Workforce Impacts of Achieving Carbon-Neutral Transportation in California

UCLA Luskin Center for Innovation

Authorship

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Acknowledgments

Funding was provided by the California State Legislature via the California Environmental Protection Agency as part of Carbon Neutrality Study (CNS) 1, authorized by the Budget Act of 2019.

We would like to thank our colleagues at UC Davis, UC Irvine, and UC Berkeley, with whom we collaborated on CNS 1: Driving California's Transportation Emissions to Zero (2021). The work in this report provided the foundation for our contributions to that groundbreaking study.

We acknowledge the Gabrielino/Tongva peoples as the traditional land caretakers of Tovaangar (the Los Angeles basin and So. Channel Islands). As a land grant institution, we pay our respects to the Honuukvetam (Ancestors), ‘Ahiihirom (Elders) and ‘eyoohiinkem (our relatives/relations) past, present and emerging.

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Cover photo: Mechanic fixing an electric car battery / iStock.

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Terms and Definitions

BEVs....................Battery electric vehicles.

BLS ......................U.S. Bureau of Labor Statistics.

CPS......................Current Population Survey.

DCFC...................Direct current fast charger.

EVs ....Electric vehicles. Includes both battery electric and fuel cell electric vehicles.

EVSE....................Electric vehicle supply equipment.

FCEVs ....Fuel cell electric vehicles.

FFVs ....Fossil fuel vehicles. Interchangeable with ICEVs.

GGE ....Greenhouse gas emissions.

GHG.....................Greenhouse gases.

HDVs...................Heavy-duty vehicles.

ICEVs...................Internal combustion engine vehicles.

L1-H......................Level 1 (120 V) home electric vehicle charging.

L2-H.....................Level 2 (240 V) home electric vehicle charging.

L2-P ....Level 2 (240 V) public and workplace electric vehicle charging.

LDVs....................Light-duty vehicles.

MDVs ....Medium-duty vehicles.

NAICS ....North American Industrial Classification System.

O*NET ....Occupational Employment Network

OES ....Occupational Employment Statistics.

QCEW ....Quarterly Census of Employment and Wages.

QWI......................Quarterly Workforce Indicators.

ZEVs....................Zero-emission vehicles. Encompasses battery electric and fuel cell electric vehicles.

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Chapter 1 – Introduction and Outline

Transportation is California's most carbon-intensive sector, accounting for 41% of the state's CO_2e emissions in 2018 (CARB 2020). Achieving carbon neutrality in this sector is thus crucial to reducing California's contribution to greenhouse gas (GHG) emissions and, more broadly, meeting the state's overall climate mitigation goals.

However, the transformative steps necessary to accomplish this goal are massive and without precedent. These steps include expanding the numbers of battery and fuel cell electric vehicles (BEVs and FCEVs) on the road by multiple orders of magnitude in the coming decades and a massive expansion of infrastructure to charge or fuel these new zero-emission vehicles (ZEVs), alongside significant decreases in the prevalence of fossil fuel-burning internal combustion engine vehicles (ICEVs) and consumption of gasoline and diesel fuels. Moreover, these sweeping changes would be taking place within a highly complex sector that is highly interconnected with and influential on the broader economy, and which directly impacts the everyday lives of Californians. Most Californian residents require transportation in some form on a daily basis, as do businesses and government entities. The process of achieving carbon neutrality in transportation will be visible and impactful to a degree not often matched in the realm of public policy.

Given the implications of such an undertaking, the California State Legislature included in the Budget Act of 2019 an authorization for the California Environmental Protection Agency (CalEPA) to oversee two studies meant to identify strategies for decarbonizing transportation in the state. The first of these studies, conducted under the auspices of the University of California Institute of Transportation Studies (UC ITS), is tasked with identifying demand-side policies to reduce fossil fuel consumption and related emissions. It also analyzes the implications of a scenario in which these policies are successfully implemented across a variety of areas, including human health, employment, and environmental justice.

The UCLA Luskin Center for Innovation's role in this study was to model and analyze the statewide impacts on workers and employment resulting from the aforementioned scenario becoming reality. The vast size of California's transportation sector means that a significant, systemic disruption such as achieving carbon neutrality will directly impact thousands of businesses and hundreds of thousands – if not millions – of Californian workers. Many of these impacts will be positive; new industries will expand and millions of job-years' worth of work will be created from the transition to ZEVs, with the potential to create hundreds of thousands of accessible, high-quality jobs. Conversely, industries dependent on the dominance of ICEVs will contract, forcing many workers to seek new employment.

The central goal of this report is to assist policy makers, community leaders, and other stakeholders in anticipating the most important employment trends that will manifest as

California transitions to ZEVs over the next 25 years. Additionally, it provides important information regarding demographics, education, geographic concentration, and other characteristics of potentially affected workers to help inform a strategy that will achieve a just transition – one in which historically marginalized groups and communities are not once again deprived of the benefitting from the opportunities such an event presents.

To this end, the report proceeds as follows:

Chapter 2: We identify and explore the key supply chains that make up California's transportation sector and provide a baseline profile for the largest industries within them. We also identify and profile *highly impacted* industries – those that will likely experience the most significant disruption as a result of the transition to ZEVs.

Chapter 3: We discuss the fundamental determinant factor used to forecast future workforce impacts: how Californian consumers, businesses, and governments spend money with respect to transportation. We then present projected spending patterns for the state's transportation economy for the next 25 years.

Chapter 4: We provide an overview of the functionality and limitations of economic input/output models such as that used to produce our employment forecasts. We present our model methodology and projected employment estimates based on the spending patterns detailed in Chapter 3. The trends identified from these results form the primary basis of our identification of highly impacted industries in Chapters 2 and 5.

Chapter 5: After discussing the tenets of a just transition, we provide profiles for highly impacted industries with respect to demographics, education, and other key measures. We then explore some key policy models that merit consideration by state and regional actors to assist in managing workforce transitions arising from transportation decarbonization. Based on this policy overview, we identify several overarching recommendations for governments to help ensure that newly created jobs in California's zero-emission transportation future are equitably accessible and of high quality, and that negatively impacted workforces are not neglected.

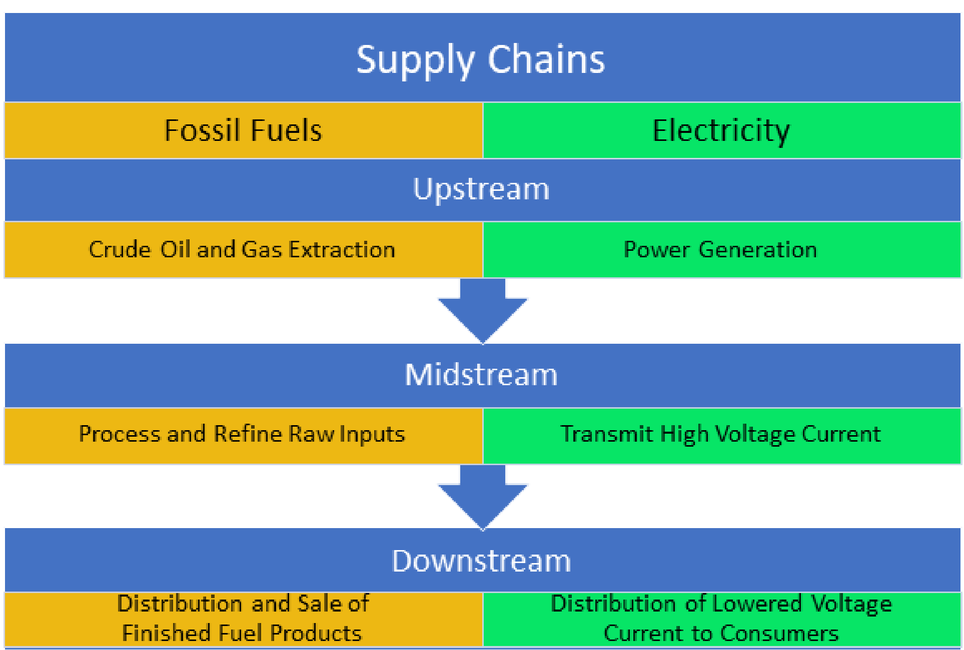
Chapter 2 – Baseline Estimates for Labor and Employment

California's transportation sector encompasses a large group of industries ranging from extractive operations to passenger movement. To discuss this broad and varied sector in a manageable way, we delineate it into three supply chains: fuels, vehicles, and transportation services. By separating the transportation sector into distinct supply chains and further dividing these supply chains into their respective streams, we can better isolate different industries and occupations related to transportation. The streams within the fuel and vehicles supply chains indicate the type of activities in which firms participate (Kazemi & Szmerekovsky, 2015):

- Upstream: Extraction of raw materials and generation of energy (e.g., oil wells and power plants)
- Midstream: Processing of raw materials and manufacture of products (e.g., petroleum refineries)
- Downstream: Distribution of completed goods (e.g., gas stations and EV charging stations)

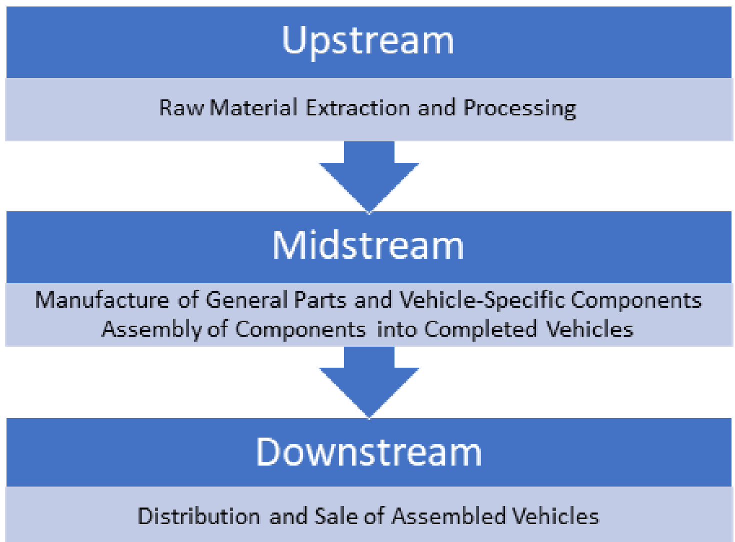
The fuel supply chain, illustrated in Figure 2-1, produces two types of fuel, fossil fuels and electricity, which engage in different operations and tasks for each stream. The fossil fuels branch extracts crude oil and natural gas, refines these raw inputs, and finally distributes the finished products (e.g., gasoline, diesel) to consumers. In contrast, the electricity branch generates electricity at a power plant, transmits the high voltage current to local transformers, and distributes the reduced voltage current to consumers.

Figure 2-1: Supply chain and streams for fossil fuels and electricity provision.



The vehicle supply chain has a similar three-stream structure for manufacturing internal combustion engine vehicles (ICEVs) and electric vehicles (EVs). However, these two branches of the vehicles supply chain are less distinct than their counterparts in the fuels supply chain, differing only in the manufacture of their respective drivetrains. Besides this distinguishing feature, the ICEV and EV supply chains follow the same general model: they extract and process raw materials (e.g. aluminum, steel, and precious metals), use these inputs to manufacture and assemble the necessary vehicle components, and distribute the completed product (vehicle or after-market part) to the end users (Figure 2-2).

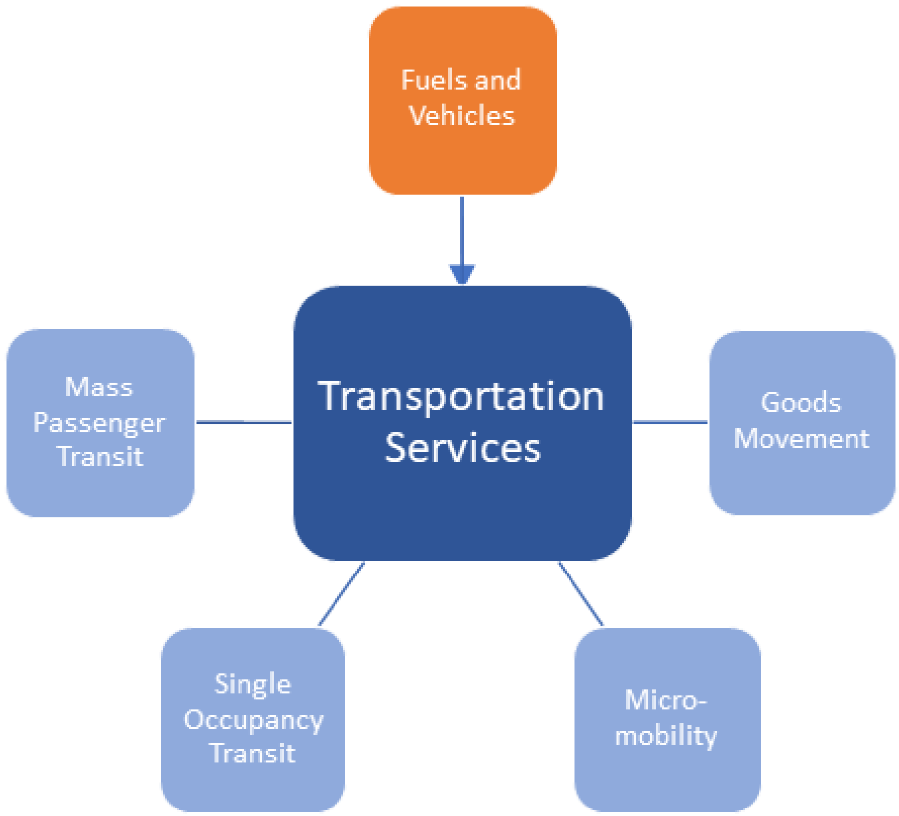
Figure 2-2: Vehicle manufacturing supply chain and streams.



The transportation services sector has variations of available services, rather than a single supply chain. While the fuel and vehicle supply chains have a single stream where one process flows into another, transportation services take vehicle and fuel inputs to provide a web of outputs. The two main branches of the transportation services supply chain are goods transportation and passenger transportation. Goods transportation includes interstate, intrastate, and local movement of products. In the same way, passenger transportation moves individuals or groups of people locally and over large geographic areas. The notable difference between these two branches is that passenger transit includes mass transit, low-occupancy transit, and micro-mobility, while goods transit is only mass movement (Figure 2-3).

Across these three supply chains, California's transportation sector employed a total of 853,706 individuals across 73 distinct industries in 2019.1 The following sections analyze total employment for each respective supply chain. Within each supply chain, we report employment, earnings, and demographics for industries with the highest employment and industries which will be highly impacted by the transition to zero-emission vehicles (ZEVs).

Figure 2-3: Transportation services supply chain inputs and service branches.



2.1 – Data Used

To capture industry employment and wages within each supply chain, we used industry-level data from BLS' (2020d) QCEW database. The QCEW data classifies industries according to the North American Industry Classification System (NAICS) and allowed us to look at detailed industry estimates in California. Additionally, we used Occupational Employment Statistics (OES) data from the U.S. Bureau of Labor Statistics (BLS) on occupations within each industry in California to account for earnings differences between occupations in an industry (BLS, 2020c). We have combined the QCEW detailed industry data with the OES detailed occupation data to estimate baseline counts for occupations and industries relevant to California's transition to net-zero emissions in the transportation sector.

The purpose of using these two data sets in tandem is that each provides detailed units of analysis in different categories. The QCEW dataset provides in-depth industry categorization with employment and wage estimates for California according to NAICS industry codes. The OES data set catalogs total occupations within high-level industry categories in California. OES includes estimates of employment, median wages, and wage percentiles for each occupation.

While QCEW and OES data provide detailed information on industries and occupations respectively, combining these data into a single set reduces the accuracy of the final data. This is because the NAICS code mapping for QCEW uses a detailed NAICS level (6-digit industry code), while OES uses a higher level NAICS code (4-digit industry code). As such, the OES information overestimates some of the real occupational data for industries. However, we proceed with this approach despite this shortcoming because no alternative data set currently exists which would provide the level of detail and clarity needed to make strong assertions.

This chapter also relies on the Quarterly Workforce Indicators (QWI) data from the U.S. Census Bureau to provide demographic data for industries. Worker race, ethnicity, and sex for each industry addressed in this chapter are derived from this data set. We sought to include Current Population Survey (CPS) data to account for worker benefits and unionization rates, but the results of the data differ substantially from estimates made by BLS (2020b). As such, we do not include the CPS estimates in our description of worker characteristics.

Using these datasets, we highlight two types of industries: high-employment industries and high-impact industries. High-employment industries are the five industries with the highest employment in a supply chain. The 15 highest employment industries across the transportation sector collectively account for 606,995 total workers, representing 71.1% of all employment in the transportation sector. High-impact industries are industries where the transition to net-zero emissions will have a sizeable impact on employment, either positive (expanding) or negative (contracting).

For this chapter, we discuss both the expanding and contracting high-impact industries, although the presentation of these industries differs. For contracting high-impact industries, we list the specific industries by NAICS code and include 2019 baseline employment and earnings estimates from QCEW data. We then discuss the occupations likely to experience the highest impact from the transition and provide baseline employment and earnings based on OES data. Regarding the expanding high-impact industries, this chapter provides a preliminary discussion of which industries are likely to grow as a result of the transition. Thorough discussion and presentation of specific projected employment growth numbers are discussed in Chapters 4 and 5.

Our unit of analysis is the median annual earnings for affected occupations and industries, since earnings is the common measure of wellbeing across data sets. For greater data detail beyond this section, see the QCEW data tables in the Appendix. Our model-driven assessment of statewide employment impacts from the ZEV transition is detailed in Chapter 4. We further discuss potential frameworks and policy strategies for managing transitional employment changes, particularly those related high-impact industries, in Chapter 5.

2.2 – Fuel Supply Chain

The fuel supply chain has two distinct branches: fossil fuels used for internal combustion engine vehicles (ICEVs), and electricity used for electric vehicles (EVs). While our data accounts for biofuels and clean fuels such as hydrogen, the production and consumption of these fuels represent an insignificant percentage of total fuel production in California (University of California, Davis, 2020).

The main divisions of the fuel supply chain, fossil fuels and electricity, each have three streams of operation, although the operations in these streams are not identical. Understandably, the transition to net-zero emissions will reduce the size of the fossil fuels industries, with commensurate reductions in employment. However, electricity industries will expand as demand for electricity as an EV fuel increases, helping to offset gross job losses in the fossil fuel sector. The following subsections explore in detail the supply chains for fossil fuels and electricity.

Fossil Fuels Supply Chain

Upstream operations in the fossil fuels supply chain predominantly focus on extraction of crude petroleum and natural gas from wells across California. These extraction operations are geographically distinct, with Kern County accounting for the vast majority of crude oil and natural gas extraction in the state:

- Kern County: 60,307 active wells
- Los Angeles County: 5,270 active wells
- Fresno County: 3,697 active wells
- Ventura County: 3,029 active wells
- Santa Barbara County: 2,216 active wells (Sedgewick, Laferriere, Hayes, & Mitra, 2019; U.S.G.S., n.d.).[2]

Extraction operations require a range of occupations, including geoscientists, well drilling machinery manufacturers, and installation and operations workers for the well sites. Additionally, upstream operations must transport the raw materials to refineries by pipeline, rail, or truck.

Midstream operations in the fossil fuel supply chain refine the raw material inputs into completed products for distribution. In 2019, California had 15 oil refineries in operation across five counties: Contra Costa County, Kern County, Los Angeles County, Santa Barbara County, and Solano County (California Energy Commission, 2019). Natural gas also undergoes processing to isolate the natural gas from other elements and package the natural gas for transportation to distribution centers (Poe & Mokhatab, 2017).

Downstream fossil fuel operations distribute the refined petroleum products to consumers. This includes transportation of goods from refineries and storage facilities to gasoline stations directly, or to wholesalers who then distribute to gasoline stations. Regarding natural gas, only a small number of light-duty vehicles (LDVs) use natural gas for fuel; most natural gas transportation fuel is used in medium-duty passenger vehicles (MDVs) and heavy-duty vehicles (HDVs), such as transit buses and refuse vehicles (U.S. Department of Energy, n.d.a.). As such, some natural gas stations are public access stations while others are dedicated closed-access MDV and HDV stations (SoCalGas, n.d.).

Electricity Supply Chain

Upstream operations for the electricity supply chain are solely concerned with power generation (U.S. Energy Information Administration, 2019). California hosts a variety of electricity generation plants, all of which are categorized as either fossil fuel-burning or renewable energy, with the exception of the Diablo Canyon nuclear plant (scheduled for decommissioning in 2024; Nikolewski, 2018; Nyberg, 2020). While most fossil fuel electricity plants in California have low production levels (oil: 36GWh, petroleum coke: 191 GWh, Waste Heat:[3] 220 GWh, and coal: 248 GWh), natural gas plants generate the most electricity in the state, producing 86,136 GWh in 2019 (Nyberg, 2020). In fact, natural gas electricity generation exceeded both hydroelectric and solar electricity generation in 2019, which produced 38,494 GWh and 28,513 GWh, respectively (Nyberg, 2020).

Midstream operations in the electricity supply chain transmit electricity from generation plants to distribution lines (U.S. Energy Information Administration, 2019). Electricity is transmitted from individual plants and consolidated at transformers which increase the voltage before transmitting the current along high-voltage transmission lines (California Energy Commission, n.d.; U.S. Energy Information Administration, 2019).

Finally, downstream electricity operations distribute electricity to consumers. EV drivers utilize electricity at charging stations, either commercial or residential. The requisite infrastructure needs for these two distribution methods are dependent upon the voltage needed. For example, a home charging station for a single vehicle will require less voltage and infrastructure development than a high voltage charging array for a fleet of transit buses (ABB, n.d.; Tesla, n.d.e.).

Hydrogen Supply Chain

According to the California Energy Commission (2020), the current level of demand for hydrogen in California is 2 million metric tons per year (MMT/yr) and is mostly used for petroleum refining. Overall, low-carbon sources produce less than 5 percent of hydrogen fuel supplies and there are no plants operating in California today dedicated to producing renewable hydrogen (California Energy Commission, 2020; Hydrogen Council, 2020). Further, research by Vijayakumar and Fulton shows that there are still less than 50 hydrogen refueling stations serving the state. As the share of FCEV vehicles grows, and efforts to reach carbon neutrality by

2045 become more urgent, California will need greater supplies of hydrogen from renewable sources and more distribution infrastructure.

For the purposes of this study, we are approximating that by 2050, 978.3 million GGE of hydrogen will be consumed by heavy-duty trucks and a further 595 million GGE for light duty vehicles in the state annually. As a supplement to in-state production, California is likely to import a meaningful amount of its future hydrogen needs and could benefit from the ongoing development of oceangoing tankers designed to carry hydrogen fuel (California Energy Commission, 2020). Globally, production and distribution costs of hydrogen from renewable sources should drop by up to 60 percent and 70 percent respectively by 2030 (Hydrogen Council, 2020). The cost decreases for distribution are expected to come from greater utilization and scale, while production costs will benefit from efficiencies of increased automation, technological improvements, scalability in manufacturing, and a greater prevalence of low cost renewable electricity (Hydrogen Council, 2020). Such improvements are likely to make hydrogen more competitive with other transportation fuel sources and encourage wider adoption throughout the state.

Of the available clean hydrogen production methods that exist today, the process most likely to scale and be competitively priced is that of electrolysis - the practice of splitting water into hydrogen and oxygen (International Energy Agency, 2019). With the rapid advancement of technology, it is estimated that after 2025 electrolysis will be the dominant driver of hydrogen production growth and that it will require less capital expenditure than steam methane reforming (SMR), the most popular current method for deriving hydrogen from natural gas (Vijayakumar & Fulton, 2020). Abundant and low-cost renewable energy will be crucial for the successful expansion of hydrogen production using electrolysis (Hydrogen Council, 2020, p. 21). As California has adequate resource potential to meet its future energy needs through continued development of renewable energy sources, this makes the state a promising location for large-scale electrolysis operations (California Energy Commission, 2020).

In addition to electrolysis, two other potential methods for the production of renewable hydrogen that should be noted are the application of carbon capture sequestration to SMR and deriving hydrogen from biomass. As mentioned, SMR is currently the dominant form of hydrogen production today and it is fossil fuel-based, deriving hydrogen from natural gas (Vijayakumar & Fulton, 2020). In theory, carbon capture and sequestration (CCS) could be applied to both the production process and energy emissions associated with SMR to reduce carbon emissions from these processes by up to 90% (International Energy Agency, 2019). Such a scenario would have significant expenses and would necessitate the development of carbon transport and storage infrastructure, but could conceivably serve as a short-term option for cleaner hydrogen procurement as electrolysis production continues to scale up. In regards to using biomass for renewable hydrogen production, this approach has promise but is relatively expensive compared to the other methods mentioned and has limited availability. These characteristics are likely to preclude it from long-term competitiveness with other methods (International Energy Agency, 2019).

The production of hydrogen falls under the broader category of Industrial Gas Manufacturing (NAICS 281399) for labor statistic tracking, so it is difficult to get exact figures for this subsector. Given that the renewable hydrogen supply chain in California is still in a nascent stage, the current footprint of renewable hydrogen production on the state's workforce is negligible. This will change as new production and distribution infrastructure is emplaced and as production increases. As we shall explore in more depth in Chapter 4, we expect new spending on hydrogen fuel and associated infrastructure to create a significant number of new jobs in the state over the next 25 years. Potential large-scale electrolysis plants in California, and their associated jobs, are likely to be concentrated across the southern half of the state, where the majority of wind and solar renewable energy generation will take place (California Energy Commission, 2020). In contrast, small-scale electrolysis production will have greater geographic variance, as on-site production equipment can be co-located with refueling stations and will therefore be concentrated around the state's metropolitan areas (California Energy Commission, 2020).

The following subsections address the specific employment, earnings, and demographic estimates for high employment industries and high-risk industries.

Top Five Highest Employment Industries

The top five industries with the highest employment in the fuel supply chain are in the fossil fuels sector, since calculated employment numbers in electricity generation – based on the proportion of electricity used to power EVs – is currently quite low (approximately 1,091 employees in 2019; see Table A-2). To estimate the number of workers employed in electricity generated solely for EVs, we first found the percentage of electricity EVs consumed in 2019 divided by the total amount of electricity consumed in California. We multiplied the total electricity supply chain employment by the resulting percentage (0.68%), which produced the employment totals listed in Table A-2.

The top five industries with the highest employment are Gasoline Stations, (51.18% of supply chain employment), Petroleum Refineries (8.73% of supply chain employment), Other Building Equipment Contractors (8.66% of supply chain employment, which includes gasoline station construction), Oil and Gas Pipeline Construction (8.06% of supply chain employment), and Support Activities for Oil and Gas Operations (5.47% of supply chain employment). The estimated 2019 employment and earnings for these industries is shown in Table 2-A.

Table 2-A: Estimated employment and wages for highest employment industries in California's fuel supply chain, 2019.

Industry Name	Establishments	Estimated Annual Employment	Estimated Annual Wage
Support Activities, Oil-Gas Operations	258	6,792	$84,284.00
Oil and Gas Pipeline Construction	176	10,016	$88,333.00
Other Building Equipment Contractors	815	10,763	$94,870.00
Petroleum Refineries	106	10,839	$174,905.00
Gasoline Stations	7,064	63,573	$28,296.00

Source: Quarterly Census of Employment and Wages (BLS, 2020d).

The industries in Table 1-A exhibit a high level of variation in earnings between groups. Understandably, the first three industries tend to require some level of educational attainment beyond High School as a condition of employment. Gasoline Stations have a large number of "low-skill" occupations with few educational barriers to employment, but typically pay substantially less than skilled positions (see Table 2-B; BLS, 2019a).

Demographic analysis of Quarterly Workforce Indicator (QWI) data from the U.S. Census Bureau (2020), shows that most employees in the high employment industries are White, with the lowest percentage in the Gasoline Station industry (67.15%) and the highest percentage in Support Activities for Oil and Gas Operations (86.71%). Similar patterns appear for worker sex, with males making up a majority of workers in the highest employment industries. The lowest percentage of male workers is in the Gasoline Station industry (56.58%), while Support Activities for Oil and Gas Operations has the highest percentage of male workers (87.85%). A slight majority of workers in these high employment industries are Hispanic or Latino, with the lowest percentage in the Oil and Gas Pipeline industry (54%) and the highest percentage in the Petroleum Refineries industry (74.57%).

Examination of the occupations within industries shows similar pay disparities between managerial and specialized workers, such as chemists and architects, and production line staff. For example, managers in the Petroleum Refineries industry make, on average, $159,650 annually, architects and engineers make $116,810 annually, and production staff make $86,380 annually. Each industry has a variety of positions ranging from management to direct production of goods and distribution preparation teams, and the earnings differences between these groups is rather stark (Table 2-B).

Table 2-B: Major occupation group employment and wages by top 5 industries in California's fuel supply chain, 2019.

Industries and Occupations	Estimated Annual Employment	Estimated Annual Median Wage
Support Activities, Oil-Gas Operations		
Management Occupations	480	$135,370.00
Architecture and Engineering Occupations	510	$73,120.00
Construction and Extraction Occupations	5,590	$55,860.00
Installation, Maintenance, and Repair Occupations	770	$54,650.00
Production Occupations	270	$49,880.00
Oil and Gas Pipeline Construction		
Management Occupations	3,180	$113,660.00
Architecture and Engineering Occupations	1,160	$96,330.00
Construction and Extraction Occupations	28,410	$60,030.00
Installation, Maintenance, and Repair Occupations	4,780	$59,690.00
Production Occupations	1,430	$53,260.00
Other Building Equipment Contractors		
Management Occupations	550	$119,130.00
Architecture and Engineering Occupations	70	$55,470.00
Construction and Extraction Occupations	4,510	$73,050.00
Installation, Maintenance, and Repair Occupations	3,070	$61,150.00
Production Occupations	260	$44,800.00
Petroleum Refineries		
Management Occupations	670	$159,650.00
Architecture and Engineering Occupations	1,430	$116,810.00
Construction and Extraction Occupations	610	$96,550.00
Installation, Maintenance, and Repair Occupations	1,350	$85,720.00
Production Occupations	5,760	$86,380.00
Transportation and Material Moving Occupations	530	$49,950.00
Gasoline Stations		
Management Occupations	1,360	$88,920.00
Sales and Related Occupations*	50,910	$26,330.00
Installation, Maintenance, and Repair Occupations	2,250	$37,770.00
Transportation and Material Moving Occupations*	3,720	$25,960.00

Note. As stated in the Data section, employment and wage estimates for QCEW (BLS, 2020d) and OES (BLS, 2020c) estimates differ due to the NAICS classification level. While the occupational data overestimates some industry employment or list different wages, the occupational estimates provide information on potentially impacted occupations within an industry.

**Denotes occupations relevant to fuel distribution only.*

As Table 2-B shows, there is a high level of earnings variability between industries, as well within industries among the various tiers of occupations. The variation between industry occupations is likely due to the differences in knowledge and skills necessary to complete the specified tasks associated with occupations in an industry. While workplace hazard pay initially appears to explain the variation, the actual number of workplace injuries documented in the first three industries is quite low.[4] This reality eliminates hazard pay as an explanation for the relatively low wages for management and installation occupations in the gasoline station industry.

Highly Impacted Industries

This subsection addresses the industries which will be directly impacted by the transition away from using fossil fuel for transportation. The expanding industries in the fuel supply chain are largely composed of those involved in electricity distribution. EV charging infrastructure construction stands out regarding projected new employment growth, with the highest occupational growth occurring among Construction Trade Workers. Further discussion of these expanding industries takes place in Chapters 4 and 5.

The main contracting industries of interest are those which are directly involved with the extraction, production, and distribution of fossil fuels. The relevant industries are listed in Table 2-C.

Table 2-C: Estimated employment and wages for rapidly contracting industries in California's fuel supply chain, 2019.

Industry Name	Establishments	Estimated Annual Employment	Estimated Annual Wage
Crude Petroleum Extraction	86	3,135	$258,697.00
Drilling Oil and Gas Wells	123	3,024	$144,655.00
Support Activities, Oil-Gas Operations	258	6792	$84,284.00
Oil and Gas Pipeline Construction	176	10,016	$88,333.00
Petroleum Refineries	106	10,839	$174,905.00

Source: QCEW (BLS, 2020d).

The rapidly contracting industries listed in Table 1-C are considered high-impact because, historically, most fossil fuels produced in California are consumed in-state (U.S. Energy Information Administration, 2015). As such, any drastic shift in consumption habits within-state will impact these industries and the workers within the industries. Notably, crude petroleum extraction, oil drilling, and support activities for these operations have unique industry-specific occupations, which may create challenges for employees in these sectors to transfer into other industries (Table 1-D).

As with the top 5 highest employment industries in the Fuel Supply Chain, workers in rapidly contracting industries are predominantly White, with the lowest percentage in Petroleum Refineries (75.03%) and the highest percentage in Support Activities for Oil and Gas (86.72%).[5] High impact industries also have a high percentage of workers who are Hispanic or Latino, with Oil and Gas Pipeline Construction at the low end (54%) and Oil and Gas Extraction at the high end (78.64%). Regarding worker sex, all high impact industries are overwhelming male (between 75.34% and 87.85%).

Rapidly contracting industries also exhibit a high degree of variation between average earnings. Oil and Gas Pipeline Construction ($88,333 annually) and Support Activities for Oil and Gas ($84,284 annually) are at the lower end of the earnings spectrum, while Crude Petroleum Extraction is the highest earning industry, averaging $258,697 annually.

Table 2-D provides a comparison of earnings between the highest average earnings contracting industry (Oil and Gas Extraction) and the lowest average earnings contracting industry (Support Activities for Oil and Gas). While we expect higher earnings for managerial positions compared to field and machinery operators, the magnitude of the wage difference is large: managers make an estimated 3 to 4.5 times the earnings of field operators.

Table 2-D: Highly impacted occupations by rapidly contracting industry in California's fuel supply chain, 2019.

Industries and Occupations	Estimated Annual Employment	Estimated Annual Median Wage
Oil and Gas Extraction		
Management Occupations	480	$176,610.00
Roustabouts, Oil and Gas	70	$38,950.00
Wellhead Pumpers	100	$48,880.00
Support Activities for Mining		
Management Occupations	480	$135,370.00
Derrick Operations, Oil and Gas	820	$52,230.00
Roustabouts, Oil and Gas	160	$41,390.00

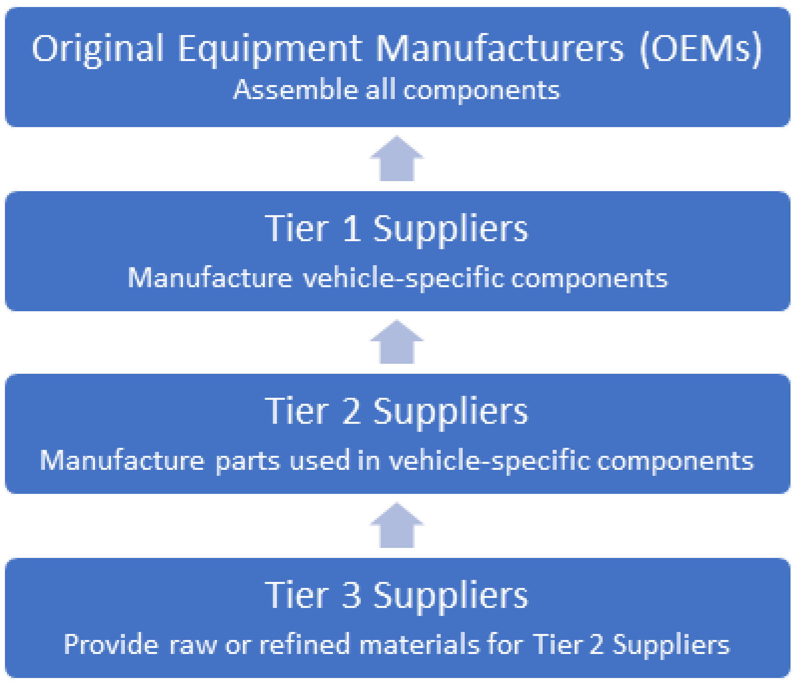
Source: OES (BLS, 2020c).

2.3 – Vehicle Supply Chain

The vehicle supply chain focuses on the manufacture and distribution of ICEVs and EVs, both of which have general components and drivetrain-specific parts. As such, this section will provide supply chain descriptions for general automotive manufacturing and distribution, the ICEV drivetrain specific supply chain, and the EV drivetrain specific supply chain.

Of the streams in the vehicle supply chain, midstream production operations are the most complex, because automotive manufacturers follow a tiered supply system based on a decentralized just-in-time model of production – no one firm produces all components in-house (Harris, 2018; Honda, 2019; Igogo, Sandor, Mayyas, & Engel-Cox, 2019; Silver, 2016; Toyota, n.d.a.).

Figure 2-4: Midstream supplier tiers in the vehicle supply chain.



Tier 3 suppliers provide either the raw or newly refined materials needed to manufacture vehicle parts. Tier 2 suppliers manufacture components which are not necessarily vehicle-specific, but are used in vehicles and sold to Tier 1 suppliers for use in a specific component. Tier 1 suppliers provide vehicle-specific components, such as fuel pumps and batteries, directly to the final vehicle original equipment manufacturer (OEM). Finally, the OEM (e.g. Tesla, Ford, Honda) assembles all the components to produce a completed vehicle ready for distribution.

General Automotive Supply Chain

The upstream operations of the general automotive supply chain extract and refine raw materials for use in the production of non-drivetrain components, such as vehicle chassis, lighting, and interior. While precious metals and rare earth elements are important, the largest upstream operation is extraction and refining of steel and aluminum, which are used in vehicle chassis, body, and numerous internal components (Automotive Industry Action Group, 2016; Onstad, 2018). California does not have any iron or bauxite extraction operations, although some companies manufacture and distribute steel and aluminum in the state (Thomas, n.d.). However, this does not guarantee use of these materials for in-state vehicle manufacturing, since no entity currently tracks raw materials from extraction through the multiple midstream tiers to the completed vehicle (Automotive Industry Action Group, 2016; Tesla, 2014). Such tracking would be highly complex and difficult.

In the midstream, Tier 3 suppliers provide raw or refined materials to Tier 2 and Tier 1 suppliers to manufacture non-drivetrain components. These include brakes, chassis, seating, and any vehicle part which is not directly involved in either combustion engine or EV battery operations. Aside from direct manufacture, midstream tiers transport components to the final facility, whether that facility is an automobile assembly plant, parts wholesaler, dealership, or automotive retail store. The final stage of the midstream process is the assembly of the final vehicle by an OEM who has either purchased or manufactured the necessary components to complete a vehicle (Silver, 2016).

Similar to the fuel supply chain, the downstream vehicle operations are focused on distribution of the final products. The most common distribution centers are automobile dealerships, who sell the completed vehicles or after-market parts directly to consumers. Dealerships may also have a repair and maintenance staff dedicated to working on the vehicle from that dealership. Vehicle component sales also occur at automotive-specific retail stores or standalone repair and maintenance shops.

ICEV Supply Chain

Upstream operations in the ICEV-specific supply chain are indistinct from the general automotive supply chain, while the midstream and downstream areas have dedicated ICEV operations. In the midstream, the ICEV supply chain manufactures components for the combustion engine drivetrain. This includes the engine block and pistons, the engine cooling and lubricating systems, and fuel lines and pumps which feed into the engine. Additionally, ICEV transmissions are different from EV transmissions, since ICEVs use a multi-gear transmission while EVs use a single-gear system (Edmunds, n.d.; Markus, 2016; Nissan, n.d., Tesla, n.d.c.).

Downstream ICEV operators maintain and repair ICEV drivetrains and their components. Engine mechanics, lubrication shops, and smog centers are directly involved in the upkeep of ICEV drivetrains. A related downstream operation is the retail sale of ICEV-specific parts, although automotive parts stores also sell non-drivetrain-related vehicle components.

BEV Supply Chain

The drivetrain manufacturing and maintenance for EVs centers on two key components: the energy-storing lithium ion battery packs, and the electric motor. Like traditional ICEVs, EV motors use steel, aluminum, and copper in motor manufacturing, but EVs also require rare earth elements to manufacture their permanent magnet motors (Desai, 2018).

Regarding batteries, the most popular battery type for EVs is lithium-ion (U.S. Department of Energy, n.d.b.). Other options include nickel-metal hydride, lead-acid, and ultracapacitors (U.S. Department of Energy, n.d.b.). Of the elements used in EV batteries, California only produces gold, although there is no evidence that the gold mined in California is used for batteries manufactured in California.

Currently, downstream maintenance and repair of EV specific components is proprietary, with firms such as Tesla having explicitly Tesla owned and operated service centers. Similarly, other firms, such as Nissan, have an implicit maintenance agreement by having Leaf-specific service centers and mechanics at Nissan dealerships (Nissan, 2019; Tesla, n.d.a.).

FCEV Supply Chain

Current mandates set goals for increased hydrogen fuel production and distribution, which will necessitate large-scale uptake of hydrogen fuel cell electric vehicles (FCEVs) across the state. Based on the low-carbon scenario upon which consumer expenditure and workforce impacts projections in Chapters 3 and 4, respectively, are predicated, we anticipate 2,313,000 light-duty FCEVs and 461,000 heavy-duty FCEVs in operation across the state by 2045. Although light-duty FCEVs make up the vast majority of future FCEV fleets in 2045 (83.38%), heavy-duty FCEVs will likely consume the majority of hydrogen fuel (835,100,000 GGE in 2045, accounting for 61.99% of total hydrogen consumption).

At present, California is one of two states in the United States which allow for the sale, registration, and operation of FCEVs, with Hawai'i being the second (Edelstein, 2020; Honda, n.d.; Toyota, n.d.b.). The total cumulative number of registered FCEVs in California was 8,654 as of September 2020 (California Fuel Cell Partnership, 2020). Despite California's almost exclusive consumption of FCEVs in the United States, no FCEVs or hydrogen fuel cells are manufactured in the state. However, the shift toward EV manufacturing in the state will likely aid the adoption of in-state FCEV manufacturing and assembly as well.

The primary component for the FCEV drivetrain is the membrane electrode assembly, which contains anodes (hydrogen delivery) and cathodes (oxygen delivery) to catalyze energy via electrochemical reaction (Alternative Fuels Data Center, n.d.a., n.d.b.; Office of Energy Efficiency & Renewable Energy, n.d.a., n.d.b.). The manufacture of these fuel cells falls under the same category as electricity fuel cell manufacturing (NAICS 335999), since they use similar components, but have different energy capture processes. Shared manufacturing materials include lithium, nickel, and metal oxides, all of which are not currently mined in California, as mentioned in the EV Supply Chain subsection (University of Washington, n.d.). As such, the FCEV supply chain parallels much of the EV supply chain.

Although California currently lacks in-state manufacturing of FCEVs, the presence of EV manufacturing establishes a precedent for the uptake of FCEV manufacturing in the future. Such facilities are likely to be geographically concentrated, as is the case with Tesla's Fremont factory and BYD's factory in Lancaster (BYD, 2019; Tesla, n.d.b.).

Highest Employment Industries

The highest employment industries in the vehicle supply chain are all in downstream operations. The largest of these is car dealerships (34.9% of supply chain employment), followed by general automotive repair shops (11.7% of supply chain employment), automotive parts and accessories stores (10.2% of supply chain employment), and motor vehicle supplies and new parts wholesalers (6.8% of supply chain employment; Table 2-E). Understandably, EV-specific industries are not highly represented, since these zero-emission industries are still developing.

Table 2-E: Estimated employment and wages for the highest employment industries in California's vehicle supply chain, 2019.

Industry Name	Establishments	Estimated Annual Employment	Estimated Annual Wage
Motor Vehicle Manufacturing	81	17,870	$94,361.00
New Car Dealers	1,998	118,818	$68,473.00
Automotive Parts and Accessories Stores	3,544	34,950	$35,814.00
Motor Vehicle Supplies and New Parts Merchant Wholesalers	2,006	23,162	$59,619.00
General Automotive Repair	9,681	39,859	$46,156.00

Source: QCEW (BLS, 2020d).

Unlike the fuel supply chain, high employment industries in the vehicle supply chain have a tighter distribution of earnings across industries, ranging from $35,814 annually (Automotive Parts and Accessories Stores) to $68,473 annually (New Car Dealers). However, approximately 80% of all industries in this supply chain report median earnings below the median wage in California ($71,228 annually, in 2018 USD), which is likely indicative of lower wellbeing for the workers in these industries (U.S. Census Bureau, n.d.).

Across all of these industries, a majority of workers are White, although the range is much narrower than the fuel supply chain. The lowest percentage of white workers occurs in Motor

Vehicle Supplies and New Parts Merchant Wholesalers (73.81%), while the highest percentage is found in the Automotive Parts and Accessories Stores industry (80.79%). Worker sex has a similar distribution for men, with male workers making up between 74% (Motor Vehicle Supplies and New Parts Merchant Wholesalers) and 79.34% (Automotive Parts and Accessories Stores) of industry employment. Ethnic groups are more evenly divided in the high employment industries, with Hispanic or Latino workers ranging from 49.78% (Automotive Parts and Accessories Stores) at the low end to 58.33% (Motor Vehicle Supplies and New Parts Merchant Wholesalers) at the high end.

Examination of non-supervisory occupations within these industries, namely retail and service/repair jobs, reveals that earnings for most positions are consistently lower than the median earnings for the industry. The only notable exception are Architecture and Engineering Occupations which make $98,750 annually, $4,389 above the Motor Vehicle Manufacturing industry median of $94,361 (Table 2-F).

As expected, there is a gap in earnings between a management position and a salesfloor or garage position, but the magnitude of the difference is quite stark. For example, average dealership management occupations earn $142,710 annually, while average floor-level salespeople earn $39,190 annually. Similarly, motor vehicle parts wholesaler managers earn an estimated $110,620 annually, while floor-level salespeople earn $47,170 annually.

Table 2-F: Major occupation group employment and wages for the top 5 industries in California's vehicle supply chain, 2019.

Industries and Occupations	Estimated Annual Employment	Estimated Annual Median Wage
Motor Vehicle Manufacturing		
Management Occupations	490	$150,060.00
Architecture and Engineering Occupations	1,380	$98,750.00
Installation, Maintenance, and Repair Occupations	1,090	$75,180.00
Production Occupations	10,920	$46,540.00
New Car Dealers		
Management Occupations	5,640	$142,710.00
Sales and Related Occupations	51,430	$39,190.00
Installation, Maintenance, and Repair Occupations	29,650	$52,760.00
Automotive Parts and Accessories Stores		
Management Occupations	1,820	$77,860.00
Sales and Related Occupations	22,150	$31,480.00
Installation, Maintenance, and Repair Occupations	16,690	$35,370.00
Motor Vehicle Supplies and New Parts Merchant Wholesalers		
Management Occupations	2,970	$110,620.00
Sales and Related Occupations	9,220	$47,170.00
Installation, Maintenance, and Repair Occupations	4,770	$48,680.00
General Automotive Repair		
Management Occupations	1,380	$79,980.00
Sales and Related Occupations	3,870	$39,410.00
Installation, Maintenance, and Repair Occupations	31,520	$45,420.00

Source: OES (BLS, 2020c).

Highly Impacted Industries

Within the vehicles supply chain, the transition to net zero emissions will impact downstream repair and maintenance industries the most acutely, especially if BEV and FCEV repair and maintenance remains proprietary (California Fuel Cell Partnership, n.d.). Based on the low-carbon scenario and the model outputs presented in Chapter 4, no industries within the vehicle supply chain can confidently be identified as rapidly expanding. There is some potential for increased manufacturing of ZEVs in the state, but the degree to which this potential will be realized is highly uncertain.

While chain or corporate repair shops should be able to handle reduced operations, small-scale or family-owned repair shops will likely experience contraction from the transition. Another industry the transition may negatively impact is the ICEV-specific drivetrain manufacturing industry. However, the complexity of the multi-tiered midstream operations in the vehicle supply chain make verifying the impacts difficult. We cannot guarantee that engines or ICEV drivetrain components made in California are used in vehicles assembled in California. Despite this equivocation, we include the Engine and Engine Parts Manufacturing industry in our baseline to account for the possibility of transitional impacts (Table 2-G).

Table 2-G: Estimated employment and wages for rapidly contracting industries in California's vehicle supply chain, 2019.

Industry Name	Establishments	Estimated Annual Employment	Estimated Annual Wage
Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	117	2,297	$66,355.00
General Automotive Repair	9,681	39,859	$46,156.00
Automotive Exhaust Repair	222	651	$38,149.00
Automotive Oil Change and Lubrication Shops	669	5,829	$31,614.00

Source: QCEW (BLS, 2020d).

Earnings for all rapidly contracting industries are well below California's median earnings, with Automotive Oil Change and Lubrication Shops earning the lowest average wages ($31,614 annually) and Motor Vehicle Gasoline Engine and Engine Parts Manufacturing ($66,355 annually). As with the high employment industries, the low earnings for these industries are likely indicative of lower worker wellbeing for employees in these industries (U.S. Census Bureau, n.d.).

A majority of these rapidly contracting industry workers are Hispanic or Latino, although the distribution is much broader than worker sex (between 55.38% for Automotive Repair and Maintenance and 69.97% for Motor Vehicle Manufacturing).

Workers in these industries are also mainly White (automotive repair and maintenance industries are all close to 78% White), although Motor Vehicle Manufacturing only has a simple majority (52.39% White) with the next largest racial group in this industry being Asian (30.53%). Worker sex is majority male with a very narrow distribution: between 76.14% (Automotive Repair and Maintenance) and 77.55% (Motor Vehicle Manufacturing).

For occupational earnings within rapidly contracting industries, automotive repair and maintenance occupations have a fairly narrow distribution, with management occupations earning between 1.8 times and 2.2 times floor-level mechanics. The notable exception is the ICEV manufacturing industry, where management occupations earn an average of $132,420 annually, while engine assemblers and gasoline component fabricators earn $31,460 and $30,060, respectively (Table 2-H).

Table 2-H: Estimated employment and wages for highly impacted occupations in California's vehicle supply chain, 2019.

Industries and Occupations	Estimated Annual Employment	Estimated Annual Median Wage
*Motor Vehicle Gasoline Engine and Engine Parts Manufacturing**		
Management Occupations	840	$132,420.00
Engine and Other Machine Assemblers	560	$31,460.00
Miscellaneous Assemblers and Fabricators	1,480	$30,060.00
*General Automotive and Exhaust Repair**		
Management Occupations	1,380	$79,980.00
Automotive Service Technicians and Mechanics	22,150	$43,700.00
Bus and Truck Mechanics and Diesel Engine Specialists	3,540	$51,060.00
Automotive Oil Change and Lubrication Shops		
Management Occupations	950	$78,840.00
Automotive Service Technicians and Mechanics	3,130	$35,760.00

Source: OES (BLS, 2020c).
**Industry estimates grouped in occupational data.*

2.4 – Transportation Services Supply Chain

The transportation services sector is less of a supply chain and more of an assortment of movement services, whether that is movement of goods or movement of passengers. Both movement of goods and movement of people occur at the interstate, intrastate, and local level, with different entities offering a variety of services. While goods movement is focused on mass product movement, passenger transportation services are more varied, including mass transit, for-hire low-occupancy transit, vehicle rental, and, to a lesser degree, micro-mobility (e.g. bikeshare, e-scooters).

Top 5 Highest Employment Industries

While mass transit is the most visible transportation service, goods movement represents the majority of employment in the transportation sector (78.9%), with freight trucking alone accounting for 34.8% of total transportation services employment in California (Table 2-I).

Table 2-I: Estimated employment and wages for top 5 highest employment industries in the transportation services supply chain, 2019.

Industry Name	Establishments	Estimated Annual Employment	Estimated Annual Wage
General Freight Trucking	9,811	93,912	$53,764.00
Specialized Freight Trucking	3,724	40,716	$55,536.00
Couriers and Express Delivery Services	976	85,029	$46,290.00
Postal Service (Public)	1,402	33,234	$66,089.00
Solid Waste Collection (Private)	858	17,462	$67,224.00

Source: QCEW (BLS, 2020d).

As with high employment industries in the vehicle supply chain, estimated earnings among high employment transportation services supply chain have a narrow distribution, between $46,290 and $66,089 annually, and all fall below California's median annual wage ($71,228 annually; U.S. Census Bureau, n.d.). A notable exception is public works employees who maintain roads and support ground transportation. This is likely driven by the collective bargaining power of public employees; a comparison of public and private workers in this industry shows a large pay gap: $104,012 annually for public workers and $43,939 annually for private workers (California Department of Industrial Relations, 2017, 2019).

Most workers in these high employment industries are White, with Couriers and Express Delivery Services at the low end (65.90%) and Solid Waste Collection at the high end (82.96%). Worker sex is predominantly male, ranging from 61.38% (Postal Service) to 81.25% (Specialized Freight Trucking). Worker ethnicity is similarly divided, with between 38.76% (Solid Waste Collection) and 57.44% (Postal Service) of workers reporting Hispanic or Latino ethnicity.

Examination of the occupations within each industry reveals that all non-supervisory occupations have annual earnings well below California's median wage (Table 2-J). The most drastic divide is between managers and non-supervisory workers in the Courier industry and Waste Collection industry, where managers earn 2.5 to 3 times more than vehicle operators.

Table 2-J: Major occupation group employment and wages by top 5 industries in California's transportation services supply chain, 2019.

Industries and Occupations	Estimated Annual Employment	Estimated Annual Median Wage
*Truck Transportation**		
Management Occupations	5,000	$83,850.00
Installation, Maintenance, and Repair Occupations	6,030	$45,500.00
Transportation and Material Moving Occupations	100,420	$43,200.00
Couriers and Express Delivery Services		

Management Occupations	780	$113,750.00
Installation, Maintenance, and Repair Occupations	1,460	$74,700.00
Transportation and Material Moving Occupations	72,440	$37,530.00
Postal Service (Public)		
Management Occupations	1,020	$84,810.00
Installation, Maintenance, and Repair Occupations	1,740	$65,440.00
Transportation and Material Moving Occupations	1,510	$63,280.00
Waste Collection		
Management Occupations	1,050	$115,890.00
Installation, Maintenance, and Repair Occupations	2,040	$55,130.00
Transportation and Material Moving Occupations	14,420	$45,340.00

Source: OES (BLS, 2020c).
**General and Specialized Freight Trucking are combined under Truck Transportation.*

Highly Impacted Industries

Unlike the other supply chains, the transportation services supply chain is unlikely to be adversely impacted by the transition to net-zero emissions. Some entities, such as LA Metro, FedEx, and Amazon, have already begun the process of electrifying their fleets, which will make the transition to zero-emission fleets easier for these groups (Coren, 2019; Goheen & Jager, 2019; Jager, 2020; Klyce, 2020).

Regarding HDVs and MDVs, some prototype electric vehicles have been introduced, but the capital costs for these electric vehicles are slightly higher than traditional ICEV HDVs and MDVs (Carpenter, 2020; Hirsch, 2020). However, one element will likely ease the electrification transition: according to manufacturers, the operating costs for electric trucks are significantly lower than their diesel and gas counterparts, (Carpenter, 2020). Average operating cost for a diesel HDV is estimated at $1.38 per mile, while an electric HDV is estimated to cost $1.26 per mile to operate. With an estimated daily roundtrip route of 250 miles, one electric HDV reduces operating costs by $10,950 annually. Assuming an electric HDV costs $150,000 to purchase and $114,975 to operate, the annual total cost of ownership (TCO) of an electric HDV is approximately $264,975, more than $10,000 cheaper than the TCO of a diesel HDV (Table 2-K; Freightliner, n.d.; Tesla, n.d.d.). As such, the long-term TCO advantages make electrification of MDV and HDV fleets fiscally sensible despite the higher upfront cost of the vehicles.

Table 2-K: Total cost of ownership for representative electric and diesel HDVs.

Annual Costs	Heavy Duty Vehicle	
	Tesla Semi (300 Mile)	*2021 Freightliner Cascadia (Diesel)*

Per Mile Operation (250 Miles Daily)	$114,975.00	$125,925.00
Capital Cost	$150,000.00	$149,900.00
Total	$264,975.00	$275,825.00

Understandably, some truck transportation companies may not have the necessary funds to invest in an electric fleet, which leads to the second element to ease the transition: state incentives. A recent memorandum, signed by the District of Columbia and 15 states, has outlined a plan of action to transition MDVs and HDVs from fossil fuels to electricity (Newsom et al., 2020). In this action plan, states have the authority to provide financial incentives to encourage adoption of electric vehicles. Such a practice will alleviate the financial burden for some companies, thus enabling them to electrify their fleets.

While this section has focused on the adoption of EVs for transportation services, FCEVs show promise as a zero-emission alternative to HDV and MDV ICEVs (Hyundai, 2020). The HDV and MDV FCEV industry is still young. The first HDV FCEV was released by Hyundai in July 2020, the early model boasts a range comparable to existing electric HDV trucks (Freightliner, 2020; Hyundai, 2020; Tesla, n.d.d.).

2.5 – Limitations

While this work has sought to provide a detailed representation of California's transportation sector, the analysis is limited due to the lack of available state-specific demographic data for occupations categorized by industry, as well as a dearth of geographic data for industries and occupations.

Regarding demographics, this work recognizes that workers have different experiences and barriers dependent upon their race, ethnicity, and gender. As such, demographically different workers will be impacted in different ways by California's transition to zero emissions in the transportation sector.

Similarly, geographic distribution of industries, occupations, and workers would provide a detailed representation of the workforce. Such data would enable this research to accurately estimate the impacts of California's transition to net-zero emissions in the transportation sector. Since no data set currently captures geographic and demographic distributions of occupations in each industry within California, further study is necessary to catalog the real demographics and geographic profile of the transportation labor force.

2.6 – Discussion

This section has provided baseline estimates for industries and occupations in the three supply chains within California's transportation sector. In particular, this section focused on employment and wage estimates for industries and occupations which are likely to be impacted by the transition to net-zero emissions for the transportation sector. A recurring element of high impact industries and occupations has been the possibility of limited job transferability combined with low earnings for these occupations. This means that high risk workers in the transportation sector will face two difficulties: unemployment and limited or no funds to gain new skills to transition to a new industry on their own. The transition to zero emissions in the transportation sector must account for the precarity of these workers and determine a transitional method which enables the affected workers to either transition to a new position in the EV sector or different industry.

Chapter 3 – Forecasted Trends in Total Transportation Expenditures on Zero Emissions and Fossil Fuels Vehicles

Introduction

The previous chapter described the types of employment that currently exist within California's three transportation-related supply chains. In order to assess how employment in these sectors will change between now and 2045, we must examine how consumer expenditures--a key driver of change in the labor market--will vary over time. In this chapter we explain the fundamental relationship between how consumers spend their money and consequent changes in the workforce, characterize Californians' current transportation-related spending, and forecast changes in these spending patterns that will drive employment changes across transportation-related supply chains between now and 2045.

In organizing our analysis, we assess four key categories of expenditures segmented by four general vehicle classifications. The examined areas of expenditure are:

- *Vehicle purchase expenditures*, which include vehicle costs spent buying new domestic and imported cars, trucks, and buses.
- *Fuel expenditures*, which include purchases on gasoline, diesel, and electricity.
- *Maintenance costs*, which include default maintenance (scheduled) and repair (unscheduled) costs.
- *Infrastructure costs* for construction of new EV charging sites and other EVSE installation, and construction of new hydrogen refueling stations.

We do not anticipate major changes in expenditures in the transportation services supply chain arising from California's ZEV transition. Past decades have shown that public transit agencies, rental fleets, and public fleets remain relatively consistent in their yearly expenditures. Transportation companies that maintain private fleets will take steps to update their vehicle fleets to become more compliant with newly introduced, more stringent emissions guidelines. Such upgrades are reflected in the vehicle numbers provided by the CNS LC1 scenario. We are not focusing on expenditures in the aviation and maritime industries, as planes and ships are expected to continue relying on fossil fuels into 2045.

Our four general vehicle categories are outlined below, with information regarding inclusion of EMFAC Vehicle Types available in Table 3-A:

- *Light-duty vehicles (LDVs)* - LDVs include all passenger cars and light-duty trucks. Passenger cars are classified as all sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers, and includes passenger cars pulling recreational or other light trailers. Light-duty trucks are four-wheel, two-axle vehicles that can be used for cargo transport, but are used primarily for passenger transport.

- *Heavy-duty Vehicles (HDVs)* - HDVs include long haul trucks, short haul trucks, and heavy-duty vocational trucks. Long haul trucks are Class 7-8 tractor trailers that do not typically return to base for refueling and have very high vehicle miles travelled (VMT). Short haul trucks are Class 7-8 tractor trailers that typically return to base for refueling and have moderate VMT. Heavy-duty vocational trucks are heavy duty trucks that use power take-off (PTO), such as refuse trucks.
- *Medium-duty Vehicles (MDVs)* - MDVs include medium-duty vocational trucks, medium-duty urban trucks, and heavy-duty pickup trucks. Medium-duty vocational trucks are medium-duty trucks that use PTO (e.g. utility bucket trucks). Medium-duty urban trucks are medium-duty delivery trucks used primarily for cargo transport (e.g. step vans, box trucks). Heavy-duty pickup trucks are Class 2b-3 trucks (light/medium trucks under 14,000 pounds).
- *Buses* - Buses include transit buses and other bus types. A transit bus is a passenger vehicle with a capacity of 15 or more persons primarily used for transport within cities.

We will characterize expenditure estimates for each of these four vehicle categories for both fossil fuel vehicles and zero emission vehicles in the following sections. In our analysis, fossil fuel vehicles refer to vehicles that run on gasoline or diesel and zero emission vehicles include both battery electric vehicles and fuel cell electric vehicles. These estimates are based on a weighted average that directly reflects the composition of the on-road fleet (Appendix B). In Chapter 4, we utilize these expenditure estimates as inputs for our state-level input/output model to forecast said employment changes.

Table 3-A: Vehicle categorization delineated by EMFAC 2007 vehicle type.

Category	Description	EMFAC 2007 Vehicle Types
Light-Duty Vehicles (LDV)	Passenger cars Light trucks	*LDA* *LDT1* *LDT2* *MDV*
Heavy-Duty Vehicles (HDV)	Long haul trucks Short haul trucks Heavy-duty vocational trucks	*T7 CAIRP* *T7 Tractor* *T7NNOOS* *T7 Ag* *T7 CAIRP Construction* *T7 Other port* *T7 POAK* *T7 POLA* *T7 Tractor Construction* *T7 Public* *T7 Single* *T7 Single Construction* *T7 SWCV*
Medium-Duty Vehicles (MDV)	Medium-duty vocational trucks Medium-duty urban trucks (delivery) Heavy-duty pickup trucks	*T6 Public* *T6 Utility* *T6 Ag* *T6 CAIRP Heavy* *T6 CAIRP Small* *T6 Instate Construction Heavy* *T6 Instate Construction Small* *T6 Instate Heavy* *T6 Instate SMall* *T6 OOS* *T6 OOS Small* *T6TS* *LHD1* *LHD2*
Buses	Transit buses Other buses	*SBUS* *UBUS* *OBUS*

3.1 – Factors Driving Change Within California's Transportation Workforce

U.S. consumer spending and employment are closely tied. When consumers shop, they directly support jobs in firms that produce, transport, and sell goods and services. They also indirectly support jobs that supply the inputs necessary for production of said goods and services. For example, when a consumer purchases a new car, they are supporting not only the jobs of employees at the plant where the vehicle was assembled, but also workers who manufactured the vehicle's component parts and those who produced and refined the raw materials necessary for said parts.

Additionally, large-scale investment in transportation infrastructure has historically generated widespread, second-order economic benefits. In the short-run, building transportation infrastructure creates jobs in construction and supporting occupations. In the long-run, modernized transportation systems offer greater efficiency and reliability, lowering the costs of moving people and goods and buoying economic well-being on a large scale.

Why Will Transportation-related Expenditures Change?

The way that consumers, firms, and governments spend money on transportation-related goods and services is mainly influenced by new ZEV policies, improving ZEV technologies, and changing consumer preferences.

California is a global leader in renewable energy, largely due to its innovative climate change policies. Transportation is the largest source of the state's greenhouse gas (GHG) emissions -- about 40 percent comes from light-duty vehicles alone (Chapple 2016). Transportation policy can shape VMT and GHG emissions, most obviously by incentivizing zero-emission vehicles. Increasingly strict ZEV policies designed to move away from reliance on fossil fuels call for improving ZEV technologies. In order to achieve new emissions goals, state agencies must set standards with the cooperation of major automakers who deploy advanced technologies to meet fuel economy requirements. Consumers' knowledge and preferences also impact the vehicle market. ZEVs represent innovation, and many consumers, especially environmentally active consumers, are predisposed to such innovation (Mills 2008). As the market becomes more saturated with ZEVs and consumers learn more about their environmental benefits, attitudes toward ZEVs will become increasingly positive.

As we move toward a zero-emissions vehicle fleet, new state policies, all three of these factors will encourage people to focus their spending on ZEVs and zero-emission fuels instead of traditional ICEVs and fossil fuels. Changes in transportation expenditure patterns will alter the demand for workers. This shift will lead to reduced demand for fossil-based fuels and vehicles and increased demand for zero-emission fuels and vehicles. Consequently, firms supplying these products then change the number and type of workers they employ; as demand shrinks for fossil fuels and vehicles that require them, firms supplying these goods will downsize and reduce their workforce. Conversely, industries manufacturing ZEVs and supplying fuels for them will need to expand to meet growing demand.

For example: the transition to zero-emissions vehicles will lead to the increased adoption of electric vehicles due to greater availability and consumer preference. This will increase demand for electricity and decrease demand for gas and diesel. Therefore, industries within the electricity generation supply chain will need to employ a larger workforce to cope with the rising demand. In contrast, the supply chain for gas and diesel will contract as smaller amounts of these fuels are consumed, producing less output and requiring fewer employees.

