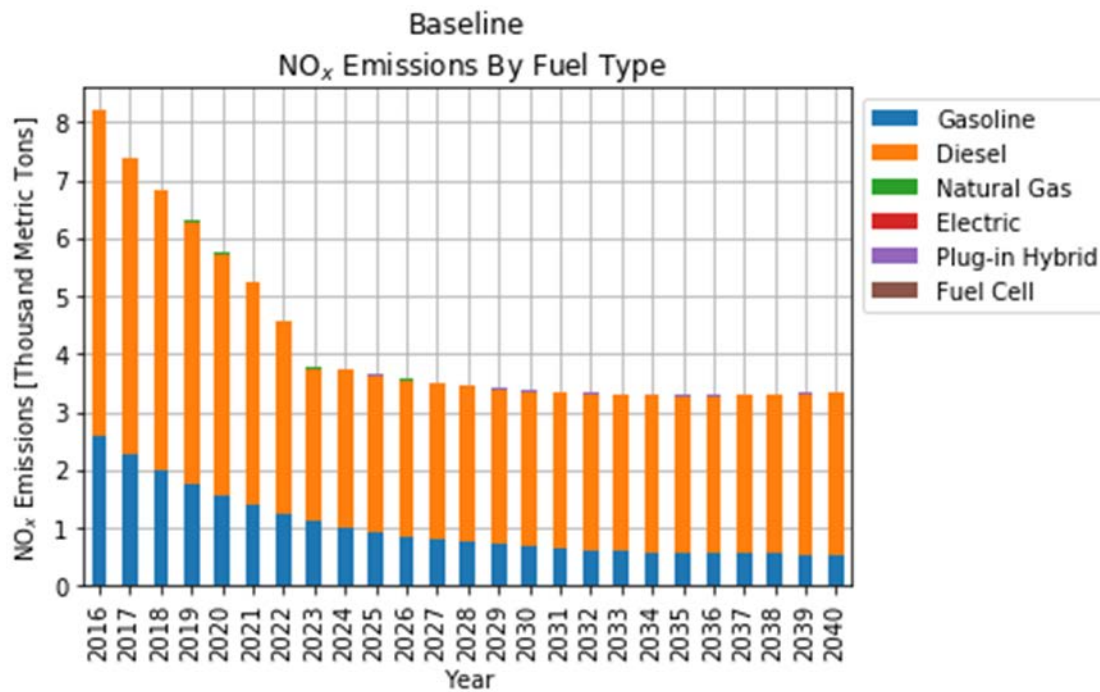
**Figure 40. Baseline NO<sub>x</sub> Emissions by Vehicle Type**



Breaking out NO<sub>x</sub> emissions by fuel type illustrates that diesel vehicles are the dominant contributor to NO<sub>x</sub> pollution given its use in the heavy-duty sector. Gasoline vehicles comprises 31 percent of annual NO<sub>x</sub> emissions in 2016 but declines to 16 percent in 2040. Other fuels contribute negligibly to NO<sub>x</sub> emissions throughout the analysis period; BEVs and FCVs produce zero NO<sub>x</sub> emissions.

<sup>182</sup> <https://ww2.arb.ca.gov/our-work/programs/truck-and-bus-regulation>

**Figure 41. Baseline NO<sub>x</sub> Emissions by Vehicle Fuel Type**



## Costs

To characterize the costs of each scenario, we calculate four types of costs:

- Vehicle purchase costs
- Fueling costs
- Fueling infrastructure costs
- Vehicle maintenance costs

The analysis tool calculates costs based on the estimated vehicle sales and VMT in a given year. Total vehicle purchase costs are estimated by applying the per-vehicle price assumptions (described above) to the vehicle sales in each analysis year. Total fueling costs are estimated by applying the unit fuel price assumptions (described above) to the vehicle fuel consumption in each analysis year. To estimate total fueling infrastructure costs, the analysis tool determines the number of fueling stations/chargers necessary to serve the vehicle population in each year; if any additional stations/chargers are needed, we assume they are constructed at a cost equal to the assumptions outlined above. Total maintenance costs are estimated by applying the per-mile cost assumptions to the VMT by vehicle type.

These costs, expressed in 2019 US dollars, can fall on different entities. Vehicle purchase costs are borne by vehicle owners – primarily households in the case of LDVs and commercial fleet owners in the case of MDVs and HDVs. Fueling costs are also borne primarily by the vehicle owner and operator. Fueling infrastructure costs are borne primarily by the commercial providers of gasoline, diesel, natural gas, and biofuels. In some cases, public sector entities may support fueling infrastructure development for alternative fuels. For electric vehicles, the costs of charging infrastructure are borne by homeowners (home charging equipment), private charging infrastructure providers, and in some cases, government

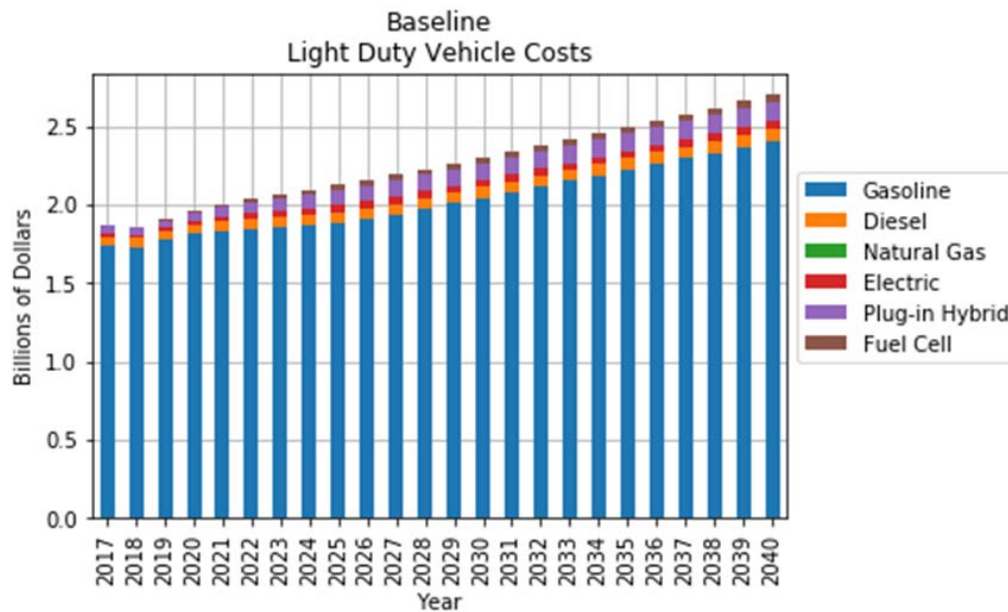
entities that install public charging infrastructure. Vehicle maintenance costs are borne by the vehicle owner and operator.

### Vehicle Purchase Costs

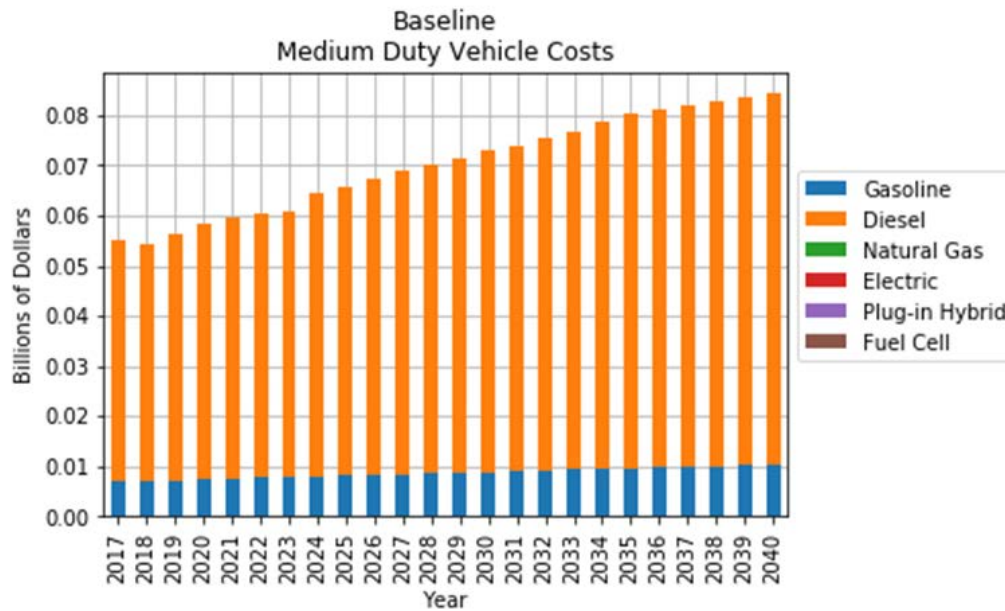
The analysis calculates aggregate vehicle purchase costs, which reflect the total expenditures on new vehicle purchasing in the study area by year. Under the Baseline Scenario, these vehicle purchase costs reflect the expenditures for new vehicles as part of normally fleet turnover. The Baseline aggregate vehicle purchase costs can be compared to costs under the other scenarios (discussed in Section 5) to show how accelerated purchasing of cleaner vehicles (e.g., gasoline or natural gas vehicles) will affect total expenditures on new vehicles.

Under the Baseline Scenario, total annual vehicle purchase costs increase from \$2 billion in 2016 to \$2.9 billion in 2040. Because LDVs account for the vast majority of new vehicle sales in the study area, they account for approximately 93 percent of annual vehicle purchase costs throughout the analysis period. The three figures below show Baseline Scenario vehicle purchase costs for LDVs, MDVs, and HDVs. Gasoline vehicles also make up 80-90 percent of vehicle purchase costs annually throughout the analysis period. In aggregate, PHEV, BEV, and FCV costs increase to nearly 7 percent of total by 2040. Diesel vehicles comprise approximately 12 percent of MDV vehicle purchase costs. HDV costs are driven almost exclusively by diesel vehicles, with natural gas vehicles contributing approximately 6 percent to total HDV costs.

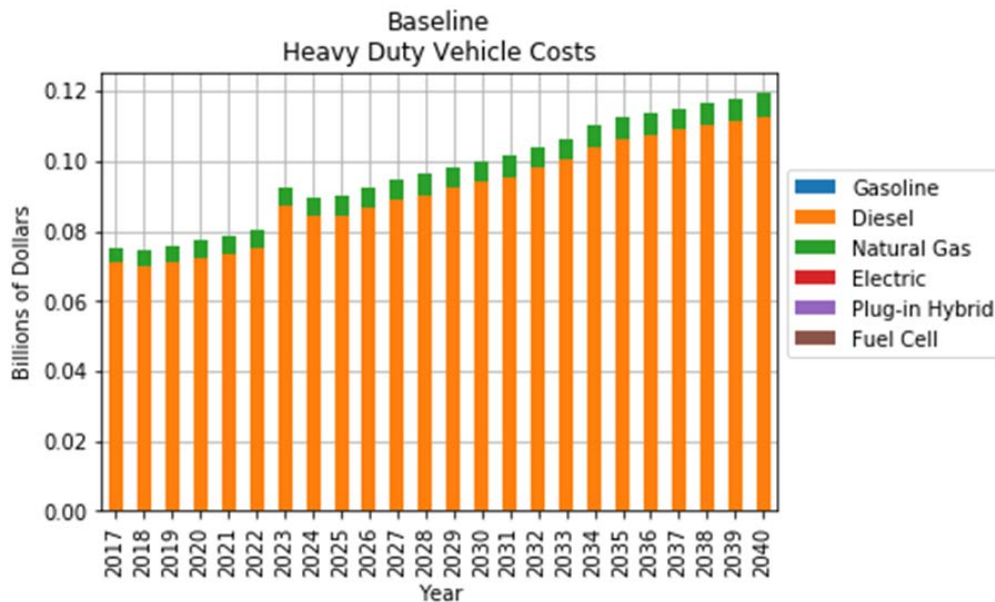
**Figure 42. Baseline Light Duty Vehicle Purchase Costs**



**Figure 43. Baseline Medium Duty Vehicle Purchase Costs**



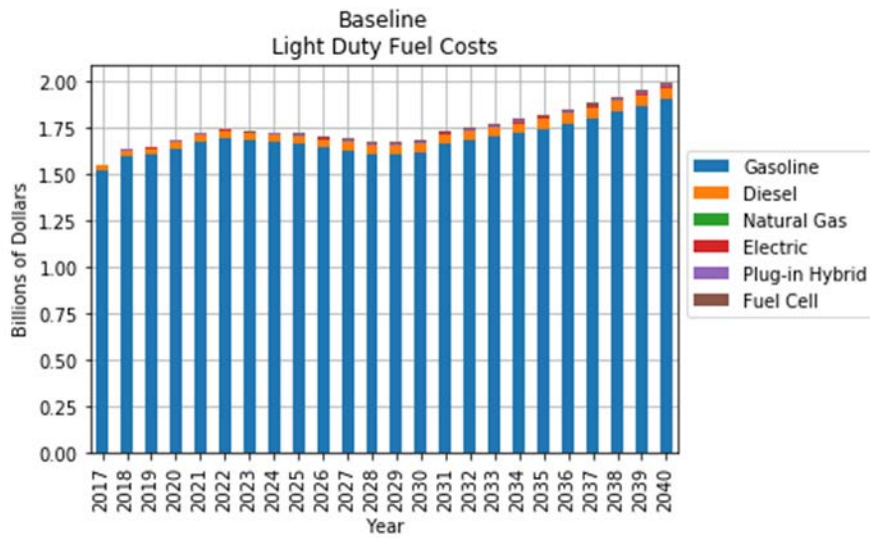
**Figure 44. Baseline Heavy Duty Vehicle Purchase Costs**



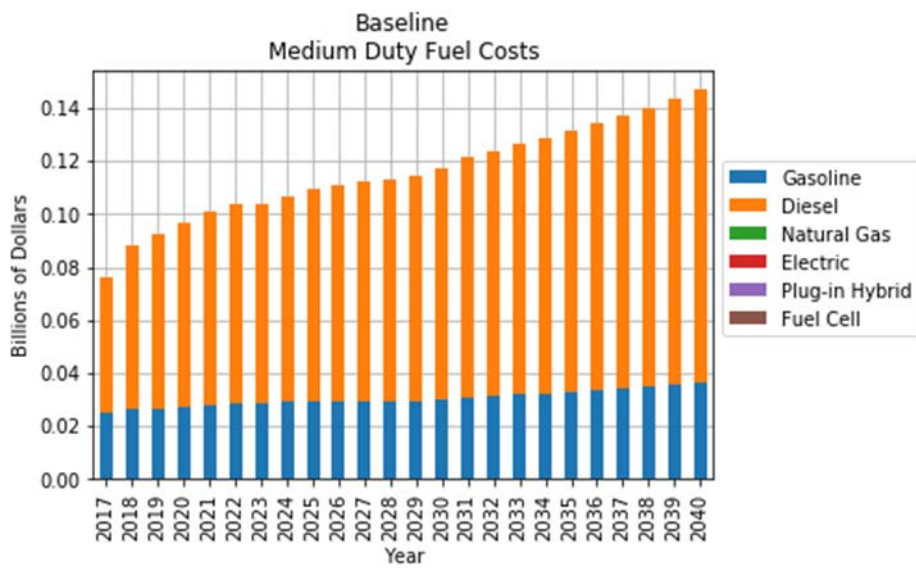
**Fueling Costs**

As illustrated in the figures below, fuel costs are generally commensurate with the composition of the vehicle population (e.g. gasoline, electric, etc.). Gasoline is the major cost driver for LDVs while diesel is the major cost driver for MDVs and HDVs. Low per-unit electricity costs make electricity’s contribution overall fuel costs *de minimis*.

**Figure 45. Baseline Light Duty Vehicle Fueling Costs**

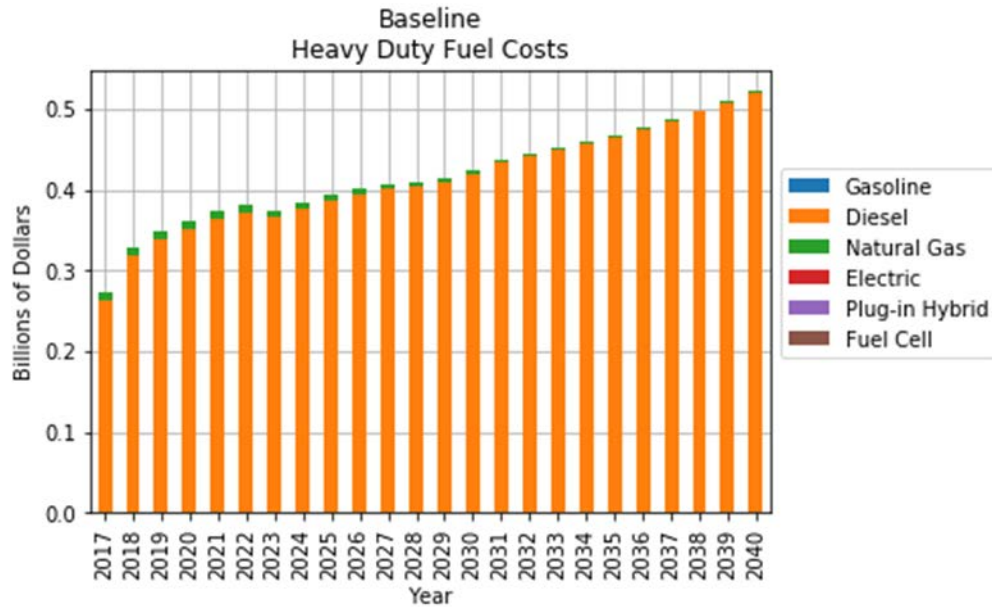


**Figure 46. Baseline Medium Duty Vehicle Fueling Costs**





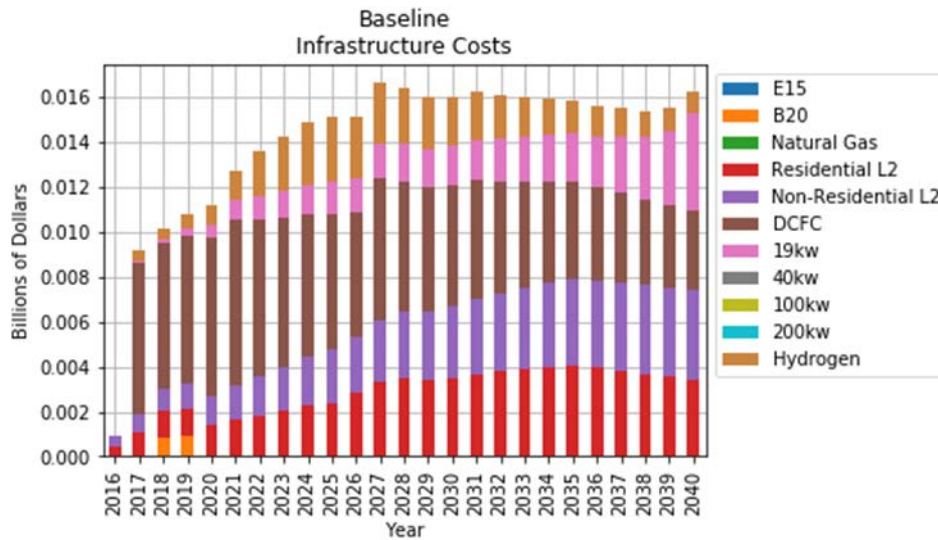
**Figure 47. Baseline Heavy Duty Vehicle Fueling Costs**



**Fueling Infrastructure Costs**

Baseline infrastructure costs in the figure below are relatively minor relative to other transportation cost categories and do not exceed \$200 million in any given year in the analysis period. These costs are primarily driven by light-duty BEV charging infrastructure. Medium-duty infrastructure is driven by 19 kW chargers while Heavy-duty infrastructure is driven by biodiesel fueling investments. These costs are relatively small because the number of alternative fuel vehicles in the Baseline Scenario is modest.

**Figure 48. Baseline Fueling Infrastructure Costs**

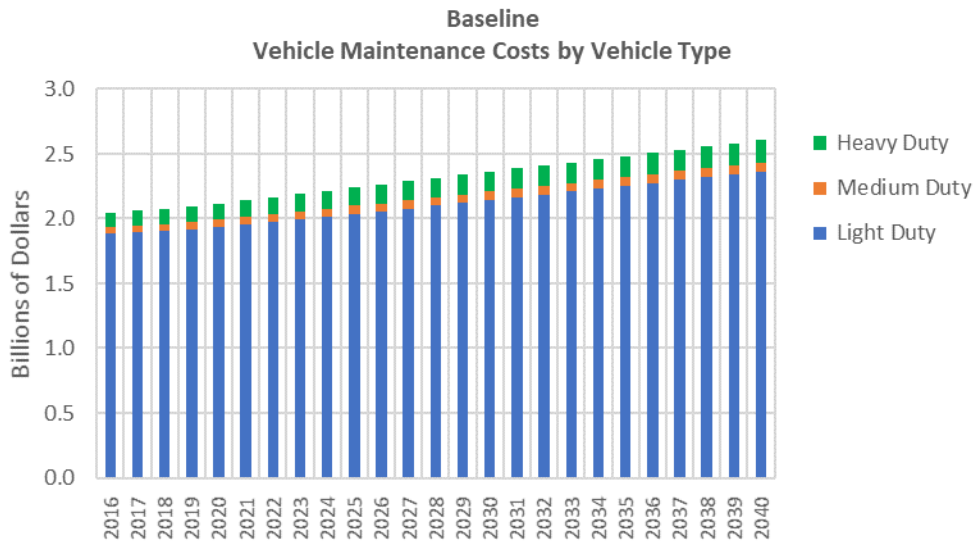




## Maintenance Costs

Baseline vehicle maintenance costs rise in step with VMT, growing from \$2 billion in 2016 to \$2.6 billion in 2040. Maintenance costs are driven primarily by LDVs. As described in Section 4.1, a gasoline powered light duty automobile is assumed to have a per-mile maintenance cost of \$0.14 versus \$0.19 for typical diesel medium and heavy duty vehicles. However, because LDVs account for the vast majority of VMT, they dominate total maintenance costs even though their per-mile cost is lower. The figure below shows aggregate vehicle maintenance costs by vehicle type. LDVs around for 91 percent of total maintenance costs.

**Figure 49. Baseline Vehicle Maintenance Costs**



The table below shows the cumulative costs over the full analysis period. The three major cost components – vehicle purchase costs, fueling costs, and maintenance costs – are all similar in magnitude, roughly \$60 billion over the full 24-year analysis period. Fueling infrastructure costs are much lower in the Baseline Scenario. This is because the scenario involves relatively few alternative fuel vehicles, and the existing fueling infrastructure for gasoline and diesel is adequate to serve the vast majority of vehicles under the Baseline Scenario.

**Table 23. Baseline Scenario Cumulative Costs, 2016 – 2040**

Cost Category	2016 - 2040 Cumulative Cost (billion)
Vehicle Purchase Costs	60.3
Fueling Costs	56.8
Fueling Infrastructure Costs	0.4
Vehicle Maintenance Costs	57.9

### 4.3 Scenario Development Process

We developed four scenarios that represent alternative paths to addressing air quality and climate change goals in San Bernardino County. To illustrate the trade-offs among the path options, these scenarios are designed to focus heavily on a single fuel type or technology. In brief, the scenarios are:

- **Electrification.** This scenario reflects a future with a faster-than-expected transition towards electrification among all vehicle types.
- **Natural Gas as a Bridge to Electrification.** This scenario relies primarily on natural gas (renewable) for heavy-duty vehicle emission reductions through the South Coast Air Basin ozone attainment period (early 2030s). NGVs essentially serve as a bridge technology until electric truck costs decline sufficiently to warrant significant deployment in medium and heavy duty sectors. For LDVs, the scenario assumes electrification.
- **Liquid Biofuels.** This scenario reflects a future with aggressive reductions across the spectrum linked to liquid biofuel consumption—including reduced carbon intensity of existing ethanol, higher consumption of ethanol in light-duty vehicles, and renewable diesel in heavy-duty vehicles. Accelerated turnover of the vehicle fleet is not needed.
- **Biofuels and Low NOx Diesel Engines.** This scenario reflects a future with low NOx diesel engines for heavy duty trucks in addition to the potential reductions linked to liquid biofuel consumption. Accelerated turnover of the vehicle fleet is not needed.

Each scenario is described in greater detail below.

#### Electrification Scenario

The Electrification Scenario assumes that sales of battery electric vehicles increase rapidly as compared to the Baseline. The assumed timing and rate of EV deployment varies by vehicle type. Electrification occurs most rapidly among the smaller light duty vehicles, reflecting the current commercial offerings and expected potential for market penetration. By 2040, this scenario assumes 80 percent of new sales of these autos and light duty trucks are EVs. For the larger and heavier light duty vehicles (EMFAC categories MDV and LHD1, or GVW 6,000 to 10,000 lbs.), we assume slower introduction of EVs, ramping up to 15 percent in 2030 and 50 percent by 2040. For MD and HD vehicles, EV sales through 2030 are based on CARB’s initial proposal for the Advanced Clean Trucks Regulation, which was subsequently adopted after the analysis was completed. The table below shows the sales percentage requirements for the proposed regulation.

**Table 24. Zero Emission Sales Requirements for Proposed Advanced Clean Trucks Regulation**

Model Year	Class 2B-3*	Class 4-8 Vocational	Class 7-8 Tractors
2024	3%	7%	0%
2025	5%	9%	0%
2026	7%	11%	0%
2027	9%	13%	9%
2028	11%	24%	11%
2029	13%	37%	13%
2030	15%	50%	15%

For the years 2031-2040, the scenario assumes a continued increase in the EV new sales fraction, reaching 75 percent for Class 4-8 vocational trucks and 35-50 percent for other medium and heavy-duty trucks. The table below summarizes the EV sales fractions for this scenario. No EV sales are assumed for out-of-state trucks, since these vehicles are unlikely to be eligible for state and local incentives and may not be subject to state or local regulations. As discussed in Section 4.1, because EMFAC breaks out the VMT and emissions associated with out-of-state vehicles, the analysis can treat these vehicles differently than in-state vehicles.

**Table 25. EV Sales Fractions by Vehicle Type – Electrification Scenario**

Vehicle Type	FHWA Class	2030	2040
Light Duty	1	41.5%	80%
Light Duty	2	15%	50%
Medium Duty	3	15%	50%
Medium Duty	4	50%	75%
Medium Duty	5	50%	75%
Medium Duty	6 (IRP and Ag)	15%	50%
Medium Duty	6 (out of state)	0%	0%
Medium Duty	6 (all other)	50%	75%
Heavy Duty	7 (IRP)	15%	35%
Heavy Duty	7 (out of state)	0%	0%
Heavy Duty	7 (all other)	50%	75%
Heavy Duty	8 (vocational)	50%	75%
Heavy Duty	8 (tractors)	15%	35%
Heavy Duty	8 (out of state)	0%	0%

Note: IRP is International Registration Plan

We also analyzed a more aggressive electrification scenario, discussed in Section 5.

### Natural Gas as a Bridge to Electrification Scenario

The Natural Gas as a Bridge to Electrification Scenario assumes rapid acceleration of natural gas vehicles (NGV) among most medium and heavy-duty vehicle types through 2030. Natural gas engines are currently available for these vehicles and are used in select applications. By 2030, this scenario assumes that NGVs account for 40 percent to 45 percent of new sales for most medium and heavy-duty truck types. After 2030, the sales fraction for NGVs begins to decline, on the assumption that EVs will become more cost effective for these vehicle types after 2030.

For small light duty vehicles (autos and light trucks), this scenario assumes new sales of EVs will be identical to the Electrification Scenario. This assumption is a reflection of the minimal interest among manufacturers and consumers for light duty NGVs.

In this scenario, all new NGVs are assumed to use renewable natural gas, which produces significantly lower GHG emissions than conventional (fossil) natural gas. As with the Electrification Scenario, no NGV or EV sales are assumed for out-of-state trucks, since these vehicles are unlikely to be eligible for state and local incentives and may not be subject to state or local regulations. The table below summarizes the NGV and EV sales fractions for this scenario.

**Table 26. NGV and EV Sales Fractions by Vehicle Type – Natural Gas as a Bridge Scenario**

Vehicle Type	FHWA Class	Natural Gas		Electric	
		2030	2040	2030	2040
Light Duty	1	0%	0%	41.5%	80%
Light Duty	2	10%	10%	5%	25%
Medium Duty	3	10%	10%	5%	25%
Medium Duty	4	25%	25%	5%	50%
Medium Duty	5	45%	35%	5%	35%
Medium Duty	6 (IRP and Ag)	40%	20%	5%	25%
Medium Duty	6 (out of state)	0%	0%	0%	0%
Medium Duty	6 (all other)	45%	35%	5%	35%
Heavy Duty	7 (IRP)	40%	20%	5%	25%
Heavy Duty	7 (out of state)	0%	0%	0%	0%
Heavy Duty	7 (all other)	45%	35%	5%	35%
Heavy Duty	8 (vocational)	45%	35%	5%	35%
Heavy Duty	8 (tractors)	40%	20%	5%	25%
Heavy Duty	8 (out of state)	0%	0%	0%	0%

### Liquid Biofuels Scenario

The Liquid Biofuels Scenario assumes significant increases in the use of biofuels (ethanol, biodiesel, renewable diesel) among all vehicle types as well as reductions in the carbon intensity of biofuels. Both changes result in reduced GHG emissions as compared to conventional gasoline and diesel vehicles, but does not affect NOx emissions. Because most biofuels can be blended with conventional gasoline or diesel and these blends can be used in conventional internal combustion engines, this scenario does not require accelerated turnover of the vehicle fleet.

This scenario assumes the ethanol blend in gasoline increases to 15 percent by 2040. Today, reformulated gasoline (RFG) contains 10 percent ethanol by volume – and RFG makes up more than 95 percent of the gasoline fuel market in the United States. This is largely driven by the federal Renewable Fuel Standard, which is a supply-side driver for ethanol production. Higher ethanol blends are currently limited by infrastructure and vehicle warranty concerns. The U.S. EPA has approved for use 15 percent ethanol blends (E15) in model year 2001 and newer light-duty conventional gas vehicles. However, some in the automotive industry contend that the use of E15 has the potential to accelerate wear and tear and ultimately lead to vehicle failure. There are also significant concerns about consumer education and outreach regarding the appropriate use of E15, and some fuel retailers are concerned about impacts on infrastructure. All of these concerns could be addressed and result in an increase in ethanol blending.

The scenario also assumes that the carbon intensity of ethanol will decline 35 percent by 2035. On a life cycle basis, ethanol produced from corn reduces GHG emissions by about 30 percent, and the Baseline Scenario assume this corn-based ethanol will continue to be used, as discussed in Section 4.2. Ethanol produced with cellulosic feedstocks can reduce lifecycle GHG emissions from 50 to 90 percent. Ethanol producers are seeking to reduce their carbon intensity, and the carbon intensity of ethanol has decreased steadily over time. Older facilities with high carbon intensity were nearly phased out by the

end of 2017, with ethanol with carbon intensity higher than 75 g/MJ decreasing from nearly 90 percent of the ethanol LCFS credits in 2011 to less than 5 percent in 2018. With a 35 percent reduction, the carbon intensity of ethanol would be 44.6 g CO<sub>2</sub>e/MJ in 2035.

For medium and heavy-duty diesel vehicles, this scenario assumes an increase in the biodiesel blend from 5 percent in the Baseline Scenario to 10 percent by 2040. As described in Section 2, biodiesel is a fatty acid methyl ester (FAME) that can be synthesized from vegetable oils, waste oils, fats, and grease. Biodiesel is generally used in low-level blends: biodiesel blended in at 5 percent by volume is considered the same as diesel, and biodiesel blended at 20 percent by volume is the upper limit of blending for the majority of transportation applications due to vehicle warranty. In California, the LCFS is driving increased use of biodiesel. However, CARB’s Alternative Diesel Fuel (ADF) Rulemaking will limit the potential for biodiesel blending in the near-term future because of concerns about biodiesel blends to increase NO<sub>x</sub> emissions. These concerns are expected to wane as older diesel vehicles are retired.

The scenario assumes the carbon intensity of biodiesel will decline to 20 g CO<sub>2</sub>e/MJ by 2030, down from the Baseline Scenario assumption of 31.05 g/MJ. Lower carbon biodiesel can be obtained from feedstocks such as corn oil, animal fats, and cooking oil. As with ethanol, lower carbon biodiesel is being driven by the LCFS.

Lastly, this scenario assumes an increase in the renewable diesel blend to 60 percent by 2040, up from the Baseline assumption of 10 percent blend. Renewable diesel is produced via biomass-to-liquid processing. In terms of chemical and physical properties, renewable diesel meets all the requirements of ASTM D975, and is therefore considered a “drop-in” fuel. For instance, Neste Oil’s NExBTL product meets the fuel quality specifications of CARB diesel, meaning no modifications are needed to existing storage and transport infrastructure. There are current five plants producing renewable diesel – the Diamond Green facility in Louisiana and four international facilities operated by Neste, including one in Singapore that serves the California market. No change in renewable diesel carbon intensity is assumed for this scenario.

The table below summarizes the assumed changes in blend percentages and carbon intensity for the Biofuels Scenario.

**Table 27. Changes in Blend Percentages and Carbon Intensity – Biofuels Scenario**

Fuel	Blend Percentage		Carbon Intensity (g CO <sub>2</sub> e/MJ)	
	Baseline	Scenario (2040)	Baseline	Scenario (2040)
Ethanol	10%	15%	68.6	44.6
Biodiesel	5%	10%	31.05	20.0
Renewable Diesel	10%	60%	32.17	32.17

## Biofuels and Low NO<sub>x</sub> Diesel Engines Scenario

This scenario includes all the assumptions of the Biofuels Scenario plus an increase in deployment of diesel engines that produce lower NO<sub>x</sub> emissions. This scenario can therefore achieve reductions in both GHG emissions and NO<sub>x</sub> emissions compared to the Baseline Scenario.

Emission standards adopted by the U.S. EPA require that new heavy-duty vehicle NO<sub>x</sub> emissions do not exceed 0.2 g/bhp-hr starting with model year 2010. The Baseline Scenario assumes this standard will remain in place throughout the analysis years. Manufacturers have generally complied with this standard through the use of selective catalytic reduction (SCR) emission control systems. Since 2010, the effectiveness of emission control technologies has improved and their costs have declined. Both EPA and CARB have announced rulemakings focused on revising the heavy-duty truck NO<sub>x</sub> emission standards, targeting 2024 to 2027 for implementation. The Manufacturers of Emission Controls Association (MECA) reports that technologies are available that can be deployed on vehicles by model year 2024 to achieve 0.05 g/bhp-hr NO<sub>x</sub> standard.<sup>183</sup>

There is uncertainty as to whether all diesel trucks could consistently achieve a 0.05 g/bhp-hr NO<sub>x</sub> standard. This scenario assumes that new sales of diesel trucks have engines that meet a 0.1 g/bhp-hr NO<sub>x</sub> standard starting in 2025 (50 percent NO<sub>x</sub> reduction from current standard of 0.2 g/BHP-hr). The low-NO<sub>x</sub> technology is assumed to add \$10,000 to the vehicle purchase price.

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<sup>183</sup> Manufacturers of Emission Controls Association, *Technology Feasibility for Model Year 2024 Heavy-Duty Diesel Vehicles in Meeting Lower NO<sub>x</sub> Standards*, June 2019.

## 5 Analysis Results

This section describes the results of the scenario analysis. Each scenario is discussed individually, including both emissions impacts and costs. The final subsection presents a summary of the results.

### 5.1 Scenario A: Electrification

The Electrification Scenario assumes a much more aggressive introduction of BEVs into the vehicle fleet than the Baseline scenario. The gasoline vehicle population reaches a peak of 931,000 vehicles in 2025 and then gradually declines to 670,000 units in 2040 as BEVs reach increasingly greater adoption levels across all vehicle classes – growing to nearly 580,000 units in 2040. In total, BEVs and PHEVs make up half the vehicle population in 2040, up from only 0.4 percent in 2016. Of the BEVs in the 2040 vehicle population, 565,000 are LDVs while the balance is comprised of approximately 9,000 MDVs and 5,000 HDVs.

Figure 50. Electrification Scenario Vehicle Population by Fuel Type

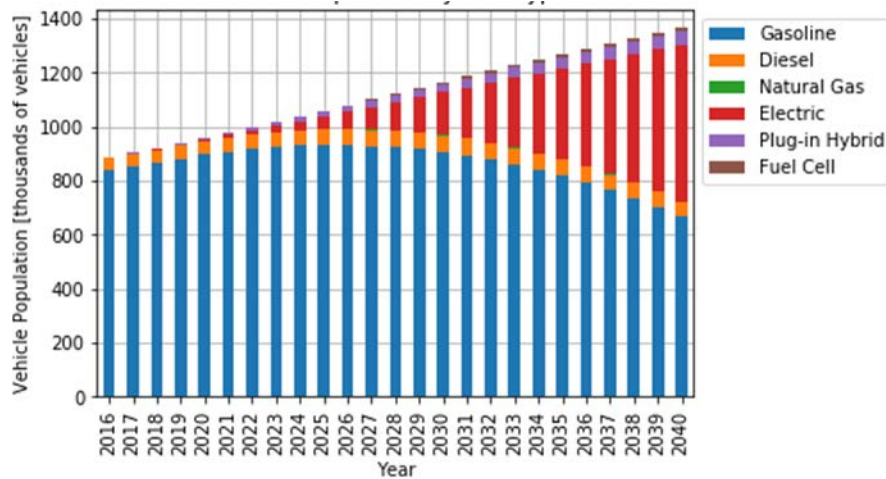


Table 28. Electrification Scenario Vehicle Population by Vehicle Type, 2016, 2031, and 2040

Type	Fuel	2016		2031		2040	
		Vehicles (000)	Percent	Vehicles (000)	Percent	Vehicles (000)	Percent
LDV	Gasoline	836.5	98%	890.1	78%	666.5	51%
	Electric	0.9	0%	185.6	16%	565.2	43%
	Plug-in Hybrid	1.0	0%	33.3	3%	48.9	4%
	Other	14.2	2%	31.3	3%	34.3	3%
<b>Sub-Total</b>		<b>852.5</b>	<b>100%</b>	<b>1140.3</b>	<b>100%</b>	<b>1314.8</b>	<b>100%</b>
MDV	Gasoline	4.3	25%	3.8	17%	3.2	12%
	Diesel	12.8	75%	17.1	74%	13.7	53%
	Electric	0.0	0%	2.1	9%	8.8	34%
	<b>Sub-Total</b>	<b>17.1</b>	<b>100%</b>	<b>23.0</b>	<b>100%</b>	<b>25.7</b>	<b>100%</b>

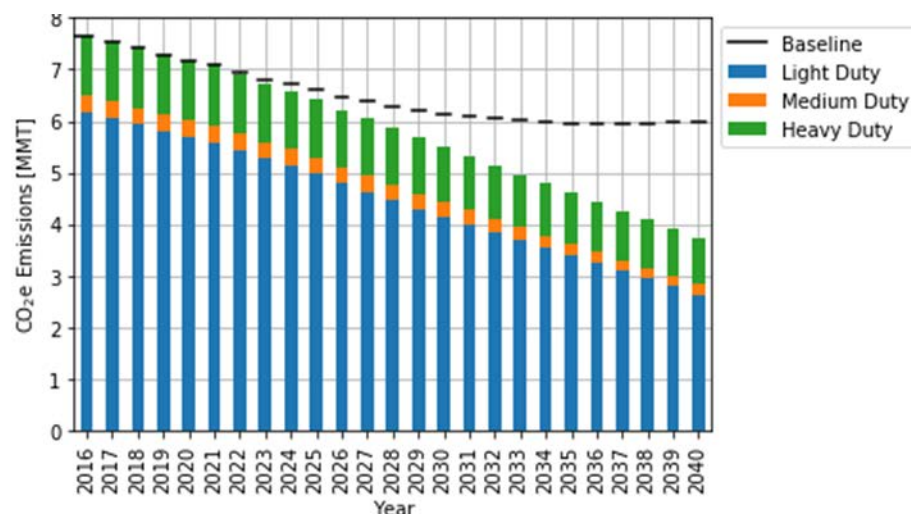


<b>HDV</b>	Diesel	16.8	95%	20.6	90%	18.2	76%
	Electric	0.0	0%	1.1	5%	5.0	21%
	Other	0.9	5%	1.1	5%	0.8	3%
	<b>Sub-Total</b>	<b>17.7</b>	<b>100%</b>	<b>22.9</b>	<b>100%</b>	<b>24.0</b>	<b>100%</b>

## Emissions Impacts

As shown in the figure and table below, GHG emissions in the Electrification scenario decline to 3.7 million metric tons (MMT) in 2040, resulting in a 37 percent reduction relative to Baseline emissions in 2040. These reductions are driven by the introduction of BEVs: despite their relatively high penetrations in the second half of the analysis period, BEVs contribute marginally to GHG emissions given their fuel efficiency and the low emissions of their fuel source – which becomes increasingly generated by renewable resources as the scenario advances. LDVs experience the most significant GHG emission reductions – in both relative and absolute terms – suggesting that a focus on light-duty electrification can yield lower on-road sector GHG emissions in the short-, medium-, and long-term.

