2021 BIENNIAL ZERO EMISSION VEHICLE REPORT

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2021 Biennial Zero-Emission Vehicle Report

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- Oregon Department of Transportation
- Oregon Public Utility Commission

Special Thanks to the stakeholders who provided input, feedback, and most importantly, a wealth of data and information used in the production of this report.

Executive Summary

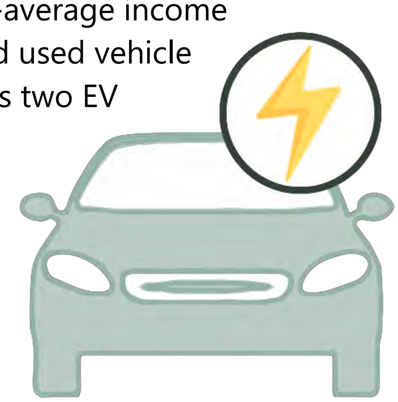
As of June 2021, there are 38,482 light-duty zero-emission vehicles registered in Oregon, comprising just over 1 percent of passenger vehicles. While ZEVs are increasingly popular, the state did not achieve its 50,000 registered ZEVs by 2020 goal, and it is not on track to achieve the 2025 or 2030 goals. However, Oregon is well-positioned to increase ZEV adoption with policies and programs that support ZEV sales in Oregon, including incentives, to help reduce up-front vehicle costs.

ZEV model availability is growing and expected to expand rapidly in the next five years. Sedan and hatchback models are the most prevalent now, while SUVs are increasingly available, and electric pickup trucks are expected by 2022. Micromobility options, including e-bikes and e-scooters, are readily available and often used in the state's urban areas. Electric transit and school buses are operating in several areas of the state, and heavy-duty freight options (some of which are being built in Oregon) are anticipated to be available soon. Electric options for business and industry are also growing, including tractors, forklifts, gantry cranes, some construction equipment, and options to plug in diesel vehicles when idling at their home facilities.

In Oregon, all ZEVs are electric vehicles, either all-electric battery models or plug-in hybrids[i] that can run on gasoline or plug in to charge a battery. Fuel cell electric (hydrogen) vehicles are also ZEVs, but not currently available in Oregon. As an emerging technology, the up-front cost of an EV is more than a comparable gasoline vehicle, but EV prices are declining. For many EVs, the total cost of ownership is less than an equivalent gasoline vehicle, especially if owners can charge at home. Some EVs cost less to purchase than a gas vehicle when incentives are available and can be used by the owner.

For EVs to be cost competitive, access to low-cost electricity is essential. At $0.11 per kilowatt-hour, the average state residential electricity rate, electric fuel is one-third the cost of gasoline. Most Oregonians in single-family homes have convenient access to low-cost electricity, whereas residents in multi-unit dwellings generally must rely on publicly available chargers to fuel their vehicles. Because EVs can charge on standard 110 V outlets, residents in single-family homes may not need to pay additional costs for charging infrastructure, whereas installation costs for multi-unit dwellings can cost $1,000 to $4,000 per charger or more if significant electrical upgrades are needed.

Low-income Oregonians do not have equitable access to EVs. While U.S. Census Bureau data lacks the granularity to comprehensively assess EV adoption by race, income level is strongly correlated with EV adoption and historical racial inequities have contributed to lower-than-average income levels for many racial groups. Higher up-front costs for EVs and a limited used vehicle market remain barriers to EV adoption for low-income families. Oregon's two EV rebate programs play a vital role in reducing up-front costs, particularly where low-income families have limited or no tax liability and are therefore unable to take advantage of the federal tax credit. More low-income Oregonians also reside in multi-unit dwellings, where access to low-cost electric fuel is limited. There are currently no specific state-led programs or policies to address the costs to provide chargers for multi-unit dwelling residents or owners. Availability and reliability of public

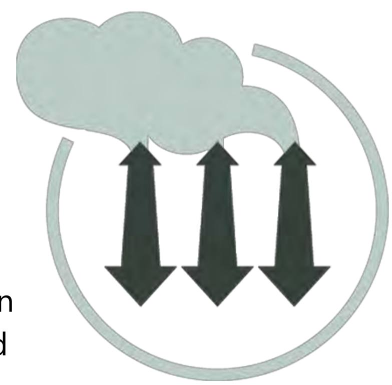


[i] Standard hybrids that have a supplemental battery than can be used with a gasoline motor and cannot be plugged in to charge the battery are not included as a zero-emission vehicle.

chargers are essential for Oregonians who rely on them as their primary fuel source or those who want to travel around the state. To provide a more robust and useful assessment of EV charging in Oregon, the terms "availability" and "reliability" would benefit from formal industry-accepted definitions that include specific metrics for assessment.

EV charger availability is a contributing factor to range anxiety – a concern that the vehicle will run out of power before the next available charging opportunity, particularly in rural parts of the state where there are fewer public charging options. Although ranges for EVs manufactured today often exceed 200 miles, national surveys continue to indicate range anxiety as a top concern for non-EV owners considering buying an EV. Only 12 percent of EVs are registered in rural parts of the state, which may be due to a combination of factors, including EV range concerns. Rural Oregonians may need publicly available electric fueling options to feel confident that EVs can meet their transportation needs.

Transportation-related emissions are the largest contributor to Oregon's GHG emissions. In the last decade, an average of 36 percent of in-state GHGs came from transportation, and light-duty vehicles alone contributed 19 percent. Passenger vehicle emissions are nearly 20 percent higher than their proportionate share of the 2020 GHG reduction goal, and current transportation trends indicate Oregon will continue to fall short of the state's future GHG goals. Significantly higher adoption of EVs across the whole transportation sector is necessary to meet the state's greenhouse gas reduction targets.



In addition to reducing GHG emissions, increased EV adoption can also reduce harmful air pollutants, such as small particulate matter, commonly referred to as PM2.5, emitted from fossil fuel motor vehicles. Low-income communities and communities of color have higher exposure rates to PM2.5, often as a result of living near major roadways and industry. This type of exposure increases the risk of lung and heart disease and premature death. Incentives designed to support EV adoption could improve the overall health in these low-income neighborhoods and communities.

Widespread EV adoption has many positive effects for Oregon's environment and communities, and business and organizations in the state are preparing for the EV-future. While electricity demand from EV charging will increase, utilities are well-positioned to meet the demand from new light-duty charging loads and provide the needed additional investments in local grid infrastructure. Impacts to Oregon's State Highway Fund from reductions in fuel taxes because of more fuel-efficient vehicles and EVs is anticipated to be negligible in the near-term, but in the long-term they may be more significant. Currently utilities and the state are running pilot programs and projects that will provide options to address the impacts of anticipated higher EV adoption levels on the State Highway Fund and the electric grid.

The complete 2021 Biennial Zero Emission Vehicle Report is available on ODOE's website: https://www.oregon.gov/energy/Data-and-Reports/Pages/Reports-to-the-Legislature.aspx

Letter from the Assistant Director

Oregon is a leader in zero-emission vehicle adoption – often among the top five when compared to other states on ZEV registrations, programs, and policies. This achievement was bolstered by Governor Brown's Executive Orders and actions by the Oregon Legislature. It's exciting to be publishing a report about an incredibly beneficial technology on the precipice of widespread adoption.

The push for zero-emission vehicles comes from the many benefits they provide to improve the lives of Oregonians, including reducing greenhouse gas emissions and our dependence on fossil fuels, improving local air quality and the public health of our communities, and reducing Oregonians' transportation costs.

The largest emitter of GHG emissions in Oregon is our transportation sector, at 36 percent of total emissions. Over half of those emissions come from passenger and light-duty vehicles – so making the switch to ZEVs can dramatically reduce emissions and help meet Oregon's climate goals. While we are not yet on track to meeting our GHG emission reduction goals or our ZEV adoption targets, there is a great deal of activity happening now and in the near future to give us all optimism.

New ZEV models are joining the market each year, and we are seeing a rapid transformation of the auto industry. In just two years, we have gone from a few mainstream auto manufacturers publicizing plans to electrify some models, to today – where nearly all major manufacturers have committed to multiple new ZEV models over the next several years. In fact, some are even pledging to go fully electric. More than a dozen models of electric passenger vehicles are now available for purchase, and an electric pickup truck model is expected in 2022. The availability of ZEV models for all transportation platforms (like heavy-duty vehicles) is poised to expand in the coming years, if we can overcome supply chain issues caused by the COVID-19 pandemic.

The cost of ZEVs is dropping fast! As this report shows, electric vehicle batteries are becoming more efficient and affordable, leading to models on the market with battery ranges up to 300 miles (or more). Experts believe the up-front cost of an electric vehicle will equal the cost of a gasoline vehicle in just two to three years. Currently, the total cost of ownership over the life of many electric vehicles can be lower than their gasoline-powered counterparts, thanks to lower fuel costs (electricity), lower maintenance costs, and federal and state incentives.

Medium and heavy-duty long-haul trucks are just around the corner, with electric heavy-duty semi-trucks coming to the market – one of which is made by Daimler Trucks of North America, based right here in Oregon. Recently we have also seen tremendous strides in electrifying other transportation segments, like new electric transit and school buses, commercial and industrial equipment, and even electric farm tractors.

The State of Oregon is working diligently to build upon and improve programs to incentivize ZEV purchases, but also to support more electric fueling infrastructure, reduce GHG emissions from all parts of the transportation sector, and to reduce the carbon intensity of our fuels. At the federal level, on August 5, 2021 President Biden signed an Executive Order setting a new target that by 2030, half of all new vehicles sold must be ZEVs. And if President Biden's infrastructure plan gets passed, it will help fund a much-needed nationwide charging station network.

On the heels of this incredible progress, there is still work to do. We must continue to increase the adoption of ZEVs in Oregon. While we have more than 38,000 registered ZEVs in Oregon at the time of this report, we need to transform the light-duty transportation sector if we hope to meet our GHG reduction goals. We need to re-double our education efforts to increase awareness of the benefits of owning a ZEV, and we need to broaden our charging infrastructure – from at-home charging to publicly-accessible charging networks. Fortunately, Oregon's electric utilities are well positioned to handle this new load from ZEVs.

Importantly, we need to continue to focus attention on standards, programs, and policies that reduce barriers to equitable access to ZEVs, so all Oregonians can benefit from ZEVs. For example, the Oregon Department of Environmental Quality's Charge Ahead Rebate is addressing equity by making rebates for new or used electric vehicles available to low- and moderate-income Oregonians, who may otherwise be priced out of the market.

The pace of change is exciting and inspiring – and we expect that in two years when we publish this biennial report again, the ZEV landscape will look completely different. Oregon has had a great start and we're in the driver's seat. And like electric vehicles, things are going to accelerate quickly – so hold on!

Alan Zelenka
Assistant Director for Planning and Innovation

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Tribal Land Acknowledgement

The Oregon Department of Energy is located in Salem, and its staff acknowledge that indigenous tribes and bands have been with the lands that we inhabit today in the Willamette Valley and throughout Oregon and the Northwest for time immemorial.

About the Oregon Department of Energy

Our Mission

The Oregon Department of Energy helps Oregonians make informed decisions and maintain a resilient and affordable energy system. We advance solutions to shape an equitable clean energy transition, protect the environment and public health, and responsibly balance energy needs and impacts for current and future generations.

Our Values

- We listen and aspire to be inclusive and equitable in our work.
- We are ethical and conduct our work with integrity.
- We are accountable and fiscally responsible in our work and the decisions of our agency.
- We are innovative and focus on problem-solving to address the challenges and opportunities in Oregon's energy sector.
- We conduct our agency practices and processes in a transparent and fair way.

Our Position

On behalf of Oregonians across the state, the Oregon Department of Energy achieves its mission by providing:

- A Central Repository of Energy Data, Information, and Analysis
- A Venue for Problem-Solving Oregon's Energy Challenges
- Energy Education and Technical Assistance
- Regulation and Oversight
- Energy Programs and Activities

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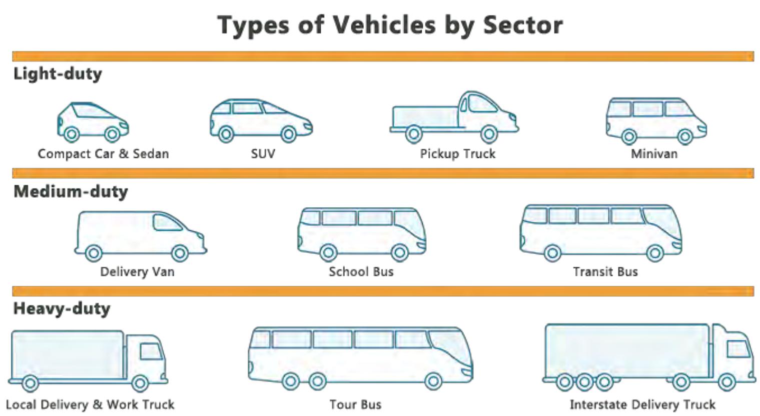
About the Report

This Biennial Zero Emission Vehicle Report is a discussion of the state of zero-emission vehicle adoption in Oregon, the barriers that exist to increasing that adoption, and the effects of ZEV use on greenhouse gas emissions in the transportation sector. The Oregon Department of Energy was directed by the Legislature in Senate Bill 1044 (2019) to provide this report using existing studies, market reports, polling data, and other publicly available information. Supporting analyses and reports are provided for all information used in the production of this report. Where ODOE conducted its own analysis of data sets, information on sources used and calculations are on file at the agency and can be provided upon request.



Because the market for ZEVs is quickly evolving, especially for medium- and heavy-duty vehicles, there is a degree of uncertainty about what ZEVs are actually available for purchase. As directed in Senate Bill 1044, ODOE focuses on commercially or near-commercially available ZEV models in this report. Some prototypes, models in research and development, or models in testing are described, but the report does not include all vehicles in this phase of development. As these models become commercially available, they will be included in future versions of this report.

Zero emission vehicles include three basic types of vehicles: battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell electric vehicles. BEVs run exclusively on power from batteries that are refueled by plugging the vehicle in to recharge. PHEVs have both a conventional fossil fuel drivetrain and an electric one, and generally the vehicle will operate fully or almost fully on electricity until the battery is nearly depleted, at which point the vehicle will then operate as an internal combustion engine vehicle, powered by gasoline. Collectively, BEVs and PHEVs are often referred to as electric vehicles, or EVs. FCEVs also operate on electricity, but the electricity comes from hydrogen, which the vehicle's fuel cell converts into electricity and water.

Fuel cell electric vehicles require hydrogen to operate, and there are no fueling stations in Oregon at this time. For this reason, ZEVs in this report generally encompass only BEVs and PHEVs. Because FCEVS are fairly uncommon in most parts of the U.S., the terms *zero emission vehicle* and *electric vehicle* are often used interchangeably. In this report, ZEV is used when referring to policies and programs that would be inclusive of FCEVs if they were available in Oregon, such as the Oregon ZEV rebate programs. The term EV is used when referring to policies, programs, or activities that are not inclusive of FCEVs, such as discussions about EV chargers.

The effects of the COVID-19 pandemic on the transportation sector continue to evolve. While it is clear that the pandemic is having widespread effects across all transportation sectors, these effects are not yet fully understood. For this reason, this report does not address impacts of COVID-19 on ZEV adoption. As a result, when discussing vehicle or fuel *trends*, the report generally does not include transportation data from 2020 or 2021. However, where specific counts are provided, these do include the most recent available data. For example, the total number of ZEVs registered in Oregon is provided through the end of May 2021, while the greenhouse gas emissions resulting from ZEV adoption are provided only through 2019. As more information, data, and analyses become available, future versions of the Biennial Zero Emission Vehicle Report will include information on the effects of COVID-19 on ZEV adoption.

Buying an electric vehicle, Photo credit: pexels.com

This section reviews numbers and sales figures of zero-emission vehicles that are owned in Oregon, and discusses whether the state is on track to meet its ZEV adoption goals:

- By 2020, 50,000 registered motor vehicles will be zero-emission vehicles;
- By 2025, at least 250,000 registered motor vehicles will be zero-emission vehicles;
- By 2030, at least 25 percent of registered motor vehicles, and at least 50 percent of new motor vehicles sold annually, will be zero-emission vehicles; and
- By 2035, at least 90 percent of new motor vehicles sold annually will be zero-emission vehicles.

Sales Figures and Progress on EV Adoption

Introduction

In 2019, the Oregon Legislature passed ambitious zero-emission vehicle goals for the state. At the time the goals were passed, they called for a doubling of registered ZEVs by 2020 and a tenfold increase by 2025. In early 2019, ZEV adoption was growing quickly, boosted by the first year in sales of the Tesla Model 3. By the end of the year, ZEV growth had slowed as Tesla completed backorders for the vehicle and resumed more normal vehicle production. In 2020, as the response to the COVID-19 epidemic ensued, ZEV growth seemed to stall, and at the end of the year Oregon had not met its 2020 goal of 50,000 registered ZEVs.

Yet, there are many actions happening across the state and nation that are encouraging. The registration numbers for all vehicles at the end of 2020 likely did not reflect the total number of vehicles in Oregon, mainly due to delays in vehicle registrations while the state allowed longer grace periods during the pandemic. As more vehicle owners act to register their vehicles, the overall numbers will be reassessed, and will likely be much higher – although still not enough to meet the goal.

In 2021, the Oregon Legislature increased the amount of the Oregon Department of Environmental Quality's Charge Ahead ZEV rebate, bringing the total potential amount of rebate dollars available to low- and moderate-income Oregonians to $7,500. In 2021, the U.S Senate passed a $1.2 trillion infrastructure bill that included $7.5 billion for electric vehicle charging infrastructure. In the last year, most major automobile manufacturers have committed to building more models of zero-emission vehicles and many have set electric model availability targets in the coming decade – some have even pledged to build only electric models. The state ZEV goals in 2025, 2030, and 2035 require big leaps forward, and the state is not currently on track to meet them – but the opportunities to support adoption are growing. With its history of being a leader in electric vehicle adoption and EV charger infrastructure, the state and its partners are well-positioned to work toward achieving the 250,000 registered ZEV goal by 2025.

Number of Zero-Emission Vehicles in Oregon

As of June 2021, the Oregon Department of Transportation Driver and Motor Vehicle Services division recorded 38,482 plug-in vehicles registered in Oregon, of which 13,410 were plug-in hybrids and 25,072 were battery electric vehicles.[1] The total number of light-duty (i.e., passenger) ZEVs in Oregon has increased over the last ten years, from 669 vehicles in 2010 to more than 33,000 in 2020. Today, ZEVs represent 1 percent of light-duty vehicles. Under current trends, the state is not on track to meet its near-term targets for 2025 and 2030. Adoption rates of ZEVs are much lower among medium- and heavy-duty vehicles (see the ZEV Platforms section of this report for more information).

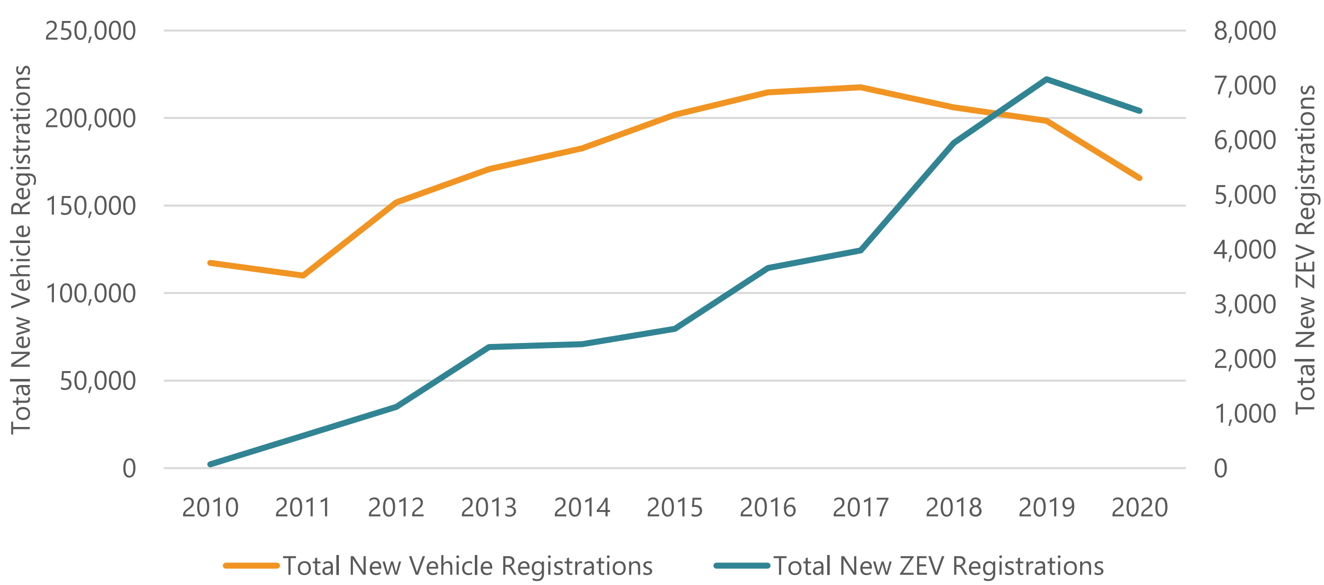
ZEV:
Oregon's Zero-Emission Vehicles include plug-in hybrids and battery electric vehicles.

Table 1: Zero-Emission Vehicles as a Proportions of Total Light-Duty Vehicles in Oregon[1]

Year	Total ZEVs	Percentage of light-duty vehicles that are ZEVs
2010	669	0.02%
2011	1,255	0.04%
2012	2,226	0.07%
2013	4,341	0.13%
2014	6,517	0.19%
2015	9,014	0.25%
2016	12,617	0.35%
2017	16,670	0.45%
2018	22,056	0.59%
2019	27,998	0.76%
2020	33,579	0.98%

Overall vehicle sales were lower in 2020 compared to 2019 due to economy-wide effects from the pandemic. Auto manufacturing plants and many dealerships shut down in April and May of 2020 to assist in mitigating the spread of COVID-19, which, in conjunction with reduced consumer activity, lowered overall vehicle sales.[2] Overall new vehicle registrations in Oregon dropped nearly 23 percent in 2020 from 214,503 to 165,770. New ZEV registrations also fell from 7,110 in 2019 to 6,532 in 2020, but at a smaller 8 percent drop. This difference in new registrations spurred an increase in ZEV overall market share – the percent of new ZEVs compared to new conventional gas vehicles – increasing from 3.3 percent in 2019 to 3.9 percent in 2020.

Figure 1: Total New Light-duty Vehicle Registrations Compared to Total New Light-duty ZEV Registrations by Year[3]



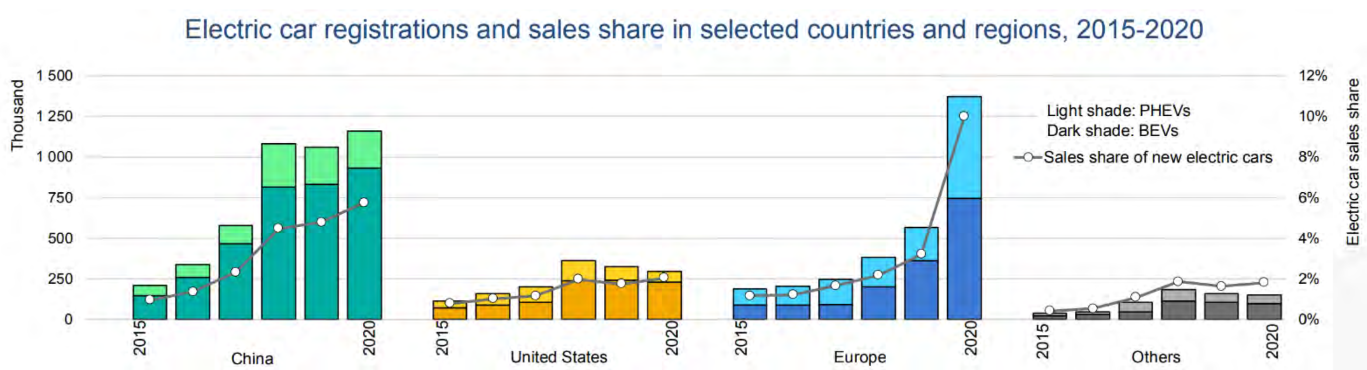
Note: Scale of Registration counts differ between total new (left side) and total new ZEV (right side).

In the three largest ZEV markets – China, Europe, and the U.S. – the impacts of COVID-19 also led to overall declines in new vehicles in 2020, with increases in ZEV market share. U.S. auto sales declined by about 34 percent in the second quarter of 2020, with sales rebounding in the third and fourth quarters to a total of 14.5 million units, about 15 percent below 2019 sales of 16.8 million.[4] In 2020, 295,000 new electric cars were registered in the U.S., representing a 2 percent market share; 78 percent of that share was fully battery electric.[5] While the pandemic is a significant factor in this downturn, the phase-out of federal incentives for Tesla and General Motors electric vehicles[i] may also have contributed to the decrease and limited growth in market share for ZEVs.[6]

Europe and Asia experienced a more marked increase in ZEV market share in 2020. In Europe, ZEV registrations more than doubled to 1.4 million, for a market share of 10 percent, even while the overall car market contracted by 20 percent.[7] This may be due in part to new CO2 emissions performance standards set by the European Union for new passenger vehicles. Effective January 1, 2020, the standards set limits on overall passenger vehicles' average emissions per kilometer. ZEV sales are a major component to meeting these emissions compliance requirements for manufacturers. Many European governments also increased incentives for ZEVs in pandemic stimulus packages.[8]

China saw a 9 percent reduction in total new car registrations from 2019 to 2020; however, market share for ZEVs increased from 4.8 percent in 2019 to 5.7 percent in 2020.[9] This increase happened despite China reducing incentives for ZEVs by 10 percent starting in 2020.[10]

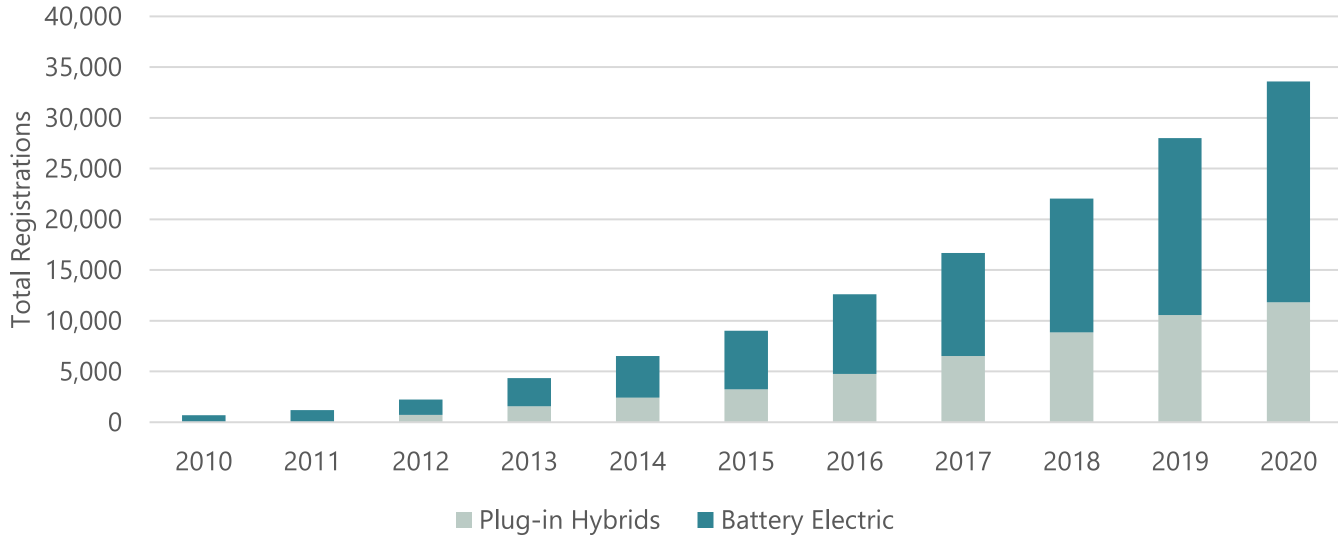
Figure 2: Global Electric Car Registrations and Market Share by Regions[11] (Lighter colors for each region indicate PHEVs and darker colors BEVs)



In Oregon, ZEV registrations at the end of 2020 totaled 33,579 vehicles – below the state goal of 50,000 ZEVs. It is likely that the reported number of registrations is lower than the actual number of ZEVs operating because of extensions on vehicle registrations enacted to help reduce the spread of the COVID-19 virus. COVID-19's economic downturn also depressed overall vehicle sales, including ZEV sales.

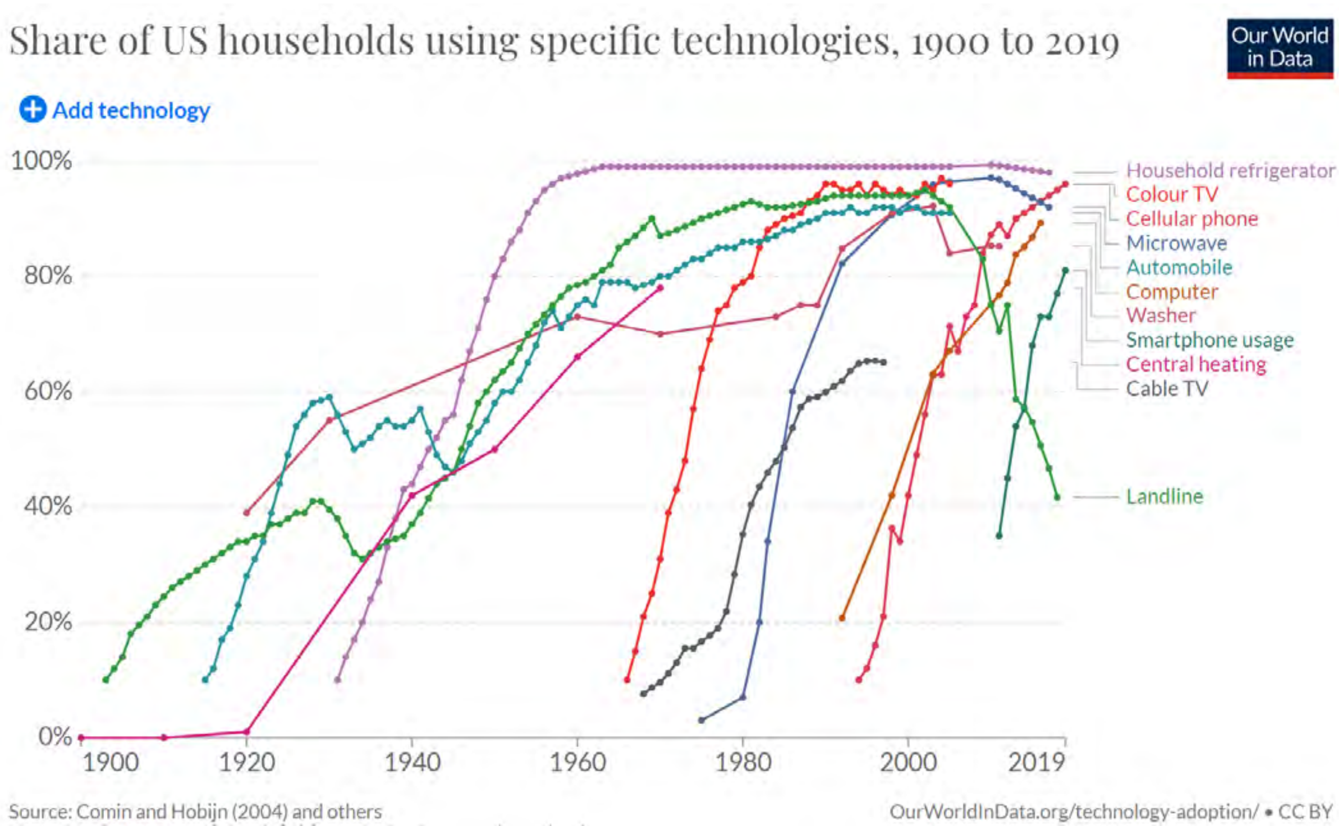
[i] The federal EV tax incentive is designed to phase out once a manufacturer reaches 200,000 EV sales. Tesla and General Motors reached their cap for eligibility in 2018 and vehicles from those manufacturers are no longer eligible for the incentive after the phase-out period. Tesla and General Motors account for most electric car registrations in the U.S. and Oregon.

Figure 3: Oregon Total Light-duty ZEV Registrations by Year[12]



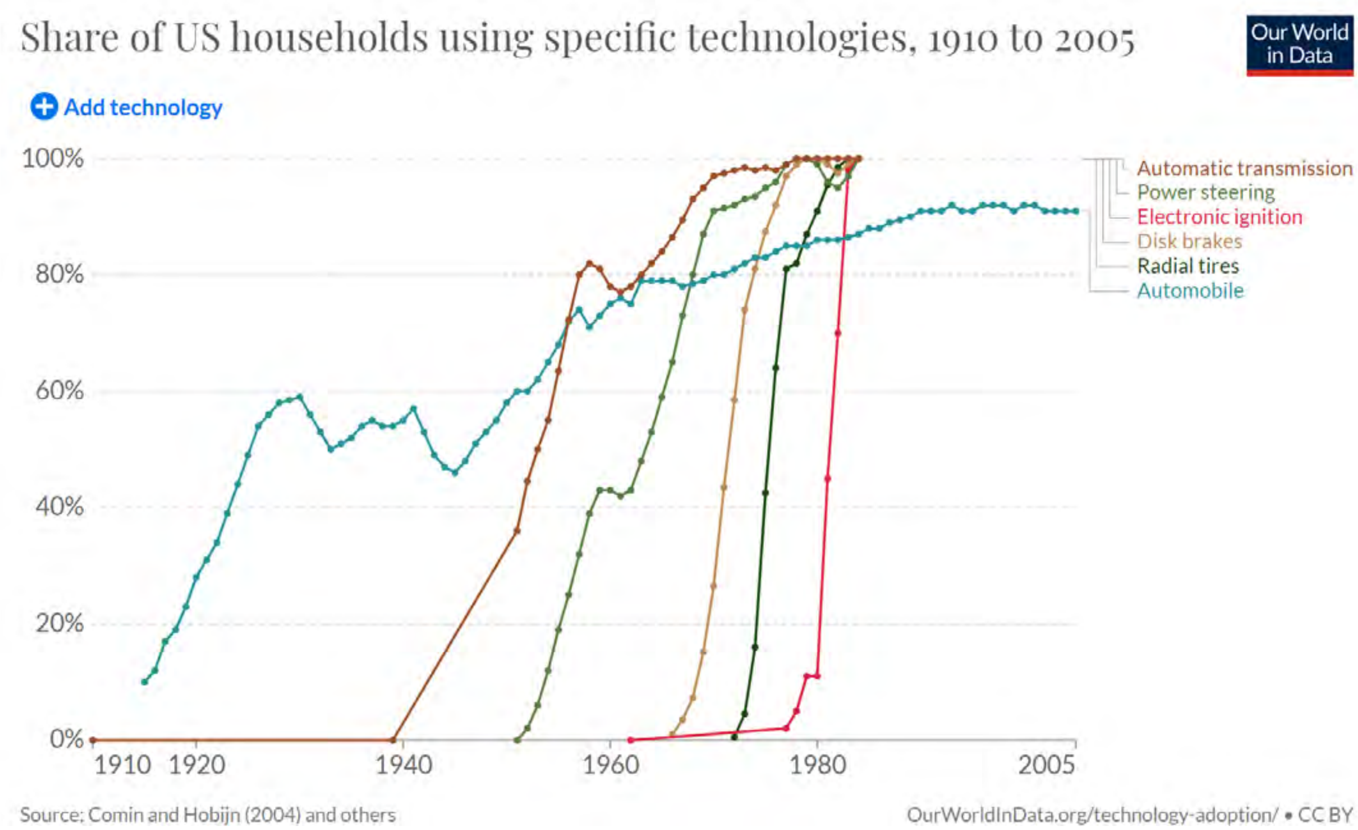
Many factors can affect the adoption rate of ZEVs (COVID being an unexpected factor in 2020 and 2021), but assessing the progress Oregon is making on future ZEV goals for 2025, 2030 and 2035 can be informed by typical adoption curves for new technologies over time. New technology is adopted in an S-curve trend, as illustrated below.

Figure 4: Technology Adoption Curves in U.S. Households[13]



Where this type of adoption curve is present, the key uncertainty in forecasting future numbers is when the initial slow rise in adoption will inflect into a much faster rate of adoption (the middle of the S). Current trends, therefore, are not useful indicators of future adoption rates. The following chart illustrates automotive technology adoption curves, which generally follow the S-curve adoption pattern. Disruptions in the S-curve can occur due to outside influences, such as the delay in the automobile adoption rate caused by the depression in the 1930s and World War II in the first half of the 1940s, as illustrated in Figure 5.

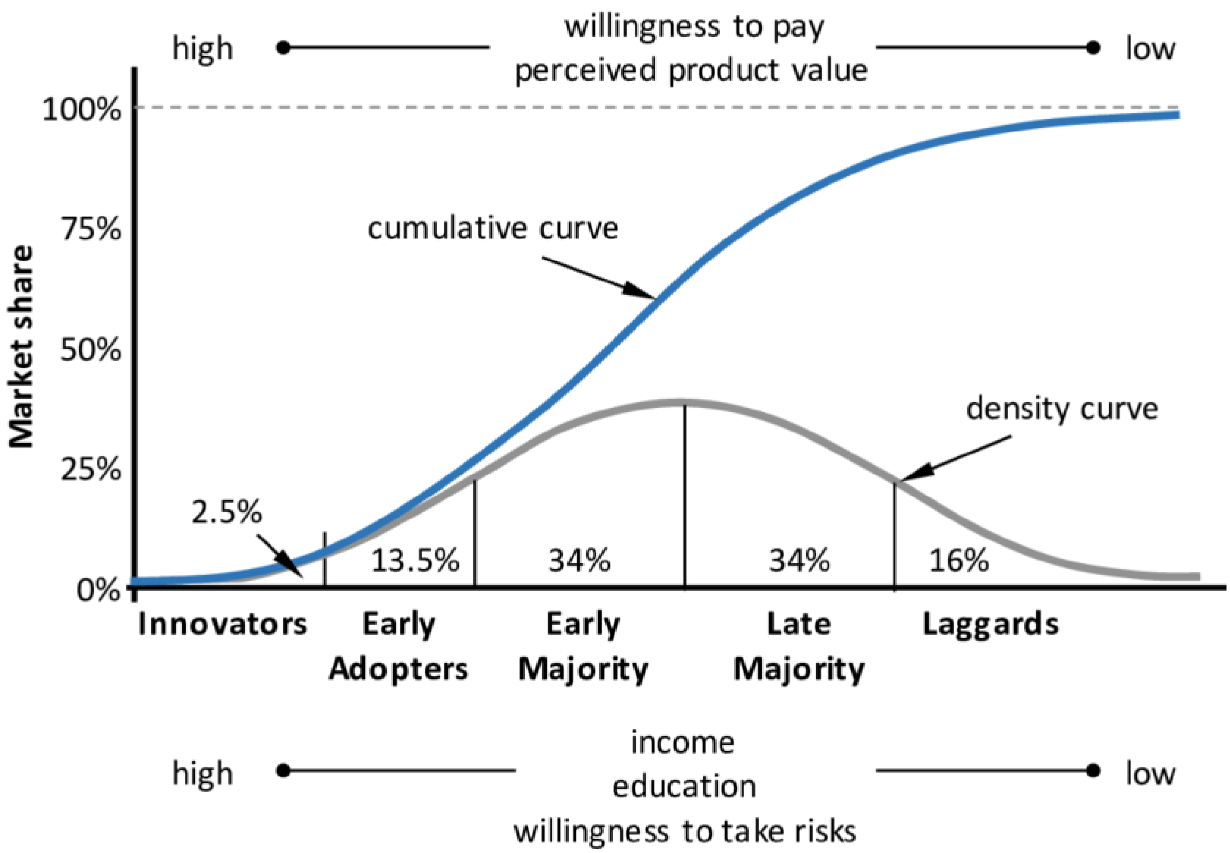
Figure 5: Automobile Technology Curves[14]



The concept of the technology curve was first explained by Sociologist and Professor Everett M. Rogers. As shown in the chart below, the S technology adoption curve and market density curve begins with the first 2.5 percent of the market share of a product that Professor Rogers considered as "innovators and risk takers" who are willing and able to pay more for a new product because they believe in it or just want to be the first to own it. "Early adopters" are the second group and comprise the next 13.5 percent. They will accept the financial and technologic risks of testing new products if they see potential benefits in using them. ZEV adoption in Oregon would be considered early in this group with new ZEV registrations above 2.5 percent market share since 2018. The "early majority," who along with the "late majority" comprise the bulk of adopters, buy new technology once they identify how it serves their needs and is competitively priced with few risks. The "late majority" adopt in reaction to peer pressure, emerging norms, or economic necessity.

Most of the uncertainty around the idea must be resolved and the price be low enough to meet their budgeting needs or practices. The last 16 percent Professor Rogers refers to as the "laggards." They tend to use more traditional technologies that are reliable and cost effective. They are often economically unable to take risks on new technologies.

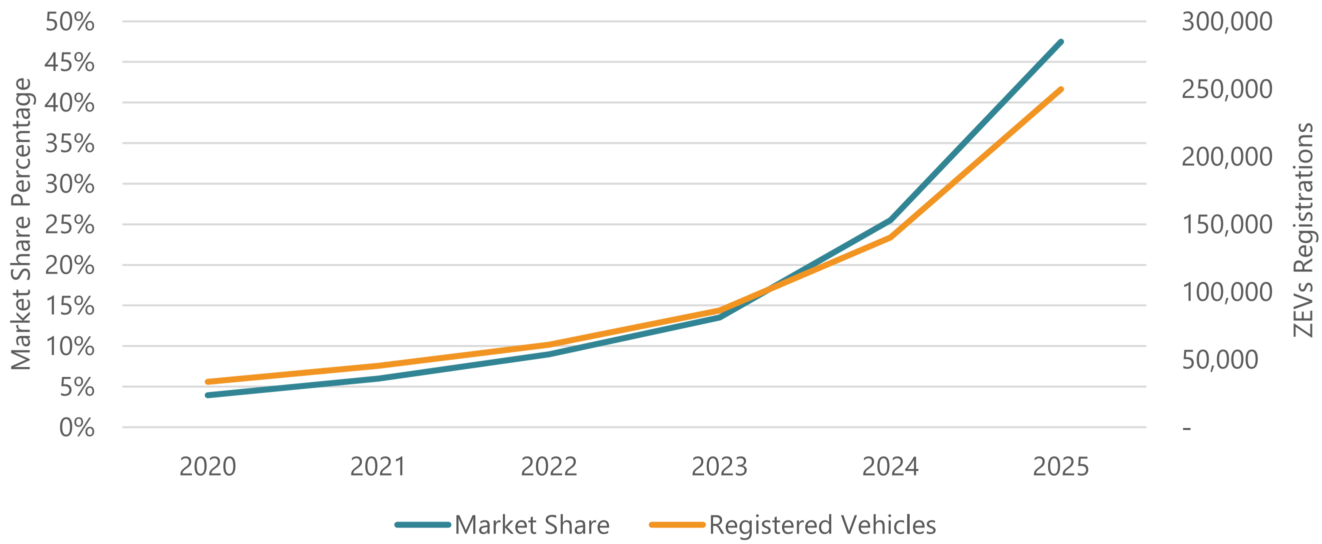
Figure 6: Technology Adoption Market Share and Density[15]



Because of the uncertainty around the inflection point, and how that might affect adoption rates, ODOE did not develop a model of actual anticipated ZEV adoptions in Oregon. To assess progress on the future ZEV goals, ODOE conducted scenario analyses to evaluate the feasibility of achieving the targets. This includes calculating the growth rate of ZEV market share needed to achieve the goals and comparing this to forecasts for ZEV market share from leading ZEV growth projection studies. ODOE also looked at California ZEV growth forecasts and applied these growth rates to assess what the state ZEV registrations would be in 2025 and 2030, and comparing this to the target numbers.

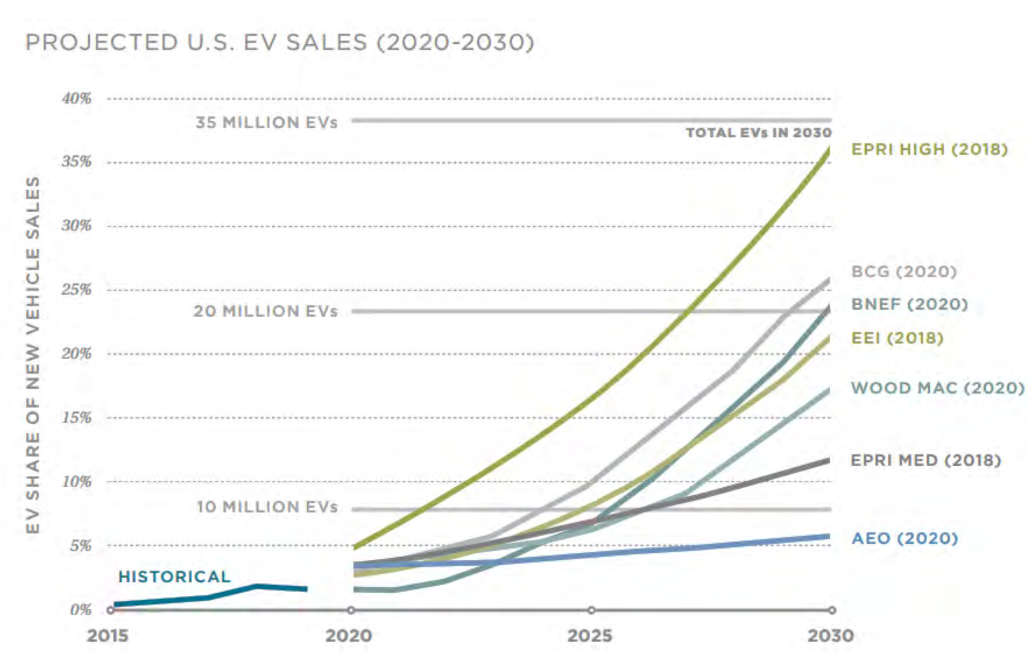
In order to achieve the 2025 goal of 250,000 registered ZEVs, the market share of ZEVs would need to grow from 4 percent in 2020 to more than 47 percent in 2025 – more than a tenfold increase.

Figure 7: Oregon Registered ZEVs and ZEV Market Share Needed to Achieve 2025 Goal[16]



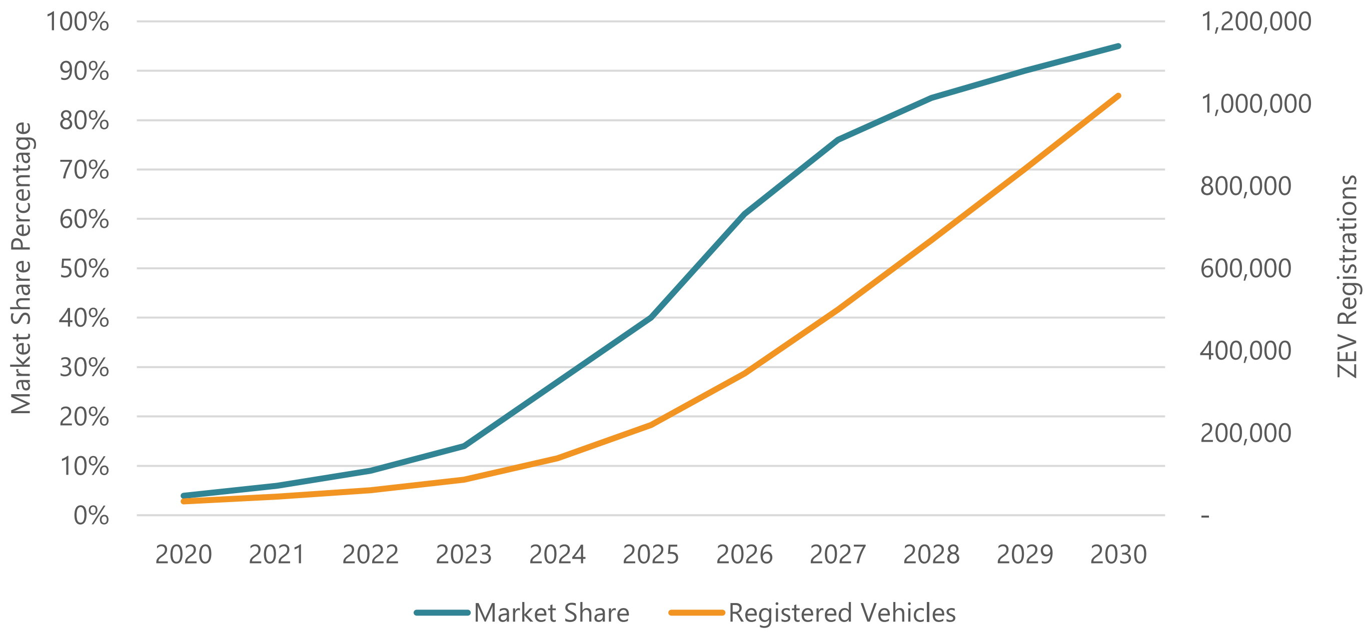
This electric vehicle market share curve shown in Figure 7 exceeds all recent EV market share forecasts by leading studies, and is twice that of the most aggressive curve (Figure 8) forecasted by the Electric Power Research Institute, which was included in a recent report from the University of Berkeley.

Figure 8: Projected U.S. EV Sales[17]



The 2030 goal for EV registrations contains two separate targets: 50 percent market share of total car sales and 25 percent of registrations. Using the same methodology as above, the state would need to reach 50 percent of market share in 2026 in order to achieve the 25 percent of total registrations, or just over 1 million ZEVs, by 2030. As shown in Figure 8 none of the studies predicts more than 40 percent market share by 2030, and most forecast less than 25 percent. Further, to achieve 1 million registered ZEVs, market share would need to be greater than 90 percent by 2030. As illustrated in Figure 9, over 90 percent market share for ZEVs by 2030 is more than double the highest estimation for the U.S.

Figure 9: Oregon Registered ZEVs and ZEV Market Share Needed to Achieve 2030 Goal[18]



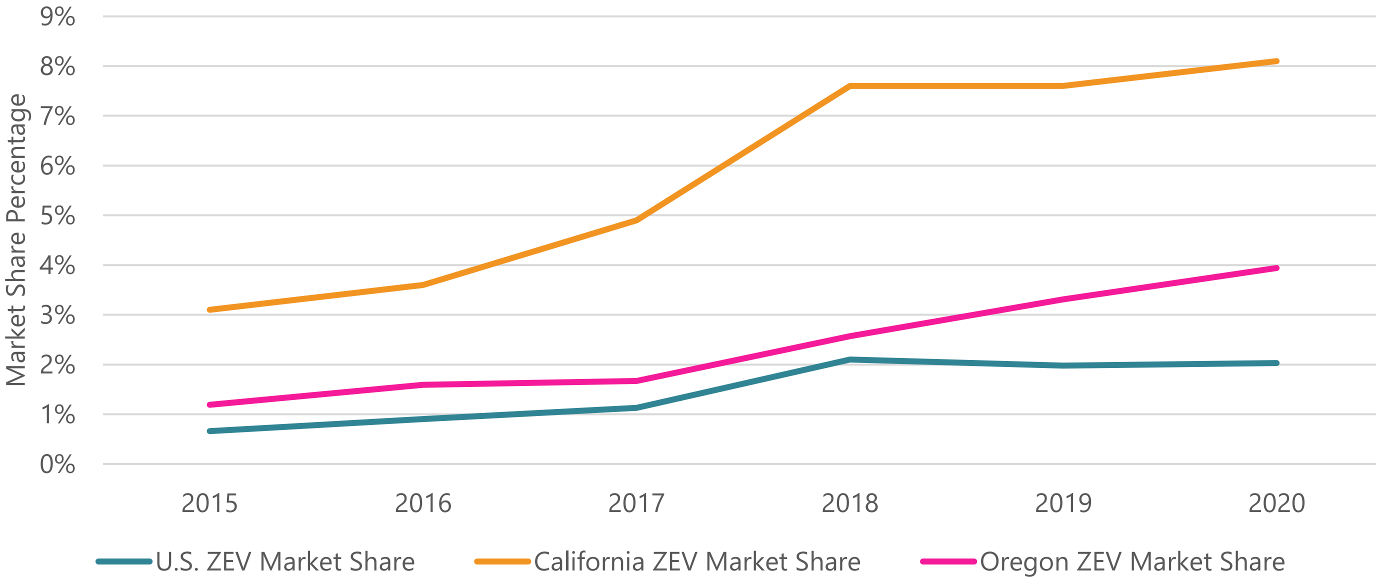
The studies listed above are forecasting national adoption trends, whereas Oregon had nearly twice the market share of ZEVs in 2020. To consider this accelerated growth rate, it is helpful to compare anticipated ZEV growth in California to the growth rates Oregon would need to achieve to meet its ZEV adoption targets. California has almost half of all ZEV sales in the U.S. (see table below) and has averaged nearly four times the market share compared to national rates and twice that of Oregon.

Table 2: U.S., California, and Oregon Total ZEV Sales and Market Share[19]

	U.S.		California		Oregon	
	Total ZEV Sales	ZEV Market Share	Total ZEV Sales	ZEV Market Share	Total ZEV Sales	ZEV Market Share
2015	114,248	0.66%	62,217	3.10%	2,548	1.19%
2016	157,181	0.90%	79,450	3.60%	3,659	1.59%
2017	194,479	1.13%	107,779	4.90%	3,978	1.67%
2018	361,307	2.10%	163,765	7.60%	5,946	2.57%
2019	329,528	1.98%	159,081	7.60%	7,110	3.31%
2020	297,939	2.03%	132,742	8.10%	6,532	3.94%

However, while U.S. adoption has remained flat since 2018, Oregon and California have continued to see growth in their ZEV market shares.

Figure 10: U.S., California, and Oregon ZEV Market Share[20]



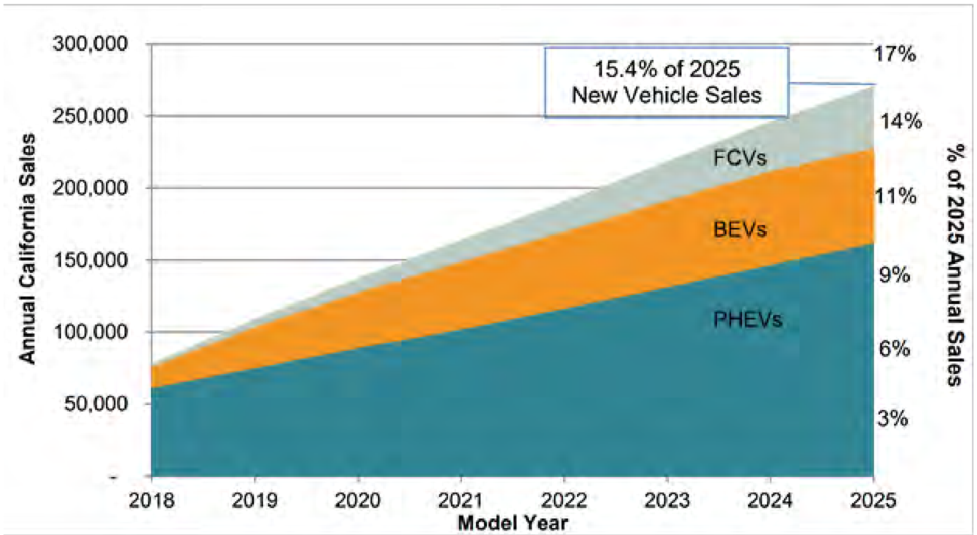
California Low Emission Vehicle Program: Advanced Clean Cars

The California Air Resources Board is developing a new set of standards (part II) for the Advanced Clean Cars program. First introduced in 2012, the ACC program combines the control of smog-causing (criteria) pollutants and GHG emissions into a single coordinated package of regulations. The ACC (part I) included a technology-forcing regulation for ZEVs, requiring that a certain proportion of manufacturers' new vehicles sold in the state emit zero emissions. This includes light-duty passenger cars and trucks and medium-duty vehicles made in 2018 and after.

