Impacts of the Advanced Clean Fleets Regulation on the Trucking Industry, Consumers, and the Economy

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Executive Summary

This report analyzes the Advanced Clean Fleets (ACF) Regulation, which was adopted by the California Air Resources Board (CARB) in April 2023. The regulation requires owners of trucking fleets to phase out their gasoline- and diesel-powered vehicles and replace them with zero emissions vehicles within the next two decades. The regulation affects fleet operations beginning in 2026 and requires that 100 percent of the operations to be zero emission by between 2035 and 2042, depending on the type of fleet and truck. The regulation is intended to help California meet its extremely ambitious goal of net-zero CO_2 emissions by 2045. Our key findings are:

The trucking industry is crucial to the operation of California's economy.
It accounts for 75 percent of all cargo shipments in California, and over 83 percent of shipments that start and end within the state. It plays a crucial role in moving products through the supply chain, from farms to factories, to warehouses, to retail stores, and to other end users such as hospitals, construction contractors, and households. Cost increases or disruptions to the trucking industry would have far-reaching effects on the whole economy, including households that would face higher prices and product shortages.

Heavy-duty trucking has long been recognized as extremely difficult and expensive to fully decarbonize. For example, a 2018 report by the California Energy Commission (CEC) found that only 50 percent of the trucking industry (mostly cargo vans and other short haul vehicles) is conducive to electrification. It also found that reducing emissions in the heavy-duty trucking sector costs as much as $1,600 per ton of avoided CO_2 emissions – by far the most expensive emissions-reducing solution of any they identified. While there has been technological progress since 2018, electrification of the heavy-duty trucking industry remains an enormously challenging and expensive proposition. This reflects several factors, including high power needs, limited driving range on a charge, long charging times, and high costs for electric trucks and chargers. Equally important is the massive investment in electrical grid upgrades needed to meet electricity demands of charging depots, which can use as much power as a small city.

Yet the ACF mandate requires elimination of diesel-powered vehicles with very little flexibility. While the ACF mandate offers two pathways (see Appendix) for fleet owners to phase out their diesel- and gas-powered vehicles, once chosen, the pathways are inflexible. Fleet owners will be forced to make expenditures for high-priced vehicles and for charger installations, regardless of whether the pace of technological improvement and battery cost reductions meet expectations. More importantly, the investments will need to be made before it is known whether the state is keeping its end of the bargain of ensuring the necessary expansions in electrical grid capacity are made. The grid expansion needed to meet the state's 2045 zero net carbon goals will require unprecedented build rates for electrical generation, battery storage, as well as transmission and distribution. There are enormous permitting, financial, and

technological challenges to these investments, and there is no assurance they will be fully completed in the required timeframe.

CARB asserts that the ACF regulation will save fleet owners money. In a break with past findings, CARB's economic impact analysis in 2022 of the costs and benefits of the ACF regulation asserts that the state can make a transition to an all-electric trucking system inexpensively. In fact, it asserts that the total cost of ownership will *fall* for fleet owners as modestly higher initial outlays for the BEV purchases are more than offset by lower fueling and other operating costs.

This conclusion, however, is based on wishful thinking and faulty cost comparisons. CARB's total cost of ownership estimates for electric trucks are based on vehicle purchase prices and electricity costs that are seriously understated. The cost comparisons between diesel and electric versions of trucks are also distorted because CARB's diesel fuel cost estimates include $1.35 per gallon in excise and sales taxes used to support roads, highway and bridges, while their operating costs for electric vehicles assume no replacement of those taxes. The loss of billions of dollars in road taxes would have devastating impacts on traffic congestion, road wear-and-tear, and traffic safety. Finally, CARB excludes from their cost comparisons losses in efficiencies associated with heavy-duty electric trucks. These include more fueling stops (due to shorter range per charge), longer fueling times, and reduced cargo capacity due to the high weight of lithium batteries needed to power BEV big rigs.

More likely outcome – major increase in trucking costs. When the cost comparisons are adjusted to reflect the above factors, we estimate the cost of ownership for electric trucks will range from 22 percent higher than their diesel counterparts for smaller cargo vans, to more than 136 percent for heavy-duty tractor trailers using roadside charging. We estimate the weighted average cost increase across fleets to be about 80 percent.

Higher trucking costs will hurt consumers. According to the U.S. Department of Transportation, each dollar of sales in the wholesale and retail trade sector requires about 9.9 cents of transportation services. Transportation accounts for smaller but still significant shares of output in other industries. Based on trucking's significant contribution to economic output in various industries, we estimate that an 80 percent increase in trucking costs would translate into a 3.6 percent increase in the cost of goods and services purchased by households in California. For an average household, that translates into about $2,500 in additional expenditures each year to maintain the same standard of living.

These costs would come on top of numerous other expenses that Californians will be incurring for the transition to clean energy. These include higher utility rates as well as expenses for vehicle chargers and heat pump installations. The ACF-related price increases to consumers would act like a regressive tax, hitting households at the lower end of the income distribution the hardest.

Other risks posed by the ACF regulation. A key risk is whether an adequate electrical grid infrastructure will be in place to accommodate the enormous charging needs of an all-electric transportation system. The ACF mandate will be occurring at the same time as all other sectors of California's economy are electrifying, which in turn will require at least a 130 percent increase in the size of the electrical grid. Actual grid demands will likely be even greater given emerging demands put on the grid by artificial intelligence (AI) data centers. At the same time, the state is shifting over to all renewable electric generation, which will require major investments in expensive technologies, such as offshore wind using untested floating platform technologies. The governor has stated that meeting these challenges will require build rates for generation and storage that are 5 times historical averages.

If the state's electrical grid expansion fails to keep up with electricity demand, the consequences for the trucking industry and, ultimately, consumers could be severe. At a minimum, shortfalls would result in electricity rationing (such as load shifting) mandated by grid operators, which would hamper fleet operations, further raise trucking costs, and in some cases, result in significant shipping delays. More serious problems would emerge if shortfalls were to result in widespread electricity supply disruptions or unplanned blackouts, which could cause product shortages and price spikes reminiscent of the Covid-19 pandemic.

Fire risks are also a concern. Early evidence suggests that the incidence of fires in battery-powered electric vehicles are similar to internal combustion engine (ICE) vehicles of a similar age. However, the consequences of a lithium battery fire are much more severe. They burn hotter, reaching 1,000 degrees (Fahrenheit), emit toxic fumes, are hard to put out, and have a tendency to reignite, sometimes days after being put out. Lithium batteries also become unstable and can explode at high temperatures. The greater fire risk raises two concerns. One is whether insurance rates for BEV trucks will rise significantly as underwriting experience is obtained about property damage and costs associated with lithium battery fires. The other is whether an exemption should be provided from the ACF mandate for vehicles hauling flammable materials. The involvement of lithium batteries in a fire started at a petroleum fuel terminal, a gas station, a charging depot, in a tunnel, or on a bridge could have dire consequences.

Renewable diesel is an attractive alternative. Given the enormous costs and risks associated with electrification of the trucking sector, it makes sense to consider a more flexible pathway to CO_2 emission reduction, such as one that allows use of renewable diesel in trucking segments that are expensive and risky to electrify. Currently, renewable diesel can be used as a replacement fuel or blended with any amount of petroleum diesel without significant modifications to the truck. According to CARB, renewable diesel has a lifecycle carbon intensity that is over 70 percent less than petroleum diesel and 53 percent less than electricity currently used by Californians. Renewable diesel is more expensive to produce than petroleum-based diesel. Thus, its usage would raise trucking transportation costs modestly – though by only a fraction of the costs and with none of the risks associated with electrification.

In summary, the ACF regulation is an inflexible mandate that could prove extremely costly to California. A much better approach to decarbonization would be one that combines incentives with policies that give fleet owners flexibility to choose cost-effective options for cutting emissions, such as renewable diesel, until full electrification becomes economically and technologically viable.

Background – California's Decarbonization Goals

Over the past two decades, California leaders have adopted legislative measures calling for progressively deeper cuts in CO_2 emissions. In 2005, Governor Schwarzenegger signed Executive Order S-3-05, which set goals for limiting greenhouse gas emissions in the state. This was followed by the Global Warming Solutions Act of 2006, commonly known as AB 32, which established a program of limiting emissions and giving the California Air Resources Board (CARB) a key role in setting rules for implementing the reductions. The goal in the 2006 legislation was to reduce CO_2 emissions to 1990s levels by 2020 – a 15 percent reduction from a "business-as-usual" baseline.

This was followed by a series of legislative measures aimed at further reducing emissions. These included SB 32 (Pavley, 2016), which requires a 40 percent reduction in greenhouse gas emissions from 1990 levels by 2030; and SB 100 (de León, 2015), which requires that 60 percent of electricity sales come from renewable sources by 2030, and that 100 percent come from renewables by 2045. More recently, the governor and legislature have set goals and directives aimed at achieving full carbon neutrality by 2045. In response to this direction, the California Air Resources Board's 2022 Scoping Plan sets forth a path for achieving carbon neutrality over the next two decades by eliminating or offsetting CO_2 emissions generated by every sector of the economy.

Early recognition that full decarbonization would be enormously expensive. Up until 2020, there was agreement among California's environmental agencies that, while significant reductions in CO_2 emissions were achievable, full elimination of all CO_2 emissions would be enormously expensive and would require implementation of as-yet unproven technologies.

The trucking industry was recognized to be one of the most difficult-to-decarbonize sectors. In a major 2018 study on deep decarbonization of California's economy, the California Energy Commission indicated that only about one-half of the medium- and heavy-duty trucking sectors were conducive to electrification (mostly delivery trucks on fixed routes). It also estimated that the incremental cost of reducing emissions from this sector would be $1,600 per ton of avoided CO_2 emissions – by far the most expensive emissions-reducing solution of any they identified.[1]

Notwithstanding the enormous costs and challenges, recent executive orders, laws, and regulations have accelerated emission reduction goals. In 2020, Governor Newsom issued Executive Order (EO) N-79-20 aimed at eliminating internal combustion engine (ICE) vehicles over the next two decades. Specifically, the EO directed CARB to develop regulations requiring that: 100 percent of in-state sales of new passenger cars

[1] See page 56 of "Deep Decarbonization in a High Renewables Future." California Energy Commission. June 2018. https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2018-012.pdf

and light-duty trucks be zero-emission by 2035; 100 percent of drayage trucks (vehicles that move cargo between ports and railyards or warehouses) be zero-emission by 2035; 100 percent of medium- and heavy-duty vehicles in the state be zero-emission by 2045, where feasible; and 100 percent of off-road vehicles and equipment be zero-emission by 2035, where feasible.

In response to the Governor's EO relating to on-road vehicles, CARB adopted three primary regulations (see **Figure 1** for details). These consist of the *Advanced Clean Cars II* (ACC II) regulation, which requires increasing shares of passenger cars and light pickup sales to be zero-emission, starting at 35 percent in 2026 and rising to 100 percent by 2035; the *Advanced Clean Trucks* (ACT) regulation, which requires increasing shares of trucks sold in California to be zero-emission; and the *Advanced Clean Fleets* (ACF) regulation (the focus of this report), which requires fleet owners to phase out internal combustion engine-powered trucks. The substance of these regulations was included in the 2022 Scoping Plan, which described a pathway for reaching carbon neutrality for all sectors of the economy by 2045.