**Figure 51. Electrification Scenario CO2e Emissions by Vehicle Type**



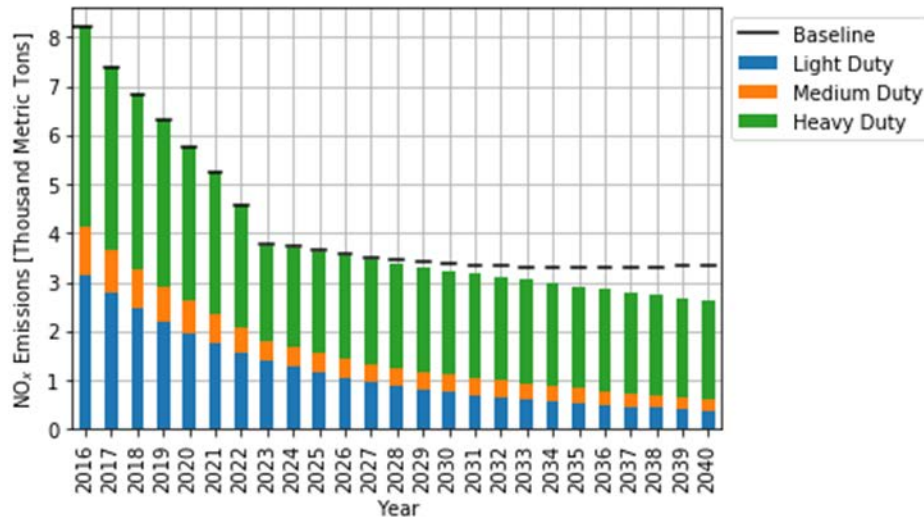
**Table 29. Electrification Scenario CO2e Emissions Impacts (MMT), 2040**

Vehicle Type	Baseline Scenario	Electrification Scenario	Difference
Light Duty	4.60	2.65	-42%
Medium Duty	0.31	0.19	-40%
Heavy Duty	1.07	0.91	-16%
<b>Total</b>	<b>5.98</b>	<b>3.74</b>	<b>-37%</b>

The figure and table below show the NOx emissions of the Electrification Scenario. As discussed in Section 4, the Baseline NOx emissions (shown with a black line in the chart) decline rapidly through 2023 due mostly to the state Truck and Bus Rule. The Electrification Scenario would reduce NOx emissions

further below the baseline levels. NOx emissions are reduced to approximately 2,600 MT in 2040, representing a 21 percent decrease in NOx emissions relative to the Baseline in 2040. Similar to the GHG emissions results, the LDV sector experiences the greatest NOx emissions reductions in both relative and absolute terms from the aggressive introduction of BEVs. HDV NOx emissions remain the largest source of NOx emissions throughout the analysis period despite a 50 percent reduction between 2016 and 2040.

**Figure 52. Electrification Scenario NOx Emissions by Vehicle Type**



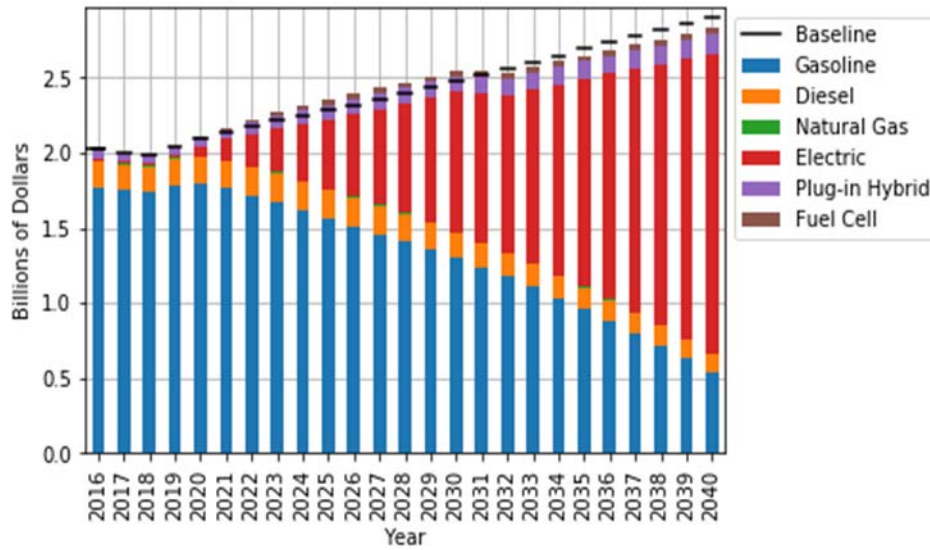
**Table 30. Electrification Scenario NOx Emissions Impacts (thousand MT), 2040**

Vehicle Type	Baseline Scenario	Electrification Scenario	Difference
Light Duty	0.58	0.38	-35%
Medium Duty	0.40	0.24	-41%
Heavy Duty	2.37	2.01	-15%
<b>Total</b>	<b>3.34</b>	<b>2.63</b>	<b>-21%</b>

### Costs

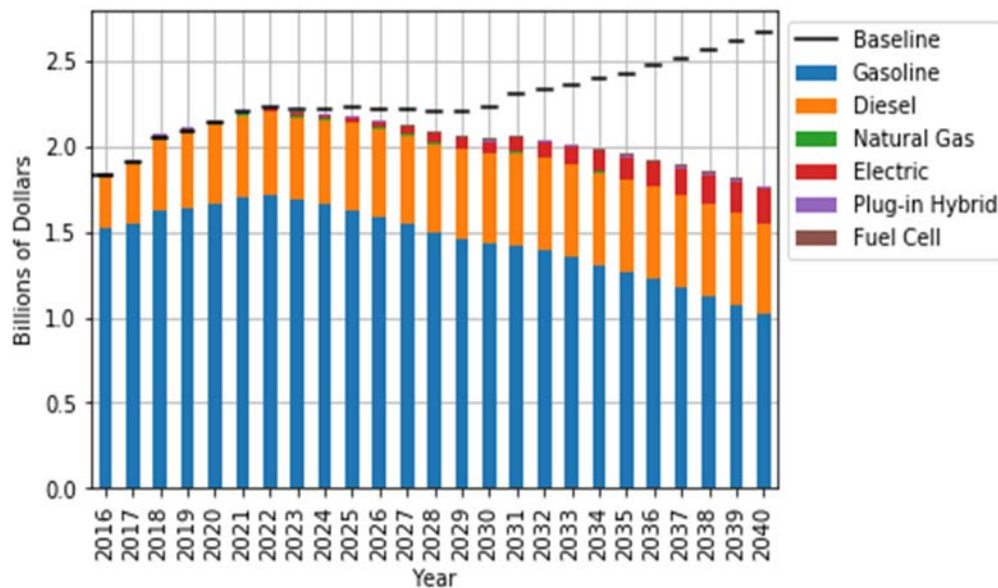
Annual vehicle purchase costs in the Electrification Scenario are similar to the Baseline Scenario, starting near \$2 billion in 2016 and escalate to \$2.8 billion in 2040, as shown below. BEVs become an increasingly salient cost driver as their adoption increases, comprising 71 percent of total vehicle costs in 2040. The Electrification scenario vehicle costs remain higher than the Baseline throughout the 2020s as BEV costs remain higher than many comparable petroleum vehicles. However, by the early 2030s, the annual vehicle costs cross over and become lower than the Baseline costs and end up approximately 3 percent lower than the Baseline in 2040. In other words, in 2040, total expenditures on new vehicles would be 3 percent lower under the Electrification Scenario. This is driven by the assumption that electric automobiles will have a slightly lower purchase price than gasoline vehicles starting in 2032, as described in Section 4.1.

**Figure 53. Electrification Scenario Vehicle Purchase Costs**



The fueling costs in the Electrification Scenario peak in 2022 at approximately \$2.2 billion and decline to \$1.8 billion in 2040. These reductions amount to a 34 percent reduction in annual fuel costs relative to Baseline fuel costs in 2040. Despite BEVs comprising over a third of the vehicle fleet in 2040, BEVs drive 11 percent of the fuel costs due to relatively low electric fuel prices. Annual gasoline fuel costs decrease by \$500 million between 2016 and 2040 as a result of greater BEV and PHEV adoption. Diesel costs largely remain constant throughout the analysis period.

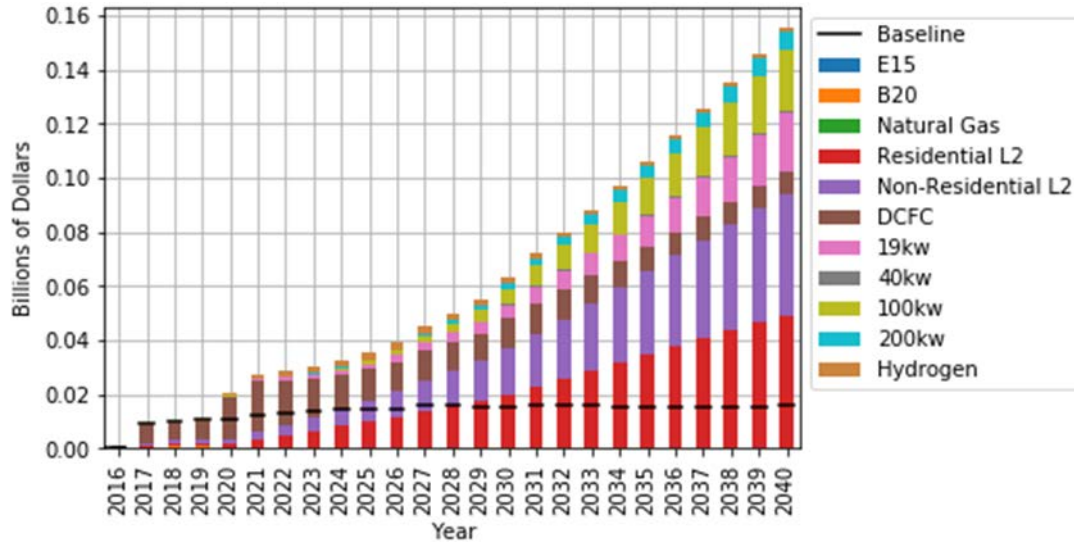
**Figure 54. Electrification Scenario Fueling Costs**



Infrastructure costs, while low relative to other transportation-related costs, are significantly higher in the Electrification Scenario than the Baseline scenario and rise to nearly \$160 million in annual investment in 2040. The majority of these costs are driven by the deployment of L2 charging stations to support LDVs at home, workplace, and public locations in the latter half of the analysis period. It is

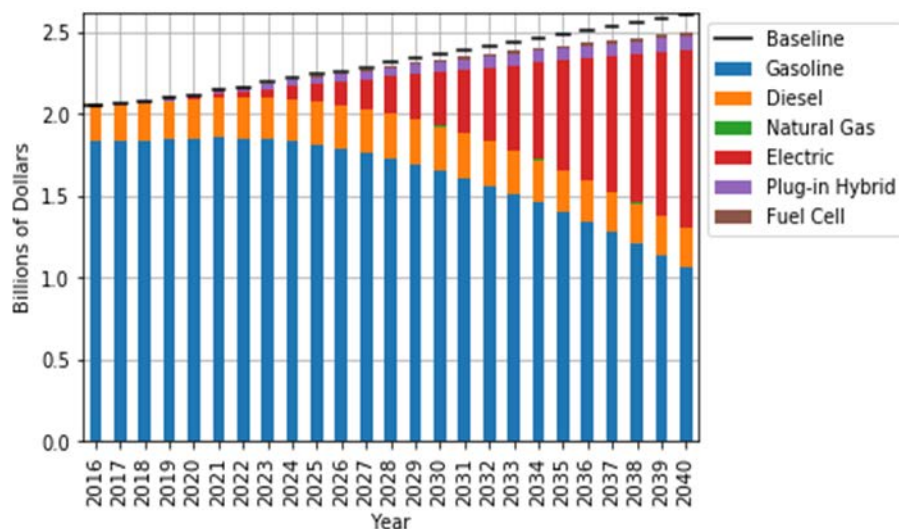
important to note that DCFC station costs drive the majority of infrastructure costs until the mid-2020s, suggesting that an accessible network of DCFC stations is necessary early on to support light-duty BEV adoption in a manner consistent with Electrification Scenario BEV projections. For MDV and HDV BEVs, infrastructure costs are primarily driven by 19 kW stations and 100 kW and stations. These infrastructure costs and investment decisions will be influenced by a number of related factors, including: vehicle battery range, vehicle duty cycle, and climate conditions under which vehicles operate.

**Figure 55. Electrification Scenario Infrastructure Costs**



Total maintenance costs in the Electrification Scenario start near \$2 billion annually in 2016 and approach \$2.5 billion annually in 2040, representing a modest 6 percent annual cost reduction relative to the Baseline scenario in 2040. BEV and PHEV maintenance costs increase to approximately half of total annual maintenance costs by 2040 while gasoline vehicle maintenance costs decline gradually from \$1.8 billion in 2016 to \$1.1 billion in 2040. Diesel maintenance costs largely remain constant throughout the analysis period. Overall, these modest total cost reductions are driven by the lower maintenance costs associated with BEVs, which do not require the same level of maintenance as comparable petroleum fuel vehicles.

**Figure 56. Electrification Scenario Maintenance Costs**



### Variation – Aggressive Electrification

At the suggestion of the study technical advisory committee, we analyzed a more aggressive electrification scenario. The 2030 and 2040 EV sales fractions for this scenario are shown below; linear interpolation was assumed for interim years. This scenario is more similar to the Advanced Clean Trucks rules adopted by CARB in June 2020.

**Table 31. EV Sales Fractions for Aggressive Electrification Scenario**

Vehicle Type	FHWA Class	Electrification Scenario		Aggressive Electrification Scenario	
		2030	2040	2030	2040
Light Duty	1	41.5%	80%	50%	100%
Light Duty	2	15%	50%	25%	75%
Medium Duty	3	15%	50%	25%	75%
Medium Duty	4	50%	75%	60%	80%
Medium Duty	5	50%	75%	60%	80%
Medium Duty	6 (IRP and Ag)	15%	50%	25%	75%
Medium Duty	6 (out of state)	0%	0%	0%	0%
Medium Duty	6 (all other)	50%	75%	60%	80%
Heavy Duty	7 (IRP)	15%	35%	25%	50%
Heavy Duty	7 (out of state)	0%	0%	0%	0%
Heavy Duty	7 (all other)	50%	75%	60%	80%
Heavy Duty	8 (vocational)	50%	75%	60%	80%
Heavy Duty	8 (tractors)	15%	35%	25%	50%
Heavy Duty	8 (out of state)	0%	0%	0%	0%

The table below shows the NOx and GHG emissions under the Aggressive Electrification Scenario as compared to the Baseline and the original Electrification Scenario. Both NOx and GHG emission reductions are substantially larger than under the original Electrification Scenario.

**Table 32. Emissions Impacts of Aggressive Electrification Scenario (thousand MT), 2040**

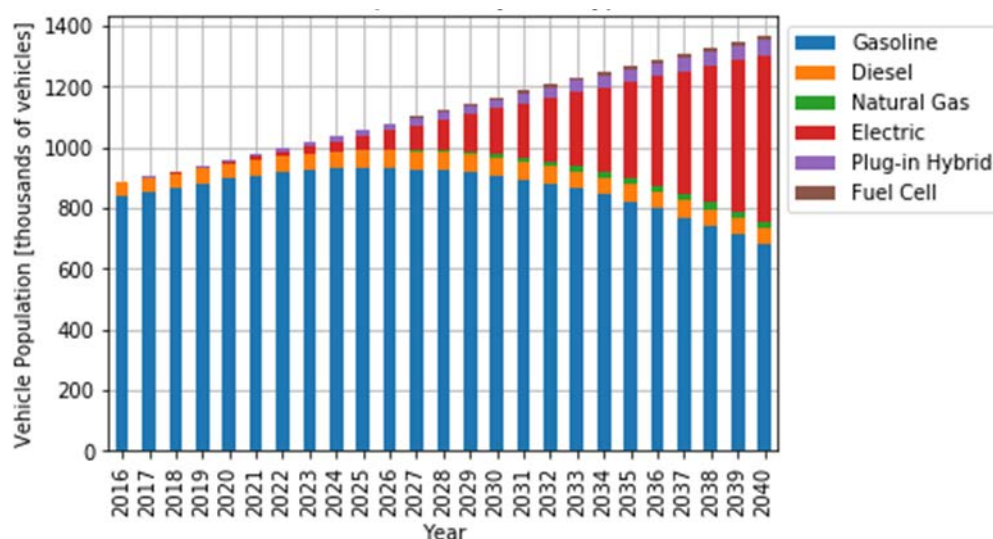
	NOx	GHGs
<b>Baseline Scenario</b>	3.34	5.98
<b>Electrification Scenario</b>	2.63	3.74
<b>Change</b>	-21%	-37%
<b>Aggressive Electrification Scenario</b>	2.40	3.12
<b>Change</b>	-28%	-48%

## 5.2 Scenario B: Natural Gas as a Bridge to Electrification

The Natural Gas as a Bridge to Electrification (Bridge) Scenario follows similar vehicle population trends as the Electrification Scenario – albeit with several key differences. Electrification of the light-duty fleet drives significant growth in BEVs throughout the analysis period, contributing to a total BEV population of nearly 550,000 vehicles in 2040. The transition from light-duty gasoline vehicles to BEVs causes the gasoline vehicle fleet to peak in 2025 at 930,000 units and decline to under 700,000 units by 2040. However, natural gas vehicles grow to become the second most common vehicle type among MDVs and HDVs by 2040 – comprising 22 and 24 percent of vehicles of these types by 2040. MDVs and HDVs still experience BEV growth, but it is more modest than the electrification scenario: these vehicle classes see BEV sales begin in the mid-2020s and grow to 12 percent of the MDV fleet and 8 percent of the HDV fleet in 2040.

The figure below shows the total vehicle population in the study area by fuel type. Because the accelerated penetration of natural gas vehicles is limited to MDVs and HDVs, and these two vehicle types make up only four percent of the total vehicle population, the number of natural gas vehicles (shown in green in the chart) remains small relative to the total vehicle population, which is dominated by LDVs.

**Figure 57. Natural Gas as a Bridge Scenario Vehicle Population by Fuel Type**



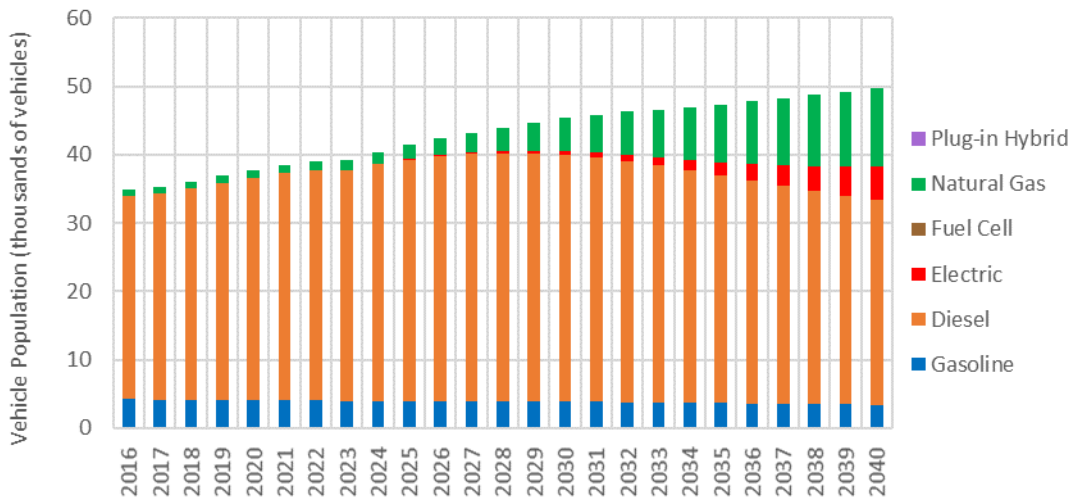
**Table 33. Natural Gas as a Bridge Scenario Vehicle Population by Vehicle Type, 2016, 2031, and 2040**

Type	Fuel	2016		2031		2040	
		Vehicles (000)	Percent	Vehicles (000)	Percent	Vehicles (000)	Percent
<b>LDV</b>	Gasoline	836.5	98%	891.0	78%	675.4	51%
	Electric	0.9	0%	180.0	16%	541.5	41%
	Plug-in Hybrid	1.0	0%	33.3	3%	48.9	4%
	Other	14.2	2%	36.1	3%	49.0	4%
	<b>Sub-Total</b>	<b>852.5</b>	<b>100%</b>	<b>1140.3</b>	<b>100%</b>	<b>1314.8</b>	<b>100%</b>
<b>MDV</b>	Gasoline	4.3	25%	3.8	17%	3.4	13%
	Diesel	12.8	75%	16.2	71%	13.6	53%
	Natural Gas	0.0	0%	2.5	11%	5.6	22%
	Electric	0.0	0%	0.4	2%	3.0	12%
	<b>Sub-Total</b>	<b>17.1</b>	<b>100%</b>	<b>23.0</b>	<b>100%</b>	<b>25.7</b>	<b>100%</b>
<b>HDV</b>	Diesel	16.8	95%	19.6	86%	16.4	68%
	Natural Gas	0.9	5%	3.0	13%	5.8	24%
	Electric	0.0	0%	0.2	1%	1.9	8%
	Other	0.0	0%	0.0	0%	0.0	0%
	<b>Sub-Total</b>	<b>17.7</b>	<b>100%</b>	<b>22.9</b>	<b>100%</b>	<b>24.0</b>	<b>100%</b>

The figure below shows the vehicle population by fuel type for only MDVs and HDVs. This figure illustrates the growing share of natural gas vehicles (shown in green) and, after 2030, electric vehicles (shown in red). Natural gas accounts for 23 percent of the combined MDV and HDV population in 2040, and electric vehicles account for another 10 percent.



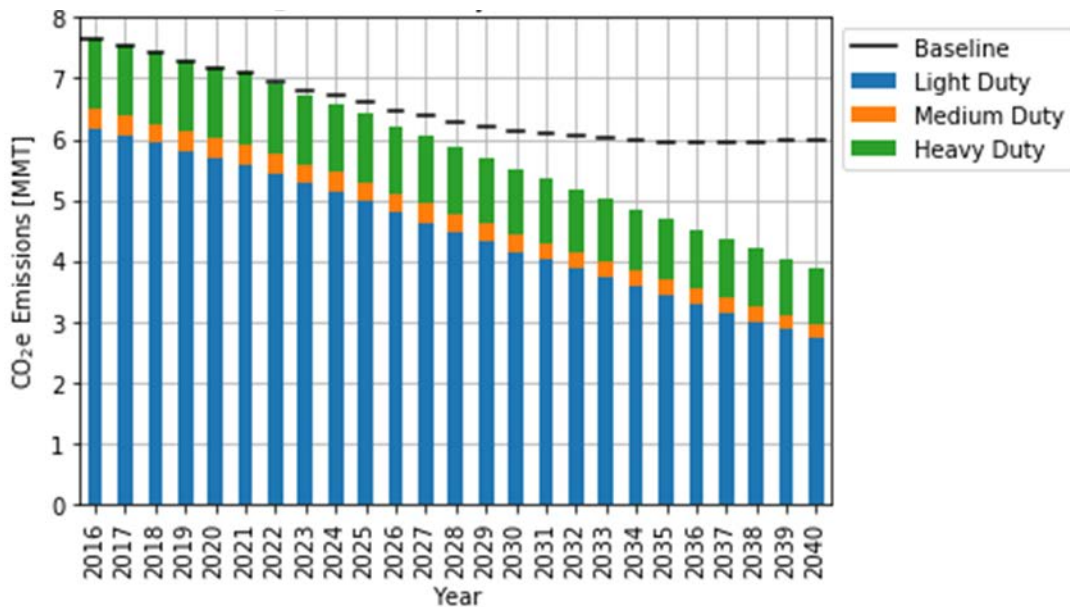
**Figure 58. Natural Gas as a Bridge Scenario Vehicle Population by Fuel Type, MDV and HDV only**



### Emissions Impacts

Annual GHG emissions in the Natural Gas as a Bridge Scenario decline to approximately 4 MMT in 2040, representing a 35 percent decrease in annual emissions relative to the 2040 Baseline figure. The LDV sector, the greatest contributor to GHG emissions throughout the analysis period, experiences the greatest emissions reductions in both relative and absolute terms from increased uptake of BEVs. The MDV and HDV sector experience moderate annual GHG emission reductions: 27 and 19 percent, respectively, between 2016 and 2040.

**Figure 59. Natural Gas as a Bridge Scenario CO<sub>2</sub>e Emissions by Vehicle Type**

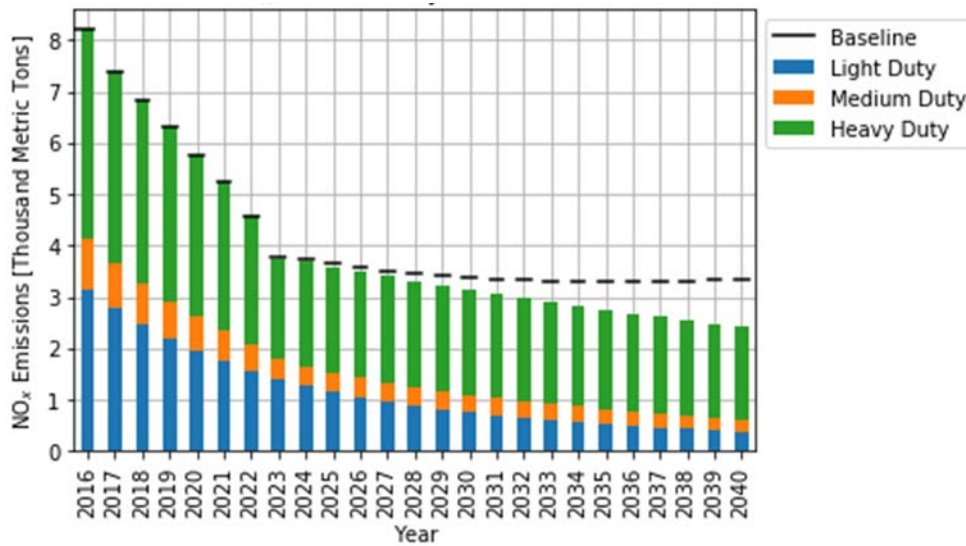


**Table 34. Natural Gas as a Bridge Scenario CO2e Emissions Impacts (MMT), 2040**

Vehicle Type	Baseline Scenario	Natural Gas as Bridge Scenario	Difference
Light Duty	4.60	2.73	-41%
Medium Duty	0.31	0.23	-27%
Heavy Duty	1.07	0.92	-14%
<b>Total</b>	<b>5.98</b>	<b>3.88</b>	<b>-35%</b>

Annual NOx emissions also experience a decline in the Bridge Scenario, falling to approximately 2,400 MT in 2040, a 27 percent decrease in annual NOx emissions relative to the 2040 Baseline figure. Despite the growth of low NOx natural gas and electric HDVs throughout the 2030s, expected increases in truck VMT keep HDV NOx emissions relatively flat during the period 2023 – 2040, although HDV NOx emissions would be 24 percent lower than the Baseline in 2040. LDVs experience significant NOx emission reductions from the transition toward BEVs and away from gasoline powered vehicles.

**Figure 60. Natural Gas as a Bridge Scenario NOx Emissions by Vehicle Type**



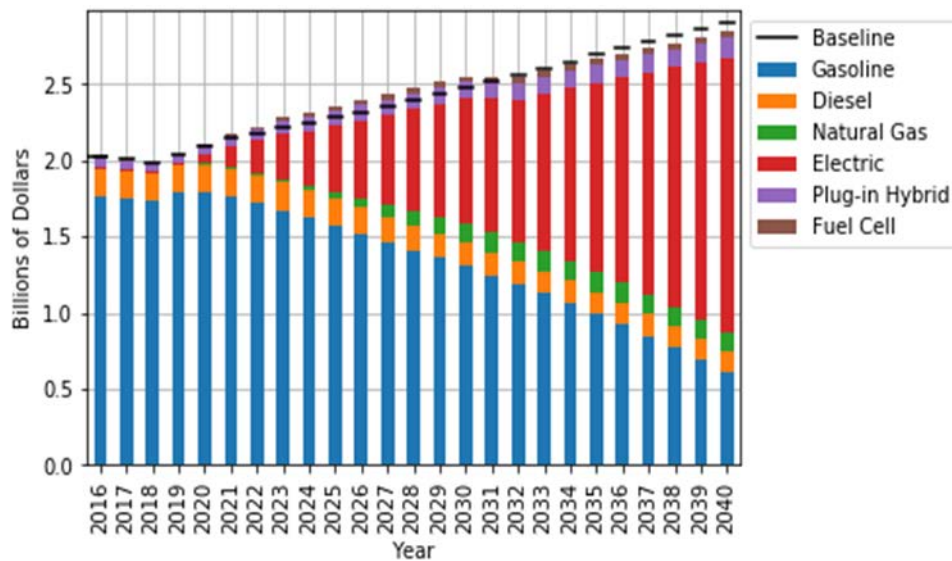
**Table 35. Natural Gas as a Bridge Scenario NOx Emissions Impacts (thousand MT), 2040**

Vehicle Type	Baseline Scenario	Natural Gas as Bridge Scenario	Difference
Light Duty	0.58	0.38	-34%
Medium Duty	0.40	0.24	-40%
Heavy Duty	2.37	1.81	-24%
<b>Total</b>	<b>3.34</b>	<b>2.43</b>	<b>-27%</b>

## Costs

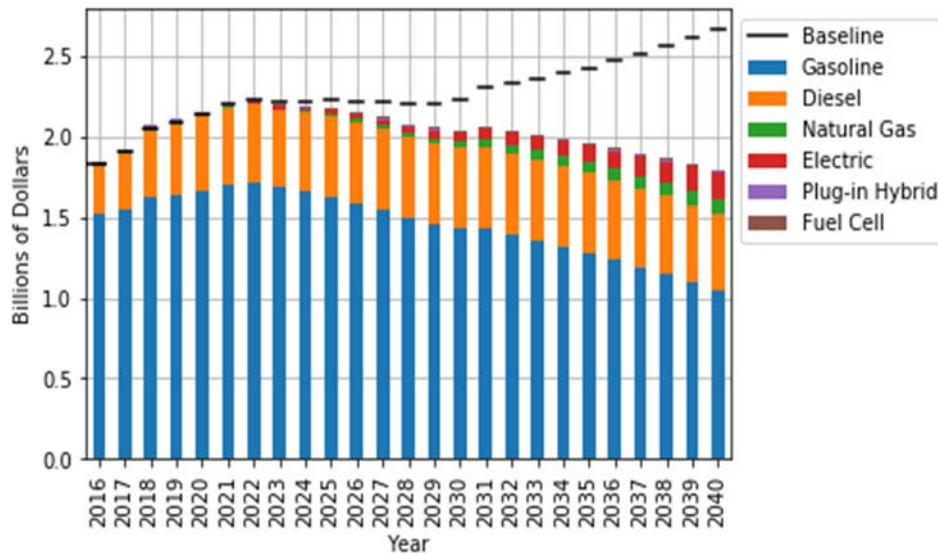
Bridge Scenario vehicle purchase costs follow a similar trend to the Electrification Scenario: BEVs become the dominant cost driver by 2040 while gasoline vehicles experience approximately \$1 billion in cost declines between 2016 and 2040 due to reduced sales. Total vehicle purchase costs also exceed the Baseline Scenario estimates at the outset of the analysis period on an annual basis, based on the assumption that electric LDVs have a higher purchase price than gasoline LDVs through 2030 (as discussed in Section 4). But by 2032, electric automobiles are assumed to have a slightly lower purchase price than gasoline automobiles. Because LDVs make up the vast majority of the vehicle population, the vehicle purchase costs are driven by these differences. Purchase costs under the Bridge Scenario gradually become lower than the Baseline in the 2030s and result in marginally lower annual vehicle costs in 2040. Diesel vehicle purchase costs also decline marginally as natural gas vehicles and BEVs replace diesel vehicle sales.

**Figure 61. Natural Gas as a Bridge Scenario Vehicle Purchase Costs**



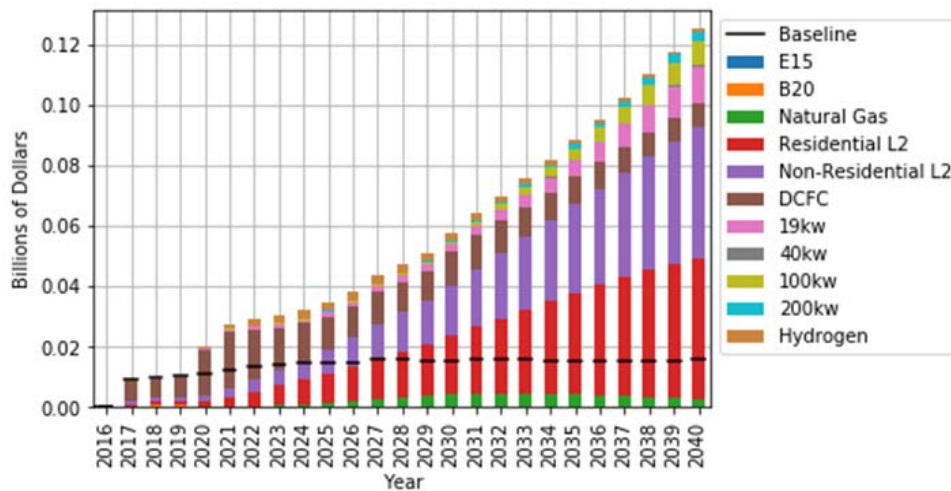
Fueling costs in the Bridge Scenario peak in 2022 at approximately \$2.2 billion and gradually decline to \$1.8 billion in 2040, a 34 percent decrease in annual fuel costs relative to the 2040 Baseline figure. Annual gasoline fueling costs decline by \$500 million by 2040 from 2016 levels as the transition to light-duty BEVs accelerates. Natural gas comprises nearly 20 percent of MDV fueling costs and 10 percent of HDV annual fueling costs in 2040; both vehicle classes experience annual fuel cost savings relative to the Baseline scenario as natural gas vehicles and BEVs are introduced to the market. However, diesel remains the primary driver of fuel costs in these vehicle classes.

**Figure 62. Natural Gas as a Bridge Scenario Fueling Costs**



Like the Electrification Scenario, the Bridge Scenario reveals significantly higher infrastructure costs relative to the Baseline Scenario in relative terms; however, infrastructure costs remain minimal relative to other cost categories. DCFC stations needed to support light-duty BEV adoption comprise the majority of costs until the mid-2020s when light-duty L2 station costs begin to accelerate. Fast charging infrastructure is still necessary to support medium- and heavy-duty BEVs, though not at levels required by the Electrification Scenario. Natural gas infrastructure costs remain relatively low throughout the analysis period and reach approximately 3 percent of annual infrastructure costs in 2040.

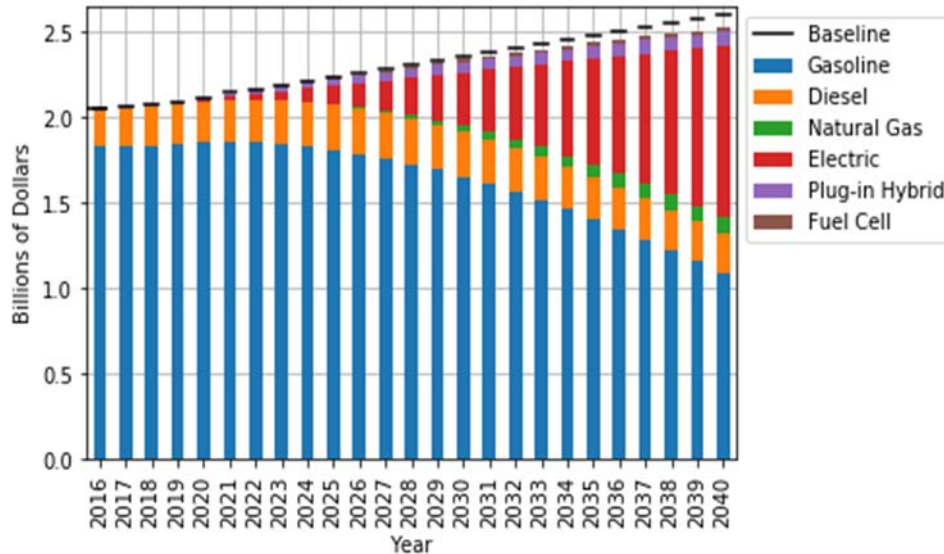
**Figure 63. Natural Gas as a Bridge Scenario Infrastructure Costs**



Maintenance costs in the Bridge Scenario begin near \$2 billion in 2016 and reach \$2.5 billion annually in 2040, representing a 3 percent reduction in annual maintenance costs relative to the Baseline at the end of the analysis period. These costs are driven by BEVs, which comprise approximately 40 percent of all maintenance costs in 2040. Broken out by vehicle class, MDV and HDV sectors’ total maintenance costs in this scenario are virtually equal to maintenance costs in the Baseline Scenario; it is the LDV sector that

experiences maintenance cost savings due to the transition to BEVs. Diesel maintenance costs rise modestly to \$250 million annually until the middle of the analysis period and decline to \$200 million annually by 2040 as natural gas and electric vehicle adoption grows.

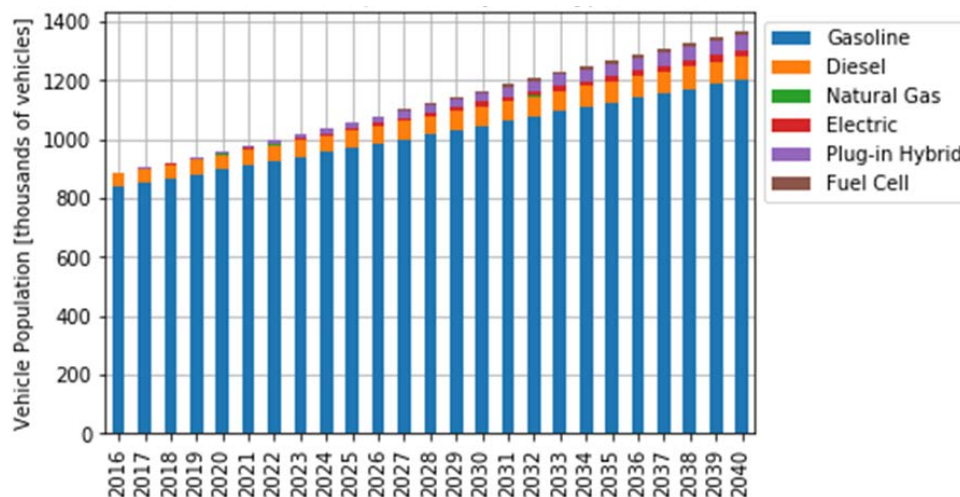
**Figure 64. Natural Gas as a Bridge Scenario Maintenance Costs**



### 5.3 Scenario C: Liquid Biofuels

In the Liquid Biofuels Scenario, the vehicle composition remains the same as the Baseline Scenario, because this scenario does not require any accelerated vehicle turnover or replacement. Gasoline LDV vehicles comprise the majority of the fleet, followed by diesel vehicles and limited quantities of alternative fuel vehicles. The primary difference in the Biofuels Scenario lies in the fuel these vehicles use. Gasoline use is offset by greater ethanol consumption, fossil natural gas is displaced by RNG, and fossil diesel is substituted for greater quantities of biodiesel and renewable diesel fuels.

**Figure 65. Biofuels Scenario Vehicle Population by Fuel Type**



## Emissions Impacts

GHG emissions in the Biofuels Scenario begin to diverge from the Baseline Scenario in the early 2020s and decrease to approximately 5 MMT in 2040 – a 14 percent decrease relative to the Baseline in 2040. LDVs continue to drive the majority of GHG emissions throughout the analysis period and are also responsible for the greatest emissions reductions in absolute terms. In percentage terms, HDVs experience the largest decline in GHG emissions, with 2040 emissions 42 percent lower than the Baseline.