The ACC (part I) rule was also adopted by Oregon[21] along with 11 other states, with four additional states in process of adopting the rule as of April 2020.[22]

Photo credit: New York Times

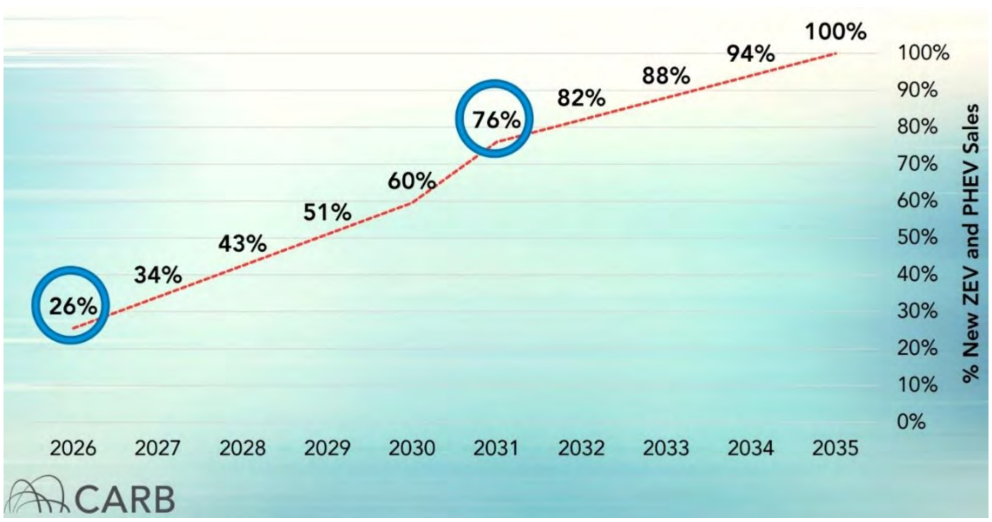
Figure 11: California Advanced Clean Car I Mid-Term Review Forecast[23]



The California Air Resources Board presented a 2017 mid-term review of its Low-Emissions Vehicle program, and included a forecast for the estimated market share of ZEV vehicles from 2018 to 2025. By 2025, CARB calculated ZEVs would be 15.4 percent of the market share in California. This is far below the 47 percent needed in Oregon to meet the 250,000 ZEV registration goal.

In May 2021, CARB released information on its Advanced Clean Cars II program, which would further increase market share of ZEVs for the years 2026 to 2035. Below are targets for ZEV market share.

Figure 12: CARB ACC II Proposed Annual Targets.[24]

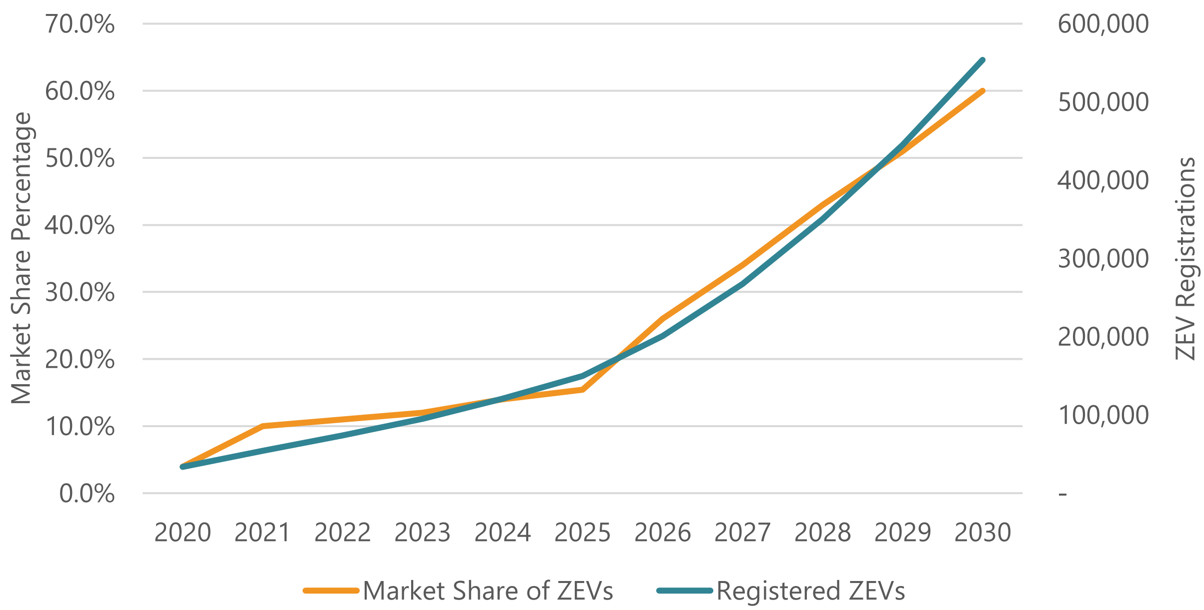


Does CA's Advanced Clean Cars II eliminate fossil fuels from passenger vehicles?

The proposal does not entirely end sales of combustion engines, leaving space for a more tightly defined plug-in hybrid that will need to go at least 50 all-electric miles.

By applying CARB's market share forecasts for the ACC I & II programs to Oregon's estimations for ZEV growth, the resulting ZEV adoption numbers and market share are not sufficient to achieve Oregon's goals. By 2025, Oregon would achieve 149,807 registered ZEVs, about 100,000 ZEVs shy of the 250,000 goal. In 2030, Oregon would partially achieve its goals, exceeding the 50 percent market share goal at just over 60 percent. However, the state would fall short of the 25 percent ZEV registration goal by more than 460,000 vehicles.

Figure 13: ODOE Analysis Using CARB Market Share Percentages and Applying Them to Oregon Registration Statistics[25]



Oregon is too early in the ZEV technology adoption curve to assess progress on the ZEV adoption goal of 90 percent ZEV market share by 2035. But because the goal is strictly based on market share and not total registrations, there is some qualitative evidence that the goal is achievable. Many vehicle manufacturers have indicated they will be ramping up production of ZEVs, and in some cases phasing out production of internal combustion vehicles altogether (see the ZEV Platforms section of this report for more information). Fourteen states, including Oregon, have adopted California's Low-Emission Vehicle program, and 12 of those have adopted ZEV program rules. Governor Kate Brown joined governors of 11 other states to urge President Biden to support policies that would end sales of gasoline-powered vehicles by 2035.[26]

Finally, recognizing that the transportation sector is a leading contributor to greenhouse gas emissions in the United States and a significant contributor around the world, the International Energy Agency released a detailed environmental plan in May 2021 indicating that achieving a 1.5 degree Celsius cap on warming and net zero carbon emissions by 2050 would require an end to sales of internal combustion engines by 2035.[27]

Oregon is well-positioned to take advantage of the increasing number of ZEV models that will be available to the market by 2025. As will be discussed later in the report, there are programs at the state level that support increasing numbers of ZEVs for purchase, programs that incentivize access to ZEVs for all Oregonians, a new study that will inform charging infrastructure deployment, and activities that allow the state to lead by example through increased purchases and use of ZEVs in the state fleet.

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PDX canopy, Portland, Ore., Photo Credit: Eclectic Jack via Flickr

This section discusses the carbon intensity of fuel consumed by the Oregon transportation sector as a whole. Carbon intensity is the amount of carbon by weight emitted per unit of energy consumed. For example, the carbon intensity of fossil-fuel based gasoline as a fuel is generally higher than that of electricity (which can come from a number of sources, including renewables) when used to fuel vehicles.

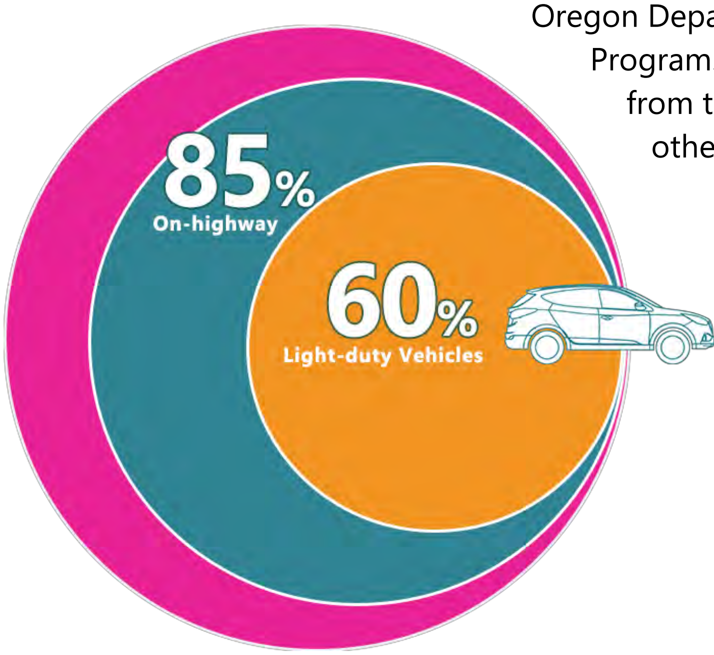
Carbon Intensity of Oregon's Transportation Sector

Introduction

The carbon intensity for the transportation sector has been declining since 2005, largely due to state and federal policies that support less carbon-intensive renewable fuels. Widespread adoption of ethanol and biodiesel, lower carbon fuels that are blended with gasoline and diesel respectively, are the primary contributors to this reduction. Electric fuel in the transportation sector is currently a small piece of the overall sector but is anticipated to grow considerably over the next decade (see the Impacts to the Grid section of this report for more information).

The transportation sector incudes fuels used for aviation, water vessels, rail, all vehicles that travel on Oregon roadways, and engine lubrication.[1] (See the ZEV Platforms section of this report for more information.) This analysis will assess carbon intensities for all fuels consumed across the entire transportation sector, and sectors where electric vehicle options are becoming more prevalent – the on-highway sector, and its subset the light-duty sector. This will be even further refined to assess the carbon intensity of just the light-duty sector, which includes only passenger vehicles, where the highest level of electric vehicle adoption exists.

Assigning carbon intensities is a core function of the Oregon Department of Environmental Quality's Clean Fuels Program, which was established to lower the carbon intensity of Oregon's transportation fuels as a whole through a market-based credit and debit system that incentivizes lower carbon fuels. Carbon intensity is a sum of the carbon footprints to extract, refine, and transport the fuels – or, in the case of electricity, generate and transmit – used for the transportation of people and goods in Oregon. In this analysis the Oregon Department of Energy used carbon intensity values from the Oregon Department of Environmental Quality's Clean Fuels Program.[i] Where data was available, ODOE used fuel volumes from the Clean Fuels Program supplemented by data from other sources.



The graphic at left illustrates how 85 percent of Oregon's whole transportation sector is on-highway traffic and that 60 percent of the whole transportation sector is light-duty vehicles.

[i] The Oregon Clean Fuels Program provided ODOE with a carbon intensity value for aviation fuels that has not been officially designated by the program.

Fuel Consumption in the Transportation Sector as a Whole

In 2019, Oregonians consumed nearly 2.8 billion gasoline gallon equivalents in transportation fuel.[3] The following table represents the total amount of energy consumed for each type of fuel used in Oregon. Gasoline and ethanol are separated in the chart below as different fuel types, but are generally blended when purchased at the pump. Combined, they make up 60 percent of fuel use in the transportation sector, most of which is consumed by light-duty vehicles. Similarly, petroleum diesel is blended with biodiesel to be sold commercially. Combined with renewable diesel – a non-petroleum-based form of diesel fuel – these add up to nearly 31 percent of total fuel consumption. Most diesel is consumed by on-highway medium- and heavy-duty trucks. The remaining fuels account for just over nine percent of transportation fuels used, with most of that as jet fuel.

Gasoline Gallon Equivalent normalizes the energy content across different types of fuels. One **gge** of any type of fuel has the same amount of energy consumed – or in essence could power the same vehicle to go the same distance.

Over 92 percent of the transportation fuels consumed in Oregon are produced from refined crude oil products. Extracted in other states and countries, crude oil is transported by pipeline, train, truck, and ship to refineries in other states – mostly Washington. Refined gasoline is blended with ethanol, and diesel with biodiesel before being transported to Oregon and distributed throughout the state for sale. DEQ reviews the individual steps along this pathway for most of the fuels consumed in Oregon and assigns the fuel an individual carbon intensity – more than 160 unique fuel pathways to date.[2]

Table 1: 2019 Oregon Transportation Sector Fuel Consumption[3]

Fuel	gge (gasoline gallon equivalent)	Trillion Btus	Percent of Total
Gasoline	1,562,023,497	181.3	55.9%
Diesel	782,042,472	90.8	28.0%
Jet Fuel	228,812,412	26.6	8.2%
Ethanol	115,567,624	13.4	4.1%
Biodiesel	61,964,789	7.2	2.2%
Renewable Diesel	17,971,995	2.1	0.6%
Lubricants	13,260,578	1.5	0.5%
Electricity	4,240,500	0.5	0.2%
Other Fuels[ii]	9,455,586	1.1	0.3%
Totals	**2,795,339,453**	**324.5**	**100%**

[ii] Other fuels includes aviation gasoline, liquified petroleum gas (LPG), compressed natural gas (CNG), liquid natural gas (LNG), Bio-CNG, Bio-LNG, and renewable LPG.

Carbon Intensity of the Overall Transportation Sector

The carbon intensity of the transportation sector in Oregon is about **98 gCO2e/megajoule, or 26.4 pounds CO2e/gge.** By way of comparison, the carbon intensity for both gasoline and diesel in 2020 were slightly higher at 100 and 101 grams CO2e/MJ.

Table 2: Oregon Clean Fuels Program 2020 Carbon Intensities[6]

Fuel	Carbon Intensity g CO2e/MJ
Diesel	101
Biodiesel	41
Renewable diesel	39
Gasoline	100
Ethanol	55
Aviation Fuels	91
Renewable natural gas	70
Fossil natural gas	80
Fossil propane	81
Renewable propane	65
Electricity[iii]	108

The carbon intensity for electricity is determined by the generation resources used to create it. Electric utilities with different generation resources have different carbon intensities. Some parts of Oregon that predominantly rely on the Pacific Northwest's clean hydropower system often have very low carbon intensities, and other utilities in Oregon that have higher amounts of coal and natural gas in their electricity mix have higher carbon intensities. As these utilities increase the amount of zero- and low-carbon renewable resources used to supply electricity, the associated carbon intensities will go down.

Electric motors are more than three times as efficient as internal combustion engines, meaning electric motors use less fuel to do the same amount of work.[4] This means that no matter where a vehicle is charged in Oregon, the overall greenhouse gas emissions are lower than a gasoline vehicle. Therefore, the carbon intensity of the fuel can be higher but still achieve lower overall emissions. The Oregon Clean Fuels Program applies a 3.4 energy economy ratio to electric fuel in the program, meaning the 108 g CO2e/megajoule carbon intensity calculates to 32 g CO2e/megajoule – less than a third that of gasoline.

[iii] Average carbon intensity for all electric utilities in Oregon.

Changes to Electricity Carbon Intensity in 2021

In 2021, the Oregon Clean Fuels Program adopted new rules for calculating Carbon Intensities for electric utilities. Over half the state's electric utilities have opted in to use their utility-specific carbon intensity for calculating their Clean Fuels Credits. Participants are many of Oregon consumer-owned utilities that have carbon intensities much lower than the statewide average – anywhere from 4.3 to 51 g CO2e/megajoule. For utilities that did not opt in to use their utility-specific value, the Clean Fuels Program calculated an adjusted statewide carbon intensity of 147 g CO2e/megajoule. This adjusted amount is the average carbon intensity of the remaining utilities. This change reduces the number of credits these utilities could receive for the same amount of electricity produced to fuel vehicles in 2021 compared to 2020. However, the program is allowing utilities to purchase and retire renewable energy certificates for the electricity consumed to fuel vehicles. When a REC is used, the resulting electricity is considered to be zero-emission, and the associated carbon intensity is determined by the type of renewable electricity used to generate the REC.

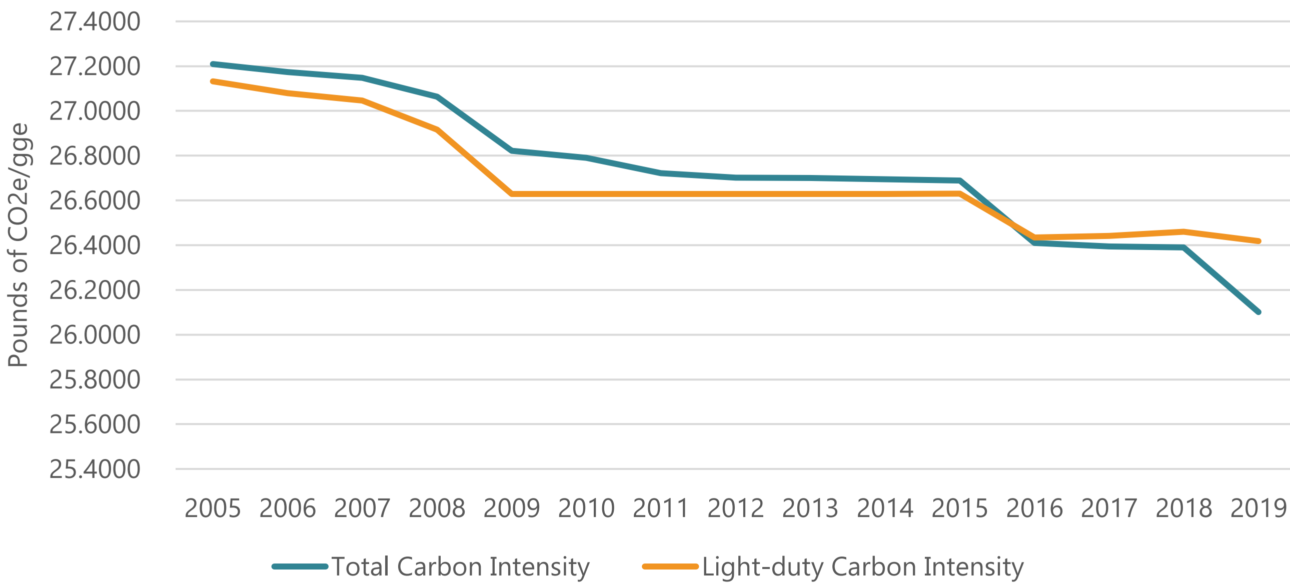
Citations: Oregon Clean Fuels Program https://www.oregon.gov/deq/ghgp/Documents/cfpUpdated2021CIs.pdf and https://www.oregon.gov/deq/ghgp/Documents/cfpRetiringRECs.pdf

Carbon Intensity of the On-Highway Transportation Sector

The carbon intensity of the on-highway sector is about 96.6 g CO2e/megajoule, or 26.1 pounds CO2e/gasoline gallon equivalent, and 97.7 g CO2e/megajoule, or 26.4 pounds of CO2e per gge for just the light-duty sector.[5] From 2005 to 2019 the total on-highway carbon intensity in Oregon decreased by 4 percent, largely due to federal and state programs.[6] In the mid-2000s, Congress and Oregon established Renewable Fuels Standards that mandated the use of lower carbon biofuels, and in 2016 the state's Clean Fuels Program was officially launched. [7] [8]

Figure 1 shows the reduction in the carbon intensity of transportation fuels for all on-highway transportation fuels compared to fuel consumed in the light-duty sector alone. The effects of the state and federal renewable standards can be seen in the large decrease across both sectors from 2005 to 2009, largely driven by the blending of ethanol into gasoline in the light-duty sector and biodiesel into diesel in the medium- and heavy-duty sectors.[9] [10] In 2016, the standing up of the Oregon Clean Fuels Program led to a second large drop in carbon intensity.

Figure 1: On-Highway Fuel Carbon Intensity by Year and Sector[11]



Diesel, used primarily in the medium- and heavy-duty sectors, is generally a higher carbon intensity fuel than gasoline. This higher carbon intensity can be seen in the higher overall carbon intensity of the total on-highway sector compared to the light-duty sector alone. As shown in Figure 1 above, this changed in 2016, when the overall on-highway sector dropped below the light-duty sector. This change in carbon intensities is largely driven by differences in the ease of adoption for lower carbon options for diesel fuel compared to gasoline.

Using electric fuel requires adoption of a new technology – an electric vehicle. The most widely adopted alternative fuel for diesel vehicles, renewable diesel, does not require a different vehicle or engine modifications. The demand for renewable diesel has grown significantly with the maturation of the Clean Fuels Program, and as a result plays a large role in driving down the carbon intensity in the medium- and heavy-duty sectors. This has led to a rapid decrease in the overall on-highway sector carbon intensity. As more electric vehicles are adopted, enabling greater use of electricity as a fuel, the average carbon intensity for the light-duty sector is also anticipated to drop considerably.

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Aerial view of freeways, Portland, Ore., Photo credit: oeconline.org

This section evaluates the adoption and use of ZEVs to determine whether they will put Oregon on course to meet its greenhouse gas emissions reduction goals:

- By 2020, achieve GHG levels that are 10 percent below 1990 levels (resulting in emissions of 52 million metric tons of carbon dioxide equivalent, MMTCO2e)
- By 2035, achieve GHG levels that are 45 percent below 1990 levels (resulting in 32 MMTCO2e)
- By 2050, achieve GHG levels that are 80 percent below 1990 levels (resulting in 12 MMTCO2e)

ZEV Impacts on Greenhouse Gas Emissions

Progress Toward Reaching the State's Greenhouse Gas Emissions Reduction Goals

Introduction

While the State of Oregon has made significant efforts to encourage adoption of zero emission vehicles (from providing rebates to informational dashboards), current plans and trends show that Oregon will not meet the proportionate share of its GHG reduction goals for light-duty vehicles without significantly higher adoption of ZEVs and other actions.

Oregon's Greenhouse Gas Emissions Reduction Goals

Oregon's goal is to significantly and rapidly reduce total GHG emissions. Set in statute (ORS 468A.200-250) and executive order (Governor Brown's EO 20-04), Oregon has three main in-state GHG reduction targets:

- By 2020, achieve GHG levels that are 10 percent below 1990 levels (resulting in emissions of 52 million metric tons of carbon dioxide equivalent, MMTCO2e)[1 2]
- By 2035, achieve GHG levels that are 45 percent below 1990 levels (resulting in 32 MMTCO2e)[3 4]
- By 2050, achieve GHG levels that are 80 percent below 1990 levels (resulting in 12 MMTCO2e)[3 4]

Because Oregon imports all of its petroleum-based transportation fuels, these targets and the Oregon Department of Environmental Quality's sector-based GHG inventory pertain to economy-wide, sector-based emissions occurring within Oregon. Within the transportation sector, in-state emissions, also known as tailpipe emissions, occur when vehicles with internal combustion engines or ZEVs use electricity from their batteries to operate. Most ZEVs emit few, if any, GHG emissions during operation; only plug-in hybrid electric vehicles have internal combustion engines, which are used to supplement a typically smaller battery.

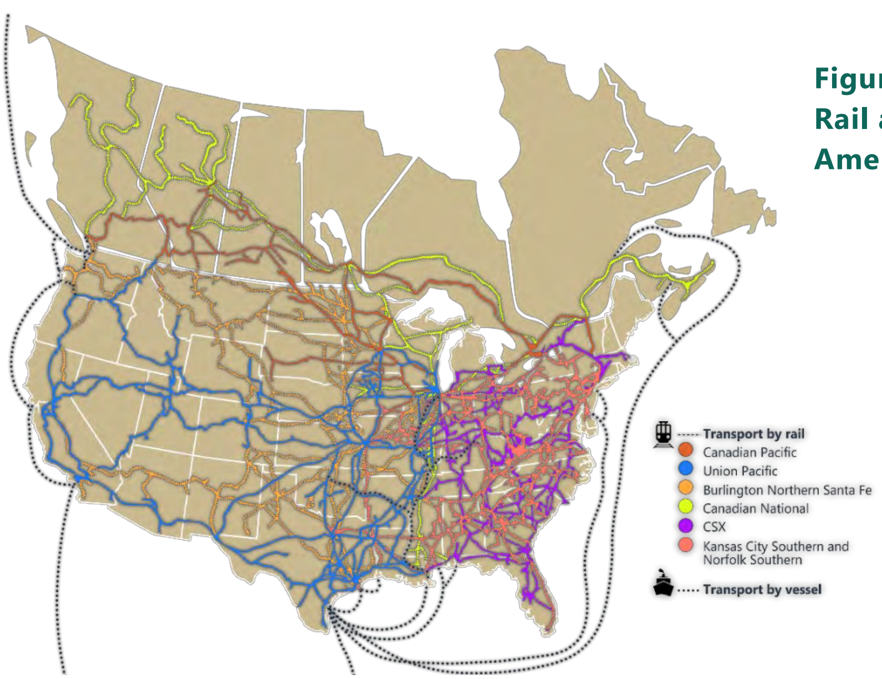


Figure 1: Oil Transport by Rail and Vessel in North America

Plug-in Hybrid Electric Vehicles: Fuel Usage and GHG Emissions

Plug-in hybrid electric vehicles, often referred to as PHEVs, may be run on electricity and/or gasoline. The hybrid nature of PHEVs makes it difficult to discern the precise amount of fuel they consume—and hence the amount of greenhouse gas emissions being released.

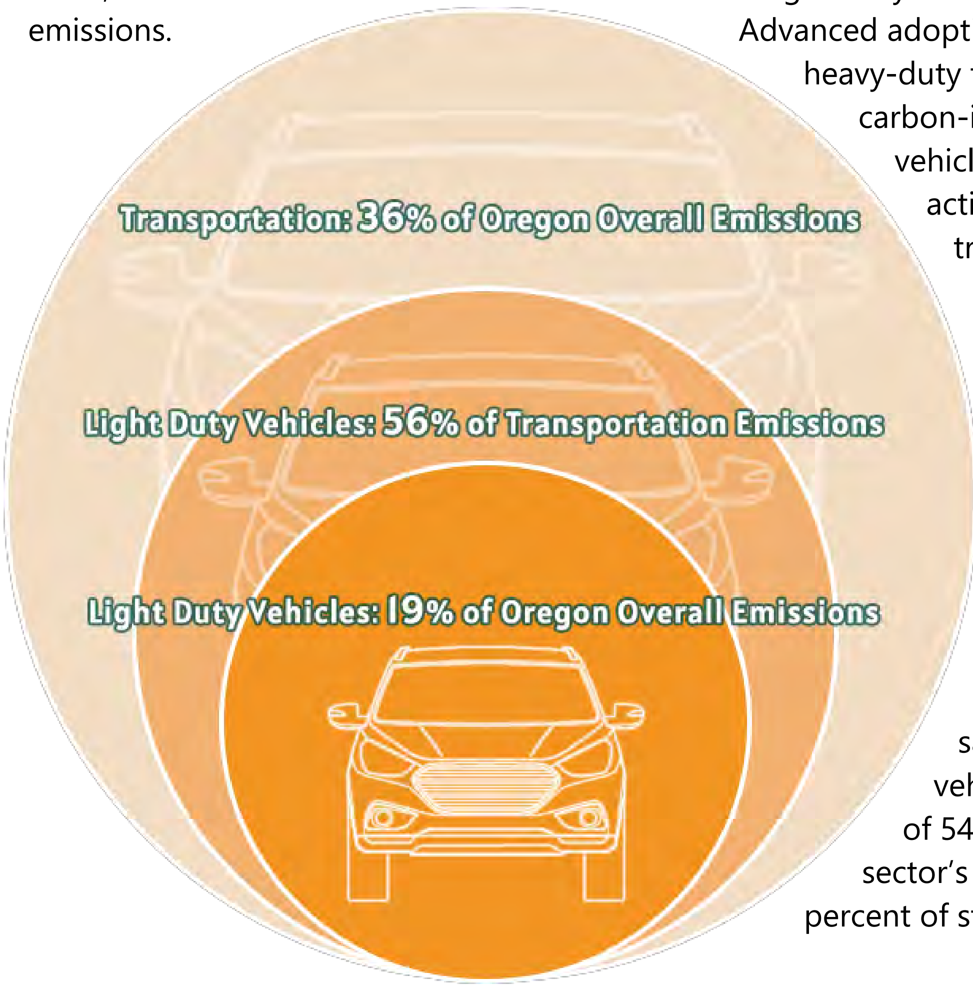
PHEVs can operate exclusively on electricity until their battery is nearly depleted and can operate using both the gasoline engine and electric motors to operate the car at a higher fuel efficiency, after which they burn gasoline for additional power. The battery is often recharged using regenerative braking and can therefore operate similarly to a standard hybrid vehicle.[5] As technology continues to advance, the "range" of ZEVs (the number of miles available from a fully charged battery) is expected to increase significantly.

Meanwhile, how PHEVs are operated creates additional uncertainty for estimating aggregate fuel usage and GHG emissions. For example, some drivers may charge their PHEVs frequently so that their batteries are always full, using little to no gasoline and emitting few to no GHG emissions as a result. Other drivers may charge their PHEVs infrequently and primarily rely on gasoline to power their vehicles. To date, there is limited data suggesting how much time various PHEVs are running on electricity versus gasoline.

Additional studies assessing how people charge their PHEVs are expected as ZEV adoption continues to grow. A USDOE-commissioned study from Idaho National Labs in 2015[6], analyzed charging behavior of more than 1,800 privately-owned PHEV Chevrolet Volts (along with other ZEVs) in 22 regions across the United States over a three-year period. The study revealed that Volt drivers tend to fully deplete their batteries prior to recharging and that their batteries were charged an average of 1.5 times per day (on the days the vehicle was driven). This type of analysis can help jurisdictions track GHG emission reductions associated with PHEVs and other ZEVs.

Role of ZEVs in Reducing In-State Greenhouse Gas Emissions

This section provides information on in-state emissions resulting from light-duty vehicles to assess the progress and potential of ZEVs in achieving the state's goals to significantly reduce GHG emissions. Because only a small number of ZEVs have been adopted among medium- and heavy-duty fleets, this section focuses on the role of ZEVs in the light-duty sector in reducing the state's GHG emissions.



Advanced adoption of ZEVs among medium- and heavy-duty fleets, which are significantly carbon-intensive—in addition to reducing vehicle miles traveled, among other actions—would substantially reduce transportation-related emissions.

Over the last 10 to 30 years, transportation-related emissions have remained the largest contributor to Oregon's in-state GHG emissions. From 2010 to 2019, an average of 36 percent of Oregon's in-state GHG emissions are derived from the transportation sector.[7] Over this same time period, light-duty vehicles have contributed an average of 54 percent of the transportation sector's emissions and contributed 19 percent of statewide emissions.

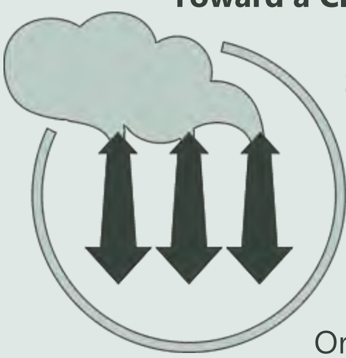
In 2019, Oregon's in-state GHG emissions reached an estimated 64.4 MMTCO2e, which is 24 percent higher than the state's 2020 goal to reduce emissions to 52 MMTCO2e. [8] Light-duty vehicles account for about 19 percent of the state's GHG emissions at about 12.4 MMTCO2e, which is nearly 20 percent higher than the proportionate share for light-duty vehicles to meet the GHG reduction target for 2020.[5]

Adoption of ZEVs has helped keep these GHG emissions levels from being even higher. Despite their modest uptake in Oregon, the use of ZEVs has avoided an estimated 338,000 metric tons of in-state, combustion-only CO2e emissions from 2010 to 2019. [9] An uptake of 50,000 ZEVs by 2020 would have mitigated about 32,000 metric tons of in-state emissions in the year 2020 alone.[7]

However, to achieve the proportionate reduction (10 percent) of in-state emissions for light-duty vehicles by 2020, Oregon would have needed 755,000 ZEVs.[7, i] By the end of 2020, Oregon had 33,579 registered light-duty ZEVs.

Although ZEVs have played an important role in avoiding GHG emissions, under current plans and trends, GHG emissions from transportation sector are only expected to decrease 15 to 20 percent by 2050.[10] The State of Oregon will not meet its GHG reduction goals without more extensive investments and adoption of ZEVs.

In-State vs. Lifecycle Emissions: Two Different Metrics to Better Understand Our Progress Toward a Cleaner Economy



States across the country maintain official inventories that measure the amount of GHG emissions produced within their jurisdictional boundaries. In alignment with guidance from the International Panel on Climate Change, Oregon's Greenhouse Gas Sector-Based Inventory measures GHG emissions produced within Oregon by economic sector and emissions associated with the electricity used in Oregon (regardless of where that electricity is generated). For example, for light-duty vehicles, our in-state inventory captures emissions resulting from the combustion of fuel (tailpipe emissions) and electricity used to charge electric vehicles. In-state inventories serve as a critical resource enabling states to provide detailed GHG emissions analysis and inform state-specific policy decisions.

Another common way to evaluate greenhouse gas emissions from transportation fuels is on a lifecycle basis which accounts for emissions resulting from the extraction, refinement, distribution, *and* combustion of fuels. For example, the Oregon Clean Fuels Program evaluates carbon intensities on a lifecycle basis. Including information on lifecycle emissions in addition to tailpipe emissions provides additional insight into what mitigation strategies might be more effective to reduce the impact on global climate change and/or local air pollution. For Oregon, most transportation lifecycle emissions occur outside of Oregon while all tailpipe emissions occur inside Oregon, so a combination of strategies is needed to reduce both. [11]

[i] This is based on the counterfactual: using the percentage of registered ZEVs that are PHEVs vs. BEVs based on 2005-2020 Oregon vehicle registration data from ODOT. Average electricity usage is calculated using the U.S. Environmental Protection Agency's fuel economy estimates for vehicles, which are then weighting by registrations of ZEVs in Oregon (by vehicle make and model from ODOT) and summed to find an aggregate efficiency number for each year. Carbon intensity factors for electricity (aggregated to the state level), gasoline, and ethanol are from DEQ's Clean Fuels Program.

Role of ZEVs in Reducing Lifecycle Greenhouse Gas Emissions

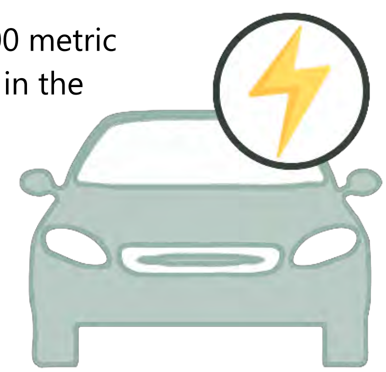
Analyzing transportation-related emissions in terms of lifecycle emissions helps provide additional context regarding the role of ZEVs in reducing GHG emissions. Lifecycle GHG emissions account for the often-substantial emissions resulting from the extraction, transport, refinement, and distribution of fuels, in addition to emissions from fuel combustion. For traditional vehicles (i.e., with internal combustion engines), lifecycle emissions include those resulting from the production and distribution of fuel that is imported into the state. For ZEVs, this includes emissions resulting from the electricity drawn from a local utility's electricity resource mix (e.g., from renewables and/or fossil fuels) used to charge the vehicle.

From 2010 to 2019, light-duty vehicles emitted an average of 33 percent more lifecycle emissions than tailpipe emissions (Table 1). While ZEVs made up only an average of 0.3 percent of light-duty vehicles over this time period, they contributed to less than 0.08 percent of the lifecycle emissions—nearly four times fewer emissions than their proportionate share. The use of ZEVs has avoided nearly 470,000 metric tons of lifecycle emissions from 2010 to 2019.[7, ii] An uptake of 50,000 ZEVs by 2020 would have mitigated about 46,000 metric tons of lifecycle emissions in the year 2020 alone.[7]

ZEVs at Work—With More Work to Do

The uptake of ZEVs (totaling about 33,579 by 2020) avoided nearly 340,000 metric tons of in-state and nearly 470,000 metric tons of lifecycle emissions from 2010-2019.[7]

50,000 ZEVs (the state's 2020 target) would have mitigated about 32,000 metric tons of in-state emissions and 46,000 metric tons of lifecycle emissions in the year 2020 alone.[7]



However, about 755,000 ZEVs would have been needed by 2020 to achieve the light-duty vehicles' proportionate share of the state's (in-state) GHG reduction target (10.4 MMTCO2e).[7]

[ii] This is based on the counterfactual: if the number of all registered ZEVs had been internal combustion vehicles, using a weighted average of vehicle miles traveled among the light-duty passenger vehicle fleet from the Federal Highway Administration, and a weighted average of miles per gallon consumed across Oregon's light-duty passenger fleet from the Oregon Department of Transportation (ODOT).

Table 1: Adoption and Emissions of Zero-Emission Vehicles among Light-Duty Vehicles in Oregon. Values in Metric Tons of CO2 Equivalent. [12]

Tailpipe Emissions ***(Metric Tons of CO2e)***		**Lifecycle Emissions** ***(Metric Tons of CO2e)***			
	Tailpipe emissions from all light-duty vehicles (including PHEVs)	Lifecycle emissions from vehicles with internal combustion engines only (excluding PHEVs)	Lifecycle emissions from ZEVs (battery-operated and PHEVs)	Lifecycle emissions from all light-duty vehicles	Portion of lifecycle emissions that are not from tailpipe (from all light-duty vehicles)
2010	13,769,959	18,502,039	1,519	18,503,557	25.6%
2011	13,257,856	17,813,247	2,036	17,815,283	25.6%
2012	12,799,805	17,196,174	3,314	17,199,488	25.6%
2013	12,939,755	17,380,983	5,952	17,386,935	25.6%
2014	13,451,439	18,064,900	8,935	18,073,835	25.6%
2015	13,702,332	18,421,463	12,726	18,434,188	25.6%
2016	13,849,473	18,289,745	15,853	18,305,598	24.3%
2017	14,078,220	18,572,600	20,576	18,593,176	24.3%
2018	14,856,277	19,557,918	28,797	19,586,715	24.2%
2019	15,113,818	19,711,658	36,619	19,748,277	23.5%

Note: Lifecycle emissions include tailpipe emissions (resulting from fuel combustion)

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Forth's interactive EV showroom, Portland, Ore., Photo credit: forthmobility.org

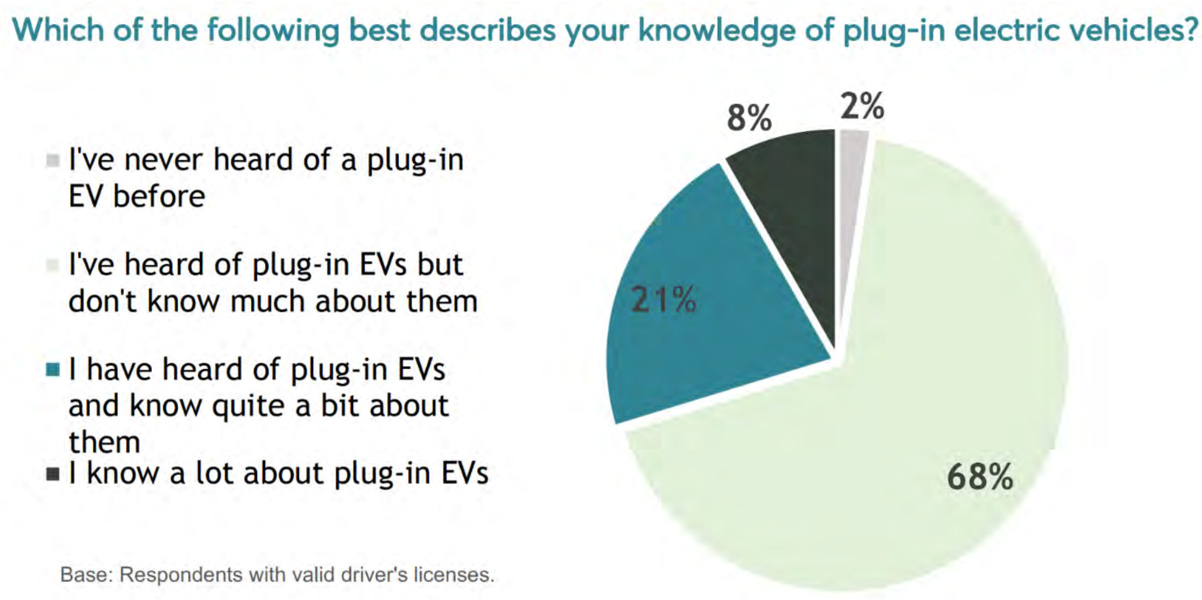
This section dives in to Oregonians' awareness of motor vehicle options, the benefits of owning zero-emission vehicles, and the true costs of motor vehicle ownership.

Oregonians' Awareness of ZEV Options and Benefits

Awareness of Motor Vehicle Options

Consumer awareness of electric vehicles, how to operate and fuel them, their costs, and their benefits is key to increasing adoption of ZEVs. The development of electric vehicle markets is tied to consumers' general awareness and understanding of the potential benefits of electric vehicles. General awareness of electric vehicles has progressed since the modern introduction of mass-produced electric vehicles in 2010 by Nissan and General Motors. A survey conducted by Deloitte in 2020 found that 41 percent of U.S. respondents would prefer an alternative powertrain vehicle, such as a hybrid or battery electric, over an internal combustion engine vehicle – up from 29 percent a year earlier. [1] A 2020 Consumer Reports survey found that approximately 98 percent of drivers say they've heard of electric vehicles, but only 30 percent say they are knowledgeable about them. [2]

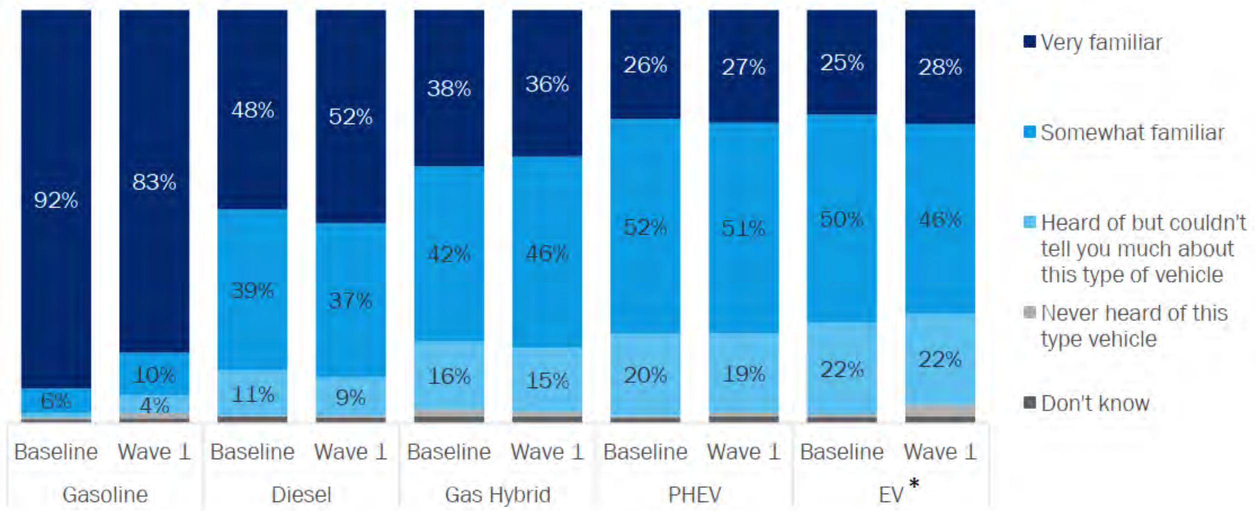
Figure 1: Consumer Reports Survey[2]



There is no statewide source of data on Oregonians' knowledge of benefits and the true costs of zero-emission vehicle ownership, but national surveys and customer surveys conducted by Portland General Electric and Pacific Power can provide insight into awareness at the state level.

In 2018, PGE conducted a general population residential customer survey, which it repeated in 2019. The 2018 survey is the baseline information, while the 2019 follow-up survey is referred to in the figure below as Wave 1.[3] For both surveys, PGE showed that its customers had moderate to high levels of familiarity with BEVs and PHEVs, with about three-quarters of respondents indicating they were at least somewhat familiar with BEVs and PHEVs, although their familiarity levels are less than that for gasoline and diesel vehicles. [4]

Figure 2: PGE Respondent Level of Familiarity with Vehicle Fuel Types[4]

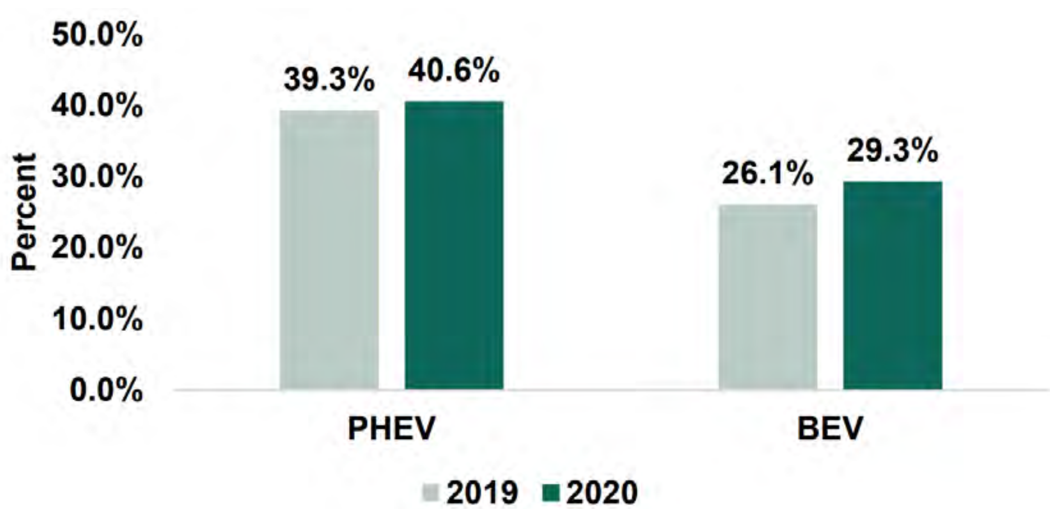


In this chart, EV refers to battery electric vehicles (BEVs)

Significantly, from 2018 to 2019 the number of respondents that indicated they planned to purchase a ZEV increased from 17 to 24 percent.[5]

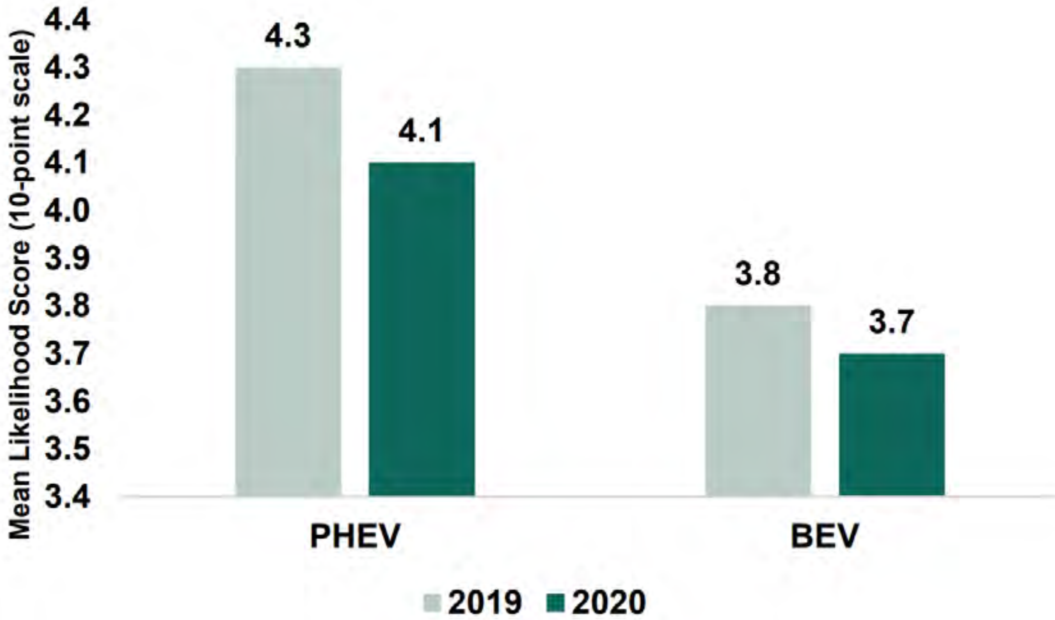
PGE territory is highly urban and where the state has the highest levels of ZEV adoption.[6] (See the Demographics section of this report for more information.) In rural parts of the state, there is some indication that ZEV awareness may be lower. Pacific Power, whose territory includes several rural communities, conducted a survey of general customers in 2019 and 2020. Less than 30 percent of respondents indicated they had driven in a BEV or PHEV and less than 15 percent indicated they had personally driven one of these vehicles. Of the 631 respondents that answered both surveys, there was a slight increase in considering a ZEV for their next vehicle purchase. [7]

Figure 3: Pacific Power Respondents Considering BEV or PHEV for Purchase[7]



However, the likelihood that respondents would purchase a ZEV stayed relatively the same, with only minor drops between 2019 and 2020.

Figure 4: Pacific Power Respondents Likelihood of Purchasing by Vehicle Type[7]

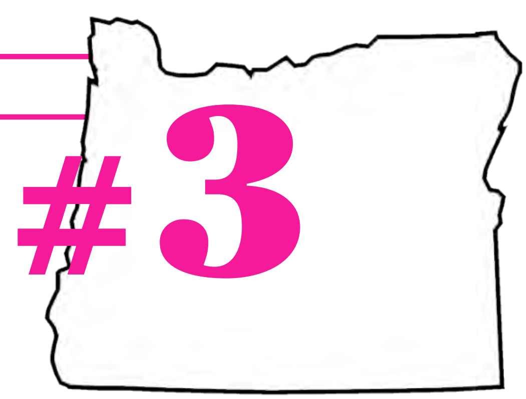


Pacific Power also indicated that in the surveys there was also little change in most measures of ZEV awareness between 2019 and 2020.

Oregon is consistently ranked near the top in independent ZEV analyses and state comparisons, which suggests that Oregonians have a higher awareness of electric vehicles. In a February 2021 report, Plug-In America ranked Oregon third among U.S. state policies and programs that support ZEV drivers. [8]

Figure 5: Plug-In America Top States for EV Driver Support *(abridged)*[8]

Rank	State	Points Received
1	California	95
2	Massachusetts	86
3	Oregon	85
4	New Jersey	82
5	Colorado	78
6	New York	77
7	Vermont	70
8	Connecticut	66
9	Maine	65
10	Washington	64



The Plug-In America rankings were developed by assessing supportive policies in four areas: for the EV driver pre-purchase, for the EV driver during ownership of the vehicle, enabling EV infrastructure build-out, and for education and outreach activities. Oregon earned high marks for electric vehicle rebates, the minor label permit program that expedites the installation of home charging equipment, and education and outreach initiatives. The report cites state agency collaboration to develop goals and metrics to assess progress on the state's ZEV goals and a strategic effort to support utilities in increasing EV adoption and providing technical assistance to their customers.[9]

Figure 6: Plug-in America - Oregon EV Driver Support Grading Card[9]

Category	Subcategories	Points Earned	Total Points Possible
Policies Supporting EV Purchase	EV purchase incentive	14	15
	Access to EVs	15	15
	HOV lane access/toll exemption	0	5
	Subtotal	***29***	***35***
Policies Supporting EV Driver During Ownership	Fair EV fee	9	9
	Clean fuels policy	7	7
	Public EVSE requirements	0	4
	Physical EVSE access	3	3
	Subtotal	***19***	***23***
Policies Enabling EV Infrastructure	Public Utility Commission activity	10	10
	Financial incentive enabling EVSE installation	8	10
	Non-financial policies enabling EVSE installation	3	3
	Ease of permitting	3*	3
	HOA policy	1	1
	Subtotal	***25****	***27***
Education and Outreach Activities	Statewide campaign	9	9
	Programs to train dealers to sell EVs	2	6
	Subtotal	***11***	***15***
	GRAND TOTAL	84*	100

**A typo in the original Plug-in America table awarded Oregon four points instead of three for "ease of permitting." ODOE has manually corrected the table for purposes of this report to reflect the accurate score.*

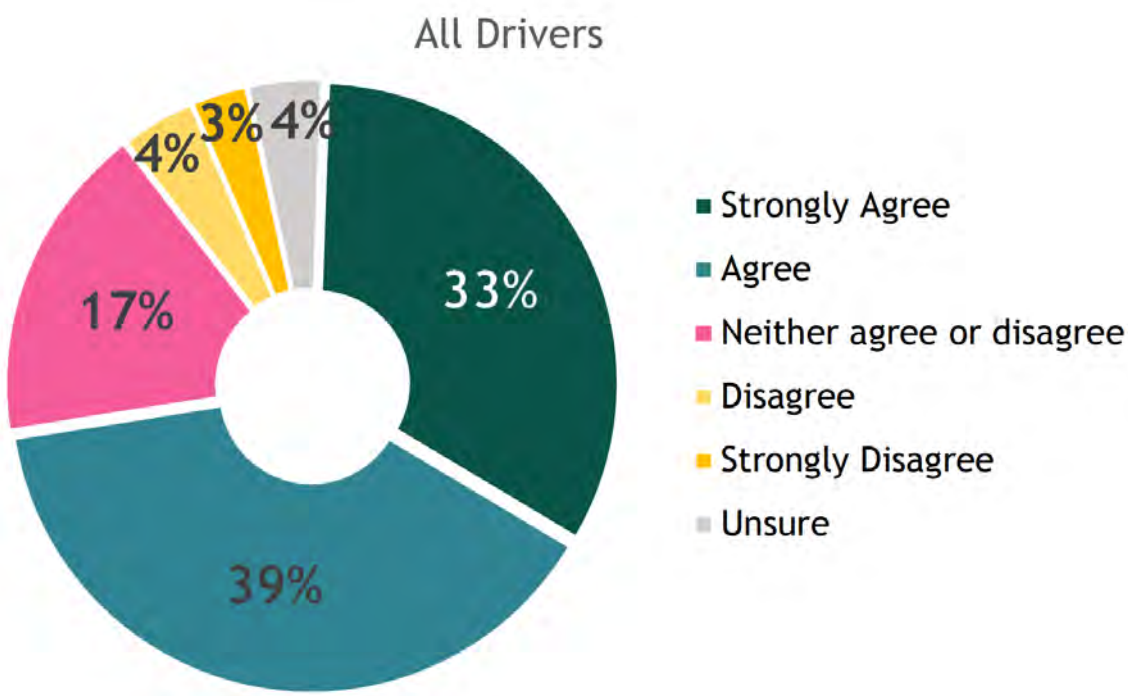
Additionally, Oregon was rated third in the country for EV market share – the percentage of new EVs sold compared to internal combustion engine vehicles – in 2017 and 2018 by EV Adoption.[10]

Figure 7: EV Adoption – EV Market Share by State *(abridged)*[10]

State	EV Sales 2017	EV Sales 2018	2018-2017 YOY Sales Increase	2017 EV Market Share W/in State	2018 EV Market Share W/in State	2018 vs 2017 YOY Share % Increase
California	94,873	153,442	61.73%	5.02%	7.84%	56.18%
Washington	7,068	12,650	78.98%	2.51%	4.28%	70.52%
Oregon	3,988	5,976	49.85%	2.36%	3.41%	44.49%
District of Columbia	398	761	91.21%	1.87%	3.34%	78.61%
Colorado	4,156	7,051	69.66%	1.57%	2.61%	66.24%

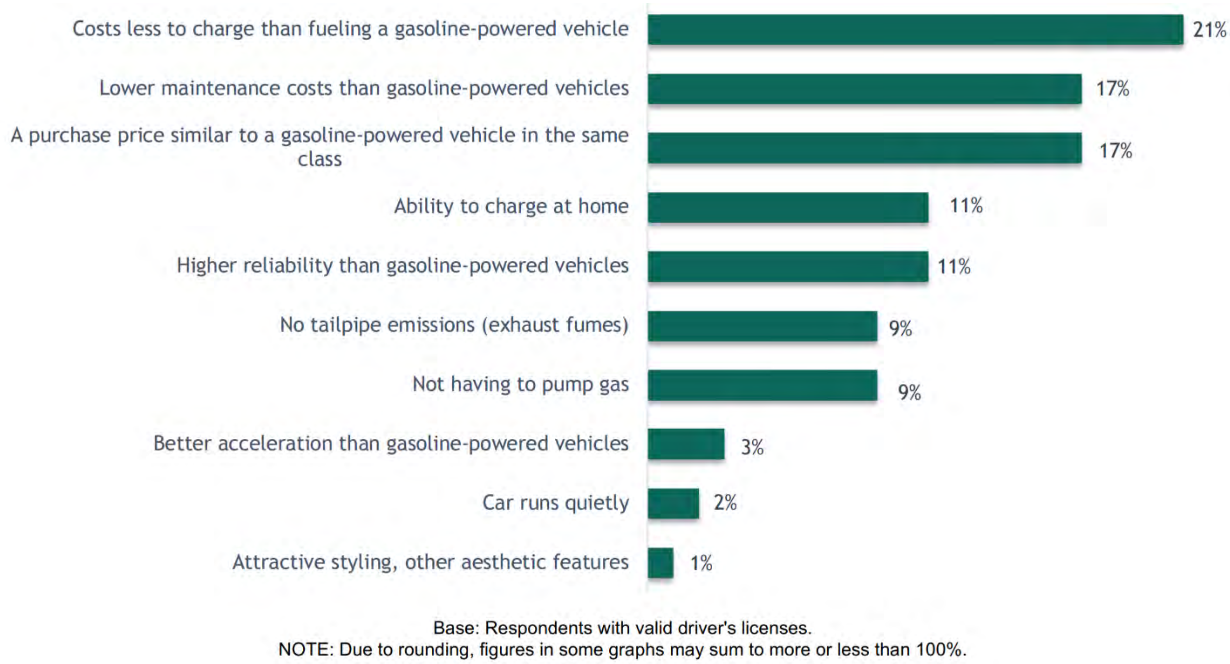
In the Consumer Reports Consumer Interest and Knowledge of EVs: 2020 Survey Results, the following was asked: *Will widespread electric vehicle use help reduce air pollution or climate pollution?* The results below show that 72 percent of respondents strongly agreed or agreed with the statement. This suggests that a large proportion of the population does have some knowledge of the benefits of electric vehicles.[11]

Figure 8: Consumer Reports – EVs Help Reduce Air or Climate Pollution[11]



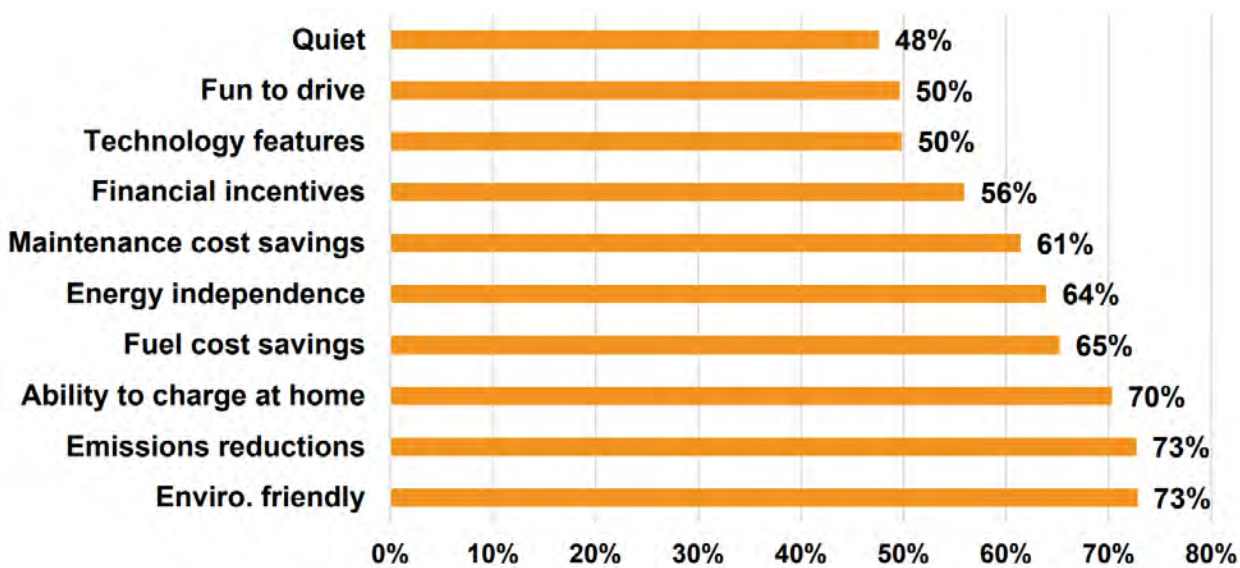
In the same survey, participants chose from a list of attributes that would most encourage them to purchase a plug-in electric vehicle. The three highest rated categories – costs less to fuel, lower maintenance costs, and a purchase price similar to gasoline-powered cars – suggests an overall familiarity with the benefits of driving an EV. [12]

Figure 9: Consumer Reports – Electric Vehicle Attributes[12]



Pacific Power asked survey respondents to rank the importance of different ZEV-related factors on their interest to buy a ZEV. Respondents' highest rated items were environmental benefits and the ability to charge at home. Fuel cost savings ranked fourth, with 65 percent of participants indicating this as a factor, and maintenance cost savings were 61 percent. Financial incentives were indicated by just over half of participants.[13]

Figure 10: Pacific Power Survey Respondents' Motivations to Purchase an Electric Vehicle[13]



Similarly, the PGE general population residential customer surveys also asked all potential vehicle buyers: *if they were to buy a ZEV, what would their main reason be for doing so?* In both the 2018 and 2019 surveys, 40 percent of respondents indicated the environmental impact was the top reason to purchase a ZEV. Of the respondents who *intended* to buy a ZEV, 64 percent cited environmental impacts followed by 25 percent who indicated lower operational costs – this was similar across all responder groups.[14]

Figure 11: PGE Respondent Unprompted Reasons Mentioned for Purchasing or Leasing an EV or PHEV[14]

Main Reason for Purchasing or Leasing an EV/PHEV (Unprompted)	All Likely Vehicle Purchasers		Wave 1 - All Likely Vehicle Purchasers		
	Baseline (n= 929)	Wave 1 (n=1026)	EV/PHEV Non-Considerers (n=526) (A)	EV/PHEV Considerers (n=253) (B)	EV/PHEV Intenders (n=247) (C)
Environmental impact	42%	40%	26% B C	45% A C	64% A B
Fuel/operating cost	33%	26% *	29% B	20% A	25%
Cost (unspecified)	9%	8%	7%	9%	10%
No/less gas used	5%	8% *	10%	5%	8%
Efficiency/fuel economy	7%	5%	3% B C	8% A	7% A
Maintenance costs	6%	5%	4%	3%	7%
Don't know	19%	25% *	31% C	26% C	9% A B

[a] Those who indicated they were intending to purchase an EV or PHEV were asked "What are the main reasons you would consider an EV PHEV for your next vehicle purchase or lease?" All other respondents were asked "If in the future you were to consider purchasing or leasing an EV /PHEV, what would you expect to be the main benefits of having an electric vehicle?"

