**Title**
California's Advanced Clean Cars II: Issues and Implications



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# Working Paper

# *California's Advanced Clean Cars II: Issues and Implications*

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## Acronyms

| | |
|---|---|
| ACC | Advanced Clean Cars |
| BEV | battery electric vehicle |
| CARB | California Air Resources Board |
| CEC | California Energy Commission |
| CPUC | California Public Utilities Commission |
| DCFC | DC fast charger |
| EV | electric vehicle (i.e., battery electric vehicle, plug-in hybrid electric vehicle, and fuel cell electric vehicle) |
| L2 | level 2 [charger] |
| GHG | greenhouse gas |
| PHEV | plug-in hybrid electric vehicle |
| ZEV | zero emission vehicle (i.e., battery electric vehicle, plug-in hybrid electric vehicle, and fuel cell electric vehicle) |

## Summary

California is about to adopt regulations requiring that 100% of light duty vehicle sales be zero emissions by 2035. The regulation is scheduled for adoption on August 11, 2022, to take effect in 2026. The proposed regulation, building on earlier iterations of the zero emission vehicle (ZEV) mandate, requires 35% of vehicle sales be zero emission in 2026, increasing linearly to 100% in 2035. It is the first requirement in the world for 100% ZEV sales, though Norway will likely attain near-100% sales much sooner, primarily through very large incentives to consumers.

The regulation is relatively simple (especially compared to previous iterations of California's ZEV mandate), intentionally so. The most important simplifying feature is that the new mandate awards one credit per vehicle—whether they are plug-in hybrid, battery, or fuel cell electric vehicles. There is no weighting based on all-electric range or other considerations, as in the past. However, the sale of plug-in hybrids (PHEVs) to meet each automakers compliance obligation is capped at 20% of their ZEV sales, and the vehicles must have a minimum all-electric range of 30 miles in 2026, increasing to 50 miles in 2029.

This regulation applies to all light duty vehicle sales, but until 2036 it excludes small manufacturers, who collectively account for less than 2% of sales.

Other important elements of the proposed regulations include battery warranty and vehicle durability requirements, voluntary credits for sales to innovative mobility organizations and low-income buyers in "environmental justice" communities, and a method for phasing out ZEV credits accumulated in recent years from the 2012 ACC I regulations (in place through 2025).

Perhaps most importantly, this new regulation goes well beyond California. Other states are planning to adopt this ACC II sales mandate for themselves, so this regulation will likely affect 30–40% of the US market. Other states are legally allowed to adopt California emission standards instead of the US EPA standards, with the explicit requirement that California's standards must be more stringent than those of the EPA. This option dates back to Section 177 of the 1977 amendments to the US Clean Air Act. As of 2022, 14 states, referred to as "Section 177 states," have adopted California's current ZEV regulation (the Advanced Clean Cars I rule from 2012): Colorado, Connecticut, Maine, Maryland, Massachusetts, Minnesota, Nevada, New Jersey, New York, Oregon, Rhode Island, Vermont, Virginia, and Washington. In addition, Delaware, Pennsylvania, New Mexico, and the District of Columbia are seriously considering joining.

Perhaps the most significant element of the proposed regulation, other than the timeline, is the role of the Section 177 states. Since the US government has no requirement for ZEVs (though the Biden Administration is adopting greenhouse gas emission standards for vehicles that will have the effect of forcing vehicle manufacturers to sell some ZEVs), California's action is instrumental in advancing the ZEV market nationwide. It is also instrumental in sending a clear signal to Europe and China, who are also adopting increasingly stringent vehicle requirements, that California and other states are global partners in transforming the automotive industry.

While the public debate over the Section 177 states is somewhat muted, the decision to adopt by these states is central to the success of the ACC II policy. It is muted because states are not the regulated party—automakers are—which means states are less inhibited from adopting the rule for themselves. In fact, many states are motivated to adopt the aggressive ZEV requirement because they are frustrated that EV sales in their states have been so low. They want to pressure automakers to try harder. As we detail in this paper, the challenge, though, is daunting: increasing sales to 100% by 2035 in most states outside California would be extremely difficult. Today, all other states have far lower ZEV sales (measured as percent of total vehicle sales) than California does and have generally invested less in incentives and energy fueling infrastructure. The controversy and risk, therefore, is that automakers will fail to meet their mandated sales in these other states, possibly leading to litigation and intervention by governors and legislatures, undermining the spread of EV policies across the nation and undermining action by the federal government.

In this paper, we summarize other key elements, including durability and warranty requirements, environmental justice credits, and flexibilities for automakers to meet requirements, especially outside California. We also assess how many vehicles will be needed in practice, and the implications for investments in charging infrastructure.

## Toward the Use of Sales Mandates

EVs play a critical role in mitigating the impact of transportation on climate change and local air quality. EVs are widely considered the single most important strategy for decarbonizing transportation (Brown et al, 2021; Sperling et al, 2021), and the second most important overall, after decarbonizing the electricity grid.