Figure 66. Biofuels Scenario CO<sub>2</sub>e Emissions by Vehicle Type

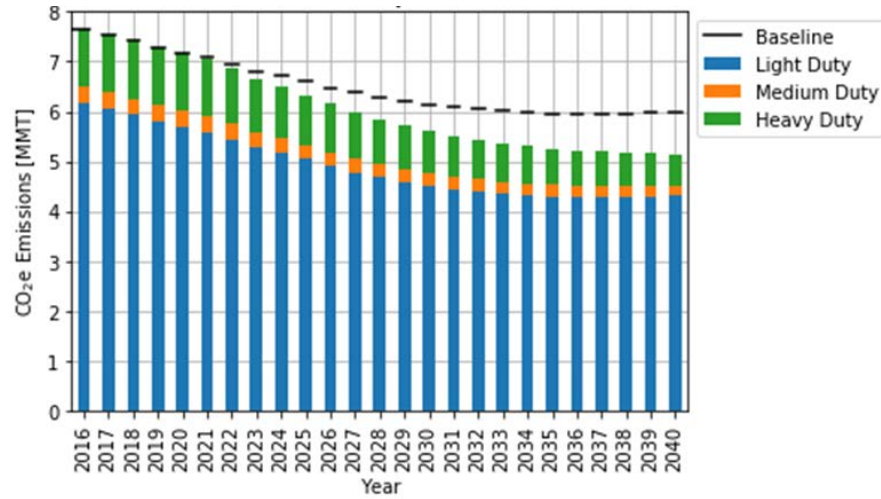


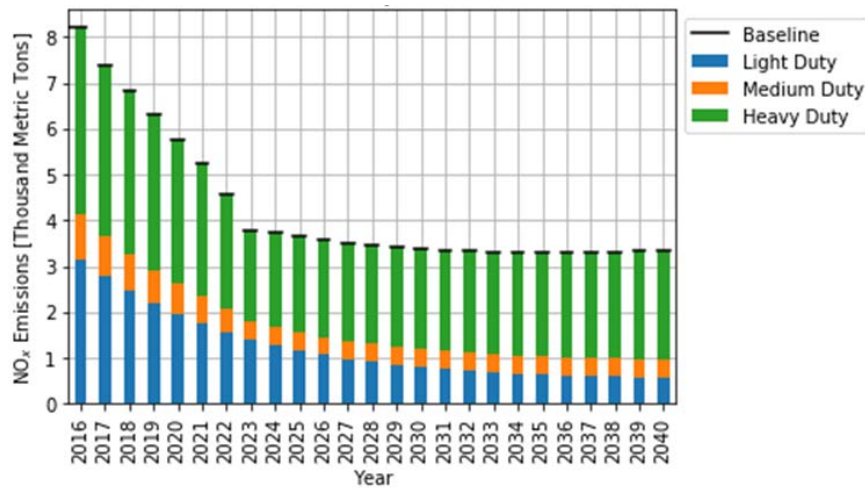
Table 36. Biofuels Scenario CO<sub>2</sub>e Emissions Impacts (MMT), 2040

Vehicle Type	Baseline Scenario	Biofuels Scenario	Difference
Light Duty	4.60	4.31	-6%
Medium Duty	0.31	0.21	-32%
Heavy Duty	1.07	0.63	-42%
<b>Total</b>	<b>5.98</b>	<b>5.15</b>	<b>-14%</b>

NO<sub>x</sub> emissions are unchanged in this scenario relative to the Baseline, consistent with the scenario assumption that biofuels use does not affect NO<sub>x</sub> emission rates.



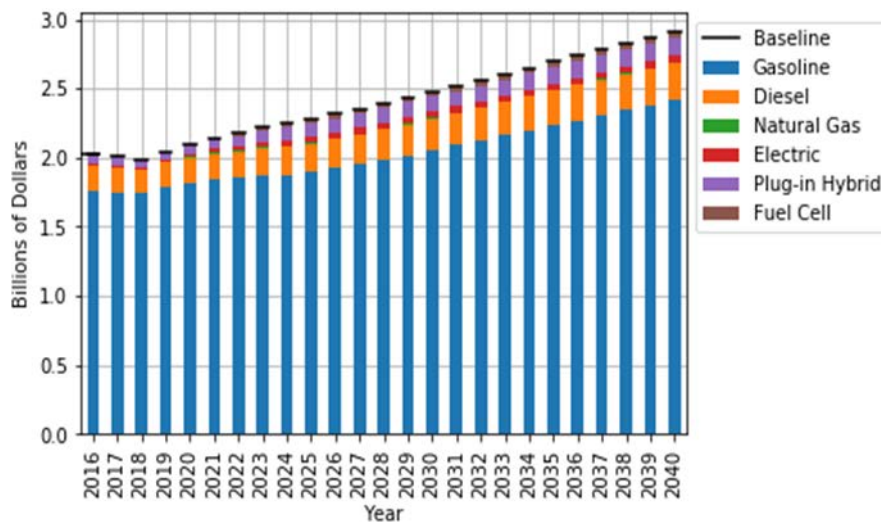
**Figure 67. Biofuels Scenario NOx Emissions by Vehicle Type**



### Costs

Because this scenario does not involve any changes to vehicle stock, vehicle costs in the Biofuels Scenario are identical to the vehicle costs under the Baseline Scenario. Gasoline vehicles – primarily LDVs – make up over 80 percent of total vehicle purchase costs in 2040. Modest gains made by BEVs, PHEVs, and FCVs are driven almost entirely by LDV and MDV sectors. HDVs are dominated by diesel vehicles throughout the analysis period with minor contributions from natural gas vehicles. Overall, these vehicles make up 8 percent of vehicle costs in 2040.

**Figure 68. Biofuels Scenario Vehicle Purchase Costs**

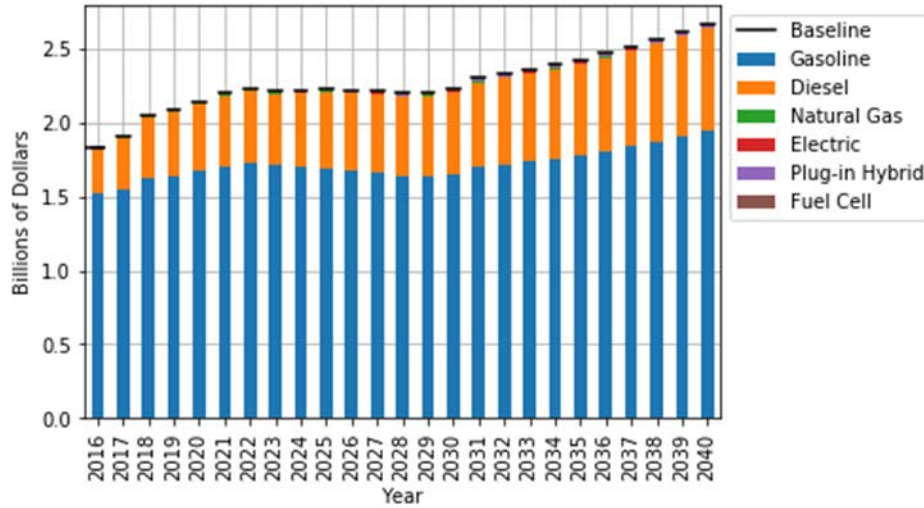


Fueling costs in the Biofuels Scenario are very similar to those in the Baseline scenario, which plateau in the mid-2020s and then continue to increase to over \$2.5 billion annually in 2040. Gasoline and ethanol comprises roughly 75 percent of total fuel costs throughout the analysis period while diesel contributes to the majority of the remaining fuel costs. Annual biodiesel consumption increases to 11.7 million gallons in 2040 (relative to 5.8 million gallons in the Baseline) and annual renewable diesel consumption



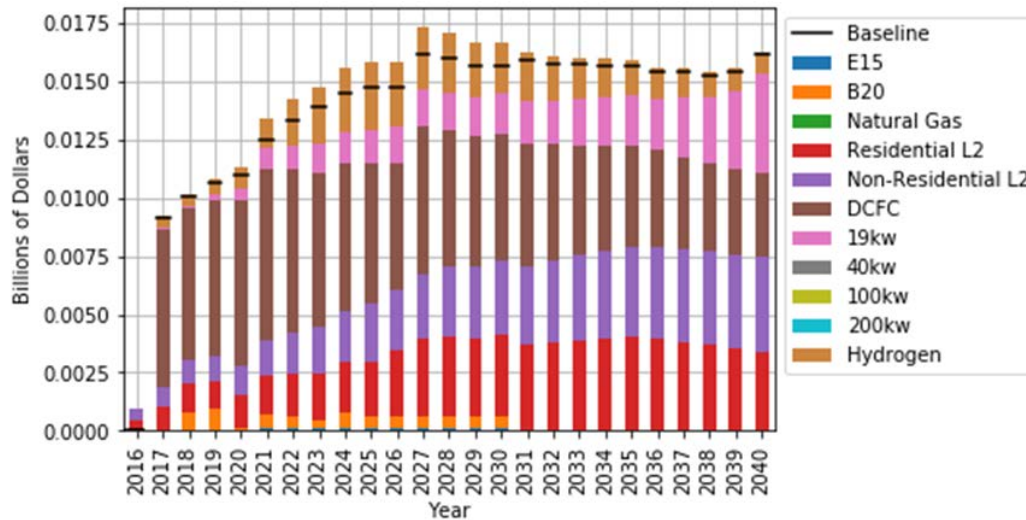
increases to 70.4 million gallons in 2040 (relative to 11.7 million gallons in the Baseline) while ULSD consumption declines to 35.2 million gallons in 2040. This finding suggests that the majority of diesel costs are driven by biofuels by the end of the analysis period.

**Figure 69. Biofuels Scenario Fueling Costs**



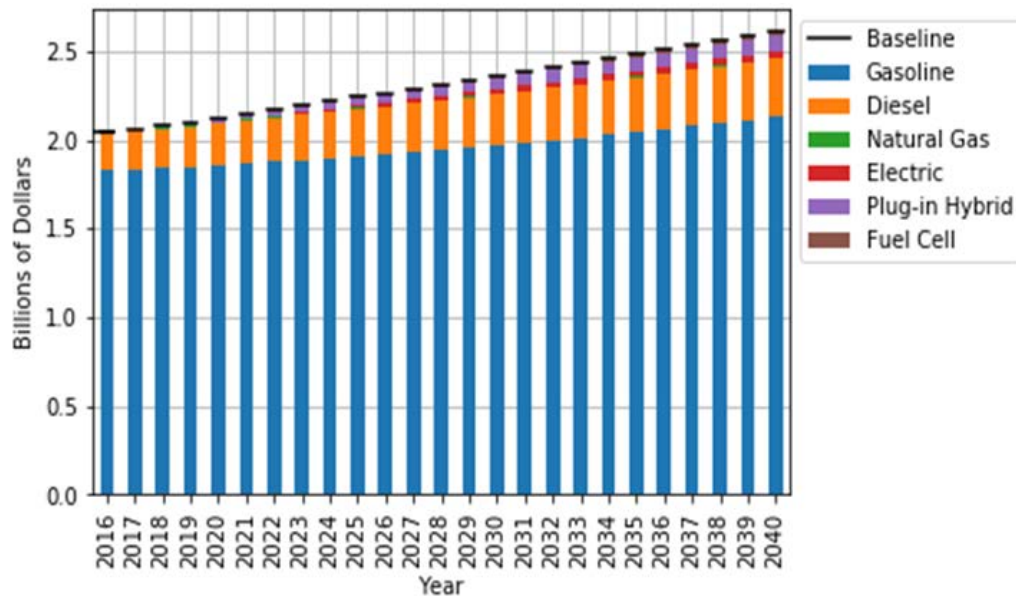
Infrastructure costs remain relatively minor in the Biofuels Scenario and slightly exceed Baseline scenario infrastructure costs. These costs continue to be driven by EV charging infrastructure costs, with minimal additional costs to support the increased use of biofuels. Infrastructure to support biodiesel and ethanol production increases infrastructure costs marginally throughout the 2020s.

**Figure 70. Biofuels Scenario Infrastructure Costs**



Overall, maintenance costs remain virtually identical to the Baseline Scenario – increasing gradually to over \$2.5 billion in 2040. There is little cost variation among vehicle classes and fuel types relative to the Baseline. These findings are bolstered by the fact that the evaluated biofuels – when blended at appropriate levels – do not significantly impact vehicle performance or operation.

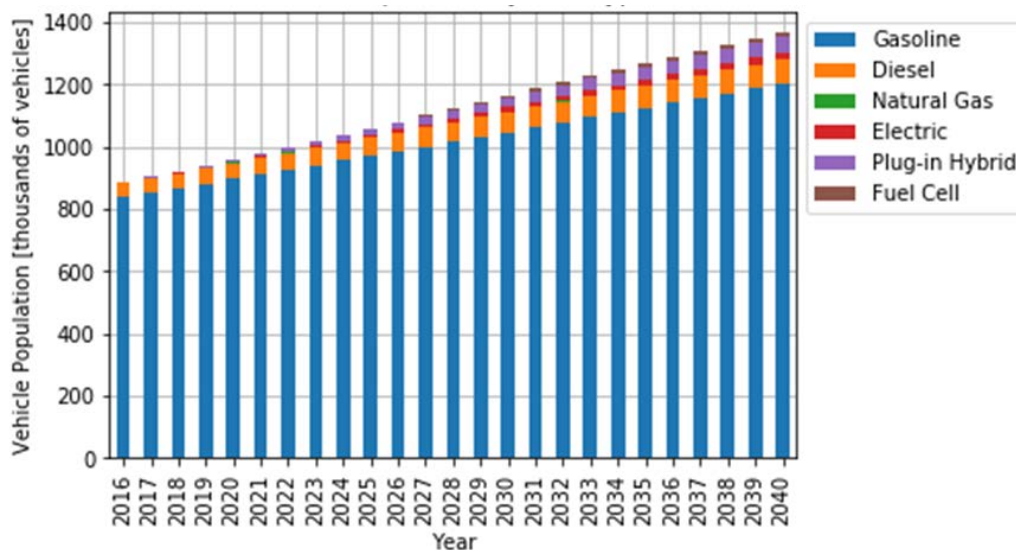
**Figure 71. Biofuels Scenario Maintenance Costs**



### 5.4 Scenario D: Biofuels and Low-NOx Diesel Engines

The Low NOx Diesel and Biofuels Scenario has the same vehicle population and composition results as the Biofuels Scenario. LDVs are dominated by gasoline powered vehicles with marginal increases in BEV, PHEV, and FCV use. MDVs and HDVs are primarily powered by diesel fuel, with modest contributions from gasoline (MDV) and natural gas (HDV). However, as of 2025, all new diesel vehicles are equipped with low NOx diesel engines, which decreases their emissions factor by 50 percent relative to a standard diesel engine.

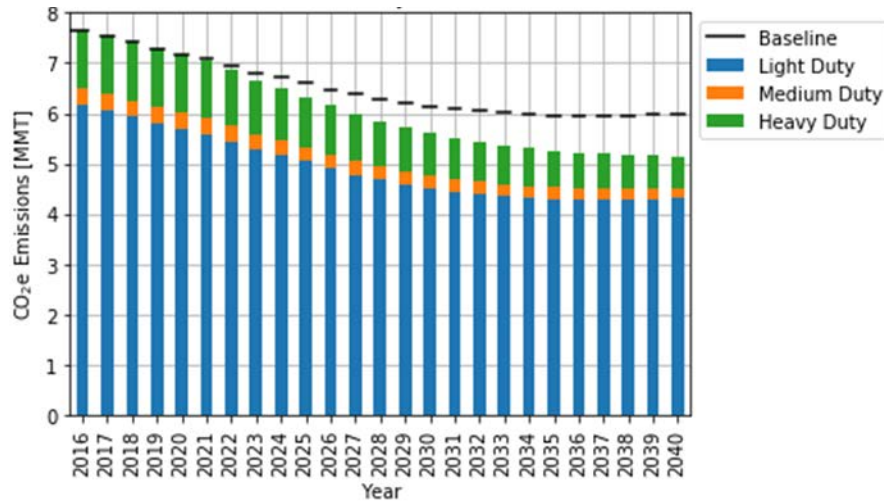
**Figure 72. Low NOx Diesel & Biofuels Scenario Vehicle Population by Fuel Type**



## Emissions Impacts

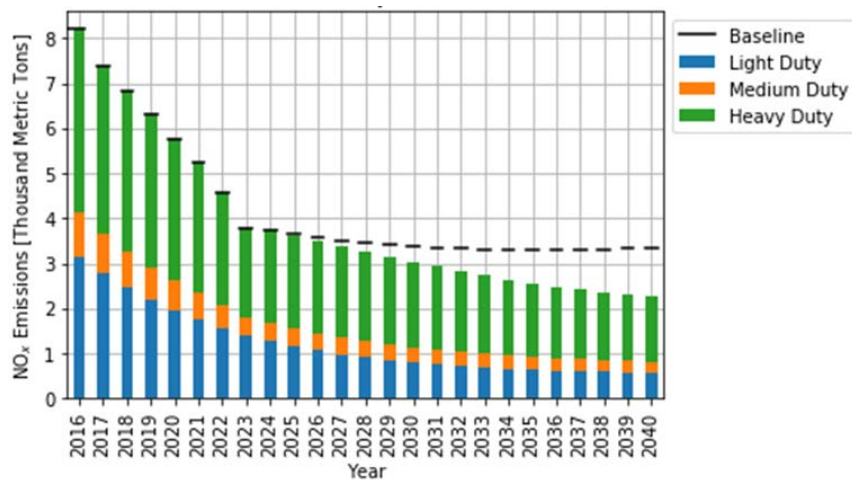
The GHG emissions impacts of the Low NOx Diesel & Biofuels Scenario are identical to the Biofuels Scenario, shown in the figure below. GHG emissions are 14 percent lower on an annual basis in 2040 relative to the Baseline, with annual emissions exceeding 5 MMT.

**Figure 73. Low NOx Diesel & Biofuels Scenario CO<sub>2</sub>e Emissions by Vehicle Type**



This scenario achieves significant NOx emission reductions, as shown in the figure and table below. Total NOx emissions would be 32 percent lower in 2040 compared to the Baseline, exceeding the reductions from the Electrification and Natural Gas as a Bridge Scenarios. The NOx reductions occur almost exclusively among MDV and HDV types, since this scenario effects NOx emissions only for diesel engines.

**Figure 74. Low NOx Diesel & Biofuels Scenario NO<sub>x</sub> Emissions by Vehicle Type**



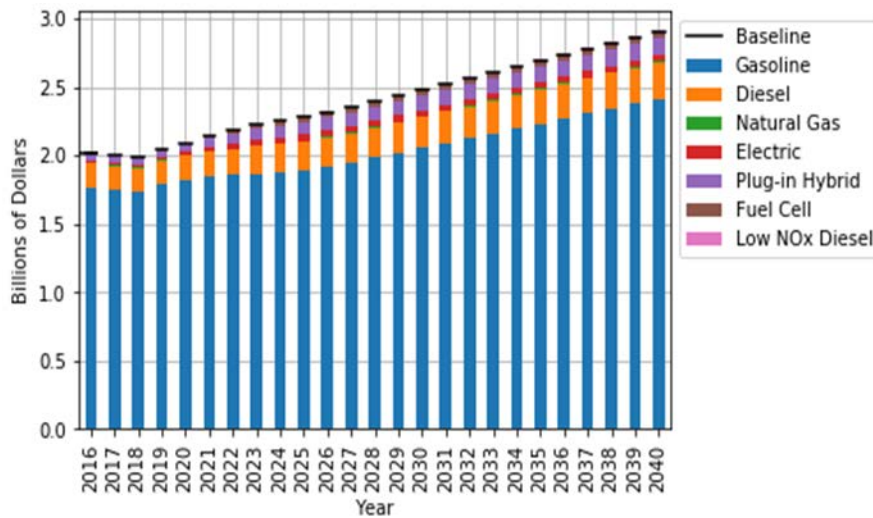
**Table 37. Low NOx Diesel & Biofuels Scenario NOx Emissions Impacts (thousand MT), 2040**

Vehicle Type	Baseline Scenario	Biofuels + Low NOx Diesel Scenario	Difference
Light Duty	0.58	0.57	-1%
Medium Duty	0.40	0.25	-38%
Heavy Duty	2.37	1.46	-38%
<b>Total</b>	<b>3.34</b>	<b>2.28</b>	<b>-32%</b>

## Costs

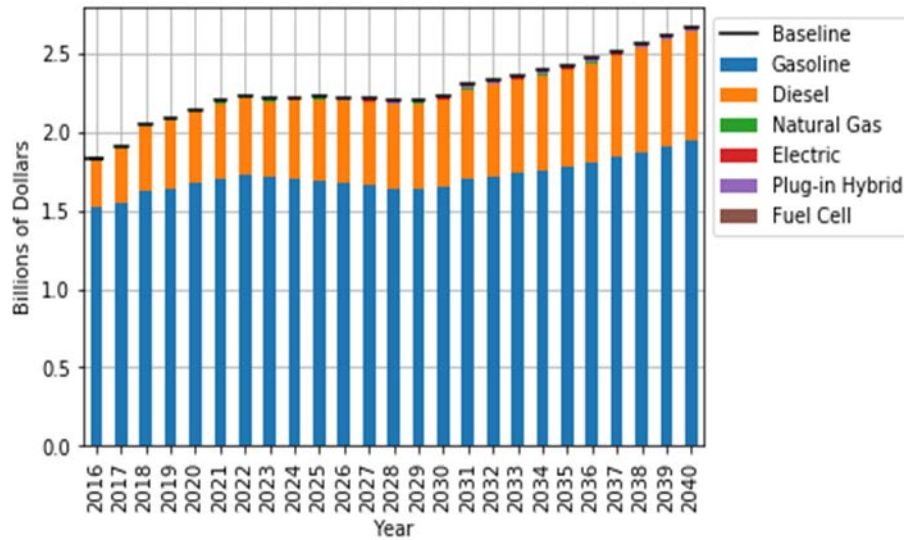
The vehicle costs in this scenario follow the Baseline Scenario vehicle costs. Gasoline remains the primary fuel for LDVs while conventional diesel vehicles continue to dominate MDV and HDV sectors.

**Figure 75. Low NOx Diesel & Biofuels Scenario Vehicle Purchase Costs**



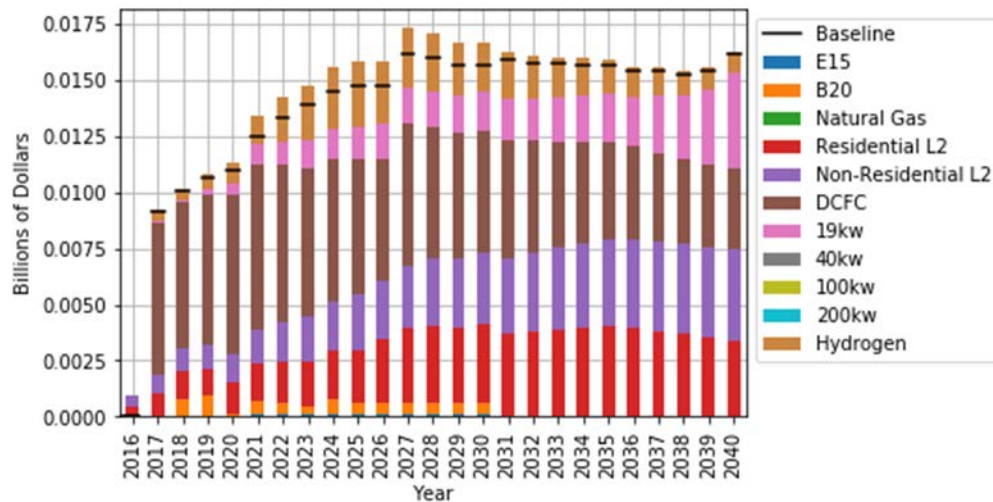
Fueling costs remain nearly equivalent to the Baseline Scenario, with gasoline and diesel contributing to the majority of total fuel costs throughout the analysis period. Natural gas, electricity, and hydrogen do not add significantly to fuel costs given the limited penetration of these vehicles in this scenario.

**Figure 76. Low NOx Diesel & Biofuels Scenario Fueling Costs**



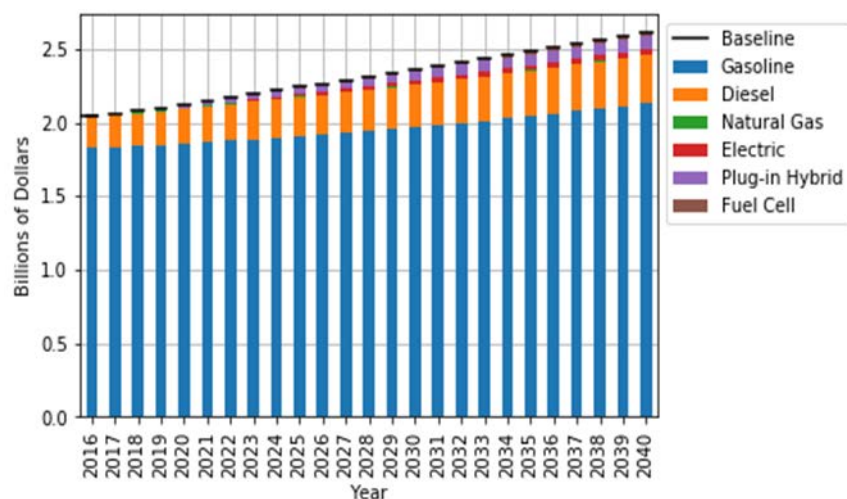
The Low NOx Diesel and Biofuels Scenario does not yield significant infrastructure costs or vary substantially from the Baseline Scenario. The bulk of these costs are driven by EV charging infrastructure investments, with minor biofuel (B20 and E15) contributions in the 2020s. The minimal variation in costs stems from the observation that low NOx diesel trucks do not require new fueling infrastructure to support their operation. Similarly, biofuels require only modest fueling infrastructure investments and in some cases, can leverage existing assets used to support gasoline and diesel refueling.

**Figure 77. Low NOx Diesel & Biofuels Scenario Infrastructure Costs**



Maintenance costs remain virtually unchanged relative to the Baseline Scenario. Diesel vehicles comprise approximately 10-15 percent of maintenance costs throughout the analysis period. The low quantities of non-gasoline and non-diesel vehicles limits their contribution to maintenance costs at approximately 6 percent of total maintenance costs in 2040.

**Figure 78. Low NOx Diesel & Biofuels Scenario Maintenance Costs**



## 5.5 Summary of Scenario Analysis Results

The scenarios evaluated present a range of emissions and cost outcomes for San Bernardino County’s on-road transportation sector. These results are heavily influenced by the availability and adoption of various vehicle technologies and alternative fuels. The following figures present a comparison of all scenarios and their performance on several key metrics: GHG emissions, NOx emissions, and total cost.

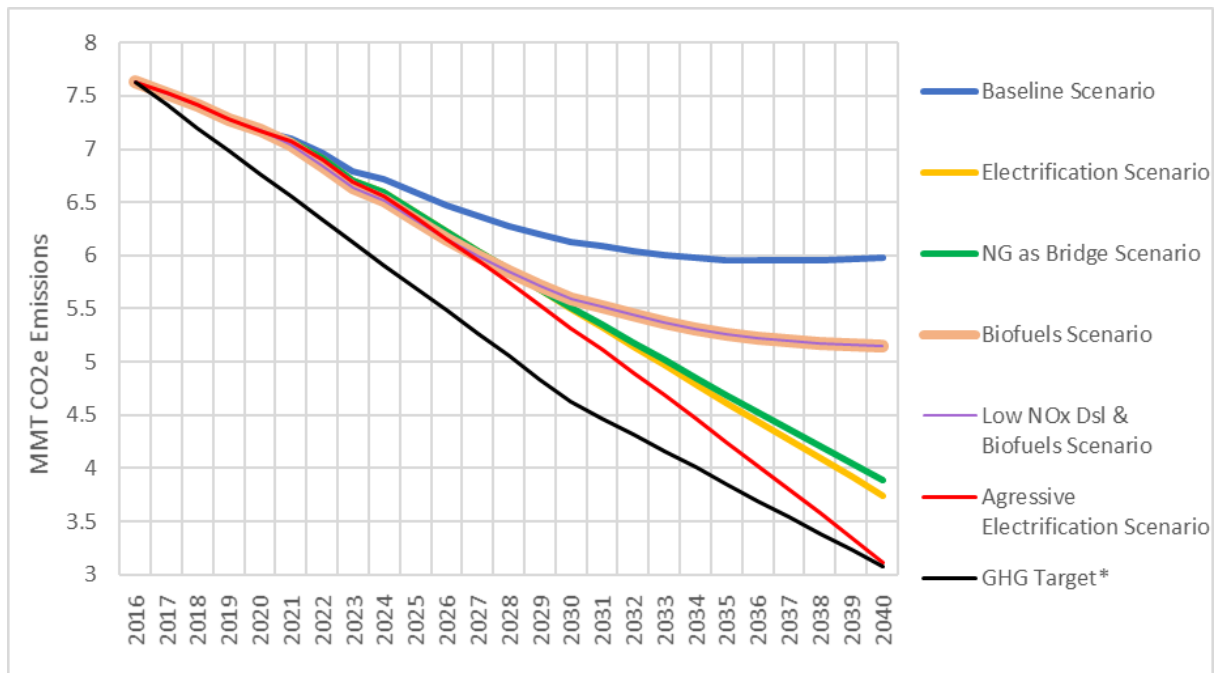
### GHG Emissions

The figure below shows the GHG emissions under the Baseline and analysis scenarios. The Electrification and Natural Gas as a Bridge Scenarios provide the largest reductions and are quite similar in terms of their GHG impacts. The Biofuels and Low NOx Diesel & Biofuels Scenarios are identical in terms of their GHG impacts, since the low NOx diesel engines do not affect GHG emissions. These two scenarios follow a similar emissions trajectory as Electrification and Natural Gas as a Bridge through 2030, but provide only modest additional reductions after 2030. The Aggressive Electrification Scenario results in significantly more GHG reductions compared to the other scenarios.

By way of comparison, the figure shows a GHG reduction target based on the statewide GHG reduction for all sectors necessary to achieve California’s 2030 emissions target. As described in the state’s 2017 Climate Change Scoping Plan, in order to achieve the state’s 2030 target, statewide emissions must decline from 429 MMT in 2016 to 260 MMT in 2030, a 39 percent reduction. None of the scenarios achieve this level of reduction by 2030, although the Aggressive Electrification Scenario reaches the target GHG reduction by 2040.



**Figure 79. Comparison of CO2e Emissions by Scenario**



\* GHG target reflects the percent reductions needed statewide from all sources to achieve California’s 2030 and 2050 emissions targets.

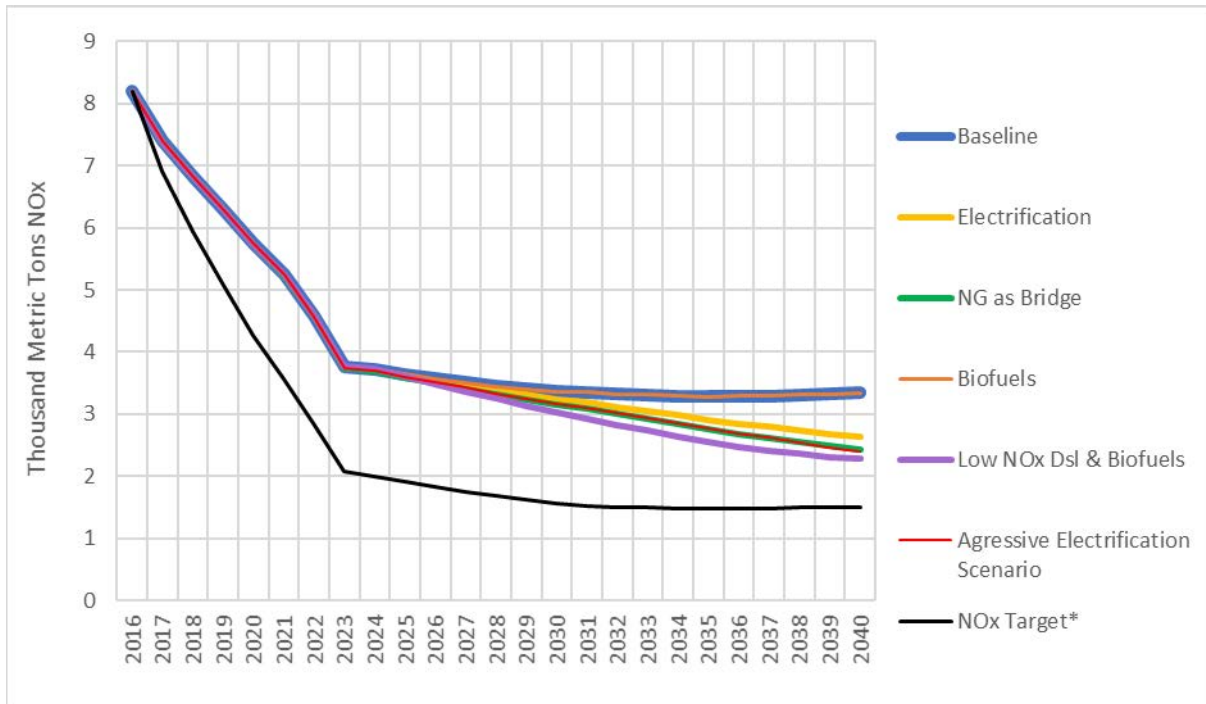
## NOx Emissions

The figure below illustrates the annual NOx emissions of the scenarios over the analysis period and their relationship to the NOx emissions target identified for the study area. The NOx reduction target is based on the 2016 AQMD Air Quality Management Plan, which called for a 45 percent NOx reduction from Baseline in 2023 and a 55 percent reduction from Baseline in 2031, considering all sources of NOx (not just on-road vehicles).

NOx emissions under all scenarios rapidly decline until 2023 – driven by CARB’s Truck and Bus regulation. Beyond 2023, all scenarios gradually reduce NOx emissions, with the Low NOx Diesel & Biofuels Scenario achieving the best performance in terms of NOx reductions over the remainder of the analysis period. Given that diesel HDVs are the largest contributor to on-road NOx emissions, the adoption of low NOx diesel engines can have an outsized impact on reducing these emissions as other alternative fuels achieve scale in the market. The Natural Gas as a Bridge and Electrification Scenarios also achieve significant NOx reductions, albeit at a slightly more gradual rate. The Biofuels Scenario has no impact on NOx emissions and thus mirrors the Baseline Scenario emissions. None of the scenarios evaluated achieve the NOx emission reductions identified by the study area NOx emission target.



**Figure 80. Comparison of NOx Emissions by Scenario**

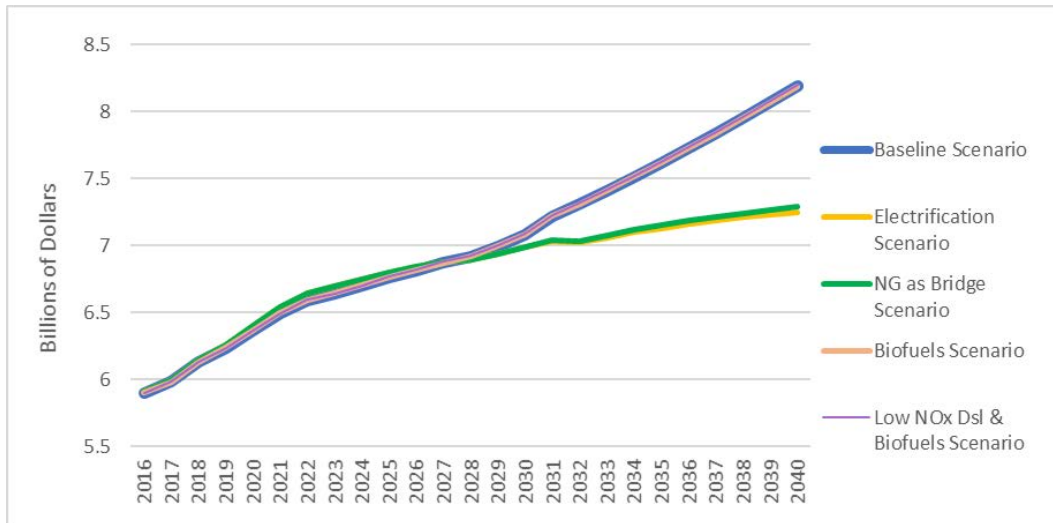


\* NOx target reflects the percent reduction in NOx emissions in the South Coast Air Basin from all sources necessary to achieve attainment with the federal ozone standard, as presented in the 2016 Air Quality Management Plan

## Costs

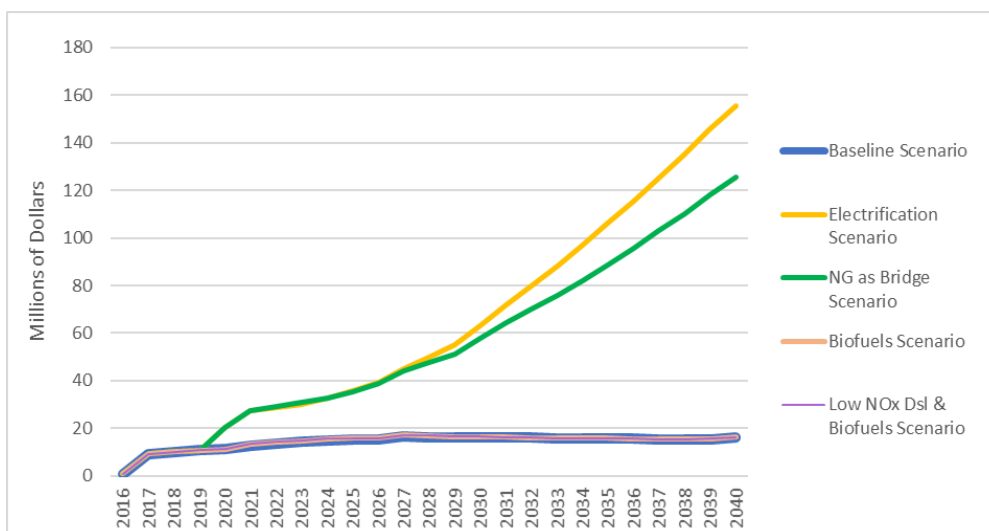
The following figure shows the aggregate annual costs for each scenario over the analysis period. Aggregate costs for all scenarios are virtually identical through 2028, after which the Electrification and Natural Gas as a Bridge Scenarios diverge with lower costs. This is driven by the assumption that fueling costs for electric and natural gas vehicles will be lower than most gasoline and diesel vehicles in the latter years of analysis, as discussed in Section 4. Aggregate costs for Biofuels and Low NOx Diesel & Biofuels Scenarios are nearly identical to the Baseline Scenario costs, since these scenario do not involve addition vehicle purchase costs and have similar operation and maintenance costs.

**Figure 81. Comparison of Total Cost by Scenario**



The aggregate costs of each scenario are dominated by vehicle purchase costs, fueling costs, and maintenance costs, most of which would be borne by the vehicle owner. In contrast, fueling infrastructure costs account for only 0.2 percent to 2.1 percent of the aggregate costs across all scenarios and analysis years. However, fueling infrastructure costs are important because they would likely be at least partly supported by government agencies seeking to encourage the deployment and use of clean vehicles. The figure below shows only the fueling infrastructure costs for the scenarios. The Electrification Scenario carries the highest costs, rising to nearly \$160 million annually by 2040. It is followed by the Natural Gas as a Bridge Scenario, which reaches \$125 million per year by 2040. In contrast, the Biofuels and Low NOx Diesel & Biofuels Scenarios are virtually identical to the Baseline in terms of fueling infrastructure costs. This is primarily due to assumption that biofuels can be dispensed at existing fueling stations, often blended with conventional fuels.

**Figure 82. Comparison of Fueling Infrastructure Costs by Scenario**



The two figures below illustrate how each scenario compares to the Baseline Scenario in terms of cumulative costs between 2016-2030 and 2016-2040. These charts show only the difference between the Baseline and each scenario (i.e., the Baseline is zero in these charts). Overall, the Biofuels and Low NOx Diesel & Biofuels Scenarios generally track the Baseline costs throughout the analysis period. These scenarios require a small incremental investment in infrastructure (\$6 million over the analysis period) – an amount that is much smaller than the other two scenarios.

The Electrification and Natural Gas as a Bridge Scenarios differ significantly from the Baseline Scenario. Both require significant incremental vehicle purchase costs, particularly in the early years of analysis. Between 2016 and 2030, these two scenarios involve a cumulative purchase cost increment of more than \$600 million. By 2040, the cumulative vehicle purchase cost increment has declined, reflecting the input assumption that EVs will become cheaper than conventional vehicles in the latter years of the analysis. Note that the vehicle purchase costs could be borne entirely by the vehicle owner, or a portion could be borne by government agencies in the form of a subsidy.