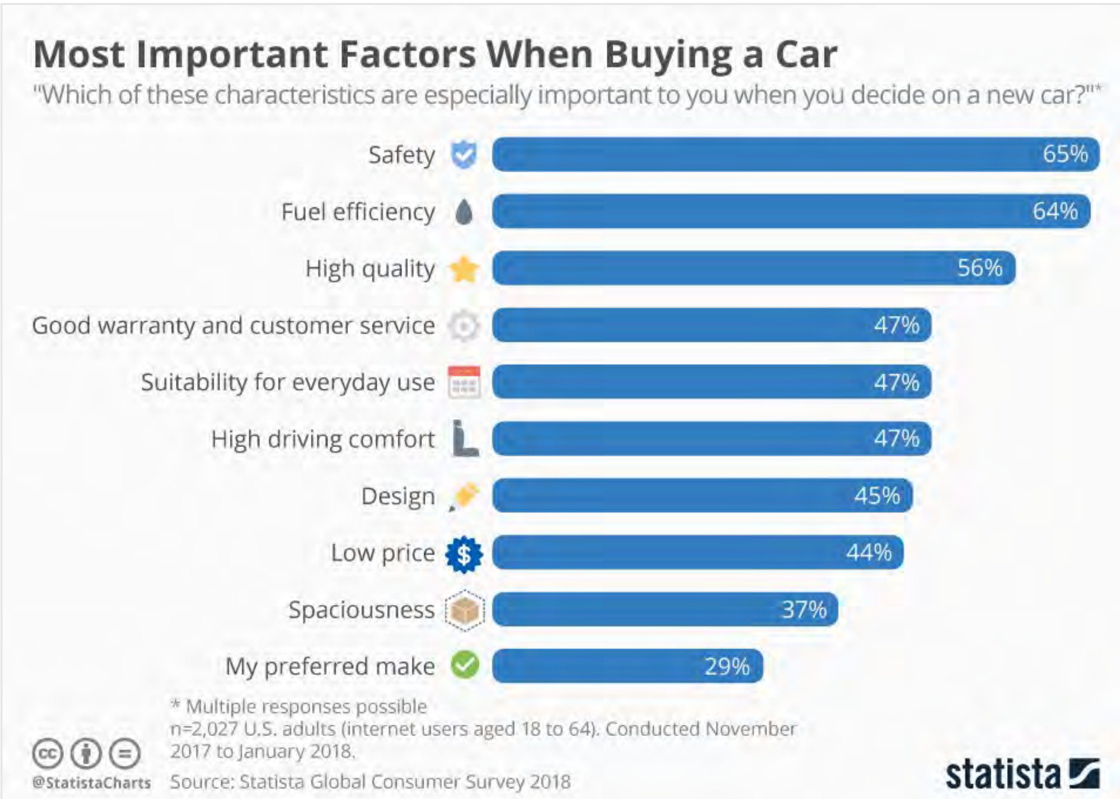
Note: Letters A - C indicate statistically significant differences between likely vehicle purchaser segments (z-test for proportions, p<.05).

* Indicates a statistically significant difference between Baseline and Wave 1 survey all likely vehicle purchasers (z-test for proportions, p<.05).

Another consideration when buying a car is the total cost of ownership, or the total cost of buying, operating, and maintaining the vehicle. As discussed in the Cost Differences section of this report, the total cost of ownership for ZEVs can be lower than their gasoline counterparts, and in some instances the overall annual costs can be lower than the internal combustion engine counterpart beginning in the first year. In most other cases the lower operational and maintenance costs will offset the higher up-front cost in 2 – 6 years, depending on how much the owner uses the vehicle. However, realization of those cost benefits means consumers must have the resources to float initially higher up-front costs until cost savings from lower operational and maintenance costs accrue. If the vehicle is owned for 12 years – the national average for car ownership – the cost savings over that timeframe are considerable.

Typically, buying a vehicle, whether new or used, is one of the biggest purchases that families and individuals make. There are many factors to consider when choosing the right one, and not everyone will have the same priorities. A survey conducted by Statista of U.S. adults on the most important factors when buying a car determined safety was the number one consideration.[15]

Figure 12: Statista – Most Important Factor When Buying a Car[15]



Although fuel efficiency is rated number two at 64 percent, it is the only factor in the top 10 that aligns with lower total cost of ownership for ZEVs. The other nine attributes could be applied to any type of vehicle and don't specifically point to any potential financial advantage in buying an electric vehicle.

The Consumer Reports survey discussed in Figure 9 above shows cost factors as the top three reasons consumers would choose a ZEV, including: if it costs less to charge than fuel a gasoline vehicle, costs less to maintain than a gasoline vehicle, and costs less up front than a gasoline vehicle. It is uncertain from the survey results if respondents understood that fuel and maintenance costs often are less for ZEVs. Further, it is uncertain to what degree the total cost of owning a ZEV is a deciding factor in purchasing a vehicle – and many Oregonians may not be able to reap the long-term financial benefits from a lower total cost of ownership because they can't meet the initial, potentially higher, investment cost (see the Cost Differences section of this report for more information).

Conclusion

Zero-emission registrations continue to rise in Oregon. Utility surveys indicate a general trend of increasing familiarity with ZEVs and their benefits, and Oregon continues to get high marks in many national rankings about ZEVs. There is anecdotal evidence that many Oregonians first encounter a ZEV through a neighbor, coworker, or friend. As the number of ZEVs continues to rise in Oregon, more people will encounter these vehicles and learn more about them. To ensure that Oregonians find the information they need, many public and private organizations will need to provide clear and consistent information on ZEVs.

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Aerial view of an Oregon suburban neighborhood, Photo source: Flikr.com

This section discusses various demographic factors influencing zero emission vehicle ownership in Oregon, including whether ZEV owners reside in urban or rural areas of the state.

Distribution of ZEVs by Demographic Group

The Demographic Distribution of Electric Vehicle Ownership in Oregon

Parsing out electric vehicle registrations by different demographic groups provides insight into which communities in Oregon are actively adopting this new technology and where there is limited or no uptake. This information can be used to inform the need for additional education and awareness efforts. It can also indicate barriers to ZEV adoption for specific demographic groups, signaling the need for different program approaches that reach all Oregonians. Differences in data among demographic groups may highlight equity gaps stemming from historically or systemically biased policies and actions, and may indicate that the ZEVs available today do not meet the needs of some communities.

The information presented in this section of the report is intended to provide insight into ZEV ownership patterns across Oregon. This assessment does not purport to fully evaluate the nuances and highly community-specific variables and barriers that make an individual's ability and desire to choose a ZEV unique. Nonetheless, ODOE has collected and assessed some available demographic information as a resource for state and community leaders to better understand the state of ZEV adoption today and inform future policies to support adoption. As the state moves toward a future where ZEVs are more commonplace, highlighting inequities is essential to ensure those Oregonians who have been marginalized or unable to take advantage of beneficial actions in the past will have equitable access to policies and programs supporting ZEV adoption and reinforce the health, economic vitality, and independence of all Oregon communities.

Data and Methods

Demographic data in this section uses address-level registration data from the Oregon Department of Transportation Department of Motorized Vehicles to identify passenger EV ownership. Because buyer-specific sales data is not available, this analysis assumes registered owners are synonymous with the buyer and includes all Oregonians with vehicles registered in the state, including Oregon buyers who purchase cars in other states. The registration data was used to assess EV ownership across several demographic categories, including rural and urban, income level, race, and housing characteristics. Because EVs are the only ZEVs operating in Oregon, the remainder of this section is specific to electric vehicles only. Should fuel cell electric passenger vehicles become prevalent in Oregon, these will be included in future versions of this report.

To address the demographic distribution of rural and urban EV adoption, ODOE cross-referenced the address level data with "Place Types" – a more granular breakout of geographic areas developed by the Oregon Department of Land Conservation and Development and the Oregon Department of Transportation as part of the Oregon Sustainable Transportation Initiative. Developed as a tool for use in their planning activities, the nine "place types" present a view not only of the urbanization level of a specific place, but also the interdependencies in each area on different types of transportation.

Place types include the physical characteristics and interdependencies of a geographic area that influence transportation choices. For example, each area was assessed for characteristics such as population density, job density and access to those jobs, access to goods and services, access to transit, and walkability. During the tool's development, ODOT and DLCD identified nine different place types in Oregon. These differentiate rural areas that are nearer to major cities and those farther away, and also define isolated cities that are denser than rural but relatively far from major metropolitan areas. Metropolitan areas are split into residential (suburban), low-density (rural but near to larger cities and towns), downtown city-centers, and mixed-use areas. The ninth-place type is commercial and industrial areas within metropolitan areas, where some ZEVs may be located if they are owned by a business.

Area Types

Suburban (Residential)

Metropolitan Mixed Use

Rural Near Major Center

Metropolitan Commercial & Industrial

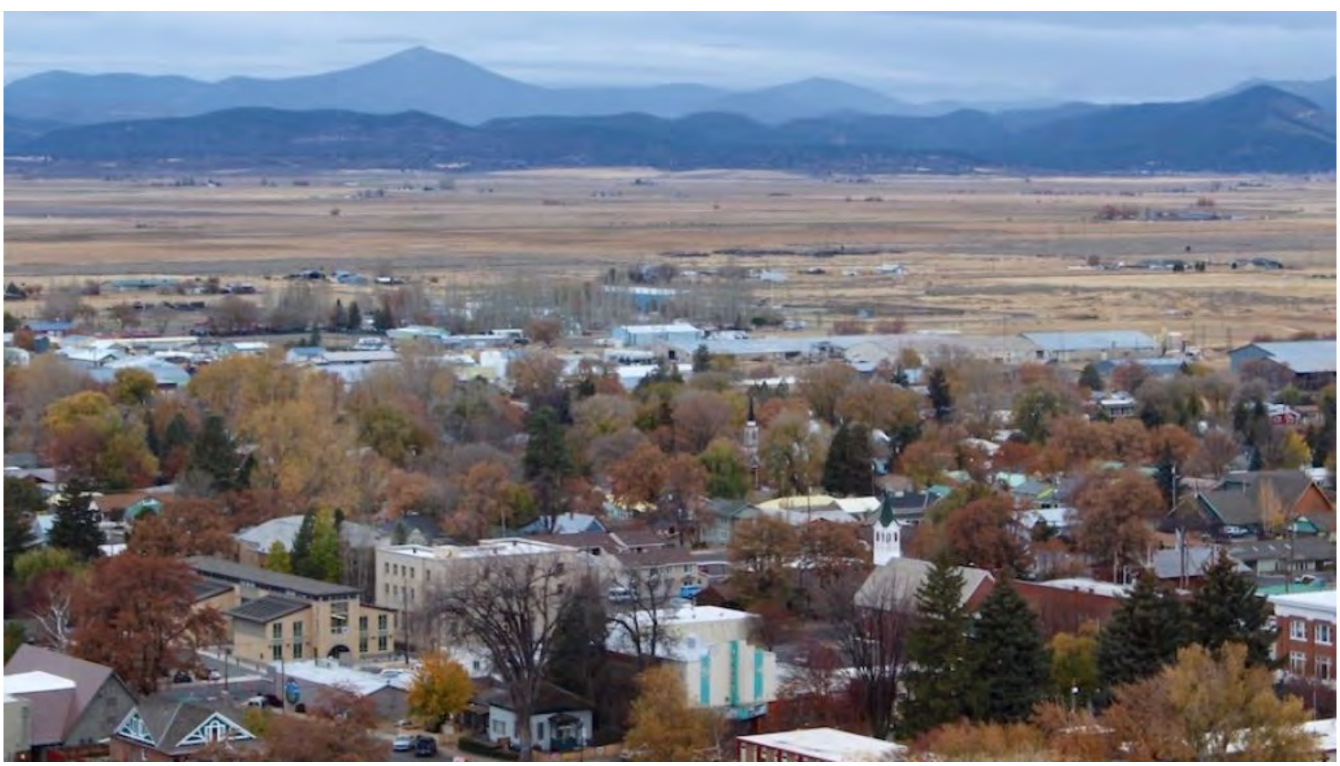
Metropolitan Low Density

Metropolitan with Transit

City Near Major Center

Rural Far from Major Center

Rural Remote



The Southern Oregon town of Lakeview is considered a Rural Remote City. Photo source: oregonbusiness.com/Caleb Diehl

The remaining demographic assessments cross referenced ZEV registration addresses with census block group data from the U.S. Census Bureau. Oregon does not collect individual demographic data for registered ZEV owners. Therefore, Census block group-level data is the most granular information available to assess ZEV adoption across different categories. This demographic data reflects the statistical prevalence of demographic groups for each census block group where ZEV owners reside, and not the specific demographics of individual ZEV owners. For example, if a census block group—the smallest geographical census unit where complete demographic data is available — has a high level of ZEV adoption and a higher-than-average income level, this analysis indicates that ZEV adoption in the census block group area is *generally* associated with Oregonians who have higher income levels.

Electric Vehicle Ownership by Level of Urbanization

Nearly 88 percent of ZEVs in Oregon are registered in metropolitan areas, with the most ZEVs located in residential suburban areas. Urban and suburban areas have many characteristics that support ZEV adoption, such as availability of charging infrastructure, access to a wider range of dealerships and vehicle models, and a wide variety of ZEV models that can meet the needs of urban drivers. In addition, many ZEV owners are self-selected ZEV ambassadors, providing information on the benefits of driving a ZEV to friends, neighbors, and people out in the community. Because ZEVs and electric chargers are more visible in high-density communities, friends, neighbors, and coworkers offer more general familiarity with this new technology.

Figure 1: Number of ZEVs per Geographic Place Type

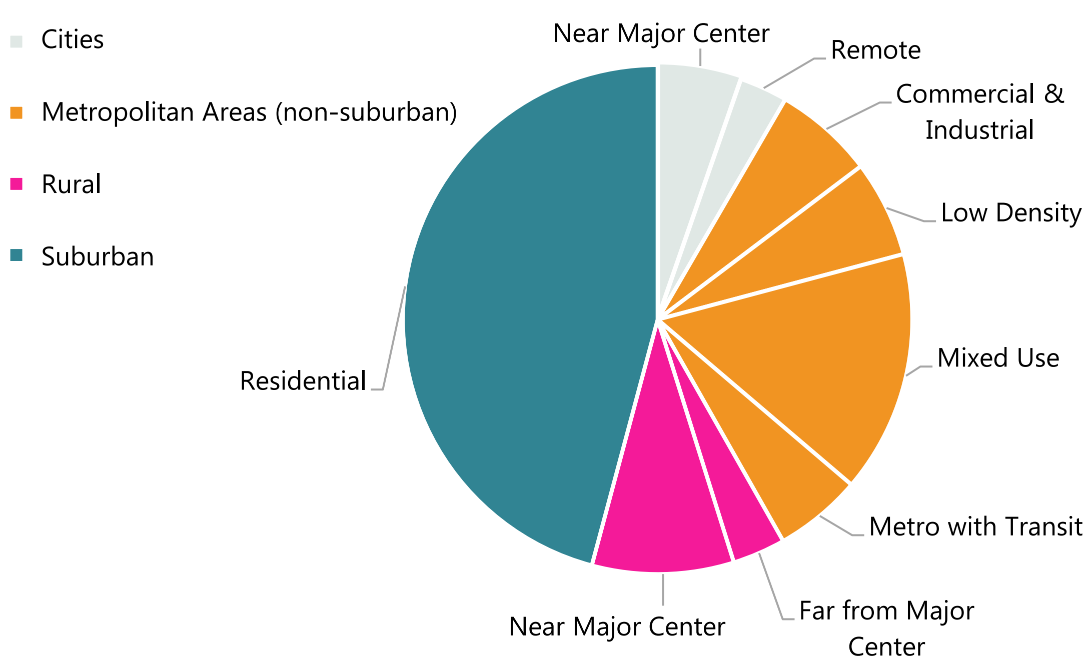


Table 1: Number of ZEVs per Geographic Place Type

Place Type		# of Evs
City	Near Major Center	1,872
	Remote	1,074
Metropolitan Areas	Commercial & Industrial	2,236
	Low Density	2,165
	Mixed Use	5,420
	Metro with Transit	1,959
Rural	Far from Major Center	1,186
	Near Major Center	3,172
Suburban	Residential	16,149

Access to EV charging in metropolitan areas is largely split between those living in single-family homes and those in multi-unit dwellings. Single-family homes that are prevalent in suburban and low-density urban areas provide the convenience of charging the vehicle at the owner's residence. Multi-unit dwelling residents, who are often located in city core and multi-use areas, generally do not have access to electric fuel at their place of residence and must rely on other fueling sources, such as a publicly available charger. These chargers are most prevalent in metropolitan and higher-density rural areas because it is more cost effective for charging companies to build in areas where there are sufficient electric vehicles to support the operational costs of the charger. Charging infrastructure in higher-density areas also tends to be more diverse, with slower charging options (e.g., Level 2) becoming more prevalent in high-traffic areas, such as shopping centers, and increasing availability of multiple fast-charging options (e.g., direct-current fast charger, or DCFCs) near places where people live, work, and play.

Unlike other place types in metropolitan areas, the downtown core city centers, particularly those located near to public transit, have lower adoption rates for ZEVs. There are a number of factors that may play a role, including easier access to public transit, lower car adoption in general, and the overall higher cost to park and garage a vehicle. Lack of dedicated EV parking, particularly for multi-unit dwellings and workplaces, may also contribute, because EV owners without access to charging at home or at work must consider public fueling costs and whether public EV chargers will be available at times that are convenient. This topic is addressed in more detail below as well as the section of the report discussing the availability and reliability of charging infrastructure. In this example from the Eugene-Springfield area, residential neighborhoods have the highest density of electric vehicles, with fewer EVs located in the downtown Eugene city center and the commercial/industrial areas.

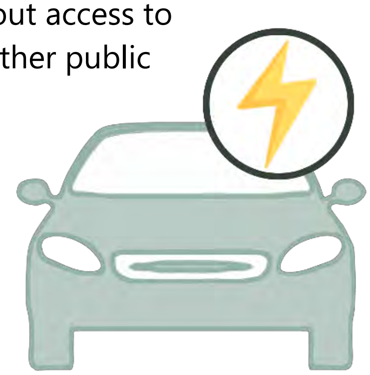
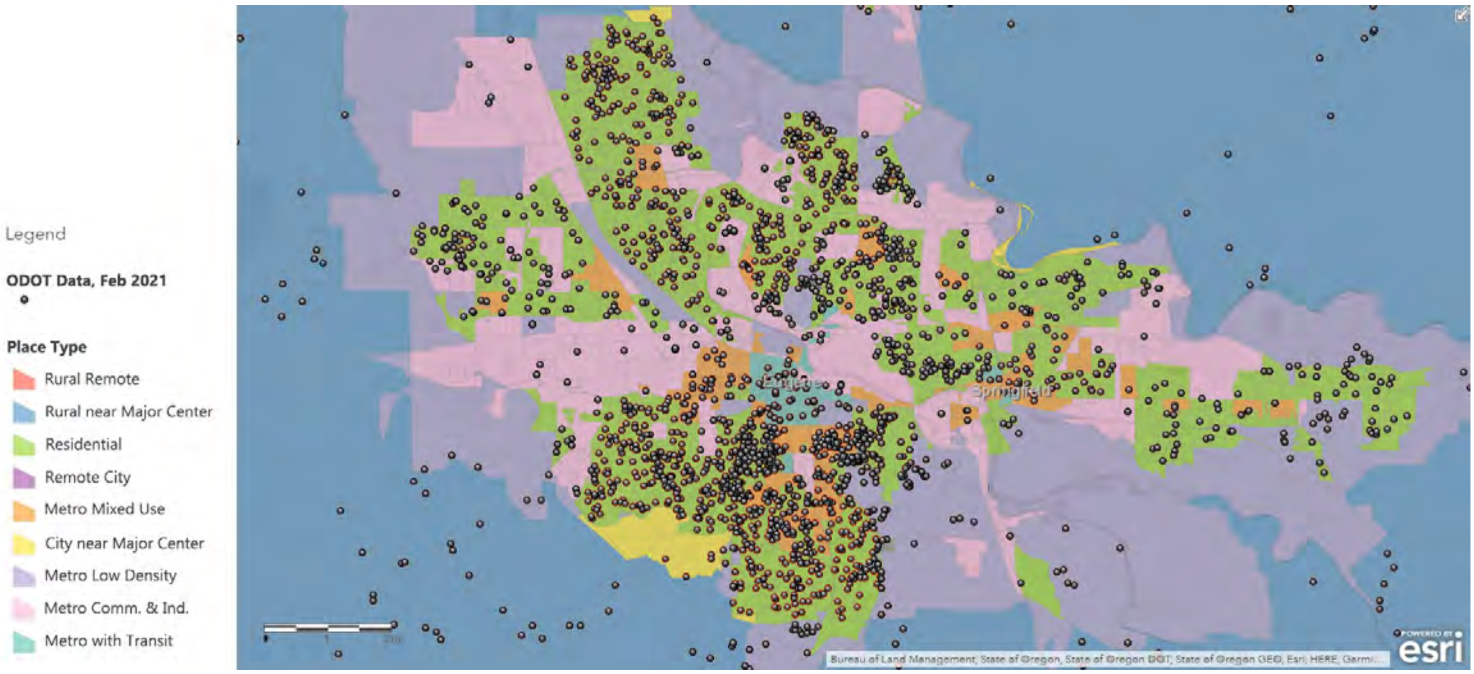


Figure 2: Distribution of EV Registration Addresses in the Eugene-Springfield Metropolitan Area



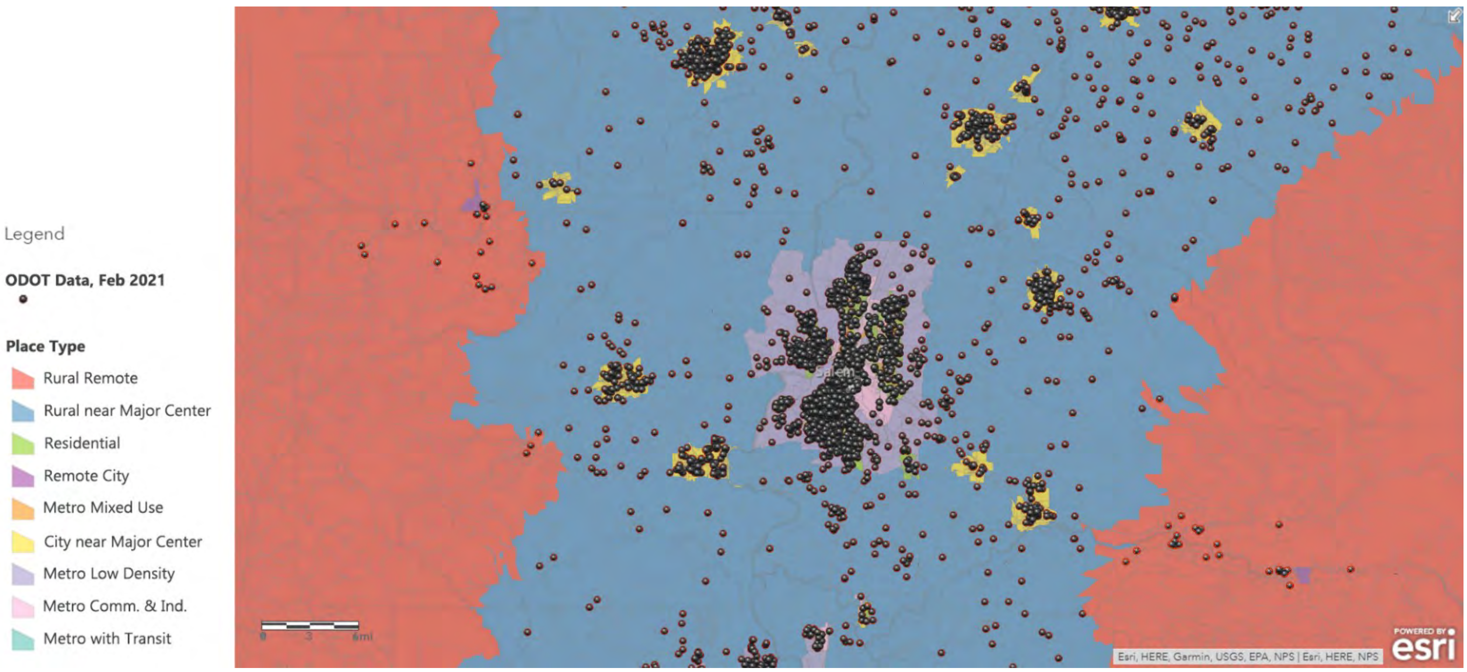
Nearly a third of Oregonians live in rural areas of the state. Just over 12 percent of EVs are registered in these areas, with rural communities near major cities[i] having nearly three times as many EVs as those further away from a city.[1] Figure 3 illustrates the distribution of ZEV adoption in central eastern Oregon (near the Idaho border), with the highest number of EVs located in Ontario and, to a lesser extent, the isolated towns of John Day and Burns-Hines on the left side of the map.

Figure 3: ZEV Registration Distributions in Rural and Isolated Towns[2]

[i]A rural area near a major city is defined as being within 15 miles of a 50,000 person or greater population center.

Rural areas near metropolitan areas have higher ZEV adoption, potentially because of the proximity of metropolitan charging infrastructure, which can help offset concerns about battery ranges needed to travel longer distances from more remote locations. In Figure 4 below, Salem and outlying towns Aumsville, Stayton, Independence, Dallas, McMinnville, Newberg, Canby, and Silverton may act as hubs for ZEVs registered in the nearby rural areas, shown in blue.

Figure 4: ZEV Registration Distributions in Metropolitan Salem and Nearby Rural Areas



The generally lower EV adoption rates in rural parts of Oregon may be due to a combination of factors, including ZEV range concerns, lack of preferred platforms like pickup trucks and large SUVs, lower average incomes, and the prevalence of colder weather in some areas that can reduce vehicle ranges. Although ZEVs manufactured today usually have ranges exceeding 200 miles, older model ZEVs will generally have lower vehicle ranges, and these vehicles may remain in use for over a decade. According to a series of annual surveys by Portland General Electric, range anxiety is still one of the highest-ranking consumer concerns.[2] (See the Awareness of ZEV Options and Benefits section of this report for more information.) Because many rural Oregonians need to travel further for jobs and services, the range of a vehicle and the ease of finding and using charging may limit adoption in these areas.

Charging needs for rural communities may also look different than for urban communities. While most rural Oregonians can access charging at home, travel distances may necessitate publicly available charging options. These chargers are likely most needed in towns and along major thoroughfares linking rural areas to the communities they rely on for jobs, goods, and services. The expense of installing DC fast chargers in these communities may be too great, though community travel needs might be met with much less expensive Level 2 chargers in places where residents tend to spend more time, such as at grocery stores, workplaces, and restaurants. In its 2020 Transportation Electrification Plan, Avista Corporation in Washington State found that Level 2 charging provided not only the benefit of supporting early adopters in these communities, it also provided benefits for the community at large by attracting visitors that support local businesses. [3]

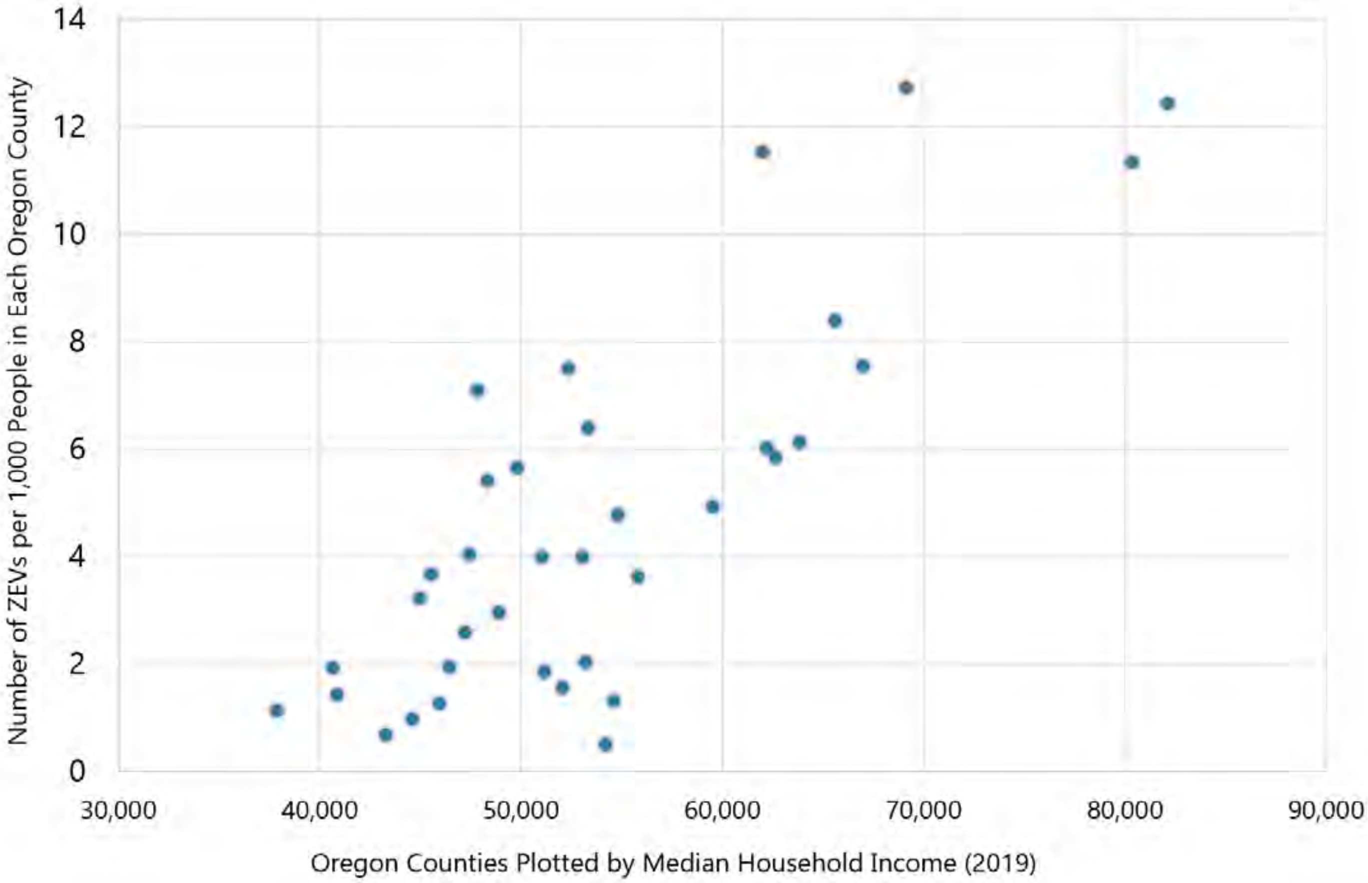
The available formats of vehicles may also be a factor in the lower adoption rates in rural Oregon, where the utility of the vehicle may be a necessary factor. Until the last few years, most electric vehicle options have been sedans. SUV models are now becoming more prevalent, and pickup truck models are anticipated in the next year (see the ZEV Platforms section of this report for more information). However, truck and SUV models are generally much more expensive than ZEV sedans, which may be a barrier for rural Oregonians, whose average incomes tend to be lower than those in many metropolitan areas (learn more in the Cost Differences section of this report).

Electric Vehicle Ownership by Income

There is a strong correlation between EV adoption and income, with higher income level areas showing the highest EV adoption levels. ZEV adoption is in the early stages of the new technology adoption curve (learn more in the ZEV Progress section of this report). Early adopters tend to have the income needed to afford the high costs of newly available technologies, and they are able and willing to accept the risks often associated with new technologies. Higher income is also associated with single-family home ownership, which often provides easy access to charging. Additionally, many of the early available ZEVs were luxury models catering to higher income buyers. Prior to the development of the Oregon ZEV rebate programs in 2018, the most universally available incentive was the federal ZEV tax credit. While this tax credit could be as much as $7,500, it was useful only to individuals with sufficient tax liability to use the credit. ZEV buyers with a smaller tax liability would receive little or no incentive to purchase a ZEV (learn more in the Cost Differences section of this report).

Electric Honda FIT, Photo source: greencarreports.com

Figure 5: Number of ZEVs per 1,000 People in Each Oregon County Compared to the Median Household Income of the County



EV adoption is largely occurring among Oregon families that make more than the state's median household income of $60,475 (five-year average data 2015-2019) in 2019 dollars, and most among families earning more than twice the median household income.[4] Oregon families making less than the median household income account for about 31 percent of registered EVs in Oregon. As the up-front cost of EVs continues to decrease and the availability of charging infrastructure increases, it is anticipated that higher adoption numbers will begin to rise among middle-income households.

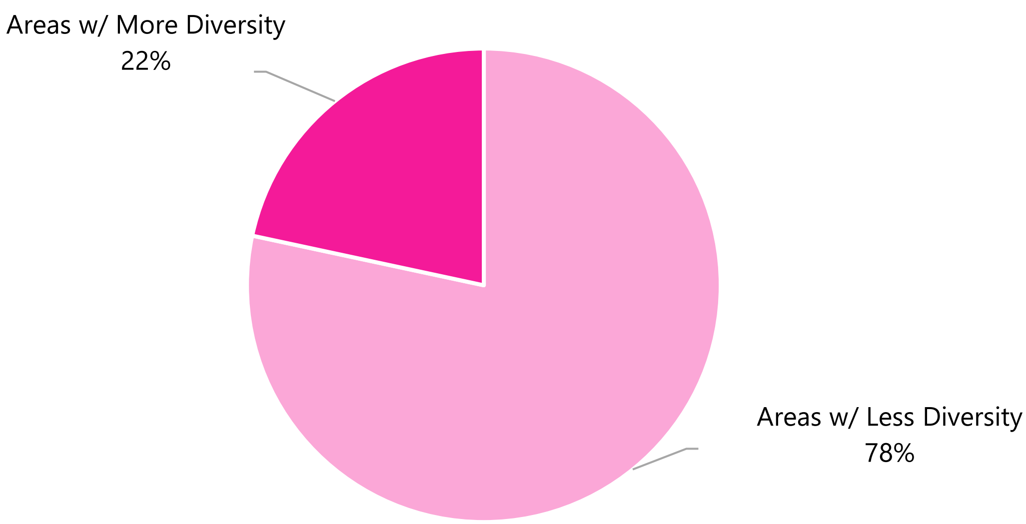
Greater availability of used EVs could also lead to higher EV adoption levels in Oregon. In 2020, nearly 75 percent of sales in the U.S. were used vehicles.[5] The lower cost of used vehicles compared to new makes the used market more accessible to many Oregonians, and the used market will likely play a vital role in supporting EV adoption for low- and moderate-income Oregonians by reducing their overall vehicle ownership costs.[6] For lower cost, or economy models, of new EVs, the International Council on Clean Transportation estimates that the upfront cost will reach price parity with the average vehicle purchased by a low-income household by 2029, further expanding the availability of EVs to a wider audience. [7]

Racial Diversity in Electric Vehicle Ownership

U.S. Census data indicates that statewide racial diversity is about 75 percent white and 25 percent non-white. Since we do not have owner-specific demographic data, to assess the racial diversity of EV owners, ODOE compared this percentage against the diversity of each of the 2,634 census block groups[8] in Oregon and labeled each block group as more or less diverse than the statewide average. The results presented here are based on whether EV registration addresses are located in block groups that are more or less diverse. This does not attribute individual EV registrations for a particular race, but rather whether the census block group where the EV is located is more or less diverse than the state as a whole.

78 percent of registered EV owners live in census block groups that are less diverse than the state as a whole.[9] While this percentage is higher than the statewide average of 75 percent, the data is not sufficient to demonstrate if a statistically significant disparity exists in adoption of EVs by non-white Oregonians. However, known historic racial inequities have led to lower-than-average income levels for many racial groups, and as described above, income level is strongly correlated with EV adoption.[10]

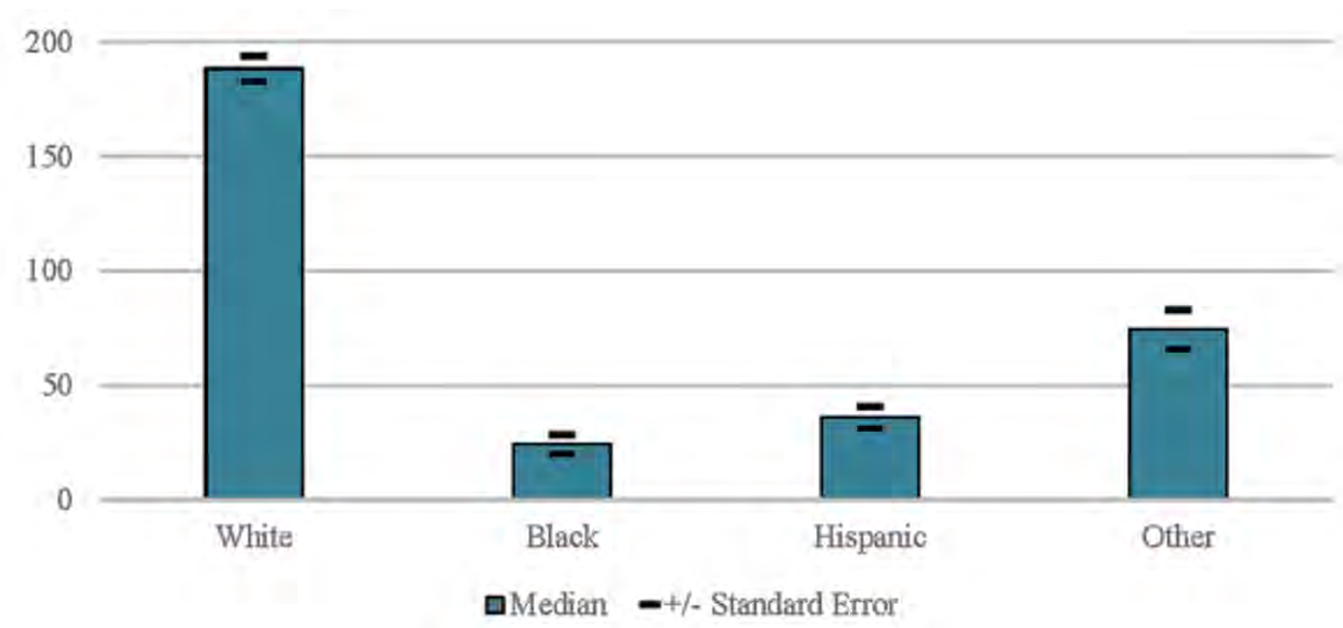
Figure 6: ZEV Registrations in Census Block Groups Differentiated by Race, Compared to Statewide Average[11]



Historical inequities coupled with higher up-front costs for ZEVs may play a role in reducing accessibility to EVs for non-white Oregonians. In addition to income gaps, there are significant and persistent wealth gaps between white and non-white Americans.[12] Income is the amount of money an individual receives on a regular basis, while wealth is the accumulation of money and assets over time. In its 2019 Survey of Consumer Finances, the Federal Reserve found that the median net worth of white Americans was eight times higher than Black Americans, and five times higher than Hispanics.[13] Much of this was created by historical racial inequities that have prevented non-white Americans from accumulating wealth that can be passed on to future generations. [14] [15]

As ZEV costs come down, more low-income and non-white Oregonians will be able to access the new technology. However, access to affordable and convenient fueling options may still be a barrier. Less non-white families own their own homes, meaning these Oregonians may live in multi-unit dwellings, where electric vehicle charging options are often limited. [16] As will be discussed in the next section, cost savings of driving an electric vehicle rely heavily on access to low-cost electricity for charging, which is most available through an EV-owner's ability to charge at home.

Figure 7: Median Net Worth by Race/Ethnicity, as Reported in the 2019 Survey of Consumer Finances[12]

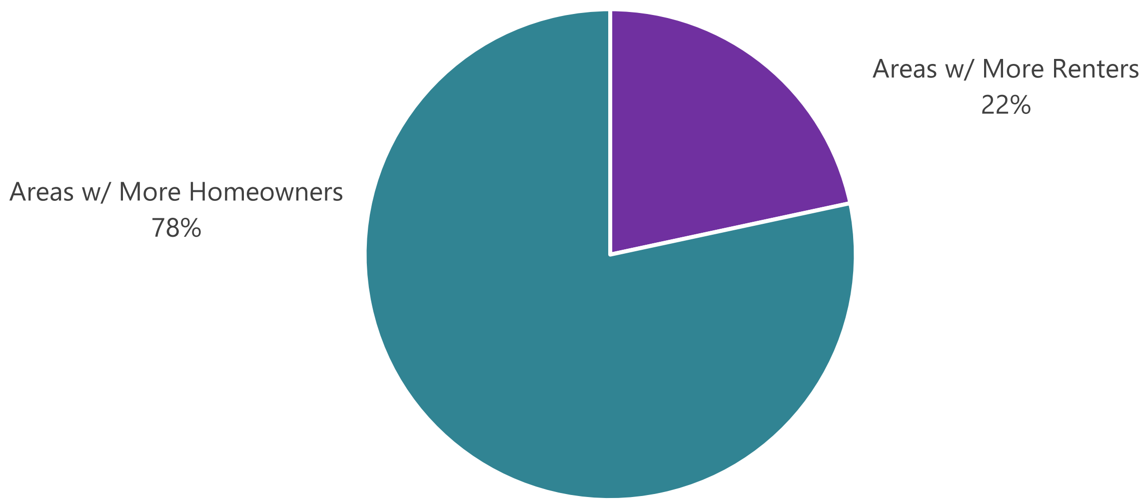


ZEV Ownership Differentiated by Housing Type

The type of housing a driver lives in can affect whether they can charge their vehicles at home, how convenient it is to charge, and how much it costs to fuel their vehicles. In a customer survey of over 600 residential Pacific Power customers, over 70 percent of respondents indicated that the ability to charge at home was a motivating factor to drive an electric vehicle.[17] In Portland General Electric's survey of over 1,000 residential customers, 73 percent indicated being able to charge at home was important to them, and this percentage increased to 87 percent among respondents who were *intending* to buy an electric vehicle.[18]

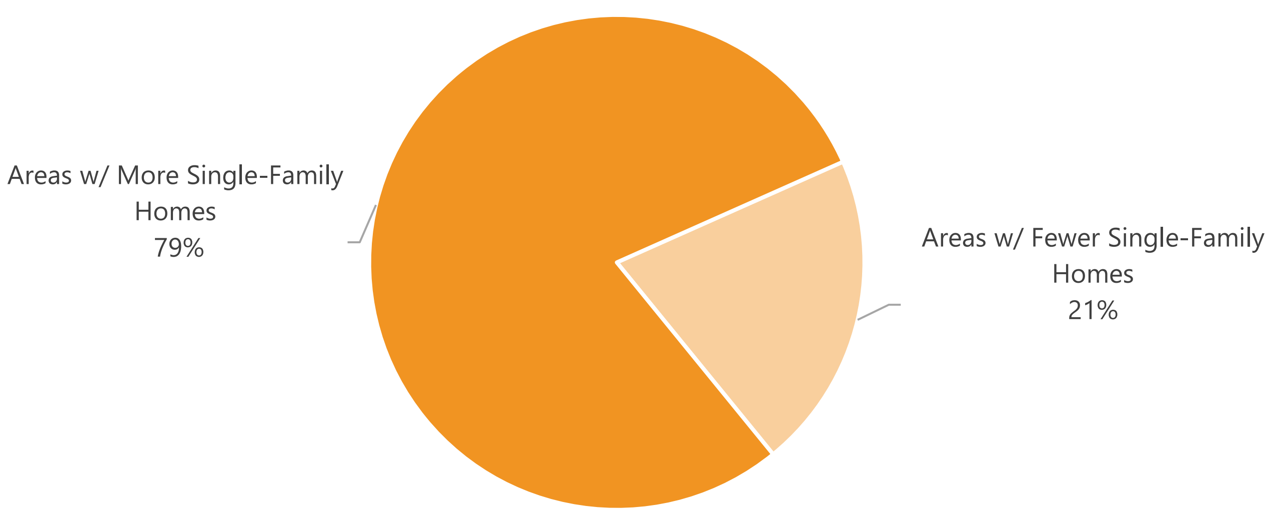
Seventy-eight percent of EVs are registered in census block groups where residents predominantly own their own home. In Oregon, roughly 65 percent of households are owner-occupied.[19] However, not all single-family homeowners have access to electric vehicle charging at home. Some single-family homes, particularly in the Portland area, have no driveways or garages, limiting access to electrical outlets needed to charge the vehicle.

Figure 8: EV Registrations in Census Block Group Areas Differentiated by Homeowners and Renters[20]



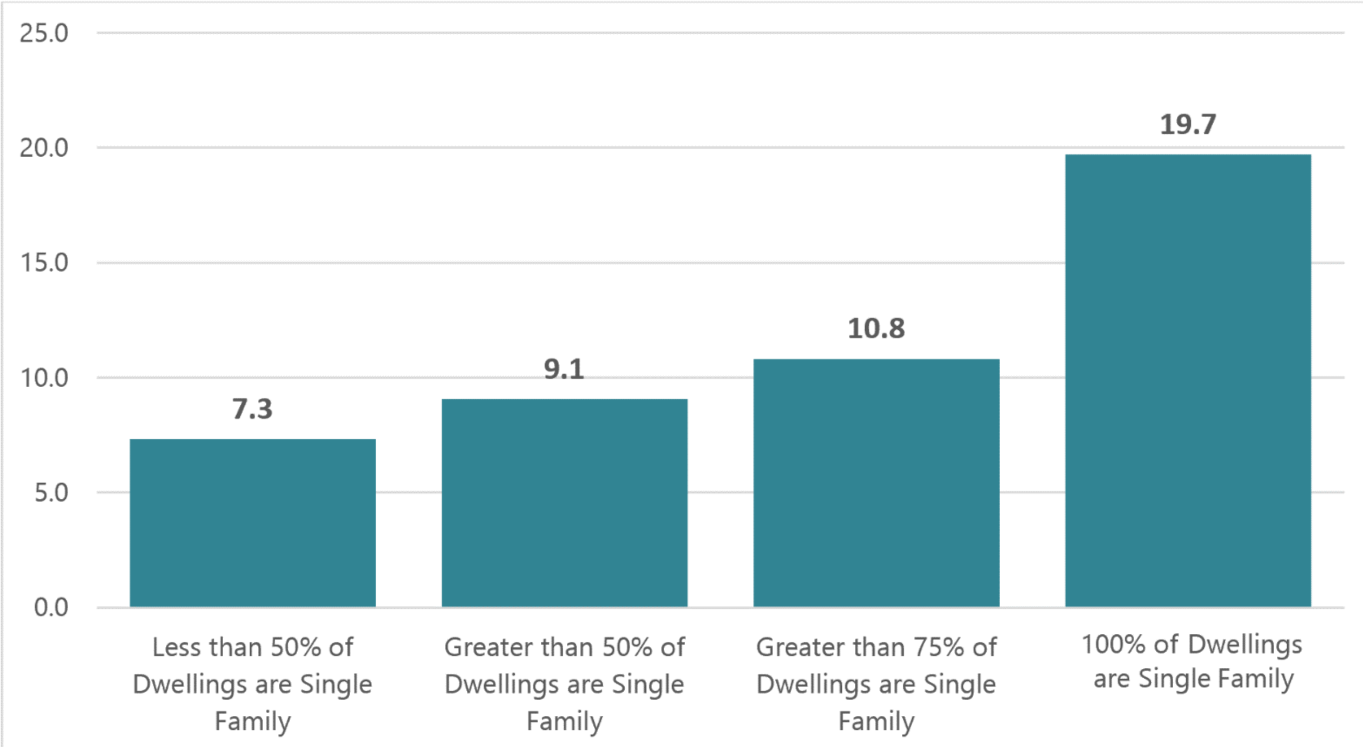
Whether they rent or own, the thirty-seven percent of Oregonians who reside in multi-unit dwellings have more limited options for EV charging than those in single-family homes, because chargers and outlets are not standard in designated parking areas.[21] Nearly 80 percent of EVs are registered in areas where most residences are single-family homes as compared to multi-unit dwellings, such as apartments, duplexes, and condominiums.[20]

Figure 9: EV Registrations in Census Block groups Differentiated by Single-Family Homes Compared to Multi-Unit Dwellings[20]



The adoption rate for ZEVs in areas where more than 75 percent of residences are single-family homes is twice that of other areas, with the highest adoption rate in areas with only single-family homes.[22] Much of this may be due to the costs and inconveniences of keeping an EV fueled for multi-unit dwelling residents.

Figure 10: ZEVs Registered per 1,000 Oregonians, Compared to Dwelling Type[22]



Generally, living in a single-family home means lower fueling costs through the home's residential electricity service (learn more in the Cost Differences section of this report). It can also offer fueling convenience for EV owners. Because workplace charging is still relatively uncommon, multi-unit dwelling owners, particularly in metropolitan areas of the state, must often rely on publicly available chargers.[23] Where public charging infrastructure is the sole charging resource for an owner, it is very likely that this will require a higher time investment from the driver to keep the vehicle fueled compared to a gasoline car. The owner will need to schedule time to take the vehicle to be charged, which may be challenging if the charger is heavily used, something that may be more likely to occur in high-density living areas. Further, the owner must wait with the vehicle while it charges or be available to retrieve the vehicle when fueling is complete to ensure that the charger is available for other customers.

The cost of charging infrastructure also tends to be significantly less for people living in single-family homes than multi-unit dwellings. Most ZEVs can be charged using a standard 100 V outlet. Provided this rate of charging can meet a driver's needs, there is no need for a driver to invest in additional charging equipment. Owners wishing to add Level 2 chargers on average pay less than $1,000 if no additional wiring is needed in the home, or up to $1,500 if wiring and a charger are needed. Comparatively, multi-unit dwelling owners face several barriers to install EV chargers on their properties. Commercial Level 2 charger costs range from $1,000 to $4,000 per charger, and the cost could be significantly more if major electrical upgrades are needed.[24] Building owners will also need to manage maintenance and repairs on any chargers once installed. While multi-unit dwellings may have some 110 V outlets available in their parking areas, they must also consider how to manage access to the charger and reimbursements from tenants using the electric fuel to charge their vehicles.

ZEV Ownership Differentiated by Number of Vehicles Per Household

Households with more than one registered vehicle account for over 75 percent of EV registrations.[25] Multi-vehicle households also tend to be higher income, which may indicate this data is a reflection of higher rate of EV adoption with higher household income.[26] This may also point to a general perception that there is less risk in adopting an electric vehicle when a second gas-powered vehicle is also available to supplement driving needs.

While the average range of an electric vehicle has increased substantially over time, range anxiety is still a concern for many non-EV drivers.[27] Even with ranges greater than 200 miles, a recent J.D. Power survey indicated that the number one factor in deciding which vehicle to purchase was the vehicle range.[28] In addition, the average age of a vehicle in the U.S. is 12 years, meaning many early EV models may still be in use.[29] The 2011 Nissan Leaf had an EPA estimated range of 74 miles, which might meet daily work and errand travel needs, but would be time-consuming for long-distance driving. Potentially some older, lower range models might not be able to access more remote areas of the state. Ready access to a second vehicle that could accommodate longer road trips or other travel and utility needs may play a role enabling non-EV owners to purchase an EV.

Conclusion

EV ownership in Oregon occurs primarily in metropolitan areas with more single-family housing. Further, EV ownership correlates strongly with household income, and EVs are often found in households with more than one registered vehicle. This is likely because higher-income households can more easily afford the higher up-front costs to purchase an EV, coupled with ready access to fueling when living in a single-family home. Oregon's two EV rebate programs play a critical role in reducing the up-front cost of an EV for Oregonians, particularly for those who have little or no tax liability and are therefore unable to take advantage of the federal tax credit. With EV prices declining, Oregon's Charge Ahead Rebate program increasing to $5,000 for a new or *used* vehicle, and EV ranges increasing, the biggest barrier for many Oregonians may be access to low-cost charging.

ZEV adoption is much lower among people who primarily live in multi-unit dwellings. More low-income Oregonians live in multi-unit dwellings, and because they are less likely to be able to use their home electricity to fuel their vehicles, they have fewer options for low-cost electric fuel. Providing EV charging in multi-unit dwellings can cost between $1,000 and $4,000 per charger, or more where significant electrical upgrades are necessary, whereas those living in single-family homes can charge their vehicles without any additional costs to provide a charger. Without state programs or policies to address the costs to provide chargers for multi-unit dwelling residents or owners, it is unlikely that EV adoption will be a viable option for these Oregonians.

