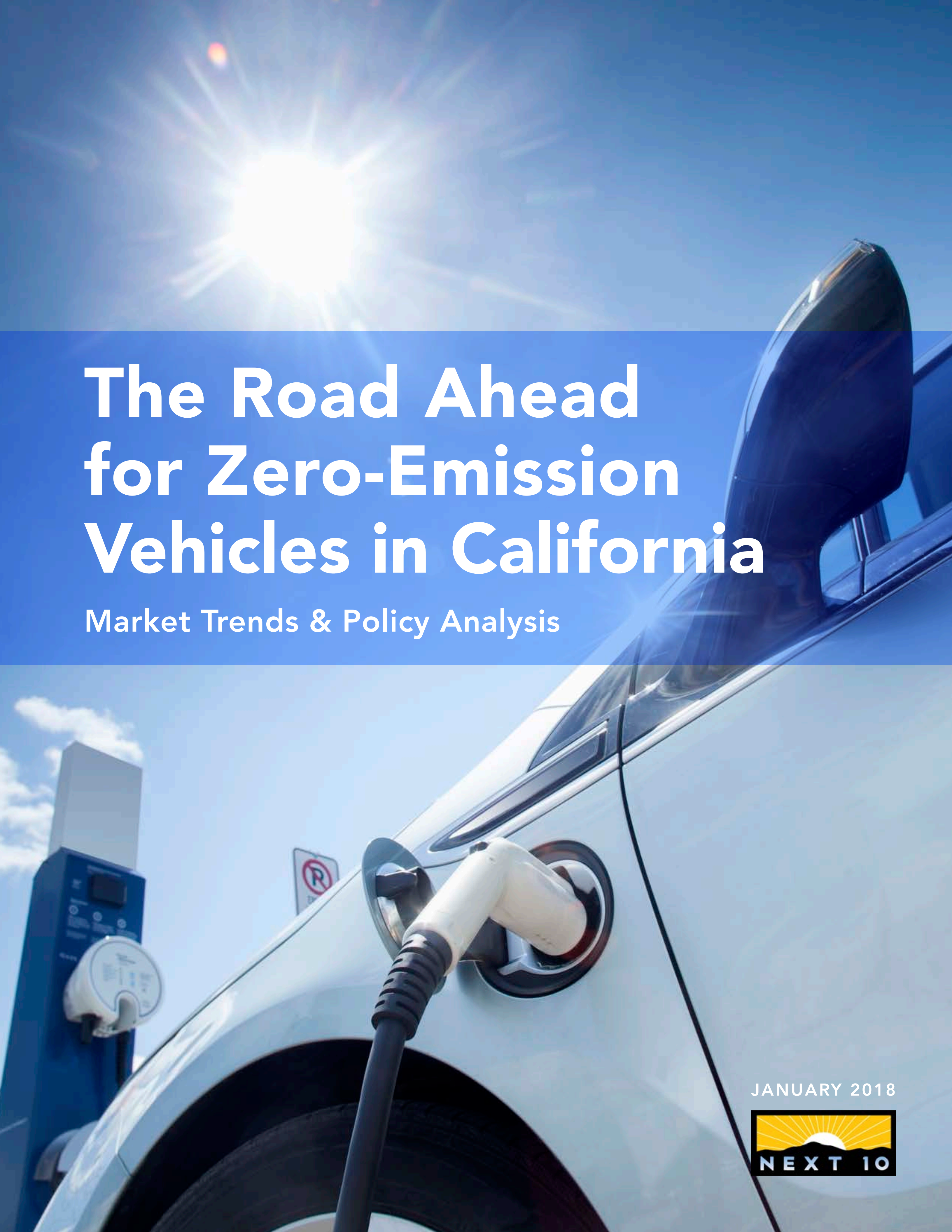

The Road Ahead for Zero-Emission Vehicles in California

Market Trends & Policy Analysis

JANUARY 2018

NEXT 10

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NEXT 10 is an independent nonpartisan organization that educates, engages and empowers Californians to improve the state's future.

Next 10 is focused on innovation and the intersection between the economy, the environment, and quality of life issues for all Californians. We provide critical data to help infrom the state's effors to grow the economy and reduce greenhouse gas emissions. Next 10 was founded in 2003 by businessman and philanthropist F. Noel Perry.

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EXECUTIVE SUMMARY

In March of 2012, Gov. Jerry Brown set a goal of putting 1.5 million zero-emission vehicles (ZEVs) on California's roads by 2025. Today, California is well on its way toward reaching that goal.

There have been bumps in the road, but technology and market trends in California and around the world are accelerating adoption of electric vehicles. And just as cell phones upended the telecommunications industry, electric and autonomous vehicle technologies, combined with new business models, promise to transform the transportation industry.

By October 2017, 337,483 ZEVs had been sold in California, and market growth is accelerating. ZEV sales increased 29.1 percent in California between October 2016 and October 2017, with ZEVs reaching 4.5 percent market share compared to 3.6 percent market share in 2016.

For the most common type of ZEV — the electric vehicle (EV) — the battery is the most expensive component by far, and battery costs are falling fast.[1] From 2010 to 2016, battery costs fell from $1,000 to $209 per kilowatt-hour.[2] This has allowed car companies to offer greater driving range and better performance at lower price points, while expanding the number and type of EV models they offer. Consumers are responding positively, not just in California but also around the world. Last year, in 2017, global passenger electric vehicle sales reached about 1 million,[3] up from half a million in 2015.[4]

As the world moves toward electrified transportation, China has emerged as a market leader. Chinese manufacturers produced 43 percent of EVs worldwide in 2016, while the U.S. produced 17 percent.[5] China is leading on the policy front, as well, joining India, France, the UK and the Netherlands in announcing intentions to ban sales of gasoline-powered cars.

As the rest of the world puts a priority on ZEVs, the U.S. government appears to be moving in the opposite direction, but California remains committed to accelerating the transition to ZEVs. A bill before the California legislature would ban sales of non-ZEV cars by 2040, and Gov. Brown has expressed interest in the idea of phasing out

1 Zero-emission vehicles (ZEVs) are defined by The California ZEV Action Plan as including battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and fuel cell electric vehicles (FCEVs). As the market share for FCEVs is miniscule compared to the other types of ZEVs, this brief will focus on BEVs and PHEVs, simplified to electric vehicles (EVs).
2 Chediak, M. (2017). "The Latest Bull Case for Electric Cars: the Cheapest Batteries Ever." Bloomberg New Energy Finance. December 5, 2017. Available at: https://www.bloomberg.com/technology
3 "Global Electric Passenger Car Sales Database, Forecast to 2025." Frost & Sullivan. September 25, 2017. Available at: https://store.frost.com/global-electric-passenger-car-sales-database-forecast-to-2025.html#.WlZPJJH6mME.link
4 "Global Plug-In Vehicle Sales 2015." EV Volumes: The Electric Vehicle World Sales Database. Available at: http://www.ev-volumes.com/news/global-plug-in-vehicle-sales/
5 "Dynamics in the Global Electric-Vehicle Market." McKinsey & Company. July 2017. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/dynamics-in-the-global-electric-vehicle-market

vehicles powered by internal combustion engines (ICEVs). As the sixth-largest economy in the world, California's actions affect the global automobile market.

This report analyzes California's ZEV market, including historic sales, costs, technology trends, forecasts and challenges. It also reviews policies and implications that could affect future market growth.

Summary of key findings

California's leadership: California is a leader among U.S. states, but ZEV sales are on the rise across the country.

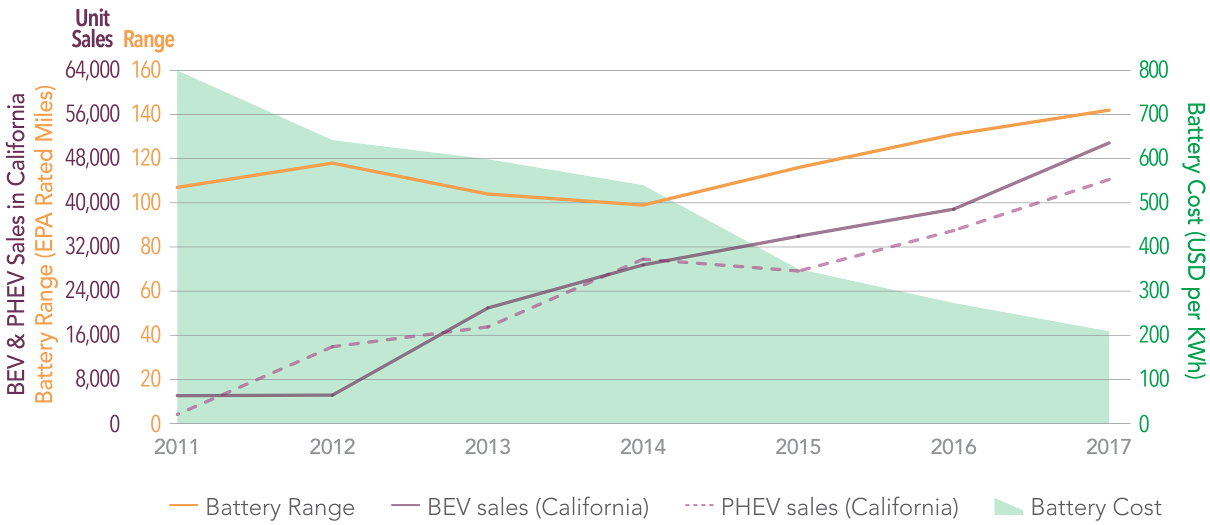
- California 2017 ZEV sales increased 29.1% over 2016, while US 2017 ZEV sales grew by 28.8% over 2016.[6]
- ZEV market share in California was 4.5% in 2017, up from 3.6 % in 2016.[7] This compares to 2017 ZEV market share of 1.1% in the U.S. and 1.8% in China.[8]
- When the state's ZEV goal was enacted in 2012, California needed to average 35.5% annual growth in ZEV sales from 2013 to 2025 to meet its goal.[9] But given the 29.1% increase in year-to-date 2017 sales, the annual growth rate required to meet the ZEV goal has decreased to 20% annually.
- Even if California's sales growth were to slow by 5%, we project the state will easily meet its 1.5 million ZEV goal by 2025, if not before.[10]

Market Trends: Factors driving acceleration or deceleration of ZEV adoption include: price, performance, choice, convenience, and public policy. Current trends suggest that cost, range, selection and charging-time barriers to EV adoption are likely to continue to lessen, while increased competition will continue to lower costs and improve technology. Figure 1 illustrates that as EV sales rates have continued to increase in the state, range has steadily improved and battery cost has steeply declined, indicating a maturing market for EVs.

Total Cost of Ownership: While upfront costs for electric vehicles are higher than their ICE equivalents, life cycle fuel and maintenance costs are decidedly lower. An analysis of 17 popular 2017 models found some ZEVs can be price competitive now, without government incentives.

6 Advanced Technology Vehicle Sales Dashboard, Alliance of Automobile Manufacturers. Available at: https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/
7 Bohlsen, M. (2017). "EV Company News for the Month of October 2017." Seeking Alpha. November 1, 2017. Available at: https://seekingalpha.com/article/4118944-ev-company-news-month-october-2017
8 "Global EV Outlook 2017 – Two Million and Counting" (2017). Clean Energy Ministerial. International Energy Agency. Available at: https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf
9 2013 ZEV Action Plan. Governor's Interagency Working Group on Zero-Emission Vehicles. Available at: http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf
10 Assumes the state has until December 2025 to meet the goal instead of January 2025

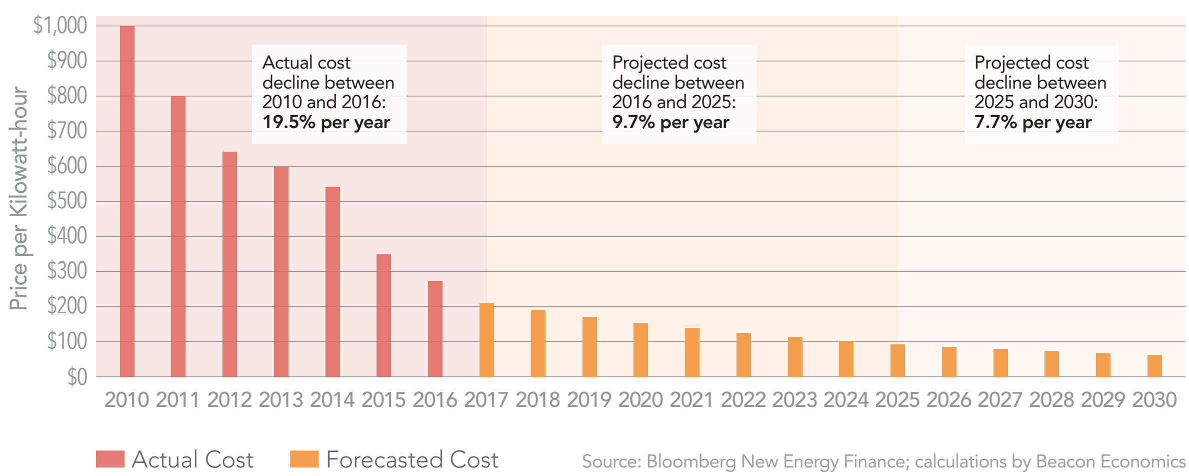
Figure 1: Lithium-Ion Battery Cost, Battery Range (BEV), and Sales in California (BEV)



Source: U.S. Department of Energy; U.S. Environmental Protection Agency; Bloomberg New Energy Finance; Alliance of Automobile Manufacturers

Note: Range estimates are based on EPA ratings (not NEDC ratings)

Figure 2: Lithium-Ion Battery Cost



Source: Bloomberg New Energy Finance; calculations by Beacon Economics

Note: The quoted lithium-ion battery costs include cell plus pack prices

Price: The most expensive component of a ZEV is the battery. From 2010-2016, average battery cost per kilowatt-hour has dropped 74% from over $1,000 to just $273/Kwh (see Figure 2).[11]

Performance: For the last 25 years, battery density has improved 5-7% annually, and in recent years, battery range has been improving considerably. In 2017, Tesla Model S had the farthest EPA-rated range for an all-electric vehicle, at 315 miles.[12]

11 Soulopoulos, N. (2017). "When Will Electric Vehicles be Cheaper than Conventional Vehicles?" Bloomberg New Energy Finance. April 12, 2017. Available at: https://data.bloomberglp.com/bnef/sites/14/2017/06/BNEF_2017_04_12_EV-Price-Parity-Report.pdf

12 Ibid.

Choice: 150 different plug-in hybrids and pure electric vehicles are available worldwide, with that number set to rise to over 240 by 2021.[13]

- In the top California cities for EV penetration, auto dealers offer 25 to 30 different models.[14]
- More than half of the U.S population lives in a metropolitan area with seven or fewer available models.[15]
- China leads with over 75 EV models. It introduced 25 new models in 2016 and saw sales jump 70%.[16]
- Volkswagen, Daimler, Volvo and Nissan have announced plans to electrify their fleets over the next 10 years. GM plans to introduce 20 new ZEV models by 2023, while Ford promises 13.

