2023 BIENNIAL ZERO EMISSION VEHICLE REPORT

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2023 Biennial Zero-Emission Vehicle Report

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Contributing Authors: Zach Baker, Rob Del Mar, Evan Elias, Michael Freels, Bilal Jones, Will Mulhern, Jessica Reichers, Amy Schlusser, Rebecca Smith, and Blake Shelide

Publication, Data, and Graphics: Erica Hertzsch and Bilal Jones

Other Contributors: Janine Benner, Jennifer Kalez, Abigail Reeser, Ruchi Sadhir, Adam Schultz, Christy Splitt, Alan Zelenka

ODOE Support: Linda Bures, Andy Cameron, Lina Fallert, Jim Gores, Danae Hammitt, Stacey Heuberger, Mary Knight, Colin Lancaster, Wendy Lorimor, Jess Miller, Michael Peppler, Tony Raeker, Linda Ross, Emily Salmeri, Monty Schindler, Jennifer Senner, Jenifer Smith, Kate Steele, Bethany Wachtler, and Michael Williams

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- Oregon Department of Environmental Quality
- Oregon Department of Housing and Community Services
- Oregon Department of Land Conservation and Development
- 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.

Cover: The Oregon Department of Energy has a plug-in hybrid RAV4 Prime in its fleet. Pictured is the RAV4 getting ready to charge up at the new public charging stations at Silver Falls State Park.

Executive Summary

Since the inaugural 2021 Biennial Zero Emission Vehicle Report, Oregon has made significant progress toward meeting its electric vehicle goals. In the first quarter of 2023, EV sales in Oregon exceeded 16 percent of all new vehicle sales, second only to California. Oregon's EV registrations more than doubled to nearly 70,000, and although it is uncertain if the state will achieve the 2025 goal of 250,000 registrations, the 2030 goal (25 percent of registrations and 50 percent of vehicle sales) and the 2035 goal (90 percent of sales) will almost certainly be met. More and more medium- and heavy-duty EVs are joining Oregon fleets, especially transit buses, school buses, and delivery vans. The state's first electric semi-truck – built in Portland – hit Oregon roads in 2023.

The state is well positioned to take advantage of unprecedented federal funding to support transportation electrification, largely from the Infrastructure Investment and Jobs Act passed in 2021. On the heels of its EV charging gap analysis and electric highway designation approvals, the Oregon Department of Transportation received approval for $52 million in National EV Incentive funds for charging deployment in the state. ODOT also stood up the Community Charging Rebates Program to bring Level 2 charging to Oregon communities. The Oregon Department of Environmental Quality updated its Clean Fuels Program to allow fleets access to funds that address the up-front costs of vehicles and charging installations. Many agencies, including the Oregon Department of Energy, are working to identify and win federal funds that support transportation electrification, with a focus on ensuring disadvantaged communities benefit from these projects.

Two new rules instituted by DEQ – Advanced Clean Trucks and Advanced Clean Cars II – provide market certainty for EV manufacturers and ensure EVs will be available for sale throughout the state. The ACT rule sets increasing delivery requirements for medium- and heavy-duty EVs, while ACC II builds on existing delivery requirements for passenger vehicles, culminating in a 100 percent EV sales requirement in 2035. These rules play an important role in maintaining EVs for purchase in the state, despite continuing supply chain disruptions that have been affecting EV and EV charger production.

Although supply chain issues linger, the number of EV passenger models is growing rapidly, and costs are beginning to reach parity with gasoline vehicles. Many manufacturers have plans for most, if not all, models to be electric in the next 15 years. In the last two years, long anticipated electric pickups hit the market, with demand exceeding manufacturer expectations. The Ford F-150 Lightning, Tesla models, and many other popular vehicles qualify for the 2022 Inflation Reduction Act federal tax credit, which can reduce purchase cost by as much as $7,500 for new or $4,000 for used vehicles. Coupled with the new ACC II rule, Oregonians will have plenty of EVs to choose from as they take advantage of these tax credits.

While vehicles are increasingly available, there is a growing need for public EV charging infrastructure, especially for Oregonians living in multi-unit homes, rental properties, and rural areas. Drivers indicate that existing public charging infrastructure doesn't meet their needs, and the availability and reliability of chargers is now one of the biggest barriers to more widespread EV adoption. The National Charging Experience Consortium, a group of industry leaders and experts from three U.S. Department of Energy laboratories, are working together to address some of these issues. Specific reliability requirements will provide metrics for assessment — and to adequately assess reliability will require access to charger data.

General awareness of EVs, how they work, and their benefits is a strong indicator of whether a person will elect to purchase an EV. Drivers are primarily exposed to EVs and their benefits through family, friends, neighbors, and co-workers. While this is a generally positive influence on EV adoption, it leaves out communities where EVs are not as prevalent, such as low-income and rural areas, multi-unit building residents, and renters. Further, the state's Charge Ahead EV rebate program, which was providing up to $5,000 to offset up-front costs for low-income Oregonians, was recently suspended due to lack of funding. Although additional funds for the program will be available in 2024, the level of funding is insufficient to support the program throughout the year. The rebate coupled with the new federal tax credits could provide as much as $12,500 for a new EV or $9,000 for used.

Medium- and heavy-duty vehicles, and specialty off-road vehicles, are in the initial stages of commercialization, with at least a few models available in every configuration. Adoption is slow, largely due to higher vehicle costs – often two to three times that of a diesel vehicle. Charging installation costs can also be high and vary widely depending on a fleet's unique needs. Public charging is largely unavailable for these vehicles. Incentives that address vehicle costs and support additional charging infrastructure are key to widespread adoption, especially for small businesses.

Electric vehicles play a critical role in reducing Oregon's transportation sector carbon intensity and greenhouse gas emissions, largely bolstered by Oregon's Clean Fuels Program and the ACC II and ACT rules. While the transportation sector did not achieve its proportionate share of emissions reductions for the state's 2020 goal, it is now on a better track to meet goals moving forward. But more work is needed to ensure the transportation sector does its part to achieve these goals, particularly emissions from medium- and heavy-duty vehicles.

Utilities do not expect resource adequacy issues related to EV load in the next five years, and any effects are likely to be limited to the local distribution system. This is particularly important for medium- and heavy-duty vehicles, which can have higher power needs than light-duty vehicles. Fleet managers should collaborate early with their local utility when planning to electrify. Where utilities can be involved in planning efforts for transportation electrification, they can help keep costs low for their customers and ratepayers.

Planning is also needed to address the effects of EVs on state funds that build and maintain Oregon's roads. As the number of light-duty EVs in the statewide fleet increases, the overall contribution of fuel taxes to the State Highway Fund will decrease, although effects have been minimal so far. EVs pay a much higher registration fee than other vehicles to address this, but this often only partially offsets the revenue loss, depending on the fuel economy of the vehicle that is replaced and how much that vehicle is driven. Other options to maintain funding, such as a road usage fee, will be necessary to ensure Oregon has the resources necessary to maintain its roads.

This report is available online: www.oregon.gov/energy/energy-oregon/Pages/BIZEV.aspx

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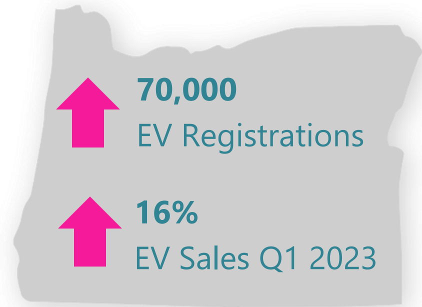
Letter from the Assistant Director



In my letter for the first *2021 Biennial Zero Emission Vehicle Report* I said that I expected the electric vehicle landscape to look completely different by the time we put out this 2023 report – and it does! We are making exciting progress in adopting EVs. Passenger vehicle registrations in Oregon have increased dramatically from 38,000 to nearly 70,000. In the first quarter of 2023, EV sales made up over 16 percent of new vehicle sales in the state, second only to California. Long awaited electric pickup trucks are now available on the market and major manufacturers are committing to more EV models, with at least five committing to sell only electric models within the next 15 years.

The Federal Inflation Reduction Act created tax credits for new and used EVs and for EV chargers in homes and businesses — and it allows direct payments to state governments and other tax-exempt entities to recoup costs for charging infrastructure projects. The Infrastructure Investment and Jobs Act is sending unprecedented funding to the states, including $7.5 billion for EV charging, and billions more to support clean transportation efforts. These funds will help the nation build 500,000 EV chargers and support a Biden Administration goal of increasing new EVs sales nationally to 50 percent by 2035.

In Oregon, we created powerful programs and regulations to stimulate EV adoption and reduce greenhouse gas emissions. By 2050, the Department of Environmental Quality's new Climate Protection Program will reduce greenhouse gas emissions from fossil fuels by 90 percent, and HB 2021 requires 100 percent of electricity from Portland General Electric and PacifiCorp to come from clean energy resources by 2040. DEQ implemented two major rules that will increase the number of EVs in Oregon: the Advanced Clean Cars II rule, requiring 100 percent of passenger car and light-duty vehicle sales to be EVs by 2035; and the Advanced Clean Trucks rule, which will enable more Oregon businesses to purchase medium- and heavy-duty EVs.

Oregon's leadership has positioned us well to take advantage of the unprecedented amount of federal funding available to support transportation electrification. For example, the Oregon Department of Transportation submitted its National EV Incentive program state plan that will bring $52 million in funds for EV charging across Oregon – and that's just the beginning. ODOT, ODOE, DEQ, and others are working hard to bring in millions of federal dollars to support the chargers that will become the backbone of our new transportation system.

The availability and reliability of public EV charging infrastructure is one of the biggest barriers to wider EV adoption in Oregon. Fortunately, EV charging continues to improve at the local and national levels. Eight vehicle manufacturers recently announced they will begin including Tesla's North American Charging Standard with their 2025 model year vehicles. EV Charging Service Providers have signed agreements to make all types of chargers available at many of their stations. The U.S. Department of Energy, three national labs, and the EV industry are coming together through the National Charging Experience Consortium to share data and information that will help make charging more reliable.

Even with all this progress, more work needs to be done, especially to ensure the benefits of EVs are available to all Oregonians. Oregon's Charge Ahead EV Rebate program had been providing a critical $5,000 on-the-hood rebate for low-income Oregonians until funds ran out. This rebate, coupled with the new federal tax credits — as much as $9,000 in total — would lower the upfront cost and bring new and *used* EVs within reach of many Oregonians. Once purchased, driving an EV saves people money because of the lower vehicle fuel and maintenance costs, all while improving local air quality. That's a win-win for Oregonians — but equitable EV adoption needs incentives or rebates to help address up-front costs for many disadvantaged individuals.

Electrifying our transportation sector also plays a central role in Oregon's efforts to address climate change. It is important for Oregon to have a strategy that allows us to decarbonize the grid and incorporate the new load from EVs while maintaining reliable and affordable electricity. This report notes that over the next five years, Oregon electric utilities and the broader western grid are not expecting resource adequacy issues associated with adoption of electric vehicles.

With all these positive developments, Oregon is making great strides to meet our EV and climate goals. In fact, the Oregon Global Warming Commission's TIGHGER project found that transportation electrification and other new climate-related policies have put Oregon on track to meet its 2035 GHG emissions reduction goal. The Commission even recommended accelerating efforts to meet the goal by 2030 based on the best available science. Making the switch to EVs can help us get there.

What a difference two years makes! I am optimistic that in 2025, this report will be celebrating even more success in reaching our EV and greenhouse emission reduction goals.

Alan Zelenka

Assistant Director for Planning and Innovation

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Tribal Land Acknowledgement

Indigenous tribes and bands have been with the lands that we inhabit today throughout Oregon and the Northwest since time immemorial and continue to be a vibrant part of Oregon today. We would like to express our respect to the First Peoples of this land, the nine federally recognized tribes of Oregon: Burns Paiute Tribe, Confederated Tribes of Coos, Lower Umpqua & Siuslaw Indians, Confederated Tribes of Grand Ronde, Confederated Tribes of Siletz Indians, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes of the Warm Springs Reservation, Coquille Indian Tribe, Cow Creek Band of the Umpqua Tribe of Indians, and The Klamath Tribes.

It is important that we recognize and honor the ongoing legal and spiritual relationship between the land, plants, animals, and people indigenous to this place we now call Oregon. The interconnectedness of the people, the land, and the natural environment cannot be overstated; the health of one is necessary for the health of all. We recognize the pre-existing and continued sovereignty of the nine federally recognized tribes who have ties to this place and thank them for continuing to share their traditional ecological knowledge and perspective on how we might care for one another and the land, so it can take care of us.

We commit to engaging in a respectful and successful partnership as stewards of these lands. As we are obliged by state law and policy, we will uphold government-to-government relations to advance strong governance outcomes supportive of tribal self-determination and sovereignty.

About the Oregon Department of Energy

The Oregon Department of Energy's mission is to help 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.

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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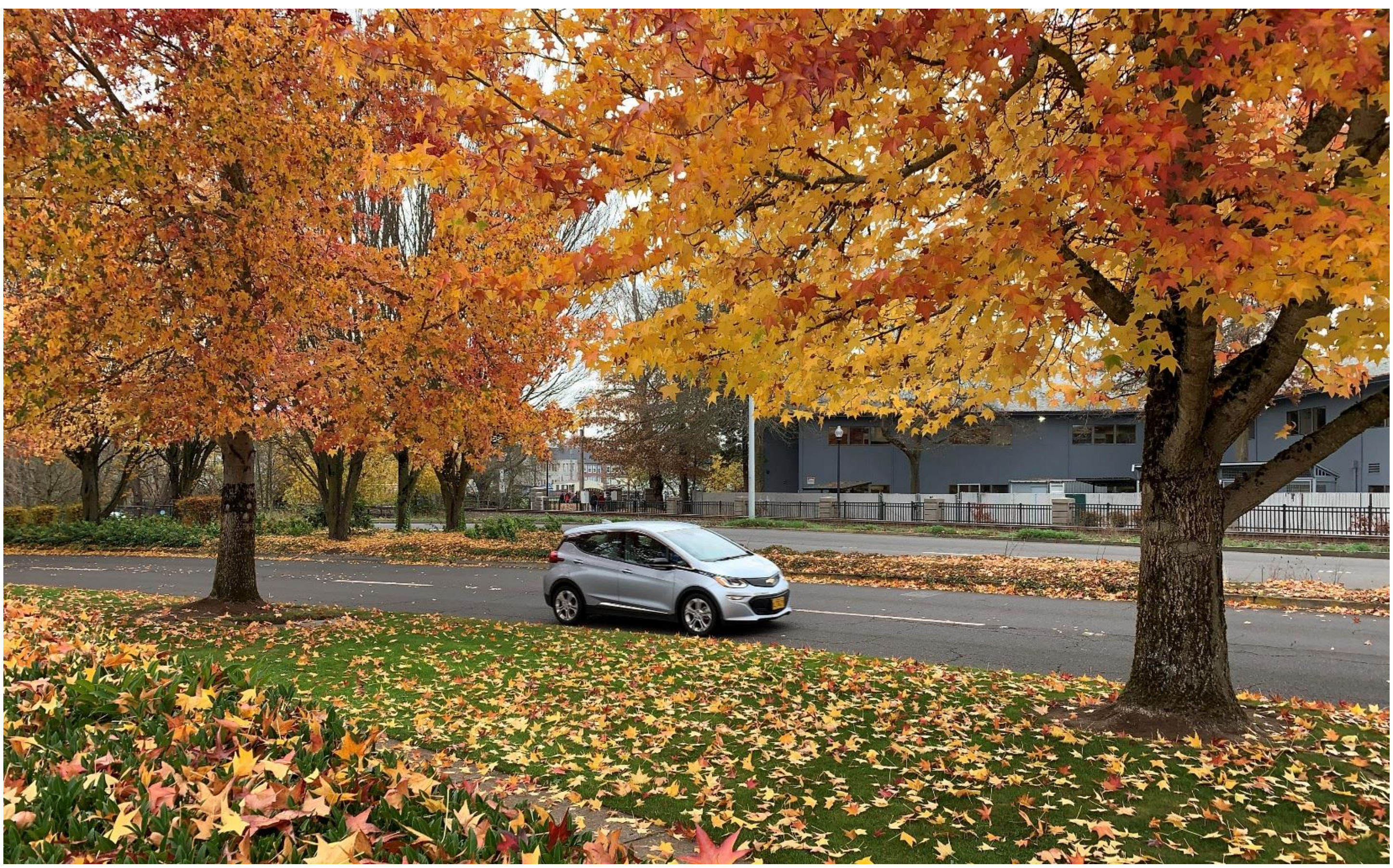
About the Report

The 2023 Biennial Zero Emission Vehicle Report examines Oregon's general progress on its electric vehicle adoption goals, identifies industry and consumer trends influencing EV ownership, and provides an overview of policies that support the state's EV adoption goals. It also examines the effects EVs have on the state's climate and energy goals. Because the greatest market transformation is happening in the light-duty sector, the data and information in the report is necessarily more thorough for this class of vehicles — though it also expands more on medium- and heavy-duty vehicles than the previous version, including their unique benefits and challenges.

Throughout the report, zero-emission vehicles are most often referred to as simply electric vehicles, or EVs. Zero-emission vehicles include battery electric, plug-in hybrid electric, and fuel cell electric vehicles (hydrogen vehicles), but because there are no hydrogen vehicles operating on Oregon's roads, these are not a significant area of report discussion. The terminology can sometimes be confusing – especially when describing vehicle needs like charging infrastructure, which is only needed for battery electric and plug-in electric vehicles. For the purposes of this report, electric vehicles and zero-emission vehicles are interchangeable, unless explicitly stated otherwise. Future iterations of this report will likely describe different types of electric and zero-emission vehicles more specifically.

https://www.oregon.gov/energy/energy-oregon/Pages/BIZEV.aspx



About the Data

Senate Bill 1044 directed the Oregon Department of Energy to produce a report on zero emission vehicle adoption in the state. The bill included guidance that ODOE should base the report on "existing studies, market reports, polling data, or other publicly available information." To do this, we prioritized data sources based on the following criteria: relevance to Oregon, credibility, and comprehensiveness.

ODOE prioritized Oregon-specific data, followed by Pacific Northwest regional data, and finally national data. The agency also selected unbiased data from credible sources, primarily state and federal agencies, academic institutions, and trusted nonprofit organizations. From these sources, we collected data that was comprehensive and detailed, with a preference for data sources we used in the 2021 report for consistency when evaluating trends. This included data from the Oregon Department of Transportation, Oregon Department of Environmental Quality, Portland State University, the U.S. Census Bureau, and Oregon electric utilities. We also incorporated the use of highly detailed and comprehensive data from newer sources such as the Atlas EV Hub.

One of the main data sources we rely on for this report is ODOT's EV registration data. This is the primary source for tracking Oregon's progress on meeting our EV adoption and climate goals. ODOT provides a data set of updated EV registrations each month for registrations that are at least two months old. This is done to ensure that any lagging registrations at the beginning of a new month do not bias the data toward a lower estimate. After two months have elapsed, ODOT and ODOE assume the data is mostly firm, although future monthly updates will account for any additional lagging registrations. For this reason, ODOE elected to report EV data through April 2023 throughout the report. Up-to-date registration data is available regularly on ODOE's EV Dashboard.

There is limited available information for some pieces of the report, such as the sales and forecasting data for medium- and heavy-duty vehicles and electric vehicle charger reliability. In these instances, ODOE identified the data limitations in the report. We strive to identify new data sources or develop proxies wherever possible, and work to address data gaps for each new report we produce.

We are proud of the efforts that went into collecting and reporting the data used for this iteration of the Biennial Zero Emission Vehicle Report. We hope the contents of this report serve to support our mission to help Oregonians make informed decisions about their energy choices, and advance solutions that will develop and maintain a more equitable clean energy future.

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 Targets

Key Takeaways

- Oregon is making great progress on its EV ownership targets, and new policies and programs enacted and updated since the last report put the state on track to have light-duty vehicles meet the 2030 and 2035 targets.
- Meeting the more immediate 2025 goal is less likely and depends on rapid domestic supply chain expansion, vehicle production, and charging infrastructure installations.
- Strong federal and state policies, as well as investments by electric utilities, are bolstering a rapid transition.[i] However, medium- and heavy-duty vehicle electrification lags light-duty, largely because it is a much more complex vehicle sector, and the barriers to adoption are often more costly and challenging.
- Oregon is well positioned to take advantage of the unprecedented amount of federal funding available to support transportation electrification.

Introduction

Electric vehicle adoption is growing rapidly in Oregon, with 69,590 registered EVs, including 47,445 battery electric vehicles and 22,145 plug-in hybrids as of April 2023.[1] Light-duty EV registrations in Oregon have grown steadily despite supply and manufacturing challenges during the COVID-19 pandemic. Electrification of the medium- and heavy-duty sector is just beginning, with electric school and transit buses, and delivery trucks leading the way. This chapter focuses on the market transformation of on-road vehicles, but there is also progress in electrifying port, warehouse, and construction equipment as well as e-micromobility, where the U.S. e-bike market expanded by 50 percent in 2021. Industry trends suggest a large market for e-bikes, especially as perceptions of these vehicles shift from a novelty or recreational vehicle to a viable and reliable mode for regular travel.[2] (Visit the Available EV Platforms chapter to learn more.)

As of April 2023, Oregon has nearly 70,000 registered electric vehicles across all 36 counties.

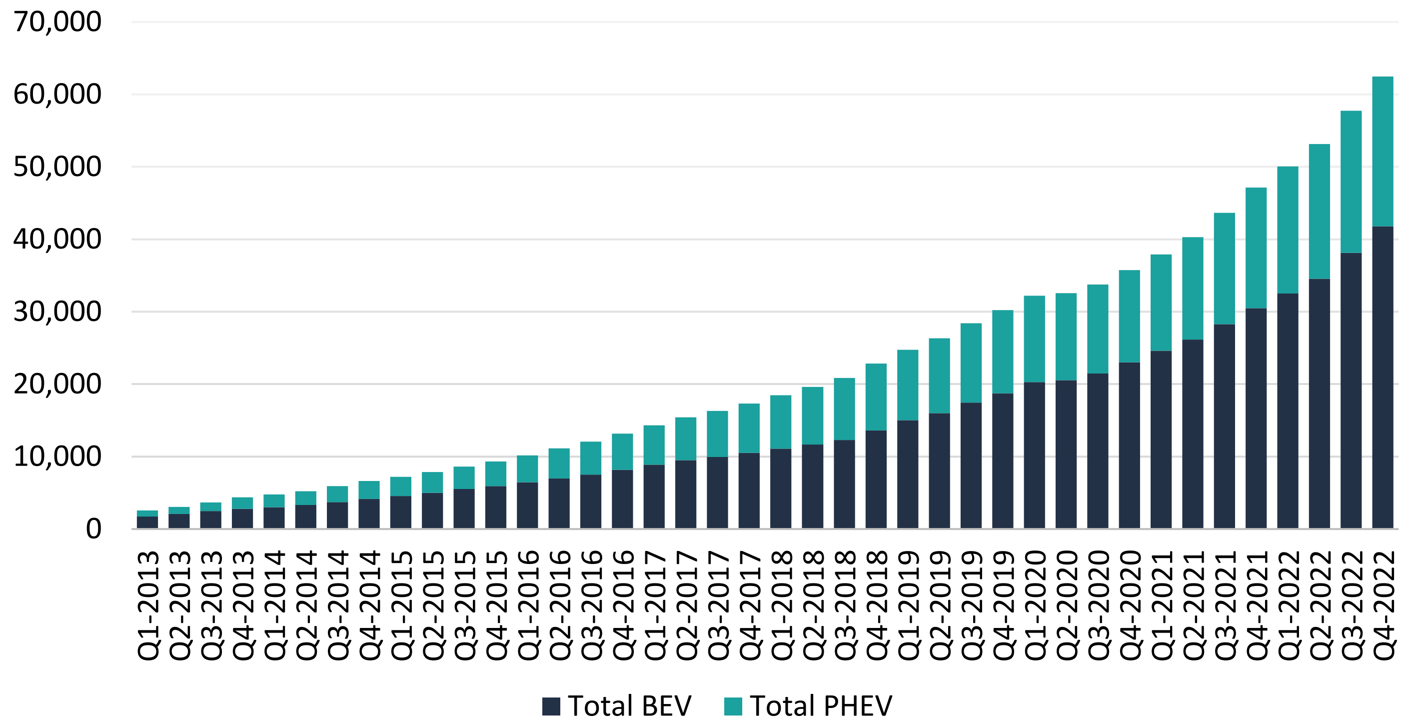
Oregon's EV market share was 12 percent at the end of 2022, almost double the national market share of 7 percent.[1]

[i] The adoption of the Advanced Clean Cars II rule in 2022 requires 100 percent of light-duty vehicles delivered to Oregon are zero-emission (electric) vehicles.

Progress on Goals

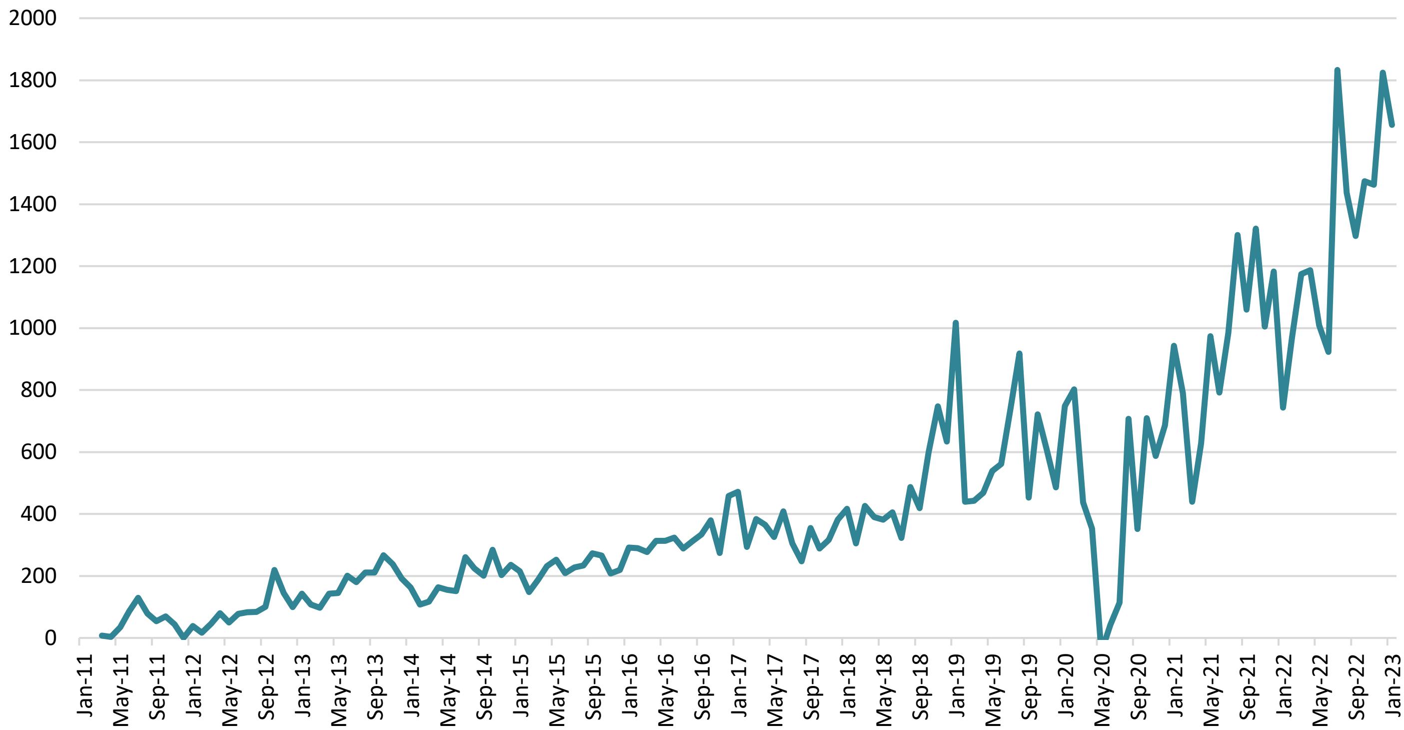
Oregon's rate of electric vehicle ownership continues to increase year-over-year, with EV registrations quadrupling in the last five years. Starting in 2021, registrations have risen quickly, as shown in Figure 1. In 2022 alone, the state gained nearly 15,000 EVs. Oregon missed the 2020 goal of 50,000 registered EVs by the end of 2020 but reached that goal in early 2022. EVs now comprise 2 percent of registered vehicles.[1]

Figure 1: Cumulative Oregon Electric Vehicle Registrations (2013-2022)[1]



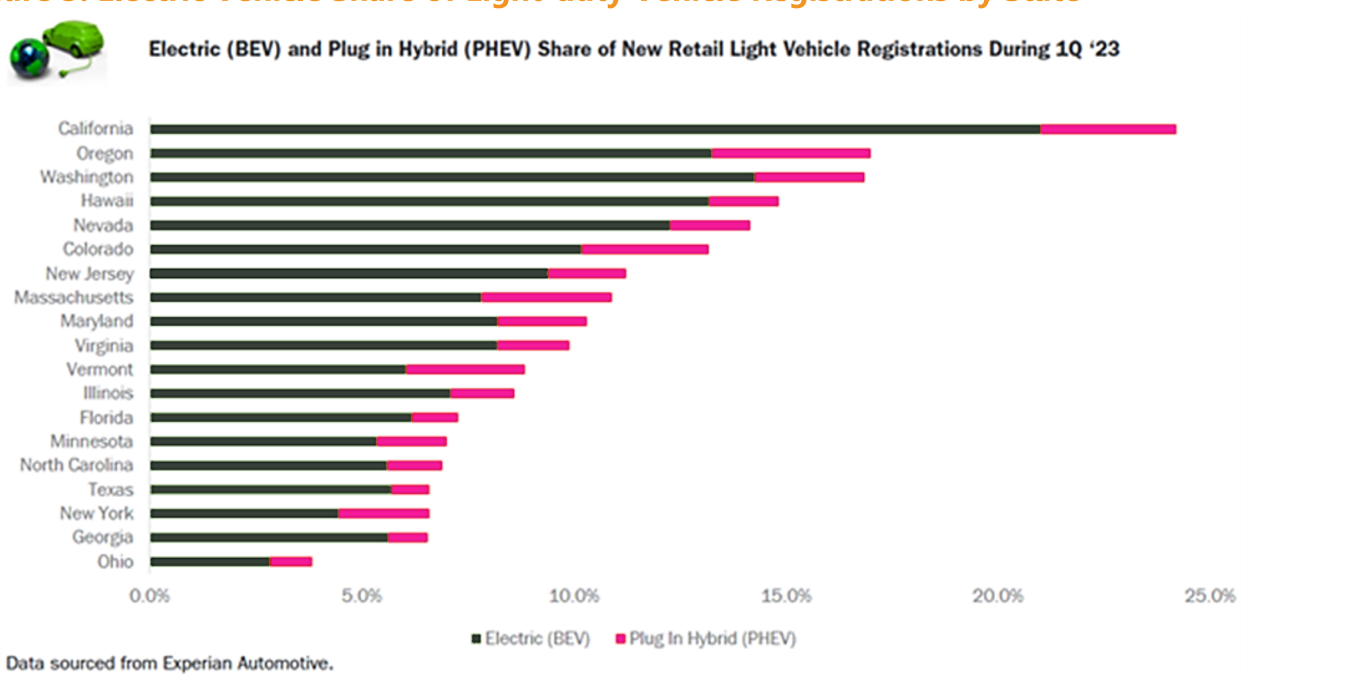
Electric vehicles are evolving with more makes and models available, and improved performance with longer battery ranges. Decreasing battery costs and manufacturer economies of scale are leading to more production and competitive pricing. Most industry forecasts anticipate a rapid jump in EV adoptions as the technology matures and drivers increasingly encounter it.[4] There are indications Oregon may have entered this phase of rapid technology uptake. Figure 2 shows the overall gain in EV registrations each month in Oregon since 2011. Eight of the top ten monthly gains in EV registrations happened in 2022, the other two occurring in the previous summer. There is some uncertainty around the data due to lagging vehicle registrations during the COVID-19 pandemic, which may bias the data toward higher adoption rates.[1] The effects on registrations were largely resolved in the first half of 2022.

Figure 2: Monthly Gain in Electric Vehicle Registrations (2011-2023)



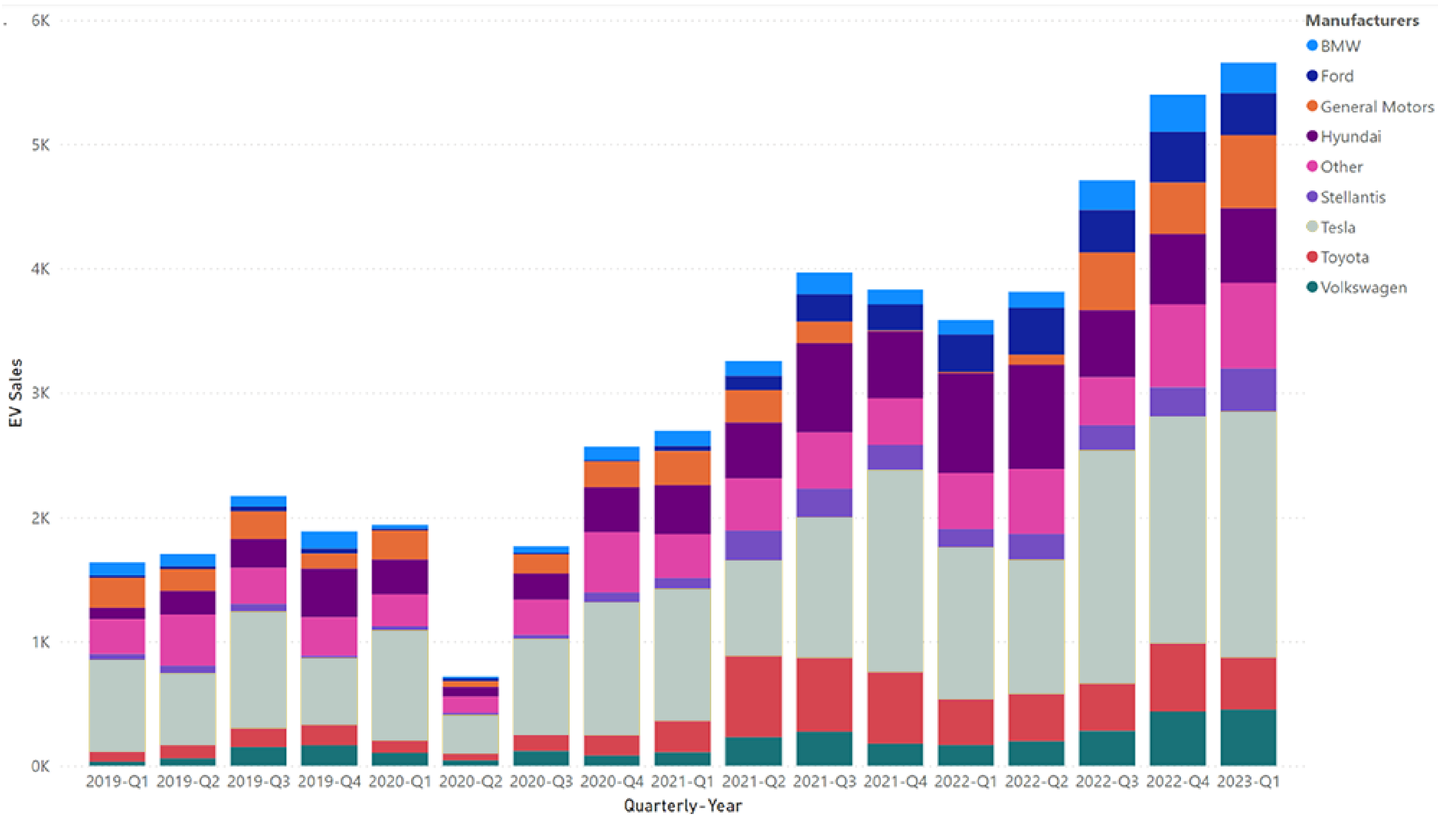
In the first quarter of 2023, Oregon had the second highest share of light-duty EV registrations for battery electric and plug in hybrid vehicles in the nation, behind only California, as shown in Figure 3.[5] Oregon's 2022 EV registrations grew by 32.6 percent, compared to 2021. Except for 2020 – when many registrations were deferred – Oregon's year-to-year growth rate in EV registrations has stayed at roughly 32 percent since 2017, which has helped Oregon lead in EV adoption rates. However, to achieve the 250,000 EVs by 2025 goal, Oregon would need an average growth rate of 58.7 percent, almost double the current rate.[1]

Figure 3: Electric Vehicle Share of Light-duty Vehicle Registrations by State[5]



In 2022, Oregon sold 143,927 passenger vehicles, and 12.2 percent were EVs, or 17,501. In comparison, the nationwide EV market share over that same period was 7.2 percent. Figure 4 shows consistent growth in Oregon EV sales since the onset of the COVID-19 pandemic. EV purchases have been supported by Oregon's adoption of the Advanced Clean Cars I and II rules, which require new EVs to be delivered for sale in Oregon.[3] These rules played a crucial role ensuring new EVs were available for sale in the state while supply chain and manufacturing interruptions limited supplies of EVs around the globe. Similar to national trends, Tesla has the largest market share in Oregon, shown as the light green portion of the bar in Figure 4, with Hyundai (purple) and General Motors (orange) second and third, respectively. Of the passenger vehicles sold in Oregon in 2022, 8.9 percent were battery electric vehicles and 3.2 percent were plug-in hybrid electric vehicles.[3]

Figure 4: Quarterly Oregon EV Sales by Manufacturer (Q1 2019 - Q1 2023)[3]

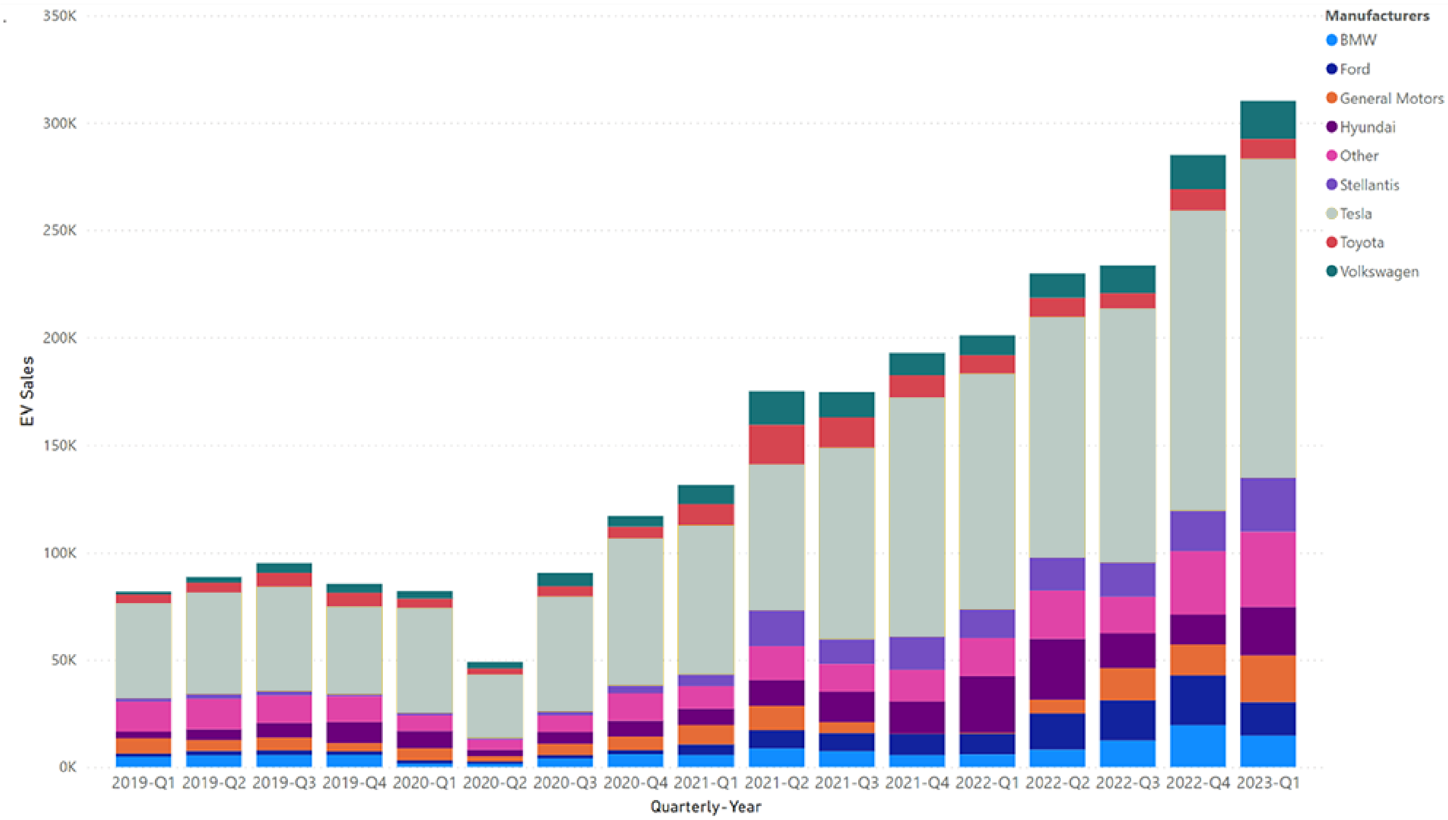


Industry and Consumer Trends

Passenger Vehicle Trends

Over the last three years, the U.S. made tremendous strides in EV ownership. After a brief low point during the first half of 2020 due to the COVID-19 pandemic and subsequent supply chain bottlenecks, national sales have surged and reached a record high in the fourth quarter of 2022. Cumulatively, 949,311 EVs were sold in the United States in 2022, an increase of roughly 41 percent over 2021. In total, 3,728,425 EVs have been sold since 2010.[3] As total sales have increased around the country, so has the market share of electric vehicles, reaching nearly 9 percent in the first quarter of 2023. Tesla has the greatest market share, shown as the light green portion of the bars in Figure 5, and its share has been increasing, along with BMW, Volkswagen, General Motors, and Ford.