While 32 percent of Oregonians live in rural parts of the state, only 12 percent of EVs are registered in rural areas, which may be due to a combination of factors, including model availability and EV range concerns.[30] EV charger availability is a contributing factor to range anxiety, particularly in rural parts of the state where there are fewer public charging options. Although ranges for EVs manufactured today often exceed 200 miles, national surveys continue to indicate range anxiety as a top concern for non-EV owners considering buying an EV. EV ranges are continuing to increase on newer models of EVs, and as the market matures, more used EVs with relatively lower cost will also have longer ranges. Nevertheless, rural Oregonians may need more publicly available electric fueling options to feel confident that EVs can meet their transportation needs.

Historic and current systems of discrimination have created inequities in resources, power, and opportunities for some Oregonians and communities. [31] Policies designed to enable equitable access to EVs and electric fuel for lower-income Oregonians should address the additional costs needed to support charging infrastructure.

Electric vehicle adoption can also address historic inequities for underserved communities near busy roadways and thoroughfares. Low-income and non-white communities living near roadways have an increased risk of lung and heart disease and premature death from higher exposure rates to particulate matter that is released from the combustion of fossil fuels.[32] Because EVs have zero tailpipe emissions,[ii] operating these vehicles, especially in these neighborhoods, can improve local air quality and would have immediate positive effects on the overall health of these communities.[33] [34]

An electric vehicle workshop at The Environmental Center, Bend, Ore., Photo source: envirocenter.org

[ii] Excluding any emissions resulting from operating the internal combustion engine of a plug-in hybrid vehicle.

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Freightliner eCascadia charges at Duck Island charging station in Portland, Ore., Photo credit: FleetOwner.com

This section discusses progress toward electrification of all fossil-based transportation modes, and outlines ZEVs that are currently available for purchase in all market segments – from passenger vehicles to large trucks to transit and school buses.

ZEV Platforms Available in All Sectors

Availability of Zero Emission Vehicles

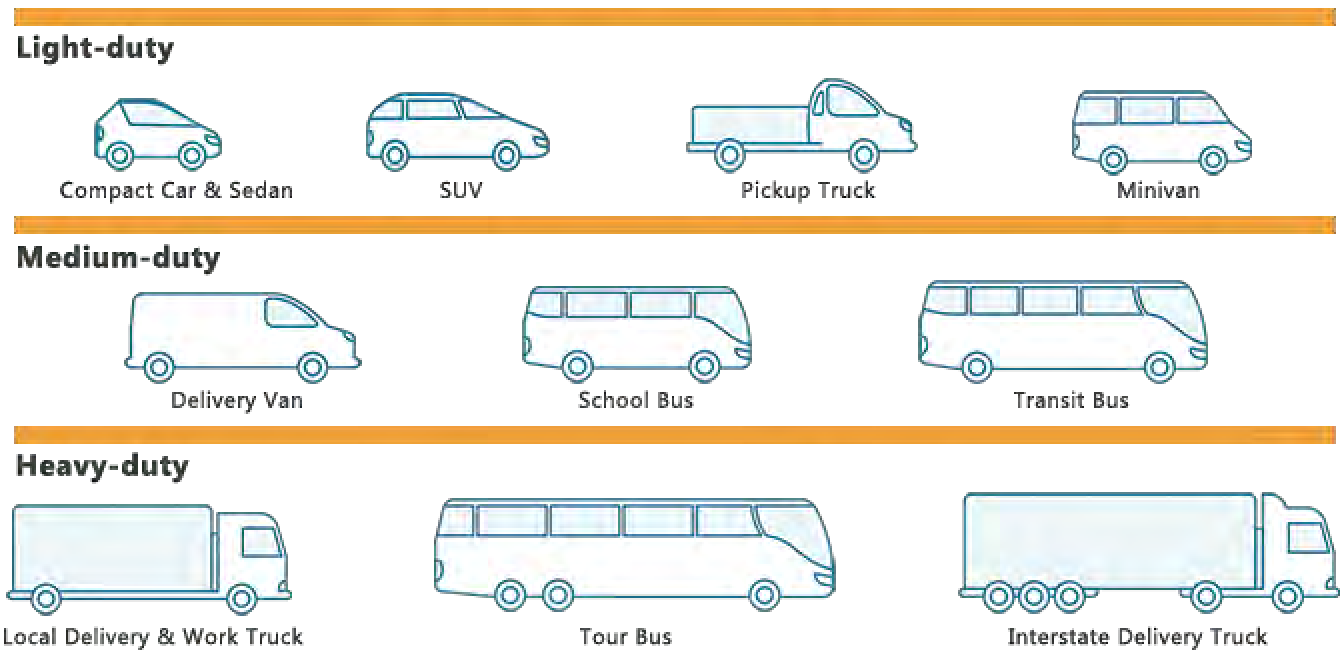
Zero-emission vehicles are becoming more popular, with ZEVs now making up 1 percent of total vehicles in Oregon. More than a dozen models of electric passenger vehicles are now available for purchase, and an electric pickup truck model is expected in late 2021 or 2022. Electric formats of transit and school buses are operating in several parts of Oregon, including Portland, Beaverton, Gresham, Eugene-Springfield, and in Josephine County. There are many models of electric micromobility transportation options, including e-bikes and e-scooters, which are often used in the state's urban areas to help people more easily make short trips in their neighborhoods or get to and from transit options. In the near future, electric heavy-duty freight trucks may also be commercially available. Beyond ZEVs on Oregon roads, more and more companies are using electric forklifts, gantry cranes, and some construction equipment for industrial and commercial business needs.

Table 1: Different Modes of Transportation[1]

On-Road	Non-Road	Aviation	Marine	Rail
Passenger vehicles	Micromobility, such as bikes, scooters, and skateboards	Passenger planes	Ships	Passenger Rail
Motorcycles, 3-wheeled on-road vehicles (Fun Utility Vehicles or FUVs), mopeds	Agricultural Equipment and Vehicles, such as tractors and combines	Light aircraft	Tugboats	Freight Rail
Recreational Vehicles (RVs)	Forestry Equipment, such as harvesters, delimbers and log loaders	Delivery planes	Small craft	Line-haul and Switch locomotives
Delivery Vans	Construction equipment, such pavers, forklifts, and backhoes	Helicopters	Ferries	
Trucks	Warehouse Equipment, such as forklifts and gantry cranes			
Transit and School Buses	Port equipment, such as airport service equipment and cranes			
	Recreational Vehicles: All-terrain vehicles (ATVs), dirt bikes, and snowmobiles.			

This section of the report will focus on which vehicle platforms are available in an electric format across the entire transportation sector. Describing vehicle availability in this rapidly-evolving ZEV market requires not only addressing the inventory of available models but also their stage of commercialization and whether a given model can accommodate different vehicle use cases. For this reason, there are two possible definitions of *available* as it relates to ZEVs: 1) "technically available" – ZEVs that are being produced but not readily available in the car market and 2) "practically available" – ZEVs that are readily available to the car market. For example, although fuel cell electric vehicles (hydrogen) are technically available to the market, because they are not sold in Oregon they are not practically available. This report will focus on practical availability but will provide some information on technical availability, particularly for options that are approaching commercial availability.

Types of Vehicles by Sector



Light-Duty

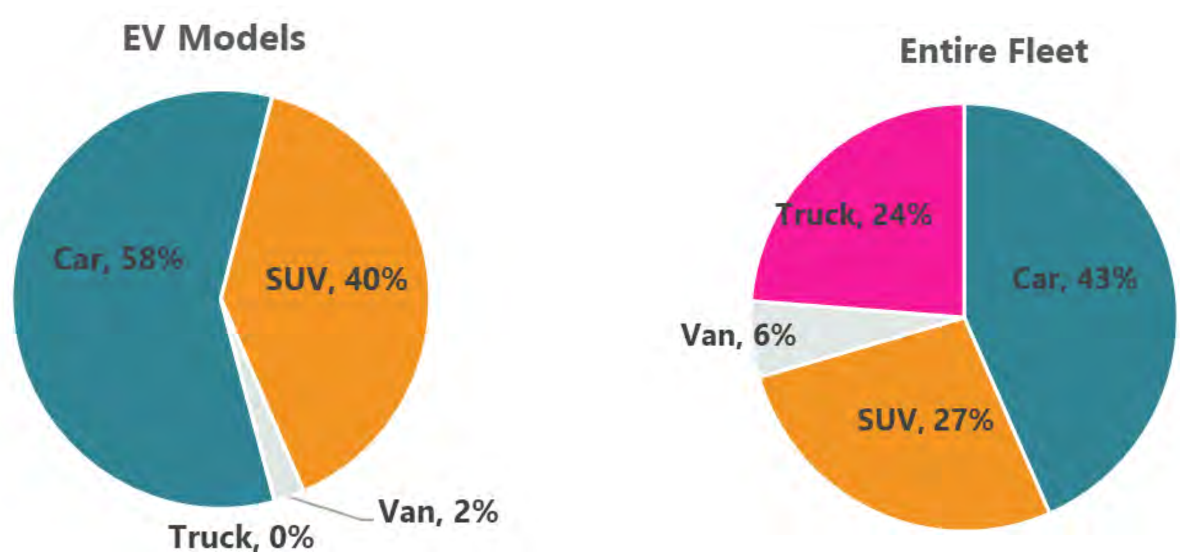
Oregon adopted the California ZEV standard in 2006, which ensures a certain number of ZEVs are delivered into California and other ZEV states for sale. The Oregon Department of Environmental Quality administers Oregon's program, and tracks the percentage of the passenger cars and light-duty trucks delivered by each manufacturer.[2] The percentages can be met using a combination of actual deliveries and credits purchased from other manufacturers (known as Transfer ZEVs or TZEVs). Delivery requirements are set to increase on an annual basis from 2018 to 2025, topping out at 22 percent. The program includes a minimum number of ZEVs to be physically delivered as well as a limit on the number TZEVs that can be used to meet the requirement.[3]

Table 2: EV Program Vehicle Delivery Requirements, as Adopted in OAR 340-257-0080

Model Years	Total ZEV Percent Requirement	Minimum ZEV Floor	TZEVs
2018	4.5%	2.0%	2.5%
2019	7.0%	4.0%	3.0%
2020	9.5%	6.0%	3.5%
2021	12.0%	8.0%	4.0%
2022	14.5%	10.0%	4.5%
2023	17.0%	12.0%	5.0%
2024	19.5%	14.0%	5.5%
2025	22.0%	16.0%	6.0%

Due in part to Oregon's ZEV program, light-duty ZEV model availability in this sector is robust and growing, with 27 makes and 43 models currently registered in the state.[4] Most available models are sedans, with a more limited selection of SUVs and vans. There are currently no pickup truck models commercially available for purchase, but several manufacturers are accepting orders for vehicles anticipated to be delivered beginning in late 2021 or 2022. Of the 2020 and 2021 model year electric light-duty vehicles registered in Oregon, 58 percent are cars, 40 percent are SUVs, and 2 percent are vans. This is similar to the breakdown of all registered vehicles (internal combustion and ZEVs) excluding pickup trucks, which account for nearly a quarter of registrations in the total light-duty fleet.

Figure 1: Light-Duty Vehicle Platforms as a Percentage of the EV Fleet Compared to the Entire Fleet



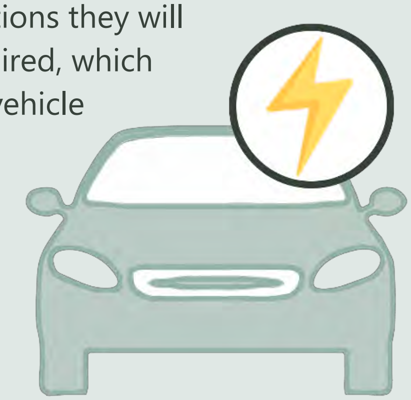
Tesla model vehicles have been and remain the most popular choice of ZEVs, accounting for half of the top 10 ZEV models registered in Oregon.

Table 3: Top 2020 and 2021 Model Year Light-Duty Vehicles Registered in Oregon

Make	Model	# Registered	Type	Format
Tesla	Model Y	1,801	BEV	Car
Tesla	Model 3	1,646	BEV	Car
Chevrolet	Bolt	782	BEV	Car
Toyota	Prius Prime	605	PHEV	Car
Nissan	Leaf	507	BEV	SUV
Tesla	Model X	371	BEV	SUV
Hyundai	Kona	272	BEV	SUV
Hyundai	Ioniq	242	BEV or PHEV	Car
Toyota	RAV4 Prime	210	PHEV	SUV
Chrysler	Pacifica	206	PHEV	Van

Commitments from most of the major passenger vehicle manufacturers indicate that the availability of light-duty makes and models will grow significantly over the next decade. Two years ago, few mainstream auto manufacturers were publicizing information on plans to electrify their vehicles, but today nearly all major manufacturers have announced support for ZEVs and many have given specific dates for the release of future ZEV models or even plans to go fully electric.

Across all vehicle types, there is a great deal of variability in how electric vehicles are manufactured and sold. Some manufacturers are building their ZEVs by hand and others are mass manufactured and mass marketed through existing and recognized dealership networks. Some ZEVs can be reserved by interested buyers in advance of the vehicle being commercially available. In these instances, manufacturers release information on the vehicle they are developing and take online orders from interested customers. This provides the manufacturer with some level of assurance on vehicle sales and information on the numbers of different vehicle options they will need to produce. A down payment from the customer is usually required, which provides some amount of cash flow to the manufacturer to support vehicle production. In return, customers are provided a guaranteed spot in line to receive a vehicle that meets their specifications once available. Apart from pre-orders, some businesses may be foregoing the in-person car buying experience altogether – where finding and financing a vehicle are completed online and the new or used vehicle is delivered directly to the customer.[5]



On August 5, 2021 President Biden signed an executive order calling for half of new passenger car sales to be battery, fuel cells, or plug-in hybrid electric by the end of the decade. The executive order is part of a set of initiatives to cut climate-warming emissions from the auto sector, including:[67]

- installing a national network of electric vehicle charging stations,
- delivering point-of-sale consumer incentives,
- financing expansion of the auto manufacturing supply chain, and
- maintaining our competitive edge by developing new clean energy technologies.

Also on August 5, three of the nation's major automakers — Ford, GM and Stellantis (formerly Fiat Chrysler) announced that 40 to 50 percent of their annual U.S. sales would be zero-emission vehicles by 2030. In their joint statement, the automakers said, "Our recent product, technology, and investment announcements highlight our collective commitment to be leaders in the U.S. transition to electric vehicles."[8]

Because pickup trucks make up nearly a quarter of Oregon's passenger vehicles, commercial availability of electric pickups is expected to boost ZEV adoption. Electrification is a hot topic across all vehicle sectors, and there is a great deal of anticipation for an electric pickup. Many electric pickup trucks were expected to be available in 2021, but production has been delayed. Microchip shortages due to the effects of the COVID-19 pandemic have slowed all vehicle production, including gasoline-powered vehicles. Startup companies Rivian, Bollinger, and Lordstown are expected to have vehicles in production by 2022. Established manufacturers such as Tesla, Ford, GM, and Nissan have plans to release electric versions of pickup trucks in the next few years.[9]

A variety of electric pick-up trucks are in development . Photo source: autoblog.com

How Delays in Microchip Production Affect Car Deliveries

In early 2020 as global responses to the COVID-19 pandemic led to steep declines in auto sales, many manufacturers shuttered plants. With production anticipated to stay low, many companies reduced their future orders for the microchips needed to operate the electronic equipment in the vehicles. At the same time, an uptick in people working from home led to increased demand for microchips in computers, tablets, and cell phones. Despite the ongoing effects of the pandemic, auto sales rebounded in the fall 2020. Many manufacturers reinstated orders for microchips, but demand now exceeded supply. Chip manufacturers are working their way through the backlog, but many manufacturers have vehicles sitting in lots – some of them EVs – waiting only for the quarter-sized chip to be ready for sale.

New Ford F-150 pickup trucks sit on a lot in Detroit, MI, waiting for semiconductors, April 15, 2021.

Source: https://www.freep.com/story/money/cars/2021/06/15/car-chip-shortage-2021/7688773002/

Other manufacturers have made signals that they are considering electrification. Stellantis, which owns the Alfa Romeo, Chrysler, Dodge, Fiat, Jeep, Maserati, and Ram truck brands, declared that the company is committed to offering fully electric vehicles. Subaru announced in early 2021 that it would offer some form of electrification on all its models by mid-decade, and Kia has stated it wants to sell 1.6 million "eco-friendly vehicles" globally by the end of the decade. Mazda says it plans to introduce an EV-only platform within the next few years. Mercedes announced that beginning in 2025 "where market conditions allow," all newly launched vehicle platforms will be electric. Toyota, a leader in providing hybrid engines in vehicles, has announced goals around producing more hydrogen fuel-cell-powered cars.

Fuel Cell Electric Vehicles, sometimes referred to as hydrogen vehicles, are also classified as ZEVs and are not yet available in Oregon. Unlike electric vehicles that can be fueled by electricity, which is nearly ubiquitous in homes and businesses, hydrogen-fueled vehicles require fueling infrastructure similar to the gasoline and diesel stations used to fuel internal combustion vehicles. The costs to create, transport, store, and deliver the fuel are high, and because hydrogen has less energy per volume than many other forms of transportation energy, the fuel must also be liquified and compressed. Hydrogen can be transported to fueling sites via pipelines or by refrigerated truck.[10] There are currently no hydrogen-only pipelines to deliver the fuel into Oregon, therefore this fuel would need to be delivered by truck.[11]

No hydrogen fueling stations for light-, medium-, or heavy-duty vehicles currently exist in Oregon. The West Coast Collaborative, a public-private partnership of governments, academia, non-profits, and businesses working to reduce diesel emissions in the western U.S., is currently working with the U.S. Environmental Protection Agency to advance alternative fuel infrastructure along I-5 and other major roadways in Oregon, California, and Washington. In its 2020 *Medium- and Heavy-Duty Alternative Fueling Infrastructure Development Plan*, the WCC's Alternative Fuel Infrastructure Corridor Coalition indicated several barriers to expansion of a hydrogen fueling network, including the high cost to develop stations, the higher cost of hydrogen fuel relative to gasoline and diesel, and uncertainties in fuel supply and demand.[12]

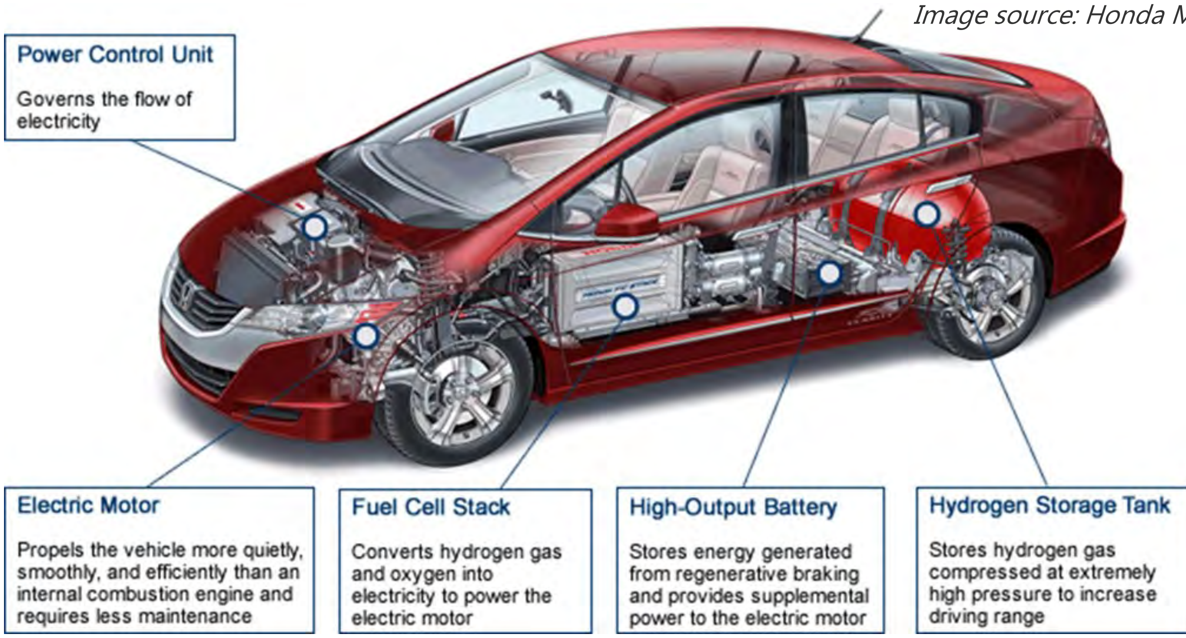
Where are the Hydrogen Vehicles?

Although Oregon currently has no authorized retail dealers for hydrogen fuel-cell ZEVs, models are available in California where hydrogen fueling infrastructure is available. Fuel Cell Electric Vehicle models available include:

- o Honda Clarity
- o Hyundai Nexo
- o Toyota Mirai

Inside a Hydrogen Vehicle

Image source: Honda Motor Corp.



Energy 101

While most hydrogen today is produced using fuels like natural gas, there is increased interest in producing renewable hydrogen by using renewable electricity to power an electrolyzer. To learn more about hydrogen and renewable hydrogen, see ODOE's 2020 Biennial Energy Report.

Electric Micromobility

Man on hands-free personal mobility device.

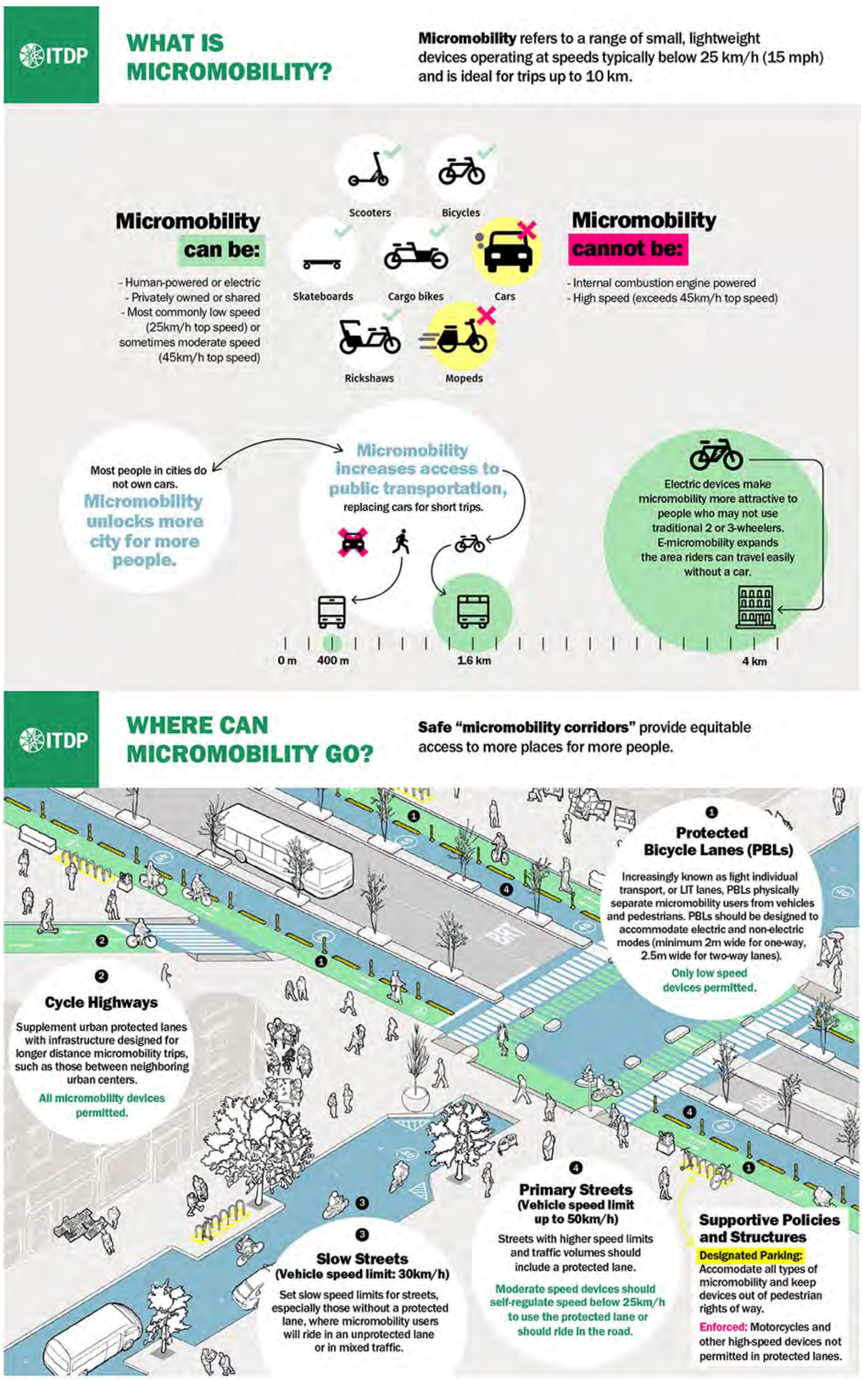
Micromobility comprises various personal mobility devices, including bicycles, scooters, skateboards, and one-wheels that provide transportation across relatively short distances – usually within a town or city. As cities become more congested, these lighter and more nimble vehicles have advantages in terms of practicality, being a valuable resource for commuting, local deliveries, or addressing the last mile between specific locations and public transit services. The Oregon Department of Transportation's Transportation Electrification Infrastructure Needs Assessment (TEINA) Study estimates micromobility to grow from three percent of urban trips in 2020 up to 25 percent in 2035, with more modest growth in rural areas.[13] Some major cities in the U.S. are closing stretches of city roads to cars, enabling more pedestrian- and micromobility-friendly environments.[14]

Micromobility modes such as bikes and scooters have electric versions, which enable faster transport and energy assistance for climbing hills or riding longer distances. Sales of e-bikes in the U.S. have risen from a total of about 185,000 in 2013 to over 400,000 per week in 2019.[15]

Row of e-scooters, Portland, Ore.

Most e-micromobility options are widely available through online and retail outlets, including bikes, scooters, and mopeds. E-bikes are more expensive than standard bikes – over half of e-bikes available in the U.S. are between $1,000 and $2,000, with only 1 percent priced under $1,000.[16] This is less than the cost of a passenger vehicle, and since most e-bike batteries are removed for charging, reduces the need for specifically identified charging spaces for bikes.[17]

Micromobility sharing programs are gaining momentum in many urban areas, including the Portland and Eugene metropolitan areas. Scooter ride sharing programs are almost exclusively electric versions. At least four e-scooter programs operate in the Portland metro area, including Spin, Bolt, Bird, and Lime.[18] Many bike sharing programs use only standard bike fleets, but e-bikes are becoming more common. Biketown, in partnership with Lyft, operates a 1,000 e-bike sharing program in Portland.[19]



Micromobility can be:

- Human powered or electric
- Privately owned or shared
- Most commonly low speed (16 mph top speed) or sometimes moderate speed (28 mph top speed)

Micromobility cannot be:

- Internal combustion engine powered
- High speed (exceeds 28 mph top speed)

Defining Micromobility - Institute for Transportation and Development Policy (itdp.org)

Medium- and Heavy-Duty Vehicles

The operational cycles of many medium- and heavy-duty vehicles have posed challenges to widespread electrification. Some of these vehicles, such as long-haul semis, have range and uptime needs that can be challenging to meet with batteries. There are also concerns that the weight and volume of batteries significantly reduces the cargo capacity for medium- and heavy-duty vehicles.[20] It is likely that the medium- and heavy-duty fleet will be a mix of full battery electric vehicles and hydrogen fuel cell electric vehicles in the future. More research and development can improve the efficiency and cost effectiveness for both battery and fuel cell technology, and the choice of fuel is highly dependent on the vehicle use case. Volvo Group's Chief Technology Officer has suggested that the "sweet spot" for transportation electrification will be different for each technology, with battery electric working best for lighter applications like local and regional distribution and hydrogen fuel cells for transcontinental transportation.[21]

Determining Models of Available ZEV Medium- and Heavy-Duty Vehicles

Table 4: U.S. Department of Commerce's 2002[i] Vehicle Inventory and Use Survey: Internal Combustion Engine Medium- and Heavy-Duty Body Types Listed[22]

Reporting on the available ZEV models of medium- and heavy-duty vehicles is not as straight-forward as with light-duty vehicles for a few reasons. First, medium- and heavy-duty vehicles are built in a wide array of customizable configurations to meet different vehicle use cases, as illustrated in Table 2. There are ZEV versions of some of these types of vehicles, but it is difficult to determine whether a ZEV version of a vehicle is available for every vehicle use case. And even when a ZEV model is available, it may not be appropriate for all end uses. For example, while electric transit buses exist and are in operation in Oregon today, some routes or territories may not yet be suitable for an electric bus – such as routes with significant elevation change.

Body Type Code	Description	% of Class 3-8 (2002)	Fleet Class*
1	Pickup	3.8%	G, P, S
5	Armored	0.1%	S
6	Beverage	0.8%	G
7	Concrete mixer	1.5%	S
8	Concrete pumper	0.1%	S
9	Crane	0.3%	S
10	Curtainside	0.1%	G
11	Dump	12.9%	S
12	Flatbed, stake, platform, etc.	15.4%	G, S
13	Low boy	0.1%	G
14	Pole, logging, pulpwood, or pipe	0.3%	G
15	Service, utility	4.0%	S
16	Service, other	3.1%	S
17	Street sweeper	0.1%	S
18	Tank, dry bulk	0.5%	G
19	Tank, liquids or gases	3.2%	G,S
20	Tow/Wrecker	2.0%	S
21	Trash, garbage, or recycling	1.8%	S
22	Vacuum	0.3%	S
23	Van, basic enclosed	10.0%	G
24	Van, insulated non-refrigerated	0.4%	G
25	Van, insulated refrigerated	1.6%	G
26	Van, open top	2.8%	G
27	Van, step, walk-in, or multistop	5.6%	G
28	Van, other	1.1%	G
99	Other not elsewhere classified	0.0%	NA
blank	Truck Tractor	27.4%	G

*Fleet class assigned by Energetics: G – goods movement, P – people movement, S – service

Source: *VIUS 2002 Microdata Data Dictionary* (U.S. DOC, 2004).

[i] 2002 is the most recent year for which there is data available from the U.S. Department of Commerce's Vehicle Inventory and Use Survey (VIUS). The next VIUS will be conducted in 2022 with a planned release of results in 2023.

Second, given that medium- and heavy-duty ZEVs are not as commercially developed as light-duty ZEVs, it is not always clear what is available for *immediate* delivery versus what is available to order for some future delivery date. CALSTART, a nonprofit organization that supports the development of a high-tech, clean transportation system, has developed an inventory of medium- and heavy-duty ZEVs. As part of this work, CALSTART assessed electric models to determine what is *actually* available as opposed to what has been announced as forthcoming. Figure 2 shows CALSTART's latest research on available medium- and heavy-duty ZEVs in North America. Figure 3 shows the same data but includes the range for each vehicle type.

Currently about 70 electric medium- and heavy-duty models from 24 manufacturers are available in the U.S. and Canada. This is expected to grow to at least 85 models from more than 30 manufacturers by 2022, including Rivian and the Tesla semi.[23] There are some Class 8 BEVs being tested in the field, primarily for shorter local routes (under 150 miles a day) in configurations that include dump trucks, concrete trucks, garbage trucks, and snowplows.[24] One study suggests that garbage trucks are likely to be an early winner for medium- and heavy-duty electrification because electric vehicles are better suited than gasoline or diesel trucks for the low-speed, stop-and-go duty cycles typical for these vehicles.[25]

Figure 2: Medium- and Heavy-Duty ZEV Model Availability in North America by Vehicle Type and Year (Source: CALSTART)

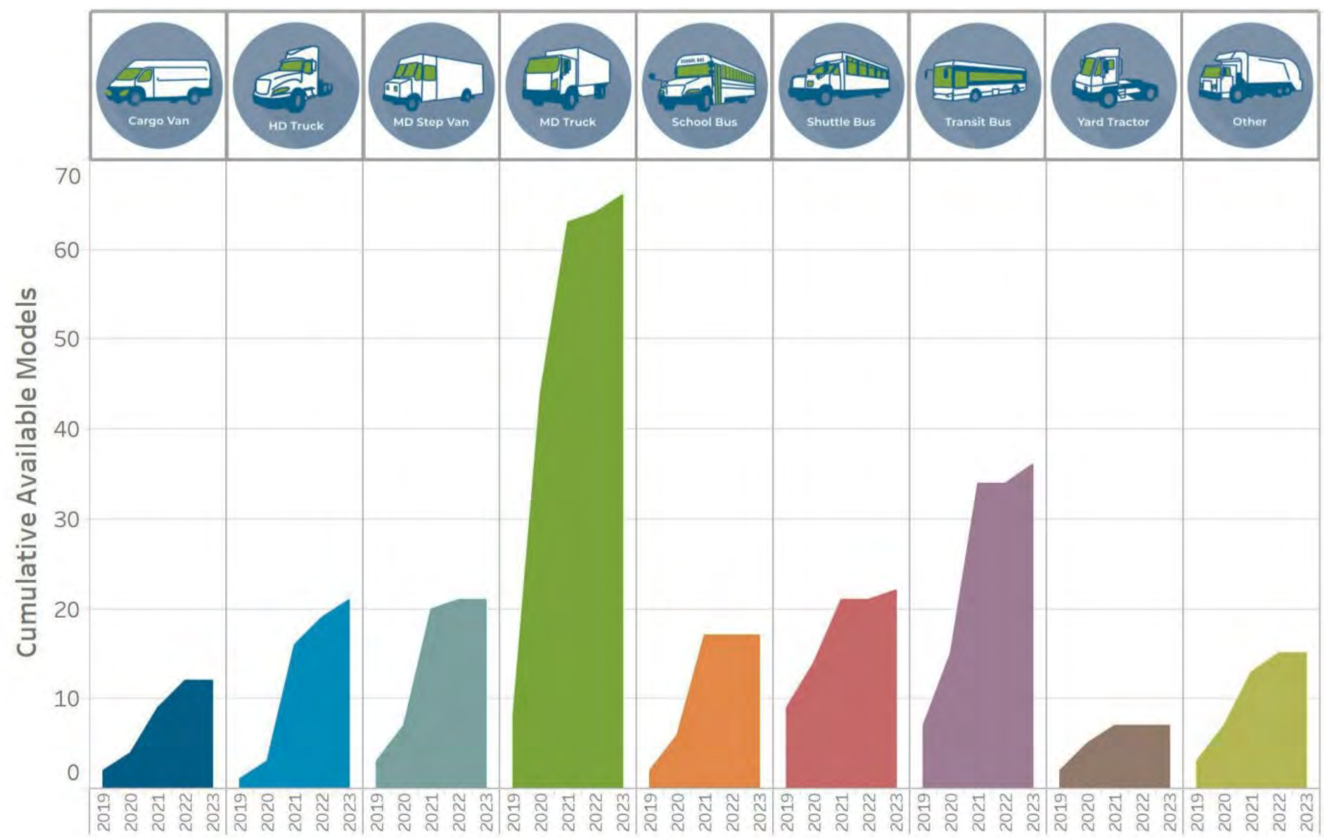
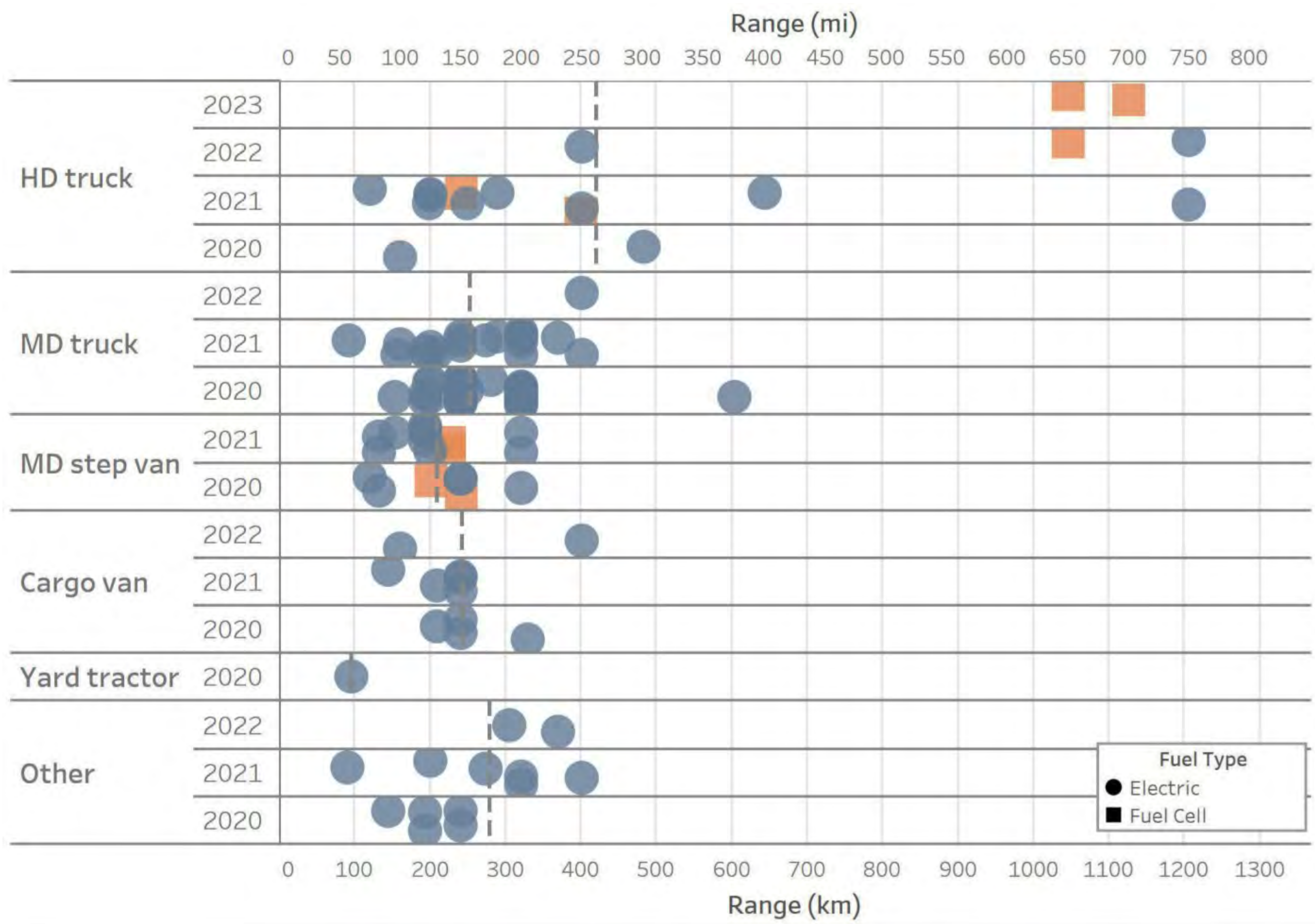


Figure 3: Current and Announced ZEV Vehicle Range by Platform and Available Year for North America (Source: CALSTART)



Freight on Oregon's roads generally incudes heavy-duty semi-trucks that are used to transport goods across long distances over many days. Beyond the design of the vehicle – which must have sufficient battery capacity to haul the load but not carry so much weight in batteries that it limits the amount of load that can be hauled – the vehicles must also have publicly accessible charging infrastructure to support the long-distance travel. Freight is also delivered by rail, ship, and air, which are discussed later in this section.

Electric Semi-Trucks Early Adoption

The first use of heavy-duty semi-trucks will likely be to deliver goods from a centralized warehouse to retailers in a localized area. This eliminates the need for publicly-accessible chargers because businesses can provide chargers at the warehouses so trucks can charge at the facility when they are not out delivering goods. ODOT's TEINA Study indicated the state would need 39 long-haul heavy-duty truck chargers by 2025 and nearly 700 by 2035.[26]

Speaking in 2020, CALSTART Northeast Regional Director Ben Mandel suggested that for heavy-duty ZEVs, "it might take a few more years for this market" to become fully developed as compared to the medium-duty ZEV market.[27] That has continued to be the case for heavy-duty semi-trucks. Production of the widely publicized Tesla Semi has been pushed back to 2022 (from an original production date of 2019) due to limited availability of battery cells.[28] And while Daimler is taking orders for its Class 8 electric semi-truck, production is not scheduled to begin until late 2022.[29] Hyundai has been piloting its FCEV Class 8 semi-trucks in Europe and plans to test these hydrogen-powered vehicles in California starting in mid-2021.[30]

Transit Buses

Electric Island – A Glimpse into an EV Fueling Future

Daimler Trucks North America partnering with Portland General Electric created a unique electric fueling station in the Swan Island area of Northwest Portland. This publicly available charging station is capable of charging everything from light-duty cars to electric freight trucks. The station is not only meant to provide electric fuel to a variety of customers, but it also serves as a test bed for research on the interactions between electric transportation vehicles and the management of the electric grid by utilities.

"...the charging station at Electric Island, the first known freight charging station on the I-5 corridor, shows that Oregon is the ideal place to innovate and develop 21st-Century transportation infrastructure." Governor Kate Brown

Source: https://portlandgeneral.com/news/2021-04-21-daimler-portland-general-electric-open-electric-charging-site

In the medium- and heavy-duty markets, transit buses may have the greatest potential for electrification, because their duty cycle usually includes travel within confined areas, though they also drive significant miles and are heavy compared to other use cases. This higher-level use profile not only improves project economics through significant fuel cost savings, it also increases the effect of other positive attributes of electrification. Transit buses may also be a good application for hydrogen fuel cells. TriMet has had some challenges with incorporating battery electric buses into its fleet, such as vehicle range, reliability, and the cost and footprint of DCFCs at its bus bases and is currently working on a feasibility study for hydrogen fuel cell buses for its fleet.[31] Thus far, TriMet has identified the uncertainty of costs for hydrogen fuel and the lack of a local supplier as two challenges affecting the feasibility of adding hydrogen fuel cell buses to its fleet.

The Oregon Department of Transportation, in collaboration with ODOE and the other members of the Zero Emission Vehicle interagency Working Group, created the Electric and Alternative Fuel Transit Bus Lifecycle Cost Analysis Tool to help transit agencies estimate costs of purchasing and maintaining electric and alternative fuel buses. Accompanying this tool is a Guide to Transit Electrification, with information and recommendations for Oregon transit agencies that are exploring a shift to electric vehicles in their fleets. It provides real world advice, including:

- Contacting your electric utility for technical assistance.
- Examining your route and hours of service.
- Building time into your procurement schedule for training.
- Defining your technical specifications and negotiating for them.
- Planning to receive the buses and testing the charging infrastructure at roughly the same time.
- Reaching out to others with experience and expertise.
- Researching the known maintenance issues with your preferred electric bus.
- Comparing warranties, especially for electric batteries.

Four transit agencies in Oregon are piloting or beginning to deploy Battery Electric Buses

TriMet began exploring battery-electric technology in April 2019 with five New Flyer Xcelsior buses, providing service on Line 62-Murray Blvd (in the Beaverton area) using on-route charging. The first of five Gillig long-range electric buses was added in March 2021 and will operate on Line 20-Burnside/Stark (from the Beaverton Transit Center to the Gresham Transit Center through downtown Portland).

One of TriMet's New Flyer Xcelsior electric buses. Source: trimet.org

South Metro Area Regional Transit will be adding the third electric vehicle in the Wilsonville transit provider's fleet. The city plans to order the bus from Proterra, and it is expected to arrive by January 2022.

Lane Transit District or LTD currently has 11 New Flyer Xcelsior electric buses, with another 19 on the way by 2023.

LTD's first of eleven New Flyer electric buses. Source: ltd.org

Josephine County placed an order with Complete Coach Works for the purchase of two 35-foot, 100 percent electric-powered transit vehicles.

More electric transit buses to come!

This summer Cherriots announced that they received $6.3 million in federal grants, which they are leveraging with another $3.2 million in funding they received in 2020, to purchase 10 new electric buses. The buses will cover their longest route from Keizer to Salem, which runs through a diverse set of neighborhoods that will benefit from reductions in local air pollution and vehicle noise.

Source: https://www.salemreporter.com/posts/4512/with-the-help-of-a-federal-grant-salems-cherriots-will-add-10-electric-buses-to-its-fleet

School Buses

The first electric school bus in Oregon was delivered to the Beaverton School District in February 2021. The school bus was made possible through a partnership with Portland General Electric. In 2019, PGE used revenues from their participation in Oregon's Clean Fuels Program to support a transportation electrification grant program to provide funding to offset the cost difference between an electric bus and a typical diesel school bus.[32] Along with four other school districts, PGE provided similar funds to bring six electric school buses to Oregon in 2021. Specific bus models differed for each district and included three Blue Bird Type D, one Blue Bird Type C, one Microbird type A, and one Lion type A bus.

Buses shown are examples of types A, B, C, and D. Photo source: blue-bird.com

Table 5: Electric School Buses Procured with Awards from PGE's Electric School Bus Program

District	Bus	Charger
Beaverton	2x Blue Bird Type D	Nuvve 19-kW Level 2
Reynolds	Blue Bird Type D	OpConnect 19-kW Level 2
Salem Keizer	Microbird Type A	Enel X 19-kW Level 2
PPS	Lion Type A	Enel X 19-kW Level 2
Newberg	Blue Bird Type C	Nuvve 60 kW DCFC

Electric school buses are in very early stages of deployment. In addition to the Blue Bird and Lion school buses mentioned above, there are eight other manufacturers producing ZEV school buses for the North American market.

Electric school buses cost significantly more than their diesel counterparts, but there are programs in Oregon that provide funding assistance. For example, PGE established a grant program to assist school districts within its service territory to cover the incremental cost for an electric bus compared to a conventionally fueled bus, as well as financial and technical support for the charging infrastructure. The Department of Environmental Quality provides grants for buying new school buses (or adding particulate management to an existing bus) using VW mitigation settlement funds through its Diesel School Bus Replacement program. ODOE assists schools interested in purchasing electric buses using funds collected through the Oregon's public purpose charge – a portion of revenues from PGE and Pacific Power that fund energy efficiency and transportation electrification for school districts in their territories. Established in 1999 by Senate Bill 1149, the law was amended by Senate Bill 1044 in 2019 to include electric vehicle and charging infrastructure expenditures.

Policy Opportunities for Electric School Buses at the Federal Level

Throughout this year there has been an increased and sustained federal interest in deploying electric school buses. President Biden proposed spending $20 billion to electrify 20% of the school bus fleet in the American Jobs Plan through a standalone program at the Environmental Protection Agency (EPA). The Infrastructure Investment and Jobs Act, which recently passed the Senate and is likely to be considered in the House in the Fall, would advance towards that goal by establishing a clean school bus program at the EPA to award funds for the replacement of existing school buses with zero-emission buses or alternative fuel school buses. For fiscal years 2022-2026 the program would have $2.5 billion for replacement zero-emission school buses and $2.5 billion for replacement zero-emission and alternative fuel school buses. This new program, if established, may also receive additional funds this year through a budget reconciliation bill that is under consideration in the House and Senate. This program would provide substantial funding for electric school buses and would advance alongside other federal programs/mechanisms related to clean vehicles and school infrastructure that can support electric school bus deployment.

ODOE, in collaboration with ODOT and support from the Zero Emission Vehicle Interagency Working Group, is developing a School Bus Cost Analysis Tool and guidebook similar to the electric transit cost analysis tool. This tool will help school districts who are interested in alternative fuel buses to conduct an initial assessment on the lifetime costs of each vehicle, including costs for fueling infrastructure.

Off-Road Vehicles

ZEV models of off-road vehicles like forklifts, scissor lifts, backhoes, trenchers, and others are increasingly available in North America. Numerous manufacturers offer multiple models of electric forklifts in the U.S., including Toyota, Komatsu, Hangcha Group, CAT, Yale, Mitsubishi, and the Junghenrich Group. Alternative fuel forklifts are eligible to generate Clean Fuels Program credits in Oregon and forklifts that are model year 2016 or newer can generate more credits than older models.

The first commercially available tractors were introduced in the U.S. by Soletrac Inc. in 2017,[33] and today a handful of both hybrid and battery electric tractors are commercially available, though deployment is thus far mostly limited to pilot projects. In the agricultural sector, Oregon's first electric tractor went into operation in Central Point at Rusted Gate Farm in the spring of 2021. Rusted Gate Farm is a non-profit organization that experiments with different agriculture practices and technologies to support small farms in Jackson County. Funded through a collaboration with Forth, Sustainable Northwest, Wy-East RC&D, staff will test the tractor, including side-by-side comparisons with diesel tractors as part of their work to support lower cost farming.[34]

Port Ground Equipment

Several U.S. ports have launched programs aimed at reducing the consumption of diesel fuel to address associated greenhouse gas and other air pollutants. A wide array of vehicles are used in port operations, including forklifts, and more specialized mobile equipment that commonly includes:[35]

- Yard tractors
- Side handlers
- Top handlers
- Reach stackers
- Straddle carriers
- Sweepers
- Rough terrain forklifts
- Rubber tired gantry (RTG) crane

As of 2017, there were only a handful of PHEV and BEV models for port cargo handling vehicles, mostly for yard tractors. Some ports have also deployed electrified RTG cranes, though the operation of RTGs leads to a high frequency of battery cycling and reduced battery life, so these vehicles may be more appropriate for electric cabling or hydrogen fuel cells.[36] In California, the Clean Off Road Equipment Voucher Incentive (CORE) Project provided funding to help companies purchase or lease *currently commercialized* zero-emission off-road freight equipment. The program ended in August 2020 after exhausting its $44 million dollars for ZEV vouchers, but until that time it allowed eligibility for electric forklifts, mobile and ground power units, and terminal tractors but did not have any eligible electric models for RTG cranes or shore power cable systems.[37]

In Oregon, a number of port- and warehouse-related vehicles were added to the list of those eligible for credit generation under the Clean Fuels Program, as shown in Figure 4.[38]

Figure 4: New Electric Vehicles Eligible for Credit Generation Under the Oregon Clean Fuels Program (Source: DEQ)

Eligible Application	Equipment
Electric Cargo Handling Equipment (eCHE) 	Loader Rubber-Tired Gantry Crane Rail Mounted Gantry Crane Automated Stacking Crane Side Handler Top Handler Reach Stacker Aerial Lift Excavator
Electric Ocean Going Vessel (eOGV) 	Various shore power provided to an ocean going vessel at-berth

Marine Vehicles

Marine vehicles include both ocean-going vessels and harbor craft – vehicles that can be used for transportation, goods movement, and recreation. Electrification of marine vessels is still in its infancy, and most electrified versions are available as concept vehicles or are built to order. According to IDTechEx Research, of the battery electric and plug-in hybrid commercial and industrial marine vessels operating in 2020, about 48 percent were ferries, 18 percent were offshore supply vessels,[ii] 4 percent were tugboats, and 4 percent were fishing vessels; the rest (at 1 percent or below) fall into the category of "other."[39] As shown in Figure 5, the number of hybrid and electric marine vessels in operation, or on order, increased slowly but steadily between 2010 and 2018, with a large leap between 2018 and 2019.[40] Hydrogen fuel cell marine vehicles are also under development, though progress has been somewhat slowed in the U.S. by the lack of U.S. Coast Guard regulations for maritime safety of hydrogen fuel cell marine vehicles.

Figure 5: Total Number of Ships with Batteries in Operation or on Order Worldwide (Source: Maritime Battery Forum 2021)

While battery electric and hybrid ferries are providing the bulk of momentum in this category, deployment is mostly occurring internationally. Hybrid ferries have diesel engines and batteries, and the batteries can be charged either from the diesel engine while the craft is in motion or with shore power.[41] These hybrid ferries can be designed to operate on battery power (all-electric mode) for some or all of their route. Existing ferries can be retrofitted to perform as hybrids or fully electric or they may be built to order.

[ii] In the U.S., offshore supply vessels are defined in federal statute as a vessel that doesn't meet the definition of a passenger vessel, is greater than 15 gross tons, and "that regularly carries goods, supplies, individuals in addition to the crew, or equipment in support of exploration, exploitation, or production of offshore mineral or energy resources."

Oregon currently has three small ferries in operation – Buena Vista, Wheatland, and Canby – each of the ferries are cable-guided ferries powered by electricity provided from shore via the cable.[43] Washington state operates 21 ferries – the largest fleet in the U.S. – and expects to add its first new hybrid ferry into operation in 2025. Washington is in the process of converting three existing diesel-powered ferries for hybrid-electric operation.[44] [45] The 2040 fleet envisioned by Washington State Ferries' System Electrification Plan is comprised of 26 vessels, 22 of which are plug-in hybrid ferries.[46] In California, a hybrid ferry powered by diesel and batteries provides cruises to Alcatraz Island and can operate solely on battery power for over an hour.[47]

First Fuel Cell Electric Ferry in the Pacific Northwest

The first commercial 100 percent hydrogen FCEV ferry launched in Bellingham, WA on August 12, 2021. Named *Sea Change*, the vessel is a 70-foot, 75-passenger ferry fabricated by All American Marine, Inc., with funding that included a $3 million grant from the California Air Resources Board.[42] *Sea Change* is powered by two 300 kW electric motors, which are powered by 360 kW of fuel cells. The vessel also has 100 kWh of lithium ion battery storage to boost speed when needed. *Sea Change* can store approximately 542 pounds of compressed hydrogen onboard, which is equivalent to about 8.3 megawatt-hours of stored energy and enough to power the vehicle for two days.

The first all-electric tugboat is expected to hit the water in New Zealand in late 2021,[48] while in Japan, seven companies have formed a consortium to develop electric tankers powered by 3.5-megawatt hour battery packs for operation in 2022.[49]

Rail and Aviation

Aviation and rail vehicles are similar in that both categories are well behind other modes in terms of commercialization of electrified or hydrogen fuel cell models. There have been some test vehicles and pilot projects, and hybrid and battery electric versions may work for shorter haul operations, but for long-haul operations, the current limitations of battery chemistry may lead to more use of alternative fuels such as hydrogen or biofuels for operations. There are examples of hydrogen-fueled rail deployments in Europe and China and hydrogen fuel cell trains are often more affordable than electric catenary trains. Ballard Power Systems manufactures hydrogen fuel cell-powered rail systems and suggests that any train route served by a diesel train can be replaced with a hydrogen fuel cell train.[50]

Catenary trains are powered by electric locomotives that get their electricity supply from overhead electric lines. The Portland Streetcar and TriMet MAX light rail are examples of catenary trains.

Where electric versions of transportation vehicles are not yet commercially available, such as marine and aviation, there are electric options to power the vehicle – or some of its components – while the vehicle is located in port. For example, the Port of Portland has installed electric air conditioning units for planes at more than 40 gates in the Portland International Airport. These units keep the plane interiors cool on hot days without using the plane's aviation fuel for power.[51]

What about electric locomotives?

Although there are no commercially available formats of electric locomotives, there is research being done on battery electric and fuel-cell electric engines. Wabtec, a global developer of freight and passenger train equipment, developed and delivered an experimental battery-electric locomotive to the Port of Los Angeles. In summer 2021, the 2400 horsepower engine along with two diesel locomotives, pulled a freight train from Barstow to Stockton, CA. Not only did the BEV reduce total diesel fuel consumption by 11 percent, but it also reduced emissions its air pollutant emissions by a similar amount.

Citation: https://www.latimes.com/california/story/2021-07-05/battery-powered-locomotives-zero-emission-train-future

Conclusion

The availability of ZEV models for all sorts of transportation platforms is poised to explode in the coming years. With commitments by nearly every major auto manufacturer for a large uptick in electric models, to the first electric heavy-duty semi-truck being delivered for sale, to electric bikes and scooters helping to reduce congestion and air pollution in Oregon's urban areas. Electric vehicles are already regularly visible on Oregon roads, and with electric versions of non-road equipment, these forms of transportation will become more commonplace in the work environment. With the benefits of reduced pollution and often lower fuel costs, the demand for electric options across the transportation sector will continue to grow.

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2020 Hyundai Kona EV vs Kona ICE vehicle comparison, Photo credit: motortrend.com

This section assesses the purchase cost difference – before and after federal and state incentives – between a zero-emission vehicle and a comparable vehicle powered by an internal combustion engine.

Cost Differences Between ZEVs and Internal Combustion Engine Vehicles

Introduction

The purchase price of zero-emission vehicles is currently higher than comparable internal combustion engine vehicles. After applying incentives, however, some electric vehicles – on a monthly cash-flow basis – can cost less today and throughout their entire life than a comparable internal combustion engine vehicle. Moreover, as EV battery costs continue to decline, the purchase price for an EV is anticipated by most experts to reach cost parity with its internal combustion engine vehicle equivalent in the next two to three years.[1] Multiple incentives can help address the higher up-front cost of EVs, including two Oregon state rebates and a federal EV tax credit. Importantly, the Oregon Charge Ahead Rebate is available for low- and moderate-income Oregonians and can be applied to purchase a *used* EV, increasing equity and opening up the EV market for many Oregonians.

While zero emission vehicles include battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell electric vehicles (powered by hydrogen), Oregon has no FCEVs in operation because there is no hydrogen fueling infrastructure available in the state. Future versions of this report may include costs for FCEVs when they are available. For now, this section of the report will focus on the cost difference between EVs (BEVs and PHEVs) compared to internal combustion engine vehicles.