Convenience:

- **Infrastructure:** From 2011 to 2016, the number of stations for charging electric vehicles increased by 1,138% in the U.S. However, in 2016 there was only one charging plug for about every six electric cars.[17]
- As of January 2018, California had a total of 16,549 public and nonresidential private-sector charging outlets, or about six times as many outlets as the next state, Texas. This only works out to 0.05 public charging outlets per ZEV, one of the lowest ratios in the country.[18]
- **Fueling time:** Tesla's Superchargers can recharge EVs to 80% in 20 to 40 minutes. Others fully charge EVs in three to four hours, while slower charging points take around six to eight hours.
- Automakers are working to reduce charging times. For example, Honda is working on high-capacity batteries capable of 15-minute charging with a 240 km range for release in 2022 models.[19]
- **Maintenance:** ZEVs require significantly less time and money spent on maintenance because they have only about 20 moving parts -- about 1,980 fewer moving parts than traditional internal-combustion vehicles.[20]

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13 "Update: California's electric vehicle market." The International Council on Clean Transportation. May 2017. Available at: https://www.theicct.org/sites/default/files/publications/CA-cities-EV-update_ICCT_Briefing_30052017_vF.pdf
14 Ibid.
15 Ibid.
16 "Dynamics in the Global Electric-Vehicle Market." McKinsey & Company. July 2017. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/dynamics-in-the-global-electric-vehicle-market
17 Alternative Fuel Station Counts by State. Alternative Fuels Data Center, U.S. Department of Energy. Data last updated on November 6, 2017
18 Ibid.
19 "Honda to halve electric cars' charging time to 15 minutes." Nikkei Asian Review. November 1, 2017. Available at: https://asia.nikkei.com/Business/Companies/Honda-to-halve-electric-cars-charging-time-to-15-minutes
20 "Rethinking Transportation 2020 – 2030." RethinkX. May 2017. Available at: https://static1.squarespace.com/static/585c3439be65942f022bbf9b/t/59f279b3652deaab9520fba6/1509063126843/RethinkX+Report_102517.pdf

Public Policy: International, national and state policy may play a role in California's ZEV market.

- National governments including China, the UK, France, the Netherlands and India have stated the intention to phase out the the internal combustion engine.
- CA and other leading states are moving to accelerate ZEV adoption. Eight states including CA signed a memorandum of understanding (MoU) committed to bring 3.5 million ZEVs on the road by 2025.
    - As of October 2017, California had fulfilled 22.5 % of the MoU goal, followed by Oregon with 10%. California appears to be the only state on track to fulfill its MoU goals.[21]
    - In January 2018, Assembly Budget Committee Chairman Phil Ting introduced a bill that would ban gas-powered cars by 2040.[22]
- There are a number of public policies and funding mechanisms within California to promote the development of charging infrastructure, including settlement funds from Volkswagen's diesel emissions case.
- The growth of ZEVs represents a significant potential drain on motor vehicle fuel taxes, which could drive a funding gap in state transportation revenue.
- Grid overload is another concern. The California Public Utilities Commission is studying the effects this may have on the grid, while SoCal Edison and the Los Angeles Air Force Base are conducting a pilot program that allows electric vehicles to act as battery storage and send power back to the grid.[23]

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21 Schulock, C. (2016). "Manufacturer Sales Under the Zero Emission Vehicle Regulation." Natural Resources Defense Council. July 21, 2016. Available at: https://www.nrdc.org/sites/default/files/media-uploads/nrdc_commissioned_zev_report_july_2016_0.pdf

22 "Assemblymember Ting Introduces Clean Cars 2040." January 3, 2018. Available at: https://a19.asmdc.org/press-releases/20180103-assemblymember-ting-introduces-clean-cars-2040

23 Zero Emission Vehicles, CPUC. http://www.cpuc.ca.gov/zev/#Vehicle

INTRODUCTION

Technology is disrupting the automobile industry at an unprecedented rate. Just as cell phones upended the phone industry and solar technology is disrupting the utility business model, electric, plug-in hybrid, and autonomous vehicle technology, combined with new business models, promise to transform the automotive industry. In fact, in many ways they already are.

2017 was a watershed year; as battery costs fell, range continued to expand dramatically. From 2010 to 2016, battery costs fell from $1,000 per kWh to $209 per KWh, according to Bloomberg New Energy Finance.[24] Auto manufacturers around the world have expanded their electric vehicle offerings and are working to improve both performance and cost. Just recently, Tesla announced the planned launch of its Roadster, which the manufacturer boasts will provide a 620 mile range. California has signaled interest in banning the internal combustion engine. Global passenger electric vehicle sales will hit about 1 million in 2017,[25] up from half a million in 2015.[26]

The world is moving quickly to electrified transportation, and China is leading the way. Chinese manufacturers produced 43 percent of electric vehicles (EVs) worldwide in 2016, while the U.S. produced only 17 percent. While air quality challenges may have driven the Chinese government to push for EV growth and innovation, utilizing subsidies to help encourage adoption, the fact remains that the global auto market is shifting increasingly toward the expansion of electric vehicle offerings. Sales of EVs in China increased 70 percent between 2015 and 2016 with cumulative EV sales reaching 650,000, overtaking the U.S. in cumulative sales for the first time. Chinese sales are spurred by a choice of approximately 75 EV models, more than any other market, with roughly 25 new EV models introduced in 2016 alone.[27]

By comparison, California has up to 30 models in largest metropolitan areas with high EV penetration as of the end of 2016.[28] China is targeting 35 million electric vehicle sales by 2025 and wants what they call "New Energy Vehicles" (NEVs) to make up

24 Chediak, M. (2017). "The Latest Bull Case for Electric Cars: the Cheapest Batteries Ever." Bloomberg New Energy Finance. December 5, 2017. Available at: https://www.bloomberg.com/technology

25 "Global Electric Passenger Car Sales Database, Forecast to 2025." Frost & Sullivan. September 25, 2017. Available at: https://store.frost.com/global-electric-passenger-car-sales-database-forecast-to-2025.html#.WlZPJJH6mME.link

26 Ayre, James. "Global Electric Car Sales Surpasses Half A Million In 2015." Clean Technica. March 8, 2016. Available at: https://cleantechnica.com/2016/03/08/global-electric-car-sales-surpasses-half-a-million-in-2015/

27 "Dynamics in the Global Electric-Vehicle Market." McKinsey & Company. July 2017. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/dynamics-in-the-global-electric-vehicle-market

28 "Update: California's electric vehicle market." The International Council on Clean Transportation. May 2017. Available at: https://www.theicct.org/sites/default/files/publications/CA-cities-EV-update_ICCT_Briefing_30052017_vF.pdf

Table 1: ZEV Sales Growth, YTD 2017 vs. YTD 2016, California

ZEV Category	YTD 2017	YTD 2016	% Change
BEV	41,455	32,868	26.1%
PHEV	35,287	26,761	31.9%
FCEV	1,311	813	61.3%
Total	78,053	60,442	29.1%

Source: Alliance of Automobile Manufacturers
Note: Year-to-date, through October 2017

at least one-fifth of the total fleet by then. Bloomberg New Energy Finance projects 530 million electric vehicles, a third of the world fleet, will be on the road by 2040.

Despite the prioritization of "new energy vehicles" and zero-emission vehicles (ZEVs)[29] globally, the current federal U.S. government has yet to see the potential for this rapidly growing market. Federal incentives for electric vehicles managed to avoid the recent tax cut–though their potential removal was contested–and vehicles emission standards agreed to by automakers, the federal government and California in 2012 are now being reevaluated – a move that could hinder ZEV innovation and sales.[30]

With a goal of putting 1.5 million ZEVs on the road by 2025, California leads the country in policy. As the sixth largest economy in the world, what the state does here has direct market impact. To better understand how California may be impacted by the evolving global ZEV industry, this report analyzes the state's ZEV market, including historic sales, costs and technology trends, forecasts and challenges, policies and implications for future market growth.

29 Zero-emission vehicles (ZEVs) are defined by The California ZEV Action Plan as including battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and fuel cell electric vehicles (FCEVs). As the market share for FCEVs is miniscule compared to the other types of ZEVs, this brief will focus on BEVs and PHEVs, simplified to electric vehicles (EVs).
30 Colias, Mike. "Tax Credit for Electric Vehicles Survives, in Win for Tesla and Other Auto Makers." Wall Street Journal. December 15, 2017. Available at: https://www.wsj.com/livecoverage/tax-bill-2017/card/1513389842

BY THE NUMBERS: TRENDS IN SALES, COST & TECHNOLOGY

Historic and Current ZEV Sales

California is the nation's leader in ZEV sales, responsible for 49.3 percent of total U.S. sales. As of October 2017, a total of 337,483 ZEVs were sold in the state, compared to the national total of 683,890.

Overall, electric vehicle average sales in California increased by 29 percent from year-to-date 2016 to year-to-date 2017. Table 1 indicates that as of October 2017, California sales of all types of ZEVs have been impressive. Battery electric vehicles (BEV) were the largest category with 41,455 sold from January to October 2017. Comparatively, 32,868 BEVs were sold during the same time period in 2016, a 26.1 percent increase. Growth in plug-in hybrid EV (PHEV) sales is also impressive, with a 31.9 percent increase over last year so far and 35,287 sold as of October 2017 year-to-date. Fuel cell electric vehicles (FCEV) had the largest marginal increase, raising sales by 61.3 percent from 813 to 1,311 sold.[31]

ZEVs are making up an increasing share of total automobile sales in California. Year-to-date ZEV sales in 2017 stands at 4.5 percent of the total market, a considerably leap from 2016's 3.6 percent share.[32] By comparison, the market share of ZEVs as percentage of total sales in the U.S. is 1.1 percent in year-to-date 2017, a slight increase over last year's 0.9 percent market share. In China, the EV market makes up 1.8 percent of the total market, up from 1.4 percent in 2016.[33]

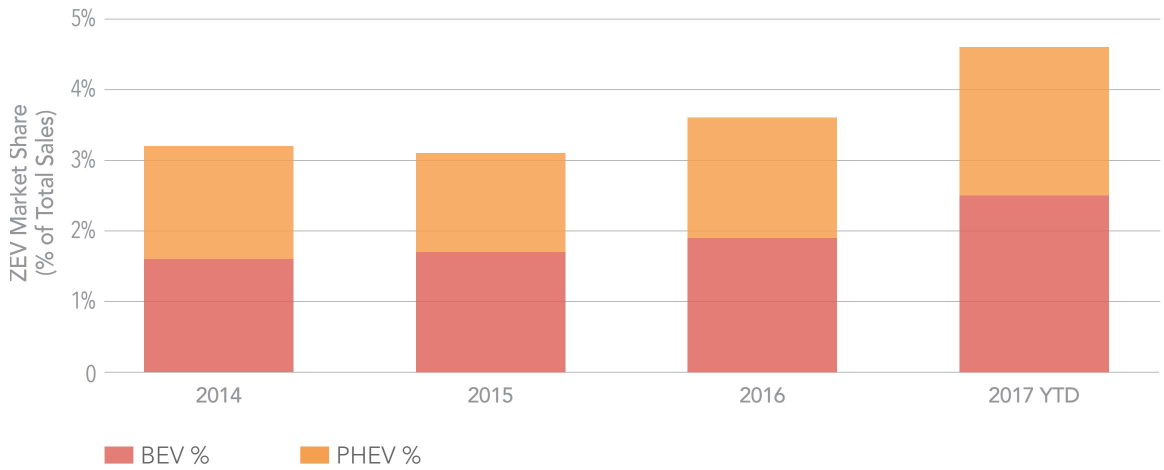
This kind of growth represents a trend with exponential implications. As of October 2017, sales growth in the U.S. without California more or less followed that of California. While national sales growth for PHEVs (+24.1%) trailed behind that of California (+31.9%), sales growth for BEVs (+33.9%) actually surpassed that of California (+26.1%) thus far. Overall, year-to-date ZEV sales in the U.S. grew by 28.8 percent, which is comparable to California's 29.1 percent.

31 Advanced Technology Vehicle Sales Dashboard, Alliance of Automobile Manufacturers. Available at: https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/

32 Bohlsen, M. (2017). "EV Company News for the Month of October 2017." Seeking Alpha. November 1, 2017. Available at: https://seekingalpha.com/article/4118944-ev-company-news-month-october-2017

33 "Global EV Outlook 2017 – Two Million and Counting" (2017). Clean Energy Ministerial. International Energy Agency. Available at: https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf

Figure 3: ZEV Market Share, California, 2014 to YTD 2017



Source: : IHS Markit
Note: 2017 year-to-date to Q2-2017

Table 2: ZEV Sales Growth, YTD 2017 vs. YTD 2016, U.S. without California

ZEV Category	YTD 2017	YTD 2016	% Change
BEV	36,992	27,634	33.9%
PHEV	37,241	30,003	24.1%
FCEV	2	3	-33.3%
Total	74,235	57,640	28.8%

Source: Alliance of Automobile Manufacturers
Note: Year-to-date, through October 2017

Of the total 152,288 ZEVs sold year-to-date 2017 in the US, 51.2 percent were sold in California, which is roughly about the same as the shares from 2013 to 2016, and a notable increase from 2012 and earlier, when ZEVs sales in California accounted for 44 percent or less of total sales.