Figure 5: Quarterly National EV Sales by Manufacturer (Q1 2019 - Q1 2023)[3]



How Supply Chain Limitations Affect Electric Vehicle Ownership

The electric passenger vehicle market is expected to grow significantly in the next decade. National EV sales are projected to grow three to nearly eight times what they are today. Because Oregon ranks high in EV sales growth, it is likely the state will trend toward the higher end of this range.

Unprecedented investments in vehicles and charging infrastructure from federal, state, and local governments, as well as electric utilities, automakers, EV charging companies, and other private organizations will also encourage higher EV ownership rates. Many auto manufacturers have committed to going all or mostly electric by 2035.[6]

Policies supporting used EV purchases are also creating affordable options for Oregonians.

Demand for vehicles, batteries, and charging infrastructure continues to grow, but manufacturers face supply shortages. Many have reported long wait times and delays in materials and products, which limit vehicle production and charging infrastructure development. Retail dealership networks are prioritizing higher margin consumer sales over fleets, which has particularly affected government vehicle electrification goals. Government fleet managers must contract for low-cost base models of vehicles, which are not as profitable as higher trim level vehicles that consumers tend to purchase.[7] In 2022, EV purchase requests for the Oregon Departments of Administrative Services and Transportation were either canceled or delayed by the manufacturer to 2023. Out of the 409 vehicles purchased by state agencies in 2022, only one was an EV. Availability for all vehicles, including EVs, remains extremely limited and is projected to extend into late 2024.[8,9]

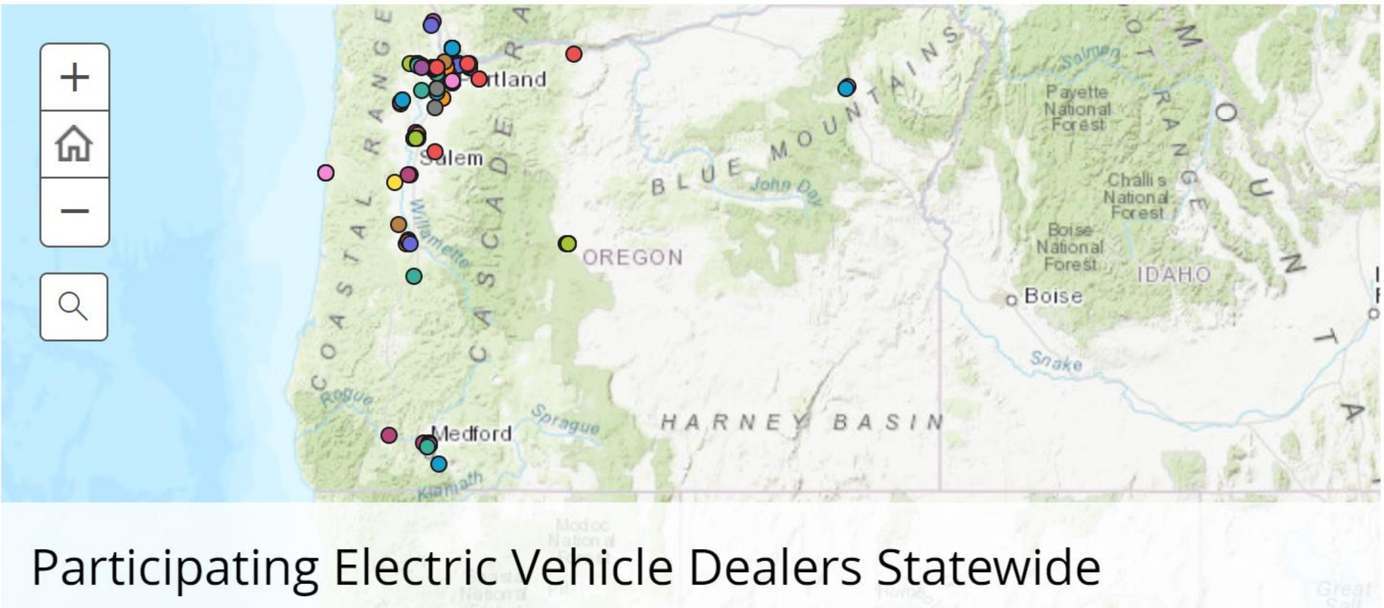
According to a 2021 technical report from the U.S. Department of Energy:

- **EVs have driven 68 million miles on electricity since 2010, reducing national gasoline consumption by 2.5 billion gallons, or about 0.54 percent.**
- **In 2021 alone, the use of EVs saved consumers an estimated $1.3 billion in fuel costs.[10]**

Used EVs play a critical role in achieving Oregon’s adoption goals, because they provide a more affordable option for purchasing an EV. High up-front cost is a barrier to low- and middle-income drivers (see the *Distribution of EVs by Demographic Groups* chapter). In January 2023, the used EV market in the U.S. tripled in size in compared to 2021. In California, used vehicles represent 28 percent of the EV inventory. While some used EVs are more expensive, early model luxury cars now entering the used market, about 40 percent of used EV stock in the U.S. is priced at $30,000 or less.[11,12] These vehicles, along with the anticipated savings in fuel and operational costs, are essential to supporting EV ownership, especially for low- and moderate-income Oregonians.

Auto dealerships play a critical role introducing prospective buyers to EVs, because exposure to EVs, and more importantly driving them, correlates highly with consumers choosing to purchase an EV. Because they are a point of opportunity to learn about and drive these vehicles, dealerships need to have EVs available to drive and purchase, coupled with sales staff that are knowledgeable about EVs and how to use them. A survey of western states by the Sierra Club found that only 27 percent of dealers had EVs in stock, although there is some indication that Oregon’s numbers may be higher.[13] There are 221 vehicle dealerships selling new light-duty vehicles in Oregon, and while EVs are not available at all of them, at least half have signed up to offer DEQ’s EV rebate for their customers, shown in Figure 6.[14,15]

Figure 6: Dealerships Enrolled in DEQ's Rebate Programs[15]



The availability of EVs to sell at dealerships varies due to demand and supply considerations. Supply chain and manufacturing issues were a contributor, but higher demand may also have played a role. The western region of the U.S. is about a quarter of the national population, but EV purchases made up 45 percent of national EV sales, which may have contributed to lower stock availability in the region.[13] There are also fewer available EV models, and some buyers may want or need vehicles that are in short supply, such as pickups and large SUVs. In the map above, there are relatively few dealerships signed up for DEQ's rebate program[ii] outside the Willamette Valley, and it is unclear as to why. Dealerships may be reluctant to sell EVs because their business models rely on revenues from their service departments, and electric vehicles don't need many of the services that gasoline vehicles require.[16] It could also indicate limited demand for EVs among their customers.

Medium-duty and Heavy-duty Adoption Trends

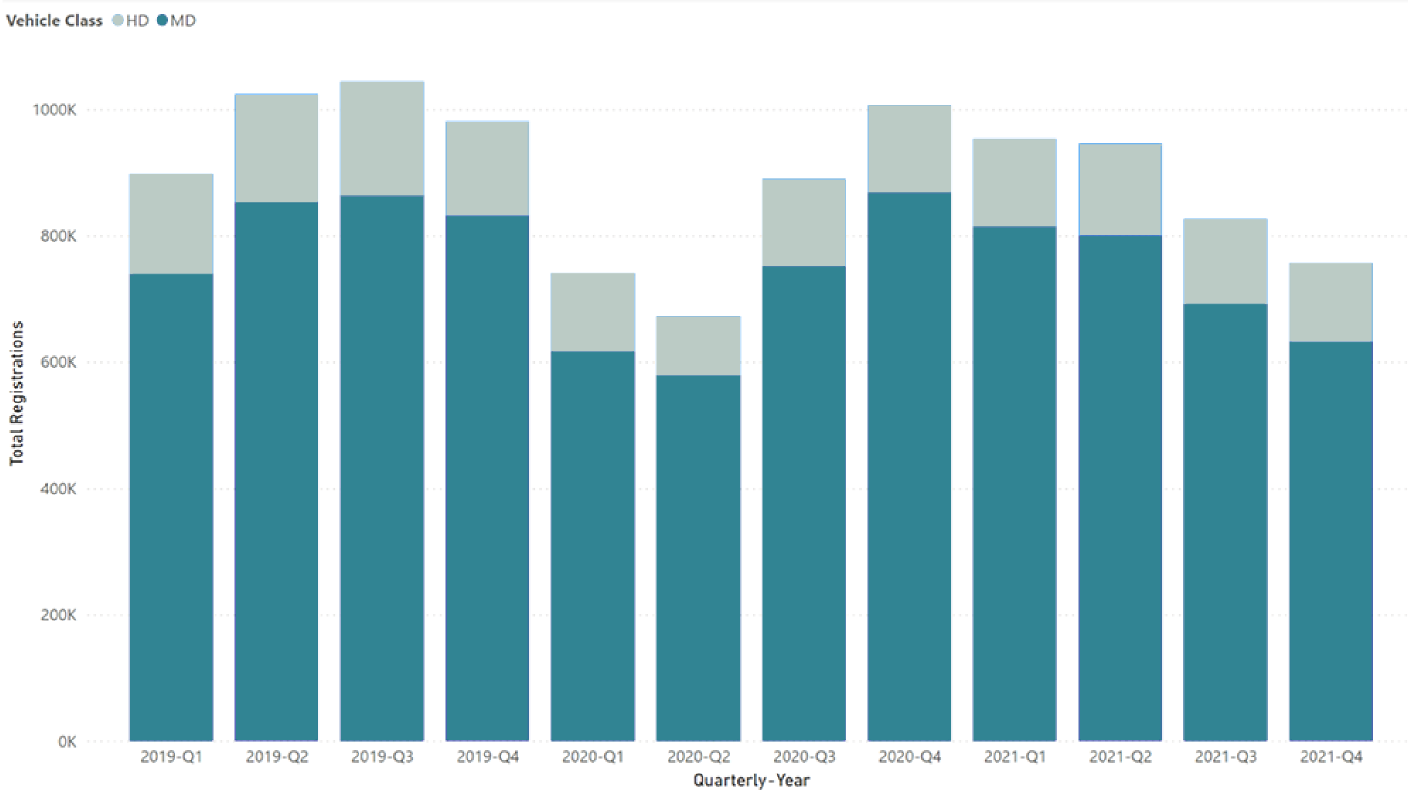
National medium- and heavy-duty electric vehicle adoption is still in early market transformation, where many of the vehicles sold are used for demonstration projects for fleet owners to learn how these new vehicles can be used to meet their needs. Nationally, registrations have fluctuated as shown in Figure 7, which is expected when the volume of vehicles sold is still very low. However, there are market signals that national medium- and heavy-duty sales are expected to grow. The federal Heavy-Duty Omnibus rule implemented stronger nitrogen oxide and particulate matter emissions standards for new fossil fuel trucks, requiring a 75 percent reduction in 2024 and a 90 percent reduction in 2027 of ozone-causing NOx pollution. Manufacturers can earn credit toward compliance by manufacturing and selling zero emission trucks. These regulations also encourage fleets to evaluate and eventually transition to electric trucks as emission standards become more restrictive.[17]

[ii] Rebates are suspended as of May 1, 2023 due to funding shortage.

Definition of MHD Vehicles

Medium-and Heavy-Duty includes all vehicles with a gross vehicle weight rating of 8,501 pounds or more regardless of the fuel used.[18]

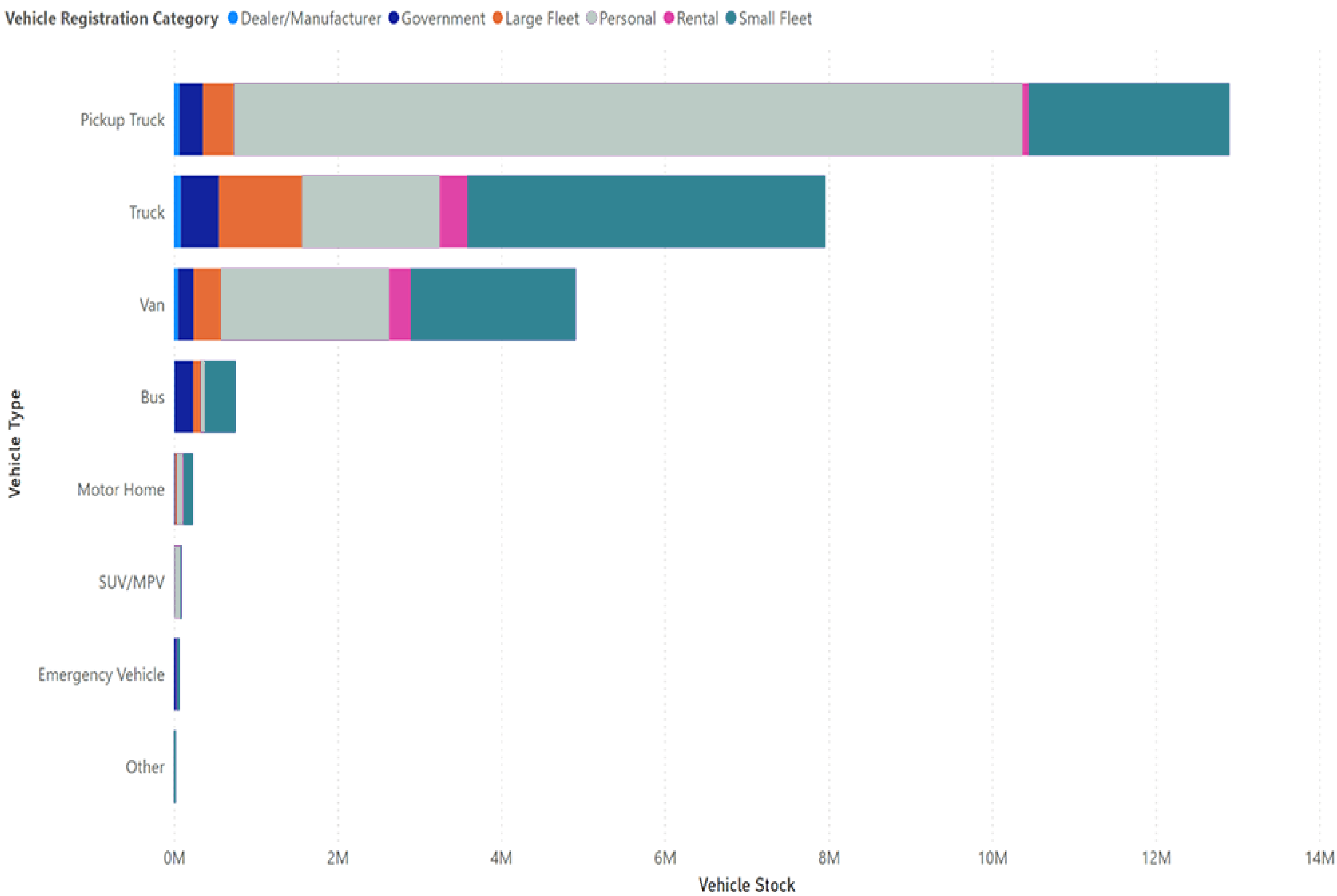
Figure 7: Quarterly National MD/HD EV Vehicle Registrations (2019-2021)[19]



Increases in private and public funding are also bolstering innovation, production, and ownership of these vehicles. There are now 125 zero-emission models of medium- and heavy-duty vehicles available from 55 manufacturers in North America.[18] Private investments in medium- and heavy-duty EVs surged in late 2020-early 2021 with startups and established manufacturers committing to new electric models with $8.5 billion in new investments in the U.S. for electric trucks and buses alone.[19] Public funding from the Volkswagen settlement, the federal Low or No Emission Vehicle Program (Low-No), federal grants from the Infrastructure Investment and Jobs Act and incentives from the Inflation Reduction Act, and state funding initiatives are also supporting increased ownership and sales. Nationwide funding for electric MHD vehicles has risen sharply, with $1.19 billion allocated for transit buses, $552 billion for electric trucks, and $480 billion for electric school buses invested through 2021.[19]

Electric pickup and delivery trucks, vans, and buses are the primary drivers of transportation electrification among medium- and heavy-duty vehicles today, as shown in Figure 8 below. In addition to having broader model availability, these vehicles are more amenable to return-to-base-operations that are not dependent on public charging infrastructure, such as pickup truck fleets, urban delivery vans, warehouse distribution trucks, shuttles, school buses, and garbage trucks. For example, PepsiCo, Inc. was the first customer to receive Tesla's electric semi-trucks, which are being used for deliveries within a 400-mile radius and for routes that require no more than 425 miles of travel. The Tesla Semi can charge up to 400 miles of range in about an hour using Tesla's 750 kW Mega Charger, which allows these vehicles to be fueled during loading and offloading operations.[20]

Figure 8: Medium and Heavy Duty Vehicle Stock by Registration Category and Vehicle Type (2019)[19]



Medium- and heavy-duty electric vehicle registrations in Oregon nearly doubled during the 12-month period ending in January 2023 (Figure 9). Most of the medium- and heavy-duty electric vehicles in use in Oregon are transit buses and delivery vans (Figure 10). TriMet, the Portland area's public transportation system, currently has about 700 diesel buses and is Oregon's largest purchaser of diesel fuel.[21] They have committed to having a 100 percent zero-emission fleet by 2040 through investments in battery-electric buses and charging infrastructure development. Lane Transit District serves the Eugene/Springfield area and has 30 battery electric and 59 hybrid buses in its fleet. LTD estimates that their electric buses and use of lower carbon emitting fuels like renewable diesel have reduced their annual greenhouse gas emissions by 77 percent.[22] [23] Like PepsiCo's, these vehicles are more amenable to electrification because they are replacing vehicles that operate within a limited geographical area. Increasing registrations for these EVs indicates that there are existing vehicle use cases for medium- and heavy-duty EVs, but less than 1/100th of a percent of Oregon's MHD fleet are electric according to available registration data.[1]

Figure 9: Growth of Medium- and Heavy-Duty EV Registrations in Oregon Feb. 2022 – Jan. 2023[1]

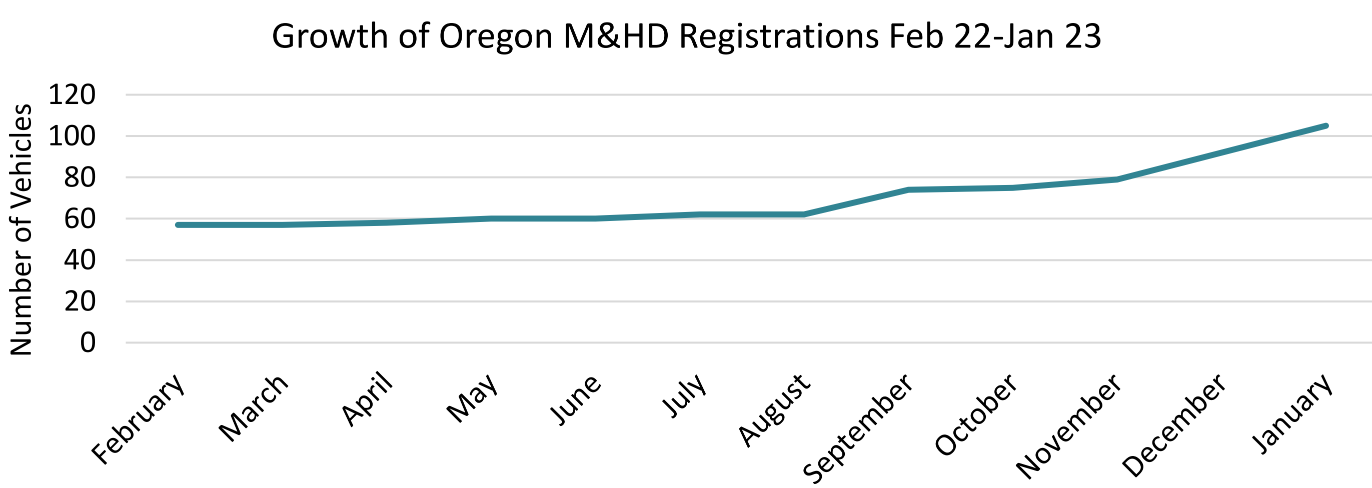
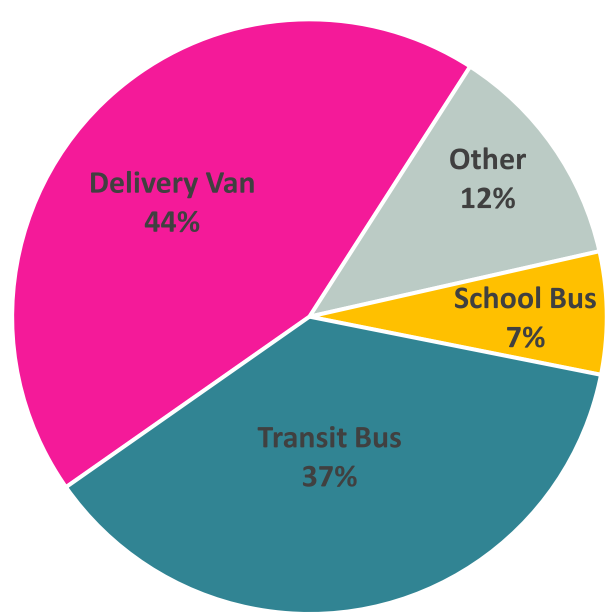


Figure 10: Oregon Registered Medium- and Heavy-Duty Electric Vehicles by Type[3]



Electric School Buses on Oregon Roads

PGE's Electric School Bus Fund, which uses funding derived from the Oregon Department of Environmental Quality's Clean Fuels Program, has awarded nine Oregon school districts (Beaverton, Centennial, Gresham-Barlow, Hillsboro, Portland, Reynolds, Salem-Keizer, Tigard-Tualatin, and West Linn-Wilsonville) with funding to purchase an electric school bus, install charging infrastructure, and receive technical and training support since 2020. In total, the program has supported the purchase of 18 electric school buses with applications currently open for 2023.

The U.S. Environmental Protection Agency awarded two Oregon school districts (Banks and Prospect) with more than $5 million of funding for electric buses and charging infrastructure. This funding comes from the EPA's "Clean School Bus Program rebate competition" (this is the first year of a 5-year, $5 billion allotment) as part of the federal government's Infrastructure Investment and Jobs Act. Banks school district will receive $4,345,000 in funding for 11 electric school buses. Prospect School District will receive $1,185,000 in funding for three electric school buses.[24]

Bend-LaPine School District received its first electric school bus in Spring 2023. They were able to use $157,500 in funding from Pacific Power's electric mobility grant program, which uses funding derived from the Oregon Clean Fuels Program, administered by Oregon's Department of Environmental Quality. Bend-LaPine also used Public Purpose Charge Funds to pay for the remaining cost of the new LionC model electric bus. The Public Purpose Charge program, administered by the Oregon Department of Energy, is funded through the state's two largest electric utilities, Portland General Electric and Pacific Power. The funds support energy and fleet audits, energy efficiency improvements, and, as of 2020, zero emission vehicles and chargers for Oregon schools.[25,26]

Hydrogen Fuel Cell Electric Vehicle Adoption Trends

Hydrogen can be used as a transportation fuel to power fuel cell electric vehicles, but ownership of FCEVs is much lower than other types of EVs. In total, only 17,313 FCEVs have been sold nationally since 2014.[27] Battery electric and plug-in hybrid electric vehicles became fully commercialized well before FCEVs and have had a jump start in building market share. In addition, electric vehicle charging infrastructure has far outpaced hydrogen fueling development. There are no hydrogen fueling stations in Oregon, compared to 695 DC fast charging stations at 234 locations (as of July 2023) throughout the state, with additional charging infrastructure in development. There are only three light-duty FCEV models available in the U.S., and models are only available for sale in states with hydrogen fueling stations – California, New York, and Hawaii.[28] [29]

There is likely to be greater hydrogen fuel cell electric vehicle adoption in the medium- and heavy-duty sector. Today, freight and other long-range MHD vehicles are more difficult to electrify due to the added weight of the batteries and because the weight of current battery technology limits the amount of cargo these vehicles can carry. A battery for an electric semi-truck will weigh about 16,000 pounds, or 20 percent of the total maximum weight of the truck.[30] [31] Hydrogen could be a viable option for these vehicles because fuel cell electric vehicles are lighter than their battery electric counterparts. Hydrogen fuel has other advantages, including shorter refueling times, longer ranges, and better operational efficiency.[iii] [32]

Hydrogen vehicles still face significant barriers in deployment, with no fueling infrastructure currently available or planned in Oregon. Further, over 95 percent of hydrogen available today is created from natural gas, meaning vehicles using this fuel have associated carbon emissions from the production of the fuel. There are existing technologies to produce green hydrogen[iv] using clean electricity, but it is less efficient to produce hydrogen as a transportation fuel than using that electricity directly to fuel a battery.[33] Hydrogen fuel cell vehicles are also more expensive than electric vehicles and face durability and reliability concerns as they have not yet consistently achieved the 150,000-mile expected lifetime to compete with conventional vehicles.[34] [35] Public education is also needed to support fuel cell technology as public awareness, understanding, and acceptance are low.[36] The public will need to become more familiar with this technology before it is embraced as a viable alternative to conventional vehicles. Despite the infrastructure, efficiency, cost, and durability challenges, hydrogen can support the transition of transportation sectors that are challenging to decarbonize like marine, aviation, and long-haul freight because it is a lighter fuel that can deliver longer ranges.

[iii] Operational efficiency refers to the efficiency of the vehicle and not production of the fuel. Hydrogen cars do not have heavy electric batteries. They are lighter and can reach longer ranges depending upon the size of the hydrogen tank.[32]

[iv] HB 2530 in the 2023 Oregon Legislative Session defined green electrolytic hydrogen as hydrogen produced through electrolysis using a renewable energy source or electricity created from a non-fossil fuel source with less than or equal carbon intensity as the state annual average for electricity served in Oregon at the time of facility construction.[23]

Investments in Clean Hydrogen Transportation Fueling

Federal funding available for research, development, and deployment may spur more availability of hydrogen fueling in the U.S. The USDOE launched its Hydrogen Shot program in June 2021, which has a goal of reducing the cost of clean hydrogen to one dollar per one kilogram in one decade and includes support for numerous research and development initiatives.[37] The Infrastructure Investment and Jobs Act includes $9.5 billion in funding related to hydrogen, including $8 billion for regional clean hydrogen hubs.[38] At least two organizations submitted applications to USDOE for hydrogen hubs that would make green hydrogen more available in Oregon and at least one organization submitted a Charging and Fueling Infrastructure grant proposal to the federal government to fund a medium- and heavy-duty EV hydrogen refueling station in Oregon. The Act also includes a production tax credit for hydrogen worth up to $3/kg for zero-carbon hydrogen from projects that meet certain labor requirements.[39] These programs and funding opportunities could create a supply of affordable and accessible hydrogen in Oregon.

Policies Supporting Zero Emission Vehicle Adoption

Federal

National initiatives support Oregon's transition to a cleaner transportation sector. Congress recently passed two landmark laws that provide significant policy support for EV ownership – the Inflation Reduction Act (2022) and the Infrastructure Investment and Jobs Act (2021).

Inflation Reduction Act

The federal Inflation Reduction Act, passed in 2022, created new federal tax credits for electric vehicles that went into effect in January 2023.[40] The IRA removed the existing 200,000 light-duty vehicle per manufacturer cap and added a new tax credit for used EVs. Tax credits are non-refundable[v] and available through the 2032 tax year but are subject to several requirements and limitations. To be eligible, the MSRP[vi] for a new EV cannot exceed $55,000 for a sedan or $80,000 for a van, pickup, or SUV. The purchase price for an eligible used vehicle cannot exceed $25,000. Eligibility to use the tax credits is also subject to income limitations, which differ for new or used EV purchases, as shown in Table 1. Income is based on the taxpayer's modified adjusted gross income.

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[v] Non-refundable tax credits lower the income tax owed by the amount of the credit, but cannot reduce the total amount of taxes owed below $0.[41]

[vi] The Internal Revenue Service defines MSRP as "the base retail price suggested by the manufacturer, plus the retail price suggested by the manufacturer for each accessory or item of optional equipment physically attached to the vehicle at the time of delivery to the dealer. It does not include destination charges or optional items added by the dealer, or taxes and fees."[42]

Table 1: New and Used EV Federal Tax Modified Adjusted Gross Income Limits

Tax Filing Status	New EVs	Used EVs
Single or Married, Filing Separately	$150,000	$75,000
Head of Household	$225,000	$112,500
Married, Filing Jointly	$300,000	$150,000

The IRA also established requirements for new EV assembly, components, and manufacturing. To be eligible for the credit, the final assembly of the vehicle must occur in North America. The total credit allowed is $7,500, but to qualify for the full amount there are two separate battery-related requirements that must be met. First, a percentage of the battery must be assembled or manufactured in North America; that percentage increases through 2029. Second, a certain percentage of the "critical minerals" used in the battery must be extracted or processed in the U.S., or within a country which has a free-trade agreement with the U.S. The requirements for each calendar year are provided in Table 2, and each is worth half of the full credit, or $3,750. Buyers can receive a partial tax credit if only one of the two requirements is met, as shown in the table. These requirements do not apply to the used EV tax credit, and the assembly requirement did not take effect until April 18, 2023. EVs purchased between January 1 and April 18, 2023 were not subject to these two requirements, but were only eligible for up to $5,000 depending on the size of the vehicle's battery.[42]

Table 2: New EV Federal Tax Credit Battery Manufacturing and Critical Minerals Requirements

Effective Year	Battery Requirement	Critical Minerals Requirement
2023	50%	40%
2024	60%	50%
2025	60%	60%
2026	70%	70%
2027	80%	80%
2028	90%	80%
2029	100%	80%
2030	100%	80%
2031	100%	80%
2032	100%	80%

Used EVs do not have manufacturing of assembly requirements but are also subject to several other requirements in addition to the income restrictions.[43] To be eligible, the used EV must be purchased from an auto dealer, and the purchase price of a used EV cannot exceed $25,000. The model year of the vehicle must be at least two years older than the calendar year. For example, a vehicle purchased in 2023 would need to be model year 2021 or earlier. The tax credit can only be used one time for a specific vehicle, meaning vehicles are no longer eligible once a buyer uses the tax credit. The tax credit is 30 percent of the purchase cost up to $4,000.

The Internal Revenue Service, in coordination with the US DOE, publishes and maintains a list of currently qualifying vehicles. As of August 28, 2023, there were 34 different makes, models, and trim levels of EVs that met at least one of the two major production requirements, and 24 qualify for the full tax credit. Among these are many of the most popular makes and models of EVs registered in Oregon, including Tesla, Ford, and General Motors EVs. The US DOE also maintains a list of qualifying used EVs with a tax credit calculator to help potential buyers assess how much of a tax credit they could receive: www.fueleconomy.gov/feg/tax2023.shtml. Table 3 provides a high-level overview of tax credit amounts across different vehicle types, but the amounts are dependent on the requirements described above.

Table 3: Federal EV Tax Credit Amounts

	New*		Used
	Battery Requirement Met	Critical Minerals Requirement Met	Tax Credit cannot exceed 30 percent of purchase cost
Potential Tax Credit Amount	$3,750	$3,750	$4,000

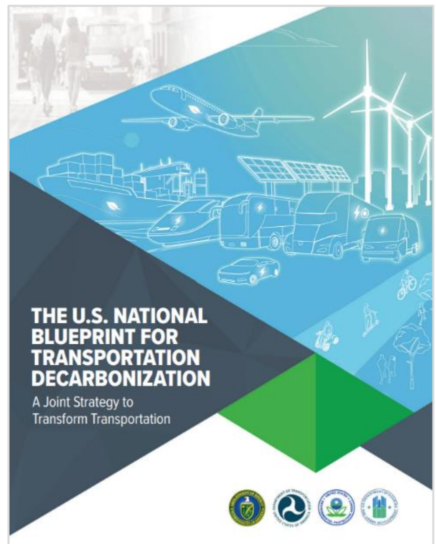
*Applies to new EVs purchased or delivered after April 17, 2023

The IRA also provides direct funding to support the conversion of heavy-duty vehicles. The new law provides $1 billion to the EPA to award grants and rebates to cover the costs of converting existing gas and diesel vehicles to electric formats. Funds can cover up to 100 percent of the incremental costs above the cost of a comparable diesel vehicle. The EPA can also use the funds to develop programs to fund heavy-duty EV charger or hydrogen fueling installations, workforce development to support heavy-duty electric vehicles, and planning activities to support vehicle deployment. Funds may be awarded to states, municipalities, tribes, or nonprofit school transportation associations or specified contractors. $400 million of the funds is set aside to replace heavy-duty vehicles in areas that do not meet certain federal air quality standards, known as nonattainment areas.[40]

Infrastructure Investment and Jobs Act

The Infrastructure Investment and Jobs Act, passed in 2021, is the largest long-term investment in infrastructure in U.S. history. It created the Joint Office of Energy and Transportation, which supports the planning and deployment of electric vehicle technologies, such as charging stations, electric school bus fleets, and zero-emission transit. The Joint Office also provides guidance and technical support to potential applicants for funding programs from the Act. Many of Oregon's state agencies, local governments, and non-governmental organizations are applying for funding and receiving technical expertise through this new office. The Act includes $20.4 billion to deploy EVs and related fueling infrastructure and $10.3 billion for grid and battery-related investments. Prior to the passage of the Act, most EV-related federal incentives focused on reducing up-front costs for the vehicle, but the passage of this bill signals that investments in charging and other fueling infrastructure are important to ensure the viability of the growing EV market.[44]

National Blueprint for Transportation Decarbonization



The U.S. National Blueprint for Transportation Decarbonization, published in January 2023, is a roadmap to complete decarbonization of the national transportation sector by 2050. The U.S. Department of Energy, Department of Transportation, Environmental Protection Agency, and Department of Housing and Urban Development collaborated on a plan to provide better transportation options, expand affordable and accessible choices to improve efficiency, and transition to zero-emission vehicles and fuels. Each federal agency is developing Action Plans with strategies to achieve a variety of decarbonization milestones, including transportation electrification. Some of the highlights include:

- Investing in research and innovation to further develop clean transportation resource and technologies, including more efficient and sustainable batteries, hydrogen electrolysis infrastructure, and sustainable fuels, and enabling seamless integration with existing energy systems.
- Expanding funding and market incentives to accelerate the uptake of low- or zero-emission vehicles and investing in supporting infrastructure, especially in low-income and overburdened communities.
- Using the transformation of the transportation system to support workforce development in disadvantaged communities and to secure domestic and international supply chain solutions to ensure the U.S. can meet the rapidly growing demand for clean vehicles and fuels.

The national blueprint and corresponding federal agency action plans help state and local governments better align with industry during this market transformation and leverage federal transportation dollars to meet state transportation emissions reduction goals.[45 46]

Oregon Policy and Programs

Oregon was an early leader in transportation electrification as a strategy to achieve our greenhouse gas emissions reduction goals. Beginning in 2005, the Oregon Environmental Quality Commission adopted the Advanced Clean Cars Rule, requiring manufacturers to deliver an increasing number of zero emission vehicles for sale in Oregon. In 2012-2013, the Oregon Department of Transportation and Oregon Department of Energy collaborated to support the creation of the West Coast Electric Highway, one of the earliest EV charging networks in the U.S. In 2018, Oregon began offering EV rebates, including one of the first for low- and moderate-income drivers and used EVs.

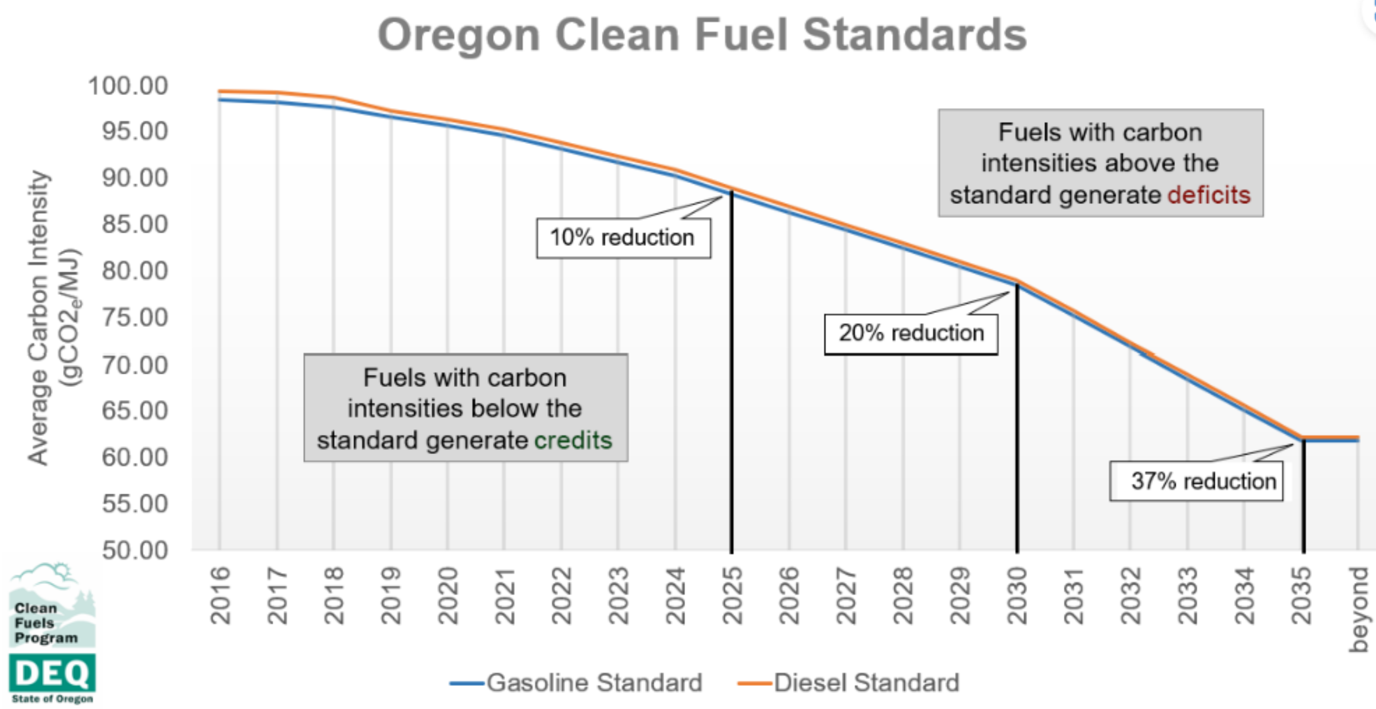
State Programs Broadly Supporting EV Adoption

Electric vehicle adoption helps Oregon mitigate greenhouse gas emissions from the transportation sector, so Oregon agencies have established multiple programs and policies to address the largest barriers to ownership: charging infrastructure, EV performance, availability, and affordability. Led by the Oregon Department of Transportation, with Oregon Department of Land Conservation and Development, Oregon Department of Energy, and Oregon Department of Environmental Quality, they collaborate through the *Every Mile Counts* initiative to develop actions supporting Oregon's Statewide Transportation Strategy to reduce emissions from the transportation sector.[47] In conjunction with this, the Zero Emission Vehicle Interagency Working Group, a collaboration of agencies, is working to align and leverage each agency's individual transportation electrification programs. The Oregon Department of Transportation also developed a five-year Climate Action Plan to reduce greenhouse gas emissions from transportation, including a number of actions supporting electric vehicle ownership, such as Oregon's Five-year EV Charging Infrastructure Roadmap.[48] [49]

DEQ Clean Fuels Program

The Oregon Department of Environmental Quality's Clean Fuels Program supports a market-driven credit and debit system that incentivizes lower carbon fuel use and establishes a goal to reduce the carbon intensity of Oregon's Transportation Fuels. The current rule requires a 10 percent reduction in average carbon intensity from 2015 levels by 2025, followed by a 20 percent reduction by 2030 and 37 percent by 2035. The graph below illustrates how the program will gradually reduce the carbon intensity of fuels in Oregon over time. The left axis of the graph shows the required reductions in average carbon intensity or level of carbon emissions when combusted. The bottom axis shows years starting from the beginning of the program in 2016.[50]

Figure 11: Clean Fuels Program[50]

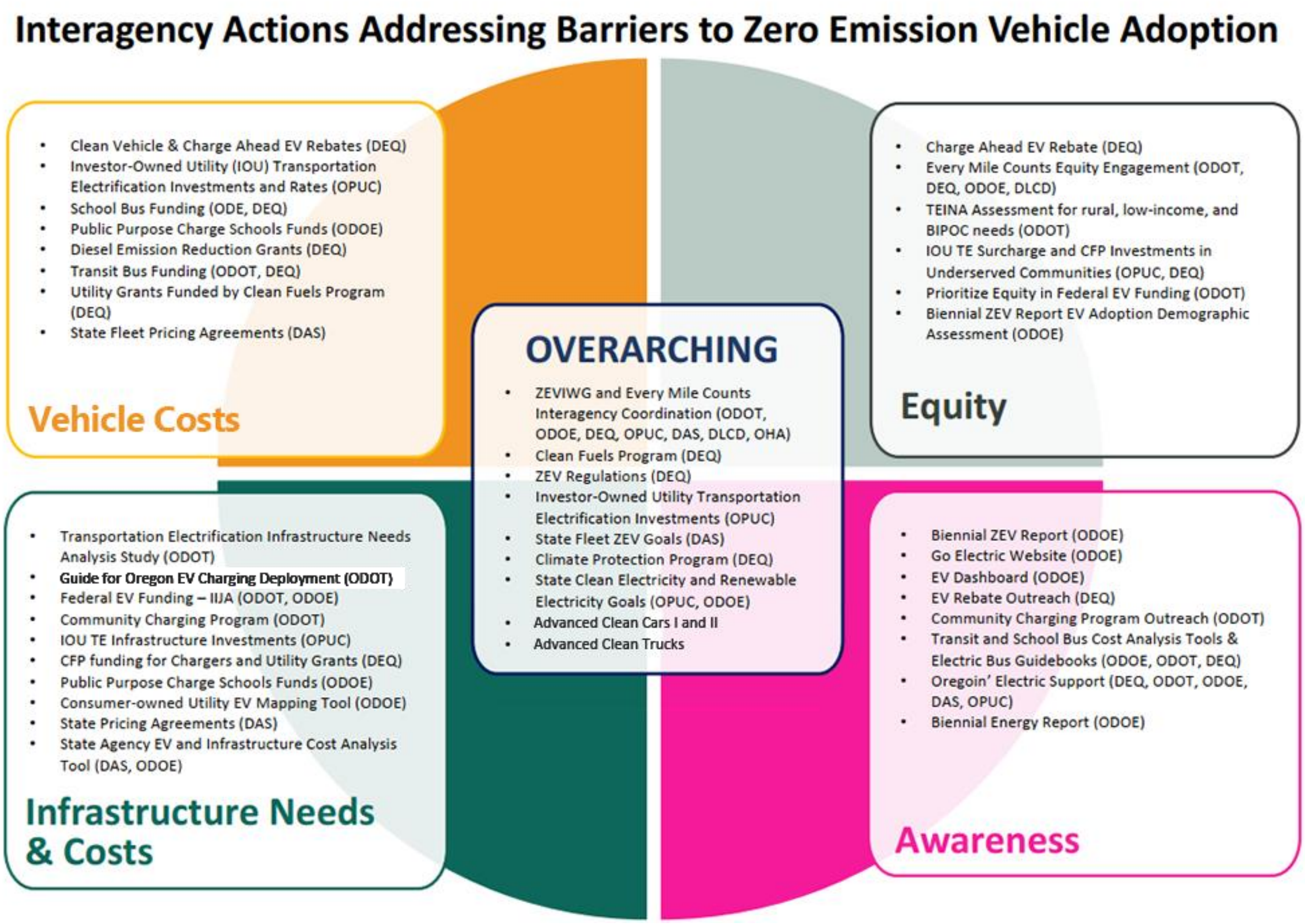


Other agency programs play a role in supporting transportation electrification:

- ODOE provides transportation-related data and analysis that informs policy decisions, including the development of this biennial report.
- The Oregon Department of Administrative Services has programs and goals to increase EV purchases and use across state agencies.
- The Oregon Public Utility Commission regulates electric utilities and oversees the development of transportation electrification plans, integrated resources plans, and distribution system plans used to prepare for increasing numbers of EVs operating on the grid.
- ODOE and the OPUC also work with utilities to plan for and develop policies that support Oregon’s target to achieve a clean and reliable electric grid to handle future EV loads.