Understanding the overall costs for EV owners can be addressed in two ways: the purchase cost of the vehicle (referred to as the up-front cost) and the operating costs over the lifetime of the vehicle. While the purchase cost is often higher for an EV, in many cases the total costs across the lifetime of the vehicle are lower because operating costs are generally lower. Electric fuel can be as little as 25 percent of the cost of fueling with gasoline, depending on how much the owner pays for electricity. Maintenance costs are lower because, with fewer moving parts and less need for lubricants, EVs do not require the same level of maintenance.[2]

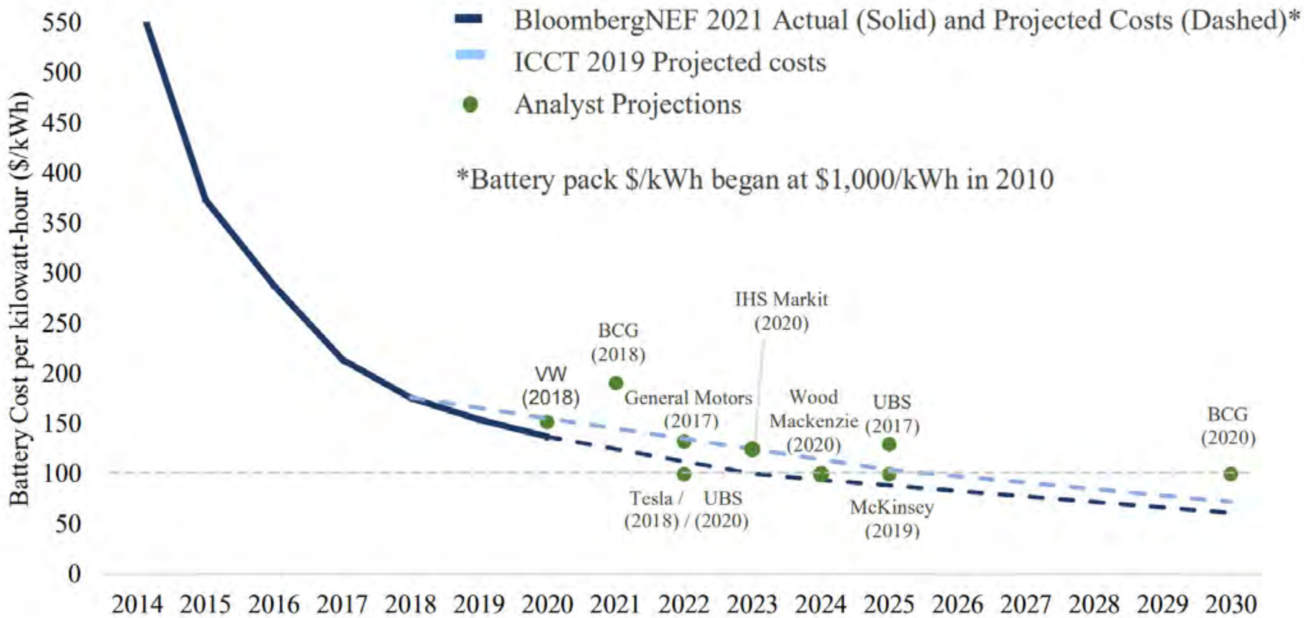
Purchase Cost

The up-front cost of an EV averages about 30 percent higher than a similar conventional vehicle, largely due to the cost of the battery. However, battery costs are falling quickly. In 2020, EV battery costs dropped 13 percent compared to 2019, from $157 per kilowatt hour to $137 per kWh.[3] Experts estimate that battery pack prices will need to reach about $100/kWh for EVs to reach cost parity with similar models of gasoline vehicles.[4] As illustrated in the figure below, several entities estimate that this will occur in the next two to three years; at the same time EV models, options, and platforms are rapidly expanding.[5]

What are Vehicle platforms?

Make and model are very specific ways to describe a vehicle, but at a higher level most light-duty vehicles can be classified into platforms such as sedan, pickup, van, sport utility vehicle (SUV), and crossover utility vehicle (CUV).

Figure 1: Actual and Projected Battery Pack Costs[6]



Cost projection shown are for battery packs. Several of the listed sources estimated battery cell costs; for these estimates the value shown includes a 25 percent mark-up to estimate pack costs.

Reduced costs for fueling and maintaining an EV can offset the higher up-front cost over time. For a buyer who drives the national average, the payback period is five to six years.[7] The higher the average annual miles driven, the faster the payback period. For example, high-mileage drivers such as Uber, Lyft, and cab drivers who exceed 30,000 miles per year could recover the additional up-front cost in two to three years.

Individual vehicle buyers do not pay a set price for vehicles – they usually negotiate with dealers individually. This means the price of a vehicle can be variable, though online tools and buyers' clubs may help reduce this variability by making purchase prices more transparent. As noted above, the up-front cost[i] of an EV is generally higher than an equivalent gas vehicle, but the difference in costs varies among vehicle models. For example, a standard 2021 Hyundai Kona SEL's Manufacturer's Suggested Retail Price, or MSRP, starts at $24,005, while its fully electric counterpart is over $14,000 higher at $38,575. Costs differences are also apparent with plug-in hybrid electric vehicle models. A gas-powered 2021 Toyota RAV4 XLE's MSRP begins at $31,783, while the PHEV 2021 Toyota RAV4 Prime SE starts at $41,488 – a difference of about $9,700.[8]

[i] While there are inconsistencies in vehicle pricing, for simplicity this report will use Manufacturer's Suggested Retail Price, or MSRP, in its comparisons.

Many EVs also come with packages that have more options and functions than the base models of equivalent combustion engine vehicles. To the extent possible, this report compares similar platforms and trim levels of vehicles; however, most EVs are sold in one or two trim levels that generally include more expensive features. Buyers willing to forego upgrades and accessories to keep vehicle costs lower may not find many no-frills selections of EVs.

Trim levels

Auto manufacturers sell cars with packages of options known as trim levels. In the case of examples used here, Hyundai uses: SE, SEL, Limited and others; and Toyota uses: LE, XLE, XLE Premium, Limited and others. For these comparisons, vehicles selected were matched by the lowest priced package for which there were matching trim levels, or the closest options packages available. Note, the RAV4 Prime uses "S" in place of the "L" in trim level names.

Below: 2021 RAV4 Prime SE interior cabin

EV purchase price is the biggest factor for Americans when considering electric vehicle adoption.[9] Because many manufacturers electrified more expensive vehicle models first, fewer lower-cost electric vehicle options are available for early adopters for whom price point is a major factor in the decision to adopt a new technology (learn more in the ZEV Progress section of this report). This limits access for low- and moderate-income customers to EVs. Price point and the availability of a basic model option can also be a barrier for fleets, who tend to purchase large quantities of very basic models to minimize their costs.

This price disparity is greater for similarly equipped versions of the most popular platforms of passenger vehicles: SUVs and pickup trucks. Of the top 10 best-selling internal combustion engine passenger vehicles sold in 2020, five were pickups and three were SUVs.[10] There are some electric formats of SUVs on the market today, but there are currently no commercially available models of electric pickup trucks. However, in the next three years, manufacturers such as Ford, Chevrolet, Hummer, Rivian, and Tesla have indicated they will offer electric pickup trucks. Where prices have been released for these pickups, the electric model costs more than its internal combustion engine counterpart.

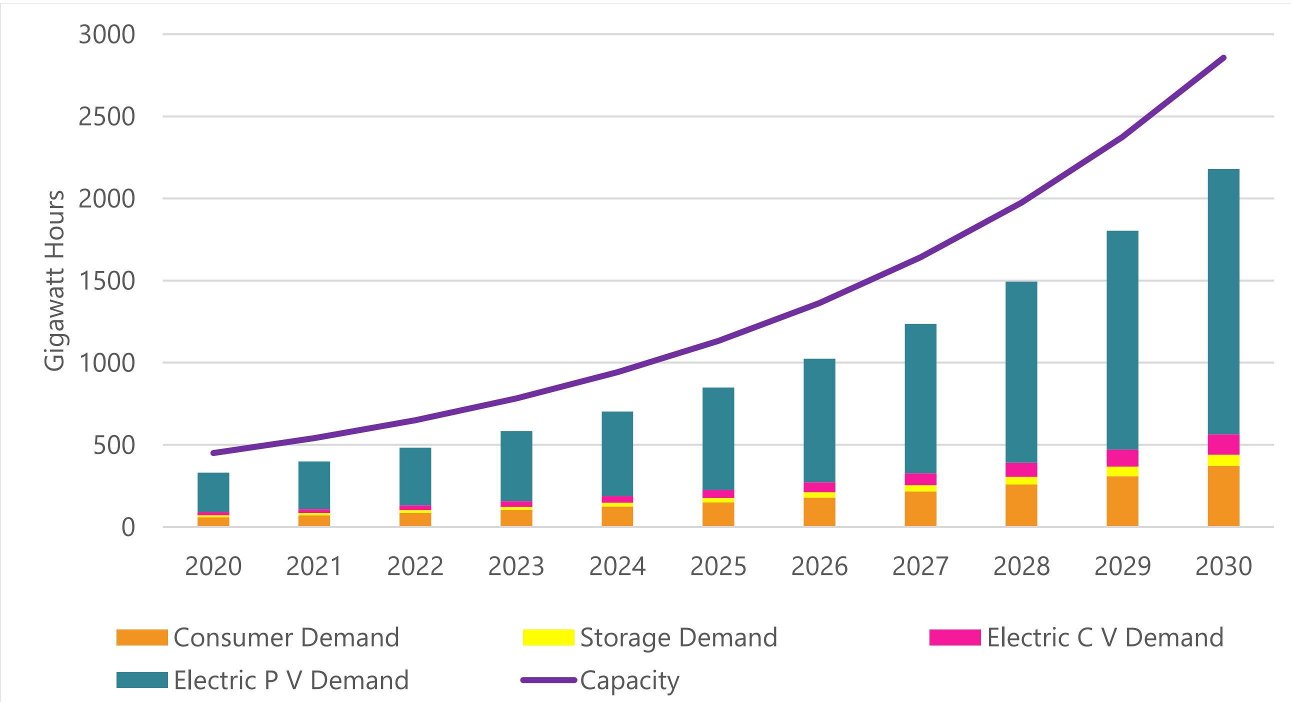
Only a few companies have released pricing for their forthcoming pickup models. For example, Ford announced the MSRP for its 230-mile range base model of the 2022 F-150 Lightning will begin at $39,974, compared to the 2021 Ford F-150 XL that starts at $35,280. However, the cost for the 300-mile extended battery range F-150 Lightning – a feature that more closely matches the range of the gasoline model – is an additional $10,000 on top of the base model Lightning MSRP.[11] The Rivian R1T, a 300-mile range luxury model electric pickup, is anticipated in January 2022 with an expected base price of $67,500.[12] [ii]

A recent study found that global EV sales will grow at a 20 percent annual growth rate over the next decade.[13] In addition to the EV manufacturer's increasing demand for batteries, battery producers will need to further ramp up production to accommodate the growing demand for other lithium-ion

[ii] Based on pre-production information; there may be differences in features between these pickup trucks in addition to battery capacity once commercially available.

battery-powered technologies. Figure 2 shows that overall battery demand is expected to rise from 450 gigawatt hours in 2020 to 2,850 GWh in 2030, approximately a 6.6-fold increase.[14] This growth requires not only additional and larger manufacturing facilities, but also significant increases in the supply chains for the raw materials and parts for the batteries. Although in the very formative stages of development, there have been more than 80 new large battery manufacturing factories announced around the globe, most of which are in Asia.[15]

Figure 2: Battery Demand Compared to Battery Capacity[16]



Considerations for Light-Duty Fleets

Fleets have several considerations when working to electrify their vehicles. The up-front costs may present additional challenges due to the generally larger number of vehicles that need to be purchased at the same time. Like all EV buyers, once purchased, they will benefit from the fuel and maintenance cost savings that will continue to accrue over the lifetime of each vehicle. Fleets may also have to pay for charging infrastructure and electrical upgrades to fuel multiple vehicles, which can add to the initial expense of switching to electric. If new charging infrastructure is developed with future demand in mind, fleet owners will be ready to charge with limited additional investments as they purchase more EVs.

Incentives

A study by the Institute of Transportation Studies at University of California, Davis showed nearly 30 percent of consumers who bought EVs in early markets cited the EV federal tax credit as a factor that influenced their purchasing decision.[17] This percentage increased for lower-priced models and for consumers in lower income brackets. In a series of annual surveys by Portland General Electric to its customers, cost and thus affordability was the number one barrier.[18] To address the higher up-front cost of EVs, the federal government and the State of Oregon offer monetary incentives.

Figure 3: Unprompted Barriers Mentioned to Purchasing or Leasing an EV or PHEV (PGE Respondents)[16]

Main Barrier to Purchasing or Leasing an EV/PHEV (Unprompted)	All Likely Vehicle Purchasers		Wave 1 - All Likely Vehicle Purchasers		
	Baseline (n= 929)	Wave 1 (n=1026)	EV/PHEV Non-Considerers (n=526) (A)	EV/PHEV Considerers (n=253) (B)	EV/PHEV Intenders (n=247) (C)
Cost/affordability (unspecified)	28%	30%	19% B C	33% A C	51% A B
Range/battery life	23%	14% *	18% B C	10% A	10% A
Recharge stations/infrastructure	22%	13% *	16% C	11%	10% A
Cost of vehicle	11%	10%	8%	10%	12%
Convenience/ease of use	7%	7%	10% B C	3% A	3% A
Cost of electricity/cost to use	5%	4%	6%	3%	2%
Cost of repairs/maintenance	6%	4% *	5% C	2%	2% A
Power/able to pull and tow	4%	4%	5% C	3%	1% A
Don't know	13%	17% *	18% C	24% C	10% A B

Note: Letters A - C indicate statistically significant differences between likely vehicle purchaser segments (z-test for proportions, p<.05).
* Indicates a statistically significant difference between Baseline and Wave 1 survey all likely vehicle purchasers (z-test for proportions, p<.05).

A federal income tax credit of up to $7,500 is available for some new EVs. This is inclusive of BEVs and PHEVs with a minimum battery capacity of 4 kWh. Standard (non-plug-in) hybrids do not qualify. For state incentives, the Oregon Department of Environmental Quality administers the Oregon Clean Vehicle Rebate and Charge Ahead Rebate programs. When combined, these rebates can save some Oregonians up to an additional $7,500[iii] on the purchase or lease of a qualifying electric vehicle. All Oregonians are eligible to receive up to $2,500 for the purchase of a new EV through the Clean Vehicle rebate, but only low- and moderate-income Oregonians[iv] are eligible for the additional $5,000 on new or used EVs from the Charge Ahead Rebate. As of July 12, 2021, the standard Clean Vehicle program has provided 11,776 rebates to Oregon EV buyers, totaling over $28 million. The Charge Ahead program has issued 1,634 rebates totaling over $4 million.[19]

[iii] The Charge Ahead rebate amount was increased from a maximum of $2,500 to $5,000 in HB 2165 in the 2021 Legislative session. The increased amount takes effect January 1, 2022.

[iv] Low- and moderate-income is based on number of people in the household and the average income of the area.

Changes to the Charge Ahead Rebate

In the 2021 Legislative session, through the passage of HB 2165, the Charge Ahead rebate amount was increased from a maximum of $2,500 to $5,000. The increased amount will take effect January 1, 2022. The Charge Ahead Rebate and the Oregon Clean Vehicle Rebate offer an effective means for addressing the barrier of cost because they can reduce it at or near the time of purchase. The availability of more affordable used EVs is also critical to transitioning the market toward EVs. Since the number of used vehicle purchases is four times higher than new vehicles in Oregon, a robust used EV market is critical if the state is to meet its EV adoption targets.

Together, the federal tax credit and two Oregon rebates could add up to as much as $15,000 in savings for qualifying vehicles and people. A person with the average Oregon adjusted gross income could qualify for all $15,000. However, eligibility for the package of incentives is largely affected by the buyer's income level. Access to the Charge Ahead Rebate is eliminated at higher incomes and access to the federal tax credit is reduced at lower incomes. There are also eligibility limitations on some EV manufacturers. The Charge Ahead program currently offers a calculator to see if someone's income qualifies. The program's eligibility criteria are changing, and after January 1, 2022 only those with an income below 400 percent of the federal poverty level will qualify. In 2019, the federal poverty level was $12,880 for a single person and $26,500 for a family of four, resulting in income limits of $51,520 and $106,000 respectively before access to the rebate is eliminated.[20]

The federal tax credit program has two main eligibility criteria. First, vehicles must meet the qualifications for the program. The federal tax credit is designed to phase out for each manufacturer once they sell 200,000 eligible vehicles, so the credit is no longer available for some of the most popular EV models on the market, including General Motors and Tesla. In Oregon, Tesla and Chevrolet (a division of General Motors) are the top two manufacturers represented among EV models driven in the state, accounting for 46.7 percent of registered EVs.[21] The third most popular model, the Nissan Leaf, still has remaining credits available but is likely to hit the 200,000 mark by the end of 2021.[22]

Second, to receive the federal tax credit, the buyer must owe federal taxes, and can only receive up to the amount of their tax liability for the year the vehicle was purchased – it cannot be rolled over into future tax years. The average Oregon Adjusted Gross Income in 2019 for all Oregon filers was $67,520,[23] and after applying the standard deduction, the resulting federal tax owed to which a tax credit could be applied would be $8,029[24] – meaning the buyer would be eligible for the full $7,500. Those with an annual gross income above $65,117 could take advantage of the full $7,500 federal tax credit, and those making less than this would qualify for a declining amount of the tax credit. Nationwide, 78 percent of EV tax credits go to households with adjusted gross incomes of $100,000 or more.[25] Because the federal tax credit is not realized until the taxes are filed, it requires the buyer to cover the amount of the credit from the time of purchase until the tax filing date, which could be up to a year later. This may be more challenging for low- and moderate-income Oregonians, who may not have the financial resources to cover the rebate amount until the tax credit is received.

In Oregon, the state rebate programs allow buyers to apply for both vehicle rebates at the time of purchase. DEQ also enables dealerships to offer the Clean Vehicle Rebate to customers at the time of sale, thereby reducing the up-front amount the customer pays or finances.

Also, unlike the federal tax credit, Oregon's Charge Ahead program offers rebates on the purchase of *used* EVs that could substantially lower the up-front cost of a vehicle. For example, the Kelley Blue Book Company estimates that a 2018 Kia Soul EV (with 36,000 miles in very good condition) has a $13,687 trade-in value – about $2,352 less than an equivalent used gas-powered Kia Soul. With the $5,000 Charge Ahead Rebate, the total cost to the EV-buyer would be $8,687.

The availability of incentives to fleets is dependent on the type of organization that is procuring the vehicles and its tax liability. Private fleets can take advantage of the federal tax credit up to the amount of their tax liability, but many public fleets are not eligible because they do not pay federal taxes. However, both private and public fleet owners can apply for the $2,500 per vehicle Oregon Clean Vehicle Rebate, for up to 10 vehicles per calendar year.

Fueling Cost

EVs are much more energy efficient than their internal combustion engine counterparts, enabling electric vehicles to travel the same distance on approximately 25 percent of the energy of a gasoline car. The U.S. Department of Energy reports that EVs convert over 77 percent of the electrical energy from the grid to move a vehicle down the road, while conventional gasoline vehicles only convert between 12 and 30 percent of the energy in gasoline to move the vehicle.[26] [27]

Table 1: Efficiency, Fuel, and Costs for a Gas-powered Vehicle vs. Electric Vehicle[28]

	Gasoline Powered Vehicle				Electric Vehicle			
Efficiency	25	mpg			3.33	mpkWh		
Fuel Needed	462	gallons			3,470	kWh		
Fuel Equivalency	15,727	kWh			102	Gallons gasoline		
Cost per Mile	$3.50	/gal	0.14	¢/mile	$0.11	/kWh	0.03	¢/mile
Annual Cost	$1,618	/year			$382	/year		
Annual Savings					**360**	**Gallons gasoline**		
					$1,261	**/year**		

The table above shows that using an average of 11,556 miles traveled in a year, an EV uses far less energy than a gasoline vehicle, saving 360 gallons of gasoline and $1,261 per year[v] – 28 percent of the cost to fuel a comparable internal combustion engine vehicle.[vi] However, fuel costs and fuel use are dependent on many variables, including vehicle type, driving behavior, electricity rates, gasoline costs, and access to EV charging. For example, using time-of-use electricity rate schedules for charging may significantly reduce EV fueling costs (learn more in the Impacts to the Grid section of this report). Conversely, where EV owners do not have access to charging at home or the workplace, fueling costs may be higher. Residential and commercial electricity rates are set by the Oregon Public Utility Commission or the governing boards of consumer-owned utilities. This creates electric fuel prices that are more stable than gasoline because electricity retail rates are not subject to the market volatility that drives changing prices at the pump. However, unlike electricity supplied from a home or business, electric fuel offered through private charging companies is not subject to the same oversight from the OPUC or utility governing boards and may be more expensive and more volatile in its pricing. This is especially relevant for EV drivers living in multi-unit dwellings who may need to rely heavily on publicly accessible charging provided by private companies for their fueling needs.

Maintenance Costs

Electric vehicles cost less to maintain than internal combustion engine vehicles. With fewer moving parts, there are fewer routine maintenance needs and parts that can wear out requiring repair or replacement. EV motors do not require many of the lubricants that internal combustion engines need, such as engine oil and transmission fluid. They also use regenerative braking systems that use the momentum of the vehicle to charge the battery, which reduces wear and tear on the friction braking system, decreasing the frequency of replacements for brake pads, rotors, and calipers.[29] In addition, EVs do not generate as much heat as internal combustion engines, so they have smaller cooling systems that require less maintenance.[30]

In its analysis of 2019 and 2020 reliability survey data from more than 329,000 vehicle owners, Consumer Reports determined that electric vehicles require approximately half the maintenance expense of an internal combustion engine vehicle.[31]

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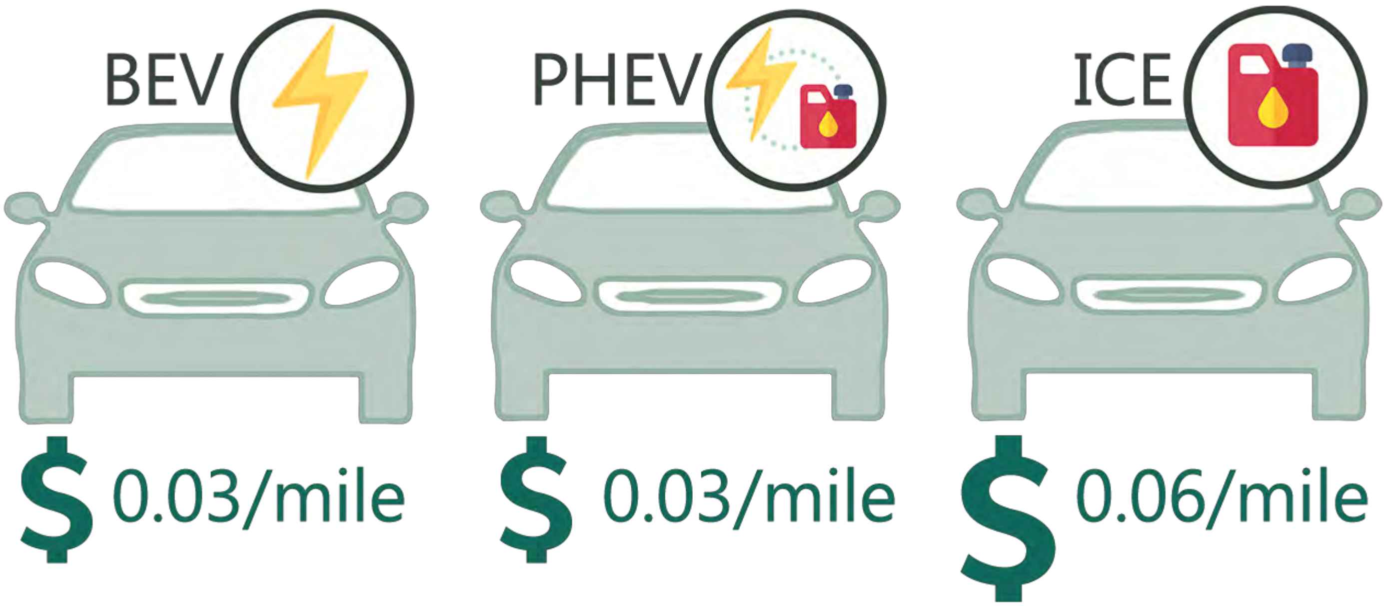
[v] This comparison is based on an EV compared to a comparable standard internal combustion engine vehicle. Fuel consumption and cost differences could be less if comparing to a high fuel efficiency vehicle, such as a standard hybrid.

[vi] Based on statewide average vehicle type, use, and costs.

Average maintenance/repair costs over vehicle lifetime:



Recycling EV Batteries

Unlike internal combustion engine vehicles, where there is an established profitable market for reselling engines and transmissions from end-of-life internal combustion vehicles, the market for used EV motor and battery parts is still evolving. For instance, there is a cost to EV owners and parts dealers to recycle old EV batteries rather than an established for-profit market for the recovery of metals and minerals to be reused or repurposed. In California, which requires EV battery packs to be recycled, it can cost as much as $1,000 for an average passenger vehicle such as a Nissan Leaf.[32]

However, as the demand for electric vehicles and batteries continues to grow, the critical rare-earth metals powering them are becoming more valuable. There is also an indication that a "second life" market is emerging for battery packs,[33] which may help offset some or all the costs to recycle used batteries. Albemarle Corporation, the world's largest lithium miner, is making investments and partnering with automotive equipment manufacturers on such a recycling effort, which it calls "critical" to its future growth.[34] EV battery recycling may also have competition from emerging pathways for repurposing used EV batteries. Some companies are already recovering and remanufacturing electric car batteries to provide backup battery support for the electric grid.[35] (Learn more in the Impacts to the Grid section of this report.)

Depreciation

Electric vehicles have tended to depreciate[vii] faster than similar gasoline vehicles. Beyond the current recycling cost, some early EV models had very limited ranges, which likely reduced their overall desirability and accelerated their depreciation. In some markets, incentives have distorted the market. Used car shoppers expect to pay less than for an equivalent new car, but incentives subtracted from

[vii] Depreciation is a reduction in the value of an asset (the EV) with the passage of time, due in particular to wear and tear.

the cost of that new EV bring its cost closer to the depreciated price of a used EV. This situation can suppress the price of used EVs, causing the depreciation rate for EVs to be higher than other cars, and reducing the overall value of both the new and used EVs. In Oregon, the Charge Ahead Rebate can be used on both new and used EVs, ensuring the differential between new and used is more constant. In addition, as newer models of EVs increase their ranges to greater than 200 and 300 miles on a single charge, and as the charging network across Oregon continues to expand and become more convenient, the experience of owning and driving an EV will feel similar to that of a gasoline-fueled vehicle – which could also slow the rate of EV depreciation. This is starting to happen with Tesla EVs. In a recent study by iseecars.com, the average three-year depreciation for all vehicles was 39.1 percent, while the Tesla Model 3 depreciated only 10.2 percent.[36]

Oregon's Charge Ahead Rebate Supports Used EV Adoption

Registration

In Oregon, electric vehicle drivers have a choice to either pay full registration fees up front or pay a lower fee plus a monthly per-mile charge by joining ODOT's OReGO program.[37] Typically, Oregon drivers pay two to four years' worth of registration fees at the time they purchase a car or renew their registration. With fee increases in 2020 and 2022, the combined up-front registration fee for an EV could amount to over $300. Drivers enrolled in OReGO pay a base registration fee of $86 per year ($172 for two years) for a new EV or $43 per year ($86 for two years) for a used EV. The program also assesses a monthly road usage charge of 1.8 cents per mile for all participants (learn more in the State Highway Fund section of this report). This reduces the up-front costs for registration and enables drivers to pay for roads and bridges as they go.

Summing Up Costs for Passenger Vehicles

While the up-front costs of an EV are often higher than those of a similar internal combustion engine model, EV incentives can bring these costs down, and in some cases make EVs less expensive than their conventional counterparts. While state and federal incentives can be combined, accessibility to these incentives is highly dependent on the vehicle model as well as an individual's income and tax liability.

Oregonians earning $65,117 (the 2019 average adjusted gross income for all filers in Oregon) or more can maximize their $7,500 federal tax incentive. As income decreases from the average, tax liability also drops, thereby reducing the amount of the federal tax credit the buyer can use. As income increases, the buyer would still get the full federal tax credit but may no longer qualify for Oregon's $5,000 Charge Ahead Rebate. Currently the Charge Ahead program has an income limitation based on the area median income (AMI) for the area where the buyer lives. The program provides a calculator for determining if a potential buyer's income level would qualify them for the rebate. However, in January 2022, the Charge Ahead program income limitation will change to a single metric – 400 percent of the federal poverty level – which is determined based on the number of people in a household. Once in effect, a single-person household making the average adjusted gross income would exceed the income limitation and would not be eligible for the rebate. However, if the income level stayed the same but the household increased to two or more individuals, they would be eligible.

Table 2 shows up-front costs for different platforms of light-duty vehicles (CUVs, SUVs, vans, and pickups), comparing BEVs and PHEVs to their gasoline-powered counterparts. The incentives shown are for a buyer with an average adjusted gross income in Oregon. Equivalent analyses for lower- and higher-incomes are in Appendix B.

Table 2: Comparison of Up-front Costs Between EVs and Gasoline Vehicles[38]

		Up-Front Costs			
		MSRP	**Incentives**	**Registration**	**Net Cost**
Trax LS (Gas)	Hatchback/CUV	$22,930	-	$132	$23,062
Bolt LT (BEV)	Hatchback/CUV	$39,295	$7,500	$306	$32,101
Volvo XC 40 T5 (Gas)	SUV	$43,155	-	$132	$43,287
Volvo XC 40 P8 (BEV)	SUV	$59,555	$15,000	$306	$44,861
2021 Pacifica Touring (Gas)	Van	$39,300	-	$132	$39,432
2021 Pacifica Touring (PHEV)	Van	$44,125	$15,000	$306	$29,431
2021 F-150 XL (Gas)	Pickup	$35,280	-	$132	$35,412
2022 F-150 Lightning (BEV)	Pickup	$39,974	$15,000	$306	$25,280

*Chevy Bolt is no longer eligible for the federal tax credit.

** Incentives are calculated using the average adjusted gross income for all filers in Oregon. Such a buyer could potentially receive $7,500 from the federal tax credit, $2,500 from the from the Oregon Clean Vehicle rebate, and $5,000 from the Charge Ahead Rebate, for a total of $15,000. This example is illustrative of the potential savings and may not reflect the incentives available for all Oregonians at this income level.

Operational costs for EVs are significantly lower than for internal combustion engine vehicles, especially when drivers are able to fuel at home. Table 3 compares estimated annual operational costs between EVs and gasoline-powered vehicles across the four main light-duty vehicle platforms. Using the $0.11 per kilowatt hour statewide residential average electricity rate, operational costs for a comparable gasoline model are more than twice as high in the examples provided below. Fuel savings will still occur at higher electricity rates; however, once electricity approaches $0.40 per kilowatt hour, the electric fuel costs are about equal to gasoline.

Table 3: Comparison of Operational Costs Between EVs and Gasoline Vehicles[39]

Operating Costs					
Make & Model	Model Type	Mileage	Fuel Cost*	Maintenance Cost**	Total Operational Costs
Trax LS (Gas)	CUV	26 MPG	$1,333	$710	$2,043
Bolt LT (BEV)	CUV	3.45 MPkWh	$369	$363	$731
Volvo XC 40 T5 (Gas)	SUV	26 MPG	$1,333	$710	$2,043
Volvo XC 40 P8 (BEV)	SUV	2.33 MPkWh	$547	$363	$909
2021 Pacifica Touring (Gas)	Van	22 MPG	$1,576	$710	$2,286
2021 Pacifica Touring (PHEV)	Van	2.44 MPkWh	$521	$342	$863
2021 F-150 XL (Gas)	Pickup	20 MPG	$1,733	$710	$2,443
2022 F-150 Lightning (BEV)	Pickup	2.17 MPkWh	$585	$363	$947

*Fuel costs are based on 11,556 miles per year state average vehicle miles traveled and $3.00/gallon or 11¢/kilowatt-hour fuel costs.

** Maintenance costs are based on Consumer Reports analysis of standard maintenance costs per mile.[40]

Definitions:

1. MPG = Miles per gallon
2. MPkWh = Miles per kilowatt-hour

Using the information and assumptions from the above analysis, the charts below reflect the total cost to own and operate comparable EV and gas models over 12 years. Understanding the economics of the total cost to own and operate an EV, like owning any vehicle, is highly user specific. Up-front costs are somewhat dependent on model availability, what buyers are willing to pay for the vehicle, and what options they choose. Operational costs depend on the vehicle, its fuel efficiency, how many miles the vehicle is regularly driven, fuel costs, and even how the owner drives the car. The Oregon Department of Energy provides a fuel cost calculator tool on the agency's EV Dashboard, where Oregonians can input specific information about their vehicle, driving habits, and fuel costs to provide a more customized look at potential fuel savings.

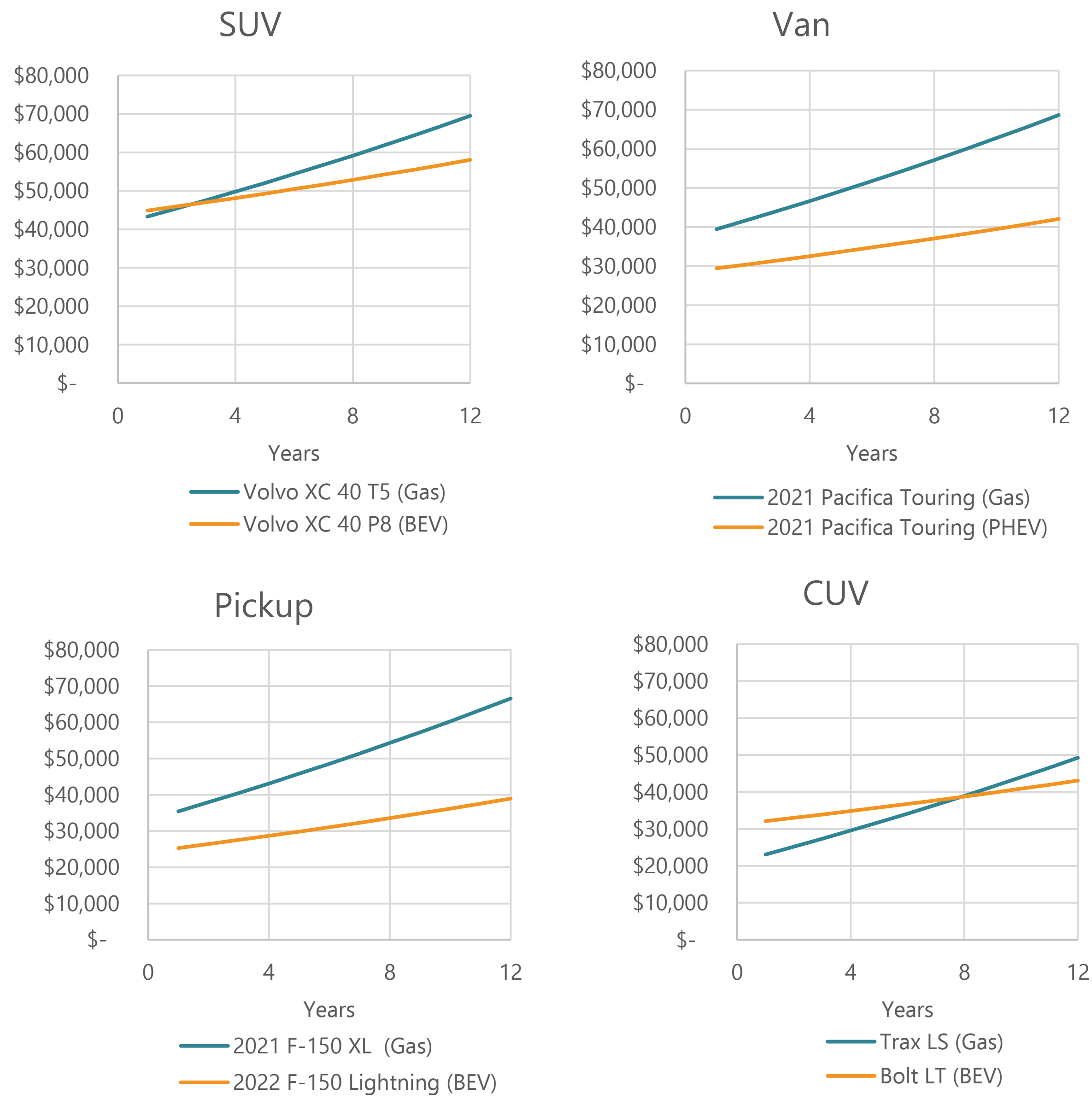
The total costs of owning and operating an EV over a 12-year period can be much lower than a similar gasoline-powered vehicle.

This is largely because of lower fuel costs, but the higher the electricity rate one pays, the longer it will take to recover the higher up-front costs with fuel savings. The two sets of charts below show the cumulative cost of owning and operating comparable EVs and gasoline powered vehicles under two purchasing scenarios – full up-front cash purchase less incentives (Figure 4) and financing with a loan (Figure 5). The graphs below show the cumulative cost of ownership for EVs, represented by orange lines, that tend to increase at a slower rate than the cumulative costs of comparable gasoline powered vehicles, represented by blue lines.

The charts in Figure 4 show the effect the incentives have on the up-front purchase cost. Assuming a buyer with the average adjusted gross income in Oregon that can take advantage of a $7,500[41] federal tax credit and the full $7,500 in Oregon rebates, the pickup (F-150) and van (Pacifica) examples cost less in the first year and continue to accrue savings over the 12 years. In the Volvo SUV example, the costs are similar for the first few years of ownership, but lower operational costs for the Volvo BEV continue to lower its cumulative cost over the 12 years to below that of the standard Volvo. In the CUV example, the up-front cost is higher for the Chevy Bolt EV because it is no longer eligible for the federal tax credit, and it takes about seven years to break even with the cumulative costs of the gasoline powered Trax; but ends up with a lower cumulative cost after 12 years.

For more information regarding the details of this analysis, see Appendix B.

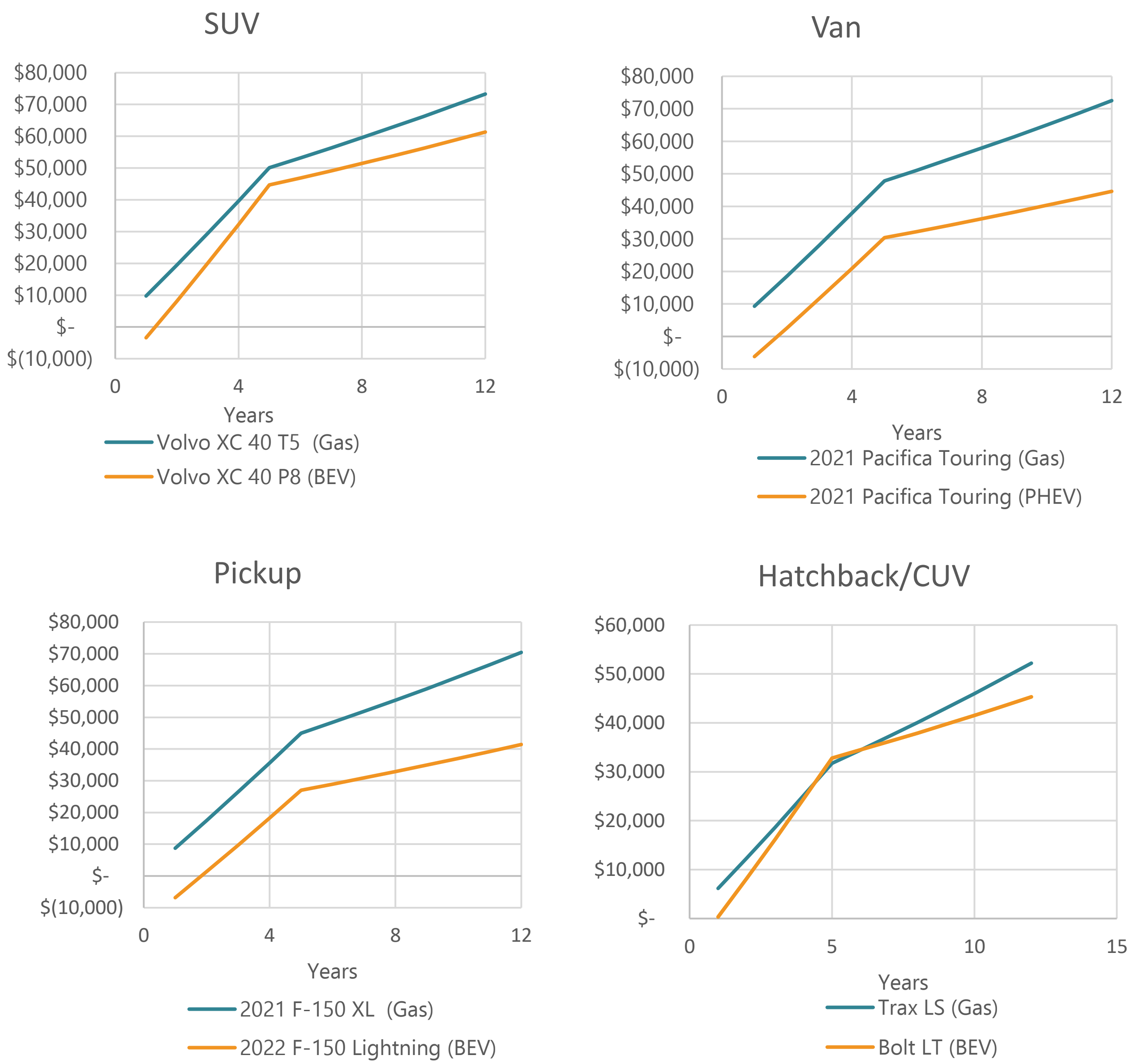
Figure 4: Cumulative Cost of Ownership with Up-front Purchase Including Incentives[42]



EVs also have lower total cumulative costs over 12 years when financing a vehicle with a loan (Figure 5). The EV buyer may be able to maintain a positive cash flow through all years of ownership compared to its gasoline counterpart. Because the full amount of the incentives is applied in the first year toward the relatively smaller 20 percent down payment, the overall cost to own and operate the EV (shown in orange) is lower than the comparable gasoline vehicle costs (shown in blue). The bend in the lines at year five shows annual ownership costs decreasing once the loan is paid off. After five years, the annual savings compared to the gasoline vehicle continues to grow throughout the 12-year period. In all four cases, the electric vehicles provided lower cumulative net costs compared to the gasoline powered vehicles in nearly every year of vehicle ownership.

See Appendix C for the specific cumulative costs used in these assessments.

Figure 5: Cumulative Cost of Ownership with Financing[43]



While the up-front purchase price of an electric vehicle is generally higher, with incentives and lower operational costs, total costs over time can be less than a comparable gasoline vehicle. It is important to note, however, that these lower annual operating costs are dependent on low electric fuel rates. Oregonians living in multi-unit dwellings are less likely to be able to access electric fuel through their home electricity rates, and therefore must rely on private charging rates, making the potential for operational cost savings more uncertain (learn more in the Demographics section of this report).

Even though incentives can lower the up-front cost of an EV and, in some cases eliminate the price difference, the relatively high up-front cost of a new vehicle can still be a barrier for many low-to-moderate income Oregonians. The Oregon Clean Vehicle Rebate and the Charge Ahead Rebate offer an effective means for addressing this barrier because they can reduce the cost of the vehicle at the time of purchase. The availability of more affordable used EVs is also critical to transitioning the market toward EVs. Since the number of used vehicle purchases is four times higher than new vehicles in Oregon, a robust used EV market is critical if the state is to meet its EV adoption targets.[44] Continuing to support used EV sales in Oregon will also help ensure equitable access for more Oregonians to the benefits of switching to an electric vehicle.

Case Study – Fleet Electrification and the Oregon Department of Administrative Services

Transportation electrification can present many benefits for fleets, including government fleets. Benefits include reduced fuel and maintenance costs, and the ability to do their part in reducing agency or organizational greenhouse gas emissions. In support of vehicle electrification, the 2019 Oregon Legislature passed a bill directing state agencies to convert the state light-duty fleet to EVs. The bill required EV procurements to increase to 25 percent of all vehicle purchases and leases by 2025.[45] In 2021, HB 2027 accelerated this adoption to 100 percent by 2025, with exceptions where there are insufficient EV options to meet specific vehicle use case needs. The following information presents a case study of the Oregon Department of Administration's work to meet this target, including considerations and challenges as the state works to transform its light-duty fleet.

In total, the state fleet has had an average inventory of approximately 7,200 light-duty vehicles over the last five years, and about 60 percent of those (more than 4,200) are managed by the Department of Administrative Services.

ODOE's Own EV Fleet

Pictured here: ODOE's all-electric Chevrolet Bolt and plug-in hybrid Chevrolet Volt charging up for the next drive!

Table 4: State-Owned Light-Duty Vehicles[46]

State Agency	2015	2016	2017	2018	2019	2020
DAS	4,116	4,221	4,208	4,266	4,214	4,267
ODOT	1,281	1,276	1,217	1,190	1,257	1,248
Forestry	374	357	394	392	394	399
State Police	860	912	1,019	998	910	911
Military	104	101	93	93	56	69
OLCC	59	60	59	67	76	76
Agriculture	318	318	221	244	237	242
Total Count	**7,112**	**7,245**	**7,211**	**7,250**	**7,144**	**7,212**

DAS replaces about 300 to 350 vehicles each year, most of which are purchased using the DAS Statewide Price Agreement. The SPA is a contract that can be used by all state entities for the procurement of products or services at agreed upon terms. Price agreements lower the costs of procurement for state agencies by leveraging higher purchase volumes and reducing administrative costs. Using the SPA, the state acquires vehicles that will meet an agency's needs at the lowest cost. Similar to vehicle options available to the public, SPA prices for internal combustion engine vehicles are generally lower than for EVs. However, as EVs reach cost parity with gasoline vehicles for the general public, prices in the SPA are also anticipated to reach cost parity.

Charge Up at ODOE

ChargePoint chargers are available for employees and guests at ODOE's building at 550 Capital St. NE in Salem.

Table 5: Comparison of Gas-Powered to Similar EV Model on Oregon State Price Agreement[47]

Model	Type	SPA Cost	Cost Difference	Percent Difference
TRAX FWD LS	Gasoline	$ 18,969		
Bolt 5Dr LT	BEV	$26,466	$7,495	28.3%
Kona SEL 2.0L 4-cyl	Gasoline	$19,407		
Kona Electric SEL 150kW FWD	BEV	$34,639	$15,232	44.0%
Escape S AWD	Gasoline	$45,845		
Mustang MACH-E AWD	BEV	$21,900	$22,805	49.7%
Prius L	Hybrid	$24,500		
Prius Prime LE	PHEV	$20,379	$2,600	10.6%
Escape FWD SE	Hybrid	$28,099		
Escape FWD SE	PHEV	$25,471	$7,720	27.5%
Voyager LX -FWD	Hybrid	$35,030		
Pacifica Touring Hybrid	PHEV		$9,559	27.3%
			Overall Average	**31.2%**

In addition to the vehicle itself, state agencies usually incur additional up-front costs to install charging equipment and upgrade electric infrastructure to deliver the needed electric fuel. There are 328 state-owned buildings located throughout Oregon, and more under lease. Unlike home charging, which may require little or no additional costs to access electricity for charging, state buildings may require investments in charging equipment, installations, and sometimes electrical upgrades to supply state EVs with electric fuel. As with many businesses and organizations, these investments can compete with funds needed for other deferred maintenance and planned improvement projects.

DAS is already planning and implementing actions to develop charging infrastructure at state buildings. The agency is also looking at options to streamline the process to provide charging infrastructure, such as standardizing the bidding process for charger suppliers, which is needed to support the rapid expansion of EVs in state fleets. This is particularly important as the state's electric fleet grows and as more medium- and heavy-duty vehicles are electrified. While EV charging infrastructure build-out could become a significant portion of the costs for agencies, at the same time this infrastructure investment will create higher levels of fuel and maintenance savings well into the future.

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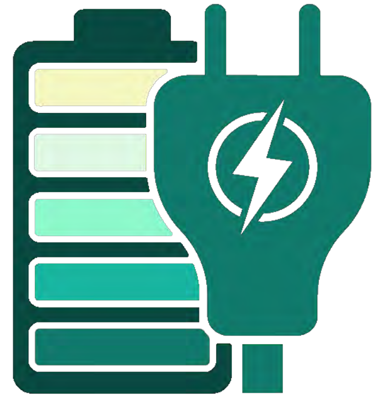
Oregonian and pup charging vehicle, Photo credit: ODOT

This section discusses the availability and reliability of the public and private electric vehicle charging infrastructure needed to support Oregon’s targets for zero-emission vehicle sales and registration. The Oregon Department of Transportation’s 2021 Transportation Electrification Infrastructure Needs Assessment (TEINA) outlined the state’s future charging infrastructure needs, so this section discusses how to define the terms “availability” and “reliability,” and suggests qualitative and quantitative metrics for measuring the two terms.

Availability & Reliability of Charging Infrastructure

Availability and Reliability of EV Charging Infrastructure



Widespread electric vehicle charging infrastructure is considered essential to the continued adoption of EVs. However, determining how much charging is needed for a certain city or state can be challenging as this need for infrastructure can be affected by factors like the average vehicle miles traveled by resident drivers, the average range of EVs commercially available, drivers' access to workplace or home charging, and even a driver's individual preference for convenience and low-cost fuel.[1] Senate Bill 1044 (2019) established Oregon's zero emission vehicle adoption goals and also directed the Oregon Department of Energy to report on the availability and reliability of EV charging infrastructure needed to meet these goals. As the Oregon Department of Transportation has already conducted a study on the state's future charging infrastructure needs, the 2021 Transportation Electrification Infrastructure Needs Assessment (TEINA), this section instead discusses how to define the terms "availability" and "reliability," suggests qualitative and quantitative metrics for measuring the two terms, and provides some figures on the current state of EV charging in Oregon. However, for ODOE to successfully report on the availability and reliability of EV charging infrastructure in future iterations of this biennial report, greater access to data will be necessary as well as guidance on what measures to include when defining availability and reliability.

Defining Availability and Reliability of EV Charging Infrastructure

While the terms reliability and availability are often used when discussing EV charging infrastructure, there are no industry-accepted definitions of each term. Reliability is commonly used to address whether charging equipment works (the terms uptime and downtime refer to whether equipment is operational or not), how often it breaks down, how long it's out of service, and how this is communicated to drivers. In contrast, availability can refer to whether a driver must be a member of a company's program to use its chargers, whether the charging is accessible day and night, or whether the price of a charging session is clearly marked.

Northeast States for Coordinated Air Use Management (NESCAUM) provides a thoughtful set of recommendations for EV charging infrastructure contract provisions that relate to "the reliability of EV charging networks and consumer confidence in charging infrastructure."[2] In the absence of accepted definitions, these recommendations can serve as a useful jumping off point for discussing availability and reliability. The relevant NESCAUM contract provision recommendations are grouped into three categories:

- Open access, payment options, accessibility, and customer service support.
- Redundancy, uptime, operations & maintenance, repairs, and operational status.
- Pricing transparency.[3]

Open access refers to the ability of a driver to use a public EV charger without being restricted by the need for a membership or subscription with the EV service equipment (EVSE) provider. **Payment options** addresses the number of ways that a driver can pay for a charging session, such as via an RFID card or fob, credit or debit cards (either via a card reader or over the phone), or mobile payment (e.g., Apple Pay or EVSE-specific app). The NESCAUM recommendations for **accessibility** for public charging focus on allowing public access to the charger 24/7 all year, having a parking space designated as reserved for EV charging, and adequate lighting from dusk until dawn. In addition to these recommendations, accessibility could also address whether the infrastructure is compliant with the Americans with Disabilities Act (ADA) or whether the site allows for multiple types of charging connectors (i.e., CHAdeMO, SAE J1772, etc.). **Customer service support** addresses whether EV charging stations have a toll-free assistance number and if stations are equipped with remote diagnostic and reboot functionality. **Redundancy** means multiple charging connectors are available at a site and **operations & maintenance** includes having a plan to minimize downtime.

The NESCAUM recommendations for contract provisions are categorized below as to whether they likely are measures of availability or reliability. However, some measures, such as redundancy, could fall under both terms – having more than one of each charging connector could make access to charging more available while it could also still allow for charging if one connector was not operational. And some measures addressed separately by NESCAUM contract provision recommendations could be considered as a single measure of reliability or availability, such as operations & maintenance and repairs. Here the recommendations are broken into measures of reliability and availability, taking into account how reliability has been generally understood to include measures of uptime, maintenance, and communication of service status; while availability relates to access, options, and accessibility, as shown in Table 1. The following sections discuss some of these measures in detail as potential components of definitions of availability and reliability. As these measures are from contract language and not definitions, not all of them may be appropriate for use in defining these terms.

Table 1: ODOE Categorization of NESCAUM Recommendations for Contract Language by Availability or Reliability

Availability	Reliability
Open access	Uptime
Payment options	Operations & maintenance
Pricing transparency	Repairs
Accessibility	Operational status
Redundancy	Redundancy
	Customer service support

Availability

Availability could include open access, payment options, accessibility, and price transparency, among other measures. Beyond the NESCAUM recommendations for contract provisions, a discussion of EV charging infrastructure availability is also often focused on the physical location of EVSE, especially in relation to major traffic corridors and areas with high EV penetration. Availability could also address equity concerns related to EVSE, including affordability of charging, whether information on payment and use are available in multiple languages, and EVSE locations relative to multi-unit dwellings.

Open Access

EV charging companies in the U.S. typically provide drivers membership opportunities where they may be able to receive an RFID fob or card to initiate and pay for charging sessions, and through which they may receive preferential pricing. EV charging company business models can vary from pay-as-you-go to a flat monthly fee to, in the case of Tesla, a period of free charging for Tesla EVs when using its proprietary network of chargers.[4] As recently as 2019, drivers who wanted to access a company's chargers usually had to first create an account either online or through an app and then provide a credit card for billing.[5] This meant some EV drivers who needed access to these chargers had to sign up with multiple charging companies even though they may only need to access their specific chargers on a one-time or infrequent basis.

Giving EV drivers greater access to charging is considered a critical factor in growing the adoption of EVs and for that reason, policymakers have begun to recommend or require that charging companies allow for "open access" of their networks – that is, the ability of non-members or non-subscribers to still access their chargers. The U.S. Department of Energy describes "… standardized, open charging systems that ensure easy access to all" as a critical component of EV infrastructure deployment,[6] and NESCAUM recommends contract language that requires charging companies to allow drivers to use public chargers regardless of membership or subscription status. California was an early adopter of open access with a 2013 bill that required open access for public charging stations,[i] and since 2019, a number of EV charging companies have created partnerships that allow EV drivers to "roam," or use partners' chargers without the need for a separate membership. For example, in January 2019, General Motors announced it would collaborate with EVgo, ChargePoint, and Greenlots to enable owners of the Chevy Bolt EV to seamlessly charge at all three charging companies' EV charging stations.[7]

Potential metrics for measuring open access:

- Yes/no whether specific EVSE companies operating chargers in Oregon allow open access at all of their charging stations.

Payment Options

Another metric that can affect access to EV charging is whether charging stations allow for multiple forms of payment, and many consider payment options to be a part of "open access." Given that only network members/subscribers will have RFID fobs or cards, allowing for payment via credit and debit cards as well as mobile payment (e.g., Apple Pay) can create greater access to EV charging. Credit and

[i] Senate Bill 454, called California's Electric Vehicle Charging Stations Open Access Act.

debit card payment can be accepted via swipe readers, chip readers, tap technology, mobile payment, or by calling a toll-free number.[8] NESCAUM recommends requiring card readers only for public DC fast chargers and that contract provisions should be revisited as technology evolves. Measuring payment options as a metric could be done either as a binary yes/no as to whether a secondary form of payment is accommodated beyond RFID cards or it could be measured based on whether a specific technology is used, such as swipe reader, chip reader, mobile, etc.

States have taken varying approaches to requirements for payment options for reasons related to cost, reliability, and equity. In California, the Air Resources Board adopted rules requiring that all publicly available chargers must allow for payment via mobile payment, toll-free number, and card readers to process credit card and debit card payments.[9] This prompted a disagreement among stakeholders as to whether requiring card reader technology went beyond the open access legislation requirement to allow users to "pay via credit card or mobile technology, or both."[10] [11] The charging industry argued that EV charging is a low-margin business and the cost of adding card reader hardware, especially for Level 2 chargers (as opposed to DC fast chargers), would impose substantial costs.[12] Beyond cost, card readers can also affect the reliability of EVSE as when the card readers go down, it can and often does render the charger itself unusable – and most card reader hardware isn't as able to withstand harsh environmental impacts as the chargers themselves.[13] Finally, card readers don't help the 21 percent of Americans without a credit card or the nearly 7.1 million unbanked[ii] households (about 5.4 percent of Americans), though California's requirement that card readers accept credit *and* debit cards allows unbanked drivers to pay for charging with a pre-paid card.[14] [15] Despite industry concerns, NESCAUM and others have applauded California's pioneering work on multiple payment methods for EV charging and suggest that requiring card readers that accept both credit and debit cards positively addresses equity concerns.[16] [17] California's EVSE standards include a requirement that all EVSE must have a credit /debit card reader, located on either the charging unit itself or a kiosk used to serve one or more chargers. The standard also provides deadlines for retrofitting existing chargers as well as installation of new chargers that conform to the requirement.[18] Vermont and Nevada have also implemented credit/debit card reader requirements for public chargers.