Figure 1
CARB Regulations Phasing Out Internal Combustion Engine Vehicles

Regulation	Date Adopted	Provisions
Advanced Clean Cars II	2022	Increases share of light-duty vehicles sold in CA. to be zero-emission (100 percent by 2035). Tightens emission standards for new ICE vehicles sold during transition period (applies to all vehicles, including trucks).
Advanced Clean Trucks	2023	Increases share of trucks and buses sold in California to be zero-emission starting in 2026, with percentage target of 40 percent to 75 percent by 2035, depending on the type of vehicle.
Advanced Clean Fleets (Focus of this Report)	2023	Requires fleet owners to replace ICE vehicles with zero-emission vehicles. • Drayage trucks – 100 percent zero emissions by 2035. • Fleets of 50 or more trucks (at least one in California) or with $50 million or more in annual gross receipts – 100 percent zero emissions by between 2035 and 2042 depending on type of truck. • Government Fleets – 100 percent purchases to be zero emissions by 2027, with emergency vehicles exempted.

CARB updated assessment: decarbonization of the trucking sector can be achieved relatively painlessly. CARB's economic impact analysis of the ACF regulation departed sharply from earlier assessments about the high costs of decarbonizing the trucking sector. In the Standard Regulatory Impact Assessment (SRIA) accompanying the ACF regulation, CARB asserted that the regulation would *save* fleet owners money. While a small portion of the dramatic shift from earlier analyses may be attributed to genuine improvements in BEV technologies, most of the difference appears to be due to wishful thinking – or more specifically, the use of unrealistic assumptions regarding the cost of shifting to an all-electric trucking industry.

In the remaining sections of this report, we discuss the crucial role of trucking in California, then turn to the question of how the ACF regulation will affect real-world trucking costs and operations in this state. We specifically evaluate the assumptions behind CARB's cost comparisons, then develop our own cost comparisons using experience reported from pilot projects and other real-world experience. We then discuss the implications of our cost comparisons for the trucking industry and, ultimately, for California households. We conclude by discussing some of the major risks associated with the zero-emission trucking mandate and discuss the benefits of a more flexible strategy using renewable diesel.

The Role of The Trucking Industry in California

In 2023, the trucking industry directly accounted for $29 billion in gross domestic product, 265,000 jobs, and $25 billion in earnings in California.[2] Of the jobs,151,000 workers were employees of fleet operators and 114,000 were self-employed independent truckers. In addition, the industry supported tens of thousands of jobs in maintenance, repair, and logistics industries. All of these jobs are vulnerable to adverse outcomes resulting from the ACF regulation and its companion ACT regulation.

[2] Source for gross domestic product: U.S. Bureau of Economic Analysis. "Gross Domestic Product by State." https://www.bea.gov/data/gdp/gdp-state. Source of jobs and earnings totals for employees: California Employment Development Department, "Quarterly Census of Employment and Wages" https://labormarketinfo.edd.ca.gov/qcew/cew-select.asp. Source of job and earnings totals for independent contractors: U.S. Census Bureau. "Non-Employer Statistics Data.".https://www.census.gov/programs-surveys/nonemployer-statistics/data/tables.html.

Trucks Affected by the ACF Regulation

The ACF regulation discussed in this report applies to vehicles with a gross vehicle weight rating (GWR) of more than 8,500 lbs. Vehicles with a GWR of less than 8,500 lbs. (passenger vehicles and light pickup trucks) are covered separately by CARB's ACC II regulation. As indicated in the table below, a wide range of vehicles are covered by the ACF regulation, from smaller cargo vans that primarily travel locally, to large tractor trailers that travel regionally and long distances. Freight is often moved through an integrated system involving several of types of these vehicles.

Classification	Weight	Examples
Passenger Vehicles Covered by the Advanced Clean Cars II Regulation		
Class1-2a	Up to 8,500 lbs.	Passenger cars, SUVs, light duty pickups, minivans.
Trucks Covered by the Advanced Clean Trucks and Advanced Clean Fleets Regulations		
Class 2b-3	6,501 lbs. to 14,000 lbs.	Heavy-duty pickup trucks, cargo vans, and passenger vans.
Class 4-5	14,001 lbs. to 19,500 lbs.	Lighter delivery vans and service trucks.
Class 6-7	19,501 lbs. to 33,000 lbs.	Heavier delivery vans, bucket trucks, rack trucks, and high-profile cab over engine trucks.
Class 8	33,001 lbs. and heavier	Fuel truck, large single unit trucks (including dump trucks), and tractor-trailers (including drayage, short to regional haul operations and long-haul operations).

The main economic impact of the trucking industry, however, relates to its crucial role in California's supply chain. It is not an exaggeration to say that virtually the whole state economy is directly or indirectly dependent on trucking. The industry connects mining, agriculture, manufacturing, wholesaling, retailing and, ultimately, consumers. Food processing manufacturers depend on timely delivery of agricultural products from farms. Building contractors depend on timely supply of lumber, aggregate and other building materials. Hospitals depend on timely delivery of medical supplies and medicines for effective patient care. And retail stores depend on trucking to keep shelves stocked with perishable fruits, vegetables, frozen foods and other groceries and merchandise. The trucking industry accounts for 75 percent of the value of freight shipments in California, and 73 percent of the tonnage. For shipments starting and ending in the state, trucking accounts for 83 percent of shipping values and 79 percent of tonnage.[3]

Prior CARB Trucking Regulations

While the focus of this report is the ACF regulation and its companion ACT regulation, it should be noted that the trucking industry has been subject to increasingly strict regulations by CARB over the past two decades. The focus of the earlier regulations was on reducing particulate matter and nitrogen oxides, as well as greenhouse gas pollution emitted by diesel engines and refrigeration units. These regulations have reduced trucking-related small-particle pollution by 80 percent and nitrogen oxide pollution by 60 percent, thus improving the health of Californians, particularly in communities adjacent to major trucking corridors. At the same time, they have increased expenses to truck owners for upgraded filters and refrigeration systems, tires and tractor redesigns, and for replacement of pre-2010 engines.

Regulation	Year First Adopted	Key Provisions
Drayage Truck Regulation	2007	Requires diesel emissions reductions as well as recordkeeping and reporting. Sunsetted in 2022 and subsumed in the Advanced Clean Fleets Regulation.
Truck and Bus Regulation	2008	Requires diesel trucks and buses with a gross vehicle weight rating greater than 14,000 pounds to reduce exhaust emissions by meeting PM filter requirements and upgrading to a 2010 or newer engine model year.
Transport Refrigeration Unit (TRU) Regulation	2004	Requires diesel-powered TRUs to meet ultra-low particulate matter standards and to use refrigerants that have low global-warming potential.
The Innovative Clean Transit (ICT) regulation (adopted in 2018)	2018	Public transit agencies to transition to zero-emission buses by 2040. Stepped-up purchase requirements for new buses, starting at 25 percent (for large agencies) by 2023, rising to 50 percent for all agencies by 2026 and 100 percent by 2029.
Zero-Emission Airport Shuttle Regulation	2019	33 percent of airport shuttles to be zero-emission by 2028 and 100 percent to be zero-emission by 2036.

[3] California Department of Transportation, 2023 Freight Mobility Plan.

Costs of the ACF Regulation

CARB's assertion that fleet owners will save money under the ACF regulation is based on comparisons of the total cost of ownership (TCO) for diesel-powered versus natural-gas powered, battery-electric powered, and fuel-cell hydrogen powered versions of the same vehicle. CARB developed these cost comparisons for six different types of trucks – a Class-2b cargo van, a Class-5 walk-in van, a Class-6 bucket truck, a Class-8 refuse packer, a Class-8 day cab used for drayage operations, and a Class-8 sleeper cab used for longer-distance freight hauling.

Our analysis focuses on four of the six vehicle Classes – the Class-2b cargo van, the Class-5 walk-in van, the Class-8 day cab, and the Class-8 sleeper cab. These four vehicle Classes move most of the cargo in California. We have also limited our TCO comparisons to the diesel-powered and battery-powered electric (battery electric or BEV) versions of each vehicle. This is because the principal zero-emission alternative to BEVs – the hydrogen-powered fuel cell vehicle – is in an even earlier stage of development. Current purchase prices of hydrogen vehicles are higher than BEVs, the fueling infrastructure has yet to be developed, and "green hydrogen" requires enormous amounts of electricity to produce and is extremely expensive. Our assumption in this area is consistent with the Scoping Plan, which assumes the great majority of zero-emission vehicles will be battery-powered over the next two decades.

Components of TCO Comparisons

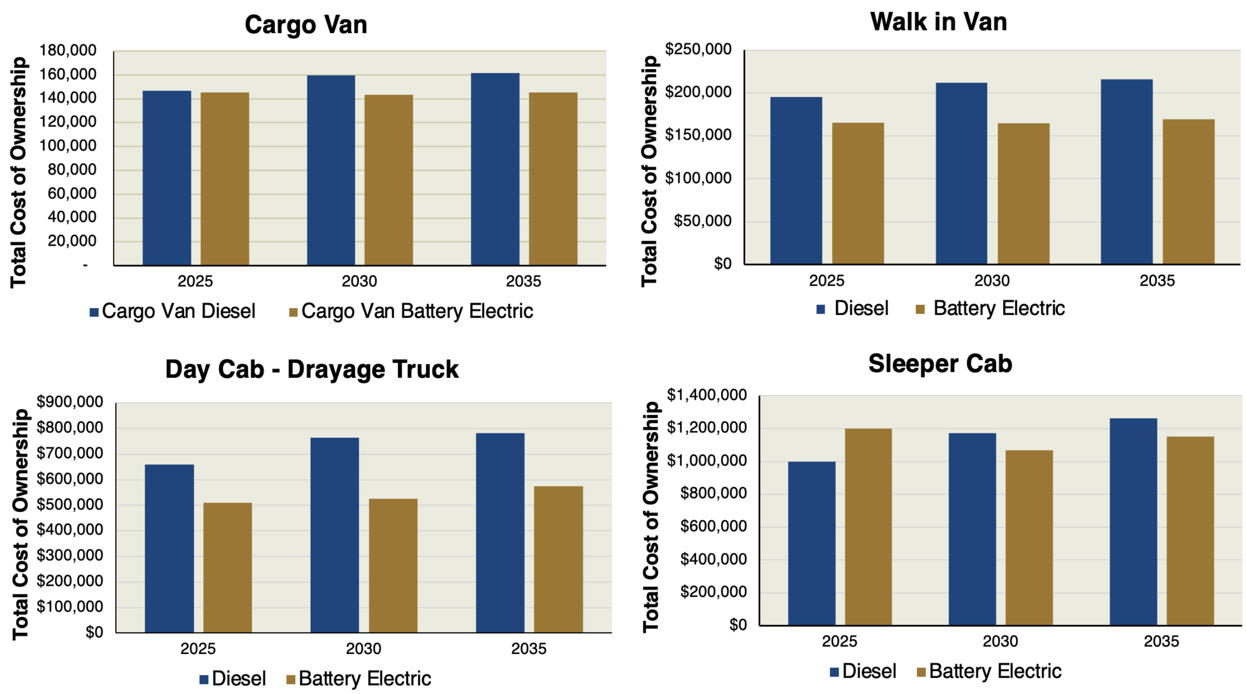
TCO comparisons are based on costs incurred over the life of a vehicle, extending from its initial purchase through the conclusion of its assumed 12 years of service. Key costs include vehicle purchase and financing; battery charger purchase and installation (including infrastructure upgrades); fueling; maintenance; and depreciation. CARB's TCO estimates for electric vehicles also include savings from the Low Carbon Fuel Standard (LCFS) program. Under the program, credits can be earned by fleets using electricity or hydrogen to power their vehicles. These credits can then be sold on the LCFS market, with the proceeds used to offset charging costs.[4]

Results of CARB's TCO Comparisons

Based on its TCO calculations, CARB asserts that battery electric vehicles will be cost competitive immediately with diesel-powered vehicles, as modestly higher upfront costs for vehicle purchases and infrastructure are offset by lower fuel costs and LCFS revenues. They further assert that relative costs for electric vehicles will fall as technology improves, to the point that their TCOs are consistently lower than their diesel-powered counterparts by 2035 (see **Figure 2**, next page).