Figure 12 shows state programs that support transportation electrification across multiple state agencies.

Figure 12: Oregon State Agency Programs Supporting Transportation Electrification



State Agency Programs Supporting Increased EV Adoption

The Oregon Department of Environmental Quality leads programs that serve to increase the availability of EVs in Oregon. In 2022, the Oregon Environmental Quality Commission adopted the Advanced Clean Cars II rule. It increases the minimum percentage of EVs to be delivered to Oregon for sale, first established in the original Advanced Clean Car rule. ACC II implementation begins with a 35 percent requirement for the 2026 vehicle model year and culminates with a 100 percent EV sales requirement for the 2035 vehicle model year. The rule also requires manufacturers to meet technology requirements, including a minimum vehicle range (BEVs at 150 miles and PHEVs at 50 miles), battery warranty and labeling standards, and minimum charging cord capabilities.[51]

The Oregon Department of Environmental Quality also provides incentives to help address the up-front costs of buying a passenger EV. In 2019, DEQ stood up Oregon's Clean Vehicle rebate, providing up to $2,500 off the cost of a new EV, and the Charge Ahead rebate program, which provided an additional $2,500 toward the purchase of a new or used EV for low- and moderate-income

Oregonians. In 2021, the Oregon Legislature increased the amount of the EV rebate for low- and moderate-income Oregonians bringing the total amount of rebate dollars available to low- and moderate-income Oregonians to $7,500.[52] While the program receives at least $12 million a year, due to its overwhelming popularity, funds were exhausted and the program had to be suspended in May 2023.[52] House Bill 2613 would have appropriated $30 million to revive the fund but did not pass out of the 2023 Legislative Session.[53] Without additional funding DEQ expects to reopen the program possibly in April 2024, but anticipates demand will again outstrip available funding in a very short period of time after reopening, resulting in another program suspension, and additional suspensions in the coming years.[54]

Oregon is a leader in facilitating the transition to medium- and heavy-duty EVs. DEQ's Advanced Clean Trucks rule requires manufacturers to produce and deliver increasing numbers of zero emission trucks starting with the 2025 model year. Even though requirements don't kick in until 2025, manufacturers can start earning compliance credit now by selling electric trucks.[54] Requirements to deliver vehicles for sale in Oregon are a critical component to transforming the sector, especially in instances where there is limited availability of these vehicles. Local truck manufacturer Daimler, located in Portland, has been rolling their new eCascadia Class 8 trucks and eM2 medium-duty electric box trucks off Oregon production lines and is supplying local fleets such as Titan Freight Systems (to learn more about Titan Freight Systems, please see the *Cost Differences Between EVs and Internal Combustion Engine Vehicles* chapter).[55]

Daimler Truck North America

Daimler Truck North America has been based in Portland for over 80 years and is a leading commercial vehicle manufacturer in North America. They are currently operating one of the only production lines for electric drive, class 8 trucks at their Portland truck building facility. Unfortunately, Daimler hasn't sold many trucks in Oregon due to the lack of charging infrastructure and incentives that bolster heavy duty EV truck demand. They have had greater success selling EV trucks in New York and California.

Daimler identifies three requirements needed to facilitate wider adoption of electric fueled commercial trucking: access to the trucks, economics that make sense to business customers, and the charging infrastructure to support deployment. With their eCascadia class 8 semi-truck and the eM2 box delivery truck, Daimler has created the trucks. First costs remain a barrier for the adoption of electric medium and heavy-duty vehicles as they can cost several times more than a comparable diesel fueled truck. Substantial fuel and maintenance expenses can be saved but are still unlikely to offset the incremental costs over the life of the vehicle. Daimler estimates that over 85 percent of their electric trucks sold have been carried by incentives, the majority operating in California.

Existing charging infrastructure is not designed for MHD trucks and adding charging infrastructure contains both cost and logistical challenges. Scaling up the capacity of charging is costly as the high-capacity chargers are more expensive and they require upgrades to the supporting electrical system. Daimler is investing in Oregon's charging infrastructure needs by partnering with PGE on a first-of-its-kind heavy-duty electric truck charging site called "Electric Island" in Portland which they are using to study energy management, charger use, and performance of their vehicles. Daimler has also announced a partnership with NextEra Energy Resources and BlackRock Renewable Power to build a network of charging sites on critical freight routes along the east and west coasts and in Texas by 2026.

Daimler wants to sell more of their MHD EV trucks in Oregon and they are hopefully state policy will support businesses investing in EV trucks with incentives and development of the charging infrastructure needed along all major traffic corridors facilitating rapid transition to clean energy.

Oregon is also an innovator in developing incentives to offset costs for MHD vehicles. HB 3409 (Sections 32-34), adopted during the 2023 Oregon Legislative session, directed DEQ to establish a Zero-Emission Medium- and Heavy-duty Vehicle Incentive Fund to provide rebates for qualifying medium- or heavy-duty EVs.[56] DEQ is developing the incentive program now and intends to implement it in early 2024. The rebate will reduce the incremental cost of purchasing a medium- or heavy-duty EV in comparison to a traditional fossil fueled vehicle for Oregon businesses.

State Agency Programs Support Charging Infrastructure Needs & Costs

Many state programs support electric vehicle charging infrastructure expansion in Oregon. EV charging needs are highly dependent on many different considerations, including the type of vehicle, where it is garaged, how much charging it needs and how quickly, and other considerations. Existing EV charger programs at the state serve to address gaps for rural and multi-unit buildings, medium- and heavy-duty fleets, alternative fuel corridors, and local communities. All of these are needed to meet the fueling needs for the growing numbers of EVs on Oregon roads and serving Oregon's economy. A deeper dive of specific EV charger policies and programs is provided in the Availability and Reliability of Charging Infrastructure chapter.

Forecasts and Projections

New policies, technology advancements, access to refueling infrastructure, mineral supply chains, and consumer attitudes and behavior can affect EV ownership rates and future forecasts.[57] The U.S. Energy Information Administration's 2023 Annual Energy Outlook highlights the significant uncertainties in projecting the rate at which electric vehicles will become more common in the light-duty vehicle market.[58] Increasing numbers of EVs in the future is certain, but the ownership rates will vary across geographic areas, vehicle model types, use cases, and sectors. While it is challenging to predict EV adoption rates in a rapidly transitioning industry, the following discussion highlights current federal and state policies, as well as industry and market advancements to inform whether Oregon will achieve its EV adoption goals. Because the Biennial Zero Emission Vehicle report is updated every two years, changes in policy, technology, and driver tastes are assessed and incorporated into this analysis on a regular basis.

National Forecasts

National EV forecasts predict steady market growth but the estimated rate of adoption by the U.S. market can vary significantly based on three key factors:[59]

1. consumer vehicle preferences
2. battery costs
3. fuel efficiency standards and environmental regulations

Changes in any of these factors can have differing effects on forecasted growth, and these changes could compound or even offset one another. As a result, there is wide variance in expert EV adoption forecasts, as can be seen in Figure 13 below. All modeled results have limitations and biases, but the value of modeling is to demonstrate the degree to which future events may affect outcomes.

Many of the more bullish forecasting models assume technology innovations will drive down battery and vehicle costs quickly, enabling EVs to reach cost parity with internal combustion engine counterparts sooner rather than later. For example, EVAdoption.com – an EV-centric data analytics company – forecasts approximately 4.7 million EV sales by 2030,[60] depicted as the purple bar in Figure 13. This is similar to Edison Electric Institute's (EEI) consensus forecast of 5.6 million EV sales by 2030 (represented by the teal bar), that was developed in coordination with automakers and members of the EV industry. Both models take into consideration historical trends and industry investments in cheaper, more advanced battery technologies that should result in increased affordability of EVs over time and higher levels of adoption.[59]

Future regulatory policies also affect modeling outputs, with more stringent climate and pollution policies driving the necessity for more EVs so that manufacturers and fuel providers can meet compliance requirements. EEI's analysis weighted existing and potential changes to rules promulgated by the USEPA's plans to reduce greenhouse gas emissions and the USDOT's National Highway Traffic Safety Administration's Fuel Economy standards, to spur the proliferation of EVs.

EV Adoption's analysis cites the introduction of more "affordable" EV models as well as increased median battery range will encourage growth in EV purchases, while also modeling consumer choices that will reduce overall vehicle growth, including EVs.[60] The most optimistic forecast comes from the EEI's Manufacturers' forecast (represented by the pink bar) based on vehicle manufacturers' announced EV sales targets and estimations of their total light-duty vehicle sales in 2030. This forecast is based on the stated goals of the leading EV automakers in the U.S. (Tesla, BMW, Ford, General Motors, etc.) and expectations that the auto industry and others will be able to address supply-chain issues and efficiently convert manufacturing to electric vehicle models.[59]

Uncertainty in the availability of minerals and manufacturing resources may slow the rate of EV adoption — leading to more modest gains in future years. The Energy Information Administration's Annual Energy Outlook 2023 is consistently a conservative model of growth, largely because it does not include any policies that have not been formally instituted. EIA's forecast, represented by the dark blue bar in Figure 13, does not include any potential changes to federal or state regulations that are likely to occur as efforts to address climate change ramp up. Wood Mackenzie, a global research and consultancy group represented by the light blue bar, projects a more modest growth in EV sales, citing a concern that battery manufacturing capacity and battery supply chains will serve as potential bottlenecks for the goals of EV manufacturers despite the ambitions of the federal government.[61]

Consumer vehicle preferences and habits can also affect EV ownership rates. Although EVAdoption.com's analysis is generally more bullish on future ownership, it also includes assumptions that the overall light-duty vehicle market will shrink by 2030, as consumers hold on to older cars longer and utilize ride-sharing services more to delay or forego the cost of purchasing a vehicle.[60]

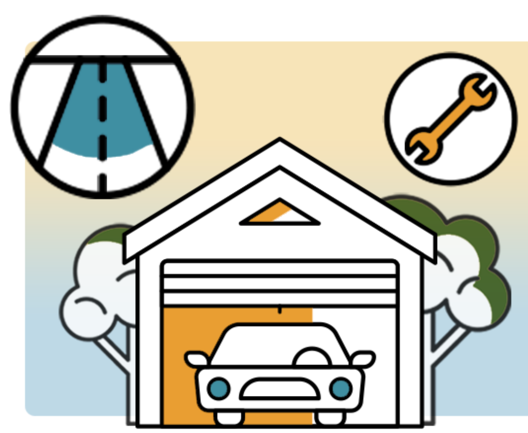
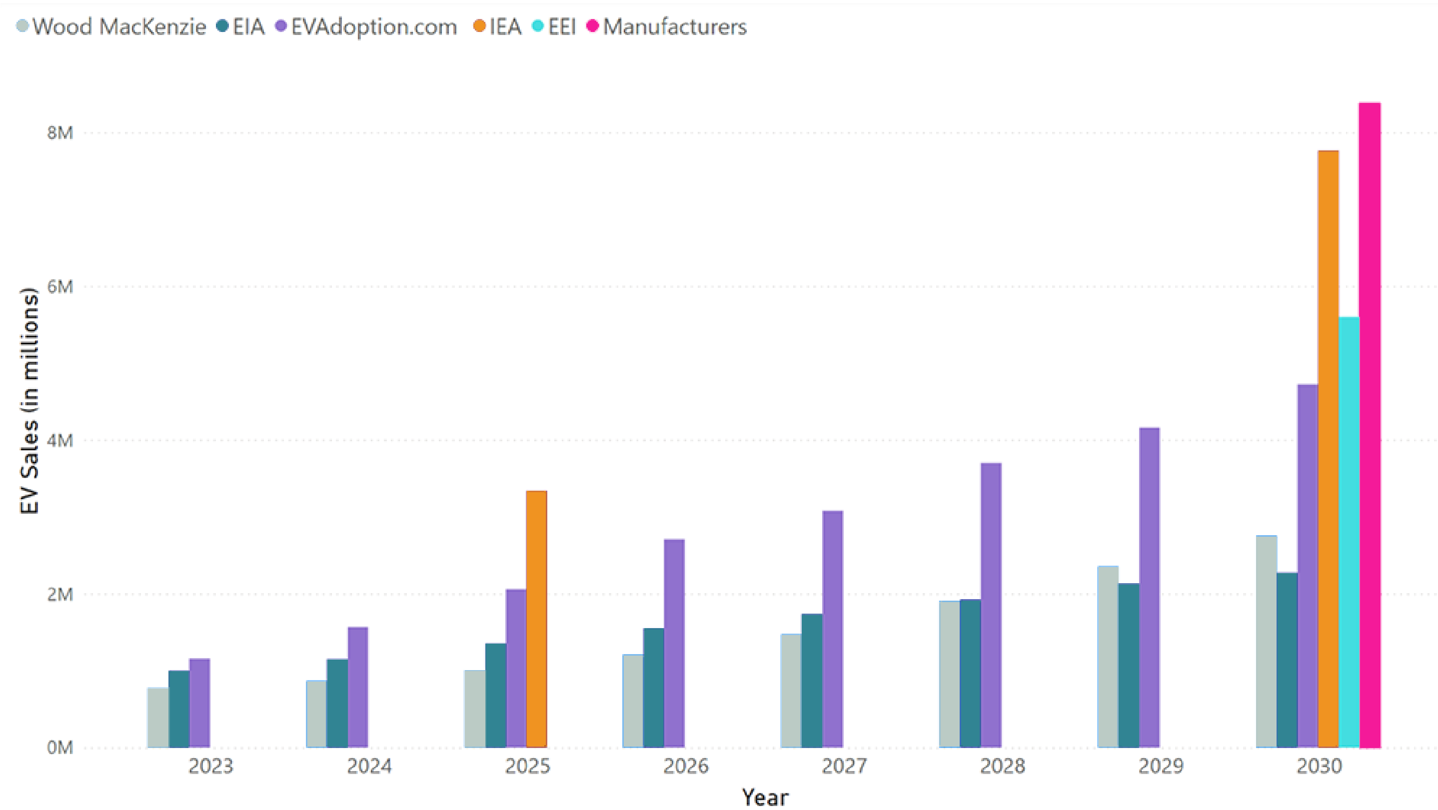


Figure 13: National EV Sales Forecasts (2023-2030)[58,60,62–64]



Consumer Preference

Polling has shown U.S. adults are ready for the transition to EVs. Morning Consult found that 51 percent of U.S. adults considering a vehicle purchase, say they are likely to consider purchasing an all-electric vehicle within the next decade and 61 percent are considering buying a hybrid. Potential EV buyers tend to trend younger on average, with 60 percent of Millennials and 58 percent of Gen Z indicating they are likely to purchase an EV in the next decade.

This surge in consumer interest coincides with the growth of the EV market. In 2022, the number of models available in the U.S. jumped from 62 to 100 and is expected to grow to 134 models by 2024. Model diversity and functionality will also spur greater ownership in EVs with more models of electric SUVs, pickup trucks, and crossovers providing customers more model options than "the five-door hatchback city cars" and "expensive luxury sedans" that currently comprise the majority of EVs on the market.[65]

Costs

Innovation is spurring cost savings in the procurement of raw materials and EV manufacturing, and industry experts anticipate EV vehicles will reach price parity with light-duty internal combustion engine counterparts soon. Battery costs are declining, and EV manufacturers are finding the production of new electric vehicle models to be more efficient and cheaper than conventional ICE vehicles as they have a more modular design and fewer components. From 2010-2021 levels, battery pack costs have dropped nearly 90 percent. The price reduction in battery packs is projected to continue in the long-term with more resources dedicated to battery research, innovation, and development despite recent supply chain issues.[66] To learn more about battery costs, please see the *Cost Differences Between EVs and Internal Combustion Engine Vehicles* chapter.

Regulation

Federal regulations support increased EV production by setting requirements for the vehicle fuel economy and emissions standards. In all cases, producing more EVs helps manufacturers meet their compliance goals across these programs. There are three primary regulatory bodies in the U.S. that influence EV production: the National Highway Transportation Safety Administration, the Environmental Protection Agency, and California's Air Resources Board.[67]

The NHTSA regulates vehicle fuel economy requirements by requiring manufacturers to meet certain *average* fuel economy standards for specific model years of cars and light-duty trucks. Electric vehicles are more than three times as efficient as comparable internal combustion engine vehicles, meaning producing more EVs improves the manufacturer's average fuel economy for their fleet. On July 28, 2023, NHTSA proposed new Corporate Average Fuel Economy, or CAFE, standards that would improve the fuel economy for cars by 2 percent and light-duty trucks by 4 percent each year from 2027 through 2032. This would raise the fuel economy of all new vehicles to around 58 miles per gallon by 2032, more than double the 2022 average of 26.4 mpg.[68]

The EPA regulates vehicle emissions nationwide to address air pollution and climate change. Regulations set standards on the amounts of emissions allowable for a vehicle, and manufacturers must demonstrate compliance before vehicles can be produced. Most electric vehicles have zero tailpipe emissions, and easily exceed the standards. In 2022, the EPA proposed new standards for heavy-duty vehicles and engines, which would start in the model year 2027 and would set updated GHG emissions standards for school buses, transit buses, commercial delivery trucks, and short-haul tractors.[69] In April 2023, the EPA proposed similar new emissions standards for light-duty and medium-duty vehicles starting in model year 2027. These new regulations would make EV adoption crucial for compliance. The agency projects that the new regulations would significantly boost EV production to as much as 67 percent of new light-duty vehicle sales and 46 percent of new medium-duty vehicle sales by 2032.[70]

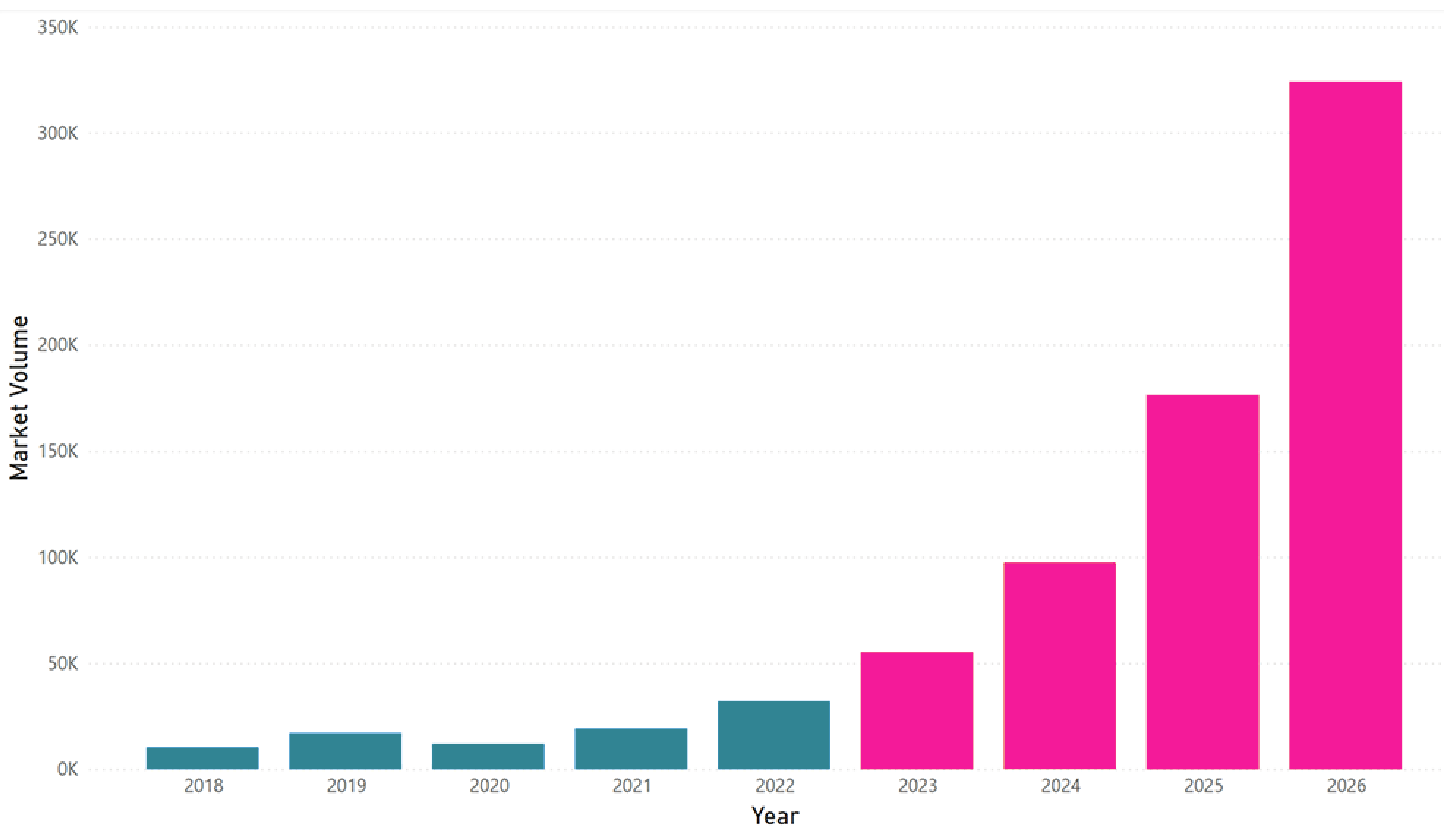
California's Air Resources Board has the authority to set its own emissions standards, and these have historically been more stringent than USEPA standards so that the state could more readily meet the requirements of the federal Clean Air Act. Other states are allowed to adopt these regulations through Section 177 of that act; Oregon and 16 other states have done so. The California Air Resources Board's Advanced Clean Cars II regulation described above will have an even stronger influence on EV adoption than the USEPA rule, with requirements for EV deliveries into the Section 177 states.[67]

In addition to these regulations, the Biden Administration passed an executive order that will electrify the federal fleet over the next 12 years. The Federal Fleet Electrification policy requires all light-duty vehicles in the fleet to be electrified by 2027 and the rest of the vehicles in the fleet by 2035. The federal vehicle fleet is the largest fleet in the nation, with about 380,000 vehicles [59] [71] As part of the electrification of the federal fleet, the United States Postal Service is acquiring at least 66,000 EVs to be used for deliveries as part of its 106,000-vehicle acquisition plan for deliveries between now and 2028. The USPS intends to be one of the largest EV fleets in the nation by 2028.[72]

Medium- and Heavy-Duty Vehicles

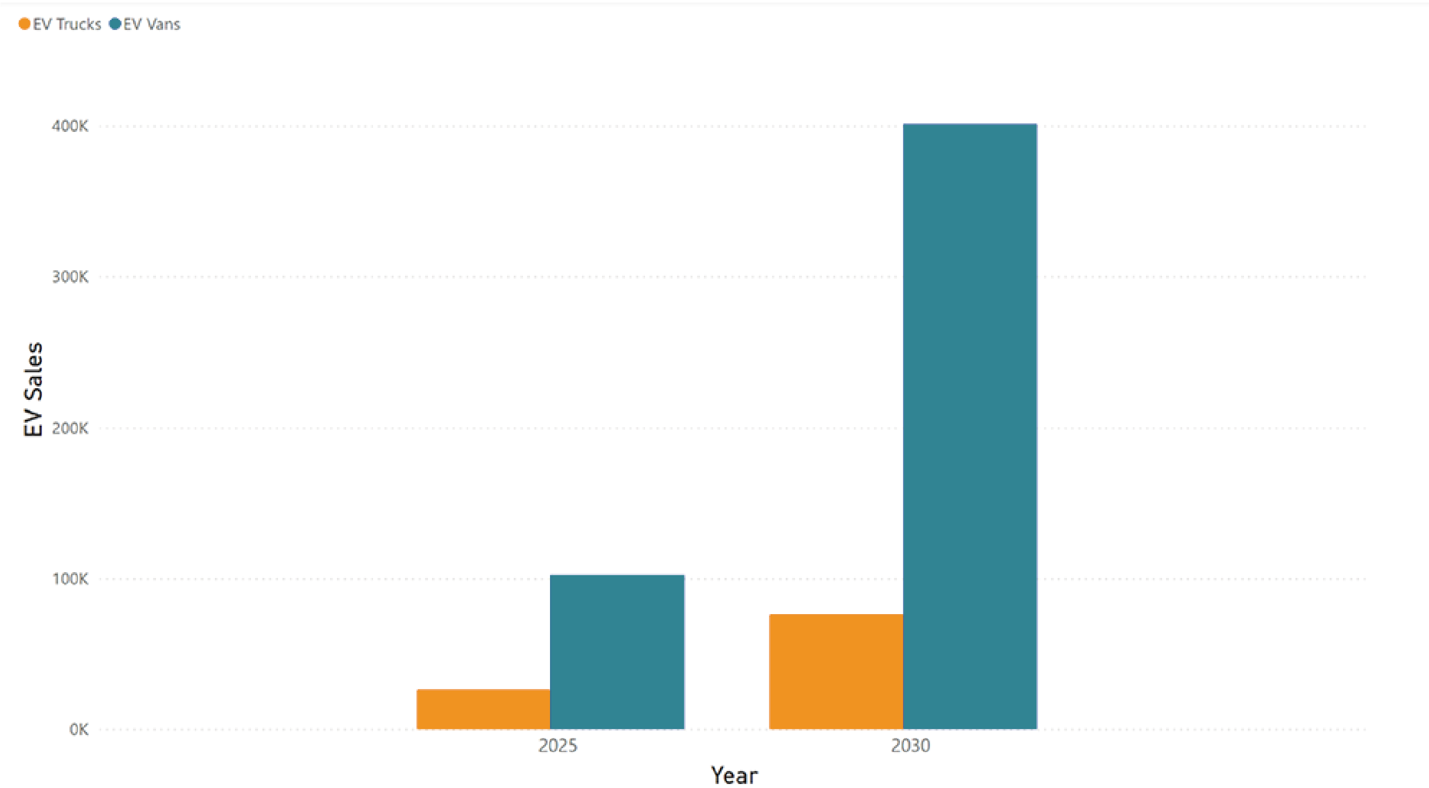
Adoption of medium- and heavy-duty EVs, including electric or hydrogen fueled trucks, is in the earliest stage of market development. Forecasted growth in the short term will be driven largely by the ownership of medium-duty vehicles like delivery vans. The generally bigger battery sizes required and the breadth of existing vehicle models are unique barriers for this sector, so it will lag light-duty vehicles in production and availability of public charging infrastructure. The forecast shown in Figure 14 indicates MHD vehicle sales will grow significantly in the next few years, largely due to innovations in battery design, increased manufacturer production, and federal and state emission regulations and funding support to develop public fueling infrastructure on major transportation corridors.[73]

Figure 14 National Medium- and Heavy-Duty Sales Forecast[73]



Smaller MHD vehicles are expected to dominate the market in the near term. The smaller size and weight of medium-duty vehicles makes the vehicle use case more amenable to electrification. The additional weight of the vehicle batteries is not as likely to conflict with overall load weight requirements, as can be the case for larger vehicles. Fleet managers, who need to balance cost and logistical challenges with a desire to reduce fleet emissions, are also more likely to be open to converting to electric models for these vehicles. This is reflected in national MHD forecasts where EV van sales are predicted to far outpace EV trucks through the end of this decade, as shown in Figure 15 below.[62]

Figure 15: Comparison of Sales Projections for Heavy-Duty EV Trucks and Medium-Duty EV Vans[62]



In a 2022 report, the U.S. Department of Energy's National Renewable Energy Laboratory released a study predicting medium- and heavy-duty electric trucks (with less than 500 miles of range) will reach cost parity with their diesel truck counterparts in the next 10 – 12 years. NREL's assessment found that global sales of EVs will be 42 percent of the MHD market by 2030, which would create economies of scale for EV manufacturing and lead to substantial reductions in production costs. NREL also found that improvements in battery chemistries and production would lead to lower battery and fuel cell costs – 73 percent and 60 percent reductions respectively from 2020. Long-haul[vii] battery electric trucks are predicted to be price competitive with heavy-duty diesel trucks by 2030 and hydrogen fuel cell trucks by 2035. In addition, the study concluded that MHD electric chargers and hydrogen fueling stations will be increasingly available and have steady pricing.[74]

Transit and School buses are also expected to transition faster to electric models. Forecasts indicate electric buses will comprise 43 percent of national bus sales by 2030 and nearly 80 percent by 2040.[75] The anticipated accelerated adoption of electric buses in comparison to other MHD vehicles is based on their current higher ownership rates. Nearly 5,500 EV buses were operating in the U.S. in 2022, a 66 percent increase over 2021. Investments from federal, state, and electric utility incentive programs

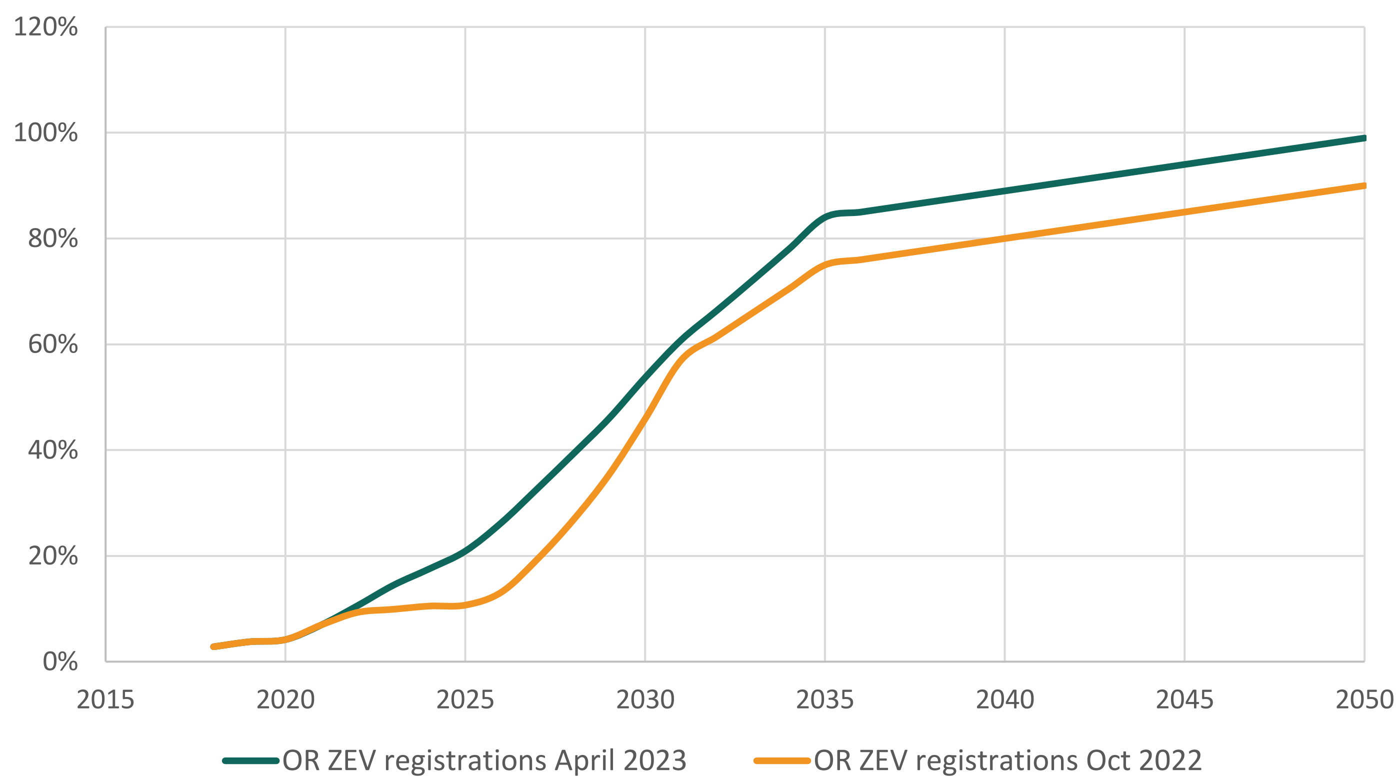
[vii] Greater than 500 miles of range

have been instrumental in increasing electric bus ownership in school districts and transit authorities, often covering the incremental cost difference between the electric bus and a typical new diesel bus. Buses are also often amenable to lower costs for charging infrastructure because they often have limited daily mileage needs and consistent scheduling that allow fleet managers to put in slower, but less costly, Level 2 chargers.[76–78]

Oregon Forecast

Oregon is strongly positioned to rapidly accelerate EV growth for light-duty vehicles in the next two decades. Figure 16 below is ODOT's 2023 vehicle stock forecast of EV passenger vehicles in the state. The brown line represents ODOT's forecast produced in October 2022, and the green line is an updated forecast developed in April 2023. The relative increase in predicted EV registrations compared to the 2022 forecast is largely due to the implementation of California's Advanced Clean Cars II rule by the Environmental Quality Commission in December 2022.

Figure 16: ODOT Forecast: EV Share of Oregon Registrations[79]



ODOT's EV forecast indicates that the state is on track to achieve its EV adoption goals. The 2025 goal of 250,000 registered EVs would comprise approximately 7 percent of all registered vehicles today. Figure 16 shows 20 percent of all registered vehicles are expected to be EVs in 2025, this will likely exceed the 2025 adoption goal by 2-3 times. The model also indicates we are likely to exceed the 2030 registration goal of 25 percent registered EVs, and the ACCII rule would require sufficient vehicles to be delivered into Oregon to achieve the 2030 goal of 50 percent of vehicle sales. Implementing the ACCII rule requiring 100 percent EV light-duty EV sales starting in 2035 puts Oregon on track to meet and exceed its 2035 goal of 90 percent EV sales. ODOT's transportation greenhouse gas reporting program forecast also modeled future adoption of EVs but included standard hybrid vehicles as well. Assuming that the majority of the forecasted vehicle ownership are EVs, this analysis also found that Oregon is on track to meet its EV adoption goals.[80]

Because MHD EV ownership is so new and there is uncertainty in the availability and affordability of EV options for these vehicles, there is insufficient data to develop an Oregon forecast. However, the Statewide Transportation Strategy includes a vision for transit and delivery vehicles for 2035, setting a goal of 90 percent of urban transit vehicles and 40 percent of smaller delivery and commercial vehicles be powered by lower-emission fuels, including electricity. DEQ's Advanced Clean Trucks rule doesn't establish adoption targets, but it does require MHD manufacturers to deliver certain percentages of EVs to Oregon beginning in 2024. Future versions of this report will contain more data on MHD ownership trends and forecasts.

Oregon Electric Utility Forecasts

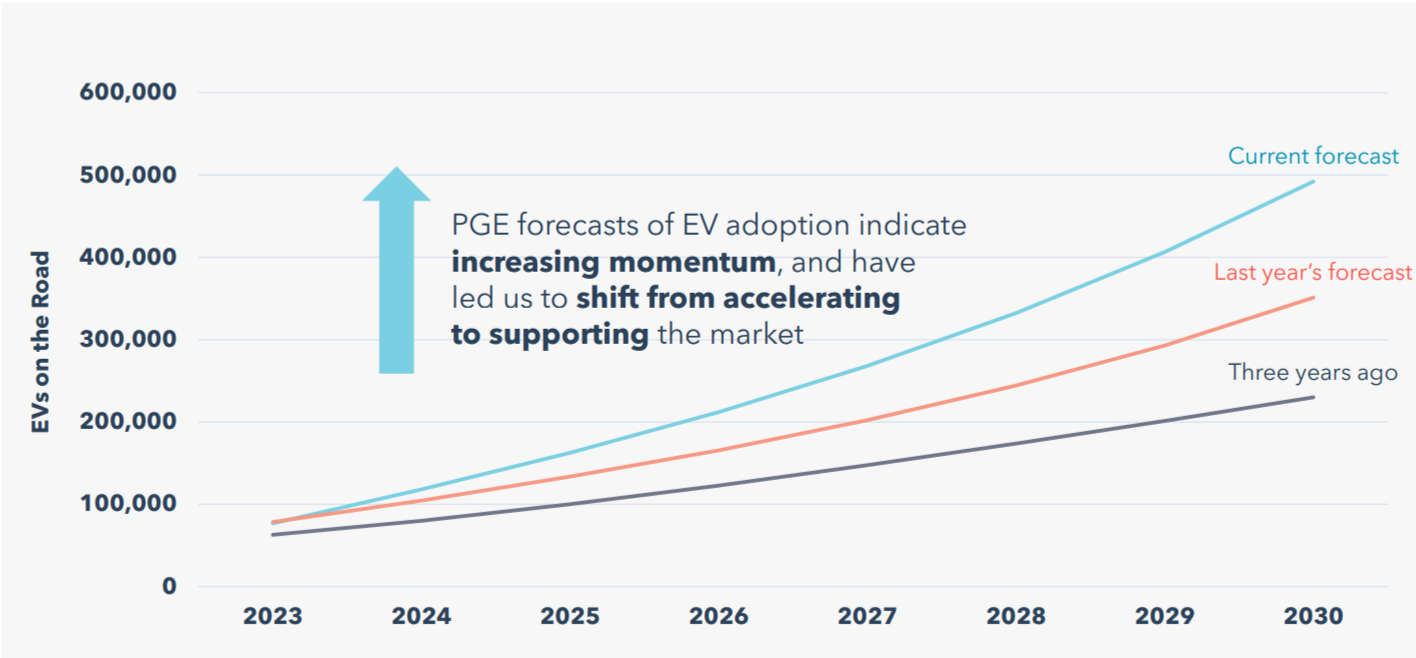
Oregon's electric utilities also modeled significant anticipated growth in light-duty EVs. Oregon investor-owned electric utilities are required to provide transportation electrification plans to the Oregon Public Utility Commission. These plans inform activities for the utilities to ensure the grid is ready to support this growing electric load (see *Opportunities to Minimize the Effects of EVs on the Electric Grid* chapter). In its draft 2023 transportation electrification plan, PacifiCorp expects a 30 percent year-over-year increase in EV model ownership in its territory in the next few years, which is in line with registration growth in Oregon over the last five years. Portland General Electric is also anticipating fast growth of EVs in its territory and indicated in its proposed 2023 plan that because market forces now seem to be driving the majority of EV ownership, the utility is shifting from a strategy of accelerating the market to supporting it with the development of charging infrastructure.