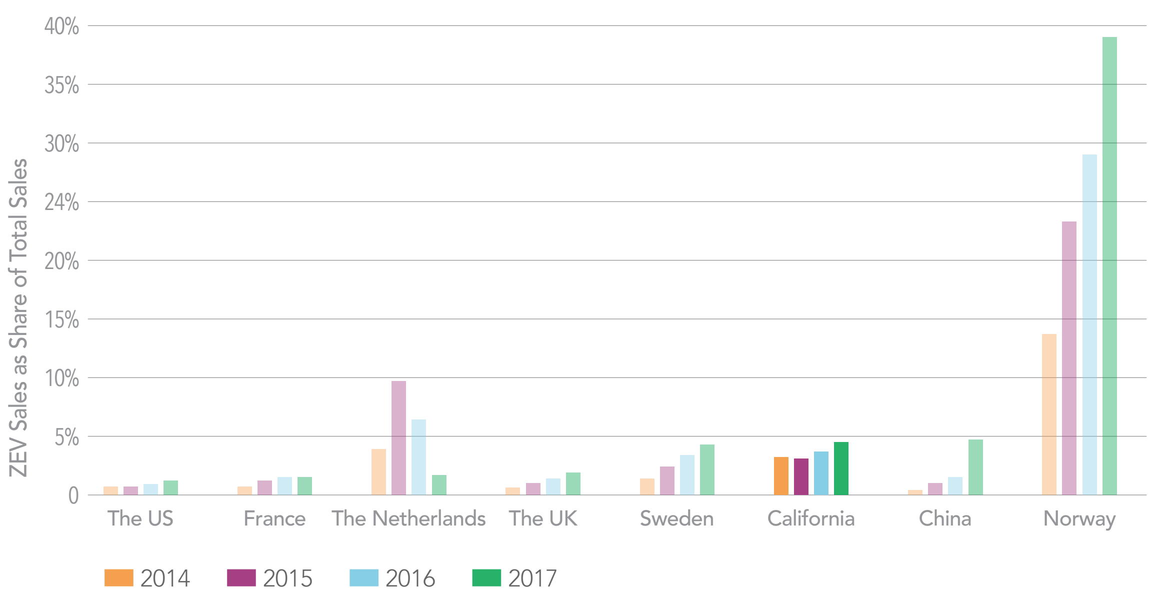
GLOBAL COMPARISONS

On the global stage, California is more comparable to the leading countries internationally – in terms of ZEV sales as percentage of total sales - than it is to the U.S. itself. California's overall ZEV sales as share of total sales was about five percent in 2017 – behind Norway's 39 percent and comparable to China's five percent.

What this Means for California

These trends bode well for California's ZEV market and policy goals. When the state's Action Plan of 1.5 million ZEVs on California roadways was introduced, California needed an average of 35.5 percent annual growth from 2013 to 2025.[34] But with the 29 percent increase in sales year-to-date, the annual growth rate required to meet the ZEV goal has decreased to 20 percent annually. Projecting forward this trend, California will handily meet the state's 1.5 million ZEV goal by 2025.[35] Even when testing with a conservative assumption of five percent diminishing growth rate, both assumptions would place the Golden State far above its self-imposed 2025 goal.

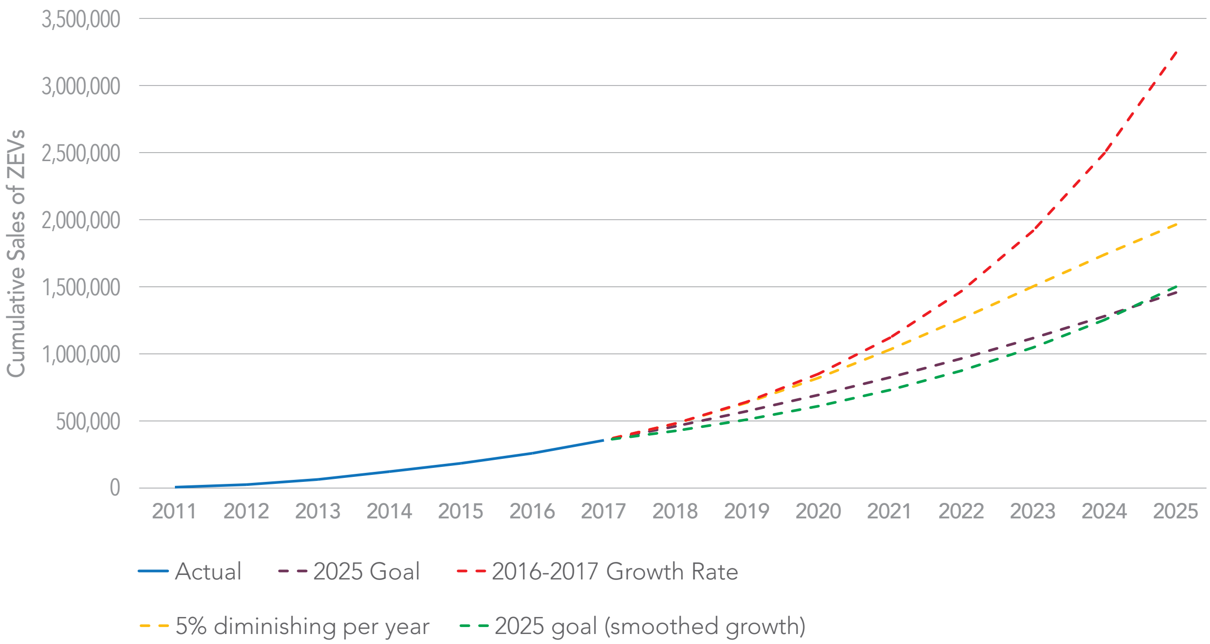
Figure 4: Global EV (BEV & PHEV) Market Share, 2014 to 2017*



Source: International Energy Agency, Clean Energy Ministerial; IHS/Markit; InsideEVs; EV Norway; The Advisory Council of Veitrafikken AS (OFV AS); BIL Sweden; The Society of Motor Manufacturers and Traders (SMMT); European Alternative Fuels Observatory; China Association of Automobile Manufacturers.
*Note: China's 2017 market share is as of November 2017. California's 2017 market share is as of Q2-2017.

34 2013 ZEV Action Plan. Governor's Interagency Working Group on Zero-Emission Vehicles. Available at: http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf
35 Assumes the state has until December 2025 to meet the goal instead of January 2025

Figure 5: Historical and Projected Cumulative ZEV Sales, Accounting for Vehicle Scrappage Rates for 2025 Goal



As Figure 5 indicates, 2017 year-to-date sales appear to be on track to meet the hypothetical growth rate needed to reach the 2025 goal. Given the 2017 year-to-date sales growth, it is reasonable to expect that – net of aberration or government policies that discourage ZEV sales - sales will continue to be strong as more infrastructure is installed, and technology continues to improve battery storage, range, charging times, and cost.

DRIVING FACTORS

While the aforementioned projection scenarios indicate that California is likely to reach 1.5 million ZEVs on the road by 2025 or earlier, there are several factors that may drive future acceleration or deceleration of adoption: Price, Performance, Choice, Convenience, and Public Policy.

To understand market growth potential of electric vehicles, it is helpful to understand critical selling points and how they differ between ZEVs (inclusive here of BEVs and PHEVs) and internal combustion engine (ICE) vehicles. This section analyzes trends in price, including current ownership costs, upfront costs, and trends in factors that affect those costs, such as batteries, R&D, materials and incentives. Technology trends affecting performance, convenience and consumer choice are also analyzed here, including range, fueling, maintenance, infrastructure and charging. Lastly, this section examines public policies at the national and subnational levels to evaluate potential impact on market growth. This analysis reveals both bridges and barriers to adoption of ZEVs. In some cases, trends suggest some of these barriers are only temporary, while others require active intervention to solve for the long-term.

PRICE

Current Cost of Ownership

At present, the MSRP of an electric vehicle is still higher than its internal combustion engine equivalent, largely due to the battery cost. But while upfront costs are higher, life cycle fuel and maintenance costs are decidedly lower.

Using a life cycle cost model, Raustad and Fairey (2014) find that based on 12,330 miles driven per year, the pure battery electric Nissan Leaf has lower five-year and 10-year life cycle costs than the internal combustion Hyundai Elantra and the plug-in hybrid Chevrolet Volt, even without the federal government incentive.[36] Similarly, the Multi-State ZEV Action Plan study (2014) concludes that the five-year cost of ownership of a 2013 model year Nissan Leaf ($36,892) is $8,057 lower than a general conventional vehicle ($44,949) and $7,433 lower than a generic hybrid vehicle ($44,325).[37]

36 Raustad, R. and P. Fairey (2014). "Electric Vehicle Life Cycle Costs Assessment." Electric Vehicle Transportation Center, FSEC-CR-1984-14

37 ZEV Program Implementation Task Force (2014). "Multi-State ZEV Action Plan." Page 9. Available at: http://www.nescaum.org/topics/zero-emission-vehicles/multi-state-zev-action-plan

Using the Alternative Fuels Data Center's (AFDC) Vehicle Cost Calculator as the basis for analysis, 17 popular vehicle models ranging from small sedans to pick-up trucks were selected in order to calculate the total cost of ownership (TCO) in five-year, ten-year, and 15-year terms, with and without government incentives. Assumptions used for the TCO calculations can be found in Appendix A. For this simulation, two scenarios were modeled with different annual miles driven: a more conservative estimate of 8,572 miles/year and a higher estimate of 14,435 miles/year driven. All models selected are the 2017 model-year version, and the results are presented in Tables 3 and 4.

Table 3: Total Cost of Ownership (TCO), 8,572 Annual Miles, Thousands of Dollars

		With Incentives			Without Incentives		
Make	**Type**	**5 Year Cost**	**10 Year Cost**	**15 Year Cost**	**5 Year Cost**	**10 Year Cost**	**15 Year Cost**
Nissan Leaf	BEV	$35.5	$45.2	$55.0	$45.5	$55.2	$65.0
smart fortwo ED	BEV	$29.5	$39.3	$49.1	$39.5	$49.3	$59.1
Tesla Model S (60 kw)	BEV	$76.6	$86.4	$96.1	$86.6	$96.4	$106.1
Chevrolet Bolt	BEV	$41.9	$51.5	$61.0	$51.9	$61.5	$71.0
BMW i3 BEV	BEV	$47.7	$58.9	$70.1	$57.7	$68.9	$80.1
Chevrolet Volt	PHEV	$40.0	$50.7	$61.4	$49.0	$59.7	$70.4
Toyota Prius Prime	PHEV	$38.1	$47.2	$56.3	$44.1	$53.2	$62.3
Ford Fusion Energi PHEV	PHEV	$43.5	$54.0	$64.6	$49.0	$59.5	$70.1
Chrysler Pacifica Hybrid	PHEV	$50.4	$61.7	$73.1	$59.4	$70.7	$82.1
Toyota Prius Hybrid	HEV	$40.0	$50.9	$61.8	$40.0	$50.9	$61.8
Honda Accord Hybrid	HEV	$45.8	$56.8	$67.9	$45.8	$56.8	$67.9
Toyota RAV4 Hybrid	HEV	$46.3	$59.1	$71.8	$46.3	$59.1	$71.8
Chevrolet Silverado 15 Hybrid	HEV	$64.8	$77.9	$91.1	$64.8	$77.9	$91.1
Honda Civic 4Dr Gasoline	ICEV	$35.0	$46.9	$58.9	$35.0	$46.9	$58.9
Dodge Grand Caravan Gasoline	ICEV	$42.4	$56.8	$71.2	$42.4	$56.8	$71.2
Lexus ES 350 Gasoline	ICEV	$57.7	$71.0	$84.3	$57.7	$71.0	$84.3
Mercedes-Benz E300 Gasoline	ICEV	$72.6	$86.3	$100.0	$72.6	$86.3	$100.0

Source: Alternative Fuels Data Center, Department of Energy; Energy Information Administration; Calculations by Beacon Economics

With California and Federal incentives, the smart fortwo ED has the lowest total cost of ownership regardless of the time horizon. The Honda Civic, one of the most economic and popular models, has the second lowest cost of ownership on a five-year basis but falls behind the Nissan Leaf due to the higher cost of fuel.[38] Without government incentives, the Honda Civic slightly edges out the smart fortwo ED and the Toyota Prius Prime.

It is important to note that the AFDC calculator very likely overstates the cost of ZEV ownership and even without government incentives, ZEVs can still be price competitive. First, the AFDC calculator assumes the same maintenance expense regardless of fuel type, despite the electric drivetrain having fewer moving parts (and thus lower maintenance costs) than conventional gasoline engine.[39] The calculator also does not take additional state incentives such as utility-rate reductions into account. For example, Pacific Gas & Electric customers with electric vehicles are eligible to receive $500 Clean Fuel Rebate for using electricity as a clean transportation fuel.[40] Also, San Diego Gas & Electric customers who own or lease a BEV or PHEV are eligible to receive credits worth $50 to $200 per vehicle.[41] Finally, Southern California Edison customers who own or lease a BEV or PHEV are eligible for a $450 Clean Fuel Rebate.[42]

It should also be taken into account that many people drive more than 8,572 miles per year. According to the U.S. Department of Transportation Federal Highway Administration, in 2015, vehicle miles per licensed driver in California was 14,435 miles per year.

At 14,435 miles driven per year and with incentives, the smart fortwo ED and the Nissan Leaf have the lowest total cost of ownership regardless of the time horizon. While the Honda Civic finishes third in the 5-year scenario, both the Toyota Prius Prime and the Ford Fusion Energi PHEV surpass the Honda Civic to finish having the third and fourth lowest cost of ownership after 15 years. Without government incentives, the Honda Civic is more expensive to own than the smart ED and comparable to the Nissan Leaf and both versions of the Toyota Prius after 15 years. Also, despite being almost 50 percent more expensive, the BMW i3 has lower cost of ownership than the Toyota RAV4 Hybrid after 15 years.[43] It is clear that ZEVs can already be competitive at present even without government incentives.[44]

38 Data from the Department of Energy indicates that on November 11, 2017, regular gasoline costs $3.24 per gallon while electricity costs $1,73 per equivalent-gallon in California

39 A more detailed discussion of maintenance expenses between electric vehicles and conventional vehicles is included in Appendix B.

40 More information can be found at: https://www.pge.com/en_US/residential/solar-and-vehicles/options/clean-vehicles/electric/clean-fuel-rebate-for-electric-vehicles.page

41 More information can be found at: https://www.sdge.com/clean-energy/electric-vehicles/electric-vehicle-climate-credit

42 The program excludes electric bikes, electric motorcycles, electric scooters and neighborhood vehicles. More information can be found at: https://www.scecleanfuel.com/

43 The MSRP for the 2017 BMW i3 BEV is $42,400, which is 46 percent higher than 2017 Toyota RAV4 Hybrid's MSRP of $29,030.