[4] For a description of the LCFS program, see California Air Resources Board, "Low Carbon Fuel Standard." https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about#:~:text=The%20LCFS%20standards%20are%20expressed,O%2C%20and%20other%20GHG%20contributors

Figure 2
CARB's TCO Estimates: Diesel Versus Electric Trucks



Our Assessment

Our analysis indicates that the TCO for battery electric vehicles in all four Classes will be substantially higher than CARB's estimate. The key reasons for this conclusion are highlighted in **Figure 3** (next page) and discussed in more detail below.

Figure 3
Key Areas Where CARB's TCO Analysis Understates Zero-Emission Vehicle Costs

	Comments
Cost of Vehicles	Understated.
Cost of Electricity	Substantially understated.
Low Carbon Fuel Standard Credits	Includes LCFS subsidies for vehicles using grid electric power, which distorts underlying comparisons. Funding for the credits will dry up as economy makes transition to low-carbon fuels.
Excluded Costs:	
- Replacement of diesel fuel taxes and vehicle fees.	BEV costs do not include offsets for the loss of $1.35 per gallon of diesel taxes currently used to support roads and highways. The lack of replacement would have devastating impacts on the economy, as well as the health and safety of the public.
- Efficiency losses	Estimates exclude BEV efficiency losses associated with longer charging times, shorter vehicle range, and – for Class 8 vehicles – reduced load capacity.

Cost of Vehicles

The CARB TCO comparisons assumes that battery-powered trucks will cost from 25 percent to 63 percent more than their diesel counterparts in 2025. It also assumes that these differentials will shrink over time as manufacturing scales up and the price of battery power (which accounts for up to 40 percent of BEV costs) fall. CARB's price estimates for EVs use a component cost-based approach, where costs of battery packs and other electric components are added to a conventional glider vehicle (i.e., a vehicle without a power train), with a 10 percent mark-up for research, development, retooling, and overhead costs.

Real world price differences are currently much larger than those used in the CARB's cost comparisons. For example, a July 2024 study by Ryder (a major trucking logistics and leasing company) found that current prices paid for electric vehicles exceeded comparable ICE vehicles by 70 percent for Class-4 cargo vans, and by up to 220 percent for Class-8 heavy-duty tractors.[5] Other reports we reviewed found BEV prices for heavy-duty trucks to be as much as three times higher than their diesel counterparts. The higher sales prices partly reflect the current lack of manufacturing scale (which drives up unit costs).

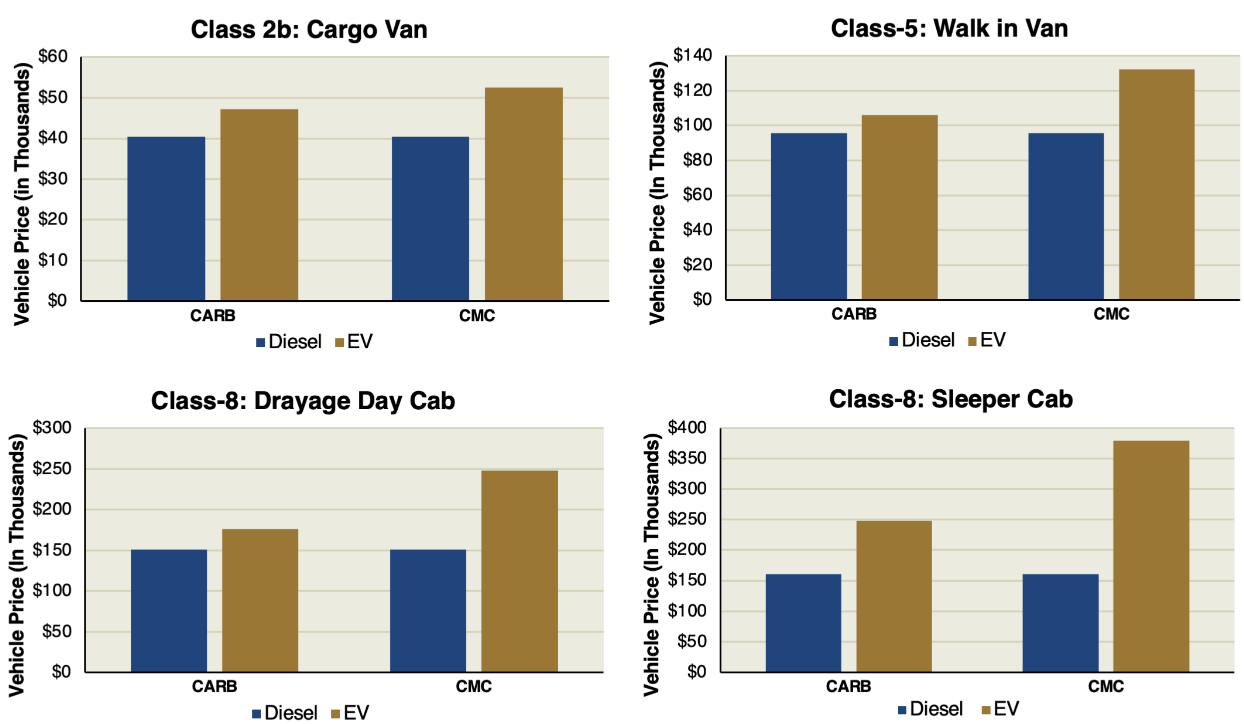
[5] See "Charged Logistics: The Cost of Electric Vehicle Conversion for U.S. Commercial Fleets." Ryder Systems, Inc. https://www.ryder.com/en-us/insights/white-papers/fleet/ev-total-cost-study.

However, they also reflect the complex engineering and software challenges for electric-powered trucks, which add considerably to research, development and production costs.

These price differentials will likely decline as BEV manufacturing scales up and battery prices fall. However, there are limits to the extent of this decline, due to BEV manufacturing complexities as well as supply constraints over the longer term for key battery metals such as cobalt, lithium, and nickel, which will drive up prices of raw materials going into batteries.[6]

Figure 4 compares our estimates (labeled "CMC") of medium- and heavy-duty truck prices to the CARB assumptions. Based on recent evidence, we assume that BEV prices will exceed CARB estimates through 2035.

Figure 4
Purchase Prices for Diesel Versus BEV Trucks – 2035



[6] After soaring in 2021 and 2022, prices of battery-metals have fallen over the past year due to slackening demand for BEVs. However, shortages will likely re-emerge in the future once BEV demand – driven by government mandates – resumes its upward trend. For discussions of recent developments and longer-term challenges in the battery-metals industries, see "Low Battery Metal Prices Set to Persist in 2024, Adding Friction to Energy Transition." Wall Street Journal. December 28, 2023. https://www.wsj.com/articles/low-battery-metal-prices-set-to-persist-in-2024-adding-friction-to-energy-transition-3773ba00, and "The Energy Transition Will Require Cobalt. America's Only Mine Can't Get Off the Ground." Wall Street Journal, July 22, 2023. https://www.wsj.com/articles/the-energy-transition-will-require-cobalt-americas-only-mine-cant-get-off-the-ground-e5ea91f1?mod=article_inline

Cost of Electricity

Based on published rates for the state's major utilities, CARB calculated that depot charging rates for trucking averaged about $0.17 per kilowatt hour (kWh) in 2021. CARB's TCO assumes that these rates will increase modestly to an average of $0.22/kWh by 2035. CARB also estimates that on-road rapid charging rates will rise from $0.34/kWh in 2021 to $0.44/kWh by 2035. CARB's projected growth rates for both depot and on-road charging are tied to the CEC's and the EIA's projections of electricity prices made in 2018 – before expensive policies requiring grid hardening, upgrades and massive expansions were adopted.

Our review suggests that future electricity rates will be substantially higher than assumed in CARB's calculations, due to three main factors:

- **Recent rate increases.** According to the EIA, the weighted average cost to all consumers in the state jumped from $0.169/kWh in May 2021 to $0.267/kWh in May 2024, a 58 percent increase in three years. Using the same source as cited in the CARB analysis for on-road charging in 2021, we find that current prices in most locations are $0.56/kWh, a 65 percent increase in three years.[7]
- **Near-term increases related to wildfires and net energy metering**. In its annual report to the Legislature on consumer utility rates, the California Public Utilities Commission (CPUC) reported that recent rate increases are set to continue through its four-year projection period. Rates for residences and small commercial businesses are projected to rise by over 8 percent per year between December 2023 and December 2027.[8] The report identifies the main contributors to these increases to be costs for wildfire risk reduction and the Net Energy Metering (NEM) program.
- **Future increases for grid upgrades, renewable power generation, and battery storage.** Notably, the rate increases through the end of 2027 do not include costs for new renewable power generation and storage, transmission, and distribution needed to meet the demands of a fully electrified economy. (The CPUC indicates that these costs will be evaluated and incorporated into rates at a later date.) We know, however, that these expenses will be large. According to estimates presented by Southern California Edison, decarbonization of California's economy will require $247 billion in incremental expenditures for renewable generation and $125 billion in new expenditures for upgrades and expansions to the electrical transmission and distribution systems. Actual expenses could be considerably higher due to soaring costs for offshore wind, which could be three or more times the amounts assumed in the Southern California Edison report.[9] We estimate that annual revenue

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[7] Source: *Electrify America*. https://www.electrifyamerica.com/. Data accessed through its charging app on August 20, 2024.

[8] See "Senate Bill 695 2024 Report." California Public Utilities Commission. July 2024. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2024/2024-sb-695-report.pdf

[9] Offshore wind is an important component of an all-renewable electric generation system because it complements solar with higher output in the evenings when electricity demand is high, onshore wind production is low, and solar production is non-existent. Evening power will be crucial to meeting overnight electricity demand from BEV charging.

requirements from ratepayers to cover these expenses will be $25 billion by 2035, which, when combined with expected power consumption during the year, will translate into a 29 percent increase in per-kilowatt rates.

Combined impact on rates. Putting these three factors together and adjusting for inflation, we estimate that average charging rates for truck depots will be approximately $0.38 in 2030 and $0.40 by 2035 (see **Figure 5**). On-road rapid charging rates are estimated to $0.66/kWh in 2030 and $0.69/kWh by 2035.

Figure 5
Comparison of Electricity Price Assumptions – 2035 (Per Kilowatt Rates) (Constant 2022 Dollars)

	CARB Estimate	CMC Estimate
Average Depot Rates	$0.22	$0.40
On-Road Retail Rates	$0.44	$0.69

The CPUC could hold the line on electrical charging rates by continuing to offer deep discounts based on time-of-day charging. However, it will become more difficult to offer deep discounts as vehicle charging requirements increase. Transportation currently accounts for about 3 percent of electrical power used in California. Under CARB's 2022 Scoping Plan, the share is expected to increase to nearly 40 percent by 2045.[10]

On the other side of the TCO calculation, CARB's estimate for diesel averages about $4.40 per gallon in 2035 (in 2022 dollars). The estimate does not incorporate the large increase in diesel prices that occurred following Russia's invasion of Iraq in 2022. Higher diesel prices raise operating costs for diesel trucks, making cost comparisons less favorable versus their BEV counterparts. While diesel prices have receded from the 2022 peaks, they remain elevated compared to CARB's estimates. Thus, in our TCO calculations, we have adjusted CARB's diesel price assumption upward to $5.00 per gallon to reflect current realities in the diesel fuel markets.