Like ODOT's EV forecast, PGE has also increased expected levels of EV ownership within its territory each time it's been modeled. PGE's forecasts consider current growth trends, federal legislation supporting EV adoption, and current and expected investments in innovation. Figure 17 shows how the utility's model results developed for the 2020, 2022, and 2023 projections dramatically increased in 2025 and 2030, largely due to policies, programs, and investments supporting EV adoption in the last three years.[81]

From Portland General Electric's 2023 Transportation Electrification Plan[82]

By 2027, we expect 141,000 electric light-duty vehicles on the road, dominated by the residential sector, and 2,100 medium and heavy duty EVs. By 2050, we expect nearly 80% of the vehicle market to be electric in all weight classes, with 1.4 million light-duty vehicles (LDV) and 33,000 medium (MDV) and heavy-duty vehicles (HDV).

Figure 17: Portland General Electric Forecasts of Electric Vehicle Adoption in their Territory[81]



Conclusion

Oregon is making great progress on its EV ownership targets, and new policies and programs enacted and updated since the last report put the state on track to meet the 2030 and 2035 targets. Accelerating EV adoption to meet the more immediate 2025 goal is in doubt and dependent on rapid domestic supply chain expansion, vehicle production, and charging infrastructure installations. Strong federal and state policies, as well as investments by electric utilities, are bolstering this rapid transition. Medium- and heavy-duty vehicle electrification lags light-duty, largely because it is a much more complex vehicle sector, and the barriers to adoption are often more costly and challenging than passenger vehicles.

Oregon is well positioned to take advantage of unprecedented federal spending on EVs and charging infrastructure, to not only support broader EV ownership but to also use this transition to benefit Oregon workers and communities. Sustained market growth for EVs depends on industry and government collaborating to overcome economic and logistical challenges, such as limited charging infrastructure, battery innovation, vehicle production, price parity with conventional vehicles, expanding supply chains, and consumer behavior. New federal policies address some of these challenges, and could drive job development and support

local economies, including union wage level jobs for charger installations, vehicle and charger maintenance, local utility operations, and component manufacturing and assembly. Preparing Oregon to participate in a burgeoning EV industry could create a positive feedback loop where investments in new EV technologies support Oregon businesses, who in turn provide living wage jobs in Oregon communities.

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"Green Bus" in Eugene, OR, ODOT

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 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

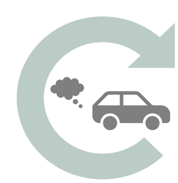
Key Takeaways

- The carbon intensity of the fuel consumed in Oregon’s transportation sector is largely decreasing due to the adoption of lower carbon fuels, including electric fuel.
- The Oregon Clean Fuels Program drives the availability of lower carbon transportation fuel choices in the state.
- Electrification is key to achieving long-term climate goals, but less carbon intensive fuels like renewable diesel are a critical piece to near-term reductions in the carbon intensity of the fuels consumed by medium-duty, heavy-duty, and non-road vehicles in Oregon.

Introduction

The carbon intensity of the fuels consumed by Oregon’s transportation sector declined between 2005 and 2019, but the effects of COVID changed the ratio of gasoline and diesel consumption in 2020 and 2021 which created an overall uptick in sector-wide carbon intensity.[1] Policies requiring the use of lower carbon intensity ethanol and biodiesel led to initial reductions, and the standup of the Clean Fuels Program in 2016 is steadily driving more reductions across the sector. Electricity is expected to play an increasingly larger role, especially as newly adopted policies – including the Advanced Clean Trucks and the Advanced Clean Cars II rules – encourage electric vehicle adoption and electric fuel use. Electric utilities will achieve further reductions in the transportation sector as they work to reach Oregon’s 100 percent clean electric grid by 2040.

What is Carbon Intensity?



The use of carbon intensity as a measure enables an apples-to-apples comparison of the lifecycle carbon emissions for different transportation fuels. A fuel’s CI represents carbon emissions (grams of carbon dioxide equivalent or gCO_2e) per amount of energy used (megajoules). Higher carbon intensities mean more greenhouse gas emissions are emitted than a fuel with a lower carbon intensity for the same amount of energy. For ease of understanding, the Oregon Department of Energy converts the amount of energy used from megajoules to gasoline gallon equivalents, or GGEs — the amount of that fuel that would move the same vehicle the same distance as a gallon of gasoline. ODOE uses CI values from the Oregon Department of Environmental Quality’s Clean Fuels Program.

How is the CI of a fuel determined?

The Oregon Department of Environmental Quality's Clean Fuels Program estimates lifecycle emissions using a modified version of Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation, or GREET model. The GREET model is used to calculate emissions associated with how an individual fuel is made – what it is made from, how it is refined, stored, and delivered into Oregon, as well as the emissions associated with combusting that fuel, when applicable. Each individual "fuel pathway" is assigned a unique carbon intensity value.[4]

Carbon Intensities of Transportation Sector Fuels

There is a broad range of carbon intensities, even among the same type of fuel. For instance, biodiesel made from a seed oil crop will have a higher CI than biodiesel made from a waste product, because raising the crop typically uses more energy than processing a waste. Renewable natural gas collected from dairy manure digesters has a much lower CI compared to fossil natural gas, because it is less energy intensive and captures methane emissions that would otherwise have been released from the manure used to create the RNG.[5] Electricity generated from renewable resources like hydroelectric dams, wind turbines, or solar panels has a lower CI compared to fossil fuel-generated electricity, like natural gas or coal.

Gasoline and diesel have some of the highest overall carbon intensities across fuels consumed in Oregon. Table 1 below shows that the average carbon intensity of gasoline is 27.04 lbCO2e/GGE or 100.14 gCO2e/MJ and diesel is 29.87 lbCO2e/GGE or 100.74 gCO2e/MJ. The only fuel with a higher CI is hydrogen produced from natural gas. This chapter of the report focuses on gasoline and diesel and the most common alternative fuels that are being used to drive carbon intensity down, including electricity.

Table 1: 2021 Oregon Transportation Sector Fuel Consumption and CI[1]

		Carbon Intensity	
Fuel Type	GGE	lbCO2e/ GGE	gCO2e/MJ
Hydrogen	20,437	42.35	156.84
Diesel	808,442,432	29.87	100.74
Lubricants	12,529,680	29.87	100.74
Asphalt & Road Oil	89,204,148	29.87	100.74
Gasoline	1,351,415,916	27.04	100.14
Aviation Gasoline	2,747,718	27.04	100.14

Jet Fuel	184,393,471	24.49	90.70
CNG	359,230	21.58	79.92
LPG	1,576,772	15.98	59.19
Ethanol	104,458,357	14.50	53.72
Biodiesel	78,005,874	11.21	41.51
Renewable Diesel	10,462,444	9.98	36.97
Bio CNG	3,825,170	8.53	31.59
Renewable LPG	211,772	6.85	25.36
Electricity (GGE)[i]	9,639,743	6.85	25.35
Total	2,657,293,162		

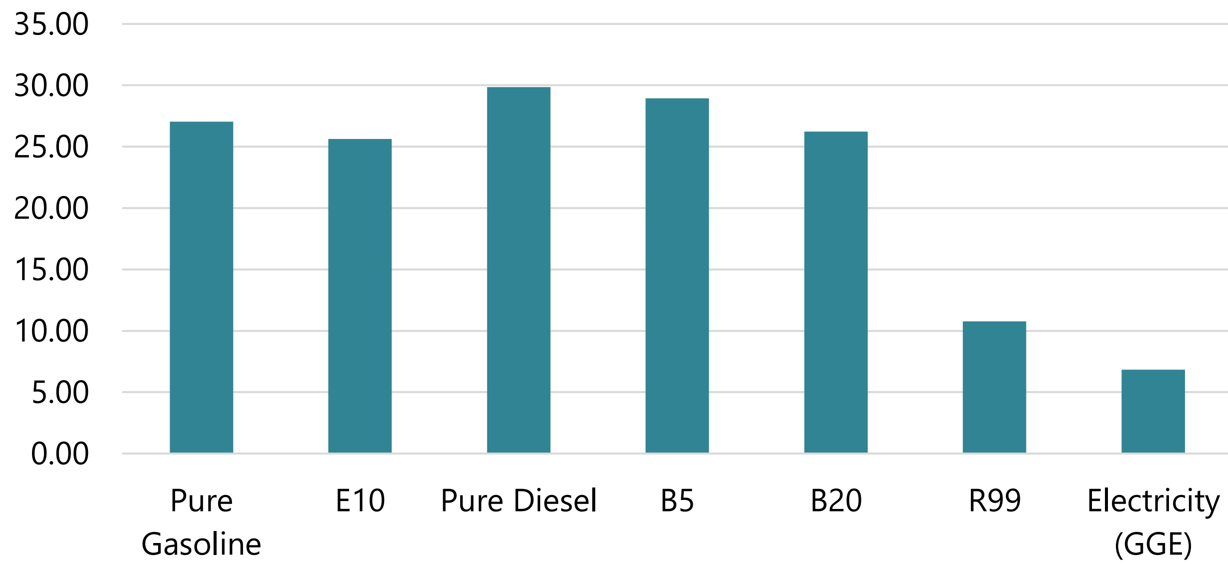
What's the difference between biodiesel and renewable diesel?

While both renewable diesel and biodiesel can be made from the same biomass-derived feedstocks, they are produced using different manufacturing processes and create different fuels with different characteristics and different emissions. These differences in production result in renewable diesel as a colorless, odorless fuel that performs better at lower temperatures, reduces engine maintenance and costs, and improves overall vehicle performance.

Biofuels that are blended into gasoline and diesel are the largest contributor to reducing sector-wide CI. Most gasoline sold in Oregon contains 10 percent ethanol (E10), and diesel contains up to 5 percent biodiesel (B5). Using E10 lowers the carbon intensity of pure gasoline by about 5 percent. Similarly, the B5 blend reduces diesel CI by about 3 percent.[7] B20, a commonly available 20-percent biodiesel blend with fossil diesel, has a nearly 10 percent reduction in CI compared to B5 alone. Renewable diesel, which can substitute fossil diesel one-to-one, is referred to as R99 and has become increasingly popular in Oregon. R99 has a CI that is 63 percent lower than B5. Figure 1 below shows the relative CIs for gasoline, diesel, and common blend fuels used in Oregon.

[i] The CIs for electricity are based on applying the energy economy ratios discussed below.

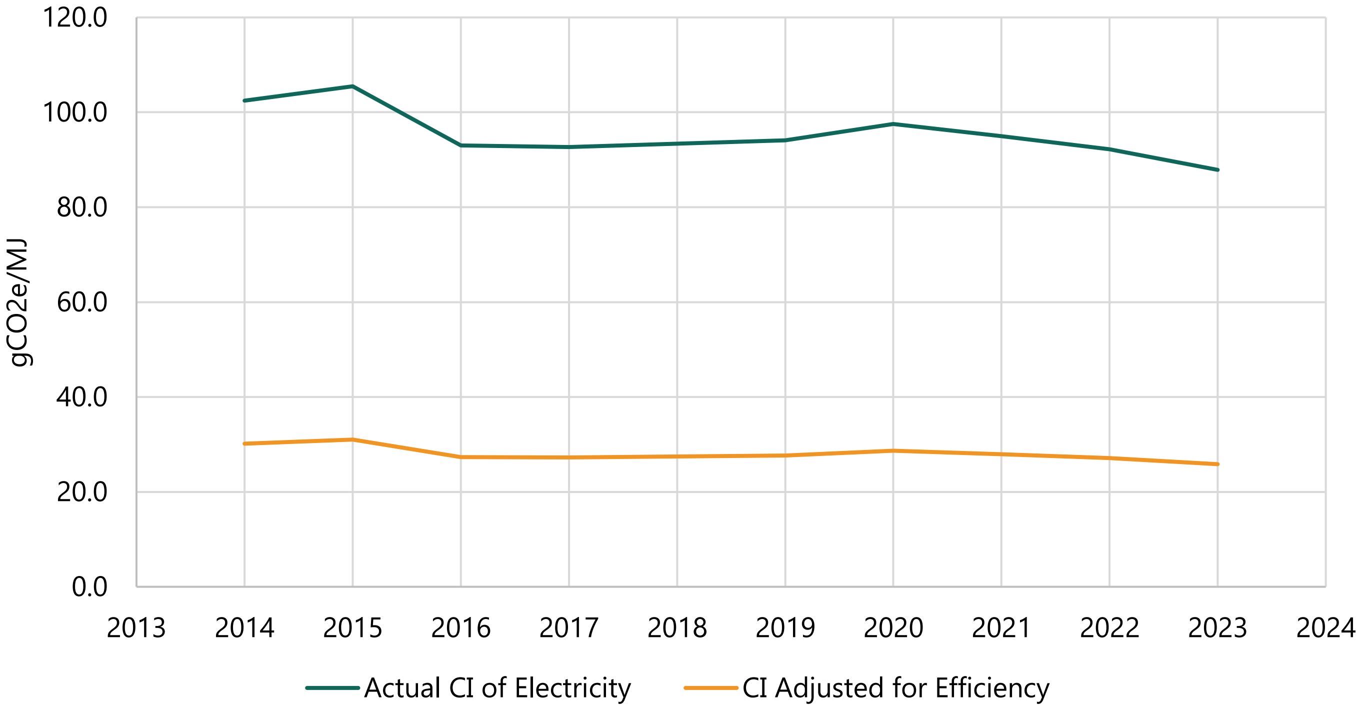
Figure 1: Average Carbon Intensities of Common Fuels Consumed in Oregon (lbCO2e/GGE)[1]



The CI for electricity used in EVs is, on average, 73 percent lower than E10 and 76 percent lower than B5 — and these will continue to drop as Oregon electric utilities work to achieve a 100 percent clean grid by 2040.[9,10] Driving an electric vehicle significantly lowers the transportation CI because it not only takes into account the lower CI of electricity, it also factors in the energy efficiency of electric motors,[ii] which are 3.4 times more energy efficient than internal combustion engines.[11] To calculate the CI for electricity used by EVs, the electricity CI is divided by a 3.4 energy efficiency ratio.[12] The CI of Oregon's statewide electricity mix is 86.19 gCO2e/megajoule (23.27 pounds CO2e/GGE). Dividing that by 3.4 calculates the CI for electricity as 25.35 gCO2e/megajoule (6.85 pounds CO2e/GGE). Figure 2 below shows the statewide electricity mix CI since 2014 as the blue line, and the CI for electric fuel that takes into account the energy efficiency ratio is shown in orange.

[ii] Energy efficiency comparisons are based on the total amount of energy needed to do the same amount of work. For example, an electric vehicle can go 3.4 times farther than a similar internal combustion engine vehicle.

Figure 2: Carbon Intensity of Oregon's Average Statewide Electricity Mix with Electric Vehicle Energy Efficiency Ratio[13]

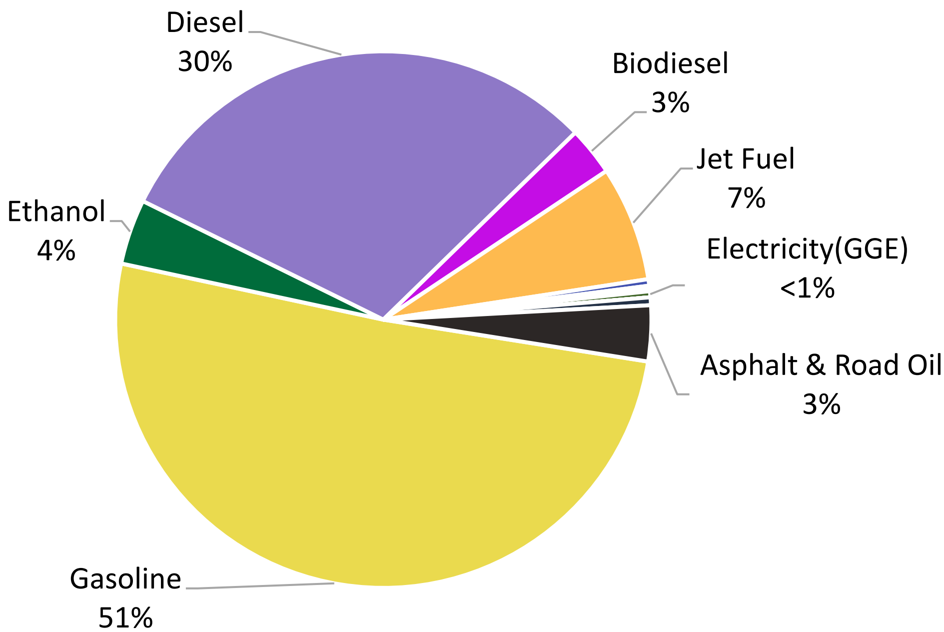


Note: Prior to 2020, a five-year rolling average was used. 2021 and after represent single years.

Carbon Intensity of Oregon's Transportation Sector

The consumption-weighted carbon intensity of the transportation sector in Oregon in 2021 was about 98.9 gCO2e/megajoule (26.7 pounds CO2e/GGE).[14] The Oregon Department of Energy assesses the carbon intensity of Oregon's transportation sector by using DEQ's individual fuel CIs combined with the amount of fuels used in Oregon, to calculate a consumption-weighted, transportation sector CI. This weighting means the total sector CI will move up or down depending on the amount of fuel consumed. Figure 3 shows the different transportation fuels used in Oregon as a percentage of total fuel consumption.

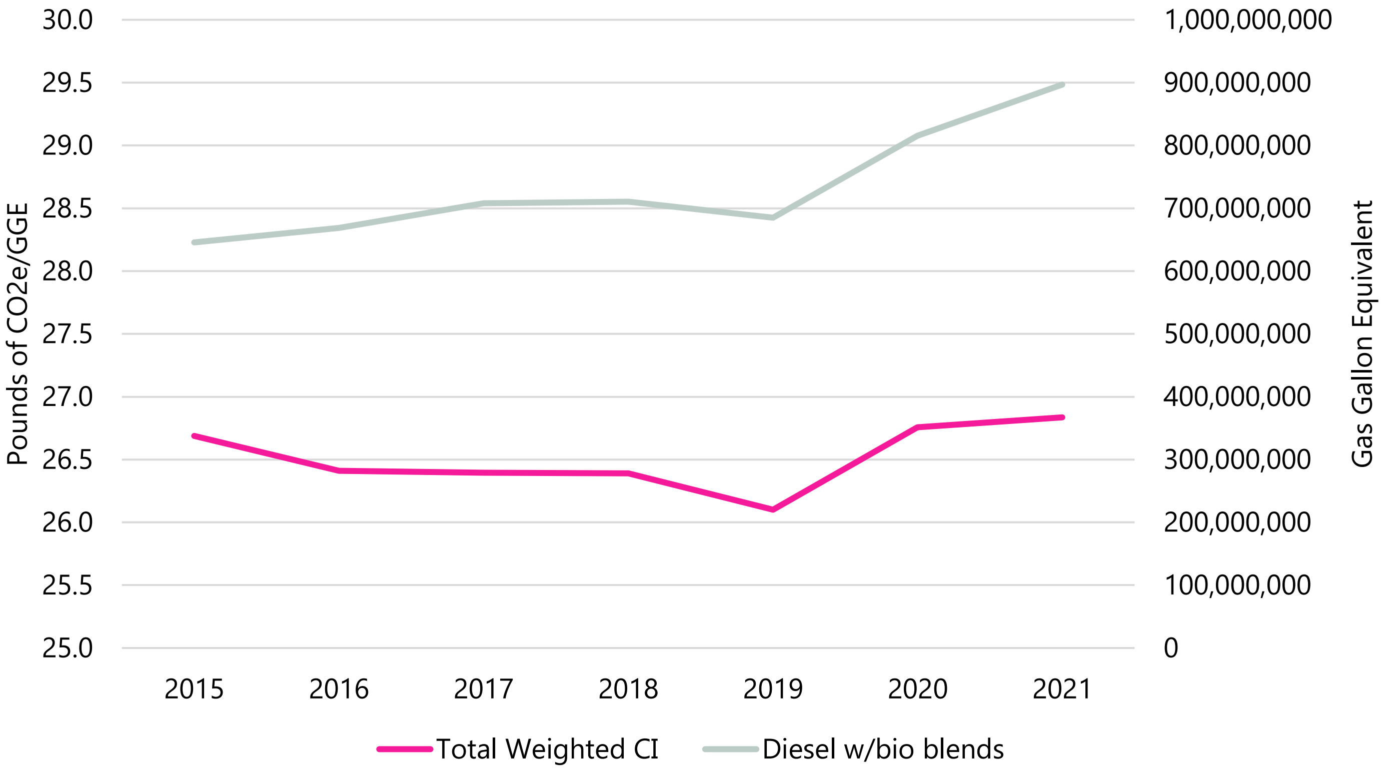
Figure 3: 2021 Transportation Fuel Consumption in Oregon[1]



LNG Fossil Fuel, LNG Landfill, Lubricants, Hydrogen, CNG, Bio CNG, LPG, Renewable LPG, Aviation Gasoline, Renewable Diesel, and Electricity all represent less than 1 percent of all fuels and are not labeled.

The COVID-19 pandemic dramatically affected the transportation sector CI, likely driven by increased demand for home delivery of products while people stayed at home.[16] Figure 4 below shows annual weighted transportation sector CIs in pink and the weighted diesel CIs in light green. Diesel consumption increased 19 percent in 2020 and 31 percent in 2021 compared to 2019, resulting in a large uptick the diesel consumption weighted CI.[1] This was reflected in the sector-wide CI shown in blue. While gasoline use fell during this same timeframe, it was not enough to offset the increased CI resulting from increased diesel use, largely because consumption of gasoline is much higher than diesel.

Figure 4: Diesel Consumption Compared with Transportation Sector Carbon Intensity[1]

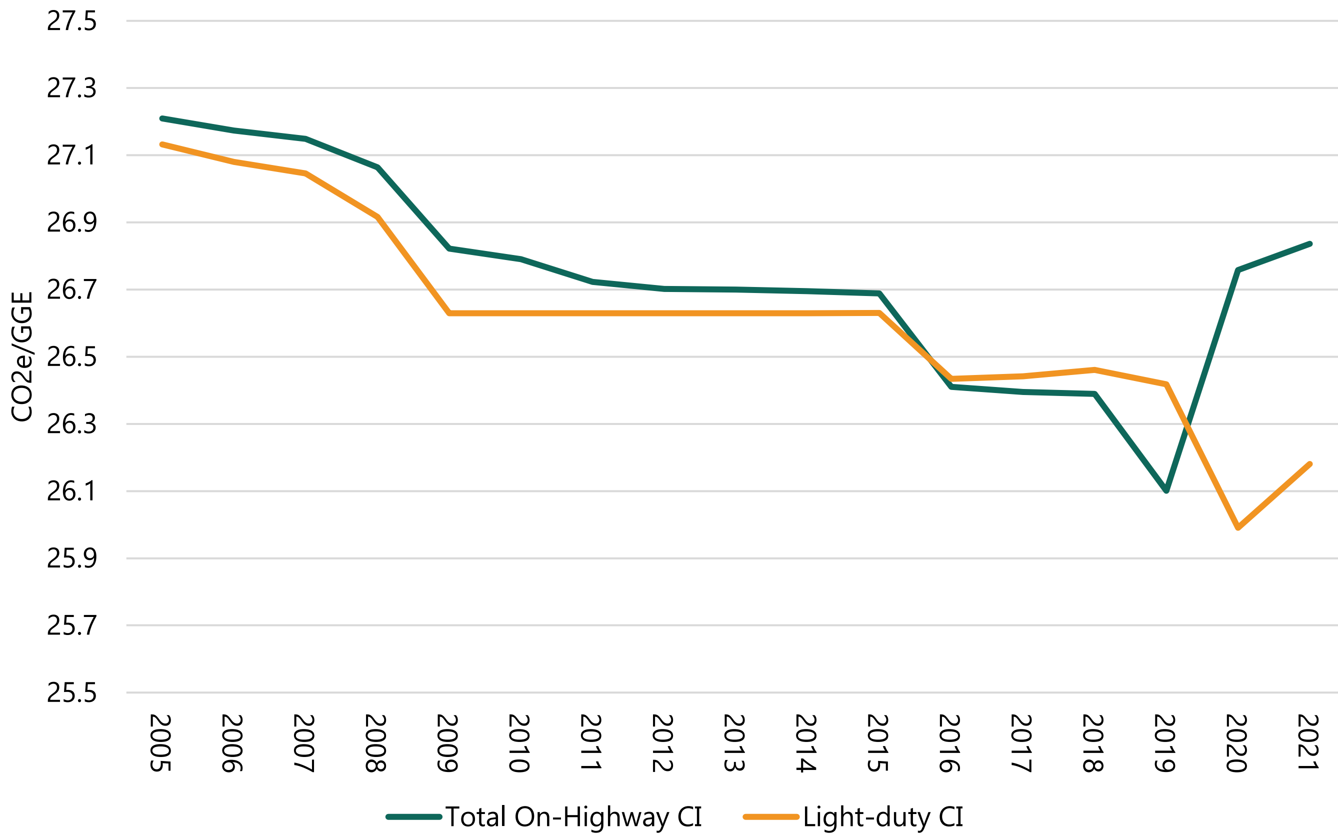


It is important to note that the increase in the transportation sector-wide carbon intensity is related only to an increase in total fuel consumption of diesel and gasoline, and not the actual carbon intensity of individual fuels. In fact, lower CI fuels are increasingly used in Oregon, and the work of the Clean Fuels Program to reduce the carbon intensity of Oregon's transportation fuels prevented an even higher jump in the consumption-weighted transportation sector CI shown above. More readily available lower carbon renewable fuels like biodiesel and renewable diesel will help ameliorate the effects of large consumption upticks, and the conversion to electric vehicles – battery and fuel cell electric – offers the most robust buffer against increasing consumption.

The pandemic also contributed to changes in the CI for fuels typically used by light-duty vehicles, including gasoline, ethanol, and electricity. Figure 5 below shows a steep decline in the CI for these fuels in 2020 represented by the orange line, rising slightly to 96.9 gCO2e/megajoule (26.2 pounds of CO2e/GGE) in 2021. The uptick in 2021 indicates light-duty fuel consumption may be trending back toward pre-pandemic levels. This contrasts with a steep rise in the combination of fuels typically used for all on-road vehicles[iii] shown as the green line, where increased diesel consumption caused a steep rise in CI to 99.4 gCO2e/megajoule (26.8 pounds CO2e/GGE) in 2021.[1] Diesel fuel consumption remains high, and it is uncertain if this trend will continue.

[iii] Gasoline, diesel, ethanol, biodiesel, renewable diesel, electricity, and natural gas.

Figure 5: Total On-Road and Light-Duty Only Carbon Intensities (lbCO2e/GGE)[15]



Policies Influencing Oregon's Transportation Carbon Intensity

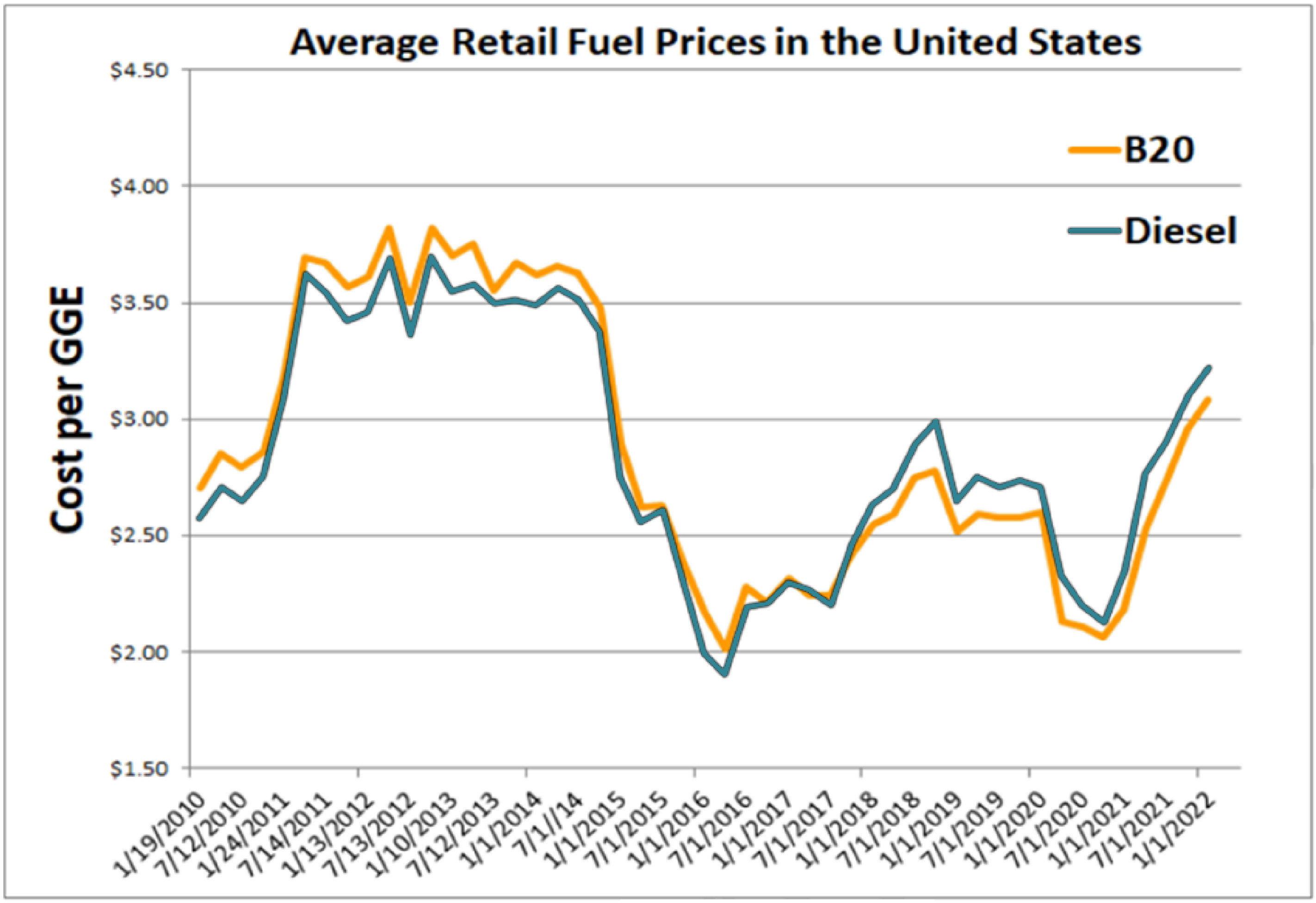
The Oregon Department of Environmental Quality's Clean Fuels Program is the policy most responsible for reductions in carbon intensity of transportation fuels; and since the program began in 2016, the sector-wide consumption weighted CI has decreased from 97.90 gCO2e/megajoule (26.43 pounds CO2e/GGE) to 96.92 gCO2e/megajoule (26.17 pounds CO2e/GGE). The program supports a market-driven credit and deficit system that incentivizes lower carbon fuel use. Fuels with CI values lower than the program standard for a given year earn credits under the program, while gasoline, diesel, and other high-carbon intensity fuels generate deficits. The standard is set to achieve a 10 percent reduction in CI by 2025 compared to the program's baseline,[iv] 20 percent by 2030, and 37 percent by 2035.[17]

The fuel costs at the pump for some lower carbon fuels can be less expensive than the fossil counterpart. For example, Figure 6 below shows that the national average retail price of B20 has been less expensive than the most commonly available diesel blend B5 since 2018.[18] In Oregon, that price may be even lower because of the potential for providers to monetize CFP credits that add to their revenues and potentially enable them to reduce costs at the pump. Although fuel contract costs are

[iv] The baseline year for the program is 2015 and the standard for that year represents 10 percent ethanol blended with gasoline and 5 percent biodiesel blended with diesel.

generally not publicly available, the Oregon Department of Administrative Services indicated that they pay the same or less for B20 than B5.[19] Some retailers in Portland blend more biodiesel with their B5 (up to 20 percent) in order to reduce the cost per gallon at the pump.[18]

Figure 6: Average Price of B20 and B5 (Diesel) in the United States: 2010 - 2022

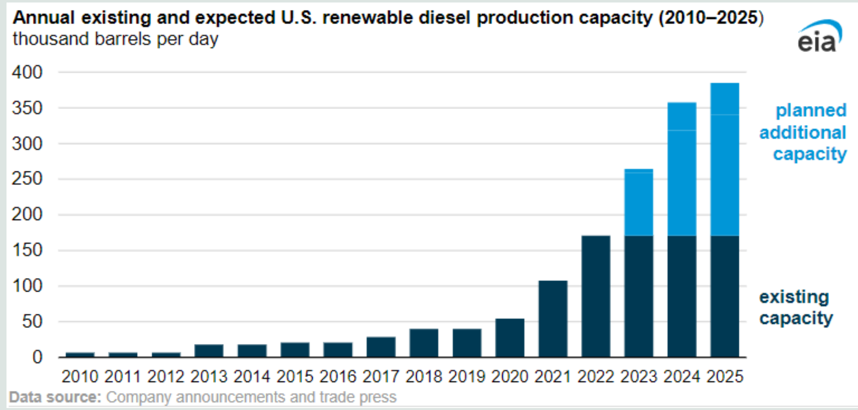


Source: afdc.energy.gov/data

The cost of renewable diesel, despite some supply limitations, has a similar cost to standard B5.[19] Investments from the revenues obtained through Oregon's CFP, and the certainty of demand it provides suppliers, supports economies of scale for lower carbon fuels, driving costs lower and increasing availability of lower CI fuels.

Renewable Diesel on the Rise

EIA estimates U.S. production capacity for renewable diesel could more than double from current levels by the end of 2025, based on several announcements for projects that are either under construction or could start development soon.[20] If all projects begin operations as scheduled, U.S. renewable diesel production capacity could reach 384,000 barrels per day (5.9 billion gallons per year) by the end of 2025.



As Clean Fuels Program carbon intensity targets reduce the carbon limits for Oregon's transportation fuels, specific fuels may change from generating credits to generating deficits. For example, fossil natural gas generates compliance credits under the current standard, but after the carbon intensity target is reduced in 2026, it will begin to generate deficits. Lower CI alternatives like renewable natural gas will remain below the standard and continue to generate credits throughout the program. Electricity will also remain below the standard and continue to decrease as Oregon's electric utilities decarbonize by 2040. Because they can be generated from zero-emission electricity, electricity and hydrogen currently have commercially viable pathways for a near-zero CI in the future.

City of Portland Renewable Fuel Standard

Similar to state and federal programs, the City of Portland has a Renewable Fuel Standard designed to reduce the carbon intensity and emissions of the fuel sold in the city.[21] The standard requires renewable fuel blends for gasoline and diesel. In December 2022, the Portland City Council updated this standard to phase in diesel blend requirements, with the goal of achieving a 99 percent renewable blend of all diesel fuel sales in Portland by 2030.[18] In addition to blend requirements, the new policy limits the lifecycle carbon intensity of biodiesel and renewable diesel to 40 gCO2e/MJ. A minimum carbon intensity serves to exclude higher carbon feedstocks that will not contribute sufficiently to reducing transportation CI. Some agricultural feedstocks, such as soybeans and canola, have higher lifecycle emissions because the process of growing and harvesting these feedstocks are more carbon intensive.[22] In 2021,

Minimum Biofuel Content Requirements

Fuel Type (by percent)	Current RFS	2020 (Reported)	2024	2026	2030
Renewable Fuel	5%	11%	15%	50%	99%
Diesel	95%	89%	85%	50%	1%

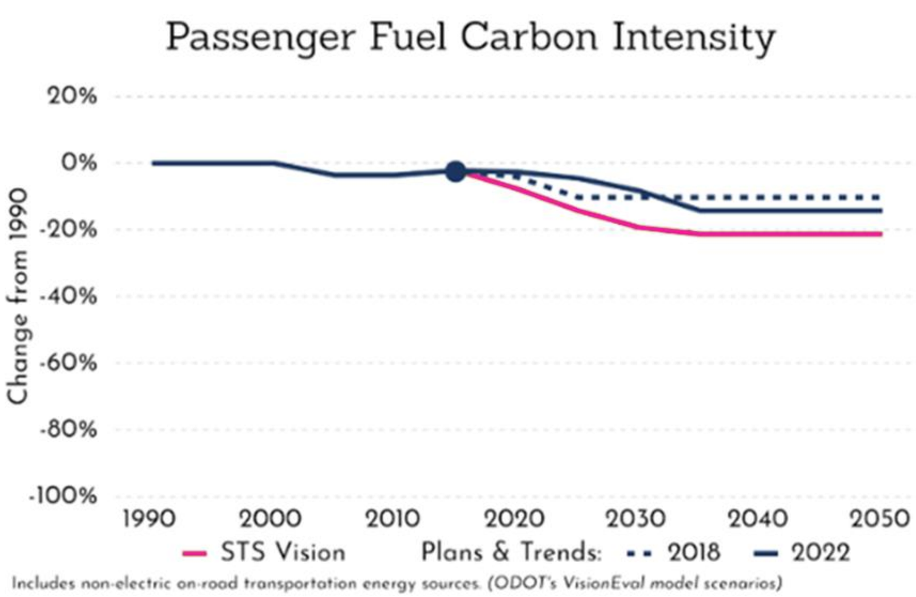
DEQ's Clean Fuels Program reported an average CI of 41.84 gCO2e/MJ for biodiesel and 36.98 gCO2e/MJ for renewable diesel, both near the city's 40 gCO2e/MJ threshold.[14]

The City of Portland also created an advisory group to evaluate the availability of clean fuel supply and recommend adjusting the blend requirements based on market conditions. This advisory group plays an important role in ensuring the standard can be achieved economically and technically. Addressing climate change to mitigate its effects requires governments to set robust goals to quickly reduce emissions. However, regular assessment of economic or technical feasibility of programs is critical ensure the transportation energy transition is achievable and does not overly burden consumers and businesses.

Future of Oregon's Transportation Fuels Carbon Intensities

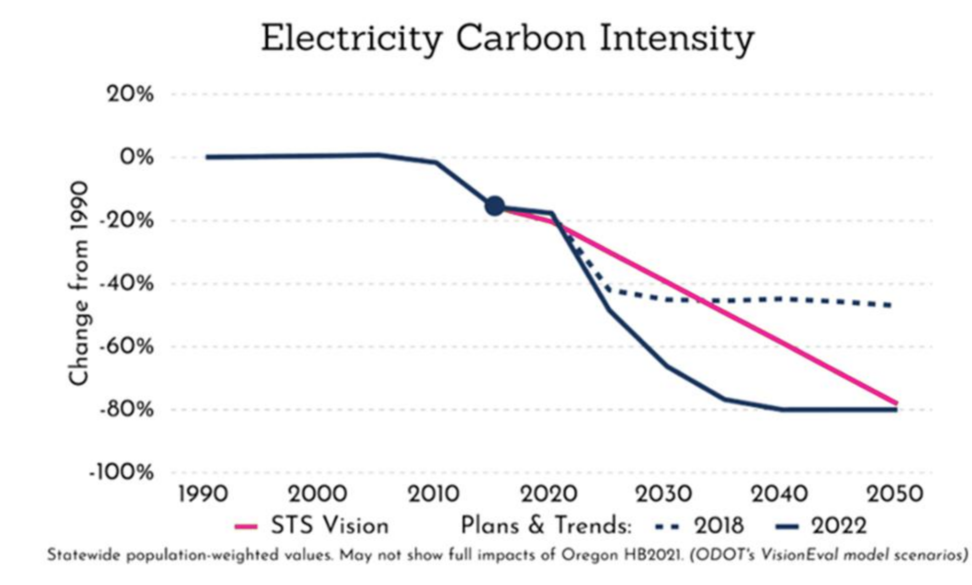
Existing policies put Oregon on track to make large reductions in transportation sector carbon intensities by 2050. The Oregon Department of Transportation modeled CI forecasts for liquid fuels and electricity through 2050 and found reductions for both types of fuel. Passenger Fuel CI shown in Figure 7 represents liquid fuels that power the light-duty sector, which is currently almost exclusively gasoline and ethanol. The dark blue line represents what ODOT modeled in 2018 and the dotted line is the updated model conducted in 2022. Reductions are modest here, largely because there are few existing non-electric options to blend with or replace gasoline.

Figure 7: Oregon Light-Duty Sector Liquid Fuels Carbon Intensity[23]



Transportation electrification is where the most significant gains are expected to be made in the light-duty sector CI. Figure 8 below shows the carbon intensity for Oregon's electricity mix since 1990 and forecasted through 2050. The large difference between ODOT's forecast in 2018 (dotted blue line) and the updated forecast in 2022 (solid blue line) was the passage of HB 2021, which sets goals to reduce the emissions associated with generating electricity consumed in Oregon. The CI for electricity used in electric vehicles is already significantly lower than gasoline, no matter which Oregon utility supplies the electricity. Decarbonization efforts from electric utilities will put a continuous downward pressure on the transportation sector CI.

Figure 8: Oregon Electricity Mix Carbon Intensity[23]



Other influences on Oregon's transportation fuel carbon intensity include existing and emerging state and local low-carbon fuels and electricity standards. Both California and Washington state have low-carbon fuels standards that will create competition for these fuels while further incentivizing producers to deliver these fuels along the entire west coast. Many western states have existing low-carbon electricity standards, many of which are becoming more stringent. The sum of these standards means electric utilities throughout the region will build more clean energy generation resources and compete for clean electricity on the market. Ongoing assessment of these and other activities is essential to inform policy development that keeps Oregon on track to lower the CI of transportation fuels and achieve greenhouse gas emissions reduction goals.

Conclusion

The carbon intensity of fuels used for light-duty vehicles is expected to decrease significantly in the next two decades, largely due to Oregon Clean Fuels Program targets that increase the availability of alternative fuels and the state's clean electricity standard. Similarly, the CI for fuels used for medium- and heavy-duty and non-road vehicles is also expected to decrease. Electrification is a critical piece of this transition, but this will need to be bolstered by lower carbon alternative fuels. Lower CI fuels, such as biodiesel and renewable diesel, play a critical role in reducing the CI for diesel vehicles while medium- and heavy-duty vehicle electrification technologies and fueling infrastructure can be developed and matured.