At COP 26 (the 26th Convening of Parties in Scotland), 54 state and regional governments agreed to adopt a goal of 100% EV sales in the next 10–20 years. These vehicles include battery EVs, fuel cell EVs and in some cases plug-in hybrid EVs. The policies to support these EV goals include demand-oriented policies that aim to change consumer decisions to purchase and use EVs, and supply-oriented policies that aim to increase the supply of EVs in the market.

The supply regulations can be incentive-based or regulatory-based, including sales mandates, performance standards, and outright bans of internal combustion engine vehicles. Europe is effectively using $CO_2$ performance standards to accelerate EV sales. They are effective because the performance standards are so aggressive that the only way for automakers to meet them is to sell many EVs. The US also has $CO_2$/GHG performance standards, but they are much weaker—even the new standards being adopted by the Biden Administration—thus the US standards do not have nearly as strong a technology forcing effect as those of the European Union.

Supply-based policies that directly require the sales of EVs are commonly known as Zero Emission Vehicle (ZEV) policies, starting with the first ZEV requirement in 1990 and following a tortuous path of revisions leading up to the Advanced Clean Car regulation of 2012 (CARB, 2012). In this paper, we use “EVs” interchangeably with “ZEV”, with EVs defined broadly to include not only battery EVs, but also fuel cell EVs and plug-in hybrid EVs (PHEVs).

This policy approach of supply-side policies—sales requirements and aggressive performance standards-—are becoming widely acknowledged as the single most effective policy for accelerating the transition to ZEVs (other than offering massive subsidies as done by Norway).

## Vehicle Sales Requirements

California's proposed Advanced Clean Cars II (ACC II) regulations will require vehicle manufacturers to produce a specific share of their model year production as zero emission vehicles (based on exhaust emissions). The regulation is officially a performance standard, in the sense that a standard of zero emissions is being required. But practically, the only vehicles that can achieve zero tailpipe emissions are those without an internal combustion engine. Current ZEVs include two main technologies: battery EVs and hydrogen fuel cell EVs.

To qualify as a ZEV, vehicles must have a minimum range of 150 miles. PHEVs have combustion engines and thus are not ZEVs. However, recognizing that some consumers would find it highly difficult to charge vehicles, and that hydrogen fuel cell EVs might not be widely available, California Air Resources Board (CARB) staff shifted from previous thinking and embraced the need for PHEVs for some consumers. For the purposes of this paper, we lump PHEVs in the ZEV category.

To assure that PHEVs would be powered by electricity most of the time, and not by combustion fuels, they are imposing a requirement that the PHEVs have a long all-electric range (unlike most PHEVs on the market today and unlike the previous iteration of the ZEV mandate which allowed PHEVs to have a range as low as 10 miles, albeit with fewer credits allowed). For the first 3 transitional years, 2026-2028, PHEVs must have a minimum range of 30 miles. Starting in 2029, the minimum range increases to 50 miles (though automakers can use a high-speed drive cycle to certify PHEVs with a 40-mile range with no engine start). As a further effort to assure that not much fuel is burned on board (emitting $CO_2$ and other greenhouse gases), CARB will allow only 20% of an automaker's obligation to be met with PHEVs.

The actual number of vehicles required by the ACC II regulation for a particular year and state cannot be definitively determined because—recognizing the challenge of ramping up so quickly—the ACC II policy includes flexibility for automakers. They can carry over credits from previous years (including from the ACC I years), bank credits for future years, pool credits across states, and gain credits for meeting certain environmental equity goals. We examine these flexibilities later. All these options, other than the ability to include up to 20% PHEVs as part of the ZEV requirement, will expire after 2035.

Figure 1 presents the proposed ZEV market share requirements (including PHEVs), and our estimate of these requirements after adjusting for the flexibilities. The blue line represents CARB's proposed annual ZEV requirement, and the lower orange line is our adjusted estimate, accounting for carryover credits from ACC I and use of environmental justice credits. Note that actual sales could be higher if market demand exceeds CARB's ZEV requirements.