While the broad trends of employment shifts generated by California's ZEV transition are fairly intuitive, the magnitude of these changes will vary across industries and geographies. Gains and losses will likely be unevenly distributed among affected sectors and occupations and fluctuate across regions and counties. Some industries will be more impacted than others for a given level of expenditure change, variation which is captured in our modeling in Chapter 4.

3.2 – Forecasted New Vehicle Sales Expenditure

Vehicle purchase expenditures are the costs spent buying new cars, trucks, and buses. Used vehicles are omitted from our data because the new vehicle market is more relevant to production and workforce changes.

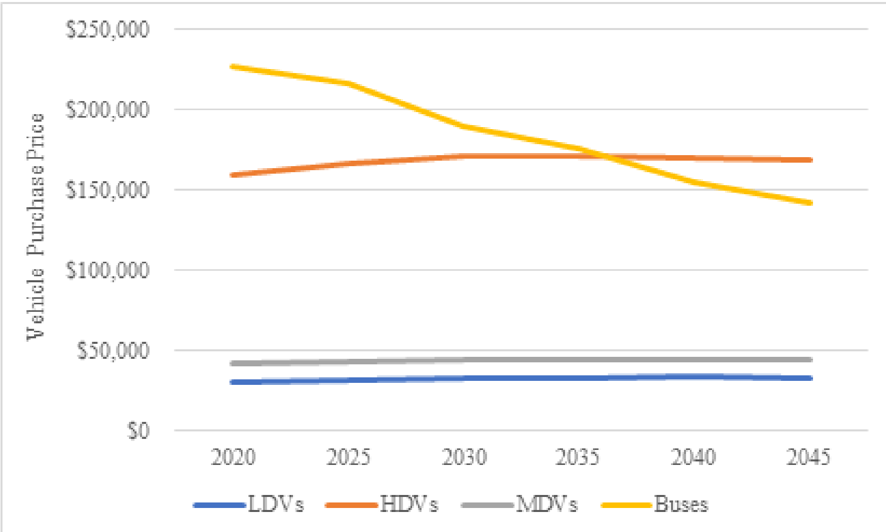
Forecasted New Vehicle Sales Data

To calculate new vehicle purchase expenditures, we multiplied the purchase price for an average vehicle in its class by the number of new vehicles purchased. We rely on purchase price estimates and sales figures provided by the CNS LC1 scenario.

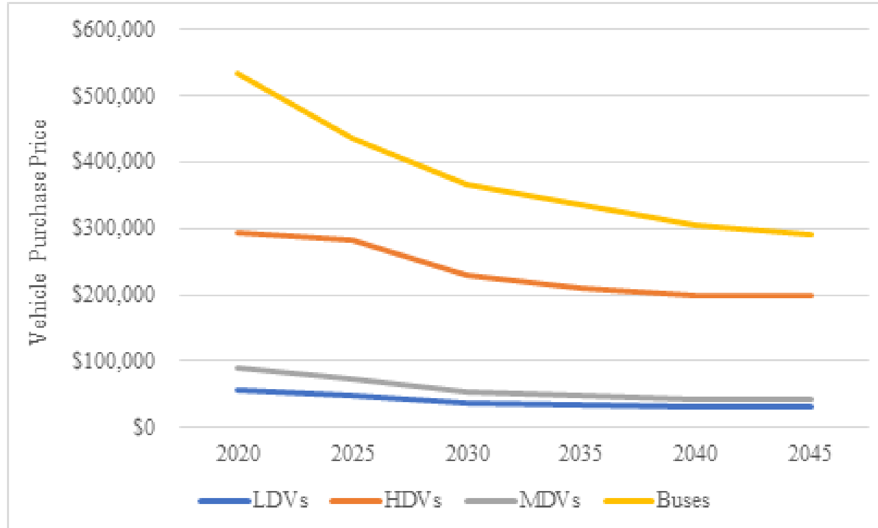
We estimate that the purchase price of fossil fuel vehicles will remain relatively constant over time (Figure 3-1). While ZEVs are currently more expensive than fossil fuel vehicles, the purchase price of ZEVs is expected to decline over time and become comparable to that of fossil fuel vehicles. It should be noted that the purchase price of electric buses is consistently much higher than that of fossil fuel buses, but thus far this has not appeared to significantly hinder purchasing of electric buses (see Appendix E).

Figure 3-1: Estimated purchase prices of new vehicles in California by fuel type and vehicle category in 2020 US Dollars by 5-year increments, 2020-2045.

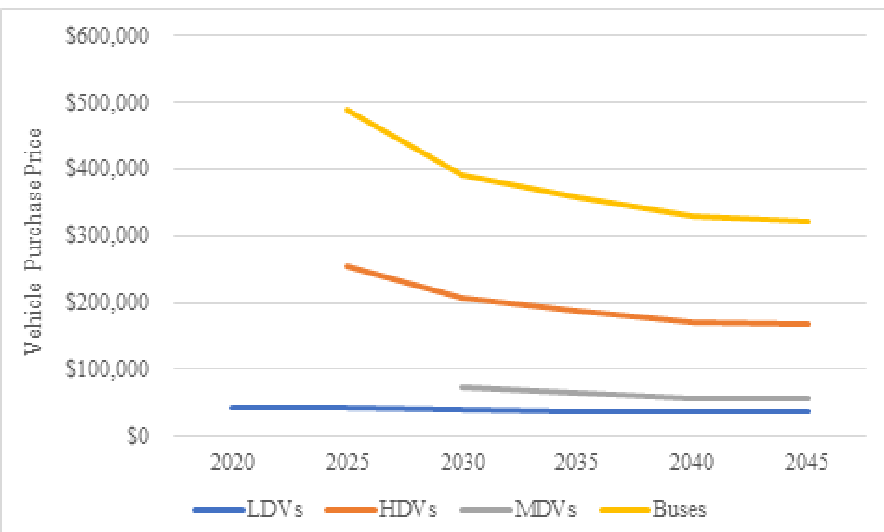
Fossil Fuel Vehicles



Battery Electric Vehicles

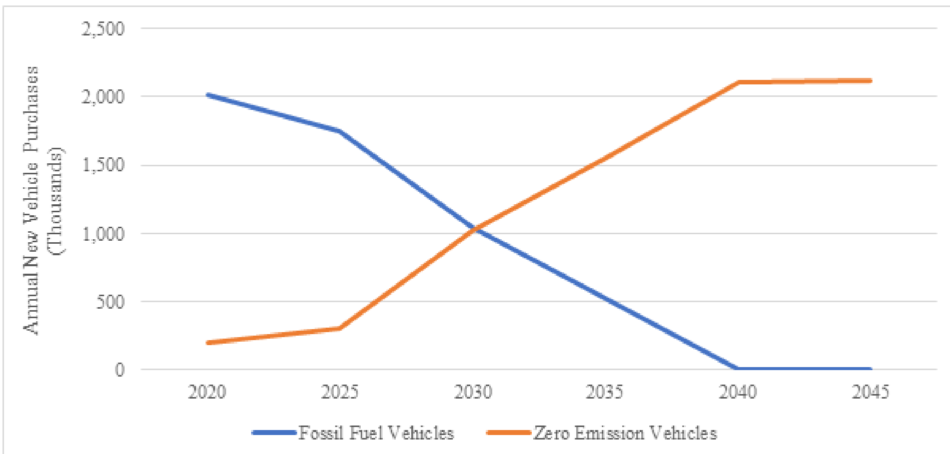


Fuel Cell Electric Vehicles



In Figure 3-2, we provide estimates for the number of vehicles purchased from now to 2045. Unsurprisingly, fossil fuel vehicles currently account for an overwhelming majority of total new vehicles purchased. However, the sales of new fossil fuel vehicles will cease by 2045 while the sales of new zero-emission vehicles will continue to climb. As the total number of vehicles on the road (Appendix C) is not expected to fluctuate drastically over time, total vehicle purchase expenditures therefore also stay relatively level.

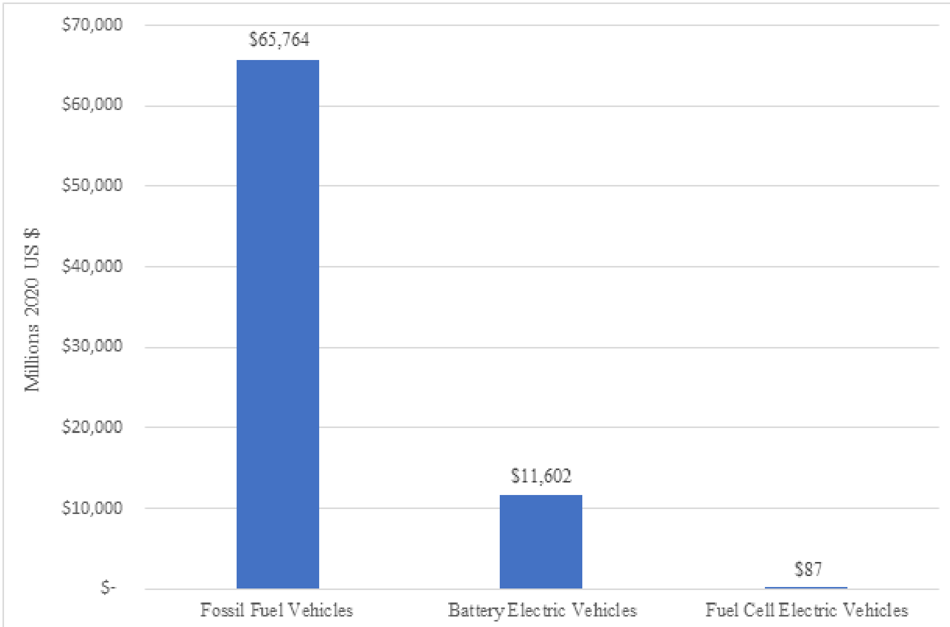
Figure 3-2: Projected number of new fossil fuel and zero-emission vehicles purchased annually in California in thousands by 5-year increments, 2020-2045. For a breakdown of ZEV purchases by drivetrain technology, see Appendix E.



Baseline New Vehicle Purchase Expenditures

We estimate that total vehicle purchase expenditures in 2020 will be approximately $77.2 billion. Currently, a significant majority of vehicle purchase expenditures – $65.7 billion – are on fossil fuel vehicles (Figure 3-3). Electric vehicles make up a substantially smaller portion ($11.3 billion), while fuel cell electric vehicles only account for $87 million of the total. There are no purchase expenditures on fuel cell trucks and buses, only LDVs. This aligns with our estimates for the number of vehicles purchased, as fossil fuel vehicles account for most of the vehicle sales in 2020.

Figure 3-3: New vehicle purchase expenditures in California by fuel type in millions of 2020 US dollars, 2020.



Projected New Vehicle Purchase Expenditures

Key Takeaways:

- Total annual new vehicle purchase expenditures drop $1.4 billion from $77.5 to $75.8 billion between 2020 and 2045.
- Purchases on new fossil fuel vehicles drop from $65.8 billion in 2020 to $0 in 2045.
- Purchases on new zero emission vehicles will rise by $64.1 billion between now and 2045, reaching $75.8 billion in 2045.

Between 2020 and 2045, total new vehicle purchases will remain relatively constant in the mid- to high- $70 billion range (Figure 3-4). However, the portion of those purchases made up of fossil fuel vehicles versus ZEVs changes dramatically over time. The sale of new fossil fuel vehicles will steadily decline each year, with no new sales of new fossil fuel LDVs and buses by 2040 (Table 3-B). By 2045, all new vehicles sold will be zero emission vehicles, creating a major, commensurate shift in new vehicle expenditures. The overall magnitude of vehicle purchase expenditures will fall by around $1.4 billion between now and 2045.

Table 3-B: Annual new vehicle purchase expenditures in California by vehicle category and drivetrain technology over 5-year increments in millions of 2020 US dollars, 2020-2045.

Vehicle Category	2020		2025		2030		2035		2040		2045	
	ICEV	ZEV	ICEV	ZEV	ICEV	ZEV	ICEV	ZEV	ICEV	ZEV	ICEV	ZEV
LDVs	$57,811	$11,449	$52,542	$14,069	$31,825	$36,644	$16,248	$51,583	$0	$64,485	$0	$64,437
HDVs	$3,346	$9	$3,111	$498	$2,106	$1,761	$1,045	$2,908	$101	$3,878	$0	$3,998
MDVs	$3,880	$9	$3,679	$618	$2,574	$2,297	$1,514	$3,566	$100	$5,323	$0	$5,552
Buses	$727	$71	$494	$1,002	$190	$1,689	$92	$1,771	$0	$1,814	$0	$1,807
Total by Drivetrain Technology	$65,764	$11,689	$59,826	$16,187	$36,696	$42,390	$18,898	$59,829	$201	$75,500	$0	$75,793
Total Overall*	$77,452		$76,013		$79,086		$78,727		$75,701		$75,793	

These figures are totals based on non-rounded, underlying estimates summed and rounded to the nearest million. Other reported numbers are individually rounded to the nearest million. Any discrepancies between totals and figures in table are a result of rounding error. For all detailed figures, see Appendix F.

Table 3-C: Annual new vehicle purchase expenditures in California for zero emission vehicles by technology type over 5-year increments in millions of 2020 US dollars, 2020-2045.

Vehicle Category	2020		2025		2030		2035		2040		2045	
	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV
LDVs	$11,513	$87	$13,242	$827	$33,681	$2,963	$46,275	$5,309	$57,594	$6,891	$56,718	$7,719
HDVs	$9	$0	$394	$104	$1,170	$590	$1,734	$1,174	$1,926	$1,953	$1,856	$2,143
MDVs	$9	$0	$618	$0	$1,549	$748	$2,410	$1,156	$3,626	$1,697	$3,757	$1,794
Buses	$71	$0	$836	$166	$1,332	$357	$1,398	$373	$1,438	$376	$1,415	$391
Total by Technology Type	$11,602	$87	$15,090	$1,098	$37,732	$4,659	$51,817	$8,012	$64,584	$10,916	$63,746	$12,047
Total Overall*	$11,689		$16,187		$42,390		$59,829		$75,500		$75,793	

These figures are totals based on non-rounded, underlying estimates summed and rounded to the nearest million. Other reported numbers are individually rounded to the nearest million. Any discrepancies between totals and figures in table are a result of rounding error. For all detailed figures, see Appendix F.

Figure 3-4: Total annual new vehicle purchase expenditures in California by fuel type over 5-year increments in billions of 2020 US dollars, 2020-2045. Fossil fuel vehicle sales in 2040, while not 0, constitute such a small portion that they are nearly invisible in this graph.

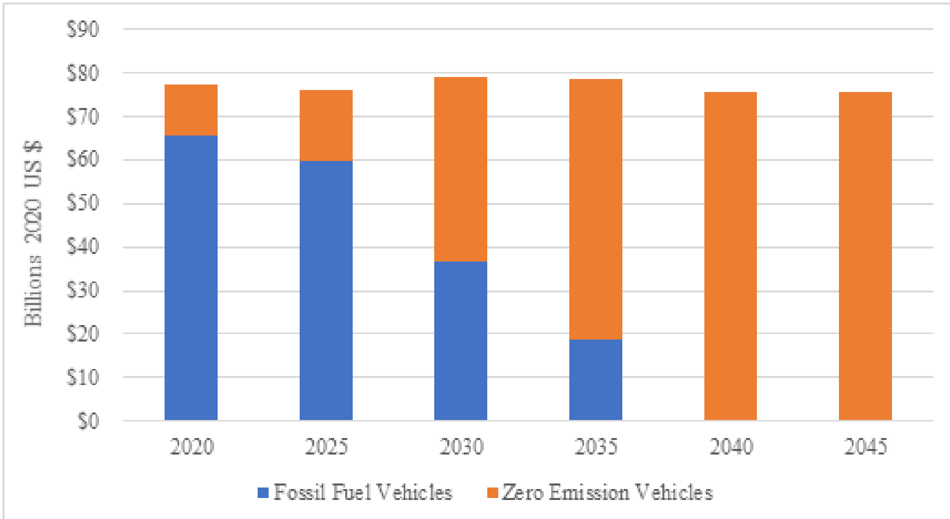


Figure 3-5: Annual new vehicle purchase expenditures for fossil fuel vehicles in California by vehicle category over 5-year increments in billions of 2020 US dollars, 2020-2045.

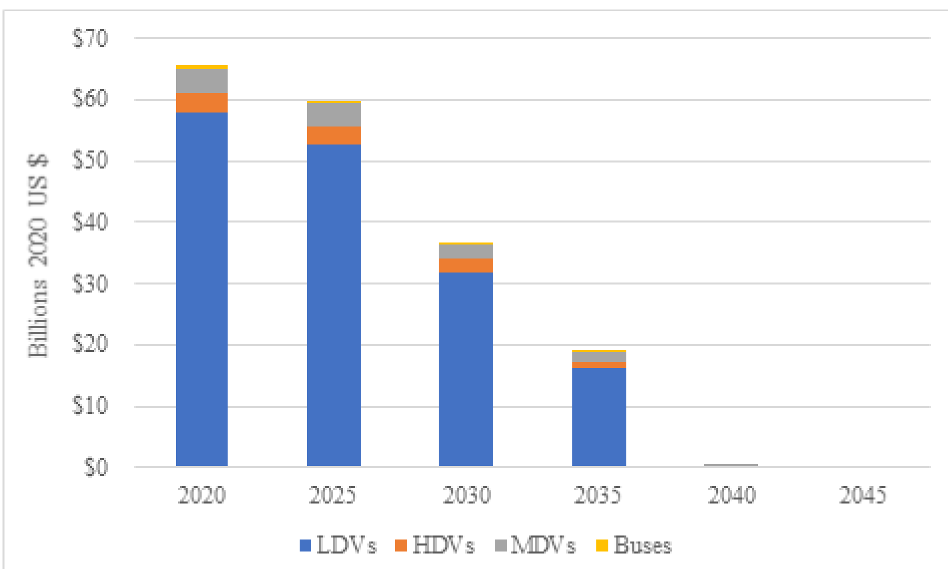
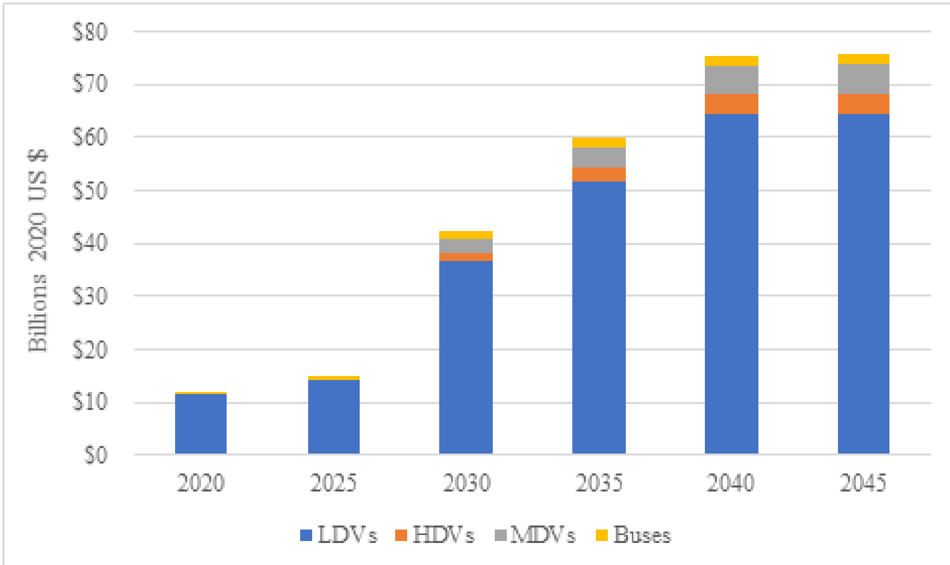


Figure 3-6: Annual new vehicle purchase expenditures for zero emission vehicles in California by vehicle category over 5-year increments in billions of 2020 US dollars, 2020-2045.



Intuitively, relative distribution of expenditures across vehicle categories and technologies resemble those of vehicles purchased. If we consider the breakdown of fossil fuel vehicles into our four vehicle categories, a significant majority of vehicle purchase expenditures are on LDVs, followed by MDVs, HDVs, and buses (Figure 3-5). This follows for zero emission vehicles (Figure 3-6).

For zero emission vehicles, the vast majority of ZEV vehicle purchase expenditures are on battery electric vehicles. Currently, there are no sales of fuel cell trucks and buses. Over the next 25 years, however, a growing amount of purchase expenditures will be made on these vehicles (Table 3-C). While the number of battery electric LDVs purchased will continue to dwarf that of fuel cell electric LDVs, vehicle purchase expenditures on fuel cell electric HDVs will rise to surpass expenditures on battery electric HDVs.

If we compare vehicle purchase expenditures from 2020 and 2045, we see the total amount spent on new vehicles is relatively equal -- just $1.4 billion lower in 2045, a 2.1% decrease (Table 3-D). This is expected since the total number of vehicles purchased will not fluctuate greatly over time (Appendix E). The greatest disparity between the two years is found in the composition of vehicle fuel types. In 2020, zero emission vehicles account for roughly 14.8% of the total (Table 3-B). In 2045, they account for 100%.

Table 3-D: Comparison of new vehicle purchase expenditures in California in 2020 versus 2045 by fuel type in 2020 US dollars.

Vehicle Fuel Type	2020	2045	Difference	Percent Change
Fossil Fuel Vehicles	$65,763,735,670	$0	-$65,763,735,670	100% decrease
Zero Emission Vehicles	$11,688,578,580	$75,793,489,360	+$64,104,910,780	548.4% increase
Total Overall	$77,452,314,250	$75,793,489,360	-$1,658,824,890	2.1% decrease

3.3 – Forecasted Fuel Expenditures

Fuel expenditures are spent on gasoline and other fuels. We focus our analysis on the dominant fuels: gasoline, diesel, electricity, and hydrogen.

Forecasted Fuel Cost Data

We obtained our fuel expenditure estimates by multiplying the on-road fleet by average annual fuel cost per vehicle. We utilized on-road fleet number estimates from the CNS LC1 scenario (Appendix C). To find average fuel cost per vehicle, we multiplied fuel price (Appendix G) by annual vehicle miles traveled (Appendix H), then divided by fuel efficiency (Appendix I).

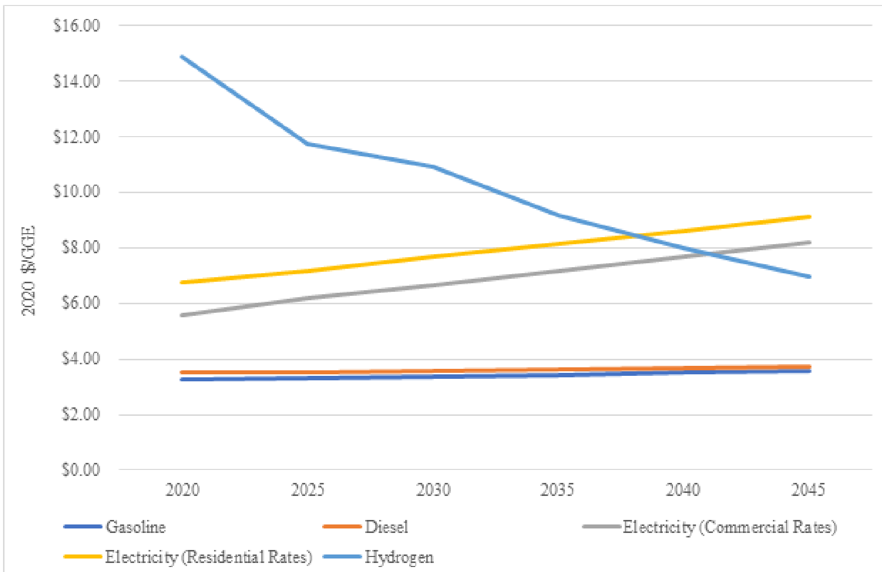
The fuel price forecasts for gasoline, diesel, electricity, and hydrogen out to 2030 come from the mid-demand scenario projections of the California Energy Commission (CEC). To estimate fuel costs for gasoline, diesel, and electricity through 2045, we used linear best fit calculations based on forecasted trends while removing certain outlier years (see Appendix G). To estimate fuel costs for hydrogen, we used a best fit exponential curve that reflects a trend of lowering costs at a diminishing rate.

Electricity prices are given as dollars per gallon of gasoline equivalent (GGE). GGE is a standardized fuel efficiency unit used to compare the energy content of all fuels and is the amount of a given fuel type with energy content equal to the energy contained in one gallon of gasoline. The CEC used the conversion factor of 1 GGE = 32.1764 kWh, consistent with the California Air Resources Board's (CARB) Low Carbon Fuel Standard (LCFS) regulations.

Hydrogen prices are also given as dollar per gasoline gallon equivalent (GGE). As fuel consumption figures for hydrogen are provided in kg, we convert these to GGE using the CARB LCFS conversion factor of 1 GGE = 0.96525 kg.

For fossil fuel vehicles, we use the cost of gasoline in our calculations for LDVs, and the cost of diesel for that of HDVs, MDVs, and buses. These assignments reflect the primary fuel type for these vehicle categories. For electric vehicles, we applied the residential rate of electricity to calculations for LDVs, and the commercial rate of electricity to that of HDVs, MDVs, and buses. This reflects the fact that, historically, a large majority of LDV electric vehicle charging occurs at residences, while non-LDVs are likely to charge predominantly at either public commercial or private fleet-owned stations. Figure 3-7 illustrates our estimated fuel prices through 2045. All prices are in 2020 US dollars.

Figure 3-7: Fuel price estimates in California by type over 5-year increments in 2020 $/GGE, 2020-2045.



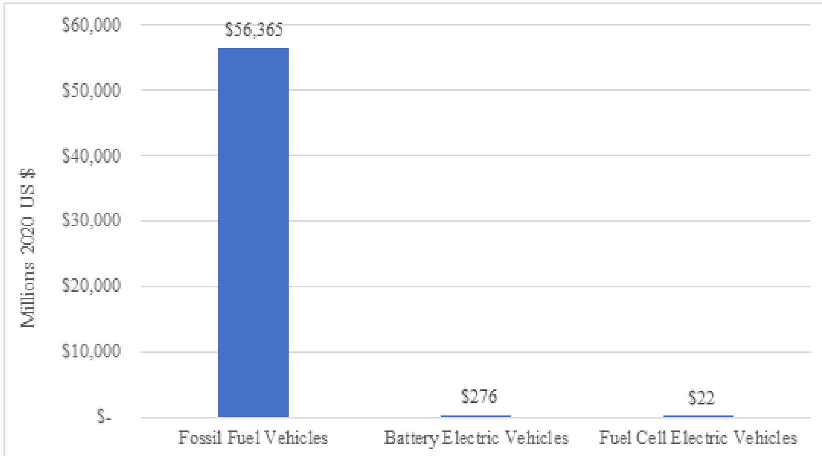
For annual vehicles miles travelled, we assumed a vehicle lifetime of ten years. We took the average of VMT estimates for vehicles age 0 to age 9 from the CNS LC1 scenario (Appendix H). Our fuel efficiency estimates come from the same source (Appendix I).

Baseline Fuel Expenditures

California currently spends approximately $56.7 billion on transportation-related fuel costs (Figure 3-8). Fossil fuels make up nearly $56.4 billion of this total and are easily the largest category. Electricity for BEVs is the next largest, though far behind at $272 million, and only $22 million is currently spent annually on hydrogen for FCEVs.

When current fuel expenditures are examined by vehicle category, fossil fuel vehicles have much higher fuel expenditures than ZEVs do (Table 3-E). Again, this is expected due to the low number of ZEVs currently on the road (see Appendix C). Fossil fuel LDVs accrue the vast majority of total fuel expenditures – approximately 72 percent. Among fossil fuel vehicles, fuel expenditures are highest for LDVs, followed by HDVs, MDVs, and finally buses. For electric vehicles, fuel expenditures are also highest for LDVs, but are second highest for buses, then MDVs, and lastly, HDVs.

Figure 3-8: Transportation fuel expenditures in California by fuel type in millions of 2020 US dollars, 2020.



Projected Fuel Expenditures

Key Takeaways:

- Total overall fuel expenditures in 2045 are projected to be over $13.1 billion lower than current fuel expenditures, dropping from $56.7 billion in 2020 to $43.5 billion in 2045.
- Fuel expenditures for fossil fuel vehicles are expected to drop $42.1 billion to $14.2 billion between now and 2045.
- Fuel expenditures for zero emission vehicles are expected to increase by $29 billion to nearly $29.3 billion between now and 2045.

Overall total fuel expenditures are expected to substantially decrease by 2045 (Figure 3-9). This decline in total overall fuel expenditures is expected, given the greater proportion of zero emission vehicles in the on-road fleet (Appendix C) and the fuel efficiency advantages such vehicles offer (Appendix I). Although electricity and hydrogen prices per GGE are higher than gasoline and diesel prices, these efficiency increases mean electric vehicle owners will spend less on fuel than fossil fuel owners to travel the same distances. Extrapolating therefrom, a vehicle fleet with more electric vehicles and fewer fossil fuel vehicles will drive total fuel expenditures down. Trends towards greater vehicle fuel efficiency overall -- for both fossil fuel and electric vehicles -- will also contribute to lower overall fuel costs.

Over time, ZEVs will make up an increasingly large proportion of fuel expenditures, while fuel expenditures for fossil fuel vehicles will decrease (Figure 3-9). By 2045, the majority of fuel expenditures will be made to supply electric vehicles. LDVs consistently make up the majority of fuel expenditures for both fossil fuel vehicles and ZEVs (Table 3-E, Figures 3-10 and 3-11). HDVs are the second most costly vehicle category, followed by MDVs, and then buses. This holds true from now to 2045.

Figure 3-9: Total annual fuel expenditures in California for fossil fuel-burning and zero-emission vehicles over 5-year increments in billions of 2020 US dollars, 2020-2045.

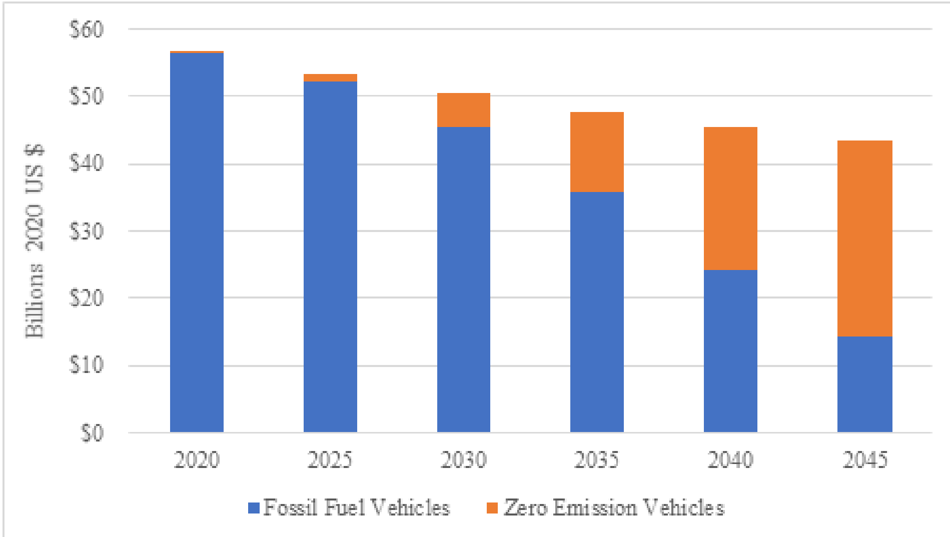


Figure 3-10: Annual expenditures on fossil fuels for ICEVs in California by vehicle category over 5-year increments in billions of 2020 US dollars, 2020-2045.

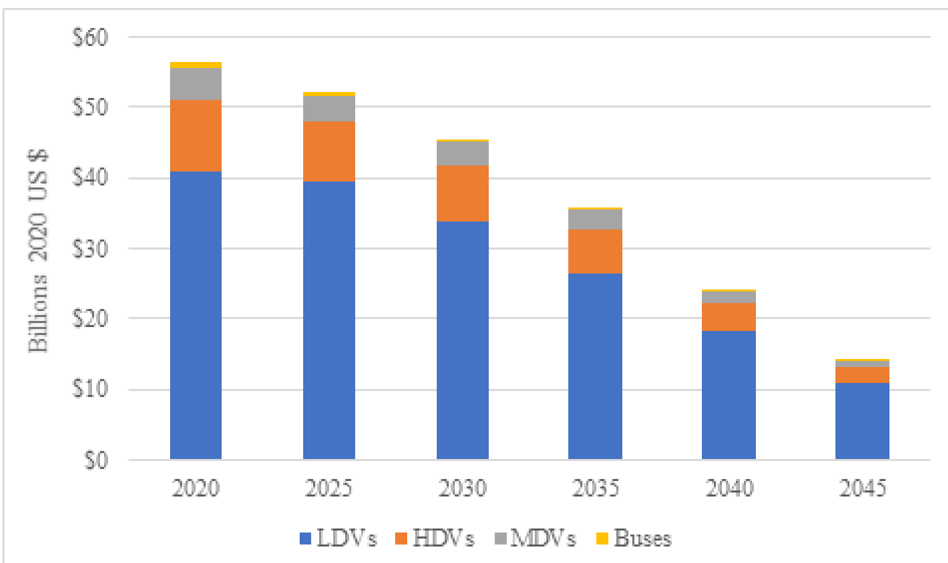


Table 3-E: Annual fuel expenditures for fossil fuel-burning and zero-emission vehicles in California by vehicle category over 5-year increments in millions of 2020 US dollars, 2020-2045.

Vehicle Category	2020		2025		2030		2035		2040		2045	
	FFV	ZEV	FFV	ZEV	FFV	ZEV	FFV	ZEV	FFV	ZEV	FFV	ZEV
LDVs	$40,895	$288	$39,399	$994	$33,824	$3,414	$26,607	$8,105	$18,182	$14,287	$10,912	$20,218
HDVs	$10,092	$.162	$8,706	$142	$7,869	$991	$6,122	$2,549	$3,991	$4,673	$2,199	$6,259
MDVs	$4,662	$.450	$3,603	$42	$3,390	$319	$2,831	$837	$1,901	$1,525	$1,040	$2,161
Buses	$716	$9	$541	$81	$413	$268	$301	$428	$177	$589	$77	$676
Total by Fuel Type	$56,365	$298	$52,248	$1,259	$45,496	$4,991	$35,862	$11,829	$24,251	$21,075	$14,227	$29,314
Total Overall*	$56,663		$53,507		$50,487		$47,690		$45,326		$43,542	

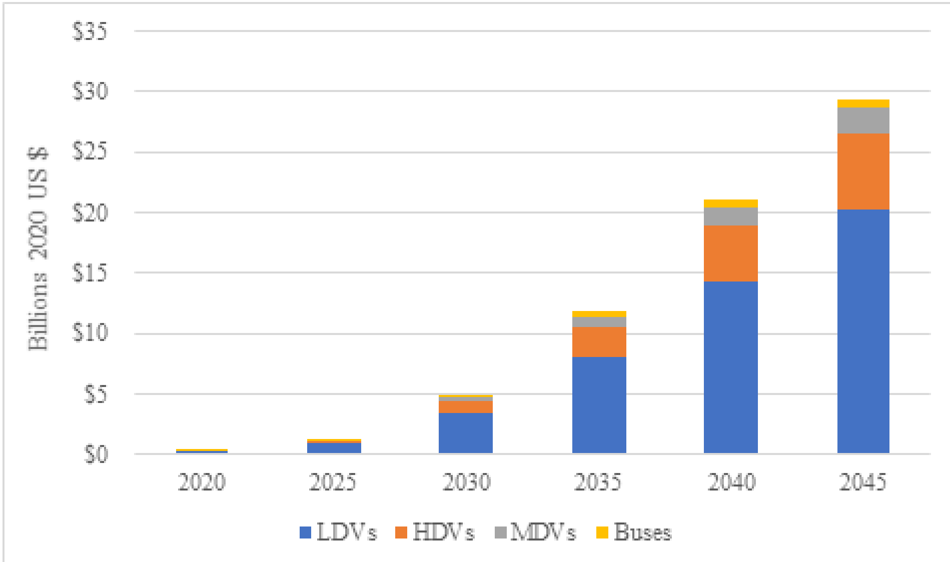
These figures are totals based on non-rounded, underlying estimates summed and rounded to the nearest million. Other reported numbers are rounded individually to the nearest million. Any discrepancies between totals and figures in table are a result of rounding error. For all detailed figures, see Appendix K.

Table 3-F: Annual fuel expenditures in California for zero-emission vehicles by technology type over 5-year increments in millions of 2020 US dollars, 2020-2045.

Vehicle Category	2020		2025		2030		2035		2040		2045	
	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV
LDVs	$266	$22	$809	$186	$2,586	$828	$6,157	$1,858	$11,335	$2,952	$16,491	$3,727
HDVs	$.163	$0	$516	$91	$262	$729	$635	$1,914	$1,096	$3,577	$1,462	$4,797
MDVs	$.450	$0	$42	$0	$199	$120	$517	$320	$990	$535	$1,483	$678
Buses	$9	$0	$57	$24	$171	$96	$306	$122	$428	$161	$521	$155
Total by Fuel Type	$276	$22	$957	$301	$3,218	$1,773	$7,615	$4,213	$13,848	$7,226	$19,957	$9,357
Total Overall*	$298		$1,259		$4,991		$11,829		$21,075		$29,314	

These figures are totals based on non-rounded, underlying estimates summed and rounded to the nearest million. Other reported numbers are individually rounded to the nearest million. Any discrepancies between totals and figures in table are a result of rounding error. For all detailed figures, see Appendix K.

Figure 3-11: Annual fuel expenditures for zero emission vehicles in California by vehicle category over 5-year increments in billions of 2020 US dollars, 2020-2045.



For zero emission vehicles, battery electric vehicles make up a greater portion of fuel expenditures (Table 3-F). However, fuel expenditures on fuel cell electric vehicles will increase steadily to make up approximately half of total fuel expenditures for ZEVs. For battery electric vehicles, LDVs will remain the largest category by far. For fuel cell electric vehicles, trucks and buses make up a much larger portion of fuel costs than they do for BEVs. In particular, HDVs will be the largest category for fuel cell electric vehicles by 2035.

Looking more closely at changes in fuel expenditures between 2020 and 2045, we see a substantial – 23.2 percent – decrease in overall fuel expenditures (Table 3-G). Whereas zero emission vehicles only account for a tiny fraction of total fuel expenditures in 2020, they make up approximately two-thirds of total fuel costs in 2045.

Table 3-G: Comparison of fuel expenditures in California in 2020 versus 2045 in 2020 US dollars.

Vehicle Fuel Type	2020	2045	Difference	Percent Change
Fossil Fuel Vehicles	$56,365,358,663	$14,227,440,391	-$42,137,918,271	74.8% decrease
Zero Emission Vehicles	$297,811,568	$29,314,323,945	+$29,016,512,377	9743.3% increase
Total Overall	$56,663,170,231	$43,541,764,337	-$13,121,405,894	23.2% decrease

3.4 – Forecasted Maintenance Expenditures

Maintenance costs include default maintenance (scheduled) and repair (unscheduled) costs. Maintenance and repairs cover a number of distinct parts and services, detailed in Table 3-H.

Table 3-H: Services included in maintenance costs.

- Tires
- Tubes
- Lubrication
- Filters
- Coolant
- Additives
- Brake and transmission fluids
- Oil change
- Tire repair
- Audio equipment
- Brake work including adjustment
- Front-end alignment
- Wheel balancing
- Steering repair
- Shock absorber replacement
- Clutch and transmission repair
- Drive shaft and rear-end repair
- Electrical system repair
- Exhaust system repair
- Body work and painting
- Motor repair
- Repair to cooling system
- Drive train repair
- Other maintenance and services
- Auto repair policies

**Battery replacement costs for electric vehicles are not included because reliable data for replacement vehicles and expected costs are not available at this time.*

Forecasted Maintenance Cost Data

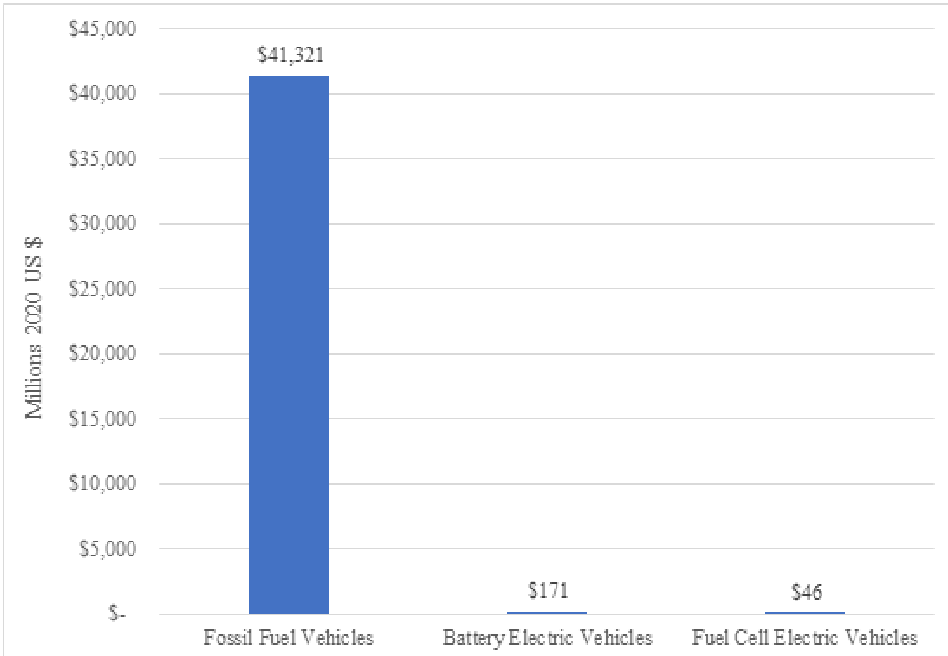
We calculated maintenance cost estimates by multiplying vehicle miles traveled, maintenance cost per mile, and on-road fleet vehicle totals. Vehicle miles traveled estimates and on-road fleet estimates came from the CNS LC1 scenario (Appendices C and H). We adopted the vehicle maintenance costs for trucks (HDVs and MDVs) and buses from "Comparison of Medium- and Heavy-Duty Technologies in California" (ICF 2019) and the CNS LC1 scenario. Some maintenance costs for trucks were estimated using formulas within the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool developed by Argonne National Laboratory (ANL). For maintenance costs for LDVs, we relied on estimates from Lutsey and Nicholas 2019.

A more detailed methodology concerning the data sources for each vehicle type can be seen in Appendix K.

Baseline Maintenance Expenditures

We estimate that total maintenance expenditures in California in 2020 will be approximately $41.5 billion. Fossil fuel vehicles make up a significant majority of these expenditures at $41.3 billion (Figure 3-12). Battery electric vehicles are the next largest category, far behind at $171 million. Fuel cell electric vehicles currently only account for $46 million, less than 1 percent of total maintenance expenditures.

Figure 3-12: Maintenance expenditures for vehicles in California by fuel type in millions of 2020 US dollars, 2020.



For both fossil fuel vehicles and ZEVs, LDVs make up the greatest proportion of maintenance expenditures (Table 3-I). The primary driver of this is the sheer size of the LDV fleet compared to other vehicle categories. For fossil fuel vehicles, MDVs have the second highest expenditure total, followed by HDVs and then buses. This corresponds to the composition of the on-road fleet (see Appendix B). For electric vehicles, buses have the next highest expenditure total, with MDVs third and HDVs last. Again, this aligns with the numbers of each type of vehicle currently on the road.

Projected Maintenance Expenditures

Key Takeaways:

- Total maintenance costs in 2045 will be $9.2 billion lower than current maintenance costs, decreasing from $41.5 billion to $32.8 billion.
- ZEV maintenance costs will make up over half of overall maintenance costs by 2045.
- From 2020 to 2045, maintenance costs for fossil fuel vehicles will fall $28.5 billion to $12.8 billion.

- From 2020 to 2045, maintenance costs for zero emission vehicles will increase nearly $12.2 billion to $12.3 billion.

Total maintenance expenditures are expected to decline substantially between 2020 and 2045 (Figure 3-13). Zero emission vehicles will account for an increasingly large portion of total maintenance expenditures each year. By 2045, the majority of overall maintenance expenditures will come from zero emission vehicles. It is expected that total maintenance expenditures will fall because zero emission vehicles are typically cheaper to maintain. As the vehicle fleet becomes increasingly green, more cars will have lower maintenance costs, contributing to a lower total.

The breakdown of maintenance expenditures into the four major vehicle categories illustrates that for both fossil fuel vehicles and zero emission vehicles, LDVs amass the highest costs by far, followed by MDVs, HDVs, and then buses (Table 3-I, Figures 3-14 and 3-15). This aligns with the number of vehicle types on the road (Appendix C). By 2045, expenditures on zero emission vehicles will surpass that of fossil fuel vehicles for each of the four vehicle categories.

Figure 3-13: Total annual maintenance expenditures on fossil fuel-burning and zero-emission vehicles in California over 5-year increments in billions of 2020 US dollars, 2020-2045.

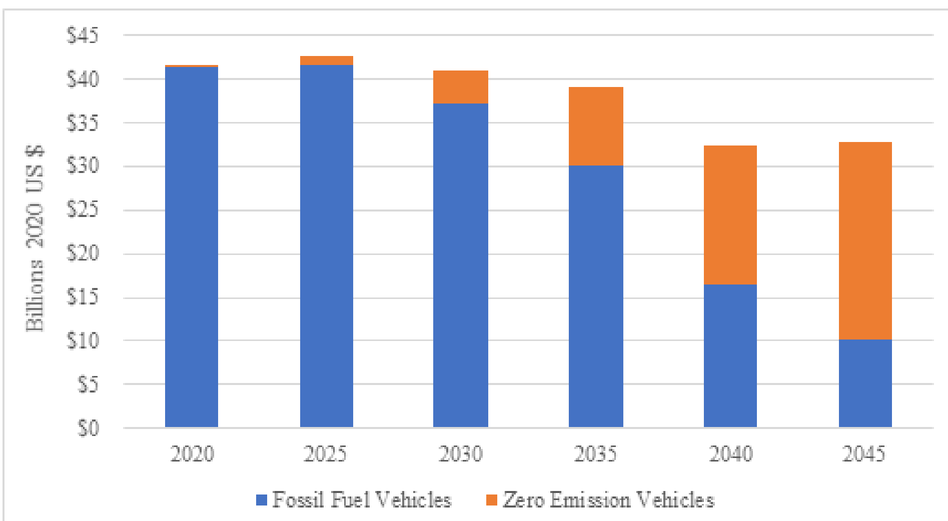


Table 3-I: Annual maintenance expenditures on fossil fuel-burning and zero-emission vehicles in California by vehicle category over 5-year increments in millions of 2020 US dollars, 2020-2045.

Vehicle Category	2020		2025		2030		2035		2040		2045	
	FFV	ZEV	FFV	ZEV	FFV	ZEV	FFV	ZEV	FFV	ZEV	FFV	ZEV
LDVs	$32,741	$201	$32,860	$789	$29,131	$2,712	$23,410	$6,303	$16,415	$11,203	$10,234	$15,686
HDVs	$2,904	$.064	$3,025	$28	$2,856	$195	$2,301	$578	$1,562	$1,176	$894	$1,818
MDVs	$4,705	$.933	$4,806	$77	$4,511	$459	$3,869	$1,219	$2,726	$2,359	$1,540	$3,685
Buses	$881	$15	$827	$134	$707	$446	$559	$770	$353	$1,135	$166	$1,367
Total by Fuel Type	$41,321	$217	$41,517	$1,029	$37,204	$3,813	$30,139	$8,870	$16,415	$15,872	$10,234	$22,557
Total Overall*	$41,538		$42,546		$41,017		$39,009		$32,288		$32,790	

**These figures are totals based on non-rounded, underlying estimates summed and rounded to the nearest million. Other reported numbers are individually rounded to the nearest million. Any discrepancies between totals and figures in table are a result of rounding error. For all detailed figures, see Appendix M.*

Table 3-J: Annual maintenance expenditures in California for zero emission vehicles by technology type over 5-year increments in millions of 2020 US dollars, 2020-2045.

Vehicle Category	2020		2025		2030		2035		2040		2045	
	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV	BEV	FCEV
LDVs	$155	$46	$463	$326	$1,468	$1,245	$3,313	$2,990	$5,769	$5,434	$7,995	$7,691
HDVs	$.064	$0	$17	$12	$83	$112	$210	$368	$3,530	$822	$491	$1,328
MDVs	$.933	$0	$77	$0	$379	$81	$948	$271	$1,805	$554	$2,828	$857
Buses	$15	$0	$108	$26	$327	$119	$584	$186	$842	$293	$1,033	$334
Total by Fuel Type	$171	$46	$665	$364	$2,256	$1,557	$5,055	$3,815	$8,770	$7,103	$12,347	$10,210
Total Overall*	$217		$1,029		$3,813		$8,870		$15,872		$22,557	

**These figures are totals based on non-rounded, underlying estimates summed and rounded to the nearest million. Other reported numbers are rounded to the nearest million. Any discrepancies between totals and figures in table are a result of rounding error. For all detailed figures, see Appendix M.*

Figure 3-14: Annual maintenance expenditures for fossil fuel-burning vehicles in California by vehicle category over 5-year increments in billions of 2020 US dollars, 2020-2045.

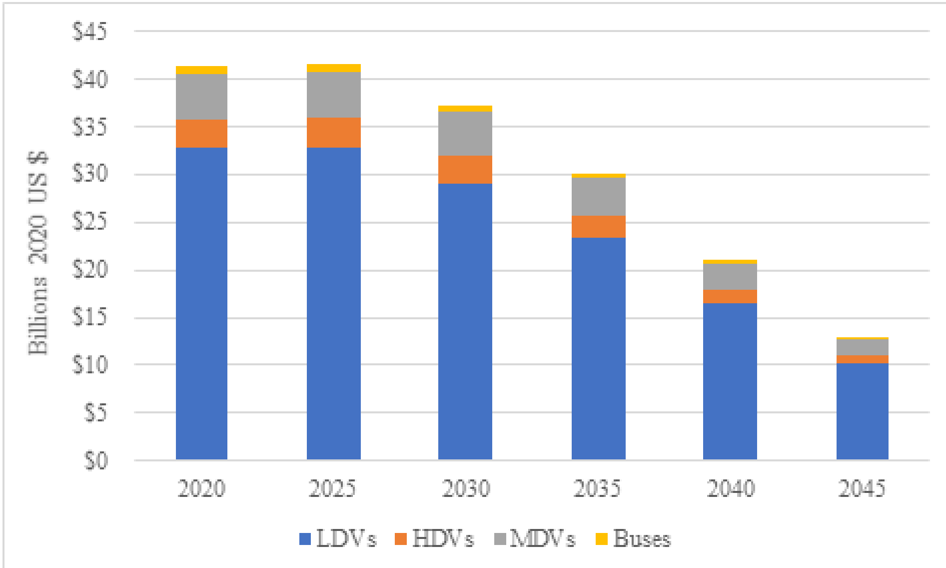
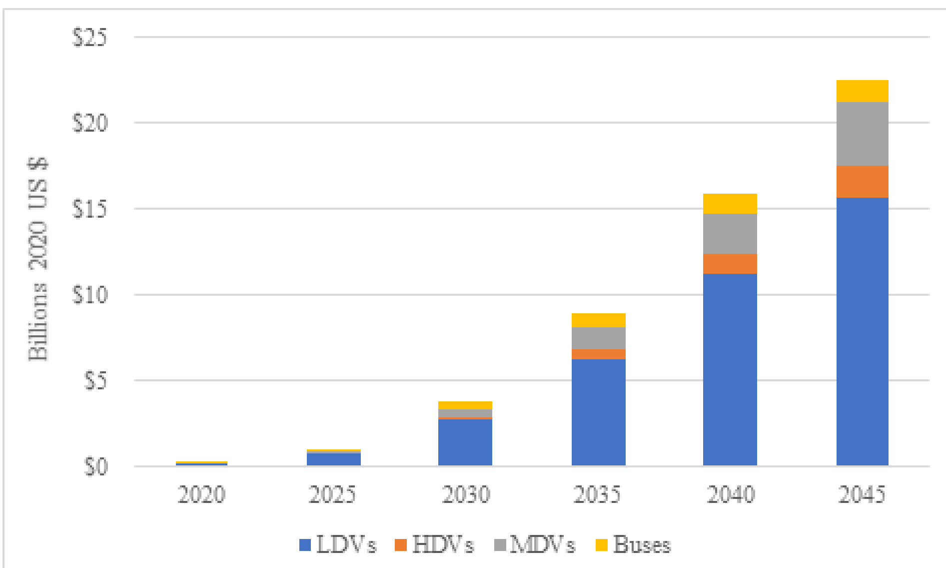


Figure 3-15: Annual maintenance expenditures for zero-emission vehicles in California by vehicle category over 5-year increments in billions of 2020 US dollars, 2020-2045.



For zero emission vehicles, the maintenance expenditures for both battery electric vehicles and fuel cell electric vehicles will increase steadily over time (Table 3-J). While maintenance costs for battery electric LDVs, MDVs, and buses are greater than maintenance costs for their fuel cell electric counterparts from now until 2025, this is not true for HDVs. The maintenance costs for fuel cell electric HDVs will surpass maintenance costs for battery electric HDVs by 2030. This gap will increase substantially each year. The gap between battery electric LDVs and fuel cell electric LDVs will narrow over time until maintenance cost estimates are about equal.

Although maintenance costs for zero emission vehicles will see a massive increase between now and 2045, we will see a 21 percent decrease in total maintenance costs (Table 3-K). This can be attributed to the relatively constant total number of vehicles on the road (Appendix C). The number of total vehicles will remain similar, but the proportion of zero emission vehicles to fossil fuel vehicles will be extremely high by 2045. ZEVs tend to have lower maintenance costs than their fossil fuel counterparts.

Table 3-K: Comparison of maintenance expenditures for fossil fuel-burning and zero-emission vehicles in California in 2020 versus 2045 in 2020 US dollars.

Vehicle Fuel Type	2020	2045	Difference	Percent Change
Fossil Fuel Vehicles	$41,321,046,100	$10,233,595,572	-$31,087,450,528	75.2% decrease
Zero Emission Vehicles	$216,807,601	$22,556,554,510	+$22,339,746,910	10,304% increase
Total Overall	$41,537,853,701	$32,790,150,082	-$19,198,106,791	21.1% decrease

3.5 – Comparison of Key Expenditures in 2020 versus 2045

Key takeaways:

- California will spend $23.3 billion less across the three key transportation expenditure categories in 2045 compared to 2020, with overall expenditures falling from $175.4 billion to $152.1 billion (a 13.3% drop).
- All three key expenditure categories will be lower in 2045 than in 2020.
- Across the next 25 years, new vehicle purchases will remain the largest expenditure category, with fuel costs second, and maintenance costs last.

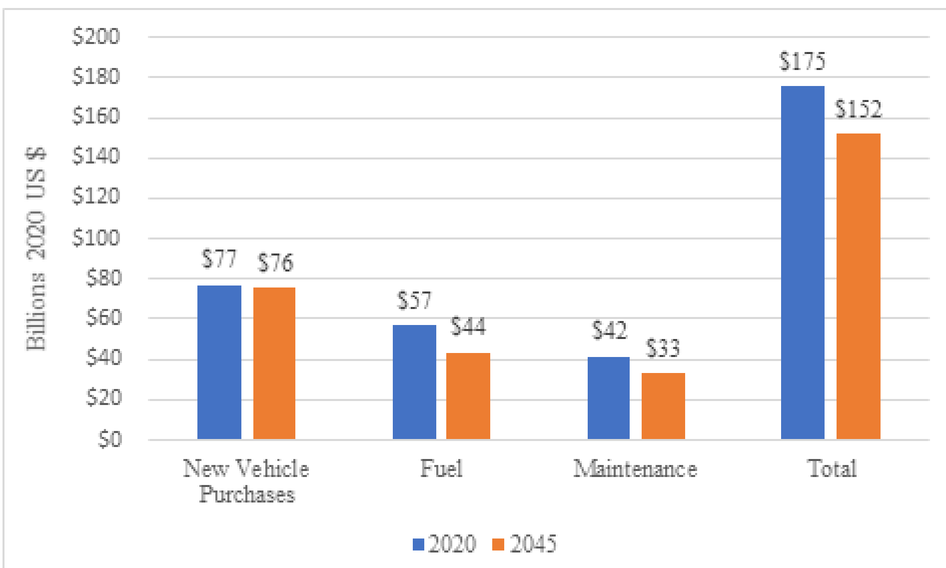
All three expenditure categories will be lower in 2045 than in 2020 (Figure 3-16). Vehicle purchase expenditures will see the smallest decrease of $1.4 billion (1.8%), with fuel expenditures and maintenance expenditures witnessing much larger drops (Table 3-L). Fuel expenditures will be lower by $13.1 billion (23.2%), and maintenance expenditures will fall by $19.2 billion (21.1%). Total overall expenditures will drop from $175.4 billion to $152.1 billion (13.3%).

For all three key expenditure categories, expenditures for ZEVs will increase over time while expenditures for fossil fuel vehicles will gradually decrease. By 2045, new vehicle purchase expenditures will solely be on ZEVs, whereas current new vehicle purchase expenditures are primarily going towards fossil fuel vehicle sales. Fuel expenditures and maintenance expenditures now are largely expenses related to fossil fuel vehicles. The majority of fuel expenditures and maintenance expenditures in 2045, however, will go towards ZEV-related expenses. Because of the growing proportion of ZEVs to fossil fuel vehicles on the road, combined with the lower maintenance and fuel costs of EVs in particular, overall fuel and maintenance expenditures will fall.

Table 3-L: Comparison of key annual expenditure estimates in California in 2020 versus 2045 in 2020 US dollars.

Expenditure Category	2020	2045	Difference	Percent Change
New Vehicle Purchases	$77,212,742,250	$75,793,489,360	-$1,419,252,890	1.8% decrease
Fuel	$56,658,609,924	$43,541,764,337	-$13,116,845,587	23.2% decrease
Maintenance	$41,537,853,701	$32,790,150,082	-$19,198,106,791	21.1% decrease
Total	$175,409,205,875	$152,125,403,779	-$23,283,802,096	13.3% decrease

Figure 3-16: Comparison of key annual expenditure estimates in California in 2020 versus 2045 in billions of 2020 US dollars.



3.6 – Forecasted EV Charging and Hydrogen Refueling Infrastructure Expenditures

Finally, we consider the distinct category of expenditures made to construct charging infrastructure for EVs, for installation of other EVSE, and for construction of hydrogen refueling stations. These investments will be necessary to supply newly demanded electricity and hydrogen for transportation purposes.

Scenario Data

Projecting future infrastructure expenditures requires estimating the amount of infrastructure that will be installed or constructed and what costs are incurred in each instance thereof. In the case of EVSE, these figures must also delineate by charging level, given significant disparities in required labor and materials among the various types of EVSE sites. We utilize four charging level categories: Level 1 Home (L1-H), Level 2 Home (L2-H), Level 2 Public or Workplace (L2-P), and Direct Current Fast Charging (DCFC).

For estimating EVSE construction and installation by year we rely on needs estimates provided by the CNS light- and heavy-duty vehicle teams. The light-duty team has constructed year-by-year projections of required EVSE based on adoption patterns, charging behavior, overall demand, and other factors (Table 3-M). They heavy-duty team has constructed multiple scenarios that vary based on different assumed levels of the charger:vehicle ratio; we utilized their estimates for the middle-of-the-road scenario, where this ratio is assumed to be 1:2 (Table 3-N). From each of these we assess the year-over-year difference and assume it to be the annual construction or installation number for the respective charging levels (Figure 3-17). As the heavy-duty estimates are provided in 5-year increments, we assume linear installation and construction rates within each 5-year period. These numbers are aggregated across both sectors, as we assume similar construction and installation costs for a given charging level, regardless of the vehicle type the charger is intended to serve.

For hydrogen we rely on total projected fuel consumption across all vehicle sectors, provided by the CNS scenarios team (Figure 3-18). These figures, when adjusted to reflect assumed utilization rates, can be translated to overall expenditures using data on capital expenditures (CapEx) per kg/day of hydrogen refueling capacity from NREL.

Our methodology concerning how EVSE per-charger cost estimates were created and our strategy for disaggregating hydrogen refueling station costs – both utilizing various categories of labor and materials – can be seen in Appendix N.

Table 3-M: Total projected EV chargers required for the light-duty vehicle sector by year and level, 2020-2045.

Year	Total EV Chargers Required by Level, Light-Duty Sector			
	L1-H	L2-H	L2-P	DCFC
2020	70,485	199,749	49,985	5,498
2021	96,095	270,504	77,312	8,386
2022	129,411	361,261	103,042	11,237
2023	172,109	475,438	125,956	13,950
2024	225,849	615,736	145,342	16,454
2025	292,115	783,586	160,053	18,627
2026	372,652	980,393	216,730	23,086
2027	468,663	1,205,328	300,973	29,641
2028	580,839	1,455,804	418,708	38,530
2029	709,253	1,727,570	580,091	50,411
2030	852,955	2,013,996	789,905	65,449
2031	1,009,127	2,304,468	1,029,962	81,907
2032	1,176,953	2,593,641	1,314,173	100,986
2033	1,355,766	2,876,965	1,644,124	122,741
2034	1,546,006	3,153,227	2,022,316	147,302
2035	1,748,966	3,424,359	2,451,561	174,791
2036	1,966,081	3,694,167	2,932,643	205,214
2037	2,197,405	3,965,597	3,466,837	238,535
2038	2,440,748	4,239,197	4,056,022	274,822
2039	2,691,040	4,512,005	4,703,220	314,325
2040	2,938,099	4,774,147	5,359,804	352,932
2041	3,171,116	5,015,741	5,996,166	388,014
2042	3,380,542	5,228,826	6,608,337	419,706
2043	3,559,065	5,407,804	7,193,827	448,278
2044	3,703,079	5,550,662	7,748,747	473,808
2045	3,813,941	5,660,232	8,287,898	497,771

Table 3-N: Total projected EV chargers required for the heavy-duty vehicle sector by year and level over 5-year increments, 2020-2045.

Year	Total EV Chargers Required by Level, Heavy-Duty Sector	
	L2-P	DCFC
2020	113	48
2025	8,246	4,441
2030	37,357	23,955
2035	94,200	60,292
2040	192,220	107,940
2045	297,869	154,099

Figure 3-17: Total projected annual EV charger installations in California by year and type, 2021-2045.

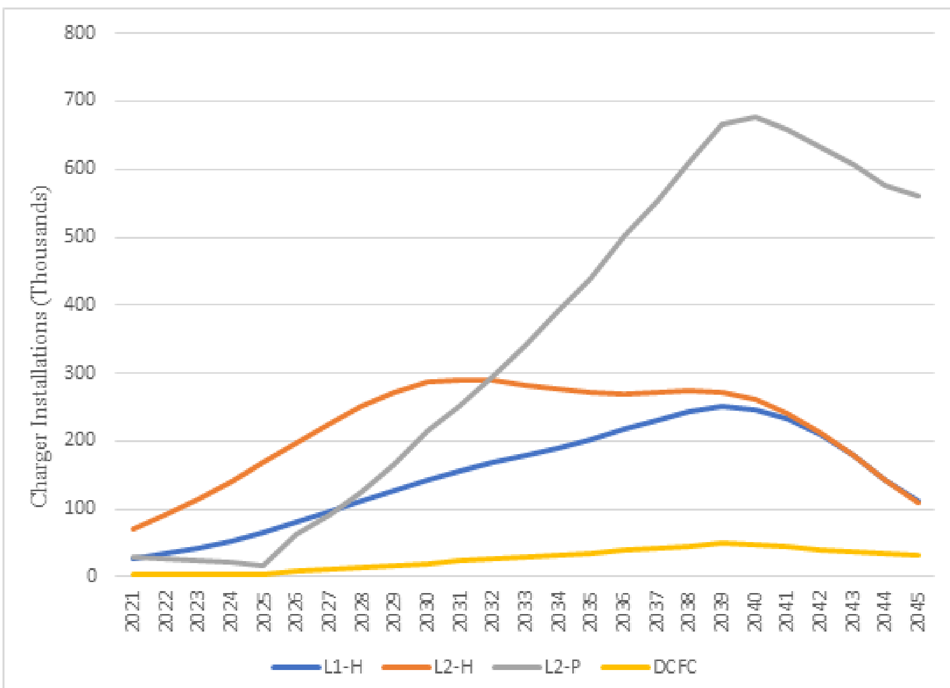
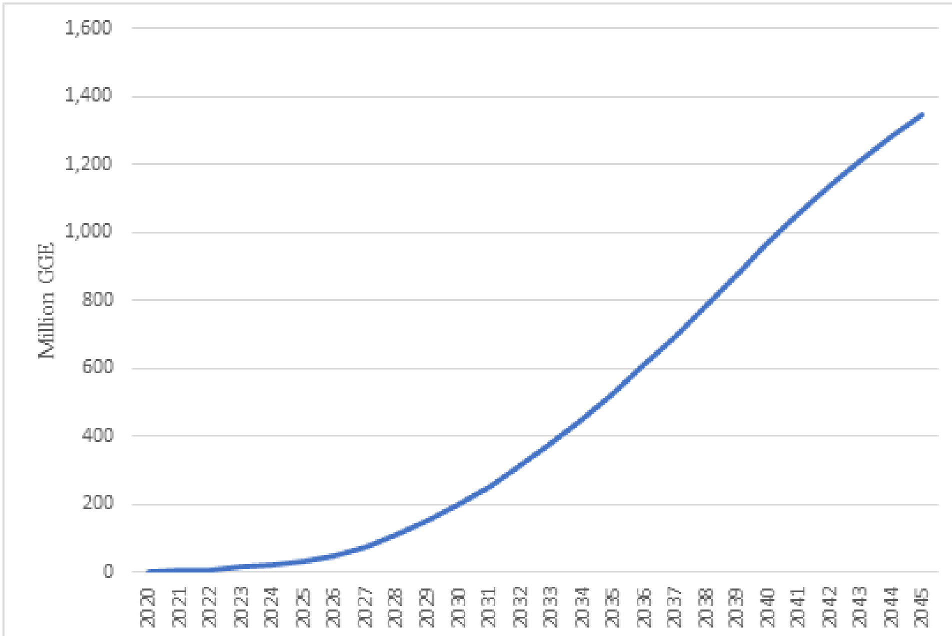


Figure 3-18: Total annual projected hydrogen fuel consumption in California in millions of GGE, 2020-2045.