Low Carbon Fuel Standard Revenues

The LCFS regulation requires the carbon intensity of California's transportation fuels to decrease by 20 percent through 2030 and maintains the standard thereafter. Fleets that own and operate their electric charging infrastructure generate LCFS credits based on the amount of energy they dispense, which can then be sold to offset the costs of these fuels. Fleets purchasing electricity on the road may indirectly benefit to the extent that the owners of on-road chargers pass along the savings they generate from dispensing electricity.

[10] Source: "AB 32 CHG Inventory Sectors Modeling Data Spreadsheet." 2022 Scoping Plan Documents. https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents

These savings are included in CARB's TCO calculations as an offset to electricity costs – even though CARB states that its TCO analysis excludes government subsidies, such as vehicle and charger rebates.[11] We exclude the LCFS subsidies in our calculation because they distort true cost comparisons. The savings are being funded by other Californians, including drivers that continue to use diesel- and gasoline-powered vehicles for economic reasons. Also, LCFS credits will no longer be available once petroleum-based fuels are phased out, so even if the subsidies are counted, it should be noted they are temporary.

Replacement of Sales and Excise Taxes on Diesel

CARB's estimate for diesel fuel costs includes government excise and sales taxes that support California's transportation system. Its estimate of BEV operating costs does not include replacement of these taxes, thus creating an "apples to oranges" comparison. BEVs do pay an annual $100 road maintenance fee, but that fee covers only a fraction of federal and state taxes on diesel-powered trucks.

The foregone excise and sales taxes do not have a massive impact on public roads at present, since BEVs account for less than four percent of total vehicles on the road. However, as California moves to an all-electric transportation system, the foregone revenues would have a devastating impact on the state. Drivers would face more traffic congestion, more road wear-and-tear, more injuries and more deaths. CARB does acknowledge the loss in government revenues in other parts of its overall economic analysis of its ACC II, ACT and ACF regulations. However, it does not include the negative impacts of decaying roads and highways on the economy, or on public health and safety.

Given the long-standing "user-pays" principle applied to transportation infrastructure financing, cost estimates for battery-powered trucks should include taxes that are comparable to those levied on diesel-powered vehicles today. (Or alternatively, prices of diesel should be adjusted downward by $1.35 per gallon to exclude current taxes paid for roads and highways).

Efficiency Losses

A key element *not* included in CARB's TCO analyses is the loss in efficiencies resulting from:

- **Longer charging times.** For heavy-duty trucks, charging times can take more than 2 hours, versus the 20 minutes needed to refuel comparable diesel vehicles.[12] The times can be longer in instances when wait times are encountered because charging depots are full.
- **Shorter driving ranges.** BEVs have one-third to one-half the driving range of their diesel-powered counterparts.

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[11] See page G-1 of "Appendix G, Total Cost of Ownership Discussion, Advanced Clean Fleets Regulation". https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appg.pdf

[12] See, for example, "Time: BEVs Less Widely Recognized Challenge." Jason Cannon in *Clean Trucking*, September 27, 2023. https://www.cleantrucking.com/battery-electric/article/15543533/time-to-charge-as-much-of-a-challenge-as-range

- **Reduced load capacity**. BEV trucks are heavier than their diesel counterparts due to battery weight. This has significant implications for Class-8 trucks, which move a considerable amount of cargo in the state. Given federal weight restrictions, the maximum freight capacity for a battery-powered Class-8 trucks is currently about 22,000 pounds compared to 29,000 pounds for diesel.

These efficiency losses, coupled with strict federal and state limitations on maximum shifts and driving time, imply that it will take more electric-powered trucks and drivers to move the same amount of freight in a given time period as compared to their diesel counterparts.

More fundamentally, a key concern about CARB's TCO estimates for electric trucks is that they are not based on real world conditions. The estimates assume all routes and deliveries are predictable, that all truck charging will occur overnight or during driver rest breaks (thus not impinging on driving time), and that BEVs will never have to alter routes to find open charging stations.

In the real world, there will be last minute trip-requests, route changes, and deliveries that are time-sensitive. Diesel-powered trucks are well-suited to handle these situations, given that diesel fueling stations are ubiquitous and fueling times are short so driver down time is limited. BEVs simply do not have that flexibility. Route changes or additions can, at a minimum, push more BEV charging into daytime periods, when it is impinging on driving time and raising costs.

An added concern is that, while CARB is assuming that fleet owners will be able to charge their vehicles when it is optimal for their operations, the California Energy Commission is asserting that successful transition to a clean-energy economy will require electricity load shifting to conform to the needs of the energy grid.[13] In an all-renewable grid, maximum power will be available during the day, when solar production is at its peak, rather than in the evening, when CARB is assuming most trucks will be charging. We discuss the consequences of this inconsistency in the section below titled "Additional Challenges and Risks Posed by the ACF Regulation."

Other Costs

Other costs include charger installation, insurance, maintenance, and registration. These are partly offset by savings from tax depreciation and proceeds from the sale of the truck at the end of its assumed 12-year lifespan. We assume modestly higher costs for charging and associated infrastructure, based on our review of cost-estimates for specific electrification projects as well as the likelihood that more fast-chargers will be needed to accommodate charging needs.[14] In other areas, we generally accepted CARB's estimates,

[13] Load-Shift Goal Report, California Energy Commission. https://www.energy.ca.gov/publications/2023/senate-bill-846-load-shift-goal-report

[14] For example, CARB's TCO estimate of charger installation for a Class-8 drayage truck is $85,000 for the charger and $100,000 for installation. In its 2021 analysis of "Proposed Rule 2305 – Warehouse Indirect Source Rule – Warehouse Actions and Investments to Reduce Emissions (WAIRE) Program and Proposed Rule 316 – Fees for Rule 2305," the South Coast Air Quality Management District estimated that chargers for Class 7 or 8 big-rigs will cost as much as $140,000 to purchase and $80,000 to install. Material and labor costs have increased significantly since 2021. CARB's TCO estimates of charger installation costs for a Class-5 walk-in van are $3,172 for a level-2 charger and $28,318 for

making adjustments for insurance, depreciation, and other factors only to reflect vehicle price differentials. Regarding insurance costs, CARB estimates assume that rates for BEV trucks are identical to their diesel versions. We adopted that assumption for purposes of the TCO comparisons. However, it is possible, even probable, that insurers will charge higher rates on BEVs as the higher costs associated with battery fires are included in their rate-setting calculations. We discuss the issue of fire risk in the section below titled "Additional Challenges and Risks Posed by the ACF Regulation."

Our Revised TCO Calculations

In this section, we present the results of our estimates of the TCO for diesel- and battery-electric versions of four types of vehicles. Our estimates incorporate the factors discussed above regarding higher prices for electric trucks, higher costs for electricity and diesel, replacement of excise and sales taxes on diesel, elimination of the LCFS subsidy, and efficiency losses.

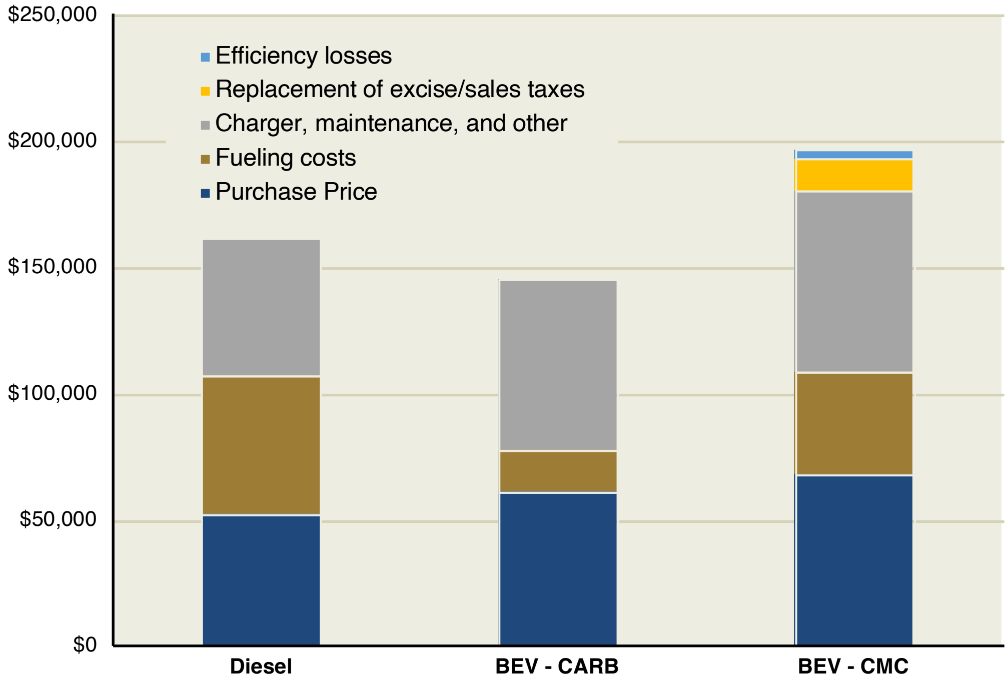
Class-2b Cargo Van

As shown in **Figure 6** (next page), we estimate that the TCO for a BEV version of a Class-2b cargo van is about 22 percent higher than a comparable diesel version. The net increase reflects higher costs for vehicle purchase and charger installation, partly offset by lower fueling costs.

Our estimated TCO for the BEV version is $51,000 higher than the CARB estimate, mainly reflecting additional costs for the vehicle purchase and electricity, and the replacement of diesel taxes. We also assume modest cost increases due to efficiency losses. These increases are limited for this vehicle Class, however, since most charging is assumed to occur overnight – thus not impinging on driver time.

installation costs. It is likely that vans of that size would require, at a minimum, a combination of level-2 and level-3 chargers.

Figure 6
TCO Comparisons – Class-2b Cargo Vans

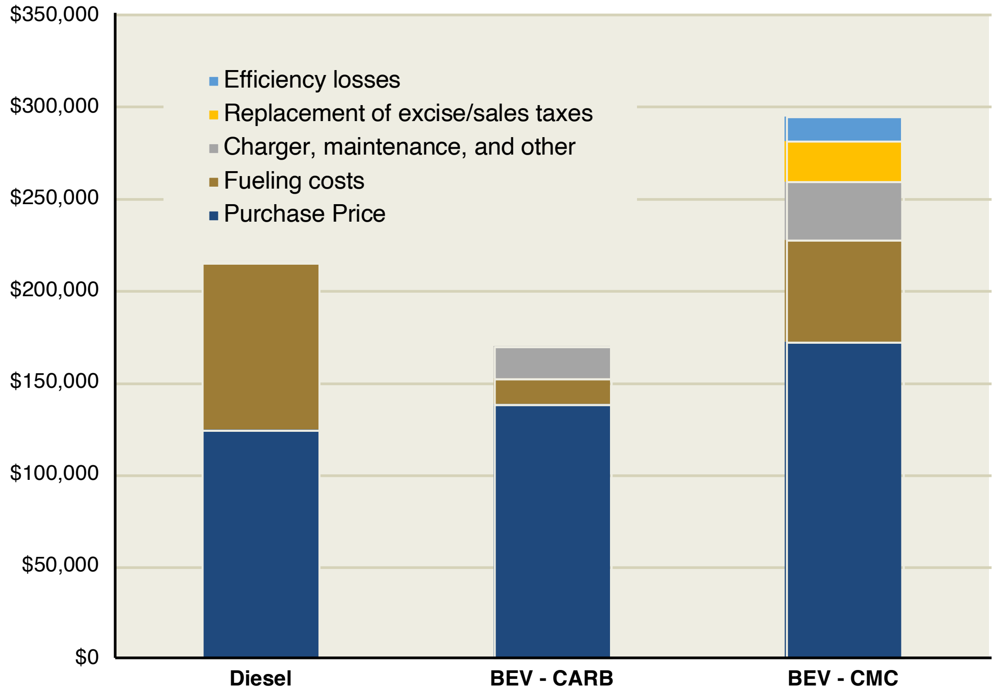


Class-5 Walk-In Van

We estimate that the TCO for a BEV version of a Class-5 walk-in van is 36 percent higher than the comparable diesel version (see **Figure 7**, next page). The net increase is due to higher costs for vehicle purchase and charger installation, which are partly offset by lower fueling costs.