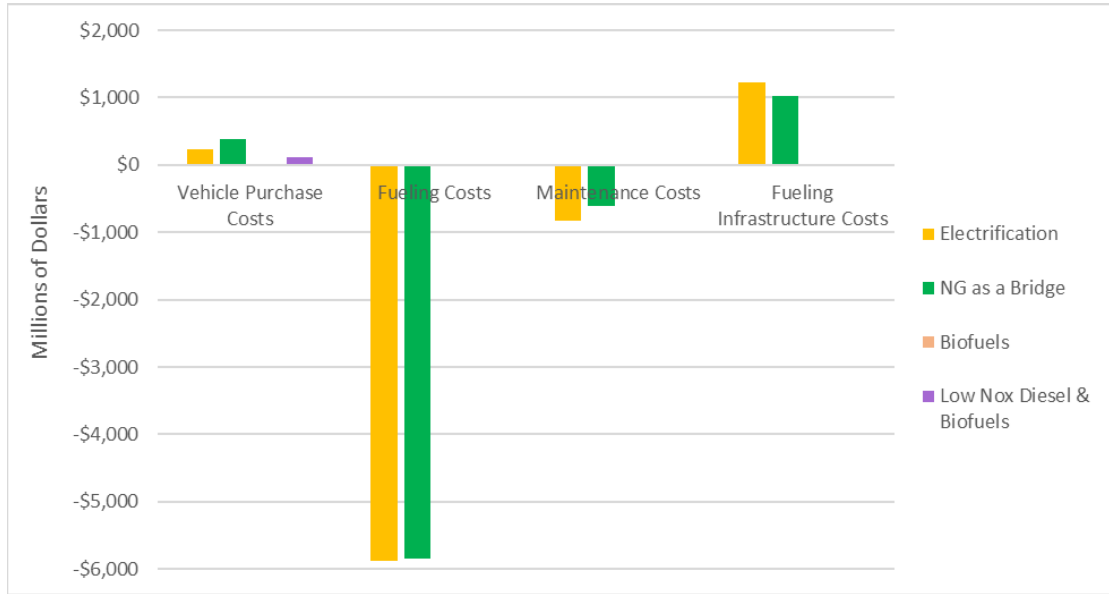
The Electrification and Bridge Scenarios result in large cost savings for fueling costs and, to a lesser extent, maintenance costs. From 2016 to 2030, the total savings in fueling and maintenance costs exceeds \$700 million for both scenarios, more than offsetting the incremental vehicle purchase costs. Considering cumulative costs out to 2040, fueling cost savings dominate the total incremental cost of these two scenarios.

The incremental cumulative fueling infrastructure costs total approximately \$250 million for both the Electrification and Bridge Scenarios by 2030, and grow to more than \$1 billion by 2040. Infrastructure costs are slightly higher under the Electrification Scenario than the Bridge Scenario. Overall, considering the full analysis period out to 2040, the Electrification and Bridge Scenarios offer the greatest potential cumulative cost savings relative to the Baseline Scenario.

**Figure 83. Incremental Cumulative Costs (Relative to the Baseline), 2016-2030**



**Figure 84. Incremental Cumulative Costs (Relative to the Baseline), 2016-2040**



## 6 Barriers to Implementation

This section discusses the economic, technological, policy, and other barriers associated with the transition to cleaner vehicles and fuels, with a specific focus on San Bernardino County. The first section focuses on challenges to the deployment of alternative fuel light-duty vehicles, including electric vehicles (EVs), fuel cell vehicles (FCVs), and ethanol-fueled internal combustion engine (ICE) vehicles. The second section addresses the challenges to the growth of alternative fuel medium-duty and heavy-duty vehicles, including EVs, FCVs, natural gas vehicles (NGVs), and vehicles running on liquid biofuels. The final section discusses regulatory authority, which applies to all vehicle types.

### 6.1 Light-Duty Vehicles

#### Electric Vehicles

Battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) represent a viable alternative fuel vehicle technology in the LDV segment. Supported by a number of federal, state, local, and utility incentive programs, cumulative statewide EV sales have surpassed 650,000 units.<sup>184</sup> However, EVs face several critical barriers that may slow their adoption in the near-term, including: high upfront vehicle costs, lack of model diversity and availability, lack of education and awareness of EVs, and lack of charging infrastructure.

The barriers to EV adoption are evident in the current market penetration in San Bernardino County. EVs comprise approximately 0.7 percent of registered vehicles in the County as of January 1, 2019.<sup>185</sup> In comparison, the statewide average EV penetration surpassed 1.6 percent in the same timeframe.<sup>186</sup> County and State EV registrations per capita figure were 0.005 and 0.013, respectively – suggesting that EV penetrations are lower in San Bernardino County than other parts of the state.<sup>187</sup>

#### High Upfront Vehicle Costs

The upfront price differential between EVs and comparable ICE vehicles is primarily driven by the cost of the vehicle battery. These costs are typically expressed in terms of dollars per kilowatt-hour (\$/kWh) of energy storage. Bloomberg New Energy Finance’s industry survey of battery costs yielded a volume-weighted average pack cost of \$176/kWh in 2018 – meaning a 60 kWh EV battery costs approximately \$10,500.<sup>188</sup> While battery pack costs are expected to decline as a result of learning by doing and economies of scale, EVs are not expected to reach upfront cost parity with comparable ICE vehicles until

<sup>184</sup> <https://www.veloz.org/>

<sup>185</sup> [https://www.dmv.ca.gov/portal/wcm/connect/e52e6d02-6fa6-483a-bbcd-d888f1b4035b/MotorVehicleFuelTypes\\_County\\_190913.pdf?MOD=AJPERES&CVID=](https://www.dmv.ca.gov/portal/wcm/connect/e52e6d02-6fa6-483a-bbcd-d888f1b4035b/MotorVehicleFuelTypes_County_190913.pdf?MOD=AJPERES&CVID=)

<sup>186</sup> [https://www.dmv.ca.gov/portal/wcm/connect/fafd3447-8e14-4ff6-bb98-e85f3aa9a207/ca\\_dmv\\_stats.pdf?MOD=AJPERES&CVID=](https://www.dmv.ca.gov/portal/wcm/connect/fafd3447-8e14-4ff6-bb98-e85f3aa9a207/ca_dmv_stats.pdf?MOD=AJPERES&CVID=); <https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/>

<sup>187</sup> *Id.*

<sup>188</sup> Bloomberg New Energy Finance, “A Behind the Scenes Take on Lithium-ion Battery Prices”, March 5, 2019, available at: <https://about.bnef.com/blog/behind-scenes-take-lithium-ionbattery-prices/>

mid- to late-2020s.<sup>189</sup> This upfront price differential will continue to challenge EV sales among price-sensitive drivers that heavily discount long-term costs in vehicle purchase decisions. The table below provides examples of ICE vehicle prices and comparable EV model prices.<sup>190</sup>

**Table 38. Price Comparison Between ICE Vehicle and EV Models**

2019 ICE Vehicle Model Base MSRP	2019 EV Model Base MSRP (without incentives)	EV Price Difference
<b>Chrysler Pacifica:</b> \$27,235	<b>Chrysler Pacifica Hybrid (PHEV):</b> \$40,245	+48%
<b>Honda Accord:</b> \$23,720	<b>Honda Clarity Electric:</b> \$36,320	+53%
	<b>Honda Clarity Plug-In Hybrid:</b> \$33,400	+41%
<b>Hyundai Kona:</b> \$19,990	<b>Hyundai Kona EV:</b> \$36,950	+85%
<b>Kia Niro:</b> \$23,490	<b>Kia Niro EV:</b> \$38,500	+64%
	<b>Kia Niro Plug-In Hybrid:</b> \$28,500	+21%
<b>Toyota Prius:</b> \$23,770	<b>Toyota Prius Prime (PHEV):</b> \$27,350	+15%
<b>Volkswagen Golf:</b> \$21,845	<b>Volkswagen eGolf:</b> \$31,895	+46%

Uncertainty surrounding the availability of the federal EV tax credit also contributes to EVs’ upfront cost challenges. Under Section 30D of the U.S. tax code, newly purchased EVs are eligible for a \$2,500 to \$7,500 tax credit.<sup>191</sup> However, the full tax credit only applies to the first 200,000 EVs sold per automaker. Once the 200,000 unit limit is reached, the tax credit value decreases on a quarterly basis until it is phased out completely approximately one year after the automaker surpasses the threshold. The graph below illustrates the relationship between the top five leading EV automakers cumulative EV sales and the federal EV tax credit sales threshold.

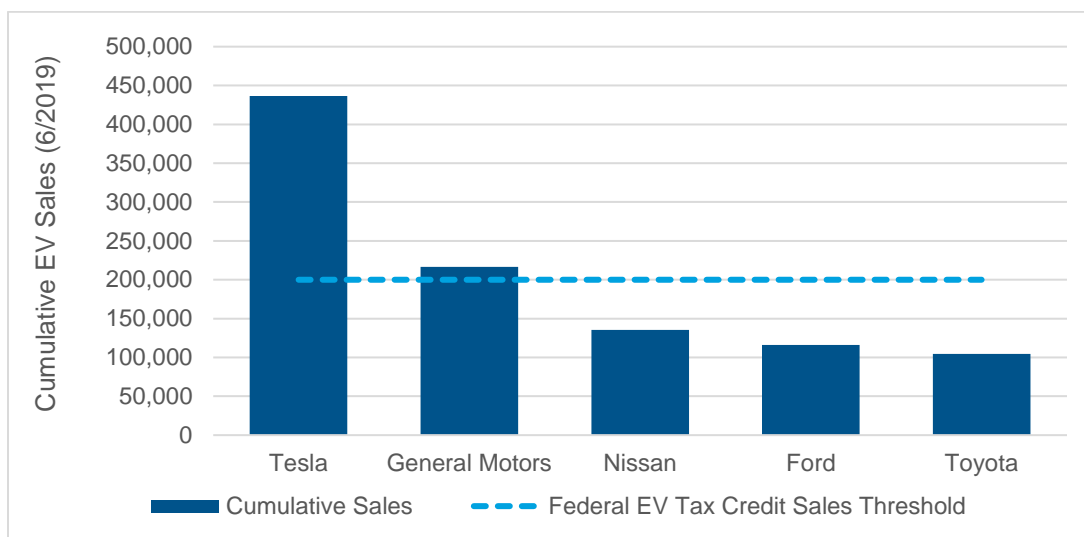
<sup>189</sup> Lutsey and Nicholas, Update on electric vehicle costs in the United States through 2030, April 2, 2019, available at: [https://theicct.org/sites/default/files/publications/EV\\_cost\\_2020\\_2030\\_20190401.pdf](https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf)

<sup>190</sup> These prices do not take into account the incentives that are available for certain EV models, which typically reduce but do not eliminate the upfront purchase price gap between EVs and ICE vehicles. Also note that some EVs have better options/trim packages than the comparable ICE model, which contributes to a higher purchase price.

<sup>191</sup> The individual vehicle tax credit amount is determined by the capacity (kWh) of the EV battery.

<https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d>

**Figure 85. Leading Automaker Domestic EV Sales and the Federal EV Tax Credit Sales Threshold**



Tesla was the first automaker to surpass the sales threshold in July 2018 and General Motors followed suit in December 2018. The early phase out and elimination of these tax credits could potentially have negative near-term sales implications for the Tesla Model 3 and Chevy Bolt – two of the most popular EVs sold in California and the United States. By setting a fixed sales threshold for every automaker, the federal tax credit effectively penalizes early market movers that made significant investments in developing EV technologies and makes their products less competitive relative to automakers that have not delivered comparable EV models and sales. This feature of the federal EV tax credit may ultimately slow EV adoption in the near term as more automakers reach the tax credit sales limit and upfront EV costs remain higher than similar ICE vehicles in the early 2020s. Efforts have been made to extend the credit: in April 2019, Sen. Debbie Stabenow (D-MI) introduced the Driving America Forward Act.<sup>192</sup> However, the bill has not been brought to a vote as of the time this report was written. Aside from automaker eligibility issues, the federal EV tax credit may not provide value to drivers that do not have enough tax liability to take advantage of the full credit value. As a result, the federal tax credit may not be considered an equitable solution for providing EV incentives to low-income drivers.

In addition to declining federal tax incentives, California’s Clean Vehicle Rebate Project (CVRP) per-vehicle incentives declined in December 2019. The CVRP rebates, which have supported the purchase of over 350,000 EVs in the state, dropped from \$2,500 to \$2,000 per vehicle for BEVs and \$1,500 to \$1,000 per vehicle for PHEVs for rebate applicants that do not qualify for elevated low- and moderate-income incentives.<sup>193</sup> The CVRP will also introduce new eligibility criteria that precludes some EV models from participating in the rebate program based on Manufacturer Suggested Retail Price caps and minimum all-electric ranges. California’s EV incentives remain some of the most robust in the country, but reducing per-vehicle rebate levels and placing additional restrictions on model eligibility may put additional pressure on EV sales in the near-term while upfront EV costs remain relatively high: according

<sup>192</sup> <https://www.congress.gov/bill/116th-congress/senate-bill/1094>

<sup>193</sup> Rebate levels for income qualified customers remain unchanged in the CVRP modification.

<https://cleanvehiclerebate.org/eng/faqs/what-should-i-know-about-december-3rd-program-changes>



to the San Bernardino County Zero Emission Vehicle Readiness and Implementation Plan, an estimated 69 percent of BEVs and 47 percent of PHEVs purchased between April 2016 and June 2018 were purchased with CVRP incentives.<sup>194</sup>

Coupled with declining EV incentives, California also plans to impose a new \$100 annual registration fee for EVs beginning with model year 2020 vehicles. The Road and Repair Accountability Act of 2017 (SB 1) raises petroleum fuel consumption taxes to fund road infrastructure improvements and also requires that new EVs pay an additional fee in lieu of contributing via gasoline and diesel tax increases. In a report required by the California Assembly, the University of California – Davis finds that this fee suffers from several deficiencies.<sup>195</sup> Aside from running directly counter to the state’s incentives to advance EV adoption, the annual registration fee is significantly higher than what comparable ICE vehicles pay on an energy-equivalent basis for gasoline, it penalizes PHEV drivers that pay the fee and gas taxes, it is disconnected from road usage impacts, and ultimately does not address long-term infrastructure funding needs. Although the fee is minor relative to the cost of a new vehicle, it further discourages drives from switching to EVs if they perceive EVs to be less economical than ICE vehicles. To advance EVs while generating sufficient revenue to support transportation infrastructure, California may need to adopt different policy mechanisms that properly account for both objectives.

EV fueling and maintenance costs are typically lower than comparable ICE vehicles, but these savings may not be large or immediate enough to overcome the EV purchase price premium for some consumers. The Department of Energy’s eGallon calculator estimates the cost to “fuel up” an EV on a gallon-equivalent basis currently stands at \$1.81 compared to \$3.92 for a gallon of gasoline.<sup>196</sup> An EV charging under Southern California Edison’s residential time-of-use rate (TOU-EV-1) during low-cost, off-peak periods of the day can refuel at costs that approach \$1 per gallon-equivalent.<sup>197</sup> However, these fuel and associated maintenance cost savings must be realized over several years before a driver can recoup the upfront purchase price premium relative to a comparable ICE vehicle. For a vehicle owner who drives 12,000 miles per year, the payback period needed to recover the purchase price premium of an EV without incentives may be 8-10 years.<sup>198</sup>

Current petroleum fuel price trends magnify this challenge: while oil prices have recovered from decade lows in 2016, they remain lower than levels seen in the early post-Recession years – keeping gasoline prices under \$4 per gallon in many cases.<sup>199</sup> Political resistance to raising the federal gas tax also further challenges to the cost competitiveness of EVs. Experts have recommended that the flat 18.4 cent per gallon tax, which has not increased in over 25 years and has lost over 35 percent of its purchasing power

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<sup>194</sup> [https://www.gosbcta.com/wp-content/uploads/2019/11/SBCOG-ZEV-Plan\\_Final-Online-Version-11619.pdf](https://www.gosbcta.com/wp-content/uploads/2019/11/SBCOG-ZEV-Plan_Final-Online-Version-11619.pdf)

<sup>195</sup> Alan Jenn, PhD., *Assessing Alternatives to California's Electric Vehicle Registration Fee*, December 2018, available at: <https://escholarship.org/uc/item/62f72449>

<sup>196</sup> <https://www.energy.gov/maps/egallon> Accessed November 18, 2019.

<sup>197</sup> Assumes the TOU-EV-1 off-peak rate of \$0.13 per kWh, EV efficiency of .27 kWh per mile, and comparable gasoline vehicle efficiency of 28.6 miles per gallon.

<sup>198</sup> Assumes an EV price premium of \$10,000 over the reference vehicle, electricity prices between \$0.13-0.17/kWh, gasoline prices between \$3.50-3.70/gallon, BEV efficiency of 0.27 kWh/mile, and ICE vehicle efficiency of 25-29 miles per gallon. For simplicity, does not assume differences in maintenance costs.

<sup>199</sup> [https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=p&s=emm\\_epm0\\_pte\\_sca\\_dpg&f=m](https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=p&s=emm_epm0_pte_sca_dpg&f=m)

since 2003, be increased to fund road infrastructure investments needed to support the U.S. transportation system.<sup>200</sup> Without the additional price signals provided by adjusting fuel taxes, drivers may be less compelled to switch – or switch early on – to electric transportation modes. In sum, while total cost of ownership may be an important factor in some vehicle purchase decisions, upfront vehicle purchase price differentials may still discourage drivers from moving toward EVs.

### Limited Model Diversity and Availability

Despite the growing number of EVs available in the market today, customers are still challenged by a lack of EV model diversity and availability. According to U.S. Department of Energy, there are currently 70 light-duty EV models available in the U.S. – comprised of 36 BEV models and 34 PHEV models. The table below shows the breakdown of these models by body type in comparison to the total number of model year 2019 vehicles available.<sup>201</sup>

**Table 39. Light-Duty Vehicle Model Availability by Body Type**

Body Type	(Sub)compact/ 2-seater	Mid-Large Sedan	Wagon and Van	SUV	Pickup Truck
<b>EV models</b>	15	35	5	15	0
<b>Non-EV Models</b>	394	303	58	352	126

Source: U.S. Department of Energy, fueleconomy.gov

While the number of EV models available in the California and U.S. is expected to materially increase throughout the early 2020s, model availability will constrain consumer choices and EV sales in the short-term. Shifting consumer preferences toward light trucks (e.g. SUVs, pickups, and vans) also creates headwinds for the EV market, which is only beginning to produce vehicles with these body types. According to the California New Car Dealers Association, nearly 57 percent of new light-duty vehicle sales in the state in the first half of 2019 were light trucks, compared to only 50 percent two years previously.<sup>202</sup> Automakers have recognized this trend and developed EVs that adapt to changing customer preferences; however, the larger batteries needed for these body types will drive additional costs that may make it more challenging for larger vehicles to achieve upfront cost parity with ICE vehicle counterparts in the near-term.

### Lack of EV Education and Awareness

General consumer and dealership knowledge gaps continue to challenge EV sales growth. A UC Davis survey found that despite significant year-over-year growth of the EV market in California, only 5 percent of households owned or actively considered purchasing an EV in 2014 and that percentage

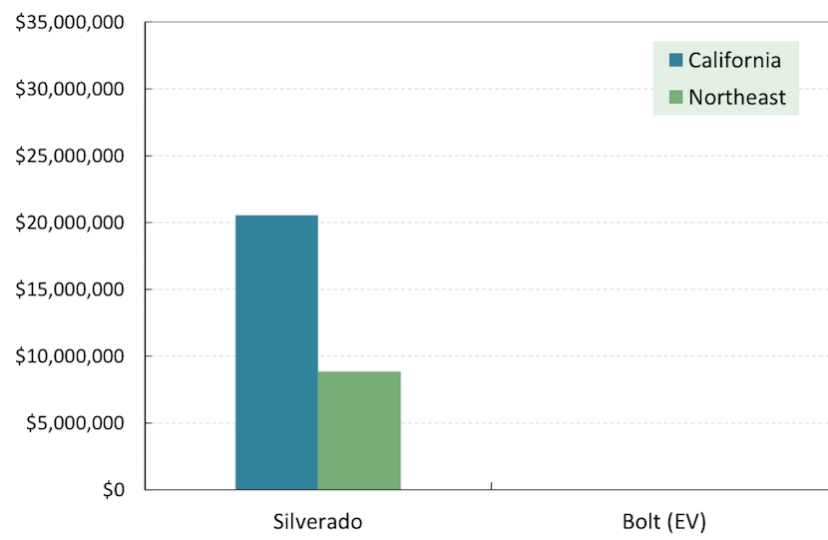
<sup>200</sup> National Academies of Sciences, Engineering, and Medicine 2019. Renewing the National Commitment to the Interstate Highway System: A Foundation for the Future. Washington, DC: The National Academies Press. Available at: <https://doi.org/10.17226/25334>.

<sup>201</sup> <https://www.fueleconomy.gov/feg/download.shtml>

<sup>202</sup> <https://www.cncda.org/wp-content/uploads/Cal-Covering-2Q-19.pdf>; <https://www.cncda.org/wp-content/uploads/California-Covering-2Q-2018.pdf>

largely remained the same in 2017.<sup>203</sup> Moreover, consumers’ ability to identify one EV model declined over the same time period. UC Davis also finds no meaningful increase in the number of customers that have claimed to have seen a charging station outside of the home despite the doubling of public charging infrastructure in California between 2014 and 2017. While automakers and other stakeholders have ramped up investment in marketing as additional EV products come to market, relative investment remains low compared to automaker spending on ICE vehicle advertising. Data from InterQ Research revealed that on average, the six automakers with the greatest EV sales (excluding Tesla) in 2018 spent \$38 million per top-selling ICE vehicle and approximately \$3.7 million per EV on marketing in California and Northeast U.S. markets combined.<sup>204</sup> A striking example of this phenomenon is shown in the figure below comparing General Motors ad spend on the Chevy Silverado against the Chevy Bolt; Bolt ad spending was *de minimis* in both regions.

**Figure 86. 2018 General Motors Ad Spend: Chevy Silverado and Chevy Bolt**



In some cases, auto dealerships may also not have the resources to effectively market and sell EVs. Although automakers may offer trainings to dealerships that sell EVs, frequent turnover among salespeople may make it challenging to retain and socialize knowledge. A recent dealer survey from Cox Automotive also suggests that dealers nationwide may not find EV sales to be economically attractive: 54 percent of dealers perceive lower profits and ROI from EV sales relative to ICE vehicles.<sup>205</sup> This survey result may be in part due to EVs requiring less dealer maintenance than ICE vehicles. Apart from the vehicles themselves, dealerships may have very little information on electric utility rates and how EV fueling costs compare to gasoline powered vehicles – a critical selling point for economically-motivated vehicle purchasers.

The lack of EV awareness and education was evident in the light duty vehicle focus group conducted by the ICF team in September 2019. Several participants seemed unaware that EV owners typically charge

<sup>203</sup> <https://its.ucdavis.edu/blog-post/automakers-policymakers-on-path-to-electric-vehicles-consumers-are-not/>

<sup>204</sup> <https://www.nescaum.org/documents/2018-ev-marketing.pdf/>

<sup>205</sup> <https://d2n8sg27e5659d.cloudfront.net/wp-content/uploads/2019/08/2019-COX-AUTOMOTIVE-EVOLUTION-OF-MOBILITY-THE-PATH-TO-ELECTRIC-VEHICLE-ADOPTION-STUDY.pdf>

their vehicles at home, and that a standard 110 volt outlet can be used to charge an EV. Some participants were also unaware of the range and performance of typically EVs. Overall, greater understanding of EVs' availability and capabilities are needed among consumers and dealers to accelerate EV adoption.

### **Lack of Accessible Charging Infrastructure**

A robust network of charging infrastructure where drivers live, work, and play is foundational to the growth of the EV market. Despite the significant progress that California has achieved in deploying charging stations to support EV adoption, the San Bernardino County Zero Emission Vehicle Readiness and Implementation Plan states that lack of accessible refueling options continues to be a critical barrier for drivers looking to adopt EVs.<sup>206</sup> In partnership with the National Renewable Energy Laboratory (NREL), the California Energy Commission (CEC) developed a state-wide gap analysis to estimate charging infrastructure needs for achieving the 1.5 million zero-emission vehicle (ZEV) goal Governor Brown's Executive Order B-16-2012 by 2025.<sup>13</sup> Using the Electric Vehicle Infrastructure Projection (EVI-Pro) tool, CEC and NREL developed quantitative estimates of charging infrastructure needs broken out by county and charging technology.

EVI-Pro is a tool for projecting consumer demand for electric vehicle charging infrastructure.<sup>207</sup> EVI-Pro was developed through a collaboration between the National Renewable Energy Laboratory (NREL) and the California Energy Commission, with additional support from the U.S. DOE. EVI-Pro uses detailed data on personal vehicle travel patterns, electric vehicle attributes, and charging station characteristics in bottom-up simulations to estimate the quantity and type of charging infrastructure necessary to support regional adoption of EVs. The tool depends on assumptions for the number of EVs to be added to an area, the mix of EVs (PHEV vs. BEV, by range), availability of home charging, and other factors. Results are reported in terms of the number of charging plugs for Workplace Level 2 Charging, Public Level 2 Charging, and Public DC Fast Charging.

In a scenario where California achieves the 1.5 million ZEV goal, EVI-Pro estimates that approximately 45,000 EVs will need to be on the road in San Bernardino County to proportionately contribute to the ZEV goal.<sup>208</sup> The table below illustrates NREL/CEC estimates for charging infrastructure needed to support this level of EV adoption by 2025.

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<sup>206</sup> [https://www.gosbcta.com/wp-content/uploads/2019/11/SBCOG-ZEV-Plan\\_Final-Online-Version-11619.pdf](https://www.gosbcta.com/wp-content/uploads/2019/11/SBCOG-ZEV-Plan_Final-Online-Version-11619.pdf)

<sup>207</sup> <https://afdc.energy.gov/evi-pro-lite>

<sup>208</sup> <https://www.nrel.gov/docs/fy18osti/70893.pdf>

**Table 40. Estimated EV Charger Needs in San Bernardino County to Meet 2025 ZEV Goal**

Charging Technology/Location	Current Charger Quantity	NREL/CEC Low Case (Chargers)	NREL/CEC High Case (Chargers)
<b>Workplace Level 2</b>	Unknown	1848	1997
<b>Public Level 2</b>	404	1444	2669
<b>Public Direct Current Fast Chargers</b>	54 Non-Tesla DCFC, 112 Tesla Superchargers	156	598

Source: NREL, CEC, U.S. DOE

Current levels of L2 and DCFC in the County are well below the estimates from the EVI-Pro analysis, demonstrating there is significant need for additional charging infrastructure deployment in the region in the market segments above. Given that California has a subsequent ZEV goal of 5 million EVs by 2030, these infrastructure estimates should be viewed as a “floor” rather than a “ceiling.”<sup>209</sup>

Deploying EV charging stations in multi-unit dwellings (MUDs) also remains a significant challenge for several reasons. First, deploying charging stations at MUDs is generally more expensive per-charger than single-family residential settings due to more complex site engineering needs and infrastructure upgrades required to support EV charging. While new 2020 CALGreen building codes require new MUDs (and other buildings) to be equipped to support EV charging at a minimum of 10 percent of parking spaces, many existing buildings were developed prior to the implementation of EV-ready building codes and require electrical capacity upgrades before EV charging stations can be deployed.<sup>210</sup> Additionally, residents at MUDs may face additional challenges to deploying infrastructure if they do not own their own parking space; deeded parking spaces that are owned by tenants may be costly to serve and switching parking spaces to serve EV drivers requires a legal transfer of property – adding an additional and potentially time-consuming step to the deployment process.<sup>211</sup> Finally, barriers to MUD charging are magnified at rental properties, where tenants may be reluctant to invest in EV charging infrastructure they may not use after they move from the property and property managers may not seek to deploy charging infrastructure in EV-only parking spaces without long-term assurance those assets will be used.

Despite deploying more charging stations than any other state, California also continues to struggle with streamlining permitting processes at the municipal level. To address permitting issues related to EV charging station installations, California passed Assembly Bill 1236 (AB 1236, 2015), which requires all cities and counties to develop expedited permitting processes for all EVSE “to achieve the timely and cost-effective installation of electric vehicle charging stations.”<sup>212</sup> To track compliance with the law, the Governor’s Office of Business and Economic Develop (GO-Biz) recently released a map scoring local jurisdictions on their permit streamlining efforts. GO-Biz finds that San Bernardino County as a whole is “in progress” with compliance, but is notably missing an online permitting checklist and timeline to fully

<sup>209</sup> <https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html>

<sup>210</sup> <http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf>

<sup>211</sup> [https://www.veloz.org/wp-content/uploads/2017/08/MUD\\_Guidelines4web.pdf](https://www.veloz.org/wp-content/uploads/2017/08/MUD_Guidelines4web.pdf)

<sup>212</sup> <http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf>

meet the requirements of the law. The map was incomplete at the time this memo was written, but of the cities that have already been evaluated by GO-Biz, Colton, Hesperia, and Big Bear Lake are “Not Streamlined.” Jurisdictions that do not comply with AB 1236 are at risk of unnecessarily extending infrastructure deployment timelines, adding to installation costs, and ultimately slowing EV adoption in the state.

## Fuel Cell Vehicles

FCVs represent an emerging technology solution to address LDV emissions, with over 7,700 light-duty FCVs on the roads in the U.S. today – the overwhelming majority located in California.<sup>213</sup> Although California has demonstrated a commitment to the growth of FCV adoption, FCVs still face a number of hurdles that challenge their penetration in the near-term.

### High Upfront Vehicle Costs

FCVs are significantly more expensive than ICE vehicles on an upfront cost basis, and more expensive than comparable EVs as well. The Toyota Mirai, comparable to a Toyota Prius in size and appearance, has a MSRP of \$58,500. The Hyundai Nexo, comparable to the Hyundai Kona, has a MSRP of \$58,300. These vehicle prices typically include hydrogen fuel for the first three years or up to \$13,000-\$15,000 – whichever comes first. New FCVs were eligible for California Clean Vehicle Rebate incentives of \$5,000 per vehicle until early December 2019; the rebate level has since dropped to \$4,500 per vehicle.<sup>214</sup> While these vehicle incentives and fueling provisions are non-trivial, they do not completely address the FCV upfront price premium relative to ICE vehicles and EVs.

For hydrogen fueling that occurs beyond the automakers’ fueling provisions, costs typically exceed comparable gasoline or electricity costs. According to the California Fuel Cell Partnership, hydrogen prices range from \$12.85 to upwards of \$16 per kilogram (kg).<sup>215</sup> At \$14 per kg, the price per energy equivalent to gasoline translates to \$5.60 per gallon. NREL estimates that fuel prices could drop to \$8-\$10 per kg within the 2020-2025 period, at which point FCVs would approach fuel cost parity with ICE vehicles, but hydrogen may still be more costly depending on future gasoline prices.

### Limited Model Diversity and Availability

There are only three FCV models available for sale in California: the Honda Clarity Fuel Cell, Hyundai Nexo, and Toyota Mirai. The Honda Clarity Fuel Cell is only available via lease. While the Hyundai Nexo is an SUV, the overall scarcity of model options may deter potential drivers from exploring and purchasing FCVs.

### Lack of FCV Education and Awareness

Similar to EVs, FCVs are also challenged by a lack of driver and dealer education. However, these education and awareness issues may be even more acute for FCVs: with only three available models and

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<sup>213</sup> <https://cafcp.org/by-the-numbers>

<sup>214</sup> <https://cleanvehiclerebate.org/eng/fags/what-should-i-know-about-december-3rd-program-changes>

<sup>215</sup> <https://cafcp.org/content/cost-refill>

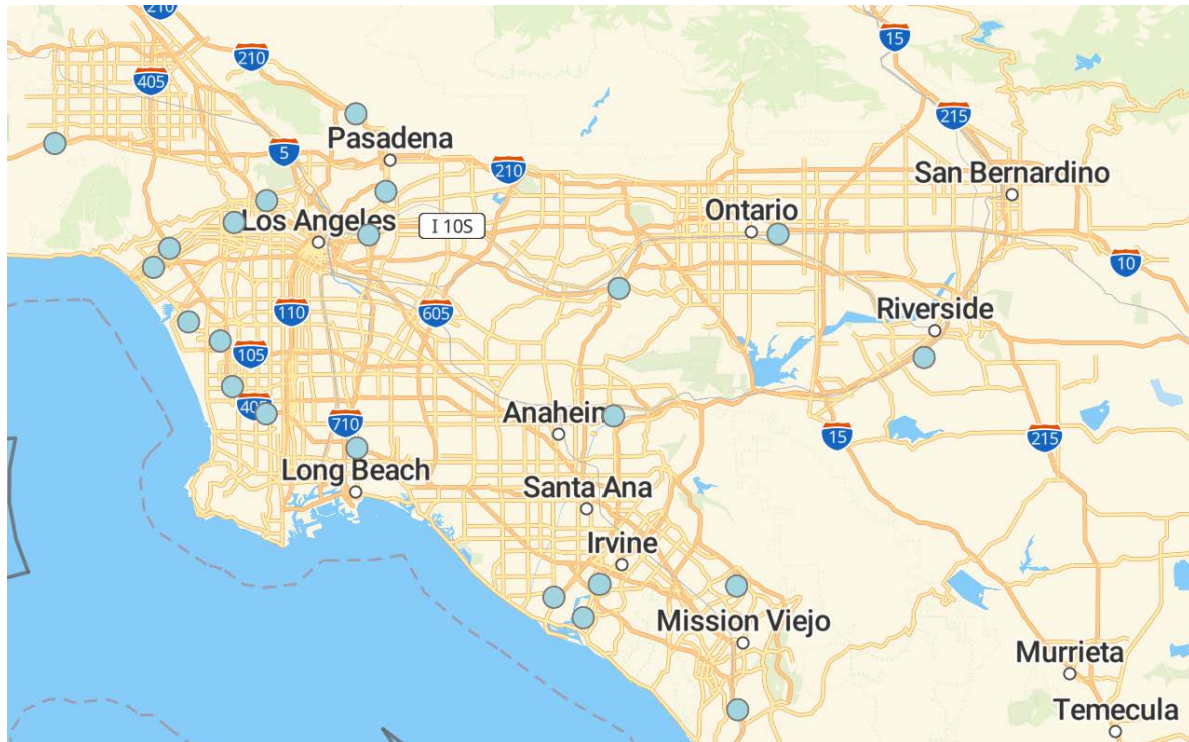


cumulative FCV sales amounting to approximately one percent of cumulative EV sales in California, FCVs may struggle to maintain visibility among customers today.

### Lack of Accessible Fueling Infrastructure

Hydrogen fueling infrastructure cost is perhaps the most significant barrier to the development of the light-duty FCV market. All-in costs, including installation and overhead, are around \$2.5 million per 180 kg/day station and up to \$4 million per 360 kg/day station according to the CEC.<sup>216</sup> The majority of these station costs are funded by the CEC today. Additionally, the California Hydrogen Fuel Cell Partnership notes there are currently 42 public hydrogen fueling stations in the state.<sup>217</sup> Only one station is currently located within San Bernardino County in Ontario, with one additional station in planning stages in Chino (see below).<sup>218</sup> Given the limited availability of refueling infrastructure for FCVs in the near term, these vehicles will be challenged to achieve greater levels of adoption in San Bernardino County.

**Figure 87. Hydrogen Fueling Stations in Southern California**



Source: U.S. Department of Energy, Alternative Fuel Data Center

### Ethanol Fuels

Gasoline in California is currently blended with 10 percent ethanol by volume (E10) and contributes to light-duty vehicle GHG emission reductions. E15, or gasoline blended with 15 percent ethanol by

<sup>216</sup> <https://www.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf>

<sup>217</sup> <https://cafcp.org/by-the-numbers>

<sup>218</sup> [https://cafcp.org/sites/default/files/h2\\_station\\_list.pdf](https://cafcp.org/sites/default/files/h2_station_list.pdf)



volume, could augment these emission reduction benefits. However, transitioning to E15 fuel requires overcoming several key challenges.

Ethanol can also be used in higher level blends, up to 85 percent (E85). While low-level ethanol blends can be used in gasoline-powered vehicles without alterations, E85 has different properties than gasoline. Consequently, only automobiles with compatible fuel systems and powertrain calibration can operate using the fuel. These vehicles are referred to as flexible fuel vehicles (FFVs). FFVs have an internal combustion engine and are capable of operating on gasoline, E85, or a mixture of the two. From the driver's perspective, the only difference between FFVs and conventional gasoline-powered vehicles is the reduced fuel economy when using E85 or other mid-level blends. Gasoline-powered vehicles can be converted to FFVs, although it requires extensive modifications to the original vehicle. San Bernardino County currently has approximately 74,000 registered FFVs, or about 4 percent of total registered vehicles.<sup>219</sup> However, many of these vehicles operate primarily or exclusively on gasoline.

### **Uncertain Regulatory Processes**

For fuel sold as gasoline in California, the maximum ethanol blend currently allowed is 10 percent. The use of E15 in California would constitute the sale of a new transportation fuel, which is subject to a state-level multimedia evaluation pursuant to California Health and Safety Code section 43830.8.<sup>220</sup> This evaluation involves a peer-reviewed assessment of public health and environment impacts of E15 use, review by the California Environmental Policy Council, and potential implementation modifications to mitigate adverse impacts to public health or the environment. Should E15 be approved as a transportation fuel in California, vapor recovery devices and fueling hardware would still need to be approved by Underwriter Laboratories for use with E15.<sup>221</sup>

### **Compatibility Issues with Existing Vehicles and Gasoline Fueling Infrastructure**

The U.S. Environmental Protection Agency (EPA) has approved the use of E15 for use in vehicles newer than model year 2001. However, for older vehicles, E15 may cause corrosion in vehicle fuel systems and affect the performance of emission control devices. While this vehicle compatibility issue will not be a significant barrier in the long-term, some automakers still do not approve the use of E15 in their new vehicles.<sup>222</sup> BMW, Daimler, Mazda, Nissan, Subaru, and Volvo have not approved E15 for all or some of their respective model year 2019 vehicles – potentially diluting the emission reduction impact E15 could have in California. Given these vehicle-related restrictions on E15, distributors of E15 are also required to adopt an EPA-approved Misfueling Mitigation Plan, which include placing informational labels on dispensers, participating in compliance surveys, and maintaining records of all E15 transfers via Product Transfer Documentation.<sup>223</sup>

Infrastructure upgrades present additional challenges. The California Air Resources Board (CARB) maintains that E15 is also not suitable for distribution in existing petroleum pipelines due to

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<sup>219</sup> Department of Motor Vehicles, [https://www.dmv.ca.gov/portal/dmv/detail/pubs/media\\_center/statistics](https://www.dmv.ca.gov/portal/dmv/detail/pubs/media_center/statistics)

<sup>220</sup> [https://ww2.arb.ca.gov/sites/default/files/2018-10/CalEPA\\_Fuels\\_Guidance\\_Document\\_10-2-18.pdf](https://ww2.arb.ca.gov/sites/default/files/2018-10/CalEPA_Fuels_Guidance_Document_10-2-18.pdf)

<sup>221</sup> Id.

<sup>222</sup> <https://ethanolrfa.org/wp-content/uploads/2019/02/RFA2019Outlook.pdf>

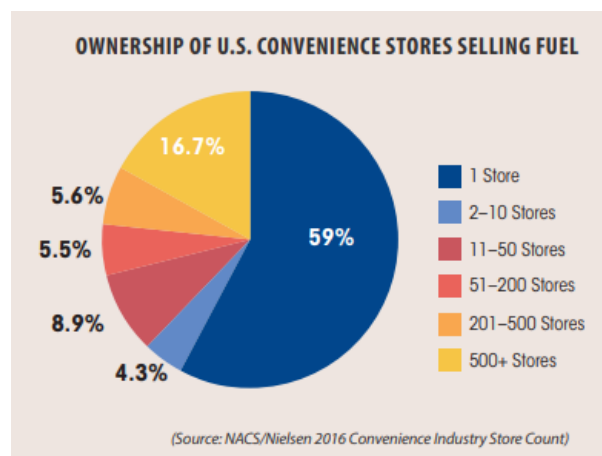
<sup>223</sup> <https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P100N3I5.pdf>

compatibility issues with jet fuel.<sup>224</sup> Distributing E15 may then require additional infrastructure upgrades to support fuel sales. Retailers offering E15 will also need to retrofit existing dispensers with UL-listed conversion kits, purchase a UL-listed E25 dispenser, or purchase a UL-listed E85 dispenser.<sup>225</sup> Additionally, some underground storage tanks (USTs) used to store E10 may not be compatible with E15 and some USTs that are compatible with E15 may not be UL-listed.<sup>226</sup> Coupled with the fact that fuel retailers are not required to keep records on equipment specifications, it may be challenging for these retailers to determine whether they need to upgrade their USTs prior to selling E15.