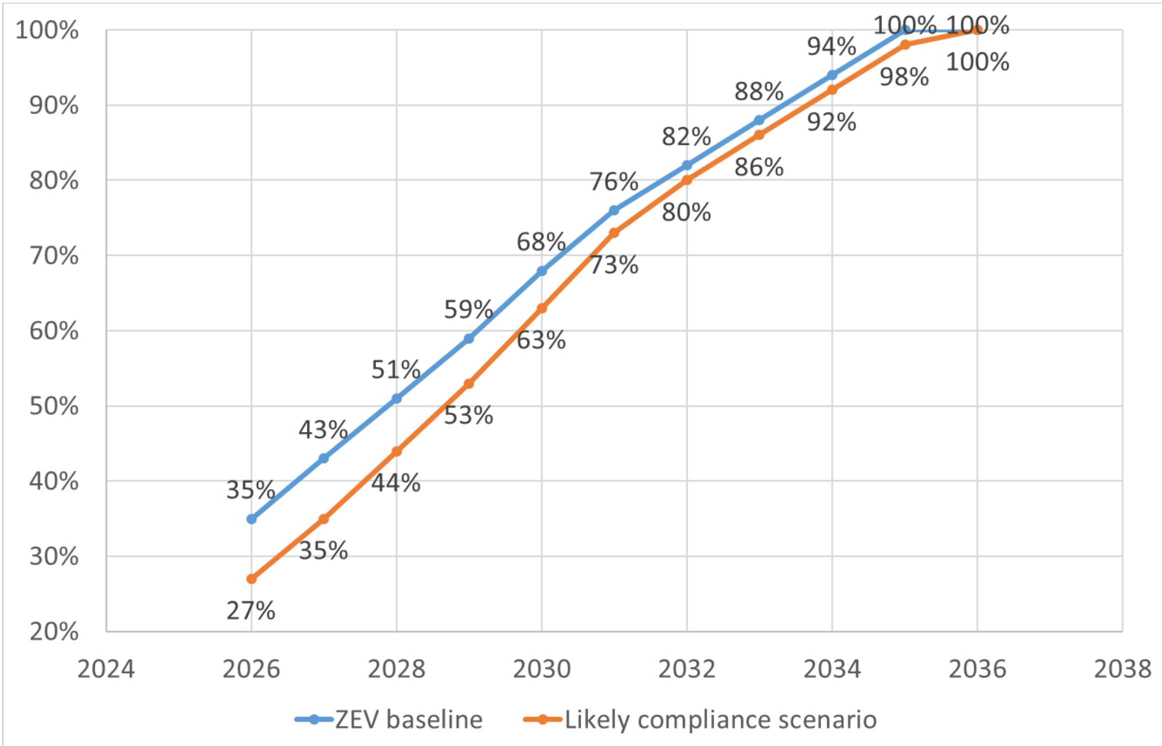


**Figure 1: Proposed ACC II ZEV requirement and authors adjusted estimate**

## Durability and Warranty Requirements

The ACC II regulation includes many technical requirements, in addition to driving range. The most prominent additional requirements relate to vehicle durability and battery warranties. CARB is proposing that automakers assure that vehicles on average retain 80% of their driving range when they are 10 years old (or reach 150,000 miles, whichever comes sooner). The intention of this requirement is to protect the consumer. This rule provides the means for CARB to enforce consumer protection. Enforcement occurs if the average for all vehicles of a particular company falls below the set requirements.

A similar proposed rule is aimed more directly at the consumer, requiring that automakers guarantee that the vehicle battery does not degrade to less than 70% of its capacity (i.e., lose 30% of its charging capacity) for vehicles sold in 2026 to 2030, and not less than 75% in later years. The warranty requirement is for 8 years or 100,000 miles, whichever comes sooner. If the battery degrades further, the automaker must replace the battery.

These requirements are similar, but not identical, to warranty and durability standards being proposed by the European Union.

## Environmental Justice Credits

CARB is proposing that automakers earn extra credit if they target their sales to disadvantaged and low-income communities and households. Three sets of credits are being offered for vehicles provided to these EJ communities.

1) ZEVs (and PHEVs) sold to community-based clean mobility programs at a discount.

   If automakers sell an EV at a 25% discount to a community-based carsharing program or other clean mobility program (such as ridesharing and innovative transit services) from 2026 to 2031, they earn an additional 0.5 credits (half a vehicle) for each BEV or fuel cell EV and 0.4 credits for each PHEV.

2) Discounted prices for used ZEVs and PHEVs.

   If automakers sell low-cost vehicles coming off-lease (through a dealership), they earn extra credits. The vehicles must have a retail price (MSRP) of less than $40,000 when new. Automakers receive an additional 0.1 credit for each such vehicle.

3) Inexpensive vehicles.

   If automakers sell vehicles with MSRP less than $20,275 for passenger cars and less than $26,670 for light-duty trucks, they can earn an additional 0.1 credit for each vehicle sold.

The goal in all three cases is to assure benefits are spread broadly and to prepare for broad market acceptance. Up to 5% of the compliance of automakers can be met with these various EJ credits.

## Flexibility for Automakers in Section 177 States

The required sales increases will be especially dramatic for the Section 177 states that join California's ACC II. While the ZEV market in California would have to roughly double to meet the 2026 ZEV compliance requirement, other west coast states would have to grow their ZEV market by 3–4 times, and most of the northeast states by 4–6 times. Minnesota would have to jump 10-fold to hit their 2026 ZEV sales targets.

This major jump in market share, for those states that adopt ACC II, will be mitigated somewhat in two ways, First, CARB is allowing automakers to carry over credit excesses from ACC I (2012 to 2025). These could be large for some automakers because the mandated levels through 2025 are modest (slowly ramping up to about 10% in 2025). CARB is adopting a formula to discount those carryover credits and limit their use. Each automaker can meet up to 15% of their obligation each year for each state using banked credits. CARB is considering a proposal to lump the 15% per year for each automaker into a single pot of credits and allow the companies to use those credits whenever they want from 2026 to 2030. Some automakers would frontload the credits because their factories will not be ready to meet the requirements in the early years (2026-2028).