Our estimated TCO for the BEV version is $125,000 higher than the CARB estimate, reflecting our assumption of higher costs for vehicle purchase and electricity. As in other comparisons, we assume replacement of diesel taxes. We also assume modest cost increases due to efficiency losses. Even though most charging for this vehicle is assumed to take place overnight in these comparisons, there will be some efficiency losses on days where there is need for daytime charging.

Figure 7
TCO Comparison – Class-5 Walk-In Van

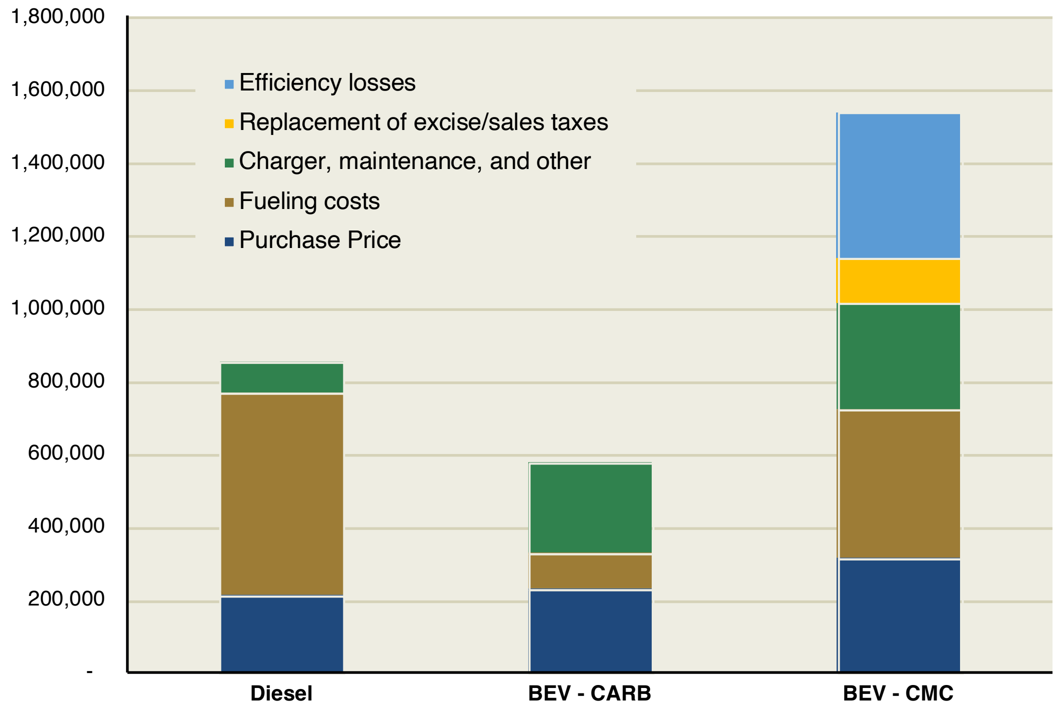


Class-8 Day Cab

We estimate that the TCO for a BEV version of a Class-8 day cab is about 80 percent higher than the cost of its diesel counterpart (see **Figure 8**, next page). The net increase reflects higher initial purchase costs and charger installation, replacement of diesel taxes, and significant efficiency losses – all of which are only partly offset by lower fueling costs. The efficiency losses for this vehicle become significant due to the need for more daytime charging and the weight limits on cargo.

Relative to the CARB estimate, our TCO for the BEV version is $962,000 higher. The increase reflects higher electricity costs, efficiency losses, our inclusion of replacement diesel taxes, and our assumption of a higher vehicle purchase price.

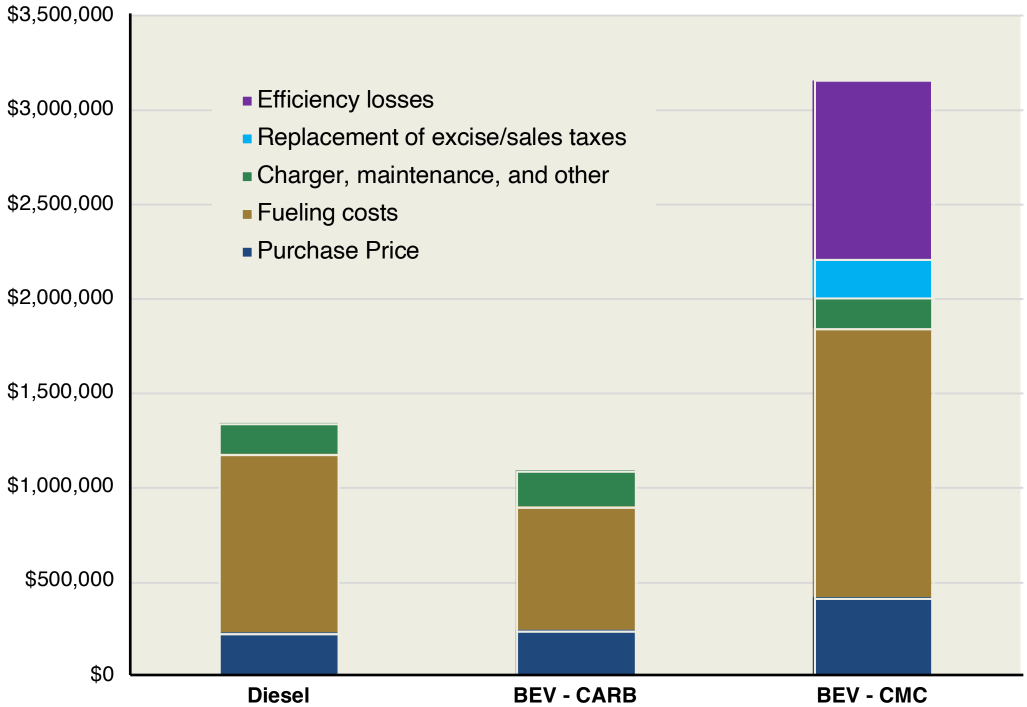
Figure 8
TCO Comparison – Class-8 Day Cab



Class-8 Sleeper Cab Exclusively Using On-Road Charging

We estimate that the TCO for a BEV version of a Class-8 Sleeper Cab is 136 percent higher than its diesel counterpart. As indicated in **Figure 9** (next page), the main additional costs are related to efficiency losses and higher costs for fueling and initial purchase. (The truck in this example does not incur expenses for charger installation because all charging is assumed to be provided by third-party charging stations located at rest stops). Our estimated TCO for the BEV version is $2.4 million more than the CARB estimate, reflecting additional costs from efficiency losses, fueling costs, replacement of taxes on diesel, and a higher purchase price.

Figure 9
TCO Comparison – Class-8 Sleeper Cab Exclusively Using On-Road Charging



In summary, we estimate that the cost of ownership will be moderately higher for the electric versions of smaller and mid-sized trucks, and sharply higher for the electric versions of Class-8 tractor trailers. We estimate the weighted average cost increase across trucks of all sizes is about 80 percent.[15]

Comparison to other assessments. Our findings regarding cost increases for electric trucks are consistent with several research studies on the subject. For example, a February 2024 study conducted by researchers at the University of Illinois found that "while it is technologically feasible to facilitate long-haul e-truck operation on the interstate highways, the prolonged journey time (between 16% and 32%) due to charging and the high initial adoption cost remain key obstacles for adoption from a fleet carrier's point of view."[16] The previously mentioned study by Ryder found that the cost of transport for electric versions of lighter-duty delivery trucks were only modestly higher than their diesel counterparts, but costs for the BEV versions of heavy-duty trucks were 114 percent above the diesel counterparts, due to higher purchase prices for the BEV version, the need to install expensive charging systems, and efficiency losses due to charging times and load restrictions. It should be noted that the Ryder costs comparisons occurred when

[15] Weighted average estimate takes into account the fact that most costs and receipts associated with freight movement is attributed to large tractor trailers, which account for virtually all long-distance shipments and a significant share of local shipments. Source of local versus long-distance trucking shipment data: U.S. Census Bureau, retrieved from FRED, Federal Reserve Bank of St. Louis, August 18, 2024. https://fred.stlouisfed.org/series/REVEF484121ALLEST
[16] "Is Electric Truck a Viable Alternative to Diesel Truck in Long-Haul Operations." Xi Cheng and Jane Lin, University of Illinois. Published in Transportation Research Part D: Transport and Environment. https://www.sciencedirect.com/journal/transportation-research-part-d-transport-and-environment

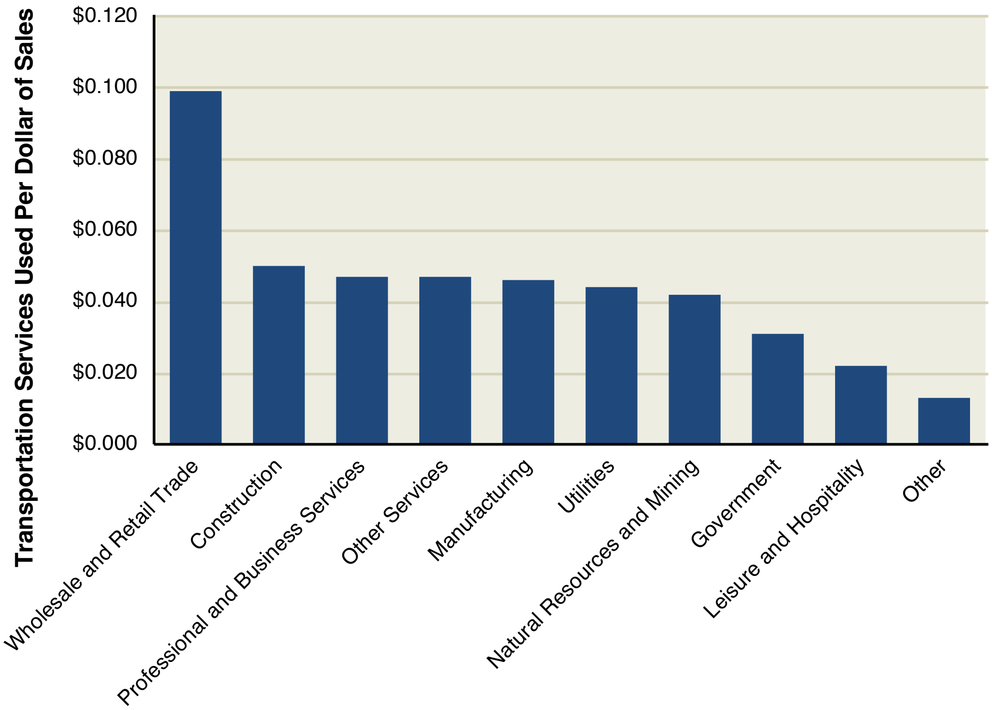
California diesel prices had temporarily spiked to $6.39 per gallon. Using today's prices for electricity and diesel, the relative cost of transportation for these BEVs would be even less favorable.

Impact on diesel-powered vehicles remaining in fleets. Beyond the direct ownership costs for BEVs, trucking companies will also face higher costs for the remaining diesel-powered trucks in their fleets. This will occur as refineries scale back or close operations due to falling petroleum demand. Fleet owners will likely face higher per-gallon fuel prices as fixed costs of the existing production, refining, distribution, and sales networks are spread across fewer and fewer gallons of products. They will also face rising maintenance and repair costs as businesses specializing in these services shut down because of declining business volume and profits.