44 This exercise does not consider battery replacement costs for two main reasons: 1. The life cycle of a battery pack depends on several factors such as the chemical components, temperature, number of times the battery pack has been recharged and 2. The replacement costs vary widely depending on the make and model of a vehicle.

Table 4: Cost of Ownership, 14,435 Annual Miles, Thousands of Dollars

Make	Type	With Incentives			Without Incentives		
		5 Year Cost	10 Year Cost	15 Year Cost	5 Year Cost	10 Year Cost	15 Year Cost
Nissan Leaf	BEV	$38.3	$50.3	$62.2	$48.3	$60.3	$72.2
smart fortwo ED	BEV	$32.1	$44.4	$56.8	$42.1	$54.4	$66.8
Tesla Model S (60 kw)	BEV	$79.3	$91.8	$104.3	$89.3	$101.8	$114.3
Chevrolet Bolt	BEV	$48.2	$58.4	$68.6	$58.2	$68.4	$78.6
BMW i3 BEV	BEV	$50.7	$62.5	$74.3	$60.7	$72.5	$84.3
Chevrolet Volt	PHEV	$43.1	$56.7	$70.3	$52.1	$65.7	$79.3
Toyota Prius Prime	PHEV	$39.2	$52.2	$65.2	$45.2	$58.2	$71.2
Ford Fusion Energi PHEV	PHEV	$47.4	$61.6	$75.9	$52.9	$67.1	$81.4
Chrysler Pacifica Hybrid	PHEV	$54.6	$69.2	$83.9	$63.6	$78.2	$92.9
Toyota Prius Hybrid	HEV	$43.1	$57.1	$71.2	$43.1	$57.1	$71.2
Honda Accord Hybrid	HEV	$49.1	$63.4	$77.7	$49.1	$63.4	$77.7
Toyota RAV4 Hybrid	HEV	$51.0	$67.8	$84.5	$51.0	$67.8	$84.5
Chevrolet Silverado 15 Hybrid	HEV	$67.8	$87.6	$107.5	$67.8	$87.6	$107.5
Honda Civic 4Dr Gasoline	ICEV	$39.0	$54.5	$70.1	$39.0	$54.5	$70.1
Dodge Grand Caravan Gasoline	ICEV	$48.5	$68.1	$87.6	$48.5	$68.1	$87.6
Lexus ES 350 Gasoline	ICEV	$62.7	$80.6	$98.5	$62.7	$80.6	$98.5
Mercedes-Benz E300 Gasoline	ICEV	$78.0	$96.1	$114.3	$78.0	$96.1	$114.3

Source: Alternative Fuels Data Center, Department of Energy; Energy Information Administration; Calculations by Beacon Economics

Battery replacement

When it comes to major vehicle maintenance costs, replacing an EV battery today is more expensive than replacing an internal combustion engine. The industry does not measure ZEV life cycles in terms of years but rather in terms of cycle charges. Note that for lithium-ion (Li-ion) batteries, when a battery capacity is below certain percent, it is considered dead. The cathode material and anode material may also affect the life cycle of a battery. A test of five Li-ion batteries with different cathode and anode materials showed capacity loss of up to 80 percent of the original capacity ranging from 240 charges to more than 1020 charges.[45] Furthermore, Li-ion batteries start degrading as soon as manufactured, even when they have never been used. High temperatures, overcharging or high voltage, deep discharges or low voltage, and high discharges or charge current can shorten the life of the battery. By controlling for these factors, the lifetime of the battery can be improved. The Tesla Roadster, for example, achieves long battery life with lithium-cobalt batteries that control for these factors.[46]

Upfront Price

While the upfront price tag of many ZEV vehicles is currently higher than equivalent ICEVs, costs are coming down rapidly. Bloomberg Finance estimates that electric vehicles will be cost-competitive with ICEV counterparts starting in 2025 onwards.[47] Two of the biggest factors driving price are research and development (R&D) and battery costs.

R&D

R&D for electric vehicles is much higher than for incremental improvements to ICE vehicles. With traditional ICE vehicles, many engines are used for multiple generations of vehicles across many models. Many automakers pay to be able to use engines from other automakers to save on research and development costs. New versions of engines can also use technology and data from the previous version to reduce costs. In other words, the mature infrastructure for ICE vehicles means research and development costs expensed on improving the internal combustion engine is very low compared to electric vehicles.

To develop electric vehicles, automakers are essentially starting from scratch, with R&D investment requirements similar to those when the internal combustion engine was being developed. ZEV R&D is still an enormous line item for automakers, which means these vehicles are both more expensive, and money losers for automakers. But as with any new technology, the more that comes online, the less expensive the cost to produce.[48]

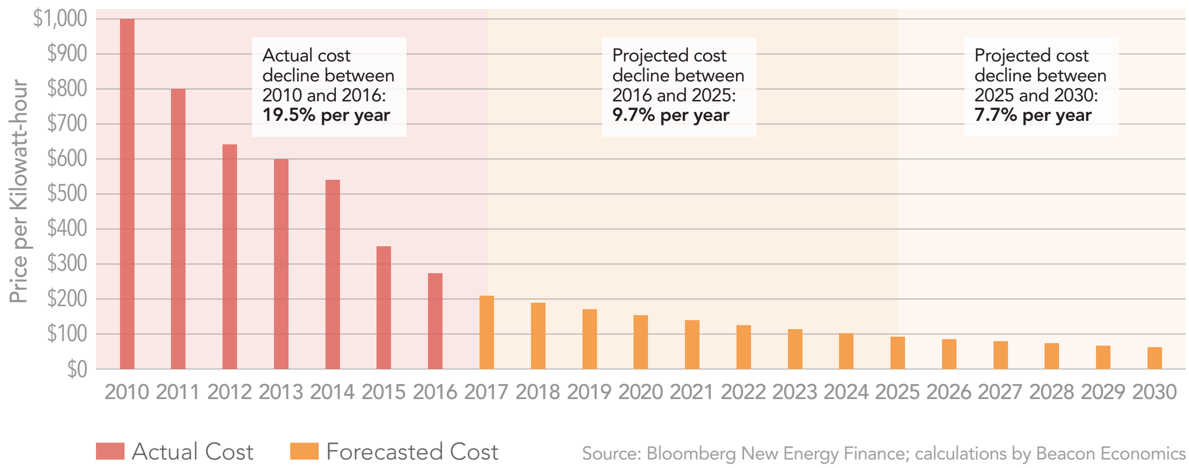
45 "A comparative study of commercial lithium ion battery cycle life in electric vehicle: Capacity loss estimation." Journal of Power Sources. December 5, 2014. Available at: http://www.sciencedirect.com/science/article/pii/S0378775314009756

46 Arcus, Christopher. "Battery Lifetime: How Long Can Electric Vehicle Batteries Last?" May 31, 2016. Available at: https://cleantechnica.com/2016/05/31/battery-lifetime-long-can-electric-vehicle-batteries-last/

47 Shankleman, J. (2017). "Pretty Soon Electric Cars Will Cost Less Than Gasoline." Bloomberg Technology. May 25, 2017. Available at: https://www.bloomberg.com/news/articles/2018-01-08/a-45-000-suv-shown-in-las-vegas-attests-to-china-s-car-ambition

48 In accounting, U.S. GAAP requires R&D costs to be expensed immediately as incurred whereas IFRS requires R&D costs to be capitalized first and then expensed as benefits are realized. This means if the cost of manufacturing ZEVs include the R&D costs (as is under IFRS), the cost of making ZEVs would be high if spread across few ZEVs. Source: http://www.kpmg-institutes.com/institutes/ifrs-institute/articles/2017/08/overview-of-r-d-under-ifrs.html

Figure 6: Lithium-Ion Battery Cost, 2010 to 2016, Projected 2030



Source: Bloomberg New Energy Finance; calculations by Beacon Economics
Note: The quoted lithium-ion battery costs include cell plus pack prices

Batteries

The most expensive component of a ZEV is the battery, and battery costs are dropping quickly and should reach a break-even point in the near future. Indeed, in the short span of just six years, average battery cost per kilowatt-hour has dropped 74 percent from over $1,000 to just $273/Kwh in 2016, and their energy density has improved 5 percent per year. Bloomberg New Energy Finance estimates that battery cost will decline by almost 10 percent until 2025, when ZEVs will reach price parity with ICE vehicles.[49]

Battery costs are projected to continue to decline rapidly, and technological advances could accelerate that decline, but there are other factors to consider.

Materials

Supply constraints for critical materials like cobalt, lithium and graphite could slow the rapid decline in battery price. Olivetti et al. (2017) find that it is less likely to be due to shortages of the metals, and more likely that there could be short-term supply chain bottlenecks of lithium and cobalt and that production cannot keep up with demand.[50] Cobalt and lithium are mined in the DR Congo (which faces uncertainty due to political instability) and China (which has an ever-growing demand for ZEVs). As a result, lithium and cobalt prices have more than doubled in the past year.[51]

49 Soulopoulos, N. (2017). "When Will Electric Vehicles be Cheaper than Conventional Vehicles?" Bloomberg New Energy Finance. April 12, 2017. Available at: https://data.bloomberglp.com/bnef/sites/14/2017/06/BNEF_2017_04_12_EV-Price-Parity-Report.pdf

50 Olivetti, E. A., G. Ceder, G. G. Gaustad, and X. Fu (2017). Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals. Joule, 2017; 1 (2): 229 DOI: 10.1016/j.joule.2017.08.019. Available at: http://www.cell.com/joule/pdf/S2542-4351(17)30044-2.pdf

51 "How to Mine Cobalt Without Going to Congo." November 30, 2017. Available at: https://www.bloomberg.com/news/articles/2017-12-01/the-cobalt-crunch-for-electric-cars-could-be-solved-in-suburbia

But cobalt is not the only metal necessary for producing lithium-ion batteries – major battery suppliers such as Samsung SDI and LG Chem have already begun development of alternative battery packs that use more nickel and less cobalt.[52] And entrepreneurs are rushing to fill the need, inventing cobalt-free alternatives.[53] American Manganese Inc. recently announced it has developed a way to produce enough cobalt to power all the electric cars on the road today without drilling into the ground: by recycling faulty batteries. It's one of many technologies in the works. American Manganese's patent pending method draws out all of the metals in rechargeable batteries, which has 100 percent cobalt, as opposed to ore that contains only two percent cobalt. Innovators have made so much progress that the companies like Tesla Inc. and Toyota Motor Corp. could count on recycling for 10 percent of their battery material needs through 2025 if companies roll out large schemes, according to Bloomberg New Energy Finance.[54]

Incentives

As detailed in the policy discussion section, there are federal, state, and local incentives for ZEV purchase.[55] While analysis shows that there are cost competitive models available now, incentives most certainly help drive sales by decreasing the cost.

52 West, K. (2017). "Carmakers' electric dreams depend on suppliers of rare minerals." The Guardian. Guardian News and Media Limited. July 29, 2017. Available at: https://www.theguardian.com/environment/2017/jul/29/electric-cars-battery-manufacturing-cobalt-mining

53 Lebedeva, N., F. Di Persio, and L. Boon-Brett (2016), Lithium ion battery value chain and related opportunities for Europe, European Commission, Petten. The Joint Research Center of Europe predicts the introduction of other cobalt-free alternatives.

54 "How to Mine Cobalt Without Going to Congo." November 30, 2017. Available at: https://www.bloomberg.com/news/articles/2017-12-01/the-cobalt-crunch-for-electric-cars-could-be-solved-in-suburbia

55 For an overview of ZEV incentives offered by participating MoU states, see Appendix C.

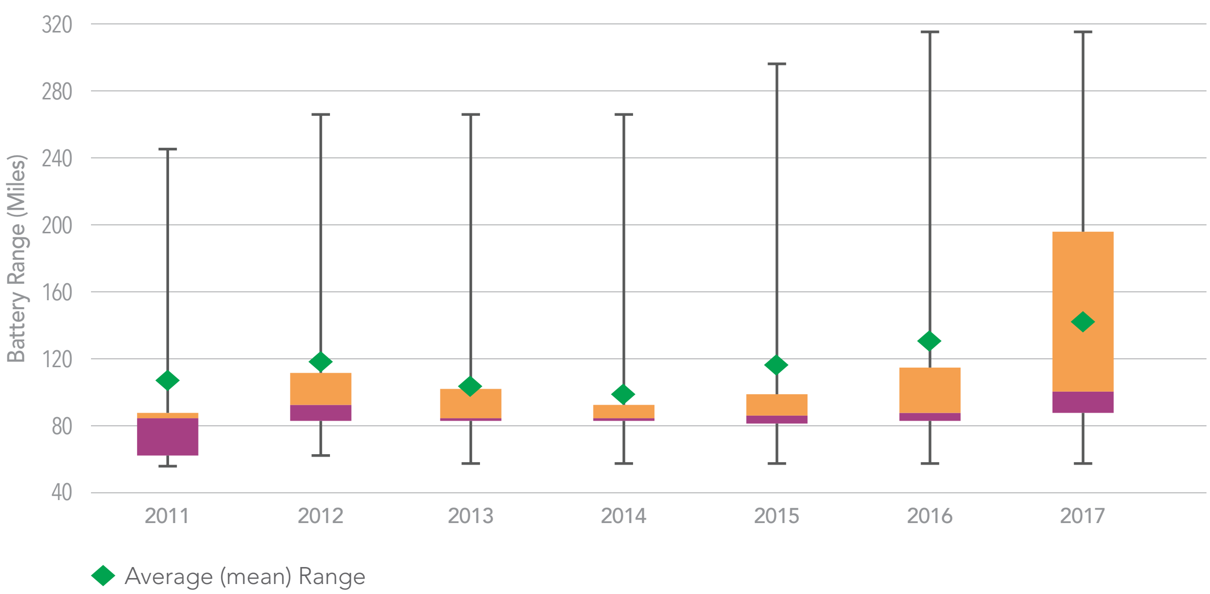
PERFORMANCE

Range

While ICE vehicles can go hundreds of miles on a tank of gas, there also is no concern about running out except in the most remote areas, as gasoline stations are ubiquitous. As a result, a significant barrier to consumer adoption is range anxiety. Even as ZEVs with 80 mile ranges can accommodate 87 percent of current consumer daily trips, prospective buyers worry over when and where a car can be recharged.[56]

The energy-density, or capacity, of lithium-ion batteries has been increasing five to seven percent annually for the last 25 years.[57] Figures 7 and 8 illustrate the battery range of BEVs and PHEVs from recent years, showing that both have improved considerably. The top and bottom ticks of these figures represent the maximum and minimum ranges, respectively. The upper, middle, and lower bound of the boxes represent the upper quartile (Q3), median (Q2), and lower quartile (Q1), respectively.