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Photo Credit: ODOT

This section evaluates the adoption and use of EVs to determine whether they put Oregon on course to meet its **greenhouse gas emissions reduction goals**.

EV Impacts on Greenhouse Gas Emissions

Key Takeaways

- While the transportation sector did not achieve its proportionate share of emissions reductions to help meet the state's 2020 greenhouse gas emissions reduction goal of 10 percent below 1990 levels; as a result of policies and programs put into place since 2020 which will accelerate the adoption of EVs, the transportation sector is on a better track to reduce emissions consistent with the state's greenhouse gas emissions reduction goals moving forward.
- Electric vehicles are expected to play a critical role in reducing Oregon's transportation sector emissions moving forward, and implementation of the policies and programs put into place since 2020, including Advanced Clean Cars II and Advanced Clean Trucks, are necessary to accelerate the adoption of EVs.
- Greenhouse gas emissions forecasts vary but indicate that there is still a lot of work to do to ensure the transportation sector achieves emissions reductions necessary to meet the state's greenhouse gas emissions reduction goals, particularly emissions from medium- and heavy-duty vehicles.

Introduction

Since the publication of the 2021 Biennial Zero Emission Vehicle report, the State of Oregon has taken actions to encourage the use of electric vehicles, including adoption of Advanced Clean Cars II and Advanced Clean Trucks. Oregon's most recent greenhouse gas emissions data (through 2021) show that the transportation sector is far from reducing its proportionate share of greenhouse gas emissions to meet the state's emissions reduction goals. However, thanks to newly adopted policies and programs, it is projected to be significantly closer to meeting the state's greenhouse gas goals moving forward — with a good deal of work still to do.

To help assess this progress in more detail, this chapter includes a brief explanation of motor vehicle GHG emissions; a summary of Oregon's GHG emissions reduction goals; discussion of the role of EVs in making progress toward the state GHG emissions reduction goals; and discussion of the role of EVs in making progress toward reducing emissions not captured by the state's GHG emissions reduction goals.

Motor Vehicles and GHG Emissions

Motor vehicles currently create substantial greenhouse gas emissions. Motor vehicle emissions primarily include tailpipe emissions and emissions from producing and distributing fuel to be used in the vehicles.

Tailpipe emissions occur when vehicles with internal combustion engines combust fuels to operate. Most EVs do not emit GHG emissions during operation; only plug-in hybrid electric vehicles have internal combustion engines, which are used to supplement a typically smaller battery. The hybrid nature of PHEVs and limited data on charging habits across PHEV owners makes it difficult to discern the precise amount of fuel they consume in aggregate—and therefore the amount of greenhouse gas emissions they release.[i]

Producing and distributing fuels also results in greenhouse gas emissions. For example, the production of gasoline requires extracting oil from the ground, transporting it to a refinery, refining the oil into gasoline, and transporting the gasoline to service stations. Each of these steps can produce additional GHGs. Likewise, for EVs, emissions can result from generation of the electricity used to power the vehicles, if the electricity is generated from fossil fuel sources.

Tailpipe emissions from combusting the fuel plus the upstream emissions from producing and distributing the fuel are referred to as "fuel-cycle emissions",[1] or in Oregon as the "lifecycle emissions" of transportation fuels.[2] Different fuels have different lifecycle emissions, which are usually assessed by calculating a carbon intensity value for each fuel. (See the *Carbon Intensity* chapter in this report and the lifecycle emissions discussion in this chapter for more details.)

The term "lifecycle emissions" is often more commonly understood to also include emissions from manufacturing and decommissioning vehicles, but these emissions are currently not as well tracked and evaluated.[3, ii]

Because petroleum-based transportation fuels (i.e., gasoline and diesel) account for the vast majority of fuel used in Oregon's vehicles, and Oregon imports all of its petroleum-based transportation fuels from production sites outside of Oregon, almost all motor vehicle emissions Oregon tracks toward its emissions goals are tailpipe emissions. Tracked by the state's Sector-Based Greenhouse Gas Emissions Inventory program, these are the most indicative of whether the state is on track to meet its GHG emissions reduction goals. At the same time, considering lifecycle emissions – which include substantial emissions outside the state – provides additional insight into opportunities to further reduce emissions.

Oregon's GHG Goals

The Oregon Legislature established the following GHG emissions reduction goals in 2007:[4]

- By 2010, Oregon will arrest the growth of greenhouse gas emissions and begin to reduce emissions;
- By 2020, Oregon will achieve greenhouse gas levels that are 10 percent below 1990 levels; and

[i] See page 25 in the 2021 Biennial Zero Emission Vehicle Report for more discussion of PHEV fuel usage.

[ii] Oregon's most recent consumption-based greenhouse gas emissions inventory (2015) which attempted to quantify these emissions, demonstrates that this is an important area for further inquiry. The Department of Environmental Quality expects to update this inventory by September 2024 per House Bill 3049 (2023).

- By 2050, Oregon will achieve greenhouse gas levels that are at least 75 percent below 1990 levels.

In 2020, Executive Order 20-04 added a 2035 interim goal and updated the 2050 goal:

- By 2035, Oregon will achieve at least a 45 percent reduction below 1990 levels.
- By 2050, Oregon will achieve at least an 80 percent reduction below 1990 levels.

In 2023, the Oregon Global Warming Commission **recommended a package of goal updates** as part of its Roadmap to 2030 including:

- By 2030, Oregon will achieve at least a 45 percent reduction below 1990 levels.
- By 2040, Oregon will achieve at least a 70 percent reduction below 1990 levels.
- By 2050, Oregon will achieve at least a 95 percent reduction below 1990 levels.
- By 2050, or as soon as practicable, Oregon will achieve net zero emissions and achieve and maintain net negative emissions thereafter.

The Oregon Global Warming Commission is a 25-member advisory group created by the 2007 Legislature through House Bill 3543.[5] Members are appointed and directed to develop long-term policy recommendations to prepare for, adapt to, and combat climate change. In 2023, the Legislature passed HB 3409 which expands the membership of the Commission to 35 members, provides additional duties and resources for the Commission, and changes the name to the Oregon Climate Action Commission effective January 1, 2024.[6] The Oregon Department of Energy provides staff support to the Commission.

EVs are expected to play an important role in achieving these goals.

Oregon's Motor Vehicle GHG Emissions and Progress Towards Oregon's GHG Goals

Assessing progress toward meeting Oregon's GHG emissions reduction goals requires a look at recent and historical emissions, as well as a forecast of future emissions.

Recent and Historical Emissions

Oregon tracks greenhouse gas emissions and progress toward its reduction goals using the Oregon Department of Environmental Quality's Sector-Based Greenhouse Gas Emissions Inventory. In alignment with guidance from the Intergovernmental Panel on Climate Change, Oregon's Sector-Based Greenhouse Gas Emissions Inventory measures emissions produced within Oregon by economic sector and emissions associated with the electricity used[iii] in Oregon. Oregon reports

[iii] Electricity emissions are inclusive of emissions associated with the generation and transmission of the electricity, regardless of where it is generated.

emissions for the transportation, residential and commercial, industrial, and agricultural sectors. Electricity emissions are spread across these sectors with emissions associated with the transportation sector not specifically identified except for a very small amount of electricity associated with the operation of light rail. As EVs become a larger portion of Oregon's vehicle stock, specifically identifying and assessing electricity emissions from the transportation sector will be important for understanding the full extent of transportation sector emissions.

Transportation has consistently been Oregon's largest sector of emissions, and transportation emissions have remained relatively steady over the last 30 years, as shown in Table 1 below. Following a slight pandemic-related decline in 2020, Oregon's transportation emissions rebounded in 2021 to 21.7 million MTCO2e,[iv] or 35 percent of the state's 2021 emissions (the most recent data available). Data for 2020 and 2021 are preliminary and marked in italics.[v]

Table 1: Oregon Emissions by in Million Metric Tons of CO2e by Sector: 1990-2021[vi]

Sector	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	*2020*	*2021*
Transportation	21	22	24	24	23	22	22	21	21	22	23	24	24	23	*20*	*22*
Residential & Commercial	16	20	23	22	23	22	20	21	21	21	20	20	20	22	*20*	*21*
Industrial	14	17	18	14	11	11	11	11	12	12	12	11	11	12	*12*	*12*
Agriculture	7	7	6	7	7	7	7	7	7	7	7	7	7	7	*7*	*7*
Totals	**57**	**66**	**70**	**67**	**64**	**62**	**60**	**60**	**60**	**63**	**61**	**62**	**62**	**63**	***58***	***61***

A closer look at the sector-based transportation emissions data shows that motor vehicle emissions – and specifically tailpipe emissions – account for most transportation sector emissions. About 87 percent of Oregon's transportation sector emissions were tailpipe emissions over the last decade, and about 90 percent in 2021. These emissions include carbon dioxide, methane, and nitrous oxide, and are emitted from a variety of types of vehicles – light-duty, medium- and heavy-duty, and offroad vehicles. To better assess progress, and inform action, these emissions can be broken down further into those associated with light-duty vehicles and those from medium- and heavy-duty vehicles.

[iv] Metric tons of carbon dioxide equivalent

[v] To provide the most current emissions estimates possible to decision makers, DEQ develops preliminary greenhouse gas estimates. These estimates are based on reported data that is often available up to a year earlier than data from EPA's State Inventory Tool. When an updated version of the inventory tool becomes available, DEQ updates and finalizes preliminary emission estimates.

[vi] In some cases, due to rounding, the totals reflected at the bottom of the Figure do not exactly equal the total of the individual sector values when added together in a given year.

Calculating Light-, Medium-, and Heavy-Duty Vehicle Emissions

DEQ's Sector-Based Inventory does not currently report total tailpipe emissions by vehicle type, so ODOE made some rough assumptions based on available data to determine emissions for different vehicle sectors. Calculations are based on using these transportation lines in DEQ's sector-based inventory: motor gasoline, distillate fuel, methane from passenger and heavy-duty vehicles, and nitrous oxide from passenger and heavy-duty vehicles. Lines referencing methane and nitrous oxide emissions from nonroad vehicles are not included in the specific calculations of light-duty vehicle and medium- and heavy-duty vehicle emissions. It is unclear how to attribute these emissions by vehicle type, these emissions are relatively small, and due to rounding do not change the percentage reported whether they are included in the calculation or not. The remaining transportation emissions, which are not apportioned to light-, medium-, or heavy-duty vehicles primarily include aviation emissions, emissions from the use of lubricants in the transportation sector, natural gas use in the transportation sector, and emissions from gases used in vehicle air conditioners.

The two biggest tailpipe sources of emissions are gasoline and diesel fuel.[vii] As a rough assumption, gasoline is largely used by light-duty vehicles and diesel fuel is largely used by medium- and heavy-duty vehicles. Using this assumption plus DEQ's sector-based inventory data on nitrous oxide and methane emissions for on-road vehicles, light-duty vehicles account for approximately 56 percent of the state's transportation emissions while medium- and heavy-duty vehicles account for approximately 34 percent. Over the last decade (2012-2021) the shares of light-duty and medium- and heavy-duty vehicle emissions have remained relatively constant, averaging approximately 56 percent and 31 percent, respectively.[viii]

As another means of comparison, in 2021 light-duty vehicles accounted for about 20 percent of the state's *overall* GHG emissions at about 12.1 MMTCO2e, and medium- and heavy-duty vehicles for about 12 percent at 7.4 MMTCO2e. Over the last decade (2012-2021) the shares of light-duty and medium- and heavy-duty vehicle emissions have remained relatively constant, averaging approximately 20 percent and 11 percent, respectively. Table 2 summarizes this data.

[vii] Respectively referred to as motor gasoline and distillate fuel in DEQ's Sector-Based Greenhouse Gas Inventory.

[viii] The last two years of data available appear to indicate an uptick in the proportion of medium- and heavy-duty vehicle emissions at 33 percent in 2021 and 34 percent in 2021. This seeming uptick could potentially be due to transportation behavior changes during the height of the COVID-19 pandemic; an increase in online shopping; and/or an increase in passenger vehicle EV adoption and should be watched closely moving forward.

Table 2: Tailpipe Emissions by Vehicle Type Compared to Total Sector-Based Transportation and Overall State GHG Emissions

		Transportation GHGs		Overall State GHGs	
	2021 Emissions (MMTCO2e)	% of transportation GHG emissions in 2021	Average % of transportation GHG emissions (2012-2021)	% of total overall state 2021 GHG emissions	Average % of overall state GHG emissions (2012-2021)
Light-Duty Vehicles (LDV)	12.1	56%	56%	20%	20%
Medium- and Heavy-Duty Vehicles (MHD)	7.4	34%	31%	12%	11%

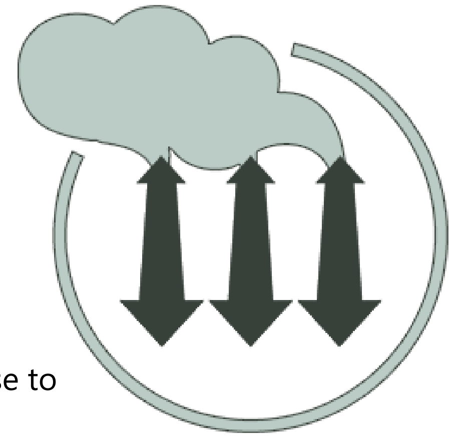
These emissions should continue to be tracked and analyzed to assess the relative effect of policies and programs on addressing emissions in the transportation sector. Emissions will need to decline dramatically to achieve the state's greenhouse gas emissions reduction goals. The Oregon Department of Energy is continuing to work with the Oregon Department of Environmental Quality and the Oregon Department of Transportation to identify whether and how the accounting shown above can be further refined for future Biennial Zero Emission Vehicle reports.

2020 Goal

Oregon had a statutory goal of reducing GHG emissions to 10 percent below 1990 levels by 2020. To help inform whether the transportation sector was on course to reduce the share of greenhouse gas emissions from motor vehicles consistent with that goal, a proportionate share of the necessary reductions was calculated for the transportation sector in the 2021 Biennial Zero Emission Vehicle report. It focused solely on emissions from light-duty vehicles. Using this method, the report found that 2019 emissions (the most recent data available at the time) indicated that emissions from light-duty vehicles were higher than their proportionate share of the 2020 GHG reduction target.[7] 2020 and 2021 emissions data are now available to compare.[ix]

The 2020 data confirmed that light-duty vehicle emissions were 10.9 MMTCO2e, higher than their proportionate share of 10.3 MMTCO2e. While this is not a large difference, it is important to note that 2020 emissions were likely lower because of the COVID-19 pandemic and associated economic shutdown. The 2021 emissions data show that light-duty vehicle emissions increased to 12.1 MMTCO2e, which is 17 percent above the light-duty sector's proportionate share of the 2020 goal.

[ix] The data that follows is calculated by multiplying the total emissions in 1990 by the 2020 goal and then applying the average percent of respective light-duty and medium- and heavy-duty emissions from 2012-2021 in Table 2 to that number.



Similarly, the 2020 and 2021 emissions data show that medium- and heavy-duty vehicle emissions were also higher than the 5.7 MMTCO2e proportionate share needed to meet the 2020 goal. In 2020, they were 6.8 MMTCO2e, almost 20 percent higher, and in 2021 emissions were even higher at 7.4 MMTCO2e – approximately 30 percent higher than their proportion of the 2020 goal.

Putting these together, in 2020 motor vehicle emissions were about 10 percent above where they should have been for the 2020 goal, and rose to 21 percent above in 2021. Table 3 below summarizes this data.

Table 3: Tailpipe and Total Sector-Based Transportation Emissions Compared to 2020 State GHG Goal Proportionate Share (2020-2021)

		2020		2021	
	2020 Goal Share (MMTCO2e)	**Actual (MMTCO2e)**	**% Above 2020 Goal Share**	**Actual (MMTCO2e)**	**% Above 2020 Goal Share**
Light-Duty Vehicles (LDV)	10.3	10.9	6%	12.1	17%
Medium- and Heavy-Duty Vehicles (MHD)	5.7	6.8	20%	7.4	30%
Total LDV and MHD	16.1	17.7	10%	19.4	21%
Total Transportation	18.6	19.6	5%	21.7	16%

In addition to the transportation sector, Oregon overall also substantially missed its 2020 goal – 13 percent above the 2020 goal and 19 percent above the 2020 goal in 2021.[8]

Despite transportation sector and motor vehicle emissions being well above the 2020 goal proportionate share, significant action was taken in the last couple of years on zero emissions vehicles (e.g., Advanced Clean Cars II and Advanced Clean Trucks rules), and other transportation emissions-related actions that this historical data does not reflect. The discussions of projections that follow incorporate many of these actions and provide a more optimistic outlook of expected progress moving forward.

Projected Emissions

Projecting emissions moving forward can help assess whether the transportation sector is on course to reduce the share of emissions consistent with the state's GHG goals. Using similar methodology as described above, the proportionate shares of motor vehicle emissions reductions necessary to meet the state's GHG goals can be calculated to provide a rough estimate of necessary reductions moving forward. In addition, as a result of recent efforts by the Oregon Global Warming Commission and ODOE, Oregon now has the most detailed forecast of emissions it has ever had. The forecast includes the expected reductions from Oregon's existing programs and regulations, providing a more detailed accounting of expected progress. Discussion of the anticipated proportionate share to meet state GHG goals is followed by a discussion of the emissions projections.

Proportionate Share of GHG Goals

Motor vehicle emissions will need to be significantly reduced to meet Oregon's GHG goals. Tables 4 and 5 below provide an estimate of where light-duty vehicles, medium- and heavy-duty vehicle emissions, and total motor vehicle emissions would need to be to meet their proportionate share of emissions reductions necessary to meet Oregon's greenhouse gas goals. Table 4 shows where emissions would need to be to meet the Executive Order 20-04 and statutory goals. Table 5 shows where these emissions would need to be to meet the updated state goals the Oregon Global Warming Commission recommended in its Oregon Climate Action Roadmap to 2030. Total transportation emissions are also included in both tables to provide a reference for where transportation sector emissions overall would need to be.

Table 4: Proportionate Share of Tailpipe and Total Sector-Based Transportation Emissions to Meet Oregon's EO 20-04 and Statutory GHG Emissions Reduction Goals

	EO 20-04		Statutory
	2035 *(45% below 1990)* **[MMTCO2e]**	**2050** *(80% below 1990)* **[MMTCO2e]**	**2050** *(75% below 1990)* **[MMTCO2e]**
Light-Duty Vehicles (LDV)	6.3	2.3	2.9
Medium- and Heavy-Duty Vehicles (MHD)	3.5	1.3	1.6
Total LDV and MHD	9.8	3.6	4.5
Total Transportation	11.4	4.1	5.2

Table 5: Proportionate Share of Tailpipe and Total Sector-Based Transportation Emissions to Meet the Oregon Global Warming Commission's Roadmap-Recommended GHG Emissions Reduction Goals

	OGWC Roadmap-Recommended		
	2030 *(45% below 1990)* **[MMTCO2e]**	**2040** *(70% below 1990)* **[MMTCO2e]**	**2050** *(95% below 1990)* **[MMTCO2e]**
Light-Duty Vehicles (LDV)	6.3	3.4	0.6
Medium- and Heavy-Duty Vehicles (MHD)	3.5	1.9	0.3
Total LDV and MHD	9.8	5.4	0.9
Total Transportation	11.4	6.2	1

While these provide useful reference points, emissions reductions are not exactly linear. For example, the transportation sector may need to do more than its proportionate share to meet Oregon's goals because other sectors may be harder to decarbonize. Similarly, within the transportation sector, light-duty vehicles may need to achieve more emissions reductions than medium- or heavy-duty vehicles, at least in earlier years as vehicle technologies for medium- or heavy-duty vehicles develop. As a result, the proportionate share methodology is only a rough reference point. Specific modeling and projections, such as those done by the Oregon Global Warming Commission, can provide more detailed insight.

The transportation sector may need to do more than its proportionate share to meet Oregon's goals because other sectors may be harder to decarbonize.

Transformational Integrated Greenhouse Gas Emissions Reduction Modeling

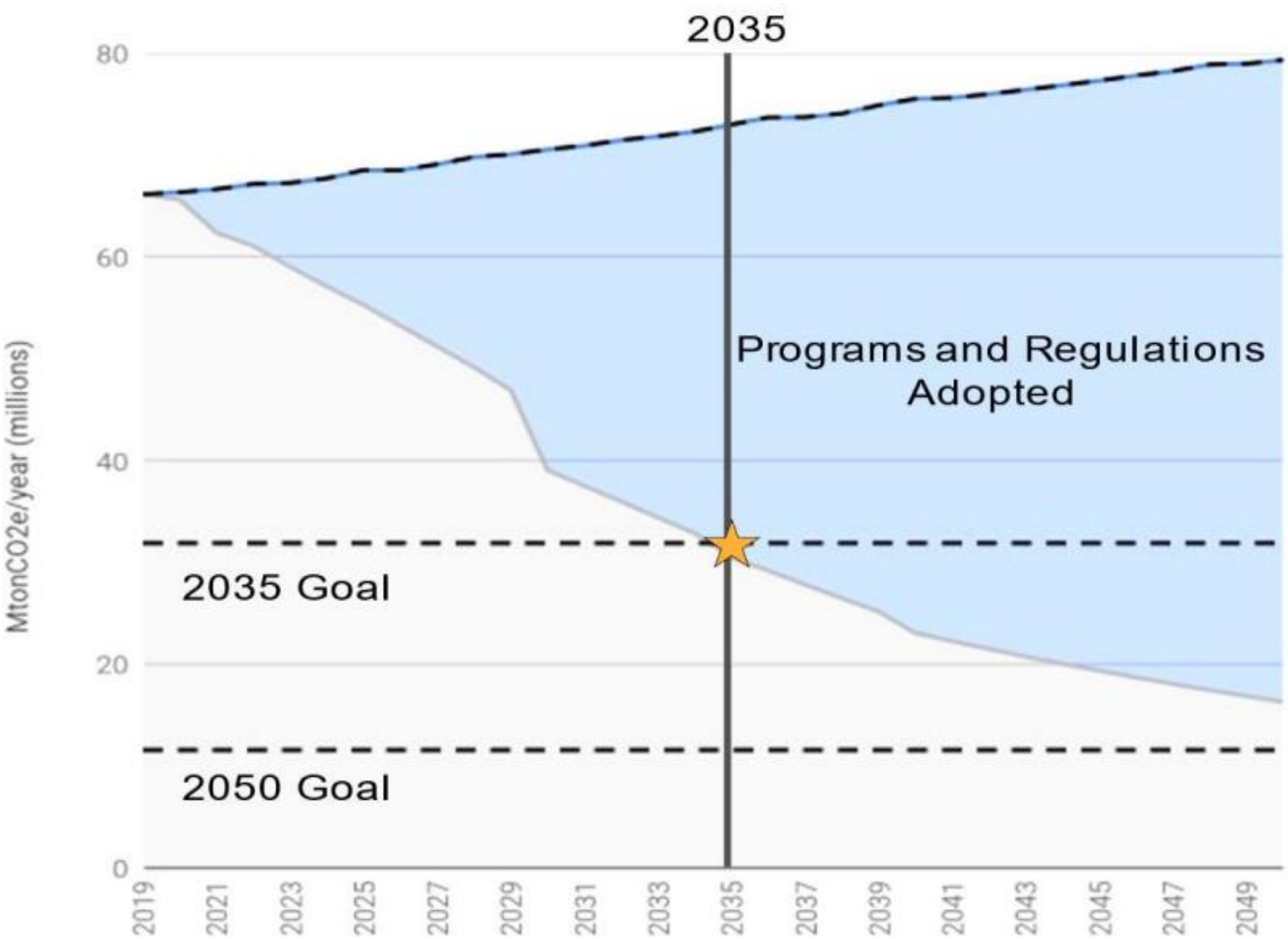
Recent modeling from the Oregon Global Warming Commission provides more insight on whether the transportation sector is on course to reduce the share of motor vehicle emissions consistent with Oregon's GHG goals. The OGWC, with grant funding from the U.S. Climate Alliance, worked with consulting firm Sustainable Solutions Group, or SSG, to develop an Oregon-specific model that forecasts the potential emission reductions from existing and new mitigation actions Oregon could take. This analysis was called the Transformational Integrated Greenhouse Gas Emissions Reduction Project and informed the Oregon Global Warming Commission's Oregon Climate Action Roadmap to 2030.[9] [10]

Executive Order 20-04 Goals and Existing Programs and Regulations

The TIGHGER analysis looked at overall statewide GHG emissions, including those from the transportation sector, and found that with continued implementation of existing programs and policies as planned, Oregon is on track to meet the Executive Order 20-04 2035 goal of at least 45 percent below 1990 levels.[11] In addition, the analysis found that these programs and regulations also have the potential to get Oregon most, but not all the way, to the EO 20-04 2050 goal.[12] Figure 1 below from the TIGHGER Project Report provides a graphic representation of this.[13]

In Figure 1, the Reference Case forecast, or Business-As-Usual (BAU) forecast, is represented by the dashed line on the top of the graph,[x] the forecasted GHG emissions reductions from the Programs and Regulations Adopted are represented by the blue wedge, and the middle-dashed horizontal line is the current 2035 GHG emission reduction goal amount (45 percent below 1990 emissions level). The graph demonstrates that with the programs and regulations adopted Oregon is on track to achieve its EO 20-04 2035 goal (denoted by the gold star).

Figure 1: TIGHGER-Projected Overall State GHG Emission Reductions from Programs and Regulations Adopted[14]



[x] The Reference Case, or BAU, starts with the Portland State University population forecast and the Oregon Employment Department's employment growth forecast through 2050; then adds the necessary residential buildings and commercial/industrial buildings to match those forecasts; and assumes the 2012 CAFE standards for fuel efficiency. For a more detailed explanation of how the BAU was developed see the presentation from the April 18, 2022 OGWC meeting.

Oregon's Existing Transportation Programs and Regulations are Critical to Achieving the State's GHG Goals. Fifteen state programs and regulations were modeled in the TIGHGER modeling.[xi, 15] Many of those specifically address reducing motor vehicle emissions or support these reductions. These include:

- Climate Protection Program
- Clean Fuels Program
- Clean Fuels Program Expansion
- Advanced Clean Cars I
- Advanced Clean Cars II
- Advanced Clean Trucks
- Clean electricity law (HB 2021)

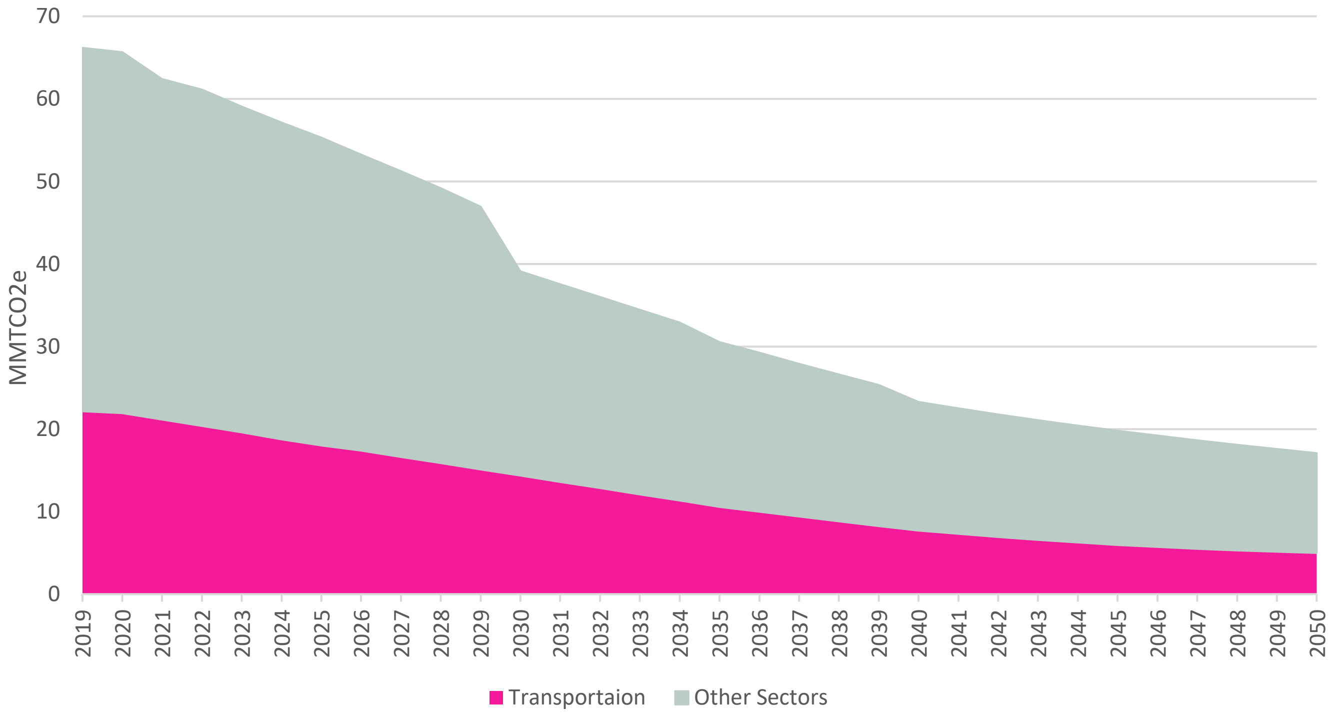
The emissions reduction contributions of these programs and regulations are detailed further in the TIGHGER Project Report.[16] In addition to the specific programs and regulations evaluated as part of the analysis, there are several other existing state programs and regulations that play an important role in reducing emissions either directly or indirectly but could not be analyzed in the TIGHGER analysis for a variety of reasons. For example, the Department of Land Conservation and Development's Climate-Friendly and Equitable Communities program provides direct and indirect emissions reduction benefits through local land use and transportation changes, and enables conditions for advancing transportation options that reduce emissions.

As the Oregon Global Warming Commission recommended in its Oregon Climate Action Roadmap to 2030, to achieve the state's GHG goals, Oregon's existing programs and regulations need to be implemented and operated as planned with necessary staffing and resources.[10] In addition, as the OGWC noted, many of these programs and regulations were put into place recently and have significant implementation and compliance work ahead. The OGWC's Roadmap Recommendations also highlighted the need for complementary actions (e.g. new or additional rebates for the purchase of electric vehicles) that can help facilitate, accelerate, or maximize their implementation. Further, the OGWC noted the importance of interagency coordination and partnerships – such as the Every Mile Counts multi-agency partnership between the Oregon Department of Transportation, DEQ, DLCD, and ODOE to implement Oregon's Statewide Transportation Strategy.

[xi] One federal program – the CAFE standards for cars and trucks – or Corporate Average Fuel Economy, expressed in miles per gallon (MPG) and most recently updated in March 2022, was also included in the modeling and is particularly relevant to motor vehicle emissions.

Using the emissions reductions from the Programs and Regulations Adopted, Figure 2 below details out the emissions reductions expected for the transportation sector represented as the pink part of the wedge. The Figure shows that transportation emissions would see significant reductions over time.

Figure 2: TIGHGER-Projected Programs and Regulations Adopted Emissions Reductions with Transportation Sector Highlight[17]



According to the modeling results, emissions from the transportation sector would be reduced to approximately 10.6 MMTCO2e in 2035 and to approximately 5 MMTCO2e in 2050.

TIGHGER Programs and Regulations Adopted Modeling vs. Proportionate Share – 2035 and 2050.

While the TIGHGER modeling results are more precise than the proportionate share calculations in Table 4, comparing the two can provide an additional data point to further triangulate whether the transportation sector is on track to meet the EO 20-04 GHG emissions reduction goals. Using the proportionate share calculation as reported in Table 4, transportation emissions would need to be at 11.4 MMTCO2e in 2035. According to the TIGHGER modeling, in 2035, transportation emissions would be approximately 10.6 MMTCO2e.[18] So, the transportation sector would be doing a little more than its proportionate share by 2035.

On the other hand, more work would be needed to meet the proportionate share in 2050. Using the proportionate share calculation as reported in Table 4, transportation emissions are expected to be approximately 4.1 MMTCO2e in 2050. According to the TIGHGER modeling, in 2050, transportation emissions would be approximately 5 MMTCO2e.[19]

The TIGHGER modeling generated a host of further detailed transportation data that ODOE, ODOT, and DEQ will work together to assess, including data projections by vehicle type and EV vehicle registrations over time.[20] The Oregon Global Warming Commission plans to update the TIGHGER modeling using similar forecasting on a biennial basis – providing a regular source of data to help inform future Biennial Zero Emission Vehicle Reports.

Beyond the data provided for the EO 20-04 goals, the TIGHGER modeling also ran scenarios to achieve the EO 2035 goal in 2030. Those results are discussed in the Roadmap-Recommended Goals section that follows.

Roadmap-Recommended Goals

Recognizing that the best available climate science continues to indicate the need to go further and faster, the TIGHGER analysis specifically assessed accelerating achievement of the EO 20-04 2035 goal to 2030.[21] This analysis, along with additional research by the OGWC, ultimately informed the Roadmap-recommended emission reduction goals of 45 percent below 1990 levels by 2030, 70 percent below 1990 levels by 2040, and 95 percent below 1990 levels by 2050.[22, xii]

The TIGHGER analysis found the accelerated goal would be achievable with a suite of additional climate actions — and there are substantial economic and health cumulative net benefits from accelerating the 2035 goal to 2030 (more than $120 billion through 2050 and beyond).[9]

Understanding that there are different pathways across multiple sectors to achieve the accelerated goal, the OGWC explored two scenarios of grouped actions: an Electrification Scenario and an Alternative Fuels Scenario. Modeling determined that a scenario relying on alternative fuels alone

[xii] The Roadmap also recommended achieving net zero emissions by 2050 or as soon as practicable and achieving net negative emissions thereafter.

could not meet the accelerated goal (i.e., there was insufficient renewable natural gas and renewable hydrogen to meet the goal). As a result, the OGWC developed a Hybrid Scenario in its place, which augmented alternative fuels actions with electrification actions. The Electrification Scenario focused exclusively on energy efficiency and incentivizing efficient electric equipment. Given the need for numerous electrification actions in both scenarios, most actions were common to both scenarios with about a dozen actions unique to each. A total of 35 actions were included across the scenarios – 23 common actions, and 12 unique actions (five in the Hybrid Scenario and seven in the Electrification Scenario).[xiii]

Eight of the actions specifically deal with transportation and were common to both scenarios:

- Implement the Medium and Heavy Duty Zero Emission Plan by 2035 (beyond Advanced Clean Trucks) (Fuel shares of: 60 percent EV, 20 percent Hydrogen, 20 percent Biodiesel; and Hybrid has 10 percent Fuel Cell EVs)
- Increase Amtrak Ridership
- Carshare Increases in Urban Areas by 2035
- 50 percent of New Off-road Vehicles Sales (farm, forestry, construction, and recreation) are EVs by 2035, 100 percent by 2050
- 100 percent of New Transit Buses are EVs by 2035
- Implement an Electric Micro-Mobility Strategy, E-Bikes & E-Scooters Gain 10 percent Mode Share in Portland Metro and Eugene Counties by 2035
- Congestion Pricing Achieves a 10 percent Transport Mode Shift Away from Private Cars to Transit in Multnomah, Lane, and Washington Counties by 2035
- Transfer 10 percent of Medium Duty Vehicle Miles Traveled to Light Duty/Electric Micro-Mobility in Urban Counties by 2035

There were also some land-use actions that could help reduce transportation emissions (e.g., Higher Residential Density in Urban Areas).

The TIGHGER analysis found that both the Electrification and Hybrid scenarios provide pathways to achieve the accelerated 2030 goal.[23] In addition, the TIGHGER projection shows that both scenarios come close to achieving the 2040 goal, but more work is needed to get to the new 2050 goal. See Figure 3 below from the Oregon Global Warming Commission's 2023 Biennial Report comparing the TIGHGER Scenario projections and the Roadmap-recommended goals.[xiv] Given the need for urgent climate action, the fact that *all* the identified actions in each scenario are needed to achieve the 2030 accelerated goal, and the majority of the actions that are common to each scenario, the OGWC recommended moving forward *all* actions from both scenarios and provided specific recommendations for doing so.[xv]

[xiii] For more details on the scenarios and actions see the TIGHGER Project Report – Pages 12-19.

[xiv] This Figure appeared as Figure 6 in the Oregon Global Warming Commission's 2023 Biennial Report to the Legislature.

[xv] See Roadmap Recommendation 3.

Figure 3: TIGHGER-Projected State GHG Emissions Reductions Scenarios Compared to Roadmap-Recommended Goals[24]

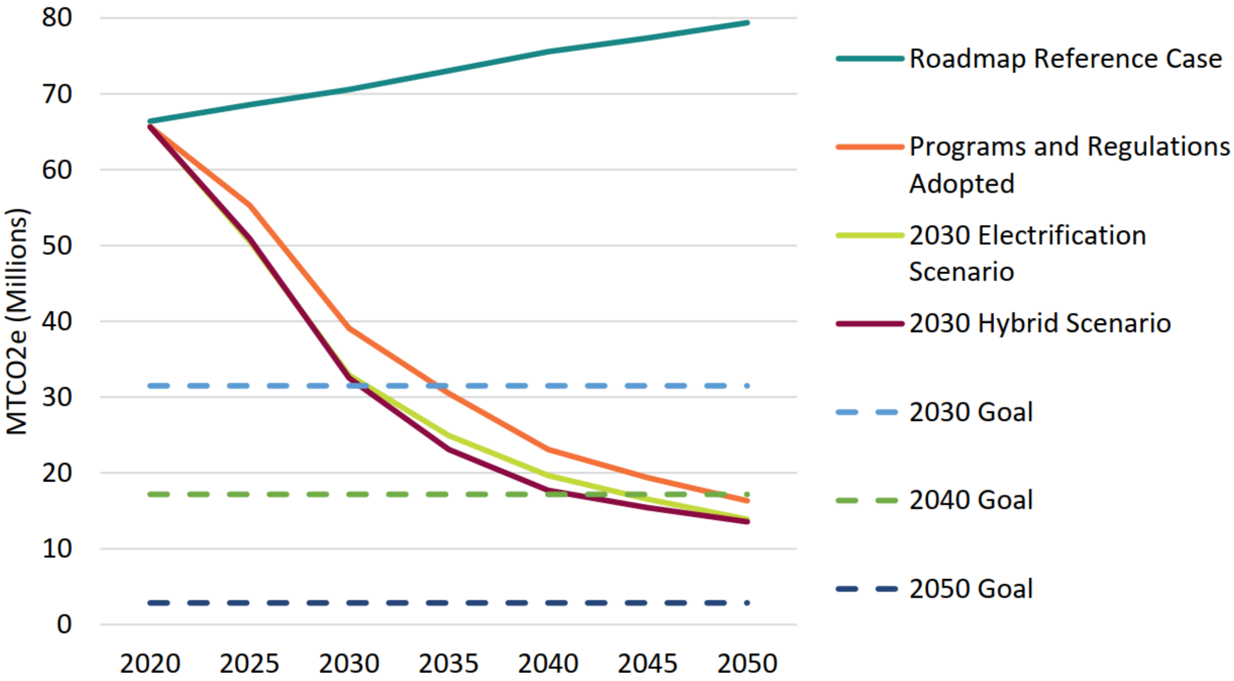
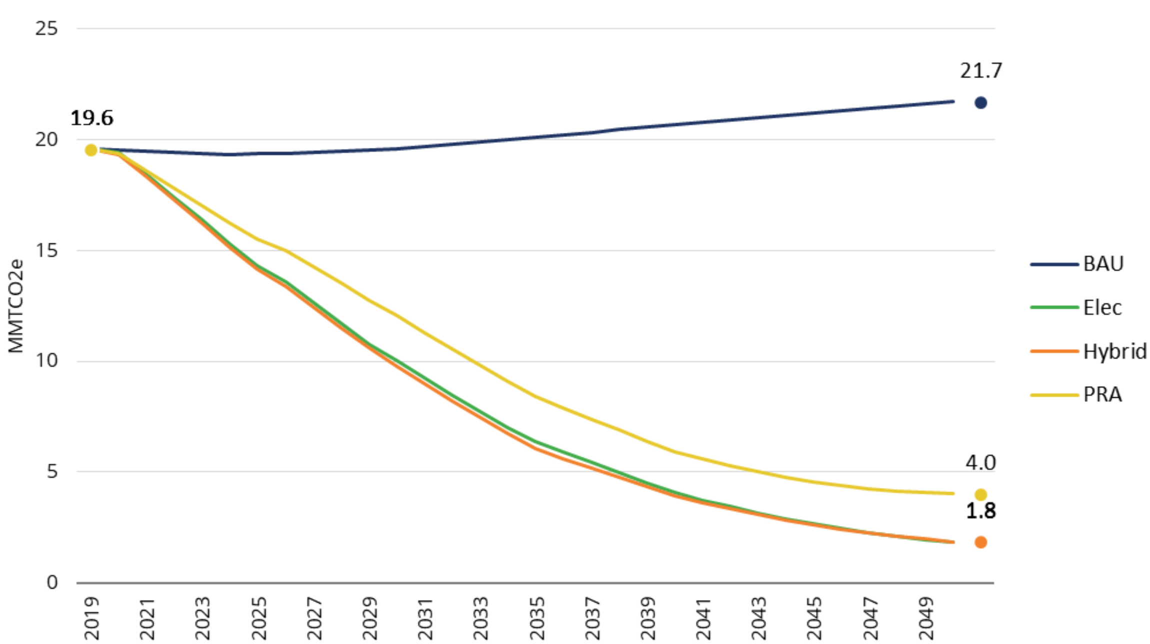


Figure 4 below shows how the scenarios with the additional actions would reduce emissions from the transportation sector compared with the Programs and Regulations Adopted scenario previously described above.