Impact of Higher Trucking Costs on Consumers

Given its integral role in the supply chain, trucking costs are an important component of virtually every product and service consumed by California households. According to the U.S. Department of Transportation, each dollar of output in the wholesale and retail trade sector required 9.9 cents of transportation services in 2022. Smaller but still significant shares were required in other industries such as construction, professional services, manufacturing, and utilities (see **Figure 10**, next page). Because of trucking's contributions to output in these other industries, any significant changes in operating costs in the trucking industry will likely be reflected in higher costs of goods and services sold to households in this state.

Figure10
Transportation Services Required per Dollar of Sales by Industry
Estimated Impacts on Households



To measure the impacts of the ACF regulation, we combined the above data on transportation's contribution to industry output with data from the Consumer Expenditure Survey (CES) on the distribution of spending by California households, to arrive at estimates of the percent of household expenditures that are indirectly attributable to trucking-related costs.[17] We then estimated the impact of an 80-percent increase in trucking costs on prices paid for each expenditure category, and tallied up the cost increases across the household's budget.[18] We performed these calculations for the average household in California, as well as for typical households in each of the quintiles of California's income distribution.[19]

Based on these calculations, we estimate that CARB's ACF regulation will result in a nearly $2,500 increase in annual expenditures for an average-income household in California. As indicated in **Figure 11** (next page), the largest increases would be for

[17] The CES is conducted by the U.S. Bureau of Labor Statistics of household spending on goods and services.
[18] More specifically, we: (1) allocated each category of consumer expenditures to the corresponding industries shown in the U.S. Department of Transportation data: (2) matched the resulting estimate of consumer purchases from each industry to the data on transportation's contribution to output; (3) reduced transportation's contribution to output for each industry sector by 25 percent to reflect trucking's share of product shipments in California; (4) calculated, for each expenditure category, the share of household spending attributable to the contribution from trucking; and (5) calculated the impact of an 80-percent increase in costs of trucking operations, assuming fleet operators and independent truckers raise shipping rates to compensate for the higher costs.
[19] Specifically, we estimated the impacts for households in the bottom 20 percentile of the income distribution (average of $15,102 in 2022), 21-40 percentile (average of $41,431 in 2022), 41-60 percentile (average of $71.964 in 2022), 61-80 percentile (average of $117,021 in 2022), and 81-100 percentile (average of $255,841 in 2022).

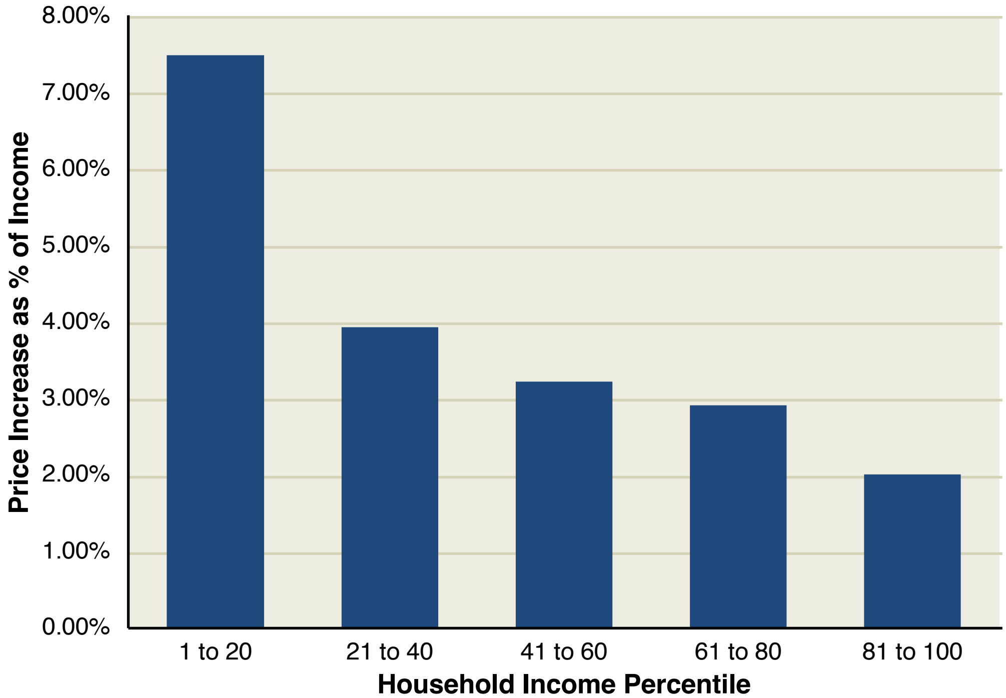
housing, transportation, and food, but virtually all categories of spending would be directly or indirectly affected. These increases would be in addition to other costs that Californians will be incurring because of the energy transition. These include expenses for vehicle chargers and associated electrical upgrades, costs for replacing natural gas heaters with electric heat pumps (and associated electrical upgrades), and higher utility rates due to the transition to renewable electric generation.

Figure 11
Impact of CARB's ACF Regulation on Expenditures of an Average Household in California

Spending Category	Price Increase	
	Amount	Percent
Housing	$984	3.3%
Transportation	$647	5.3%
Food	$509	4.8%
Services	$235	1.7%
Clothing	$124	5.9%
Total	$2,499	3.6%

The price increases would have a regressive impact on households in California, hitting those at the bottom of the income distribution the hardest. As shown in **Figure 12** (next page), the price increases stemming from the ACF regulation would consume 7.5 percent of income for households in the bottom 20 percent of California's income distribution, with the percentages declining to 2.0 percent for those in the top 20 percent. The reason for this regressive impact is that low-income households spend a higher percentage of their income on food and other products and services affected by the regulation than households at the high end of the distribution.

Figure 12
Regressive Impact of ACF Regulation on Household Budgets
Expenditure Increase as a Percent of Income, by Quintile

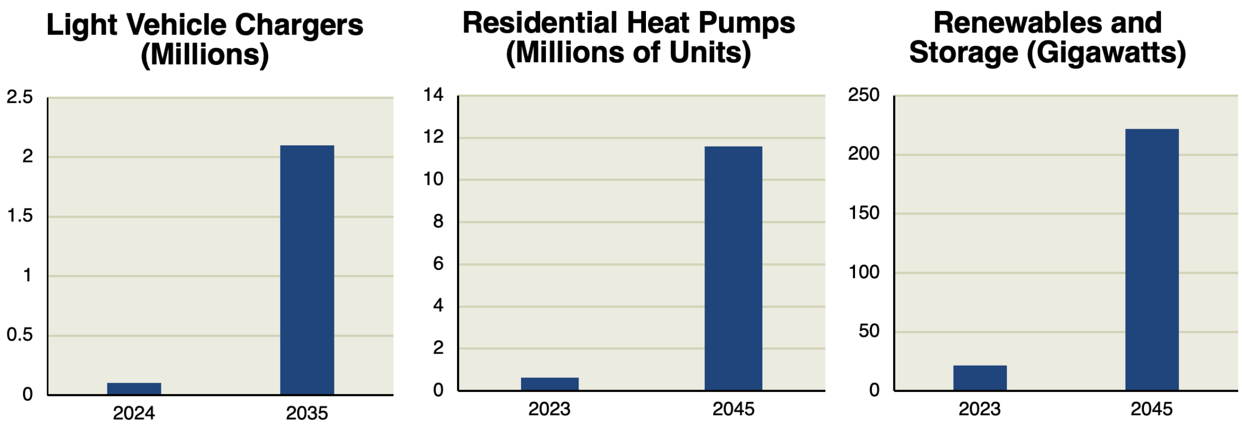


Additional Challenges and Risks Posed by the ACF Regulation

The increased costs to households shown above assume that, while electricity will cost more, it will be available to power California's electrified transportation system. However, this is a highly questionable assumption. As noted above, the trucking mandate does not exist in a vacuum. While truckers are replacing their fleets with electric trucks and creating massive new facilities to charge them, California law and regulations will be requiring a massive expansion of electrical power generation, transmission, and distribution (i.e., "the grid"); a transition to all renewable electricity generation; a transition to all-electric buildings (e.g., the elimination of natural gas for heating and cooking); and the elimination of natural gas for high-process heat used in manufacturing. The state will also be creating a charging infrastructure to power 28 million cars and light trucks.

Figure 13 (next page) highlights some of the investments that will be needed to meet the state's decarbonization goals. According to the California Energy Commission's most recent BEV charging assessment, the state will need 2.1 million light-vehicle public and shared private chargers to meet charging demands by 2035, up from the 105,000 chargers in place as of early-2024.[20] According to the 2022 Scoping Plan, California will need to build 200 gigawatts of renewable power generation by 2045, and homeowners will need to install 11 million electric heat pumps over the next two decades.[21]

Figure 13
Examples of Investments Needed to Achieve State's Emission Reduction Goals



The additional demands on the energy grid comes at a time when artificial intelligence (AI) and other technologies are already straining the nation's electricity generation and transmission systems. A recent analysis by the global law firm Vinson and Elkins indicates that AI data centers could account for as much as 15 percent of U.S. power demand by 2030 — up from less than 3 percent today.[22] A significant share of these power demands will occur in California, where utilities have already received dozens of applications for AI center connections[23] and future demand will likely soar due to the state's leading role in AI development. As another article noted: "The advancement of new technologies appears to have given rise to a new problem across the United States: a crippling power shortage on the horizon. The advent of these technologies, such as eco-friendly factories and data centers, has renewed concerns that America could run out of electrical power."[24]

For California specifically, the Federal Energy Regulatory Commission has stated that "the (region that includes California) could face a resource shortfall under an extreme demand scenario and may need to rely on operating mitigations."[25] In another survey,

[20] Source: "Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment." March 2024. https://www.energy.ca.gov/publications/2024/assembly-bill-2127-second-electric-vehicle-charging-infrastructure-assessmen

[21] Source: "AB 32 CHG Inventory Sectors Modeling Data Spreadsheet." 2022 Scoping Plan Documents. https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents

[22] See "AI's Power Consumption Could Put the Grid – and Energy Regulators – to the Test." Vinson and Elkins. May 30, 2024. https://www.velaw.com/insights/ais-power-consumption-could-put-the-grid-and-energy-regulators-to-the-test/

[23] See "Power-hungry AI Data Centers are Raising Electric Bills and Blackout Risk." Melody Peterson. Los Angeles Times, August 12, 2024. https://www.latimes.com/environment/story/2024-08-12/california-data-centers-could-derail-clean-energy-goals

[24] Is America Running out of Electric Power? March 2024, The Week. https://theweek.com/environment/electrical-power-risks-grid-america-artificial-intelligence-climate

[25] "Summer Energy Market and Electric Reliability Assessment", 2024, Federal Energy Regulatory Commission, Office of Energy Policy and Innovation. https://www.ferc.gov/sites/default/files/2024-05/24_Summer%20Assessment_0523_0940.pdf p.1

California is ranked 49th of the 50 states in resilience of its electrical grid (measured as excess reserves available to avoid blackouts during peak demand hours).[26]

The massive grid expansion also comes at a time when the state's major investor-owned utilities are struggling to keep up with applications for routine power hookups, with new housing and commercial projects waiting for months, or even years, for connections to the grid.[27]

The costs and challenges associated with electrification will be particularly intense in the heavy-duty transportation sector. A single rest stop with 15 charging stalls will require 5.2 megawatts of power, which is the equivalent of the electricity used by a major football stadium. A 60-stall depot, which will be needed to fulfill on-road charging demands by 2035, will require 21 megawatts of power - equivalent to the electricity needed by a small city.