A second form of flexibility is the use of pooling. In this case, automakers can use excess credits generated in one state, say California, to meet their obligations in another state. In this case, CARB is proposing to limit the use of pooled credits (i.e., credits moved from one state to another) to 25% of obligations for each company in each state. This 25% limit is for 2026; it drops to 5% in 2030 and beyond. In practice, California is likely to be the only state where sales exceed requirements, and thus any pooled credits will be from the California market.

The actual required increases in vehicle sales are considerably greater than implied by the use of market share numbers. That is because the overall size of the vehicle market in recent years (2020-2021) was depressed by the pandemic, chip shortages, and supply chain bottlenecks. In California, for instance, total light duty vehicle sales dropped 15% from 2018 to 2021. In 2021, the ZEV sales share was 15%. It will need to increase to ~27% in 2026 (based on our estimates)—which does not seem an intimidating jump. But, if the vehicle market recovers in the coming years, then the increase in ZEV sales will be proportionately much greater—rather than a twofold jump (15% to 27%), it would be more like a threefold jump in terms of number of vehicles sold, from more than 600,000 in 2021 to about 1.8 million in 2026. For other states, the jump is much greater, as indicated in Figure 2.

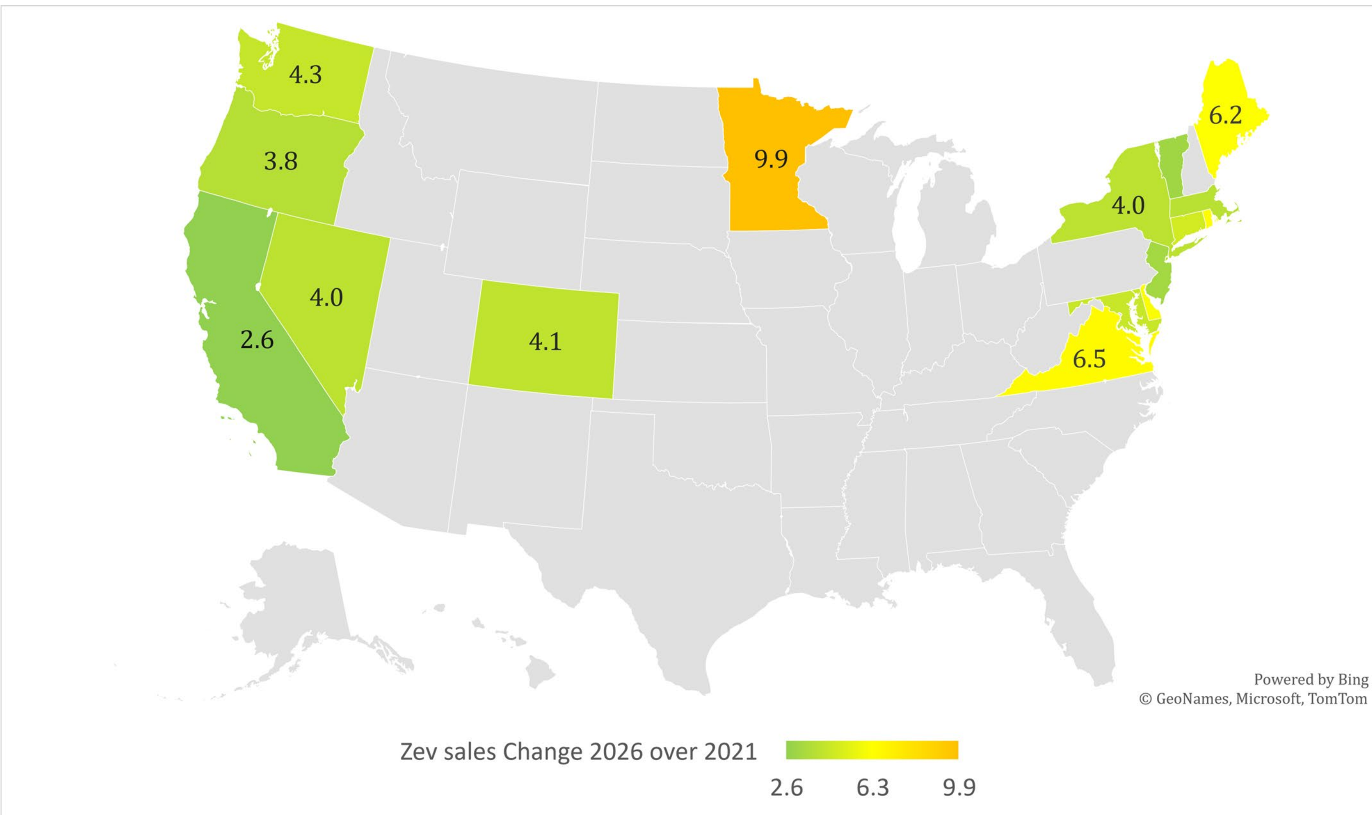


**Figure 2: Multiples of market growth for ZEVs from 2021 to 2026, for each state. See text for explanation.**

## Implications for Charging Infrastructure

Adoption of ACC II will require a massive investment in charging infrastructure, and possibly hydrogen stations. There are multiple ways to meet the charging needs of vehicles, ranging from current reliance on relatively low-speed charging at home and workplace destinations, to use of direct-current fast chargers (DCFCs). CARB is not responsible for charging (and hydrogen) stations and infrastructure. From a policy perspective, the California Energy Commission (CEC) and California Public Utilities Commission (CPUC) play a far more important role, providing incentives and grants in the case of the CEC, and approving funding requests by investor-owned electric utilities (Pacific Gas & Electric [PG&E], Southern California [SoCal] Edison, etc.) in the case of the CPUC. Many private companies are also investing in charging infrastructure, and publicly owned (municipal) utilities (Sacramento Municipal Utility District, Los Angeles Department of Water and Power, etc.) also play a large role.