Figure 4: Comparison of Projected Transportation Emission Reductions in TIGHGER Scenarios[25] [xvi]



[xvi] This has a different starting point for transportation emissions than Figure 2 above. Aviation emissions are not included in this Figure which is how Sustainable Solutions Group provided this data to ODOE. For the purposes of this report, this provides a closer approximation to just motor vehicle emissions.

According to the data, transportation emissions in the accelerated scenarios would reach between approximately 9.8 MMTCO2e and 10 million MMTCO2e in 2030, between approximately 3.9 MMTCO2e and 4.1 MMTCO2e in 2040, and approximately 1.8 MMTCO2e in 2050.[17]

TIGHGER Modeling vs. Proportionate Share – 2030, 2040, and 2050.

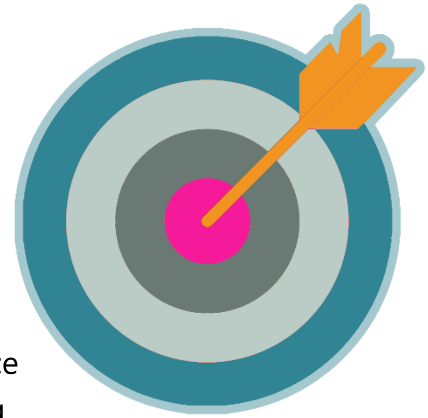
While the TIGHGER modeling results are more precise than the proportionate share calculations in Table 5, comparing the two can provide an additional data point to further triangulate whether the transportation sector is on track to meet the *Roadmap*-recommended Goals. In this case, because aviation emissions are not included in the transportation emissions numbers underlying Figure 4, a more relevant comparison here would be to the Light-Duty Vehicle and Medium- and Heavy-Duty Vehicle line in Table 5 instead of overall transportation sector emissions.

Using the proportionate share calculation as reported in Table 5, motor vehicle tailpipe emissions would need to be 9.8 MMTCO2e in 2030. According to the TIGHGER modeling, existing programs and regulations adopted would reduce transportation emissions down to approximately 12 MMTCO2e in 2030.[26] According to the accelerated TIGHGER scenario modeling of additional actions in the Hybrid and Electrification scenarios, in 2030, transportation emissions would be between approximately 9.8 and 10 MMTCO2e, respectively.[27] So, with either accelerated scenario, the motor vehicle emissions would likely be on track to its proportionate share by 2030.

Using the proportionate share calculation as reported in Table 5, total motor vehicle tailpipe emissions would need to be at 5.3 MMTCO2e in 2040. According to the TIGHGER modeling, existing programs and regulations adopted would reduce transportation emissions down to approximately 5.9 MMTCO2e.[28] According to the TIGHGER Hybrid and Electrification accelerated scenario modeling, in 2040, transportation emissions would be between approximately 3.9 and 4.1 MMTCO2e, respectively.[29] So, with either accelerated scenario, motor vehicle emissions would likely be doing more than its proportionate share by 2040.

On the other hand, even with the additional policies and investments of these accelerated scenarios, more work would be needed to meet the proportionate share in 2050. Using the proportionate share calculation as reported in Table 5, motor vehicle tailpipe emissions would need to be at approximately 0.9 MMTCO2e in 2050. According to the TIGHGER modeling, existing programs and regulations adopted would reduce transportation emissions down to approximately 4.0 MMTCO2e.[30] According to the accelerated scenario TIGHGER modeling, in 2050, transportation emissions would be approximately 1.8 MMTCO2e.[31]

Summary of Goals Progress and Projections



Moving forward, the transportation sector is on a better track to reduce emissions consistent with the state's greenhouse gas reduction goals. While it did not achieve its proportionate share of reductions to help meet the state's 2020 goal of 10 percent below 1990 levels, policies and programs put into place since 2020, including Advanced Clean Cars II and Advanced Clean Trucks, will accelerate the adoption of EVs. The TIGHGER modeling projects that the transportation sector will reduce emissions consistent with achieving the EO 20-04 2035 goal, and getting most, but not all of the way to the EO 20-04 2050 goal. These projections rely on existing programs and regulations being fully implemented and operated as planned with necessary staffing and resources. To meet the Roadmap-recommended 2030, 2040, and 2050 goals, even more action will be needed in the transportation sector. The TIGHGER modeling identified a number of additional transportation-related actions, including some related to medium- and heavy-duty EVs, that can help make progress toward those goals.

Role of EVs in Reducing Lifecycle Greenhouse Gas Emissions

Analyzing transportation-related lifecycle emissions helps provide additional context regarding the role of EVs in reducing GHG emissions and progress in reducing transportation-specific emissions. As noted earlier, in addition to tailpipe emissions, lifecycle emissions also account for the often-substantial emissions from the extraction, transport, refinement, and distribution of fuels. And, unlike tailpipe emissions, many of the other components of lifecycle emissions primarily occur outside of the state and are not captured by the sector-based inventory used to track progress on Oregon's greenhouse gas reduction goals.

Oregon's lifecycle emissions accounting facilitates an apples-to-apples comparison of fuels, including electricity. Oregon's Sector-Based Greenhouse Gas Emissions Inventory accounts for emissions inside the state. There is one important exception to this – electricity. The sector-based inventory covers emissions from both in and outside Oregon for the generation of electricity consumed in Oregon.[32] However, because the sector-based inventory does not distinguish between electricity used for transportation and electricity used for other purposes, it cannot be readily used to calculate electricity emissions from the transportation sector. Further, because the inventory does not calculate the lifecycle emissions of other transportation fuels, even if the electricity transportation fuel portion could be parsed out it would not provide an apples-to-apples comparison. Fortunately, data from Oregon's Clean Fuels Program, which assesses the lifecycle emissions of electricity and other transportation fuels, can be used to compare emissions.

Different fuels have different lifecycle emissions. Oregon's Clean Fuels Program measures a fuel's carbon intensity across the entire "life" of a fuel, including what it's made from, how it's made, how it's transported to Oregon, and how it's used to power the vehicles.[33] See the *Carbon Intensity* chapter for more details.

Assessing progress on lifecycle emissions requires a look at current lifecycle emissions as well as a forecast of future lifecycle emissions.

Recent Lifecycle Emissions

Using Oregon Clean Fuels Program data, ODOE calculated lifecycle emissions of the transportation sector to be 32.2 MMTCO2e in 2021 (the most recent data available). Lifecycle emissions from gasoline and diesel constitute about 86 percent of the total lifecycle emissions in 2021. [34] When compared with the 2021 transportation sector-based emissions of 21.7 MMTCO2e from the sector-based inventory represented in Table 1 above; lifecycle emissions constitute approximately 49 percent more emissions. This difference also includes emissions from biofuels, which are not accounted for in the sector-based inventory.

This data reinforces the need to also track and consider lifecycle emissions when considering how to reduce greenhouse gas emissions. While many of these emissions occur outside Oregon, climate change is a global problem.

ODOT Modeling Projections

The Oregon Department of Transportation has been tracking Oregon's transportation greenhouse gas emissions since 2012. Recent analysis in 2022 helps shed additional light on Oregon's progress toward reducing emissions.[35] Unlike the TIGHGER analysis described in the previous section, ODOT also included lifecycle emissions in its analysis and focused only on ground transportation. ODOT used the state's EO 20-04 goal as a benchmark for the analysis, although it included emissions beyond what is tracked in the sector-based inventory. Because ODOT included lifecycle emissions and the TIGHGER modeling did not, the results are not directly comparable, but still instructive. Further, the ODOT and TIGHGER modeling made different assumptions about the pace and scale of actions, with ODOT projecting more gradual market adoption than TIGHGER.[xvii]

ODOT uses the VisionEval modeling tool to project future GHGs from Oregon transportation. It's a long-range strategic planning tool that forecasts how community development and transportation investment choices, in addition to detailed assumptions on vehicle and fuel regulations, could influence planning goals, land use goals, and other community livability outcomes.[xviii] ODOT

[xvii] ODOT scenarios make more gradual assumptions about adoption given uncertainties in funding and incentives, regulation and implementation pathways, and market trends such as supply limitations and post-COVID impacts.

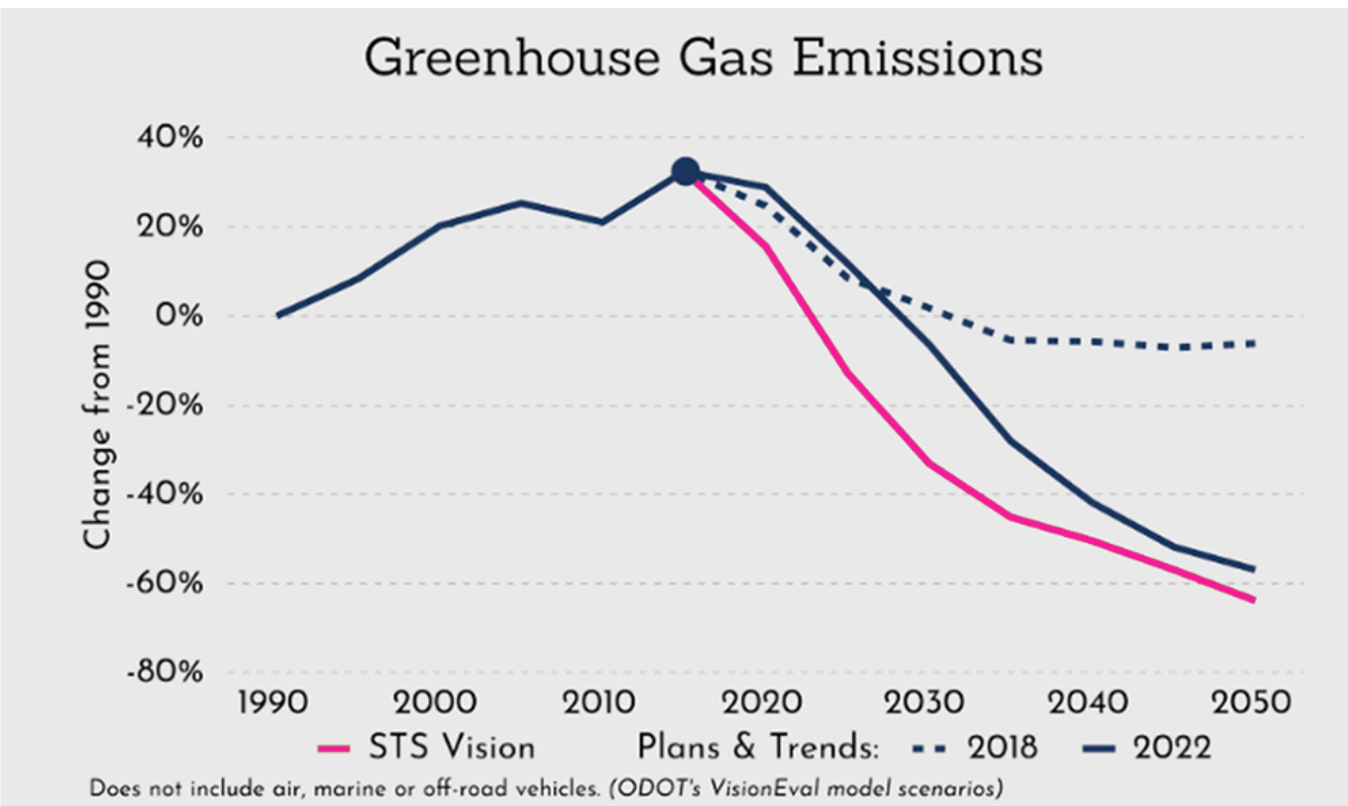
[xviii] Assumptions for the STS Vision scenario are reflected in Appendix 5 of the Statewide Transportation Strategy. The Plans & Trends scenario values are updated over time; 2022 assumptions are noted in the Oregon Transportation Emissions Website Progress page. More information about the VisionEval tool, including national awards (ODOT Tools webpage), and how it is used in Oregon can be found on the ODOT website.

developed and maintains two scenarios in their model, which make assumptions about policies and investments within Oregon's eight largest metropolitan planning areas (MPOs) and statewide.

1. **STS Vision** – The preferred set of policies from a two-year stakeholder process to meet statewide GHG reduction goals, published in the 2012 Statewide Transportation Strategy (STS).
2. **Plans & Trends** – The current set of policies reflected in adopted plans and market trends, updated in 2018 and 2022.

ODOT's 2022 modeling forecasts that under current state programs, policies, and laws, Oregon transportation greenhouse gas emissions reductions will reach nearly 60 percent below 1990 emission levels by 2050.[36] That's short of the state's 80 percent reduction goal, but a big improvement from the prior analysis in 2018. The progress is largely due to the vehicle and fuel regulations of the last few years, many of which were highlighted above in the TIGHGER analysis discussion. Figure 5 below shows the GHG emissions reduction projections using the STS and existing plans and trends.

Figure 5: ODOT Forecast of Lifecycle Ground Transportation Emissions Reductions[37]



The chart indicates that transportation emissions reductions based on ODOT's more gradual assumptions of current plans and trends are projected to fall short of the Executive Order 20-04 goal markers. Instead of 45 percent below 1990 levels, ground transportation emissions would be reduced to approximately 30 percent below 1990 levels. If the state were to achieve the full STS Vision scenario, ground transportation emissions would potentially reach the EO 20-04 goal in 2035, but still fall short of the 2050 goal with an approximately 65 percent reduction instead of 80 percent. If one were to apply the OGWC Roadmap-recommended goals, even more work would need to be done.

To provide additional insight, ODOT collaborated with ODOE, DLCD, and DEQ to analyze, review, and report on two objectives (clean up each mile and reduce vehicle miles) and identified progress needed in six categories – all of which are necessary to reduce transportation emissions:

- Vehicle Technology
- Fuel Technology
- Land Use
- Transportation Options
- Pricing, Funding and Markets
- System Operations

Given the focus of this report, only progress on vehicle technology is discussed in more detail below.

Table 6 below provides a general sense of how the state is projected to do on vehicle technology (EV adoption and fuel efficiency) across vehicle types. Progress is assessed based on current plans and trends. ODOT and its state agency partners indicate that passenger vehicles are largely on track, while transit and delivery vehicles are not on track in the near-term but are expected to make strong progress toward the state's 2050 goal. Long haul trucks are not on track in the near-term or long-term and much more work will be needed.

Table 6: Oregon Assessment of Expected Vehicle Technology (EV adoption and fuel efficiency) Progress by Vehicle Type[38]

Vehicle Technology	2025	2050
Passenger vehicles	strong progress towards goals	meets or exceeds goals
Transit vehicles	little or no progress towards goals	strong progress towards goals
Delivery vehicles	little or no progress towards goals	strong progress towards goals
Long haul trucks	little or no progress towards goals	little or no progress towards goals
Rail, ship, aviation yard equipment	little or no progress towards goals	strong progress towards goals
Planes, boats, trains	*	*

Key: meets or exceeds goals; strong progress towards goals; little or no progress towards goals; moves away from goals

* = not tracked

To help inform additional efforts moving forward, state agency partners identified barriers to progress and how Oregon can improve efforts for these different vehicle types.[39] As one example, state agencies recommended that the state could help transit agencies and fleet owners apply for federal and state diesel emission mitigation grants for lower emission fuel vehicles.[40]

Summary of Progress on Lifecycle Emissions

ODOT projects that ground transportation lifecycle emissions will decrease approximately 60 percent by 2050. While this assessment is short of the EO 20-04 2050 goal marker, it is a huge improvement from the previous trajectory projected by ODOT in 2018. That improvement is largely due to recent vehicle and fuel policies and programs including DEQ's Advanced Clean Cars II, Advanced Clean Trucks, and expansion of the Oregon Clean Fuels Program. But even more work is needed to reduce lifecycle emissions consistent with the EO 20-04 GHG emissions reduction goal markers and the Oregon Climate Action Roadmap to 2030-recommended goal markers.

Conclusion

EVs are expected to play a critical role in reducing Oregon's transportation sector emissions moving forward, and implementation of the policies and programs put into place since 2020, including Advanced Clean Cars II and Advanced Clean Trucks, are necessary to accelerate the adoption of EVs. While the transportation sector did not achieve its proportionate share of emissions reductions to help meet Oregon's 2020 greenhouse gas reduction goal, it is now on a better track to reduce emissions consistent with the state's GHG reduction goals – but there is still a good deal of work to do.

Since the 2021 Biennial Zero Emission Vehicle Report, specific modeling has been done that is instructive on progress. The Oregon Global Warming Commission's TIGHGER modeling provides a look across sectors at achieving the state's GHG goals. ODOT's transportation-specific modeling incorporates lifecycle emissions to provide another lens. The modeling results are not directly comparable because they incorporate different amounts and types of emissions and make different assumptions about the pace and scale of actions; however, both models point to a few common themes:

1) Recent policies and programs such as Advanced Clean Cars II and Advanced Clean Trucks have put Oregon on a better track to meet its goals. These and other existing programs and policies are crucial to EV adoption and reducing emissions from motor vehicles to meet the state's GHG emissions reduction goals.
2) Whether transportation emissions are on track for reductions consistent with EO 20-04's 2035 goal as the TIGHGER model projects, or need more work as the ODOT modeling projects, substantial progress toward the goal is expected to be made. The Biennial Zero Emission Vehicle report is a key vehicle to report on transportation emissions data, ongoing progress tracking, and updated modeling results that will help inform action.

3) Additional actions are needed to reduce transportation emissions consistent with EO 20-04's 2050 goal, and the OGWC *Roadmap*-recommended 2030, 2040, and 2050 goals. While a suite of additional actions will be needed, a particularly key action is increasing EV adoption and use for medium- and heavy-duty vehicles as there is much more work to do for these particular vehicle types.

Consistent with Recommendation 3 in the 2021 Biennial Zero Emission Vehicle Report, ODOE plans to continue working with DEQ and ODOT to develop and refine methodologies for assessing the effects of EV adoption on Oregon's greenhouse gas emissions to provide consistent reporting across state agencies and the best possible data to inform decisionmakers.

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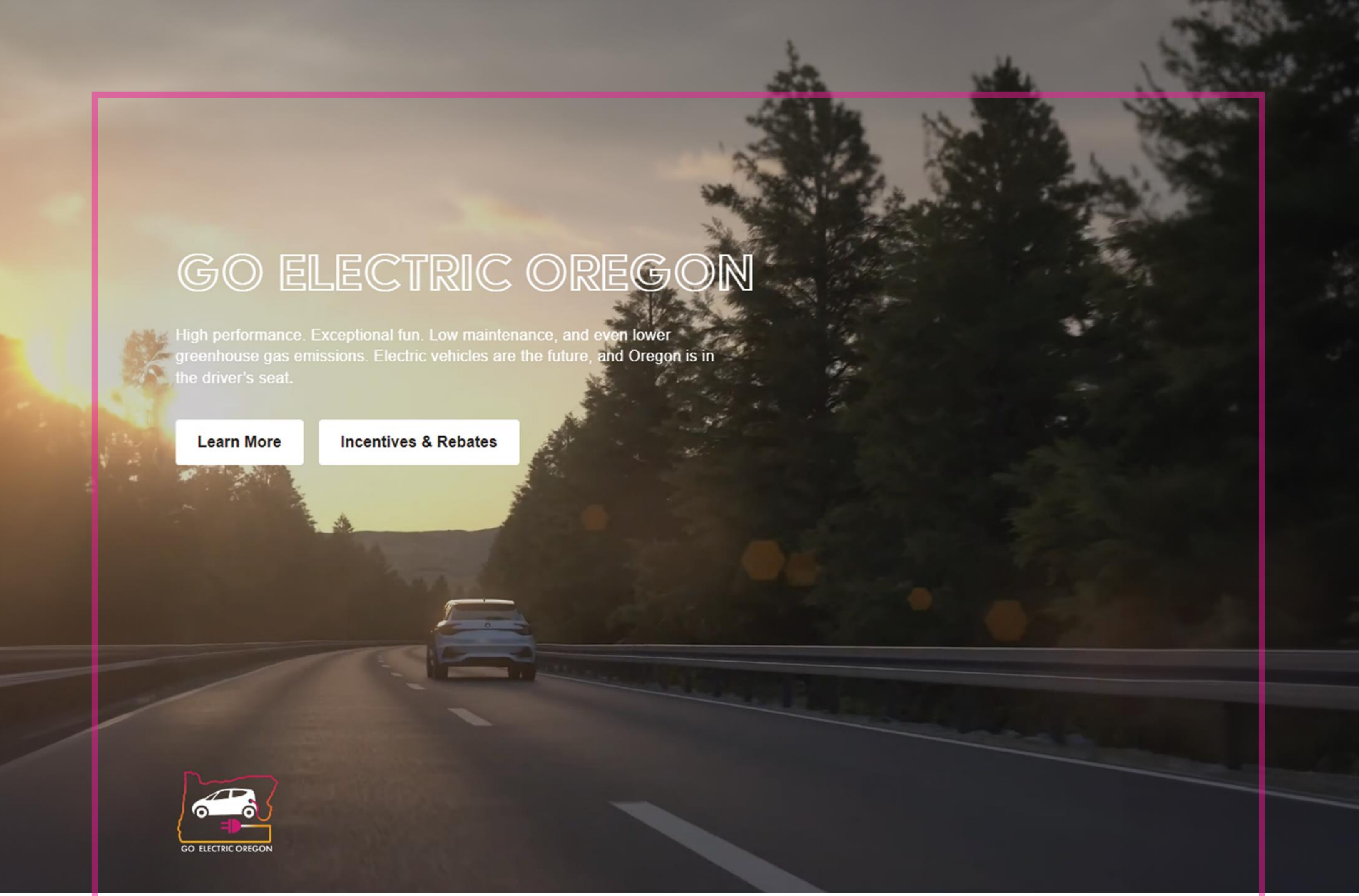


GoElectric.Oregon.gov Home Page

Oregonians' **awareness of motor vehicle options**, the benefits of owning zero-emission vehicles and the true costs of motor vehicle ownership.

Oregonians' Awareness of Electric Vehicle Options and Benefits

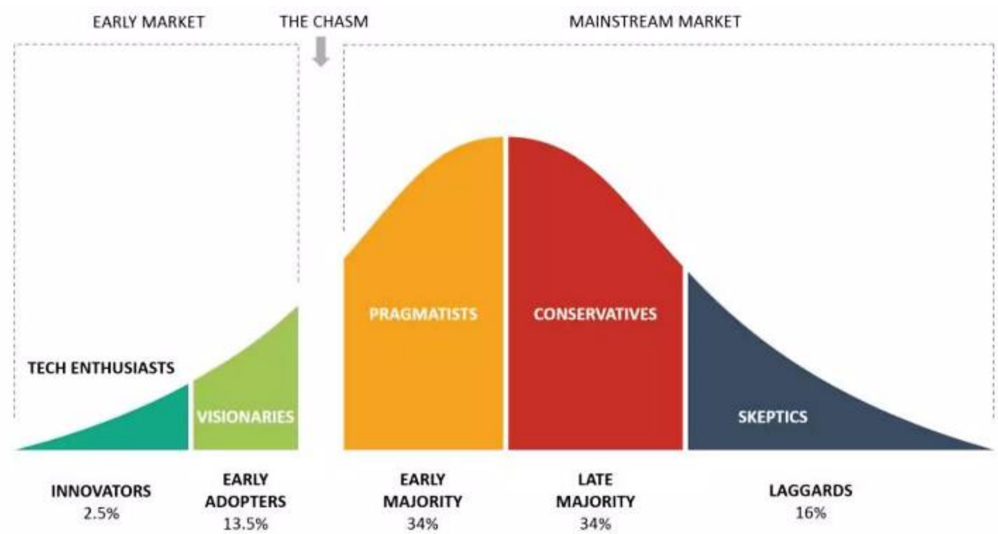
Key Takeaways

- Oregonians have a higher degree of electric vehicle awareness than people in most states.
- People who talk to other EV drivers about their experience or test drive an EV are more likely to purchase an EV as their next vehicle.
- Drivers are exposed to EVs and their benefits primarily through interactions between family, friends, neighbors, and co-workers.
- Awareness of EVs and their benefits is a key indicator if someone will purchase an EV; but awareness is limited in low-income and rural communities, and communities of color.
- In addition to their awareness of benefits, many consumers have questions and concerns about whether EV ranges can meet their needs, the availability of charging, EV safety, and their environmental impact.

Introduction

In 2023, 2 percent of Americans owned a battery-electric vehicle and, in Oregon, nearly 2 percent of registered vehicles are EVs.[1][2] The United States is still in the early stages of market transformation, but major vehicle manufacturers are introducing new EV options and the market is growing rapidly. Continued growth is dependent on building awareness in Oregon and beyond. Consumer Reports found that most current EV owners identify as "being one of the first to adopt new/advanced technology."[1] Figure 1 represents a generic adoption curve for new technology. The figure highlights a 13.5 percent adoption rate as the threshold at which consumers who are not visionaries or tech enthusiasts adopt a technology. In the first quarter of 2023, EVs constituted 16 percent of new car sales in Oregon, which may mean the state's more pragmatic consumers are starting to buy EVs.[3] This heralds a rapid upswing in EV sales. Consumers' general awareness of, exposure to, and understanding of EVs and their potential benefits is key to this transition; as is addressing concerns around costs, convenience, and safety. Consumer understanding and trust in EV and EV charging technologies will lead to increasingly wider adoption in Oregon.

Figure 1: EV Adoption Curve[4]



EV Consumer Interest

Deloitte's 2020 Global Automotive Consumer Study 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.[5]

Medium- and Heavy-Duty Electric Vehicle Awareness:
Columbia-Willamette Clean Cities Supporting Electrification of Commercial Fleets

The U.S. Department of Energy sponsors Clean Cities organizations that promote the use of alternative fueled vehicles, fuel, and the development of infrastructure to facilitate their use. Alternative fuels are non-petroleum-based fuels that produce less harmful GHG emissions when combusted including electricity and hydrogen. Clean Cities groups facilitate work with local stakeholders in government, industry, and advocacy to leverage resources to develop joint projects, collaborate on public policy issues, and promote transportation alternatives.

The Columbia-Willamette Clean Cities Coalition has been Oregon's clean cities organization since 1994. They provide technical assistance to commercial fleets and facilitate awareness-building activities to help individuals and organizations better understand the benefits and challenges of electrifying the transportation sector. CWCC leads regional conferences such as the Green Transportation Summit & Expo (GTSE), tech talk webinars such as the Mindful Mobility Tech Talks, ride-and-drive events, and workshops at the Portland International Auto Show and other events to build awareness and understanding.

Why Electric Vehicle Awareness Matters

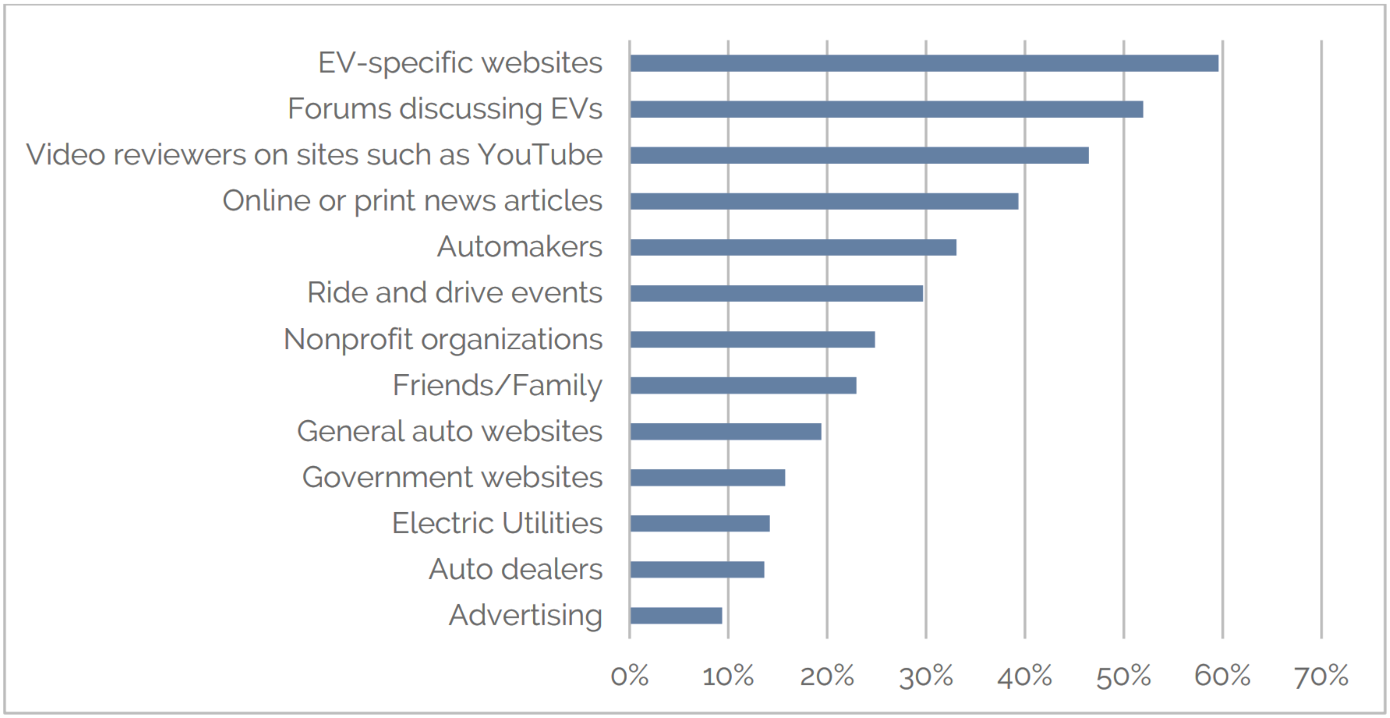
For EV adoption to rapidly increase, drivers will need to feel more at ease with purchasing them. Success is dependent on consumer trust and buy-in. Early adopters are more comfortable with the cost and risk of owning new technologies, while others need greater assurance that EVs are a sound investment. Consumers may research information about EVs to better understand their operation and benefits, but more often exposure to EVs and EV drivers within their communities is the largest influence on non-EV owners. This “neighborhood effect” is common with the adoption of many new technologies and is driven by technology ambassadors within the community.[6] EV ambassadors are trusted resources for friends, neighbors, and colleagues, providing experiential information about the vehicles and their operation and maintenance that will be more relevant to their daily lives.[7] [8]

What Drives Electric Vehicle Awareness

Many existing EV owners identify online websites, forums, and videos as the top-ranked resources of information they used before purchasing their vehicle, but this may reflect the habits of early adopters. Figure 2 below reflects existing EV owners’ experiences with various information sources and how helpful they found them. Online resources are an easy and convenient way to learn about EVs and their operation but require the buyer to actively seek out the information. The high response rate for these resources is indicative of early adopters who are more apt to research and spend time learning about a new technology. In 2022, Consumer Reports’ Survey and Research Department conducted a national survey and found that two-thirds of Americans who indicated they would definitely purchase an EV, were at least “somewhat” familiar with the technology and how to use it.[1]

Forth.org Electric Vehicle Showcase, Portland, OR

Figure 2: Potential EV Owner Information Sources[9]

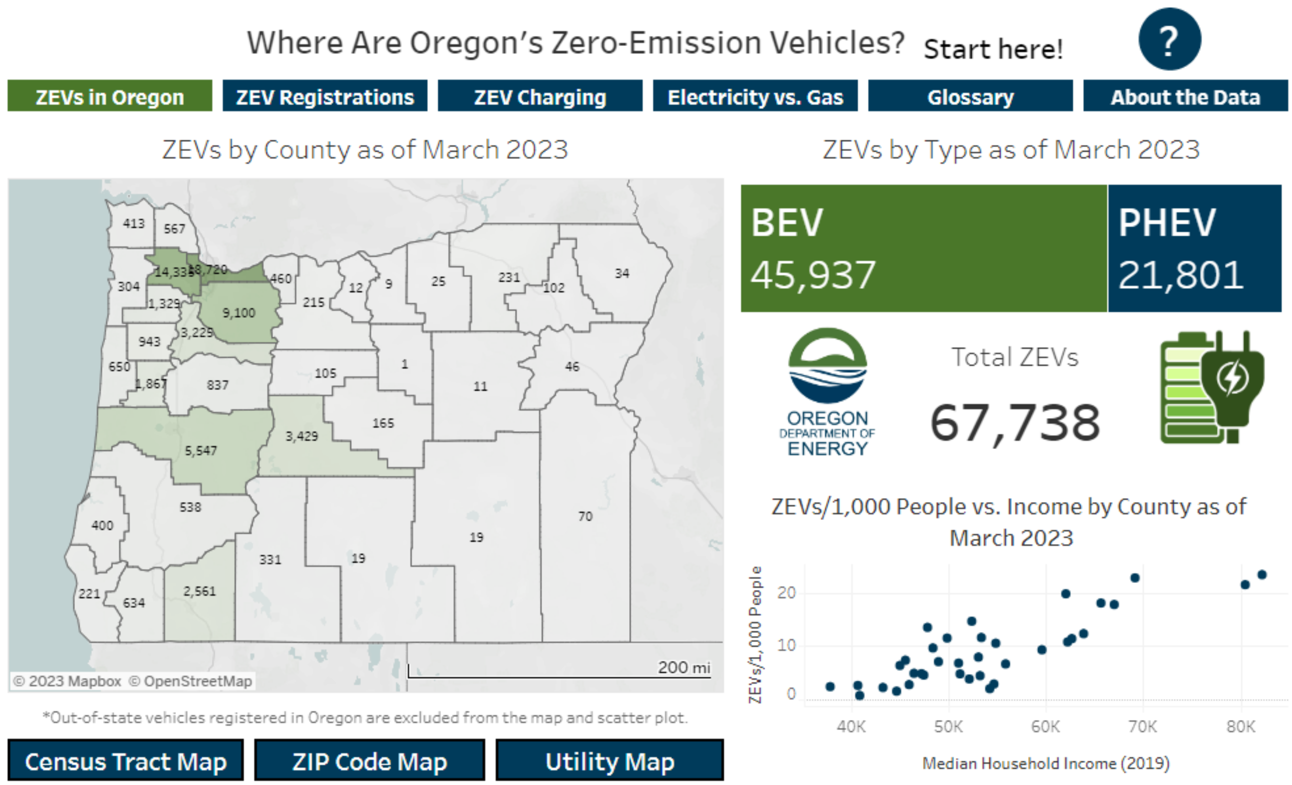


Personal interactions with EV drivers and vehicles, coupled with online research, may be a critical factor for more widespread EV adoption to take place. For example, communities with more exposure to EVs are likely to see adoption grow at a faster rate. Researchers from the University of California Davis Institute of Transportation Studies evaluated the sales of electric vehicles and identified a neighborhood and workplace effect in their geographic distribution. Exposure to a new EV "within a 1-mile radius of a block group… is associated with a 0.2 percent increase in [EV] sales in the whole block group." There was also a connection between the neighborhood and workplace effects and EV sales in the area.[7] Conversely, communities with low EV ownership, and thus less community exposure, may lag in adoption rates without external support.

Where are the EVs in Oregon?

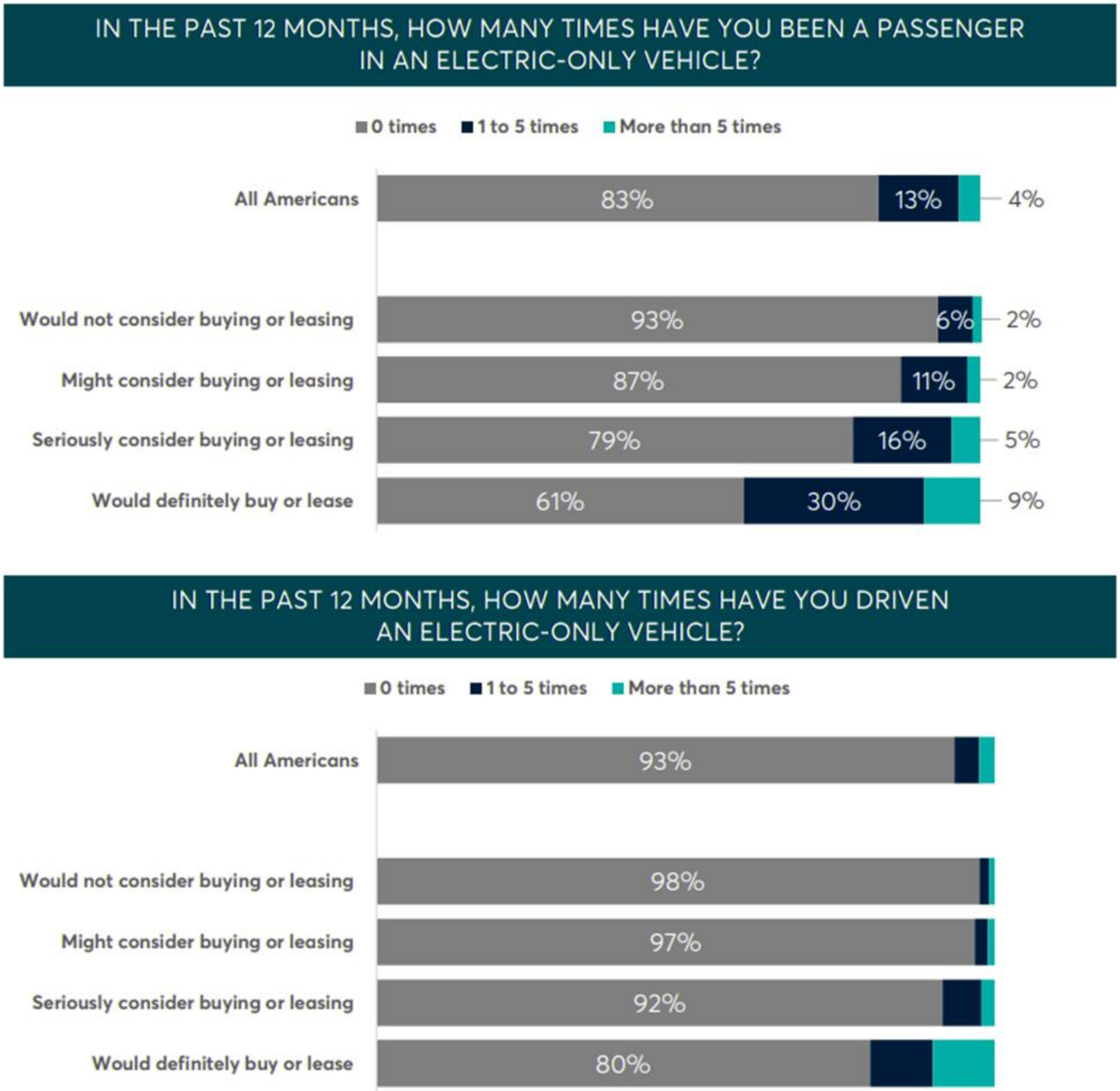
The Oregon Department of Energy hosts an Electric Vehicle Dashboard with up-to-date counts of vehicle adoption and charging infrastructure installations around the state. Visitors can review the counts of electric vehicles registered in their counties or by zip code to see how adoption varies from one community to another.

https://www.oregon.gov/energy/Data-and-Reports/Pages/Oregon-Electric-Vehicle-Dashboard.aspx



While there are considerable online resources about light-duty EVs, consumers may not be able to find answers to their specific questions, find conflicting information, or may be uncertain about what resources are most relevant to them.[10] The experience of riding in and/or driving an EV can be effective at building comfort with and knowledge of EVs, and many organizations support and sponsor "ride-and-drive" events that allow potential buyers a more hands-on experience. Figure 3 below shows results from a national Consumer Reports survey where respondents were asked to answer whether they had ridden in an EV (dark and light green portions of the bar) compared with the question of how likely they would be to purchase an EV. People who had ridden in or driven an EV at least once were much more likely to say they, "would definitely buy or lease" an EV, at 39 percent.[1] However, exposure to EVs is relatively small, with only 17 percent of Americans riding in an EV in the past 12 months, and only 7 percent driving one.

Figure 3: Consumer Reports Survey Results[1]



Having readily available EVs to test drive at dealerships allows potential buyers to experience them.[11] Because Oregon, California, and Washington have the highest EV market share in the country, vehicles are in high demand and often do not remain long on dealership lots. This regional popularity of EVs, coupled with vehicle supply chain issues, has contributed to reduced availability of EVs on dealership lots for customers to test drive.[11] Pacific Power, an electric utility that serves many rural areas of the state, conducted listening sessions about EVs in the communities they serve.

One key takeaway from these sessions was that for drivers to feel comfortable transitioning to an EV they need access to test drive opportunities and more information on available market options.[12] This slow transition has implications for Oregon's climate and energy goals, because the average life of a light-duty vehicle in Oregon is 16 years, meaning any gasoline vehicle purchased in 2023 will likely remain in Oregon's statewide fleet until about 2039.[13]

Some dealerships are partnering with electric utilities, cities, and organizations that support EV adoption to facilitate **ride-and-drive events** within their communities, where EVs and knowledgeable people are available to share information and answer questions.