The Scoping Plan for carbon neutrality by 2045 contains a pathway for achieving this massive transition. However, its assumptions regarding the costs and feasibility of each step along the way are – in its own words - "fundamentally based on hope."[28] While CARB asserts that this hope is grounded in "experience and science," no one can dispute that the magnitude, scope and speed of the transformation of the state's energy system that it calls for is unprecedented.

In a separate study, Southern California Edison found that many of the technologies needed to achieve carbon neutrality "have yet to be affordably demonstrated at scale, including Carbon Capture and Storage (CCS), floating offshore wind turbines and vehicle-to-grid (V2G) energy, even as many will be essential to meet our net-zero goals."[29]

The California Energy Commission has said that current progress toward these goals is far behind what is needed.[30] Specifically, to achieve these goals, the state will have to triple the annual rate of solar and wind generation currently being added and increase the annual rate which the state is adding battery power by 8-fold. Adding to the challenges is the fact that California does not have a detailed infrastructure and financing plan for achieving its aggressive goals. While one-time federal and state funding has been devoted to grid upgrades, charging incentives and vehicle subsidies, the commitments are only a fraction of what will be needed. There are few, if any, ongoing budget commitments to help sustain California's electrification goals, and none are likely to be forthcoming given the state's projected ongoing budget deficits.

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[26] Grid Clue State Profiles. https://gridclue.com/StateProfile

[27] See, for example, Committee analyses of SB 83, which was introduced in 2023 to address lengthy backlogs in power hookups. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240SB83

[28] 2022 Scoping Plan, California Air Resources Board, page 11. https://ww2.arb.ca.gov/sites/default/files/2023-04/2022-sp-es.pdf

[29] "Countdown to 2045, Realizing California's Pathway to Net Zero", Southern California Edison. See page 4. https://download.newsroom.edison.com/create_memory_file/?f_id=6508e6633d63325f2e763f1b&content_verified=True

[30] "Achieving 100 percent Clean Energy in California — An Initial Assessment", California Energy Commission, March 2021. See page 10. https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

Despite these challenges, many of the changes outlined in the Scoping Plan – like the truck mandate – are now required by law and/or regulation and will not be easily modified. Such changes will require a major shift in political will and would likely have to go through lengthy political and regulatory processes. This summary of New York's recent challenges provides a cautionary example of how such plans can go wrong:

"New York has long pushed to rely on 70 percent renewable electricity by 2030. It's clear now the state is no longer on track — derailed by growing costs, canceled projects and regulators' refusal to provide more ratepayer-funded subsidies. Part of the problem is there are simply not enough existing, awarded and contracted projects in the pipeline to hit the 2030 target. The biggest blow: Two offshore wind contracts with the state's energy authority were terminated last week, taking a bite out of the state's inventory of investments set to be operational before the statutory deadline to reach 70 percent renewable electricity."[31]

No one knows whether government-mandated transformation to carbon neutrality by 2045 will suffer a similar fate. But we do know that California's goals are much more ambitious and its technological and financial challenges are much greater than in New York, or for that matter, anywhere on earth.[32] We also know that California ratepayers are already nearing a breaking point, due to a doubling of electricity rates over the past decade. Imposing the ACF mandate on top of all the other changes creates an enormous risk for the state, its economy, and its residents. Some of these risks, along with their consequences, are highlighted in **Figure 14** (next page) and discussed below.

[31] "Why New York's ambitious climate goals are drifting away." Politico. 2/07/2024 https://www.politico.com/news/2024/02/07/new-york-energy-climate-goals-00139979

[32] See: California Globe, "Ringside: The Cost of Offshore Wind vs Carbon Sequestration" 28 March 2024, which reviewed a report produced in 2021 by a consortium of offshore wind developers in the world and found that "a best case estimate" to install floating offshore wind turbines capacity similar to what California's needs would be $150 billion. https://californiaglobe.com/fr/ringside-the-cost-of-offshore-wind-vs-carbon-sequestration

Figure 14
ACF Risks and Consequences

Type of Impact	Impacts on Fleets	Impact on Economy
Electricity Rationing	Higher costs due to: • Alteration in depot charging schedules to avoid peak-demand shortfalls. • Longer routes to find on-road charging. • Longer wait times in crowded on-road charging depots.	Higher cargo transport costs. Higher product prices to consumers as shipping costs are passed along in the supply chain.
Early Phase-out of ICE Fueling Infrastructure and Support	Difficulty in maintaining ICE fleet through transition.	Loss of cargo transport capacity. Higher shipping costs. Higher product prices.
Blackouts, Supply Chain Disruptions and Food Insecurity	Disruption to freight movement. Spoilage of perishable goods.	Shortages of food and other products. Large price spikes to consumers.

Electric Power Rationing

Even with current electricity demand and supply, utilities are increasing plans to use such "load shifting" or "load flexibility" tools as variable rates to disincentivize electric use when demand is high, and encouraging consumers to install meters that can automatically cut off high energy appliances such as air conditioners. The California Energy Commission has indicated that these rationing techniques will be essential as the state moves toward 2045 carbon neutrality.[33]

[33] Load-Shift Goal Report, California Energy Commission. https://www.energy.ca.gov/publications/2023/senate-bill-846-load-shift-goal-report .The Energy Commission describes the need for load flexibility as follows: "Load flexibility is the capability to shift or shed electric load or demand away from times when electricity is expensive, polluting, and scarce to times when it is inexpensive, clean, and plentiful. Load flexibility must play a critical part in meeting each of these challenges by aligning customer demand with the supply of clean energy to integrate new renewables onto the grid, reduce the strain new electric load places on the grid, and help maintain electric reliability during extreme events, such as record setting heat, droughts, and wildfires. Hundreds of millions of new electric vehicles, heat pumps, and other electric loads will be coming onto the grid between now and 2045, resulting in the need for investments in grid infrastructure to support the expansion. California has an urgent opportunity to expand load flexibility as a large-scale planning and reliability resource."

While load flexibility can reduce resource needs, it has serious implications for the heavy-duty trucking industry, where flexible scheduling and routing are crucial to ensuring that cargo gets to its destination in a timely and cost-effective manner.

Since the bulk of renewable electricity generation occurs in the middle of the day when the sun is shining, that is likely to be the optimal time for charging from the perspective of overall electrical grid operations. Yet, it is a less-than-optimal time from the standpoint of trucking fleet operations. CARB's conclusion that electric trucks can be cost-effective rests on the assumption that most charging occurs in depots overnight, or otherwise during periods that fit in with driving schedules and optimal routing. Load shifting implies more charging will have to occur during daytime hours, which will interfere with driver and delivery schedules.

These costs would quickly add up. We estimate that if load shifting were to impinge on one hour of driving time per day for a typical truck, the total cost of operations for a fleet would rise by 15 percent beyond the TCO estimates shown earlier. These costs would likely be passed along to consumers.

In addition, on hot days, daytime truck charging will be occurring at the same time as Californians are running their air conditioners, putting stress on the grid. Load shifting could then force a choice between grocery delivery and home appliance use.

Difficulties in Fueling and Maintaining Diesel Trucks Through the Transition

Beyond the direct ownership costs for BEVs, trucking companies will also face challenges in maintaining operations of the remaining diesel-powered trucks in their fleets. At a minimum, fleet owners will face higher operating costs for these trucks during the transition period. This is because per-gallon diesel prices will likely rise as fixed costs of California's existing diesel production, refining, distribution, and sales network are spread across fewer and fewer gallons of supplies. Fleet owners will also face higher costs for keeping their legacy vehicles on the road as specialized maintenance and repair shops shut down because of declining business volume and profits.

The major risk, however, is that the network of support will scale back to the point that continued operations of diesel-powered vehicles are no longer viable. If this were to occur before an adequate amount of grid and charging infrastructure needed to support BEVs is in place, the result would be a reduction in cargo capacity, which would have negative implications for cargo rates, product availability, and consumer prices.

Supply Chain Disruptions

Most Californians vividly recall the supply chain disruptions caused by the COVID lockdown and shifting demands toward various tangible goods. While the challenges associated with the pandemic period were primarily centered on manufacturing production and global shipping, parallel disruptions could occur under the ACF regulation if cargo shipments were disrupted by an unsuccessful transition to an electric-powered trucking industry. Such disruptions could easily occur if any of several assumptions in the Scoping Plan do not materialize. For example, a failure to add enough generating or storage capacity, or to adequately expand transmission and distribution systems, could mean recurring power outages. Those, in turn, would leave trucks stuck on the road or in depots without the ability to charge their batteries for hours or even days. Such disruptions, especially if they were frequent, would cause spoilage and shortages. The most likely time for such shutdowns would be on hot days when electricity demand is at its peak. If such conditions were to persist, trucks could be unable to deliver products for days, disrupting construction projects and manufacturing, and causing spoilage of perishables such as fresh fruits, vegetables, dairy and meats.

What is also clear from the aftermath of the Covid-19 pandemic is that product shortages can quickly translate into vicious cycles of hoarding, further product shortages, and price hikes.

As an indication of how significant these price hikes could be, consider that between mid-2021 to mid-2022, the California consumer price index jumped 8.6 percent. This compared to an average annual increase of just 2.2 percent over the prior 10-year period. For a typical household, a 6.4 percent increase over trend translates into an increase of $4,350 in annual spending needed to maintain the same standard of living.

Fire Risks

An important consideration with regard to BEVs, especially in the heavy-duty trucking segment, is fire risk associated with lithium batteries. According to the National Fire Protection Association, while lithium-ion batteries are an effective and efficient power source, they are prone to overheating, catching on fire, and exploding.

Early evidence suggests that the incidence of fires for BEVs are similar to ICE vehicles when the age of the vehicle is taken into account. However, the consequences of a lithium battery fire are much more severe (see **Figure 15**).

Figure 15
Key Risks of Lithium Battery Fires

- They burn extremely hot.
- They are difficult to extinguish.
- They can leak toxic chemicals.
- They can reignite after initial fire is put out.
- Batteries are vulnerable to surrounding heat.
- Batteries are prone to thermal runaway.

Lithium batteries can burn up to 1,000 degrees (Fahrenheit) hotter than a combustion engine fire, thereby posing a greater risk to others in the vicinity. They can be extremely difficult to put out. They can also leak toxic chemicals, putting first responders and others in the vicinity at risk to fumes and runoff. Lithium battery fires can also reignite after the initial fire has been doused. Lastly, when overheated, lithium batteries can become unstable and experience thermal runaway – a phenomenon that occurs when the heat generated within the battery cell exceeds its ability to dissipate heat, leading to further fires and explosions.

Recent on-road lithium battery fires illustrate these risks. For example, on July 26, 2024, a big-rig truck carrying lithium batteries rolled over on I-15 near Baker, California. The batteries caught fire, which took firefighters two days to extinguish. The roadway remained closed for most of the period – stranding thousands of motorists – due to toxic gasses associated with the blaze and potential for rapid spread of the fire.[34] On August 19, 2024, an electric-powered tractor trailer crash on I-80 near Emigrant Gap led to a lithium battery fire that took four hours to extinguish and closed the highway for 16 hours.[35]

This added fire risk is not incorporated into CARB's cost-of-ownership assumptions, as they assume that insurance rates for BEVs are identical to their ICE counterparts. This seems optimistic. While insurance rates for BEVs and ICE vehicles appear to be comparable today, underwriters are clearly aware of the added challenges and risks posed by lithium battery fires. We would not be surprised to see rates increase in the future as BEV ownership increases and more experience is accumulated.

The heightened risks associated with lithium batteries also raises the question of whether an exemption should be provided from the ACF mandate for vehicles hauling hazardous materials, such as gasoline, diesel, and liquified natural gas. The involvement of lithium batteries in a fire started at a petroleum fuel terminal, a charging depot, in a tunnel, or on a bridge, could have dire consequences for lives and property.