Figure 7: Pure Battery Electric Vehicle Range Distribution

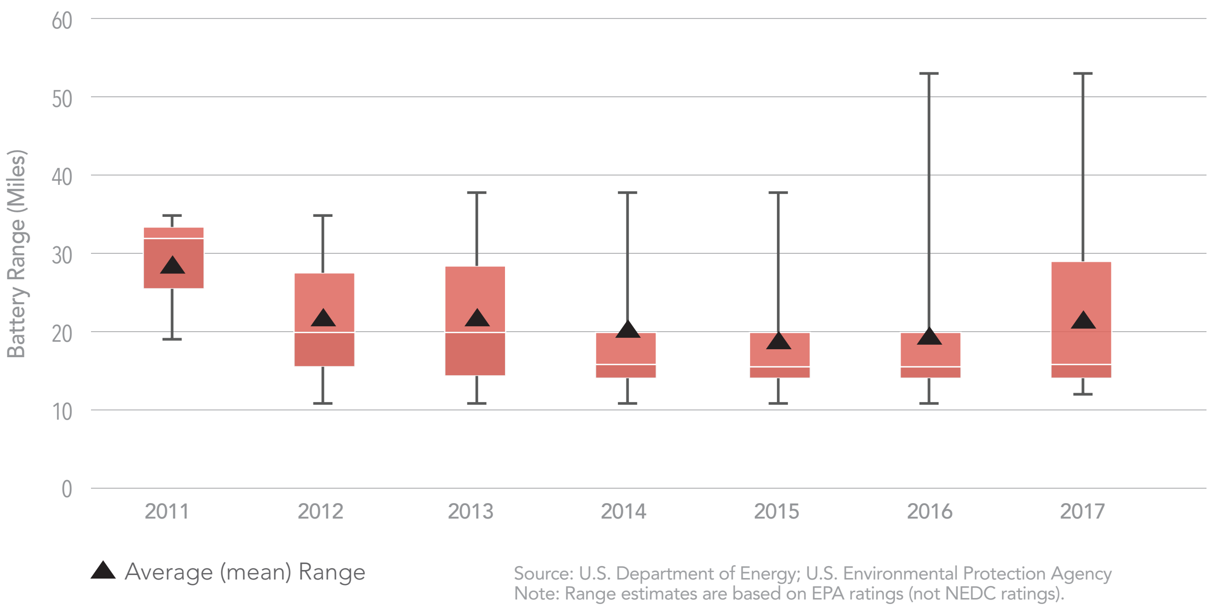


Source: U.S. Department of Energy; U.S. Environmental Protection Agency
Note: Range estimates are based on EPA ratings (not NEDC ratings).

56 Needell, A., J. McNerney, M. Chang, and J. Trancik. (2015). "Potential for widespread electrification of personal vehicle travel in the United States." Nature Energy. August 15, 2016. Available at: https://www.nature.com/articles/nenergy2016112

57 Zeyuan, C. et al. (2016). "An Ambient-air Stable Lithiated Anode for Rechargeable Li-ion Batteries with High Energy Density" Nano Letters, 2016, 16(11), pp. 7235 – 7240. DOI: 10.1021/acs.nanolett.6b03655

Figure 8: Plug-in Hybrid Electric Vehicle Range Distribution



Source: U.S. Department of Energy; U.S. Environmental Protection Agency
Note: Range estimates are based on EPA ratings (not NEDC ratings).

In 2017, Tesla Model S had the longest BEV range rated by the Environmental Protection Agency (315 miles), which was 71 miles longer than Tesla Roadster, the longest range BEV in 2011 with 244 miles. As for the rest of the BEVs, most models have a range of 80 to 100 miles. A number of BEVs within the 80- to 90-mile range were introduced in 2014, decreasing the average range among all models from 104.1 miles in 2013 to 98.5 miles in 2014. There has been considerable spike in the average range of the upper echelon of these vehicles in 2017 due to the existence of Chevrolet Bolt and the introduction of Tesla Model 3.

In 2017, for PHEVs, the Chevrolet Volt has an impressive 53 mile range rated by the Environmental Protection Agency, which is 16 miles longer than Cadillac ELR, which has the second longest range with 37 miles. As for the rest of the PHEVs, 2014 again saw a number of PHEVs with low battery range, which decreased the median range among all models from 20 miles in 2013 to 16 miles in 2014. Battery range for PHEVs continued to improve in 2017, after the introduction of the second-generation Chevrolet Volt in 2016, and three new models – Chrysler Pacifica Hybrid, Cadillac CT6, and Kia Optima, which boast a range of 33 miles, 31 miles, and 29 miles, respectively. This brings the number of PHEV models with at least 25 miles range from four models to seven models.

Traditional automotive companies such as Ford, Nissan, and Honda are introducing new, longer-range ZEV options. In addition, more unconventional automakers have either entered the market or are in stages of development – ranging from startups such as Faraday Future and Lucid Motors to well established companies in other industries not related to electric vehicles such as Dyson.[58]

58 Kahn, J. (2017). "Dyson to Spend £1 Billion Making 'Radical' Electric Car." Bloomberg Technology. September 26, 2017. Available at: https://www.bloomberg.com/news/articles/2017-09-26/dyson-will-build-radically-different-electric-car-by-2020

CHOICE & CONVENIENCE

Model Choices

Automakers around the world are ramping up their EV model offerings. Currently there are 150 different plug-in hybrids and pure electric vehicles available worldwide, with more offered in some markets than others. In the top California cities for EV penetration, which account for 81 percent of the state's EV sales, auto dealers offer 25 to 30 different models. Mid-sized California markets had 13 to 21 models available. Comparatively, more than half of the U.S population lives in a metropolitan area with seven or fewer available models.[59]

The overall number of global electric vehicles models is set to rise to over 240 by 2021. China is leading the way, with over 75 EV models, introducing 25 in 2016 alone, and is spurring urgency among other automakers.[60] Volkswagen, Daimler, Volvo and Nissan have made aggressive plans to electrify their vehicle fleet over the next 10 years. General Motors announced they plan to introduce 20 new ZEV models by 2023, while Ford promises 13.

As the lead global EV adopter, China sales jumped 70 percent with the introduction of 25 new models in 2016. More choices in California could help accelerate sales. However, it is worth noting that China's favorable subsidies help drive increased vehicle choice. The government offers generous incentives but requires that qualifying ZEVs are domestic, providing significant demand for domestic ZEV production and increased vehicle model choices.[61]

As illustrated in Figure 9, despite having a similar number of models, sales vary between California, Sweden, and the UK. However, the population of Sweden is about one-fourth that of California and the UK has roughly 25 million more people than California.

CONVENIENCE

Infrastructure

The electric charging infrastructure in the United States has grown at a rapid pace. In just five years, from 2011 to 2016, the number of plugs for charging electric vehicles increased by 1,138 percent. This increase comes despite the high cost of building charging stations. To offset the high costs, many local governments are offering rebates and loans specifically for charging stations. For example, the largest rebate is offered by the city of Santa Barbara, offering up to $20,000 for a DC fast charger to public entities or nonprofits.[62] There are 25 states that currently offer their own unique rebate or loan programs to help incentivize more chargers.[63]

Even with such rapid development of charg-

59 "Update: California's electric vehicle market." The International Council on Clean Transportation. May 2017. Available at: https://www.theicct.org/sites/default/files/publications/CA-cities-EV-update_ICCT_Briefing_30052017_vF.pdf

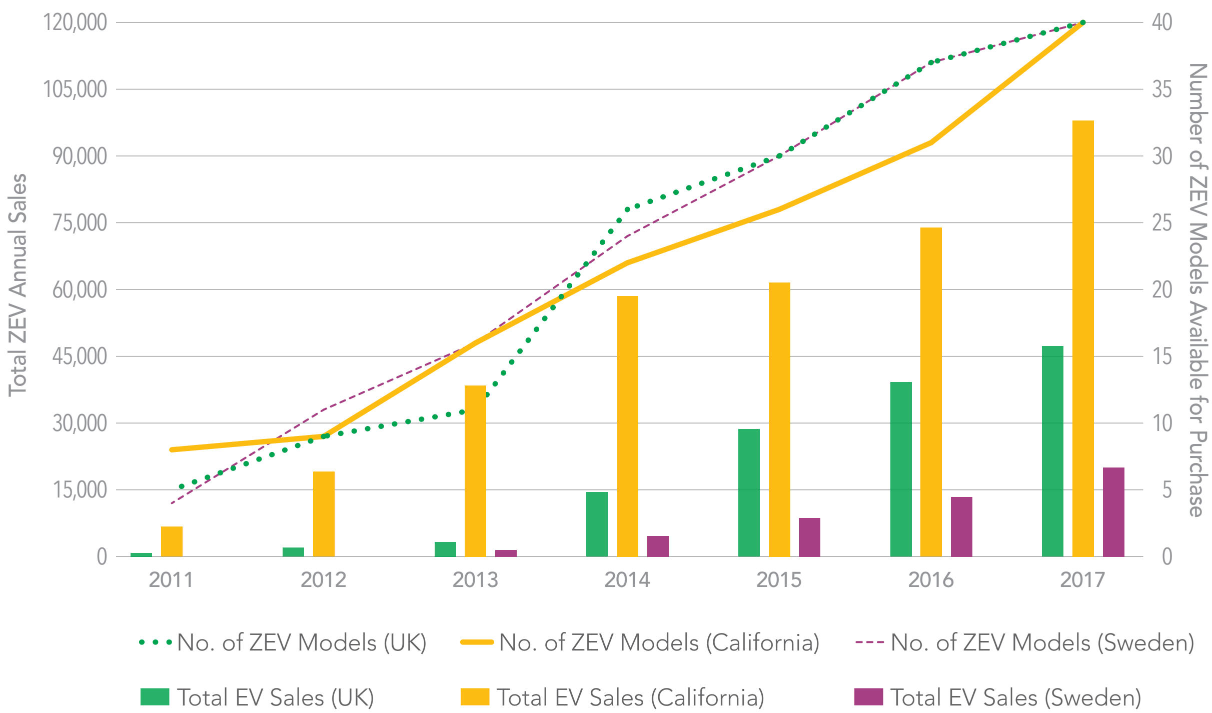
60 Ibid.

61 "Dynamics in the Global Electric-Vehicle Market." McKinsey & Company. July 2017. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/dynamics-in-the-global-electric-vehicle-market

62 For more information, please visit Santa Barbara County Air Pollution Control District's website at: https://www.ourair.org/ev-charging-program/

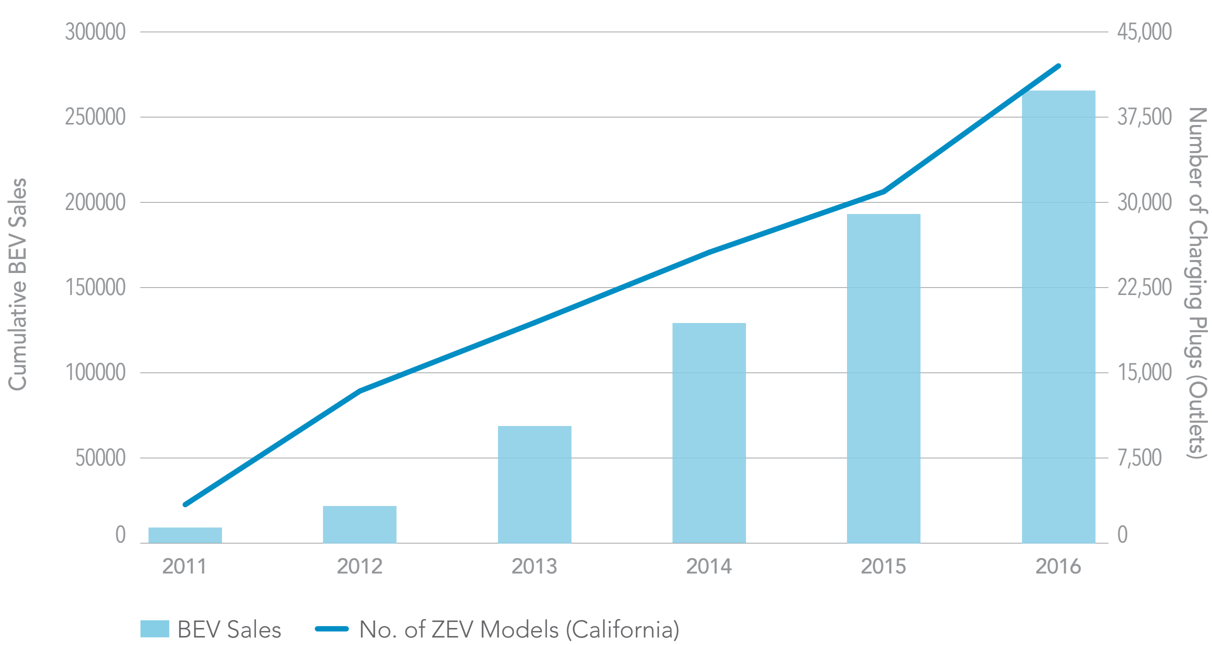
63 Guinn, S. (2017). EVSE Rebates and Tax Credits, by State. Clipper Creek. October 10, 2017. Available at: https://www.clippercreek.com/evse-rebates-and-tax-credits-by-state/

Figure 9: ZEV Models and Sales, United Kingdown, California & Sweden, 2011 to 2017*



Source: Vehicles Statistics, Department for Transport; European Alternative Fuels Observatory; the RAC Foundation; U.S. Department of Energy; U.S. Environmental Protection Agency; Alliance of Automobile Manufacturers; BIL Sweden; The Society of Motor Manufacturers and Traders (SMMT)
Note: California figures for November and December 2017 are projected based on historical and current sales trends.

Figure 10: Cumulative Battery Electric Vehicle Sales vs. Charging Plugs Deployment in the U.S.