Auto dealerships are a central point of contact for car buyers with questions about EV operation, fueling, and maintenance; and as demand increases, they will need more EV-knowledgeable sales staff to meet consumer needs. A Plug-In America survey of existing EV owners found that only 15 percent considered the salesperson they interacted with to have "very high" EV knowledge.[14] While this response may reflect the relatively higher degree of expertise common with early EV adopters, dealerships need to be able to provide reliable and helpful information to customers who are not as familiar with the technology. Manufacturers are developing robust training and certification programs to better prepare dealership sales staff for consumer questions.[15] The Oregon Department of Environmental Quality's Oregon Clean Vehicle Rebate Program is addressing this challenge by conducting trainings, hosting listening sessions, creating outreach material in multiple languages, and regularly communicating with dealers throughout Oregon to increase EV and program awareness.[i] [17] Tesla, who produces only electric vehicles, does not rely on third-party dealerships, and instead sells directly to customers using sales staff trained with detailed information about their cars.[16]

[i] The Oregon EV rebate program funds have been exhausted for 2023. Additional funding for the rebate programs will be available in 2024.


Photo Courtesy of F150 Lightning Forum.com

Limited exposure to EVs and availability of charging infrastructure in and around disadvantaged communities contribute to lower EV adoption. There are fewer electric vehicle registrations in low-income and rural communities and in areas where more people rent their homes and/or live in multi-unit buildings (see the *Distribution of Electric Vehicles by Demographics* chapter). While there are many economic, social, and environmental influences on EV adoption rates, the low adoption rate itself perpetuates the issue. Vehicle exposure may be more important in disadvantaged communities, especially because new technologies can feel out of reach for many residents. Experiential feedback from people within the community provides a trusted source of information about how they learned about, purchased, and financed an EV, in addition to questions on use, maintenance, and how and where to charge. Through its Charge Ahead Rebate program, DEQ targets outreach to low- and moderate-income households, and partners with community-based organizations to get the word out about EVs, charging, and available incentives and listening to these communities about the barriers they face.[17]

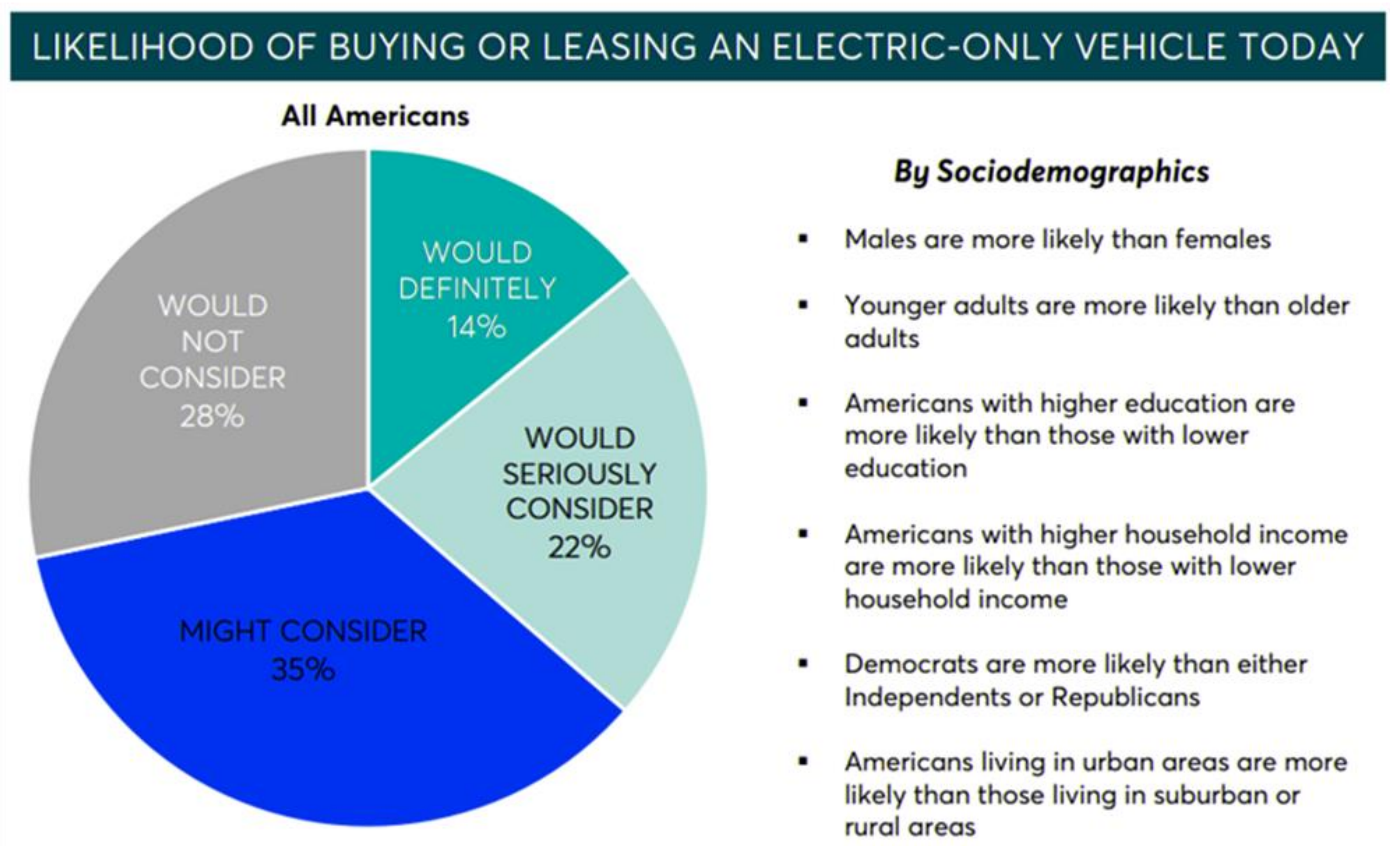
Several organizations in Oregon also collaborate to support more electric vehicles and chargers in underserved communities, some of which provide low-cost EVs for community use. Several utilities, including the Eugene Water and Electric Board and Central Electric Cooperative have programs that provide EVs near affordable housing within their territories.[18] Pacific Power and the U.S. Department of Energy funded the CruSE project that makes available five Nissan LEAF EVs located throughout the Hood River area for community ridesharing use, with two reserved for residents in affordable housing areas. Forth is also partnering with Pacific Northwest National Laboratory to evaluate and publish findings about the affordability and environmental gains of a sustainable, rural-focused, ridesharing platform.[19]

Electric Vehicle Awareness

Oregonians likely have a higher degree of awareness of electric vehicles than others nationally. National surveys indicate many Americans are aware that EVs exist, but far fewer know much about how they work. Compared with surveys conducted in Oregon, national surveys tend to have fewer respondents indicating they would likely buy an EV. Oregon's EV market share of new car sales was 16 percent in the first quarter of 2023 which was exceeded by only California. Nationally, EV market share of new car sales was nearly 9 percent in the first quarter of 2023. Higher sales rates signal a significant portion of Oregon car buyers are familiar enough with the technology to purchase it at a higher rate.[3] (See the *Sales Figures and Progress to EV Adoption Targets* chapter.)

EV awareness overall is increasing, nationally and in Oregon. In an annual national EV awareness survey, CarGurus – an automotive research and shopping firm – found that the numbers of respondents indicating they expect to own an electric vehicle in the next five years grew from 30 percent in 2021 to 40 percent in 2023.[14] A 2022 survey by Consumer Reports found 36 percent of respondents would definitely or seriously consider buying an EV, and in the same year a survey by the American Automobile Association, or AAA, found 25 percent of those surveyed would likely buy an EV.[20] However, awareness of how EVs are operated remains low. Only 9 percent of respondents in the Consumer Reports study indicated they were very familiar with EV fundamentals.[1]

Figure 4: Consumer Reports Study of Consumers Likelihood of Purchasing an EV[1]



Urban communities in the major metropolitan areas of Oregon have high EV adoption rates, indicating people living in these areas likely have more incidental opportunities to see EVs and chargers in their communities and to talk to EV drivers about their experiences. Figure 5 below demonstrates the registered EVs in the Salem area and Figure 6 illustrates the lower density of EVs in the Pendleton area. Since 2018, a series of surveys conducted in the metropolitan Portland area found that EV awareness is growing. In 2021, 32 percent of survey respondents indicated they intended to purchase an EV as their next vehicle, up from 17 percent in 2019. Twenty-four percent of respondents reported they had driven an EV, which is higher than many national surveys.[21]

Figure 5: EVs in the Salem Metropolitan Area (Urban)[2]

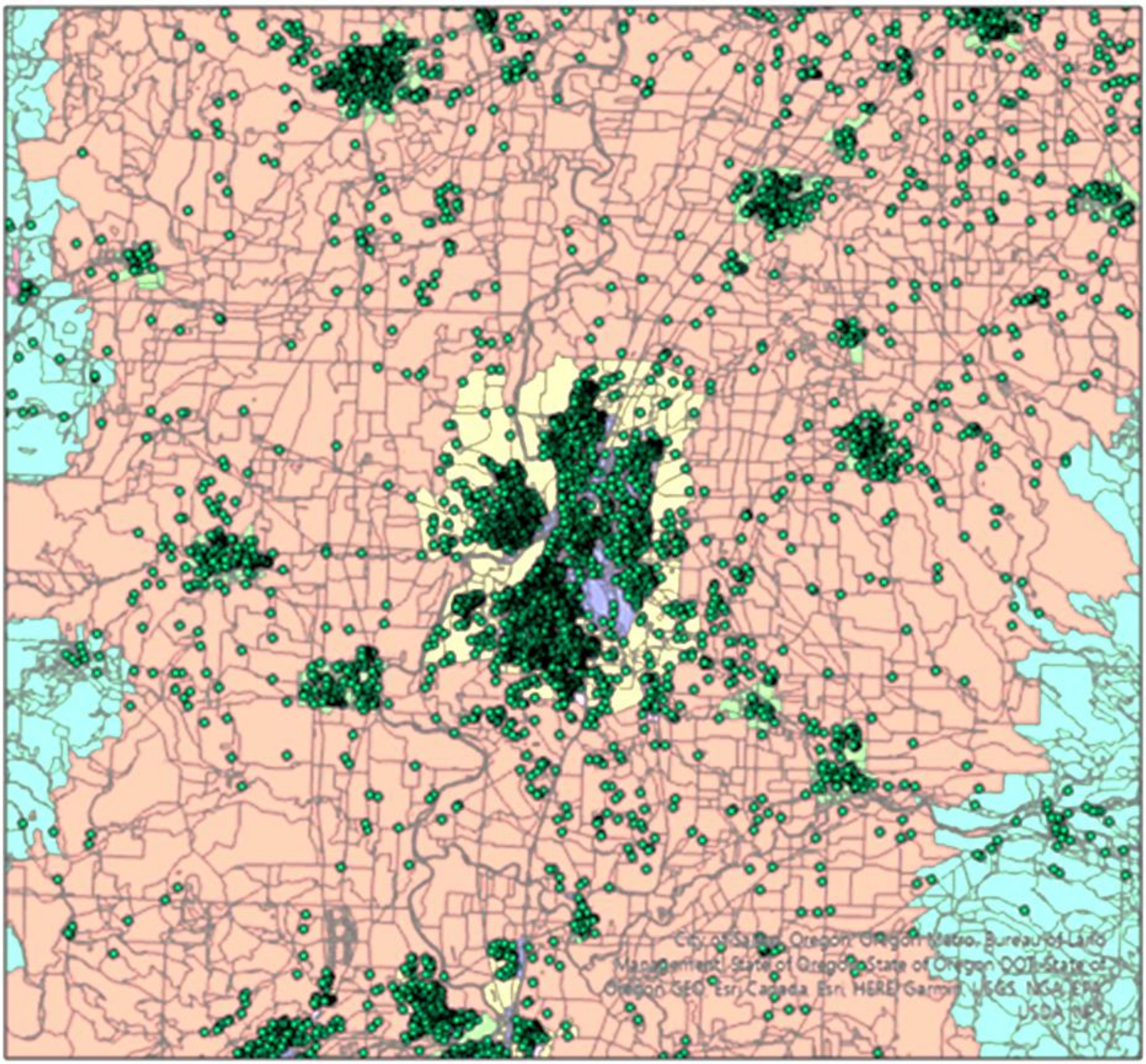
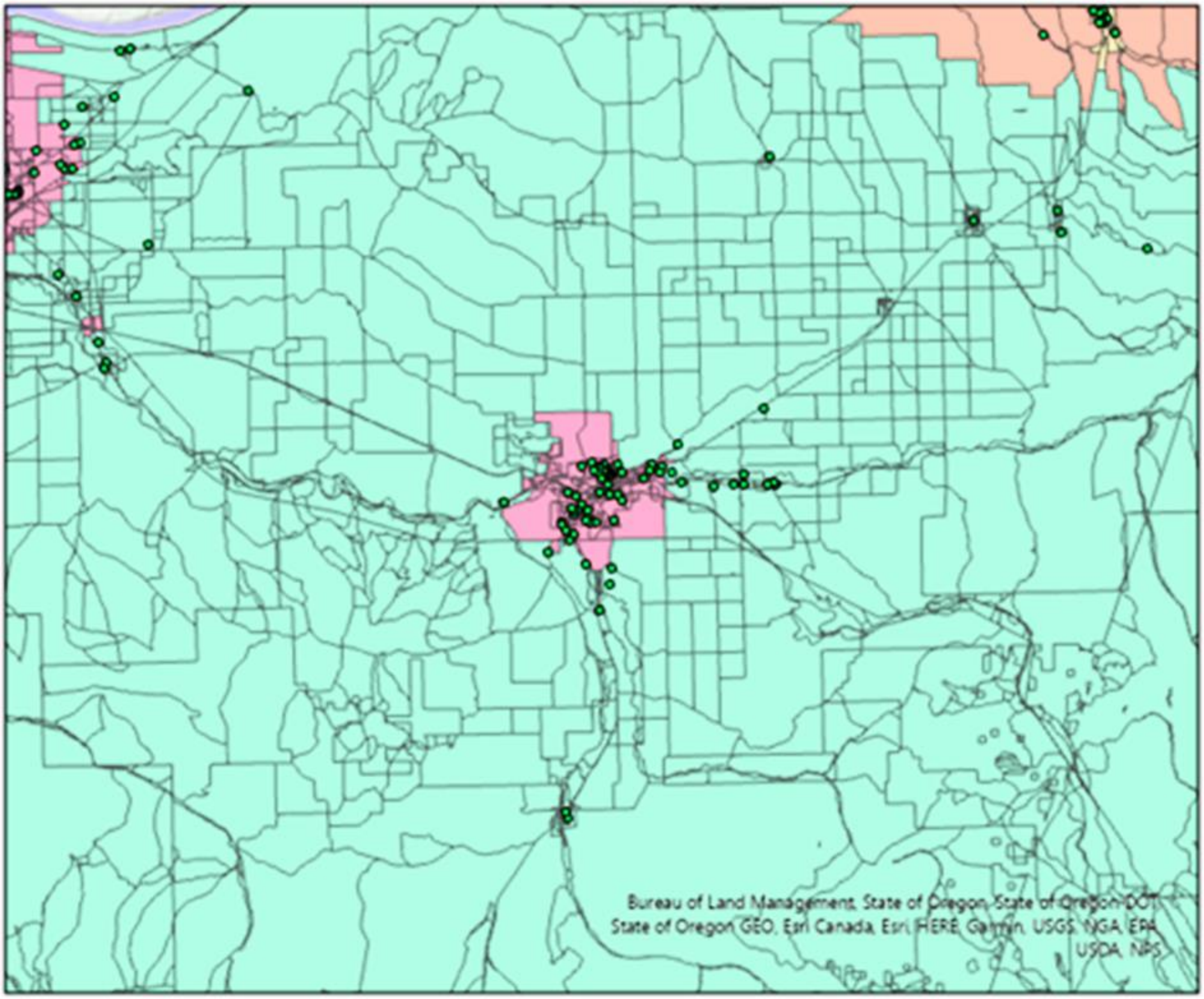
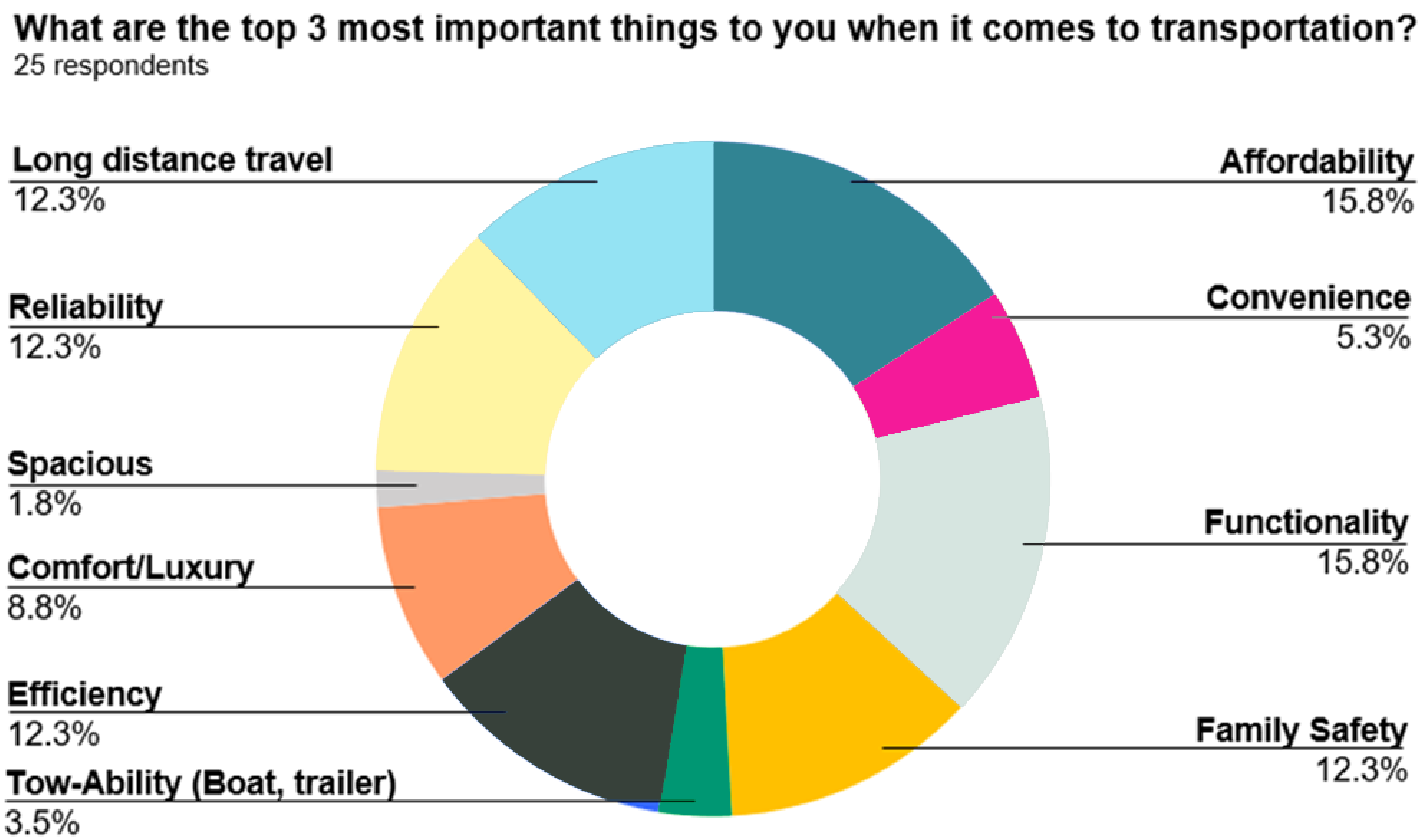


Figure 6: EVs in the Pendleton Area (Rural)[2]



Rural areas in Oregon have significantly lower EV adoption rates, which tracks more closely with national data. In 2022, Pacific Power facilitated six community listening sessions with customers in their rural service territories to better understand community-level interest in and awareness of EVs and barriers to adoption. Charging infrastructure and general community information about EVs, incentives, and how EVs can meet community needs were key takeaways from these meetings. Figure 7 illustrates results from one of the community listening sessions, and is generally reflective of what Pacific Power heard in these engagements.[12] (See the *Availability and Reliability of Charging Infrastructure* chapter.)

Figure 7: Pacific Power Community Listening Session Results[12]



There is little information on fleet owner electric vehicle awareness. Some fleets consist of light-duty vehicles, some have medium- or heavy-duty vehicles, and some may be a mix of vehicle types. Commercial fleets need additional resources to convert their fleets, largely due to charging infrastructure needs (see the *Availability and Reliability of Charging Infrastructure* chapter). As more fleet owners are interested in electrifying, there are organizations helping fleet owners better understand electric vehicle options, how to plan for EV charging needs, and financing mechanisms to fund the vehicles and infrastructure. As more information is available, future iterations of this report will have more information on the relative awareness of fleet owners about EVs and their benefits.

The Breaking Barriers Collaborative

The Breaking Barriers Collaborative was founded by Climate Solutions, Oregon Business for Climate, the Wave Foundation, Clean and Prosperous Washington, and the Washington Build Back Black Alliance, with the mission to help Pacific Northwest businesses accelerate efforts to equitably reduce their climate emissions. In 2023, the Collaborative launched its first Fleet Decarbonization Accelerator program. The 13-week program is designed to help Oregon and Washington small to medium-sized businesses evaluate and come up with actionable transportation electrification plans for their fleets. Participants receive one on one coaching from fleet decarbonization experts and a curriculum that builds awareness of the market and guides them through the process of building a fleet decarbonization plan.

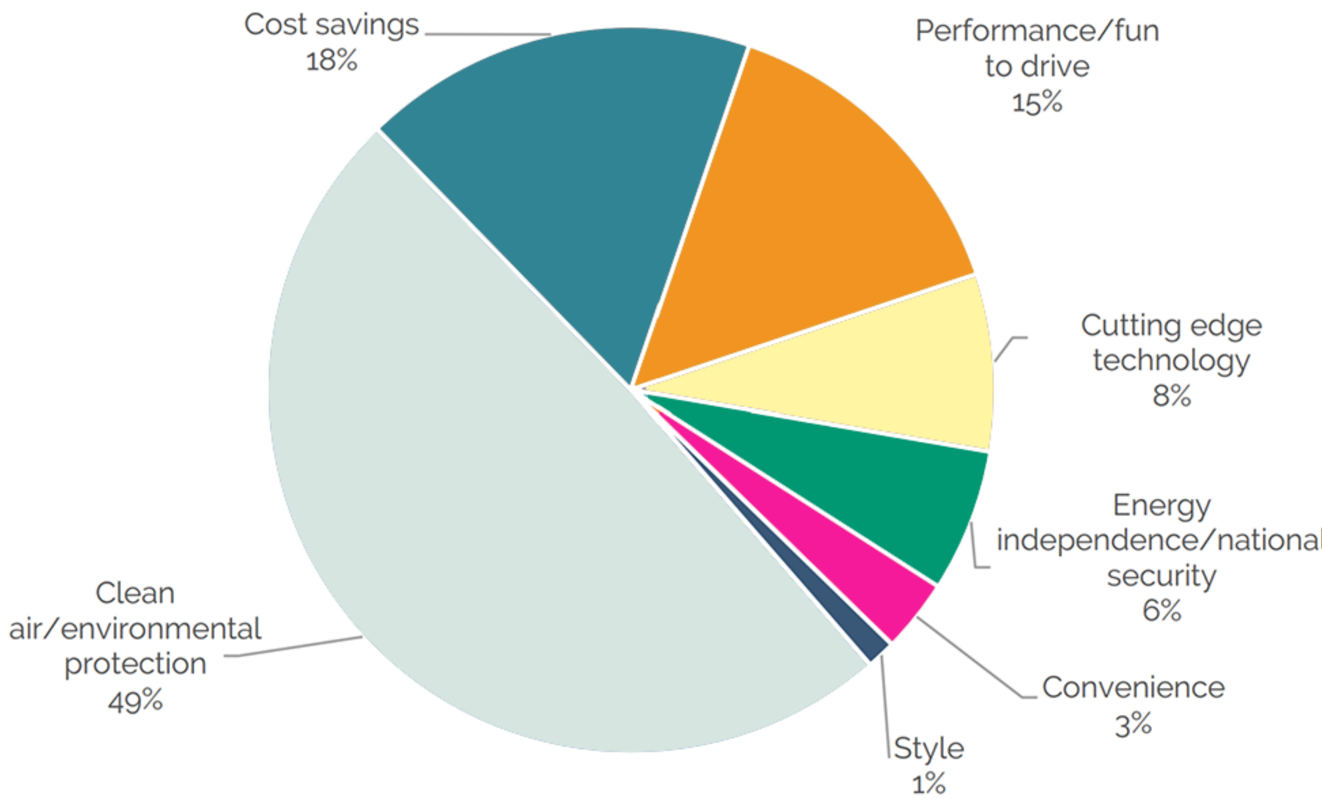
As Paul Bloom, Program Director of Breaking Barriers Collaborative, said, "It is a lonely place to be an early adopter," and the Breaking Barriers Collaborative wanted to get businesses together to learn, grow and be successful together. Most businesses are focused on converting their light- and medium-duty vehicles first due to the greater challenges in converting heavy-duty vehicles. Participating organizations were qualified before being accepted into the Accelerator to guarantee their level of commitment with published company climate goals, and a willingness to act. The Breaking Barriers Collaborative hopes the Accelerator will help the 20 participating businesses and non-profits build awareness, confidence, and save the time and money needed to build an actionable decarbonization plan.

The first round of the Accelerator has been a success and the Breaking Barriers Collaborative has announced a second cohort beginning in October 2023. More information is available at www.breakingbarrierscollaborative.org.

Awareness of the Benefits of Driving an Electric Vehicle

The benefits of driving an electric vehicle can be an important motivating factor in a driver's decision to buy an EV. Driving an EV offers a host of benefits, like lower greenhouse gas emissions, improved local air quality, lower fueling costs, the convenience of fueling at home, and a quieter ride. In a Plug In America survey of existing EV owners, almost half of respondents indicated environmental and air quality benefits were the primary motivator to purchase an EV, with 59 percent considering it very important or vital to fuel their EV with renewable energy. Further, 90 percent indicated they are likely or very likely to purchase an EV as their next vehicle.[9] Existing owners have a strong understanding of the benefits of EVs and are likely to share those experiences within their communities.

Figure 8: Plug In America Survey Results on the Primary Motivating Factor to Purchase an Electric Vehicle for Existing Owners[9]



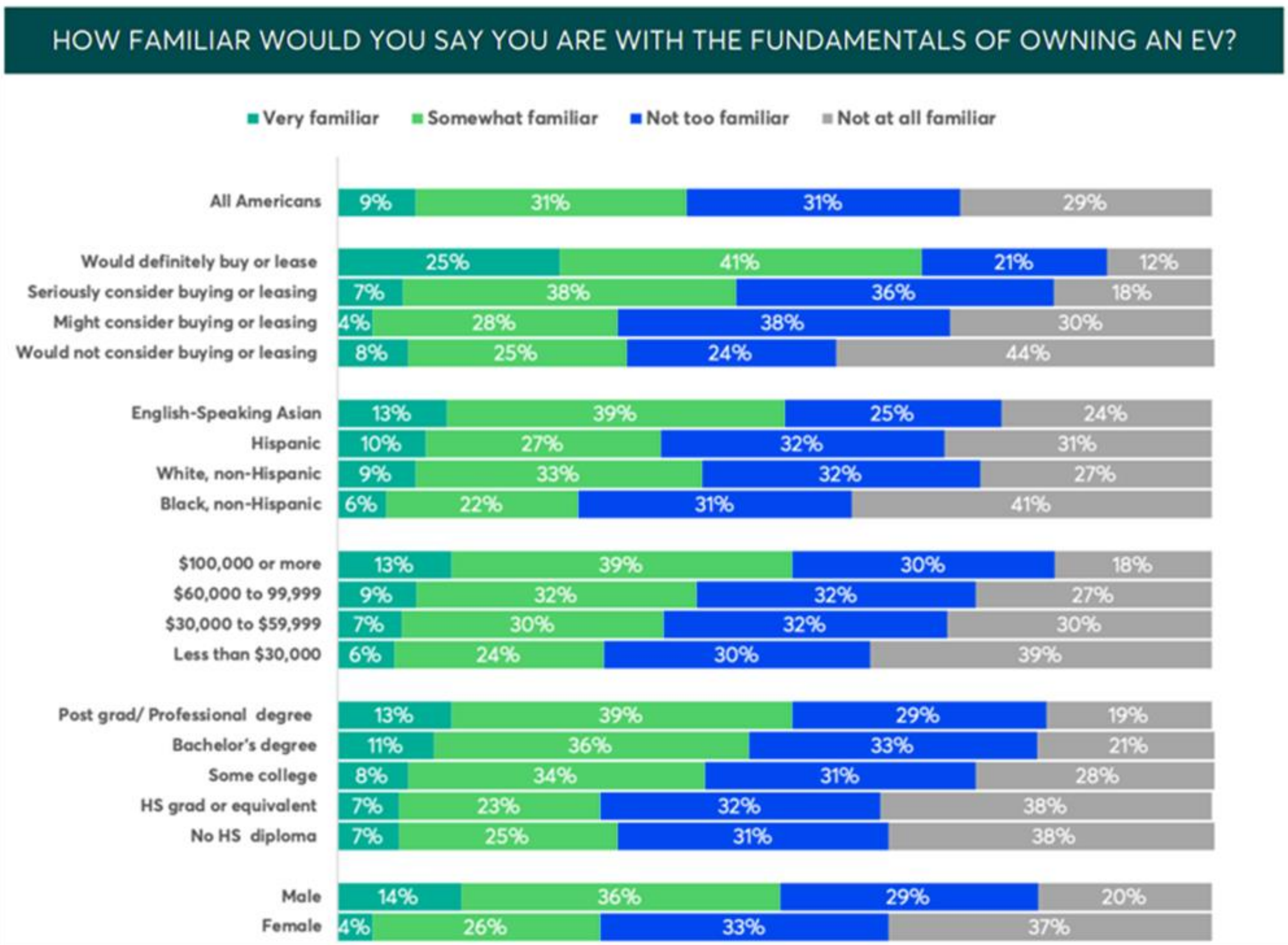
Cost savings is also a major motivator for drivers considering an EV, although data resources are not consistent in the degree to which consumers feel savings are important. A 2021 survey in the Portland metro area found respondent's understanding of EV fuel costs compared to gasoline vehicles has improved over time, but understanding of other EV benefits, such as lower maintenance costs, has remained low.[21] About 18 percent of respondents to the Plug In America survey indicated cost savings was the primary motivating factor in purchasing an EV, although those intending to buy an EV were more likely to indicate this as a motivating factor than existing owners.[9] The Consumer Reports' survey found that nearly a third of respondents indicated lower fuel and maintenance costs was a motivating factor, and the 2022 AAA consumer study found 77 percent of respondents indicated lower fuel costs as the primary motivation to purchase an EV.[1] [20]

The convenience of being able to charge at home was also an important factor for consumers interested in buying an EV. Many EV owners prefer charging at home to using a gas station and are content with a simple Level 1 charger.[9] EV owners with a dedicated space and outlet to charge a vehicle can generally plug a vehicle in when it is not in use. This is sufficient to meet most of their daily driving needs, and it saves them the time they would normally spend refueling their vehicle. This benefit also explains the high number of EV drivers living in single-family homes where charging is convenient and readily available. Potential buyers living in multi-unit buildings, where access to charging is often less convenient, might not have scored this attribute as highly.

Gaps in Electric Vehicle Awareness

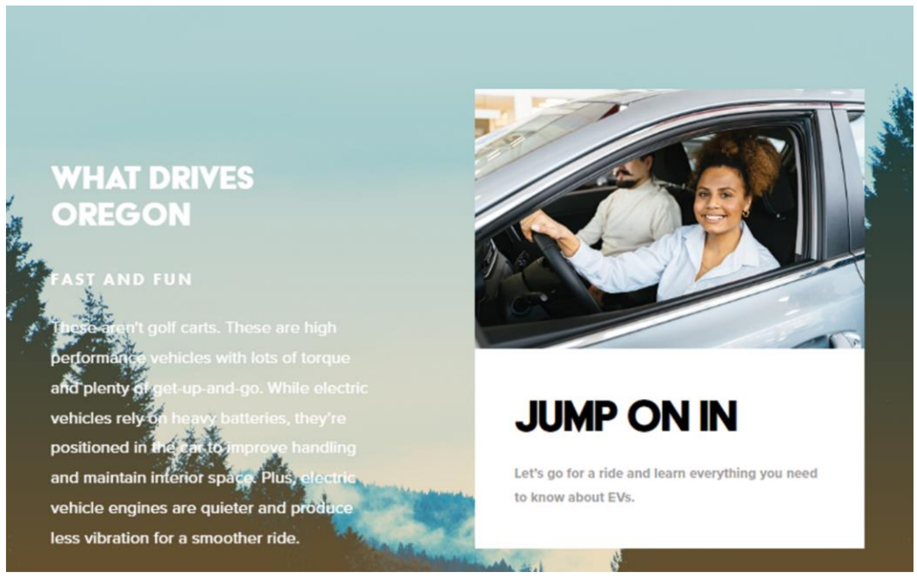
Electric vehicle awareness is growing nationally and in Oregon, with stakeholders actively promoting EV understanding and the benefits of adoption, but it is not consistent across all demographic groups. Consumer Reports found that Black Americans are less familiar with EVs compared to white, Hispanic, and English-speaking Asian Americans. Also, men, higher income households, and people with higher levels of educations are more likely to be familiar with the fundamentals of owning an electric vehicle.[1] (See the *Distribution of EVs by Demographic Groups* chapter.)

Figure 9: Consumer Reports Survey Comparison of Electric Vehicle Awareness Across Demographic Groups[1]



General awareness of incentives to address up-front costs is also lagging. Consumer Reports' found almost half of those surveyed were not aware of any incentives available for EV owners.[1] The Portland metro area survey found that only 44 percent of respondents were aware of state and federal incentives.[21] Incentives could play a greater role in increasing adoption if the information were more readily available to low- and middle-income communities.

Oregon's Role in Building Electric Vehicle Awareness

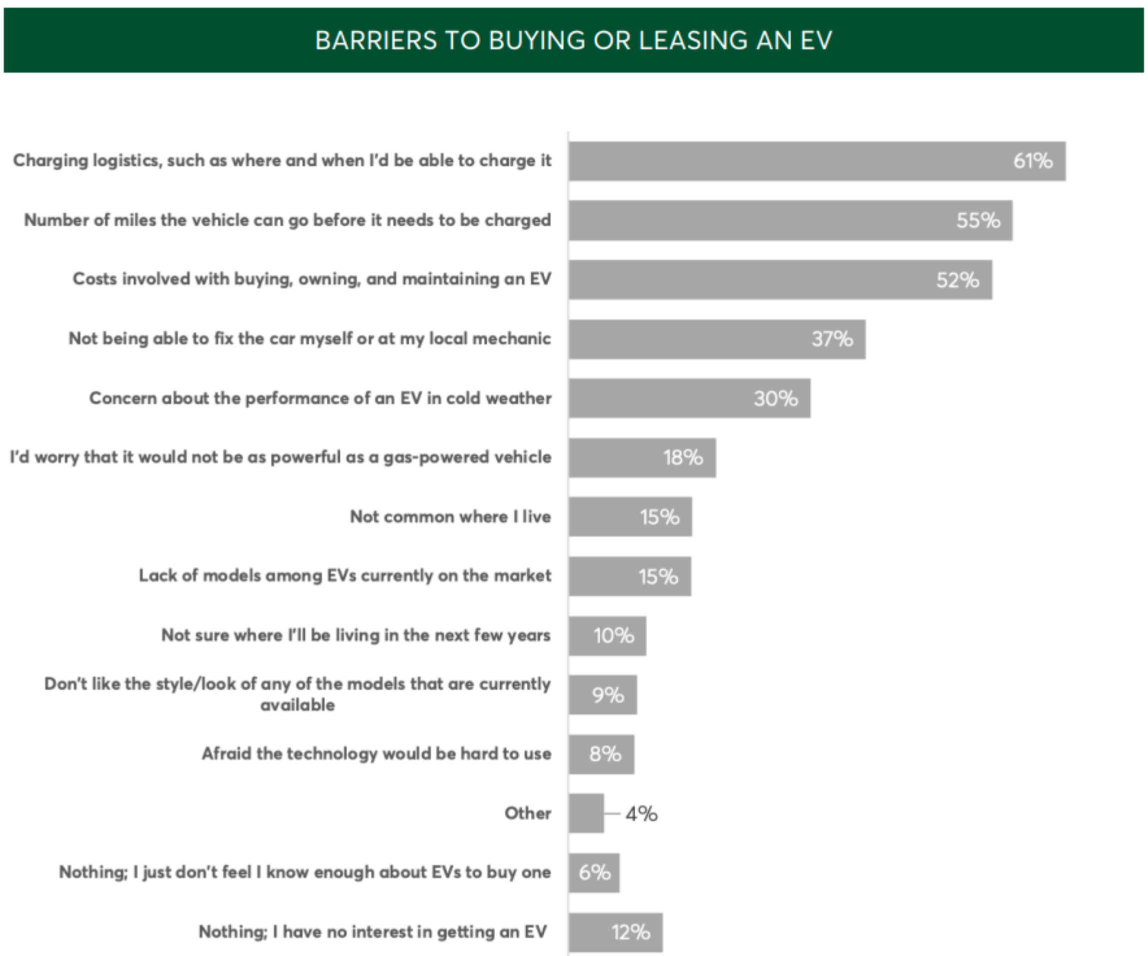


The Oregon Department of Energy helps inform Oregonians about EVs and their benefits. The agency provides the GoElectric.oregon.gov website and the agency's EV dashboard. GoElectric provides resources on the operation and maintenance of EVs, incentives, charging infrastructure, Oregon EV news, and a list of external resources to help prospective buyers and new owners navigate questions they have about EVs and where to charge them. The EV Dashboard showcases registration data, providing EV counts across counties, utility service territories, and zip code. It also breaks out registered EVs by make, model, and model year, and provides a cost analysis tool that allows potential owners an easy way to calculate fuel and greenhouse gas savings by switching to an EV. Other state agencies host sites providing information on specific programs they administer that help encourage more EVs on Oregon's roads (see the *Sales Figures and Progress to EV Adoption* Targets chapter for more information on specific state agency programs).

Consumer Concerns Relating to Electric Vehicle Ownership

Electric vehicle sales and market share continue to grow in Oregon, but most consumers are still purchasing conventional internal combustion new and used vehicles. In the Consumer Reports' study, the top three barriers to purchasing an EV indicated by respondents were availability of charging, vehicle range, and the costs to buy, own, and maintain an EV.[1] Consumers' understanding of whether an EV can conveniently replace their existing gasoline vehicle is an important factor when deciding whether to purchase an EV. ODOE received many questions during the development of this report about EVs, including specific questions about charger availability, costs to own and operate an EV, vehicle safety, effects of heavier vehicle weight, effects on Oregon's electric system, and the environmental impacts of manufacturing EVs and their batteries. An overview of charger availability is addressed in the *Availability and Reliability of Charging Infrastructure* chapter, electric grid effects are addressed in the *Opportunities to Minimize Effects of EVs on the Electric Grid* chapter*,* and costs are addressed in the *Cost Difference Between EVs and Internal Combustion Engine Vehicles* chapter. The remainder of this section addresses other concerns members of the public have voiced since the last iteration of this report.