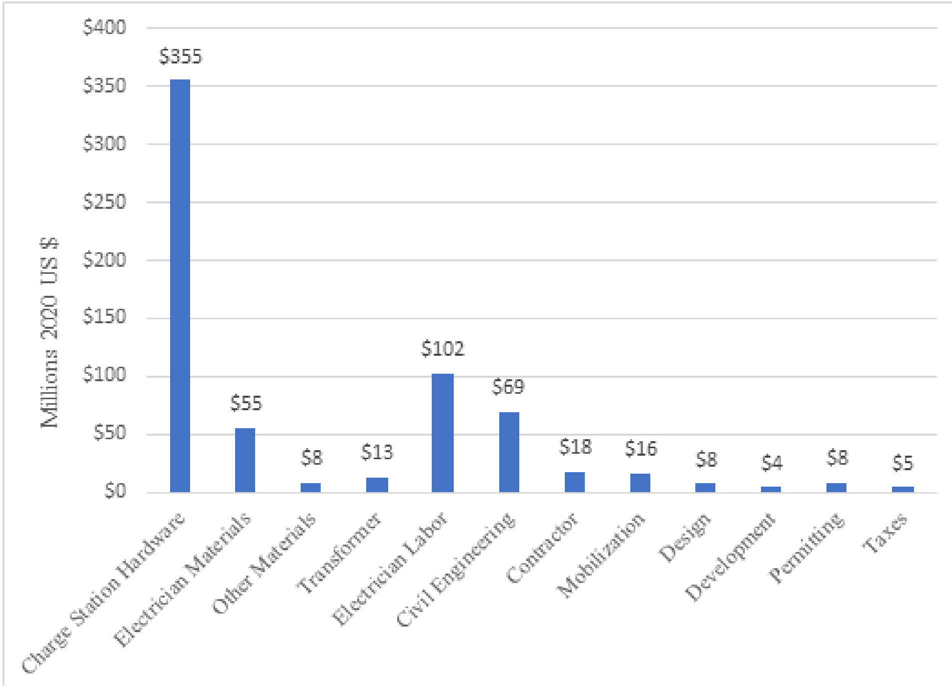


Baseline Expenditures: EV Charging Infrastructure

Unlike the other expenditure categories, robust data on current EVSE installation is scant. Therefore, we present estimates for 2021 as akin to a baseline. In discussing both baseline and future expenditure estimates, all cost figures are given in 2020 US dollars.

We estimate that total expenditures on EV charging infrastructure construction and EVSE installation in 2021 will be approximately $662 million. The majority of this--$355 million – is attributed to the cost of charge station hardware (Figure 3-19). Specialized labor categories – namely, electrician labor and civil engineering labor – are the next largest, accounting for approximately $102 million and $69 million, respectively. The remainder is accounted for among various other categories of materials and labor.

Figure 3-19: Baseline expenditure estimates on EV charging infrastructure construction and EVSE installation in California by category in millions of 2020 US dollars, 2021.



Projected Expenditures: EV Charging Infrastructure

Key Takeaways:

- Total annual expenditures on EVSE installation and EV charging infrastructure are expected to steadily increase until 2039, peaking at nearly $8.9 billion – a growth of over $8 billion, or 1338% – compared to our 2021 baseline.
- Annual expenditures on EV charging infrastructure are expected to subside slightly between 2039 and 2045, declining by approximately $2.2 billion to $6.4 billion.
- Expenditures on charge station hardware are consistently the largest cost category, accounting for over half of expected costs in every year.

We expect expenditures on EVSE installation and EV charging infrastructure construction to remain fairly steady at less than $400 million annually until 2026, at which point expenditures steadily increase each year until peaking in 2039 at nearly $8.9 billion (Figure 3-20). The industry is expected to break the $1 billion threshold in 2026, and exhibits sustained growth of between $200 million and $400 million each year until 2039. This trend is driven by significant and sustained ramp-up in charger provision serving both the light- and heavy-duty sectors; however, in both this period and more generally, trends are more heavily driven by the light-duty sector, given the sheer numbers of EV LDVs predicted in the scenario and the lower representation of EVs in the heavy-duty sector.

After 2039 the rate at which new EV chargers are added within the state is expected to decline, creating a commensurate drop in annual expenditures on associated installation and construction. Starting in 2040, overall expenditures are projected to drop by between $300 million and $600 million each year through to 2045, our last year of analysis. In this final year considered, projected expenditures sit at approximately $6.4 billion. This subsidence is driven mainly by reduced rates of installation for chargers serving LDVs; expansion of service for MDVs and HDVs remains fairly constant for the final 10 years of our analysis, reflecting the slower rate of EV technology uptake in these vehicle sectors.

Charge station hardware is the largest single expenditure category – constituting over 50% of expenditures – in every year considered. A key driving factor behind this is the high cost of DCFC charge station hardware. The high per-charger expense of this equipment outweighs the relatively small number of annual DCFC installations forecasted. Figure 3-21 illustrates this phenomenon by showing total expenditures in 2039, the year of peak activity, broken down by charge station hardware (CSH) expenses in each category and all other labor and materials. In this year, despite fewer than fifty thousand DCFC installations taking place, expenditures on DCFC CSH exceed $3 billion. This figure is over double that of L2-P CSH, even though nearly 667 thousand L2-P installations are projected taking place in 2039. All other expenditures on labor and materials state-wide barely exceed $4 billion during the same time period, showcasing the significant profile of CSH cost within the overall estimates.

Figure 3-20: Projected annual expenditures on EV charging infrastructure construction and other EVSE installation in California by material and labor categories in millions of 2020 US dollars, 2021-2045.

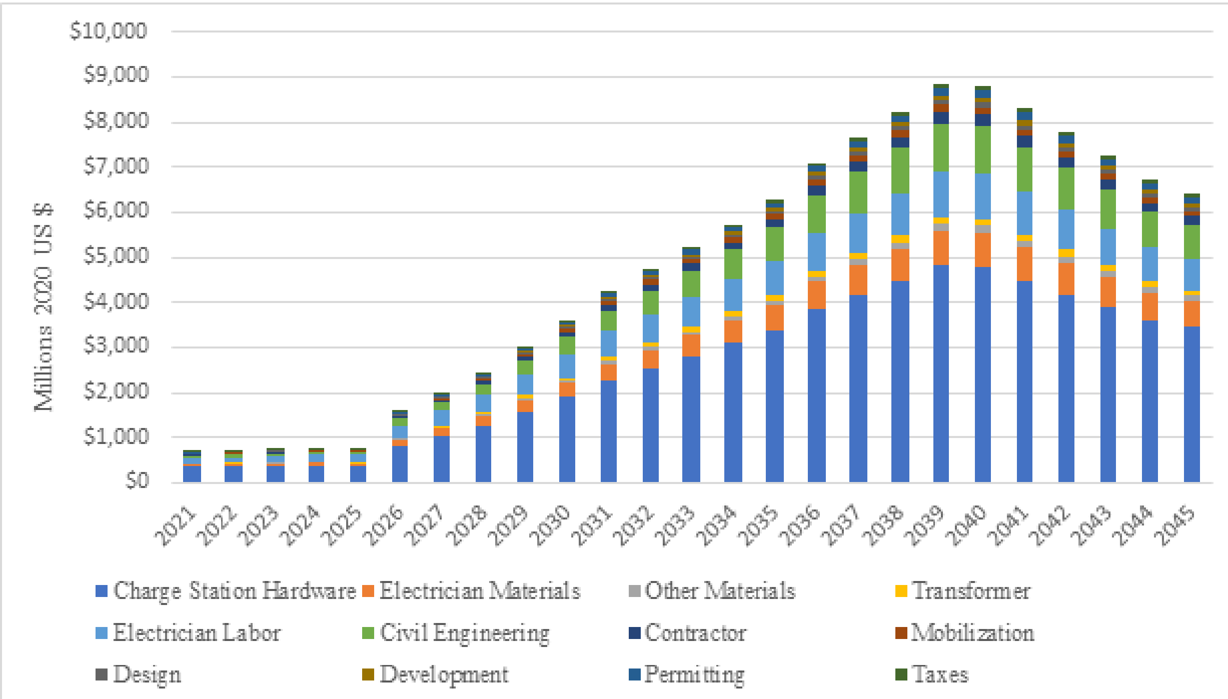
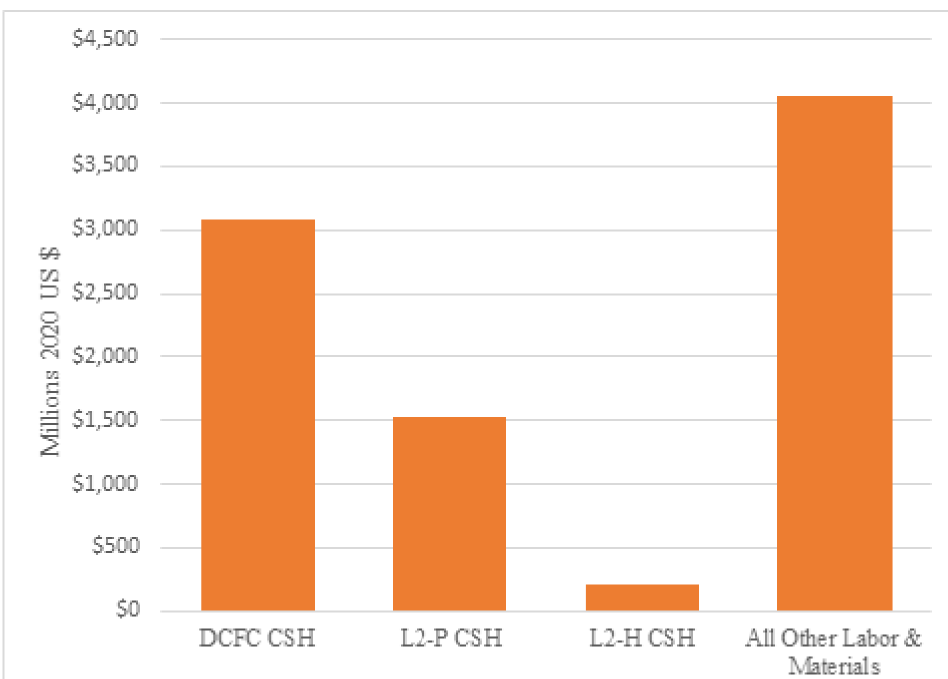


Figure 3-21: Projected expenditures on charge station hardware by charger type versus all other EV charging infrastructure-related expenditures in millions of 2020 US dollars, 2039.



However, it is important to stress that our estimates for the cost of charge station hardware reflect the current state of the market. Per-charger costs for this equipment may drop in the coming years as economies of scale are achieved by manufacturers, which would lower the overall magnitude of our expenditure estimates for later years. However, the impact of such lower costs on our workforce impacts analysis in Chapter 4 is likely to be somewhat muted, as EVSE manufacturing is a largely capital-intensive (as opposed to labor-intensive) industry with a relatively low profile in California.

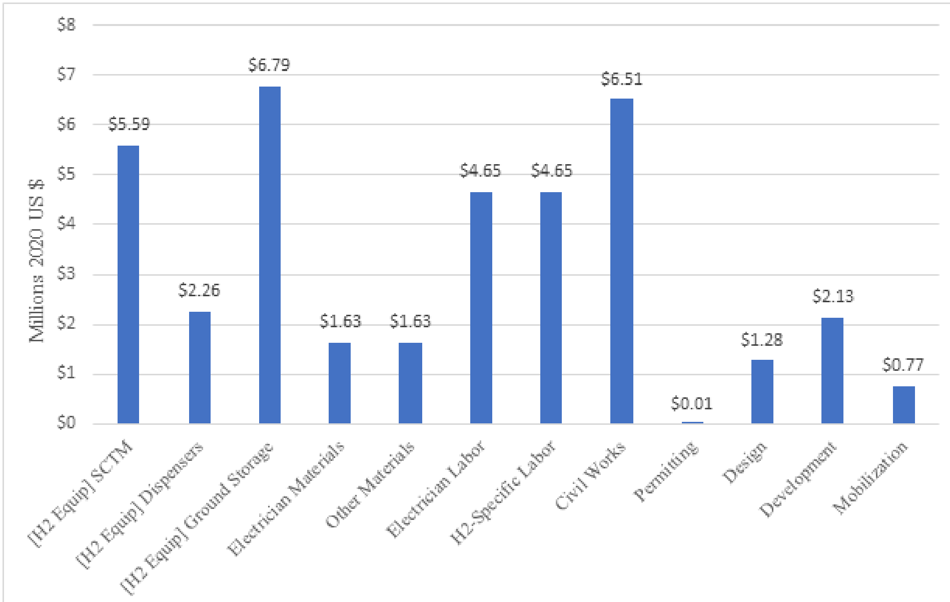
Among the labor-related cost categories, electrician labor and civil engineering are the largest by overall magnitude. These are driven in part by relatively high wages in these sectors, meaning that their cost profile does not necessarily translate to greatest realized workforce impacts. Likewise, lower prevailing wages in occupations related to contractor labor and mobilization mean that the lower levels of expenditures in these areas may create unexpectedly high numbers of jobs, albeit lower quality ones. Improving job quality in these areas in the future would inflate overall expenditures in these labor sectors.

Baseline Expenditures: Hydrogen Refueling Infrastructure

Even more so than EV charging infrastructure, there is a dearth of information on the nascent hydrogen refueling industry. As such, we once again present our estimates for 2021 as the baseline to which industry expansion will be compared. However, the novelty of the hydrogen refueling industry creates significant uncertainty regarding how quickly infrastructure to support these transportation technologies will expand in the short-term. Similarly, as with charge station hardware, specialized equipment necessary for hydrogen refueling stations has not yet achieved economies of scale that may reduce the magnitude of overall construction costs in the future. However, such cost categories in hydrogen refueling infrastructure are not as dominant as charge station hardware is to the EV charging space and are similarly capital-intensive, meaning that potential impacts of lower equipment costs on our workforce analysis in Chapter 4 are once again likely to be small.

We estimate that overall spending on hydrogen refueling infrastructure in 2021 will be approximately $37.9 million (Figure 3-22). Two material categories specific to hydrogen gas – SCTM (Storage, Compression, and Thermal Management) equipment necessary for on-site hydrogen production, and ground storage equipment – stand out as noticeably high at approximately $5.6 million and $6.8 million, respectively. The highest expenditure labor category is civil works at just over $6.5 million, followed by specialized electrician and hydrogen equipment-related labor at $4.65 million apiece. Other material and labor categories account for less than $2.5 million each.

Figure 3-22: Baseline expenditure estimates on hydrogen refueling infrastructure in California by category in millions of 2020 US dollars, 2021.



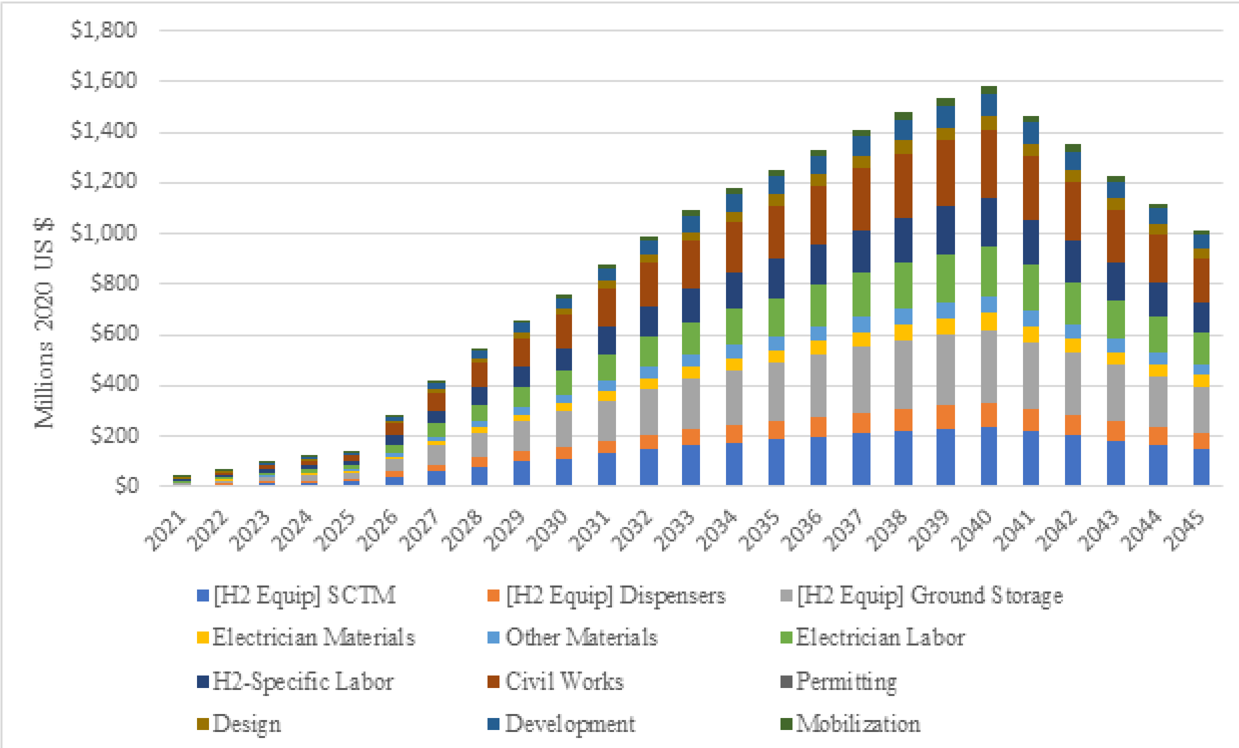
Projected Expenditures: Hydrogen Refueling Infrastructure

Key Takeaways:

- Total annual expenditures on hydrogen refueling infrastructure are expected to rise slightly from 2021-2025, then at a higher rate until 2040, where they peak at nearly $1.6 billion. This represents growth of over $1.5 billion from baseline to peak, or 4179.5%.
- Annual expenditures on hydrogen refueling infrastructure begin to decline noticeably after 2040, falling more than $500 million to just over $1 billion by 2045.
- The largest material categories are for specialized hydrogen equipment, especially that related to ground storage and SCTM. Civil works represents the largest labor expenditure category, followed by electrician and hydrogen-specific labor.

We expect expenditures on construction of hydrogen refueling infrastructure in California to rise slightly from 2021-2025, with annual amounts rising to approximately $139 million in 2025 (Figure 3-23). However, a period of rapid expansion in annual expenditures begins in 2026, with annual expenditures rising by between $80 million and $120 million each year until 2034. This is followed by a period of more tepid growth until reaching the industry peak in 2040 at approximately $1.58 billion. Shrinkage begins to occur throughout the later years of our analysis, as annual expenditures contract by approximately a third between 2040 and 2045. Expenditures in the final year of our analysis sit at just over $1 billion.

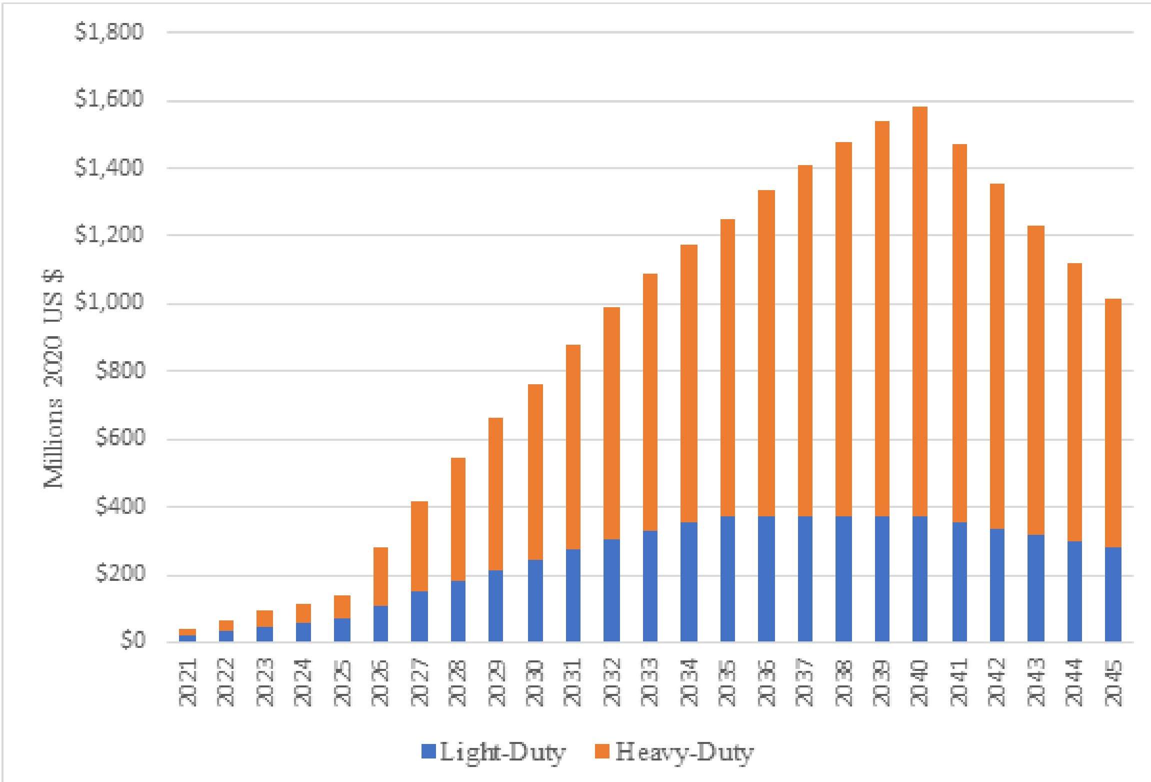
Figure 3-23: Projected annual expenditures on hydrogen refueling infrastructure construction in California by material and labor categories in millions of 2020 US dollars, 2021-2045.



Up until 2025, expenditures on hydrogen refueling infrastructure construction are driven roughly evenly by fuel demand from the light- and heavy-duty sectors. The large growth and subsidence trends seen post-2025 are largely driven by the needs of the heavy-duty sector, where FCEVs are projected to make significantly greater gains in fleet representation compared to LDVs. Fuel demands in the heavy-duty sector are expected to drive 2-3 times the magnitude of expenditures on hydrogen refueling infrastructure construction in all years of our analysis after 2027 (Figure 3-24).

In the aggregate, equipment specific to hydrogen refueling constitutes the largest expenditure category by far: over one-third of the expenditures in a given year. This encompasses three categories of hardware identified in Figure W: SCTM, dispensers, and ground storage. Even in isolation, ground storage equipment is the highest single overall cost category, followed closely by labor related to Civil Works and SCTM equipment. As aforementioned, our cost estimates for hydrogen-related equipment may represent an overestimate in terms of expenditure magnitude in the long run, as economies of scale reduce the costs of this hardware. Furthermore, we assume that SCTM equipment – necessary for on-site production of hydrogen at refueling stations – is present at half of constructed stations, with the other half relying on delivery of compressed or liquid hydrogen from centralized production sites (e.g. large-scale electrolysis facilities).

Figure 3-24: Projected annual hydrogen refueling infrastructure expenditures in California, delineated by the vehicle sector (light- or heavy-duty) whose fuel consumption is driving construction in millions of 2020 US dollars, 2021-2045.



3.7 – Potential Impacts of Executive Order N-79-20 On Our Estimates

On September 23, 2020, California Governor Gavin Newsom issued executive order N-79-20, directing CARB to pursue regulations that would completely phase out sales of new light-duty ICEVs by 2035, with this transition occurring for other vehicle classes in later years. Our estimates are based on the CNS LC1 scenario, which projects that sales of new light-duty ICEVs will drop to zero in 2040, five years later than the goal articulated within the executive order. Our fossil fuel medium- and heavy-duty truck sale estimates align with the executive order's goals.

If the goals outlined in executive order N-79-20 are achieved, the steeper drop in new ICEV LDV sales would lead to some variations in the expenditure forecasts outlined above, although overall total purchase expenditures are likely to stay relatively constant. Since ZEVs and fossil fuel vehicles will become increasingly comparable in price and overall number of vehicles purchased is unlikely to change drastically, the speedier transition's impact on this category is likely to be muted.

A faster transition to an all emissions-free vehicle fleet will speed up the accompanying declines in fuel costs and maintenance costs. We expect to see overall fuel costs and maintenance costs drop earlier than our estimates suggest, since electric vehicles are typically associated with lower annual fuel and maintenance costs. However, because our vehicle sales estimates for HDVs, MDVs, and buses will remain consistent with the new scenario introduced by the executive order, only LDV sales will be majorly impacted. Therefore, we expect the declines in each key expenditure category to come primarily from LDV expenditures.

Chapter 4 – Model Methodology, Specifications, and Limitations

In Chapter 3 we projected how expenditures by consumers, businesses, and government will change across California's transportation sectors between now and 2045. We utilize those expenditures as inputs in our effort to model the consequent changes in the state's workforce resulting from the transition to ZEVs. These figures are entered into IMPLAN Pro Version 3.1, an economic input-output model commonly used to assess how investment drives job creation. This model utilizes the 2018 California State Total data package, aligning calculated workforce impacts to the economic conditions of the state in that year.

The outputs from this model estimate the workforce impacts of our forecasted transportation-related expenditures across three categories. Direct jobs are those in industries supplying goods and services on which money is being spent, such as EV manufacturing workers and hydrogen refueling station staff. Indirect jobs are created in industries within the supply chain of those where direct jobs are created, such as workers refining the raw metals and materials from which EVs are built. Finally, induced jobs represent those supported through broader economic activity stimulated by salary spending associated with the creation of direct and indirect jobs; examples include grocery store workers and health care providers.

In this Chapter we first delineate the scope of our modeling work, detailing the chronological, geographic, and fiscal boundaries of our study. We then explain the basics of how an economic input/output model functions and discuss the specific forms our inputted expenditure data and outputted jobs data take. A discussion of the model's limitations follows. Lastly, we present the resulting workforce impact estimates and discuss key patterns, trends, and underlying driving factors.

4.1 – Scope of Study

The job estimates forecasted in this study are specific to a particular scope with regards to time, geography, and types of expenditures considered. The details of these boundaries are presented below:

Study Period

This study forecasts the change in jobs resulting from California's transition to ZEVs from 2020-2045, relative to the 2019 baseline numbers presented in Chapter 2. Forecasts reflect economy-wide spending patterns in the state during that period, based on projections for vehicle sales and fuel consumption from the CNS LC1 scenario.

Geographic Boundary

All workforce impacts forecasted in this study are limited to the State of California. Out of state and international jobs supported by expenditures made by Californian consumers (e.g.

manufacturing jobs for EV batteries in Japan) are not accounted for. Jobs within the state that depend on out-of-state inputs or supporting workforces (e.g. the transport of EV batteries to a California-based facility and the manufacturing of EVs within California using those batteries) are captured.

Expenditures Considered

As outlined in Chapter 3, we consider amalgam expenditures by all actors – consumers, businesses, and governments – related to transportation in California. We do not distinguish between expenditures made by one set of actors versus another, as the economic activity generated by a given amount of money spent is identical, regardless of its source. For this same reason, exactly who bears the burden of particular costs (e.g. whether an EVSE retail business or the utility pays for the cost of installing a new transformer to service a DCFC station) is irrelevant for purposes of estimating overall workforce impacts. It is for this reason also that, in the case of purchasing electricity as a transportation fuel, we assess costs using projected residential and commercial retail rates of electricity without incorporating amortized cost of newly built infrastructure; expenditures associated with constructing said infrastructure are considered separately, and therefore their workforce impacts are already captured.

To reiterate the scope of the expenditure analysis presented in Chapter 3, we considered the following key expenditure categories and subcategories related to California's transportation sector:

- Vehicle Expenditures: new vehicle sales of all technology types for LDVs, MDVs, HDVs, and buses.
- Fuel Expenditures: expenditures made on gasoline/diesel, electricity, and hydrogen for transportation purposes.
- Maintenance: expenditures made to maintain and repair vehicles across all technology types and categories.
- Infrastructure: construction and installation of new EVSE hardware and stations, both residential and public, serving both the light- and heavy-duty sectors; construction of new hydrogen refueling stations.

Financial Savings

In addition to shifting spending patterns in California's transportation sector, the transition to carbon neutrality will result in significant financial savings in certain areas. For instance, between 2020 and 2045, annual expenditures on fuels and maintenance are expected to drop by over $22 billion and $16 billion, respectively. These savings translate to an effective increase in consumer purchasing power, stimulating increased expenditures in other, non-transportation-related sectors. These expenditures will generate their own set of beneficial workforce impacts.

However, these benefits are *not* captured by the model, and are not reflected in the ZEV-related job creation figures detailed below.

Overhead Costs

Several key expenditure categories considered within our scope include costs related to administrative tasks in both the private and public sectors. For instance, construction of infrastructure for EV charging and hydrogen refueling necessitates labor expenditures for personnel involved in permitting such sites. Where data is available we have explicitly estimated the magnitude of such overhead costs within the expenditure categories explored in Chapter 3. However, IMPLAN is not equipped to model the job impacts of such expenditures; they are treated as "leakage" within the model due to high levels of uncertainty concerning how money spent in these categories stimulates job growth. Therefore, overhead cost-related expenditures – which are very small in magnitude – do not factor in the reported jobs numbers.

Net Jobs

This study only considers gross job numbers resulting from expenditures made by California's consumers, businesses, and governments; it does not assess whether these are net positive jobs. IMPLAN modeling treats a given expenditure as stimulating novel economic activity within the geographic area of study – in this case, California. It does not compare the resulting jobs numbers to any type of alternative scenario, *i.e.* one in which California's transportation sector continues to utilize a high-polluting model where fossil fuel-combusting vehicles dominate. In such a situation, most of the monetary expenditures captured in our analysis in Chapter 3 would still be spent in the state, although spending patterns across sectors would be quite different. This alternate spending scenario would support its own set of in-state jobs. Thus, our reported jobs figures may represent a transfer of jobs from one sector to another.

Producing a net job analysis in this case would require repeating our analytical process for quantifying expenditure and modeling workforce impacts using the CNS BAU (business-as-usual) scenario for vehicle sales, fuel consumption, and VMT figures. The jobs numbers resulting from this repeated process could be compared to those produced from our modeling of the low-carbon scenario's workforce impacts. While doable, such an analysis is outside the scope of this study, in addition to entertaining a scenario for California's transportation sector that is incompatible with the state's emissions reduction goals.

4.2 – Model Overview

All job estimates reported in this study were generated in an economic input-output model (IMPLAN Pro Version 3.1) with the 2018 California State Total data package. Economic input-output models such as IMPLAN work by mapping the interdependent relationships between all of the industrial sectors in a defined economy by tracking the flow of commodities (goods and services) and money. In other words, an economic input-output model shows how the outputs of one particular industry become the inputs of another industry, and vice versa. By mapping these interdependent relationships, the ripple effects of a change in one industry can be quantified across all other industries. For example, if there is a spike in the sales of zero-emission vehicles, additional demand is placed on the auto manufacturing sector, which in turn places additional demand on supporting sectors such as automobile equipment manufacturers, marketing services, financial services, etc. An economic input-output model captures all of these ripple effects and quantifies them according to a number of economic measures (e.g., value added, jobs supported, etc.), both across the entire economy of a given region and within each industry. In this study, we focus exclusively on employment.

The potential for a given magnitude of expenditures to support jobs ultimately varies by the industry within which that expenditure takes place. Since industries are heterogeneous in their production processes, they are also heterogeneous in their labor needs, yielding different demands on the workforce given the same level of investment. The number of jobs supported per dollar spent within that industry is referred to as an employment multiplier and is usually expressed as a ratio of job-years per million dollars of spending. A "job-year" or FTE (Full-time Equivalent) simply means the equivalent of employing one person for one full year. In practice, one job-year may take the form of two employees for six months each, three employees for four months each, or any other combination of employees that adds up to one year's worth of labor. All jobs have been converted to FTEs in this study because some industries employ a number of part-time workers, and a standard unit was needed for comparing the jobs supported by different investments.

While many categories of transportation-related expenditures can be readily coded to appropriate industrial sectors in IMPLAN, others – notably, young industries like EVSE and hydrogen FCEVs that do not have a corresponding IMPLAN industry sector available – must be manually mapped onto the existing IMPLAN framework. In total, there are 546 industry codes in IMPLAN, each representing an industry sector. In general, these industry codes map very closely to the six-digit North American Industry Classification System (NAICS) codes, especially for manufacturing sectors. However, many of the service, agricultural, and construction sectors in IMPLAN have been consolidated into unique industry categories created by the Minnesota IMPLAN Group (e.g., construction of new highways and streets). Given the general overlap between NAICS and IMPLAN industry codes, the 2017 NAICS definitions were used to infer which IMPLAN codes were most appropriate for describing the various industries within which transportation-related expenditures will increase or decline as a result of California's transition to ZEVs. Our methodology for mapping expenditure categories to sets of IMPLAN codes is detailed in *Model Specifications* below.

Another major task was identifying how to allocate expenditures when they involved multiple industries. The assumptions used to allocate investment dollars to different industrial sectors are detailed in *Model Specifications* below. The following subsections describe the model in more detail, including a description of the dataset used to build the model, relevant model inputs and outputs, specifications required by IMPLAN for each model input, and limitations that constrain the precision of model outputs.

4.3 – Model Specifications

Here is the detailed account of how different cost items are assigned and mapped to corresponding IMPLAN industry sectors to represent expenditure under each of the four aforementioned categories (vehicle cost, fuel, maintenance, and infrastructure) and subcategories. This step essentially prepares and tunes the model to use the conclusions from Chapter 3 as inputs for employment impact analysis. Items mapped under *vehicle cost, fuel,* and *maintenance* are organized by vehicle technologies, while items under *infrastructure* are setup separately. Following each model specification chart for vehicle type are the graphs showing the distribution of weights of all listed cost items under each category as they change over the years. The weights are derived from expenditure amount provided in Chapter 3.

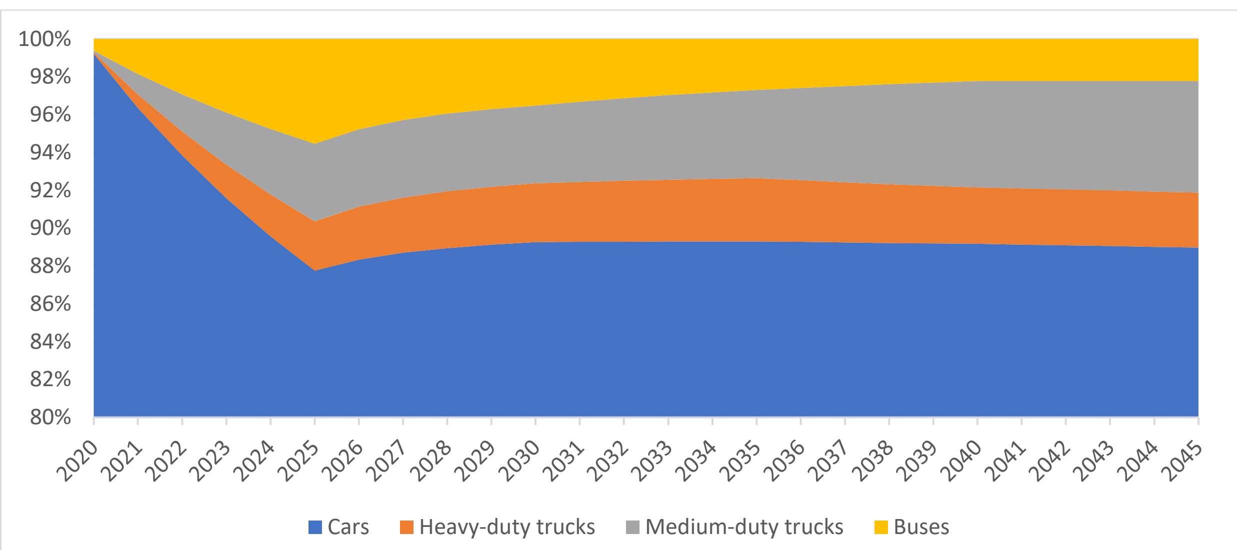
With the mapping and weight assignment, expenditure associated with each cost item is put into the model as economic demand generated for each industry sector and jobs are modeled as created in the process of fulfilling such demand. To fully utilize IMPLAN's ability to adjust for inflation/deflation for best possible accuracy, actual expenditure amounts are broken down and put into the model on a year-to-year basis. Thus, the amount for each of the four years between every two increments is linear-extrapolated. For example, for Cost Item X, the expenditure is expected to be $10M in 2040 and $0 in 2045. Then the expenditure extrapolated and put into the model for 2041, 2042, 2043 and 2044 are $8M, $6M, $4M and $2M respectively.

Table 4-A: Model specifications for BEV-related industry sectors by cost category and item.

Category	Cost Item	Corresponding IMPLAN Industry Sector
Vehicle Cost	Light-duty Vehicles	Automobile Manufacturing
	Heavy-duty Trucks	Heavy Duty Truck Manufacturing
	Medium-duty Trucks	
	Buses	
Electricity Fuel Cost	Hydroelectricity	*N/A
	Combined Heat and Power (CHP), Coal, and Gas	Electric Power Generation – Fossil Fuel
	Nuclear	*N/A
	Solar	Electric Power Generation – Solar
	Wind	Electric Power Generation – Wind
	Geothermal	*N/A
	Biomass	Electric Power Generation - Biomass
	All Other & Imported	Not modeled as a power generation source
	Electricity Retail & Distribution Service	Electric Power Transmission and Distribution Service (excluding electricity purchase)
Maintenance Cost	Light-duty Vehicle Maintenance	Automotive Repair and Maintenance
	Heavy-duty Truck Maintenance	
	Medium-duty Truck Maintenance	
	Buses	

**These items are not modeled as the corresponding IMPLAN industry sectors are missing from the 2018 California State Total data pack.*

Figure 4-1: Projected BEV cost distribution in California by vehicle category, 2020-2045.



Note that the weight scale starts from 80%, indicating expected market dominance of LDVs over all other vehicle types.

Figure 4-2: Projected cost distribution for electricity as a transportation fuel in California by generation technology, 2020-2045.

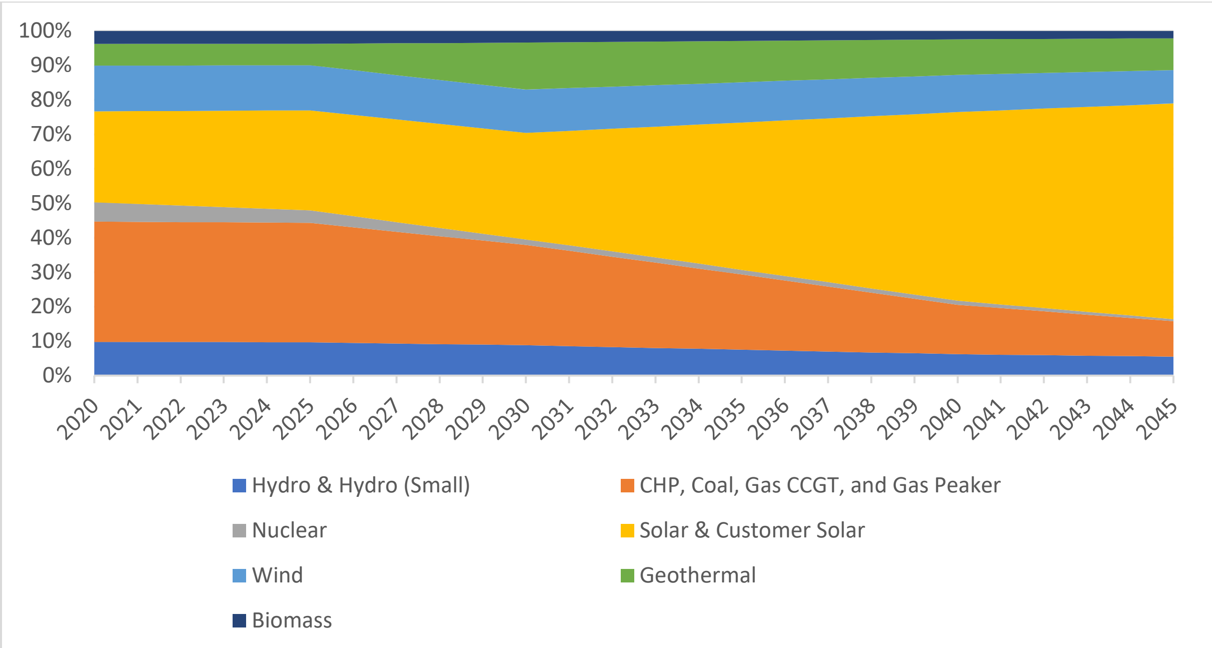


Figure 4-3: Projected BEV maintenance cost distribution in California by vehicle category, 2020-2045.

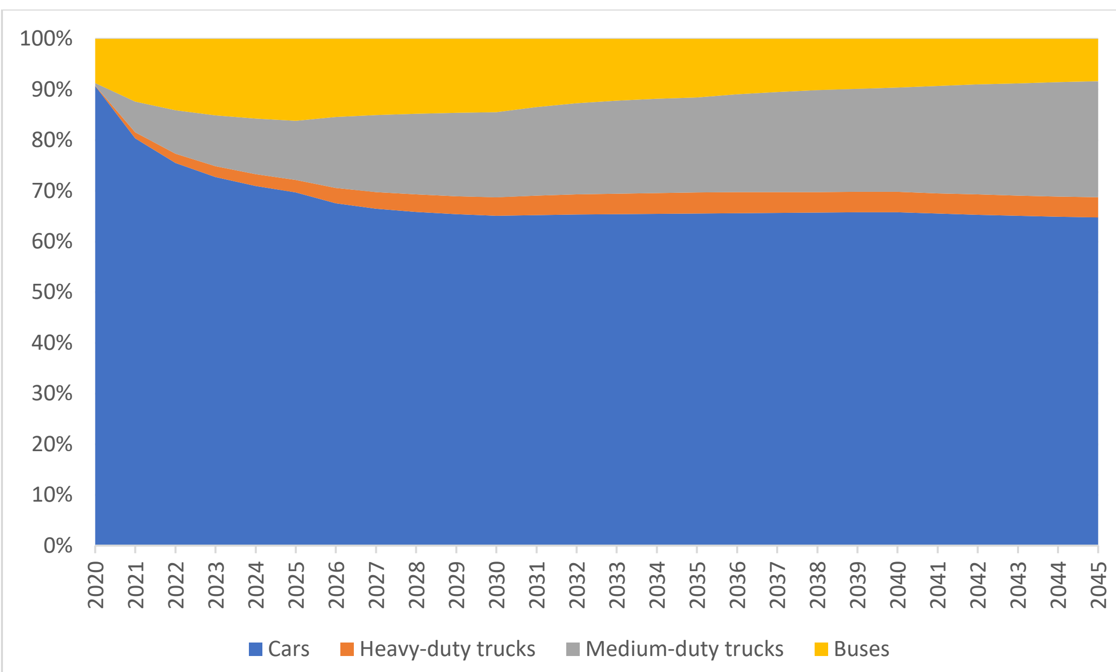


Table 4-B: Model specifications for FCEV-related industry sectors by cost category and item.

Category	Cost Item	Corresponding IMPLAN Industry Sector
Vehicle Cost	Light-duty Vehicles	Automobile Manufacturing
	Heavy-duty Trucks	Heavy Duty Truck Manufacturing
	Medium-duty Trucks	
	Buses	
Hydrogen Fuel Cost	Hydrogen	Industrial Gas Manufacturing
Maintenance Cost	Light-duty Vehicle Maintenance	Automotive Repair and Maintenance
	Heavy-duty Truck Maintenance	
	Medium-duty Truck Maintenance	
	Buses	

Figure 4-4: Projected FCEV cost distribution in California by vehicle category, 2020-2045.

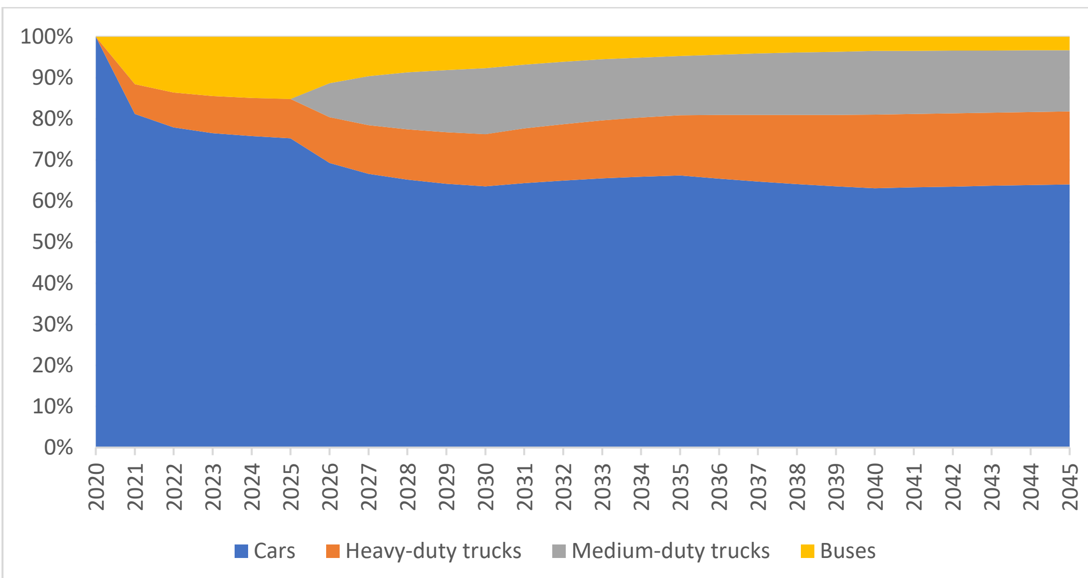


Figure 4-5: Projected hydrogen fuel cost distribution in California by vehicle category, 2020-2045.

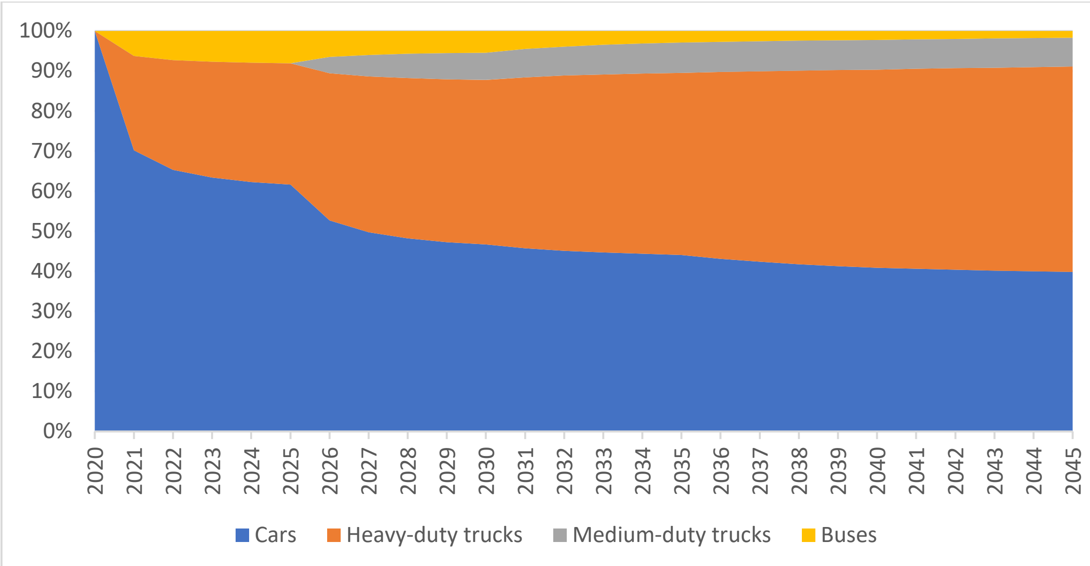


Figure 4-6: Projected FCEV maintenance cost distribution in California by vehicle category, 2020-2045.

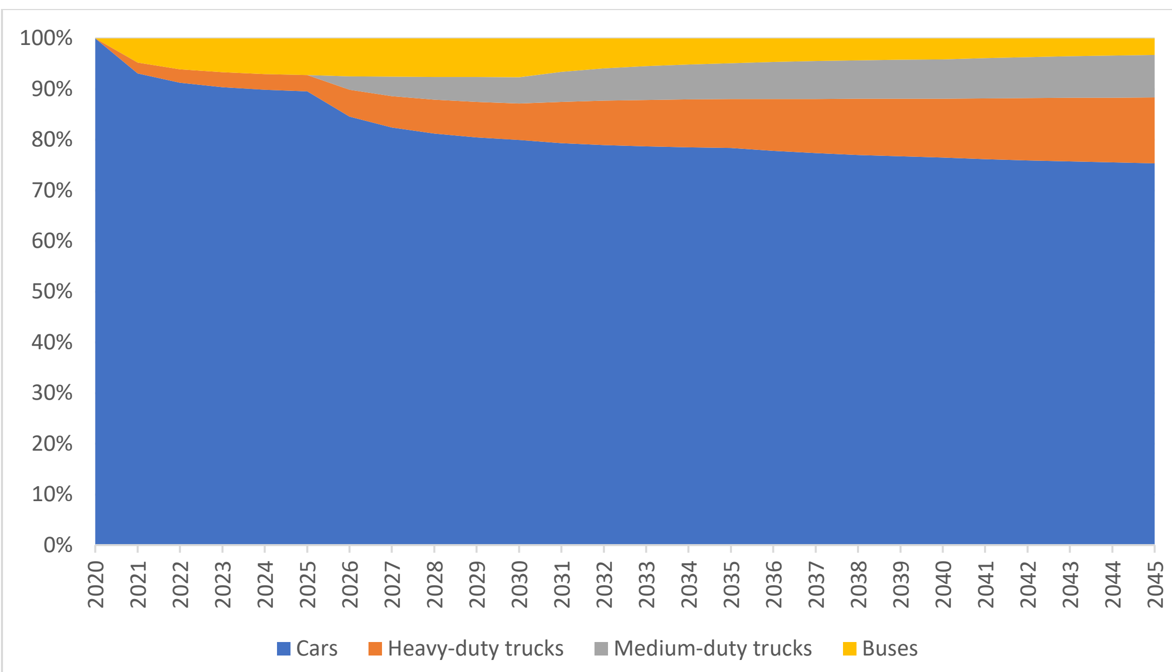
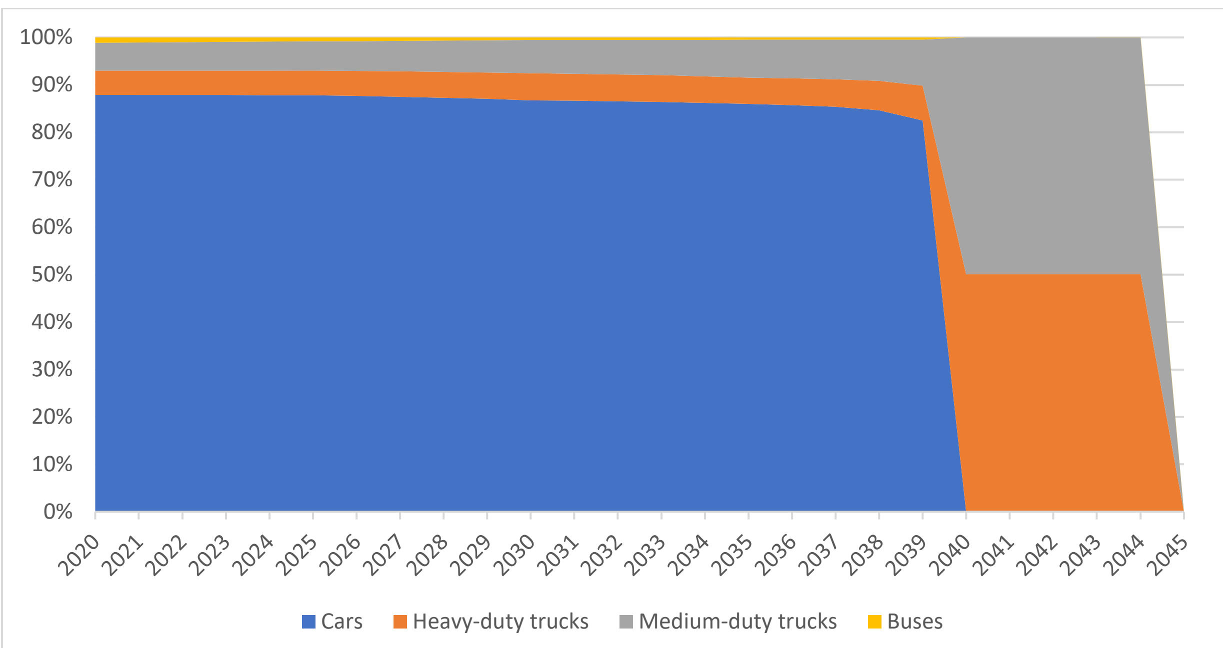


Table 4-C: Model Specifications for ICEV-related industry sectors by cost category and item.

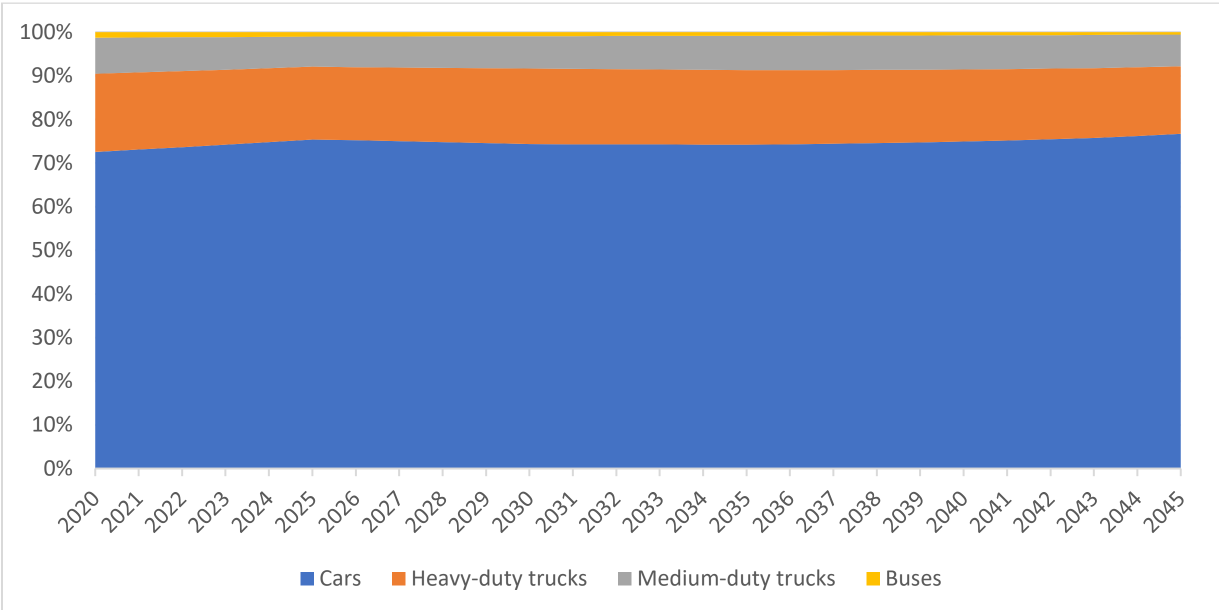
Category	Cost Item	Corresponding IMPLAN Industry Sector
Vehicle Cost	Light-duty Vehicles	Automobile Manufacturing
	Heavy-duty Trucks	Heavy Duty Truck Manufacturing
	Medium-duty Trucks	
	Buses	
Fossil Fuel Cost	Hydrogen	Refined Petroleum Product Manufacturing
Maintenance Cost	Light-duty Vehicle Maintenance	Automotive Repair and Maintenance
	Heavy-duty Truck Maintenance	
	Medium-duty Truck Maintenance	
	Buses	

Figure 4-7: Projected ICEV cost distribution in California by vehicle category, 2020-2045.



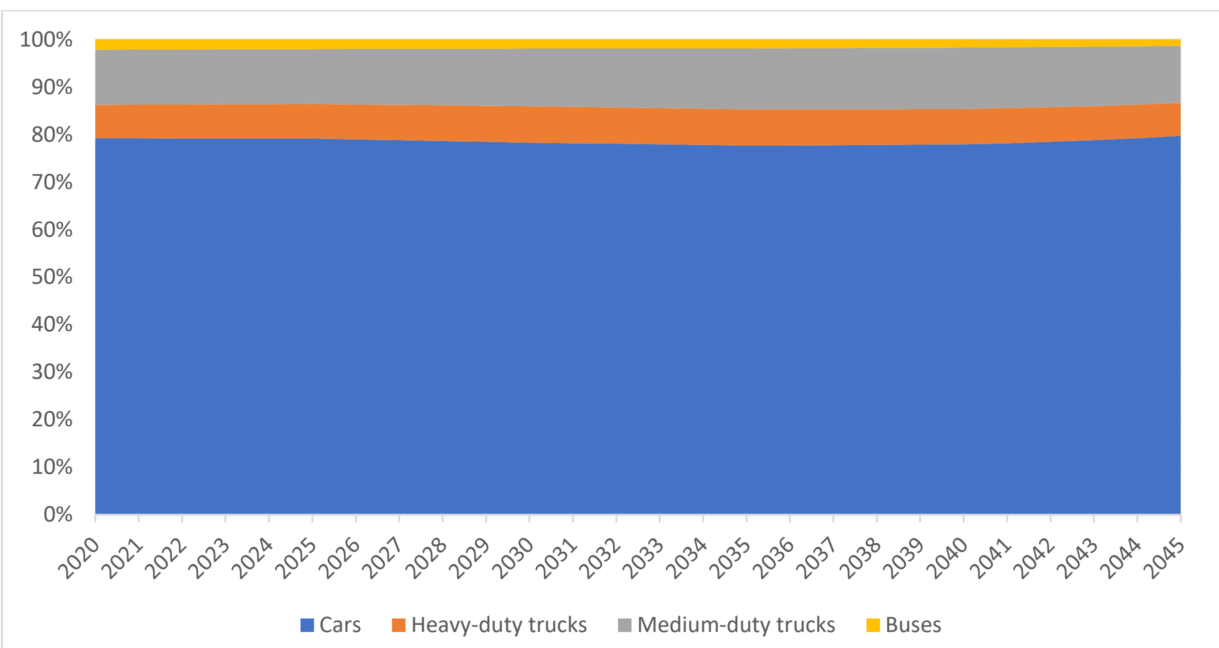
Note that the sudden drops to zero are the result of the expected phasing out of each particular vehicle type, which result in the remaining categories taking up the total market. Light-duty ICEVs are expected to phase out first, followed by simultaneous phaseout of medium- and heavy-duty ICEVs.

Figure 4-8: Projected fossil fuel cost distribution in California by vehicle category, 2020-2045.



Note that, although the sales of new ICEVs are expected to phase out completely by 2045, the composition of ICEV-related maintenance expenditures is expected to remain relatively stable over the same period. However, the absolute amount of such expenditures is expected to continuously decline.

Figure 4-9: Projected ICEV maintenance cost distribution in California by vehicle category, 2020-2045.



Note that, although the sales of new ICEVs are expected to phase out completely by 2045, the composition of fossil fuel expenditures is expected to remain relatively stable over the same period. However, the absolute amount of such expenditures is expected to continuously decline.

Table 4-D: Model specifications for construction of new EV charging infrastructure and EVSE installation.

Category	Cost Item	Corresponding IMPLAN Industry Sector
Material	Charge Station Hardware	Construction of New Commercial Structures
	Electrician Materials	All Other Miscellaneous Electrical Equipment and Components Manufacturing
	Other Materials	Construction of New Commercial Structures
	Transformer	Power, Distribution, and Specialty Transformers Manufacturing
Labor	Electrician Labor	Maintenance and Repair Construction of Non-residential Structures
	Civil Engineering	Architectural, engineering, and related services
	Contractor	Construction of New Commercial Structures
	Mobilization	Truck Transportation Services
	Design	Architectural, engineering, and related services
	Development	Construction of New Commercial Structures
	Permitting	*Not Modeled
	Taxes	

**Employment impact associated with tax and government income is beyond the capability of IMPLAN and not modeled.*

Table 4-E: Model specifications for construction of new hydrogen refueling infrastructure.

Category	Cost Item	Corresponding IMPLAN Industry Sector
Material	[H2 Equipment] SCTM	Air and Gas Compressor Manufacturing
	[H2 Equipment] Dispensers	Other Fabricated Metal Product Manufacturing
	[H2 Equipment] Ground Storage	Metal Tanks (heavy gauge) Manufacturing
	Electrician Materials	All Other Miscellaneous Electrical Equipment and Components Manufacturing
	Other Materials	Construction of New Commercial Structures
Labor	Electrician Labor	3060 Maintained and Repaired Non-residential Structures
	H2-Specific Labor	Architectural, engineering, and related services
	Civil Works	
	Design	
	Development	Construction of New Commercial Structures
	Mobilization	Truck Transportation Services
	Permitting	*Not Modeled

**Employment impact associated with tax and government income is beyond the capability of IMPLAN and not modeled.*

4.4 – Model Inputs

As articulated above, our model inputs consist of annual expenditure quantities in 2020 US dollars across four distinct categories: new vehicle sales, fuel consumption, maintenance and repairs, and new fueling infrastructure. Each of the three former categories is further segmented by technology type, focusing on the three predominant drivetrain types: ICEVs, EVs, and FCEVs. Fueling infrastructure is segmented by vehicle technology served – BEVs versus FCEVs.

When expenditure quantities are entered into IMPLAN, the model treats them as a new influx of money into the California economy. In reality, some portion of these dollars would have been spent in California even in the absence of a transition to ZEVs, just on a different set of economic activities. For this reason, the job numbers reported in this study should not be viewed as net employment gains. Rather, they should be viewed as the gross number of jobs supported by California's transportation sector as it adjusts to achieve carbon neutrality.

4.5 – Model Limitations

Input-output models have several advantages for estimating the employment impacts of different investment decisions. They capture employment impacts across an entire economy (i.e., direct, indirect, and induced jobs) and they can be used to forecast employment impacts when data from the field is impossible to collect. Input-output models, however, have a number of limitations that constrain their ability to perfectly quantify the employment impacts of a given investment. The limitations of the input-output model used in this study, IMPLAN Version 3.1, are described below:

» *Static Relationships:* The interdependent relationships between economic sectors in IMPLAN are static (i.e., frozen in time), providing a snapshot of the economy in the year captured by the data package. In this study, the data package reflects industrial purchasing patterns in 2018. Thus, job outputs from the model do not account for changes in consumer or industry behavior that may occur after 2018, such as an economic downturn or a technological innovation, which in turn could change industrial purchasing patterns. Notably, the model outputs have no basis by which to evaluate short- or long-term economic impacts of the COVID-19 pandemic. Similarly, IMPLAN does not account for price elasticity. In other words, the prices of goods and services are not affected by a surge of investment into the economy. For example, a construction boom, as modeled in IMPLAN, would not raise the price of building materials following a sudden influx in demand. Given the significant size of California's transportation sector and the magnitude of expenditures associated with it, the inability of the model to account for price elasticity means that significant variation from real-world conditions is possible.

» *Linear Relationships:* The relationships between economic sectors in IMPLAN are also linear. In other words, employment multipliers are not sensitive to the magnitude of an investment. For example, the jobs supported by $1 billion of expenditures on EV charging stations will be exactly

1,000 times greater than $1 million of expenditures on the same set of projects. In reality, industries face supply constraints, such that there may not actually be enough EVSE manufacturing capacity to meet such a spike in demand. In addition, industries face declining marginal costs as their operations grow, allowing firms to spend more money on labor instead of capital costs. In the EVSE example, a $100 million investment may allow manufacturers who produce chargers and related equipment to spend more money on product development (e.g., engineers, designers, consultants, etc.), and less on capital investments (e.g., assembly lines, transportation equipment, etc.). Since IMPLAN is a linear model, these supply constraints and cost considerations are not accounted for in this study. The size of California's transportation sector means that a nonlinear model would likely yield notable differences from the results presented herein.

» *Timing of Impacts:* IMPLAN does not specify when job gains will actually be realized. The job totals that IMPLAN reports are based on the ripple effects felt in the economy by a particular investment. Some of those effects will occur sooner than others. For example, an investment in EV manufacturing may create direct jobs in that sector immediately, but the secondary industries that supply EV manufacturers with vehicle parts (e.g., steel mills, glass manufacturers, rubber manufacturers, etc.) may need a ramp up period to respond to additional demand (i.e., time to mine materials, manufacture automotive parts, transport those parts to the assembly site, etc.). Assessing how long each industry needs to respond to additional demand is difficult to predict, so IMPLAN does not provide a time range in which all job-years will be completed.