Source: Alternative Fuel Data Center, Departtment of Energy; IHS/Markit; Alliance of Automobile Manufacturers ing stations and plugs, the number of BEV vehicles on the road is increasing at an even faster rate - a 3,765 percent increase in BEV sales during the same period. This is less of a concern for PHEVs as they can also rely on gasoline in addition to electricity. In 2016, there was only one charging plug for about every six pure electric cars (BEVs) in the United States. The disparity is expected to increase as more mass produced electric cars enter the market. Additionally, the lack of adequate charging options may depress sales.[64]

As of January 9, 2018, California had a total of 16,549 public and private (nonresidential but privately owned)[65] charging outlets, or about six times as many outlets as the next state, Texas, with 2,727 charging outlets. While California has substantially more charging outlets than other states, these only accounted for 31.6 percent of the U.S. total, while it has 50 percent of all ZEVS on the road nationwide. As of January 2018, California only had 0.05 public charging outlets per ZEV, one of the lowest ratios in the country (see Appendix D for maps of California charging stations).[66] Studies have shown that California will need 125,000 to 220,000 charging ports from private and public sources by 2020 in order to provide adequate infrastructure, not to mention hundreds of thousands at multi-unit dwellings.[67]

The majority of ZEV owners charge at home, but for electric vehicles to become mainstream, there have to be local options for those living in multi-family units, and urban areas with limited off-street parking. Renters – who make up almost half of California's households (45.6%) – have limited options to charge at home, especially in multi-unit dwellings.[68] Furthermore, metro areas with the highest ZEV adoption rates – namely Los Angeles, San Francisco, San Jose, and San Diego metros – have higher shares of renter households (48.3% collectively) compared to the state overall.[69]

The cost of a new public single port charging station varies. A level two charging station can cost between $1,000 and $1,900 depending on permits and planning requirements. A DC fast charging station can cost between $14,000 and $91,000.[70] A level two charger takes about four hours to fully charge an average electric car, while a DC fast charger can take as little as 30 minutes.[71] With the technology quickly improving, many cities are hesitant to double down on current technology if prices are due to fall drastically in the near future or if

64 Alternative Fuel Station Counts by State. Alternative Fuels Data Center, U.S. Department of Energy. Data last updated on November 6, 2017

65 Public stations include such places as charging stations at train, park and Ride parking lots, University charging stations, airport charging stations, etc. Private stations include charging stations at dealerships, business establishments (for employees only), apartment complexes (for residents only). It does not include residential private stations.

66 Alternative Fuel Station Counts by State. Alternative Fuels Data Center, U.S. Department of Energy. Data last updated on November 6, 2017

67 "Plugging Away: How to Boost Electric Vehicle Charging Infrastructure." UC Berkeley Center for Law, Energy & the Environment. June 2017. https://www.law.berkeley.edu/wp-content/uploads/2017/06/Plugging-Away-June-2017.pdf

68 According to the 2016 American Community Survey 1-year estimates.

69 Based on total CVRP rebates, which was discussed in the 2017 California Green Innovation Index, available at http://next10.org/2017-gii

70 Smith, M. and J. Castellano (2015). "Costs Associated with Non-Residential Electric Vehicle Supply Equipment." U.S. Department of Energy Vehicle Technologies Office. November 2015. Available at: https://www.afdc.energy.gov/uploads/publication/evse_cost_report_2015.pdf

71 More information can be viewed at ChargePoint at https://www.chargepoint.com/files/Quick_Guide_to_Fast_Charging.pdf

current charging tech become completely obsolete.

California has been leading the way with rebates to ensure infrastructure growth. In addition, California's settlement with Volkswagen over its diesel emissions scandal includes substantial investment in charging infrastructure (more details in the Public Policy section).

Fueling time

While EV owners who charge at home have the luxury of time and convenience, reducing charge time is important for consumer acceptance. Some, like Tesla's network of Superchargers, can recharge EVs to 80 percent in 20 to 40 minutes. Meanwhile, others fully charge EVs in three to four hours, while slower charging points take around six to eight hours. Charging times that take more time than refueling petrol and diesel cars have been seen as a roadblock to the mass adoption of ZEVs.

Vehicle makers are responding to the concern with innovations to reduce charge times. For example, Honda recently announced that they are developing high-capacity batteries capable of ultra-fast 15 minute charging with a 240 km range for release in 2022 models.[72] This supercharging technology, coupled with Honda's dynamic charging system, could have significant implications for ZEV convenience.

Maintenance

Maintenance expenses were assessed in the cost of ownership analysis discussed earlier. Here, maintenance is addressed from a convenience standpoint. ZEVs have about 1,980 fewer moving parts than ICE vehicles. With a total of about 20 moving parts per vehicle, ZEVs have far fewer maintenance issues, visits and costs than ICE vehicles. This small number of parts also makes EV assembly and part replacement relatively simple and inexpensive.[73] UBS Group AG has found that the Chevy Bolt is almost maintenance-free since fewer parts need to be replaced over the car's life and it does not require a regular change of fluids, like engine oil.[74] The electric motor has just three moving parts compared with 133 in a four-cylinder internal combustion engine.[75]

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72 "Honda to halve electric cars' charging time to 15 minutes." Nikkei Asian Review. November 1, 2017. Available at: https://asia.nikkei.com/Business/Companies/Honda-to-halve-electric-cars-charging-time-to-15-minutes

73 "Rethinking Transportation 2020 – 2030." RethinkX. May 2017. Available at: https://static1.squarespace.com/static/585c3439be65942f022bbf9b/t/59f279b3652deaab9520fba6/1509063126843/RethinkX+Report_102517.pdf

74 Hummel, P., et. al. "UBS Evidence Lab Electric Car Teardown – Disruption Ahead?" May 18, 2017. http://www.advantagelithium.com/_resources/pdf/UBS-Article.pdf

75 "How Electric Cars Can Create the Biggest Disruption Since the iPhone." Bloomberg Technology. September 22, 2017. Available at: https://www.bloomberg.com/news/articles/2017-09-21/how-electric-cars-can-create-the-biggest-disruption-since-iphone

PUBLIC POLICY

Public policy can accelerate or erect barriers to electrification of transportation. There are many moving policy parts - from national to state, public utilities to municipal - that can help create a virtuous or vicious cycle when it comes to ZEV adoption. While California moves forward to clean up its fleets, national and international policy plays a role in the state's markets as well.

International

National governments around the world including the UK, France, the Netherlands and even India have officially stated the intention to phase out the internal combustion engine domestically, as shown in Table 5. While their statements have typically lacked specific measures, they are indicative of the fast changing landscape.

China, which faces well-documented air quality challenges, is likewise strongly committed to deploying zero-emission vehicles, or "new energy vehicles." China is expected to announce a ZEV credit policy this year modeled after California's program resulting from collaborative efforts led by the China-US ZEV Policy Lab.[76] A national "road map" for the country's auto market aims for ZEVs to account for at least 20 percent of total vehicle sales by 2025, or about 7 million vehicles a year.[77]

Pollution and climate change are the primary drivers of policy aimed at accelerating the electrification of transportation. As such, the world's largest cities choked by transportation emissions may move faster than their national counterparts. For example, Paris has announced it will ban ICE vehicles by 2030, ten years ahead of France.[78]

Emissions standards, both at home and abroad, are incentivizing automakers to expand EV options. In the U.S., the "clean car states," California and Section 177 states are moving ahead with policies to accelerate the adoption of cleaner cars.[79] Abroad, the EU's emissions standards impose heavy fines on automakers that do not comply. In 2021, new targets for cars

76 Clegern, Dave. "California and China team up to push for millions more zero-emission vehicles." California Air Resources Board. June 7, 2017. Available at: https://www.arb.ca.gov/newsrel/newsrelease.php?id=934

77 Ibid.

78 Mulholland, Rory. "Paris to ban all petrol cars from the city by 2030 in pollution crackdown." October 12, 2017. Available at: http://www.telegraph.co.uk/news/2017/10/12/paris-ban-petrol-cars-city-2030-pollution-crackdown/

79 Under the Clean Air Act (CAA), Section 209 provides California with the right to set its own vehicle emissions standards and Section 177 provides other states with the right to choose between California standards and the federal standards.

Table 5: Possible Actions Promised by Leading Countries

Country/State	Action	Earliest Date
California	Will ban gas-powered cars	2030
Norway	Will only sell electric and hybrid vehicles	2030
The Netherlands	Will only sell electrified vehicles	2025
France	Will ban the sale of gas and diesel cars	2040
United Kingdom	Will ban the sale of gas and diesel cars	2025
China	Will only sell electric and hybrid vehicles	N/A

Source: Alliance of Automobile Manufacturers
Note: Year-to-date, through October 2017

sold in the EU come into force, and many car makers are focused on increasing EV options in order to be able to comply.[80] Even as the United States has indicated its intention to opt out of the Paris Accord and weaken car emissions standards and the ZEV mandate in Clean Car states, automakers may feel pressure to clean up their fleets to stay competitive.

Subnational

In 2013, eight states including California signed a memorandum of understanding (MoU) committed to bring 1.5 million ZEVs on the roadways by 2025. Seven other states have also committed to varying goals that amount to over 3.4 million ZEVs on the road by 2025.[81]

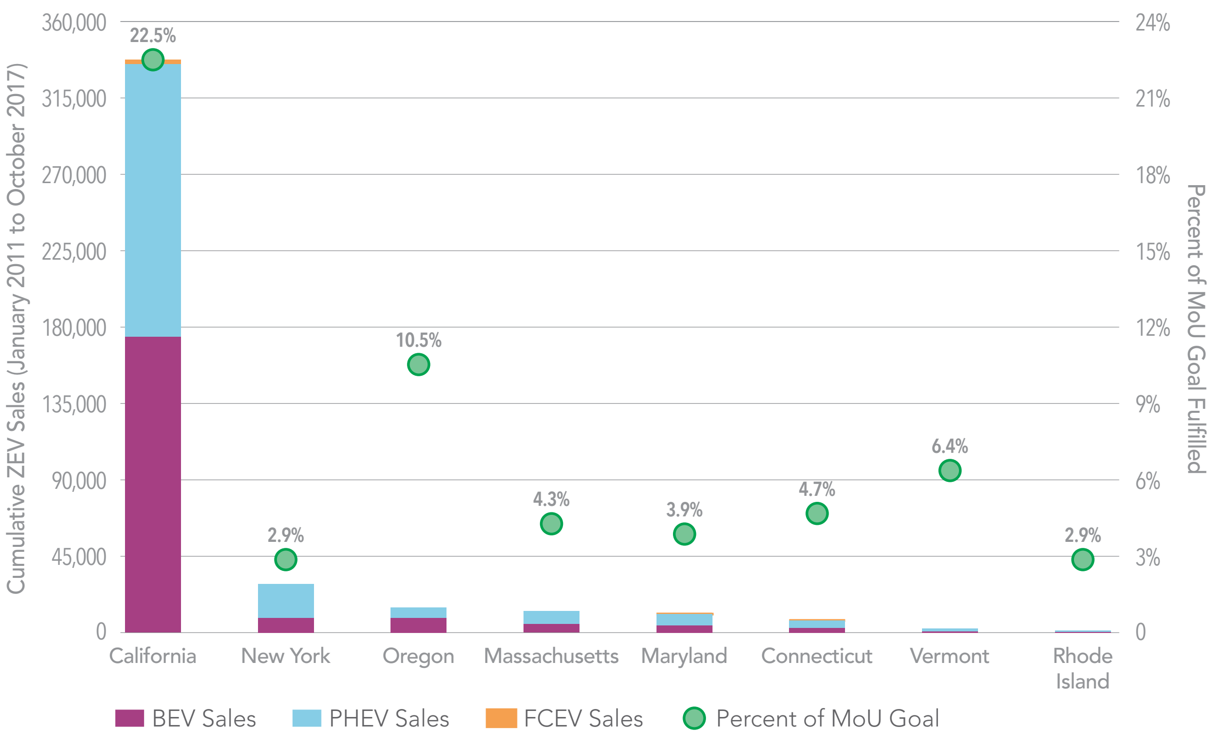
Table 6: ZEV Goal by States

State	MoU Goal
California	1,500,000
New York	1,000,000
Oregon	140,000
Massachusetts	300,000
Maryland	280,000
Connecticut	150,000
Vermont	37,000
Rhode Island	44,000
Total	**3,451,000**

Source: ZEV Task Force (2014)

80 Wilmot, Steven. "Car Makers Count Costs of Global Warming Emissions Standards." November 16, 2017. Available at: https://www.wsj.com/articles/car-makers-count-costs-of-global-warming-emissions-standards-1510844143
81 ZEV Program Implementation Task Force (2014). "Multi-State ZEV Action Plan." Page 9. Available at: http://www.nescaum.org/topics/zero-emission-vehicles/multi-state-zev-action-plan

Figure 11: Cumulative ZEV Sales and Percent of Memorandum of Understanding Goal Fulfilled as of August 2017



Source: Alliance of Automobile Manufacturers, R.L. Polk & Co.
Note: Cumulative Sales as of October 2017.

As of October 2017, California has fulfilled 22.5 percent of the MoU goal, followed by Oregon with 10.5 percent fulfilled and Vermont with 6.4 percent of the goal fulfilled. With the exception of California, it appears that none of the other states are on track to fulfill the goals parlayed in the MoU. A recent NRDC study calls for a 'tune-up' of the ZEV program to stay on track.[82]

California

California vies with China for leadership in ZEV policy. After China announced it would ban the ICE, Governor Jerry Brown expressed interest in a similar ban and conferred with Mary Nichols, chairman of the California Air Resources Board (CARB), to determine whether or not it was something California could soon pursue.

Assembly Budget Committee Chairman Phil Ting introduced a bill in January 2018 that would ban gas-powered cars by 2040. Rather than use the authority of the Clean Air Act, which requires a waiver and is unlikely under the current Administration, the bill would enable California's motor vehicle department to only register zero-emission vehicles starting in 2040.