Potential metrics for measuring payment options:

- Yes/no whether a charging station allows multiple payment methods.
- Yes/no whether a charging station allows a specific payment method, such as mobile, card reader (swipe), card reader (chip), card reader (tap), or toll-free number.

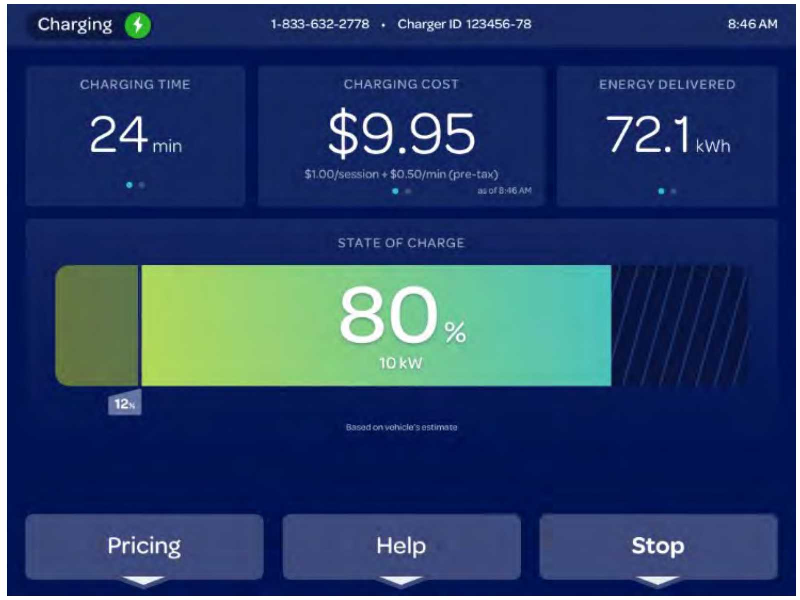
[ii] FDIC defines an unbanked household as one where no one has a checking or savings account at a bank or credit union.

Pricing Transparency

Drivers of internal combustion engine vehicles generally know how much it costs to fuel their vehicle and this price is always clearly posted at filling stations. In contrast, the price of EV charging can vary widely based on whether a driver is a member in a charging company's network, the charging company's overall business model, the price of electricity, and any extra demand charges. To help normalize the EV charging experience, NESCAUM recommends that EV charging stations be required to provide the following information clearly before a driver begins a charging session:

- Unit of sale, such as by kWh or by unit of time spent charging.
- Price per unit of sale.
- Any additional fees.[19]

For DC fast chargers, NESCAUM recommends requiring that charging stations also clearly state the maximum power level in kW (or another equivalent unit).



Charging interface from electrifyamerica.com

As part of its goals to ensure public charging is a user-friendly and consistent experience and that EV charging offers the benefit of lower fueling costs, the TEINA study recommends that Oregon address transparency in EV charging rates and encourages utilities to develop specific rates for distinct types[iii] of EV charging.[20]

Potential metrics for measuring pricing transparency:

- Yes/no whether charging station clearly states costs associated with charging before a driver initiates a charging session.
- Yes/no whether charging station clearly states specific information related to charging costs, such as unit of sale, price per unit of sale, or any additional fees.

Accessibility

Accessibility can refer to factors that facilitate public access to charging, from ADA compliance to multiple types of charging connectors. NESCAUM recommends that public charging stations be accessible to drivers 24/7, while also acknowledging that this won't always be possible. However, given how vital DC fast chargers serving highway corridors are to keeping EV drivers fueled up, NESCAUM does include in its draft contract language a requirement that DC fast chargers near highway corridors be available to the public at all times.[21]

[iii] Distinct types of charging can refer to differences related to charging profiles (including whether the charging happens during a peak period that triggers demand fees or time-of-use fees), charger types, and user groups.

Federal law requires that all goods and services available to the public must comply with the ADA, including public EV charging stations. However, the ADA does not provide any specific design considerations or guidance relating to EVSE and in most states, including Oregon, ADA compliance is determined at the local level and handled jurisdiction by jurisdiction. California added specific accessibility standards to its EV charging station building codes in 2017, including requiring a certain number of accessible charging stalls per total number of chargers at a facility and accessible routes from the charging stall to a building entrance.[22] Electrify America indicated that they incorporate accessibility at every site they build and that each site includes one space with an additional five feet for a clearance aisle to increase access (A. Dick, personal communication, April 15, 2020). With respect to whether a disabled parking pass is required to use an EV charging stall, it depends on whether EV charging or parking is the primary purpose of the stall. If EV charging stations are provided in addition to parking at a site, then EV charging is generally considered to be the primary purpose of the stall associated with the charger and anyone may use that stall to charge their vehicle, regardless of whether they have a disabled parking pass.

Electrify America Charging Station in Salem, Oregon with Extra-Wide Clearance for Accessibility. Source: Electrify America

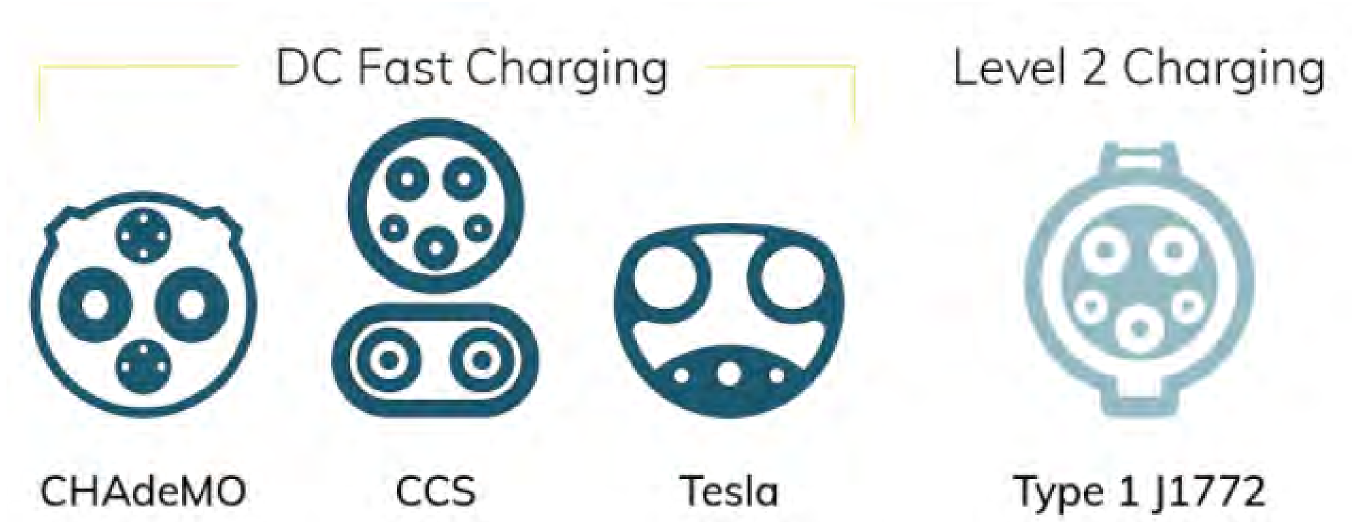
Another concern related to accessibility is whether a charging station is available for charging – if there is a designated parking spot at the charger and whether the charger is in use. Drivers wishing to use a charger may find that a non-EV is parked in the spot in front of the charger or that an EV that is not being charged is in the spot. Some states and municipalities have adopted requirements for "EV Charging Only" signage and prohibitions for non-EVs parking at public chargers marked accordingly. Some jurisdictions also require that EVs parked in these spaces must be connected to the EVSE and actively charging while parked in the spot, and some have instituted time limits for occupancy of the spot.[23]

For all EVs in North America, the SAE J1772 is the industry standard charging connector type for Level 2 charging.[iv] However, there has been less standardization for DC fast chargers, and an EV in North America could require one of three different connector types for fast charging – CHAdeMO, SAE Combo CCS (sometimes referred to as CCS), or Tesla. CHAdeMO was the standard for some automakers for early EV models, such as the Nissan Leaf or the first-generation Kia Soul EV, but in recent years, the industry has converged on CCS as the dominant standard. Nissan, the last automaker

[iv] Tesla EVs have a proprietary charging port but each also come with an adapter to use SAE J1772.

offering an EV with a CHAdeMO port in North America, announced[24] in 2020 that it would not be equipping future EV models with CHAdeMO, and Electrify America's Cycle 3 ZEV National Investment Plan[25] stated it would no longer be installing CHAdeMO connectors at any of its charging stations (except in California).

Figure 1: Level 2 and DC Fast Charging Connectors for EV Charging in North America[26]



In Oregon, each of the three DC fast charging connector types accounts for about one-third of all available DC fast charge connectors, though CCS and CHAdeMO charging connectors are often available at the same stations.[27] NESCAUM's recommendations for EV charging contract language are from 2019, one year before Nissan's announcement, and they include a suggested provision that public DC fast chargers must offer both CHAdeMO and CCS charging connectors. Even as all new EVs bound for North America roll off the assembly line with the same DC fast charging port, it may be good practice to continue support for CHAdeMO in Oregon. From an equity standpoint, some of the used EVs in Oregon will have a CHAdeMO port and some of those will be purchased by low- and moderate-income households. If an affordable used EV is likely to have a CHAdeMO charging port and if existing DC fast charger CHAdeMOs are not kept in good repair, then DC fast chargers might increasingly only be available to Oregonians who can afford newer and more expensive EVs.

Potential metrics for measuring accessibility:

- Yes/no whether a public charger is accessible 24-hours, seven days a week.
- Yes/no whether charging station offers ADA-compliant stall(s).
- Number and type of ADA-compliant stalls per charging station.
- Yes/no whether charging station offers multiple charging connectors.
- Yes/no whether charging station offers multiple charging connector types, and what types.

Geographic Location

While the NESCAUM model contract language does not address the geographic location of EVSE, some Oregon stakeholders have indicated that location is an important part of "availability" of charging infrastructure (see *Defining Availability and Reliability for Oregon* subsection, below), including charging located near major travel corridors and charging for those who don't have access to home charging. ODOT's TEINA study identified six EV infrastructure goals to support meeting Oregon's ZEV adoption goals, the first of which relates to the location of charging infrastructure.

One of Six EV Infrastructure Goals Identified in 2021 ODOT TEINA Study (Source: ODOT)

The majority of the early adopters of EVs have been homeowners, and ODOT's TEINA study assumes that about 90 percent of EV charging currently takes place at home in Oregon, based on analysis by RMI.[28] (Learn more in the Demographics section of this report.) ODOT's TEINA study assumes that 90 percent of light-duty urban and rural EV charging occurred at home in 2020, but is expected to decline to about 60 percent by 2035.[29] This decline in the overall percent of home charging is due to an expectation that as EVs become more mainstream, EV buyers' housing types will begin to resemble that of general new vehicle buyers over time, including a greater number of multi-unit dwellings.[30] EV drivers without access to dedicated overnight charging at home will need public charging located nearby, which contributes to the growing need for EVSE, especially in urban areas. With respect to EVSE in urban areas, there has also been an increasing push to ensure that chargers are deployed in a way that benefits frontline and environmental justice communities.[v] These communities are overburdened by transportation-related air pollution and often have limited access to affordable and safe transportation options.[31] Some states, such as New York and California, require that a certain percentage of make-ready infrastructure[vi] for charging light-duty EVs be deployed in these communities.[32]

Make-ready can be distinguished from a similar term, **EV-ready**:
Make-ready incudes the electric infrastructure necessary to support the charger, whereas EV-ready would include the actual chargers.

[v] These communities generally include indigenous peoples, communities of color, low-income communities, and others.

[vi] Make-ready infrastructure refers to all the necessary electrical infrastructure to power an EV charger, such as wires or conduit, as well as all necessary concrete work for mounting chargers, and, in some cases, all necessary cellular repeaters.

Finally, availability could be defined not only by EVSE located where one lives, but also where one travels. While Oregon has worked to ensure access to EVSE, especially DC fast chargers, along travel corridors in the state, the TEINA study estimated a need for a five-fold increase in existing publicly available DC fast chargers by 2025.[33]

Potential metrics for measuring geographic location:

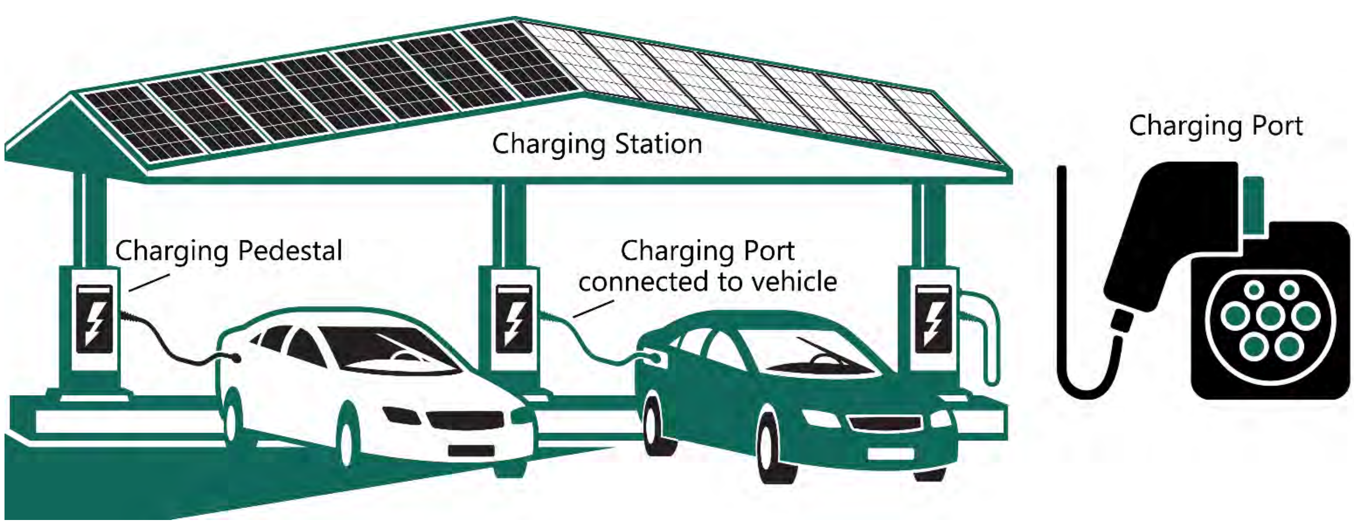
- Number or percent of charging stations located within a specific distance to areas with some percent of multi-unit dwellings in the housing mix.
- Percent of make-ready infrastructure located in or near identified frontline or environmental justice communities.
- Number or percent of charging stations located in or near identified frontline or environmental justice communities.
- Number or percent of charging stations located on or near identified travel corridors.
- Distance in miles between charging stations located on or near identified travel corridors.
- Density of charging ports or charging stations per population
- Density of charging ports per registered EVs in a given area.

Reliability

When discussing EVSE, reliability is generally used to refer to whether the charging equipment is working as expected, whether and how a driver can get support when charging equipment isn't working, the timeframe for a return to functionality, and whether real-time information on the function status of charging equipment is available online.

Uptime

Uptime is defined as the share of time that a charging station is functional and available for use and is the primary accepted measure of reliability. Uptime can be measured separately for each charging port, for each charging pedestal (i.e., if there is at least one functional port at a charging pedestal), or for each charging site.[34] A charging port is the hardware that supplies electricity to an EV and includes the connector that directly plugs into the vehicle. A charging pedestal or column is what houses the charging hardware and can have a single charging port or multiple ports.[35]



A charging station or charging site can refer to a single charging port located individually or it can refer to multiple charging pedestals installed in proximity to one another.

A calendar year has 8,760 hours in it, except in the case of a leap year, and so an uptime of 99 percent would represent 8,672 hours of functionality, or 361 days. While only four percentage points lower, an uptime of 95 percent would represent 8,322 hours or 347 days of functionality, which is a difference of 14 days or 350 hours.[36] For its state grant and procurement contract language recommendations, NESCAUM suggests a 99 percent uptime requirement, or no more than 1.7 hours of cumulative downtime in a period of seven days, but only for DC fast charger infrastructure.[37] The technical specifications and branding standards for the Oregon portion of the West Coast Electric Highway, in contrast, require that each connector on each DC fast charger or Level 2 charger must be operational 95 percent of the time (based on a period of 24 hours and 7 days a week), and that charging infrastructure operators must have a plan for meeting 99 percent uptime.[38]

Potential metrics for measuring uptime:

- Percent uptime per charging port or charging station.
- Available plan for meeting specific percent uptime by EVSE.

Repairs

The time it takes an EVSE operator to make repairs to non-functioning equipment directly affects uptime, and so the interval between when a functionality issue is reported and when repairs are initiated is another metric sometimes used in determining reliability. NESCAUM recommends that repairs should be initiated within 24 hours of notice of an issue. The Oregon portion of the West Coast Electric Highway requires this 24-hour response time, with an additional requirement that the EVSE must be repaired within 2-5 days.

Potential metrics for measuring repair time:

- Time elapsed between notice of issue and repair of issue by charging port or charging station.
- Yes/no whether repair initiated within specific timeframe of notice.

Defining Availability and Reliability for Oregon

Should Oregon choose to develop formal definitions for the terms “availability” and “reliability” for EV charging infrastructure, care should be taken to define the terms broadly enough so that Oregon’s approach doesn’t discourage standardization of the industry, but still provides a basis for meaningful, measurable metrics. Such definitions should address equity and inclusion considerations and should also avoid prescriptive requirements that may lead to unintended consequences.

Oregon should also consider supporting opportunities to include reasonable data reporting requirements in any codified definitions or contract language so that progress towards availability and reliability metrics can be adequately measured over time and aid in policymaking.

Determining how to define these terms raises complex issues around technology, access, and equity, and there are likely to be proponents on both sides of some of the issues addressed. Following are further thoughts on availability and reliability from Oregon stakeholders and from ODOT’s TEINA study that should inform any development of definitions for these terms in Oregon, but they should also be taken as the viewpoints of some but not all stakeholders.

Oregon Stakeholder Feedback on Defining Availability and Reliability

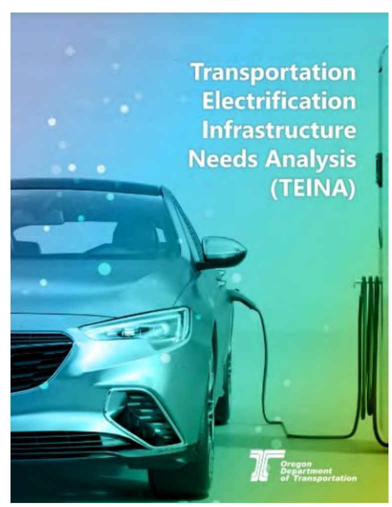
In May 2021, at a public meeting of the Zero Emission Vehicle Interagency Working Group (ZEVIWG), ODOE asked stakeholders to provide feedback on how best to define availability of EV charging infrastructure for the purposes of the BiZEV report.[vii] At this meeting, ODOE presented a working definition of availability for consideration that reflected the NESCAUM recommendations in Table 1, and then asked for thoughts on how best to incorporate physical location and equity into a definition. Following are some of the views expressed by stakeholders about how to define availability when discussing EVSE expressed at this meeting:

- **Location:** Location *and* density are both important for EV charging. Density could be measured by the number of EV charging stations per quantity of registered EVs in the state.
- **Affordability:** Concern that EV charging rates are not regulated by the state and that, as defined by NESCAUM and used by other jurisdictions, open access does not preclude an EV charging company to offer preferential charging rates to members/subscribers.
- **Accessibility:** Concern about internal combustion engine vehicles parking in spaces reserved for EV charging, suggestion that ODOE include EV parking signage (or lack thereof) as affecting availability.
- **Equity:** One equity concern was voiced about how integral smartphones and apps have become for locating chargers, paying for charging, and, in some cases, adding a driver to a queue for a specific charger. Seniors can have difficulties with smartphones, and not all Oregonians can necessarily afford them.

TEINA Study Recommendations Related to Availability and Reliability

The TEINA study suggests a number of initiatives to develop a public charging experience that is "user-friendly, convenient, safe, and consistent."[39] These include the following:

- Lead a public process to identify EV charging needs and standards to create a more consistent EV charging experience; address all items of consistency, including transparency in rates, multiple payment methods, open access, roaming, interoperability, reliability, redundancy, resiliency, ADA compliance, safety/lighting;
- Engage with national, regional, and other multi-state actors to harmonize the EV charging experience;
- Require all incentive funding for infrastructure development to meet certain standards for user experience, including interoperability and reporting requirements; and
- Ensure consistent signage and labeling for EV fueling.



[vii] See Appendix A for minutes from this meeting. Reliability was briefly touched upon during the meeting, but the discussion focused on availability.

Performance Data and Metrics for Current EV Charging Infrastructure in Oregon

Despite a lack of accepted definitions for availability and reliability when it comes to EV charging infrastructure, ODOE reached out to EVSEs that operate public EV charging infrastructure in Oregon for data on the most accepted metric associated with reliability, which is uptime. Currently Oregon does not require that charging companies share such data with State of Oregon entities, and none of these entities were able or willing to share it voluntarily. ODOE also reached out to organizations that aggregate data from charging infrastructure, but they either did not have data on uptime or were not able or willing to share data at this time.

Utilization data on the chargers associated with the West Coast Electric Highway is publicly available, including use patterns by month and by site, and the chargers with the highest and lowest utilization.[40] However, no data on uptime is currently available. ODOE also received data from the Eugene Water and Electric Board for its two publicly available chargers in Eugene, Oregon, though this data did not include information on uptime either. Finally, PGE provided qualitative information regarding downtime of its Electric Avenue pilot program as part its reporting for the Oregon Public Utility Commission's transportation docket, UM 1811. PGE reported that numerous hardware and software issues have resulted in charger downtime as an ongoing problem, but that in working with EVSEs, there has been some resolution of issues causing downtime.[41]

The Senate Bill 1044 statute that requires ODOE to report on the availability and reliability of EV chargers indicated that the report should include reliability data only if it was provided by the data holders. For future iterations of this report, ODOE will continue to reach out to EVSE companies and utilities for performance data and other information to inform this specific reporting requirement. Further, the state is considering stipulating reliability data reporting requirements for future contracts where financial support is provided for EV infrastructure development. For ODOE to successfully report on the availability and reliability of EV charging infrastructure in future iterations of this biennial report, greater access to data will be necessary.

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EV Charging pedestal in front of electricity transmission lines. Photo source: betterenergy.org

This section evaluates opportunities to minimize effects on the electric grid from transportation electrification, including rate design, managed charging, vehicle-to-grid services, and electricity conservation techniques.

Opportunities to Minimize the Effects of ZEVs on the Electric Grid

Introduction

It is anticipated that in the near term (three to five years) the impact of EVs on the grid will be minimal. Beyond five years, utilities are already investigating potential solutions to meet increased electric demand from EVs and minimize impacts to the grid. Electrifying Oregon's transportation sector has the potential to drive growth in demand for electricity, but understating when and where that growth will occur on the grid is key to addressing it. While electric vehicles are not that dissimilar from other large end-use electric loads – dryers, refrigerators, or ovens – there are several differences that pose unique challenges for managing the grid, particularly at the local level. However, electric utilities have experience planning to meet growing demand for electricity and ensuring sufficient resources are available to meet customer needs.

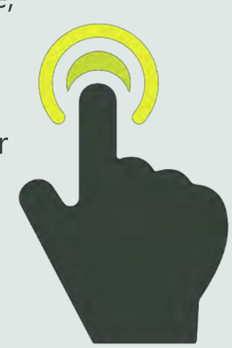
Utilities have several options to help accommodate more electric vehicles, including rate design, managed charging, vehicle-to-grid services, and electricity conservation techniques. These strategies not only help manage higher electricity demand resulting from electricity fueling, but some strategies also have the potential to play a role in managing the grid of the future.

This section of the report will consider both the total annual energy consumption of EVs (measured in kilowatt hours) and the peak demand for electricity needed from the grid to charge EVs (measured in kilowatts). Both metrics are important and have different potential implications for grid management. These impacts will be considered at the local level, with respect to one or a handful of EVs charging in proximity to one another, as well as how all EVs charging may affect the grid at the system level.

Energy 101: Demand vs. Energy

Historically, it has not been cost-effective to store electricity in large volumes. As a result, the electric system is sized to be able to satisfy the largest requirements for electricity over time—called **peak demand.** Utilities need to provide for peak demand even though consumers use less (often significantly less) during most hours of the day-month-year. This results in an electric generation and delivery system that is, by design, oversized and underutilized much of the time.

Demand is a measurement of the maximum amount of electricity required during a one-hour interval within a billing period, measured in kilowatts (kW). Meanwhile, **energy**, measured in kilowatt-hours (kWh), is the amount of electricity actually consumed over a defined period of time.



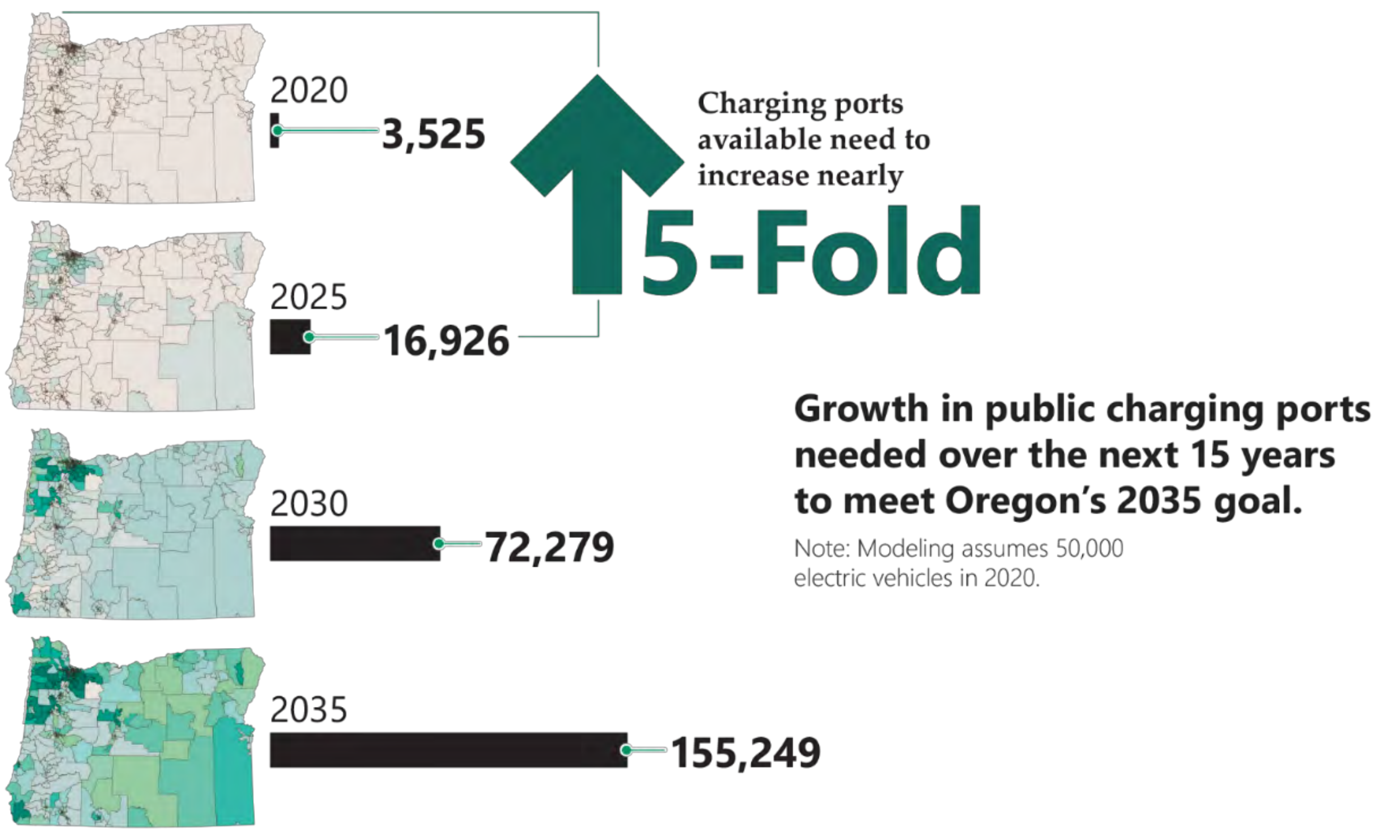
The more appliances one runs at the same time, the more demand (kW) for electricity increases. The more often one runs appliances over time, the more energy consumption (kWh) increases.

To handle peak demands, the electricity sector has long engaged in multi-year capacity planning to forecast future peak demands on the grid and to identify whether new resources are required to meet those demands. Several years of advanced notice could be required to develop new generating resources needed to meet growing demand. The expected arrival of new demand for electricity from EV charging is no different and can be incorporated into resource planning by electric utilities.

What's Coming: ZEV Charging Infrastructure in Oregon

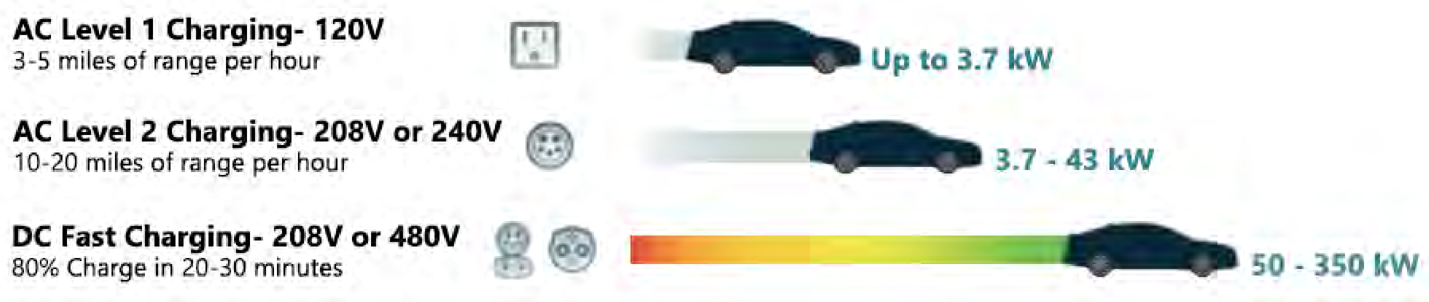
The state's ZEV goals will require significant charging infrastructure to provide fuel for the increasing numbers of electric vehicles on Oregon's roads (learn more in the ZEV Progress section of this report). The Oregon Department of Transportation published a study in 2021 on the charging infrastructure needed to accommodate Oregon's 2025, 2030, and 2035 ZEV adoption goals.[1] The Transportation Electrification Infrastructure Needs Analysis (TEINA) study's business-as-usual scenario analysis found that, compared to 2020 levels, the number of charging ports would need to increase by nearly five-fold across Oregon to meet the 2025 goal, by more than 20-fold to meet the 2030 goal, and over 44-fold by 2035.

Figure 1: Transportation Electrification Business-as-Usual Modeling for EV Charger Growth Needed to Meet Oregon's ZEV Adoption Goals[2]



According to the study, about 75 percent of charging needs would be met with Level 1 and Level 2 charging, while the remaining 25 percent of charging would be met by higher-voltage DC Fast Chargers. Released in June 2021, the TEINA study did not assess grid needs or impacts from this rapid expansion of EV charging, but highlighted that the state should ensure utilities are well-positioned for what is expected to occur throughout the state.[3]

Figure 2: Level Up: Peak Demand of Different EV Chargers [4]



Note: Many chargers offer charging on 350 kW chargers, which can significantly reduce charging times, depending on how empty the battery is at time of charging and how full the driver wants the battery to get before ending the charging session.

By 2035, the TEINA study concluded that there will be more than 1.5 million home charging ports in Oregon, while chargers for medium- and heavy-duty commercial and industrial vehicles would need to increase from about 10 available ports in 2020 to more than 1,800 by 2035.[i]

Figure 3: Home Charging Ports Needed (Business as Usual), 2020-2035

Home Charging Ports Needed (Business as Usual Scenario)	2020	2025	2030	2035
Note: Each cell identifies the number of home charging ports needed by year and, in parentheses, the percentage of homes assumed to have access to a home charging port.	45,000 (90%)	200,000 (80%)	770,000 (70%)	1,500,000 (60%)

Electric school buses would charge on overnight Level 2 charging, and transit buses on faster 60 kW chargers, increasing from about 15 chargers in 2020 to more than 7,400 in 2035. Long-haul trucking, which has no commercially available models today, is also anticipated to grow significantly by 2035. Due to the larger loads and travel distances, the charging requirements for freight trucks are likely to be more powerful than what is in use today, and will require significant electric grid infrastructure investments to accommodate new EV freight trucks.

The potentially large, localized increase in peak demand (kW) from this scale of EV charger build-out is likely to pose the most significant challenge for utilities. While the sheer size and number of next-generation DC Fast Chargers (as high as 350 kW) will require utility planning and likely system upgrades to deploy, a similar impact could occur locally at the distribution level from the simultaneous charging of multiple EVs on Level-2 chargers located on the same residential

[i] This assumes all charging ports are 350 kW or equivalent. For example, 1,800 350 kW chargers is equivalent to 12,600 50 kW chargers. 350 kW chargers are being installed today and are likely necessary to achieve shorter charging time, especially for larger medium-duty and heavy-duty vehicles.

transformer. This may drive utility investments, for example, from upgrading distribution transformers in residential neighborhoods. Utilities could also make investments in systems able to monitor the demand on the distribution grid down to the level of individual residential transformers that provide electricity to only a few homes or buildings.[5]

It is important to note that these types of investments will be occurring within a broader clean energy transition that is revolutionizing the power sector and driving significant new investments across the grid. Bloomberg New Energy Finance, for example, estimates annual grid investments in the United States to increase from approximately $49 billion in 2020 to $123 billion by 2050, with 14 percent of those investments associated with upgrades necessary to accommodate increased electrification, including the transportation sector.[6]

Potential Grid Impacts from Transportation Electrification

The amount of new generating capacity needed to meet light-duty EV charging load demand is no greater than typical resource buildouts in the last several decades. However, localized effects from EV charging could be more pronounced because as adoption grows, charging EVs will not be distributed evenly across the grid. This uneven distribution, coupled with uncertainty of when individual EVs will appear on the grid, will present utility planners with a challenge to make necessary distribution system upgrades at the opportune time.

While the growth in demand for electricity from electrification of light-duty vehicles is likely to be significant in gross terms, it is expected to be comparable to the rates of historic annualized load growth—both with respect to peak demand and total energy consumption—that the electric industry has successfully managed for many decades.

The average Oregon residential customer consumed 10,205 kWh of electricity in 2019,[7] and a typical passenger EV might consume between 3,000 and 4,000 kWh of electricity annually, resulting in a sizable increase in electricity consumption for an individual household that charges its EV at home.[ii] By comparison, there are approximately 3.5 million light-duty vehicles operating in Oregon today. Even if 100 percent of those light-duty vehicles were converted to EVs, they would consume between 8 and 14 billion kWh of electricity annually[iii] — or approximately a 15 to 25 percent increase over the 50 billion kWh consumed in Oregon in 2019 by residential customers.[8] This level of growth would be manageable if it occurred over time.

The annual total electricity consumption per individual light-duty EV is comparable to the amount of several existing large in-home electric appliances. At low levels of EV adoption (e.g., 1 percent of all light-duty vehicles or ~35,000 EVs), total electricity consumption from EV charging statewide is modest and only a fraction of what all existing in-home electric appliances currently consume across the state. However, it is the higher peak demand – individually and in aggregate – that differentiates EV charging from other in-home appliances. For instance, the peak demand impacts on the local

[ii] Assuming that an average light-duty vehicle travels between 9,000 and 12,000 miles per year, and that the average EV travels approximately 3 miles per kWh of charge.
[iii] Representing 3,000 to 4,000 kWh of annual consumption per 3.5 million light-duty vehicles in Oregon today.

distribution grid from EV charging can be much higher than any single conventional in-home electric appliance, especially when using Level 2 chargers. Once EV adoption reaches approximately 10 percent of all light-duty vehicles (~350,000 EVs), total annual electricity demand from EVs statewide is likely to become comparable to total statewide electricity demand from all residential refrigerators or all in-home electric dryers.

Although the discussion in this report focuses largely on impacts to residential electric distribution systems from light-duty EV charging, it is important to note that high-powered DCFCs create an even greater demand on the system. While these chargers will not likely be used in the home, they could be used at commercial or industrial sites and will be used much more frequently for medium- and heavy-duty EVs, affecting a different part of the local distribution grid. DCFCs will also increasingly be located along travel corridors, where all types of EVs will benefit from a fueling network to support longer distance driving. The potential grid impacts of this type of charging are likely to be the subject of future iterations of this report as options for these vehicles become more commercially available (learn more in the ZEV Platforms section of this report).

In the near-term, the most consequential impacts from the electrification of light-duty vehicles are likely to occur in localized areas of the residential distribution grid, driven by increases in peak demand due to the simultaneous charging of multiple EVs in residential areas. As a result, most of the opportunities to minimize the overall grid impacts from transportation electrification are currently focused on addressing this issue.

Energy Consumption (kWh) from Light-Duty EV Charging

Annual growth in total energy consumption from light-duty EVs is not expected to differ significantly in scale from the rates of annual load growth seen in the industry over the last 70 years. A study commissioned by the U.S. Department of Energy compared the expected total national energy demand for light-duty EV charging against previous annual increases in energy demand.[iv]

What's Watt – How to Convert Energy and Capacity Units

k = kilo, M = mega, G = giga

Watts measure how much energy can be generated or consumed by an object.

kW = kilowatt = 1000 watts
MW = megawatt = 1000 kilowatts
GW = gigawatt = 1000 megawatts

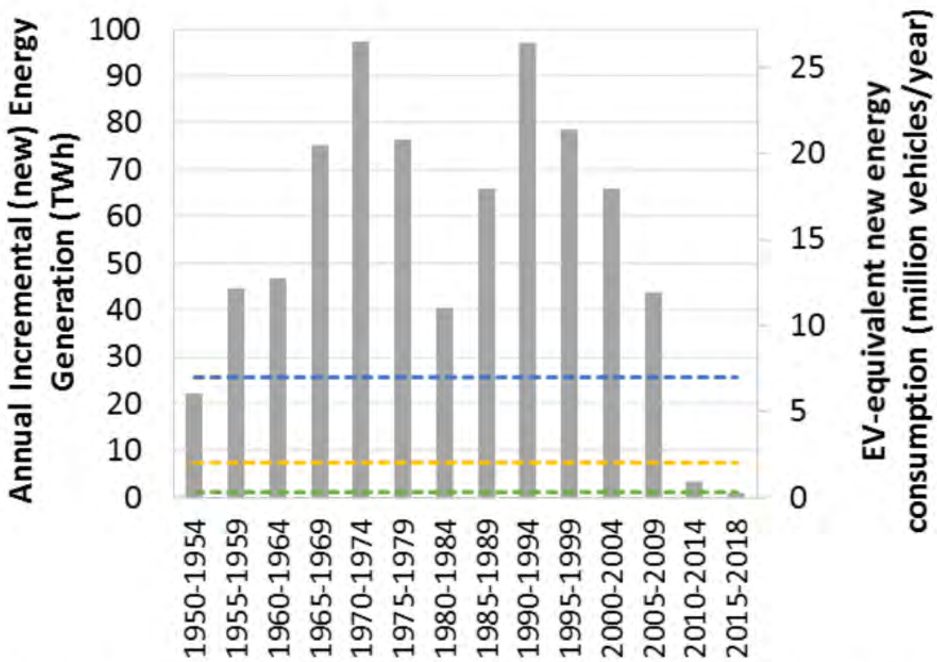
Watt-hours measure how much energy was actually generated or consumed over the course of an hour.

kWh = kilowatt-hour = consuming 1000 watts in an hour
MWh = megawatt-hour = consuming 1000 kilowatts in an hour
GWh = gigawatt-hour = consuming 1000 megawatts in an hour

[iv] This study only evaluated the potential impacts from electrification of *light-duty vehicles*. The study acknowledges that market growth scenarios for *medium-* and *heavy-duty vehicles* have not been incorporated in this analysis and that additional evaluation of their impacts on the grid is warranted.

The study concluded that, even comparing against its highest forecast of light-duty EV adoption by 2030 (the blue dotted line below), annual growth in electricity demand from light-duty EV charging would be less than 30,000,000 MWh. For comparison, historic average annual growth in national electricity demand (the gray bars in the graph below) exceeded 40,000,000 MWh per year from the 1950s through 2010, and in some years grew by more than 90,000,000 MWh.[9]

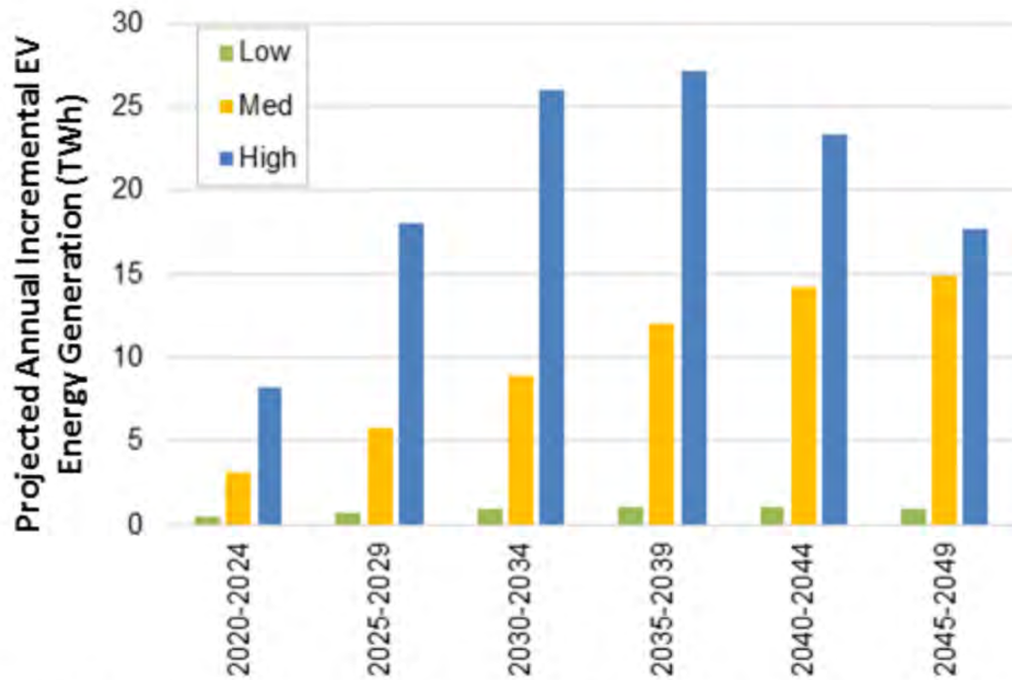
Figure 4: U.S. Annual Incremental (New) Energy Generation Over Time, 5-Year Increments



Historical data showing U.S. annual incremental (new) energy generation over time, averaged in 5-year increments. Energy generation associated with EV sales shown for the 2030 low, medium, and high scenarios considered at 1, 8, and 26 TWh, respectively, for context.

During previous waves of electrification—driven, for example, by the adoption of kitchen and laundry appliances in the early 1970s and again by residential air conditioning in the 1990s—high growth rates in new annual energy consumption would be comparable to adding more than 25 million light-duty EVs charging on the grid annually. This would be roughly equivalent to 1.5 times the total number of all annual new light-duty vehicle sales in the U.S. today.[10] The graph below shows the study's expected actual annual increase in energy consumption from light-duty EVs across its three adoption scenarios (high, medium, and low) for five-year periods through 2050. The peak ocurred in the late 2030s at around 27,000,000 MWh of load growth per year.[11]

Figure 5: Projected Annual Incremental Energy Generation to Support EVs (5-Year Periods)

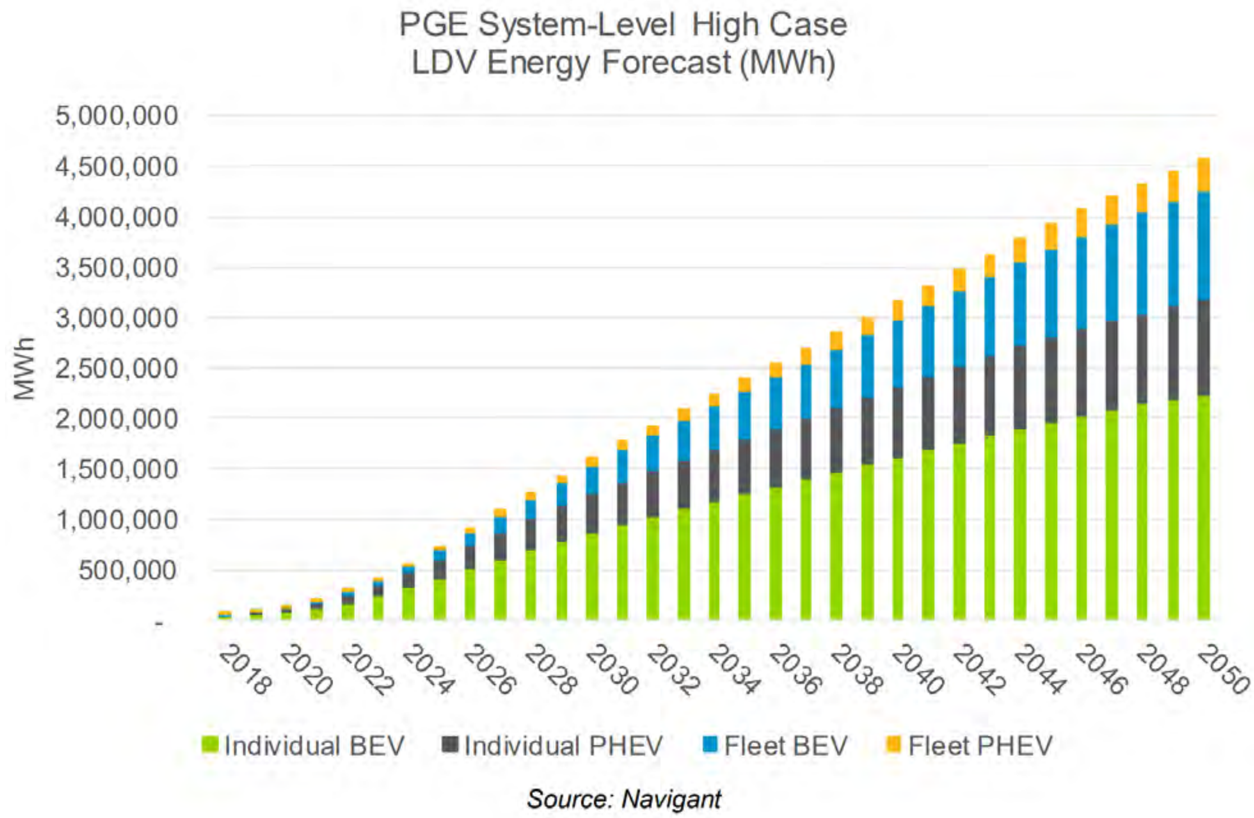


Projected annual incremental energy generation to support EVs, averaged to five-year periods for the low, medium, and high market penetration scenarios.

Recent studies by the Electric Power Research Institute and the National Renewable Energy Laboratory also projected the potential national annual growth rates for electricity consumption to be in the range of 0.6 percent to 1.8 percent. In all cases, transportation electrification is a "leading contributor" to this growth.[12] At the state level, Portland General Electric included an analysis by Navigant in its 2019 Integrated Resource Plan, estimating total energy consumption from light-duty EV adoption[v] (both individual and fleet vehicles) to be as much as 1,600,000 MWh (High Case) in 2030, and growing to as much as 4,600,000 MWh (High Case) by 2050.[13] For reference, 4,600,000 MWh would represent an approximately 26.5 percent increase in total electricity sales for PGE by 2050 over its total electricity sales in 2019 (17,304,691 MWh).[14]

[v] Similar to the U.S. DOE study cited above, Portland General Electric did not include a forecast for medium- and heavy-duty vehicles in its 2019 IRP, but indicated that it intends to do so in future planning cycles.

Figure 6: PGE System-Level High Case Lighty-Duty Vehicle Energy Forecast (MWh)



Peak Load (kW) from Light-Duty EV Charging

Light-duty EVs tend to be charged at similar times by customers (after work and in the overnight hours) and they are often located in clusters in residential areas. As a result, it is anticipated that the simultaneous charging of multiple light-duty EVs will be the biggest challenge for electric utilities to manage, especially when this occurs during peak demand periods. Electric utilities have long managed the electric grid to accommodate varying levels of peak demand on the system at different times of the day and year, not only by procuring sufficient electricity generation to meet that demand but also by encouraging customers to more efficiently manage their electricity use. For example, the following visual from Columbia River PUD encourages residential customers to stagger the use of their large, in-home appliances to minimize the simultaneous coincident peak demand on the grid.[15]

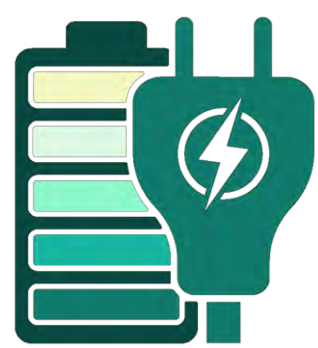
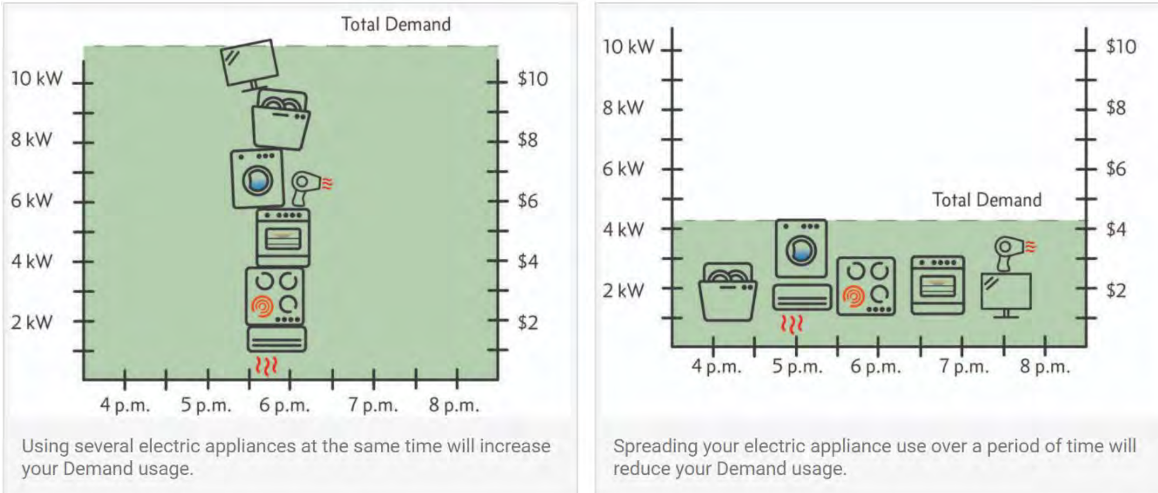


Figure 7: Columbia River PUD Graphic Showing Effects on Overall Demand by Staggering Appliance Use



Given the level of demand that individual EV chargers can place on the grid, demand management will likely be even more important for utilities to encourage going forward. Utilities have several tools available to them to assist with this that will be explored in greater detail below.

To assess the cumulative potential peak demand impacts of EV charging on the grid, assumptions must be made about the ***level of charging*** EVs are likely to utilize, ***how many*** EVs are likely to be using those chargers, and ***when*** they are likely to charge. The aggregate impact of large volumes of EVs using Level-2 charging, as indicated in the TEINA study, could actually impose a greater demand on the ***overall*** electric grid than DC fast chargers, which are likely to be used by fewer vehicles and with less frequency, despite the latter having ten times or more demand per individual charger.

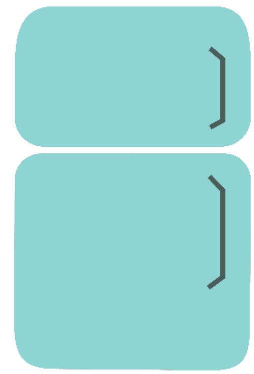
The result on the ***local*** grid, however, could be the reverse and will likely be highly location-specific.[16] For example, turning on a 50 kW DCFC creates an instantaneous, large electricity demand peak at a specific location. Although the peak will be relatively short-lived (minutes to hours), the local electric system must be able to accommodate that spike in demand whenever it is needed. As more powerful DC Fast Chargers become common in the years ahead, local distribution systems will need to be able to accommodate the higher peak demands. The challenges to local grid management can be even greater when the charger has a lower utilization rate because the demand is not only large but highly intermittant. Hawaiian Electric Company has expressed concern, for example, that higher output 350 kW DC Fast Chargers may result in fairly low utilization rates, resulting in very "peaky" load profiles.[17]

In addition to charger type, the time of day when vehicles are charging will have disparate effects on the grid. The demand from multiple light-duty EVs charging simultaneously could place a larger coincident peak demand on the grid than if those EVs were all charged at different times. Some degree of staggered vehicle charging will occur naturally as a result of different consumer behaviors, but charging could also be proactively staggered by scheduling specific charging start times for the vehicles – either by the customer, the utility, or a third-party. Controlled management of all light-duty EVs charging on the grid may be the optimal solution, but it is not prerequisite to the adoption of modest numbers of EVs.

What does 350 kW of demand look like to the grid?

A typical refrigerator has a peak demand of around 0.5 kW. So an EV charging at a 350 kW DC Fast Charger would have the same power draw on the electric grid as 700 typical refrigerators!

0.5 kW

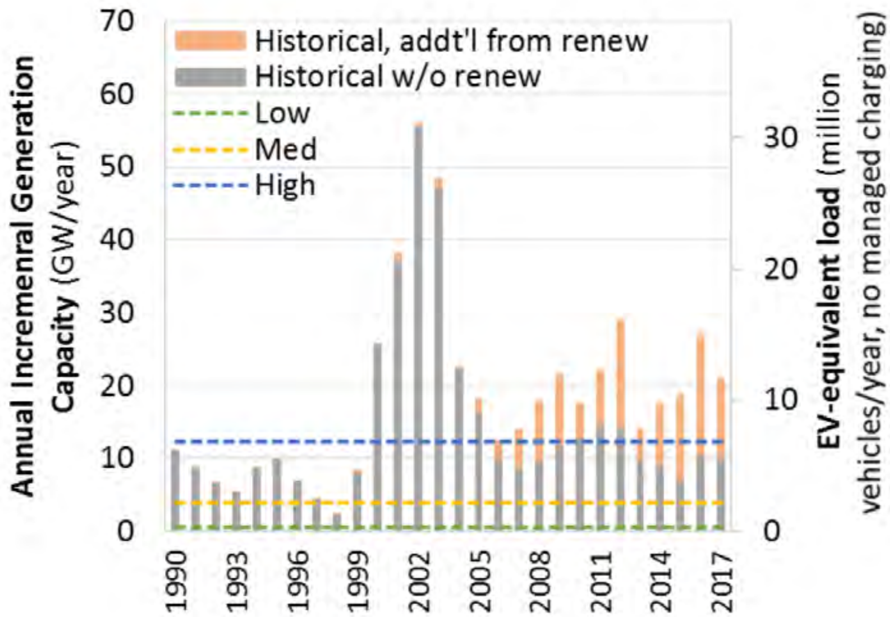


A recent study using a National Renewable Energy Laboratory modeling tool demonstrated that even with unmanaged charging for 100,000 light-duty EVs using Level 2 charging, the effects on peak load would be manageable at the overall grid level. The natural distribution in expected charging behavior among customers reduced the potential per vehicle demand by about 80 percent – from a range of 6.6 to 10 kW, the power demand modeled for an individual Level 2 charger in the study, to between 1.50 and 2.05 kW per vehicle.[18] This is only 20 to 25 percent of the potential total coincident peak load.

Nationally, the scale of generating capacity added to the grid on an annual basis in recent decades could accommodate even high levels of ***unmanaged*** charging of light-duty EVs. A recent study estimated the ***system-level*** effects across the United States for low, medium, and high light-duty EV adoption scenarios (see figure 8 below) and estimated additional peak capacity needs of 0.7, 4.5, and 14 GW,[vi] respectively.[19] As an example, 10 GW of new generating capacity could meet the peak ***unmanaged*** charging demand of 4 to 5 million new light-duty EVs.[20] In recent decades, it has not been unusual to add 10 GW of new generation resources annually to accomodate growth in peak demand aross the U.S. In the early 2000s, in fact, the national grid added significantly more than 10 GW of new capacity annually – soaring above 40 GW in some years, or roughly the equivalent capacity needed to serve as many as 25 million unmanaged light-duty EVs on the system.[21] In short, the increase in peak demands expected from charging light-duty EVs is well within the scale of what the annual build-out of new generating capacity in recent decades has accommodated.

[vi] 1 Gigawatt (GW) = 1,000 Megawatts (MW) = 1,000,000 kilowatts (kW).