### Decentralized Status of Fuel Retailer Market

If E15 fuel is authorized for retail sale as an option among other gasoline-based fuels, the decentralized nature of the fuel retailer market may pose challenges for the broad adoption of E15. Although many gasoline retailers are branded with support of major oil companies, oil companies own a vanishingly small number of retail fueling stations nationwide. Four out of every five gallons of gasoline consumed by Americans are purchased at convenience stores, and as shown in the figure below, nearly 60 percent of these convenience stores are single-store operations.<sup>227</sup> Seventy-two percent of stations are owned by retailers that own 50 or fewer stores.

**Figure 88. Ownership of U.S. Convenience Stores Selling Fuel**



Source: National Association of Convenience Stores

Given this market dynamic, decisions to incorporate E15 would likely take place at the gas station level and potentially slow the adoption of E15 relative to a scenario where retail station ownership was more concentrated. The CEC estimates that there are 400-799 gas stations in San Bernardino County, meaning that the widespread availability of E15 would likely be dependent on the individual decisions of hundreds of individual gas station owners if E15 sales were permitted.<sup>228</sup> For branded stations, there

<sup>224</sup> [https://ww2.arb.ca.gov/sites/default/files/2018-10/CalEPA\\_Fuels\\_Guidance\\_Document\\_10-2-18.pdf](https://ww2.arb.ca.gov/sites/default/files/2018-10/CalEPA_Fuels_Guidance_Document_10-2-18.pdf)

<sup>225</sup> [https://afdc.energy.gov/files/u/publication/e15\\_infrastructure.pdf](https://afdc.energy.gov/files/u/publication/e15_infrastructure.pdf)

<sup>226</sup> <https://ethanolrfa.org/wp-content/uploads/2019/06/retailadvisory.pdf>

<sup>227</sup> <https://www.convenience.org/Topics/Fuels/Documents/2016/2016-Retail-Fuels-Report>

<sup>228</sup> [https://ww2.energy.ca.gov/almanac/transportation\\_data/gasoline/piira\\_retail\\_survey.html](https://ww2.energy.ca.gov/almanac/transportation_data/gasoline/piira_retail_survey.html)

may also be minimum E15 sales volume requirements stipulated by oil companies or refineries that present new contract risks for retailers.<sup>229</sup>

### **E85 Fueling Infrastructure**

There are currently seven public E85 fueling stations in San Bernardino County, and most are co-located with a Chevron or 76 gasoline fueling station. Because FFVs can run on gasoline available at hundreds of other gas stations in the county, it is unlikely that FFV drivers would refuel at an E85 station unless it was located on or near their typical commute or if E85 were significantly cheaper than gasoline. If FFV adoption were to increase, it is likely that many more E85 stations would be needed to achieve the emissions reduction benefits associated with E85. However, because E85 and gasoline are substitutes in FFVs, drivers may still drive FFVs on gasoline if it is a more convenient or accessible fueling option.

### **Ethanol Feedstocks and Carbon Intensity**

The vast majority of ethanol produced in the U.S. and consumed in California is made from corn. According to CARB, typical corn ethanol has a 27-48 percent lower carbon intensity (CI) compared to pure gasoline on a lifecycle basis.<sup>230</sup> Much lower GHG reductions are possible from ethanol produced from cellulosic material because the feedstocks are either waste, co-products of another industry (wood, crop residues), or are dedicated crops (such as switchgrass) with low water and fertilizer requirements compared to corn.<sup>231</sup> For example corn stover and corn kernel fiber projects can have a 58-69 percent lower CI relative to gasoline.<sup>232</sup> Supply of cellulosic ethanol is limited, however, because it is typically more expensive to produce than corn ethanol. There are also near-term concerns about evaporative emissions from E15 and its contribution to smog formation. Until recently, EPA banned the sale of E15 during summer months due to these emissions concerns; however, EPA announced in May 2019 that it lifted its restriction on the summertime use of E15.<sup>233</sup> The move has drawn a lawsuit from small fuel retailers as well as public opposition from the oil industry.<sup>234</sup>

### **Lack of Awareness and Education about Ethanol**

Many, perhaps most, light duty vehicle owners and operators lack a basic understanding of ethanol and FFVs. Even in corporate and government fleets that comprise FFVs, drivers are sometimes unaware that the vehicles can be fueled with E85. In the focus group conducted by the ICF team in September 2019,

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<sup>229</sup> [https://afdc.energy.gov/files/u/publication/e15\\_infrastructure.pdf](https://afdc.energy.gov/files/u/publication/e15_infrastructure.pdf)

<sup>230</sup> [https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/current-pathways\\_all.xlsx](https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/current-pathways_all.xlsx) Assumes the typical carbon intensity of corn ethanol is between 50-70 gCO<sub>2</sub>e/MJ. Note that the carbon intensity of pure corn ethanol is much lower than E15, which contains up to 15% ethanol.

<sup>231</sup> U.S. Department of Energy, Alternative Fuel Data Center.

[https://afdc.energy.gov/fuels/ethanol\\_fuel\\_basics.html](https://afdc.energy.gov/fuels/ethanol_fuel_basics.html)

<sup>232</sup> [https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/current-pathways\\_all.xlsx](https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/current-pathways_all.xlsx) Assumes the typical carbon intensity of corn stover and corn kernel fiber projects are 30-40 gCO<sub>2</sub>e/MJ.

<sup>233</sup> <https://www.epa.gov/newsreleases/epa-delivers-president-trumps-promise-allow-year-round-sale-e15-gasoline-and-improve-0>

<sup>234</sup> <https://www.reuters.com/article/us-usa-ethanol-lawsuit/small-fuel-retailers-sue-trump-epa-over-e15-gasoline-rule-filing-idUSKCN1UZ25M>

most participants claimed that they did not have enough information about ethanol vehicles to comment on their pros and cons.

## 6.2 Medium- and Heavy-Duty Vehicles

### Electric Vehicles

EVs are a promising zero-emission technology with relatively low operational costs. However, these vehicles face notable challenges in the MDV and HDV segments.

#### High Upfront Vehicle Costs

Similar to light-duty EVs, medium- and heavy-duty EVs have experienced significant cost declines as battery technology and manufacturing improves. However, battery costs continue to be the primary driver for vehicle cost differentials between EVs and ICE vehicles. Based on recent literature, ICF estimates the average upfront cost of a new electric transit bus is \$820,000, while the average cost of a new, comparable diesel bus is around \$435,000.<sup>235</sup> Electric medium-duty vans and trucks were estimated to cost approximately \$130,000-\$170,000 whereas the conventional diesel vehicle costs approximately \$80,000 in 2015.<sup>236</sup> Estimates for heavy-duty trucks are more speculative given the current limited availability of electric models. Class 6-8 short-haul electric trucks are priced around \$200,000-\$300,000 relative to \$145,000 for a comparable diesel truck; given that many electric trucks in the U.S. are imported from China, the electric truck prices include estimated tariffs levied on the import of these vehicles. Electric drayage trucks were estimated to cost \$208,000 relative to \$108,000 for conventional drayage trucks in 2020.<sup>237</sup> Thor and Tesla estimate their long-haul Class 8 semi-trucks will cost approximately \$150,000-\$250,000 depending on model's range, compared to \$125,000 for a diesel equivalent.<sup>238</sup>

Given these higher upfront costs, the adoption of EVs in these segments has been heavily dependent on grants and incentives. Since 2009, CARB and CALSTART have administered the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). The HVIP Program has approved 3,400 vouchers worth \$387 million toward the purchase of zero-emission vehicles, the majority of which have been EVs.<sup>239</sup> 234 of these vouchers worth over \$26 million have supported the purchase of zero-emission vehicles in San Bernardino County. While the program has been a boon for the adoption of medium- and heavy-duty EVs, HVIP funding is limited relative to demand. A week after HVIP funding was replenished with \$142 million in fiscal year 19-20 funding, the program was oversubscribed and placed on hold.<sup>240</sup> While this demand for HVIP funding demonstrates strong interest in EVs, it also highlights the reliance on near-

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<sup>235</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

<sup>236</sup> *Id.*

<sup>237</sup> ICF Resources, LLC, Economic Impacts of the Accelerated Deployment of Zero- and Near-Zero NOx Emissions Technologies in the Heavy-Duty Vehicle Sector Task 2: Implementation Scenarios Technical Memorandum, May, 1, 2019

<sup>238</sup> *Id.*

<sup>239</sup> <https://www.californiahvip.org/tools-results/#program-numbers>

<sup>240</sup> <https://content.govdelivery.com/accounts/CARB/bulletins/2699f43>

term government incentives to support the market. Stop-start funding cycles can increase fleet owners’ uncertainty about transitioning to EVs and ultimately hinder near-term EV adoption. South Coast Air Quality Management District’s (SCAQMD) Voucher Incentive Program (VIP) also offers complementary incentives for small fleets up to \$60,000 per truck.<sup>241</sup> While these incentives are significant, they may not be enough to encourage fleet owners to move toward EVs given their upfront price premium.

### Limited Model Availability

The number of commercial EV model offerings continues to grow, but availability is still limited relative to ICE vehicles – particularly in the heavy-duty long-haul segment. The table below reveals eligible EV models under the HVIP program, including a small number of conversions. All Class 7-8 trucks eligible for incentives are delivery or other short-haul trucks.

**Table 41. EV Models Eligible for HVIP Incentives**

Transit Bus	School Bus	Class 3 Truck	Class 4-6 Truck	Class 7-8 Truck
29	16	6	32	14

While Class 8 tractor truck manufacturers such as Tesla, Freightliner, and Navistar have all announced commitments to selling all-electric trucks, these trucks are not expected to begin production until the early to mid-2020s, limiting their effectiveness as a near-term solution for addressing emissions from HDVs.

### Negative Views of EV Performance

Closely related to model availability challenges are real and perceived notions of inferior EV performance among fleet owners. Long-haul semi-trucks currently face clear challenges to electrification due to limited electric range relative to their diesel counterparts, which may disrupt the typical duty cycle of long-haul trucks. These challenges are reflected in the concerns raised by stakeholders in the September 2019 focus group conducted by the ICF team; participants noted that the combination of range and limited charging infrastructure would severely curb any interest in electric semi-trucks. Truck drivers in the focus group stated they drive between 100 and 500 miles a day. While the upgraded Tesla Semi is equipped to drive an estimated 500 miles on a single charge, the base Tesla Semi model and upcoming Freightliner eCascadia long-haul Class 8 trucks are expected to achieve 250-300 miles of range. Given the size of the batteries in these vehicles, the time required for on-route charging may not be feasible for some fleet owners.

Aside from range concerns, truck drivers in the focus group had several additional issues with EVs, including skepticism about the overall life of the battery, likelihood of battery overheating, lack of vehicle torque and power, high vehicle costs, and lack of charging infrastructure along major routes.

For some heavy truck operators, a switch from diesel to EV could also reduce payload carrying capacity. Because of the large battery needed to power a heavy electric truck, the empty (tare) weight of the

<sup>241</sup> [http://www.aqmd.gov/docs/default-source/vip/vip\\_brochure\\_english.pdf?sfvrsn=23](http://www.aqmd.gov/docs/default-source/vip/vip_brochure_english.pdf?sfvrsn=23)

vehicle may be higher than a comparable diesel truck. Carriers that are transporting relatively dense, heavy cargo might need to reduce their payload in order to comply with federal and state weight limits. However, Assembly Bill 2061 of 2018 increases the state weight limit for near-zero and zero-emission vehicles by up to 2,000 pounds to compensate for the additional weight of batteries and other applicable powertrain components.<sup>242</sup>

### Lack of Accessible Charging Infrastructure

Accessible charging infrastructure is critical to the operation of medium- and heavy-duty EVs, and lack of charging infrastructure is currently a barrier to all classes of EVs. Although the industry is converging on standards for conductive (i.e. plug-based) charging such as J3068 for alternating current (AC) charging and J3105 for overhead catenary charging, infrastructure cost and optimization may prove to be a challenge for fleet operators considering EVs.

Infrastructure cost can be broken out into three primary categories: charging station costs, maintenance costs, and “make-ready” costs, which include all costs related to upgrading electrical equipment upstream of the station to support EV charging. Although some medium- and heavy-duty EVs may utilize Level 2 charging equipment, which is relatively inexpensive and charges at a slower rate than DCFC stations, the battery capacities and duty cycles of these vehicles may require much faster charging in depot configurations. 50 kW charging stations may cost up to \$50,000 per charger, while 150 kW and 350 kW stations may cost approximately \$75,000 and \$140,000 per charger, respectively.<sup>243</sup> However, these costs do not account for the electrical equipment upgrades needed to connect these charging stations to the grid. Estimated per-charger DCFC make-ready costs are shown in the table below.

**Table 42. Per-Charger DCFC Make-Ready and Installation Costs**

	50 kW				150 kW				350 kW			
	1 charger per site	2 chargers per site	3-5 charger per site	6-50 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-20 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-10 chargers per site
<b>Labor</b>	\$19,200	\$15,200	\$11,200	\$7,200	\$20,160	\$15,960	\$11,760	\$7,560	\$27,840	\$22,040	\$16,240	\$10,440
<b>Materials</b>	\$26,000	\$20,800	\$15,600	\$10,400	\$27,300	\$21,840	\$16,380	\$10,920	\$37,700	\$30,160	\$22,620	\$15,080
<b>Permit</b>	\$200	\$150	\$100	\$50	\$210	\$158	\$105	\$53	\$290	\$218	\$145	\$73
<b>Taxes</b>	\$106	\$85	\$64	\$42	\$111	\$89	\$67	\$45	\$154	\$123	\$92	\$62
<b>Total</b>	\$45,506	\$36,235	\$26,964	\$17,692	\$47,781	\$38,047	\$28,312	\$18,577	\$65,984	\$52,541	\$39,097	\$25,654

Source: International Council on Clean Transportation

While per-charger costs decline as the number of chargers per site increases, the magnitude of these deployment costs can be a significant barrier to adopting EVs.<sup>244</sup> These costs will only increase as EV

<sup>242</sup> [https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill\\_id=201720180AB2061](https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB2061)

<sup>243</sup> Nicholas, Michael, *Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas*, August, 2019, available at:

[https://theicct.org/sites/default/files/publications/ICCT\\_EV\\_Charging\\_Cost\\_20190813.pdf](https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf)

<sup>244</sup> Southern California Edison’s \$342 million medium and heavy-duty infrastructure program, approved in May 2018 will help offset a portion of these costs at an estimated 840 sites to support the electrification of over 8,000



charging service providers explore the possibility of charging stations capable of delivering one megawatt of power or more.

Closely related to infrastructure constraints are fuel cost concerns. Electricity is generally a cheaper fuel than diesel on a per-mile basis. However, demand charges can significantly affect the economics of refueling EVs at DCFC stations, particularly for MD and HD vehicles. Demand charges recover costs based on a customer’s highest instantaneous power demand (kW) during a given month or year as opposed to the energy (kWh) consumed at a site. Left unmanaged, DCFC stations can significantly increase the peak electricity demand and customer electricity bills at a given site – particularly when multiple vehicles are fast charging simultaneously. SCE’s recently approved commercial time-of-use (TOU) rate for EV customers shown below eliminates demand charges for customers during the first five years of enrollment and then gradually phases demand charges back into the rate design – allowing customers to become familiar with EV technologies and determine how to best manage their electricity demand.

**Table 43. SCE TOU-EV-8 Electricity Rate for Commercial EV Customers**

<b>TOU-EV-8</b>		2019-2023	2024	2025	2026	2027	2028	2029+
<b>Large Power with Monthly Max Demand between 21 - 500 kW</b>		<u>All Energy Rate</u>						<u>Full FRD Rate</u>
<b>EV-Only</b>		<u>Year 5</u>	<u>Year 6</u>	<u>Year 7</u>	<u>Year 8</u>	<u>Year 9</u>	<u>Year 10</u>	<u>Year 11</u>
<b>TOU Period</b>								
Summer On - \$/kWh	4-9pm weekdays	\$0.41816	\$0.41131	\$0.40447	\$0.39762	\$0.39077	\$0.38393	\$0.25882
Summer Mid - \$/kWh	4-9pm weekends	\$0.27718	\$0.27034	\$0.26349	\$0.25664	\$0.24980	\$0.24295	\$0.20051
Summer Off - \$/kWh	All except 4-9pm all days	\$0.12550	\$0.11866	\$0.11181	\$0.10496	\$0.09812	\$0.09127	\$0.10135
Winter Mid - \$/kWh	4-9pm all days	\$0.27801	\$0.27116	\$0.26432	\$0.25747	\$0.25062	\$0.24378	\$0.20134
Winter Off - \$/kWh	9pm-8am all days	\$0.13206	\$0.12522	\$0.11837	\$0.11152	\$0.10467	\$0.09783	\$0.11078
Winter Super-Off- \$/kWh	8am-4pm all days	\$0.08133	\$0.07448	\$0.06764	\$0.06079	\$0.05394	\$0.04710	\$0.05837
<b>Customer Charge (\$/Month)</b>		<b>\$106.75</b>	<b>\$106.75</b>	<b>\$106.75</b>	<b>\$106.75</b>	<b>\$106.75</b>	<b>\$106.75</b>	<b>\$106.75</b>
FRD (\$/kW)		\$0.00	\$1.99	\$3.99	\$5.98	\$7.97	\$9.97	\$11.96
% of Final FRD		0	16.67%	33.33%	50.00%	66.67%	83.33%	100.00%
FRD % Increase By Year			16.67%	16.67%	16.67%	16.67%	16.67%	16.67%

Source: California Public Utilities Commission

This rate will likely help fleet owners manage their electricity costs as they transition to EVs. However, as demand charges get phased back in over time, operators of heavy-duty EVs will need to carefully manage electricity demand to ensure fuel cost savings relative to diesel fuel. Customers that can stagger and spread out EV charging over the course of the day will likely benefit the most from this rate design. However, customers that consume significant amounts of power in short periods of time will likely face more challenging refueling economics for their EVs.

## Fuel Cell Vehicles

FCVs have the potential to provide clean transportation options to the long-haul heavy-duty segment. However, they face several critical challenges that may limit their adoption in the near-term.

medium and heavy-duty vehicles in its service territory. 40 percent of program budget must be invested in disadvantaged communities.



## High Upfront Vehicle Costs

Reliable vehicle cost data is scarce due to the limited deployment of medium- and heavy-duty FCVs to date. However, it is clear that medium- and heavy-duty FCVs will command a high price premium relative to ICE vehicles in the near-term. In 2016, CARB estimated that fuel cell electric transit buses (FCEBs) cost approximately \$1.235 million.<sup>245</sup> The NREL FCEB assessment from 2018 reveals that recent bus orders cost \$1.27 million, down from \$2.5 million in 2010.<sup>246</sup> An order of 40 buses could push costs closer to \$1 million per FCEB.<sup>247</sup> Truck cost data is difficult to obtain. Nikola anticipates offering an all-in long-haul semi-truck, fueling, and maintenance cost package for around \$900,000 over the million-mile life of the vehicle.<sup>248</sup> ICCT predicts that the total cost of ownership for heavy-duty FCVs may be 5-30 percent less than diesel vehicles in 2030, but these assumptions are dependent on hydrogen fuel and infrastructure costs declining over time and still suggest that FCVs will still cost more than diesel vehicles on an upfront basis.<sup>249</sup> However, new truck ownership and leasing models may make FCVs competitive on a cost per-mile basis with diesel trucks.<sup>250</sup>

## Limited Model Diversity and Availability

FCV model availability is very limited in medium- and heavy-duty segments. Currently, only four FCV models are eligible for HVIP incentives – two of which are transit buses manufactured by New Flyer and two of which are transit buses manufactured by Eldorado National. According to the California Fuel Cell Partnership, 31 hydrogen transit buses are currently in operation in California and 21 are under development.<sup>251</sup>

Beyond transit buses, medium- and heavy-duty FCV deployments have primarily been limited to demonstration projects in port and parcel delivery applications. Toyota, in partnership with Kenworth, is testing fuel cell powertrains for Class 8 drayage trucks in the Los Angeles region: ten Kenworth T680 models outfitted with Toyota fuel cell technology will transport cargo from Ports of Los Angeles and Long Beach throughout the region and are expected to drive more than 300 miles per fill.<sup>252</sup> Nikola Motors is currently in the demonstration phase of producing two fuel cell tractor models that are expected to reach mass production around 2025 with ranges upwards of 500 miles per fill.<sup>253</sup> While these pilots are essential for assessing the performance of FCVs in real-world settings, their timelines suggest that FCVs will not be a near-term solution to addressing HDV emissions.

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<sup>245</sup> [http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review\\_Final\\_December\\_2018.pdf](http://www.caletc.com/wp-content/uploads/2019/01/Literature-Review_Final_December_2018.pdf)

<sup>246</sup> <https://www.nrel.gov/docs/fy19osti/72208.pdf>

<sup>247</sup> *Id.*

<sup>248</sup> <https://www.trucks.com/2019/04/17/nikola-unveils-trucks-launches-1-5-billion-investment-drive/>

<sup>249</sup> [https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks\\_ICCT-white-paper\\_26092017\\_vF.pdf](https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf)

<sup>250</sup> <https://www.truckinginfo.com/329836/nikola-plans-a-different-truck-ownership-model-for-its-hydrogen-and-electric-trucks>

<sup>251</sup> <https://cafcp.org/by-the-numbers>

<sup>252</sup> <https://www.truckinginfo.com/330270/toyota-and-kenworth-unveil-jointly-developed-hydrogen-fuel-cell-truck>

<sup>253</sup> Couch et al., 2018 Feasibility Assessment for Drayage Trucks, prepared for The Port of Los Angeles and Port of Long Beach, April 2019, available at: <http://www.cleanairactionplan.org/documents/final-drayage-truck-feasibility-assessment.pdf/>

### **Lack of FCV Education and Awareness**

Education and awareness issues surrounding FCVs are significant given the maturity of the technology and limited number of vehicles available to date. Their estimated ranges and fueling dynamics closely mirror those of diesel vehicles, providing FCVs with an advantage over EVs in this regard. However, the new powertrain and fuel associated with FCVs may cause concern for some fleet owners skeptical of new technology.

### **Lack of Accessible Fueling Infrastructure**

As with LDVs, fueling infrastructure cost is perhaps the most significant barrier to the development of the medium- and heavy-duty FCV market. The larger fuel tanks in medium- and heavy-duty FCVs require higher capacity, more expensive fueling stations than LDVs: hydrogen stations for transit buses are reported to cost \$5 million per station.<sup>254</sup> CEC awarded an \$8 million grant to Shell for the development of one high-capacity hydrogen station at the Port of Long Beach.<sup>255</sup> Hydrogen stations are currently scarce in California (45 public fueling stations) and are virtually nonexistent beyond California – potentially limiting the opportunity for interstate FCV trucking operations in the near-term. As the U.S. Department of Energy notes, it is difficult to develop a comprehensive infrastructure network for distribution of hydrogen to hundreds or thousands of fueling stations.<sup>256</sup> Producing hydrogen on site may reduce distribution costs, but it raises production costs if on-site production facilities are not already available. Hydrogen costs do not provide any meaningful cost savings at current diesel prices.<sup>257</sup> In short, FCVs will continue to be challenged by high infrastructure costs and limited distribution networks in the near term.

## **Natural Gas Vehicles**

NGVs provide a viable technological alternative to diesel vehicles while reducing emissions. However, NGVs share some similar challenges as medium- and heavy-duty EVs and FCVs as well as some unique regulatory risks.

### **High Upfront Vehicle Costs**

Although upfront costs for medium- and heavy-duty NGVs are not as pronounced as other alternative fuel vehicles, they may still present a barrier to adoption. Medium-duty NGVs have an incremental price between \$25,000-\$50,000 above comparable petroleum fueled vehicles while heavy-duty NGVs typically have an incremental price of \$40,000-\$60,000 over conventional diesel vehicles. This price increment is driven mainly by the cost of the fuel tanks for compressed or liquified natural gas.

Until October 2019, HVIP provided \$40,000-\$50,000 in incentives for 31 types of low-NOx vehicles and engines, including NGVs. However, new program modifications came into effect in October that eliminates HVIP funding for low-NOx vehicles and engines with the exception of the 11.9L low-NOx

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<sup>254</sup> <https://h2stationmaps.com/costs-and-financing>

<sup>255</sup> [https://www.energy.ca.gov/business\\_meetings/2018\\_packets/2018-11-07/Item\\_18\\_ARV-18-002.pdf](https://www.energy.ca.gov/business_meetings/2018_packets/2018-11-07/Item_18_ARV-18-002.pdf)

<sup>256</sup> [https://afdc.energy.gov/fuels/hydrogen\\_production.html](https://afdc.energy.gov/fuels/hydrogen_production.html)

<sup>257</sup> <https://h2stationmaps.com/costs-and-financing>

natural gas engine. Currently, only 14 NGVs and engines meet this new specification.<sup>258</sup> In addition, HVIP now requires all NGVs purchased with program funding to procure all fuel from in-state produced renewable natural gas (RNG), which may pose an additional barrier.<sup>259</sup>

### Negative Views on NGV Performance

Despite the technological maturity of NGVs relative to other alternative fuels, NGVs still suffer from real or perceived concerns about vehicle performance. Truck drivers that participated in the heavy-duty vehicle focus group in September 2019 noted issues with the poor reliability of natural gas engines. Additionally, they noted that there may be a lack of qualified mechanics to service NGVs when they experience issues. Another describes potential safety concerns related to the flammability of natural gas in a potential accident scenario. Additionally, some expressed concern that the weight of NGVs brings down their performance relative to diesel vehicles.

### Lack of Accessible Refueling Infrastructure

Natural gas fueling infrastructure options may be limited for certain fleets looking to transition to NGVs. For larger fleets that can take advantage of depot refueling opportunities, infrastructure costs may be substantial. Large, off-site natural gas fueling stations can cost up to \$1.8 million in certain cases. The table below illustrates natural gas fueling infrastructure costs.<sup>260</sup>

**Table 44. Natural Gas Fueling Infrastructure Costs**

Size	Type	Examples of Vehicles Supported	Total Cost
<b>Small Station (85-170 DGE per day)</b>	Fast Fill	15-25 pickups/delivery vans	\$400,000-\$600,000
	Time Fill	5-10 refuse vehicles	\$250,000-\$500,000
<b>Medium Station (425-680 DGE per day)</b>	Fast Fill	50-80 medium-duty trucks	\$700,000-\$900,000
	Time Fill	25-40 refuse trucks	\$550,000-\$800,000
<b>Large Station (1,275-1,700 DGE per day)</b>	Fast Fill, Retail	More than 100 MDVs and HDVs	\$1.2-\$1.8 million

Unlike EVs, NGVs cannot currently take advantage of utility programs that support the deployment of fueling infrastructure. Natural gas fueling stations are, however, eligible for incentives under the Carl Moyer Program administered by the South Coast Air Quality Management District. Southern California Gas Company (SoCalGas) offers natural gas at discounted rates to customers fueling natural gas vehicles.<sup>261</sup>

<sup>258</sup> <https://mailchi.mp/ee5457ceaf51/new-evse-voucher-requirements-for-hvip-770537?e=%5bUNIQID%5d>

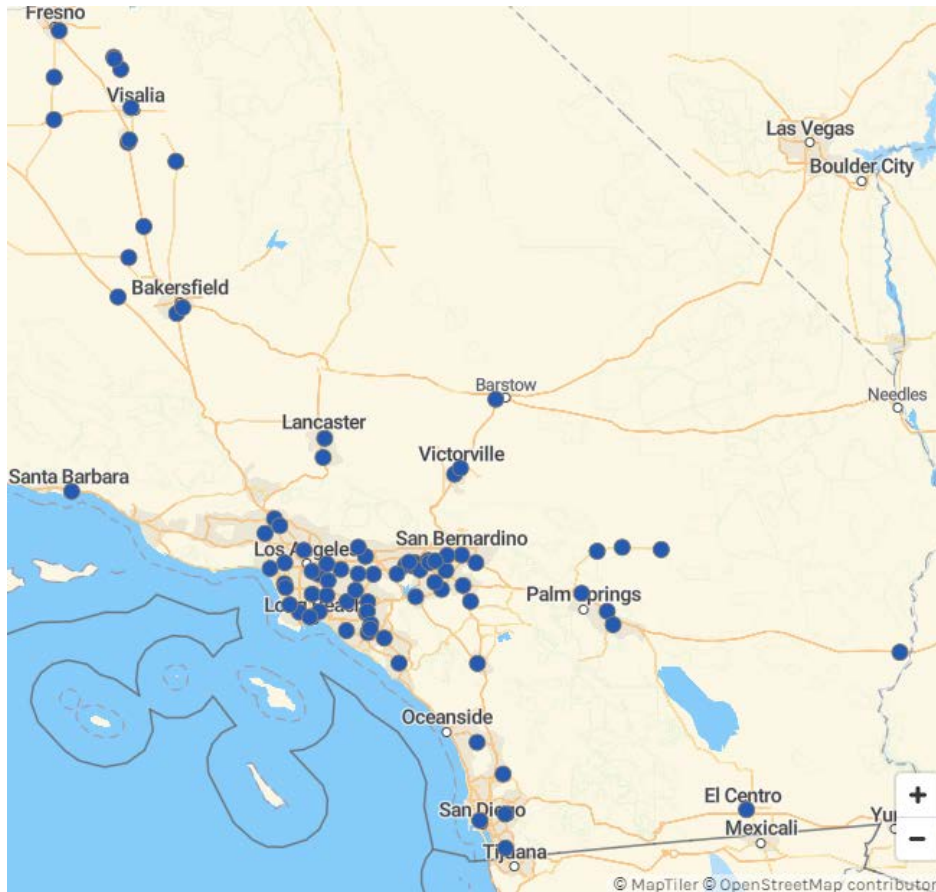
<sup>259</sup> <https://www.californiahvip.org/low-nox-incentives/#low-nox-natural-gas-engines>

<sup>260</sup> [https://afdc.energy.gov/files/u/publication/cng\\_infrastructure\\_costs.pdf](https://afdc.energy.gov/files/u/publication/cng_infrastructure_costs.pdf)

<sup>261</sup> <https://afdc.energy.gov/fuels/laws/NG?state=CA>

For long-haul trucking operations, the current number of fast fill stations available today may deter some fleet owners from purchasing NGVs. While the greater Los Angeles area is relatively well-covered by fueling stations today, other parts of the state and neighboring states have infrastructure gaps – shown in the figure below – that may preclude long-haul natural gas trucking operations in certain cases.

**Figure 89. Heavy-Duty Fast Fill NGV Fueling Infrastructure Locations**



Source: U.S. DOE

### Regulatory Risks

Natural gas has traditionally been encouraged at the state and local level as an alternative to diesel fuel. However, pending and existing regulations promulgated by CARB may increase risks associated with transitioning to NGVs in certain circumstances and reduce the penetration of NGVs in the state.

The first example of regulatory risk is CARB’s Innovative Clean Transit rule. Finalized in December 2018, the regulation establishes a requirement for transit agencies in the state to transition to completely zero-emission bus fleets by 2040.<sup>262</sup> To meet this goal, all new transit bus sales starting in 2029 must be zero-emission. Because CARB’s definition of “zero-emission” is limited to all-electric and fuel cell buses in the regulation, California natural gas bus sales are anticipated to decline rapidly and end within the

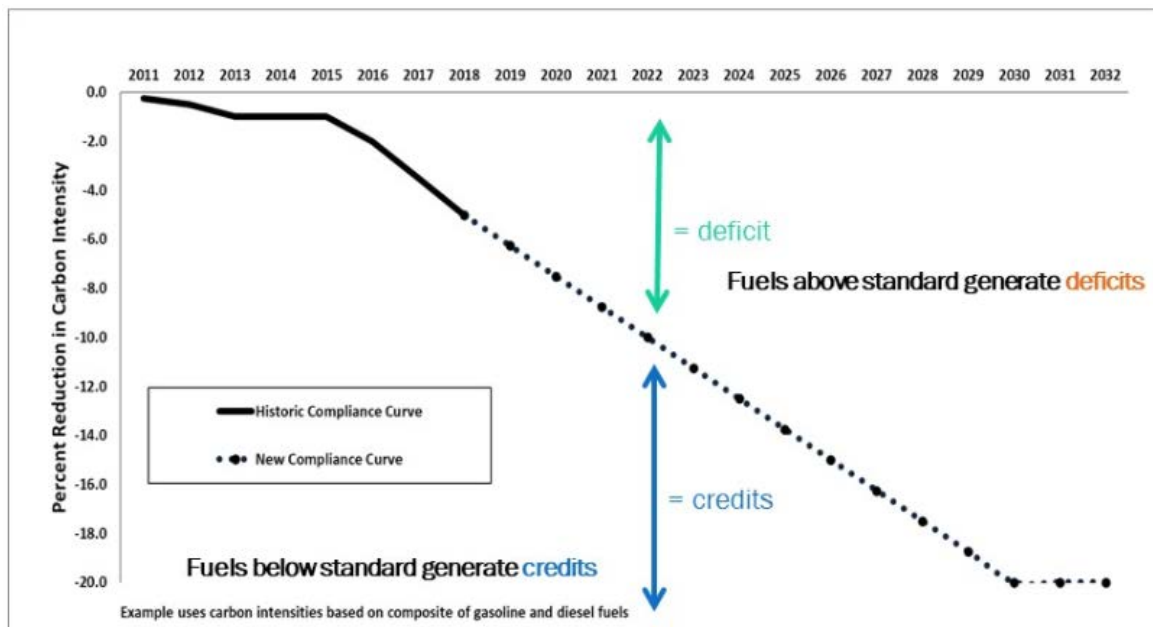
<sup>262</sup> <https://ww3.arb.ca.gov/regact/2018/ict2018/ictfro.pdf>

next decade. This regulation suggests that CARB is willing and able to exercise its authority to require lower-emission alternatives to fossil fuels as those alternatives become more technologically and economically feasible.

CARB is moving ahead with the Advanced Clean Trucks Regulation, a rule that would require Class 2B-8 vehicle and chassis manufacturers to sell an increasing percentage of zero-emission trucks between 2024 and 2030. Specifically, the proposed regulation would require 50 percent of Class 4-8 truck sales to be zero-emission and 15 percent of all other medium- and heavy-duty truck sales (including Class 7-8 tractors) to be zero-emission by 2030.<sup>263</sup> The regulation would also require additional reporting to CARB from retailers, manufacturers, brokers, and other parties on vehicle shipments. While the proposed regulation does not prohibit the sale or use of NGVs, the regulation sends a strong market signal that the state is interested in advancing zero-emission vehicles across all vehicle classes. As a result of the proposed Advanced Clean Trucks Regulation, conservative fleet owners may also begin hedging against more aggressive future ZEV regulations by purchasing and become familiar with zero-emission technologies now.

Finally, the Low Carbon Fuel Standard (LCFS) may also create some additional challenges for the use of fossil natural gas as a transportation fuel. The LCFS is a market-based program designed to encourage cost-effective reductions in the carbon intensity (CI) of transportation fuels in California with a goal of achieving a 20 percent overall CI reduction in 2030 relative to 2010 levels. As shown below, regulated entities that produce fuels with CIs above the target CI in a particular year (e.g. gasoline and diesel) generate deficits while entities that produce fuels with CIs below the target CI (e.g. hydrogen and electricity) generate credits that can be sold on the LCFS market to parties with credit deficits.

**Figure 90. Illustrative Graphic of LCFS Declining CI Curve**



<sup>263</sup> [https://ww2.arb.ca.gov/sites/default/files/2019-08/190821draftregmanu\\_0.pdf](https://ww2.arb.ca.gov/sites/default/files/2019-08/190821draftregmanu_0.pdf)

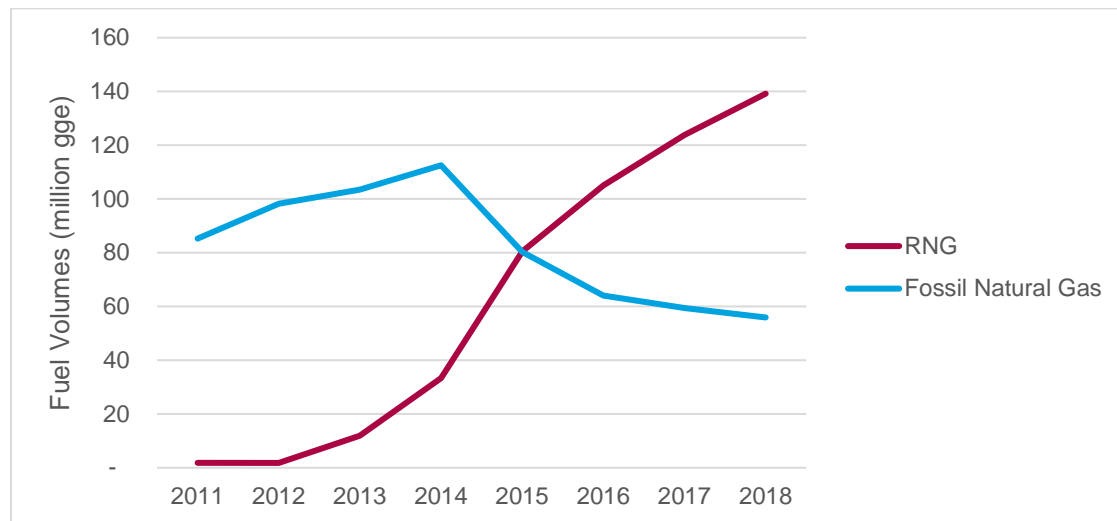
Source: CARB

Fossil natural gas has generally been below the declining annual CI target in the early years of the LCFS and therefore has been eligible to generate credits that can then be sold for monetary value. However, as the program becomes more stringent and the annual CI target continues to decrease, some natural gas producers will transition from credit-generating parties to deficit generating parties. This change may reduce natural gas suppliers’ interest in providing fossil natural gas as a transportation fuel, raise the cost of fossil natural gas as a transportation fuel, and ultimately reduce fleet interest in purchasing vehicles that use this fuel. Additionally, as it becomes more difficult for the transportation fuel mix to achieve the increasingly-stringent annual CI target, LCFS credit prices will continue to rise and raise the cost of producing carbon-intensive fuels – putting additional pressure on fossil natural gas.

### Renewable Natural Gas Supply Risk

One solution to overcome the risks and limitations associated with the use of fossil natural gas is renewable natural gas (RNG), which can be used as a drop-in substitute in NGVs. RNG use is now required for NGVs purchased with HVIP incentives and generally has a significantly lower CI than fossil natural gas, meaning that RNG suppliers will likely continue to generate credits under the LCFS through 2030. The graph below illustrates how RNG has largely displaced fossil natural gas as fuel for NGVs in the LCFS program: approximately 70 percent of the natural gas used for transportation in California in 2018 was RNG.<sup>264</sup>

**Figure 91. RNG and Fossil Natural Gas LCFS Annual Fuel Volumes**



Source: CARB

While RNG has several advantages over fossil natural gas, concerns over limited supply and cost may create additional risk for transitioning to NGVs. First, California is not the only jurisdiction to implement a low carbon fuel standard. Oregon and British Columbia also have similar programs that encourage the production and distribution of RNG with increasingly strict CI targets. Additionally, the Puget Sound

<sup>264</sup> <https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm>

region<sup>265</sup>, Colorado<sup>266</sup>, and Canada<sup>267</sup> are considering the implementation of LCFS in their respective jurisdictions, with Canada’s Clean Fuel Standard coming into force as early as 2022. The growth of LCFS policies has the potential to increase demand for RNG and increase the value of low carbon intensity RNG – making more RNG projects economical. There is a small risk that the RNG market becomes increasingly supply-constrained, limiting the potential for California to secure RNG needed to meet transportation demand, but with the combined Federal RFS and LCFS incentives, transportation within the US will be a priority end destination for RNG over other uses. According to UC Davis, Canada’s Clean Fuel Standard alone could nearly double the volume of fuels covered under a LCFS-style policy.<sup>268</sup> Additionally, the versatility of RNG as a source of building heat and electricity generation may create additional headwinds for use of RNG as a transportation fuel. If new programs or regulations in these sectors require or otherwise encourage the use of RNG, it could exacerbate supply constraints for RNG as a transportation fuel. California passed SB 1440 which requires the California Public Utilities Commission to consider the adoption of biomethane procure targets for utilities, which is a precursor to a renewable gas standard.<sup>269</sup> Finally, the use of RNG does not make NGVs “zero-emission vehicles” as defined by the Innovative Clean Transit regulation or the proposed Advanced Clean Truck regulation.