» *Job Quality:* Information about job quality is critical for assessing the impact of an investment on the economic well-being of hired workers. Unfortunately, IMPLAN does not provide sufficient information for assessing job quality, such as detailed data on wages by occupation, retirement packages, health benefits, paid leave, training opportunities, or prospects for career advancement. IMPLAN does provide information about the industrial sectors that are impacted by investment flows, including the number of job-years supported in each industry and total amount of employee compensation (salaries plus benefits) generated within each industry. While an average compensation package for each industry could be deduced from these outputs (employee compensation divided by total job-years), such a metric would mask the significant wage disparity that exists in many industries, and is therefore not presented in this study. However, in Chapter 5 we do provide an overview of characteristics for industries identified as rapidly contracting or rapidly expanding based on the model outputs.

» *Geographic Granularity:* IMPLAN does not provide data on the location of jobs, just the gross number of jobs that are supported within a defined geographic boundary. In this study, the geographic boundary was defined as the entire state of California. While we cannot provide specific numbers for jobs with higher geographic resolution, we discuss expected, high-level patterns of job geographic distribution (e.g. concentrated versus dispersed) in identified highly-impact industries in Chapter 5.

Key Contextual Factors

In addition to the broad limitations of the IMPLAN model discussed above, there are several model-related quirks and associated challenges that affect the results presented below, particularly with respect to key trends and occupational labor figures:

1. *Adjustments for Inflation*: Since IMPLAN maps the interdependent relationships between industries and employment multipliers based on the economic reality of the data pack year, IMPLAN adjusts for inflation when computing employment numbers related to future expenditures. Consequently, employment generated from a given level of expenditures is deflated when examining periods many years into the future, even when considering similar or identical industries. These trends also reflect the tendency of industries to achieve greater worker productivity and other efficiencies over time that reduce the labor generated for a given level of expenditures over time.

   In the model results presented below, this is especially notable when comparing employment generated in EV- versus ICEV-related industries. While the number of vehicles sold and total expenditures on new vehicles are similar in the respective peak years for these two sectors, the peak of new EV sales occurs many years in the future; thus, the model calculates peak employment in this area as being noticeably lower, both per unit of expenditure and in overall magnitude, than that for ICEV-related sectors.

2. *Simplified Occupational Breakdowns*: the IMPLAN occupational matrix used to disaggregate job totals within industries into figures for specific occupations uses a static set of proportional values to calculate an industry's breakdown. These values are national, weighted averages of industries aggregated into sectors under the IMPLAN industry categorization scheme. Thus, the breakdowns do not necessarily reflect the actual occupational makeup of industries in California and are susceptible to aggregation bias.

   For instance, if Industry Sector A is made up of 10 industries and is nationally composed of 50% Occupation X and 50% Occupation Y across those industries, applying the matrix to a job total for any industry within Industry Sector A will always split those jobs between Occupations X and Y, 50-50, regardless of what overall jobs figures are for that specific industry in California. Additionally, any future changes in occupational breakdown for that industry or the industry sector are not captured.

   This presents a challenge in assessing the accuracy of occupation-specific job estimates many years into the future. Again, the case of employment generated from new BEV sales is a relevant example. As aforementioned, overall estimated employment generated by a given level of expenditures decreases in this sector over time as the model compensates for inflation and increasing labor productivity. Applying the occupational matrix produces estimates that split the final job numbers across occupations according to fixed proportions. It is unable to account for the possibility that employment in occupations may respond differently to changing conditions over time (e.g. that manufacturing jobs experience an outsized decline compared to other occupations due to productivity gains). Additionally, the model cannot recognize the potential for employment in certain occupations to be more responsive to variables other than total expenditures – for instance, the possibility that retail vehicle sales employment fluctuates more in response to numbers of vehicles sold than vehicle purchases themselves.

3. *Differences in Classification Schemes versus Baseline Data*: comparing projected employment figures versus baseline data for specific occupations is made difficult by mismatched classification schemes. The categories for employment utilized by our baseline data sources – the Quarterly Census of Employment and Wages (QCEW) and data from the Occupational Employment Statistics (OES) program, both managed by the U.S. Bureau of Labor Statistics (BLS) – are not identical to those used within the IMPLAN occupational matrix. This means that in some cases, figures related to certain fields of employment produced by the model may appear to be greater in magnitude than their closest baseline categorical counterpart, due to inclusion of a broader array of workers within that number.

   Additionally, IMPLAN may account for jobs in particular fields that are either not captured within BLS surveys or are classified in such a way that they are accounted for in categories not necessarily reflective of the occupation. Regarding the former, a key example is that the model estimates employment for mechanics based on expenditures derived from fleet size, vehicle miles traveled (VMT), and per-mile maintenance cost. Unpaid, non-professional maintenance performed on a vehicle by the owner would be reflected in IMPLAN's job totals while not appearing in BLS data. In the case of the latter, IMPLAN would capture hours performed maintaining vehicles by an employee of a private fleet, even if these tasks are not the employee's primary responsibility. In both cases, the modeled job numbers would exceed those reflected in baseline BLS figures.

4. *Limited Ability to Account for Labor in Nascent Industries*: IMPLAN utilizes a static set of relationships to quantify employment generated by a given industry. However, such established frameworks do not exist in the case of certain nascent industries relevant to this study, such as the operation of public DCFC stations for BEVs. In such cases the workforce impact of these firms are generally modeled as their closest analogue.

   However, this creates the possibility of the model significantly underestimating employment in certain occupations. For instance, the model results indicate consumption of electricity as a transportation fuel creates a meager number of retail sales jobs, meaning that most of the gross losses of gasoline station jobs would manifest as net losses. While this outcome is likely to be realized to some extent due to the expansion of home and workplace charging, it is possible that the tens of thousands of public DCFC stations could generate new employment in a business model that resembles that of gasoline stations. The potential scale of such impacts is highly uncertain, depending on factors such as the number of chargers at a station, the prevalence of automation, and the propensity of linked businesses to co-locate. Regardless, these jobs are not reflected in the model's totals because this industry does not exist in its current framework.

Chapter 5 – Model Results, Highly Impacted Sectors, and Discussion of Workforce Transition Policy Ramifications

In Chapter 2, we explored how California's transportation sector comprises a large group of industries that we have categorized within three supply chains: fuels, vehicles and transportation services. Furthermore, we have identified *high impact* industries: industries where the transition to net-zero emission vehicles will have a sizeable impact on employment, either positive or negative. This section will further examine profiles and trends in declining ICEV-related industries and occupations and expanding ZEV-related industries and occupations.

Expanding ZEV-related industries and occupations will need to significantly expand their workforce and operations in order for California to meet its transportation-related emissions goals by 2045, while contracting ICEV-related industries and occupations will face significant job loss due to the transition. The following subsections will examine the occupations in these affected industries, industry demographics, their education and training requirements, and the geographic distribution of these industries, to the best of the ability that available data will allow.

In this chapter, after presenting the results of the IMPLAN economic input/output model, we merge the model outputs with data from the U.S. Bureau of Labor Statistics (BLS) and the U.S. Department of Labor's Occupational Information Network (O*NET) database, to the best of our ability. IMPLAN has its own occupational names and codes, while BLS and O*NET use Standard Occupational Classification (SOC) codes to classify occupations. While there is no perfect crosswalk between these two systems, we allow for equivalencies where they are obvious. For example, IMPLAN predicts a decline in fossil fuel consumption which leads to a decline in occupations in petroleum refineries. We assume that this is equivalent to BLS's Petroleum Refineries industry classification for the purposes of this report. Where such evident equivalences cannot be drawn, we have added comments in our analysis below.

Regarding industry demographics, we use the U.S. Census Bureau's (2020) Quarterly Workforce Indicators (QWI) which provides counts of worker age, ethnicity, race, and sex. One shortcoming of this dataset is that workers are not linked across demographic categories, so we cannot know all the demographic categories of a single worker (e.g. if a worker is female and Hispanic or Latina, or if a worker is male and Asian). Despite this, the QWI data allow us to assess the overall demographic makeup of the workforce in a particular industry, which is crucial for our transition analysis.

While this match of IMPLAN with both BLS and O*NET data is not perfect, we would be remiss in not attempting to describe profiles of affected industries and occupations in some quantifiable way, especially because IMPLAN provides no information on demographics or education and training. The purpose of this analysis is to allow existing data to point to relevant policy questions and to reveal gaps in understanding that must be studied in greater detail in the future.

As discussed in Chapter 4, the IMPLAN model produces workforce impact estimates related to the forecasted transportation-related expenditures across three categories:

- Direct jobs in industries supplying goods and services on which money is being spent, such as EV manufacturing workers and hydrogen refueling station staff.
- Indirect jobs in industries within the supply chain of those where direct jobs are created, such as workers refining the raw metals and materials from which EVs are built.
- Induced jobs which are supported through broader economic activity stimulated by the creation of direct and indirect jobs, such as grocery store workers and health care providers.

Our model output results are discussed in two forms: full-time equivalent (FTE) job-years, and annualized FTEs. A single FTE job-year represents sufficient economic activity to support the equivalent of one employee working full-time for one year. Such employment could take multiple forms, including two 50% part-time employees working for one year or one 50% part-time employee working for two years. The model does not allow us to predict which employment features – such as unionization rates or usage of independent contractors – will manifest in expanding industries in the future, which matter greatly for the future wages, benefits, and job security for workers filling these jobs. Our discussion of these job aspects focuses on current patterns in industries predicted to expand. Annualized FTEs are estimates for FTEs generated by expenditures made in a given year, which may or may not be realized in that specific year.

We refer to three distinct employment categories in discussing the characteristics of areas highly impacted by the transition: industries, occupations, and workers. *Industries* refers to employers or groups of employers that encompass and depend on many different types of employees to deliver goods and services; for instance, Oil and Gas Extraction employs a variety of engineers, operators, and managers (among other employees) with a range of skills. *Occupations* are types of jobs defined by a particular skill-set or set of duties, such as petroleum engineers within Oil and Gas Extraction. A given occupation may be used across many different industries (such as executives) or may be relatively specific to one or a few industries (such as petroleum engineers). *Workers* refers generally to employees of firms predicted to be impacted by the transition to ZEVs, and it is at times used interchangeably with *occupations*.

For more information on how we utilized O*NET data to profile the education and training of impacted workforces, see Appendix P.

5.1 – Overall Model Results

Overall, the model projects that between 2020 and 2045, California's transition to ZEVs will create over 7.3 million full-time equivalent (FTE) job-years' worth of employment through expansion of ZEV-related industries and associated charging and fueling infrastructure (Figure 5-1). An estimated 514,000 FTEs are realized in 2045, the year of greatest overall annual employment within the study period. In the final years considered, there is a trend of the ZEV economy expanding at a rate of approximately 10,000 FTEs per year, likely indicating that employment in ZEV-related sectors will continue to expand after 2045.

Contractions in industries related to ICEVs and fossil fuels are predicted to simultaneously lead to a gross reduction of slightly over 730,000 FTEs when comparing 2020 and 2045. Figure 5-2A shows the magnitude of employment generated by California's ICEV-related sectors as fossil fuel-burning vehicles are phased out, while Figure 5-2B provides a complementary representation of the magnitude of declines in employment for these sectors. The greatest number of these reductions occur in jobs related to ICEV maintenance, which decline from over 400,000 FTEs in 2020 to less than 100,000 in 2045. A small fraction of jobs related to fossil fuel consumption also persist through to 2045, as millions of vehicles requiring gasoline and diesel fuels are predicted to still be on the road at that time. In contrast, jobs related to new ICEV sales are expected to essentially cease to exist after 2040, down from over 250,000 FTEs in 2020. This is the logical outcome of a cessation of new fossil fuel-burning vehicles in the state after 2040, as reflected in the scenario.

As we did not model the business-as-usual scenario to determine workforce impacts, we do not have a valid baseline over time against which to compare employment in ICEV-related sectors. Therefore, we cannot state with confidence the total FTE job-years lost due to the contraction of these sectors.

Figure 5-1: Projected estimates for annual total FTEs resulting from expansion of ZEV-related industries in California in thousands of FTEs by sector, 2020-2045.

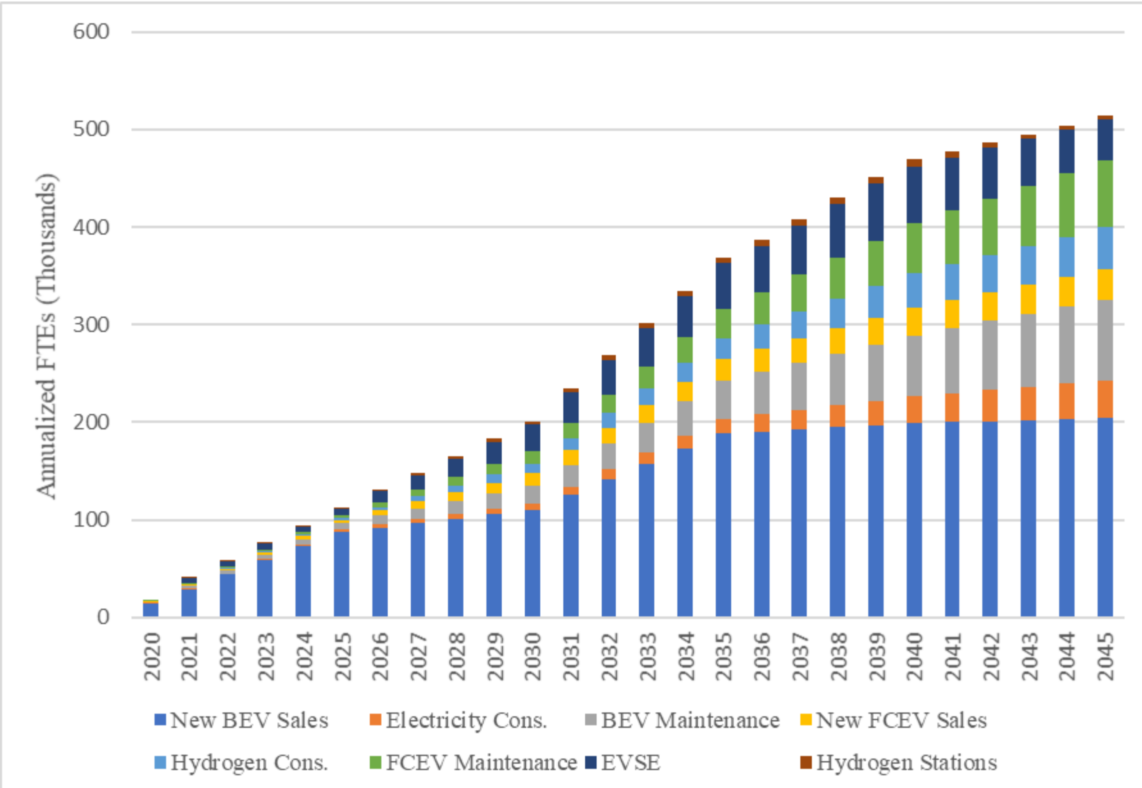
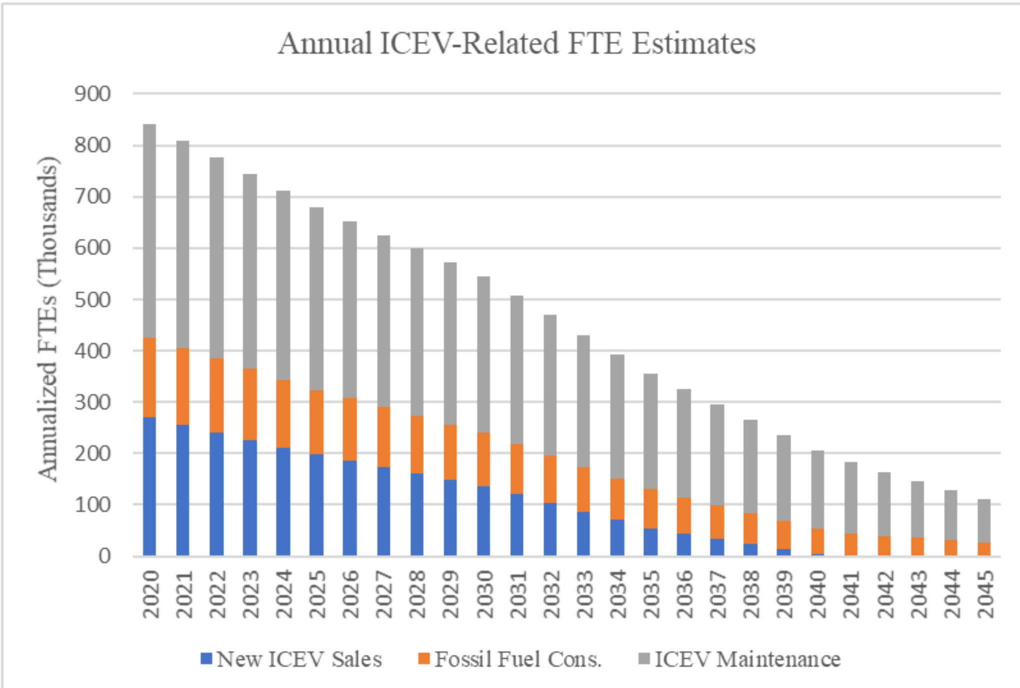
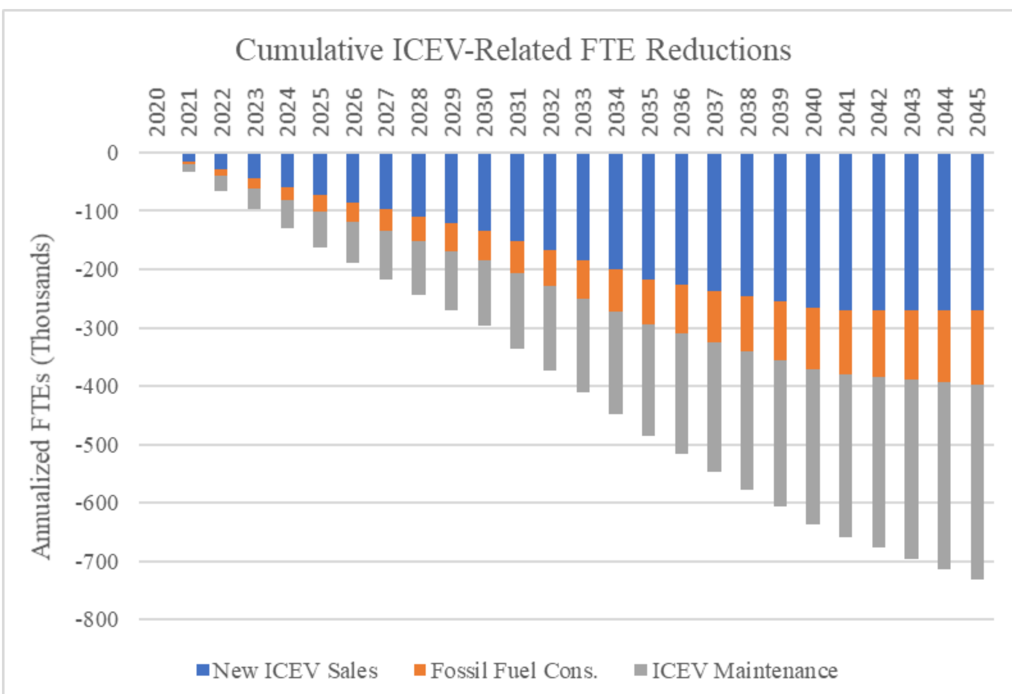


Figure 5-2: Projected estimates for annual total FTEs supported by ICEV-related industries (A) and cumulative year-over-year FTE reductions (B) resulting from contractions in these industries in California in thousands of FTEs by sector, 2020-2045.

A



B



5.2 – Sector-Specific Model Outputs and Policy Discussion

The overall figures presented above represent an amalgamation of our discrete, sector-specific model results. Below, we present these results and provide demographic and education and training profiles for the most impacted types of workers.[1] We then identify and address the most salient policy questions that arise from the results, accompanied by a discussion of policies likely to be helpful in assisting the transition for workers in both negatively and positively impacted industries.

1. ICEV-Related Sectors: jobs created through expenditures on new ICEV sales, fossil fuel consumption, and ICEV maintenance. This sector is unique among those considered in that it is anticipated to contract over the study period, rather than expand.
2. EV-Related Sectors: jobs created through expenditures on new BEV sales, electricity consumption for use as a transportation fuel, and BEV maintenance.
3. FCEV-Related Sectors: jobs created through expenditures on new FCEV sales, hydrogen fuel consumption, and FCEV maintenance.
4. EVSE: jobs created from expenditures on construction of new EV charging infrastructure and other EVSE installation.
5. Hydrogen Refueling: jobs created from expenditures on the construction of new hydrogen refueling stations.

Annualized FTE figures utilized herein are derived from FTE job-year figures aggregated over the 5-6 year modeled periods. Raw outputs from the model are available in Appendix O.

5.3 – Workforce Impacts Related to ICEV Sales, Fuels, and Maintenance

The reduction in usage of ICEVs and the commensurate drop in consumption of fossil fuels and ICEV maintenance services is expected to reduce annualized FTE employment in California from 841,914 FTEs in 2020 to 111,165 in 2045, a drop of just over 730,000 FTEs (Figure 5-3).[2] Approximately 270,000 of these FTE job reductions between the bookend years are attributed to reduced sales of ICEVs, 127,000 to reduced consumption of fossil fuels, and 333,000 to lower demand for maintenance and repairs of ICEVs. Importantly, these figures include induced jobs – those supported by economic activity generated from these sectors but not necessarily directly linked to them. We predict continuous contraction at rates that are relatively steady within each sector, with the following highlights:

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*[1] Education and training profiles are based on industry-wide, aggregated O*NET survey data. For an in-depth discussion of our utilization of this data, see the Technical Report.*

[2] To estimate annual FTE figures for 2020-2045 we assign the mean FTE value for each modeled period to its midpoint year, then extrapolate FTE values for interim years assuming linear rates of contraction within each modeled period.

a. Total jobs related to new ICEV sales (Figure 5-3A) decline between approximately 9,000 to 17,000 FTEs per year until 2040, after which the lack of ICEV MDV and HDV sales leaves only a vestigial industry remaining. From its peak at more than 260,000 total FTEs in 2020, the industry falls below 50,000 in 2036 and is almost nonexistent in 2045.
b. Jobs related to fossil fuel consumption (Figure 5-3B) decline by approximately 4,000 to 6,000 FTEs per year for the entire study period. By 2045, fossil fuels for on-road vehicles continue to generate in excess of 25,000 FTEs, reflecting the continued presence of a greatly downsized but still substantial ICEV fleet on California's roads.
c. Jobs related to ICEV maintenance (Figure 5-3C) decline between approximately 10,000 and 14,000 FTEs per year over the entirety of the study period. Maintenance is the largest ICEV-related sector in terms of jobs over the course of the study, continuing to directly employ over 50,000 FTE workers and generate over 30,000 additional indirect and induced FTEs in 2045.

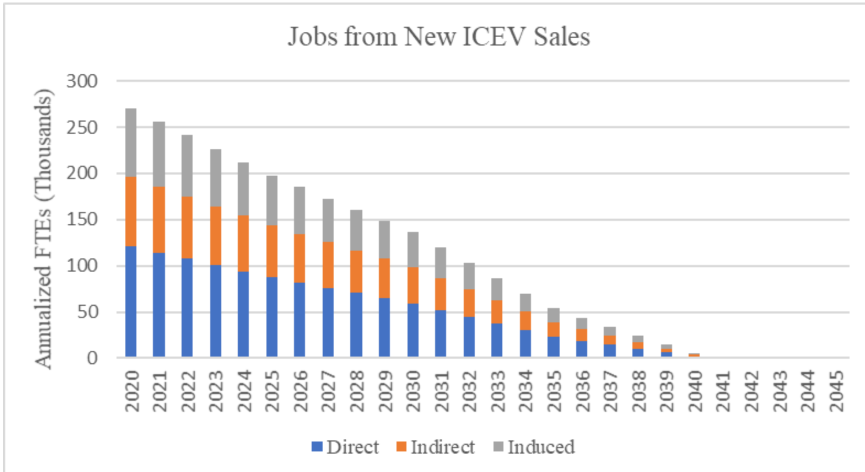
Workforce Impacts at the Occupational Level

Table 5-A shows the estimated FTEs for the top five occupations[3] within each ICEV-related sector in both 2020 and 2045, along with the calculated difference. The greatest reductions in annualized FTEs occur within two occupations: 1) Vehicle and Mobile Equipment Mechanics, Installers, and Repairers, and 2) Retail Sales Workers. Reductions in new ICEV sales contribute to the declines in both these occupations, while reduced fossil fuel consumption and reduced ICEV maintenance contribute to lower numbers of sales workers and mechanics etc., respectively. To provide a rough estimate of annual FTE reductions between the first and last year of the study period, we combine overall occupational FTE job-year figures with proportions of overall FTEs in 2020 and 2045, then calculate the difference (Table 5-A).

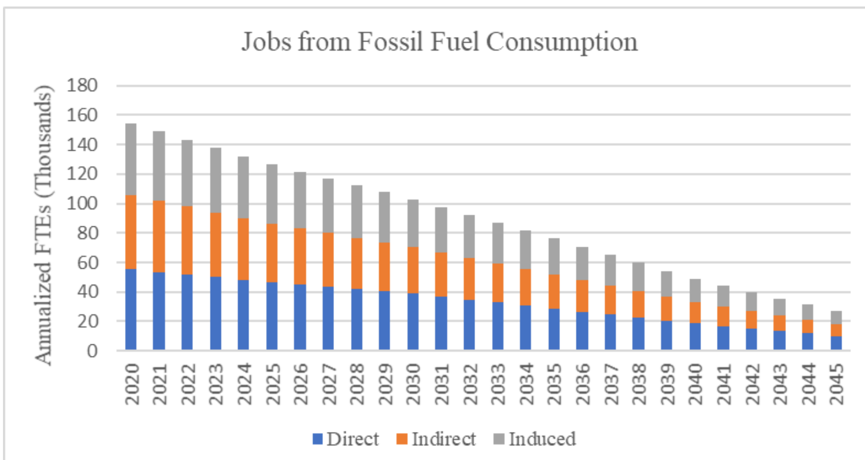
[3] Top five occupations for each sector are determined by the five occupations with the greatest number of FTE job-years generated across the entire study period.

Figure 5-3: Projected estimates for annual direct, indirect, and induced jobs resulting from new ICEV sales (A), fossil fuel consumption (B), and ICEV maintenance (C) in California in thousands of FTEs, 2020-2045.

A



B



C

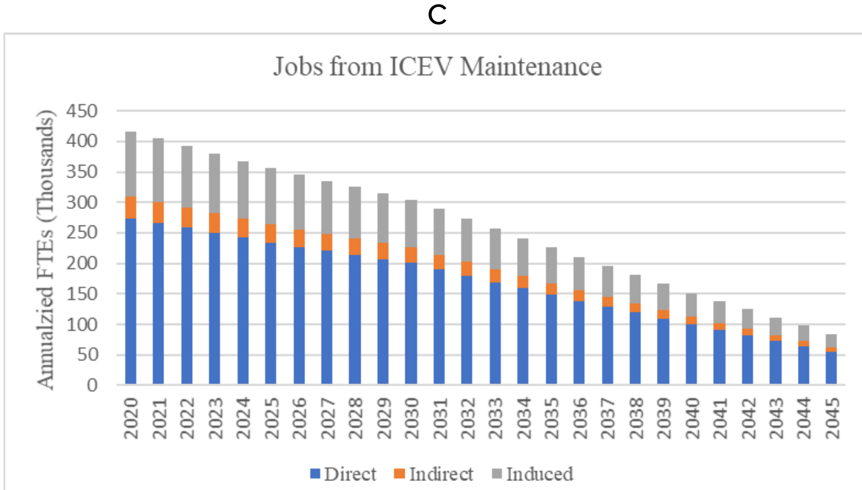


Table 5-A: Estimated direct and indirect annual FTEs in 2020 and 2045 and the calculated reduction for the top 5 occupations in each ICEV-related sector in California.

Rank	Occupation by Sector	Estimated Direct & Indirect Annual FTEs 2020	2045	Estimated Reduction 2020-2045
New ICEV Sales				
1	Retail Sales Workers	27,229.64	2.93	-27,226.71
2	Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	23,072.88	2.49	-23,070.39
3	Motor Vehicle Operators	15,905.25	1.71	-15,903.54
4	Material Moving Workers	15,269.72	1.65	-15,268.07
5	Assemblers and Fabricators	11,059.58	1.19	-11,058.39
Fossil Fuel Consumption				
1	Retail Sales Workers	25,533.78	4,445.07	-21,088.71
2	Motor Vehicle Operators	6,629.18	1,154.05	-5,475.13
3	Material Moving Workers	6,047.13	1,052.72	-4,994.41
4	Sales Representatives, Wholesale & Manufacturing	4,738.13	824.84	-3,913.29
5	Supervisors of Sales Workers	3,934.18	684.89	-3,249.30
ICEV Maintenance				
1	Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	156,115.18	31,545.00	-124,570.18
2	Other Office and Administrative Support Workers	15,955.38	3,223.98	-12,731.39
3	Supervisors of Installation, Maintenance, and Repair Workers	15,670.35	3,166.39	-12,503.97
4	Other Production Occupations	14,784.46	2,987.38	-11,797.08
5	Retail Sales Workers	13,523.64	2,732.62	-10,791.02

Table 5-B: Declines in estimated annual FTEs in the top five affected industries in ICEV-related sectors between 2020 and 2045. Industries whose presence in top ten driven overwhelmingly by induced jobs not included. Additional industries outside top 5 included in cases where direct or indirect employment effects are notably high.

Major Industry by Sector	Estimated Annual FTEs		
	2020	2045	Estimated Reduction 2020-2045
New ICEV Sales			
Retail - Motor vehicle and parts dealers	78,317.59	8.44	-78,309.15
Wholesale - Motor vehicle and motor vehicle parts and supplies	26,329.31	2.84	-26,326.47
Automobile manufacturing	12,255.58	1.32	-12,254.26
Truck transportation	7,109.65	0.77	-7,108.89
Other real estate	6,910.51	0.74	-6,909.77
Fossil Fuel Consumption			
Retail – Gasoline stores	36,117.14	6,287.48	-29,829.66
Wholesale electronics markets and agents and brokers	11,936.67	2,078.01	-9,858.67
Oil and gas extraction*	6,616.18	1,151.78	-5,464.39
Truck transportation	6,297.74	1,096.35	-5,201.39
Other real estate	3,959.95	689.37	-3,270.58
Warehousing and storage	3,768.00	655.96	-3,112.05
Wholesale – Petroleum and petroleum products*	3,603.07	627.24	-2,975.82
Petroleum refineries*	3,496.59	608.71	-2,887.89
ICEV Maintenance			
Automotive repair and maintenance (except car washes)	275,990.51	55,767.30	-220,223.22
Other real estate	8,254.48	1,667.92	-6,586.56
Retail – Motor vehicle and parts dealers	4,401.32	889.34	-3,511.98
Retail – General merchandise stores	3,227.12	652.08	-2,575.04
Employment services	3,054.57	617.21	-2,437.36

**Percentile declines in fossil fuel-related industries reflect losses compared solely to jobs created from spending on gasoline and diesel for on-road vehicles in California and do not reflect other jobs in these industries driven by fossil fuel exports or consumption in other sectors like aviation and maritime transportation.*

Workforce Impacts at the Industry Level

While the previous subsection focused on workforce changes in ICEV-related sectors at the occupational level, we now turn to industry-level analysis in order to provide further insight into how these reductions impact specific types of workers. The top five industries by FTE job-years (with some adjustments) for each ICEV-related sector are compared based on annualized FTE estimates for 2020 and 2045 (Table 5-B). Industry classifications are used here to allow for better alignment with the North American Industry Classification System (NAICS) and to capture workers whose specific occupations may represent a smaller magnitude of jobs, but whose industries are likely to experience acute contractions (e.g., fossil fuel-related industries).

Across all three ICEV-related sectors, jobs related to automotive repair and maintenance see the most significant losses in overall magnitude – a reduction of approximately 181,000 annual FTEs between the two modeled periods. Retail sectors for both motor vehicles and parts and gasoline stations also undergo significant losses (approximately 69,000 and 23,000 FTEs, respectively). Wholesalers of motor vehicles and motor vehicle parts and supplies follow close behind with over 22,000 lost FTEs.

The greatest proportional declines occur in jobs related to sales of new ICEVs, as these halt before the end of the study period under the LC1 scenario. Industries related to fossil fuel consumption by on-road vehicles and ICEV maintenance are somewhat more persistent in 2045, losing between 70% and 80% of estimated annual FTEs. This reflects the fact that some ICEVs are expected to persist on the road for years after sales of new ICEVs drop to zero.

5.4 – Identifying and Describing Declining ICEV-Related Industries

Based on the data presented above, we focus our subsequent analysis on two groups of ICEV-related occupations where significant workforce declines are likely:

- Installation, maintenance, and repair occupations
- Motor vehicle parts wholesale and manufacturing

In the case of mechanics and other workers involved in maintenance and repair of vehicles, the sheer drop in demand for such services that will come as a consequence of more resilient ZEVs dominating the market will almost certainly produce some contraction (though likely to a smaller degree than indicated by the model, as aforementioned). Furthermore, there is not perfect overlap in the skillset necessary for a laborer to maintain a ZEV versus an ICEV, meaning that retraining opportunities for such workers will be in demand, regardless of the shift in the labor market.

In the case of motor vehicle and parts dealers and manufacturers, lowered maintenance requirements for a ZEV-dominated fleet will likely reduce the demand for replacement parts. Accompanying this will be a transition in the types of parts and components such businesses manufacture and sell. The labor impacts of this transition are uncertain; capital investment and retooling may suffice, or a scenario could arise where workers in this industry require significant additional skills training. Consistent downward trends also occur in industries and occupations related to the fossil fuel industry.

We identify the declining industries within California's fuel and vehicle supply chains below, using the naming used in U.S. Bureau of Labor Statistics (BLS) data, so that we may look at the current makeup of those industries to establish a baseline. We match installation, maintenance and repair occupations from the IMPLAN model with two industries: Automotive Mechanical and Electrical Repair and Maintenance, and Other Automotive Repair and Maintenance. We add the Motor Vehicle Parts Manufacturing industry to match with IMPLAN's motor vehicle parts wholesale and manufacturing projections.

A notable occupation that is not included among the declining occupations is retail workers for gasoline stations. There are two reasons for this exclusion: firstly, we have reason to believe that the IMPLAN model may be significantly undercounting job creation in analogous businesses for EV charging that would exhibit similarly low barriers to entry and geographic ubiquity (explained in Chapter 4); and secondly, because developing a profile for such workers is limited by the lack of data that distinguishes between retail workers based on specific vendor types. For example, we have no way of distinguishing between a gas station worker and a cashier at a grocery store.

We must first understand how many workers are currently employed in impacted industries matched with IMPLAN model results. According to BLS data, an estimated total of 173,060 workers are currently employed in declining occupations. In the fuel supply chain, these occupations concern the extraction, manufacture and distribution of fossil fuels. The estimated 75,740 workers in this category of occupations work in Oil and Gas Extraction, Petroleum and Coal Products Manufacturing, or their respective supportive industries: building and maintaining the infrastructure, operations, and technologies needed to support the fossil fuel economy. The majority of these workers (63%, 48,080 workers) can be found in Utility System Construction.

Declining occupations in the vehicle supply chain concern the manufacture and maintenance of vehicles that run on fossil fuels, especially any occupation concerning internal combustion engines or anything that pulls combustion out of an engine, such as exhaust or smog checks. An estimated 97,320 workers are employed in these industries.

Four major industries will likely experience a significant contraction due to the transition to net zero emissions. Employment and wage data for these industries can be seen in Table 5-C.

- Oil and Gas Extraction
- Support Activities for Mining
- Petroleum Refineries
- Automotive Repair and Maintenance

Table 5-C: Estimated employment and wages for contracting industries in California's fuel and vehicle supply chains.

Industry	Employment	Annual Median Earnings
Oil and Gas Extraction	4,740	$87,880.00
Support Activities for Mining	10,050	$57,820.00
Utility System Construction	48,080	$61,390.00
Petroleum and Coal Products Manufacturing	12,870	$89,620.00
Fuel Subtotal	75,740	
Motor Vehicle Parts Manufacturing	12,580	$40,620.00
Automotive Mechanical and Electrical Repair and Maintenance	45,410	$43,400.00
Other Automotive Repair and Maintenance	39,330	$27,620.00
Vehicle Subtotal	97,320	
Total Employment	173,060	

These industries fall under upstream and midstream operations in the fuel supply chain and contain occupations whose activities are directly linked to the consumption of fossil fuels in the state of California. Fossil fuel-dependent occupations within these industries will likely experience the greatest difficulty transitioning as their industries contract, due to the highly specialized nature of their skills. For example, non-fossil fuel related occupations, such as accountants and service managers, will likely find employment in a different industry. In contrast, oil derrick operators and petroleum pump system operators are unlikely to find employment beyond their industry since these occupations are specific to petroleum manufacturing. In Oil and Gas Extraction and Support Activities for Mining, key occupations include:

- Petroleum engineers (SOC code 17-2171)
- Service unit operators for oil and gas (SOC code 47-5013)
- Oil derrick operators (SOC code 47-5011)
- Wellhead pumpers (SOC code 53-7073)
- Unskilled laborers engaged in daily field operations (roustabouts) (SOC code 47-5071)
- Petroleum pump system operators (SOC code 51-8093)

The combined employment from these occupations accounts for approximately 29% (4,340) of total employment in these industries (14,790).

Regarding the Petroleum Refineries industry, key occupations are similar to the extraction and mining support, with petroleum engineers and petroleum pump system operators making up the highest occupational employment in the industry (4,410 workers representing 34.27% of the industry employment).

As seen previously in Table 5-B, the annualized FTE impact in these industries will be approximately 5,464 in Oil and Gas Extraction, approximately 2,888 in Petroleum Refineries, and approximately 220,000 in Automotive Repair and Maintenance. It is important to reiterate that these figures include indirect and induced job impacts resulting from changes in employment in these industries. On an additional note, the industries in the IMPLAN model do not match exactly with the industry classifications in BLS data. This means that in some cases, figures related to certain fields of employment (such as Automotive Repair and Maintenance) produced by the model appear to be greater in magnitude than their closest baseline categorical counterpart, due to inclusion of a broader array of workers within that number. This is because IMPLAN accounts for jobs in particular fields that are not captured within BLS surveys.

Also worth reiterating, the model estimates employment related to Automotive Repair and Maintenance based on expenditures derived from fleet size, vehicle miles traveled (VMT), and per-mile maintenance cost. Unpaid, non-professional maintenance performed on a vehicle by the owner would be reflected in IMPLAN's job totals while not appearing in BLS data. Additionally, the IMPLAN model estimates are FTEs, representing the number of people working full-time over the enumerated time periods. This could mean one person working full-time for all of those years, or five people each working one year full-time.

Demographic Exploration of Declining ICEV-Related Industries

The declining ICEV-related industries in California all have similar demographics, since these industries fall under the upstream and midstream operations of the fuel supply chain. We focus on three demographic characteristics: race, ethnicity, and gender. Including these demographics allows us to account for how the contraction of the fossil fuel industries will impact different workers. Table 5-D provides demographic percentages for each contracting industry.

Most workers in the contracting industries report Hispanic and Latino ethnicity. The highest concentration of Hispanic and Latino workers is in Oil and Gas Extraction (78.64%), followed by Petroleum Refineries (74.57%), then Automotive Repair and Maintenance (55.38%) and the lowest concentration is in Support Activities for Mining (54.88%).

Across all contracting industries, workers are predominantly White, with the lowest concentration in Petroleum Refineries (75.03%) and the highest concentration in Support Activities for Mining (86.71%). White as a racial demographic is marked separately from Hispanic or Latino as an ethnic identity. While we do not know for sure how many workers who identify as Hispanic or Latino in term of ethnic identity also identify as White (or non-White) in terms of racial identity, we can assume there is overlap.

The only other racial group to attain double-digit percentages is Asian, which reaches a maximum of 12.54% for Petroleum Refineries, followed by 10.88% for Automotive Repair and Maintenance. The percentage of workers who report Asian race are low in Oil and Gas Extraction (9.45%) and Support Activities for Mining (4.52%).

Worker sex is highly skewed across all industries, with men accounting for 75.34% of employment in Oil and Gas Extraction, 76.14% of employment in Automotive Repair and Maintenance, 80.59% of employment in Petroleum refineries, and 87.85% of employment in Support Activities for Mining.

Finally, worker age is highly concentrated across four consecutive age groups: 25-34, 35-44, 45-54, and 55-64. Petroleum Refineries and Support Activities for Mining both have the highest concentration of workers in the 35-44 age range. While Oil and Gas Extraction does have a high percentage of this age group, most workers in this industry are in the 55-64 age range.

Table 5-D: Demographic profile of declining industries.

Industry Demographics	Oil and Gas Extraction	Support Activities for Mining	Petroleum Refineries	Automotive Repair and Maintenance
Ethnicity				
Hispanic or Latino	78.64%	54.88%	74.57%	55.38%
Not Hispanic or Latino	21.36%	45.12%	25.43%	44.62%
Race				
White	82.23%	86.71%	75.03%	78.77%
Black or African American	4.51%	4.52%	7.42%	4.61%
American Indian and Alaska Native	0.91%	2.19%	1.08%	1.87%
Asian	9.45%	3.59%	12.54%	10.88%
Native Hawaiian/Other Pacific Islander	0.48%	0.56%	0.77%	0.66%
Two or More	2.42%	2.42%	3.16%	3.22%
Sex				
Female	24.66%	12.15%	19.41%	23.86%
Male	75.34%	87.85%	80.59%	76.14%
Age				
14-18	N/A	0.13%	0.06%	1.49%
19-21	0.30%	1.67%	0.51%	4.48%
22-24	0.97%	4.04%	1.47%	5.88%
25-34	16.35%	26.86%	16.87%	21.70%
35-44	26.50%	30.04%	26.43%	21.05%
45-54	22.34%	19.15%	25.55%	20.58%
55-64	27.33%	13.74%	24.62%	17.20%
65-99	6.23%	4.38%	4.49%	7.62%

Industry Geography

The geographic placement of some contracting industries is somewhat limited to a few counties in California, while others (such as Automotive Repair and Maintenance) are distributed throughout. The highest concentration of extraction is in Kern County, where oil and gas extraction operations employed 1,770 workers in 2019 (almost 40% of total industry employment in 2019), with remaining extraction-related employment mostly concentrated in Southern California and the Central Coast region. Two counties dominate refining employment: Contra Costa County (4,423 workers in 2019) and Los Angeles County (4,631 workers in 2019). These two counties accounted for an overwhelming majority of employment in the petroleum refinery industry (83.53% of total industry employment) with Kern County and Orange County accounting for the remaining employment, 629 workers and 75 workers, respectively.[4]

Education and Training Profile for Declining ICEV-Related Occupations

We will examine the trends in education and training requirements for declining ICEV-related occupations (and for the expanding BEV-related occupations in the following sections) by type of education or training, and by supply chain. This is done by examining the SOC codes of occupations within impacted industries in the O*NET database. More information on O*NET and the methods by which we utilize data derived therefrom can be found in Appendix P.

As we shall see in our recommendations for further study, the state cannot rely solely on O*NET to provide adequate analysis on education and training requirements during this transition. More specific surveys must be done. However, O*NET data can reveal what certain further studies should be, as well as spark relevant policy questions, which was the purpose of our analysis and are explored below.

Figure 5-4 illustrates the distribution of survey responses – data taken from O*NET – from current employees regarding education, experience, and training requirements in declining industries. We see that the majority of impacted workers in declining ICEV-related occupations require only a High School Diploma or less to do the job. This applies to approximately 26 percent in the fuel supply chain and 46.4 percent in the vehicle supply chain, making up a combined 72.5 percent of employees in the declining ICEV-related occupations. In the fuel supply chain, a small, but not insignificant, minority of impacted workers require some additional post-secondary certificate (9.7 percent).

The plurality of workers in the vehicle supply chain need either 1-3 months of related work experience or 1-2 years of related work experience (23 percent and 21.1 percent respectively).

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[4] *Additional refineries are in operation in Santa Barbara County and Solano County. However, QCEW does not have 2019 estimates for petroleum refinery employment for these counties.*

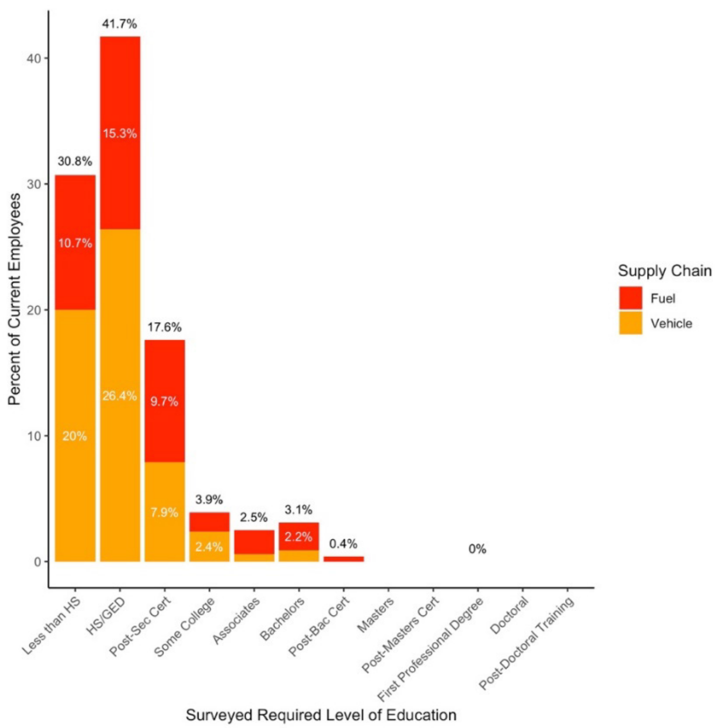
The fuel supply chain is much more centrally distributed, with the majority of workers needing somewhere between 3 months to 4 years of training. Most, at 12.3 percent, need 3-6 months of related work experience, with incrementally smaller and smaller percentages of employees needing additional amount of related work experience.

Very few employees in either supply chain need more than one year of either on-the-job training or in-plant training. The majority of fuel supply chain workers require anywhere from one month to one year of either on-the-job or in-plant training. Most vehicle supply chain workers also require anywhere from one month to one year of on-the-job training, but unlike fuel supply chain workers, they skew heavily toward requiring less of it. A combined 49.4 percent of them will need up to 6 months, with only 5 percent of them requiring 6-12 months. They require much less in-plant training as well. Most either need only up to one month of in-plant training (23.7%) or 3-6 months (22.6%).

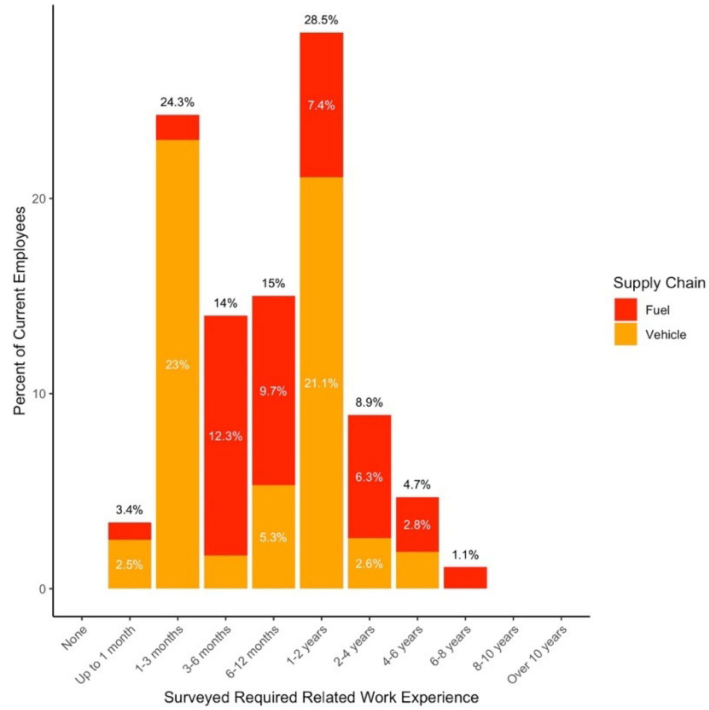
All of this points to a landscape in which the workers who lose their jobs due to California's transition to ZEV's are in occupations that mostly do not require any college education, where most of the skills can be learned on the job in less than a year.

Figure 5-4: Distribution of responses among current employees in declining ICEV-related industries regarding required level of education (A), amount of related work experience (B), on-the-job training (C), and on-site and in-plant training (D) by supply chain. Information from O*NET database.

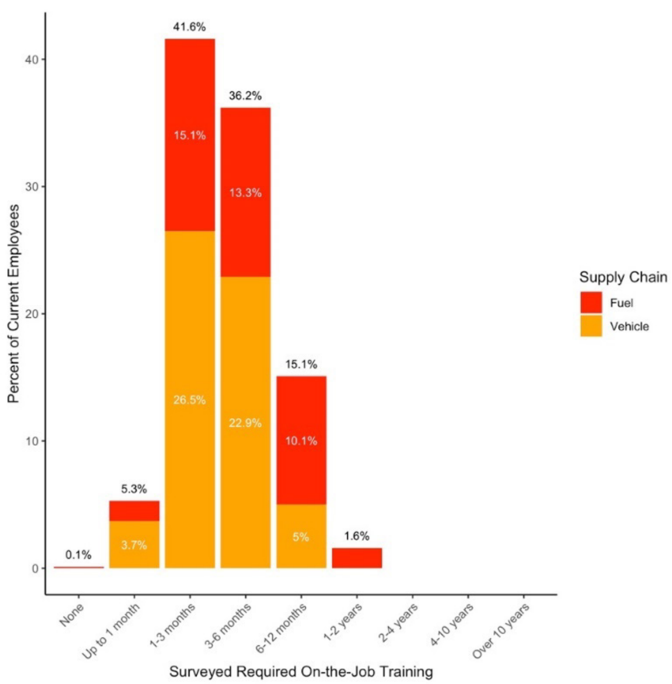
A: Required Level of Education Experience



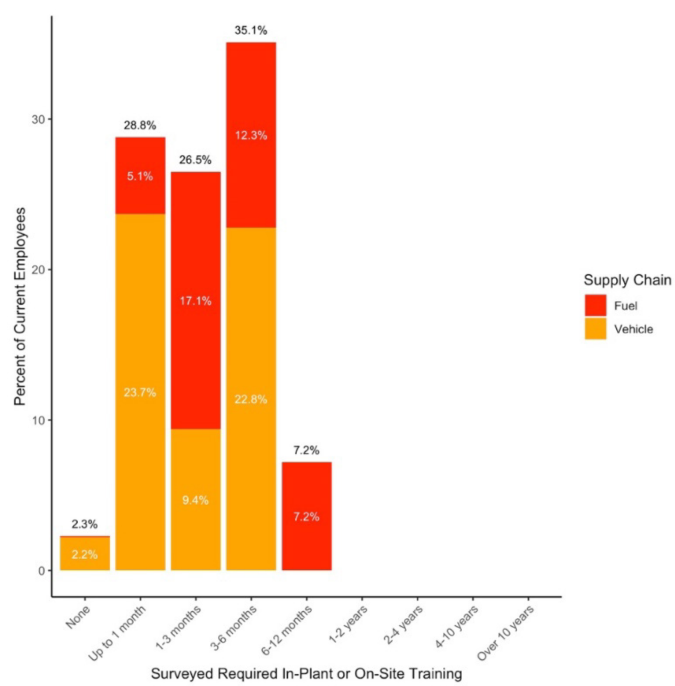
B: Required Amount of Related Work



C: Required Amount of On-the-Job Training



D: Required Amount of On-Site and In-Plant Training



5.5 – Policy Questions Related to Declining ICEV-Related Industries

Two policy questions are immediately prompted when examining declining industries, the occupations within them, and their demographic, geographic and education/training profiles:

- How might the state protect workers in declining industries during an unpredictable and disruptive transition to ZEVs?
- What are efficacious strategies for the state to support the transition of workers in declining industries, given the significant uncertainties and high variability of conditions across geographies and demographic groups?

While this transition to ZEVs will yield tremendous net job growth, some industries will experience some job loss, especially in Oil and Gas Extraction, Support Activities for Mining, Petroleum Refineries and Gasoline Retail. Some impacted workers are found throughout the state (such as those in gasoline retail), while others are in very concentrated areas (like those who work in refineries). Some may be willing to enter into more education and training, but some of the older workers may not.

As California moves towards carbon neutrality in its transportation sector, there will be too many unique, localized, and individualized workforce transition needs to accurately predict. Data, while useful, is imperfect, and the preferences of frontline and vulnerable community members[5] must take center-stage in the decision-making process. Since it is impossible to predict every localized issue, the state's role should be that of a convener and advocate for frontline and vulnerable communities.

Implementing just transition policies must involve consensus and dialogue with frontline and vulnerable communities at all stages of policy design, implementation and evaluation. State-level officials should manage, mandate and maintain a robust system of local taskforces to ensure that decision making is happening with significant community voice and impact, and that worker preferences are being taken into account.

Nonprofits, government agencies, post-secondary education institutions and public workforce development agencies create a complex and interconnected set of institutions who work with employers and labor unions to create training programs, set standards, ensure accountability and more. (Zabin, et al., 2020) This transition presents an opportunity for the state to implement policies early-on that ensure that working groups and taskforces are created as specific

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[5] *Frontline and vulnerable communities refer to those who have been disproportionately impacted by climate change: indigenous peoples, communities of color, migrant communities, deindustrialized communities, depopulated rural communities, low-income communities, women, the elderly, the unhoused, people with disabilities and youth. (H. Res. 109, 116th Cong. (2019))*

transition scenarios arise, and to step in with expertise, guidance and technical assistance to local players.

Managing the convenings and ensuring equity in the planning and implementation phases should be looped into the duties of the existing workforce development system or ceded to the appropriate local player. CBOs should be at the decision-making table along with business leaders. Other key players may include LEAs, post-secondary institutions, Adult Basic Education providers, or economic development organizations.

For example, as detailed above, the majority of workers in declining occupations in Oil and Gas Extraction in the state are in the 55-64 age range. Currently, we cannot predict exactly when and how they may lose their jobs, or if they may be retained if the industry shifts to provide more fuel for aviation and maritime purposes, etc. Regardless, if it becomes evident that the aging workers in Oil and Gas Extraction may lose their jobs, the state should ensure that the preferences of the workers drive the transition implementation. They may not have the funds to retire, even if pension packages are offered, and may need to keep working. Some may be willing to transition to new industries, and may be willing to work past the age of 67. Another group of vulnerable workers are Gasoline Retail workers, many of whom have very little education (either a High School Diploma or less) but are used to running a small business. Some may be willing to relocate or opt for education programs to upskill into a better career pathway. Some may wish to transition their small business skills into another industry, but still in a service centered role.

The state should ensure that the preferences of impacted workers drive the transition planning process.

5.6 – Workforce Impacts Related to BEV Sales, Fuels, and Maintenance

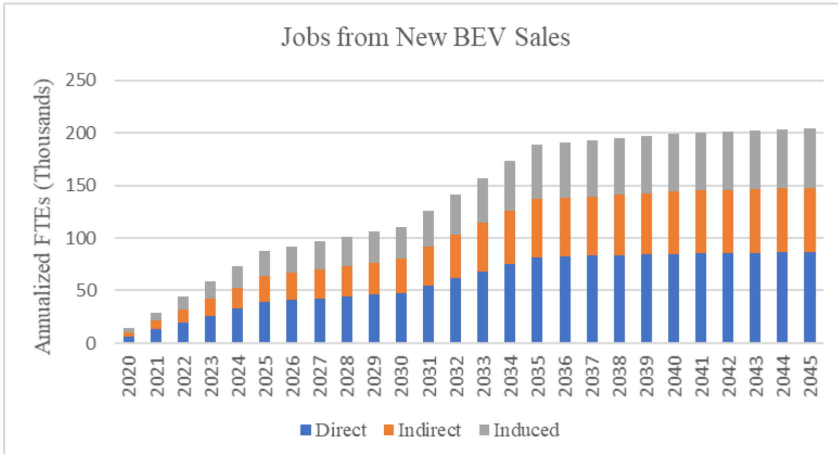
The adoption of BEVs is projected to create over 4.8 million FTE job-years in California over the next twenty-five years through labor related to the sales of new BEVs, consumption of electricity as a transportation fuel, and maintenance for BEVs. A significant majority of these are derived from expanding numbers of new BEV sales, which account for over 3.5 million FTE job-years. Over 370 thousand FTE job-years – nearly two-thirds of them induced – arise from consumption of electricity for transportation. Maintenance of BEVs accounts for over 883 thousand FTE job-years.

To estimate FTEs in each year from 2020-2045, we assign the mean annual FTE value for each modeled 5-6 year increment to the chronological midpoint of that period, then extrapolate FTE values for other years assuming a linear rate of job growth within each period (Figure 4). We predict continuous growth in jobs across all three BEV-related sectors over the entire study period, with the following highlights:

a. Annual new BEV sales FTEs (Figure 5-5A) are predicted to go through two pronounced periods of expansion. By 2025 annual FTEs are expected to exceed 87 thousand, after which job growth is modest through 2030. From 2031 to 2035, annual FTEs once again rise quickly, reaching nearly 190 thousand FTEs in 2035. Minor growth continues thereafter, with annual FTEs in 2045 exceeding 200 thousand.
b. Annual electricity consumption for transportation FTEs (Figure 5-5B) see relatively little growth through 2030, exceeding 5,000 FTEs for the first time in 2029. Growth accelerates slightly after 2030, with consistent year-over-year growth of a few thousand FTEs. Annual FTEs related to this sector exceed 38 thousand in 2045. The most concentrated area of job growth in this sector is within the solar electric power generation industry.
c. Annual BEV maintenance FTEs (Figure 5-5C) follow a similar growth pattern to jobs related to electricity consumption for transportation, albeit at a greater magnitude. Annual FTEs in this sector first exceed 10 thousand in 2027. After 2030 year-over-year growth is consistently a few thousand FTEs per year, such that the sector accounts for over 83 thousand FTEs in 2045.

Figure 5-5: Projected estimates for annual direct, indirect, and induced jobs resulting from new BEV sales (A), consumption of electricity for transportation (B), and BEV maintenance (C) in California in thousands of FTEs, 2020-2045.

A



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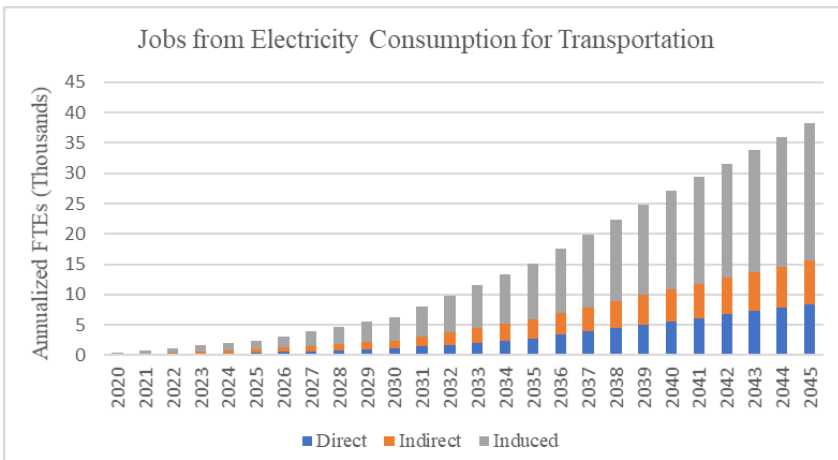

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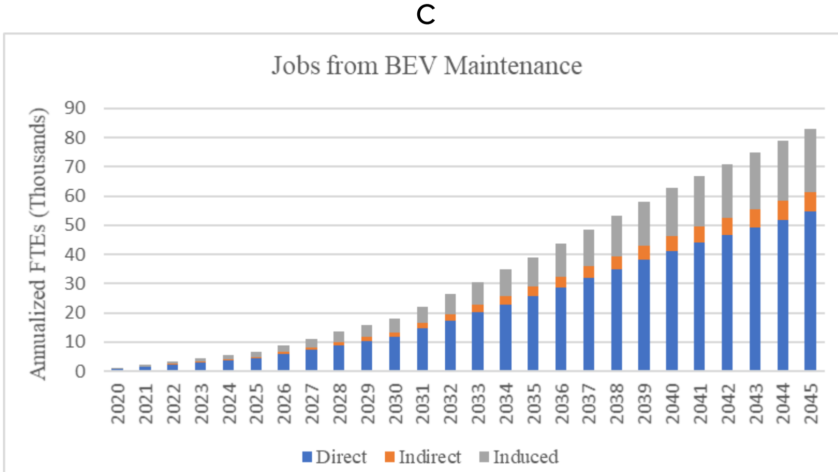


Table 5-E: Top 5 occupations by total FTE job-years resulting from expenditures on new BEV sales, electricity consumption for transportation, and BEV maintenance, respectively, in California, 2020-2045.

Rank	Occupation	FTE Job-Years, 2020-2045	Estimated FTEs, 2045
New BEV Sales			
1	Retail Sales Workers	347,609.15	19,824.73
2	Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	296,001.41	16,881.46
3	Motor Vehicle Operators	209,309.92	11,937.30
4	Material Moving Workers	201,043.72	11,465.86
5	Assemblers and Fabricators	160,779.40	9,169.52
Electricity Consumption for Transportation			
1	Construction Trades Workers	14,985.64	1,544.78
2	Business Operations Specialists	12,569.16	1,295.68
3	Other Installation, Maintenance, and Repair Occupations	10,812.14	1,114.56
4	Engineers	9,407.98	969.81
5	Top Executives	6,165.09	639.46
BEV Maintenance			
1	Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	330,851.10	31,105.01
2	Other Office and Administrative Support Workers	33,813.84	3,179.01
3	Supervisors of Installation, Maintenance, and Repair Workers	33,209.80	3,122.22
4	Other Production Occupations	31,332.12	2,945.69
5	Retail Sales Workers	28,660.25	2,694.50

When direct and indirect jobs are broken down by occupation, the sheer magnitude of the new BEV sales sector drives expansion in most of the largest-growing occupations (Table 5-E). However, the concentration of labor growth in mechanics and similar fields as pertains to BEV maintenance supplements similar labor growth related to new BEV sales, making this occupational category significantly larger in overall FTE job-years (nearly 627 thousand) than retail sales workers for BEVs (just below 348 thousand), the second-largest growth occupation. While the top 5 occupations related to each sector are presented below, it is worth noting that the scale of job growth created by new BEV sales is sufficiently large that all occupational growth from the other two BEV-related sectors is overshadowed by occupations related to the former, even outside of the top 5 (with the exception of mechanics, installers, and repairers involved in BEV maintenance).

5.7 – Identifying and Describing Expanding BEV-Related Industries

Based on the model outputs for employment created from expanding BEV-related industries, while also taking into account changes resulting from declines in ICEV usage that affect similar workers (e.g. car dealership employees), we focus our analysis on industries that we can confidently predict will see significant expansion as a result of BEV prevalence. Such industries are those responsible for generating and distributing the electricity for BEV charging. Table 5-F provides employment and wage data for these expanding industries, which currently employ an estimated 145,330 workers.

Table 5-F: Estimated employment and wages for expanding industries in California's fuel supply chain.

Industry	Employment	Annual Median Earnings
Electric Power Generation, Transmission and Distribution	18,200	$100,100.00
Power and Communication Line and Related Structures Construction	16,860	$63,730.00
Electrical Contractors and Other Wiring Installation Contractors	110,290	$60,550.00
Total Employment	145,350	

All of the expanding BEV-related occupations in the fuel supply chain concern electric power generation, transmission and distribution, and their supportive industries. The vast majority (76%, 110,290 workers) are electrical contractors.

Currently, EV consumption of electricity accounts for 0.68% of total electricity consumed in the state. To accommodate the increased demand of electricity by EVs, two specific industries will likely grow: Electric Power Generation, Transmission, and Distribution; and Electrical and Wiring Contractors. The latter industry is responsible for the installation of electric vehicle charging stations which are provided by a manufacturer.

While each of these industries encompass a variety of occupations, certain occupations are directly linked to upgrading infrastructure and increasing output for increased voltage consumption. In addition to power generation and transmission, end-user consumption infrastructure (i.e. charging station installation) will require more electricians, as manufacturers often contract out charging station installation to local electricians. Key occupations for each industry are shown below:

- Electric Power Generation, Transmission, and Distribution
  - Electricians (SOC code 47-2111)
  - Solar Photovoltaic Installers (SOC code 47-2231)
  - Electrical and Electronics Repairers (SOC code 49-2094)
  - Wind Turbine Service Technicians (SOC code 49-9081)
  - Power Plant Operators (SOC code 51-8013)
- Electrical and Wiring Contractors
  - Construction Laborers (SOC code 47-2061)
  - Electricians (SOC code 47-2111)
  - Solar Photovoltaic Installers (SOC code 47-2231)
  - Helpers Electricians (SOC code 47-3013)

The combined worker estimates for key occupations in the Electric Power Generation, Transmission, and Distribution industry represent 14.64% (2,670 workers) of total industry employment (18,239 workers in 2019). This is substantially lower than the key occupation counts from the contracting industries. Conversely, key occupations in Electrical and Wiring Contractors account for 55.63% (62,630 workers) of industry employment in 2019 (112,583).

Demographic Profile of Expanding BEV-Related Industries

The demographic profiles of the growing industries are similar, with race, ethnic, and sex percentages aligning across both industries. We include growing industry demographics to account for any existing demographic disparities in these industries. Table 5-G lists the demographic profiles of the two growing industries.