Figure 8: U.S. Annual Incremental (New) Grid Capacity from 1990 to 2017[vii]



U.S. annual incremental (new) grid capacity from 1990 to 2017. The additional demand associated with EV sales for the low, medium, and high scenarios considered at 0.7, 4.5, and 14 GW, respectively, for context.

While the study above looks at the anticipated scale of capacity needs across the entire country, the ability to meet peak capacity needs from EV charging will vary across specific locations on the grid. Electricity does not flow seamlessly across the country, but rather is constrained by the physical capabilities of the system in specific locations—from the availability of nearby power plants to generate more power, to the excess capacity on transmission and distribution wires to move that power, to the rated operating limits of specific pieces of hardware, like the residential transformer outside a home. As a result, there is significant industry attention on how EV charging might affect the grid at the local level, particularly at times of existing peak system demand.

Opportunities to Minimize Grid Impacts of EV Charging

For most electric utilities, the share of total light-duty vehicles that have converted to EVs remains quite small. This provides an opportunity for utilities to investigate the potential future effects of EV charging on their systems by developing models and conducting real-world pilot programs and demonstration projects to inform their planning and operational activities. Today, most strategies revolve around informing and incentivizing charging behavior to move light-duty EV charging away from times of existing system peak over to off-peak hours. Emerging strategies include enabling utilities to have some degree of control over when and how fast light-duty EVs are charging on the

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[vii] Modeled, ***unmanaged*** peak capacity impacts across the low, medium, and high EV adoption scenarios (dotted lines) are overlaid with historical data of new generating capacity resource builds since 1990. The historical bars in gray and pink differentiate additional generation builds that were renewable (pink) and non-renewable (gray).

system. As EV adoption accelerates in the future, utilities may leverage advanced control systems to help more actively manage charging to assist with grid management.

Absent a specific rate design or incentive to encourage off-peak charging, it is assumed that EV charging will be uncontrolled or unmanaged. This is considered the default behavior, similar to how cell phones or laptops are charged at home today – by plugging in when the battery is depleted or when not in use, and charging at a constant rate until the battery is full or the device is unplugged. As discussed above, even unmanaged charging of light-duty EVs is likely to follow some natural distribution throughout the day.

In addition to the strategies explored below, there are also several ways that electricity conservation techniques can help to minimize potential grid impacts of transportation electrification. Broadly, the continued regional acquisition of energy efficiency as a resource will help meet increased electricity demand from transportation electrification. Consumers can also reduce energy consumption by choosing less energy-intensive models of electric vehicles – similar to choosing a gasoline vehicle that can achieve more miles per gallon. For example, according to the U.S. Department of Energy, a 2021 Tesla Model 3 requires 24 kWh to travel 100 miles, while a 2021 Porsche Taycan requires 50 kWh to travel the same distance.[22] In addition, similar to conventional gasoline vehicles, drivers can reduce their overall energy consumption by avoiding energy intensive actions like unnecessarily aggressive acceleration or excessive use of in-vehicle accessories (e.g., air conditioning, lighting, and entertainment systems, etc.) that reduce the vehicle's overall efficiency.

Rate Design and Incentives

One tool available to utilities to guide EV charging is the development of EV-specific rate structures. These rates can be as simple as offering an "on-peak" and a lower "off-peak" charging rate that provides an incentive to steer customers toward voluntarily charging their EVs during periods that will have less impact on the electric grid. Rates could also be more varied or even potentially dynamic based on real-time grid conditions. Utilities can also develop direct customer rebates or incentives to encourage different types of EV charging behavior.

For example, Hawaii and much of the southwestern U.S. often have excess electricity capacity during the middle of the day, when solar power is widely available, and sometimes at night when overall electricity demand is low. Hawaiian Electric Company noted that its EV customers' default charging behaviors tend to be at home in the evening and overnight hours. Evening hours are coincident with the utility's peak demand for electricity, and overnight hours do not allow for EVs to be charged with lower cost solar power.[23] Offering price incentives to shift charging out of those hours would lower overall costs for the utility and for EV owners.

To encourage off-peak charging, some utilities also offer incentives toward the purchase and installation of programmable Level 2 chargers that can be used to schedule specific times for the vehicle to charge. Eugene Water and Electric Board, for example, offers $500 rebates to residential customers to install programmable Level-2 chargers and encourages those customers to set EV charging to occur during off-peak hours:[24]

A time-differentiated rate structure, however, has the potential to create a new simultaneous spike in demand on the grid at a different time. For example, if rates get significantly cheaper at midnight, a large share of EV drivers may program chargers to start at exactly that time. As an alternative, utilities could create a variety of different rate structures for EV owners and select the one best suited to their needs.[25] Theoretically, the diversity in selection, while better aligned with the needs of individual EV owners, would also help distribute charging loads across a wider spectrum of time.

The flexibility of the power generating resources available to a utility—which can change seasonally, daily, or even hourly—can also affect these considerations. For example, the flexibility of the hydropower resource that provides the foundation of the electric mix in the northwest can help to manage these variations in demand for power from EV charging or other end-uses. Thermal gas plants or, increasingly in the years ahead, battery storage systems can also help to provide this type of flexibility. And it is within this context of the flexibility of the existing power system, or lack thereof, that utilities will evaluate flexible rate design options for EV charging.

As part of its Smart Charging Program, for example, Portland General Electric offers customers a $25 bill incentive twice a year if they install a utility-approved Level 2 charger. To receive the rebate, customers must meet certain usage and participation requirements, which enable PGE to manage charging when needed at any time of day. These requirements are set across six-month "charging seasons" (October to March, and April to September), and to be eligible participants must shift EV charging to low-demand times of day at least three times, keep their charger connected to the internet 50 percent of the time, and charge the EV at least 13 times.[26]

Find current EV rebates and incentives offered by Oregon electric utilities at Go Electric Oregon: https://goelectric.oregon.gov/incentives-rebates

Charging for medium- and heavy-duty vehicles may have similar challenges for light-duty vehicles, but timing for these vehicles will vary depending on the business need for that vehicle. For example, transit buses may need to run continuously during the day, requiring quick charging bursts, while school buses would operate in the morning and afternoon and therefore be able to charge more slowly mid-day or overnight.

Utilities already have specialized rates for many different types of commercial and industrial facilities and customers. EVs may add an additional consideration for utilities and regulators as transportation electrification increases.

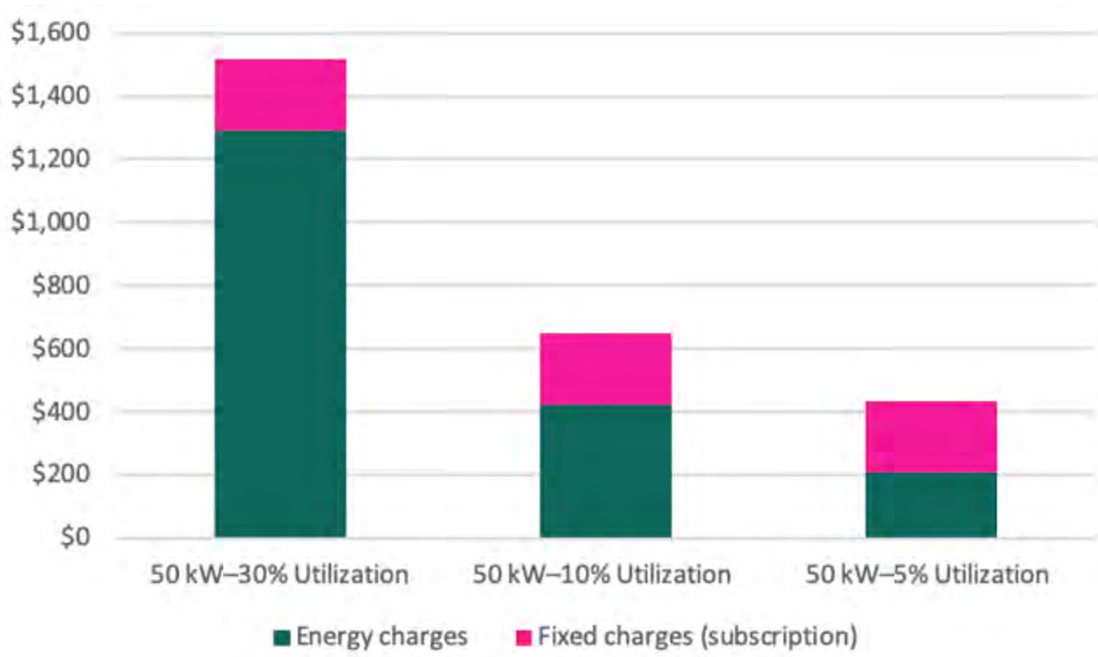
One element of rate design that is often a part of commercial and industrial electricity rates is the demand charge. ***Demand charges*** are based on the customer's highest peak demand usage as measured over a monthly or yearly time interval. As the visual below illustrates, the demand charge (labeled *energy charges*) may represent a large portion of the total bill (as much as 90 percent as identified in some locations in California) for a DC Fast Charger compared to their volumetric rate per kWh of electricity consumed when total system utilization rates are low.[27] [28] As the utilization of a DC fast charger increases, however, the demand charge will become a smaller share of the overall cost of the electricity. Note that stand alone demand charges, by and large, are not imposed on residential customers and thus are generally not applicable to considerations of Level-1 or Level-2 residential charging of light-duty vehicles.

Why Do Utilities Have Demand Charges?

Electric utilities are required to serve the load needs of their customers. Earlier in this section we described how utilities build the grid to accommodate the highest energy load that might occur at any given time. Charging only by consumption allows the company to recoup costs for the actual energy delivered, but it doesn't take into account building additional resources to cover the resources that are only needed to meet load needs for a few days or even hours during the year. Demand charges are designed to recover the costs to build those additional resources.

Demand-Charge-Fact-Sheet.pdf (cleanegroup.org)

Figure 9: Costs for 50 kW DCFC Using Xcel Energy's DCFC Tariff



What is uncontrolled or unmanaged EV charging?

"Vehicles charge at full power from the time when they are plugged in until they reach a full charge or unplug for their next trip. The power transfer rate is determined only by the type of charger the vehicle is plugged into."[29]

Managed charging, often referred to as grid-to-vehicle or ***V1G***, enables a utility to communicate with a charger to slow down or speed up the rate at which an EV charges – or in some cases even temporarily stop charging altogether for a short period of time. The state of charging can be dictated by a simple timer, a dynamic price signal from the electric grid, or other algorithms that take grid conditions into account.[30] In these programs, customers retain control of the charging – able to override the utility programs or algorithms as needed. V1G charging has been identified as a successful strategy for mitigating the grid impacts from EV charging.

What is managed charging or V1G?

"Vehicles can alter their charging rates to provide grid services. For instance, vehicles may reduce (or entirely deactivate) their charging during evening peaks and maximize charging during daytime over-generation. We assume that the controllable charging power can range from zero up to the maximum power transfer rate for the type of charger."[31]

V1G mechanisms require additional levels of electronic controls, communication systems, and precise metering between the EV, the charger, and the electric grid than what has typically been in place for other end-use customer loads. One step that has occurred in some places are requirements that new EV chargers have these types of controls and communication functionality built in.[32] Once these systems are in place, it is anticipated that grid operators could shift approximately 1,000 to 2,000 kW of peak load for every 500 EVs on their system.[33]

As an example, in California, eMotorWerks (a subsidiary of EnelX) successfully piloted a V1G program across its network of 6,000 EV chargers that enables EV drivers to "set it and forget it" when they plug in their vehicles at home. In this instance, the third-party aggregator can collectively manage the charging across these chargers based on market conditions without having an adverse effect on customer needs.[34]

While V1G allows for varying the rate of charging of an EV battery, there is also the potential for utilities to export energy from the EV battery back to the grid. This bidirectional communication is often referred to as vehicle-to-grid or ***V2G***, and it offers the potential for electric utilities to utilize the large battery capacity of all EVs plugged into the system to help manage electricity supply and demand. At-scale deployment of V2G charging holds the potential to help the state integrate more variable renewable energy or maintain electricity system reliability. [35] [36]

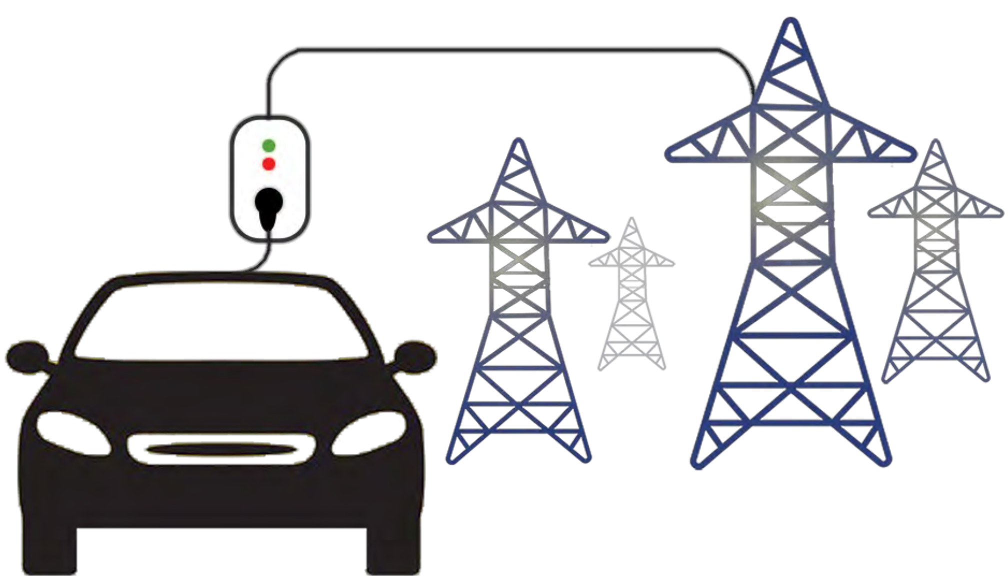
What are Vehicle-to-Grid services or V2G charging?

"Vehicles can either charge or discharge at any time step. For instance, vehicles may discharge during evening peaks while charging during daytime over-generation. We assume that the controllable charging power can range from zero to the maximum power transfer rate in either direction depending on the type of charger." [37]

Most V2G applications have been explored through utility pilot programs, such as with school buses in California.[38] V2G charging has not yet been widely utilized for several reasons, including:

- **Battery degradation:** There are issues concerning the potential premature degradation of EV batteries from extra discharge cycles for exports of power back to the grid.[39]
- **V2G capable chargers:** There are economic barriers to deploying V2G capable chargers due to the added cost of chargers with that functionality, and the potential need for other on-site electrical upgrades.[40]
- **EV manufacturers:** Many EV manufacturers either do not technically allow their vehicles to discharge power or void the EV battery warranty if a customer uses the vehicle for this purpose. [41]
- **Grid controls:** Additional investments are likely needed to enable electric utilities to dynamically control distributed EV charging stations and have sufficient visibility into location-specific grid conditions to optimize the use of the EV battery fleet as an electricity resource.

For these and other reasons, Energy Innovation, a national policy think tank working on clean energy and climate change issues, finds that V2G applications are "predominantly only feasible post 2030."[42] In the near-term, V2G might have limited specific applications, such as to provide local resilient back-up power to homes and other buildings.[43]



Can Your Vehicle Keep the Lights on During a Power Outage?

Electric vehicles have batteries that are significantly more powerful than the batteries that are found in fossil-fuel vehicles. In the case of a power outage an EV can be a resource to charge a phone or as heat or cooling source, but could your EV actually power your home?

In the recent public unveiling of their first electric pick-up truck, Ford indicated that the 80-amp charging station for the vehicle could be installed to automatically discharge the truck's battery to power the customer's house for a period of 3 days (based on typical usage) or for up to 10 days if power is rationed.[44] The F-150 Lightning, an all-electric version of their best-selling pick-up truck, is scheduled for release in 2022.[45]

2022 Ford F-150 Lightning showing off front trunk storage space

A study by Lawrence Berkeley National Laboratory found that V1G managed charging and V2G bidirectional charging could each have an "equally profound effect" on making the overall load increase from EVs more manageable for the grid.[46] In fact, studies have found that utilization of V1G alone can be effective at maintaining peak demand levels on the grid at the same level that they were before the addition of EV charging loads.[47]

Table 1: Examples of U.S. Utility V1G and V2G Programs and Grid Management Techniques[48]

Application	Utility	Approach
Peak Shaving	Con Edison (NY)	Con Edison's pilot program uses FleetCarma's technology to tap into EVs' on-board diagnostics to monitor battery state of charge and control charging. This approach enables Con Edison to effectively implement critical peak pricing for EV charging without deploying a dedicated smart meter for the vehicle.
	Eversource (MA)	Eversource managed the impact of EV charging on peak demand by throttling Level 2 charging down to Level 1 as needed.
V1G solutions to shift load to integrate solar power and manage distribution grid impacts	Southern California Edison (CA)	The CPUC is currently considering SCE's proposal for "Matinee" TOU Rates that offer commercial customers discounts for charging during peak solar generation hours, especially in the winter and shoulder months. The rates also include temporary demand charge relief.
	San Diego Gas and Electric (CA)	SDG&E is piloting a day ahead dynamic rate that encourages participants to charge their vehicles when and where grid benefits are greatest. The program aims to minimize impacts of EV charging on SDG&E's distribution system and encourage charging when solar power is abundant.
	Pacific Gas and Electric (in partner-ship with BMW) (CA)	This pilot provided conventional DR services to the grid operator while ensuring that customers' mobility needs are always met. BMW acted as an aggregator, curtailing home charging in response to program calls. Customers had the option to opt out, while BMW was able to use a bank of second use batteries to augment customers' response as needed to fulfill its obligation to the California ISO (CAISO).
V2G to provide ancillary services to grid using vehicle's battery	Southern California Edison (in partner-ship with the U.S. Air Force) (CA)	The U.S. Air Force partnered with SCE to demonstrate the potential for its fleet of EVs to bid frequency regulation into the CAISO ancillary services market. The pilot employed two-way chargers using Open ADR, and bid into CAISO ancillary service markets protocol.

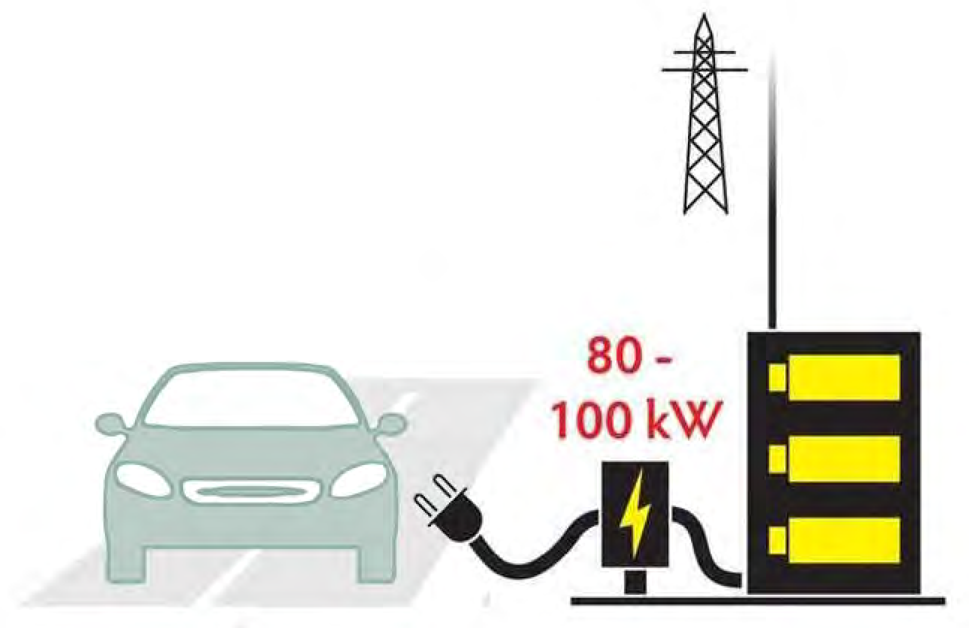
Infrastructure Solution: Battery Buffers

The strategies described so far have focused on shifting EV charging to reduce the impacts to the grid and moving EV charging to off-peak times. Another option is to create and store the electricity when demand is low and discharge that energy to EVs on demand – essentially buffering the grid from those impacts. Coincidentally, the technology to do this uses the same types of batteries that power those EVs.

Electrify America—a subsidiary of Volkswagen that owns several thousand EV chargers across the United States—wants to provide increased certainty with consistent, non-variable pricing for its customers.[49] To achieve this, Electrify America is exploring co-locating grid-connected batteries with some of its EV chargers.[50] Other entities in the industry have also identified the use of stand-alone "buffer batteries" as a potential solution, particularly as it relates to the impacts of DC Fast Chargers and with medium- and heavy-duty EV charging.[51] [52] These types of large batteries could help to smooth out the load spikes that the grid would otherwise see from EVs charging at a DC Fast Charger, and could instead allow the battery system to draw a steady lower voltage from the grid over a longer period of time to remain fully charged.[53] (Learn more in the Cost Differences section of this report.)

As the cost of grid-connected batteries continues to decline, it is possible that the deployment of batteries co-located with EV charging infrastructure could become more common in the years ahead.

Figure 10: Battery Buffers Reduce Demand to the Grid from Individual Chargers



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This section discusses, in consultation with the Department of Transportation, the impact the sales and ownership of zero-emission vehicles have on revenues that would otherwise accrue to the State Highway Fund.

Impacts of ZEV Sales on the State Highway Fund

The Impact of Sales and Ownership of ZEVs on State Highway Fund Revenues

As the number of hybrid and fully electric light-duty vehicles operating in the state has increased in recent years, some stakeholders have questioned whether Oregon's approach to collecting revenue for the State Highway Fund should change to reflect its changing fleet. This section describes the kinds of revenues from light-duty vehicles that flow into the State Highway Fund and provides a static look at how battery electric vehicles (BEVs)[i] in the state could affect those revenues.

Factors Affecting State Highway Fund Revenues

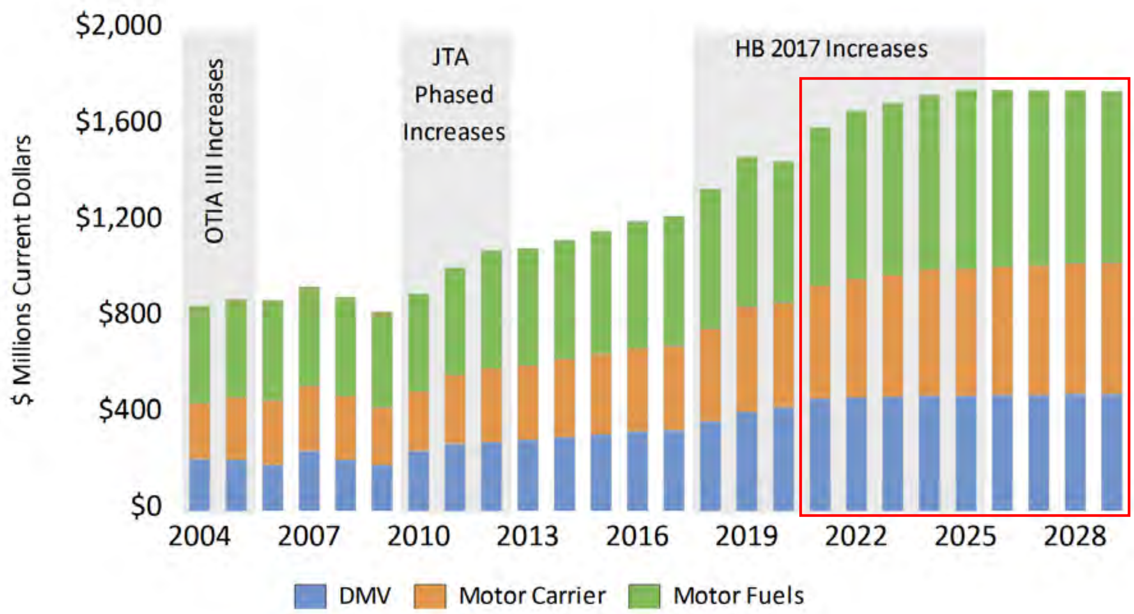
Oregon has based the financing of its highways on the principle of cost responsibility – the idea that road users should pay for their share of road costs – for more than 70 years, and this principle was included in the Oregon Constitution by vote in the November 1999 special election.[1] To determine the cost responsibility of each class of road user, Oregon has undertaken cost allocation studies periodically, starting in 1937, and now biennially, as required by the state constitution.[2]

One of the key funding sources for transportation infrastructure in Oregon is the State Highway Fund, a resource that funds the state highway program, county roads, and city streets.[3] Revenues from the State Highway Fund are constitutionally required to be spent on roads within the highway right of way, which can include bikeways and walkways. Funds can be used not only for construction, but also for day-to-day maintenance and operation of roads.[4] Oregon's State Highway Fund receives revenue from three main sources: motor fuels taxes; fees and taxes on heavy trucks, including registration and a weight/mile tax (referred to as motor carrier fees); and Driver and Motor Vehicle fees, including registration fees. The motor fuels tax is by far the biggest contributor among the three to the State Highway Fund revenue, as shown in Figure 1.

According to the Oregon Department of Transportation's 2020 State Highway Fund Revenue Forecast, revenue growth from all three of the State Highway Fund's main funding sources peaked in 2015-2016, with growth slowing through 2017.[5] However, the passage of the Keep Oregon Moving transportation funding package in 2017 (House Bill 2017) included increases in vehicle title and registration fees, the motor fuels tax, and the weight-mile tax on heavy trucks, which in turn led to increases in revenue for fiscal years 2018 and 2019 and beyond. Each of the three revenue streams feeding into the State Highway Fund was affected by HB 2017, as well as other different factors that affect growth.

[i] Throughout this chapter, battery electric vehicle, or BEV, is used to refer to battery electric vehicles that are fully electric. Hybrid vehicles are referred to as standard hybrids and plug-in electric hybrids.

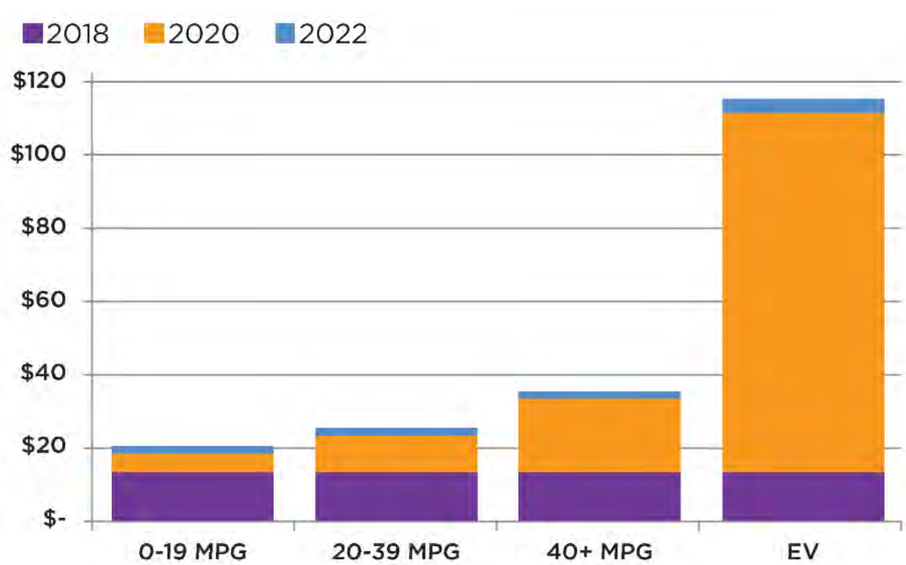
Figure 1: Total Gross State Highway Revenues by Fiscal Year (Source: ODOT)[ii]



DMV Fees

For light-duty vehicles, the main DMV fees are for registration and titling. HB 2017 created new tiers of vehicle registration fees for light-duty vehicles based on EPA fuel economy (miles per gallon, or MPG), where vehicles with higher fuel economy have a higher registration fee and all-electric EVs have a separate, higher registration fee, as shown in Figure 2.[6]

Figure 2: Passenger Registration Annual Increases from HB 2017 (Starting Rate $43) (Source: ODOT)



[ii] In Figure 1, OTIA III refers to increased DMV fees as part of the Oregon Transportation Investment Act, as passed in 2003 with HB 2041. JTA refers to increased DMV fees as part of the Jobs and Transportation Act, as passed in 2009 with HB 2001. The red outline for years 2021-2029 is meant to show that these years represent forecasts.

The rationale for higher registration fees for more fuel-efficient vehicles is to ensure that drivers of such vehicles still pay their share of road costs even as they are paying less in fuel taxes. Because drivers of vehicles that are fully electric would not pay any fuel taxes, these vehicles have the highest registration fee at $306 per 2-year registration/renewal. These new fees went into effect on January 1, 2020.

Table 1: DMV Registration/Renewal Fees for Passenger Vehicles

Vehicle MPG	Registration / Renewal Fee (2-yr)
0-19	$122
20-39	$132
40+	$152
Fully electric vehicles	$306

DMV revenues are an indicator of the broader demographic and economic variables at play in the state as they are affected by population changes, employment, and economic factors. However, DMV revenues are affected more by demographics than economic variables. Oregon's growing population, the economic rebound from the 2008 recession, and implementation of the increased DMV fees included in the HB 2017 transportation package have all contributed to recent growth in revenue for the DMV.[7]

Motor Carrier Fees

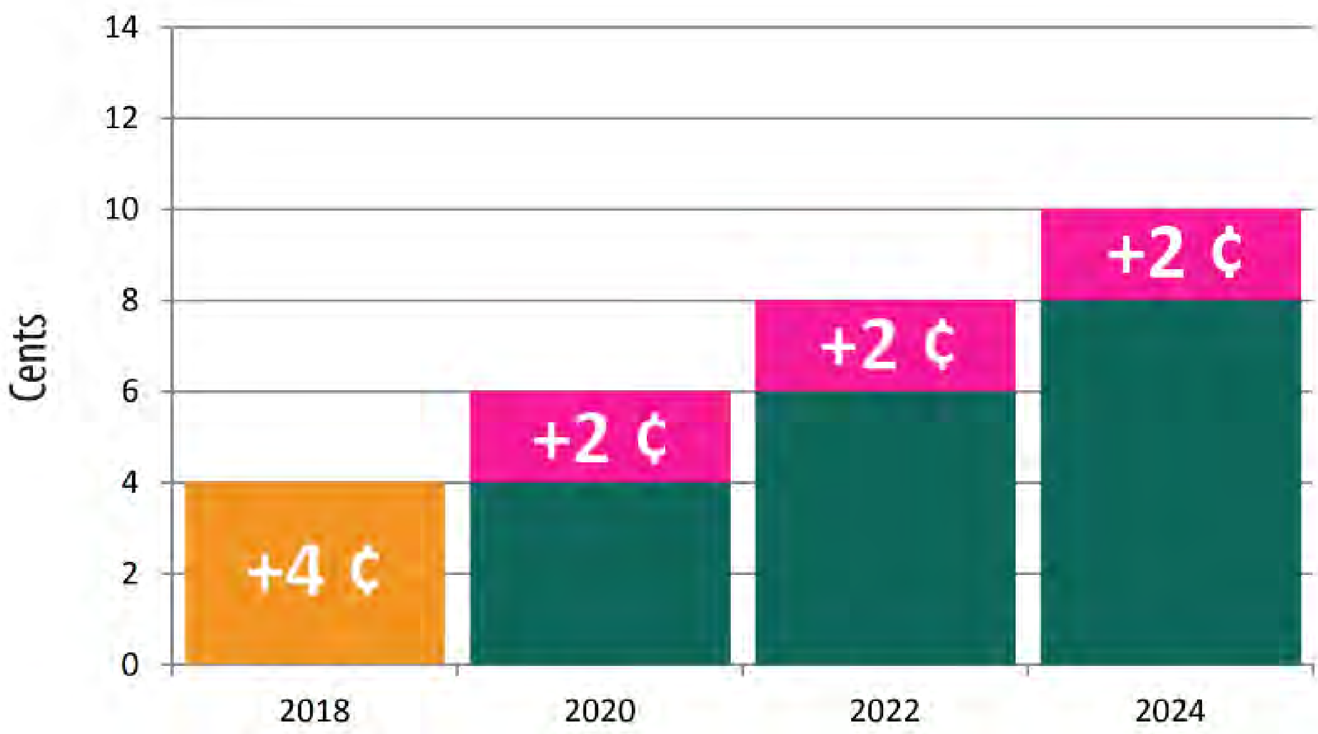
Motor carrier fees include the weight-mile tax on all commercial motor vehicles with declared gross weights in excess of 26,000 lbs. This weight-mile tax takes the place of the fuels tax as vehicles that are subject to the weight-mile tax are not also subject to the fuels tax.[8] HB 2017 included weight-mile tax rate increases in 2018, 2020, 2022, and 2024. Revenue from motor carrier fees is affected by state and national economic conditions, as well as state and federal legislation. As the focus of this analysis is on light-duty vehicles, motor carrier fees are not discussed in further detail.

Motor Fuels Taxes

In Oregon, a tax is levied on every gallon of gasoline or diesel fuel sold by an authorized seller and the tax is collected at the point of sale. The current tax as of 2021 is $0.36 per gallon, which was raised from $0.34 in 2020; HB 2017 also included two-cent tax increases per gallon in 2022 and 2024 (see Figure 3), though those are conditional on certain requirements being met. The revenue from taxes levied on transportation fuels is affected by the price of fuel, the fuel efficiency of light-duty passenger vehicles operating in the state, and the number of passenger vehicles in the state.

In the U.S., the average fuel economy of light-duty vehicles has risen from 14.9 MPG in 1980 to 22.2 MPG in 2019.[9] The average fuel economy of light-duty vehicles increased to 25.7 MPG for model year 2020,[10] but it takes time to see newer, more fuel-efficient vehicles affect the national average light-duty vehicle MPG. An analysis from the Massachusetts Institute of Technology looking at the effect of Corporate Average Fuel Economy, also known as CAFÉ standards, on fleet fuel efficiency estimated that, at minimum, it would take 19.6 years for newer vehicles to comprise 90 percent of the U.S. on-road fleet of passenger vehicles.[11]

Figure 3: Guaranteed and Conditional Increases (per Gallon) in Oregon's Motor Fuels Tax from HB 2017[12]



As HB 2017 included both guaranteed fuels tax increases and conditional fuels tax increases, ODOT included forecasts of motor fuels tax revenue for both a guaranteed six-cent increase and a conditional ten-cent increase in its 2021 State Highway Fund transportation revenue forecast. In the guaranteed scenario, ODOT's forecast concludes that the revenue from the tax increase will be offset by increasing vehicle fuel efficiency. For this reason, revenue from the motor fuels tax is expected to remain fairly steady until about 2026, at which time increasing fuel efficiency is expected to outweigh the effects of economic growth.[13] However, in the conditional scenario, where ODOT assumes that the requirements for triggering the next two two-cent rate increases in the motor fuels tax are met, revenue increases significantly as compared to the guaranteed scenario.

OReGO Program

To address the gap between actual road use and revenue from fuels taxes, Oregon launched a road usage tax program, called OReGO, in July 2015. OReGO is a voluntary program and any light-duty vehicle registered in Oregon can be enrolled in the program if it has a combined efficiency of at least 20 miles per gallon. Participants are sent a device to self-install in their vehicle that collects data on mileage and fuel consumption. They are charged 1.8 cents per mile[iii] and are provided a non-refundable tax credit for gas taxes paid at the pump. Drivers of electric vehicles or of vehicles rated at 40+ MPG can also save money on vehicle registrations when enrolled in OReGO; instead of paying the higher registration fees based on their vehicle's MPG, these drivers would instead pay $86 for a two-year registration once enrolled in OReGO (registration fees are double for new vehicles), as shown in Table 2.

Table 2: Difference in DMV Registration Fees for High-MPG and Electric Vehicles Based on Enrollment in OReGO[14]

	2 Year Registration Fee
40+ MPG Not in OReGO	$152
40+ MPG enrolled in OReGO	$86
Full electric Not in OReGO	$306
Full electric enrolled in OReGO	$86

Impacts of Electric Vehicles on State Highway Fund Revenues

As referenced above, the Oregon Constitution requires submission of a biennial highway cost allocation study, which determines the proportional cost responsibility for the state's highways based on *vehicle weight*. However, to determine the cost responsibility based on different vehicle *fuel types*, HB 2017 requires that the Oregon Transportation Commission (OTC) complete a study on the cost responsibility of road users with vehicles powered by "different means." The study must also determine whether vehicles powered by different means are paying their proportionate share of highway costs and, if not, to provide recommendations for legislation.

As the OTC study on proportional cost responsibility by vehicle fuel types is not due to the legislature until September 15, 2023, ODOE was not able to draw on the OTC study for this report, though that analysis will likely inform future versions of this report. Instead, ODOE collaborated with ODOT to develop a scope of analysis that could draw upon existing data about light-duty vehicles in the state to provide an illustrative example of how electric vehicles *might* affect State Highway Fund revenues. However, the figures provided here do not represent real financial impacts.

Data

ODOT provided ODOE with data that included currently registered (as of February 2021) light-duty vehicle counts, average MPG, and estimated annual vehicle miles traveled (VMT) by vehicle type (cars, pickup trucks, sport utility vehicles (SUVs), and vans), and by registration group, where BEVs are separate from all other vehicles (see Table 3). Standard hybrid vehicles and plug-in hybrid vehicles are included in their respective DMV MPG registration group. For more detail on the data used in this analysis, see Appendix E.

[iii] The OReGO road charge will increase to 1.9 cents per mile on January 1, 2022.

Table 3: ODOT Data on Oregon Light-Duty Fleet

Vehicle Type	Registration Group	Total Count	Count of Records with MPG	Percent records w/ MPG	Average MPG	Estimated Annual VMT
Car	BEV	20,590	20,015	97%	115	7,674
Car	MPG 0-19	461,541	90,130	20%	18	6,949
Car	MPG 20-39	928,562	928,562	100%	27	9,151
Car	MPG 40 +	79,470	79,470	100%	54	10,793
SUV	BEV	2063	2,063	100%	95	12,041
SUV	MPG 0-19	481,754	369,965	77%	16	9,267
SUV	MPG 20-39	400,686	400,686	100%	24	10,423
SUV	MPG 40 +	8,312	8,312	100%	44	11,084
Truck	BEV	6	0	0%	N/A	113
Truck	MPG 0-19	738174	302243	41%	15	9,421
Truck	MPG 20-39	49564	49564	100%	21	8,706
Van	BEV	3	0	0%	N/A	1,484
Van	MPG 0-19	140967	93657	66%	16	9,645
Van	MPG 20-39	48967	48967	100%	22	11,129
Van	MPG 40 +	570	570	100%	83	10,191

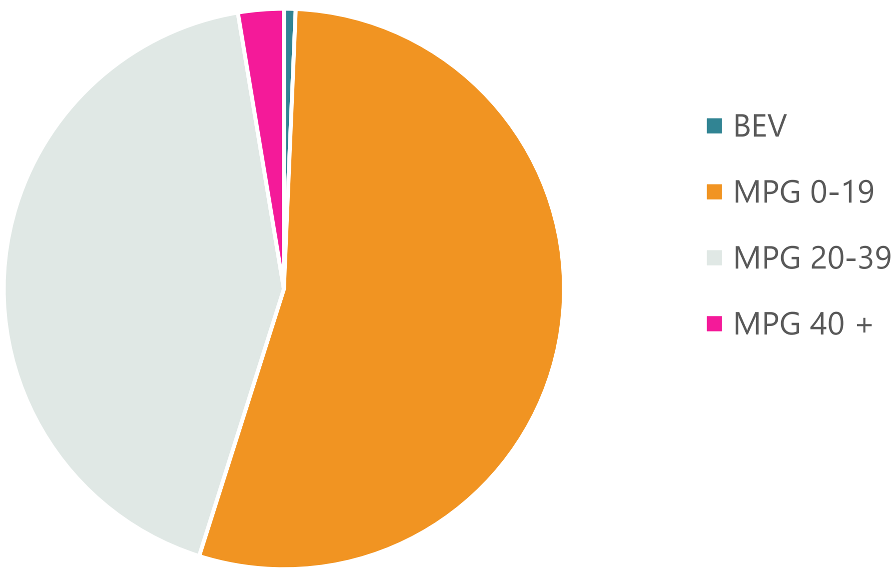
Results

The estimated fuels tax revenue from all light-duty vehicles in the ODOT data set is shown in Table 4. Given that the DMV MPG group of 0-19 has the most vehicles (54 percent, see Figure 4) and that these vehicles require more fuel to travel the estimated annual VMT, it is unsurprising that the majority of estimated fuels tax revenue would come from vehicles in the 0-19 MPG group (61 percent of revenue). BEVs comprise only 0.67 percent of total vehicles in the data set and thus currently have a de minimis effect on the fuels tax revenue in this analysis. As Oregon's light-duty fleet is increasingly comprised of more fuel-efficient internal combustion engine vehicles, hybrids, and BEVs, the annual fuels tax revenue should decline. However, as discussed earlier, this effect should be offset in the near term if all the fuels tax increases from HB 2017 are implemented.

Table 4: Estimated Annual Gas Tax Revenue for All Light-Duty Vehicle Types by DMV Registration Group

DMV Registration Group	Estimated Annual Fuels Tax Revenue ($0.36/gal)
MPG 0-19	$330,167,936
MPG 20-39	$195,336,774
MPG 40 +	$6,485,439
Total	$532,582,784

Figure 4: Total Light-Duty Vehicles by DMV Registration Category as of February 2021



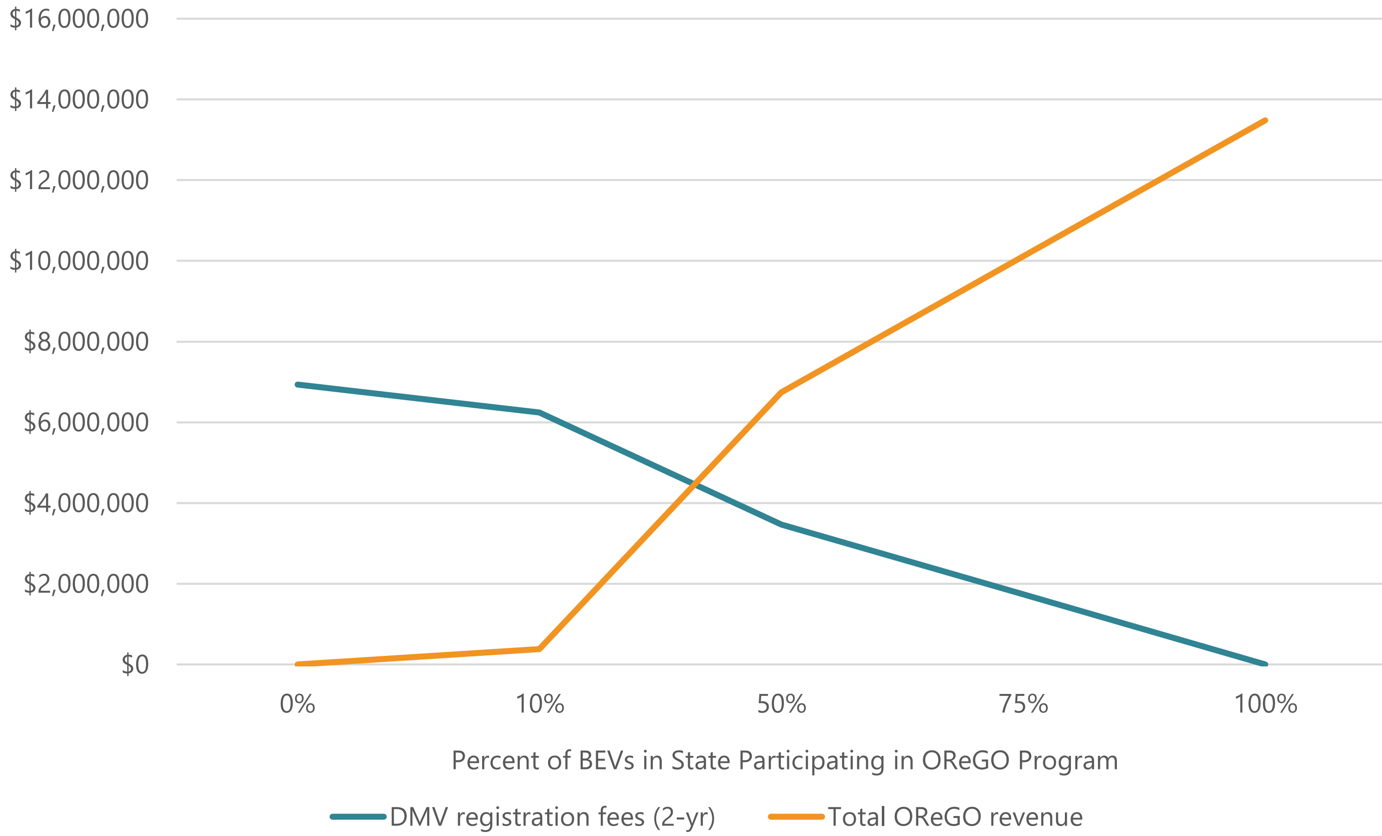
Given that drivers of BEVs do not pay any fuels tax, ODOE looked at the OReGO road use charge program to provide an example of how participation in the OReGO program could affect State Highway Fund revenues. Using ODOT's February 2021 registration data and average annual VMT estimates (see Table 3), ODOE calculated the potential OReGO registration and road use charges for a range of percent BEV participation in the program (0, 10, 50, 75, and 100 percent).

If none of the BEVs in Oregon participated in OReGO, these 22,662 vehicles would provide a little over $6.9 million in revenues from two-year DMV registrations and zero in fuels taxes (see Table 5). At 10 percent participation in OReGO, the revenue from DMV registrations for BEVs not enrolled in OReGO (about $6.24 million) still dwarfs the revenue from registration fees and road use charges (RUC in Table 5) for enrolled BEVs (just over $381,000). However, at 50 percent participation of BEVs in the program, the revenue from OReGO (a little over $6.74 million) is nearly double that of the revenue from BEVs not enrolled (about $3.46 million). If 100 percent of the currently registered BEVs were enrolled in the OReGO program, ODOE calculated potential revenues of almost $13.5 million, which is almost twice as much as the revenue if none of these vehicles participated (just over $6.9 million). This relationship is shown graphically in Figure 5.

Table 5: Estimated DMV Registration and OReGO Fees of BEVs Registered in Oregon, by Percent Participation in OReGO (as of Feb 2021)

	Percent of BEVs in State Participating in OReGO Program				
	0%	10%	50%	75%	100%
OReGO registration fees (2-yr)	$0	$378,093	$6,726,535	$10,089,802	$13,453,070
OReGO annual RUC by avg MPG	$0	$2,944	$14,719	$22,079	$29,438
Total OReGO revenue	**$0**	**$381,037**	**$6,741,384**	**$10,111,881**	**$13,482,508**
DMV registration fees (2-yr)	$6,934,572	$6,241,115	$3,467,254	$1,733,643	$0
Total Revenue OReGO + DMV	**$6,934,572**	**$6,622,151**	**$10,208,540**	**$11,845,524**	**$13,482,508**

Figure 5: Estimated Revenue Based on Percent Participation Level in OReGO of BEVs Currently Registered in Oregon



The goal of this analysis is to provide a broad understanding of how BEVs might affect the revenue that accrues to the State Highway Fund, using available data and simple calculations. While ODOT will provide a robust statistical analysis to the Legislature by 2023, this analysis illustrates two key interactions between BEVs and State Highway Fund revenues:

- While BEVs make up less than 1 percent of the state's light-duty fleet, the effect on the fuels tax revenue is negligible. With current policies, as the light-duty fleet share of more efficient ICE vehicles, hybrids, and BEVs increases, so too will the effect on the fuels tax.
- If all the currently-registered fully electric BEVs in Oregon participated in OReGO, nearly twice as much revenue would accrue to the State Highway Fund than if none of these vehicles participated in OReGO.

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Recommendations

Because the state is not on track to achieve the zero-emission vehicle adoption targets established in Senate Bill 1044 (2019), the Legislature directed the Oregon Department of Energy to include recommendations to support greater ZEV adoption and set the state on a course to achieve its future goals. The recommendations presented here are grounded in the types of policies and programs in which the state has jurisdiction and sway, and do not address recommendations that are outside the scope of state government authorities. They were developed with input from stakeholders during the report development process, and include recommendations to provide additional data and analysis necessary for state policymakers to make informed decisions and identify policy options to support increased and equitable adoption of ZEVs.

Zero-emission vehicle adoption has many benefits for individuals, businesses, communities, and the state. The ZEV adoption targets established in Senate Bill 1044 were created to address greenhouse gas emissions in the transportation sector, which continue to rise in Oregon. Today's vehicles predominantly operate by combusting petroleum-based fuels, such as gasoline and diesel, so electric vehicles present the fastest and most cost-efficient option to reduce emissions from light-duty vehicles in the state. Electric fuel powering highly-efficient vehicles results in lower emissions today and has the added benefit of additional future emissions reductions as the state's electric utilities continue to work toward decarbonizing their generation resources. For these reasons, the overarching recommendation of this report is that the state should continue to support ZEV adoption in Oregon and make ZEV adoption a key pillar of the state's decarbonization efforts.

Recommendation 1: Support the policy recommendations in the Oregon Department of Transportation's Transportation Electrification Infrastructure Needs Analysis Study to significantly increase access to electric vehicle charging in Oregon

The TEINA study states that "rapid growth in public charging is essential to achieve mainstream adoption of EVs." While there are several state policies that support access to ZEVs, the state has few policies designed to support development of and access to the charging infrastructure needed to provide fueling support for these vehicles. This report found that ZEV adoption rates are lower in areas where access to charging infrastructure is limited, such as multi-unit dwellings and rural areas of the state. ODOT's TEINA study provided an in-depth analysis of the charging infrastructure needed to support the state's ZEV adoption goals – and as part of that report, provided policy options to help support fueling infrastructure availability across all vehicle sectors through 2035. While ODOT is in the process of developing a charging infrastructure grant program, funding and resources for this work are limited. More support is needed to support adequate charging infrastructure, particularly for areas where charging is not widely available.

The policy recommendations provided in the TEINA study are extensive and cross-reference to the specific modeled EV adoption scenario of the study. ODOE recommends support for these policy options, particularly those that seek to address charger availability for multi-unit dwellings, low-income areas, rural areas, among communities of color, and in historically underserved communities, including:

- Support for state building codes and local ordinances that include EV-readiness requirements for new or renovated buildings.
- Support for policies that incentivize workplace charging and charging for existing multi-unit dwellings.
- Requirements for state incentive funding for infrastructure development to meet certain standards that will harmonize the user experience.
- Investigate ways to coordinate and ensure charging access and affordability for those eligible for the Charge Ahead rebate.
- Encourage appropriate rates for distinct EV charging users, especially multi-unit dwelling residents without access to home electricity charging.
- Consider incentives that drive infrastructure development across the entire transportation landscape, including medium- and heavy-duty vehicles.
- State charging investment programs should focus on supporting charging infrastructure development in areas that are low- and moderate-income, multi-unit dwellings, rural, and communities of color.
- The state should support more outreach and education programs and provide more technical resources for communities of color, low- and moderate-income, and rural communities, and to multi-unit dwelling owners about ZEV charging for all transportation modes.

Recommendation 2: Identify and implement best practices for collecting and assessing ZEV adoption data across different segments of the transportation sector to better inform policy makers about options to support increased ZEV adoption across the entire transportation landscape.

As ZEV adoption increases, more specific data on trends is needed to assess progress on the ZEV targets established in Senate Bill 1044 and provide policymakers with information on where policies or programs could be strengthened to achieve these goals. The assessments provided in this report can also be used by local governments to assess progress on climate and sustainability goals and by utilities to supplement distribution system planning that can be affected by large numbers of electric vehicles charging in very localized areas. Providing information on available electric options can also be a resource to businesses and organizations interested in transportation electrification.

This inaugural Biennial Zero Emission Vehicle Report provided an assessment of ZEV adoption across all transportation sectors, and much of the detail was based on light-duty registration data from the Oregon Department of Transportation's Driver and Motor Vehicle Services Division. While 19 percent of Oregon's in-state greenhouse gas emissions were from the light-duty vehicle segment, the rest of the transportation sector contributed 17 percent. Identifying data sources that can provide insight on ZEV uptake beyond light-duty vehicles will help Oregon better understand the effect other ZEV platforms can have on reducing emissions.

Tracking transportation electrification across all vehicle types will require examination of data from multiple state agencies. Data and analysis may not be available for all transportation segments or vehicle types and may require additional data collection or modeling using existing data. This recommendation calls for collaboration to identify data needs, research potential data sources, and review those sources to determine the robustness of each data set and identify potential areas of data duplication. Data-possessing entities would develop a data sharing agreement and work together to create a centralized data management system to manage data flow, sharing, validation, and security.

Oregon's Zero Emission Vehicle Interagency Working Group is well positioned to coordinate efforts to identify, collect, and assess data on ZEV adoption for other transportation areas apart from passenger vehicles. Initially established as a venue for the coordination of state agency efforts supporting ZEV adoption and to provide information to Oregonians about ZEVs, the ZEVIWG aligned individual data practices and agreed on the light-duty ZEV registration counts now used by all agencies. Similar data standards and procedures are needed to inform ZEV adoption for:

- New and used light-duty ZEV *sales.*
- New and used e-micromobility sales.
- Medium- and heavy-duty ZEV sales or registrations.
- Non-road ZEV sales or registrations.
- Available ZEV models for on-road and non-road vehicles in Oregon.

Recommendation 3: Develop a methodology for assessing effects of ZEV adoption on Oregon's greenhouse gas emissions to provide consistent reporting across state agencies, and as a tool for local governments and businesses to assess and monitor policies and programs that address emissions for their jurisdictions or transportation operations.

Assessing the effects of ZEV adoption on greenhouse gas emissions in a consistent manner can be a powerful tool for the state, local governments, and businesses working on greenhouse gas mitigation activities and plans. The Oregon Department of Environmental Quality's Greenhouse Gas Reporting program collects data from fuel suppliers to assess both in-boundary emissions and consumption-based emissions, and their Clean Fuels Program assesses the carbon intensity of most transportation fuels in Oregon. In the development of this report, ODOE used data sets from both programs in conjunction with statewide vehicle miles traveled data and average vehicle fuel efficiencies to assess greenhouse gas emissions using a bottom-up approach.

Future versions of this report should build on this methodology, providing a consistent approach that can be used by other organizations interested in tracking greenhouse gas savings by switching to an electric vehicle. Developing standardized methodologies for determining lifecycle and in-boundary emissions in this bottom-up approach could be approximated in a number of ways, including assessments based on vehicle types, vehicle efficiencies, and fuel carbon intensities – some of which could potentially be assessed at the county level. State agencies have expertise and data that can inform best practices to develop a standardized approach that could be replicated or used by other organizations. To the extent feasible, methodologies developed should address the following:

- Provide insight on the net change of all vehicles in Oregon by fuel type to differentiate between ZEV adoption that replaces an internal combustion vehicle compared to ZEVs that are additional to the overall fleet.

- Account for the electric fuel use for light-duty vehicles compared to medium- and heavy-duty vehicles.
- Account for the electric fuel use for non-road vehicles, such as construction, agriculture, and forestry.
- Assess the average fuel use ratio for electric fuel and petroleum fuel consumption for plug-in hybrid vehicles.
- Assess ZEV-specific average annual vehicle miles traveled.
- Account for hydrogen fuel use and associated emissions for all of the above methodologies when hydrogen fuel cell vehicles are commercially available in Oregon.

Recommendation 4: Engage with underserved communities to assess ZEV adoption data and inform the development of metrics that can track equitable access to ZEVs and ZEV fueling

Oregon's Diversity, Equity, and Inclusion Action Plan describes disaggregating data as a means to effect positive change in state policy. In this report, ODOE used U.S. Census Bureau data to provide some high-level analysis on ZEV adoption across several demographic groups as a starting point for discussion, but without input from many of the underserved communities around the state, the data may lack appropriate context. More granular data and context is necessary to provide an assessment that can adequately inform policy development.

More granular demographic data would provide better insight on access to ZEVs. This type of data may not be readily available as part of the vehicle registration data or other program data that the state collects. For future versions of this report, the Oregon Department of Energy will seek to engage with community-based organizations and underserved communities such as tribes, communities of color, low-income communities, rural communities, and people with disabilities. Their review and input on Census and other available data sets and analyses can provide valuable perspectives to interpret the data and further learn about barriers to equitable ZEV adoption in the state.

Best practices around data collection are readily available; however, these practices must be updated to include stakeholder engagement with underserved communities throughout the data collection and interpretation process. This provides the opportunity for the state to engage more closely with these communities while also building a more robust set of data. Further, this process can build trust with communities who have not always received equitable responsiveness and support from government agencies.

Recommendation 5: Support Oregon-focused data collection and studies to provide greater insight into ZEV awareness across the state and among Oregon's diverse communities.

There is no *statewide* assessment of Oregonians' awareness of ZEVs, their benefits, and their costs, although many organizations across the state collect related information. A better understanding of what Oregonians know about ZEVs could be a valuable resource to inform policies to address the different adoption barriers that exist for the diversity of vehicle owners, businesses, and transportation sectors in Oregon.