## Biodiesel and Renewable Diesel Fuels

Biodiesel (B20) and renewable diesel (RD100) fuels are drop-in fuels that can be used in medium- and heavy-duty diesel trucks today. Despite the relative ease of incorporating these alternatives to diesel into the transportation fuel mix, they present their own challenges and risks.

### Compatibility Issues with Existing Vehicles and Fueling Infrastructure

Although B20 is used interchangeably with diesel, there are additional precautions B20 fuel suppliers may consider before safely selling biodiesel. The Department of Energy provides a checklist for installing equipment to support B20 fueling, which includes the cleaning of storage tanks, labeling of B20 dispensers, verifying the use of UL-listed infrastructure, monitoring storage tanks for signs of corrosion from microbial growth, and notifying local fire departments about the use of B20 fuel.<sup>270</sup> Additionally, while cold weather is not commonplace in Southern California, concerns about the gelling of B20 at lower temperatures may also pose an additional barrier to the use of the fuel among some fleet owners.

### Potentially Higher Emissions Profile than Alternatives

While RD100 has demonstrable GHG and NOx emission reduction benefits relative to diesel, B20 has shown minimal NOx abatement potential relative to diesel. In some cases, B20 blends have been shown

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<sup>265</sup> <https://psc.air.gov/528/Clean-Fuel-Standard>

<sup>266</sup> <https://www.argusmedia.com/en/news/1965542-qa-colorado-lays-groundwork-for-lcfs>

<sup>267</sup> <https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard.html>

<sup>268</sup> <https://steps.ucdavis.edu/wp-content/uploads/2017/05/Witcover-BiofuelTracker-2017-2018-.pdf>

<sup>269</sup> [https://leginfo.ca.gov/faces/billTextClient.xhtml?bill\\_id=201720180SB1440](https://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1440)

<sup>270</sup> [https://afdc.energy.gov/files/u/publication/biodiesel\\_handling\\_use\\_guide.pdf](https://afdc.energy.gov/files/u/publication/biodiesel_handling_use_guide.pdf)

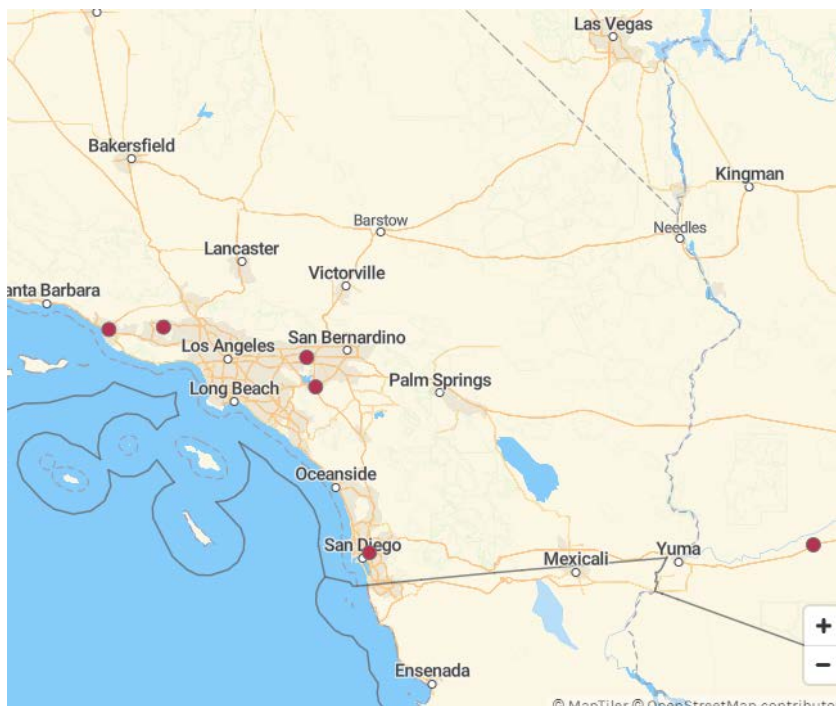


to produce more NOx than conventional diesel.<sup>271</sup> This has been a major barrier to use of biodiesel, particularly in Southern California. In January 2019, CARB updated the LCFS regulation to ensure that B20 fuel suppliers that participate in the program produce biodiesel in a manner that does not increase NOx emissions relative to conventional diesel and identify additives that would achieve this result.<sup>272</sup> Given the relatively minor NOx emissions reduction benefits of B20, widespread use of B20 may not advance the region’s air quality goals to the same degree as RD100 or other alternative fuels.

### Lack of Accessible Fueling Infrastructure

Access to B20 and RD100 is limited in San Bernardino County. The figure below illustrates where B20 stations are located in Southern California.

**Figure 92. B20 Fueling Station Locations in Southern California**



Source: DOE

Currently, there is only one public B20 fueling station in San Bernardino County in Ontario and one nearby station in Riverside County – reflecting the concerns about the NOx impacts of using biodiesel. Options for RD100 are even more limited. Neste, one of the largest RD100 producers globally, only has four stations available in Central and Northern California.<sup>273</sup> Fleet owners can also purchase RD100 direct from suppliers. However, if renewable diesel prices are comparable to diesel prices when accounting for LCFS credits and Renewable Fuel Standard renewable identification numbers (RINs),

<sup>271</sup> [https://ww3.arb.ca.gov/fuels/diesel/altdiesel/20140630carb\\_b20\\_%20additive\\_study.pdf?\\_ga=2.262185932.1549680135.1574709844-545298116.1556149337](https://ww3.arb.ca.gov/fuels/diesel/altdiesel/20140630carb_b20_%20additive_study.pdf?_ga=2.262185932.1549680135.1574709844-545298116.1556149337)

<sup>272</sup> [https://ww3.arb.ca.gov/regact/2018/lcfs18/frolcfs.pdf?\\_ga=2.35187297.1549680135.1574709844-545298116.1556149337](https://ww3.arb.ca.gov/regact/2018/lcfs18/frolcfs.pdf?_ga=2.35187297.1549680135.1574709844-545298116.1556149337)

<sup>273</sup> <https://www.neste.us/neste-my/find-fuel>

there is little incentive for fleets to procure RD100 if it is more convenient to fuel vehicles at conventional diesel stations.

### **Regulatory Risks**

Like natural gas fuel, biodiesel and renewable diesel fuels face regulatory risk from existing and future clean vehicle regulations in California. The proposed Advanced Clean Truck regulation will require the sale and use of medium- and heavy-duty vehicles that do not run on biofuels, potentially curbing long-term fleet owner interest in pursuing these fuels from a regulatory risk viewpoint. B20 and RD100 are also federally incentivized by the Renewable Fuel Standard (RFS), a policy designed to encourage the increasing use of renewable fuels to displace petroleum-based transportation fuel demand. Qualified renewable fuel providers can generate RINs that can be sold on RIN markets in a manner similar to LCFS credits. However, the program's annual renewable fuel volume targets are only established through 2022.<sup>274</sup> While the RFS is unlikely to be terminated, there remains uncertainty surrounding how EPA – the RFS administrator – will extend the program and provide additional revenue opportunities for suppliers of renewable fuels.

### **Fuel Supply Risks**

Biodiesel and renewable diesel fuels have played an important and growing role in achieving compliance with California's LCFS. However, both fuels face supply risks that may impact their viability in the long-term. Both fuels generally rely on the same feedstocks: animal fats, plant oils, and greases.<sup>275</sup> While increasingly higher LCFS credit prices will continue to make more biofuels production economically feasible, there is a risk that demand for these fuels may outstrip supply. This outcome may occur in part because of the inelasticity of certain feedstock supplies, meaning that their production will not necessarily increase in response to higher prices for that feedstock. In addition, the Innovative Clean Transit regulation requires large transit agencies, starting in 2020, to purchase only renewable diesel when renewing fuel purchase contracts which will increase the demand for these low carbon fuels. Combined with the possibility of additional LCFS programs launching in other jurisdictions, this demand-side pressure may strain economical biofuel production and limit the volumes of biofuels used for California LCFS compliance. Additionally, as other LCFS programs become established, biofuel producers strategically located near other covered jurisdictions may theoretically experience lower fuel transport costs to serve other LCFS markets – diverting biofuels that would have otherwise been imported by California.

## **6.3 Regulatory Authority**

In addition to challenges specific to light-duty, medium-duty, or heavy-duty vehicles, other implementation challenges relate to the absence of regulatory authority at the local and regional level.

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<sup>274</sup> <https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard>

<sup>275</sup> These feedstocks are also critical inputs in the production of other end-uses, and demand for these other products may affect the quantity of feedstock available for biofuel production.

## Local Authority

Local governments and regional agencies do not have authority to regulate the sale of new or used vehicles. Thus, a municipality or agency such as SCAG, SBCTA, or AQMD could not require that vehicles must meet certain emissions standards, or that a certain fraction of vehicles comply with technology specifications.

Local and regional authority to influence vehicle sales is primarily limited to incentives. Local governments and regional agencies can offer incentive funding to help offset the cost of clean vehicles. For example, the City of Riverside offers up to \$500 for the purchase or lease of a new EV. Most of the low and zero emission vehicle incentive programs in the region are provided by AQMD, many of which involve state funding. AQMD also offers an Old-Vehicle Scrapping Program, which provides cash payments to owners of old but functioning vehicles in return for agreeing to scrap the vehicle.

To generate funding for transportation improvements, counties can implement a local-option sales tax, with revenues dedicated to transportation projects. Twenty-five counties in the state have these programs, which requires super majority (two-thirds) voter-approval. In San Bernardino County, Measure I authorized a half-cent sales tax for transportation improvements; the measure was first approved in 1989 and an extension to 2040 was approved in 2004. Revenue from these programs must be spent in accordance with an expenditure plan. In San Bernardino County, the Measure I expenditure plan identifies highway projects, local street projects, and transit improvements (rail and bus) to receive funding.

## State Authority

California has unique authority to regulate vehicle sales for emission reduction. In general, federal preemption prohibits states and local jurisdictions from enacting emission standards and other emission-related requirements for new vehicles and engines. However, the Clean Air Act (CAA) allows California to seek a waiver of the federal preemption, and in the past, this waiver was routinely granted, allowing California to set its own vehicle emission standards. In September 2019, the U.S. Environmental Protection Agency announced it is withdrawing California's waiver under the CAA to set its own vehicle emission standards. That action is currently being challenged in court.

Under CAA waivers, California has in the past set tailpipe emission standards that were more stringent than federal standards, for both light-duty and heavy-vehicles. The CAA waiver was also used to establish California's zero emission vehicle (ZEV) mandate, administered by CARB. Dating back to 1990, the program requires the largest vehicle manufacturers to deliver for sale a sufficient number of ZEV credit-producing vehicles – battery electric, plug-in hybrid electric, and fuel cell electric vehicles – such that each manufacturer attains specific ZEV credit and minimum ZEV sales percentages. The requisite percentages ramp up gradually through model year 2025.

## 7 Implementation Strategies

### 7.1 Introduction

#### Role of Clean Vehicles and Fuels

As discussed in the preceding section, a variety of barriers have limited the penetration of alternative vehicles and fuels to date including vehicle purchase costs, fueling infrastructure availability and costs, lack of customer awareness, perceptions of vehicle performance, and uncertainty surrounding technology development and regulation. This section identifies strategies and solutions to help local governments overcome these barriers and thereby advance clean vehicles and fuels in San Bernardino County. These strategies focus primarily on actions that local and regional public agencies can pursue.

As a framework for considering clean vehicle and fuel implementation strategies, it is helpful to group vehicles and associated strategies into the following three categories:

- **Municipal fleet vehicles** – vehicles owned and operated by local governments.
- **Private vehicles** – primarily light-duty vehicles driven by those who live or work in the County
- **Commercial fleet vehicles** – primarily heavy-duty vehicles operated by or serving businesses in the County

The implementation strategies in this section are organized around these three categories, recognizing that there may be some overlap in term of the types of vehicles addressed by a particular strategy.

#### Vehicle Technology and Fuel Options

There are many options for advanced technology and alternative fuel vehicles that can reduce emissions as compared to conventional gasoline and diesel vehicles. These options are discussed in detail in Section 2 of this report and listed in the table below.

**Table 45. List of Clean Vehicle and Fuel Options**

Light-duty vehicle and fuel options	Medium- and heavy-duty vehicle and fuel options
Battery electric vehicle	Battery electric vehicle
Plug-in hybrid electric vehicle	Plug-in hybrid electric vehicle
Fuel cell vehicle	Fuel cell vehicle
Natural gas vehicle	Natural gas vehicle
E85 flexible fuel vehicle	Renewable natural gas
	Propane
	Biodiesel
	Renewable diesel

The clean vehicle options vary widely in terms of the level of technology readiness and commercial availability, as well as their emissions benefits. At this point, no one can say for certain which technologies and fuels will win out in the marketplace and prove to be the best option for vehicle owners in the long run. This uncertainty creates a dilemma for local governments, who may be eager to support the transition to clean vehicles and fuels but are wary about investing in vehicles and fueling infrastructure that may be obsolete in the future. While this uncertainty calls for careful planning and analysis before devoting municipal resources, it does not warrant inaction. Local governments can make well-informed decisions today that carry little risk of obsolete technologies and stranded assets.

For light-duty vehicles, it is abundantly clear that electric vehicles (including battery electric and plug-in hybrid electric) are the right choice. The price of EVs is declining, the number of commercial offerings is expanding significantly, and the emissions benefits are clear. More than 150,000 EVs were sold in California in 2019, or approximately 8 percent of total vehicle sales. In contrast, fuel cell vehicles (FCVs) face a much more uncertain future for the light-duty sector. Only about 2,000 FCVs were sold in California in 2019. Globally, EV sales were 300 times higher than FCV sales (2.2 million vs. 7,500) in 2019. While FCVs may have important niche applications in the future, at this stage it would be risky for local governments to invest in this option. E85 flexible fuel vehicles (FFVs) have been around since the late 1990s, and there are currently more than 1 million registered in California. But manufacturers have significantly reduced FFV production in recent years, as both consumer and regulator preferences have shifted to EVs.

For medium- and heavy-duty vehicles, the outlook is much less clear. Electric vehicle options for trucks are limited, vehicle prices are high, and the technology is not currently suitable for some applications (e.g., long-haul combination trucks). CARB's Advanced Clean Truck Rule will help to drive growth in electric trucks, but even that regulation calls for only 15 percent of new sales to be electric for Class 2B-3 and Class 8 combination trucks by 2030. That said, many regulatory agencies and industry observers believe that EVs will be the technology of choice in the long-term. Fuel cell technology is being explored for heavy trucks and may offer a viable alternative in some situations. However, the cost of future FCVs is uncertain because, other than transit buses, medium- and heavy-duty FCV deployments have primarily been limited to demonstration projects, and fueling infrastructure cost is likely to be the most significant barrier to the development of the medium- and heavy-duty FCV market. Natural gas vehicles are currently available for many medium- and heavy-duty vehicle applications, and by using renewable natural gas (RNG), these vehicles can dramatically lower both NOx and GHG emissions. Many industry observers believe natural gas will remain an attractive alternative for some applications for at least the next decade or two. Renewable diesel provides an opportunity to reduce GHG emissions from the existing fleet of diesel vehicles without modification. This variety of options and uncertainty in the near-term has been described as the "messy middle". For the next 10-20 years, a number of different technologies and fuels will offer the optimized solution for medium- and heavy-duty vehicles, while in the long-run, electric powertrains are expected to dominate the marketplace.<sup>276</sup>

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<sup>276</sup> North American Council for Freight Efficiency, Guidance Report: Viable Class 7/8 Electric, Hybrid and Alternative Fuel Tractors, 2019. <https://nacfe.org/report-library/guidance-reports/>

## 7.2 Municipal Fleet Vehicles

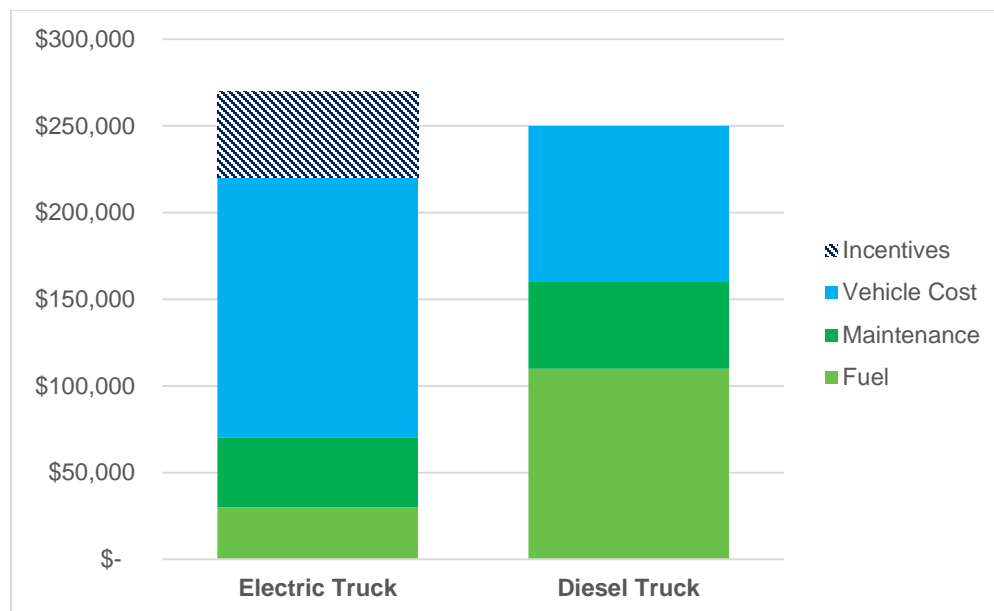
If local governments in San Bernardino County seek to maximize the use of clean fuels and technologies for vehicle operating in the region, it is important that they lead by example. Local governments can play an important role in maximizing the deployment of cleaner transportation technologies. Government fleets contain just a small fraction of the total vehicle population that operates in the County. But government fleets have historically been leaders in the use of low-emission fuels and vehicles. By adding these vehicles to municipal fleets, cities help to reduce emissions, develop markets for the clean technologies, and demonstrate their environmental stewardship to the private sector.

### Strategy 1: Conduct a fleet assessment

A first step in local government fleet greening is to conduct a fleet assessment to identify the best opportunities to replace gasoline and diesel vehicles that are being retired with alternative fuel vehicles. This starts with documenting a city’s current fleet, including the number of vehicles of each type and fuel, vehicle annual mileage, fuel consumption, and fueling location(s). Establishing a baseline for fuel use and fuel expenditures will help a city identify opportunities for improvement and allow the city to track progress over time. If city vehicles do not re-fuel at a centralized location, the city might need to implement new record-keeping procedures to track fuel purchasing.

When upgrading their own fleets, understanding the cost implications of fleet greening is critical. Many alternative fuel vehicles carry a higher up-front purchase price but have lower operating costs. A city should conduct a total cost of ownership (TCO) analysis, taking into account purchase price, any incentives available, resale value, fuel costs, and maintenance costs. The figure below shows an example of the results of a TCO analysis for a hypothetical electric vs. diesel medium-duty truck.

**Figure 93. Example of Total Cost of Ownership Analysis**



Information on vehicle purchase prices can be obtained truck dealers, trade groups, or other research reports (such as those listed in Strategy 4 below). Estimating the change in fueling costs can be challenging because of differences in units of measurement, differences in fuel economy for alternative fuel vehicles, and changes in both tax incentives and market prices that make it difficult to accurately forecast fuel prices. The U.S. Department of Energy’s Clean Cities *Alternative Fuel Price Report* comes out every 3 months and provides up-to-date information on the price of alternative fuels in the United States in relation to gasoline and diesel prices. Alternatives to gasoline and diesel differ in their energy content, which also needs to be considered when evaluating fuels. For example, 85 percent ethanol (E85) currently costs less per gallon than gasoline, but because ethanol has about 35 percent less heating value than gasoline, the effective price of E85 is higher than gasoline.

## **Strategy 2: Establish EV procurement goals for a city’s light duty fleet**

As discussed in Section 7.1, EVs are the recommended choice for replacement light-duty gasoline vehicles. City and County governments can accelerate the adoption of EVs through leadership by example and procure EVs for their own fleets. Local governments can establish goals for the purchase of EVs in the near-term, potentially extending and increasing through 2030 and beyond. Procurement targets are advantageous because they are directly within local governments’ control, provide local governments with firsthand experience owning and operating EVs, and potentially allow for significant fuel and maintenance cost savings over the life of the vehicles. As a complementary measure, local governments can update procurement guidance to require justification for the purchase of non-EVs.

The California Air Resources Board’s (CARB) CVRP for Fleets offers incentives for the purchase or lease of up to 30 eligible EVs annually for local, State, and tribal government entities.<sup>277</sup> Moreover, many cities have already made commitments to accelerate the electrification of their light-duty fleets. For example, the City of Sacramento has established a comprehensive Fleet Sustainability Policy that required a minimum of 50 percent of light-duty vehicles purchased in 2018 to be zero-emission vehicles and a minimum of 75 percent by 2020.<sup>278</sup> Cities can also use State fleet procurement goals as a baseline: Executive Order B-16-2012 directed state agencies to make 10 percent of new vehicle sales electric by 2015 and 25 percent by 2020.<sup>279</sup> More recently, the Governor’s Office of Business and Economic Development stated a new goal of 100 percent EV purchases by 2030 – with the exception of certain vehicle types.<sup>280</sup>

## **Strategy 3. Expand charging infrastructure for a city’s light duty EV fleet**

Cities must accommodate additional EVs with corresponding investments in fleet charging infrastructure. Fleet managers should seek to deploy charging stations that meet the performance requirements and duty cycles of the EV fleet while minimizing costs. For vehicles used regularly during daytime hours, Level 2 (L2) charging stations will likely allow for these vehicles to be fully charged overnight at centralized depots. For vehicles that are used infrequently or travel short distances daily,

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<sup>277</sup> <https://cleanvehiclerebate.org/eng/fleet/public-agencies>

<sup>278</sup> <https://www.cityofsacramento.org/-/media/Corporate/Files/Public-Works/Fleet/FleetSustainabilityPolicy-00-Policy-Procedure-Cover.pdf?la=en>

<sup>279</sup> <https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html>

<sup>280</sup> <https://static.business.ca.gov/wp-content/uploads/2019/12/2018-ZEV-Action-Plan-Priorities-Update.pdf>



Level 1 (L1) charging stations may be appropriate for recharging vehicles overnight. Installation of Direct Current Fast Charging (DCFC) stations can be significantly more expensive than L1 or L2 charging options and may be considered as a backup option. Alternatively, city fleets could leverage the existing public DCFC stations in San Bernardino County in cases where refueling is necessary. As fleets deploy charging infrastructure to meet their near-term needs, fleet managers may consider “futureproofing” their parking sites by making electrical upgrades necessary to support future charging station deployments. This approach to fleet planning could generate long-term savings when higher penetrations of EVs are incorporated into city fleets. Southern California Edison’s (SCE) Charge Ready EV charging station incentive program is no longer accepting applications, but opportunities for additional incentives may become available in the near future with SCE’s proposed Charge Ready 2 program.<sup>281</sup> South Coast Air Quality Management District (SCAQMD) is also implementing a rebate program for EV charging stations deployed at government and non-profit sites in the City of San Bernardino.<sup>282</sup> CARB’s Low Carbon Fuel Standard can also generate additional revenue streams from the use of electricity as transportation fuel. For example, the Orange County Transit Authority’s fleet reported the LCFS covered the cost of fuel and generated a \$3 million surplus for the authority over 3 years.<sup>283</sup>

#### **Strategy 4. Identify medium and heavy-duty vehicle replacement options**

As discussed in Section 7.1, the appropriate clean vehicle and fuel options for medium- and heavy-duty vehicles (MD/HD) are not as clear as with light-duty vehicles. But feasible options exist for nearly every MD/HD vehicle type. Local governments should explore these options, identify appropriate choices, and integrate these vehicles into fleet purchasing decisions. To learn more about options for MD/HD vehicles, the Department of Energy’s Alternative Fuel Data Center (<https://afdc.energy.gov/>) is a good starting point. It provides an unbiased overview of vehicle technologies and fueling infrastructure, and includes links to other resources. More detailed descriptions of clean vehicle technologies and fuels are available in other documents. Some of these are developed by entities affiliated with a specific industry group, and readers should therefore understand that the document reflect biases towards a particular technology or fuel. Resources include:

- Edison Electric Institute, Preparing to Plug In Your Fleet, 2019. [www.eei.org/issuesandpolicy/electrictransportation/Documents/PreparingToPlugInYourFleet\\_FINAL\\_2019.pdf](http://www.eei.org/issuesandpolicy/electrictransportation/Documents/PreparingToPlugInYourFleet_FINAL_2019.pdf)
- California Electric Transportation Coalition, Comparison of Medium- and Heavy-Duty Technologies in California, 2019. <https://caletc.com/comparison-of-medium-and-heavy-duty-technologies-in-california/>
- North American Council for Freight Efficiency, Guidance Report: Viable Class 7/8 Electric, Hybrid and Alternative Fuel Tractors, 2019. <https://nacfe.org/report-library/guidance-reports/>
- North American Council for Freight Efficiency, Guidance Report: Electric Trucks Where They Make Sense, 2018. <https://nacfe.org/report-library/guidance-reports/>

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<sup>281</sup> <https://www.sce.com/business/electric-cars/Charge-Ready>

<sup>282</sup> [https://www.driveclean.ca.gov/Calculate\\_Savings/Incentives.php](https://www.driveclean.ca.gov/Calculate_Savings/Incentives.php)

<sup>283</sup> The fleet also includes medium and heavy-duty vehicles <https://www.act-news.com/news/generate-revenue-with-clean-fuels-lcfs/>

- Gladstein, Neandross & Associates, Game Changer Technical White Paper: Next Generation Heavy-Duty Natural Gas Engines Fueled by Renewable Natural Gas, 2016.  
<https://ngvgamechanger.com/>

Once cities have identified candidate replacement options, they should perform a total cost of ownership analysis, as described in Strategy 1.

### **Strategy 5. Establish goals and procure EVs for MD/HD vehicles were appropriate**








For MD/HD vehicle applications that are suitable for electrification, local governments can continue to advance transportation electrification by establishing EV fleet procurement goals and incorporating EVs into purchasing decisions. Several overlapping state and regional incentives can significantly reduce the upfront cost of purchasing EVs and charging equipment, helping to offset a higher initial purchase price. Cities can complete assessments to determine which vehicle types are best suited for electrification and reevaluate procurement options as EV technologies improve; vehicles that run short, predictable routes with access to centralized depot charging may be ideal candidates. The figure below summarizes the current stages or commercialization of medium and heavy-duty EVs. Information and best practices for municipal fleets can be shared through SCAQMD, SCAG, SBCTA, and local utilities. Cities may consider using relevant EV sales targets from the pending Advanced Clean Truck Regulation as a procurement target baseline.<sup>284</sup> Transit agencies in the County are required to meet the zero-emission bus provisions established in the Innovative Clean Transit Rule.<sup>285</sup>

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<sup>284</sup> <https://ww3.arb.ca.gov/regact/2019/act2019/appa.pdf>

<sup>285</sup> <https://ww3.arb.ca.gov/regact/2018/ict2018/ictfro.pdf>

**Table 46. Commercialization Stages of Medium and Heavy-Duty EV Technologies**

Vehicle Weight Class	EV Commercialization Stage		
	Commercially Available	Limited Commercial Availability	Demonstration/Prototype
Class 3 (10,001-14,000 lbs.)	 Mini Bus		
Class 4 (14,001- 16,000 lbs.)	 City Delivery		
Class 5 (16,001-19,500 lbs.)	 Large Walk In		
Class 6 (19,501-26,000 lbs.)	 School Bus		
Class 7 (26,001-33,000 lbs.)	 City Transit Bus		
Class 8 (33,001+ lbs.)	 Heavy Semi Tractor		 Semi Sleeper

CARB’s Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), CARB’s Volkswagen Beneficiary Mitigation Plan, CARB’s Air Quality Improvement Program, CEC’s Clean Transportation Program demonstration project funding, Caltrans Low Carbon Transit Operations Program, SCE’s Charge Ready Transport program, SCAQMD’s Carl Moyer Program, and CARB’s Low Carbon Fuel Standard all provide various incentives for MD/HD EVs. In many cases, vehicle, infrastructure, and fueling incentives can be stacked such that fleet managers can achieve significant savings relative diesel alternatives. The table below provides more information on State-administered programs available to facilitate the transition to MD/HD vehicles; San Bernardino County and SCAQMD have already participated directly in several of these programs.

**Table 47. State Agency MD/HD EV Incentive Programs**

Program Name	Lead Agency	Program Description
<a href="#">Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP)</a>	CARB	HVIP provides incentives for purchasers and lessees of zero-emission and low NOx MD/HD vehicles on a first-come, first-served basis. Unlike other incentive programs, HVIP does not require scrappage of replaced vehicles and can be combined with other funding sources. Vehicles operating in disadvantaged communities are eligible for increased incentives.
<a href="#">Carl Moyer Program</a>	CARB	The Carl Moyer Program is a voluntary grant program that provides funding toward the incremental cost of clean MD/HD and off-road vehicles and engines that contribute to compliance with national ambient air quality standards – operating in partnership with local air districts. The program requires scrappage of baseline vehicles.
<a href="#">VW Beneficiary Mitigation Plan (BMP)</a>	CARB	The BMP provides funding for zero-emission and low-NOx vehicles and related infrastructure that reduce the impact of NOx emissions attributable to VW’s non-compliant diesel vehicles. The BMP is primarily a scrap-and-replace program for a wide variety of MD/HD vehicle types and platforms.
<a href="#">Goods Movement Emission Reduction Program</a>	CARB	This program provides funding to local agencies to reduce air pollution attributable to freight movement in the State’s busiest transit corridors. Funding may go towards new vehicle purchases or retrofits that reduce particulate matter emissions. This program has been fully awarded.
<a href="#">Advanced Technologies Demonstration Projects</a>	CARB	This initiative is intended to accelerate the adoption of near-commercial vehicle technologies that reduce emissions. Per-vehicle incentives are relatively high for these early-stage demonstrations and intended to facilitate the commercialization of promising MD/HD vehicles across a variety of use cases.
<a href="#">Clean Off-Road Equipment Voucher Incentive Project (CORE)</a>	CARB	CORE seeks to scale the deployment of commercially available off-road equipment and on-road freight vehicles by reducing upfront cost barriers. Similar to HVIP, it will be offered on a first-come, first-served basis and offer a streamlined purchasing experience for fleets.
<a href="#">Zero and Near-Zero Emission Freight Facilities Project</a>	CARB	This project seeks to assess transformative strategies to accelerate zero and near-zero emission on-road vehicles in a manner that reduces GHGs, air pollutants, and other contaminants. SCAQMD received \$45 million for a series of zero-emission projects in and adjacent to San Bernardino County.
<a href="#">Community Air Protection Incentives</a>	CARB	The Community Air Protection Incentives program establishes a community-driven process to assess and deploy vehicles and infrastructure that improve public health in disadvantaged communities.
<a href="#">Low Carbon Fuel Standard (LCFS)</a>	CARB	The LCFS is a market-based program intended to reduce the carbon intensity of transportation fuels in California. MD/HD fleets can be

		eligible to receive revenue from LCFS credits generated by the use of low carbon fuels.
<a href="#">Low Carbon Transit Operations Program (LCTOP)</a>	Caltrans	LCTOP provides funding to transit agencies to expand transit service while reducing greenhouse gas emissions, including zero-emissions buses and fueling infrastructure. A majority of funding must benefit disadvantaged communities.
<a href="#">Intercity Rail Capital Program (TIRCP)</a>	Caltrans	TIRCP provides grant funding to modernize and decarbonize transit operations, which includes the purchase of zero-emission buses.
<a href="#">Advanced Freight and Fleet Vehicle Projects</a>	CEC	This project is funded by CEC’s Clean Transportation Program and provides funding for a range of alternative fuel MD/HD demonstration projects. A majority of projects funded to date are focused on medium or heavy-duty EVs.

### Strategy 6. Establish goals and procure natural gas MD/HD vehicles where appropriate

For MD/HD vehicle applications that are suitable for natural gas, local governments can accelerate natural gas vehicle (NGV) adoption by establishing NGV procurement targets for their fleets. Cities can prioritize NGV procurements for vehicle types that may not be suited for zero-emission vehicles in the near-term and reevaluate procurement options as zero-emission technologies become increasingly competitive. NGVs will allow cities to reduce their emissions footprint while potentially realizing fuel cost savings relative to diesel. Many of the programs identified in Table 3 such as HVIP, Carl Moyer, and Volkswagen Beneficiary Mitigation Plan all provide incentives for fleet purchases of NGVs. SCAQMD’s Vehicle Incentive Program and SCAQMD’s Lower Emission School Bus Incentive Program also provide a local source of funding for NGV purchases. For example, the City of Ontario leveraged SCAQMD funding to procure 60 NGVs – including solid waste and medium-duty trucks – that reduce its dependence on diesel fuel.<sup>286</sup>

### Strategy 7: Take advantage of vehicle master purchase contracts

Cities can often buy fuel efficient and alternative fuel vehicles at lower prices by using a state or county master contract. By leveraging these procurement programs, a city can take advantage of the larger state or county purchase contracts to gain more favorable pricing than it might otherwise. Cities have used the state Department of General Services (DGS) and Los Angeles County contracts for this purpose.

DGS awards master vehicle contracts to individual dealerships for specific models of vehicles within a general class of vehicles, such as hybrid sedans. Local agencies can order vehicles directly from selected dealerships under the DGS master vehicle contracts. Local agencies can order vehicles directly from the selected dealerships under the DGS master contracts. More detailed information on the purchasing

<sup>286</sup> <https://www.socalgas.com/documents/innovation/natural-gas-vehicles/NGV-Ontario-Solid-Waste-CNG-Trucks.pdf>

process can be found on DGS’s website, including the following resource:

<https://www.green.ca.gov/fleet/Documents/147013-DGS-DriveGreen-2019-ADA.pdf>.

### **Strategy 8: Establish RNG procurement goals for natural gas fleet vehicles**

If a city is operating natural gas vehicles, the GHG emissions from these vehicles can be significantly reduced by using renewable natural gas (RNG). Some state incentive programs, such as HVIP, already require vehicles purchased through the program to secure RNG contracts to cover all of the planned vehicle fuel use. However, local governments can build on this requirement by procuring RNG to cover the fuel use of all NGV fleet vehicles – reducing the emissions associated with fleet vehicle operations. For example, the City of Ontario signed a five-year, 3 million gallon-equivalent RNG contract with Clean Energy in 2019 to support city fleet operations.<sup>287</sup>

### **Strategy 9: Establish renewable diesel procurement goals for fleets**

For diesel vehicles in city, county, and school district fleets, local governments can establish renewable diesel procurement goals to lower the GHG emissions associated with vehicle operation – including vehicles typically exempted from SCAQMD source specific standards such as Rule 1191 or Rule 11196.<sup>288</sup> Renewable diesel is a drop-in replacement for fossil diesel at all blend levels, and cities can contract with fuel suppliers to supply renewable diesel to support their fleet operations at prices comparable to fossil diesel.<sup>289</sup> The City of Oakland procures Neste renewable diesel to fuel all 366 diesel vehicles in their fleet.<sup>290</sup>

## **7.3 Private Vehicles**

Most of those who live in, work in, or visit San Bernardino County drive a light duty passenger vehicle. As discussed in Section 7.1, EVs are the recommended alternative for reducing both air pollution and GHG emissions from light duty vehicles. This section describes strategies for local governments to encourage the purchase and use of EVs in their jurisdictions. Most detailed information in SBCTA’s recently completed Zero-Emission Vehicle Readiness and Implementation Plan.<sup>291</sup>

### **Strategy 10: Assess clean vehicle registrations in local jurisdictions**

Cities can plan more effectively for the transition to alternative fuel vehicles by completing a detailed assessment of vehicle registrations in their jurisdiction. The California Department of Motor Vehicles compiles and reports data on vehicle registrations by fuel type, by county, city, or zip code.<sup>292</sup> This data

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<sup>287</sup> <https://www.greencarcongress.com/2019/11/20191106-rng.html>

<sup>288</sup> <http://www.aqmd.gov/docs/default-source/rule-book/reg-xi/rule-1191.pdf?sfvrsn=4>;  
<http://www.aqmd.gov/docs/default-source/rule-book/reg-xi/rule-1196.pdf?sfvrsn=6>

<sup>289</sup> Renewable diesel is currently more expensive to produce than fossil diesel, but Low Carbon Fuel Standard credit revenue allows renewable diesel to be priced more competitively with fossil diesel.

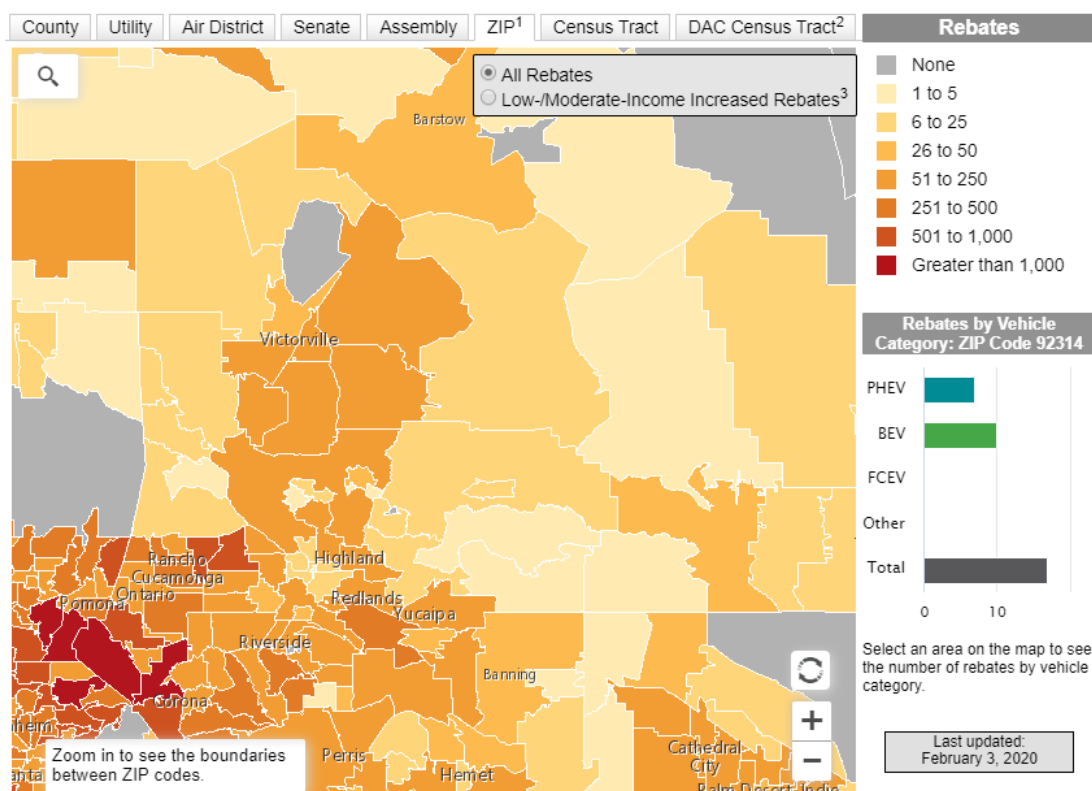
<sup>290</sup> <https://www.oaklandca.gov/news/2019/city-of-oakland-drives-environmental-progress-with-new-renewable-diesel-model>

<sup>291</sup> [https://www.gosbcta.com/wp-content/uploads/2019/10/ICT-fact-sheet\\_011620.pdf](https://www.gosbcta.com/wp-content/uploads/2019/10/ICT-fact-sheet_011620.pdf)

<sup>292</sup> [https://www.dmv.ca.gov/portal/dmv/detail/pubs/media\\_center/statistics](https://www.dmv.ca.gov/portal/dmv/detail/pubs/media_center/statistics)

source can be used to determine the number and percent of battery electric, plug-in hybrid, fuel cell, ethanol, and natural gas vehicles are registered at the city level. Officials can develop estimates by assuming its share of the vehicle registrations is commensurate with a city’s share of the total County population. Officials can also develop more accurate estimates of EVs and FCEVs in their jurisdiction by using CVRP data. According to the Zero-Emission Vehicle Readiness and Implementation Plan, 52 percent of CVRP rebates were for PHEVs, 46 percent for BEVs, and 2 percent for FCEVs.<sup>293</sup> The Center for Sustainable Energy also maintains a rebate map that provides zip code and census tract-level information that cities can use. The figure below shows CVRP participation by zip code across a portion of San Bernardino County.