Worker ethnicity is predominantly Hispanic or Latino, with 60.40% or workers in the electrical contractor industry and 67.55% of workers in power generation, transmission, and distribution reporting Hispanic or Latino ethnicity.

Similar to the contracting industries, workers in both growing industries are majority White: 73.28% for Electric Power Generation, Transmission, and Distribution, and 83.71% for Electrical and Wiring Contractors. Asian workers are the next highest represented group, with 12.99% in power generation and 6.33% in the electrical contractor industry. No other racial group reaches double-digit percentages.

Table 5-G: Demographic profile of growing industries in California's fuel supply chain.

Industry Demographics	Electric Power Generation, Transmission, and Distribution	Electrical and Wiring Contractors
Ethnicity		
Hispanic or Latino	67.55%	60.40%
Not Hispanic or Latino	32.45%	39.60%
Race		
White	73.28%	83.71%
Black or African American	8.86%	4.31%
American Indian and Alaska Native	1.44%	1.79%
Asian	12.99%	6.33%
Native Hawaiian/Other Pacific Islander	0.42%	0.65%
Two or More	3.02%	3.22%
Sex		
Female	26.05%	17.58%
Male	73.95%	82.42%
Age		
14-18	0.16%	0.49%
19-21	0.47%	2.59%
22-24	1.57%	5.14%
25-34	15.36%	25.35%
35-44	28.01%	26.75%
45-54	26.77%	20.44%
55-64	22.97%	14.34%
65-99	4.68%	4.90%

Regarding worker sex, workers are overwhelming male: 73.95% in power generation, transmission, and distribution, and 82.42% in the electrical contractor industry.

Across both industries, most workers fall within the 25-64 age range. Workers in power generation, transmission, and distribution tend to be older, with the highest concentration of workers age 35-44 (28.01%), followed by workers age 45-54 (26.77%) and 55-64 (22.97%). Conversely, electrical and wiring contractors have a higher concentration of younger workers, with 35-44 being the highest (26.75%), 25-34 coming next (25.35%), and workers age 45-54 third (20.44%).

Industry Geography

Unlike the contracting industries, the growing industries are not geographically distinct, as power plants and transmission lines are spread across the entire state (California Energy Commission, 2020a, 2020b). Similarly, electric vehicle charging stations will be dispersed across the entire state in a manner akin to gasoline stations. However, the bulk of growth of these industries is likely to occur initially in areas where EV usage is already rising, such as California's major urban centers, especially since infrastructure developments are a large financial undertaking.

Education and Training Profile for Expanding BEV-Related Occupations

We will now examine the trends in education and training requirements for growing occupations by type of education or training and by supply chain in the same fashion as we examined declining industries above. Since there are no growing vehicle supply chain occupations, all of the graphs represent percentages solely for the fuel supply chain. Figure 5-6 illustrates the distribution of O*NET survey responses regarding the four measures of education and training.

The vast majority of workers in expanding ZEV-related occupations (63.2 percent) currently only need some post-secondary certificate in order to be able to get their job. While some workers need between 3 months to 2 years of related work experience (a combined 36 percent), the vast majority of affected workers in this category needed more; 54 percent need between 2-4 years of related work experience.

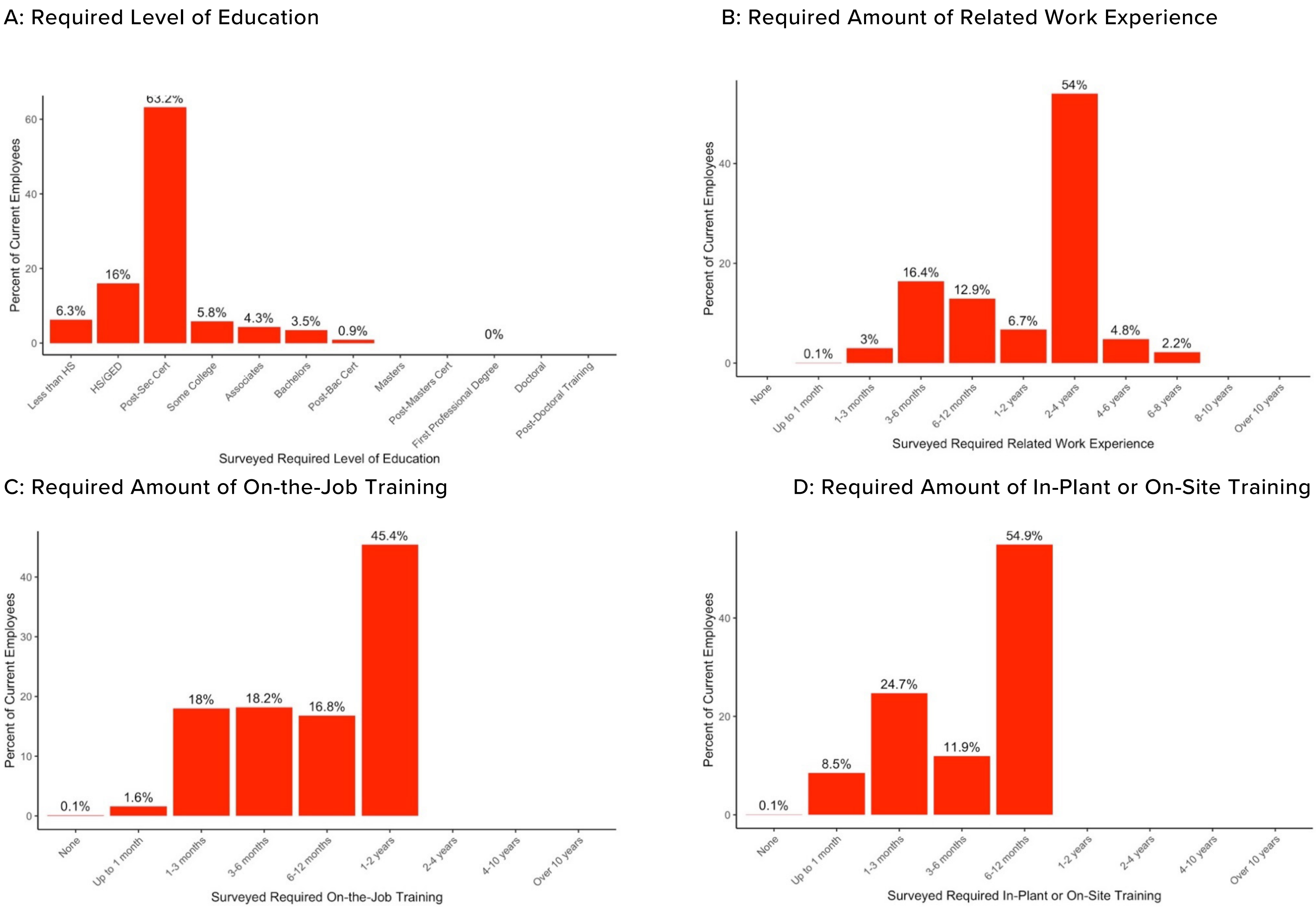
Approximately half of workers in expanding occupations require up to one year of on-the job training (a combined 53 percent), with the remaining half requiring 1-2 years (45.4 percent). Similarly, approximately half of the workers (at 54.9 percent) needed 6-12 months of classroom training provided by their employer, which the remaining half (45.1 percent) required 6 months or less.

This profile indicates that apprenticeship programs – already a priority for the state – are well-suited to enable new workers to access these occupations. Apprenticeships do not require a Bachelor's degree, can provide three years of combined on-the-job and on-site training, where the 2-4 years of required experience can be gained through the apprenticeship program while the apprentice is being paid.

California has already taken many steps in ensuring access to high-quality job pipelines for frontline and vulnerable communities through the implementation of its High Road Training Partnerships (HRTP) and High Road Construction Careers (HRCC) programs. In doing so the state has learned much about industry-led problem solving, the prioritization of partnerships over programs, and the incorporation of worker voice and expertise in ensuring equitable jobs in managing climate change. (California Workforce Development Board, 2020) Further models and design elements are discussed below.

Additionally, for an example of further analysis that can be done using O*NET data, see Appendix Q. We provide an example of how the state may use the O*NET Related Occupations Matrices (ROM) to gain insight into how the state may anticipate, and therefore help facilitate, key workforce transitions. While the data is not perfect, the analysis can help gain some purely descriptive, rather than prescriptive, information.

Figure 5-6: Distribution of responses among current employees in declining ICEV-related industries regarding required level of education (A), amount of related work experience (B), on-the-job training (C), and on-site and in-plant training (D) by supply chain. Information from O*NET database.



5.8 – Workforce Impacts Related to Hydrogen FCEV Sales, Fuels, and Maintenance

The adoption of hydrogen FCEVs is expected to create over 1.5 billion FTE job-years in California over the next twenty-five years through labor related to the sales of new FCEVs, hydrogen fuel consumption, and maintenance for FCEVs. Approximately 430 thousand of these FTE job-years come as a result of vehicle sales, 474 thousand from fuel consumption, and nearly 688 thousand from maintenance.

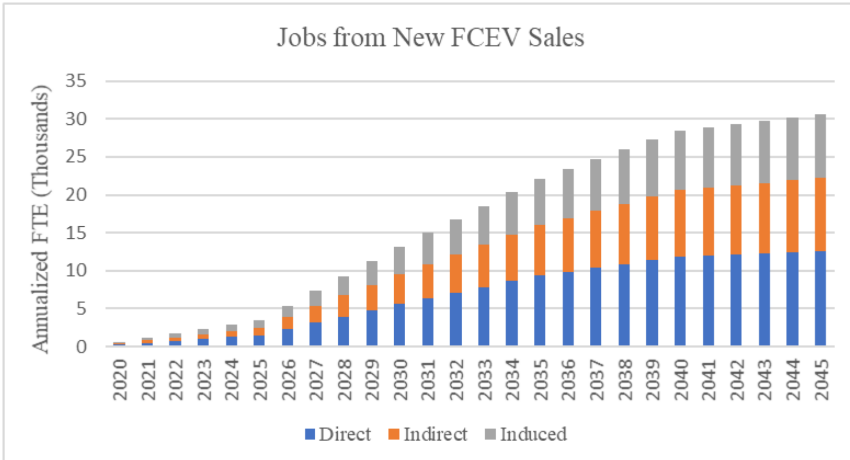
Each category's created jobs include a single outlier industry that constitutes a majority of its created direct jobs, and is therefore the modal industry for job creation within each sector. In FCEV sales, this industry is Retail Motor Vehicle and Parts Dealers (nearly 104 thousand FTE job-years). Retail Fuel Stores constitute the vast majority of direct jobs related to hydrogen fuel consumption (nearly 174 thousand FTE job-years). The entirety of direct jobs created from FCEV maintenance are predicted to be within Automotive Repair and Maintenance.

To estimate FTEs in each year from 2021-2045 we assign the mean FTE value for each 5-year increment to the midpoint year of that period, then extrapolate FTE values for other years assuming a linear rate of growth across each 5-year period (Figure 5-7). We predict continuous year-over-year increases for the entire study period in jobs related to all three sectors, with the following highlights:

a. Annual FCEV Vehicle Sales FTEs (Figure 5-7A) first break 5,000 in 2026 and expand at a pace of a few thousand per year until 2040, after which growth slows somewhat. FTEs from this sector sit just above 30 thousand in 2045.
b. Annual Hydrogen Fuel Consumption FTEs (Figure 5-7B) exceed 5,000 for the first time in 2027, after which year-over-year growth accelerates slightly to between 3,000 and 6,000 for the remainder of the study period. FTEs from this sector exceed 43 thousand in 2045.
c. Annual FCEV Maintenance FTEs (Figure 5-7C) are similar in scale to the other two hydrogen-related sectors pre-2030, breaking 5,000 in 2027. However, growth in FTEs resulting from activity in this sector outstrips growth in the other two hydrogen-related sectors post-2030. FCEV Maintenance FTEs are projected to reach nearly 30 thousand in 2035, and close to 70 thousand in 2045.

Figure 5-7: Projected estimates for annual direct, indirect, and induced jobs resulting from new FCEV sales, hydrogen fuel consumption, and FCEV maintenance in California in thousands of FTEs, 2021-2045.

A



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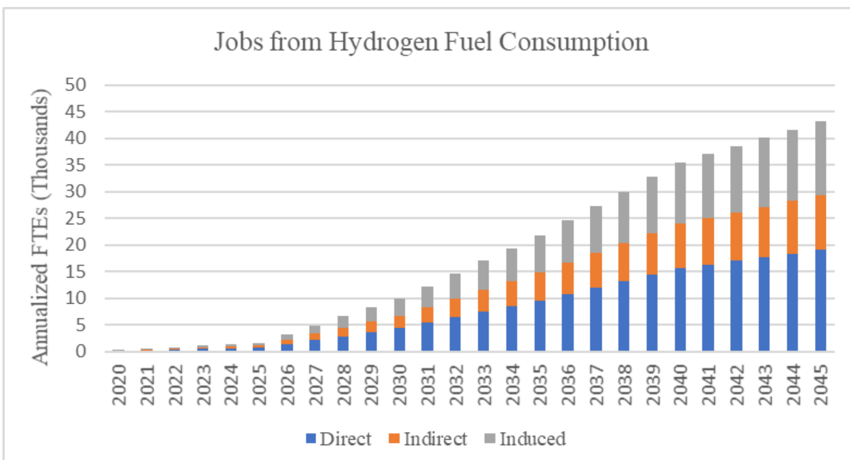

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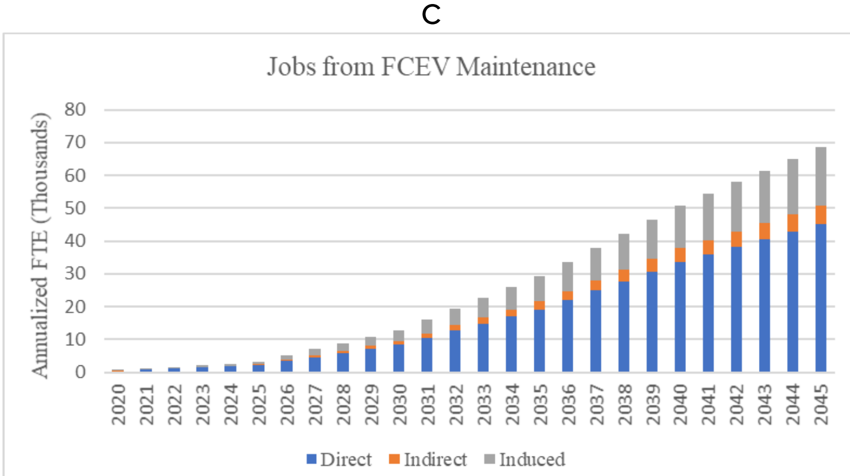


Workforce Impacts at the Occupational Level

Table 5-H shows FTE job-years realized for the top five occupations within each FCEV-related sector across the entire study period. Retail Sales Workers and Vehicle and Mobile Equipment Mechanics, Installers, and Repairers make up a significantly greater number of the FTE job-years generated over the 25-year study period than other occupations across the three FCEV-related sectors. Retail Sales Workers are the largest occupation by FTE job-years in both the new FCEV sales sector (37,261) and the hydrogen fuel consumption sector (120,879), while also being the fifth-largest occupation in the FCEV maintenance sector (22,315). Vehicle and Mobile Equipment Mechanics, Installers, and Repairers are the most heavily represented occupation by far within the FCEV maintenance sector by FTE job-years (257,596) and the second-most common in the new FCEV sales sector (32,112).

Table 5-H: Top 5 occupations by total FTE job-years resulting from expenditures on new FCEV sales, hydrogen fuel consumption, and FCEV maintenance, respectively, in California, 2021-2045.

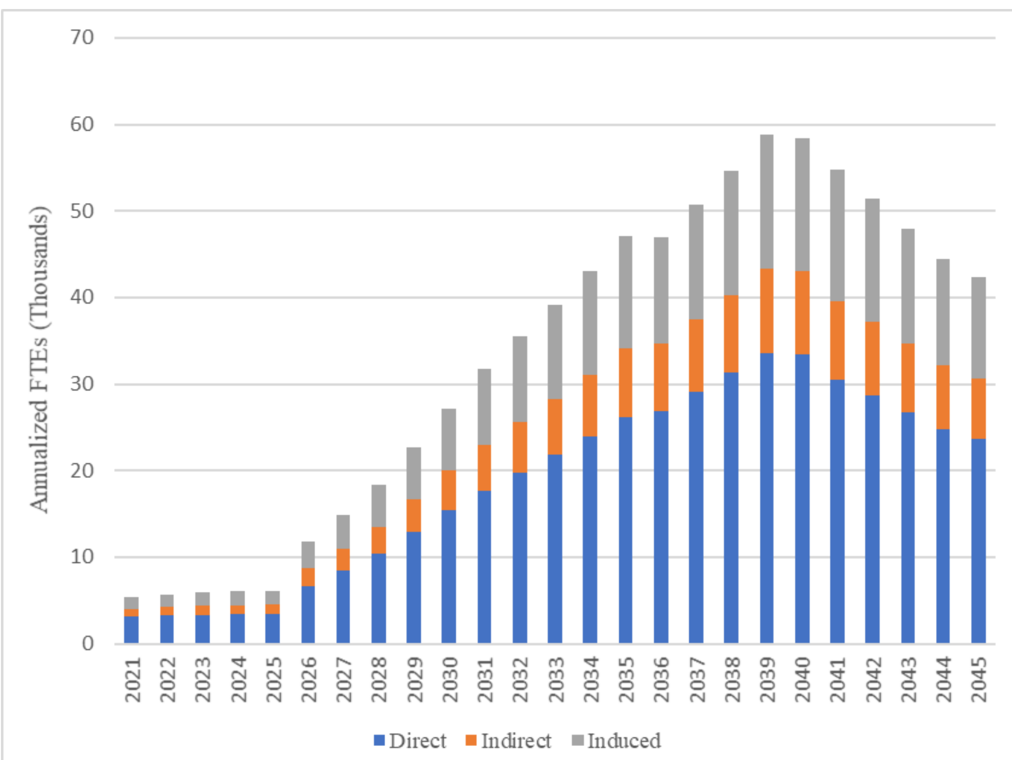
Rank	Occupation by Sector	FTE Job-Years, 2020-2045
	New FCEV Sales	
1	Retail Sales Workers	37,260.53
2	Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	32,112.05
3	Assemblers and Fabricators	26,273.57
4	Motor Vehicle Operators	23,806.40
5	Material Moving Workers	23,298.12
	Hydrogen Fuel Consumption	
1	Retail Sales Workers	120,878.60
2	Supervisors of Sales Workers	17,576.35
3	Material Moving Workers	16,738.57
4	Motor Vehicle Operators	13,181.11
5	Food and Beverage Serving Workers	11,623.49
	FCEV Maintenance	
1	Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	257,595.96
2	Other Office and Administrative Support Workers	26,326.98
3	Supervisors of Installation, Maintenance, and Repair Workers	25,856.67
4	Other Production Occupations	24,394.87
5	Retail Sales Workers	22,314.51

5.9 – Workforce Impacts Related to New EV Charging Infrastructure Construction and EVSE Installation

Construction of EV charging infrastructure and installation of new EVSE is expected to create over 805 thousand FTE job-years over the next twenty-five years. This translates to an average of slightly over 32 thousand full-time jobs across the entire time period. A majority of these--over 460 thousand FTE job-years--are directly created, predominantly through jobs associated with the construction of new commercial buildings. Nearly 134 thousand FTE job-years are created indirectly across myriad industries, and over 211 thousand FTE job-years are induced.

We estimate FTEs in each year from 2021-2045 by allocating the 5-year increment job figures based on spending patterns within each period (Figure 5-8). The resulting figures show a relatively modest job market (between 5,000 and 7,000 FTEs) where EVSE is concerned before 2025, after which growth quickly accelerates. FTEs in 2026 are expected to be nearly double those in 2025, driven by a pronounced ramp-up in expenditures on new EVSE installation and infrastructure construction. The sector is projected to continue adding multiple thousands of FTEs nearly every year until the peak in 2039, after which FTEs begin to fall as the pace of new EVSE installation and infrastructure construction slows.

Figure 5-8: Projected estimates for annual direct, indirect, and induced jobs resulting from EV charging infrastructure construction and other EVSE installation in thousands of FTEs, 2021-2045.



Workforce Impacts at the Occupational Level

Table 5-I shows the top five occupations related to EV charging infrastructure construction and new EVSE installation in terms of total realized FTE job-years across the study period. We project the greatest number of FTE job-years, by far, among Construction Trades Workers (nearly 209,000 FTE job-years between 2021 and 2045). This reflects the labor-intensive nature of contractor labor for construction of new EV charging infrastructure. The remaining occupations within the top five by FTE job-years across the 25 year period are Other Installation, Maintenance, and Repair Occupations (30,488), Supervisors of Construction and Extraction Workers (26,134), Motor Vehicle Operators (23,491), and Other Office and Administrative Support Workers (20,066).

Table 5-I: Top 20 occupations related to EV charging infrastructure construction and other EVSE installation by FTE job-years, 2021-2045.

Rank	Occupation	FTE Job-Years, 2021-2045
1	Construction Trades Workers	208,708.33
2	Other Installation, Maintenance, and Repair Occupations	30,488.02
3	Supervisors of Construction and Extraction Workers	26,133.91
4	Motor Vehicle Operators	23,490.93
5	Other Office and Administrative Support Workers	20,066.24
6	Business Operations Specialists	19,788.34
7	Other Management Occupations	17,972.63
8	Engineers	17,398.54
9	Material Moving Workers	16,229.22
10	Secretaries and Administrative Assistants	14,764.63
11	Top Executives	14,761.03
12	Financial Clerks	12,076.18
13	Helpers, Construction Trades	11,926.24
14	Drafters, Engineering Technicians, and Mapping Technicians	9,706.68
15	Information and Record Clerks	9,335.30
16	Metal Workers and Plastic Workers	8,832.80
17	Material Recording, Scheduling, Dispatching, and Distributing Workers	8,438.01
18	Computer Occupations	8,232.97
19	Other Production Occupations	7,986.36
20	Sales Representatives, Services	7,889.35

5.10 – Workforce Impacts Related to New Hydrogen Refueling Infrastructure Construction

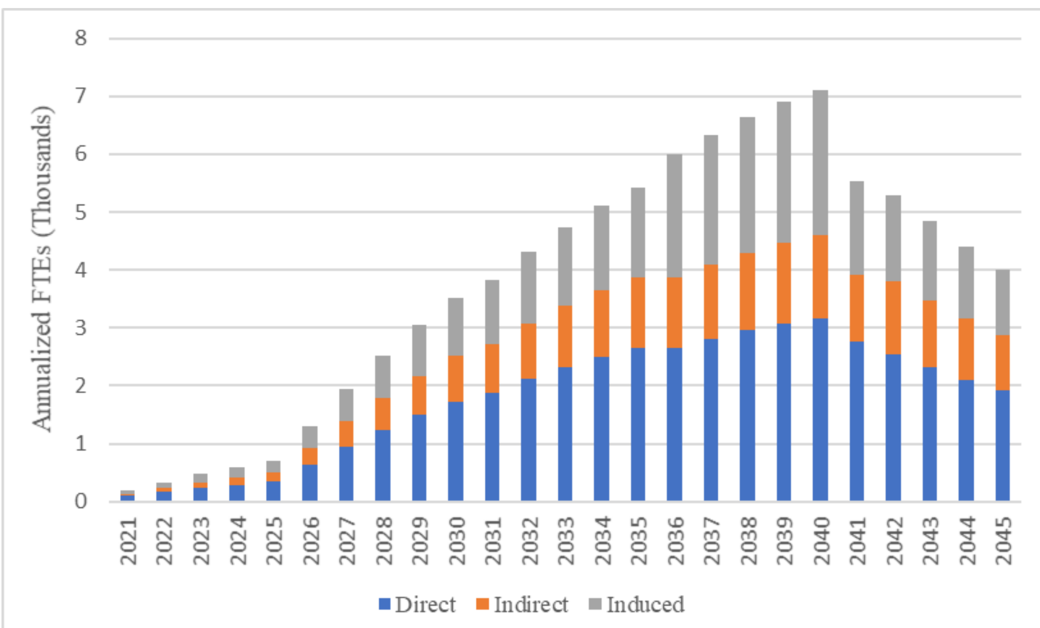
Construction of new hydrogen refueling infrastructure is expected to create nearly 92 thousand FTE job-years between 2021 and 2045, which translates to nearly 3,700 average annual FTEs.

As with EV charging infrastructure, a majority of these jobs (44,913 FTE job-years) are directly created, with the two most prominent industries being Architectural, Engineering, and Related Services (20,725 FTE job-years) and Construction of New Commercial Structures (10,993 FTE job-years). Indirect and induced jobs are similar in magnitude, generating 20,485 and 26,463 FTE job-years over the 25-year period, respectively.

As with EV charging infrastructure and EVSE, above, we estimate FTEs in each year from 2021-2045 by allocating the 5-year increment job figures based on spending patterns within each period (Figure 5-9). Projections once again indicate relatively modest job growth up to 2025, with FTEs in any given year not exceeding 1,000 during this period. A period of significant job growth begins in 2026 and continues until the peak year of 2040, when total FTEs reach 7,000. As new construction begins to slow in 2041 we project that FTEs in each year fall abruptly to just over 5,000 in that year, with slight annual declines thereafter. FTEs in 2045 sit at roughly 4,000.

Overall, this pattern of workforce impacts is similar to that of EVSE, but at a reduced magnitude that reflects the smaller profile of FCEVs versus EVs in the California fleet.

Figure 5-9: Projected estimates for annual direct, indirect, and induced job creation from hydrogen refueling infrastructure construction in thousands of FTEs, 2021-2045.



Workforce Impacts at the Occupational Level

Table 5-J showcases the top twenty employing occupations in the hydrogen refueling infrastructure sector by FTE job-years realized over the entire study period. The data indicate

that Construction Trades Workers constitute the largest category by FTE job-years (10,320) over the 25-year period, as was the case with EVSE. Engineers (5,920), Drafters, Engineering Technicians, and Mapping Technicians (3,428), Business Operations Specialists (2,903), and Motor Vehicle Operators (2,655) round out the top five occupations. Outside of the three most high-profile occupations, we see few standout areas of concentrated employment related to hydrogen refueling infrastructure construction.

Table 5-J: Top 20 occupations by FTE job-years created from expenditures on new hydrogen refueling station construction in California, 2021-2045.

Rank	Occupation	FTE Job-Years, 2021-2045
1	Construction Trades Workers	10,320.09
2	Engineers	5,920.15
3	Drafters, Engineering Technicians, and Mapping Technicians	3,427.96
4	Business Operations Specialists	2,903.18
5	Motor Vehicle Operators	2,654.82
6	Computer Occupations	2,221.90
7	Other Office and Administrative Support Workers	2,162.89
8	Architects, Surveyors, and Cartographers	2,087.17
9	Other Installation, Maintenance, and Repair Operations	2,066.48
10	Material Moving Workers	2,018.35
11	Other Management Occupations	1,981.34
12	Secretaries and Administrative Assistants	1,847.91
13	Top Executives	1,691.70
14	Metal Workers and Plastic Workers	1,535.92
15	Information and Record Clerks	1,483.73
16	Other Production Occupations	1,353.35
17	Financial Clerks	1,325.35
18	Supervisors of Construction and Extraction Workers	1,325.26
19	Material Recording, Scheduling, Dispatching, and Distributing Workers	1,148.37
20	Financial Specialists	1,078.30

5.11 – Policy Questions Related to Expanding ZEV-Related Industries

The data presented above indicate that the transition to ZEVs in California will create a large number of potentially high-quality jobs that do not require a Bachelor's degree, and will also greatly expand (even in the lower-employment sectors) many nascent industries. Many impacted workers are Hispanic or Latino, and Asian, while many in the electrical and wiring contractors industry skew younger. The fact that much of the employment is driven by BEV sales also foreshadows much procurement and state-level activity with manufacturing and logistics firms. To that end, two policy questions immediately arise:

- What are the best models and design elements to ensure that frontline and vulnerable communities continue to have access to apprenticeship programs that lead to quality careers, and how might the state grow upon what it is already doing in that area?
- How might the state ensure that employers, especially those who receive public tax dollars and incentives in this transition, commit to providing high-quality jobs, and are held accountable to those commitments?

The potential explosion in robust apprenticeship and pre-apprenticeship programs that lead people into skilled trades on quality career pathways is exciting and should be capitalized upon to provide opportunities to many members of frontline and vulnerable communities. However, those facing significant barriers to full-time employment – such as formerly incarcerated individuals, individual with disabilities, or older workers – struggle to access robust apprenticeship programs, even if they specifically geared toward local hires from target populations. For example, in an evaluation of a Joint Workforce Investment (JWI) between the Amalgamated Transit Union Local 265 (ATU) and the Santa Clara Valley Transportation Authority (VTA) designed to help veteran coach operators help novice drivers, it was discovered that the candidate pool for VTA bus operators was dominated by those with already existing connections to VTA's employees. A key factor underlying this outcome was that the application window for their apprenticeship program was unpublicized and only lasted one week. (Mackey, Dresser, & Young-Jones, 2018)

Another illustrative case is that of the Los Angeles Department of Water and Power (LADWP), which also has its own community hire program, the Utility Pre-Craft Trainee (UPCT) program. While the UPCT program offers an excellent career pathway and exposure, its recruitment system involves signing a book at the Union Hall for IBEW Local 18, which must be re-signed every three months (either online, via fax or by dropping off a re-sign slip). This complicated process (and lack of a formal referral network to the program) favors recruits with pre-existing connections to the LADWP workforce.

Designing a viable career pathway for target populations, and ensuring that it is accessible to those with barriers to full-time employment, means adding supportive services to ensure that target populations survive the hiring process and meet the necessary requirements. The longer the hiring process, the more skilled the job, and more restrictive the requirements, the more supportive services are needed to ensure that those with barriers to full-time employment become stable, full-time employees.

For example, jobs in industries such as Electric Power Generation may be unionized, if at a municipal utility, or not. If we are looking to expand unionized, civil service positions at municipal utilities, frontline and vulnerable communities risk being cut out due to the stringent requirements for the civil service hiring process.

Candidates from frontline and vulnerable communities also face skill gaps or other common challenges include limited job experience and insufficient access to adequate or high-quality education. This makes it difficult for them to perform on the job without intensive training.

Successful pipeline programs must also address many structural barriers to full-time employment, such as lack of access to transportation, credentials, childcare, or stable housing that makes it challenging for frontline and vulnerable communities to meet the skill requirements of a job (such as showing up on time or attending required training after work hours or off-site). Target populations often need to navigate barriers from as small as setting up an email to as large as finding stable housing.

It is not up to the state to micromanage the recruitment, training and support practices of the numerous pipeline programs that will be created to enable the transition to ZEVs. However, it does have the opportunity to set certain standards to ensure equal access and support to pipeline programs for frontline and vulnerable communities when agencies are setting aside workforce and training dollars. The state should coordinate common language and standards along with local agencies concerning:

- Transparent and accessible recruitment to targeted pipelines, especially for pre-apprenticeship programs. To equalize pipeline access for frontline and vulnerable communities who are not plugged into existing networks of employment for expanding occupations, guidelines should be set on adequately long recruitment windows and the public advertisement of those recruitment windows, as is appropriate to the context of the pipeline. Target population lists should also be enumerated and posted publicly, along with recruitment and retention goals for those populations, for transparency and access. Additionally, community-based organizations (CBOs) who act as recruitment partners should be formalized into a referral network that is publicly disclosed. This ensures that referral networks adequately represent target populations and are located in relevant communities. Finally, whenever possible, WorkSource Centers should provide a neutral location to process referrals.
- Bilingual human resources capacity. Even if a specific occupation is accessible to those with limited English proficiency, having recruitment, training and hiring materials solely in English often presents a barrier to non-English-speaking frontline and vulnerable communities. Every stage of the pipeline, from recruitment to training to selection, should be accessible to those with limited English proficiency as is appropriate for the occupation.
- Case management services to help target populations overcome barriers to full-time employment. Workforce pipelines that feature CBOs as a crucial part in providing

case management services to mitigate barriers should be advantaged over pipelines that do not. The Flintridge Center in Los Angeles County is an excellent example of a scalable framework for case management services. Flintridge provides services to over 500 individuals each year (pre-COVID-19 pandemic), from middle-school youth to adults, who were either formerly incarcerated or heading towards the path of violence and incarceration. One of their main programs, the Apprenticeship Preparation Program, receives Proposition 39 funding. After many years of trial and error, Flintridge leaders have settled on the following four categories of case management services:

- Mental health services that focus on coping with trauma, life skills and domestic violence prevention,
- Substance use recovery,
- A record change clinic where trainees work on clearing traffic tickets, dealing with outstanding fines, etc., and
- Housing services through community partners who help trainees secure permanent or transitional housing. (Flintridge Center, 2019)

Case management services do not have to be provided in-house. Flintridge partners with many other local CBOs, including the Pasadena Public Health Department (PPHD) and local law school clinics, to provide its services. Prior to the COVID-19 pandemic, union leaders in charge of the City of Los Angeles's Targeted Local Hire (TLH) program were looking to formalize a "workforce coordinator" position who would be able to act as a case manager for their recruits, referring them to services provided by a pre-approved and public list of CBOs. Incentivizing local workforce programs to partner with CBOs to provide case management services would greatly enhance the likelihood that frontline and vulnerable communities will be able to fully access new high-quality careers.

Setting standards to ensure transparent and accessible recruitment, bilingual human resources capacity, and case management services will set a baseline that will allow local leaders to prioritize the services that are most needed for their specific context. Such a strategy will also help bring about a just transition without localities being micromanaged by the state. Additionally, the state can help localities by providing technical assistance in deciding targeted recruitment, increasing bilingual capacity and providing case management services.

Ensuring Consistent Implementation of Just Transition Principles

As we have seen in previous sections of this report, expanding electric charging infrastructure, the capacity of electricity generation, and transitioning entire vehicle fleets from internal combustion to zero-emission vehicles will have a large impact in both creating new jobs and the need to transition existing ones. Much of this work will be driven by the expenditure of public dollars by government agencies.

This presents an expansive opportunity for state and local agencies to use the power of procurement to expand high-quality employment practices by coordinating language and expectations *before* they start awarding contracts. This will ensure that regardless of the source of the RFA, whether from a local transit agency or from Sacramento itself, employers are held to the same standard in workplace expectations.

There are many national and local models that illustrate ways to incorporate just transition principles into procurement. The "Green Transit Green Jobs" legislation, introduced in the New York state legislature earlier this year, would require public transit systems to use the best-value contracting framework. Such a framework would have contracts include employment plans that enumerate wage and benefits, as well as jobs for underrepresented individuals and local community benefits. (Kennedy, 2020)

The Build Local Hire Local Act, introduced at the Federal level by Senator Gillibrand and Congressmember Bass, also attempts to incentivize a best-value contracting framework, allowing government agencies to evaluate bids on factors such as equity, high-quality job and business opportunities, environment and climate justice and more. However, key elements of the bill also prioritize targeted local hiring, accessibility of data, and the use of the U.S. Employment Plan.[6] The U.S. Employment Plan is a customizable tool that public agencies at all levels of government can incorporate into their bidding process that allows companies to be evaluated on the location of the jobs they will create, salaries, benefits, training programs and their hiring of frontline and vulnerable communities (Jobs to Move America, 2020).

Regardless of the specific model used, California should capitalize on this opportunity to coordinate consistent language and evaluation standards around the following procurement deliverables:

- Targeted local hiring plans that involve recruitment and retention goals for frontline and vulnerable communities.
- Training plans incorporating structures that take advantage of worker wisdom and collaborative decision making.
- Reporting of jobs created and retained, including those for frontline and vulnerable communities.
- Descriptions of compensation and benefits for all hires, including benefits for partners and dependents.

[6] *H.R.4101, 116th Congress (2019-2020)*

Ensuring Government Agencies and Advocates Working on Behalf of the Public Can Hold Employers Accountable for Promoting High-Quality Job Practices

In October of 2017, the Los Angeles County Superior Court ruled that New Flyer of America, Inc. ("New Flyer") had to disclose unredacted, line-item wage information to Jobs to Move America (JMA) under the California Public Records Act (CPRA). In 2013, New Flyer had won a bid with LA Metro to provide 900 compressed natural gas transit buses, in part because it had promised to bring high-quality jobs to the area. LA Metro's RFA had incorporated the U.S. Employment Plan.[7] In order to verify that New Flyer was keeping its promises, JMA requested line-item wage information, albeit with the employee's names redacted. New Flyer claimed that under the trade-secret exemption in the CPRA, it did not have to disclose the information, arguing that the information would allow competitors to undercut it on future bids and provide competitors with nonpublic information to compete for skilled labor or poach current employees.[8]

However, the court ruled in favor of JMA's argument, stating that there was substantial public interest in the disclosure of the information since the public had the right to verify whether New Flyer was fulfilling its job creation and wage promises, especially since those promises helped to secure LA Metro's contract. The CPRA leaves it to agencies to exercise their discretion on what information is or is not a trade secret. LA Metro had itself expressed some inability to "determine whether New Flyer's USEP data, in fact, constitutes confidential proprietary and trade secret information," even though it did eventually decide to disclose.[9]

Such cases, and the ambiguity in which they leave government agencies, are becoming more and more common, especially as even the smallest localities rely on external contractors to fulfill many services. (Spivack, Public contracts shrouded in secrecy, 2016) Because many agencies, especially local ones, lack expertise in the nuances of public disclosure, they often rely on the contractor to decide what is and is not a trade secret. (Spivack, L.A. transit agency must show if Canadian firm created jobs , 2017)

Subcontracting and staffing agencies add a complicated layer in many industries key to California's transition to ZEVs. For example, employers in Inland Southern California's logistics industry often rely on staffing agencies to fill positions such as forklift drivers, material movers, and packagers. (Allison, Herrera, Huston, & Reese, 2015) In a survey of local warehouse workers, UC Riverside found that there was a significant gap in wages between direct hires and those hired as temporary workers through a staffing agency, with direct hires earning $2,000 more per year (with $16,000 in annual median earnings as opposed to $14,000 for staffing

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[7] *New Flyer of America, Inc. v. Los Angeles County Metropolitan Transportation Authority, et. al. (2017), Superior Court of the State of California for the County of Los Angeles.*
[8] *Ibid.*
[9] *Ibid.*

agency workers). American Community Survey data for the same group in 2013 dollars found the gap to be even wider, with direct hires earning $13,000 more per year. (Allison, Herrera, Huston, & Reese, 2015) Advocates working to transition warehouses to high-quality workplaces also note that the presence of subcontractors and staffing agencies makes it harder both for a nonunionized warehouse to unionize and for a unionized warehouse to stay unionized, since unionized employees become much more replaceable.

Complex and nested layers of subcontractors can sometimes throw a wrench into even the best funded transitions for certain highly vulnerable communities. The adoption of the Statewide Truck and Bus rule and the Heavy Duty Vehicle Greenhouse Gas Emission Reduction measure in 2008 by the California Air Resources Board (CARB) offers an illustrative example. These two rules combined required truck owners to install diesel exhaust filters on their rigs, replace engines older than the 2010 model year according to a staggered implementation schedule and install fuel efficient tires and aerodynamic devices on their trailers. (Caesar, 2008)

The state was very accommodating to the needs of truck owners in upgrading their vehicles, offering over $1 billion in funding opportunities through various grant and loan programs, providing three compliance options so that there was flexibility in meeting regulation requirements, and making administrative changes on the back end to minimize paperwork and gives grants and loans simultaneously to reduce a truck owners' monthly payments. (Caesar, 2008)

However, nearly ten years later, investigative journalists and advocates discovered that almost all of the 800 companies operating out of LA ports turned to some form of lease-to-own model for replacing the trucks, pushing the cost onto individual drivers, paid not by the hour but by the number and kind of containers they move. (Murphy, 2017) Journalists uncovered a string of similar stories – drivers, many of whom spoke little English, were given contracts by managers with no time to seek legal advice or interpreters, threatened to be fired if they did not sign. They then entered into a sub-lease contract for their individual truck with their employer, trading in their old trucks (which they owned outright) as down payment. Suddenly, they found themselves $100,000 in debt to their employer, without the right to use their truck to work for other companies. (Murphy, 2017) In a world where large retailers hired large shipping and logistics firms to then line up trucking companies through a myriad of subcontractors, accountability was incredibly difficult to track. In the end, this transition led to many drivers working well beyond the federally mandated 11 hours per day limit (by falsifying log books) on garnished wages where they took home nothing, only to lose it all when they got fired. (Murphy, 2017)

For frontline and vulnerable communities, who are used to having promises made to them that are go unfulfilled, accountability after the contract has been awarded is just as important as equitable incentives beforehand. California should prioritize insourcing and exclusive franchise contracting models to maintain labor standards (Zabin, et al., 2020), but it must also provide technical assistance and guidelines to communities and local agencies to ensure that the many contractors with whom they engage are fulfilling their promises. Few places have public players with the wherewithal and resources to go through litigation, as JMA or LA Metro do. The state can play a crucial role in ensuring the public has the information it needs *before* such legal actions become necessary.

Additionally, for industries like truck transportation, where mazes of subcontractors and owner-operator structures are the norm, the state must prioritize investigative strategies to catch otherwise law-abiding employers whose subcontractors are violating standards. (Smith, Marvy, & Zerolnick, 2014) For example, the state may use its power as an auditor to ask for data and reporting that unearths red flags for abuse, and then pass that on to a partnering investigative agency to see if violations are actually taking place. This not only takes the burden of investigation off of a non-investigative agency, but also adds capacity to investigative agencies through the eyes of auditors already on site at workplaces.

More ambitiously, the state may also take this opportunity to clarify ambiguities about trade secrets, and contractor and staffing agency standards, through legislation or the rule-making process.[10]

5.12 – Conclusion

Much of California's transition to ZEVs will happen by "greening" many existing occupations, rather than creating new, niche "green" occupations. (Zabin, et al., 2020) This presents the state with a golden opportunity to create not only new, high-quality jobs, but to also ensure that many existing industries and occupations transition to better practices.

Without a cohesive vision and guidance from the state level, there is a risk that California will exacerbate negative labor market trends as it pursues its climate goals. A scenario in which the state depends on low-wage, low-security jobs to decarbonize its transportation sector would be an undesirable outcome.

California has already taken many steps in ensuring robust economic development policies for frontline and vulnerable communities. It now has the opportunity to expand on these practices to manage the complex task of moving the entire transportation sector to zero-emissions, and leap on the chance to make systemic changes that will have sustainable and long-lasting impacts those with barriers to full-time employment across the state.

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[10] *For example, SB 749 of 2019 (Durazo), attempts to clear up what is and is not a trade secret, such as wages, benefits and other employment terms and conditions if those wages, benefits and terms relate to work performed under the contract of a state or local agency.*

This report has shown that while data is incredibly useful in helping to identify certain problems, it does not point to exact solutions because it may be incomplete and may require some assumptions needed to perform the analysis. Additionally, the significant job growth our study predicts will present many unique scenarios depending on locality, industry and timing as many key players put out and respond to Requests for Applications (RFA), recruit and train future employees, retrain or upskill current workers, expand education programs, relocate, hold town halls and listening sessions, and much, much more. Therefore, implementing just transition policies must involve strong community buy-in and dialogue with frontline and vulnerable communities at all stages of policy design, implementation and evaluation in order to catch and resolve issues in real-time.

State and local agencies will be primary players in driving change in the fuel, vehicle and transportation services supply chains, as well as in directly or indirectly influencing transportation expenditures. As key investors in infrastructure, they can use their purchasing power to ensure quality employment practices. Through the state and local workforce development and education systems, they can ensure pipelines only go to high-quality jobs. Using their power to audit and mandate accountability, they can ensure that frontline and vulnerable communities have a seat at the table and that employers are holding true to their promises in ensuring quality employment.

Next Steps and Further Studies

In researching this report, the team faced some data limitations that limited our ability to create worker profiles for groups of workers on whom we did not have descriptive data. Some custom surveying must be done in order to create actual transition plans for certain groups of workers, and to understand the changes that must be made to provide a just transition to workers in certain industries.

1. At time of writing, rates of unionization cannot be found specifically for California in BLS databases. Given that California has a much higher rate of unionization than many states nationally, this made it difficult for us to include such information in our analysis.
2. Demographic data only exists at a high level by industry. At some points in our analysis, we needed the demographic makeup of an occupation by industry or by county/municipality. This data could not be found. There was also no way to understanding the granularity of demographic identification by cross-referencing subgroups. For example, we do not know how many Hispanic workers are over 50, or how many female workers are also non-White.
3. For certain subgroups, such as older workers, it was difficult to find information about other sources of income of wealth. This would have been crucial in anticipating impacts of job loss.

Surveying for this data should be looped into the process of local taskforces, who can not only gather the data from impacted workers and communities, but also share and interpret it them as part of a collaborative decision-making process. Localized impacts or deeper studies can be done with data purchased from firms or from customized data pulls from BLS or O*NET. While the research team attempted to get custom data pulls for California from DOL databases, it was unfeasible given the timeline for this report.

This transition will also necessitate the rapid expansion of nascent Hydrogen and EVSE industries, and their related occupations. Given that these industries are new, it was difficult to find adequate data to make some predictions.

1. Hydrogen and EVSE occupational and industry classifications are often nested under other categories. For example, Hydrogen fuel is nested under Industrial Gas Manufacturing, which includes CO2, natural gas and many other forms of fuel. Getting Hydrogen coded separately under Transportation Fuel would make it easier to forecast needs.
2. A consumption study on Hydrogen must be done to fine the conversation rate from gasoline stations to Hydrogen.
3. An in-depth study focused on in-state versus out-of-state projections of Hydrogen production and the and the feasibility of building large scale, carbon-free Hydrogen production will be needed.

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Chapter 2

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Appendices

A – Baseline Employment Data Tables

Table A-1: 2019 employment estimates for California's fossil fuel supply chain.

Employment Title	NAICS Code	Establishments	Estimated Annual Employment	Estimated Annual Wages
Crude Petroleum Extraction	211120	86	3,135	$285,697
Natural Gas Extraction	211130	38	1,294	$132,088
Drilling Oil and Gas Wells	213111	123	3,024	$144,655
Support Activities, Oil-Gas Operations	213112	258	6,792	$84,284
Oil and Gas Pipeline Construction	237120	176	10,016	$88,333
Other Building Equipment Contractors	23829	815	10,763	$94,870
Petroleum Refineries	324110	106	10,839	$174,905
Petroleum Lubricating Oil and Grease Manufacturing	324191	32	727	$81,919
All Other Petroleum and Coal Products Manufacturing[a]	324199	4	95	$93,366
Ethyl Alcohol Manufacturing	325193	4	225	$89,679
Oil and Gas Field Machinery and Equipment Manufacturing	333132	36	1,374	$74,397
Measuring, Dispensing, and Other Pumping Equipment Manufacturing	333914	78	1,838	$82,690
Petroleum Bulk Stations and Terminals	424710	176	2,952	$83,824
Petroleum and Petroleum Products Merchant Wholesalers	424720	372	5,139	$90,171
Gasoline Stations (Public)	4471	8	186	$28,918
Gasoline Stations (Private)	4471	7,064	63,573	$28,296
Fuel Dealers	454310	273	2,654	$62,253
Pipeline Transportation of Crude Oil	486110	29	508	$108,244
Pipeline Transportation of Natural Gas	486210	25	390	$143,470
Pipeline Transportation of Refined Petroleum Products	486910	64	775	$120,545
Employment Totals		9,767	126,299	

Note: Many of the midstream categories contain hydrogen cell manufacturing, because the companies making them fall under one of these categories. However, California does not appear to currently have any cell manufacturing.

[a] Contains biofuel production.

Table A-2: 2019 employment estimates for California's electricity supply chain.

Employment Title	NAICS Code	Establishments	Estimated Annual Employment	Estimated Annual Wages
Electric Power Generation	22111	2	92	$156,563
Electric Power Transmission and Distribution	22112	1	31	$138,832
Power and Communication Line and Related Structures Construction	237130	3	121	$120,993
Electrical and Wiring Contractors	23821	65	761	$78,506
Turbine and Turbine Generator Set Units Manufacturing	333611	1	31	$130,256
Electrical Equipment Manufacturing	33531	2	55	$83,170
Employment Totals		74	1,091	

Note. Estimated employment based on existing employment multiplied by the percentage of EV electricity consumption in comparison to total electricity consumption in California, roughly 0.68%.

Table A-3: 2019 employment estimates for California's general vehicle supply chain.

Employment Title	NAICS Code	Establishments	Estimated Annual Employment	Estimated Annual Wages
Industrial Truck, Trailer, and Stacker Manufacturing	333924	36	440	$52,610
Motor Vehicle Manufacturing	3361	81	17,870	$94,361
Motor Vehicle Body Manufacturing	336211	89	3,412	$57,554
Motor Vehicle Steering and Suspension Components (except Spring) Manufacturing	336330	44	608	$46,417
Motor Vehicle Brake System Manufacturing	336340	16	588	$54,758
Motor Vehicle Seating and Interior Trim Manufacturing	336360	51	903	$52,181
Motor Vehicle Metal Stamping	336370	15	387	$50,702
New Car Dealers	441110	1,998	118,818	$68,473
Used Car Dealers	441120	1,398	12,825	$51,511
Automotive Parts and Accessories Stores (Public)	441310	3	14	$27,774
Automotive Parts and Accessories Stores (Private)	441310	3,544	34,950	$35,814
Passenger Car Rental	532111	1,403	17,788	$49,684
Passenger Car Leasing	532112	48	204	$87,289
Truck, Trailer, and RV Rental and Leasing	532120	604	7,619	$57,618
Other Commercial and Industrial Machinery Equipment Rental and Leasing	532490	1,238	12,016	$67,498
Other Automotive Mechanical and Electrical Repair and Maintenance	811118	542	2,837	$46,546
All Other Automotive Repair and Maintenance	811198	1,236	4,869	$47,227
Employment Totals		12,737	236,148	

Table A-4: 2019 employment estimates for California's motor vehicle supply chain.

Employment Title	NAICS Code	Establishments	Estimated Annual Employment	Estimated Annual Wages
Other Engine Equipment Manufacturing	333618	28	415	$91,699
Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	336310	117	2,297	$66,355
Motor Vehicle Transmission and Power Train Parts Manufacturing	336350	57	955	$68,331
Other Motor Vehicle Parts Manufacturing	336390	174	4,614	$52,345
Motorcycle, Bicycle, and Parts Manufacturing	336991	123	1,899	$51,769
Automobile and Other Motor Vehicle Merchant Wholesalers	423110	600	11,975	$85,843
Motor Vehicle Supplies and New Parts Merchant Wholesalers	423120	2,006	23,162	$59,619
Motor Vehicle Parts (Used) Merchant Wholesalers	423140	217	2,293	$58,273
General Automotive Repair	811111	9,681	39,859	$46,156
Automotive Exhaust System Repair	811112	222	651	$38,149
Automotive Transmission Repair	811113	457	1,578	$42,596
Automotive Oil Change and Lubrication Shops	811191	669	5,829	$31,614
Employment Totals		13,960	95,527	

Table A-5: 2019 employment estimates for California's electric vehicle supply chain.

Employment Title	NAICS Code	Establishments	Estimated Annual Employment	Estimated Annual Wages
Storage Battery Manufacturing	335911	45	1,686	$72,446
Miscellaneous Electrical Equipment Manufacturing	335999	201	6,130	$106,820
Employment Totals		246	7,816	

Table A-6: 2019 employment estimates for California's transportation services supply chain.

Employment Title	NAICS Code	Establishments	Estimated Annual Employment	Estimated Annual Wages
General Freight Trucking	4841	9,811	93,912	$53,764
Specialized Freight Trucking	4842	3,724	40,716	$55,536
Bus and Other Motor Vehicle Transit Systems (Public)	485113	61	16,049	$75,179
Bus and Other Motor Vehicle Transit Systems (Private)	485113	76	4,163	$45,493
Interurban and Rural Bus Transportation (Public)	485210	8	1,045	$58,927
Interurban and Rural Bus Transportation (Private)	485210	28	1,069	$42,167
Taxi Service	485310	160	10,527	$432,072**
Limousine Service	485320	642	5,400	$40,774
School and Employee Bus Transportation (Public)	485410	106	5,488	$47,629
School and Employee Bus Transportation (Private)	485410	188	11,380	$39,991
Charter Bus Industry	485510	175	3,188	$45,645
Special Needs Transportation	485991	443	10,485	$37,184
All Other Transit and Ground Passenger Transportation	485999	307	4,728	$51,678
Scenic and Sightseeing Transportation, Land (Public)	487110	3	492	$39,867
Scenic and Sightseeing Transportation, Land (Private)	487110	144	2,140	$51,995
Motor Vehicle Towing	488410	1,279	12,075	$43,190
Other Support Activities for Road Transportation (Public)	488490	5	489	$104,012
Other Support Activities for Road Transportation (Private)	488490	390	3,288	$43,939
Postal Service (Public)*	491110	1,402	33,234	$66,089
Postal Service (Private)	491110	105	742	$36,008
Couriers and Express Delivery Services	492110	976	85,029	$46,290
Local Messenger and Local Delivery	492210	1,088	16,717	$48,419
Solid Waste Collection (Public)	562111	1	7	$43,200
Solid Waste Collection (Private)	562111	858	17,462	$67,224
Hazardous Waste Collection	562112	130	4,192	$70,715
Other Waste Collection	562119	154	1,141	$52,312
Automobile Driving Schools	611692	300	1,667	$29,096
Employment Totals		22,564	386,825	

**USPS carrier employment estimate based on BLS percent of industry employment, 53.78%.*
***This number seems high, which might be due to omission of leasing costs for vehicles and the cost of insurance.*

B – On-Road Fleet Composition Data

We identified four general vehicle categories: light-duty vehicles (LDVs), heavy-duty vehicles (HDVs), medium-duty vehicles (MDVs), and buses. The estimates for each vehicle category are based on a weighted average that directly reflects the composition of the on-road fleet. The following tables demonstrate the breakdown of each vehicle category (fossil fuels, battery electric vehicles, and fuel cell electric vehicles) into percentages of the on-road fleet. These estimates come from the CNS LC1 scenario.

Table B-1: Projected on-road fleet composition for *fossil fuel LDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Cars	55%	53%	51%	48%	45%	40%
Light-duty trucks	45%	47%	49%	52%	55%	60%

Table B-2: Projected on-road fleet composition for *fossil fuel HDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Long Haul Diesel	58%	57%	58%	60%	62%	66%
Short Haul	13%	13%	13%	13%	13%	13%
Heavy-duty vocational	29%	30%	29%	27%	25%	22%

Table B-3: Projected on-road fleet composition for *fossil fuel MDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
MD Urban diesel	16%	17%	18%	18%	19%	19%
MD Vocational diesel	2%	2%	2%	2%	1%	1%
HD pickup diesel	40%	43%	44%	45%	47%	48%
MD Urban gas	5%	4%	3%	2%	1%	1%
HD pickup gas	37%	33%	32%	32%	32%	32%

Table B-4: On-road fleet composition for *fossil fuel buses* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Transit bus diesel	27%	23%	18%	17%	11%	12.4%
Other bus diesel	33%	45%	61%	69%	78%	87%
Transit bus gas	15%	15%	11%	7%	6%	0%
Other bus gas	25%	17%	11%	7%	6%	0%

Table B-5: On-road fleet composition for *battery electric LDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Cars	67%	61%	59%	58%	57%	57%
Light-duty trucks	33%	47%	41%	42%	43%	43%

Table B-6: On-road fleet composition for *battery electric HDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Long Haul	0%	23%	24%	17%	16%	14%
Short Haul	0%	6%	5%	11%	13%	14%
Heavy-duty vocational	100%	70%	71%	72%	71%	71%

Table B-7: On-road fleet composition for *battery electric MDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
MD Urban	25%	35%	37%	37%	34%	32%
MD Vocational	2%	4%	3%	3%	3%	3%
HD pickup	73%	62%	60%	60%	63%	65%

Table B-8: On-road fleet composition for *battery electric buses* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Transit bus	99%	86%	81%	76%	69%	65%
Other bus	1%	14%	19%	24%	31%	35%

Table B-9: On-road fleet composition for *fuel cell electric LDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Cars	100%	63%	48%	42%	41%	39%
Light-duty trucks	0%	37%	52%	58%	59%	61%

Table B-10: On-road fleet composition for *fuel cell electric HDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Long Haul	0%	100%	90%	88%	88%	86%
Short Haul	0%	0%	10%	12%	11%	10%
Heavy-duty vocational	0%	0%	0%	0%	1%	4%

Table B-11: On-road fleet composition for *fuel cell electric MDVs* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
MD Urban	0%	0%	27%	26%	23%	21%
MD Vocational	0%	0%	3%	2%	2%	2%
HD pickup	0%	0%	70%	72%	75%	77%

Table B-12: On-road fleet composition for *fuel cell electric buses* in California in percentages over 5-year increments, 2040-2045.

Vehicle Type	2020	2025	2030	2035	2040	2045
Transit bus	0%	100%	80%	75%	69%	67%
Other bus	0%	0%	20%	25%	31%	33%

C – On-Road Fleet Size Data

The on-road fleet represents the number of vehicles in California that regularly use the nation's roadways. Tables C-1 through C-3 illustrate the on-road fleet size in number of vehicles from 2020-2045 for each vehicle type. This data comes from the CNS LC1 scenario.

Table C-1: On-road fleet numbers for *fossil fuel vehicles* by vehicle category in California over 5-year increments, 2040-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	29,408,000	29,094,000	25,755,000	20,390,000	12,089,000	8,538,000
HDVs	304,000	320,000	299,000	236,000	157,000	87,000
MDVs	1,357,000	1,320,000	1,234,000	1,056,000	735,000	414,000
Buses	52,000	47,000	38,000	29,000	18,000	8,055
Total	31,121,000	30,781,000	27,326,000	21,711,000	12,999,000	9,047,055

Table C-2: On-road fleet numbers for *battery electric vehicles* by vehicle category in California over 5-year increments, 2040-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	350,000	1,006,000	3,085,000	6,959,000	12,109,000	16,781,000
HDVs	23	4,262	21,000	53,000	89,000	118,000
MDVs	310	26,000	125,000	313,000	605,000	910,000
Buses	1,006	7,000	21,000	37,000	52,000	63,000
Total	351,339	1,043,262	3,252,000	7,362,000	12,855,000	17,872,000

Table C-3: On-road fleet numbers for *fuel cell electric vehicles* by vehicle category in California over 5-year increments, 2040-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	7,000	70,000	325,000	856,000	1,581,000	2,313,000
HDVs	0	1,000	10,000	33,000	74,000	122,000
MDVs	0	0	30,000	100,000	208,000	324,000
Buses	0	1,000	5,000	8,000	13,000	15,000
Total	7,000	72,000	370,000	997,000	1,876,000	2,774,000

D – New Vehicle Purchase Price Data

Vehicle purchase price represents the average price of a vehicle in its vehicle category. Tables D-1 through D-3 illustrate the vehicle purchase prices for each vehicle type from 2020-2045. These estimates come from the CNS LC1 scenario.

Table D-1: Vehicle purchase prices for *fossil fuel vehicles* by vehicle category in California over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$30,347	$31,863	$32,675	$33,227	$33,833	$33,300
HDVs	$160,073	$167,083	$171,504	$170,971	$170,462	$168,956
MDVs	$41,730	$43,170	$44,063	$44,211	$44,196	$44,419
Buses	$226,387	$216,604	$190,085	$176,225	$154,853	$141,971

Table D-2: Vehicle purchase prices for *battery electric vehicles* by vehicle category in California over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$56,997	$48,863	$37,465	$34,898	$32,484	$32,281
HDVs	294796	$283,378	$229,060	$211,238	$198,949	$199,302
MDVs	$89,034	$72,125	$53,908	$47,926	$43,288	$43,148
Buses	$534,676	$435,262	$365,809	$334,423	$303,391	$291,853

Table D-3: Vehicle purchase prices for *fuel cell electric vehicles* by vehicle category in California over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$43,341	$41,332	$39,501	$37,650	$36,077	$35,903
HDVs	—*	$254,854	$206,456	$186,308	$169,940	$168,446
MDVs	—*	—*	$73,738	$63,884	$56,755	$55,707
Buses	—*	$489,502	$392,396	$358,769	$329,839	$320,783

**No weighted average using percentages of the on-road fleet presented due to lack of vehicles on the road.*

E – New Vehicle Purchases Data

Vehicles purchased represent the number of new vehicles purchased in California. Tables E-1 through E-3 provide the projected number of vehicles purchased for years 2020-2045. These estimates come from the CNS LC1 scenario.

Table E-1: Number of new *fossil fuel vehicles* purchased in California by vehicle category over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	1,905,000	1,649,000	974,000	489,000	0	0
HDVs	20,900	18,620	12,280	6,110	590	0
MDVs	92,990	85,220	58,420	34,250	2,270	0
Buses	3.210	2,280	1,000	520	0	0
Total	2,022,100	1,755,120	1,045,700	529,880	2,860	0

Table E-2: Number of new *battery electric vehicles* purchased in California by vehicle category over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	202,000	271,000	899,000	1,326,000	1,773,000	1,757,000
HDVs	30	1,390	5,110	8,210	9,680	9,310
MDVs	102	8,570	28,730	50,290	83,760	87,080
Buses	132	1,920	3,640	4,180	4,740	4,850
Total	202,264	282,880	936,480	1,388,680	1,871,180	1,858,240

Table E-3: Number of new *fuel cell electric vehicles* purchased in California by vehicle category over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	2,000	20,000	75,000	141,000	191,000	215,000
HDVs	0	410	2,860	6,300	11,490	12,720
MDVs	0	0	10,150	18,100	29,900	32,210
Buses	0	340	910	1,040	1,140	1,220
Total	2,000	20,750	88,920	166,440	233,530	261,150

F – New Vehicle Purchase Expenditure Calculations

To calculate new vehicle purchase expenditures, we multiplied the purchase price for an average vehicle in its class (Appendix D) by the number of new vehicles purchased (Appendix E). Tables F-1 through F-3 illustrate detailed figures for vehicle purchase expenditures.

Vehicle Purchase Expenditures = purchase price × # of new vehicles purchased

Table F-1: New vehicle purchase expenditures for *fossil fuel vehicles* by vehicle category in California in 2020 US dollars over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$57,811,035,000	$52,542,087,000	$31,825,450,000	$16,248,003,000	$0	$0
HDVs	$3,345,525,700	$3,111,085,460	$2,106,069,120	$1,044,632,810	$100,572,580	$0
MDVs	$3,880,472,700	$3,678,947,400	$2,574,160,460	$1,514,226,750	$100,324,920	$0
Buses	$726,702,270	$493,857,120	$190,085,000	$91,637,000	$0	$0
Total	$65,763,735,670	$59,825,976,980	$36,695,764,580	$18,898,499,560	$200,897,500	$0

Table F-2: New vehicle purchase expenditures for *battery electric vehicles* by vehicle category in California in 2020 US dollars over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$11,513,394,000	$13,241,873,000	$33,681,035,000	$46,274,748,000	$57,594,132,000	$56,717,717,000
HDVs	$8,843,880	$393,895,420	$1,170,496,600	$1,734,263,980	$1,925,826,320	$1,855,501,620
MDVs	$9,081,468	$618,111,250	$1,548,776,840	$2,410,198,540	$3,625,802,880	$3,757,327,840
Buses	$70,577,232	$835,703,040	$1,331,544,760	$1,397,888,140	$1,438,073,340	$1,415,487,050
Total	$11,601,896,580	$15,089,582,710	$37,731,853,200	$51,817,098,660	$64,583,834,540	$63,746,033,510

Table F-3: New vehicle purchase expenditures for *fuel cell electric vehicles* by vehicle category in California in 2020 US dollars over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$86,682,000	$826,640,000	$2,962,575,000	$5,308,650,000	$6,890,707,000	$7,719,145,000
HDVs	$0	$104,490,140	$590,464,160	$1,173,740,400	$1,952,610,600	$2,142,633,120
MDVs	$0	$0	$748,440,700	$1,156,300,400	$1,696,974,500	$1,794,322,470
Buses	$0	$166,430,680	$357,080,360	$373,119,760	$376,016,460	$391,355,260
Total	$86,682,000	$1,097,560,820	$4,658,560,220	$8,011,810,560	$10,916,308,560	$12,047,455,850

G – Fuel Price Data

Fuel prices are given in 2020$ per gasoline gallon equivalent (GGE) in Table G-1. Price forecasts from 2020-2030 are from CEC's mid-demand forecasts. To estimate fuel costs for gasoline, diesel, and electricity through 2045, we used linear best fit calculations based on forecasted trends while removing certain outlier years. To estimate fuel costs for hydrogen, we used a flattening exponential curve.

Table G-1: Forecasted fuel prices for gasoline, diesel, electricity, and hydrogen in California in 2020 US $/GGE over 5-year increments, 2020-2045.

Fuel Type	2020	2025	2030	2035	2040	2045
CaRFG (reformulated gasoline)	$3.27	$3.32	$3.36	$3.43	$3.50	$3.55
ULSD	$3.50	$3.50	$3.56	$3.64	$3.69	#.74
Electricity (Commercial Rate)	$5.59	$6.17	$6.67	$7.19	$7.68	$8.18
Electricity (Residential Rate)	$6.74	$7.17	$7.67	$8.12	$8.61	$9.10
Hydrogen	$14.87	$11.73	$10.92	$9.19	$7.99	$6.94

H – Vehicle Miles Traveled Data

Vehicle miles traveled (VMT) is the total annual miles of vehicle travel. Tables H-1 through H-3 illustrate the average vehicle miles traveled per vehicle for each vehicle type in California. We assumed a ten-year lifetime for each vehicle. The following figures are the average of ten-year VMT estimates (for vehicles age 0 to age 9) from the CNS LC1 scenario.