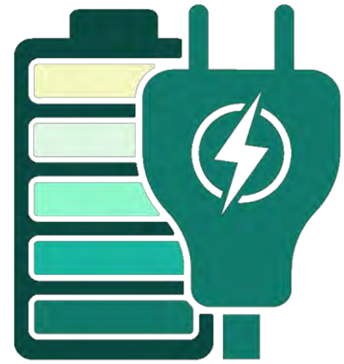
The state should support an in-depth assessment about ZEV awareness within Oregon. Using this assessment, data gaps for specific vehicle segments or markets could be identified. Where feasible, the state should work through existing data collection activities to inform and support additional data collection to address these gaps. Potential data resources and partners for this include:

- The Department of Environmental Quality's Clean Vehicle and Charge Ahead Rebate Programs, Clean Fuels Program, and Low-Emissions Vehicle Program
- The Department of Transportation's Transportation Electrification Infrastructure Needs Analysis Study and data collected through the agency's Climate Office
- The Public Utility Commission's electric utility transportation electrification planning activities
- Community-based organizations, particularly those in underserved communities, communities of color, low-income communities, and multi-unit dwelling communities
- Utility surveys and ZEV-focused customer engagements
- Organizations conducting outreach and engagement with the public on ZEVs and alternative fuels
- Fleet surveys through Oregon Clean Cities programs
- Fleet-specific data on fueling and operational costs
- Government and business sustainability activities
- Electric vehicle charging company surveys and data
- Workplace surveys

In addition to data collection and analysis, studies may also be needed to assess potential barriers accessing ZEVs, ZEV fueling, and ZEV-related educational resources for all Oregonians. In addition, where barriers are identified, research and an Oregon-focused assessment of potential policy options that could help address these barriers may be needed. This report identified two areas needing additional study that could inform policy discussions addressing equitable access to ZEVs:

- Conduct a literature review and outreach with organizations that have developed financing mechanisms to address up-front costs of ZEVs for low- and moderate-income individuals, women- and minority-owned businesses, and rural businesses.
- Conduct a study to compare the fueling costs for Oregon electric vehicle drivers using home charging compared to private charging networks for daily charging needs.

Recommendation 6: Consider adopting standardized definitions and metrics for electric vehicle charger availability and reliability to enable consistent assessment of Oregon's electric vehicle fueling infrastructure.



There are no agreed-upon definitions or metrics to assess the availability and reliability of electric vehicle charging in Oregon. While these terms are often used to broadly indicate how to assess the overall state of electric vehicle charging, more formal metrics and terminology is needed to enable consistent and ongoing assessment of electric vehicle charger infrastructure in Oregon. As described in this report, ODOE conducted a public meeting to hear initial input on potential ways to define and measure these terms. Responses were robust, with general consensus around some metrics as well as more diverse input that reflected the needs of particular communities.

Additional public input and engagement on how to define these terms is needed to ensure any metrics or definitions are informed by a variety of individual, community, and business needs. Further, engagement with electric vehicle charging companies is critical to develop definitions and metrics that are not disruptive to the evolving market related to EV fueling infrastructure.

Report Background

Senate Bill 1044 (2019)

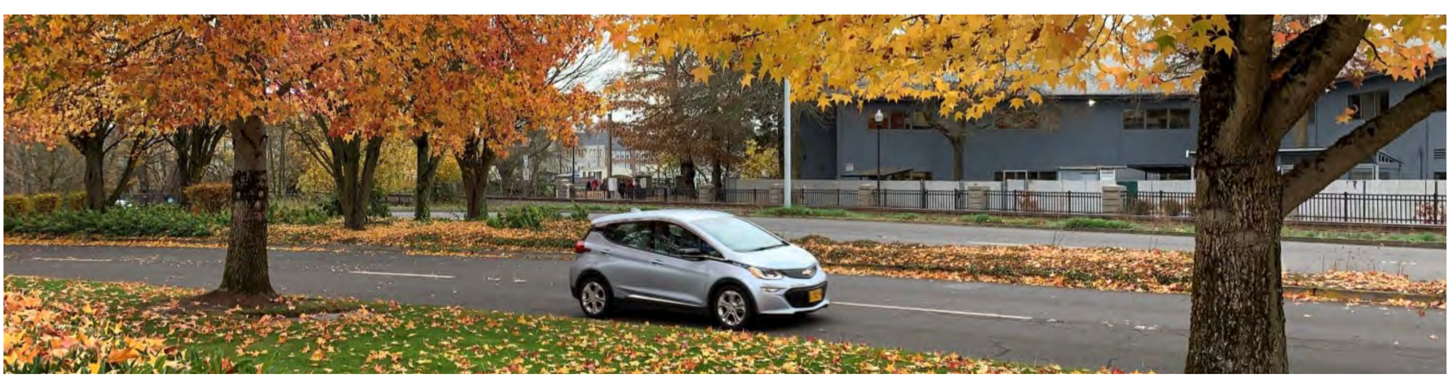
In 2019, the Oregon State Legislature passed Senate Bill 1044, which directed the Oregon Department of Energy to produce a biennial report on the state of zero-emission vehicle adoption in Oregon, beginning in 2021. Due to the Legislature and Governor on September 15 of every odd-numbered year, the report includes the state's progress toward reducing greenhouse gas emissions in the transportation sector as a result of ZEV adoptions. The statute also established three state policy goals:

1. The adoption and use of zero-emissions vehicles must be evaluated regularly to determine whether the rate of the adoption and use of zero-emission vehicles will put the state on course to meet its greenhouse gas emissions reduction goals.
2. Transformation of the motor vehicle market must occur no later than 2035.
3. Programs and support must be provided to accelerate Oregonians' purchase and use of zero-emission vehicles until greenhouse gas emissions from vehicles are declining at a rate consistent with this state's greenhouse gas emissions reduction goals set forth in ORS 468A.205.

The bill directed ODOE to assess progress on these goals and the date by which the state is expected to achieve these goals. This and future reports serve to address the first goal above, to evaluate ZEVs in Oregon. This report will also provide insight on the last two goals, although specific dates of achievement are not provided in this inaugural report because there is currently insufficient information or data available to provide this assessment. As electric vehicle options become more prevalent, future iterations of this report may be able to provide accurate forecasts for these goals.

In addition to the policy goals, the bill established ZEV adoption targets for the state:

- By 2020, 50,000 registered motor vehicles will be zero-emission vehicles.
- By 2025, at least 250,000 registered motor vehicles will be zero-emission vehicles.
- By 2030, at least 25 percent of registered motor vehicles, and at least 50 percent of new motor vehicles sold annually, will be zero-emission vehicles.
- By 2035, at least 90 percent of new motor vehicles sold annually will be zero-emissions vehicles.



To assess the status of ZEV adoption in Oregon, the bill also directed ODOE to address 11 specific reporting requirements in the report:

1. Whether the transportation sector is on course to reduce the share of greenhouse gas emissions from motor vehicles, as defined in ORS 801.360, consistent with the greenhouse gas emissions reduction goals set forth in ORS 468A.205.
2. The sales figures and numbers of zero-emission vehicles that are owned in Oregon, including forecasts as to whether the state is on track to achieve the ZEV adoption goals.
3. The sales figures and numbers of zero-emission vehicles that are owned in Oregon, differentiated, to the extent feasible, by demographic factors, including whether persons that own zero-emission vehicles reside in urban or rural areas.
4. The availability and reliability of public and private electric vehicle charging infrastructure that is needed to support the targets for zero-emission vehicle sales and registration identified in the ZEV adoption goals. The department shall assess reliability under this paragraph only if the department requests and obtains information on reliability from providers of electric vehicle charging infrastructure.
5. The incremental purchase cost difference, before and after federal and state incentives, between the purchase cost of a zero-emission vehicle and the purchase cost of a comparable vehicle powered by an internal combustion engine.
6. The zero-emission vehicles that are available for purchase in all market segments.
7. Oregonians' awareness of motor vehicle options, the benefits of owning zero-emission vehicles and the true costs of motor vehicle ownership.
8. The carbon intensity of fuel consumed by the Oregon transportation sector as a whole.
9. The general progress toward electrification of all fossil fuel-based transportation modes.
10. Opportunities to minimize impacts to the electric grid from transportation electrification, including rate design, managed charging, vehicle-to-grid services and electricity conservation techniques.
11. In consultation with the Department of Transportation, the impact of the sales and ownership of zero-emission vehicles on revenues that would otherwise accrue to the State Highway Fund under ORS 366.505.

Report Development and Stakeholder Outreach

ODOE began planning for the report in late 2019 and conducted outreach to interested stakeholders, tribes, and agencies in early 2020. These meetings included a review of the reporting requirements and proposed scope of information needed to address them, and resources the agency identified to inform each reporting requirement. Stakeholders provided input on additional data, analytical resources, and scoping considerations to improve the report. Incorporating this input, ODOE conducted research and developed the report throughout 2020, holding meetings with stakeholders to solicit additional technical information and resources. Further, ODOE's authors attended conferences, seminars, and other training opportunities to stay informed about recent technology and policy advancements throughout the development of the report.

In collaboration with the Zero Emission Vehicle Interagency Working Group, ODOE worked with sister agencies to inform several sections of the report. The Oregon Department of Transportation, Department of Environmental Quality, Department of Administrative Services, and Public Utility Commission each play an important role in supporting ZEV adoption in Oregon. Led by ODOT, the ZEVIWG is a vital interagency working group that ensures the work of the state is highly coordinated and builds upon each agency's work in a way that has helped make Oregon a leader in ZEV programs and policies. Through this group, ODOE engaged with other agencies throughout the report production process and used the ZEVIWG as a forum for stakeholder engagement to inform the report.

Apart from ZEVIWG agencies, ODOE engaged with stakeholders across multiple sectors to identify data and analysis resources and to seek input on addressing the reporting requirements. These stakeholders included U.S. Department of Energy national labs, local governments, electric vehicle charging companies, utilities, ZEV and environmental advocacy organizations, auto sales organizations, and community-based organizations. These stakeholders each have a unique perspective on the ZEV world and helped provide a robust set of information and considerations which ODOE used in developing this report.

Recommendations Development and Stakeholder Outreach

Senate Bill 1044 also directed ODOE to develop recommendations to support ZEV adoption if the state is not on track to meet its ZEV adoption goals. As will be discussed in more detail in the body of the report, the state did not meet the 2020 ZEV registration goal, and the state is not on track to meet the 2025 registration goal. In July and August 2021, ODOE developed a list of draft recommendations based on the key findings for each reporting requirement and presented these to stakeholders. Draft recommendations were focused on actions to address data gaps that would benefit future iterations of the report and policy recommendations that would support increased ZEV adoption in Oregon. Feedback was generally supportive of the draft recommendations, and ODOE used the feedback to produce the final recommendations outlined at the end of this report.

Appendix A-1: Minutes and Summary Table from Public ZEVIWG Meeting Discussion of Availability and Reliability, May 12, 2021

Meeting Attendees:

- Caroline Cilek, Lewis & Clark (law student)
- Colin Cortes, City of Woodburn
- Rebecca Smith, ODOE
- Jessica Reichers, ODOE
- Evan Elias, ODOE
- Cory Ann Wind, DEQ
- Rachel Sakata, DEQ
- Eric Shierman, OPUC
- Eric Smith, SemaConnect
- Jillian DiMedio, ODOT
- Mary Brazell, ODOT
- Zechariah Heck, ODOT
- Joe Hull, Mid-State Electric Co-op
- Kylie Grunow, Meriwether Strategies for BP
- Laura Feldman, Willamette River Advocacy Group
- Charlie Loeb, Emerald Valley Electric Vehicle Association
- Michael Goetz, CUB
- Robert Roseman, Schneider Electric
- Scott Reimer, R&W Engineering
- Tomas Endicott, BEF
- Bob Yuhmke, Elders Climate Action
- Greg Harr, Evergreen Consulting
- Anthony Gamallo, City of Salem
- Haley Ellett, City of Hood River
- Brian King, DAS
- Steven Ingham

Check-in and Introductions – Mary Brazell, ODOT

Overview of SB 1044 BiZEV Report – Jessica Reichers, ODOE

- SB 1044 (2019) directs Oregon Department of Energy (ODOE) to submit a biennial report on the adoption of zero emission vehicles (ZEVs) in Oregon and progress the state is making to reduce greenhouse gas (GHG) emissions in the transportation sector.
- Inaugural biennial zero emission vehicle report (BiZEV) is due to legislature September 15, 2021.
- Statute enumerates reporting requirements for the BiZEV, including (but not limited to) numbers of ZEVs registered in the state, ZEV incremental purchase cost difference,

commercially available ZEVs, carbon intensity of the state's transportation fuels, and the availability and reliability of charging infrastructure needed to meet state ZEV goals.

Introduction to BiZEV Reporting Requirement re Availability – Rebecca Smith, ODOE

- For the BiZEV, ODOE must report on the availability and reliability of EV charging infrastructure needed to support the state's ZEV targets. As ODOT is in the process of completing its Transportation Electrification Infrastructure Needs Assessment (TEINA), ODOE will discuss in the BiZEV current approaches to defining "availability" and "reliability" as they relate to EV charging infrastructure.

Discussion of Defining "Availability" of Charging Infrastructure for BiZEV – Group

- Q: Does "availability" need to include metrics on whether public charging infrastructure is available at all -- in some parts of the state, it isn't -- within a certain X number of miles. Also a per-EV availability, X number of charging opportunities within a certain distance of registered EV addresses. As mentioned, need separate look at DCFC and Level 2, as well as compatibility.
  - A: ODOE has suggested that the location and density of charging may be parameters it includes in a definition of availability. Additionally, the ODOE EV dashboard does show data for EV charging infrastructure locations in the state.
- Q: Will availability include compatibility options - CHAdeMO v. CCS v. Tesla DCFC?
  - A: Yes, ODOE plans to include parameters related to different charging port types and different charging speeds into its definition of availability.
- Q: In the ODOE presentation, for "open access" does "drivers need not be a member of a specific charging network to use their chargers" mean that drivers will simply be allowed to use the station or that they may not be charged more if they are not a part of the network?
  - A: The best practices recommended by NESCAUM and others are that drivers not be barred from using a charger if they are not a member of the company/network associated with the charger. However, NESCAUM and others make no recommendations against allowing companies to provide preferential rates for members, only that all fees be transparent to a driver before initiating a charging session.
- Q: Still have concerns about the potential for high EV charging rates, especially for people who are not members of a particular EV supply equipment (EVSE) company.
  - A: ODOE may address the concern for lack of consistency in pricing when discussing availability in the BiZEV. Any policy recommendations would be reserved for consideration in the recommendations section of the report.
- Q: With respect to affordability, how are EV charging rates regulated by the state?
  - A: There are no regulations in Oregon by the state on what EVSE companies can charge. However, the PUC does regulate what electric utilities can charge EVSE providers, which in turn affects the kWh price that an EVSE can offer a driver.
- Q: There are several different methods used in other states to substitute for demand charges. Oregon should explore ways of ameliorating demand charges.
  - A: ODOE will think about this from standpoint of BiZEV recommendations. TEINA addresses rates.

- A: ODOT would approach this as a discussion around whether EV drivers understand what the various fees are. Uncertainty around what you pay for fuel would fall under availability. The TEINA study addresses rates.
- Q: How would definition of availability address the issue of charging station spots being taken by internal combustion engine (ICE) vehicles or by EVs that have completed a charging session or for which a charging session was not initiated?
  - One stakeholder commented that signage needs to warn of fines for ICE blocking charging spots and that ICE vehicles are often parked in EV charging spots.
  - Another asked how to enforce parking re ICE vehicles parked at chargers or EVs parking after charging.
  - Another stakeholder described that there is lighting that can be added to EV charging stations to identify what is happening with that charging station, i.e. whether the vehicle there is in an active charging session.
  - A: ODOE will consider whether signage for EV charging stations should be included in the definition of availability.
- Q: The app "Pay with Plugshare"? This app and some others can allow drivers to digitally queue for charging stations that are currently in use. How would this affect availability? Could help availability in that could help drivers to get an opportunity to charge at a selected charging station.
  - A: ODOE will definitely consider how apps that allow drivers to digitally queue to use a charger affect both availability and equity.
- Q: What about availability parameters related to the use of a smart phone, such as locating and paying for charging? A lot of seniors can have difficulty with smart phones, which could affect how charging infrastructure is available to them. Suggest EV educational talks in senior centers in Oregon – EVs could be great for retirees.
  - A: ODOE agrees that there are equity concerns around the need for a smart phone and data plan usage for a lot of tasks related to locating and using charging infrastructure.
- Q: With respect to quantifying uptime, there should be an understanding that it can be hard to get an electrician out to service/repair a corridor charger located outside of town. This metric may improve in the near term if EVSE companies start doing more remote diagnostics for charging equipment not working correctly.
- Q: ODOE asked the stakeholders if ODOE should consider having the same parameters for availability for both public charging and private charging, or if there were elements that might relate to one more than the other.
  - A: Private charging that is in a publicly accessible area, such as an open parking lot, can be tricky because the chargers may show up on apps as available to the public, but they may not actually allow charging from non-employees. For example, stakeholder went to Seattle for the weekend and expected to charge at empty ChargePoint chargers at Google office building. However, upon arriving found that the chargers were only available for Google employees (an available setting within the charger itself).
  - A: ODOE suggests that this raises a good point about the boundaries between what's public and what's private and will consider this in the BiZEV.

Wrap up and adjournment – Mary Brazell, ODOT and Rebecca Smith, ODOE

Appendix A-2: Potential Metrics for Measuring Availability and Reliability of EV Charging Infrastructure

AVAILABILITY	RELIABILITY
Open access • Yes/no whether specific EVSE companies operating chargers in Oregon allow open access at all of their charging stations.	**Uptime** • Percent uptime per charging port or charging station. • Available plan for meeting specific percent uptime by EVSE.
Payment options • Yes/no whether a charging station allows multiple payment methods. • Yes/no whether a charging station allows a specific payment method, such as mobile, card reader (swipe), card reader (chip), card reader (tap), or toll-free number.	**Repairs** • Time elapsed between notice of issue and repair of issue by charging port or charging station. • Yes/no whether repair initiated within specific timeframe of notice.
Pricing transparency • Yes/no whether charging station clearly states costs associated with charging before a driver initiates a charging session. • Yes/no whether charging station clearly states specific information related to charging costs, such as unit of sale, price per unit of sale, or any additional fees.	
Accessibility • Yes/no whether a public charger is accessible 24-hours, seven days a week. • Yes/no whether charging station offers ADA-compliant stall(s). • Number and type of ADA-compliant stalls per charging station. • Yes/no whether charging station offers multiple charging connectors. • Yes/no whether charging station offers multiple charging connector types, and what types.	

Geographic location	
• Number or percent of charging stations located within a specific distance to areas with some percent of multi-unit dwellings in the housing mix. • Percent of make-ready infrastructure located in or near identified frontline or environmental justice communities. • Number or percent of charging stations located in or near identified frontline or environmental justice communities. • Number or percent of charging stations located on or near identified travel corridors. • Distance in miles between charging stations located on or near identified travel corridors. • Density of charging ports per registered EVs in a given area.	

Appendix B: Comparison of Up-Front Costs Between Electric Vehicles and Gasoline Vehicles

Median Adjusted Gross Income

Comparison of Up-front Costs Between EVs and Gasoline Vehicles

		Up-Front Costs			
		MSRP	Incentives	Registration	First Cost
Trax LS (Gas)	Hatchback/CUV	$ 22,930	$ -	$ 132	$ 23,062
Bolt LT (BEV)	Hatchback/CUV	$ 39,295	$ 7,500	$ 306	$ 32,101
Volvo XC 40 T5 (Gas)	SUV	$ 43,155	$ -	$ 132	$ 43,287
Volvo XC 40 P8 (BEV)	SUV	$ 59,555	$ 15,000	$ 306	$ 44,861
2021 Pacifica Touring (Gas)	Van	$ 39,300	$ -	$ 132	$ 39,432
2021 Pacifica Touring (PHEV)	Van	$ 44,125	$ 15,000	$ 306	$ 29,431
2021 F-150 XL (Gas)	Pickup	$ 35,280	$ -	$ 132	$ 35,412
2022 F-150 Lightning (BEV)	Pickup	$ 39,974	$ 15,000	$ 306	$ 25,280

Assumptions

1. Owner can make use of all eligible incentives (Chevrolet not eligible for Federal)
2. Median Oregon Adjusted Gross Income is $67,520; tax owed $8,029
3. Loan terms: 20% down, 60 Mo, 4% interest rate.

Median Adjusted Gross Income

Comparison of Operational Costs Between EVs and Gasoline Vehicles								
		Operating Costs						
Make & Model	Model Type	Mileage	Fuel Cost*	Maint Cost**	Total Ops Cost	Loan Pmt/Yr	Reg Fee	Total Annual Cost
Trax LS (Gas)	Hatchback/CUV	26 MPG	$ 1,333	$ 710	$ 2,043	$ 4,054	$ 66	$ 6,163
Bolt LT (BEV)	Hatchback/CUV	3.45 MPkWh	$ 369	$ 363	$ 731	$ 6,947	$ 153	$ 7,832
Volvo XC 40 T5 (Gas)	SUV	26 MPG	$ 1,333	$ 710	$ 2,043	$ 7,630	$ 66	$ 9,739
Volvo XC 40 P8 (BEV)	SUV	2.33 MPkWh	$ 547	$ 363	$ 909	$ 10,529	$ 153	$ 11,591
2021 Pacifica Touring (Gas)	Van	22 MPG	$ 1,576	$ 710	$ 2,286	$ 6,948	$ 66	$ 9,300
2021 Pacifica Touring (PHEV)	Van	2.44 MPkWh	$ 521	$ 342	$ 863	$ 7,801	$ 153	$ 8,817
2021 F-150 XL (Gas)	Pickup	20 MPG	$ 1,733	$ 710	$ 2,443	$ 6,237	$ 66	$ 8,747
2022 F-150 Lightning (BEV)	Pickup	2.17 MPkWh	$ 585	$ 363	$ 947	$ 7,067	$ 153	$ 8,168

Assumptions

1. Loan terms: 20% down, 60 Mo, 4% interest rate.
2. Vehicle Miles Traveled per year = 11,556
3. Fuel costs: $3.00/gal and 11¢/kWh
4. Maint. Per mile:

    0.0614 Gas Maintenance/mi

    0.030 PHEV Maintenance/mi

    0.031 BEV Maintenance/mi

Median Adjusted Gross Income

	Cash Flow with Outright Purchase												
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Grand Total
Trax LS (Gas)	$ 23,062	$ 2,109	$ 2,160	$ 2,212	$ 2,265	$ 2,319	$ 2,375	$ 2,432	$ 2,490	$ 2,550	$ 2,611	$ 2,674	$ 49,258
Bolt LT (BEV)	$ 32,101	$ 884	$ 905	$ 927	$ 949	$ 972	$ 996	$ 1,019	$ 1,044	$ 1,069	$ 1,095	$ 1,121	$ 43,083
Volvo XC 40 T5 (Gas)	$ 43,287	$ 2,109	$ 2,160	$ 2,212	$ 2,265	$ 2,319	$ 2,375	$ 2,432	$ 2,490	$ 2,550	$ 2,611	$ 2,674	$ 69,483
Volvo XC 40 P8 (BEV)	$ 44,861	$ 1,062	$ 1,088	$ 1,114	$ 1,141	$ 1,168	$ 1,196	$ 1,225	$ 1,254	$ 1,284	$ 1,315	$ 1,347	$ 58,054
2021 Pacifica Touring (Gas)	$ 39,432	$ 2,352	$ 2,408	$ 2,466	$ 2,525	$ 2,586	$ 2,648	$ 2,711	$ 2,776	$ 2,843	$ 2,911	$ 2,981	$ 68,639
2021 Pacifica Touring (PHEV)	$ 29,431	$ 1,016	$ 1,040	$ 1,065	$ 1,091	$ 1,117	$ 1,144	$ 1,171	$ 1,199	$ 1,228	$ 1,258	$ 1,288	$ 42,049
2021 F-150 XL (Gas)	$ 35,412	$ 2,509	$ 2,569	$ 2,631	$ 2,694	$ 2,759	$ 2,825	$ 2,893	$ 2,962	$ 3,033	$ 3,106	$ 3,181	$ 66,576
2022 F-150 Lightning (BEV)	$ 25,280	$ 1,100	$ 1,127	$ 1,154	$ 1,182	$ 1,210	$ 1,239	$ 1,269	$ 1,299	$ 1,330	$ 1,362	$ 1,395	$ 38,946

Assumptions

1. Escalation rate 2.4%

	Cash Flow with Loan:												
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Grand Total
Trax LS	$ 6,163	$ 6,163	$ 6,311	$ 6,463	$ 6,618	$ 2,723	$ 2,788	$ 2,855	$ 2,923	$ 2,993	$ 3,065	$ 3,139	$ 52,204
Bolt LT	$ 332	$ 7,832	$ 8,020	$ 8,212	$ 8,409	$ 1,664	$ 1,704	$ 1,744	$ 1,786	$ 1,829	$ 1,873	$ 1,918	$ 45,322
Volvo XC 40 T5 (Gas)	$ 9,739	$ 9,739	$ 9,973	$ 10,212	$ 10,457	$ 3,078	$ 3,152	$ 3,228	$ 3,305	$ 3,385	$ 3,466	$ 3,549	$ 73,283
Volvo XC 40 P8 (BEV)	$ (3,409)	$ 11,591	$ 11,870	$ 12,155	$ 12,446	$ 2,216	$ 2,269	$ 2,323	$ 2,379	$ 2,436	$ 2,495	$ 2,555	$ 61,326
2021 Pacifica Touring	$ 9,300	$ 9,300	$ 9,523	$ 9,752	$ 9,986	$ 3,277	$ 3,356	$ 3,436	$ 3,519	$ 3,603	$ 3,690	$ 3,778	$ 72,519
2021 Pacifica Touring Hybrid	$ (6,183)	$ 8,817	$ 9,029	$ 9,245	$ 9,467	$ 1,893	$ 1,939	$ 1,985	$ 2,033	$ 2,082	$ 2,132	$ 2,183	$ 44,623
2021 F-150 XL	$ 8,747	$ 8,747	$ 8,957	$ 9,172	$ 9,392	$ 3,380	$ 3,461	$ 3,544	$ 3,629	$ 3,716	$ 3,805	$ 3,896	$ 70,444
2022 F-150 Lightning EV	$ (6,832)	$ 8,168	$ 8,364	$ 8,564	$ 8,770	$ 1,913	$ 1,959	$ 2,006	$ 2,054	$ 2,104	$ 2,154	$ 2,206	$ 41,429

Assumptions

1. Escalation rate 2.4%

Low Adjusted Gross Income

Comparison of Up-front Costs Between EVs and Gasoline Vehicles		Up Front Costs			
		MSRP	Incentives	Registration	First Cost
Trax LS (Gas)	Hatchback/CUV	$ 22,930	$ -	$ 132	$ 23,062
Bolt LT (BEV)	Hatchback/CUV	$ 39,295	$ 7,500	$ 306	$ 32,101
Volvo XC 40 T5 (Gas)	SUV	$ 43,155	$ -	$ 132	$ 43,287
Volvo XC 40 P8 (BEV)	SUV	$ 59,555	$ 11,243	$ 306	$ 48,618
2021 Pacifica Touring (Gas)	Van	$ 39,300	$ -	$ 132	$ 39,432
2021 Pacifica Touring (PHEV)	Van	$ 44,125	$ 11,243	$ 306	$ 33,188
2021 F-150 XL (Gas)	Pickup	$ 35,280	$ -	$ 132	$ 35,412
2022 F-150 Lightning (BEV)	Pickup	$ 39,974	$ 11,243	$ 306	$ 29,037

Assumptions

1. Owner can make use of all eligible incentives (Chevrolet not eligible for Federal)
2. Low Adjusted Gross Income (66% of median) $45,013; tax owed $3,743
3. Loan terms: 20% down, 60 Mo, 4% interest rate.

Low Adjusted Gross Income

Comparison of Operational Costs Between EVs and Gasoline Vehicles

Make & Model	Model Type	Mileage	Fuel Cost	Maint Cost	Total Ops Cost	Loan Pmt/Yr	Reg Fee	Total Annual Cost
Trax LS (Gas)	Hatchback/CUV	26 MPG	$ 1,333	$ 710	$ 2,043	$ 4,054	$ 66	$ 6,163
Bolt LT (BEV)	Hatchback/CUV	3.45 MPkWh	$ 369	$ 363	$ 731	$ 6,947	$ 153	$ 7,832
Volvo XC 40 T5 (Gas)	SUV	26 MPG	$ 1,333	$ 710	$ 2,043	$ 7,630	$ 66	$ 9,739
Volvo XC 40 P8 (BEV)	SUV	2.33 MPkWh	$ 547	$ 363	$ 909	$ 10,529	$ 153	$ 11,591
2021 Pacifica Touring (Gas)	Van	22 MPG	$ 1,576	$ 710	$ 2,286	$ 6,948	$ 66	$ 9,300
2021 Pacifica Touring (PHEV)	Van	2.44 MPkWh	$ 521	$ 342	$ 863	$ 7,801	$ 153	$ 8,817
2021 F-150 XL (Gas)	Pickup	20 MPG	$ 1,733	$ 710	$ 2,443	$ 6,237	$ 66	$ 8,747
2022 F-150 Lightning (BEV)	Pickup	2.17 MPkWh	$ 585	$ 363	$ 947	$ 7,067	$ 153	$ 8,168

Assumptions

1. Loan terms: 20% down, 60 Mo, 4% interest rate.
2. Vehicle Miles Traveled per year = 11,556
3. Fuel costs: $3.00/gal and 11¢/kWh
4. Maint. Per mile:

    0.0614 Gas Maintenance/mi

    0.030 PHEV Maintenance/mi

    0.031 BEV Maintenance/mi

Low Adjusted Gross Income

	Cash Flow with Outright Purchase:												
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Grand Total
Trax LS	$ 23,062	$ 2,109	$ 2,160	$ 2,212	$ 2,265	$ 2,319	$ 2,375	$ 2,432	$ 2,490	$ 2,550	$ 2,611	$ 2,674	$ 49,258
Bolt LT	$ 32,101	$ 884	$ 905	$ 927	$ 949	$ 972	$ 996	$ 1,019	$ 1,044	$ 1,069	$ 1,095	$ 1,121	$ 43,083
Volvo XC 40 T5	$ 43,287	$ 2,109	$ 2,160	$ 2,212	$ 2,265	$ 2,319	$ 2,375	$ 2,432	$ 2,490	$ 2,550	$ 2,611	$ 2,674	$ 69,483
Volvo XC 40 P8	$ 48,618	$ 1,062	$ 1,088	$ 1,114	$ 1,141	$ 1,168	$ 1,196	$ 1,225	$ 1,254	$ 1,284	$ 1,315	$ 1,347	$ 61,811
2021 Pacifica Touring	$ 39,432	$ 2,352	$ 2,408	$ 2,466	$ 2,525	$ 2,586	$ 2,648	$ 2,711	$ 2,776	$ 2,843	$ 2,911	$ 2,981	$ 68,639
2021 Pacifica Touring Hybrid	$ 33,188	$ 1,016	$ 1,040	$ 1,065	$ 1,091	$ 1,117	$ 1,144	$ 1,171	$ 1,199	$ 1,228	$ 1,258	$ 1,288	$ 45,806
2021 F-150 XL	$ 35,412	$ 2,509	$ 2,569	$ 2,631	$ 2,694	$ 2,759	$ 2,825	$ 2,893	$ 2,962	$ 3,033	$ 3,106	$ 3,181	$ 66,576
2022 F-150 Lightning EV	$ 29,037	$ 1,100	$ 1,127	$ 1,154	$ 1,182	$ 1,210	$ 1,239	$ 1,269	$ 1,299	$ 1,330	$ 1,362	$ 1,395	$ 42,703

Assumptions

1. Escalation rate 2.4%

	Cash Flow with Loan:												
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Grand Total
Trax LS	$ 6,163	$ 6,163	$ 6,311	$ 6,463	$ 6,618	$ 2,723	$ 2,788	$ 2,855	$ 2,923	$ 2,993	$ 3,065	$ 3,139	$ 52,204
Bolt LT	$ 332	$ 7,832	$ 8,020	$ 8,212	$ 8,409	$ 1,664	$ 1,704	$ 1,744	$ 1,786	$ 1,829	$ 1,873	$ 1,918	$ 45,322
Volvo XC 40 T5	$ 9,739	$ 9,739	$ 9,973	$ 10,212	$ 10,457	$ 3,078	$ 3,152	$ 3,228	$ 3,305	$ 3,385	$ 3,466	$ 3,549	$ 73,283
Volvo XC 40 P8	$ 348	$ 11,591	$ 11,870	$ 12,155	$ 12,446	$ 2,216	$ 2,269	$ 2,323	$ 2,379	$ 2,436	$ 2,495	$ 2,555	$ 65,083
2021 Pacifica Touring	$ 9,300	$ 9,300	$ 9,523	$ 9,752	$ 9,986	$ 3,277	$ 3,356	$ 3,436	$ 3,519	$ 3,603	$ 3,690	$ 3,778	$ 72,519
2021 Pacifica Touring Hybrid	$ (2,426)	$ 8,817	$ 9,029	$ 9,245	$ 9,467	$ 1,893	$ 1,939	$ 1,985	$ 2,033	$ 2,082	$ 2,132	$ 2,183	$ 48,380
2021 F-150 XL	$ 8,747	$ 8,747	$ 8,957	$ 9,172	$ 9,392	$ 3,380	$ 3,461	$ 3,544	$ 3,629	$ 3,716	$ 3,805	$ 3,896	$ 70,444
2022 F-150 Lightning EV	$ (3,075)	$ 8,168	$ 8,364	$ 8,564	$ 8,770	$ 1,913	$ 1,959	$ 2,006	$ 2,054	$ 2,104	$ 2,154	$ 2,206	$ 45,186

Assumptions

1. Escalation rate 2.4%

High Adjusted Gross Income

Comparison of Up-front Costs Between EVs and Gasoline Vehicles		Up-Front Costs			
		MSRP	Incentives	Registration	First Cost
Trax LS (Gas)	Hatchback/CUV	$ 22,930	$ -	$ 132	$ 23,062
Bolt LT (BEV)	Hatchback/CUV	$ 39,295	$ 2,500	$ 306	$ 37,101
Volvo XC 40 T5 (Gas)	SUV	$ 43,155	$ -	$ 132	$ 43,287
Volvo XC 40 P8 (BEV)	SUV	$ 59,555	$ 10,000	$ 306	$ 49,861
2021 Pacifica Touring (Gas)	Van	$ 39,300	$ -	$ 132	$ 39,432
2021 Pacifica Touring (PHEV)	Van	$ 44,125	$ 10,000	$ 306	$ 34,431
2021 F-150 XL (Gas)	Pickup	$ 35,280	$ -	$ 132	$ 35,412
2022 F-150 Lightning (BEV)	Pickup	$ 39,974	$ 10,000	$ 306	$ 30,280

Assumptions

1. Owner can make use of all eligible incentives (Chevrolet not eligible for Federal)
2. High Adjusted Gross Income (twice median) $135,040; tax owed $23,656
3. Loan terms: 20% down, 60 Mo, 4% interest rate.

High Adjusted Gross Income

Comparison of Operational Costs Between EVs and Gasoline Vehicles

Make & Model	Model Type	Mileage	Fuel Cost	Maint Cost	Total Ops Cost	Loan Pmt/Yr	Reg Fee	Total Annual Cost
Trax LS (Gas)	Hatchback/CUV	26 MPG	$ 1,333	$ 710	$ 2,043	$ 4,054	$ 66	$ 6,163
Bolt LT (BEV)	Hatchback/CUV	3.45 MPkWh	$ 369	$ 363	$ 731	$ 6,947	$ 153	$ 7,832
Volvo XC 40 T5 (Gas)	SUV	26 MPG	$ 1,333	$ 710	$ 2,043	$ 7,630	$ 66	$ 9,739
Volvo XC 40 P8 (BEV)	SUV	2.33 MPkWh	$ 547	$ 363	$ 909	$ 10,529	$ 153	$ 11,591
2021 Pacifica Touring (Gas)	Van	22 MPG	$ 1,576	$ 710	$ 2,286	$ 6,948	$ 66	$ 9,300
2021 Pacifica Touring (PHEV)	Van	2.44 MPkWh	$ 521	$ 342	$ 863	$ 7,801	$ 153	$ 8,817
2021 F-150 XL (Gas)	Pickup	20 MPG	$ 1,733	$ 710	$ 2,443	$ 6,237	$ 66	$ 8,747
2022 F-150 Lightning (BEV)	Pickup	2.17 MPkWh	$ 585	$ 363	$ 947	$ 7,067	$ 153	$ 8,168

Assumptions

1. Loan terms: 20% down, 60 Mo, 4% interest rate.
2. Vehicle Miles Traveled per year = 11,556
3. Fuel costs: $3.00/gal and 11¢/kWh
4. Maint. Per mile:

   0.0614 Gas Maintenance/mi

   0.030 PHEV Maintenance/mi

   0.031 BEV Maintenance/mi

High Adjusted Gross Income

	Cash Flow with Outright Purchase:												
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Grand Total
Trax LS	$ 23,062	$ 2,109	$ 2,160	$ 2,212	$ 2,265	$ 2,319	$ 2,375	$ 2,432	$ 2,490	$ 2,550	$ 2,611	$ 2,674	$ 49,258
Bolt LT	$ 37,101	$ 884	$ 905	$ 927	$ 949	$ 972	$ 996	$ 1,019	$ 1,044	$ 1,069	$ 1,095	$ 1,121	$ 48,083
Volvo XC 40 T5	$ 43,287	$ 2,109	$ 2,160	$ 2,212	$ 2,265	$ 2,319	$ 2,375	$ 2,432	$ 2,490	$ 2,550	$ 2,611	$ 2,674	$ 69,483
Volvo XC 40 P8	$ 49,861	$ 1,062	$ 1,088	$ 1,114	$ 1,141	$ 1,168	$ 1,196	$ 1,225	$ 1,254	$ 1,284	$ 1,315	$ 1,347	$ 63,054
2021 Pacifica Touring	$ 39,432	$ 2,352	$ 2,408	$ 2,466	$ 2,525	$ 2,586	$ 2,648	$ 2,711	$ 2,776	$ 2,843	$ 2,911	$ 2,981	$ 68,639
2021 Pacifica Touring Hybrid	$ 34,431	$ 1,016	$ 1,040	$ 1,065	$ 1,091	$ 1,117	$ 1,144	$ 1,171	$ 1,199	$ 1,228	$ 1,258	$ 1,288	$ 47,049
2021 F-150 XL	$ 35,412	$ 2,509	$ 2,569	$ 2,631	$ 2,694	$ 2,759	$ 2,825	$ 2,893	$ 2,962	$ 3,033	$ 3,106	$ 3,181	$ 66,576
2022 F-150 Lightning EV	$ 30,280	$ 1,100	$ 1,127	$ 1,154	$ 1,182	$ 1,210	$ 1,239	$ 1,269	$ 1,299	$ 1,330	$ 1,362	$ 1,395	$ 43,946

Assumptions

1. Escalation rate 2.4%

	Cash Flow with Loan:												
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Grand Total
Trax LS	$ 6,163	$ 6,163	$ 6,311	$ 6,463	$ 6,618	$ 2,723	$ 2,788	$ 2,855	$ 2,923	$ 2,993	$ 3,065	$ 3,139	$ 52,204
Bolt LT	$ 5,332	$ 7,832	$ 8,020	$ 8,212	$ 8,409	$ 1,664	$ 1,704	$ 1,744	$ 1,786	$ 1,829	$ 1,873	$ 1,918	$ 50,322
Volvo XC 40 T5	$ 9,739	$ 9,739	$ 9,973	$10,212	$ 10,457	$ 3,078	$ 3,152	$ 3,228	$ 3,305	$ 3,385	$ 3,466	$ 3,549	$ 73,283
Volvo XC 40 P8	$ 1,591	$11,591	$ 11,870	$12,155	$ 12,446	$ 2,216	$ 2,269	$ 2,323	$ 2,379	$ 2,436	$ 2,495	$ 2,555	$ 66,326
2021 Pacifica Touring	$ 9,300	$ 9,300	$ 9,523	$ 9,752	$ 9,986	$ 3,277	$ 3,356	$ 3,436	$ 3,519	$ 3,603	$ 3,690	$ 3,778	$ 72,519
2021 Pacifica Touring Hybrid	$ (1,183)	$ 8,817	$ 9,029	$ 9,245	$ 9,467	$ 1,893	$ 1,939	$ 1,985	$ 2,033	$ 2,082	$ 2,132	$ 2,183	$ 49,623
2021 F-150 XL	$ 8,747	$ 8,747	$ 8,957	$ 9,172	$ 9,392	$ 3,380	$ 3,461	$ 3,544	$ 3,629	$ 3,716	$ 3,805	$ 3,896	$ 70,444
2022 F-150 Lightning EV	$ (1,832)	$ 8,168	$ 8,364	$ 8,564	$ 8,770	$ 1,913	$ 1,959	$ 2,006	$ 2,054	$ 2,104	$ 2,154	$ 2,206	$ 46,429

Assumptions

1. Escalation rate 2.4%

Federal Tax Liability

Effects of Income on Incentive Eligibility Based on Average Adjusted Gross Income (2019)

Income level	2019 Oregon Average AGI	2019 Standard Deduction	2019 Taxable Income	2019 Federal Tax Liability	Federal Tax Credit	State Rebates	**Total Incentive**
Median	$ 67,520	$ 12,200	$ 55,320	$ 8,029	$ 7,500	$ 7,500	**$ 15,000**
High (twice Median)	$ 135,040	$ 12,200	$ 122,840	$ 23,656	$ 7,500	$ 2,500	**$ 10,000**
Low (2/3 of median)	$ 45,013	$ 12,200	$ 32,813	$ 3,743	$ 3,743	$ 7,500	**$ 11,243**

Appendix C: Cash Flow of Costs for Owning and Operating an EV Compared to a Gas Vehicle Over 12 Years

These tables estimate cash flow over 12 years of vehicle ownership.[i]

Cash Flow* (in dollars) Without Vehicle Financing

Year	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven	Twelve	Grand Total
Trax LS	23,062	2,109	2,160	2,212	2,265	2,319	2,375	2,432	2,490	2,550	2,611	2,674	**49,258**
Bolt LT	32,101	884	905	927	949	972	996	1,019	1,044	1,069	1,095	1,121	**43,083**
Volvo XC 40 T5	43,287	2,109	2,160	2,212	2,265	2,319	2,375	2,432	2,490	2,550	2,611	2,674	**69,483**
Volvo XC 40 P8	45,144	1,062	1,088	1,114	1,141	1,168	1,196	1,225	1,254	1,284	1,315	1,347	**58,337**
2021 Pacifica Touring	39,432	2,352	2,408	2,466	2,525	2,586	2,648	2,711	2,776	2,843	2,911	2,981	**68,639**
2021 Pacifica Touring Hybrid	29,714	1,016	1,040	1,065	1,091	1,117	1,144	1,171	1,199	1,228	1,258	1,288	**42,332**
2021 F-150 XL	35,412	2,509	2,569	2,631	2,694	2,759	2,825	2,893	2,962	3,033	3,106	3,181	**66,576**
2022 F-150 Lightning EV	25,563	1,100	1,127	1,154	1,182	1,210	1,239	1,269	1,299	1,330	1,362	1,395	**39,229**

* Annual cost escalation rate of 2.4 percent.

Cash Flow* (in dollars) With Vehicle Financing

Year	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven	Twelve	Grand Total
Trax LS	6,163	6,163	6,311	6,463	6,618	2,723	2,788	2,855	2,923	2,993	3,065	3,139	**52,204**
Bolt LT	332	7,832	8,020	8,212	8,409	1,664	1,704	1,744	1,786	1,829	1,873	1,918	**45,322**
Volvo XC 40 T5	9,739	9,739	9,973	10,212	10,457	3,078	3,152	3,228	3,305	3,385	3,466	3,549	**73,283**
Volvo XC 40 P8	(3,126)	11,591	11,870	12,155	12,446	2,216	2,269	2,323	2,379	2,436	2,495	2,555	**61,609**
2021 Pacifica Touring	9,300	9,300	9,523	9,752	9,986	3,277	3,356	3,436	3,519	3,603	3,690	3,778	**72,519**
2021 Pacifica Touring Hybrid	(5,900)	8,817	9,029	9,245	9,467	1,893	1,939	1,985	2,033	2,082	2,132	2,183	**44,906**
2021 F-150 XL	8,747	8,747	8,957	9,172	9,392	3,380	3,461	3,544	3,629	3,716	3,805	3,896	**70,444**
2022 F-150 Lightning EV	(6,549)	8,168	8,364	8,564	8,770	1,913	1,959	2,006	2,054	2,104	2,154	2,206	**41,712**

* Annual cost escalation rate of 2.4 percent.

[i] Data on file at the Oregon Department of Energy.

Appendix D: Light-Duty Electric Vehicle Models, 2020 & 2021

Cars			
Make	**Model**	**# Registered**	**Type**
Audi	A7	0	PHEV
Audi	A8	1	PHEV
BMW	3 Series	10	PHEV
BMW	5 Series	14	PHEV
BMW	7 Series	4	PHEV
BMW	I3	26	Either
BMW	I8	0	PHEV
Chevrolet	Bolt	782	BEV
Ferrari	SF90 Stradale	1	PHEV
Ford	Fusion	62	PHEV
Honda	Clarity	106	Either
Hyundai	Ioniq	242	Either
Karma	GS-6	0	PHEV
Karma	Revero	1	PHEV
Kia	NIro	125	Either
Kia	Optima	8	PHEV
Mercedes	S560e	0	PHEV
Mini	Countryman	9	PHEV
Mini	Hardtop	44	BEV
Polestar	1	0	PHEV
Polestar	2	2	BEV
Porsche	Panamera	2	PHEV
Porsche	Taycan	42	BEV
Subaru	Crosstrek	202	PHEV
Tesla	Model 3	1646	BEV
Tesla	Model S	198	BEV
Tesla	Model Y	1801	BEV
Toyota	Prius Prime	605	PHEV
Volvo	S60	6	PHEV
Volvo	V60	3	PHEV
Volvo	S90	0	PHEV

SUVs			
Make	**Model**	**# Registered**	**Type**
Audi	e-tron sportback	0	BEV
Audi	e-tron	34	BEV
Audi	Q5	168	PHEV
Bentley	Bentayga	0	PHEV
BMW	X3	65	PHEV
BMW	X5	62	PHEV
Ford	Escape	0	PHEV
Ford	Mustang Mach-E	6	BEV
Hyundai	Kona	272	BEV
Jaguar	I-Pace	21	BEV
Jeep	Wrangler 4xe	0	PHEV
Kia	Soul	0	BEV
Land Rover	Range Rover	10	PHEV
Lincoln	Aviator	9	PHEV
Lincoln	Corsair	0	PHEV
Mercedes	GLC 350e	31	PHEV
Mitsubishi	Outlander	7	PHEV
Nissan	Leaf	508	BEV
Porsche	Cayenne	10	PHEV
Tesla	Model X	371	BEV
Toyota	RAV4 Prime	210	PHEV
Volkswagen	ID.4	0	BEV
Volvo	XC40 Recharge	0	BEV
Volvo	XC60	70	PHEV
Volvo	XC90	58	PHEV

Vans			
Make	**Model**	**# Registered**	**Type**
Chrysler	Pacifica	206	PHEV

Pickups
None

Motorcycle & Moped			
Make	**Model**	**# Registered**	**Type**
Arcimoto	FUV, Reverse Trike	27	BEV
Alta Motors	Redshift EXR	0	BEV
Cake	OSA	1	BEV
Changzhou Yamasaki	N-GT Series, NQI GTS Series, M+Sport	11	BEV
Chongqing Zongshen	City Slicker	1	BEV
Energica	Ego, Eva, SS9	3	BEV
Harley Davidson	LiveWire, LIV, ELW, ELV	5	BEV
Huck Cycles	Stinger	1	BEV
Vespa	Elettrica	3	BEV
Vespa	GTS RST	1	PHEV
Zero	DS, DSR, FX, FXS, RS, S, SR, SRF	26	BEV

Low-Speed Car			
Make	**Model**	**# Registered**	**Type**
Club Car	CA7, Carryall 510 LSV, Villager 2 LSV	6	BEV
Garia	Gari	1	BEV
Polaris	GEM	2	BEV

Source: March 2021 ODOT DMV EV Data, and Fueleconomy.gov data accurate as of July 2021.

Appendix E: Data for ODOE's Analysis on the Impact of ZEVs on State Highway Fund Revenues

Fuel Economy (MPG)

For the EPA mileage rating, or MPG, ODOT provided vehicle counts and an average MPG for each of the four DMV registration groups: under 20 MPG; 20-39 MPG; 40+ MPG, and fully electric vehicles. DMV obtains the MPG of a vehicle from DataONE software through a VIN decoding process. The U.S. Environmental Protection Agency provides city, highway, and combined MPG ratings, and DataONE uses these EPA ratings for vehicle fuel efficiency figures. ODOT uses the combined EPA ratings to determine the MPG group for a vehicle and to calculate average MPG. As shown in Table 3 of the *Impacts of Sales and Ownership of ZEVs on the State Highway Fund*, the 0-19 MPG registration group has the highest number of vehicles that did not have an exact MPG match. This is because, as a default, DMV puts non-electric vehicles that don't have an exact MPG match into this registration group. Overall, 71 percent of light-duty vehicles currently registered with DMV have an exact match to EPA fuel efficiency ratings, resulting in an overall average MPG of 24.

Vehicle Miles Traveled

For VMT, ODOT provided ODOE with average estimates by vehicle type and registration group. ODOT derived these estimates from available odometer readings. Vehicles must have at least two odometer readings for ODOT to be able to calculate their average VMT. Typically, DMV receives odometer readings when there is a title transaction. An additional source of odometer readings is available in the Portland Metro and Medford areas, where vehicles are required to undergo emissions testing at the time of registration renewal, and odometer readings are collected in the process. The VMT data takes time to "mature" as most newly-registered vehicles won't get their second odometer reading until they are sold or are subject to emissions testing for registration renewal, four years after the initial registration. For that reason, ODOT uses four-year average VMT estimates from 2017-2020 calendar years.

ODOT VMT figures are lower than what the Federal Highway Administration (FHWA) estimates for Oregon for light-duty vehicles. The FHWA estimates national VMT statistics by using state reported Highway Performance and Monitoring System data, fuel consumption data, vehicle registration data, and other sources. Other analyses in this report use FHWA estimates for VMT, but for these calculations on State Highway Fund revenues, ODOE used the VMT averages from ODOT since these are the figures that ODOT uses for its analyses.

Hybrid Vehicles

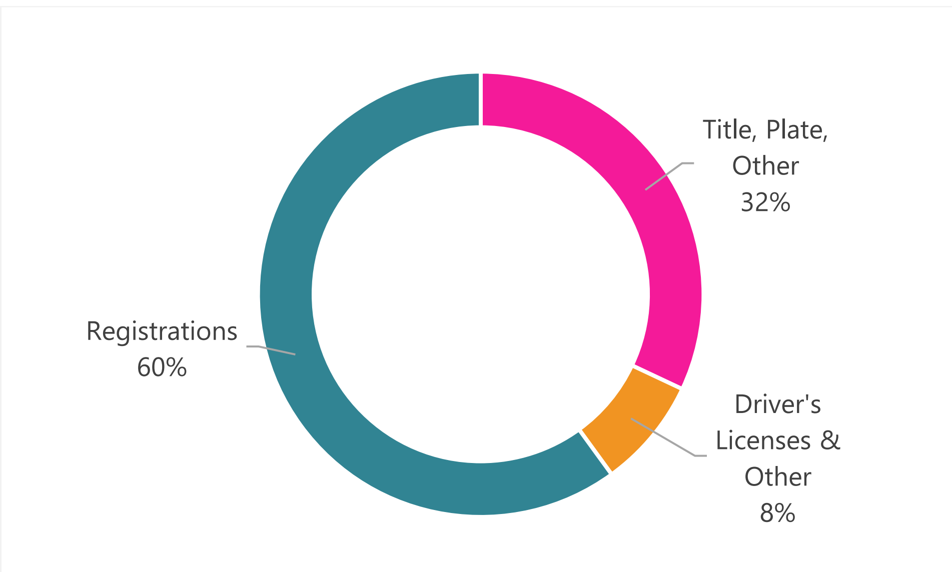
When calculating potential revenue from the fuels tax, vehicles are separated by fuel type such that fully electric BEVs are one category and vehicles using all other fuel types are another category. These non-electric and hybrid vehicles are further categorized according to the DMV registration MPG groups. Hybrid electric vehicles (both those that do and do not plug in) are not counted with fully electric vehicles but are instead included in their respective DMV registration mpg groups. Given that these vehicles will have relatively high mpg figures compared to non-electric vehicles, they will necessarily be charged a higher registration fee than less efficient ICE vehicles, unless enrolled in the OReGO program.

Standard hybrids are not considered zero emissions vehicles, though plug-in hybrid electric vehicles are. Plug-in hybrids have both a conventional fossil fuel drivetrain and an electric one, and generally the vehicle will operate fully or almost fully on electricity until the battery is nearly empty, at which point the vehicle will then operate as an ICE vehicle.

DMV Fees

Although there are three categories of DMV fees that provide revenue for the State Highway Fund, ODOE only analyzed DMV registration fees. For FY 2019, registration fees made up 60 percent of the DMV fee revenue that went to the State Highway Fund).

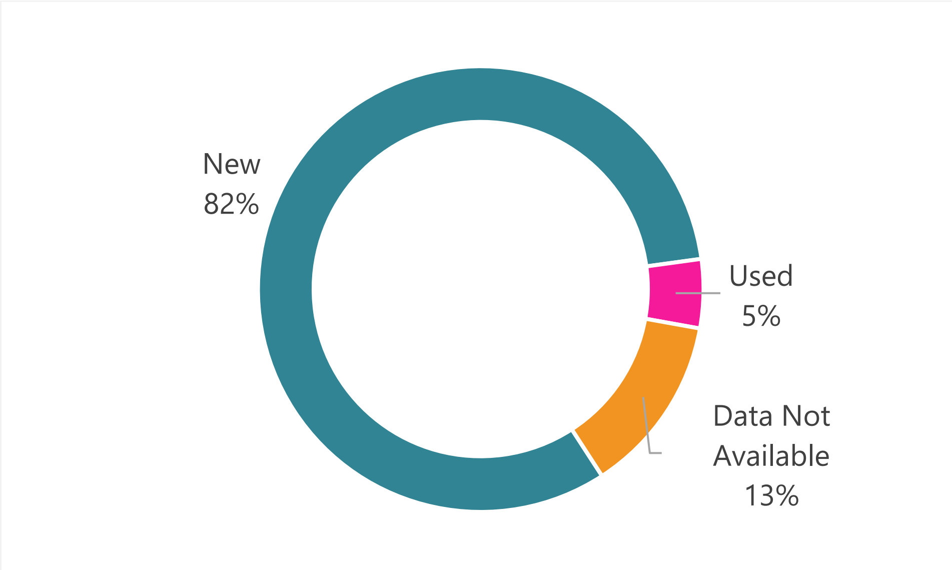
Percent Contribution of DMV Fees Revenue to State Highway Fund for FY 2019[1]



OReGO Program and Road Use Charge Versus Fuels Tax

When determining how best to illustrate the effect on revenues to the State Highway Fund from BEV participation in the OReGO program, ODOE and ODOT had concerns that BEVs currently enrolled in the OReGO program may not be representative of the fleet of light-duty BEVs in Oregon at large. For this reason, ODOE chose to use the data on average annual VMT for each vehicle type provided by ODOT instead of data from the OReGO program. ODOE used the cost of a two-year DMV vehicle registration for BEVs not enrolled in the OReGO program and then compared that to the combined cost of BEV registration fees and BEV per-mile road usage charges for BEVs enrolled in OReGO to determine the differences in revenue represented by the percent of the overall BEV fleet participating in the program. The OReGO charges a registration fee of $86 for a two-year registration for BEVs but doubles this fee to $172 for new vehicles. According to the Oregon Clean Vehicle Rebate Program,[2] about 82 percent of ZEV rebates were provided for new vehicles while 5 percent were provided for used vehicles). However, the data show 13 percent as unknown (data not available) and given that this is almost three times as large as the percent for used vehicles, ODOE proportionally attributed the 13 percent unknown to the new and used categories, resulting in 94 percent new vehicles and six percent used vehicles. ODOE then used these new percent figures in calculations to determine the attribution of the $172 registration fee for new EVs or the $86 registration fee for used BEVs in the OReGO program.

Percent of Oregon Clean Vehicle Rebates by New or Used Vehicle[3]



[1] Oregon Department of Transportation. (2021, April). *ODOT State Highway Fund Transportation Revenue Forecast.* https://www.oregon.gov/odot/Data/Documents/April%202021%20Forecast%20document.pdf
[2] Center for Sustainable Energy. (2021). Oregon Clean Vehicle Rebate Program Statistics. Data last updated April 26, 2021. https://www.evrebate.oregon.gov/rebate-statistics
[3] Center for Sustainable Energy. (2021). Oregon Clean Vehicle Rebate Program Statistics. Data last updated April 26, 2021. https://www.evrebate.oregon.gov/rebate-statistics