Here we sketch out the large investments needed to build energy infrastructure in a timely way, to support the ACC II ZEV requirements. We focus on electricity charging, since BEVs and PHEVs will dominate the ZEV market. The 2035 vehicle sales mix will include some fuel cell vehicles in select markets, and thus hydrogen will play some role in light-duty transportation, but we do not include the cost of hydrogen infrastructure in this analysis. See Fulton et al (2022) for a more complete consideration of the role of hydrogen in decarbonizing transportation.

For the purposes of this analysis, we assume that the least expensive way to meet the minimum charging needs for these vehicles will be to focus on level 2 (L2) charging, while providing enough DCFC to support long-distance travel in BEVs. L2 charging estimates are based on per-vehicle charger demand estimates from the home-priority charging scenario developed at UC Davis (Davis et al., 2022). This study projects that most EVs will be charged primarily at home but that the need for shared L2 charging will increase as EV adoption expands to households with more difficulty installing chargers at home. In this analysis, chargers at commute destinations are intended specifically for providing charging while people are at work, while public chargers serve a mix of users, including commuters. DCFC charging estimates are based on the current ratio in California and adjusted to reflect the likelihood of an individual BEV being used for long-distance travel. Our analysis does not include chargers that might be used for vehicle-to-grid. We assume that most long-distance travel will be done by a single vehicle in each household and that households with a mix of vehicle types are less likely to use BEVs for long trips (see Appendix.)

Using a set of assumptions based on extensive market research, as documented in the appendix, we estimate the following minimum charging needs of BEVs and PHEVs sold in California and the Section 177 states by 2035: 15.6 million L2 chargers in single-family homes, 2.7 million in multi-unit dwellings, 1.6 million at commute destinations, and 3.7 million at public locations. In California, this will require installing an additional 850,000 chargers at commute and public locations by 2030 and 1.9 million by 2035, representing an increase of 12- and 24-fold over the current number of public and shared private EV chargers in California. In the Section 177 states, this will require installing an additional 710,000 chargers by 2030 and 3.2 million by 2035, a jump of 20- and 100-fold over current chargers (for current charging infrastructure in California see CEC (2022), and for the Section 177 states see US DOE (2022)).

Through 2026, almost all the charger needs will be in single-family homes, but other charging locations are increasingly important after 2026, as shown in Figure 3.