Table H-1: Average annual VMT for *fossil fuel vehicles* by vehicle category in California over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	14,459	14,480	14,501	14,533	14,564	14,617
HDVs	50,271	49,749	50,271	51,314	52,357	54,065
MDVs	14,723	14,739	14,739	14,657	14,719	14,703
Buses	22,037	22,016	21,967	21,942	21,904	21,881

Table H-2: Average annual VMT for *battery electric vehicles* by vehicle category in California over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	14,261	14,395	14,416	14,427	14,438	14,438
HDVs	16,315	30,160	30,257	28,319	28,369	27,725
MDVs	15,048	15,681	15,946	15,946	15,702	15,540
Buses	22,336	22,268	22,241	22,215	22,178	22,157

Table H-3: Average annual VMT for *fuel cell electric vehicles* by vehicle category in California over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	13,983	14,374	14,533	14,596	14,607	14,628
HDVs	—*	68,463	66,102	65,630	65,345	64,016
MDVs	—*	—*	15,134	15,129	14,885	14,723
Buses	—*	22,341	22,236	22,210	22,178	22,168

*No weighted average using percentages of the on-road fleet presented due to lack of vehicles on the road.

I – Fuel Efficiency Data

Fuel efficiency is a measure of how far a vehicle can travel per unit of fuel. Tables I-1 through I-3 illustrate the average fuel efficiency in miles per gasoline gallon equivalent (GGE) for each vehicle type from 2020-2045. These estimates come from the CNS LC1 scenario.

Table I-1: Fuel efficiency for *fossil fuel vehicles* in California by vehicle category in mi/GGE over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	34	35.5	37.1	38.2	39.5	40.6
HDVs	5.3	6.4	6.8	7.2	7.6	8
MDVs	15	18.9	19.1	19.9	21	21.9
Buses	5.6	6.7	7.2	7.7	8.2	8.6

Table I-2: Fuel efficiency for *battery electric vehicles* in California by vehicle category in mi/GGE over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	126.3	128.4	131.9	132.4	132.8	133.7
HDVs	12.9	15.7	16.2	17	17.7	18.3
MDVs	57.9	60.3	66.8	69.4	73.7	78
Buses	13.5	17	18.2	19.3	20.7	21.9

Table I-3: Fuel efficiency for *fuel cell electric vehicles* in California by vehicle category in mi/GGE over 5-year increments, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	67.6	63.6	62.3	61.8	62.5	63
HDVs	N/A*	8.8	9.9	10.4	10.8	11.3
MDVs	N/A*	N/A*	41.3	43.5	46.2	48.8
Buses	N/A*	10.8	12.6	13.4	14.3	14.9

*No weighted average using percentages of the on-road fleet presented due to lack of vehicles on the road.

J – Annual Fuel Cost Per Vehicle Calculations

The annual fuel cost per vehicle is the estimated cost of fueling a vehicle over the course of a year, depending on vehicle miles traveled (VMT) and a price per gasoline gallon equivalent (GGE) of fuel. Tables J-1 through J-3 estimate annual fuel cost per vehicle from 2020-2045 using the VMT estimates from Appendix G and the fuel efficiency estimates provided in Appendix H.

Annual fuel cost per vehicle is calculated by dividing VMT (Appendix H) by fuel efficiency (Appendix I), then multiplying by fuel price (Appendix G).

Annual fuel cost per vehicle = (Annual VMT/fuel efficiency) × fuel price

Table J-1: Annual fuel cost per *fossil fuel vehicle* in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$1,391	$1,354	$1,313	$1,305	$1,290	$1,278
HDVs	$33,198	$27,206	$26,318	$25,942	$25,421	$25,275
MDVs	$3,435	$2,729	$2,747	$2,681	$2,586	$2,511
Buses	$13,773	$11,501	$10,861	$10,373	$9,857	$9,516

Table J-2: Annual fuel cost per *battery electric vehicle* in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$761	$804	$838	$885	$936	$983
HDVs	$7,070	$11,853	$12,458	$11,977	$12,309	$12,393
MDVs	$1,453	$1,605	$1,592	$1,652	$1,636	$1,630
Buses	$9,249	$8,082	$8,151	$8,276	$8,228	$8,276

Table J-3: Annual fuel cost per *fuel cell electric vehicle* in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$3,076	$2,651	$2,547	$2,171	$1,867	$1,611
HDVs	—*	$91,258	$72,913	$57,994	$48,343	$39,316
MDVs	—*	—*	$4,002	$3,196	$2,574	$2,094
Buses	—*	$24,265	$19,271	$15,232	$12,392	$10,325

*No weighted average using percentages of the on-road fleet presented due to lack of vehicles on the road.

K – Fuel Expenditure Calculations

We obtained our fuel expenditure estimates by multiplying the on-road fleet (Appendix B) by average annual fuel cost per vehicle (Appendix J). Tables K-1 through K-3 provide detailed figures for fuel expenditures.

Fuel expenditures = on road fleet × annual fuel cost per vehicle

Table K-1: Fuel expenditures for *fossil fuel vehicles* in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$40,895,223,219	$39,398,685,025	$33,823,992,906	$26,607,450,107	$18,181,586,987	$10,912,310,549
HDVs	$10,092,140,377	$8,706,075,000	$7,869,185,771	$6,122,330,356	$3,991,050,107	$2,198,958,713
MDVs	$4,661,792,567	$3,602,866,667	$3,390,000,867	$2,831,113,713	$1,900,958,850	$1,039,522,241
Buses	$716,202,500	$540,542,090	$412,735,522	$300,804,873	$177,422,400	$76,648,889
Total	$56,365,358,663	$52,248,168,782	$45,495,915,065	$35,861,699,048	$24,251,018,344	$14,227,440,391

Table K-2: Fuel expenditures for *battery electric vehicles* in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$266,363,413	$808,655,942	$2,586,130,942	$6,157,308,483	$11,334,970,472	$16,490,539,340
HDVs	$162,606	$50,516,156	$261,610,987	$634,795,372	$1,095,524,231	$1,462,364,973
MDVs	$450,374	$41,717,181	$199,026,609	$517,089,260	$989,929,075	$1,483,034,000
Buses	$9,304,251	$56,573,819	$171,170,158	$306,210,179	$427,874,690	$521,387,597
Total	$276,280,644	$957,463,097	$3,217,938,696	$7,615,403,294	$13,848,298,467	$19,957,325,910

Table K-3: Fuel expenditures for *fuel cell electric vehicles* in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$21,530,924	$185,573,764	$827,891,124	$1,857,952,709	$2,952,294,389	$3,727,172,606
HDVs	$0	$91,258,067	$729,125,091	$1,913,808,663	$3,577,396,731	$4,796,554,591
MDVs	$0	$0	$120,045,966	$319,621,862	$535,447,602	$678,392,395
Buses	$0	$24,264,808	$96,356,000	$121,856,657	$161,092,927	$154,878,443
Total	$21,530,924	$301,096,640	$1,773,418,181	$4,213,239,892	$7,226,231,650	$9,356,998,035

L – Maintenance Cost per Mile Data

Maintenance costs per mile include default maintenance (scheduled) and repair (unscheduled) costs.

We rely on estimates for LDVs from Lutsey and Nicholas 2019, which provides maintenance cost per mile estimates for cars, crossovers, and SUVs. Since our LDV vehicle categories are strictly cars and light-duty trucks, we adapted the ICCT estimates to fit our categories. For cars, we use the halfway figure between cars and crossovers from ICCT. For light-duty trucks, we use the SUV figure from ICCT. This applies to both fossil fuel LDVs and electric LDVs.

Estimates for HDVs, MDVs, and buses are primarily derived from ICF 2019. For fossil fuel medium-duty trucks and buses, we assumed that maintenance costs for gasoline trucks and buses would be ⅓ less than their diesel counterparts. Maintenance costs per mile for all other medium- and heavy-duty fossil fuel and battery electric trucks and buses were adopted from ICF.

For fuel cell electric vehicles, we use maintenance cost per mile figures for LDVs and MDVs provided by the CNS LC1 scenario. For fuel cell electric HDVs, we rely on ICF. For fuel cell electric buses, we use the value given for “articulated bus”, whereas for fossil fuel and battery electric buses, we use the values given for “school bus.”

Table L-1: Maintenance costs per mile for *fossil fuel vehicles* in California by vehicle category over 5-year increments in 2020 US dollars/mile, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$0.077	$0.078	$0.078	$0.079	$0.080	$0.082
HDVs	$0.190	$0.190	$0.190	$0.190	$0.190	$0.190
MDVs	$0.240	$0.247	$0.248	$0.250	$0.252	$0.253
Buses	$0.769	$0.799	$0.847	$0.878	$0.896	$0.940

Table L-2: Maintenance costs per mile for *battery electric vehicles* in California by vehicle category over 5-year increments in 2020 US dollars/mile, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$0.031	$0.032	$0.033	$0.033	$0.033	$0.033
HDVs	$0.170	$0.130	$0.130	$0.140	$0.140	$0.150
MDVs	$0.200	$0.190	$0.190	$0.190	$0.190	$0.200
Buses	$0.660	$0.690	$0.700	$0.710	$0.730	$0.740

Table L-3: Maintenance costs per mile for *fuel cell electric vehicles* in California by vehicle category over 5-year increments in 2020 US dollars/mile, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$0.473	$0.324	$0.264	$0.239	$0.235	$0.227
HDVs	—*	$0.170	$0.170	$0.170	$0.170	$0.170
MDVs	—*	—*	$0.177	$0.179	$0.179	$0.180
Buses	—*	$1.180	$1.074	$1.048	$1.016	$1.005

*No weighted average using percentages of the on-road fleet presented due to lack of vehicles on the road.

M – Maintenance Expenditure Calculations

We calculated maintenance cost estimates by multiplying vehicle miles traveled (Appendix H), maintenance cost per mile (Appendix L), and on-road fleet vehicle totals (Appendix B).

Maintenance cost = VMT × maintenance cost per mile × on-road fleet vehicle totals

Table M-1: Maintenance expenditures for *fossil fuel vehicles* in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$32,741,190,944	$32,859,927,360	$29,130,913,890	$23,409,901,730	$16,415,375,680	$10,233,595,572
HDVs	$2,903,652,960	$3,024,739,200	$2,855,895,510	$2,300,919,760	$1,561,809,310	$893,694,450
MDVs	$4,794,986,640	$4,805,503,560	$4,510,605,648	$3,869,448,000	$2,726,253,180	$1,540,021,626
Buses	$881,215,556	$826,766,848	$707,029,862	$558,687,204	$353,267,712	$165,676,368
Total	$41,321,046,100	$41,516,936,968	$37,204,444,910	$30,138,956,694	$16,415,375,680	$10,233,595,572

Table M-2: Maintenance expenditures for battery electric vehicles in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$154,731,850	$463,403,840	$1,467,620,880	$3,313,117,269	$5,769,381,486	$7,995,374,574
HDVs	$63,792	$16,710,450	$82,601,610	$210,126,980	$353,477,740	$490,732,500
MDVs	$932,976	$77,464,140	$378,717,500	$948,308,620	$1,804,944,900	$2,828,280,000
Buses	$14,830,211	$107,554,440	$326,942,700	$583,588,050	$841,876,880	$1,032,959,340
Total	$170,558,828	$665,132,870	$2,255,882,690	$5,055,140,919	$8,769,681,006	$12,347,346,414

Table M-3: Maintenance expenditures for fuel cell electric vehicles in California by vehicle category over 5-year increments in 2020 US dollars, 2020-2045.

Vehicle Category	2020	2025	2030	2035	2040	2045
LDVs	$154,731,850	$463,403,840	$1,467,620,880	$3,313,117,269	$5,769,381,486	$7,995,374,574
HDVs	$63,792	$16,710,450	$82,601,610	$210,126,980	$353,477,740	$490,732,500
MDVs	$932,976	$77,464,140	$378,717,500	$948,308,620	$1,804,944,900	$2,828,280,000
Buses	$14,830,211	$107,554,440	$326,942,700	$583,588,050	$841,876,880	$1,032,959,340

Total	$170,558,828	$665,132,870	$2,255,882,690	$5,055,140,919	$8,769,681,006	$12,347,346,414

N – Data, Methods, and Results for Projecting Expenditures on New EVSE, EV Charging Infrastructure, and Hydrogen Refueling Infrastructure

We have attempted to disaggregate cost categories for construction of EVSE infrastructure to enable the use of input/output modeling for workforce impacts analysis. However, the ability to do so is constrained by the limits of existing literature and other public information, and by the fact that information from private actors in this sector is proprietary. Taking these factors into account, we classify EVSE expenditures by the following categories:

EVSE Material Categories

1. Charge Station Hardware: all EVSE-specific hardware, such as pedestals, EV charging cables, networking equipment, and other components.
2. Electrician Materials: non-EVSE-specific electrical hardware, including cables, conduits, breakers, and wiring. Does not include the cost of transformers, but does cover materials necessary for transformer installation.
3. Other Materials: all material costs not covered by other categories. Primarily materials related to general site construction (e.g. concrete, rebar).
4. Transformer: industrial transformer, for sites where power demand is sufficiently high that new transformer installation is required (i.e. DCFCs).

EVSE Labor Categories

1. Electrician Labor: specialized labor required for the installation of electrical equipment and charge station hardware.
2. Civil Engineering Labor: specialized labor required for the construction of charging stations and sites.
3. Contractor Labor: general construction labor required for tasks related to site construction, such as trenching and laying concrete.
4. Mobilization: costs related to construction labor at the outset of a project.
5. Permitting: costs related to the permitting and approval process for new EVSE sites.
6. Taxes: paid taxes by EVSE suppliers. Classified under labor as their workforce impact will be most applicable in labor resulted to tax processing.
7. Design: soft costs related to initial design of charging stations and sites.
8. Development: soft costs related to development of charging stations and sites.

Currently, hydrogen fueling infrastructure is in an even more nascent stage than EVSE. As such, publicly available high-resolution data on fueling station costs is scarce. We rely primarily on a cost breakdown for a Shell-Toyota heavy-duty hydrogen fueling station presented by Munster and Blieske in December 2018. In order to replicate our EVSE expenditure classification system to the greatest degree possible – for purposes related to its utility in input/output modeling – we further disaggregate some key categories using conservative assumptions. These latter assumptions carry substantial uncertainty, and are a key area where further academic study has the potential to increase accuracy of future hydrogen infrastructure cost forecasting.

We classify our hydrogen fueling infrastructure expenditures within the following categories:

Hydrogen Fueling Infrastructure Material Categories

1. Storage, Compression, and Thermal Management (SCTM) equipment: compressors and other equipment related to on-site production of hydrogen.
2. Dispensers: hydrogen dispensing equipment necessary for vehicle refueling.
3. Ground Storage: hardware necessary for ground storage of hydrogen.
4. Electrician Materials: wiring, utility upgrades, and other electrical hardware.
5. Other Materials: non-hydrogen-specific, non-electrical materials. Includes basic construction materials like concrete.

Hydrogen Fueling Infrastructure Labor Categories

1. Electrician Labor: specialized labor required for the installation of electrical equipment.
2. Hydrogen-Specific Labor: specialized labor required for the installation of hydrogen-related SCTM equipment, dispensers, and ground storage.
3. Civil Works: Construction-related civil engineering and contractor labor.
4. Mobilization: costs related to construction labor at the outset of a project.
5. Permitting: costs related to the permitting and approval process for new hydrogen fueling sites.
6. Design: soft costs related to initial design of hydrogen fueling stations.
7. Development: soft costs related to development of hydrogen fueling stations.

EVSE Per-Charger Costs: Data, Methods, and Assumptions

In the interest of clarity, we discuss our data sources and methods – along with key assumptions – organized by EVSE type. We examine four categories of EVSE: Level 1 home (L1-H), Level 2 home (L2-H), Level 2 public and workplace (L2-P), and DCFCs. Home charging refers to EVSE installed at EV owner residences, while L2-P includes both curbside and parking garage charge points. DCFCs are further segmented by power level; we consider 50 kW, 150 kW, and 350 kW charging points.

Level 1 Home

Level 1 charging is unique among the various categories considered in that no specialized charging hardware or equipment is required. Level 1 charging operates at 120 Volt power levels supplied by normal home outlets. However, in some cases, electrical upgrades may be necessary to provide a residence with the required capacity.

In the absence of definitive figures in this regard, we adopt a conservative assumption that 50% of L1-H chargers will require a new breaker installation. The overall cost of breaker installation is estimated at $750 in 2014 USD – the middling value of the $500 to $1000 cost range provided by RMI and published in that year. Based on figures from the Homewyse Circuit Breaker Installation Calculator online tool, we assume that 74% of this cost ($560) goes towards electrician labor and 26% ($190) goes towards electrician materials. Taking into account the 50% requirement assumption, the average cost per charge site is $280 for electrician materials and $95 for electrician labor.

Level 2 Home

We assessed cost components for L2-H chargers based on cost ranges published by RMI in 2014. We found middling values for the ranges in each of the applicable cost categories. Electrician materials and electrician labor costs were supplemented with costs for new breaker installation, using the same magnitude assumptions as for L1-H but with 100% necessity. These figures were then adjusted to 2020 USD (Table N-1).

Table N-1: Level 2 Home per-charger cost estimates by expenditure category.

Cost Category	RMI Cost Estimates ($/charger, 2014)			L2-H Final Cost Estimates ($/charger, 2020)
	Lower Bound	Upper Bound	Middling Value	
Charge Station Hardware	$450	$1,000	$725	$797.50
Electrician Materials	$240	$340	$290	$319.00
Electrician Labor	$660	$910	$785	$863.50
Mobilization	$50	$200	$125	$137.50
Permitting	$0	$100	$50	$55.00
Total	$1,400	$2,550	$1,975	$2,172.50

Level 2 Public/Workplace

Overall cost figures per charger, specific to California, are taken from Nicholas 2019. These provide 2019 USD amounts for charge station hardware, labor, materials, permitting, and taxes. Scaled cost estimates are provided based on the number of chargers located at a given site; we assume that a typical site will have four chargers, and therefore use Nicholas' cost estimates for 3-5 chargers/site.

To disaggregate material costs, we first identified middling values in the cost ranges for Level 2 parking garage (i.e. workplace) and curbside (i.e. public) chargers published by RMI, which are also utilized as a data source by Nicholas. We use these totals to calculate intra-category cost proportions – that is, the percentage of materials made up of electrician versus other materials, and the percentage of labor that is electrician labor versus other labor versus mobilization. As Nicholas' figures already isolate permitting and tax costs, these proportions are not included in our calculations of proportionate labor breakdown. Because Nicholas consolidates both public and workplace chargers into a single category, we then average the calculated cost proportions of both categories to produce a single, overall estimate. We assess the final proportionate costs of materials to be 83.6% electrician materials and 16.4% other materials. Within labor, 50% is assessed as electrician labor, 41.6% as other labor, and 8.4% as mobilization. Note that these are figures exclude the cost of the charge station hardware itself.

It is worth noting that the disparities in material proportions between public and workplace chargers are relatively small (80% vs 87.1% for electrician materials, respectively; 20% vs 12.9% for other materials, respectively), but the differences in proportionate cost of labor between the two are significant (Public: 25% electrician labor, 69.3% other labor, 5.7% mobilization; Workplace: 74.9% electrician labor, 13.9% other labor, 11.2% mobilization). This difference is likely driven by the greater propensity of public charge sites to require significant amounts of construction-related labor (e.g. trenching, pouring concrete).

We further disaggregate other labor costs into civil engineering labor and contractor labor, with 79.5% of other labor costs going towards the former and 20.5% towards the latter. The proportions utilized here are based on information in the Clean Corridors EVSE Job Creation working draft (CC draft), provided by Kevin Miller at ChargePoint (methodology explained in *DCFC* below). This data relates to the construction of DCFC stations, but in the absence of more definitive information we assume that proportionate expenditures across these two labor categories – independent of magnitude – are similar in the case of L2-P sites.

Finally, we supplement with figures for design and development soft costs. Once again, these estimates are made based on data from the CC draft (methods discussed below). We apply an arbitrary discount, assuming that L2-P sites would require roughly 80% of the design expenditures and 20% of the development expenditures compared to DCFC sites. This results in expenditures of $257.18 for design and $109.25 for development per charger.

Table N-2 shows the final cost estimates for L2-P chargers, along with intermediate steps.

DCFC

Our primary data source for DCFC costs is Michael Nicholas of ICCT, who provided us with higher-resolution cost estimates that underlie his 2019 publication (Table N-3). These figures cover costs for 50 kW, 150 kW, and 350 kW stations scaled to 1, 2, 3-5, and 6+ chargers per site. We assume that a typical site will possess four chargers, and therefore use the figures for 3-5 chargers per site. Nicholas' data provides us with per-charger costs for electrician labor, other labor, mobilization, electrician materials, other materials, permitting, taxes, and charge station hardware.

To disaggregate “other labor” we use proportionate labor figures derived from the CC draft. This document provides upper and lower bounds of civil engineering and contractor job hours necessary for a single DCFC site. We first take the middle value of these ranges (250 hours for civil engineering, 100 hours for contractor). Hours are translated to labor costs using California-specific hourly wage estimates calculated from annual wage figures in the Bureau of Labor Statistics’ Occupational Employment Statistics dataset. We assume 2080 hours worked annually. Resulting hourly wage estimates are $37.41/hour for civil engineering, $24.12/hour for construction laborers (contractors). Resulting labor costs per site are $9,352.50 and $2,412,00, respectively.

Due to ambiguity within the CC draft as to the number of chargers per site, and given that disparities exist in the overall magnitude of Nicholas’ “other labor” costs and the magnitude of labor costs in these two categories, we use the labor costs per site figures to calculate a proportionate breakdown of civil engineering versus contractor labor costs to apply to the “other labor” figure. This assumes that the entirety of “other labor” falls into these two labor categories. We estimate that 79.5% consists of civil engineering costs, with the remaining 20.5% accounted for by contractor costs. Applying these proportions to the “other labor” aggregate cost results in per-charger expenditure estimates of $6,956 for civil engineering labor and $1,794 for contractor labor.

As with L2-P sites, we incorporate design and development soft costs using information from the CC draft. In the same fashion as civil engineering and contractor labor costs, we take the middling value of the upper and lower bound of job hours per site: 38 hours for design, 50 hours for development. We then calculate labor costs using hourly wage figures calculated from BLS’ OES, using occupational wage data for Electrical and Electronics Drafters for design and Electrical Engineers for development. Resulting hourly wage estimates are $33.84/hour and $43.70/hour, respectively. We then calculate total labor costs per site ($1,285.92 and $2,185.00, respectively) and labor costs per charger therefrom, assuming four chargers per site ($321.48 and $546.25, respectively). Unlike the aforementioned labor categories, we assume that differences in soft costs are relatively static across sites with 2 or 4 chargers, negating concerns regarding the ambiguity of chargers per site assumptions in the CC draft. We also assume that these costs are independent of charger power level.

It is also necessary to address additional costs DCFC stations will incur for installation of new transformers to serve their power needs. We rely on Ribberink et al. 2017 for transformer cost estimates, as they provide figures for both the cost of the transformer itself and aggregated civil and electrical costs required for installation. These figures are delineated by cluster size: 200 kW, 600 kW, and 1600 kW, reflecting sites with four chargers at the 50 kW, 150 kW, and 350 kW power levels, respectively.

Table N-2: Level 2 Public/Workplace per-charger cost estimates by expenditure category.

Cost Category	Nicholas 2019 Cost Estimates ($/charger, 2019; 3-5 chargers/site)	Disaggregated Cost Categories	Disaggregating Proportions	Disaggregated Cost Estimates ($/charger, 2019)	L2-P Final Cost Estimates ($/charger, 2020)
Charge Station Hardware	$2,238	—	—	$2,238	$2,282.76
Materials	$1,014	Electrician Materials	83.6%	$848.64	$864.59
		Other Materials	16.4%	$166.36	$169.69
Labor	$1,491	Electrician Labor	50%	$744.84	$759.73
		Civil Engineering	33.1%	$493.15	$503.01
		Contractor	8.5%	$127.18	$129.73
		Mobilization	8.4%	$125.83	$128.35
		Design*	—	—	$257.18*
		Development*	—	—	$109.25*
Permitting	$110	—	—	$110	$112.20
Taxes	$128	—	—	$128	$130.56
Total	—	—	—	—	$5,447.05

**Soft costs calculated based on CC draft data, as outlined in text.*

Table N-3: DCFC per-charger cost estimates by expenditure category and power level. Provided by Michael Nicholas, ICCT.

Cost Category	Nicholas 2019 Cost Estimates by Charger Power Level ($/charger, 2019; 3-5 chargers/site)		
	50 kW	150 kW	350 kW
Charge Station Hardware	$28,401	$75,000	$140,000
Electrician Materials	$400	$420	$580
Other Materials	$200	$210	$290
Electrician Labor	$2,066.67	$2,170	$2,996.67
Other Labor	$8,333.33	$8,750	$12,083.33
Mobilization	$800	$840	$1,160
Permitting	$100	$105	$145
Taxes	$64	$67	$92

Table N-4: Transformer hardware and installation costs for DCFC station service by power level.

Cost Category	Ribberink et al. Cost Estimates by Cluster Power Level (Canadian $/cluster, 2017)			Adjusted Cost Estimates by Cluster Power Level (US $/cluster, 2020)			Disaggregated Cost Categories	Dis-aggregating Proportions	Disaggregated Cost Estimates by Cluster Power Level (US $/cluster, 2020)		
	200 kW	600 kW	1600 kW	200 kW	600 kW	1600 kW			200 kW	600 kW	1600 kW
Transformer	$14,000	$21,000	$41,000	$11,278.40	$16,917.60	$33,029.60	Transformer	—	$11,278.40	$16,917.60	$33,029.60
Civil & Electrical	$82,000	$82,000	$90,000	$66,059.92	$66,059.20	$72,504.00	Electrician Materials	10%	$6,605.92	$6,605.92	$7,250.40
							Other Materials	5%	$3,302.96	$3,302.96	$3,625.20
							Electrician Labor	15%	$9,908.88	$9,908.88	$10,875.60
							Civil Engineering	56%	$36,993.15	$36,993.15	$40,602.24
							Contractor	14%	$9,248.29	$9,248.29	$10,150.56

Disaggregated Cost Categories	Disaggregated Per-Charger Cost Estimates (US $/Charger, 2020)		
	50 kW*	150 kW	350 kW
Transformer	$1,409.80	$4,229.40	$8,257.40
Electrician Materials	$825.74	$1,651.48	$1,812.60
Other Materials	$412.87	$825.74	$906.30
Electrician Labor	$1,238.61	$2,477.22	$2,718.90
Civil Engineering	$4,624.14	$9,248.29	$10,150.56
Contractor	$1,156.04	$2,312.07	$2,537.64

**Assumes transformer installation required at 50% of 50 kW DCFC sites. Per-charger costs weighted accordingly.*

For transformer hardware costs, we simply convert Ribberink et al.'s figures from 2017 Canadian dollars to 2020 US dollars. The resulting estimates are comparable to listed retail prices for 480 V industrial transformers with the necessary specifications from a California-based manufacturer.

Regarding installation, we first repeat the currency conversion and inflation adjustment process with Ribberink et al.'s figures to produce a set of aggregated costs in 2020 US dollars. However, segmenting this overall amount into key materials and labor categories carries significant uncertainty. Neither a review of publicly available information nor outreach to multiple utilities provided us with definitive transformer installation cost data at this higher-resolution level. We therefore make informed estimates on the proportions of the overall cost that fall into each category, relying on general knowledge of related material and labor costs and observed cost trends in DCFC installation.

We first assume that 10% of overall installation costs goes towards electrician materials (e.g. cables, conduits) and an additional 5% goes towards other materials (e.g. concrete, other construction materials). This mirrors patterns seen in DCFC cost estimates, where labor constitutes the vast majority of overall costs when charge station hardware is not considered – an omission replicated here by transformer hardware costs being addressed separately. For the remaining 85% assessed as labor costs, we apply two breakdowns based on patterns consistent in DCFC installation estimates. First, we assume a 5:1 other labor:electrician labor breakdown, resulting in 15% of the overall transformer installation costs going towards electrician labor and 70% towards other labor. We apply our second breakdown – a 4:1 civil engineering:contractor labor cost ratio – to this 70% other labor figure. The resulting estimate is that 56% of overall transformer installation costs go towards civil engineering labor and 14% towards contractor labor.

These percentile figures are applied to the original aggregate installation cost estimates derived from Ribberink et al. We then quarter both the transformer hardware costs and these disaggregated installation costs to produce per-charger costs, reflecting the underlying assumption of four chargers per site. We assume that new transformer installation will occur at 100% of 150 kW and 350 kW sites, but only 50% of 50 kW sites. Therefore, we halve the per-charger costs for 50 kW sites. The resulting final breakdown of transformer installation costs by site power level, along with intermediate steps and hardware costs is shown in Table N-4.

As the final step to create a single set of cost estimates per DCFC charger, we calculate average values for each expenditure category weighted by power level proportion. We assume proportionate representation of power levels consistent with ICCT's future year scenarios: 44.4% 50 kW, 44.4% 150 kW, and 11.2% 350 kW. These values serve as the weights for their respective power level categories, producing an economy-wide average cost estimate for each expenditure category per DCFC (Table N-5).

Table N-5: Per-charger DCFC cost estimates by cost category and power level, including weighted average for "typical" DCFC site. All figures adjusted to 2020 US dollars. Includes costs of transformer hardware and installation.

Cost Category	Per-Charger Cost Estimates by Charger Power Level* ($/Charger, 2020; 4 chargers/site)			Weighted Per-Charger Cost Estimates by Charger Power Level****			Weighted Average Per-Charger DCFC Costs ($/Charger, 2020; 4 chargers/site)
	50 kW	150 kW	350 kW	50 kW (44.4%)	150 kW (44.4%)	350 kW (11.2%)	
Charge Station Hardware	$28,969	$76,500	$142,800	$12,862.24	$33,966.00	$15,993.60	$62,821.84
Transformer	$1,409.80	$4,229.40	$8,257.40	$625.95	$1,877.85	$924.83	$3,428.63
Electrician Materials	$1,233.74	$2,079.88	$2,404.20	$547.78	$923.47	$269.27	$1,740.52
Other Materials	$616.87	$1,039.94	$1,202.10	$273.89	$461.73	$134.64	$870.26
Electrician Labor	$3,346.95	$4,690.62	$5,775.84	$1,486.05	$2,082.64	$646.89	$4,215.58
Civil Engineering**	$11,381.64	$16,343.41	$19,948.68	$5,053.45	$7,256.47	$2,234.25	$14,544.18
Contractor**	$2,899.22	$4,141.95	$5,064.18	$1,287.25	$1,839.03	$567.19	$3,693.47
Mobilization	$816	$856.80	$1183.20	$362.30	$380.42	$132.52	$875.24
Design***	$321.48	$321.48	$321.48	$142.74	$142.74	$36.01	$321.48
Development***	$546.25	$546.25	$546.25	$242.54	$242.54	$61.18	$546.25
Permitting	$102	$107.10	$147.90	$45.29	$47.55	$16.56	$109.41
Taxes	$65.28	$68.34	$93.84	$28.98	$30.34	$10.51	$69.84
Total	$51,708.25	$110,925.17	$187,745.07	$22,958.46	$49,250.78	$21,027.45	$93,236.69

**Incorporates per-charger costs from Nicholas 2019 (Table 3), adjusted to 2020 US dollars, and per-charger cost estimates of transformer hardware and installation (Table 4).*
***Subcategory cost estimates disaggregated from "Other Labor" for Nicholas data and transformer data as outlined in text.*
****Soft costs calculated based on CC draft data, as outlined in text.*
*****Power levels weighted according to ICCT future scenario representation estimates: 44.4% 50 kW, 44.4% 150 kW, 11.2% 350 kW.*

EVSE Annual Expenditure Estimates: Data, Methods, Assumptions, and Results

Having produced per-charger cost estimates in the relevant material and labor categories for each context and power level, we now calculate total annual expenditures from 2021-2045 for charger installation. Doing so requires an estimate of how many chargers will be installed in California for each year under consideration.

For this information we depend on forecasts from UC ITS teams studying the future of California's light- and heavy-duty vehicle sectors as part of the Carbon Neutrality Studies authorized under AB74. The forecast data for EVSE serving LDVs considers forecasted EV sales figures, charging behavior and EV adoption patterns, and related factors under the study's low-carbon scenario to project the number of chargers necessary to supply the state's EV LDV fleet in each year (Table N-6). We simply calculate the year-over-year difference (YoYD) in number of required chargers to estimate the number of chargers installed in a given year by type.

The heavy-duty team has produced a similar set of required charger estimates to serve the needs of the state's EV medium- and heavy-duty vehicles. These estimates were calculated in two subsets: chargers serving Class 2B/3 vehicles, and those serving Class 4-8 vehicles. EVSE estimates for these two vehicle classes have been summed to create a single set of estimates covering the entire heavy-duty sector. We utilize estimates assuming a 1:2 charger:vehicle ratio – a middle-of-the-road scenario. In contrast to LDV-serving EVSE, chargers serving this sector fall into only two categories: L2-P and DCFC (Table N-7). Unlike the forecasts of LDV-serving EVSE, the heavy-duty forecasts are provided in 5-year increments. In calculating year-over-year installation requirements, we again calculate year-over-year differences in required charger numbers, assuming that installations taking place within each increment are evenly spread across all five years.

We then combine the required installation numbers for L2-P chargers and DCFCs from both vehicle sectors, creating a single, economy-wide figure for year-over-year installations (Table N-8). This assumes there is no significant variation in the costs incurred in constructing charging sites for the difference vehicle classes.

Finally, we multiply the per-charger cost figures by the number of installations in each setting and power level category to produce yearly state-wide expenditure estimates (Table N-9, Figure N-1).

Table N-6: Estimates of EVSE required to serve California's light-duty sector by year, 2020-2045, and annual installation requirement estimates calculated therefrom.

Year	L1-H Chargers	L1-H YoYD	L2-H Chargers	L2-H YoYD	L2-P* Chargers	L2-P YoYD	DCFC Chargers	DCFC YoYD
2020	70,485	—	199,749	—	49,985	—	5,498	—
2021	96,095	25,611	270,504	70,755	77,312	27,327	8,386	2,888
2022	129,411	33,316	361,261	90,756	103,042	25,730	11,237	2,852
2023	172,109	42,698	475,438	114,177	125,956	22,914	13,950	2,713
2024	225,849	53,740	615,736	140,298	145,342	19,386	16,454	2,504
2025	292,115	66,266	783,586	167,850	160,053	14,711	18,627	2,174
2026	372,652	80,537	980,393	196,807	216,730	56,676	23,086	4,459
2027	468,663	96,011	1,205,328	224,935	300,973	84,243	29,641	6,555
2028	580,839	112,176	1,455,804	250,476	418,708	117,736	38,530	8888
2029	709,253	128,415	1,727,570	271,767	580,091	161,383	50,411	11,881
2030	852,955	143,701	2,013,996	286,426	789,905	209,813	65,449	15,038
2031	1,009,127	156,172	2,304,468	290,472	1,029,962	240,057	81,907	16,458
2032	1,176,953	167,826	2,593,641	289,173	1,314,173	284,211	100,986	19,079
2033	1,355,766	178,813	2,876,965	283,324	1,644,124	329,951	122,741	21,755
2034	1,546,006	190,240	3,153,227	276,263	2,022,316	378,192	147,302	24,561
2035	1,748,966	202,961	3,424,359	271,131	2,451,561	429,244	174,791	27,489
2036	1,966,081	217,115	3,694,167	269,808	2,932,643	481,083	205,214	30,423
2037	2,197,405	231,324	3,965,597	271,430	3,466,837	534,193	238,535	33,321
2038	2,440,748	243,343	4,239,197	273,600	4,056,022	589,185	274,822	36,287
2039	2,691,040	250,292	4,512,005	272,808	4,703,220	647,198	314,325	39,502
2040	2,938,099	247,059	4,774,147	262,142	5,359,804	656,584	352,932	38,607
2041	3,171,116	233,017	5,015,741	241,594	5,996,166	636,362	388,014	35,082
2042	3,380,542	209,426	5,228,826	213,085	6,608,337	612,171	419,706	31,692
2043	3,559,065	178,523	5,407,804	178,978	7,193,827	585,491	448,278	28,572
2044	3,703,079	144,014	5,550,662	142,858	7,748,747	554,919	473,808	25,529
2045	3,813,941	110,862	5,660,232	109,570	8,287,898	539,151	497,771	23,963

**L2-P numbers represent sum of Level 2 Public and Level 2 Workplace charger figures.*

Table N-7: Estimates of EVSE required to serve California's heavy-duty sector by 5-year period, 2020-2045, and 5-year and annual installation requirements calculated therefrom.

Year	L2-P Chargers	L2-P 5-Year Difference	L2-P Annual Installations (5-Year Period)	DCFC Chargers	DCFC 5-Year Difference	DCFC Annual Installations (5-Year Period)
2020	113	—	—	48	—	—
2025	8,246	8,133	1,626.6	4,441	4,393	878.6
2030	37,357	29,111	5,822.2	23,955	19,514	3,902.8
2035	94,200	56,843	11,368.6	60,292	36,337	7,267.4
2040	192,220	98,020	19,604	107,940	47,648	9,529.6
2045	297,869	105,649	21,129.8	154,099	46,159	9,231.8

Table N-8: Estimates of annual EVSE installations in California by type, 2021-2045.

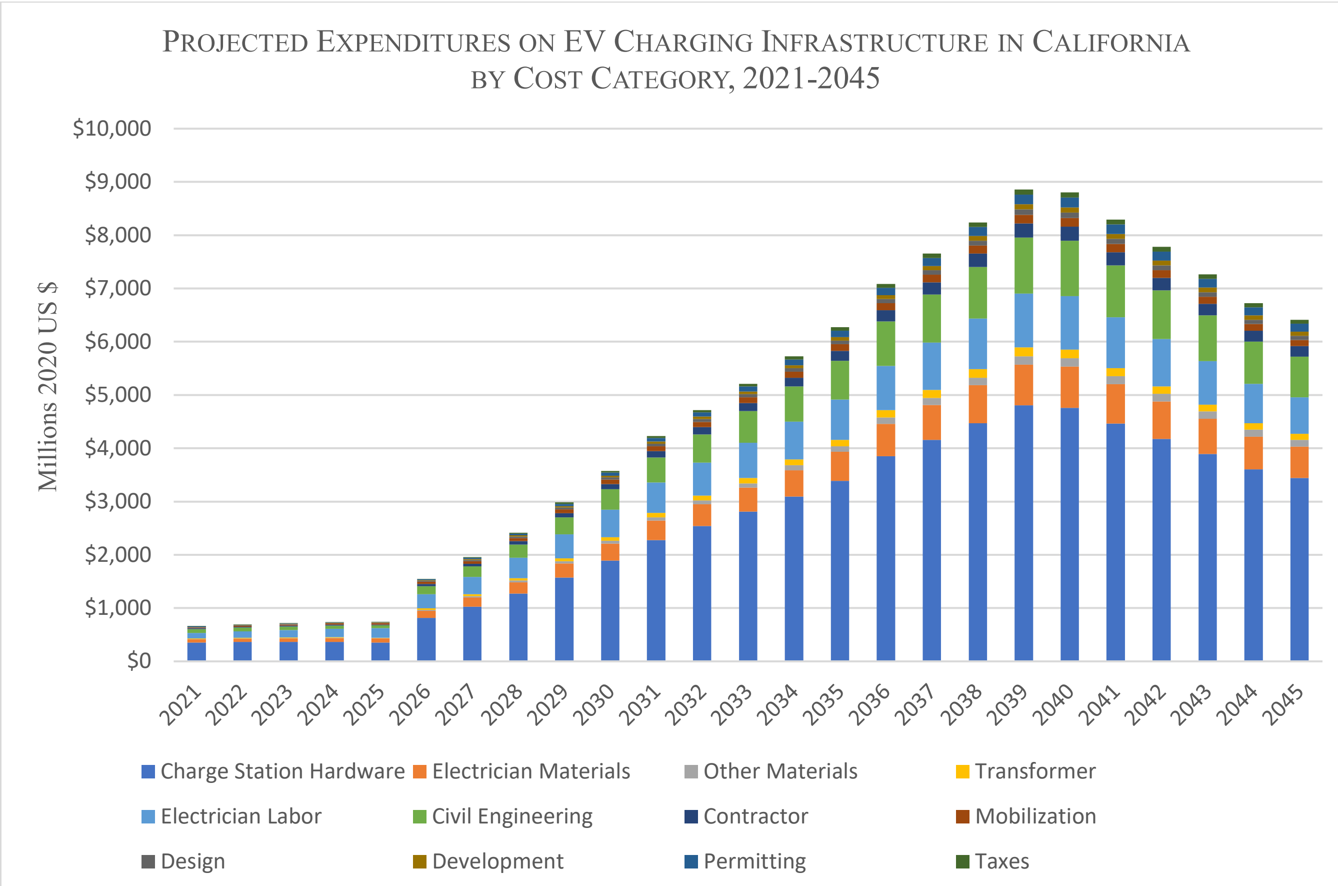
Year	L1-H Installations	L2-H Installations	L2-P Installations	DCFC Installations
2021	25,611	70,755	28,953.7	3,766.5
2022	33,316	90,756	27,356.7	3,730.6
2023	42,698	114,177	24,540.7	3,591.4
2024	53,740	140,298	21,012.4	3,382.1
2025	66,266	167,850	16,338.0	3,052.1
2026	80,537	196,807	62,498.7	8,361.8
2027	96,011	224,935	90,064.8	10,458.0
2028	112,176	250,476	123,557.9	12,791.1
2029	128,415	271,767	167,205.1	15,783.6
2030	143,701	286,426	215,635.6	18,941.3
2031	156,172	290,472	251,426.1	23,725.4
2032	167,826	289,173	295,579.7	26,346.6
2033	178,813	283,324	341,319.5	29,022.5
2034	190,240	276,263	389,561.0	31,828.4
2035	202,961	271,131	440,612.9	34,756.1
2036	217,115	269,808	500,686.5	39,953.0
2037	231,324	271,430	553,797.4	42,850.2
2038	243,343	273,600	608,789.3	45,816.8
2039	250,292	272,808	666,801.8	49,031.9
2040	247,059	262,142	676,188.4	48,137.0
2041	233,017	241,594	657,491.6	44,314.2
2042	209,426	213,085	633,300.3	40,923.5
2043	178,523	178,978	606,620.5	37,804.2
2044	144,014	142,858	576,049.1	34,761.0
2045	110,862	109,570	560,281.2	33,195.2

Table N-9: Total projected expenditures on construction of EV charging infrastructure and installation of EVSE in California by cost category, 2021-2045. Includes all charging levels across infrastructure serving all vehicle sectors.

	Materials				Labor								Total
YEAR	Charge Station Hardware	Electrician Materials	Other Materials	Transformer	Electrician Labor	Civil Engineering	Contractor	Mobilization	Design	Development	Permitting	Taxes	
2021	$355,035,237	$55,194,519	$8,190,974	$12,913,876	$102,417,041	$69,344,394	$17,667,424	$16,034,060	$7,691,370	$4,427,153	$8,235,123	$4,836,720	$661,987,891
2022	$363,925,778	$60,472,733	$7,888,748	$12,790,828	$119,440,271	$68,019,121	$17,327,700	$18,347,792	$8,528,307	$4,216,143	$7,812,865	$4,642,645	$693,412,930
2023	$366,072,159	$65,704,022	$7,289,750	$12,313,562	$138,356,750	$64,578,062	$16,448,253	$20,850,655	$9,391,569	$3,838,757	$7,043,869	$4,258,952	$716,146,361
2024	$364,187,963	$71,169,804	$6,508,911	$11,596,054	$159,110,221	$59,759,625	$15,217,607	$23,545,124	$10,304,989	$3,363,485	$6,069,166	$3,759,170	$734,592,119
2025	$353,159,504	$76,012,674	$5,428,525	$10,464,549	$180,086,104	$52,608,571	$13,392,321	$26,169,120	$11,149,537	$2,730,158	$4,760,912	$3,068,229	$739,030,205
2026	$813,513,030	$135,221,344	$17,882,351	$28,669,593	$265,121,301	$153,053,243	$38,991,800	$40,433,133	$19,636,163	$10,479,065	$17,090,002	$9,660,348	$1,549,751,372
2027	$1,028,924,378	$172,640,121	$24,384,247	$35,856,549	$322,188,007	$197,406,196	$50,309,935	$49,392,055	$24,392,898	$14,224,485	$24,853,434	$13,816,970	$1,958,389,277
2028	$1,270,840,729	$214,903,293	$32,098,137	$43,856,001	$382,899,419	$248,187,125	$63,272,221	$58,989,424	$29,708,701	$18,760,294	$34,217,398	$18,750,573	$2,416,483,316
2029	$1,574,217,384	$265,843,388	$42,108,908	$54,116,293	$450,723,641	$313,666,055	$79,987,218	$69,925,184	$36,019,128	$24,667,858	$46,404,789	$25,153,695	$2,982,833,540
2030	$1,893,983,164	$319,145,506	$53,075,070	$64,942,760	$517,275,184	$383,952,755	$97,932,644	$80,773,903	$42,546,109	$31,211,466	$59,875,463	$32,169,600	$3,576,883,624
2031	$2,279,223,360	$360,916,517	$63,311,778	$81,345,731	$571,715,097	$471,536,764	$120,245,573	$90,070,716	$48,809,260	$37,703,124	$69,100,510	$37,208,286	$4,231,186,718
2032	$2,543,722,784	$404,487,090	$73,085,335	$90,332,833	$618,859,114	$531,869,629	$135,654,741	$97,866,274	$53,983,810	$43,650,884	$81,298,787	$43,463,900	$4,718,275,179
2033	$2,811,914,320	$448,108,785	$83,175,628	$99,507,437	$663,590,620	$593,795,699	$151,471,654	$105,333,248	$59,110,295	$49,809,543	$93,922,562	$49,922,666	$5,209,662,456
2034	$3,093,088,263	$493,806,864	$93,803,601	$109,127,868	$709,934,969	$658,871,355	$168,093,370	$113,080,433	$64,469,824	$56,303,909	$107,231,545	$56,725,777	$5,724,537,777
2035	$3,389,759,133	$542,853,118	$105,014,495	$119,166,024	$760,872,448	$727,132,642	$185,529,656	$121,541,108	$70,256,466	$63,173,707	$121,302,480	$63,902,473	$6,270,503,751
2036	$3,852,388,540	$604,924,964	$119,730,995	$136,984,055	$831,719,757	$832,934,035	$212,517,113	$133,631,156	$79,171,538	$72,282,104	$136,749,388	$72,402,047	$7,085,435,692
2037	$4,156,836,012	$657,851,512	$131,264,716	$146,917,535	$889,958,786	$901,787,003	$230,107,748	$143,190,466	$85,530,297	$79,418,596	$151,340,056	$79,787,014	$7,653,989,740
2038	$4,470,342,398	$712,458,155	$143,178,029	$157,088,995	$949,683,059	$972,595,644	$248,198,759	$153,121,707	$92,135,600	$86,805,519	$166,436,802	$87,415,396	$8,239,460,063
2039	$4,804,164,175	$768,703,100	$155,820,152	$168,112,401	$1,008,817,000	$1,048,537,621	$267,599,376	$163,280,548	$98,955,974	$94,604,166	$182,390,282	$95,509,512	$8,856,494,307
2040	$4,761,483,288	$771,768,316	$156,634,146	$165,044,019	$1,002,640,052	$1,040,243,192	$265,511,674	$162,342,164	$99,367,297	$95,767,181	$184,516,663	$96,046,143	$8,801,364,136
2041	$4,463,454,488	$741,404,017	$150,134,695	$151,937,177	$951,542,127	$975,239,600	$248,966,972	$153,976,679	$95,961,369	$92,884,767	$178,321,148	$92,089,728	$8,295,912,766
2042	$4,174,137,033	$703,688,551	$143,078,851	$140,311,594	$888,775,940	$913,755,660	$233,305,160	$144,269,169	$91,422,185	$89,489,549	$171,009,476	$87,594,638	$7,780,837,807

2043	**$3,892,054,210**	**$661,874,122**	**$135,836,986**	**$129,616,842**	**$818,529,454**	**$854,968,502**	**$218,323,246**	**$133,766,097**	**$86,347,974**	**$85,788,384**	**$163,145,062**	**$82,975,973**	**$7,263,226,851**
2044	**$3,604,374,003**	**$615,855,170**	**$128,000,919**	**$119,182,646**	**$742,924,288**	**$795,329,186**	**$203,117,195**	**$122,573,479**	**$80,742,819**	**$81,584,461**	**$154,304,266**	**$77,973,681**	**$6,725,962,112**
2045	**$3,445,395,023**	**$586,185,992**	**$123,962,576**	**$113,814,011**	**$687,479,386**	**$764,624,098**	**$195,288,357**	**$114,934,980**	**$77,104,649**	**$79,416,441**	**$149,745,613**	**$75,395,699**	**$6,413,346,826**

Figure N-1: Total projected expenditures on construction of EV charging infrastructure and installation of EVSE in California by cost category, 2021-2045. Includes all charging levels across infrastructure serving all vehicle sectors.



Hydrogen Refueling Station Expenditures: Data, Methods, Assumptions, and Results

Our approach to estimating expenditures on hydrogen refueling stations in California fundamentally differs from that used for estimating EVSE expenditures. Whereas in calculating EVSE costs we follow a "bottom-up" approach – estimating per-charger costs in the relevant material and labor categories independent of each other – hydrogen station costs rely on capital expenditure (CapEx) costs per kg/day of station capacity. From the resulting overall cost figures we disaggregate the various cost categories based on proportional cost breakdowns and, where necessary, conservative assumptions.

The first step is calculating state-wide required daily hydrogen refueling capacity in each year under consideration. Here we rely on annual hydrogen fuel consumption forecasts for both the light- and heavy-duty vehicle sectors from the CNS LC1 scenario. These figures were produced in GGE; we convert these numbers to kg using a conversion ratio of 0.96525 kg/GGE, consistent with CARB's LCS. We then divide kg of annual consumption by 365.25 to estimate mean daily consumption.

However, infrastructure that merely delivers the bare minimum of required daily capacity is insufficient, due to fluctuations in daily demand, high-travel periods, and other factors. We therefore adjust our mean daily consumption estimates upwards, assuming a utilization rate of 80% in the light-duty sector – consistent with assumptions for the "larger stations" category in the NREL HSCC (Melaina and Penev 2013) – and a middle-of-the-road value of 50% for the heavy-duty sector. Summing the resulting sector-specific figures produces an estimate of total state-wide required daily hydrogen refueling capacity, by year. Calculating the year-over-year difference (YoYD) in required daily capacity provides an estimate of how much new capacity must be built in a given year. Finally, we multiply these numbers by a CapEx conversion rate of $3,707 per kg/day. This CapEx per capacity figure is for "larger stations" (1,500 kg/day) – the largest station size for which concrete CapEx estimates have been identified – and has been adjusted for inflation since being derived from the NREL HSCC (Melaina and Penev 2013). The resulting annual expenditure estimates, along with intermediate steps, are shown in Tables N-10 and N-11.

To disaggregate these overall cost estimates into key material and labor categories, we primarily rely on a CapEx breakdown for a first-generation Shell-Toyota heavy-duty hydrogen refueling station presented by Shell Global Hydrogen (SGH) in 2018 (Figure N-2) – the only hydrogen station cost breakdown with the necessary level of resolution identified at time of writing (Munster and Blieske 2018).

Table N-10: Projected annual hydrogen fuel consumption, daily hydrogen refueling capacity requirements, required yearly capacity expansion, and yearly capital expenditure requirements for hydrogen refueling infrastructure serving light-duty vehicles in California, 2020-2045.

Year	LDV H_2 Consumption (Million GGE)	LDV H_2 Consumption (Million kg)	Mean Daily Consumption (kg/day)	Req. Daily Capacity (kg/day; 80% Util)	Daily Capacity YoYD (kg/day)	Annual CapEx (2020 US $)
2020	1.61	1.56	4,265	5,331	—	—
2021	3.23	3.12	8,532	10,665	5,334	$19,771,774
2022	5.89	5.69	15,573	19,466	8,802	$30,956,460
2023	9.62	9.29	25,427	31,784	12,317	$43,783,835
2024	14.28	13.78	37,729	47,162	15,378	$54,770,745
2025	19.96	19.27	52,752	65,940	18,778	$66,986,629
2026	28.82	27.82	76,164	95,205	29,265	$105,443,903
2027	40.83	39.41	107,906	134,883	39,678	$143,330,745
2028	55.66	53.72	147,089	183,861	48,978	$176,911,150
2029	73.05	70.51	193,048	241,311	57,450	$207,330,986
2030	92.77	89.55	245,177	306,472	65,161	$234,893,532
2031	114.91	110.91	303,661	379,577	73,105	$263,309,043
2032	139.52	134.67	368,708	460,885	81,308	$292,670,355
2033	166.36	160.58	439,643	549,554	88,669	$318,894,800
2034	195.20	188.41	515,844	644,805	95,251	$342,234,599
2035	225.80	217.95	596,719	745,899	101,094	$362,850,276
2036	256.52	247.60	677,896	847,370	101,471	$363,232,106
2037	287.34	277.35	759,355	949,194	101,824	$363,638,373
2038	318.22	307.16	840,956	1,051,195	102,002	$363,486,149
2039	349.06	336.93	922,459	1,153,074	101,879	$362,300,496
2040	379.78	366.58	1,003,648	1,254,560	101,486	$360,188,659
2041	408.95	394.74	1,080,747	1,350,933	96,373	$340,645,918
2042	436.69	421.51	1,154,037	1,442,547	91,614	$322,530,308
2043	463.05	446.96	1,223,699	1,529,624	87,077	$305,339,542
2044	488.07	471.11	1,289,827	1,612,284	82,660	$288,672,364
2045	511.78	494.00	1,352,489	1,690,611	78,328	$272,394,652

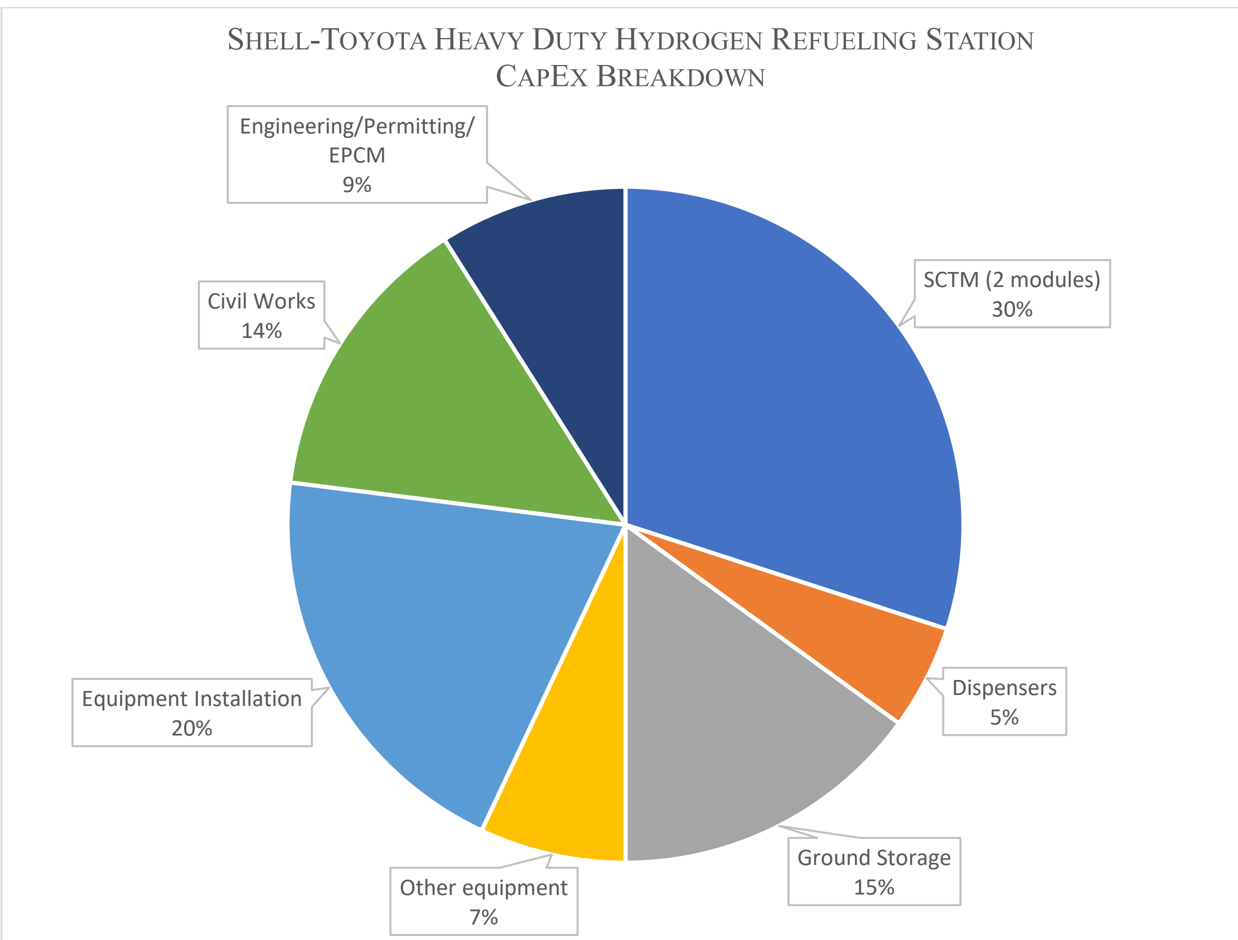
Table N-11: Projected annual hydrogen fuel consumption, daily hydrogen refueling capacity requirements, required yearly capacity expansion, and yearly capital expenditure requirements for hydrogen refueling infrastructure serving trucks (MDVs and HDVs) in California, 2020-2045.

Year	Truck H_2 Consumption (Million GGE)	Truck H_2 Consumption (Million kg)	Mean Daily Consumption (kg/day)	Req. Daily Capacity (kg/day; 50% Util)	Daily Capacity YoYD (kg/day)	Annual CapEx (2020 US $)
2020	0.01	0.01	29	59	—	—
2021	0.90	0.87	2388	4776	4,718	$17,488,832
2022	2.62	2.53	6915	13831	9,054	$32,815,534
2023	5.12	4.94	13522	27044	13,213	$47,649,230
2024	8.27	7.99	21866	43732	16,688	$59,959,889
2025	11.99	11.57	31685	63371	19,639	$70,368,522
2026	20.94	20.21	55327	110653	47,282	$172,352,533
2027	34.98	33.77	92446	184891	74,238	$270,835,297
2028	53.86	51.99	142347	284694	99,802	$363,592,239
2029	77.08	74.41	203712	407424	122,730	$446,234,766
2030	104.18	100.56	275330	550659	143,236	$519,733,460
2031	135.95	131.22	359264	718527	167,868	$608,465,706
2032	172.04	166.06	454643	909287	190,760	$690,603,129
2033	211.89	204.53	559970	1119940	210,653	$761,553,612
2034	255.01	246.15	673917	1347834	227,893	$822,665,385
2035	300.92	290.46	795232	1590463	242,630	$874,545,537
2036	351.22	339.02	928180	1856360	265,897	$958,132,364
2037	405.62	391.53	1071944	2143889	287,529	$1,035,586,453
2038	463.65	447.54	1225286	2450573	306,684	$1,103,822,821
2039	524.80	506.57	1386904	2773808	323,235	$1,162,417,276
2040	588.63	568.18	1555581	3111161	337,353	$1,212,031,671
2041	647.72	625.22	1711745	3423491	312,329	$1,116,615,328
2042	701.89	677.50	1854895	3709789	286,299	$1,018,020,697
2043	750.88	724.79	1984359	3968718	258,929	$914,958,180
2044	795.14	767.51	2101335	4202670	233,952	$821,214,100
2045	835.05	806.04	2206805	4413610	210,940	$735,125,495

We further disaggregate SGH's "Other Equipment," "Equipment Installation," and "Engineering, Permitting, and EPCM" categories using a number of informed and conservative, albeit uncertain, assumptions:

1. A 50-50 split of "Other Equipment" into Electrician Materials and Other Materials
2. A 50-50 split of "Equipment Installation" into Electrician Labor and Hydrogen-Specific Labor.
3. "Engineering, Permitting, and EPCM" costs are accounted for within four categories: Permitting, Mobilization, Design, and Development.
4. Fixed Permitting costs of $1,000 per station, on average.
5. Mobilization accounts for 2% of overall CapEx, similar to proportionate mobilization costs for DCFC stations.
6. The ratio of Design:Development costs is 3:5, split from the remaining "Engineering, Permitting, and EPCM" once Permitting and Mobilization costs are deducted.

Figure N-1: CapEx breakdown of a first-generation Shell-Toyota heavy duty hydrogen refueling station. Reproduced from Munster & Blieske (2018), copyright Shell New Energies.



Unlike the other cost categories, our treatment of Permitting as a fixed cost on a per-station basis necessitates estimating the distinct number of stations. To do so, we divide required daily capacity by approximate mean economy-wide station capacity. In calculating the latter we rely on a working paper provided by Vishnu Vijayakumar and Lewis Fulton at the University of California Davis, who project the number of 1,500 kg/day and 5,000 kg/day hydrogen refueling stations in California in 2025, 2030, and 2035. We do not rely on these numbers for assessing total number of stations; rather, we assume that the proportionate numbers of these two station sizes reflect economy-wide trends in terms of how overall capacity is accounted for among stations of differing sizes. We therefore calculate the ratio of 1,500 kg/day stations to 5,000 kg/day stations in each of the three noted years, then use a best-fit power function to calculate this ratio for each year, 2021-2045 (Table N-12). This function reflects a scenario wherein a greater proportion of state-wide capacity is accounted for by smaller stations early on, with larger stations supplying greater portions over time in an asymptotic fashion.

Dividing required daily capacity by mean station capacity produces an estimate of how many existing stations will be needed within the state in a given year (Table N-12). The resulting figures in the earliest years considered (pre-2025) are not an accurate reflection of reality; California is already home to several dozen hydrogen stations. However, this discrepancy is explained by significant differences between assumptions regarding future conditions and current utilization rates (~36% in 2018) and capacity (60-500 kg/day). These present-day figures are almost certainly not representative of long-term market conditions. Therefore, while our estimates on station numbers carry substantial uncertainty, we believe them to be reasonable over the long term. Moreover, it is worth reiterating that our estimate of the number of individual stations pertains only to the Permitting costs involved in station construction – a relatively minute category. The consequent impacts of variation in this category on others disaggregated from the "Engineering, Permitting, and EPCM" SGH classification are similarly small.

With annual figures for existing hydrogen refueling stations in hand, we calculate the year-over-year difference to estimate the number of stations built in a given year. This number is used to calculate Permitting costs, after which we proceed with the proportionate disaggregation approach outlined above. Table N-13 and Figure N-3 show the final annual expenditure breakdown.

Table N-12: Projected estimates on mean hydrogen refueling station capacity and total existing hydrogen refueling stations in California by year, 2021-2045.