**Figure 94. CVRP Rebates by Geography: San Bernardino County**



Source: Center for Sustainable Energy

### Strategy 11: Identify gaps in EV charging infrastructure

Similar to the clean vehicle registration assessment, cities can also identify gaps in local EV charging infrastructure networks by developing a greater understanding of current public charging investments. The U.S. Department of Energy’s Alternative Fuels Data Center Station Locator tool provides detailed information on publicly available charging infrastructure, including: station address, contact number, charging station type, plug type, number of outlets, and hours of accessibility.<sup>294</sup> Station Locator maps can provide cities with a comprehensive view of where public charging infrastructure exists and where

<sup>293</sup> [https://www.gosbcta.com/wp-content/uploads/2019/10/SBCOG-ZEV-Plan\\_Final-10-4-19\\_Online-3.pdf](https://www.gosbcta.com/wp-content/uploads/2019/10/SBCOG-ZEV-Plan_Final-10-4-19_Online-3.pdf)

<sup>294</sup> <https://afdc.energy.gov/stations/#/find/nearest>



gaps remain. Maps may be particularly valuable for closing gaps in DCFC infrastructure needed to enable intercity highway corridor travel and reduce range anxiety among prospective EV drivers. SBCTA’s Zero-Emission Vehicle Readiness and Implementation Plan recommends deploying DCFC stations at least every 50 miles to facilitate inter- and intra-county travel.<sup>295</sup> Planned Electrify America charging stations will address charging access in some areas, but infrastructure gaps will remain across rural areas in the County and on major corridors such as I-15 and I-40. The table below presents recommendations from the Zero-Emission Vehicle Readiness and Implementation Plan on potential DCFC station sites.

**Table 48. Potential DCFC Sites in San Bernardino County**

New DCFC Location	Potential Sites	Rationale
<b>Ludlow (I-40)</b>	Dairy Queen, Chevron, Ludlow Inn	Additional coverage between Barstow and planned Electrify America station
<b>Fenner (I-40)</b>	Hi Sahara Oasis	Additional coverage between Needles and planned Electrify America station
<b>Needles (I-40)</b>	Needles Chamber of Commerce	Provide CCS/CHAdEMO coverage in Needles
<b>Vidal (SR 62)</b>	Vidal Chevron	Additional coverage between Needles and County Line
<b>Twentynine Palms (SR 62)</b>	Phoenix Redevelopment Site	Additional coverage between Yucca Valley and County Line, provide CCS/CHAdEMO coverage in Twentynine Palms
<b>Yucca Valley (SR 62)</b>	Stater Bros. Market, Southern California Edison, Vons	Additional coverage between Los Angeles and Big Bear and Twentynine Palms
<b>Big Bear Lake (SR 18)</b>	Big Bear Lake Convention Center	Additional coverage between Los Angeles and Yucca Valley

Source: Center for Sustainable Energy, *Zero-Emission Vehicle Readiness and Implementation Plan*, Prepared for San Bernardino County Transportation Authority, 2019.

### Strategy 12: Streamline EV charging station permitting processes in accordance with AB 1236

Assembly Bill (AB) 1236 requires most California cities to develop ordinances to streamline EV charging station permitting processes and provide clarity for EV charging service providers, site hosts, and local governments seeking to accelerate EV adoption.<sup>296</sup> The table below illustrates the key requirements of the bill.

**Table 49. AB 1236 Requirements**

AB 1236 Compliant	Not AB 1236 Compliant (Challenging to Deploy Charging)

<sup>295</sup> [https://www.gosbcta.com/wp-content/uploads/2019/10/SBCOG-ZEV-Plan\\_Final-10-4-19\\_Online-3.pdf](https://www.gosbcta.com/wp-content/uploads/2019/10/SBCOG-ZEV-Plan_Final-10-4-19_Online-3.pdf)

<sup>296</sup> [https://leginfo.ca.gov/faces/billNavClient.xhtml?bill\\_id=201520160AB1236](https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB1236)

Ordinance creating an expedited, streamlined permitting process for electric vehicle charging stations (EVCS) including level 2 and direct current fast chargers (DCFC) has been adopted	No permit streamlining ordinance; and/or ordinances that create unreasonable barriers to EVCS installation
Checklist of all requirements needed for expedited review posted on Authority Having Jurisdiction (usually a city or county) website	No checklist for EVCS permitting requirements
EVCS projects that meet expedited checklist are administratively approved through building or similar non-discretionary permit	Permitting process centered around getting a discretionary use permit first
EVCS projects reviewed with the focus on health and safety	EVCS projects reviewed for aesthetic considerations in addition to building and electrical review
AHJ accepts electronic signatures on permit applications	Wet signatures required on one or more application forms
EVCS permit approval not subject to approval of an association (as defined in Section 4080 of the Civil Code)	EVCS approval can be conditioned on the approval of a common interest association
AHJ commits to issuing one complete written correction notice detailing all deficiencies in an incomplete application and any additional information needed to be eligible for expedited permit issuance	New issue areas introduced by AHJ after initial comments are sent to the station developer

Source: California Governor’s Office of Business and Economic Development (GO-Biz)

Many cities in San Bernardino County have not fully met the requirements of the law. In order to efficiently deploy charging infrastructure on a large scale while conserving local governments’ time and resources, cities can develop a streamlining ordinance and publish an online checklist for an expedited review of charging station permit applications. Cities can also strive to exceed the requirements of the law by publishing relevant permitting guidance documents, designating a charging station permitting expert on staff, holding pre-application meetings with prospective charging station site hosts, conducting concurrent permit reviews among relevant city departments, and taking additional steps to increase transparency in the application process. According to the California Governor’s Office of Business and Economic Development (GO-Biz), the City of Riverside has a “streamlined” permit application process and an online checklist available for applicants seeking a permit for charging station installations.<sup>297</sup>

<sup>297</sup>[https://library.municode.com/ca/riverside/codes/code\\_of\\_ordinances?nodet=PTIICOOR\\_TIT16BUCO\\_CH16.23\\_ELVECHSTSTPEPR](https://library.municode.com/ca/riverside/codes/code_of_ordinances?nodet=PTIICOOR_TIT16BUCO_CH16.23_ELVECHSTSTPEPR); <https://www.riversideca.gov/building/drawings.asp>

## Strategy 13: Update and strengthen EV-Ready building codes beyond CALGreen requirements

The state’s green building code, CALGreen, sets requirements for the construction of new buildings in California and has recently developed requirements for the installation of electrical infrastructure (e.g. conduit, panels) that supports the deployment of EV charging stations. As of January 2020, newly constructed buildings are required to meet the updated specifications outlined in the table below.

**Table 50. CALGreen 2020 EV Ready Requirements**

Building Type	Requirement
<b>Single Family Residences, Duplexes, and Townhomes (with garages)</b>	Must install conduit and panel capacity to support future installation of Level 2 charging stations
<b>Multi-unit Dwellings</b>	Must install conduit and panel capacity to support future installation of Level 2 charging stations at a minimum of 10% of parking spaces
<b>Non-Residential Buildings</b>	Must install conduit and panel capacity to support future installation of Level 2 charging stations at 4-10% of parking spaces depending on number parking spaces available.

Source: California Department of General Services

CALGreen has also developed “reach codes” that outline how local jurisdictions can exceed the requirements specified in the building code. These reach codes typically require higher percentages of parking spaces to be equipped with conduit and panel capacity necessary for additional Level 2 charging station deployments. Cities can also demonstrate leadership by strengthening EV readiness requirements beyond the furnishing of conduits and panels to include the installation circuits and wiring to support EV charging stations – further reducing the cost and complexity of deploying EV charging stations at the building site. Cities can also extend building codes to include existing buildings – particularly in cases when existing buildings undergo major retrofits. Cities can also explore and encourage the use of EV energy management systems (EVEMS) in meeting building code requirements for multi-unit dwellings and non-residential buildings. At a fundamental level, EVEMS allow more charging stations to be deployed with a fixed amount of electrical capacity by sharing, cycling, or delaying EV charging across multiple stations; these systems can potentially reduce the cost of complying with building codes without significantly altering the charging experience for EV drivers.

The City of Oakland’s EV-readiness ordinance requires new electric panel capacity to service 20 percent of parking spaces in new multi-unit dwellings and non-residential buildings as well as full circuits installed for 10 percent of parking spaces.<sup>298</sup> The City of San Francisco applies EV-ready building codes to existing buildings undergoing “major alterations” – defined as significant upgrades where the area of construction exceeds 25,000 square feet.<sup>299</sup> The City of Vancouver requires 100 percent of parking

<sup>298</sup> <http://www2.oaklandnet.com/oakca1/groups/pwa/documents/report/oak063669.pdf>

<sup>299</sup> <https://sfbos.org/sites/default/files/o0092-17.pdf>

spaces in new multi-unit dwellings to be EV-ready but does not require panel upgrades to serve 100 percent of spaces at full power – suggesting that buildings can employ EVEMS to meet the requirements of the code without significant panel upgrades.<sup>300</sup>

### **Strategy 14: Update and strengthen EV-Ready parking and zoning ordinances for new buildings**

City parking regulations and requirements can also encourage EV charging station deployment. Many cities and municipalities have minimum parking requirements that govern the number of spaces that real estate developers need to provide for certain building types. Developers may be hesitant to deploy charging in new and existing buildings if parking spaces equipped with charging infrastructure are not counted toward minimum parking requirements – particularly in urban areas with limited land availability. Updated parking ordinances that recognize EV charging equipped spaces as parking spaces (and not traditional fueling stations) will create certainty for project developers looking to deploy charging stations at commercial properties. Cities can go further to incentivize EV charging stations in new buildings by allowing EV charging equipped spaces to count as *two* parking spaces for the purposes of meeting local minimum parking requirements – potentially reducing developer costs associated with satisfying zoning requirements. For example, the City of Stockton allows parking spaces equipped with EV charging stations to count as two parking spaces for up to 10 percent of total parking required by the local zoning ordinance.<sup>301</sup> Cities can also encourage EV car sharing by modifying parking ordinances to reduce parking requirements when EV car sharing is used on site: for every space designated for car sharing, the City of Santa Monica allows building developers to reduce their parking requirement by two spaces.<sup>302</sup> Finally, cities can designate priority parking spaces at municipally owned lots as EV-only and update local parking codes to enforce compliance via fines or other mechanisms.<sup>303</sup>

### **Strategy 15: Deploy charging infrastructure through existing and pending utility transportation electrification programs, state programs, and regional programs**

SB 350 has been the legislative driver behind the portfolio of investor-owned utilities' transportation electrification programs – providing over \$1 billion in cumulative investment to support the electrification across all vehicle classes.<sup>304</sup> SCE has implemented and in the process of implementing several programs to increase access to EV charging across its service territory, and SCE's Charge Ready 2 program is currently pending before the California Public Utilities Commission. Local officials can coordinate early on with SCE to determine whether municipally owned parking lots at parks, schools, libraries, and other locations would be eligible and suitable sites under the program. Cities can also avail themselves of funding from the California Energy Commission's (CEC) Southern California Incentive Project (SCIP) under CALeVIP.<sup>305</sup> The SCIP provides up to \$80,000 per Direct Current Fast Charger and

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<sup>300</sup> <http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf>

<sup>301</sup> [https://qcode.us/codes/stockton/view.php?topic=16-3-16\\_64-16\\_64\\_030&frames=off](https://qcode.us/codes/stockton/view.php?topic=16-3-16_64-16_64_030&frames=off)

<sup>302</sup> [http://www.qcode.us/codes/santamonica/view.php?topic=9-3-9\\_28-9\\_28\\_180](http://www.qcode.us/codes/santamonica/view.php?topic=9-3-9_28-9_28_180)

<sup>303</sup> Note that cities can adapt priority parking spaces to include other alternative fueled vehicles such as FCVs.

<sup>304</sup> [https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill\\_id=201520160SB350](https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350)

<sup>305</sup> CALeVIP is the California Electric Vehicle Infrastructure Project.

has allocated \$2 million to support fast charging deployment in San Bernardino County.<sup>306</sup> At the time this memo was written, over \$700,000 in incentives remain available; city and county officials can leverage these funds to support fast charging deployment at municipal sites along major highway corridor routes and other high demand areas. Metropolitan Planning Organizations have also established EV charging station incentive programs to achieve light-duty vehicle greenhouse gas emissions reductions pursuant to SB 375.<sup>307</sup> In its 2016 Regional Transportation Plan/Sustainable Communities Strategy, SCAG proposed a \$274 million Regional Charging Station Network initiative to support the deployment of 380,000 Level 1 and 2 stations across SCAG’s footprint.<sup>308</sup> SCAQMD has developed the Residential EV Charging Incentive Pilot Program, which provides up to \$500 in rebates toward the purchase of residential Level 2 chargers for qualified residents in the air district’s jurisdiction.<sup>309</sup> Cities may also want to partner with utilities to engage directly with convenience stores in their jurisdictions; convenience stores may be ideal locations for new Direct Current Fast Charging stations

### **Strategy 16: Explore the feasibility of implementing EV car sharing services**

Cities have begun promoting alternatives to vehicle ownership via EV car sharing and other shared mobility services. Car sharing services could provide access to e-mobility for residents that may not be able to afford a personal vehicle and may serve as a complement to public transit. Charging infrastructure deployment at designated car sharing parking spaces may also be necessary to refuel EVs in a timely manner and maintain high utilization levels. CARB’s CVRP, California Strategic Growth Council Transformative Climate Communities Grants, and private company investment could all serve as potential funding sources for car sharing initiatives. Los Angeles’ BlueLA is all-electric car sharing service with approximately 100 vehicle and 200 charging stations at 35 Central Los Angeles locations.<sup>310</sup> The service is available 24/7 and members do not incur any maintenance, parking, or insurance fees. Low-income members qualify for discounted pricing.

### **Strategy 17: Advocate for new and existing programs and policies that advance EVs at the state level**

Local government and SCAQMD can engage the California Assembly and state agencies to encourage the expansion of programs and increased stringency of regulations that would accelerate EV adoption in San Bernardino County. Participation in public hearings and comment periods can help demonstrate San Bernardino County’s leadership and commitment to advance transportation electrification. Examples of existing state level incentive programs for light duty vehicles are included in the following table.

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<sup>306</sup> <https://calevip.org/incentive-project/southern-california>

<sup>307</sup> [https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill\\_id=200720080SB375](https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200720080SB375)

<sup>308</sup> [http://scagrtpscs.net/Documents/2016/final/f2016RTPSCS\\_MobilityInnovations.pdf](http://scagrtpscs.net/Documents/2016/final/f2016RTPSCS_MobilityInnovations.pdf)

<sup>309</sup> <http://www.aqmd.gov/home/programs/community/community-detail?title=ev-charging-incentive>

<sup>310</sup> <https://www.bluela.com/>

**Table 51. State Agency Light Duty EV Incentive Programs**

Program Name	Lead Agency	Program Description
<a href="#">Clean Vehicle Rebate Project (CVRP)</a>	CARB	CVRP provides incentives toward the purchase of new, qualified battery electric and plug-in hybrid electric vehicles for qualified drivers. Funds are awarded on a first-come, first-served basis.
<a href="#">Clean Cars 4 All Program</a>	CARB	Clean Cars 4 All promotes cleaner air by providing low-income residents in eligible air districts with incentives to scrap and replace their old vehicle with low-emission options such as EVs or transit passes. The program also supports incentives for residential EV chargers.
<a href="#">Clean Mobility Options</a>	CARB	Clean Mobility Options is a grant-based program to address the transportation needs of low-income and disadvantaged community residents. The program supports initiatives such as zero-emission carsharing and vanpooling.
<a href="#">VW Beneficiary Mitigation Plan (BMP)</a>	CARB	The BMP provides modest funding opportunities to support fueling infrastructure for zero-emission vehicles, including EVs.
<a href="#">Financing Assistance for Lower-Income Consumers</a>	CARB	This initiative provides attractive financing options for qualified California residents on a grant basis for the purchase of low and zero-emission vehicles.
<a href="#">Zero-Emission Assurance Project (ZAP)</a>	CARB	ZAP provides incentives toward the replacement of EV batteries and fuel cells in used EVs for qualified California drivers. The program will launch in 2020.
<a href="#">CALeVIP</a>	CEC	CALeVIP provides rebates for the purchase and installation of publicly accessible and shared use charging infrastructure on a first-come, first-served basis. The program has funded both L2 and DCFC charging infrastructure to date.

Local jurisdictions can also encourage their state representatives to support new statutes that provide explicit authority for cities to advance regulations that advance EVs and other alternative fuel vehicles. For example, statutes that enable cities to establish zero-emission zones could accelerate EV adoption while providing local governments with a new source of revenue.<sup>311</sup> These zones may be effective in larger, more congested cities and would be accessible to non-zero-emission vehicles for fee, further encouraging drivers to transition to EVs. Equity will be an important consideration as cities contemplate the location of zones, pricing schedules, and potential exemptions.

<sup>311</sup> <https://ww2.arb.ca.gov/sites/default/files/2019-12/SB%20498%20Report%20Draft%20121719.pdf>

## **Strategy 18: Engage disadvantaged and low-income communities on the benefits of EVs**

Residents in disadvantaged communities (DACs) and low-income communities (LICs) often face significant challenges to owning EVs. Recent initiatives taken by state and local actors, including CARB's Clean Mobility Options program, are beginning to support a more equitable transition to EVs for residents in these communities. Local and regional agencies, in partnership with community-based organizations, should seek opportunities to engage and educate low-income residents – providing information on EV technologies, benefits, relevant local events, and relevant programs to accelerate transportation electrification in DACs and LICs. All presentations and outreach materials should be available in appropriate languages. Cities and metropolitan planning organizations can also designate an internal liaison to lead engagements with local community partners. For example, SCAG has an Environmental Justice (EJ) Working Group, which serves as a forum to share information on EJ issues related to planning and transportation. SCAG's extensive network of local government members also allows for SCAG to compare outreach and engagement efforts across local jurisdictions.

## **Strategy 19: Develop a Climate Action Plan (CAP) that prioritizes clean vehicles and fuels**

Cities and county governments can develop and regularly update CAPs in accordance with local and state climate goals. CAPs leverage existing information from greenhouse gas inventories to establish greenhouse gas mitigation targets, identify cost-effective strategies to achieve these targets, and develop monitoring mechanisms to evaluate progress. Light-duty vehicles are a leading source of greenhouse gas emissions in many local jurisdictions, and cities have identified actions to accelerate the adoption of alternative fuel vehicles – including EVs.<sup>312</sup> CAPs can introduce a series of aggressive EV adoption and transportation sector emission reduction targets while outlining the necessary actions needed to reach these goals. The California Strategic Growth Council Sustainable Communities Planning Grants, along with city funding, can provide resources needed to draft and support implementation of local CAPs.<sup>313</sup> For example, the City of Brawley received a grant from the California Strategic Growth Council to develop a climate action plan, which included measures to increase EV adoption and streamline city regulations to encourage EV charging station deployment.<sup>314</sup> San Bernardino County is also currently updating its CAP.

## **7.4 Commercial Fleet Vehicles**

Most of the commercial vehicles in San Bernardino County are medium- and heavy-duty used to transport freight. Given its concentration of warehouses, logistics providers, and transportation companies, the County has a disproportionately large share of commercial vehicle travel and emissions. There are opportunities for local governments to encourage cleaner vehicles among commercial fleets based in the County and among trucks serving County businesses. The County is also traversed by

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<sup>312</sup> CAPs can encourage the adoption of a wide variety of low carbon transportation fuels, including but not limited to: electricity, hydrogen, renewable natural gas, and liquid biofuels.

<sup>313</sup> <http://bondaccountability.resources.ca.gov/Program.aspx?ProgramPK=121&Program=SGC%20Sustainable%20Communities%20Planning%20Grants%20-%20DOC&PropositionPK=4>

<sup>314</sup> [http://www.brawley-ca.gov/cms/kcfinder/upload/files/planning/Brawley\\_Draft\\_Climate\\_Action\\_Plan.pdf](http://www.brawley-ca.gov/cms/kcfinder/upload/files/planning/Brawley_Draft_Climate_Action_Plan.pdf)



several major freeways that carry trucks moving between Southern California seaports and the rest of the U.S. Because many of these vehicles do not stop in San Bernardino County, there is less opportunity for local governments to influence them, although the provision of charging stations and other alternative fuel infrastructure could be beneficial.

As discussed earlier in this section, the most appropriate clean vehicle technologies and fuels for medium- and heavy-duty trucks differ by vehicle type and application, and in some cases are unclear because technology development and acceptance lags behind that of light-duty passenger vehicles. For this reason, it would be inappropriate for a city to invest significant public resources in a particular technology or fuel type. Rather, cities should remove any barriers to private sector investment in clean vehicles and fuels, and should support public projects that have a strong likelihood of long-term usefulness.

### **Strategy 20: Streamline EV charging station permitting processes in accordance with AB 1236**

Similar to light-duty EVs, MD/HD EVs benefit from streamlined permitting processes for the deployment of corresponding EV charging infrastructure. However, the need for streamlined permitting may be even more critical in the case of MD/HD EVs. Protracted permitting processes can negatively impact a fleet owner's experience in transitioning to EVs and may reinforce negative perceptions about vehicle performance. Moreover, the battery size and duty cycles of MD/HD vehicles may require a greater proportion of charging stations to be Direct Current Fast Charging stations – which may require a more complex permit review process. Streamlining permitting for MD/HD fleets will accelerate the region's progress toward meeting climate and air quality goals while making the charging station deployment process simpler for fleet owners.

### **Strategy 21: Educate and enroll fleet customers in beneficial electricity rate plans**

Electricity rates can significantly affect the total cost of ownership of EVs and influence fleet operators' willingness to transition to electric technologies. Determining electric fuel costs under rate schedules that vary by time of use (kilowatt-hours) and electricity demand (kilowatts) may also be new to many operators. SCE's current general service time of use (TOU) EV rates, including the tariff shown below, eliminate demand charges for customers through 2024, and then gradually phases demand charges back into the rate design – allowing customers to become familiar with EV technologies and determine how to best manage their electricity demand. These rates will likely help fleet owners manage their electricity costs as they transition to EVs. However, SCE should actively encourage MD/HD EV customers to enroll in the appropriate EV rate plan and educate customers on how they can manage their electricity demand to reduce exposure to demand charges, mitigate the risk of utility electrical upgrades, and improve the total cost of ownership of operating EV fleets.

**Table 52. SCE TOU-EV-8 Electricity Rate for Commercial EV Customers**

TOU-EV-8 Large Power with Monthly Max Demand between 21 - 500 kW EV-Only		2019-2023	2024	2025	2026	2027	2028	2029+
TOU Period		All Energy Rate Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Full FRD Rate Year 11
Summer On - \$/kWh	4-9pm weekdays	\$0.41816	\$0.41131	\$0.40447	\$0.39762	\$0.39077	\$0.38393	\$0.25882
Summer Mid - \$/kWh	4-9pm weekends	\$0.27718	\$0.27034	\$0.26349	\$0.25664	\$0.24980	\$0.24295	\$0.20051
Summer Off - \$/kWh	All except 4-9pm all days	\$0.12550	\$0.11866	\$0.11181	\$0.10496	\$0.09812	\$0.09127	\$0.10135
Winter Mid - \$/kWh	4-9pm all days	\$0.27801	\$0.27116	\$0.26432	\$0.25747	\$0.25062	\$0.24378	\$0.20134
Winter Off - \$/kWh	9pm-8am all days	\$0.13206	\$0.12522	\$0.11837	\$0.11152	\$0.10467	\$0.09783	\$0.11078
Winter Super-Off- \$/kWh	8am-4pm all days	\$0.08133	\$0.07448	\$0.06764	\$0.06079	\$0.05394	\$0.04710	\$0.05837
Customer Charge (\$/Month)		\$106.75	\$106.75	\$106.75	\$106.75	\$106.75	\$106.75	\$106.75
FRD (\$/kW)		\$0.00	\$1.99	\$3.99	\$5.98	\$7.97	\$9.97	\$11.96
% of Final FRD		0	16.67%	33.33%	50.00%	66.67%	83.33%	100.00%
FRD % Increase By Year			16.67%	16.67%	16.67%	16.67%	16.67%	16.67%

Source: California Public Utilities Commission

SCE’s TOU-EV-8 rate plan provides opportunities for fleet operators to realize potential fuel cost savings relative to standard commercial electricity rates. SCE also has a dedicated transportation electrification team committed to advising commercial customers on charging infrastructure and rate options for MD/HD EVs.<sup>315</sup>

### Strategy 22: Advocate for programs and policies that advance MD/HD EVs at the state level

Local government actors can drive the electrification of MD/HD vehicles by encouraging the expansion of supportive policies and programs. Participation in public hearings and comment periods can help demonstrate San Bernardino County’s leadership and commitment to advance MD/HD EVs. Beyond advocating for incentive programs described above, local jurisdictions can play an active role influencing pending CARB regulations.

New statutory authority to establish zero-emission zones could also encourage the adoption of MD/HD EVs. Green loading or logistics zones in areas with elevated criteria pollutant emissions could create further incentives to adopt zero-emission vehicles, which may not be subject to fees or access limitations to these zones.<sup>316</sup> Zone-based regulations may be dynamic and become increasingly stringent as EV technologies become more commercially available.

### Strategy 23: Update and streamline permitting requirements for hydrogen fueling stations

As discussed in Section 7.1, the future is uncertain for fuel cell vehicles. Investment of public funds in hydrogen fueling infrastructure is not recommended due to this uncertainty. However, if there is private sector interest in hydrogen fueling infrastructure, local governments should not discourage this investment. FCVs may prove feasible for select MD/HD applications, and if to, local agencies will have an

<sup>315</sup> <http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf>

<sup>316</sup> <https://ww2.arb.ca.gov/sites/default/files/2019-12/SB%20498%20Report%20Draft%20121719.pdf>

important role to play in the siting and installation of hydrogen fueling infrastructure for MD/HD vehicles. Cities can improve installation processes by identifying hydrogen as a transportation fuel in zoning ordinances, reviewing permit applications solely based on health and safety criteria, exempting hydrogen fueling stations from CEQA review processes where appropriate. All permitting requirements can be made accessible via an online checklist for station developers and fleet managers seeking to streamline installation processes. SCAQMD can potentially advise cities on best practices and experiences with deploying fueling infrastructure for fuel cell demonstration projects.

### **Strategy 24: Update and streamline permitting requirements for natural gas fueling stations**

NGVs powered by RNG will likely remain part of a comprehensive strategy to reduce emissions from MD/HD vehicles in San Bernardino County, and expanding natural gas fueling infrastructure will be critical for supporting the adoption of new NGVs. Inefficient and opaque review processes can cause project delays that hinder the adoption of CNG vehicles and delay the transition away from diesel vehicles. Cities can facilitate private investment this infrastructure by ensuring that permitting of natural gas fueling stations is streamlined and efficient. Zoning ordinances can clarify natural gas' use as a transportation fuel, and permitting officials could review applications solely based on health and safety criteria – ensuring that reasonable fueling projects get approved. Permitting requirements can be made accessible via online checklist for station developers and fleet managers seeking to deploy CNG fueling stations. Similar to hydrogen fuel cell projects, SCAQMD may also be able to provide guidance to cities on best practices for streamlining CNG station deployment.

### **Strategy 25: Encourage clean trucks through permitting of warehouses and industrial facilities**

In some instances, cities can use the permitting process to encourage cleaner vehicles at new warehouses and industrial facilities. Cities may require a conditional use permit (CUP) for approval of new development. CUPs are intended as a tool for the city to review and provide input on a facility's design and place restrictions on its operations, prior to project approval. CUPs are conventionally used to address environmental concerns in new land uses. CUPs place performance standards on a new land development in order to ensure compliance with general plan policies and local ordinances.

For warehouses and industrial facilities, performance standards in CUPs could include:

- If the facility owner operates a truck fleet at the site, a requirement that a portion of the fleet be a zero emission or near-zero emission vehicle.
- Requirement to install onsite electric truck charging infrastructure or hydrogen fueling infrastructure
- Requirement that facility developers and owners to establish an investment plan supporting zero-emission infrastructure.
- Requirement that the facility operator adopt a rate structure that incentivizes contracting with trucking companies that utilize the lowest emitting transport technologies.

Property and Business Improvement Districts (PBID) or Enhanced Infrastructure Financing Districts (EIFD), AB 617 Community Air Protection Incentives, and CARB's Zero and Near Zero Emission Freight

Facility program all provide potential funding sources for fleet managers to leverage for transitioning to alternative fuel vehicles.

### **Strategy 26: Invest in knowledge maintenance on emerging clean vehicle technologies**

The MD/HD transportation sector is undergoing rapid change with the emergence of zero-emission alternatives to traditional diesel vehicles across an array of vehicle platforms. Many new models are expected to be commercially available in 2021 or shortly thereafter. However, many pilots and vehicle demonstration projects are underway now assessing the performance of these emerging technologies. Some of these efforts are taking place in or adjacent to San Bernardino County as part of a continued effort to reduce local emissions. Cities can reach out to CARB and other State and regional agency funders of these projects to gather more information on pilot parameters and gain preliminary insights into the viability of various zero-emission vehicle options. For example, Volvo LIGHTS (Low Impact Green Heavy Transport Solutions) is a program using funding from California Climate Investments (Cap-and-Trade revenue) to demonstrate battery electric trucks across Southern California. Several of the pilots are located in San Bernardino County, including:

- Dependable Supply Chain Solutions in Ontario is installing two 150 KW fast charging stations and deploying three Volvo heavy-duty battery electric trucks;
- TEC Equipment in Fontana and La Mirada will deploy 15 Volvo heavy-duty battery electric trucks, two 150 KW fast charging stations, and two 50 KW fast charging stations; and
- San Bernardino Valley College (SBVC) Heavy/Medium Duty Truck Technology Department is designing Certificate and Associate's degree-level training program specific to heavy-duty, battery electric truck maintenance to promote the region's workforce development.

## 8 Conclusion – Discussion of Opportunities and Risks

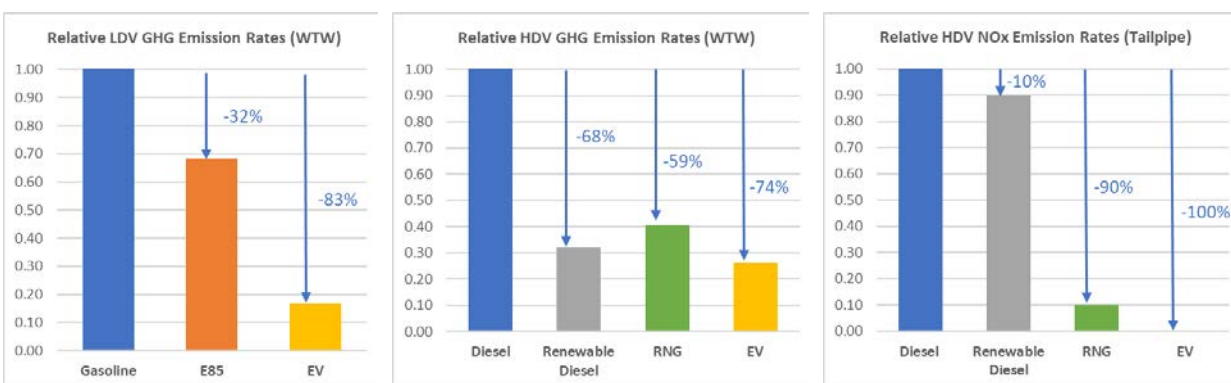
The information presented in this report shows the complexity involved in reducing emissions from the transportation sector. Each clean vehicle technology and alternative fuel option differs in terms of emissions benefits, vehicle and fuel costs, infrastructure requirements, technology readiness, and other factors. Some of the options are evolving rapidly, which adds to the uncertainty regarding future conditions. Given the complexities and uncertainties, it is impossible to identify, with a high degree of precision, a single set of actions for public and private sector entities seeking to advance clean transportation. The best approach is to understand the opportunities and risks associated with each clean transportation option, and to use this understanding to guide actions, with the recognition that shifts in direction may be needed over time. As a conclusion to the report, this section summarizes these opportunities and risks.

### Emissions Benefits

Tackling the dual challenge of climate change and ozone air pollution requires reducing emissions of two key pollutants: GHGs and NOx. Both EVs and natural gas vehicles using RNG will result in large reductions of these two pollutants. There are slight differences in the emissions benefits of these two options. GHG impacts depend on the electricity generation sources (which are becoming cleaner over time) and the source of RNG feedstock. EVs emit zero tailpipe emission of NOx, while NGVs emit small levels of NOx. Nonetheless, these differences are minor relative to the magnitude of emission reductions from both EVs and NGVs. In other words, emissions benefits alone should not be used to make a choice between EVs and NGVs – both options are highly beneficial.

Liquid biofuels, in contrast, can achieve large GHG reductions but only small NOx reductions. For this reason, biofuels such as ethanol, biodiesel, and renewable diesel can play an important role but should not be the centerpiece of the emission reduction strategy for San Bernardino County. The figure below illustrates the differences in emission rates for a typical LDV and HDV in 2018.

**Figure 95. Relative Emission Rates of Sample Vehicles, 2018**



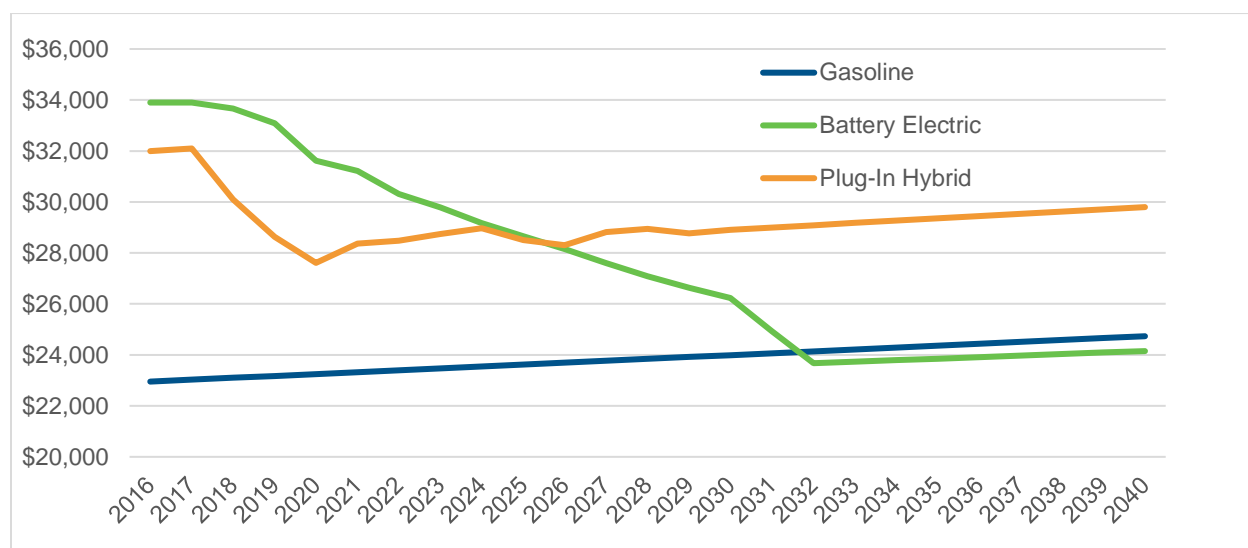
## Vehicle Costs and Incentives

One of the primary barriers to mass adoption of EVs and NGVs is the higher purchase price of these vehicles as compared to conventional gasoline and diesel vehicles. A light duty automobile EV currently costs 20 to 50 percent more than a similar gasoline vehicle; the price premium for an EV truck is even greater. A heavy-duty natural gas truck currently costs 20 to 50 percent more than a comparable diesel truck. EVs and NGVs benefit from lower fueling and operating costs (discussed below), so the total cost of ownership for EVs and NGVs can be lower, especially for vehicles with high annual mileage. But the current price premium prevents many buyers from considering these cleaner options, particularly given today’s low gasoline and diesel fuel prices. A major benefit of biofuels like renewable diesel is that they can be used in existing vehicles with little or no modification.

Government incentives can help overcome clean vehicle purchase costs, but existing incentive programs are inadequate to achieve significant market transformation. The federal tax credit of up to \$7,500 has helped spur EV sales as discussed in Section 6, but it is now being phased out as leading manufacturers reach the sales threshold. State incentive programs like HVIP have encouraged early adoption of heavy-duty EVs, but grant funding from these programs is regularly oversubscribed. Moreover, it is challenging to design and implement vehicle purchase incentives in a way that achieves the desired outcomes – enabling sales of clean vehicles that would not have otherwise occurred. For example, some have criticized state incentive programs like the CVRP for distributing funds to high income buyers who might have purchased an EV even without the rebate.

Looking ahead, it is widely expected that the price premium for EVs will decline, due largely to the drop in battery prices. CEC forecasts that battery electric automobiles will achieve price parity with gasoline vehicles by 2032, as illustrated in the figure below; other forecasters expect EV price parity even sooner. These price changes will reduce the need for government purchase incentives. However, the timing of the EV price changes is uncertain, which makes it hard for government agencies to plan and implement effective incentive programs.

**Figure 96. CEC Forecast Vehicle Purchase Costs for a Typical Light Duty Automobile**



Source: California Energy Commission

## Fueling and Operating Costs

One of the most attractive features of alternative fuel vehicles is the potential for lower fueling and operating costs. Fuel cost savings for EVs can be significant, particularly when drivers can take advantage of off-peak electricity rates. In California, the average price of an eGallon (gallon of gasoline equivalent for EVs) was \$1.74 compared to \$3.22 a gallon for regular gasoline as of March 2020.<sup>317</sup> EVs are also cheaper to maintain than conventional vehicles due greater reliability of batteries and electric motors as well as fewer fluids and moving parts. Automobile drivers who switch to an EV will typically save \$3,000 to \$4,000 over the first five years of vehicle ownership. Operators of medium and heavy-duty EVs can also see significant operating cost savings, with the magnitude of savings depending heavily on annual mileage.

Natural gas trucks benefit from fueling costs that are approximately 25 percent lower than comparable diesel trucks. Natural gas prices have also historically been more stable than diesel, allowing fleet owners to better predict their operating costs. Natural gas vehicle maintenance costs are comparable to diesel, according to Argonne National Laboratory's AFLEET Tool.

Fuel cell vehicles currently face higher fueling costs. At an average hydrogen price of \$14 per kilogram, the price per energy equivalent to gasoline translates to \$5.60 per gallon. Some industry experts predict that hydrogen fuel prices could drop to \$8-\$10 per kilogram within the next five to ten years, at which point FCVs would approach fuel cost parity with gasoline and diesel vehicle vehicles.

Retail prices of liquid biofuels such as ethanol, biodiesel, and renewable diesel are similar to gasoline and diesel. Although biofuels may be more expensive to produce, their lower carbon intensity can generate credits under California's low carbon fuel standard, which are typically used to offset any purchase price premium.

## Technology Readiness

Gasoline and diesel internal combustion engines have been manufactured and continually improved for more than a century. These technologies have been optimized for the performance and reliability demanded by customers. While clean vehicle technologies like EVs, NGVs, and FCVs all show promise, they remain relatively new, and therefore face questions about how ready these technologies are to replace conventional vehicles across the full spectrum of vehicle types and applications.

As discussed in Section 2, EVs are rapidly growing in sales and commercial availability. EV sales in California have doubled in the last three years and accounted for 7.7 percent of all California light duty vehicle registrations in 2019. More than 100 models of light duty EVs are expected by 2022. Most current EVs are sedans or small SUVs; while there have been several recent manufacturer announcements of EV pickups, EVs are not expected to make significant inroads in the light truck market for at least five to ten years.

EV technology for medium- and heavy-duty vehicles has been slower to gain market share, although technology is now developing at a rapid pace. Transit buses are the most widely deployed heavy-duty

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<sup>317</sup> U.S. Department of Energy, "Saving on Fuel and Vehicle Costs," [www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs](http://www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs)



EV. In contrast, only a small number of medium- and heavy-duty EV trucks have been deployed. Long-haul tractor-trailer trucks currently face challenges to electrification due to limited electric range relative to their diesel counterparts. This market is evolving, and several major manufacturers have recently announced planned new offerings.

NGVs are an established alternative to diesel among segments of the heavy-duty vehicle sector. Cummins Westport currently produces three certified CNG engines (6.7, 9, and 12 liter), which can be used in a variety of heavy-duty trucks. Southern California has a significant number of natural gas vehicles in service for port drayage, regional freight hauling, refuse fleets, and transit buses. For example, NGVs make up about 3 percent of the drayage fleet at the Ports of Los Angeles and Long Beach. However, many truck owners and operators remain skeptical about NGVs due to concerns about maintenance issues, power, fuel availability, and other issues.