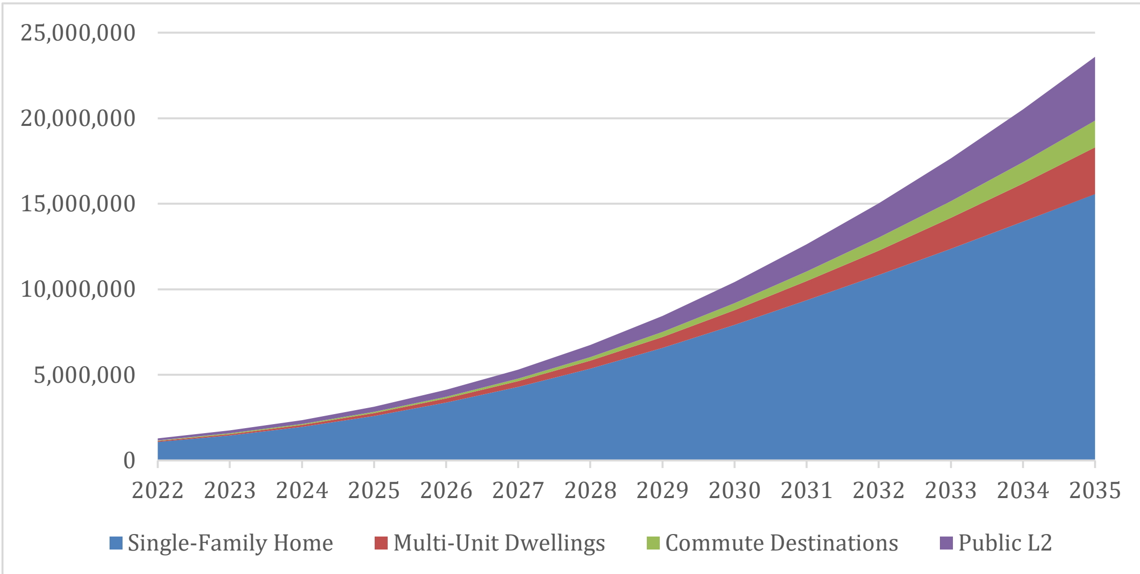


**Figure 3. Total L2 charger needs by location type, ZEV states**

These charger needs are converted into total infrastructure costs by estimating the number of additional chargers needed each year and the cost of chargers in that year. The assumptions are provided in the appendix. Based on those assumptions, for California to meet the ZEV sales targets in ACC II, charger installation costs will total $20 billion between 2022 and 2035, and among Section 177 states and California, costs will total almost $55 billion by 2035. The average cost would be about $1,580 per vehicle.

These costs are large but not extraordinary, given the large sums already being invested by the federal government and many states, as well as private companies.

## Reflecting on the Challenges

The ACC II regulation is innovative and aggressive, yet fundamentally simple. It is a policy tool to shift the market from fossil fuels to cleaner hydrogen and electricity. Innovative features include battery and powertrain warranties and requirements, and environmental justice incentives, as well as mechanisms to ease the transition.

We assessed the implications of the overall ACC II regulation on EV sales and charging infrastructure. From this assessment, we judge that California is well positioned to achieve the ZEV sales targets and infrastructure investments, the result of decades of investments, incentives, marketing, and communication—though it will be tremendously challenging.

The challenge for other states is far greater. Current ZEV sales are much lower, investment in charging (and hydrogen) infrastructure is much less, and leaders in those states have not mounted the scale of communication and marketing seen in California. All states will have to grow the market dramatically. Most states and all automakers have already begun to accelerate their efforts. Ramping up sales before 2026 will generate credits that can be used in 2026 and beyond and thus smooth the transition somewhat, but for some states the growth is exceptionally steep.

Infrastructure is another huge challenge, though largely outside the scope of the ACC II. The slow rate of DCFC installation may not be a large problem in early years, though it will result in longer delays waiting for charging at high demand times. Over time, it may become problematic enough to prevent households from moving to all electric fleets, cause slow adoptions by those in apartments and condominiums, and push users back to internal combustion engine vehicles in later years. Likewise, the home charging needs should not be especially difficult in the early years, partly because most early adopters are self-selected occupants of single-family houses, but also because many owners can use 120V in the early years. Again, the cost and shortfalls in home charging (especially for multi-family units) may be problematic, slowing a full transition to EV-only households in later years.

There is much debate about many of the detailed rules. Some argue, for instance, that the trajectory to 100% should be faster and more frontloaded. Indeed, if one believes that urgency in addressing climate change trumps transitional costs, then faster is better. On the other hand, if one is concerned about the cost imposed on automakers and thus consumers, and if one is concerned with the acceptability of ACC II to a broader set of states, then the CARB proposed trajectory is more compelling.

Another issue is the treatment of PHEVs. Should they be treated less generously in terms of credits per vehicle, caps placed on compliance credits, and minimum all-electric range allowed—or should they be treated more generously? The answer depends on whether one believes that PHEVs will be an important option for getting to 100% EV market penetration.

Still another issue regards the warranty and durability requirements. Are they even needed? By imposing these requirements, CARB is likely increasing the cost of the new vehicles because automakers will "overbuild" them to assure that they will not run the risk of violating the rules. One automaker estimated the cost of "overbuilding" at $10,000. On the other hand, these requirements protect the consumer of older vehicles and, most importantly, assure that used vehicle buyers will not need to replace the battery, which can cost over $10,000.

The environmental justice (EJ) credits are also controversial. Many environmental and EJ groups are advocating that automakers be mandated to use these credits, and that they not be voluntary. Another approach to increase their impact is to increase credits and caps to provide more incentive to automakers to use these credits.

As one delves deeper into details, many other issues emerge. Perhaps most instrumental are those related to flexibility in the use of credits. For instance, should automakers have more discretion regarding when they can use banked credits from ACC I? And should limits on the amount of pooling across states be tightened or loosened? Of concern is the low sales of EVs outside California. These other states want to make sure that automakers do not bypass them, and thus want to obligate automakers to sell large numbers in their states. Given that the burden on automakers to dramatically boost EV sales is large, the counterargument is that automakers should be given large amounts of flexibility to assure success overall.