Year	Vijayakumar & Fulton Station Estimates		Calculated Best-Fit Station Ratio* (1,500:5,000 kg/day)	Projected Mean Station Capacity (kg/day)	Total Req. Daily Capacity (kg/day)	Estimated Existing Stations
	1,500 kg/day	5,000 kg/day				
2021			5.45	2,042	15,441	8
2022			4.57	2,129	33,297	16
2023			4.12	2,184	58,828	27
2024			3.82	2,225	90,894	41
2025	89	24	3.61	2,259	129,311	57
2026			3.45	2,287	205,858	90
2027			3.31	2,311	319,774	138
2028			3.20	2,333	468,554	201
2029			3.11	2,352	648,734	276
2030	349	124	3.02	2,370	857,131	362
2031			2.95	2,386	1,098,104	460
2032			2.89	2,400	1,370,172	571
2033			2.83	2,414	1,669,495	692
2034			2.78	2,427	1,992,639	821
2035	847	297	2.73	2,439	2,336,362	958
2036			2.68	2,451	2,703,730	1,103
2037			2.64	2,461	3,093,083	1,257
2038			2.60	2,472	3,501,768	1,417
2039			2.57	2,481	3,926,882	1,583
2040			2.53	2,491	4,365,721	1,753
2041			2.50	2,500	4,774,424	1,910
2042			2.47	2,508	5,152,336	2,054
2043			2.44	2,516	5,498,342	2,185
2044			2.42	2,524	5,814,954	2,304
2045			2.39	2,532	6,104,222	2,411

**Ratio calculated using best-fit power function applied to Vijayakumar & Fulton's estimates in 2025, 2030, and 2035. Equation takes the form of $R = 5.454x^{-0.256}$, where R is the ratio of 1,500 kg/day stations to 5,000 kg/day stations and x is a reference number to the year (x = 1 in 2021, x = 25 in 2045).*

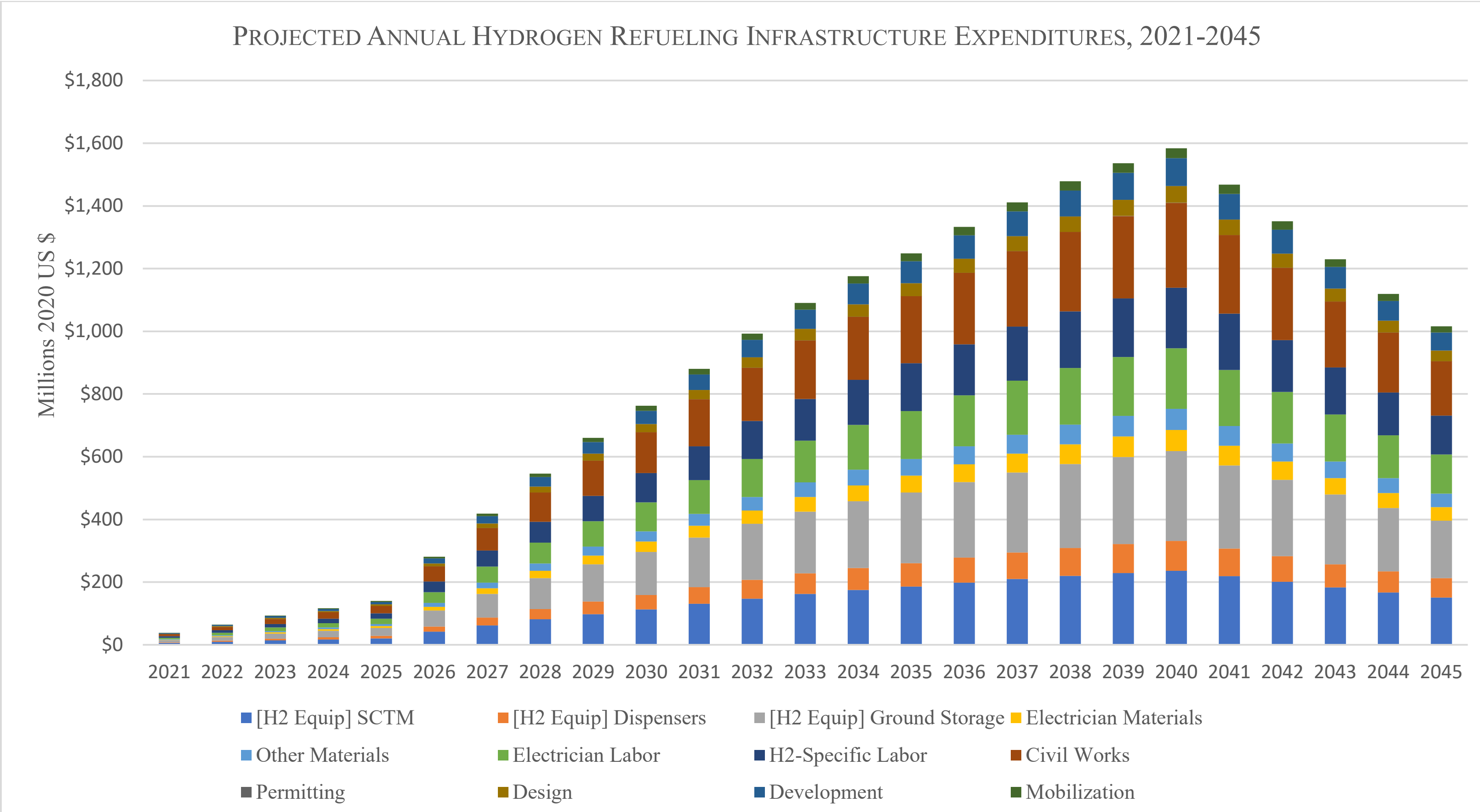
Table N-13: Projected annual estimates for expenditures on hydrogen refueling infrastructure in California by cost category, 2021-2045. All figures in 2020 US dollars.

YEAR	Materials						Labor							TOTAL
	All Hydrogen Equipment*	[H2 Equip] SCTM	[H2 Equip] Dispensers	[H2 Equip] Ground Storage	Electrician Materials	Other Materials	Electrician Labor	H2-Specific Labor	Civil Works	Permitting	Design	Development	Mobilization	
2021	$14,638,095	$5,589,091	$2,262,251	$6,786,753	$1,627,802	$1,627,802	$4,650,863	$4,650,863	$6,511,208	$5,059	$1,280,510	$2,134,183	$766,025	$37,892,411
2022	$25,053,283	$9,565,799	$3,871,871	$11,615,613	$2,779,554	$2,779,554	$7,941,584	$7,941,584	$11,118,218	$8,288	$2,186,667	$3,644,445	$1,308,026	$64,761,204
2023	$35,920,133	$13,714,960	$5,551,293	$16,653,880	$3,983,843	$3,983,843	$11,382,408	$11,382,408	$15,935,371	$11,578	$3,134,190	$5,223,650	$1,874,750	$92,832,173
2024	$45,072,749	$17,209,595	$6,965,788	$20,897,365	$4,998,565	$4,998,565	$14,281,615	$14,281,615	$19,994,262	$14,257	$3,932,599	$6,554,332	$2,352,266	$116,480,826
2025	$53,960,952	$20,603,273	$8,339,420	$25,018,260	$5,987,432	$5,987,432	$17,106,950	$17,106,950	$23,949,730	$16,825	$4,710,681	$7,851,134	$2,817,615	$139,495,701
2026	$109,134,314	$41,669,465	$16,866,212	$50,598,637	$12,042,210	$12,042,210	$34,406,314	$34,406,314	$48,168,840	$33,422	$9,474,502	$15,790,836	$5,666,922	$281,165,884
2027	$162,708,088	$62,124,906	$25,145,795	$75,437,386	$17,922,665	$17,922,665	$51,207,614	$51,207,614	$71,690,660	$49,220	$14,101,289	$23,502,149	$8,434,195	$418,746,160
2028	$212,340,617	$81,075,508	$32,816,277	$98,448,832	$23,367,116	$23,367,116	$66,763,190	$66,763,190	$93,468,465	$63,580	$18,385,125	$30,641,876	$10,996,290	$546,156,565
2029	$256,757,974	$98,034,863	$39,680,778	$119,042,333	$28,240,311	$28,240,311	$80,686,603	$80,686,603	$112,961,245	$76,209	$22,219,566	$37,032,610	$13,289,558	$660,190,990
2030	$296,460,604	$113,194,049	$45,816,639	$137,449,916	$32,597,067	$32,597,067	$93,134,477	$93,134,477	$130,388,268	$87,316	$25,647,719	$42,746,198	$15,339,796	$762,132,989
2031	$342,482,937	$130,766,212	$52,929,181	$158,787,544	$37,639,408	$37,639,408	$107,541,165	$107,541,165	$150,557,630	$100,145	$29,615,340	$49,358,900	$17,712,662	$880,188,760
2032	$386,286,011	$147,491,023	$59,698,747	$179,096,242	$42,443,780	$42,443,780	$121,267,944	$121,267,944	$169,775,122	$112,231	$33,395,766	$55,659,610	$19,973,544	$992,625,732
2033	$424,461,876	$162,067,262	$65,598,654	$196,795,961	$46,632,375	$46,632,375	$133,235,357	$133,235,357	$186,529,499	$122,603	$36,691,714	$61,152,857	$21,944,647	$1,090,638,660
2034	$457,639,279	$174,734,998	$70,726,070	$212,178,211	$50,273,774	$50,273,774	$143,639,355	$143,639,355	$201,095,096	$131,476	$39,557,136	$65,928,561	$23,658,247	$1,175,836,052
2035	$486,119,784	$185,609,372	$75,127,603	$225,382,809	$53,400,961	$53,400,961	$152,574,174	$152,574,174	$213,603,843	$138,962	$42,017,974	$70,029,957	$25,129,864	$1,248,990,653
2036	$519,107,471	$198,204,671	$80,225,700	$240,677,100	$56,970,483	$56,970,483	$162,772,808	$162,772,808	$227,881,931	$147,561	$44,826,873	$74,711,455	$26,809,639	$1,332,971,512
2037	$549,695,467	$209,883,724	$84,952,936	$254,858,808	$60,280,457	$60,280,457	$172,229,876	$172,229,876	$241,121,827	$155,450	$47,431,562	$79,052,603	$28,367,274	$1,410,844,849
2038	$576,442,810	$220,096,345	$89,086,616	$267,259,848	$63,173,692	$63,173,692	$180,496,264	$180,496,264	$252,694,769	$162,237	$49,708,352	$82,847,253	$29,728,796	$1,478,924,129
2039	$598,996,267	$228,707,666	$92,572,150	$277,716,451	$65,610,914	$65,610,914	$187,459,755	$187,459,755	$262,443,657	$167,834	$51,626,333	$86,043,888	$30,875,724	$1,536,295,043
2040	$617,657,986	$235,833,049	$95,456,234	$286,368,703	$67,625,049	$67,625,049	$193,214,426	$193,214,426	$270,500,197	$172,340	$53,211,409	$88,685,682	$31,823,553	$1,583,730,117
2041	$572,495,490	$218,589,187	$88,476,576	$265,429,727	$62,695,574	$62,695,574	$179,130,212	$179,130,212	$250,782,296	$159,209	$49,332,818	$82,221,364	$29,503,800	$1,468,146,548
2042	$526,645,038	$201,082,651	$81,390,597	$244,171,790	$57,694,867	$57,694,867	$164,842,477	$164,842,477	$230,779,468	$146,012	$45,398,134	$75,663,557	$27,150,526	$1,350,857,424

2043	$479,402,677	$183,044,658	$74,089,505	$222,268,514	$52,545,650	$52,545,650	$150,130,427	$150,130,427	$210,182,598	$132,548	$41,346,552	$68,910,920	$24,727,364	$1,230,054,813
2044	$436,026,825	$166,482,970	$67,385,964	$202,157,892	$47,815,889	$47,815,889	$136,616,826	$136,616,826	$191,263,557	$120,241	$37,624,991	$62,708,318	$22,501,595	$1,119,110,956
2045	$395,811,487	$151,128,022	$61,170,866	$183,512,598	$43,428,910	$43,428,910	$124,082,600	$124,082,600	$173,715,640	$108,882	$34,173,122	$56,955,203	$20,437,134	$1,016,224,488

**All Hydrogen Equipment represents a sum of expenditures on SCTM, Dispensers, and Ground Storage. It is not incorporated into the total expenditure figures, as this would constitute double-counting.*

Figure N-2: Total projected expenditures on construction of hydrogen refueling infrastructure in California by cost category, 2021-2045. Includes infrastructure serving all vehicle sectors.



O – Raw Model Output Figures and Multipliers

This appendix presents the raw FTE job-year totals and multipliers (jobs per $1 million invested) for each modeled period. These values are the basis of estimated, annualized figures presented and discussed in Chapter 4. FTE figures and multipliers are delineated by direct, indirect, and induced jobs, along with overall totals. Outputs are organized by sector, as follows:

7. ICEV-Related Sectors: New ICEV sales, fossil fuel consumption, and ICEV maintenance.
8. BEV-Related Sectors: New BEV sales, electricity consumption for transportation, and BEV maintenance.
9. FCEV-Related Sectors: New FCEV sales, hydrogen fuel consumption, and FCEV maintenance.
10. EV Charging Infrastructure
11. Hydrogen Refueling Infrastructure

ICEV-Related Sectors

Table & Figure O-1: Raw FTE model outputs related to *new ICEV sales* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	625,258.96	352,847.86	188,288.61	52,503.68	146.56
Indirect	394,445.96	230,848.16	126,618.11	36,217.51	172.43
Induced	384,019.34	220,648.02	119,383.94	33,714.47	118.23
Total	1,403,724.26	804,344.05	434,290.67	122,435.66	437.22

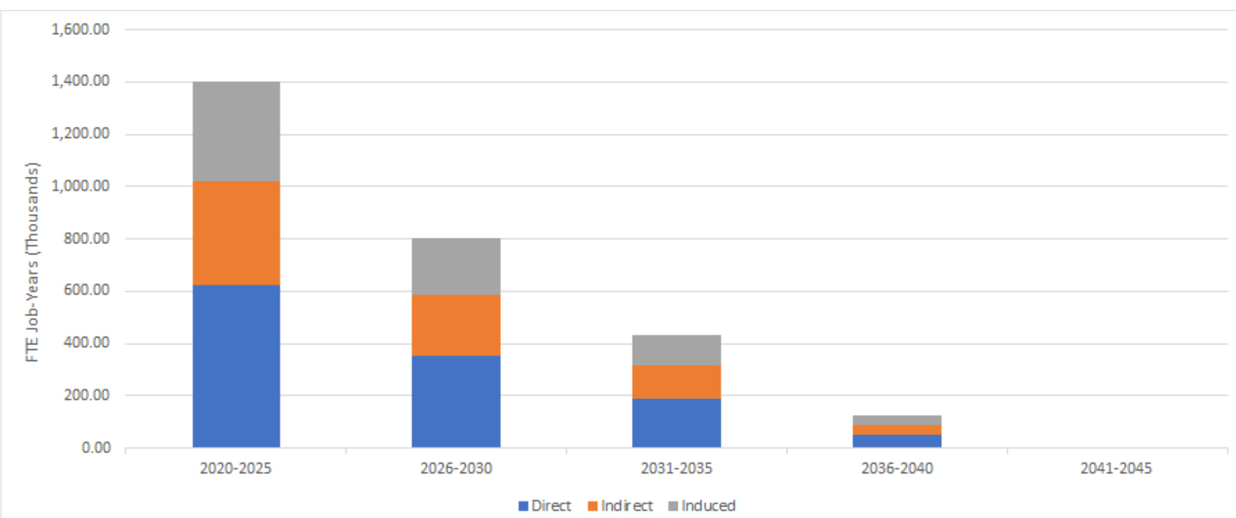


Table & Figure O-2: Job multiplier figures for direct, indirect, induced, and total jobs related to *new ICEV sales* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	3.73	1.66	1.05	1.02
2026-2030	3.50	1.54	1.00	0.96
2031-2035	3.34	1.45	0.97	0.92
2036-2040	3.19	1.37	0.94	0.88
2041-2045	1.09	0.36	0.43	0.29
Total	3.57	1.57	1.02	0.98

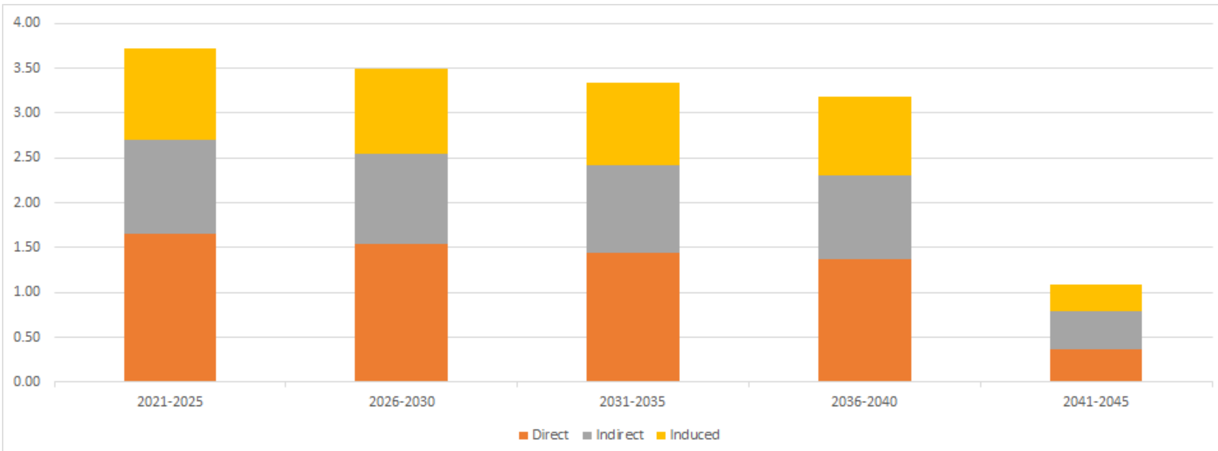


Table & Figure O-3: Raw FTE model outputs related to *fossil fuel consumption* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	305,827.02	210,577.14	163,947.07	112,865.92	67,399.89
Indirect	269,672.12	172,713.23	132,792.87	91,069.26	54,175.89
Induced	267,834.84	178,747.29	138,442.61	95,162.25	56,742.19
Total	843,333.97	562,037.65	435,182.55	299,097.42	178,317.97

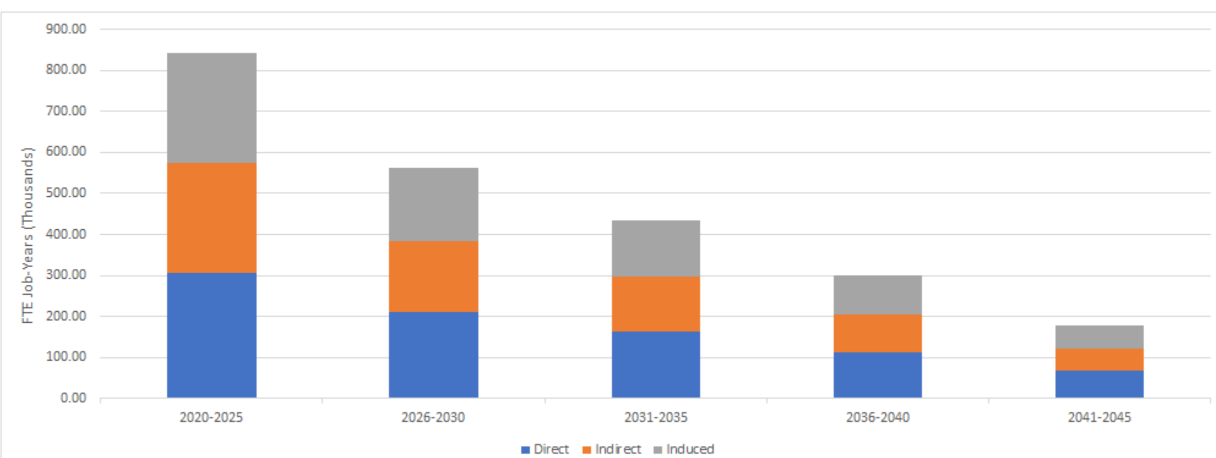


Table & Figure O-4: Job multiplier figures for direct, indirect, induced, and total jobs related to *fossil fuel consumption* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	2.59	0.94	0.83	0.82
2026-2030	2.33	0.87	0.72	0.74
2031-2035	2.19	0.83	0.67	0.70
2036-2040	2.07	0.78	0.63	0.66
2041-2045	1.96	0.74	0.59	0.62
Total	2.32	0.86	0.72	0.74

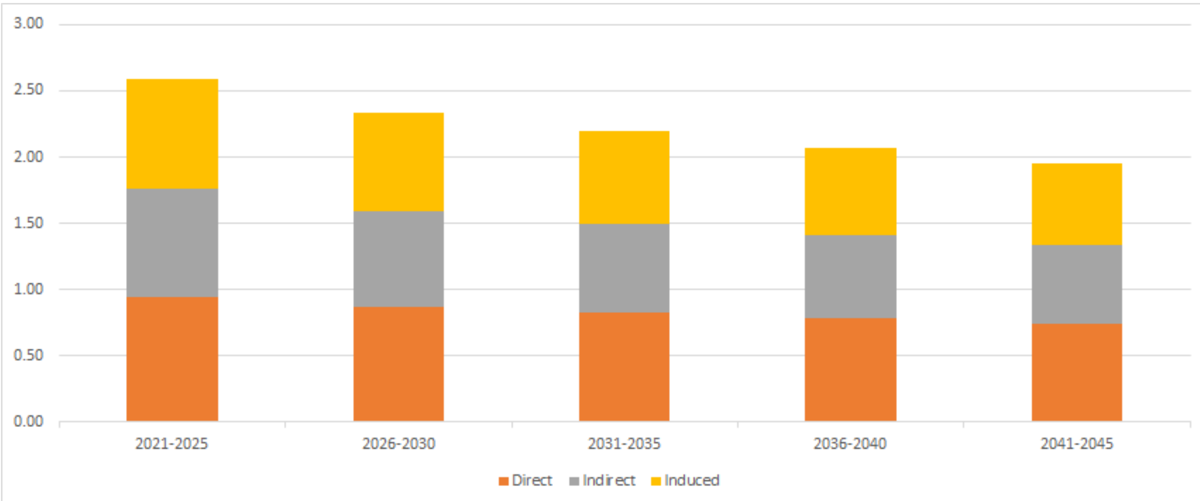


Table & Figure O-5: Raw FTE model outputs related to *ICEV maintenance* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	1,524,120.46	1,069,176.12	845,918.29	595,295.93	365,233.76
Indirect	192,235.63	134,854.29	106,692.89	75,082.57	46,065.76
Induced	601,067.53	421,650.42	333,605.16	234,766.80	144,036.27
Total	2,317,423.62	1,625,680.83	1,286,216.33	905,145.30	555,335.79

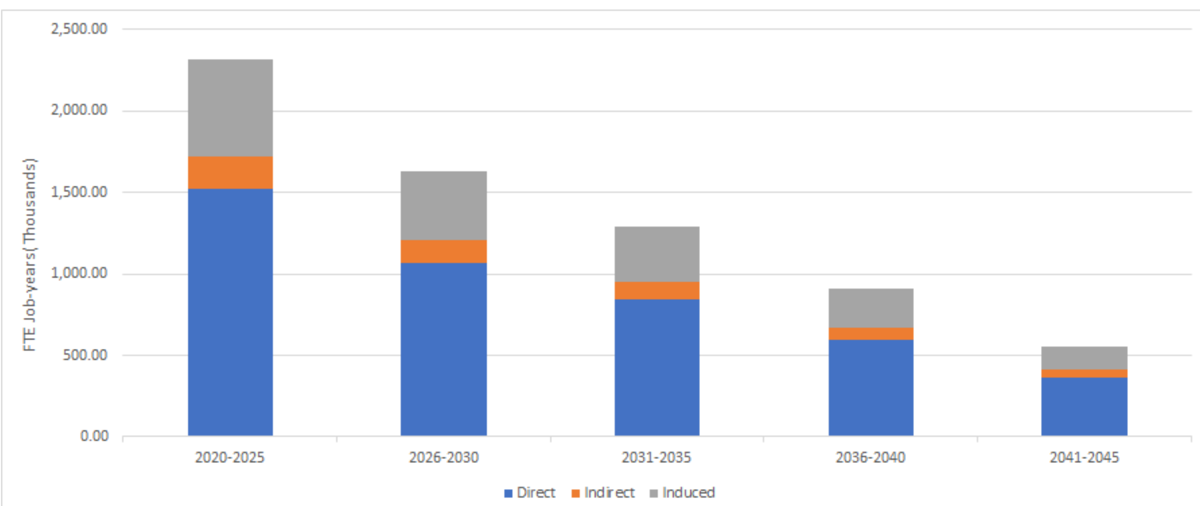


Table & Figure O-6: Job multiplier figures for direct, indirect, induced, and total jobs related to *ICEV Maintenance* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	9.33	6.13	0.77	2.42
2026-2030	8.35	5.49	0.69	2.17
2031-2035	7.80	5.13	0.65	2.02
2036-2040	7.33	4.82	0.61	1.90
2041-2045	6.89	4.53	0.57	1.79
Total	8.24	5.42	0.68	2.14

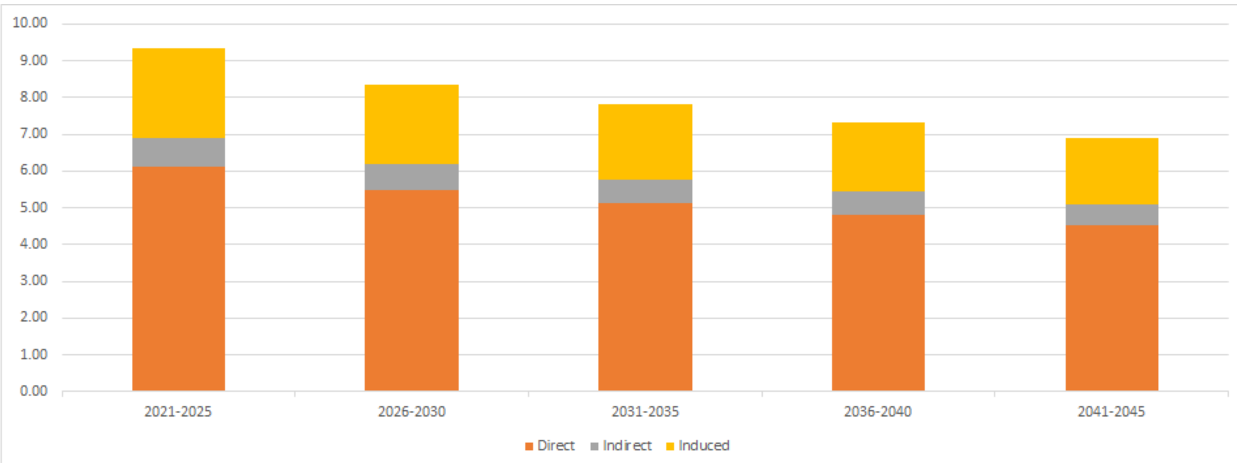


Table & Figure O-7: Raw FTE model outputs related to *new BEV sales* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	137,089.55	221,996.09	341,285.03	418,431.47	429,472.35
Indirect	85,716.95	145,172.17	228,522.67	287,323.62	302,634.05
Induced	83,931.52	138,855.78	216,113.30	268,471.75	279,344.95
Total	306,738.02	506,024.04	785,921.00	974,226.84	1,011,451.35

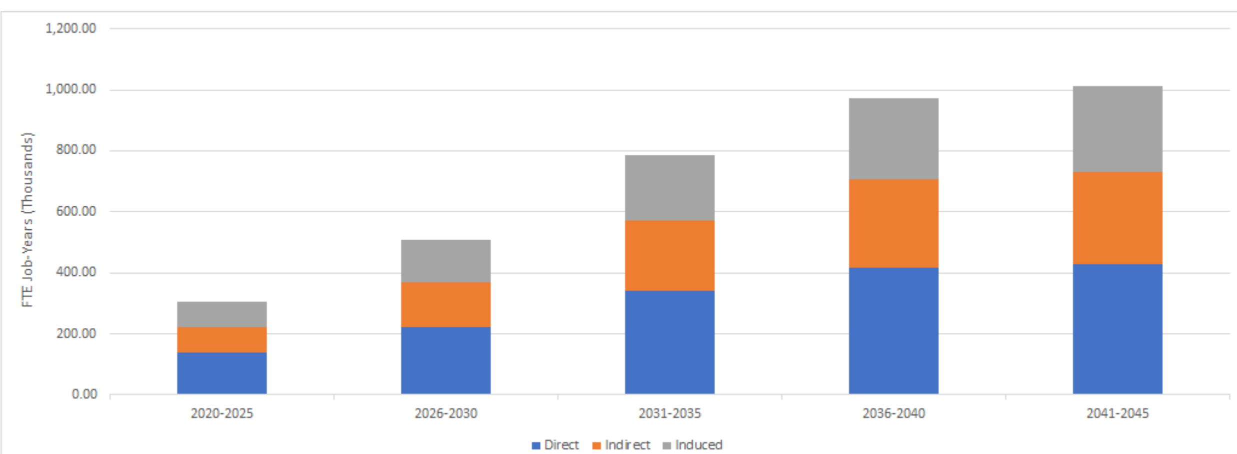


Table & Figure O-8: Job multiplier figures for direct, indirect, induced, and total jobs related to *new BEV sales* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	3.87	1.73	1.08	1.06
2026-2030	3.53	1.55	1.01	0.97
2031-2035	3.40	1.48	0.99	0.94
2036-2040	3.28	1.41	0.97	0.90
2041-2045	3.16	1.34	0.94	0.87
Total	3.35	1.45	0.98	0.92

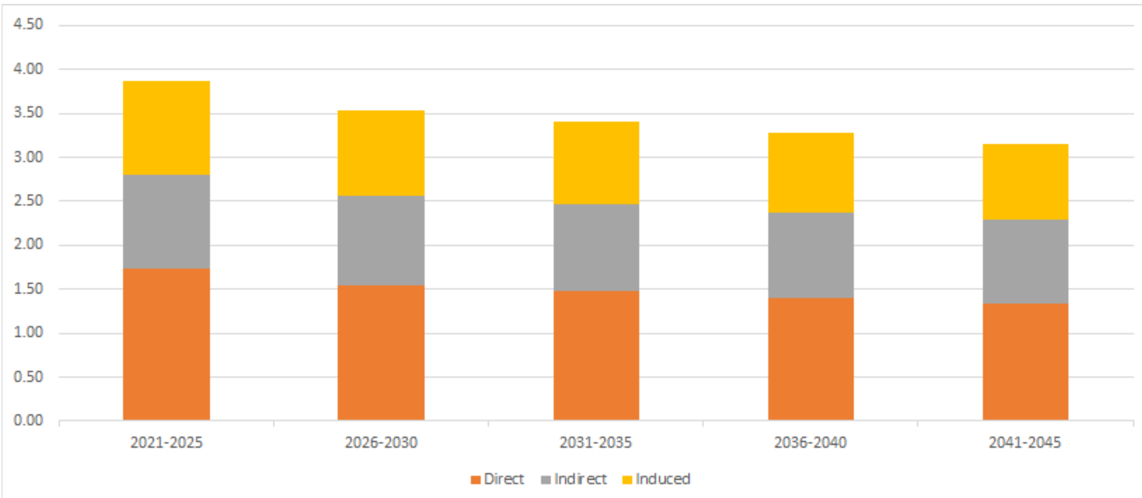


Table & Figure O-9: Raw FTE model outputs related to *electricity consumption for transportation* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	1,355.03	3,909.87	10,461.77	22,391.43	36,277.60
Indirect	1,855.65	5,169.45	12,118.74	22,105.41	32,135.05
Induced	5,022.19	14,575.11	35,504.48	67,305.74	100,583.65
Total	8,232.86	23,654.44	58,085.00	111,802.58	168,996.30

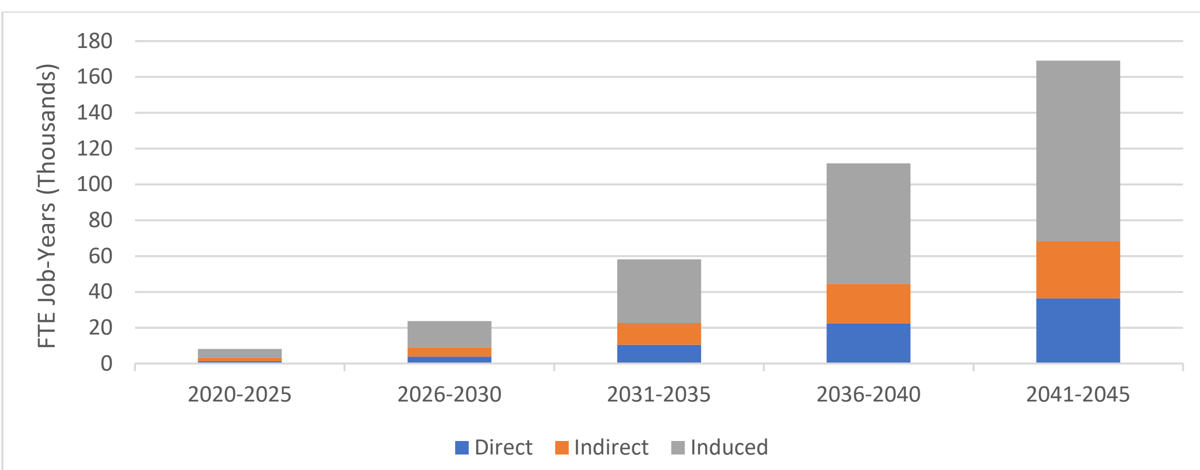


Table & Figure O-10: Job multiplier figures for direct, indirect, induced, and total jobs related to *electricity consumption for transportation* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	2.23	0.37	0.50	1.36
2026-2030	2.04	0.34	0.45	1.26
2031-2035	1.98	0.36	0.41	1.21
2036-2040	1.97	0.39	0.39	1.19
2041-2045	1.93	0.41	0.37	1.15
Total	1.96	0.39	0.39	1.18

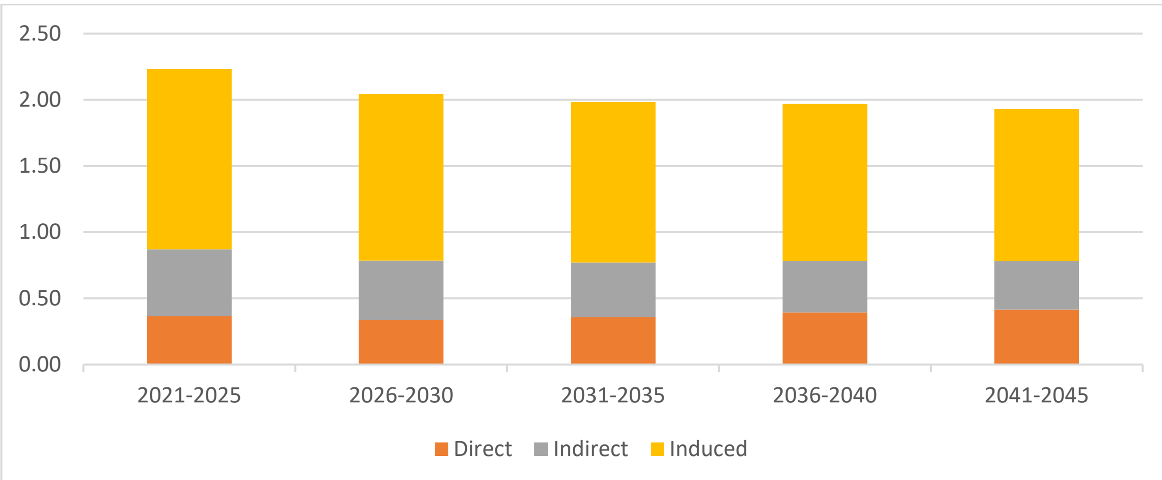


Table & Figure O-11: Raw FTE model outputs related to *BEV maintenance* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	15,133.33	44,153.15	100,516.14	174,846.35	246,251.57
Indirect	1,909.25	5,567.69	12,677.31	122,052.19	31,058.80
Induced	5,974.14	17,411.25	39,639.74	68,953.86	97,133.97
Total	23,036.72	67,132.09	152,833.19	265,833.19	374,424.34

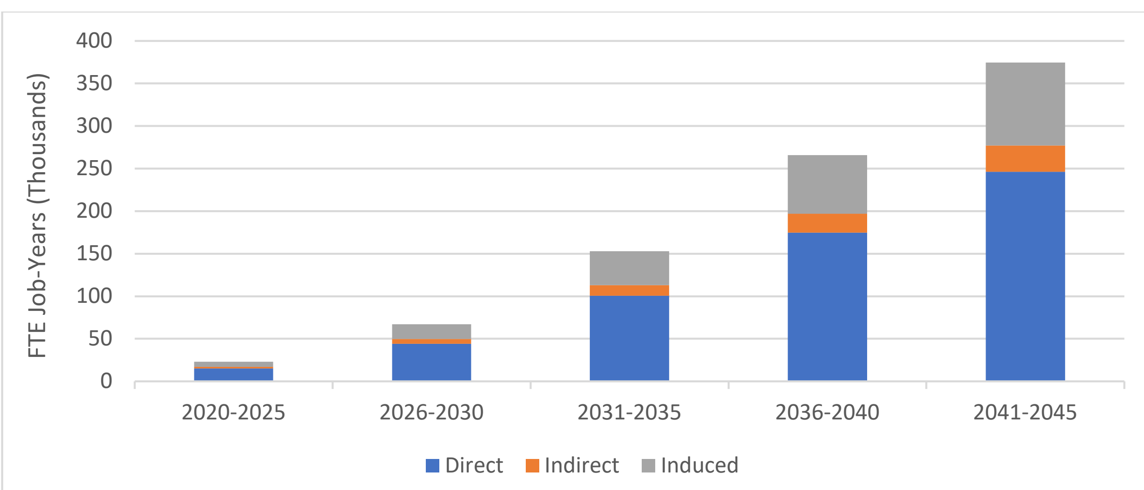


Table & Figure O-12: Job multiplier figures for direct, indirect, induced, and total jobs related to *BEV maintenance* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	9.19	6.04	0.76	2.38
2026-2030	8.29	5.45	0.69	2.15
2031-2035	7.77	5.11	0.64	2.01
2036-2040	7.30	4.80	0.61	1.89
2041-2045	6.86	4.51	0.57	1.78
Total	7.28	4.79	0.60	1.89

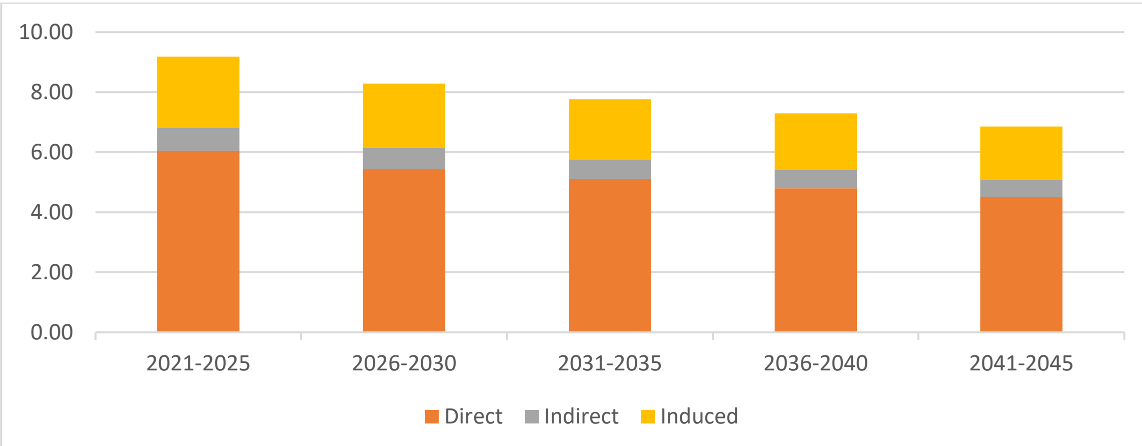


Table & Figure O-13: Raw FTE model outputs related to *new FCEV sales* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	5,255.75	19,870.99	39,329.91	54,307.83	61,597.12
Indirect	3,421.55	13,823.54	28,006.60	39,793.94	46,338.09
Induced	3,267.39	12,723.36	25,491.53	35,709.90	41,062.52
Total	11,944.69	46,417.88	92,828.04	129,811.66	148,997.73

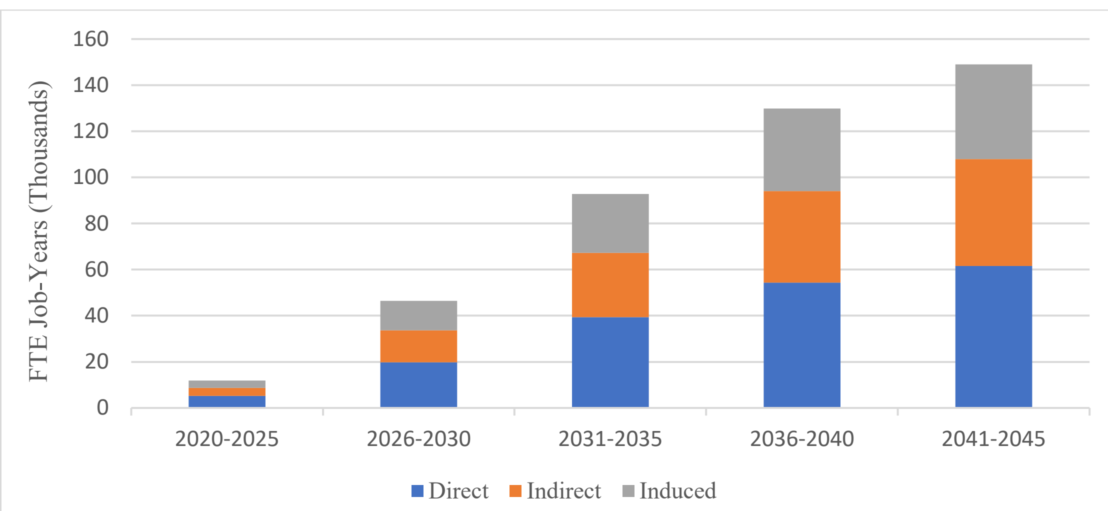


Table & Figure O-14: Job multiplier figures for direct, indirect, induced, and total jobs related to *new FCEV sales* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	3.36	1.48	0.96	0.92
2026-2030	2.87	1.23	0.85	0.79
2031-2035	2.78	1.18	0.84	0.76
2036-2040	2.66	1.11	0.82	0.73
2041-2045	2.57	1.06	0.80	0.71
Total	2.69	1.13	0.82	0.74

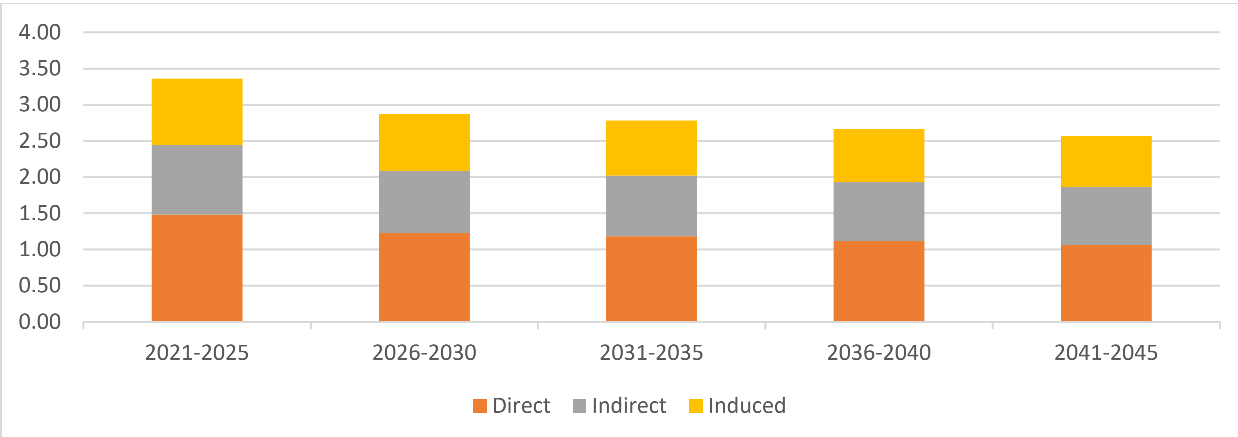


Table & Figure O-15: Raw FTE model outputs related to *hydrogen fuel consumption* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	2,515.91	14,495.19	37,538.53	66,112.75	88,427.25
Indirect	1,373.69	7,829.56	20,226.78	35,560.67	47,476.91
Induced	1,845.48	10,600.99	27,433.37	48,292.76	64,561.65
Total	5,735.07	32,925.74	85,198.68	149,966.18	200,465.81

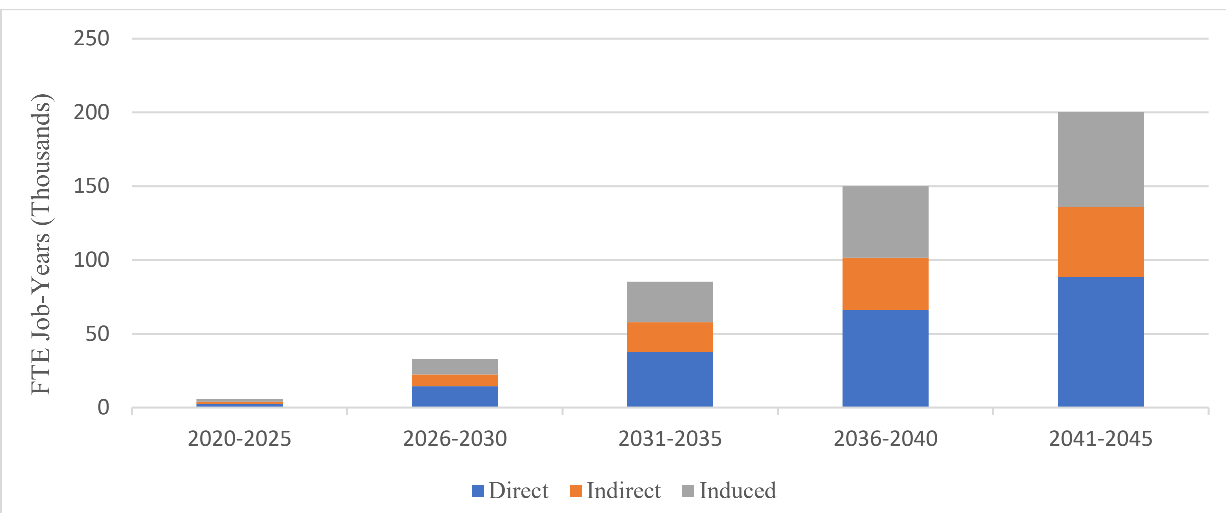


Table & Figure O-16: Job multiplier figures for direct, indirect, induced, and total jobs related to *hydrogen fuel consumption* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	5.93	2.60	1.42	1.91
2026-2030	5.49	2.42	1.31	1.77
2031-2035	5.26	2.32	1.25	1.69
2036-2040	4.98	2.20	1.18	1.60
2041-2045	4.71	2.08	1.12	1.52
Total	5.96	2.18	1.18	1.60

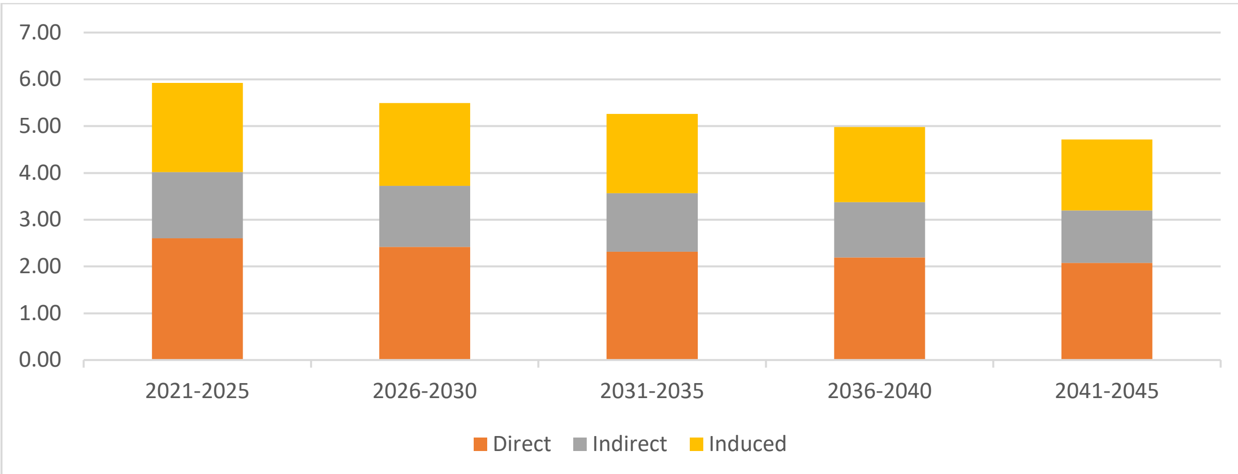


Table & Figure O-17: Raw FTE model outputs related to *FCEV maintenance* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	7,401.53	29,409.13	74,344.39	138,889.22	202,252.15
Indirect	931.81	3,707.56	9,375.37	17,515.25	25,508.50
Induced	2,917.77	11,597.81	29,318.31	54,773.63	79,761.28
Total	11,251.11	44,714.50	113,038.07	211,178.10	307,521.93

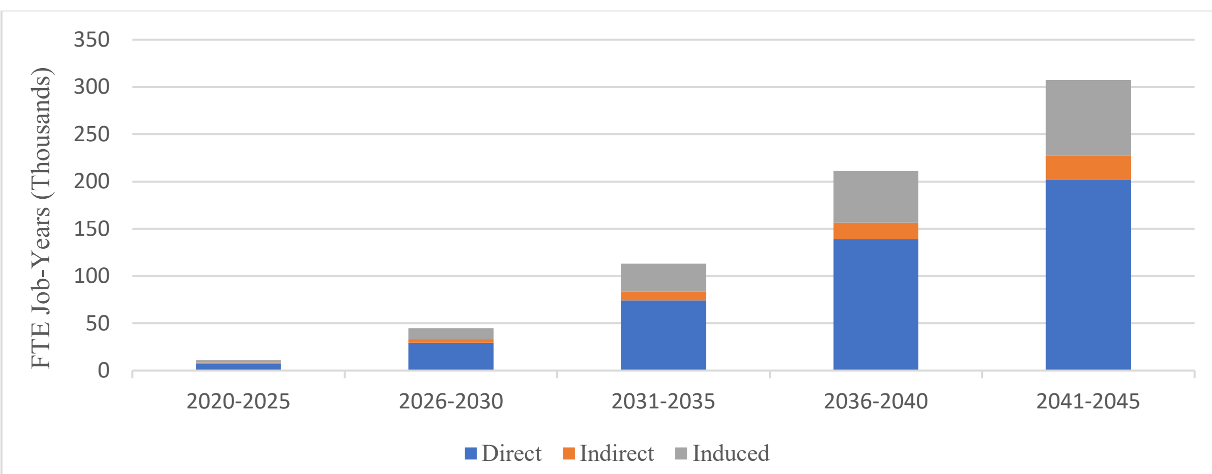


Table & Figure O-18: Job multiplier figures for direct, indirect, induced, and total jobs related to *FCEV maintenance* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	9.15	6.02	0.76	2.37
2026-2030	8.28	5.45	0.69	2.15
2031-2035	7.76	5.11	0.64	2.01
2036-2040	7.30	4.80	0.61	1.89
2041-2045	6.86	4.51	0.57	1.78
Total	7.24	4.76	0.60	1.88

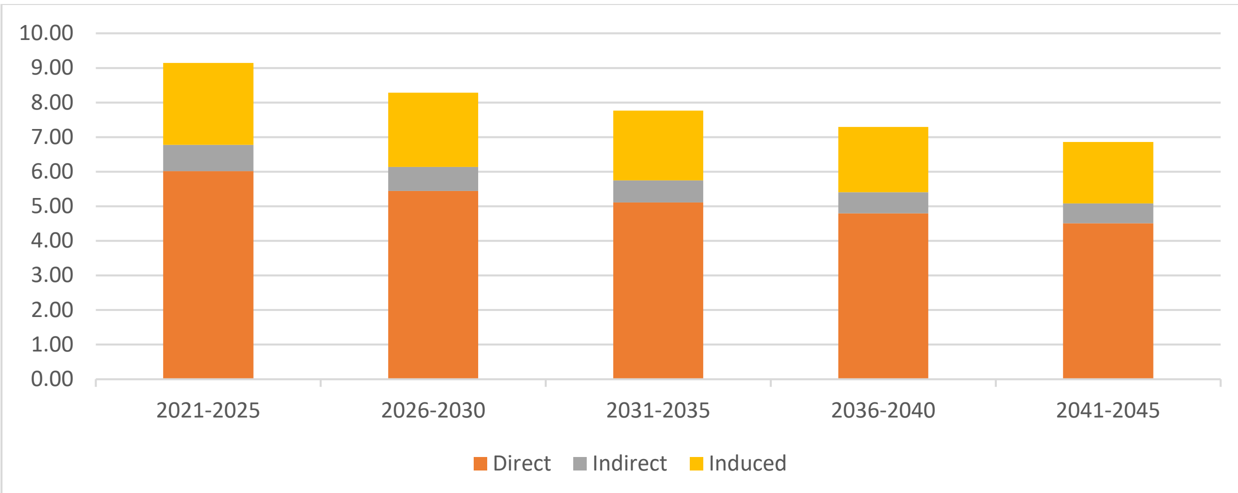


Table & Figure O-19: Raw FTE model outputs related to *new EV charging infrastructure construction and EVSE installation* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	16,555.99	53,815.88	105,652.88	154,314.28	129,691.18
Indirect	5,017.23	16,031.41	30,729.92	44,593.48	37,482.74
Induced	7,627.48	24,844.49	48,471.07	70,769.74	59,521.64
Total	29,200.69	94,691.79	184,853.86	269,677.51	226,695.56

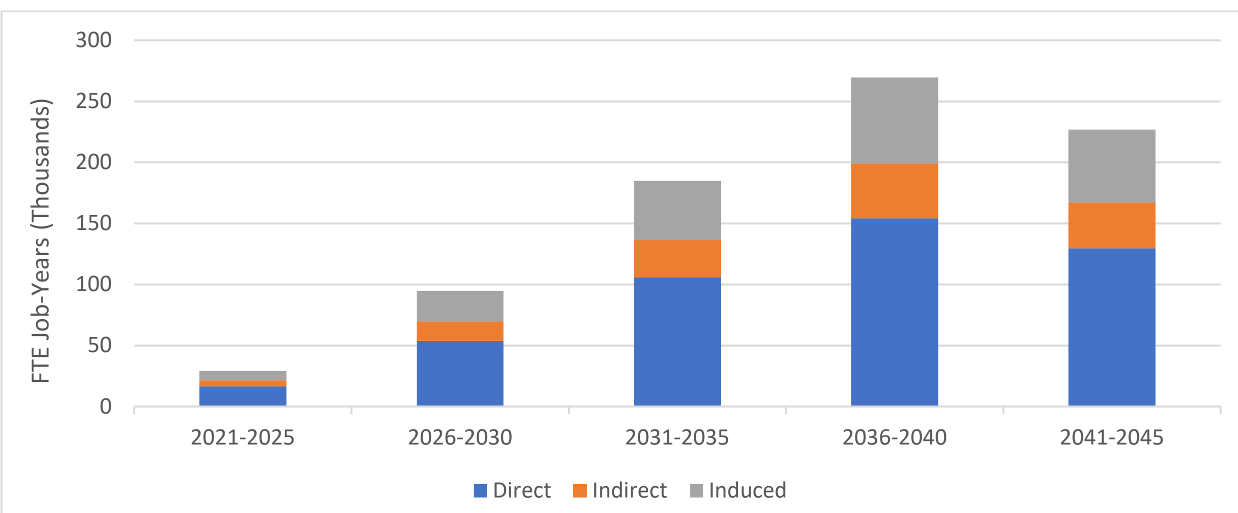


Table & Figure O-20: Job multiplier figures for direct, indirect, induced, and total jobs related to *new EV charging infrastructure construction and EVSE installation* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	8.24	4.67	1.42	2.15
2026-2030	7.58	4.31	1.28	1.99
2031-2035	7.07	4.04	1.17	1.85
2036-2040	6.64	3.80	1.10	1.74
2041-2045	6.21	3.56	1.03	1.63
Total	6.75	3.86	1.12	1.77

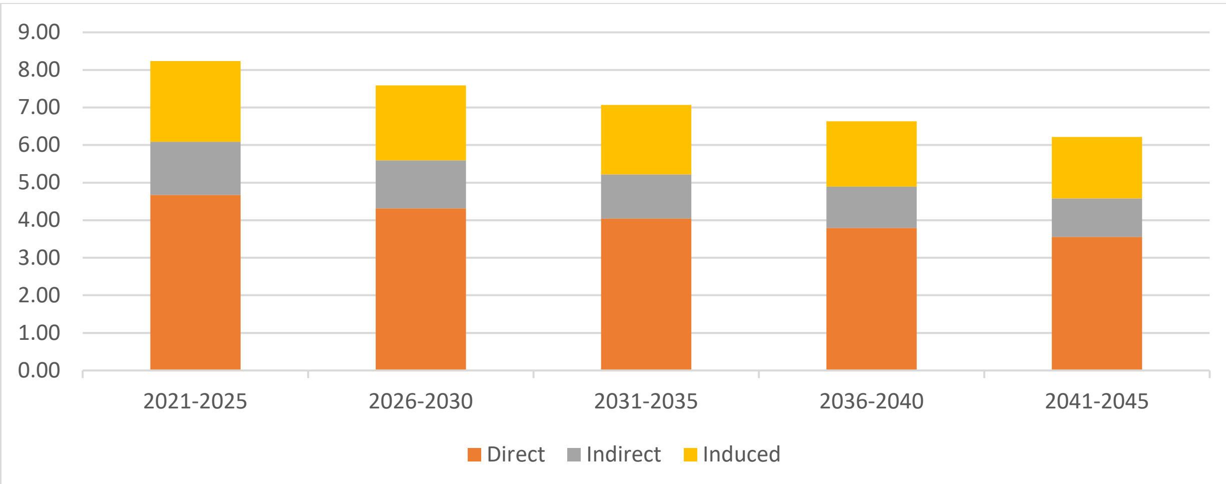


Table & Figure O-21: Raw FTE model outputs related to *new hydrogen refueling infrastructure construction* by job type and modeled period.

FTE Type	2020-2025	2026-2030	2031-2035	2036-2040	2041-2045
Direct	1,121.13	6,039.07	11,455.19	14,661.57	11,635.35
Indirect	510.03	2,752.02	5,223.68	6,687.15	5,305.66
Induced	659.53	3,557.66	6,748.72	8,638.01	6,855.34
Total	2,290.69	12,348.76	23,427.59	29,986.72	23,796.35

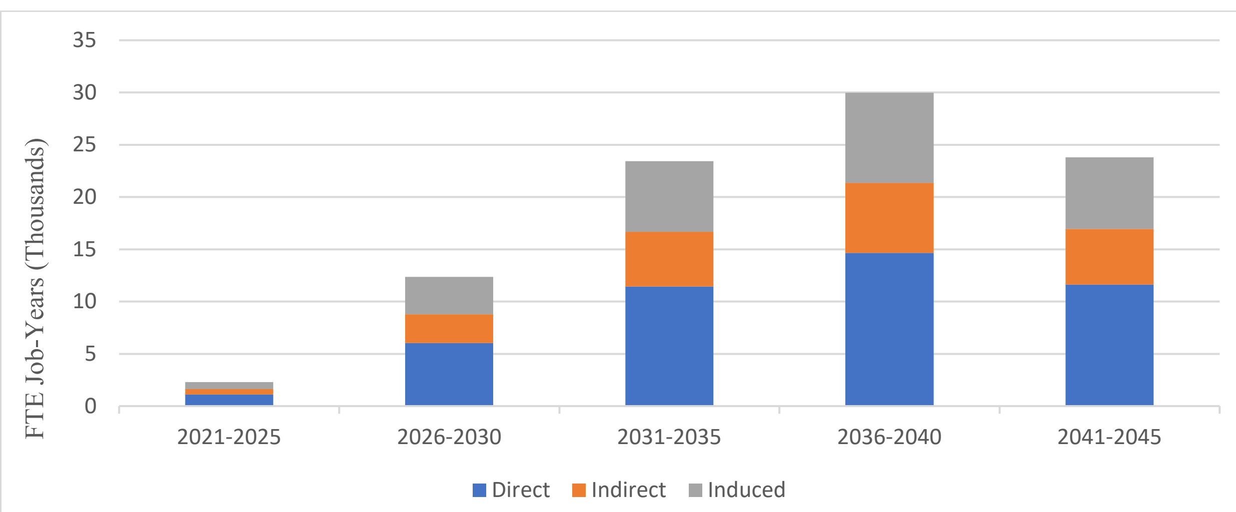
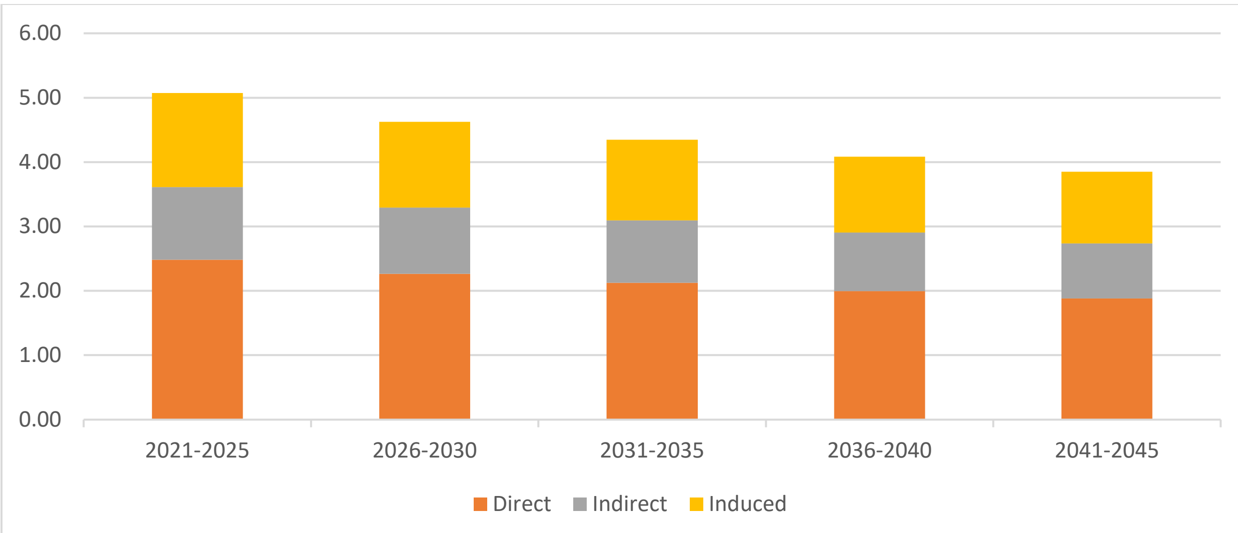


Table & Figure O-22: Job multiplier figures for direct, indirect, induced, and total jobs related to *new hydrogen refueling infrastructure construction* by modeled period.

Multipliers	Total	Direct	Indirect	Induced
2021-2025	5.08	2.48	1.13	1.46
2026-2030	4.63	2.26	1.03	1.33
2031-2035	4.35	2.13	0.97	1.25
2036-2040	4.08	2.00	0.91	1.18
2041-2045	3.85	1.88	0.86	1.11
Total	4.17	2.04	0.93	1.20



P – O*NET Education, Training, and Experience Analysis

To analyze trends in the education, training and experience requirements for the occupations outlined in Tables 5-A and 5-C, we used the Education, Training and Experience database at the Occupational Information Network (O*NET). The broader O*NET database is maintained by the U.S. Department of Labor (DOL) and is a primary source for comprehensive occupational information, beyond simply education and training. It details worker attributes and job characteristics through several hundred ratings and tags measuring a particular occupation's knowledge, skills, abilities, tasks, work values, activities, technology and tools used, and other features.[11] The data is based on survey responses by a statistically random sample of businesses and a random sample of workers within those businesses.

The O*NET database measures four types of education, training and experience requirements:

- Required Level of Education, which refers to the level or formal degrees, diplomas, certificates or credits.
- Related Work Experience, which refers to the amount of time (in months or years) a worker must have spent in other jobs that prepared them for their current job.
- On-the-Job Training, which refers to the amount of time (in months or years) a worker must serve as a learner or trainee on the job under the instruction of a more experienced worker.
- On-Site or In-Plant Training, which refers to the amount of time (in months or years) a worker must spend in organized classroom study provided by their employer.

These measures are based on four questions in their *Knowledge* survey, where participants are asked to mark the required level of education, related work experience, on-site or in-plant training, and on-the-job training needed for that specific occupation. Survey respondents are told not to mark the level of education, training or experience they personally have, but rather that which is needed for "someone" being hired to perform their current job. The response choices are ordinal and range from "Less than a High School Diploma" to "Post-Doctoral Training" for amount of education, and "None" to "Over 10 years" for amount of experience and training, in regular increments. Each answer is then coded as a number on a scale. Required Level of Education, for example, is coded on a 1-12 scale, with one corresponding to "Less than a High School Diploma" and 12 to "Post-Doctoral Training" (see Appendix R)[12].

The database subsequently reports the percentage of respondents who marked each answer for each question, for each SOC code. For example, for one of the key expanding occupations, Solar Photovoltaic Installers (SOC code 47-2231), 55.53 percent of survey respondents stated a

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[11] https://www.onetcenter.org/dataCollection.html
[12] https://www.onetcenter.org/dl_files/omb2018/AppendixA-Estab-Knowledge.pdf

person would need a high school diploma (coded as 2) to obtain the job. However, 16.14 percent of respondents stated a person would need an Associate's degree (coded as 5) and 14.02 percent said a Post-Secondary Certificate (coded as 2) would be required.[13] In order synthesize these varying answers into a concise descriptive figure, we took the weighted average of the required levels of education, work experience, on-site/in-plant training and on-the-job training, using the percentage of survey respondents who picked that value as the weight. Table P-1 provides an example of this method, outlining the raw O*NET data for Solar Photovoltaic Installers, along with our weighted averages.

Table P-1: Education, training, and experience O*NET survey data for Solar Photovoltaic Installers (SOC code 47-2231).