82 Schulock, C. (2016). "Manufacturer Sales Under the Zero emission Vehicle Regulation." Natural Resources Defense Council. July 21, 2016. Available at: https://www.nrdc.org/sites/default/files/media-uploads/nrdc_commissioned_zev_report_july_2016_0.pdf

While California competes with China for leadership, it also collaborates with Beijing to grow the market. In June 2017, Governor Edmund G. Brown and CARB Chair Mary Nichols met with Chinese officials and automakers to forge greater cooperation and facilitate developing new ZEV models for the US market. They announced a new working group through the China-US ZEV Policy Lab at UC Davis to expand cooperation with Chinese zero-emission vehicle and battery technology companies. Automakers included BYD, Beijing Auto Group, Great Wall, Geely, Dongfeng Xiao Kang, Yangtze Motors and a half dozen other vehicle and battery companies.

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Charging Infrastructure

Additionally, there are a number of public policies within California to promote the development of charging infrastructure. ZEV electric infrastructure in California has grown with substantial investments in the past several years, and accelerated investments are expected as new infrastructure developments emerge. More than 10,000 Level 2 and 1,500 direct current fast charger (DCFC) connectors have been deployed across California.[83]

Volkswagen Settlement – California ZEV Investments: Appendix C of the consent decree (the ZEV Investment Commitment) requires Volkswagen to invest $800 million in ZEV projects in California over a 10-year period. Eligible projects include installing ZEV fueling infrastructure (for both electric- and hydrogen-powered cars), funding brand-neutral consumer awareness campaigns, and investing in projects such as car-sharing programs that will increase access to ZEVs for all consumers in California, including those in lower-income and disadvantaged communities. Volkswagen will submit four ZEV investment plans, valued at up to $80.0 million per year, to the CARB.[84]

Assembly Bill 118 created the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). To date, ARFVTP funds have provided 38.8% of statewide total public charging sites and 37.9 percent of charging outlets – specifically, 1,418 publicly accessible sites (includes planned sites) with 4,635 public charging outlets (includes planned outlets).[85]

83 Ibid.
84 "Zero Emission Vehicles and Infrastructure." California Energy Commission. July 5, 2017. Available at: http://www.energy.ca.gov/renewables/tracking_progress/documents/electric_vehicle.pdf
85 Ibid

EC Grants: In 2017, the Energy Commission awarded $2.1 million (total of $9.75 million and 43 grants) for nine ZEV Regional Readiness Planning and Implementation grants. These grants aim to streamline the permitting process for future ZEV infrastructure, promote regional coordination through the establishment of ombudsman positions, conduct siting analysis, establish best practices for "ZEV-ready" building and public works guidelines, and provide public ZEV education and outreach.[86]

Utilities/SB 350: In 2014, the CPUC adopted Decision 14-12-079 in Rulemaking 13-11-007, which allows for the consideration of utility ownership of EV charging stations and infrastructure on a case-specific basis. Subsequently, in 2016 the CPUC approved light-duty infrastructure pilot programs for Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric Company (SDG&E), and Southern California Edison (SCE) to install charging stations.[87]

AQMD's: The Bay Area Air Quality Management District's "Charge!" program is an incentive program that offers grant funding to help offset a portion of the cost of purchasing, installing, and operating new publicly available charging stations at workplaces, multiunit homes, and public locations. The goal of the Charge! Program is to rapidly expand access to charging stations to achieve the region's deployment goal of 247,000 EVs by 2025. The program has $5 million available from the TCFA Regional Fund.[88]

Implications for Infrastructure and the Grid

Even as California moves forward with powerful ZEV policies, policy makers are aware of certain consequences of their success. Since BEVs and FCEV's do not consume motor vehicle fuel, they pay little to no motor vehicle fuel taxes. Mass adoption of these vehicles represents a significant potential drain on state transportation revenue and will require innovative policy solutions to make up the funding gap.[89]

Another potential impact of mass adoption of ZEVs is grid overload. Significant research and innovative policy proposals point to a future electricity system, that, as the Department of Energy describes, is seamless, cost-effective electricity system, from generation to end-use, and capable of meeting all clean energy demands and capacity requirements.[90]

86 Ibid.
87 Ibid.
88 Ibid.
89 "Beyond the Gas Tax: Funding California Transportation in the 21st Century." Next 10 and Beacon Economics April 2017. Available at: http://next10.org/transportation-funding
90 "Vision of the Future Grid." U.S. Department of Energy, Office of the Undersecretary for Science and Energy. Available at: https://energy.gov/under-secretary-science-and-energy/vision-future-grid

The CPUC is currently studying the effects this may have on the grid. SoCal Edison is partnering with the Los Angeles Air Force Base to conduct a pilot program that allows its electric vehicle fleet to act as battery storage and send power back to the grid. The fleet of 34 electric and hybrid vehicles serve as a storage resource for the California grid. The program went live in 2015 and ran through September 2017, though the results have not yet been made public.[91]

Summary of Current Trends

As the section above details, current trends suggest that the cost, range, models and fueling time barriers to EV adoption are likely to be reduced. Increased competition will continue to lower costs and improve technology. Further, ZEV performance and maintenance are superior to ICE vehicles and therefore are a bridge to adoption. Assuming current growth rates, California is on track to meet its 1.5 million ZEV by 2025 goal.

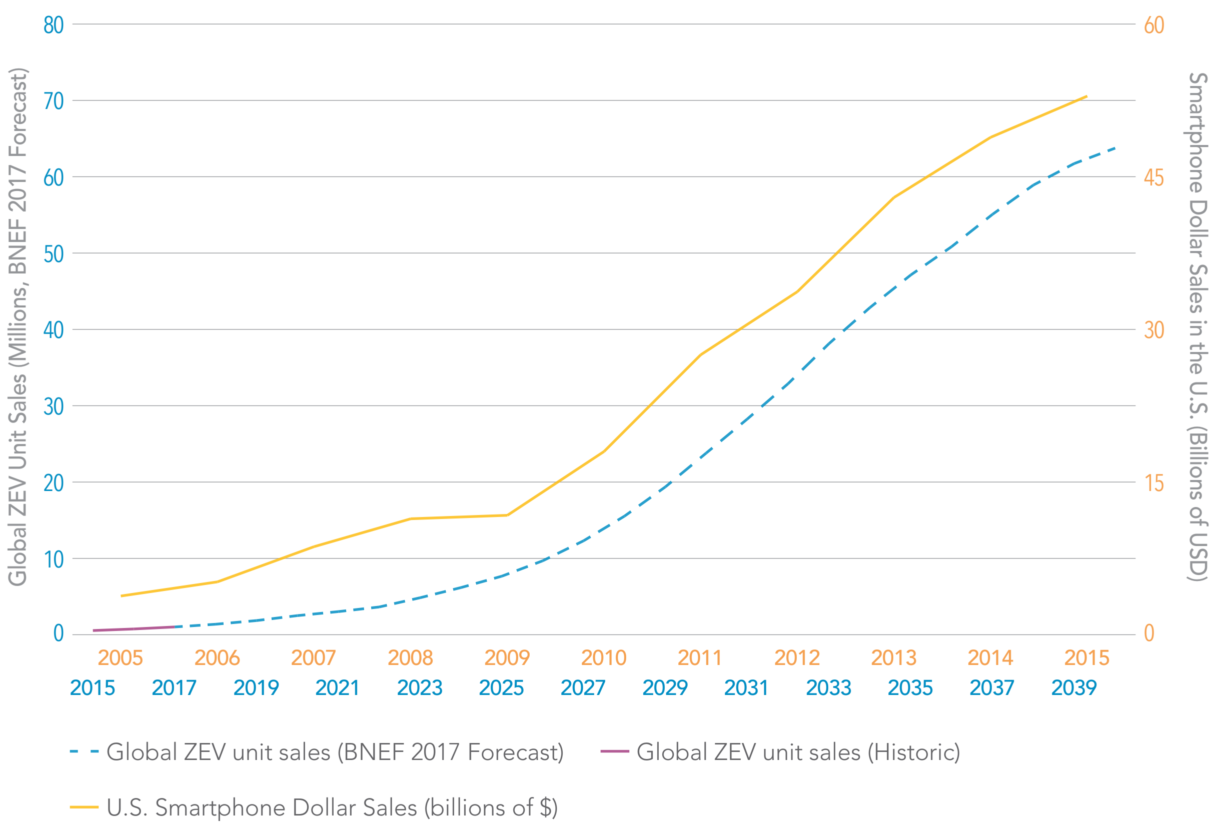
This is not to suggest that the next three to five years are not critical. Automakers are still losing money on these vehicles and dealers have less incentive to sell them as the maintenance costs are lower. The relative absence of charging infrastructure has not significantly dampened sales yet, as most ZEV owners charge overnight at home, but this will likely be a challenge going forward. To achieve mass adoption, people of all income levels and in different residence types must be able to easily and cost-effectively charge their vehicles.

91 Zero Emission Vehicles, CPUC. http://www.cpuc.ca.gov/zev/#Vehicle

FUTURE TRENDS: HOW FAR, HOW FAST?

Advanced technology typically follows an s-curve rather than incremental adoption, and it appears that ZEV technology is no different. Figure 12 shows the adoption rates for smartphones from 2005 to 2015, as compared to the projected adoption rates of ZEVs from 2015 to 2039. Both technologies follow the s-curve, and ZEVs will likely be as ubiquitous in 2040 as smartphones are today.

Figure 12: U.S. Smartphone Adoption vs. Global ZEV Adoption (Forecasted to 2039)



Source: International Energy Agency, OECD; Blooomberg New Energy Finance; and Statista.

Technological adoption also increases exponentially. As reported in the Harvard Business Review, it took 30 years for electricity and 25 years for telephones to reach 10 percent adoption but less than five years for tablet devices to achieve the ten percent rate. It took an additional 39 years for telephones to reach 40 percent penetration and another 15 before they became ubiquitous. Smartphones, on the other hand, accomplished a 40 percent penetration rate in just ten years.[92]

Historic innovations that have disrupted the economy are more systemic than incremental. The iPhone did far more than change the way people made phone calls, it created the App, which led to an entirely new economy for multibillion-dollar companies, and completely disrupted the mobile phone and camera industries.[93]

Similarly, new mobility business models such as ride hailing or car sharing are building momentum around the world and poised to dramatically disrupt the transportation sector. With the advent of autonomous vehicles, set to debut in the 2020s, many experts predict transportation will become a service, with consumers buying kilometers of mobility from service providers instead of individual vehicles. At high utilization rates, electric vehicles have much lower costs per kilometer. This trend would dramatically accelerate the transportation transformation.[94]

Rethink X, a think tank that analyzes technology-driven disruption, predict the combination of electric, autonomous and ride sharing/hailing will upend the car market and individual car ownership quickly, due primarily to cost. Additionally, the cost of owning electric and oil-fueled vehicles will reach parity for shared-mobility fleets by 2020 - five years earlier than for individually-owned vehicles, according to Bloomberg New Energy Finance.[95] Lyft, Uber and other ride hail companies are driving down the prices of transport and driving the internal combustion engine out of the market.

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92 Beginning with the 2002 shipment of the first BlackBerry that could make phone calls and the first Palm-OS-powered Treo model.

93 "Rethinking Transportation 2020 – 2030." RethinkX. May 2017. Available at: https://static1.squarespace.com/static/585c3439be65942f022bbf9b/t/59f279b3652deaab9520fba6/1509063126843/RethinkX+Report_102517.pdf

94 "How Electric Cars Can Create the Biggest Disruption Since the iPhone." Bloomberg Technology. September 22, 2017. Available at: https://www.bloomberg.com/news/articles/2017-09-21/how-electric-cars-can-create-the-biggest-disruption-since-iphone

95 Ibid.

Conclusion

The transportation sector is the largest contributor of greenhouse gas emissions not only in California, but throughout the United States and much of the globe. As the state and world look to reduce greenhouse gas emissions, the rapid decarbonization of transportation options has become a critical priority. California is among those taking a lead by encouraging a transition toward ZEV adoption, though countries such as China and Sweden outpace both U.S. and the Golden State's ZEV market growth.

2017 marked a turning point for the zero-emission vehicle and, more specifically, battery electric vehicle. Leading economies and global automobile manufacturers have drawn a line in the sand to demonstrate that the future of the auto industry will be electric. As more countries, states, cities, and manufacturers commit to prioritize EVs and phase out ICEVs, California can play an important part in the continued growth of this accelerating market.

As one of the world's largest economies, California is a major driver in the global ZEV marketplace. The state's car culture predisposes drivers to adopt better performing, cost competitive cars. With a host of policies to encourage increased sales of high-performing ZEVs as well as expanded infrastructure for charging, California has led the nation in establishing a rapidly maturing ZEV market. Improvements in battery cost and vehicle performance, paired with increased choice and expanded infrastructure will continue to bolster the market.

National ZEV sales are following the trends seen in California, with sales rates for the U.S. now comparable to the Golden State's. And California policy aims to push the industry forward as it moves past critical thresholds to mass adoption, providing a model for other governing bodies. This brief's analysis indicates California will reach 1.5 million ZEVs on the road by 2025, but it could be much faster. The transportation sector is quickly evolving, with rideshare and transportation services playing a greater role. As companies like Lyft and Uber transition to ZEVs and autonomous EVs, the adoption curve for electric vehicles could shift more rapidly than has been estimated.

With such tremendous promise and growth in this industry, California stands to gain by reducing its carbon emissions, and demonstrating its leadership in supporting the rapid acceleration of the ZEV market.

APPENDIX A-COST OF OWNERSHIP MODELING ASSUMPTIONS

Vehicle Information

The vehicles chosen for analysis are conventional internal combustion engine (ICEV), hybrid electric (HEV), plug-in hybrid electric (PHEV), and pure battery electric (BEV) available in California. The model year is selected as 2017. High-end luxury and economy vehicles are included for comparative purposes. At least one typical popular vehicle model is included for each type of vehicle for comparative purposes as well. Table A.1 provides an overview of the vehicles selected. Overall, seventeen vehicle models were selected.