How one views these challenges is premised on how urgent one views action on climate change, and how much cost states and the nation are willing to absorb. The good news is that the evidence is overwhelming that electric vehicles will soon bring economic, as well as environmental and health, benefits. Most EVs in most applications will soon be economically superior to gasoline vehicles on a total cost of ownership basis (because the lower electricity and maintenance costs of EVs will more than offset their higher purchase cost). But almost no consumers purchase a new or used vehicle based on the total cost of ownership. They base the decision on initial purchase price. And for that reason, incentives will be needed all the way to 2035 to motivate consumers to purchase the vehicles that CARB is mandating that automakers must sell. Likewise, it is very difficult to earn a profit selling electricity for vehicles, without public or private subsidies. And thus, again, government must invest in accelerating the deployment of charging infrastructure. It is all possible, but clearly not easy.

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## Appendix: Needed Investment in Charging Infrastructure

The following information is part of a new paper entitled "How many chargers must California install to complete the transition to electric vehicles? An analysis of electric vehicle adoption and potential charging infrastructure needs 2022-2045" and is based on previous work that is also reflected in the flowing infrastructure tool: https://gis.its.ucdavis.edu/toolbox/sgc/about

DCFC installations will need to increase greatly to ensure that battery electric vehicles (BEVs) can be used for long-distance travel. In all states, more than half of the total increase in DCFC needs will occur between 2030 and 2035, as shown in Table A-1. This reflects both the overall increase in ZEV sales and the increasing proportion of BEV-only households as adoption increases. To meet DCFC charging needs by 2035, these states will need to expand their DCFC networks over the current size by a factor of 16 (California) to 66 (Minnesota), with an overall increase of 23-fold over the present installations.

**Table A-1. Total DCFC needs by state, with present charger totals and ratio of needs in 2035 to present.**

| State | Present | 2025 | 2030 | 2035 | Ratio (2035 / Present) |
|---:|---|---|---|---|---|
| California | 7,230 | 18,680 | 54,840 | 118,540 | 16 |
| Colorado | 620 | 1,500 | 6,090 | 15,760 | 26 |
| Connecticut | 320 | 830 | 3,510 | 9,260 | 29 |
| Delaware | 100 | 210 | 940 | 2,520 | 26 |
| Maine | 150 | 310 | 1,430 | 3,820 | 26 |
| Maryland | 640 | 1,390 | 5,790 | 15,120 | 23 |
| Massachusetts | 480 | 1,530 | 6,190 | 16,040 | 33 |
| Minnesota | 240 | 1,230 | 5,780 | 15,620 | 66 |
| Nevada | 350 | 680 | 2,890 | 7,610 | 21 |
| New Jersey | 590 | 1,940 | 7,930 | 20,670 | 35 |
| New York | 960 | 3,230 | 13,320 | 34,860 | 36 |
| Oregon | 450 | 1,200 | 4,570 | 11,620 | 26 |
| Rhode Island | 50 | 220 | 980 | 2,620 | 58 |
| Vermont | 90 | 180 | 670 | 1,720 | 20 |
| Virginia | 800 | 1,920 | 8,670 | 23,150 | 29 |
| Washington | 790 | 2,200 | 8,350 | 21,250 | 27 |
| **Total** | 13,850 | 37,240 | 131,940 | 320,170 | 23 |

These charger needs are converted into total infrastructure costs by estimating the number of additional chargers needed each year and the cost of chargers in that year.

The cost per charger for home level 2 (L2) charging is fixed at an estimated $1,200 over the forecasting period; this cost assumes that potential decreases in equipment costs will be offset by the increasing need for chargers in homes where installation is more complicated and expensive. The cost per L2 chargers in commute destinations and public locations is fixed at $2,500 to reflect the higher costs of smart networked chargers and more vehicles charging at once in a location. DCFC chargers are expected to become much less expensive by 2035, through a decrease in equipment cost and the lower cost of adding chargers to existing charging locations, as opposed to installing new chargers in new locations. The cost for DCFC installed in 2022 is set to $150,000 per charger, and the cost in 2035 is set to $30,000 per charger.

Based on these assumptions, for California to meet the ZEV sales targets in ACC II, charger installation costs will total $20 billion between 2022 and 2035, and among all the ZEV states, costs will total almost $55 billion by 2035, as shown in Table A-2. If these investments are made by 2035, an additional $53 billion will be needed by 2045 to support the continuing expansion of electric vehicle ownership. In most states, the costs are divided roughly equally into three categories: L2 for home charging, L2 for charging away from home, and DCFC for long-distance travel. Providing enough DCFC to cover daily travel would greatly increase the total cost of charging installation. Installing the charging infrastructure needed to serve BEVs and PHEVs on the road in ZEV states by 2035 will be $1,580 per vehicle.