FCVs are commercially available but lag far behind EVs in terms of manufacturer offerings and new sales. Approximately 2,000 FCVs were sold nationally in 2019, or less than 1 percent of EV sales. For heavier vehicles, transit buses are the most mature application of fuel cell technology; approximately 40 fuel cell buses currently operate in California. Beyond transit buses, medium- and heavy-duty FCV demonstration projects have been primarily focused at ports.

## Fuel Supply

Operating a significant number of alternative fuel vehicles will require an adequate fuel supply. There may be risks with investment in vehicles and infrastructure if the supply of fuel cannot meet demand. These concerns are expressed most often for low-carbon fuels. However, domestic investment in biofuel production has been growing, due in part to the demand created by California's LCFS, and fuel supply does not appear to be a serious concern in terms of the scenarios explored for San Bernardino County.

Under the Natural Gas as a Bridge scenario described in Section 5, vehicle natural gas fuel consumption would be 13 million diesel-gallon equivalent (DGE) in 2030 and 32 million DGE in 2040. All this fuel would need to be RNG to achieve the GHG benefits calculated for the scenario. For comparison, the total RNG used for transportation in California was 139 million DGE in 2019, and CARB projects significant increases by 2030.<sup>318</sup> So the state's RNG supply would be more than 20 times the projected maximum use in San Bernardino County. This appears to be an adequate supply given that trucks in the study area account for only about four percent of the California total truck population and VMT.

Under the Biofuels scenario, diesel fuel would contain a 60 percent renewable diesel blend by 2040, which equates to 70 million gallons of renewable diesel (RD). For comparison, there were 618 million gallons of renewable diesel used statewide in 2019, based on reporting for the LCFS.<sup>319</sup> CARB projects renewable diesel production to more than double by 2030. So similar to RNG, the state's renewable diesel supply would be more than 20 times the maximum volume projected for use in San Bernardino

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<sup>318</sup> California Air Resources Board, LCFS Quarterly Data Spreadsheet. Available at <https://ww3.arb.ca.gov/fuels/lcfs/lrtgsummaries.htm>

<sup>319</sup> California Air Resources Board, LCFS Quarterly Data Spreadsheet. Available at <https://ww3.arb.ca.gov/fuels/lcfs/lrtgsummaries.htm>

County under the Biofuels scenario. Again, this appears to be an adequate supply given that trucks in the study area account for only about four percent of the California total truck population and VMT.

## Infrastructure Requirements

Another potential barrier to large-scale deployment of alternative fuel vehicles is the infrastructure necessary to provide fueling or charging. Public agencies have an opportunity to support clean vehicles and fuels by streamlining infrastructure permitting processes, mandating fueling or charging infrastructure as part of permit approvals, or investing directly in the development of infrastructure. However, public agencies may be concerned about investing in infrastructure for fuels or technologies that later fall out of favor, leading to stranded assets and suboptimal use of public resources.

As discussed in Section 2, there are a variety of types of EV charging infrastructure depending on the location and power. The vast majority of passenger vehicle EV charging is expected to occur at home, with infrastructure costs borne by the homeowner. However, most apartment dwellers lack access to home charging, as property owners are not incentivized to install charging infrastructure. For medium and heavy-duty trucks, most charging infrastructure is expected to be installed at truck yards and garaging locations, although there are still many uncertainties about where and how EV trucks will charge.

Although there is consensus among experts that large-scale electrification of the vehicle fleet is inevitable, there are still risks of stranded assets for public agencies seeking to invest in charging infrastructure. For example, the types and locations of charging preferred by EV drivers may shift over time; a strong preference for DC fast charging could leave some level 2 chargers unused, for example. A major investment in infrastructure will be needed to support electrification of the fleet. As shown in Section 5, the Electrification Scenario would involve more than \$1 billion in cumulative infrastructure costs through 2040 just for San Bernardino County, more than any other scenario analyzed.

Infrastructure for natural gas vehicle fueling can also be substantial; the cost of a single large CNG fueling station can be more than \$1 million. But the total investment needed in NGV fueling stations is far less than the investment needed in EV charging infrastructure. This is in part because natural gas would be used only by medium and heavy-duty vehicles, and the population and aggregate fuel consumption of these vehicles is far less than LDVs. In addition, many medium and heavy-duty vehicles belong to fleets that can fuel centrally, which can be more efficient in terms of the number of vehicles served per station.

As noted above, if public agencies are helping to fund alternative fuel stations such as natural gas or hydrogen, they may be concerned about stranded assets if long term demand for the fuel does not materialize. If so, it may be an option to contract with a private developer to build, own, and operate the station. Examples of private natural gas station developers are Trillium CNG and Clean Energy. This option does not require public capital expenditure for the station but usually requires a long-term fueling agreement that guarantees a minimum fuel throughput for the operator. The fuel costs for this station option are usually higher than if the public agency were to build the station itself.

For fleets that are considering a transition to natural gas or possible hydrogen, the transition requires a significant “all-in” commitment to guarantee that the fleet can recoup any necessary infrastructure and vehicles costs. In other words, natural gas and hydrogen differ from most other alternative fuels in that

fleets cannot simply “try out” the fuel with a few vehicles, unless the fleet is able to use public fueling station or one owned by another fleet.

Infrastructure requirements are a major challenge to widespread deployment of FCVs. Currently, there are only 42 public hydrogen fueling stations available in the U.S., nearly all of them in California. CEC estimates a development cost of about \$2 million per station.

## Summary Table

The table below summarizes the key benefits, risks, and uncertainties highlighted in this section.

**Table 53. Summary of Benefits, Risks, and Uncertainties**

	EVs	FCVs	NGVs (with RNG)	Liquid Biofuels
<b>Emissions Benefits</b>	<ul style="list-style-type: none"> <li>• 100% NOx reduction</li> <li>• 70-80% GHG reduction</li> </ul>	<ul style="list-style-type: none"> <li>• 100% NOx reduction</li> <li>• 30-50% GHG reduction (depends on fuel source)</li> </ul>	<ul style="list-style-type: none"> <li>• 90% NOx reduction</li> <li>• 50-80% GHG reduction (depends on feedstock)</li> </ul>	<ul style="list-style-type: none"> <li>• Small NOx reduction</li> <li>• 20-60% GHG reduction (E85)</li> <li>• 60-80% GHG reduction (RD)</li> </ul>
<b>Vehicle Costs</b>	<ul style="list-style-type: none"> <li>• 20-50% higher cost (LDV)</li> <li>• 100-200% higher cost (HDV)</li> <li>• Costs declining rapidly</li> </ul>	<ul style="list-style-type: none"> <li>• Currently 2-3 times higher</li> <li>• Uncertain due to low production volumes</li> </ul>	<ul style="list-style-type: none"> <li>• 20-50% higher cost (HDV)</li> </ul>	<ul style="list-style-type: none"> <li>• No cost increment</li> </ul>
<b>Fueling and Operating Costs</b>	<ul style="list-style-type: none"> <li>• 50% lower fueling costs</li> <li>• Lower maintenance costs</li> </ul>	<ul style="list-style-type: none"> <li>• 80-90% higher fueling costs, although future decline expected</li> </ul>	<ul style="list-style-type: none"> <li>• 25% lower fueling costs</li> <li>• Comparable maintenance costs</li> </ul>	<ul style="list-style-type: none"> <li>• Fueling costs similar to gasoline and diesel</li> </ul>
<b>Technology Readiness</b>	<ul style="list-style-type: none"> <li>• Numerous commercial models available and rapid expansion</li> <li>• Range is a limiting factor for some applications</li> </ul>	<ul style="list-style-type: none"> <li>• Small number of LD and HD models available</li> <li>• Limited sales (less than 1% EV sales)</li> </ul>	<ul style="list-style-type: none"> <li>• Established technology for HDVs; 3 certified CNG engines</li> <li>• Widespread use among refuse trucks and buses</li> </ul>	<ul style="list-style-type: none"> <li>• E85 FFVs – proven technology, but declining consumer and manufacturer interest</li> <li>• RD – drop-in fuel</li> </ul>
<b>Fuel Supply</b>	<ul style="list-style-type: none"> <li>• Some distribution system upgrades needed</li> </ul>	<ul style="list-style-type: none"> <li>• Hydrogen supply uncertain</li> </ul>	<ul style="list-style-type: none"> <li>• Adequate RNG supply expected</li> </ul>	<ul style="list-style-type: none"> <li>• Adequate RD supply expected</li> </ul>
<b>Infrastructure Requirements</b>	<ul style="list-style-type: none"> <li>• More than 400 public charging outlets in SB County</li> <li>• Total cost for all future EVSE in SB County is \$1B+</li> </ul>	<ul style="list-style-type: none"> <li>• Very limited currently (42 in entire US)</li> <li>• Very high cost</li> </ul>	<ul style="list-style-type: none"> <li>• Approx. 20 NG stations in SB County</li> <li>• New CNG stations can cost \$1M+</li> </ul>	<ul style="list-style-type: none"> <li>• E85: 11 stations in SB County</li> <li>• RD: Fuel can be blended w/ conventional diesel</li> </ul>

## Appendix A. Regulations and Incentive Programs

This section provides brief, plain-language summaries of the current federal, state, and regional/local regulations, policies, and programs that will or could have a significant effect on emissions from on-road light-, medium-, and heavy-duty vehicles during the study period.

### Federal Regulations

Relevant federal provisions include the regulations and programs set forth below.

#### National Ambient Air Quality Standards (NAAQS)

Under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) sets and periodically reviews and revises ambient air quality standards, known as NAAQS, for pollutants that are considered harmful to public health and the environment. NAAQS exist for six so-called criteria air pollutants – ozone, particulate matter (PM), carbon monoxide (CO), lead, sulfur dioxide, and nitrogen dioxide; EPA established the current [2008] ozone and [2012] PM<sub>2.5</sub> standards in 2015 and 2012, respectively. In addition to setting the NAAQS, EPA determines whether geographic areas of the country are meeting (attaining) the standards. For more on the NAAQS, see the relevant EPA webpages.<sup>320</sup>

As detailed on the South Coast Air Quality Management District’s (SCAQMD) website, the South Coast Air Basin is designated as a nonattainment area for the 2008 8-hour ozone NAAQS, with a target attainment date of July 20, 2032, and as a nonattainment area for the 2012 annual PM<sub>2.5</sub> NAAQS, with a target attainment date of December 31, 2025.<sup>321</sup> The *Final 2016 Air Quality Management Plan*, described in section 2.4 below, discusses the strategies SCAQMD is taking “to achieve attainment as expeditiously as practicable.”<sup>322</sup>

#### LDV Emission and Corporate Average Fuel Economy Standards

The current emission standards for LDVs (and also medium-duty passenger vehicles) control emissions of criteria pollutants and greenhouse gases (GHGs). Established by EPA in 2014 as the follow-on to Tier 2, the criteria pollutant standards, known as Tier 3, also apply to some light HDVs, and limit tailpipe emissions of non-methane organic gases, nitrogen oxides (NO<sub>x</sub>), CO, PM, and formaldehyde. Further details on the Tier 3 standards can be found on EPA’s website.<sup>323</sup>

In 2012, EPA and the National Highway Traffic Safety Administration (NHTSA), in collaboration with the California Air Resources Board (CARB), issued coordinated Phase 2 GHG emission and corporate average

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<sup>320</sup> <https://www.epa.gov/criteria-air-pollutants> and <https://www.epa.gov/naaqs>. The actual standards are listed at <https://www.epa.gov/criteria-air-pollutants/naaqs-table>.

<sup>321</sup> <http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/naaqs-caaqs-feb2016.pdf?sfvrsn=14>.

<sup>322</sup> <http://www.aqmd.gov/home/air-quality/clean-air-plans>.

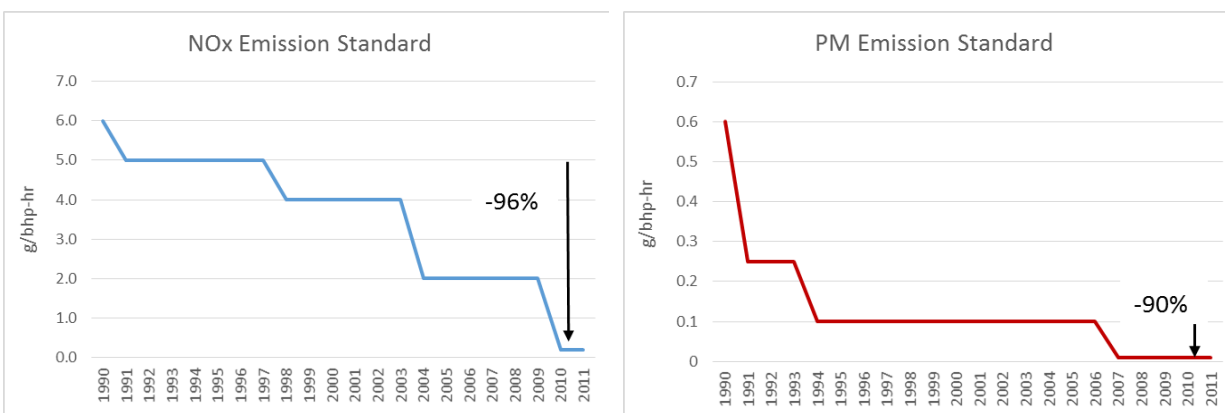
<sup>323</sup> <https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3>. A good description of the Tier 3 standards can also be found at [https://www.dieselnet.com/standards/us/ld\\_t3.php](https://www.dieselnet.com/standards/us/ld_t3.php).

fuel economy (CAFE) standards for LDVs (as well as medium-duty passenger vehicles), after having jointly established the Phase 1 standards in 2010. The Phase 2 standards cover model years 2017 through 2025 and thereafter. Further details on the coordinated GHG emission and CAFE standards can be found on the agencies’ relevant webpages.<sup>324</sup>

### HDV Emission and Fuel Efficiency Standards

The current EPA criteria pollutant emission standards for diesel (and gasoline) engines used in MDV: Medium-Duty Trucks and HDVs like trucks and buses have been in full effect since 2010. The standards limit exhaust emissions of NOx, non-methane hydrocarbons, CO, and PM. Comprehensive information on the standards is available on the relevant EPA webpages.<sup>325</sup> Most notably, the Federal regulations set a standard for NOx emissions of 0.2 grams per brake horsepower-hour, which reflects a 90% reduction from the previous standard and a 96% reduction compared to the standard for HDVs in the mid-1990s. The PM standard that took effect in 2007, 0.01 grams per brake horsepower-hour, reflects a 90% reduction compared to previous levels, as illustrated in the figure below.

**Figure 97. Changes in Federal HDV NOx and PM Emission Standards**



In 2016, EPA and NHTSA, again in collaboration with CARB, issued the Phase 2 GHG emission standards and corresponding fuel consumption standards for medium- and heavy-duty engines and vehicles, after having jointly established the Phase 1 standards in 2011. Under Phase 2, the Phase 1 standards, which originally applied through 2018, will remain in effect through 2020, with incrementally tighter standards

<sup>324</sup> <https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-passenger-cars-and> and <https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy#corporate-average-fuel-economy-heavy-duty-vehicles>. A useful description of the harmonized GHG emission and CAFE standards can also be found at [https://www.dieselnet.com/standards/us/fe\\_ghg.php](https://www.dieselnet.com/standards/us/fe_ghg.php).

<sup>325</sup> <https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-smog-soot-and-other-air-pollution-commercial> and <https://www.epa.gov/emission-standards-reference-guide>. A good description of the diesel engine standards can also be found at <https://www.dieselnet.com/standards/us/hd.php>.

becoming applicable in 2021, 2024, and then in 2027. Further details on the harmonized GHG emission and fuel consumption standards can be found on the agencies' relevant webpages.<sup>326</sup>

### **Renewable Fuel Standard (RFS)**

The RFS, implemented by EPA, requires that domestic transportation fuels contain a minimum volume of renewable fuel (for example, ethanol and biodiesel). The mandated minimum volume increases on an annual basis; by 2022, 36 billion gallons of renewable fuel must be blended into the nation's transportation fuel supply to replace or reduce petroleum. EPA determines percentage standards each year by dividing the annual amount of renewable fuel specified by Congress for each of four categories by the quantity of gasoline and diesel estimated to be produced that year. Refiners and importers of gasoline and diesel fuel are directly affected by the RFS program, and must achieve compliance each year by blending renewable fuels into their transportation fuels or by obtaining credits. More information on the RFS program can be found on the relevant EPA webpage.<sup>327</sup>

## **California Regulations**

Relevant California regulations and policies are set forth below. State programs that provide funding for clean vehicles and fuels are described in the following section.

### **Advanced Clean Cars Program**

The Advanced Clean Cars (ACC) program, adopted in 2012 and applicable to LDVs and MDV: Medium-Duty Trucks manufactured through model year 2025 and beyond, is an amalgam of CARB's Low-Emission Vehicle III (a/k/a LEV III) criteria pollutant and GHG exhaust emission standards and its Zero-Emission Vehicle (ZEV) standards. The program regulates emissions of smog- and soot-causing pollutants (non-methane organic gases, NOx, CO, PM, and also formaldehyde) as well as GHGs, and simultaneously requires vehicle manufacturers to produce increasing numbers of battery electric, fuel cell electric, and plug-in hybrid electric vehicles. At present, the LEV III criteria pollutant and GHG emission standards are largely consistent with the federal standards (described above). More information and resources on the ACC program and its component regulations can be found on CARB's ACC webpage.<sup>328</sup>

### **HDV Emission Standards**

The California emission standards for new heavy-duty diesel (and gasoline) engines and vehicles limit exhaust emissions of NOx, non-methane hydrocarbons, CO, PM, and GHGs, and are consistent with the EPA emission standards discussed above. In 2014, CARB amended the California standards by adding optional low NOx standards "to encourage development of lower NOx engines and reduce [NOx]

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<sup>326</sup> <https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-commercial-trucks> and <https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy#corporate-average-fuel-economy-heavy-duty-vehicles>. A good description of the harmonized standards can also be found at [https://www.dieselnet.com/standards/us/fe\\_hd.php](https://www.dieselnet.com/standards/us/fe_hd.php).

<sup>327</sup> <https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard>. A helpful overview of the RFS program can also be found at <https://www.afdc.energy.gov/laws/390>.

<sup>328</sup> <https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program>.

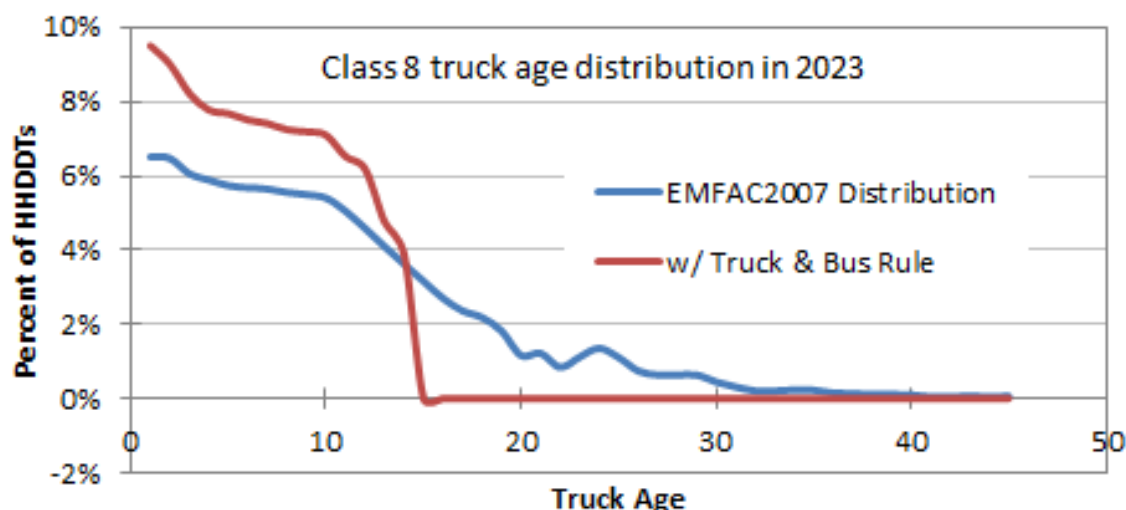
emissions” below the current mandatory NOx standard.<sup>329</sup> For more information on California’s HDV emission and optional low NOx standards, visit the relevant CARB webpages.<sup>330</sup>

### Truck and Bus Regulation

The Truck and Bus Regulation, originally adopted by CARB in 2008, affects roughly one million diesel HDVs (diesel vehicles heavier than 14,000 pounds) operating in California. Unlike the Federal and California emission standards described above, which apply only to new vehicles, the Truck and Bus Regulation applies to existing vehicles on the road. The regulation “requires privately and federally owned diesel-fueled trucks and buses and privately and publicly owned school buses to fully upgrade” to 2010 or newer model year engines by January 1, 2023.<sup>331</sup> Further details on the regulation, including the specific compliance requirements, can be found on CARB’s Truck and Bus Regulation webpage.<sup>332</sup>

The main implication of the Truck and Bus Regulation (and the Drayage Truck Regulation discussed below) is that, by 2023, nearly all California trucks on the road will meet the Federal and State HDV emissions standards that took full effect in 2010 (i.e., 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM). Accelerating fleet turnover with replacement by new diesel vehicles will produce no significant emissions benefit. So further emission reductions must come from the introduction of advanced technology and alternative fuel HDVs.

**Figure 98. Impact of CARB Truck & Bus Rule on Truck Age Distribution**



<sup>329</sup> <https://www.arb.ca.gov/regact/2013/hdghg2013/hdghgnodlownox.pdf>.

<sup>330</sup> <https://www.arb.ca.gov/msprog/onroadhd/onroadhd.htm>; <https://www.arb.ca.gov/msprog/onroad/optionnox/optionnox.htm>; and <https://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm>.

<sup>331</sup> CARB, *Mobile Source Strategy*, at 77-78 (May 2016), available at <https://www.arb.ca.gov/planning/sip/2016sip/2016mobsr.pdf>.

<sup>332</sup> <https://www.arb.ca.gov/msprog/onrdiesel/onrdiesel.htm>.



### Drayage Truck Regulation

Under the Drayage Truck Regulation, which dates back to 2007, all diesel-fueled drayage trucks – trucks heavier than 26,000 pounds that transport cargo to or from California’s ports and intermodal rail yards – must have 2010 or newer model year engines by January 1, 2023. More information is available on CARB’s Drayage Truck Regulation webpage.<sup>333</sup>

### Advanced Clean Truck Regulation

On June 25, 2020, CARB adopted the Advanced Clean Truck Regulation. It requires that, for manufacturers who sell medium and heavy-duty trucks in California, a specified percentage of sales must be zero emission vehicles. Exemptions are provided for companies with less than annual sales of less than 500 vehicles. The table below shows the minimum ZEV sales fractions under this regulation.<sup>334</sup>

**Table 54. Advanced Clean Truck Regulation ZEV Sales Percentage Schedule**

Model Year	Class 2b-3 Group*	Class 4-8 Group	Class 7-8 Tractors Group
2024	5%	9%	5%
2025	7%	11%	7%
2026	10%	13%	10%
2027	15%	20%	15%
2028	20%	30%	20%
2029	25%	40%	25%
2030	30%	50%	30%
2031	35%	55%	35%
2032	40%	60%	40%
2033	45%	65%	40%
2034	50%	70%	40%
2035 and beyond	55%	75%	40%

### Alternative Diesel Fuels (ADF) Regulation

CARB’s ADF Regulation provides a framework for low-carbon, and usually less-polluting, “diesel fuel substitutes to enter the commercial market in California, while mitigating any potential environmental or public health impacts.”<sup>335</sup> Adopted in 2015, the regulation includes a three-stage process for ADFs to be introduced and in-use requirements for biodiesel, the first fuel recognized in the state as an ADF. The ADF regulation consolidates what had been many separate administrative and regulatory practices into one regulation that provides a clear framework for commercialization of ADFs. It was introduced in part

<sup>333</sup> <https://www.arb.ca.gov/msprog/onroad/porttruck/porttruck.htm>.

<sup>334</sup> <https://ww2.arb.ca.gov/rulemaking/2019/advancedcleantrucks>

<sup>335</sup> <https://ww2.arb.ca.gov/our-work/programs/alternative-diesel-fuels/about>.

due to concerns that biodiesel can, in some circumstances, increase NOx emissions. The regulation applies to any diesel fuel substitute. More information can be found on the CARB ADF Regulation website.<sup>336</sup>

### **Low Carbon Fuel Standard (LCFS)**

Adopted by CARB in 2009 and implemented since 2011, the LCFS regulation is designed to encourage the production and use of cleaner, low-carbon fuels in California and thereby reduce GHG emissions from the transportation sector. Performance-based and fuel-neutral, the LCFS allows the market to determine how the carbon intensity of California's transportation fuels will be reduced. The program uses lifecycle assessment to examine the GHG emissions associated with the production, distribution, and end use of a given transportation fuel, and subjects the lifecycle GHG ratings to a declining carbon intensity benchmark for the transportation fuel pool in California so as to result in a decrease each year in the total lifecycle GHG emissions from fuels used in the state. More information on the LCFS can be found on the relevant CARB webpage.<sup>337</sup>

### **Renewables Portfolio Standard (RPS) & Senate Bill 100**

California's RPS dictates how much of the state's electricity – the fuel used in plug-in electric vehicles (PEVs) – must be generated from renewable energy resources like solar, wind, and geothermal. Jointly implemented by the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC), the RPS was amended most recently by the 100 Percent Clean Energy Act of 2018 (Senate Bill (SB) 100). When SB 100 went into effect on January 1, 2019, the RPS increased to 60 percent by the end of 2030. SB 100 also establishes the state policy that renewable energy and zero-carbon resources supply 100 percent of California's electricity by the end of 2045. For more information on the RPS, see the CPUC and CEC RPS webpages.<sup>338</sup> Further details on SB 100 can be found on the California Legislature's website.<sup>339</sup>

### **Assembly Bill 32 & SB 32**

The California Global Warming Solutions Act of 2006, commonly known as Assembly Bill (AB) 32, created a comprehensive, multi-year program to reduce GHG emissions in the state. Among other things, the law directed CARB to develop and update periodically a Scoping Plan that describes the approach California will take to reduce GHGs to achieve the goal of reducing emissions to the 1990 level by 2020. CARB approved the initial Scoping Plan in 2008, and the First Update in 2014. Two years later, the California Legislature passed SB 32, codifying into law the GHG emissions reduction target that had been set by Executive Order B-30-15 – 40 percent below the 1990 level by 2030. CARB then updated the

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<sup>336</sup> <https://ww2.arb.ca.gov/our-work/programs/alternative-diesel-fuels>.

<sup>337</sup> <https://www.arb.ca.gov/fuels/lcfs/lcfs.htm>.

<sup>338</sup> [http://cpuc.ca.gov/RPS\\_Homepage/](http://cpuc.ca.gov/RPS_Homepage/) and <https://www.energy.ca.gov/portfolio/index.html>.

<sup>339</sup> [http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill\\_id=201720180SB100](http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB100).

Scoping Plan to reflect the SB 32 2030 target.<sup>340</sup> For more information on AB 32 and SB 32, see the relevant CARB webpages.<sup>341</sup>

### **Executive Order B-48-18**

Issued by former Governor Jerry Brown on January 26, 2018, Executive Order B-48-18 establishes the California target of having 5 million ZEVs on the state’s roads by 2030. The Order also establishes targets of 200 hydrogen fueling stations and 250,000 PEV charging stations by 2025. For more information, see Governor Brown’s press release.<sup>342</sup>

### **Executive Order B-32-15**

This Order, issued by Governor Brown in mid-July of 2015, directed various state agencies and departments to develop an integrated action plan for an efficient, competitive, and environmentally sustainable freight system in California. The *California Sustainable Freight Action Plan* was released one year later, on July 29, 2016. The Action Plan is “intended to integrate investments, policies, and programs across several State agencies to help realize a singular vision for California’s freight transport system,” and includes recommendations on “a long-term 2050 Vision and Guiding Principles for California’s future freight transport system, targets for 2030 to guide the state toward meeting the Vision, opportunities to leverage state freight transport system investments, actions to initiate over the next five years to make progress towards the targets and the Vision, [and] pilot projects to achieve on-the-ground progress in the near-term.”<sup>343</sup> For more information on the Executive Order and resulting Action Plan, see the relevant Department of Transportation webpage.<sup>344</sup>

## **California Funding Programs**

### **Carl Moyer Program**

As explained by CARB, “[t]he Carl Moyer Program is a voluntary grant program that reduces air pollution from vehicles and [off-road] equipment by providing incentive funds to private companies and public agencies to purchase cleaner-than-required engines, equipment, and emission reduction technologies. The program has been implemented since 1998 through a partnership between [CARB] and California’s 35 local air pollution control and air quality management districts. By funding emission reductions that are surplus – earlier and/or beyond what is required by regulation – the Moyer Program complements California’s regulations.”<sup>345</sup> Among other things, grant funding under the program is available for the

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<sup>340</sup> [https://ww3.arb.ca.gov/cc/scopingplan/scoping\\_plan\\_2017.pdf](https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf)

<sup>341</sup> <https://www.arb.ca.gov/cc/ab32/ab32.htm> and <https://www.arb.ca.gov/cc/scopingplan/scopingplan.htm>.

<sup>342</sup> <https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/>.

<sup>343</sup> *California Sustainable Freight Action Plan*, at 2-3 (July 2016), available at [http://dot.ca.gov/hq/tpp/offices/ogm/cs\\_freight\\_action\\_plan/Documents/CSFAP\\_Main%20Document\\_FINAL\\_07272016.pdf](http://dot.ca.gov/hq/tpp/offices/ogm/cs_freight_action_plan/Documents/CSFAP_Main%20Document_FINAL_07272016.pdf).

<sup>344</sup> [http://dot.ca.gov/hq/tpp/offices/ogm/cs\\_freight\\_action\\_plan/main.html](http://dot.ca.gov/hq/tpp/offices/ogm/cs_freight_action_plan/main.html).

<sup>345</sup> [https://www.arb.ca.gov/msprog/moyer/factsheets/moyer\\_program\\_fact\\_sheet.pdf](https://www.arb.ca.gov/msprog/moyer/factsheets/moyer_program_fact_sheet.pdf).

scrapping of older, high-emitting LDVs and the purchase of new on-road HDVs equipped with low NOx engines. Further details on the Carl Moyer Program are available on CARB’s website.<sup>346</sup>

### Low Carbon Transportation & Air Quality Improvement Programs

The CARB Low Carbon Transportation and Air Quality Improvement Programs (AQIP) provide incentive funding to reduce GHG, criteria pollutant, and air toxic emissions from mobile sources through the development and use of advanced technology and clean transportation. Specific funding programs include:

- **Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)** – A CARB-created, CALSTART-administered voucher program designed to accelerate the early market introduction of clean, low-carbon hybrid and zero-emission trucks and buses and low NOx natural gas engines in California. The program helps build the market by reducing the incremental purchase cost of these vehicles and engines for truck and bus fleets that operate in the state. More information can be found on the California HVIP website.<sup>347</sup>
- **Zero- and Near Zero-Emission Freight Facilities (ZANZEFF) Project** – Provides funding for projects that deploy emission reducing technologies used in freight movement and freight facilities.<sup>348</sup> Eligible vehicles and equipment types include on-road trucks, cargo handling equipment, marine vessels, locomotives, and others including supporting infrastructure. Freight facility improvements are also eligible and include advanced strategies to reduce emission from vehicles and equipment such as preferential queuing, renewable energy generation and storage. ZANZEFF project funded in FY 2018-19 are listed below.
- **Clean Vehicle Rebate Project (CVRP)** – Promotes clean vehicle adoption by offering rebates of up to \$7,000 for the purchase or lease of new, eligible zero-emission vehicles, including electric, plug-in hybrid electric and fuel cell vehicles. As long as funds are available, eligible California residents can follow a simple process to apply for a CVRP rebate after purchasing or leasing an eligible vehicle.<sup>349</sup>

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<sup>346</sup> <https://www.arb.ca.gov/msprog/moyer/moyer.htm>.

<sup>347</sup> <https://www.californiahvip.org/>.

<sup>348</sup> Descriptions of the 11 FY 2017-18 ZANZEFF projects that CARB funded, including the locations, CARB funding contributions, and other project details, can be found in the table and associated hyperlinks beneath “Fiscal Year 2017-18 Zero- and Near Zero-Emission Freight Facilities Projects Approximate Project Timelines: Winter 2019 – Spring 2021” posted at [https://www.arb.ca.gov/msprog/lct/posters.htm?\\_ga=2.15345781.252993114.1553546474-535199278.1480428436](https://www.arb.ca.gov/msprog/lct/posters.htm?_ga=2.15345781.252993114.1553546474-535199278.1480428436).

<sup>349</sup> <https://cleanvehiclerebate.org/eng>

**Table 55: ZANZEFF Project Awarded Fiscal Year 2017-18**

Grantee	Project Title
City of San Francisco	Zero Emission from Farm to Table: Reducing Pollution Emissions and Health Risks from the Movement of Produce along Two Adjacent Trade Corridors in California
Center for Transportation and the Environment	Fuel Cell Hybrid Electric Delivery Van Deployment
Center for Transportation and the Environment	Next Generation Fuel Cell Delivery Van Deployment
Center for Transportation and the Environment	Zero-Emission Beverage Handling and Distribution at Scale
Gas Technology Institute	Zero Emissions for California Ports
Port of Los Angeles	Zero-Emission Freight "Shore to Store" Project
Port of Long Beach	Sustainable Terminals Accelerating Regional Transformation
Project Clean Air	Net-Zero Farming and Freight Facility Demonstration Project
South Coast Air Quality Management District	Volvo Low Impact Green Heavy Transportation Solutions
San Joaquin Valley Air Pollution Control District	Flexible Solutions for Freight Facilities - San Joaquin Valley Zero and Near-Zero Emission Enabling Freight Project
San Joaquin Valley Air Pollution Control District	Frito Lay Transformative Zero and Near Zero Emission Freight Facility Project

More information on all the CARB incentive programs can be found on the relevant CARB webpage.<sup>350</sup> CARB approved funding of more than \$500 million for these programs for the 2019-20 fiscal year. The table below shows the proposed funding allocation.

<sup>350</sup> <https://www.arb.ca.gov/msprog/aqip/aqip.htm>.

**Table 56: Funding for 2019-2020 Low Carbon Transportation & Air Quality Improvement Programs**

Project Category	Allocation (millions)
<b>LIGHT-DUTY VEHICLE AND TRANSPORTATION EQUITY INVESTMENTS</b>	
Clean Vehicle Rebate Project (CVRP)	\$238
Transportation Equity Projects	\$65
<i>Light-Duty Vehicle and Transportation Equity Investment Sub-Total</i>	<i>\$303</i>
<b>HEAVY-DUTY VEHICLE AND OFF-ROAD EQUIPMENT INVESTMENTS</b>	
Clean Truck and Bus Vouchers (HVIP + Low NOx Engine Incentives)	\$142
Freight Equipment Advanced Demonstration and Pilot Commercial Deployment Project	\$40
Truck Loan Assistance Program	\$48
<i>Heavy-Duty Vehicle and Off-Road Equipment Investment Sub-Total</i>	<i>\$230</i>
<b>TOTAL</b>	<b>\$533</b>

Source: CARB, Proposed Fiscal Year 2019-20 Funding Plan for Clean Transportation Incentives for Low Carbon Transportation Investments and the Air Quality Improvement Program, <https://ww2.arb.ca.gov/sites/default/files/2019-09/fy1920fundingplan.pdf>

### Alternative and Renewable Fuel and Vehicle Technology Program

The Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), which is administered by the CEC, “provide[s] to specified entities, upon appropriation by the Legislature, grants, loans, loan guarantees, revolving loans, or other appropriate measures, for the development and deployment of innovative technologies that would transform California’s fuel and vehicle types to help attain the State’s climate change goals.”<sup>351</sup> A full description of the program is available on the CEC’s ARFVTP webpage.<sup>352</sup>

### Regional/Local Regulations and Programs

Relevant regional and local regulations, programs, and policies include the following SCAQMD and Southern California Association of Governments (SCAG) measures and efforts.

#### SCAQMD Fleet Rules

To reduce toxic and smog-forming pollutants, SCAQMD some years ago put in place a number of rules that seek to shift public agency and certain private entity fleets to lower-emitting and alternative fuel vehicles whenever a fleet operator with 15 or more vehicles replaces or purchases new vehicles. The fleet rules affect street sweepers, light- and medium-duty public fleet vehicles, transit buses, waste collection vehicles, commercial airport ground access vehicles (LDVs like LDA: Passenger Cars and

<sup>351</sup> SCAQMD, *2016 Air Quality Management Plan – Appendix IV-A*, at IV-A-154 (Mar. 2017), available at <http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2016-air-quality-management-plan/final-2016-aqmp/appendix-iv-a.pdf?sfvrsn=4>.

<sup>352</sup> <https://www.energy.ca.gov/transportation/arfvtp/>.

medium- and heavy-duty transit vehicles like shuttle buses), school buses, and HDVs operated by public entities. More information on the fleet rules is available on the relevant SCAQMD webpage.<sup>353</sup>

### **SCAQMD Warehouse Indirect Source Rule (Proposed)**

In May 2018, the SCAQMD Governing Board directed staff to develop a proposed indirect source rule for warehouses. Although it is still under development and has yet to be formally proposed by SCAQMD, the rule, once in place, likely would focus on reducing emissions from the trucks that service warehouse distribution centers rather than emissions from the facilities themselves.<sup>354</sup>

### **Final 2016 Air Quality Management Plan (AQMP)**

SCAQMD's *Final 2016 AQMP* is the latest blueprint for achieving the federal ambient air quality standards and healthful air in the South Coast region. The plan "represents a thorough analysis of existing and potential regulatory control options, includes available, proven, and cost-effective strategies, and seeks to achieve multiple goals in partnership with other entities promoting reductions in [GHGs] and toxic risk, as well as efficiencies in energy use, transportation, and goods movement."<sup>355</sup> The complete plan is available on the SCAQMD website.<sup>356</sup> Of particular note is Appendix IV-A, which addresses, among other things, mobile source control measures.

### **Connect SoCal: The 2020-2045 Regional Transportation Plan/Sustainable Communities Strategy**

Connect SoCal, SCAG's 2020-2045 Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) "is a long-range visioning plan that builds upon and expands land use and transportation strategies established over several planning cycles to increase mobility options and achieve a more sustainable growth pattern. It charts a path toward a more mobile, sustainable and prosperous region by making connections between transportation networks, between planning strategies and between the people whose collaboration can improve the quality of life for Southern Californians."<sup>357</sup>

The plan "outlines more than \$638 billion in transportation system investments through 2045. It was prepared through a collaborative, continuous, and comprehensive process with input from local governments, county transportation commissions, tribal governments, non-profit organizations, businesses and local stakeholders within the counties of Imperial, Los Angeles, Orange, Riverside, San Bernardino and Ventura." The 2020 RTP/SCS can be found on the SCAG website.

Pursuant to SB 375, the RTP/SCS must demonstrate that the region will reduce its per-capita light duty vehicle GHG emissions to achieve targets set by CARB. The figure below shows the CARB targets and the GHG emissions as forecast for the RTP/SCS.

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<sup>353</sup> <http://www.aqmd.gov/home/rules-compliance/rules/fleet-rules>.

<sup>354</sup> <https://www.aqmd.gov/docs/default-source/news-archive/2018/indirect-source-measures.pdf>.

<sup>355</sup> *Final 2016 AQMP* - Executive Summary, at ES-1, available at <http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2016-air-quality-management-plan/final-2016-aqmp/executive-summary.pdf?sfvrsn=4>.

<sup>356</sup> <http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan/final-2016-aqmp>.

<sup>357</sup> <https://www.connectsocial.org/Pages/Connect-SoCal-Final-Plan.aspx>



**Table 57: Per Capita GHG Reductions Reported in SCAG’s 2020 RTP/SCS**

Year	% Reduction from 2005 Levels		
	ARB Target	Connect SoCal	% Difference
2020	8%	8%	0%
2035	19%	19%	0%

**Air Quality Management District & Mobile Source Air Pollution Reduction Review Committee (MSRC) Funding**

Under a 1991 California law, local governments in the South Coast region have been able to receive funds, apportioned to and distributed by SCAQMD, for the implementation of programs that reduce air pollution from motor vehicles, as well as clean transportation discretionary funds apportioned to and distributed by the Mobile Source Air Pollution Reduction Review Committee (MSRC). For more information on these funding mechanisms, see the MSRC website.<sup>358</sup>

<sup>358</sup> <http://www.cleantransportationfunding.org/>