Table A.1. Vehicle Information

Make	Type	5 Year Cost	MPGe/MPG
Nissan Leaf	BEV	$30,680	112/--
smart fortwo ED	BEV	$23,800	108/--
Tesla Model S (60 kw)	BEV	$68,000	104/--
Chevrolet Bolt	BEV	$36,620	119/--
BMW i3 BEV	BEV	$42,400	124/--
Chevrolet Volt	PHEV	$33,220	106/42
Toyota Prius Prime	PHEV	$27,100	133/54
Ford Fusion Energi PHEV	PHEV	$33,120	97/42
Chrysler Pacifica Hybrid	PHEV	$41,995	84/32
Toyota Prius Hybrid	HEV	$23,475	--/52
Honda Accord Hybrid	HEV	$29,605	--/48
Toyota RAV4 Hybrid	HEV	$29,030	--/32
Chevrolet Silverado 15 Hybrid	HEV	$35,790	--/20
Honda Civic 4Dr Gasoline	ICEV	$18,740	--/36
Dodge Grand Caravan Gasoline	ICEV	$25,995	--/20
Lexus ES 350 Gasoline	ICEV	$38,900	--/24
Mercedes-Benz E300 Gasoline	ICEV	$52,150	--/25

Source: Federal Highway Administration

Mileage Information

For this simulation, two cases were considered based on vehicle miles driven per capita (8,572 miles/year) and vehicle miles traveled per licensed driver (14,435 miles/year). Furthermore, the mileage inputs are divided into city travel and highway travel. Since most of a typical commuter's travel is driven on the highway, the model assumes 75 percent for highway and 25 percent for city.

Table A.2. Driving Statistics

Make	Low	High
Daily Miles	20	40
Days per Week	5	5
Weeks per Year	50	50
Daily Miles Total	5,000	10,000
Other Trips	3,572	4,435
Annual Miles Driven	8,572	14,435
Percent Highway	75%	75%
Highway Distance	6,429	10,826
City Distance	2,143	3,609

Source: Federal Highway Administration

Fuel Cost Assumption

For BEVs and PHEVs, the electricity component of the fuel cost is based on the average electricity prices in California. For PHEVs, HEVs and ICEVs, the gasoline component of the fuel cost is based on California average fuel cost for November 11, 2017 from the Energy Information Administration. All models are assumed to run on unleaded regular except for Mercedes-Benz E300, which requires unleaded premium fuel. Information on annual fuel consumption and annual fuel cost are provided in Table A.3. below.

All ZEVs are assumed to be charged once daily. For PHEVs, during normal weekday driving, battery electricity is used until the battery is depleted and then gasoline is used; for both electricity and gasoline, the city-highway mileage split is assumed to be the same for the miles on electricity and the miles on gasoline.

Table A.3. Annual Fuel Consumption and Cost

Make	Based on 8,572 miles/year			Based on 14,435 miles/year		
	Annual Fuel Use	Annual Elec Use	Annual Fuel/Elec Cost	Annual Fuel Use	Annual Elec Use	Annual Fuel/Elec Cost
Nissan Leaf	0 gal	2,725 kWh	$474	0 gal	4,589 kWh	$799
smart fortwo ED	0 gal	2,893 kWh	$503	0 gal	4,872 kWh	$848
Tesla Model S (60 kw)	0 gal	2,872 kWh	$500	0 gal	4,266 kWh	$742
Chevrolet Bolt	0 gal	2,533 kWh	$441	0 gal	4,836 kWh	$841
BMW i3 BEV	0 gal	2,464 kWh	$429	0 gal	4,150 kWh	$722
Chevrolet Volt	64 gal	1,896 kWh	$537	79 gal	3,597 kWh	$882
Toyota Prius Prime	51 gal	1,543 kWh	$432	133 gal	1,927 kWh	$766
Ford Fusion Energi PHEV	65 gal	2,095 kWh	$576	190 gal	2,346 kWh	$1,023
Chrysler Pacifica Hybrid	81 gal	2,427 kWh	$685	154 gal	3,866 kWh	$1,172
Toyota Prius Hybrid	168 gal	0 kWh	$545	283 gal	0 kWh	$918
Honda Accord Hybrid	181 gal	0 kWh	$585	304 gal	0 kWh	$985
Toyota RAV4 Hybrid	277 gal	0 kWh	$899	467 gal	0 kWh	$1,513
Chevrolet Silverado 15 Hybrid	387 gal	0 kWh	$1,254	652 gal	0 kWh	$2,111
Honda Civic 4Dr Gasoline	230 gal	0 kWh	$745	387 gal	0 kWh	$1,254
Dodge Grand Caravan Gasoline	383 gal	0 kWh	$1,242	645 gal	0 kWh	$2,091
Lexus ES 350 Gasoline	316 gal	0 kWh	$1,025	533 gal	0 kWh	$1,726
Mercedes-Benz E300 Gasoline	312 gal	0 kWh	$1,091	525 gal	0 kWh	$1,837

Source: Department of Energy

Other Assumptions

The model does not take resale value or depreciation expense into account. Previous studies that include resale value or depreciation indicate that all else equal, BEVs and PHEVs have lower resale value compared to HEVs and ICEVs. Indeed, the simulation results show that the 5-year total ownership costs for ZEVs tend to be high compared to HEVs and ICEVs. However, the reverse is true beyond five years due to the lower annual fuel costs and other recurring expenses.

The acquisition cost of vehicle is based on the default assumptions on the Department of Energy (DOE) calculator. No separate assumptions are made regarding purchase and finance costs since every person's financial situation is different. The DOE assumed the buyer financed 90% of the vehicle price and took out a five-year loan at 6% interest.

Furthermore, because of uncertainties in expected life and future costs associated with high-performance batteries, the cost to replace the battery pack has not been included in the calculation.

APPENDIX B - MAINTENANCE EXPENSES OF ZERO-EMISSION VEHICLES AND INTERNAL COMBUSTION ENGINE VEHICLES

Most consumers see the upfront costs of ownership and assume ZEVs are more expensive to own than ICEVs. This is not always the case, however, since ZEVs have significantly fewer moving parts and thus require less maintenance. On average, ICE vehicles have 2,000 moving parts, many of which are found in the engine, transmission, and emissions systems. On the other hand, ZEVs have about 20 moving parts altogether.

Fewer moving parts can ease consumer's minds because it greatly reduces the chance for anything to break during ownership. Apart from malfunctioning parts, scheduled preventative maintenance is also much lower on ZEVs. ICE vehicles require oil changes every three to five thousand miles, costing $20-55 for regular oil and $45-70 for synthetic. In addition, brake maintenance costs about $150 per axle every 50 thousand miles, depending on driving habits. Lastly, many ICE vehicles require changing out the timing chain every 40,000 and 100,000 miles, costing on average several hundred dollars. ZEVs have none of these costs, except for brakes. Furthermore, brakes endure less wear and tear due to the ZEVs regenerative braking systems, leading to brake changes less frequently than ICEVs.

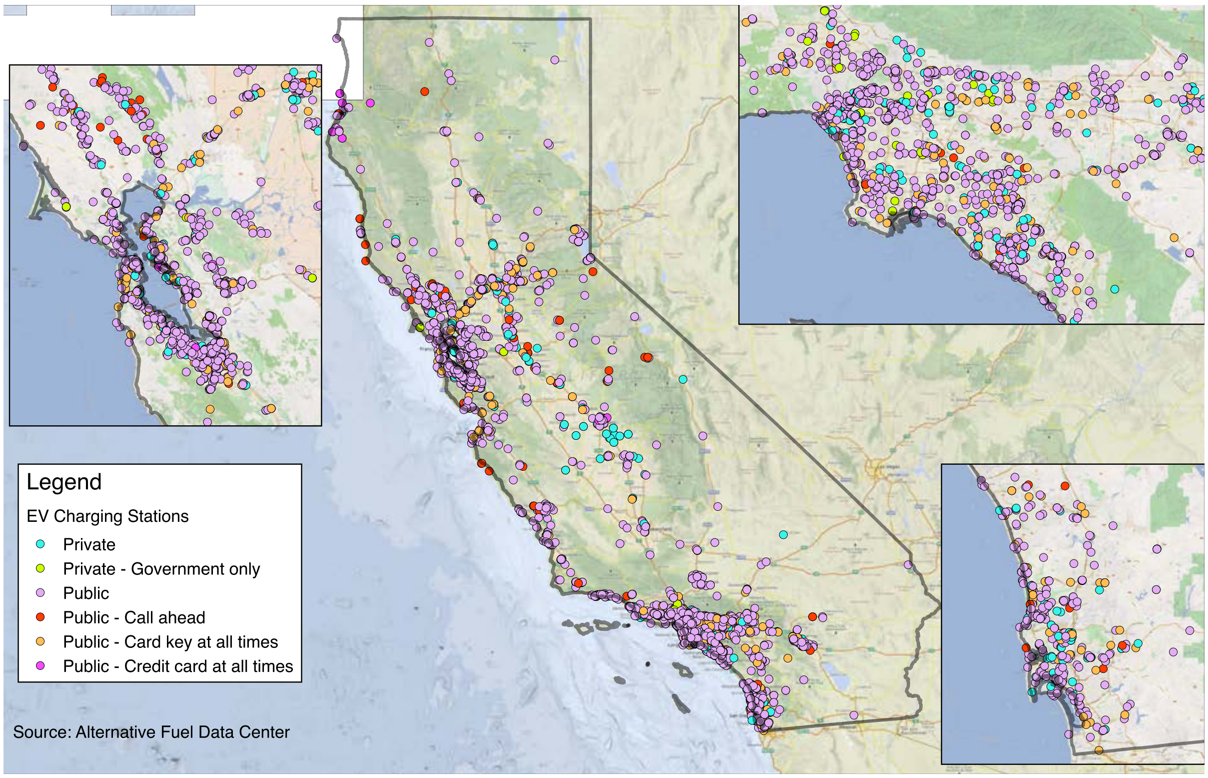
APPENDIX C - MOU STATES ZEV INCENTIVES

Table C.1. MOU States ZEV Incentives

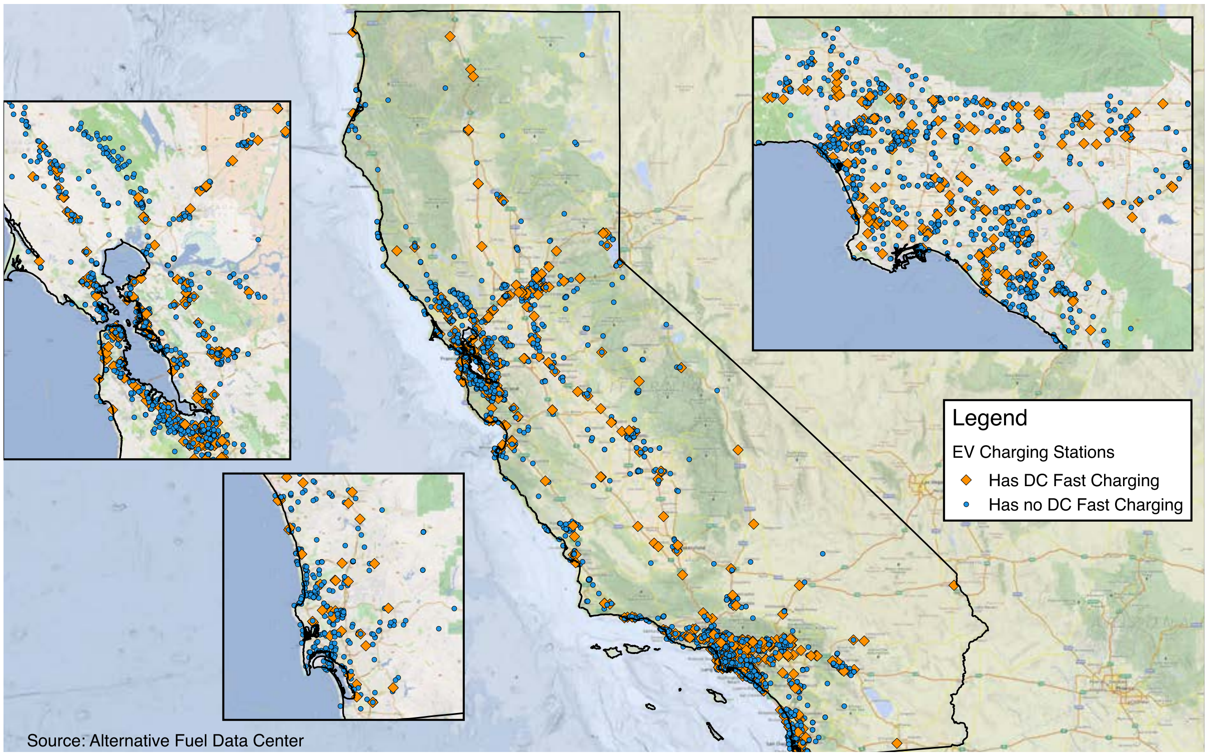
State	BEV	PHEV	FCEV	Annual Fuel Use
California	$2,500	$1,500	$5,000	Qualifying low-income households may receive an additional $2,000 for vehicles purchased or leased after November 1, 2016 or an additional $1,500 for vehicles purchased or leased between March 29, 2016 and October 31, 2016.
Connecticut	$500 (<100 miles) $2,000 (100 - 174 miles) $3,000 (175 miles+)	$500 (<40 miles) $2,000 (40 miles+)	$5,000	Tier incentive amounts for BEVs and PHEVs based on PEA rated electric range.
Maryland	$100 times the kilowatt-hours of battery capacity of the vehicle up to $3,000	$100 times the kilowatt-hours of battery capacity of the vehicle up to $3,000		Excluding ZEVs in which purchase price exceeds $60,000, this would make the Toyota Prius PHEV (First Generation), which has a battery capacity of 4.4kWh, to not qualify for the excise tax credit.
Massachusetts	$1,000 (Tesla Model S/X) $2,500 (all others)	$1,000 or $1,500 or $2,500	$2,500	
New York	$500 (>20 miles) or $1,100 (20 - 39 miles) or $1,700 (40 - 119 miles) or $2,000 (120 miles+)			Electric cars with MSRP greater than $60,000 are eligible for $500 regardless of EPA all-electric range
Oregon	N/A	N/A	N/A	Currently, Oregon does not offer any incentives. HB 2017, which established the rebates framework, became effective on October 6, 2017. However, the amount of funds collected will not be sufficient to start granting rebates until the summer of 2018.
Rhode Island	$1,500 or $2,500	$1,500 or $2,500	N/A	Program suspended on July 10, 2017 due to program funding unavailability.
Vermont	N/A	N/A	N/A	190 gal

APPENDIX D - ELECTRIC VEHICLE CHARGING INFRASTRUCTURE MAPS

Map D.1 Available Public and Private Charging Stations in California, as of November 14, 2017



Map D.2 All Electric Vehicle Charging Stations in California, As of November 14, 2017



Map D.2 Number of Charging Outlets per Station in California, as of November 14, 2017