Renewable Diesel – A Cost Effective Alternative

Given the enormous costs and risks associated with electrifying the heavy-duty trucking sector, a logical question to ask is whether there are viable alternatives to electrification that would achieve most of the environmental benefits at a lower cost to the industry and, ultimately, households in California. Fortunately, such an alternative does exist in the form of renewable diesel.

Renewable diesel is a fuel made from fats and oils, such as soybean oil or canola oil, and is processed to be chemically the same as petroleum diesel. It can be used as a

[34] See July 28, 2024 press release from the California Department of Transportation ("Caltrans Statement on San Bernardino County I-15 Fire). https://dot.ca.gov/news-releases/news-release-2024-027
[35] See "Tesla Semi Catches Fire, Closes Interstate." Commercial Carrier Journal, August 20,2024. https://www.ccjdigital.com/alternative-power/battery-electric/article/15682073/tesla-semi-fire-closes-california-interstate

replacement fuel or blended with any amount of petroleum diesel without any modifications to the truck.

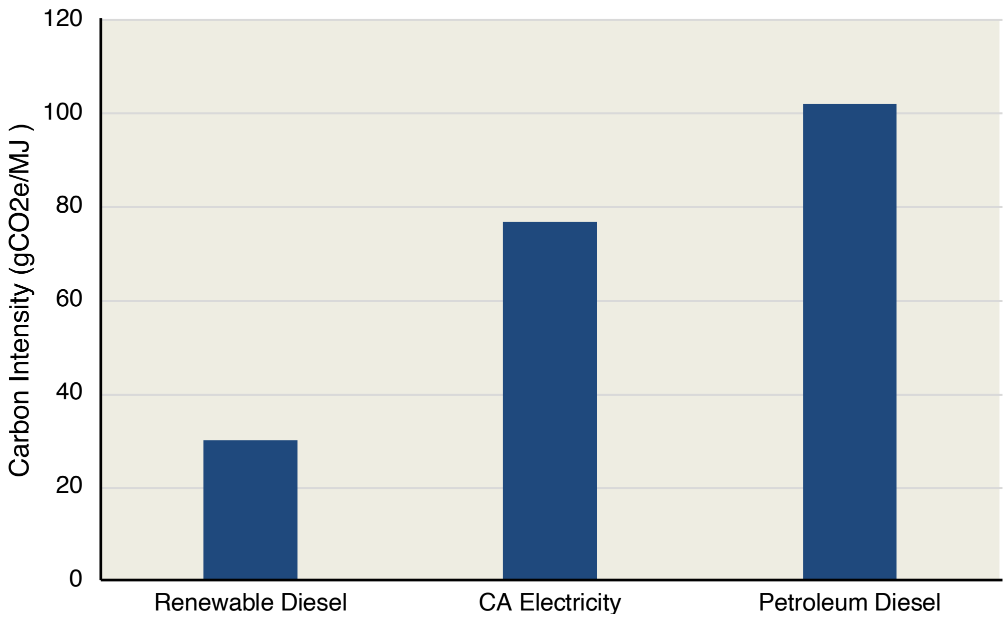
According to CARB, renewable diesel has an average lifecycle carbon intensity of 30 grams of carbon dioxide equivalent per megajoule (30 gCO2e/MJ).[36] As indicated in **Figure 16** (next page), this represents a more than 71 percent reduction from petroleum diesel (102 gCO_2e/MJ) and a 53 percent reduction from electricity currently used by Californians (77 gCO_2e/MJ).

Renewable diesel is more expensive to produce than petroleum-based diesel. The cost differential is currently about $0.85 per gallon, though the difference in retail prices paid are currently less because of benefits received from California's LCFS program. Using the $0.85 price differential, we estimate that substituting renewable diesel for regular diesel would result in a 16 percent increase in the total cost of ownership for a heavy-duty sleeper cab. While significant, the increase is merely a fraction of the up-to-136 percent increase that would result from conversion to electric trucks.

The bottom line is that biofuels produce less CO_2 emissions today than electricity, and this will continue to be the case until a large percentage of California's electricity generation is from renewable power sources. Even after this transition occurs, electricity from California's grid will not be fully carbon-free, due to the ongoing need for electricity imports, not all of which will be carbon free, and the use of natural gas-powered generation to cover peak load needs. Taking these factors into account, we estimate that renewable diesel will still achieve 70 to 80 percent of the emission reduction that can be realistically achieved through electrification of the trucking sector even in the longer term. These reductions will occur at a fraction of the cost and with none of the risk associated with full electrification of the trucking sector.

[36] "LCFS Pathway Certified Carbon Intensities." California Air Resources Board. https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities

Figure 16
Lifecycle Carbon Intensity of Fuels



Conclusion

Imposing a zero-emission mandate on the trucking industry before having assurances that the necessary technology and infrastructure will be in place is akin to jumping out of a plane and designing a parachute on the way down. It may end well, but it may not, and failure will have dire consequences.

The extraordinary improvements that have taken place over the past 100-plus years in transportation, communications, computers and other areas have largely been market-driven. Integration of new innovations in these areas occurred gradually at first, then more rapidly once technological barriers were overcome, the advances gained public acceptance, and the economics of mass production became favorable. During these past transition periods, old technologies were seldom, if ever, eliminated by government mandates. No one thought it was a good idea to outlaw horses and buggies when automobiles were first being developed. No one suggested burning slide rules in the early days of computer development. And no one suggested eliminating of land lines when cell phones first entered the market.

Yet mandated extinction of a tried-and-true technology is exactly what is happening under the ACF regulation. The regulation calls for the phase-out of ICE vehicles before there is assurance that the replacement electricity-based system will be economically and technologically viable.

Proponents of such an approach assert that there is a moral imperative to force the transition because of the existential threat posed by global warming. The counter to this assertion is that a government-mandated energy transition based on fanciful assumptions poses a real and more immediate threat to Californians, many of which are already struggling to make ends meet. California accounts for less than one percent of global CO_2 emissions, so the environmental benefits from CO_2 emissions reduction will be diffuse, while all the costs of a failed transition will fall squarely on California residents.

It may well make sense to use government incentives and related policies to encourage a transition to clean energy. However, the inflexible mandate imposed by the ACF is a high-risk strategy that could prove extremely costly to California. A much better approach would be one that combines incentives with policies that give fleet owners flexibility to choose cost-effective options for cutting emissions, such as renewable diesel, until full electrification becomes technologically and economically viable.

Appendix

Key Provisions of the ACT and ACF Regulations

The two main regulations implementing CARB's zero emissions in trucking mandate are the Advanced Clean Trucks (ACT) and Advanced Clean Fleets (ACF) regulations.

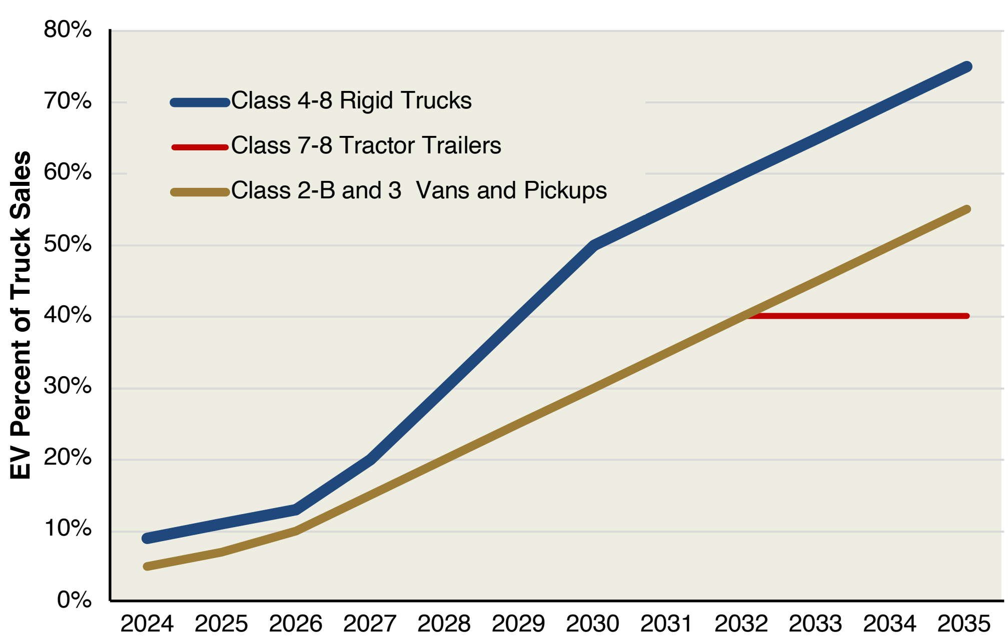
ACT Regulation

Key provisions of the ACT regulation are:

- **Zero-emission truck sales**. Requires manufacturers that certify Class 2b-8 chassis or complete vehicles with combustion engines to sell zero-emission trucks as an increasing percentage of their annual California sales from 2024 to 2035. By 2035, zero-emission truck/chassis sales would need to be 55% of Class 2b-3 van and pickup sales, 75% of Class 4-8 rigid truck sales, and 40% of Class 7-8 tractor-tractor sales.

- **Company and fleet reporting:** Requires large employers including retailers, manufacturers, brokers and others to report information about shipments and shuttle services. Fleet owners, with 50 or more trucks, are required to report about their existing fleet operations.

ACT Sales Requirement Timeline
(Percent of Total Sales Required to be zero emission)



ACF Regulation

The ACF regulation (the focus of this report) sets forth zero emission vehicle (ZEV) purchase and operation requirements for three types of fleet owners. These are:

- High priority fleets – 50 or more trucks, of which one or more vehicle is in California, or fleets with $50 million or more in gross annual revenue.
- Fleets of any size owned by federal, state or local government agencies.
- Fleets that perform drayage operations.

The regulation specifies timelines for each type of fleet to phase out internal combustion engine trucks and buses. For high priority fleets, the regulation provides two compliance pathways - a *model year pathway*, which requires that all new trucks added to the fleet be zero emissions starting in 2024, and a *milestones pathway,* which requires that an increasing percentage of its fleet be zero emission.

High Priority Fleet Milestone Compliance Pathway

	Percent of Fleet to Be Zero Emissions				
	10%	25%	50%	75%	100%
	Year Percent Attainment Required				
Group 1*	2025	2028	2031	2033	2035 and beyond
Group 2**	2027	2030	2033	2036	2039 and beyond
Group 3***	2030	2033	2036	2039	2042 and beyond

* Group 1 includes: Box trucks, vans, buses with two axles, yard tractors, and package delivery vehicles.
** Group 2 includes: Work trucks, day-cab tractors, pickup trucks, buses with three axles.
*** Group 3 includes: Sleeper cab tractors and specialty vehicles.

The ACF has more stringent rules for drayage trucks, which are typically large tractor trailers that transport cargo between seaports and rail yards and regional warehouses. The ACF regulation requires existing drayage trucks to be entered into the Truck Regulation Upload Compliance and Reporting System (TRURS) by January 2024, and that all diesel trucks be removed from service when they reach 18 years or 800,000 miles of service, or after 13 years of service for trucks already surpassing the 800,000-mile limit. All drayage trucks must be zero emission by 2035.

Federal, State and Local Government fleets. The ACF requires that, beginning January 1, 2024, 50 percent of federal, state, and local government fleet purchases be ZEV, and that the percentage increase to 100 percent by 2026. Delayed implementation is allowed for fleets of 10 or less, and exemptions are allowed for school buses (which are subject to other regulations), emergency vehicles, and military tactical vehicles.