Category Code	Category Meaning	Percent of Survey Respondents
	Required Level of Education	
1	Less than a High School Diploma	12.03
2	High School Diploma - or the equivalent (for example, GED)	55.53
3	Post-Secondary Certificate - awarded for training completed after high school (for example, in agriculture or natural resources, computer services, personal or culinary services, engineering technologies, healthcare, construction trades, mechanic and repair technologies, or precision production)	14.02
4	Some College Courses	1.79
5	Associate's Degree (or other 2-year degree)	16.14
6	Bachelor's Degree	0.49
7	Post-Baccalaureate Certificate - awarded for completion of an organized program of study; designed for people who have completed a Baccalaureate degree but do not meet the requirements of academic degrees carrying the title of Master.	0
8	Master's Degree	0
9	Post-Master's Certificate - awarded for completion of an organized program of study; designed for people who have completed a Master's degree but do not meet the requirements of academic degrees at the doctoral level.	0
10	First Professional Degree - awarded for completion of a program that: requires at least 2 years of college work before entrance into the program, includes a total of at least 6 academic years of work to complete, and provides all remaining academic requirements to begin practice in a profession.	0
11	Doctoral Degree	0
12	Post-Doctoral Training	0
	Weighted Average of Category Codes	2.6
	Related Work Experience	

[13] https://www.onetcenter.org/dictionary/25.0/excel/education_training_experience.html

1	None	23.1
2	Up to and including 1 month	10.62
3	Over 1 month, up to and including 3 months	0
4	Over 3 months, up to and including 6 months	11.64
5	Over 6 months, up to and including 1 year	33.06
6	Over 1 year, up to and including 2 years	14.73
7	Over 2 years, up to and including 4 years	1.88
8	Over 4 years, up to and including 6 years	4.97
9	Over 6 years, up to and including 8 years	0
10	Over 8 years, up to and including 10 years	0
11	Over 10 years	0
	Weighted Average of Category Codes	4.0
	On-Site or In-Plant Training	
1	None	19.33
2	Up to and including 1 month	40.18
3	Over 1 month, up to and including 3 months	20.08
4	Over 3 months, up to and including 6 months	2.32
5	Over 6 months, up to and including 1 year	18.1
6	Over 1 year, up to and including 2 years	0
7	Over 2 years, up to and including 4 years	0
8	Over 4 years, up to and including 10 years	0
9	Over 10 years	0
	Weighted Average of Category Codes	2.6
	On-The-Job Training	
1	None or short demonstration	10.62
2	Anything beyond short demonstration, up to and including 1 month	30.86
3	Over 1 month, up to and including 3 months	3.34
4	Over 3 months, up to and including 6 months	29.78
5	Over 6 months, up to and including 1 year	10.66
6	Over 1 year, up to and including 2 years	9.76
7	Over 2 years, up to and including 4 years	0
8	Over 4 years, up to and including 10 years	4.97
9	Over 10 years	0
	Weighted Average of Category Codes	3.5

We interpreted a weighted average of 2.6 in Required Level of Education to mean that Solar Photovoltaic Installers mostly needed a High School Diploma, with some minority of workers requiring more. A weighted average of 4.0 for Related Work Experience meant that the majority of workers needed approximately 3-6 months. The majority of Solar Photovoltaic Installers needed approximately one month of on-site training and 1-3 months of on-the-job training, as denoted by the weighted averages of 2.6 and 3.5 respectively in those categories. See

Appendix R for a detailed table of all relevant occupations and their respective weighted averages.

In using the O*NET Education, Training and Experience database, we assumed that required levels of education, training and experience for each occupation in California would be comparable to trends nationwide and across industries. The database only provides responses at the national level, and does not differentiate between workers in different industries under the same SOC code. Regardless, we assume that occupations with rigid education and training requirements nationally (such as Industrial Engineers) would have similar standards in California and across various industries. Likewise, we assume that occupations with highly varying education and training requirements nationally (such as Administrative Assistants) would be similarly varying in California and across industries.

Not every single major SOC code labeled as highly impacted from Chapter 2 is found in the O*NET Education, Training and Experience database. Chapter 2 named 395 SOC codes, of which 352 could be matched with the O*NET database. This means that there are some employee counts not included in the analysis. However, 87 percent of the employee counts are in fact represented by SOC codes in the O*NET database and they are evenly distributed between expanding and declining industries. Correspondingly, 87 percent of employees in expanding occupations and 86 percent of employees in declining employees are represented in the analysis.

Q – O*NET Transition Analysis for Declining Industry Workers

Our intent in this appendix is to showcase sample information available in the O*NET database which may be useful to state and local actors as they assist workers in declining industries transition to new employment. We herein focus on occupations in two fossil fuel-related industries, Oil and Gas Extraction and Support Activities for Mining. Key occupations in these industries include:

- Petroleum engineers (SOC code 17-2171)
- Service unit operators for oil and gas (SOC code 47-5013)
- Oil derrick operators (SOC code 47-5011)
- Wellhead pumpers (SOC code 53-7073)
- Unskilled laborers engaged in daily field operations (roustabouts) (SOC code 47-5071)
- Petroleum pump system operators (SOC code 51-8093)

The 9,020 workers who work in these occupations will have to transition to other jobs, perhaps in very different industries. The O*NET Related Occupations Matrices (ROMs) provide valuable insight into how the state may anticipate, and therefore help facilitate, key workforce transitions.

Data Used

O*NET has two ROMs, a Career Changers Matrix and a Career Starters Matrix. We used the Career Changers Matrix, which answers for each occupation the question "Is this a job I can pursue with minimal additional preparation?"[14] Organized by SOC code, the O*NET Career Changers Matrix uses a Change algorithm to generate a list of the ten most related occupations (again by SOC code) for each occupation, which it refers to as a target occupation. The algorithm is designed to find the most transferable occupations for an individual in the target occupation, i.e. the top ten occupations that would require the least amount of additional training, education or experience.[15]

The Change algorithm considers the hundreds of tags in the O*NET database in its domains of Knowledge, Skills, Abilities, Interests, Work Styles, Work Values, Generalized Work Activities, Work Context, and Job Zone that are attached to each SOC code, and then analyses the metric similarity between the profile elements, and then the correlations between different profiles.[16] Similarity matrices for each descriptor domain were then created, standardized (if necessary)

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[14] *https://www.onetcenter.org/dl_files/Related.pdf*
[15] *Ibid.*
[16] *The metric similarity is calculated using several metrics. Metric similarity between profile elements was calculated using the Raw Euclidean Distance and the Mahalanobis' mean differences, which are weighted by the pooled within-entity variance-covariance matrix. The correlations between different profiles were calculated suing the Standardized Euclidean Distances and the Pearson Correlation.*

and then combined to the overall ROM. This provides the top ten related SOC codes per each target occupation. For example, Table Q-1 provides the Career Changers Matrix for Petroleum Engineers (SOC code 17-2171).

Table Q-1: Top ten related occupations for petroleum engineers (SOC code 47-2231).

Related O*NET-SOC Code	Related Title	Index
19-2042.00	Geoscientists, Except Hydrologists and Geographers	1
17-2199.03	Energy Engineers	2
17-2151.00	Mining and Geological Engineers, Including Mining Safety Engineers	3
17-2199.02	Validation Engineers	4
13-1081.01	Logistics Engineers	5
13-1081.02	Logistics Analysts	6
17-2112.00	Industrial Engineers	7
17-2071.00	Electrical Engineers	8
17-2111.02	Fire-Prevention and Protection Engineers	9
17-2051.00	Civil Engineers	10

Related Occupations Analysis

Table Q-2 outlines the top ten related occupations for each of the six, key, contracting occupations in Oil and Gas Extraction and Support Activities for Mining identified above. It also shows the total number of employees per target SOC code in California. Related occupations highlighted in green indicate expanding occupations as identified in this report.

Table Q-2: Top ten related occupations for key contracting occupations. Green indicates a related occupation likely to expand as a result of the transition to ZEVs.

O*NET-SOC Code	Title	
17-2171.00	Petroleum Engineers	Total Employees: 1330
Related O*NET-SOC Code	Related Title	Index
19-2042.00	Geoscientists, Except Hydrologists and Geographers	1
17-2199.03	Energy Engineers	2
17-2151.00	Mining and Geological Engineers, Including Mining Safety Engineers	3
17-2199.02	Validation Engineers	4
13-1081.01	Logistics Engineers	5
13-1081.02	Logistics Analysts	6
17-2112.00	Industrial Engineers	7
17-2071.00	Electrical Engineers	8
17-2111.02	Fire-Prevention and Protection Engineers	9
17-2051.00	Civil Engineers	10
47-5011.00	Derrick Operators, Oil and Gas	Total Employees: 820
Related O*NET-SOC Code	Related Title	Index
47-5071.00	Roustabouts, Oil and Gas	1
47-3011.00	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	2
47-5013.00	Service Unit Operators, Oil, Gas, and Mining	3
47-4061.00	Rail-Track Laying and Maintenance Equipment Operators	4
47-5012.00	Rotary Drill Operators, Oil and Gas	5
47-4071.00	Septic Tank Servicers and Sewer Pipe Cleaners	6
47-2072.00	Pile-Driver Operators	7
45-2093.00	Farmworkers, Farm, Ranch, and Aquacultural Animals	8
45-3011.00	Fishers and Related Fishing Workers	9
37-3013.00	Tree Trimmers and Pruners	10
47-5013.00	Service Unit Operators, Oil, Gas, and Mining	Total Employees: 2290
Related O*NET-SOC Code	Related Title	Index
47-4061.00	Rail-Track Laying and Maintenance Equipment Operators	1
51-9012.00	Separating, Filtering, Clarifying, Precipitating, and Still Machine Setters, Operators, and Tenders	2

37-3013.00	Tree Trimmers and Pruners	3
53-7071.00	Gas Compressor and Gas Pumping Station Operators	4
47-5012.00	Rotary Drill Operators, Oil and Gas	5
53-4021.00	Railroad Brake, Signal, and Switch Operators	6
47-5081.00	Helpers--Extraction Workers	7
49-3043.00	Rail Car Repairers	8
51-4023.00	Rolling Machine Setters, Operators, and Tenders, Metal and Plastic	9
53-7032.00	Excavating and Loading Machine and Dragline Operators	10
47-5071.00	Roustabouts, Oil and Gas	Total Employees: 230
Related O*NET-SOC Code	Related Title	Index
47-3011.00	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	1
47-5011.00	Derrick Operators, Oil and Gas	2
49-3093.00	Tire Repairers and Changers	3
47-5051.00	Rock Splitters, Quarry	4
47-4061.00	Rail-Track Laying and Maintenance Equipment Operators	5
47-2061.00	Construction Laborers	6
47-2071.00	Paving, Surfacing, and Tamping Equipment Operators	7
45-2093.00	Farmworkers, Farm, Ranch, and Aquacultural Animals	8
47-5061.00	Roof Bolters, Mining	9
49-9045.00	Refractory Materials Repairers, Except Brickmasons	10
51-8093.00	Petroleum Pump System Operators, Refinery Operators, and Gaugers	Total Employees: 4250
Related O*NET-SOC Code	Related Title	Index
51-9011.00	Chemical Equipment Operators and Tenders	1
51-9012.00	Separating, Filtering, Clarifying, Precipitating, and Still Machine Setters, Operators, and Tenders	2
51-8091.00	Chemical Plant and System Operators	3
53-7072.00	Pump Operators, Except Wellhead Pumpers	4
53-7071.00	Gas Compressor and Gas Pumping Station Operators	5
17-3029.01	Non-Destructive Testing Specialists	6
51-8092.00	Gas Plant Operators	7
51-9193.00	Cooling and Freezing Equipment Operators and Tenders	8
53-7121.00	Tank Car, Truck, and Ship Loaders	9
51-8013.00	Power Plant Operators	10
53-7073.00	Wellhead Pumpers	Total Employees: 100

Related O*NET-SOC Code	Related Title	Index
53-7071.00	Gas Compressor and Gas Pumping Station Operators	1
49-9043.00	Maintenance Workers, Machinery	2
47-2072.00	Pile-Driver Operators	3
53-7072.00	Pump Operators, Except Wellhead Pumpers	4
47-4061.00	Rail-Track Laying and Maintenance Equipment Operators	5
49-9012.00	Control and Valve Installers and Repairers, Except Mechanical Door	6
51-9012.00	Separating, Filtering, Clarifying, Precipitating, and Still Machine Setters, Operators, and Tenders	7
53-7032.00	Excavating and Loading Machine and Dragline Operators	8
51-9193.00	Cooling and Freezing Equipment Operators and Tenders	9
47-5013.00	Service Unit Operators, Oil, Gas, and Mining	10

Discussion

The estimated 1,330 Petroleum Engineers have the most related occupations that would be expanding (7 in total), which makes intuitive sense given how skilled an occupation it is. The estimated 100 Wellhead Pumpers have two expanding related occupations, and the estimated 230 Roustabouts may be transitioned into construction work.

The estimated 4,250 Petroleum Pump System Operators, Refinery Operators, and Gaugers will be harder to transition. They only have one expanding related occupation, Power Plant Operators. The combined estimated 3,110 Derrick Operators and Service Unit Operations in Oil, Gas, and Mining do not have a single related expanding occupation.

Using the O*NET Career Changers Matrix in combination with employment estimates will help predict the scale of transitions that will have to occur as implementation begins, as well as potential areas where the state may prioritize giving workers in declining occupations the right to have their job application considered before that of the general public. Taskforces with affected workers should be created so that the workers themselves, especially those with no readily available declining related occupation, may voice their preferences in where and how they would like to proceed to new employment. For example, Derrick Operators can transfer to other industries that are completely unrelated to the transportation sector (such as Fishers and Related Fishing Workers). The state should take collective worker preferences into account when planning transfer programs.

R – Required Education and Training Weighted Averages for Relevant Occupations

NAICS Code	Industry	SOC	Occupation	Supply Chain	Contracting or Growing?	Weighted Averages: On-the-Job Training	Weighted Averages: In-Plant/ On-site Training	Weighted Averages: Required Level of Education	Weighted Averages: Required Amount of Related Work Experience
211100	Oil and Gas Extraction	41-3395	Financial Managers	Fuel	Contracting	3.3	3.0	6.3	8.5
211100	Oil and Gas Extraction	26-01198	Construction Managers	Fuel	Contracting	5.4	5.6	5.7	9.1
211100	Oil and Gas Extraction	26-45027	Property, Real Estate, and Community Association Managers	Fuel	Contracting	3.9	4.2	5.0	6.8
211100	Oil and Gas Extraction	13-1041	Compliance Officers	Fuel	Contracting	4.5	3.9	5.5	6.1
211100	Oil and Gas Extraction	13-1081	Logisticians	Fuel	Contracting	4.6	3.9	5.8	7.2
211100	Oil and Gas Extraction	13-2011	Accountants and Auditors	Fuel	Contracting	5.0	3.6	6.0	5.0
211100	Oil and Gas Extraction	17-2112	Industrial Engineers	Fuel	Contracting	4.5	4.3	6.7	6.9
211100	Oil and Gas Extraction	17-2171	Petroleum Engineers	Fuel	Contracting	4.9	3.7	6.2	8.3
211100	Oil and Gas Extraction	19-2041	Environmental Scientists and Specialists, Including Health	Fuel	Contracting	4.0	3.4	7.6	6.8
211100	Oil and Gas Extraction	19-2042	Geoscientists, Except Hydrologists and Geographers	Fuel	Contracting	4.3	3.6	7.5	5.7
211100	Oil and Gas Extraction	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Fuel	Contracting	3.6	3.2	3.4	6.0
211100	Oil and Gas Extraction	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Fuel	Contracting	3.2	3.2	3.4	5.1
211100	Oil and Gas Extraction	43-9061	Office Clerks, General	Fuel	Contracting	3.1	2.4	3.4	5.1
211100	Oil and Gas Extraction	47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Fuel	Contracting	5.7	5.0	3.3	7.3
211100	Oil and Gas Extraction	47-2111	Electricians	Fuel	Contracting	6.1	5.7	3.0	7.4
211100	Oil and Gas Extraction	47-5012	Rotary Drill Operators, Oil and Gas	Fuel	Contracting	5.0	4.6	2.6	6.1
211100	Oil and Gas Extraction	47-5013	Service Unit Operators, Oil and Gas	Fuel	Contracting	3.9	2.5	1.6	4.9
211100	Oil and Gas Extraction	47-5071	Roustabouts, Oil and Gas	Fuel	Contracting	2.9	2.5	1.7	2.8
211100	Oil and Gas Extraction	49-9041	Industrial Machinery Mechanics	Fuel	Contracting	5.2	4.4	3.2	6.9

211100	Oil and Gas Extraction	51-1011	First-Line Supervisors of Production and Operating Workers	Fuel	Contracting	4.7	3.8	3.5	8.6
211100	Oil and Gas Extraction	51-8093	Petroleum Pump System Operators, Refinery Operators, and Gaugers	Fuel	Contracting	4.4	4.8	2.6	5.3
211100	Oil and Gas Extraction	53-7073	Wellhead Pumpers	Fuel	Contracting	4.1	3.3	2.3	5.1
213100	Support Activities for Mining	11-1021	General and Operations Managers	Fuel	Contracting	4.0	3.9	4.9	8.1
213100	Support Activities for Mining	42-0700	Industrial Production Managers	Fuel	Contracting	5.0	4.8	4.9	7.8
213100	Support Activities for Mining	26-01198	Construction Managers	Fuel	Contracting	5.4	5.6	5.7	9.1
213100	Support Activities for Mining	13-1051	Cost Estimators	Fuel	Contracting	5.8	4.3	5.9	6.6
213100	Support Activities for Mining	17-2112	Industrial Engineers	Fuel	Contracting	4.5	4.3	6.7	6.9
213100	Support Activities for Mining	17-2171	Petroleum Engineers	Fuel	Contracting	4.9	3.7	6.2	8.3
213100	Support Activities for Mining	19-2042	Geoscientists, Except Hydrologists and Geographers	Fuel	Contracting	4.3	3.6	7.5	5.7
213100	Support Activities for Mining	43-1011	First-Line Supervisors of Office and Administrative Support Workers	Fuel	Contracting	4.6	3.9	4.6	6.8
213100	Support Activities for Mining	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Fuel	Contracting	3.6	3.2	3.4	6.0
213100	Support Activities for Mining	43-5032	Dispatchers, Except Police, Fire, and Ambulance	Fuel	Contracting	3.1	2.8	2.6	4.4
213100	Support Activities for Mining	43-5061	Production, Planning, and Expediting Clerks	Fuel	Contracting	4.0	3.7	3.8	6.4
213100	Support Activities for Mining	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Fuel	Contracting	3.2	3.2	3.4	5.1
213100	Support Activities for Mining	43-9061	Office Clerks, General	Fuel	Contracting	3.1	2.4	3.4	5.1
213100	Support Activities for Mining	47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Fuel	Contracting	5.7	5.0	3.3	7.3

213100	Support Activities for Mining	47-2061	Construction Laborers	Fuel	Contracting	3.1	3.5	1.9	4.1
213100	Support Activities for Mining	47-2073	Operating Engineers and Other Construction Equipment Operators	Fuel	Contracting	4.8	4.4	2.1	6.1
213100	Support Activities for Mining	47-5011	Derrick Operators, Oil and Gas	Fuel	Contracting	3.2	3.5	1.5	4.7
213100	Support Activities for Mining	47-5012	Rotary Drill Operators, Oil and Gas	Fuel	Contracting	5.0	4.6	2.6	6.1
213100	Support Activities for Mining	47-5013	Service Unit Operators, Oil and Gas	Fuel	Contracting	3.9	2.5	1.6	4.9
213100	Support Activities for Mining	47-5071	Roustabouts, Oil and Gas	Fuel	Contracting	2.9	2.5	1.7	2.8
213100	Support Activities for Mining	47-5081	Helpers--Extraction Workers	Fuel	Contracting	3.0	2.6	2.1	2.5
213100	Support Activities for Mining	49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Fuel	Contracting	5.1	4.9	3.4	7.8
213100	Support Activities for Mining	49-3042	Mobile Heavy Equipment Mechanics, Except Engines	Fuel	Contracting	4.9	4.6	2.8	6.2
213100	Support Activities for Mining	49-9041	Industrial Machinery Mechanics	Fuel	Contracting	5.2	4.4	3.2	6.9
213100	Support Activities for Mining	49-9071	Maintenance and Repair Workers, General	Fuel	Contracting	4.7	3.9	2.6	5.9
213100	Support Activities for Mining	51-4121	Welders, Cutters, Solderers, and Brazers	Fuel	Contracting	4.0	4.1	2.3	5.5
213100	Support Activities for Mining	51-8093	Petroleum Pump System Operators, Refinery Operators, and Gaugers	Fuel	Contracting	4.4	4.8	2.6	5.3
213100	Support Activities for Mining	53-3032	Heavy and Tractor-Trailer Truck Drivers	Fuel	Contracting	3.6	3.7	2.4	5.3
221100	Electric Power Generation, Transmission and Distribution	11-1021	General and Operations Managers	Fuel	Growing	4.0	3.9	4.9	8.1
221100	Electric Power Generation, Transmission and Distribution	44-866	Sales Managers	Fuel	Growing	4.0	3.7	6.0	8.0
221100	Electric Power Generation,	40-9743	Computer and Information Systems Managers	Fuel	Growing	3.8	3.5	5.6	8.9

	Transmission and Distribution								
221100	Electric Power Generation, Transmission and Distribution	41-3395	Financial Managers	Fuel	Growing	3.3	3.0	6.3	8.5
221100	Electric Power Generation, Transmission and Distribution	42-0700	Industrial Production Managers	Fuel	Growing	5.0	4.8	4.9	7.8
221100	Electric Power Generation, Transmission and Distribution	44-6267	Human Resources Managers	Fuel	Growing	3.1	3.0	6.3	8.2
221100	Electric Power Generation, Transmission and Distribution	26-01198	Construction Managers	Fuel	Growing	5.4	5.6	5.7	9.1
221100	Electric Power Generation, Transmission and Distribution	26-08503	Architectural and Engineering Managers	Fuel	Growing	4.6	4.0	6.6	8.6
221100	Electric Power Generation, Transmission and Distribution	13-1041	Compliance Officers	Fuel	Growing	4.5	3.9	5.5	6.1
221100	Electric Power Generation, Transmission and Distribution	13-1071	Human Resources Specialists	Fuel	Growing	4.6	3.5	5.8	7.1
221100	Electric Power Generation, Transmission and Distribution	13-1111	Management Analysts	Fuel	Growing	4.7	4.1	7.2	8.0
221100	Electric Power Generation, Transmission and Distribution	13-2011	Accountants and Auditors	Fuel	Growing	5.0	3.6	6.0	5.0
221100	Electric Power Generation, Transmission and Distribution	17-2051	Civil Engineers	Fuel	Growing	5.1	3.7	6.8	6.8

221100	Electric Power Generation, Transmission and Distribution	17-2071	Electrical Engineers	Fuel	Growing	4.5	3.8	6.4	7.4
221100	Electric Power Generation, Transmission and Distribution	17-2112	Industrial Engineers	Fuel	Growing	4.5	4.3	6.7	6.9
221100	Electric Power Generation, Transmission and Distribution	17-3012	Electrical and Electronics Drafters	Fuel	Growing	4.1	3.6	4.2	6.6
221100	Electric Power Generation, Transmission and Distribution	17-3024	Electro-Mechanical and Mechatronics Technologists and Technicians	Fuel	Growing	5.4	4.5	4.2	7.1
221100	Electric Power Generation, Transmission and Distribution	19-2041	Environmental Scientists and Specialists, Including Health	Fuel	Growing	4.0	3.4	7.6	6.8
221100	Electric Power Generation, Transmission and Distribution	23-1011	Lawyers	Fuel	Growing	5.2	4.4	10.3	6.4
221100	Electric Power Generation, Transmission and Distribution	33-9032	Security Guards	Fuel	Growing	2.0	2.0	2.2	3.3
221100	Electric Power Generation, Transmission and Distribution	41-4011	Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	Fuel	Growing	3.5	3.0	4.6	6.3
221100	Electric Power Generation, Transmission and Distribution	43-4051	Customer Service Representatives	Fuel	Growing	3.2	3.4	4.4	5.9
221100	Electric Power Generation, Transmission and Distribution	43-5032	Dispatchers, Except Police, Fire, and Ambulance	Fuel	Growing	3.1	2.8	2.6	4.4
221100	Electric Power Generation,	43-5061	Production, Planning, and Expediting Clerks	Fuel	Growing	4.0	3.7	3.8	6.4

	Transmission and Distribution								
221100	Electric Power Generation, Transmission and Distribution	43-6011	Executive Secretaries and Executive Administrative Assistants	Fuel	Growing	3.2	2.9	4.5	6.7
221100	Electric Power Generation, Transmission and Distribution	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Fuel	Growing	3.2	3.2	3.4	5.1
221100	Electric Power Generation, Transmission and Distribution	47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Fuel	Growing	5.7	5.0	3.3	7.3
221100	Electric Power Generation, Transmission and Distribution	47-2111	Electricians	Fuel	Growing	6.1	5.7	3.0	7.4
221100	Electric Power Generation, Transmission and Distribution	47-2231	Solar Photovoltaic Installers	Fuel	Growing	3.5	2.6	2.6	4.0
221100	Electric Power Generation, Transmission and Distribution	49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Fuel	Growing	5.1	4.9	3.4	7.8
221100	Electric Power Generation, Transmission and Distribution	49-2095	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	Fuel	Growing	6.9	5.8	3.7	6.5
221100	Electric Power Generation, Transmission and Distribution	49-9012	Control and Valve Installers and Repairers, Except Mechanical Door	Fuel	Growing	5.6	5.2	2.7	6.7
221100	Electric Power Generation, Transmission and Distribution	49-9041	Industrial Machinery Mechanics	Fuel	Growing	5.2	4.4	3.2	6.9
221100	Electric Power Generation, Transmission and Distribution	49-9081	Wind Turbine Service Technicians	Fuel	Growing	4.3	3.7	3.1	5.8

221100	Electric Power Generation, Transmission and Distribution	51-1011	First-Line Supervisors of Production and Operating Workers	Fuel	Growing	4.7	3.8	3.5	8.6
221100	Electric Power Generation, Transmission and Distribution	51-8013	Power Plant Operators	Fuel	Growing	5.0	5.6	2.4	5.5
221100	Electric Power Generation, Transmission and Distribution	53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Fuel	Growing	2.5	2.3	2.1	3.3
237100	Utility System Construction	11-1021	General and Operations Managers	Fuel	Contracting	4.0	3.9	4.9	8.1
237100	Utility System Construction	41-3395	Financial Managers	Fuel	Contracting	3.3	3.0	6.3	8.5
237100	Utility System Construction	26-01198	Construction Managers	Fuel	Contracting	5.4	5.6	5.7	9.1
237100	Utility System Construction	26-08503	Architectural and Engineering Managers	Fuel	Contracting	4.6	4.0	6.6	8.6
237100	Utility System Construction	13-1051	Cost Estimators	Fuel	Contracting	5.8	4.3	5.9	6.6
237100	Utility System Construction	13-1071	Human Resources Specialists	Fuel	Contracting	4.6	3.5	5.8	7.1
237100	Utility System Construction	13-2011	Accountants and Auditors	Fuel	Contracting	5.0	3.6	6.0	5.0
237100	Utility System Construction	17-2051	Civil Engineers	Fuel	Contracting	5.1	3.7	6.8	6.8
237100	Utility System Construction	17-2071	Electrical Engineers	Fuel	Contracting	4.5	3.8	6.4	7.4
237100	Utility System Construction	17-2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors	Fuel	Contracting	5.0	4.4	6.0	6.9
237100	Utility System Construction	17-3011	Architectural and Civil Drafters	Fuel	Contracting	4.1	3.5	5.5	5.8
237100	Utility System Construction	33-9091	Crossing Guards and Flaggers	Fuel	Contracting	1.6	1.7	2.0	2.1
237100	Utility System Construction	43-1011	First-Line Supervisors of Office and Administrative Support Workers	Fuel	Contracting	4.6	3.9	4.6	6.8

237100	Utility System Construction	43-3021	Billing and Posting Clerks	Fuel	Contracting	3.3	2.8	3.1	5.3
237100	Utility System Construction	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Fuel	Contracting	3.6	3.2	3.4	6.0
237100	Utility System Construction	43-3051	Payroll and Timekeeping Clerks	Fuel	Contracting	3.0	2.5	3.5	6.1
237100	Utility System Construction	43-4161	Human Resources Assistants, Except Payroll and Timekeeping	Fuel	Contracting	3.7	2.9	4.5	6.1
237100	Utility System Construction	43-4171	Receptionists and Information Clerks	Fuel	Contracting	2.7	2.5	2.6	4.5
237100	Utility System Construction	43-5032	Dispatchers, Except Police, Fire, and Ambulance	Fuel	Contracting	3.1	2.8	2.6	4.4
237100	Utility System Construction	43-5061	Production, Planning, and Expediting Clerks	Fuel	Contracting	4.0	3.7	3.8	6.4
237100	Utility System Construction	43-6011	Executive Secretaries and Executive Administrative Assistants	Fuel	Contracting	3.2	2.9	4.5	6.7
237100	Utility System Construction	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Fuel	Contracting	3.2	3.2	3.4	5.1
237100	Utility System Construction	43-9061	Office Clerks, General	Fuel	Contracting	3.1	2.4	3.4	5.1
237100	Utility System Construction	47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Fuel	Contracting	5.7	5.0	3.3	7.3
237100	Utility System Construction	47-2031	Carpenters	Fuel	Contracting	4.7	4.1	2.5	6.2
237100	Utility System Construction	47-2051	Cement Masons and Concrete Finishers	Fuel	Contracting	4.0	3.0	1.6	3.7
237100	Utility System Construction	47-2061	Construction Laborers	Fuel	Contracting	3.1	3.5	1.9	4.1
237100	Utility System Construction	47-2071	Paving, Surfacing, and Tamping Equipment Operators	Fuel	Contracting	4.0	3.5	1.8	4.7
237100	Utility System Construction	47-2073	Operating Engineers and Other Construction Equipment Operators	Fuel	Contracting	4.8	4.4	2.1	6.1
237100	Utility System Construction	47-2111	Electricians	Fuel	Contracting	6.1	5.7	3.0	7.4

237100	Utility System Construction	47-2151	Pipelayers	Fuel	Contracting	4.2	4.3	2.1	5.4
237100	Utility System Construction	47-2152	Plumbers, Pipefitters, and Steamfitters	Fuel	Contracting	5.8	5.0	2.5	5.6
237100	Utility System Construction	47-3015	Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters	Fuel	Contracting	4.1	3.4	3.0	3.8
237100	Utility System Construction	47-4011	Construction and Building Inspectors	Fuel	Contracting	4.3	4.2	4.6	7.3
237100	Utility System Construction	47-5081	Helpers--Extraction Workers	Fuel	Contracting	3.0	2.6	2.1	2.5
237100	Utility System Construction	49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Fuel	Contracting	5.1	4.9	3.4	7.8
237100	Utility System Construction	49-3023	Automotive Service Technicians and Mechanics	Fuel	Contracting	4.9	4.4	2.6	6.4
237100	Utility System Construction	49-3031	Bus and Truck Mechanics and Diesel Engine Specialists	Fuel	Contracting	5.3	4.5	2.2	6.4
237100	Utility System Construction	49-3042	Mobile Heavy Equipment Mechanics, Except Engines	Fuel	Contracting	4.9	4.6	2.8	6.2
237100	Utility System Construction	49-9012	Control and Valve Installers and Repairers, Except Mechanical Door	Fuel	Contracting	5.6	5.2	2.7	6.7
237100	Utility System Construction	49-9043	Maintenance Workers, Machinery	Fuel	Contracting	5.1	4.1	3.0	6.8
237100	Utility System Construction	49-9051	Electrical Power-Line Installers and Repairers	Fuel	Contracting	5.9	4.4	2.6	4.5
237100	Utility System Construction	49-9052	Telecommunications Line Installers and Repairers	Fuel	Contracting	4.6	3.7	2.3	4.6
237100	Utility System Construction	49-9071	Maintenance and Repair Workers, General	Fuel	Contracting	4.7	3.9	2.6	5.9
237100	Utility System Construction	49-9098	Helpers--Installation, Maintenance, and Repair Workers	Fuel	Contracting	2.8	2.8	1.9	3.6
237100	Utility System Construction	51-1011	First-Line Supervisors of Production and Operating Workers	Fuel	Contracting	4.7	3.8	3.5	8.6
237100	Utility System Construction	51-4041	Machinists	Fuel	Contracting	4.6	4.1	2.9	6.1

237100	Utility System Construction	51-4121	Welders, Cutters, Solderers, and Brazers	Fuel	Contracting	4.0	4.1	2.3	5.5
237100	Utility System Construction	51-8031	Water and Wastewater Treatment Plant and System Operators	Fuel	Contracting	4.6	4.1	3.1	5.8
237100	Utility System Construction	51-9198	Helpers--Production Workers	Fuel	Contracting	2.8	2.5	1.9	3.4
237100	Utility System Construction	53-3032	Heavy and Tractor-Trailer Truck Drivers	Fuel	Contracting	3.6	3.7	2.4	5.3
237100	Utility System Construction	53-7021	Crane and Tower Operators	Fuel	Contracting	4.1	3.9	2.5	4.9
237100	Utility System Construction	53-7051	Industrial Truck and Tractor Operators	Fuel	Contracting	3.3	2.8	2.0	4.6
237100	Utility System Construction	53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Fuel	Contracting	2.5	2.3	2.1	3.3
237100	Utility System Construction	53-7072	Pump Operators, Except Wellhead Pumpers	Fuel	Contracting	4.3	2.8	2.3	3.7
237130	Power and Communication Line and Related Structures Construction	11-1021	General and Operations Managers	Fuel	Growing	4.0	3.9	4.9	8.1
237130	Power and Communication Line and Related Structures Construction	26-01198	Construction Managers	Fuel	Growing	5.4	5.6	5.7	9.1
237130	Power and Communication Line and Related Structures Construction	13-1051	Cost Estimators	Fuel	Growing	5.8	4.3	5.9	6.6
237130	Power and Communication Line and Related Structures Construction	13-2011	Accountants and Auditors	Fuel	Growing	5.0	3.6	6.0	5.0
237130	Power and Communication Line and Related Structures Construction	17-2051	Civil Engineers	Fuel	Growing	5.1	3.7	6.8	6.8
237130	Power and Communication Line and Related Structures Construction	17-2071	Electrical Engineers	Fuel	Growing	4.5	3.8	6.4	7.4

237130	Power and Communication Line and Related Structures Construction	33-9091	Crossing Guards and Flaggers	Fuel	Growing	1.6	1.7	2.0	2.1
237130	Power and Communication Line and Related Structures Construction	43-1011	First-Line Supervisors of Office and Administrative Support Workers	Fuel	Growing	4.6	3.9	4.6	6.8
237130	Power and Communication Line and Related Structures Construction	43-3021	Billing and Posting Clerks	Fuel	Growing	3.3	2.8	3.1	5.3
237130	Power and Communication Line and Related Structures Construction	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Fuel	Growing	3.6	3.2	3.4	6.0
237130	Power and Communication Line and Related Structures Construction	43-5061	Production, Planning, and Expediting Clerks	Fuel	Growing	4.0	3.7	3.8	6.4
237130	Power and Communication Line and Related Structures Construction	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Fuel	Growing	3.2	3.2	3.4	5.1
237130	Power and Communication Line and Related Structures Construction	43-9061	Office Clerks, General	Fuel	Growing	3.1	2.4	3.4	5.1
237130	Power and Communication Line and Related Structures Construction	47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Fuel	Growing	5.7	5.0	3.3	7.3
237130	Power and Communication Line and Related Structures Construction	47-2061	Construction Laborers	Fuel	Growing	3.1	3.5	1.9	4.1
237130	Power and Communication Line and Related Structures Construction	47-2073	Operating Engineers and Other Construction Equipment Operators	Fuel	Growing	4.8	4.4	2.1	6.1
237130	Power and Communication Line	47-2111	Electricians	Fuel	Growing	6.1	5.7	3.0	7.4

	and Related Structures Construction								
237130	Power and Communication Line and Related Structures Construction	47-2152	Plumbers, Pipefitters, and Steamfitters	Fuel	Growing	5.8	5.0	2.5	5.6
237130	Power and Communication Line and Related Structures Construction	49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Fuel	Growing	5.1	4.9	3.4	7.8
237130	Power and Communication Line and Related Structures Construction	49-3023	Automotive Service Technicians and Mechanics	Fuel	Growing	4.9	4.4	2.6	6.4
237130	Power and Communication Line and Related Structures Construction	49-3031	Bus and Truck Mechanics and Diesel Engine Specialists	Fuel	Growing	5.3	4.5	2.2	6.4
237130	Power and Communication Line and Related Structures Construction	49-3042	Mobile Heavy Equipment Mechanics, Except Engines	Fuel	Growing	4.9	4.6	2.8	6.2
237130	Power and Communication Line and Related Structures Construction	49-9051	Electrical Power-Line Installers and Repairers	Fuel	Growing	5.9	4.4	2.6	4.5
237130	Power and Communication Line and Related Structures Construction	49-9052	Telecommunications Line Installers and Repairers	Fuel	Growing	4.6	3.7	2.3	4.6
237130	Power and Communication Line and Related Structures Construction	49-9071	Maintenance and Repair Workers, General	Fuel	Growing	4.7	3.9	2.6	5.9
237130	Power and Communication Line and Related Structures Construction	51-4121	Welders, Cutters, Solderers, and Brazers	Fuel	Growing	4.0	4.1	2.3	5.5
237130	Power and Communication Line and Related Structures Construction	53-3032	Heavy and Tractor-Trailer Truck Drivers	Fuel	Growing	3.6	3.7	2.4	5.3

237130	Power and Communication Line and Related Structures Construction	53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Fuel	Growing	2.5	2.3	2.1	3.3
238210	Electrical Contractors and Other Wiring Installation Contractors	11-1021	General and Operations Managers	Fuel	Growing	4.0	3.9	4.9	8.1
238210	Electrical Contractors and Other Wiring Installation Contractors	44-866	Sales Managers	Fuel	Growing	4.0	3.7	6.0	8.0
238210	Electrical Contractors and Other Wiring Installation Contractors	40-9743	Computer and Information Systems Managers	Fuel	Growing	3.8	3.5	5.6	8.9
238210	Electrical Contractors and Other Wiring Installation Contractors	41-3395	Financial Managers	Fuel	Growing	3.3	3.0	6.3	8.5
238210	Electrical Contractors and Other Wiring Installation Contractors	44-6267	Human Resources Managers	Fuel	Growing	3.1	3.0	6.3	8.2
238210	Electrical Contractors and Other Wiring Installation Contractors	26-01198	Construction Managers	Fuel	Growing	5.4	5.6	5.7	9.1
238210	Electrical Contractors and Other Wiring Installation Contractors	26-08503	Architectural and Engineering Managers	Fuel	Growing	4.6	4.0	6.6	8.6
238210	Electrical Contractors and Other Wiring Installation Contractors	13-1051	Cost Estimators	Fuel	Growing	5.8	4.3	5.9	6.6
238210	Electrical Contractors and Other Wiring Installation Contractors	13-1071	Human Resources Specialists	Fuel	Growing	4.6	3.5	5.8	7.1
238210	Electrical Contractors and Other Wiring	13-1081	Logisticians	Fuel	Growing	4.6	3.9	5.8	7.2

	Installation Contractors								
238210	Electrical Contractors and Other Wiring Installation Contractors	13-1161	Market Research Analysts and Marketing Specialists	Fuel	Growing	3.8	2.2	6.8	6.3
238210	Electrical Contractors and Other Wiring Installation Contractors	13-2011	Accountants and Auditors	Fuel	Growing	5.0	3.6	6.0	5.0
238210	Electrical Contractors and Other Wiring Installation Contractors	17-1022	Surveyors	Fuel	Growing	5.2	3.7	5.4	6.3
238210	Electrical Contractors and Other Wiring Installation Contractors	17-2051	Civil Engineers	Fuel	Growing	5.1	3.7	6.8	6.8
238210	Electrical Contractors and Other Wiring Installation Contractors	17-2071	Electrical Engineers	Fuel	Growing	4.5	3.8	6.4	7.4
238210	Electrical Contractors and Other Wiring Installation Contractors	17-2072	Electronics Engineers, Except Computer	Fuel	Growing	4.8	4.2	5.8	7.6
238210	Electrical Contractors and Other Wiring Installation Contractors	17-2199	Engineers, All Other	Fuel	Growing	4.2	3.6	6.8	6.7
238210	Electrical Contractors and Other Wiring Installation Contractors	17-3012	Electrical and Electronics Drafters	Fuel	Growing	4.1	3.6	4.2	6.6
238210	Electrical Contractors and Other Wiring Installation Contractors	17-3023	Electrical and Electronic Engineering Technologists and Technicians	Fuel	Growing	4.4	4.2	4.2	6.5
238210	Electrical Contractors and Other Wiring Installation Contractors	37-2011	Janitors and Cleaners, Except Maids and Housekeeping Cleaners	Fuel	Growing	3.1	2.8	2.2	2.8

238210	Electrical Contractors and Other Wiring Installation Contractors	43-1011	First-Line Supervisors of Office and Administrative Support Workers	Fuel	Growing	4.6	3.9	4.6	6.8
238210	Electrical Contractors and Other Wiring Installation Contractors	43-3021	Billing and Posting Clerks	Fuel	Growing	3.3	2.8	3.1	5.3
238210	Electrical Contractors and Other Wiring Installation Contractors	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Fuel	Growing	3.6	3.2	3.4	6.0
238210	Electrical Contractors and Other Wiring Installation Contractors	43-3051	Payroll and Timekeeping Clerks	Fuel	Growing	3.0	2.5	3.5	6.1
238210	Electrical Contractors and Other Wiring Installation Contractors	43-4161	Human Resources Assistants, Except Payroll and Timekeeping	Fuel	Growing	3.7	2.9	4.5	6.1
238210	Electrical Contractors and Other Wiring Installation Contractors	43-4171	Receptionists and Information Clerks	Fuel	Growing	2.7	2.5	2.6	4.5
238210	Electrical Contractors and Other Wiring Installation Contractors	43-5032	Dispatchers, Except Police, Fire, and Ambulance	Fuel	Growing	3.1	2.8	2.6	4.4
238210	Electrical Contractors and Other Wiring Installation Contractors	43-5061	Production, Planning, and Expediting Clerks	Fuel	Growing	4.0	3.7	3.8	6.4
238210	Electrical Contractors and Other Wiring Installation Contractors	43-5071	Shipping, Receiving, and Inventory Clerks	Fuel	Growing	3.9	3.6	2.8	4.0
238210	Electrical Contractors and Other Wiring Installation Contractors	43-6011	Executive Secretaries and Executive Administrative Assistants	Fuel	Growing	3.2	2.9	4.5	6.7
238210	Electrical Contractors and Other Wiring	43-6014	Secretaries and Administrative Assistants,	Fuel	Growing	3.2	3.2	3.4	5.1

	Installation Contractors		Except Legal, Medical, and Executive						
238210	Electrical Contractors and Other Wiring Installation Contractors	43-9061	Office Clerks, General	Fuel	Growing	3.1	2.4	3.4	5.1
238210	Electrical Contractors and Other Wiring Installation Contractors	47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Fuel	Growing	5.7	5.0	3.3	7.3
238210	Electrical Contractors and Other Wiring Installation Contractors	47-2061	Construction Laborers	Fuel	Growing	3.1	3.5	1.9	4.1
238210	Electrical Contractors and Other Wiring Installation Contractors	47-2073	Operating Engineers and Other Construction Equipment Operators	Fuel	Growing	4.8	4.4	2.1	6.1
238210	Electrical Contractors and Other Wiring Installation Contractors	47-2111	Electricians	Fuel	Growing	6.1	5.7	3.0	7.4
238210	Electrical Contractors and Other Wiring Installation Contractors	47-2152	Plumbers, Pipefitters, and Steamfitters	Fuel	Growing	5.8	5.0	2.5	5.6
238210	Electrical Contractors and Other Wiring Installation Contractors	47-2231	Solar Photovoltaic Installers	Fuel	Growing	3.5	2.6	2.6	4.0
238210	Electrical Contractors and Other Wiring Installation Contractors	47-3013	0	Fuel	Growing	4.4	3.2	2.0	4.6
238210	Electrical Contractors and Other Wiring Installation Contractors	47-4011	Construction and Building Inspectors	Fuel	Growing	4.3	4.2	4.6	7.3
238210	Electrical Contractors and Other Wiring Installation Contractors	49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Fuel	Growing	5.1	4.9	3.4	7.8

238210	Electrical Contractors and Other Wiring Installation Contractors	49-2022	Telecommunications Equipment Installers and Repairers, Except Line Installers	Fuel	Growing	4.7	4.9	3.4	4.9
238210	Electrical Contractors and Other Wiring Installation Contractors	49-2092	Electric Motor, Power Tool, and Related Repairers	Fuel	Growing	4.1	3.3	3.1	5.2
238210	Electrical Contractors and Other Wiring Installation Contractors	49-2094	Electrical and Electronics Repairers, Commercial and Industrial Equipment	Fuel	Growing	4.9	4.5	4.0	7.4
238210	Electrical Contractors and Other Wiring Installation Contractors	49-2098	Security and Fire Alarm Systems Installers	Fuel	Growing	5.4	5.0	2.7	6.0
238210	Electrical Contractors and Other Wiring Installation Contractors	49-3023	Automotive Service Technicians and Mechanics	Fuel	Growing	4.9	4.4	2.6	6.4
238210	Electrical Contractors and Other Wiring Installation Contractors	49-3042	Mobile Heavy Equipment Mechanics, Except Engines	Fuel	Growing	4.9	4.6	2.8	6.2
238210	Electrical Contractors and Other Wiring Installation Contractors	49-9051	Electrical Power-Line Installers and Repairers	Fuel	Growing	5.9	4.4	2.6	4.5
238210	Electrical Contractors and Other Wiring Installation Contractors	49-9052	Telecommunications Line Installers and Repairers	Fuel	Growing	4.6	3.7	2.3	4.6
238210	Electrical Contractors and Other Wiring Installation Contractors	49-9071	Maintenance and Repair Workers, General	Fuel	Growing	4.7	3.9	2.6	5.9
238210	Electrical Contractors and Other Wiring Installation Contractors	49-9098	Helpers--Installation, Maintenance, and Repair Workers	Fuel	Growing	2.8	2.8	1.9	3.6
238210	Electrical Contractors and Other Wiring	51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	Fuel	Growing	4.0	3.7	2.5	4.9

	Installation Contractors								
238210	Electrical Contractors and Other Wiring Installation Contractors	53-3032	Heavy and Tractor-Trailer Truck Drivers	Fuel	Growing	3.6	3.7	2.4	5.3
238210	Electrical Contractors and Other Wiring Installation Contractors	53-3033	Light Truck Drivers	Fuel	Growing	2.3	2.1	1.8	3.3
238210	Electrical Contractors and Other Wiring Installation Contractors	53-7051	Industrial Truck and Tractor Operators	Fuel	Growing	3.3	2.8	2.0	4.6
238210	Electrical Contractors and Other Wiring Installation Contractors	53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Fuel	Growing	2.5	2.3	2.1	3.3
324100	Petroleum and Coal Products Manufacturing	11-1021	General and Operations Managers	Fuel	Contracting	4.0	3.9	4.9	8.1
324100	Petroleum and Coal Products Manufacturing	42-0700	Industrial Production Managers	Fuel	Contracting	5.0	4.8	4.9	7.8
324100	Petroleum and Coal Products Manufacturing	26-08503	Architectural and Engineering Managers	Fuel	Contracting	4.6	4.0	6.6	8.6
324100	Petroleum and Coal Products Manufacturing	13-1071	Human Resources Specialists	Fuel	Contracting	4.6	3.5	5.8	7.1
324100	Petroleum and Coal Products Manufacturing	13-1081	Logisticians	Fuel	Contracting	4.6	3.9	5.8	7.2
324100	Petroleum and Coal Products Manufacturing	13-1111	Management Analysts	Fuel	Contracting	4.7	4.1	7.2	8.0
324100	Petroleum and Coal Products Manufacturing	13-1151	Training and Development Specialists	Fuel	Contracting	3.9	3.8	6.3	7.3
324100	Petroleum and Coal Products Manufacturing	13-2011	Accountants and Auditors	Fuel	Contracting	5.0	3.6	6.0	5.0

324100	Petroleum and Coal Products Manufacturing	17-2141	Mechanical Engineers	Fuel	Contracting	3.8	3.2	6.7	6.7
324100	Petroleum and Coal Products Manufacturing	17-2171	Petroleum Engineers	Fuel	Contracting	4.9	3.7	6.2	8.3
324100	Petroleum and Coal Products Manufacturing	19-2031	Chemists	Fuel	Contracting	4.2	3.8	6.2	5.0
324100	Petroleum and Coal Products Manufacturing	19-2041	Environmental Scientists and Specialists, Including Health	Fuel	Contracting	4.0	3.4	7.6	6.8
324100	Petroleum and Coal Products Manufacturing	19-4031	Chemical Technicians	Fuel	Contracting	3.6	3.3	4.6	4.4
324100	Petroleum and Coal Products Manufacturing	27-3031	Public Relations Specialists	Fuel	Contracting	3.4	2.5	6.2	7.3
324100	Petroleum and Coal Products Manufacturing	43-1011	First-Line Supervisors of Office and Administrative Support Workers	Fuel	Contracting	4.6	3.9	4.6	6.8
324100	Petroleum and Coal Products Manufacturing	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Fuel	Contracting	3.6	3.2	3.4	6.0
324100	Petroleum and Coal Products Manufacturing	43-4051	Customer Service Representatives	Fuel	Contracting	3.2	3.4	4.4	5.9
324100	Petroleum and Coal Products Manufacturing	43-5061	Production, Planning, and Expediting Clerks	Fuel	Contracting	4.0	3.7	3.8	6.4
324100	Petroleum and Coal Products Manufacturing	43-5071	Shipping, Receiving, and Inventory Clerks	Fuel	Contracting	3.9	3.6	2.8	4.0
324100	Petroleum and Coal Products Manufacturing	43-6011	Executive Secretaries and Executive Administrative Assistants	Fuel	Contracting	3.2	2.9	4.5	6.7
324100	Petroleum and Coal Products Manufacturing	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Fuel	Contracting	3.2	3.2	3.4	5.1

324100	Petroleum and Coal Products Manufacturing	43-9061	Office Clerks, General	Fuel	Contracting	3.1	2.4	3.4	5.1
324100	Petroleum and Coal Products Manufacturing	47-2111	Electricians	Fuel	Contracting	6.1	5.7	3.0	7.4
324100	Petroleum and Coal Products Manufacturing	47-2152	Plumbers, Pipefitters, and Steamfitters	Fuel	Contracting	5.8	5.0	2.5	5.6
324100	Petroleum and Coal Products Manufacturing	47-5012	Rotary Drill Operators, Oil and Gas	Fuel	Contracting	5.0	4.6	2.6	6.1
324100	Petroleum and Coal Products Manufacturing	49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Fuel	Contracting	5.1	4.9	3.4	7.8
324100	Petroleum and Coal Products Manufacturing	49-9041	Industrial Machinery Mechanics	Fuel	Contracting	5.2	4.4	3.2	6.9
324100	Petroleum and Coal Products Manufacturing	49-9071	Maintenance and Repair Workers, General	Fuel	Contracting	4.7	3.9	2.6	5.9
324100	Petroleum and Coal Products Manufacturing	51-1011	First-Line Supervisors of Production and Operating Workers	Fuel	Contracting	4.7	3.8	3.5	8.6
324100	Petroleum and Coal Products Manufacturing	51-4041	Machinists	Fuel	Contracting	4.6	4.1	2.9	6.1
324100	Petroleum and Coal Products Manufacturing	51-8093	Petroleum Pump System Operators, Refinery Operators, and Gaugers	Fuel	Contracting	4.4	4.8	2.6	5.3
324100	Petroleum and Coal Products Manufacturing	51-9011	Chemical Equipment Operators and Tenders	Fuel	Contracting	4.8	4.7	3.0	5.9
324100	Petroleum and Coal Products Manufacturing	51-9023	Mixing and Blending Machine Setters, Operators, and Tenders	Fuel	Contracting	4.0	3.2	2.2	4.9
324100	Petroleum and Coal Products Manufacturing	51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	Fuel	Contracting	4.0	3.7	2.5	4.9
324100	Petroleum and Coal Products Manufacturing	51-9111	Packaging and Filling Machine Operators and Tenders	Fuel	Contracting	2.7	2.1	1.9	3.8

324100	Petroleum and Coal Products Manufacturing	51-9198	Helpers--Production Workers	Fuel	Contracting	2.8	2.5	1.9	3.4
324100	Petroleum and Coal Products Manufacturing	53-3032	Heavy and Tractor-Trailer Truck Drivers	Fuel	Contracting	3.6	3.7	2.4	5.3
324100	Petroleum and Coal Products Manufacturing	53-7051	Industrial Truck and Tractor Operators	Fuel	Contracting	3.3	2.8	2.0	4.6
324100	Petroleum and Coal Products Manufacturing	53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Fuel	Contracting	2.5	2.3	2.1	3.3
336300	Motor Vehicle Parts Manufacturing	11-1021	General and Operations Managers	Vehicle	Contracting	4.0	3.9	4.9	8.1
336300	Motor Vehicle Parts Manufacturing	44-866	Sales Managers	Vehicle	Contracting	4.0	3.7	6.0	8.0
336300	Motor Vehicle Parts Manufacturing	41-3395	Financial Managers	Vehicle	Contracting	3.3	3.0	6.3	8.5
336300	Motor Vehicle Parts Manufacturing	42-0700	Industrial Production Managers	Vehicle	Contracting	5.0	4.8	4.9	7.8
336300	Motor Vehicle Parts Manufacturing	26-08503	Architectural and Engineering Managers	Vehicle	Contracting	4.6	4.0	6.6	8.6
336300	Motor Vehicle Parts Manufacturing	13-1081	Logisticians	Vehicle	Contracting	4.6	3.9	5.8	7.2
336300	Motor Vehicle Parts Manufacturing	13-1161	Market Research Analysts and Marketing Specialists	Vehicle	Contracting	3.8	2.2	6.8	6.3
336300	Motor Vehicle Parts Manufacturing	13-2011	Accountants and Auditors	Vehicle	Contracting	5.0	3.6	6.0	5.0
336300	Motor Vehicle Parts Manufacturing	17-2112	Industrial Engineers	Vehicle	Contracting	4.5	4.3	6.7	6.9
336300	Motor Vehicle Parts Manufacturing	17-2141	Mechanical Engineers	Vehicle	Contracting	3.8	3.2	6.7	6.7
336300	Motor Vehicle Parts Manufacturing	17-3013	Mechanical Drafters	Vehicle	Contracting	3.8	3.3	5.1	6.8
336300	Motor Vehicle Parts Manufacturing	17-3023	Electrical and Electronic Engineering Technologists and Technicians	Vehicle	Contracting	4.4	4.2	4.2	6.5
336300	Motor Vehicle Parts Manufacturing	17-3026	Industrial Engineering Technologists and Technicians	Vehicle	Contracting	4.7	4.1	4.0	6.8

336300	Motor Vehicle Parts Manufacturing	17-3027	Mechanical Engineering Technologists and Technicians	Vehicle	Contracting	5.0	3.7	5.0	6.8
336300	Motor Vehicle Parts Manufacturing	27-1024	Graphic Designers	Vehicle	Contracting	3.0	2.5	5.4	5.9
336300	Motor Vehicle Parts Manufacturing	37-2011	Janitors and Cleaners, Except Maids and Housekeeping Cleaners	Vehicle	Contracting	3.1	2.8	2.2	2.8
336300	Motor Vehicle Parts Manufacturing	41-4011	Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	Vehicle	Contracting	3.5	3.0	4.6	6.3
336300	Motor Vehicle Parts Manufacturing	41-4012	Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products	Vehicle	Contracting	3.5	3.6	5.1	7.2
336300	Motor Vehicle Parts Manufacturing	43-1011	First-Line Supervisors of Office and Administrative Support Workers	Vehicle	Contracting	4.6	3.9	4.6	6.8
336300	Motor Vehicle Parts Manufacturing	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Vehicle	Contracting	3.6	3.2	3.4	6.0
336300	Motor Vehicle Parts Manufacturing	43-4051	Customer Service Representatives	Vehicle	Contracting	3.2	3.4	4.4	5.9
336300	Motor Vehicle Parts Manufacturing	43-5061	Production, Planning, and Expediting Clerks	Vehicle	Contracting	4.0	3.7	3.8	6.4
336300	Motor Vehicle Parts Manufacturing	43-5071	Shipping, Receiving, and Inventory Clerks	Vehicle	Contracting	3.9	3.6	2.8	4.0
336300	Motor Vehicle Parts Manufacturing	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Vehicle	Contracting	3.2	3.2	3.4	5.1
336300	Motor Vehicle Parts Manufacturing	43-9061	Office Clerks, General	Vehicle	Contracting	3.1	2.4	3.4	5.1
336300	Motor Vehicle Parts Manufacturing	49-9041	Industrial Machinery Mechanics	Vehicle	Contracting	5.2	4.4	3.2	6.9
336300	Motor Vehicle Parts Manufacturing	49-9043	Maintenance Workers, Machinery	Vehicle	Contracting	5.1	4.1	3.0	6.8
336300	Motor Vehicle Parts Manufacturing	49-9071	Maintenance and Repair Workers, General	Vehicle	Contracting	4.7	3.9	2.6	5.9

336300	Motor Vehicle Parts Manufacturing	51-1011	First-Line Supervisors of Production and Operating Workers	Vehicle	Contracting	4.7	3.8	3.5	8.6
336300	Motor Vehicle Parts Manufacturing	51-2031	Engine and Other Machine Assemblers	Vehicle	Contracting	4.4	2.9	2.5	5.2
336300	Motor Vehicle Parts Manufacturing	51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	Vehicle	Contracting	4.0	3.9	2.2	4.7
336300	Motor Vehicle Parts Manufacturing	51-4033	Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, Operators, and Tenders, Metal and Plastic	Vehicle	Contracting	3.6	4.0	2.2	4.3
336300	Motor Vehicle Parts Manufacturing	51-4034	Lathe and Turning Machine Tool Setters, Operators, and Tenders, Metal and Plastic	Vehicle	Contracting	2.5	2.6	2.5	4.2
336300	Motor Vehicle Parts Manufacturing	51-4041	Machinists	Vehicle	Contracting	4.6	4.1	2.9	6.1
336300	Motor Vehicle Parts Manufacturing	51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	Vehicle	Contracting	4.1	3.6	1.8	4.6
336300	Motor Vehicle Parts Manufacturing	51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	Vehicle	Contracting	3.8	3.2	2.2	5.2
336300	Motor Vehicle Parts Manufacturing	51-4111	Tool and Die Makers	Vehicle	Contracting	4.9	4.6	3.4	7.6
336300	Motor Vehicle Parts Manufacturing	51-4121	Welders, Cutters, Solderers, and Brazers	Vehicle	Contracting	4.0	4.1	2.3	5.5
336300	Motor Vehicle Parts Manufacturing	51-6031	Sewing Machine Operators	Vehicle	Contracting	3.7	3.4	1.6	4.5
336300	Motor Vehicle Parts Manufacturing	51-6093	Upholsterers	Vehicle	Contracting	3.6	3.1	1.6	5.4
336300	Motor Vehicle Parts Manufacturing	51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	Vehicle	Contracting	4.0	3.7	2.5	4.9
336300	Motor Vehicle Parts Manufacturing	51-9111	Packaging and Filling Machine Operators and Tenders	Vehicle	Contracting	2.7	2.1	1.9	3.8
336300	Motor Vehicle Parts Manufacturing	51-9198	Helpers--Production Workers	Vehicle	Contracting	2.8	2.5	1.9	3.4

336300	Motor Vehicle Parts Manufacturing	53-7051	Industrial Truck and Tractor Operators	Vehicle	Contracting	3.3	2.8	2.0	4.6
336300	Motor Vehicle Parts Manufacturing	53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Vehicle	Contracting	2.5	2.3	2.1	3.3
336300	Motor Vehicle Parts Manufacturing	53-7064	Packers and Packagers, Hand	Vehicle	Contracting	1.9	2.0	2.1	2.4
811110	Automotive Mechanical and Electrical Repair and Maintenance	11-1021	General and Operations Managers	Vehicle	Contracting	4.0	3.9	4.9	8.1
811110	Automotive Mechanical and Electrical Repair and Maintenance	44-866	Sales Managers	Vehicle	Contracting	4.0	3.7	6.0	8.0
811110	Automotive Mechanical and Electrical Repair and Maintenance	42-8005	Transportation, Storage, and Distribution Managers	Vehicle	Contracting	4.0	3.6	5.1	7.4
811110	Automotive Mechanical and Electrical Repair and Maintenance	13-1051	Cost Estimators	Vehicle	Contracting	5.8	4.3	5.9	6.6
811110	Automotive Mechanical and Electrical Repair and Maintenance	13-1151	Training and Development Specialists	Vehicle	Contracting	3.9	3.8	6.3	7.3
811110	Automotive Mechanical and Electrical Repair and Maintenance	13-2011	Accountants and Auditors	Vehicle	Contracting	5.0	3.6	6.0	5.0
811110	Automotive Mechanical and Electrical Repair and Maintenance	37-2011	Janitors and Cleaners, Except Maids and Housekeeping Cleaners	Vehicle	Contracting	3.1	2.8	2.2	2.8
811110	Automotive Mechanical and Electrical Repair and Maintenance	41-1011	First-Line Supervisors of Retail Sales Workers	Vehicle	Contracting	3.9	3.4	2.7	5.9
811110	Automotive Mechanical and Electrical Repair and Maintenance	41-1012	First-Line Supervisors of Non-Retail Sales Workers	Vehicle	Contracting	3.4	3.4	4.7	7.3

811110	Automotive Mechanical and Electrical Repair and Maintenance	41-2011	Cashiers	Vehicle	Contracting	2.3	1.7	1.7	2.3
811110	Automotive Mechanical and Electrical Repair and Maintenance	41-2021	Counter and Rental Clerks	Vehicle	Contracting	3.2	2.8	3.4	3.5
811110	Automotive Mechanical and Electrical Repair and Maintenance	41-2022	Parts Salespersons	Vehicle	Contracting	3.7	3.3	2.3	5.9
811110	Automotive Mechanical and Electrical Repair and Maintenance	43-1011	First-Line Supervisors of Office and Administrative Support Workers	Vehicle	Contracting	4.6	3.9	4.6	6.8
811110	Automotive Mechanical and Electrical Repair and Maintenance	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Vehicle	Contracting	3.6	3.2	3.4	6.0
811110	Automotive Mechanical and Electrical Repair and Maintenance	43-4051	Customer Service Representatives	Vehicle	Contracting	3.2	3.4	4.4	5.9
811110	Automotive Mechanical and Electrical Repair and Maintenance	43-4171	Receptionists and Information Clerks	Vehicle	Contracting	2.7	2.5	2.6	4.5
811110	Automotive Mechanical and Electrical Repair and Maintenance	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Vehicle	Contracting	3.2	3.2	3.4	5.1
811110	Automotive Mechanical and Electrical Repair and Maintenance	43-9061	Office Clerks, General	Vehicle	Contracting	3.1	2.4	3.4	5.1
811110	Automotive Mechanical and Electrical Repair and Maintenance	49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Vehicle	Contracting	5.1	4.9	3.4	7.8
811110	Automotive Mechanical and	49-3021	Automotive Body and Related Repairers	Vehicle	Contracting	3.1	2.5	2.1	3.8

	Electrical Repair and Maintenance								
811110	Automotive Mechanical and Electrical Repair and Maintenance	49-3023	Automotive Service Technicians and Mechanics	Vehicle	Contracting	4.9	4.4	2.6	6.4
811110	Automotive Mechanical and Electrical Repair and Maintenance	49-3031	Bus and Truck Mechanics and Diesel Engine Specialists	Vehicle	Contracting	5.3	4.5	2.2	6.4
811110	Automotive Mechanical and Electrical Repair and Maintenance	49-3093	Tire Repairers and Changers	Vehicle	Contracting	3.0	2.7	2.3	3.9
811110	Automotive Mechanical and Electrical Repair and Maintenance	49-9071	Maintenance and Repair Workers, General	Vehicle	Contracting	4.7	3.9	2.6	5.9
811110	Automotive Mechanical and Electrical Repair and Maintenance	49-9098	Helpers--Installation, Maintenance, and Repair Workers	Vehicle	Contracting	2.8	2.8	1.9	3.6
811110	Automotive Mechanical and Electrical Repair and Maintenance	53-3032	Heavy and Tractor-Trailer Truck Drivers	Vehicle	Contracting	3.6	3.7	2.4	5.3
811110	Automotive Mechanical and Electrical Repair and Maintenance	53-3033	Light Truck Drivers	Vehicle	Contracting	2.3	2.1	1.8	3.3
811110	Automotive Mechanical and Electrical Repair and Maintenance	53-6031	Automotive and Watercraft Service Attendants	Vehicle	Contracting	4.1	3.1	2.1	3.4
811110	Automotive Mechanical and Electrical Repair and Maintenance	53-7061	Cleaners of Vehicles and Equipment	Vehicle	Contracting	3.1	2.4	1.8	3.9
811190	Other Automotive Repair and Maintenance	11-1021	General and Operations Managers	Vehicle	Contracting	4.0	3.9	4.9	8.1

811190	Other Automotive Repair and Maintenance	41-1011	First-Line Supervisors of Retail Sales Workers	Vehicle	Contracting	3.9	3.4	2.7	5.9
811190	Other Automotive Repair and Maintenance	41-2011	Cashiers	Vehicle	Contracting	2.3	1.7	1.7	2.3
811190	Other Automotive Repair and Maintenance	41-2021	Counter and Rental Clerks	Vehicle	Contracting	3.2	2.8	3.4	3.5
811190	Other Automotive Repair and Maintenance	43-3031	Bookkeeping, Accounting, and Auditing Clerks	Vehicle	Contracting	3.6	3.2	3.4	6.0
811190	Other Automotive Repair and Maintenance	43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	Vehicle	Contracting	3.2	3.2	3.4	5.1
811190	Other Automotive Repair and Maintenance	43-9061	Office Clerks, General	Vehicle	Contracting	3.1	2.4	3.4	5.1
811190	Other Automotive Repair and Maintenance	49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Vehicle	Contracting	5.1	4.9	3.4	7.8
811190	Other Automotive Repair and Maintenance	49-3023	Automotive Service Technicians and Mechanics	Vehicle	Contracting	4.9	4.4	2.6	6.4
811190	Other Automotive Repair and Maintenance	49-3093	Tire Repairers and Changers	Vehicle	Contracting	3.0	2.7	2.3	3.9
811190	Other Automotive Repair and Maintenance	53-6031	Automotive and Watercraft Service Attendants	Vehicle	Contracting	4.1	3.1	2.1	3.4
811190	Other Automotive Repair and Maintenance	53-7061	Cleaners of Vehicles and Equipment	Vehicle	Contracting	3.1	2.4	1.8	3.9

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