**Table A-2.Total costs to meet charging needs by 2035, ZEV states, millions of USD**

| State | Single-Family Home | Multi-Unit Dwellings | Commute Destinations | Public | DCFC | Total |
|---|---|---|---|---|---|---|
| California | $6,030M | 1,230 | 1,500 | 3,410 | 7,850 | 20,010 |
| Colorado | 910 | 160 | 180 | 440 | 1,020 | 2,720 |
| Connecticut | 540 | 90 | 110 | 260 | 600 | 1,600 |
| Delaware | 150 | 30 | 30 | 70 | 160 | 440 |
| Maine | 220 | 40 | 40 | 110 | 250 | 660 |
| Maryland | 880 | 150 | 180 | 420 | 980 | 2,610 |
| Massachusetts | 930 | 160 | 190 | 450 | 1,040 | 2,760 |
| Minnesota | 920 | 160 | 180 | 440 | 1,020 | 2,720 |
| Nevada | 440 | 80 | 90 | 210 | 490 | 1,320 |
| New Jersey | 1,200 | 200 | 240 | 580 | 1,330 | 3,550 |
| New York | 2,020 | 350 | 410 | 980 | 2,250 | 6,000 |
| Oregon | 670 | 110 | 140 | 320 | 750 | 1,990 |
| Rhode Island | 150 | 30 | 30 | 70 | 170 | 460 |
| Vermont | 100 | 20 | 20 | 50 | 110 | 290 |
| Virginia | 1,360 | 230 | 270 | 650 | 1,510 | 4,020 |
| Washington | 1,220 | 210 | 250 | 590 | 1,380 | 3,650 |
| **Total** | 17,730 | 3,230 | 3,860 | 9,070 | 20,910 | 54,800 |
| **Cost per Charger** | $1,200 | $1,200 | $2,500 | $2,500 | $150,000 (2022); $30,000 (2035) | |

The distribution of charger installation costs will change substantially from now to 2035, as shown in Figure A-1. Through the mid-2020s, home charging and DCFC will make up almost all annual charger installation costs, but by 2035, the annual cost of installing L2 charging at commute destinations and public locations will be larger than for DCFC and single-family homes. While the need for DCFC chargers increases dramatically over the study period, this will be largely offset by the decrease in costs, and the annual cost of DCFC installation will remain consistent over the study period. Since ZEV ownership will increase first among households that can easily install charging at home, the annual cost of installing chargers at single-family homes will largely stop increasing by 2031. After this, there will be a much greater need for charging installation at shared locations to support the needs of households that cannot install charging at home.

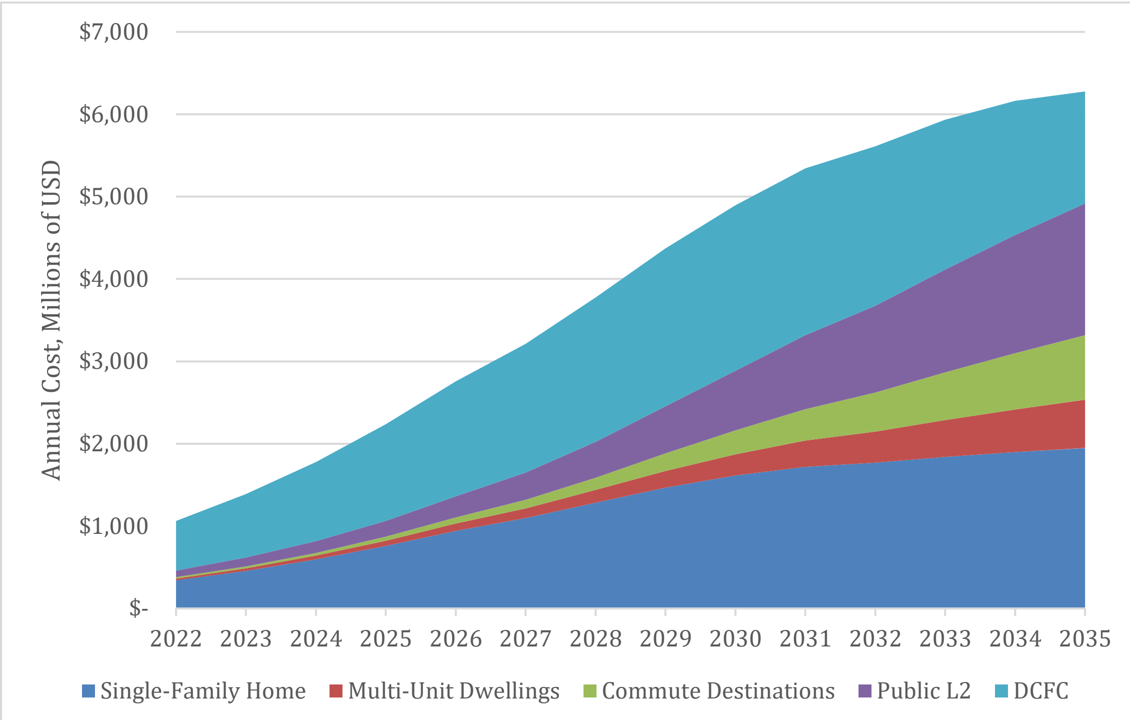


**Figure A-1. Charger costs per year by location type, ZEV states**