Figure 10: Consumer Reports Survey Barriers to Consumers Deciding to Purchase an Electric Vehicle[1]



Electric Vehicle Range

Consumers continue to have general concerns about electric vehicle performance. AAA's 2022 consumer study identified vehicle range, suitability for long-distance travel, and limited availability of charging stations as primary consumer concerns.[20] As displayed in Figure 11, the average range of EVs is rising every year, with new models of battery electric vehicles[ii] often exceeding 300 miles of range. That is more than the 235 miles per week driven by the average Oregonian.[22] [23] However, according to that same study, consumers indicated a strong understanding of current electric vehicle range, which

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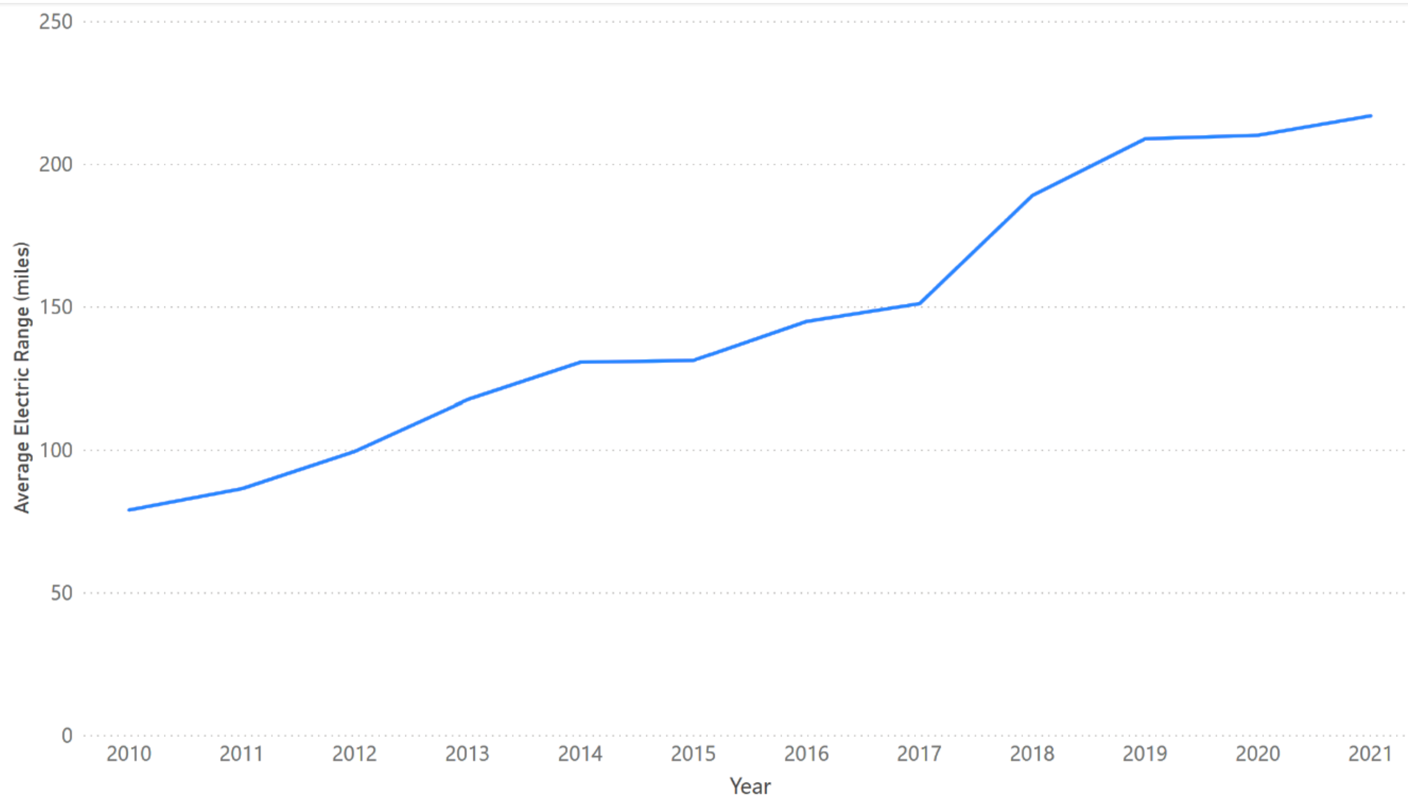
[ii] This discussion does not include plug-in hybrid electric vehicles, which have a battery that can be supplemented by a gasoline generator or internal combustion engine, which largely negates concerns with charging infrastructure availability.

suggests higher vehicle range alone may not fully address consumer range performance concerns. While actual charging gaps exist and some new and used models of EVz have limited vehicle ranges, drivers may not readily encounter the charging infrastructure near to their daily travel routes, leading to the perception that chargers are not widely available. Drivers may need to see more charging infrastructure in their normal daily routines to feel confident that chargers will be available when and where they might be needed.[20]

Figure 11: Average Range of Battery Electric Vehicles: 2010-2021[24]



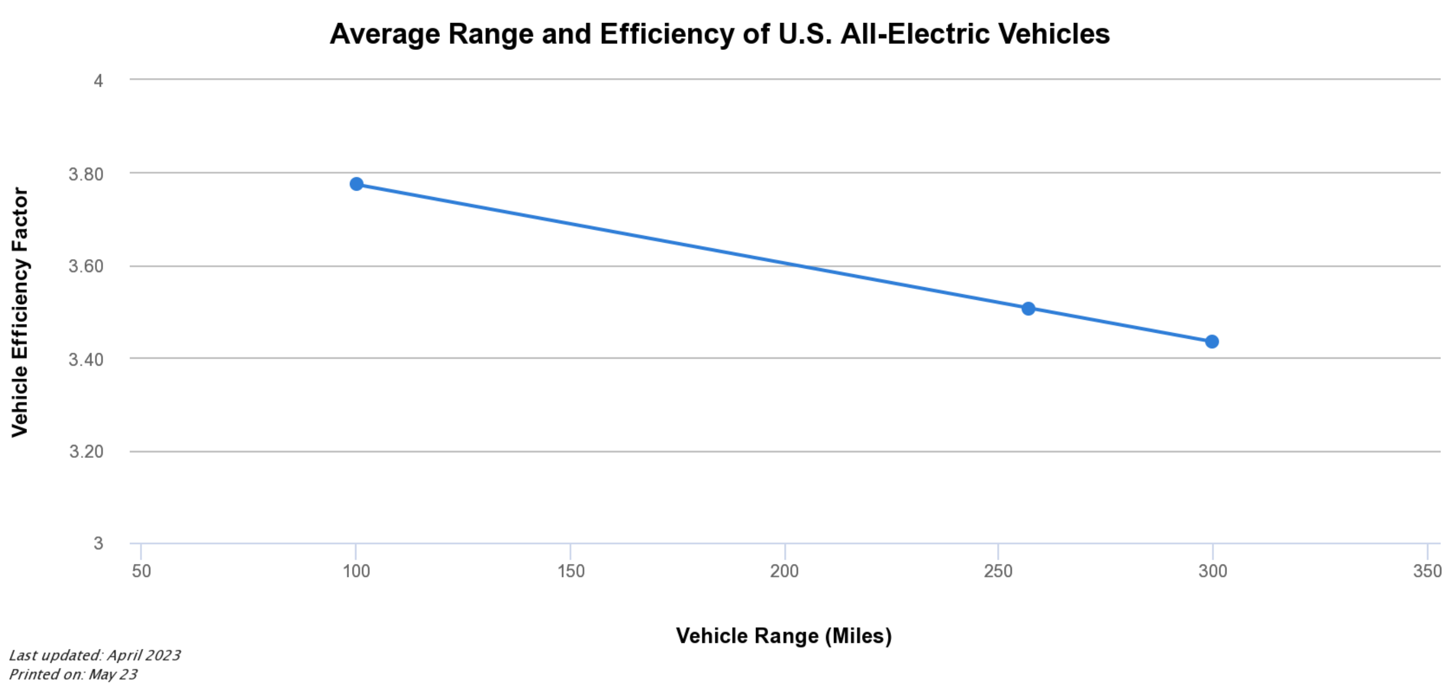
Vehicle range is a greater barrier for some medium- and heavy-duty vehicles as well as for certain light-duty vehicles used for specific purposes. The reported vehicle range is based on typical usage patterns, but certain road and climate conditions, as well as how vehicles are used, can reduce range. Vehicles that carry heavy loads, regularly drive on rough terrain or roads, or operate in very cold or hot conditions will have reduced ranges. Adding more batteries can increase range but, due to their weight, have a significant effect on the carrying capacity of the vehicle. This is particularly important for heavy-duty electric vehicles that are designed to carry large loads, such as tractor trailers, or for trucks that tow equipment. The overall weight of the battery limits the weight of the load an electric truck can carry. This could also limit the towing capacity of all types of trucks. However, there have been improvements in battery performance and efficiency in the last decade. The US DOE and many private entities are researching new battery chemistries with the aim of developing a battery technology with more energy density than current lithium-ion technology – meaning the batteries will weigh less to do the same amount of work.[25]

While range limitations may reduce viability in some rural areas of the state, driving an electric vehicle in metropolitan environments provides significant gains in fuel efficiency and range, especially where vehicles operate in stop-and-go conditions. EVs recapture energy while braking to charge the battery, and are more fuel efficient than gasoline or diesel vehicles in these conditions because internal combustion engines require additional power to get a vehicle moving from a full stop.[26] Driving an EV reduces fuel costs by as much as 34 percent, especially for vehicles with many stops and starts, like school and transit buses, postal and delivery trucks, and refuse trucks.[20]

Batteries and Range

EV manufacturers design vehicles to balance the fuel cost of the battery weight with sufficient range for the vehicle to operate in most normal conditions. While adding more batteries to a vehicle increases the vehicle range, some of this increase is offset by the additional fuel needed to move more battery weight. Similarly, gasoline vehicles also have reduced fuel efficiency if a larger gas tank is added. Figure 12 show reductions in the fuel efficiency of an EV as additional batteries are added. Efficiency drops about 5 percent when going from 50 miles of battery to 250. That means a car with a 50-mile range that currently gets 3.5 miles per kilowatt hour[iii] would only get 3.3 miles per kWh with a 250-mile range. While still over three times more efficient than a similar internal combustion engine vehicle, more or larger batteries equate to fewer miles per kWh.[27]

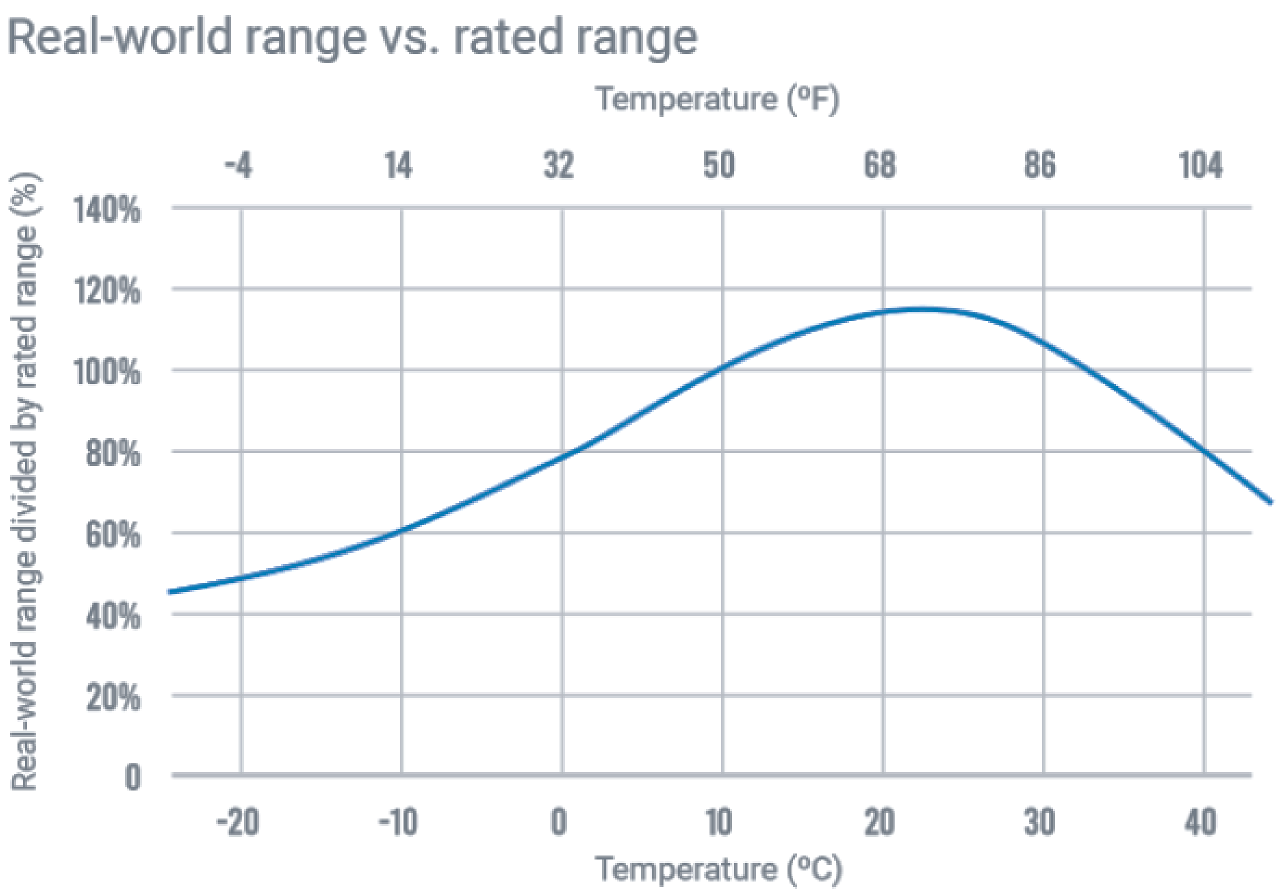
Figure 12: Average Range and Efficiency of EVs[27]



[iii] Miles per kilowatt hour is the representation of an EV's fuel efficiency and is equivalent to miles per gallon in a gasoline vehicle.

Oregonians living in eastern Oregon or at higher elevations may experience more variability in the day-to-day operation of their vehicles due to a wider range of ambient temperatures that affect charging times and battery range. Figure 13 shows the bell curve of actual miles versus the vehicle mileage rating compared across different outside temperatures. EVs operate best at about 70 degrees (F) and can exceed the rated range but have a derated range at higher or lower temperatures. Some of this loss is due to heating, air conditioning, or seat warming, while some of it is due to the efficiency losses of the battery chemistry outside of the optimal temperature rance.[28] As seen in Figure 13, both cold and heat can affect range, but low temperatures have the largest effect on the range of the battery. Widely available and accessible charging infrastructure can help address driver concerns resulting from reduced range due to lower or higher temperatures.

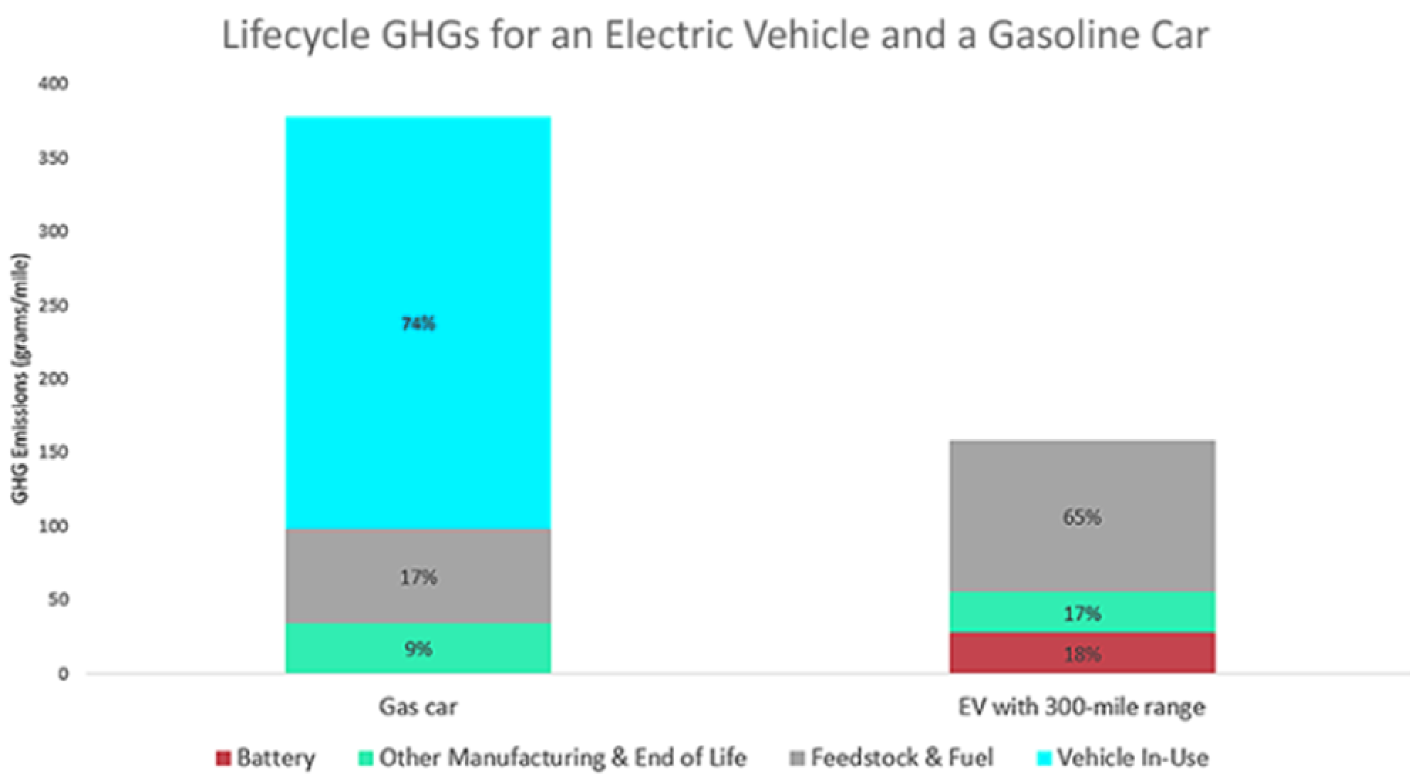
Figure 13: Actual Range Compared to EV's Rated Range Across Different Ambient Operating Temperatures[29]



Environmental Effects of EV Batteries

There are environmental and social impacts from the production of any technology, so it is important to weigh the lifetime environmental, societal, and economic effects of choosing one technology over another. For example, while gasoline vehicles tend to have lower manufacturing GHG emissions, they create 2.5 times more lifetime emissions than an EV.[30] Figure 14 below shows the results of an Argonne National Laboratory study that evaluated GHG emissions for both a gasoline vehicle and an EV with a 300-mile range. The red bar represents emissions from producing the battery, including extracting and refining source materials. The manufacturing emissions, represented by the green bar, includes those from extracting materials, manufacturing, and assembling the vehicle to its recycling and/or disposal at end-of-life. The gray bar representing feedstock & fuel includes the average emissions associated with producing the gasoline or electricity to power the vehicles. EVs currently have higher manufacturing and feedstock emissions (100 versus 150 grams of GHG emissions per mile driven), but the vehicle-in-use (tailpipe) emissions represented by the blue bar comprise the vast majority of emissions. Over the lifetime of both, the gasoline vehicle will emit about twice as much GHGs as the EV. (To learn more, please visit the *Impacts on GHG Emissions of Transportation* chapter.)

Figure 14: Estimated Lifecycle GHG Emissions of a Gas and Electric Car[30]

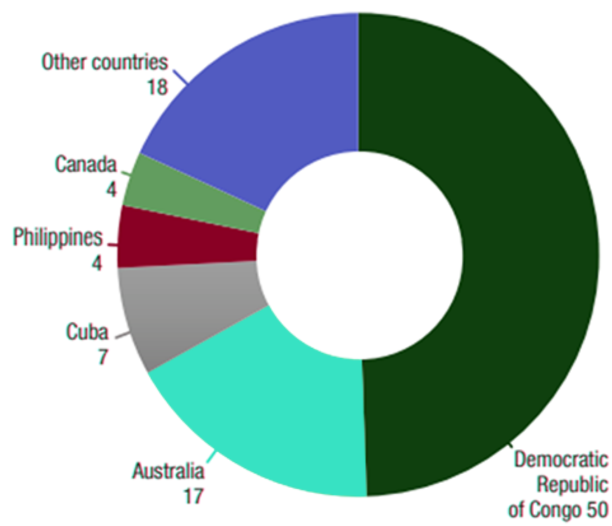


The environmental and societal effects of transitioning to EVs is not insignificant. Beyond GHG emissions, the production of EVs includes mining resources and minerals needed to produce lithium-ion batteries – primarily cobalt, lithium, and nickel. The mining process consumes large amounts of water and generates toxic waste, which can harm local communities. Some of this mineral production comes from mining in developing countries, many of whom have less stringent environmental and labor policies than the United States. Instances of human rights abuses have been associated with mining activities in some countries, such as the Democratic Republic of Congo, which currently produces about 70 percent of the world's cobalt.[31]

The U.S. and other countries, as well as battery and vehicle manufacturers, are establishing policies that protect the health, environment, local economy, and well-being of the people living and working near mining and production operations. For example, Australia and the U.S. signed the Climate, Critical Minerals and Clean Energy Transformation Alliance to support the responsible expansion of clean energy and critical minerals supply chains to meet the growing demands of both countries.[33] Australia holds 19 percent of the world's known lithium reserves and 17 percent of cobalt reserves, shown in green in the charts below.[34] Some automakers and component suppliers are forming agreements to provide more transparency around the source of these materials, and some battery manufacturers are investing in mining communities to clean up existing environmental waste, while supporting more effective mining policies going forward. [35] [36]

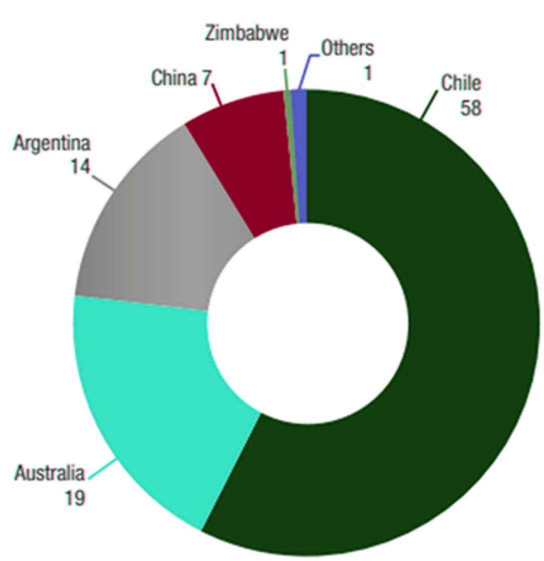
Figure 15: Estimated Total Global Cobalt and Lithium Reserves by Country[34]

Figure 2. Cobalt reserves, 2018
(Percentage)



Source: USGS National Minerals Information Center (2018)

Figure 3. Lithium reserves, 2018
(Percentage)



Source: USGS National Minerals Information Center (2018)

Research and development for battery advancements could provide more sustainable and environmentally friendly battery options in the future.[37] Governments and industries are investing in research to increase the energy density of EV batteries, including assessing new battery chemistries. Some of these chemistries may require different minerals, potentially more readily available components such as silica, sodium, and iron, which are much more plentiful resources and less environmentally costly to produce. The US DOE and others are also investigating opportunities to make existing battery technology more efficient, so that they will last longer, ultimately requiring fewer materials and resources over the long-term.

Just as there are concerns about the environmental costs of producing batteries, there are similar concerns about what will happen with batteries at the end of their useful lifetime. Batteries contain hazardous materials that should not end up in waste streams. Battery recycling programs can not only prevent the creation of a new waste stream, but also incentivize the recovery of the source minerals, which can be used to refurbish existing batteries or create new ones. California is pursuing the development of a recycling market for EVs by requiring battery producers to create or fund stewardship programs for collecting and recycling most batteries sold in the state.[38] At the federal level, the National Blueprint for Lithium Batteries established a goal of 90 percent of lithium EV batteries to be recycled by 2030, and several US DOE programs are working to achieve this goal.[25]

Minerals used in battery manufacturing could eventually become a self-sustaining resource, reducing the need for mining. Unlike fossil fuels, which are consumed when combusted, the minerals in lithium-ion batteries are not consumed as the battery ages and can be recaptured and used in the creation of new batteries. Currently 99 percent of lead acid batteries are recycled, and the minerals in Li-ion batteries are more valuable, meaning a ready market for these recycled minerals exists when efficient recycling technologies are developed. Once a certain threshold of batteries is produced from raw materials, recycling batteries could eventually meet most or even all demand, supporting the manufacturing of new batteries without the need to extract more minerals.[39 40]

Electric Vehicle Battery Second Life

A secondary market is emerging for previously used batteries to be tested, repackaged, and used as backup battery support for the electric grid. In California, 1,300 recycled electric vehicle batteries were added to a solar farm to provide 25 MWh of grid-scale energy storage. Grid-scale projects like this help utilities support more renewable energy development and better manage the electric grid.[41] Creating a demand for previously used EV batteries may help offset some or all the costs to recycle used batteries.[42]

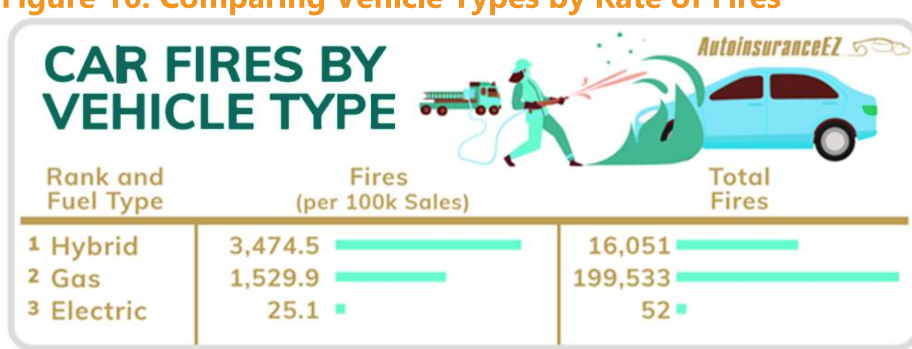
There are tradeoffs in moving from fossil fuel energy to clean energy technologies. New mining operations for EV batteries have some positive effects, such as economic inputs for local communities and some negative effects, including local environmental costs. When evaluating the tradeoffs for both, it is important to consider that clean energy requires less mining and will emit less overall emissions than fossil fuel energy, because less overall energy is needed to produce the same amount of force.[43] One analysis found that the total amount of mining needed for the anticipated global clean energy needs[iv] is about 535 times less than the total volume of fossil fuels mined today.[44] While this does not provide insight into the total land use needs or specifics on where these changes would take place, it does illustrate an overall benefit from this transition. EVs are more fuel efficient than internal combustion engine vehicles, and as a greater percentage of electricity generation is from renewable resources like solar and wind, there is an overall reduction in the amount of extractable energy needed to produce electricity. In the long run, a clean energy-based transportation sector will use less energy and fewer resources, which, coupled with existing efforts to positively influence environmental and human rights policies in countries where minerals and resources are extracted, means the clean energy future will have lower overall negative effects.

Electric Vehicle Safety

Electric vehicles are generally as safe as internal combustion engine powered vehicles, and like all on-road vehicles, they must meet federal motor vehicle safety standards. Some safety requirements are the same across both vehicles. The main differences are that EVs must have safety features designed to ensure the battery and high-voltage wiring in the car do not harm drivers or first responders. To achieve this, EV batteries are encased in a protective shell that not only shields them from damage in most accidents, but also creates a barrier between the battery and the rest of the vehicle. Batteries are tested by being subjected to overcharge, vibration, extreme temperatures, short circuit, humidity, fire, collision, and water immersion conditions, and must meet specific standards for each test. EVs also have high voltage electrical lines that are insulated and will be deactivated if they detect a collision or short circuit.[45]

Emerging data indicates that fire risk from electric vehicles is lower than for internal combustion engine vehicles. AutoinsuranceEZ assessed data from reported vehicle fires and found that electric vehicles were over 100 times less likely to catch fire than gasoline cars, and that more gasoline vehicles were recalled due to potential fire risks than EVs. In all the EV cases, the fire-risk recall was because of a defective battery, whereas for gasoline vehicles the issues included electrical shorts, braking system malfunctions, and fuel leaks. Although the data reported was per 100,000 vehicles sold, these numbers could be low due to the still relatively small number of EVs on the market, and the lower average age of those vehicles.[61]

Figure 16: Comparing Vehicle Types by Rate of Fires[61]

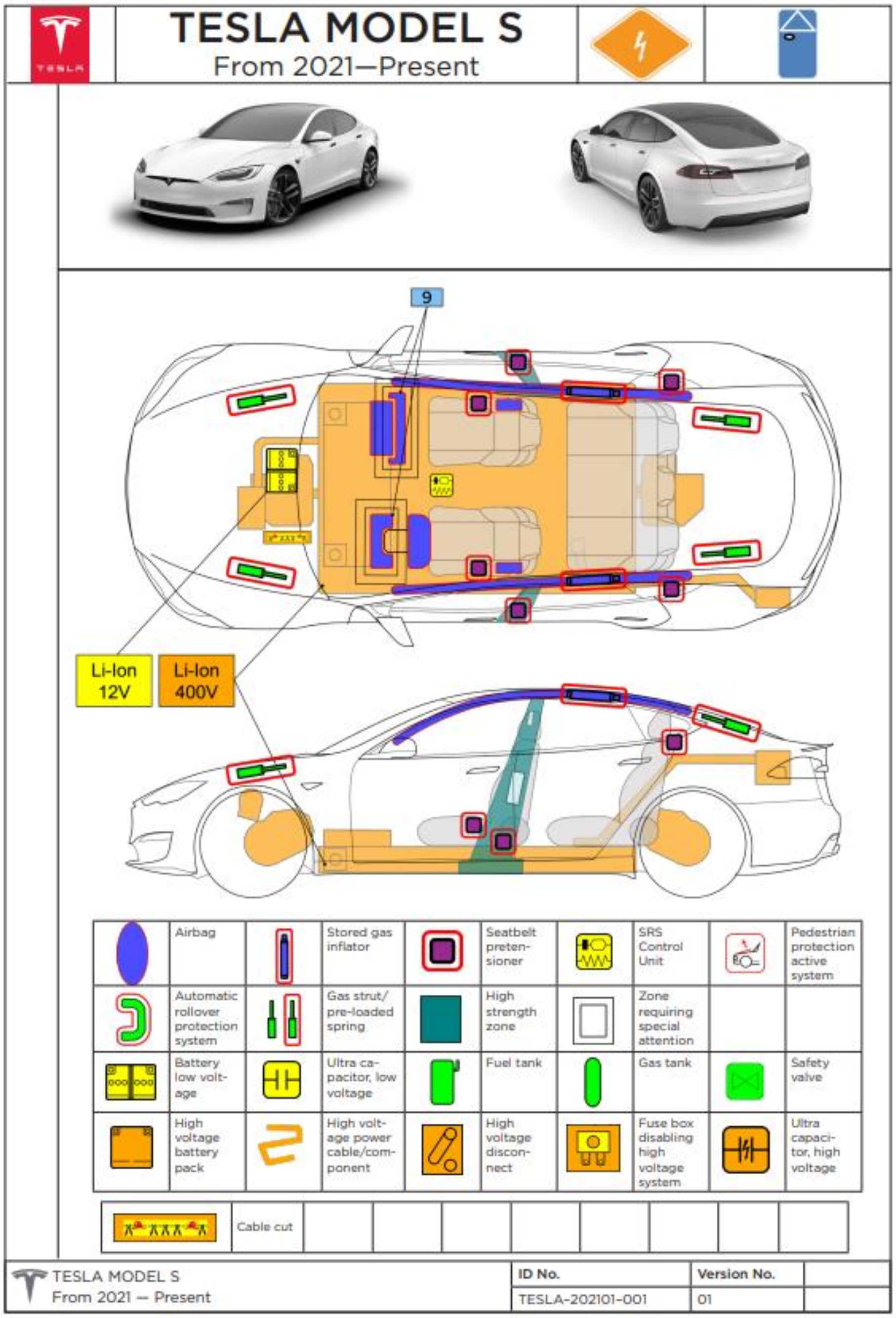


iv This includes the entire energy sector, not just transportation fuels.

When EV battery fires occur, they are more difficult to put out, and create an electrocution risk for anyone near the vehicle. Once a lithium-ion battery catches fire, the chemical reaction that occurs is self-perpetuating and will continue to burn until it is sufficiently cooled or runs out of chemicals or gas to burn. Training is essential, and not all emergency responders have been trained on how to safely manage an EV crash or respond to a battery fire.[46] Organizations like the National Fire Protection Association are working to provide online and in-person training for firefighters and first responders in both urban and rural areas.[45] Most vehicle manufacturers also provide educational resources for emergency responders. For example, General Motors maintains online training materials and delivers in-person sessions throughout the country.[47] Oregon Trail Electric Cooperative and the Federated Rural Electric Insurance Exchange created 360-degree, high-definition videos on electrical safety, viewable online or on VR headsets. The trainings help support small and volunteer fire departments in OTEC territory that are eager for training to address potential electrical hazards, including an electric vehicle fire.[48]

National Transportation Safety Board released a report in 2020 that identified two major safety gaps for first responders: inadequate emergency response guidance from vehicle manufacturers and a lack of testing data and research on high-speed, high-severity crashes.[49] As of 2022, eight manufacturers have released updated emergency response guides meeting NTSB recommendations, and another 12 are in the process of completing their update.[49] The UL's Fire Safety Research Institute is in the process of conducting more experiments on EV fires and best practices for fire suppression.[50] The NTSB also continues to gather data and information to assess root causes of vehicle fires and develop best practices for first responders.

Figure 17: TESLA Model S Instructions for First Responders[62]



How Do Firefighters Put Out EV Battery Fires?

In a crash, EVs have automated cutoff switches to isolate the battery and disable the electric system, but if this fails, first responders are trained to avoid contact with high-voltage areas of the vehicle, depicted above as orange-colored lines. EV Manufacturers publish emergency response guides and provide training for emergency responders on best practices for reducing the risk of electrocution or starting a fire by damaging batteries or other high-voltage areas. When fires do occur, manufacturers recommend using water to help cool the batteries down and, once the fire is out, submerging the battery in water for at least 24 hours to ensure it does not reignite.[45 46]

Electric Vehicle Weight

Electric vehicles weigh more than comparable conventional vehicles, largely due to the weight of the batteries. For example, the Ford F-150 Lightning weighs about 1,600 pounds more than a similar gas-powered F-150 truck. The larger the battery to provide greater power or range, the heavier the vehicle. The 2023 GMC Hummer EV is one of the heaviest light-duty vehicle models on the market at over 9,000 pounds.[51] The added weight actually makes riding in an EV safer, but conversely, has a negative effect on the safety of passengers in a conventional or lighter vehicle impacted by that EV in a traffic collision. The difference in the weight between the two vehicles can lead to more crash fatalities.[52] The National Bureau of Economic Research found that "controlling for own-vehicle weight, being hit by a vehicle that is 1,000 pounds heavier results in a 47 percent increase in the baseline fatality probability."[51]

The overall higher weight of EVs can affect costs to maintain roads and have local environmental effects. Heavier vehicles create greater wear on roads and bridges. As heavier EVs become a larger proportion of the overall fleet, existing infrastructure may need to be repaired or replaced more frequently.[52]

The additional weight and faster acceleration of EVs also means tires wear down about 20 to 30 percent faster than on conventional vehicles.[53] Emissions resulting from tire wear contribute to particulate air pollution and the accumulation of microplastics in the environment. The higher abrasion of tires and asphalt creates more unhealthy microscopic particles in the air along traffic corridors.[54] [55] There is the potential for these emissions to more adversely affect neighborhoods near roadways, many of which are disadvantaged communities. Manufacturers and tire companies are developing more durable tires for EVs, to improve life expectancy and reduce the resulting particulate emissions.[56] More studies are needed to fully assess the local environmental effects of tire wear, particularly with the advent of increasing numbers of heavier EVs on Oregon's roads.

For medium- and heavy-duty EVs, the added weight of the vehicle battery can limit freight capacity. A semi-truck can legally weigh a maximum of 80,000 pounds in Oregon, including its cargo. ODOT allows an exception of an additional 2,000 pounds for an electric vehicle, but a battery for an electric semi-truck will weigh about 16,000 pounds, or 20 percent of the total maximum weight of the truck.[57] The greater the weight of the battery, the less cargo trucks can haul on their routes. A trucking company's profits are tied to the amount of freight it can efficiently haul per mile, and heavier loads may need to be reduced to meet overall weight restrictions. For some companies, converting to electric trucks today may not be viable until more energy dense batteries are commercially available or there are changes to weight restrictions.[58] [59] Advocates of electric trucks have recommended federal increases in vehicle weight limits by 10 percent, or 8,000 pounds, allowing carriers to regain lost load capacity, but truck weight increases would have safety, infrastructure, and environmental considerations. Decision-makers will need to weigh the relative tradeoffs when considering policy options enabling more electric trucks.[60]

Conclusion

Oregon consumers have a higher degree of electric vehicle awareness than many other states, largely because EVs are more prolific in many parts of the most populous areas of the state. Drivers who encounter EVs and charging infrastructure are more likely to purchase an EV, and most people first encounter EVs through family members, friends, neighbors, and coworkers. However, some Oregonians have limited exposure to the vehicles and charging infrastructure, particularly disadvantaged communities such as low-income, rural, and communities of color. State programs that support EVs and charging in these communities can help increase exposure and overall adoption.

Consumers have many questions and concerns about EV adoption, including environmental and human rights effects from building and disposing of batteries, the effects of EVs on Oregon roads, safety, and whether existing EV ranges and charging infrastructure can meet their daily travel needs. Oregon decisionmakers require ongoing assessment of the relative environmental, economic, and societal trade-offs to inform EV policy development.

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Snowboarders jump over an electric vehicle at the Mt. Hood EV celebration, Photo credit: ODOT

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

Distribution of EVs by Demographic Groups

Key Takeaways

- Where people live and their financial security are strongly correlated with EV ownership in Oregon. Low-income drivers, People of Color, rural Oregonians, renters, and multi-unit housing residents have lower adoption rates than the state average.
- The up-front costs of EVs and limitations on access to charging infrastructure are significant barriers for low-income and rural Oregonians.
- The distribution of EVs is not equal across all demographic groups and many Oregonians are not able to take advantage of the economic and environmental benefits of driving an EV.
- Oregonians' uses of transportation are changing due to urbanization, telecommuting, and generational views on car ownership, public transportation, and carsharing.

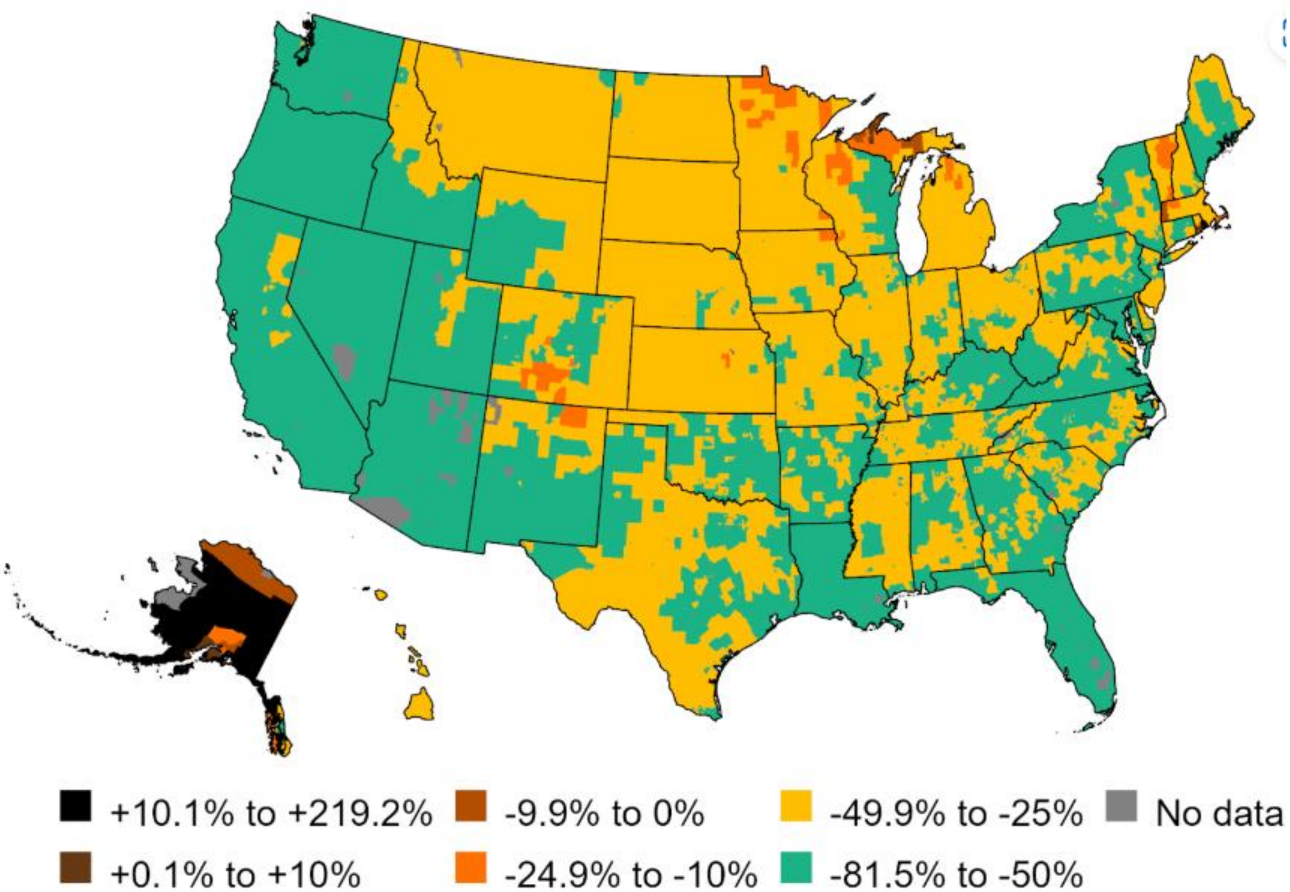
Introduction

EV ownership is not consistent across all communities in Oregon. This chapter uses Oregon EV sales and registration data to provide insight on ownership trends for different geographic and demographic communities, as well as potential underlying causes contributing to lower adoption rates. Understanding the specific challenges to EV ownership for different communities can inform program and policy designs that enable higher and more equitable adoption rates.

Benefits of Electric Vehicles

EVs offer many benefits for individuals, families, and communities, including lower fuel and operational costs, local air quality improvements, and less traffic noise.[1,2] A University of Michigan study found that "More than 90 percent of vehicle-owning households in the United States would see a reduction in the percentage of income spent on transportation energy—the gasoline or electricity that powers their cars, SUVs and pickups—if they switched to electric vehicles."[3] The Pacific Northwest has some of the lowest electricity rates in the country and also the highest gasoline prices.[4] Driving electric vehicles can significantly lower fuel costs for drivers. Figure 1 below shows how adopting an EV in the U.S. can have different economic outcomes. Areas shaded in green, including Oregon, stand to benefit the most with 50 to 81.5 percent reductions in the driver's transportation energy costs.

Figure 1: Potential Transportation Energy Burden Change from Conversion to EVs[3]



EV adoption can help address transportation energy burden in Oregon, particularly for low-income communities, because they have lower operating costs.[5] In 2020, Argonne National Laboratory evaluated the transportation energy burden of counties in the U.S. to demonstrate the sharp disparities in affordability across socioeconomic variables. ANL reported that "Suburban and rural households spend more on vehicle fuel costs compared to urban households primarily due to less fuel-efficient vehicles and higher annual VMT… wealthier census tracts have better fuel economy on average. Based on this analysis, the ownership of more fuel-efficient vehicles, especially among low-income households, could have the biggest impact on improving household transportation energy burden." In Figure 2, darker shaded counties have greater transportation energy burden, including many of Oregon's rural eastern counties.[6]

Figure 2: National Transportation Energy Burden by County[6]

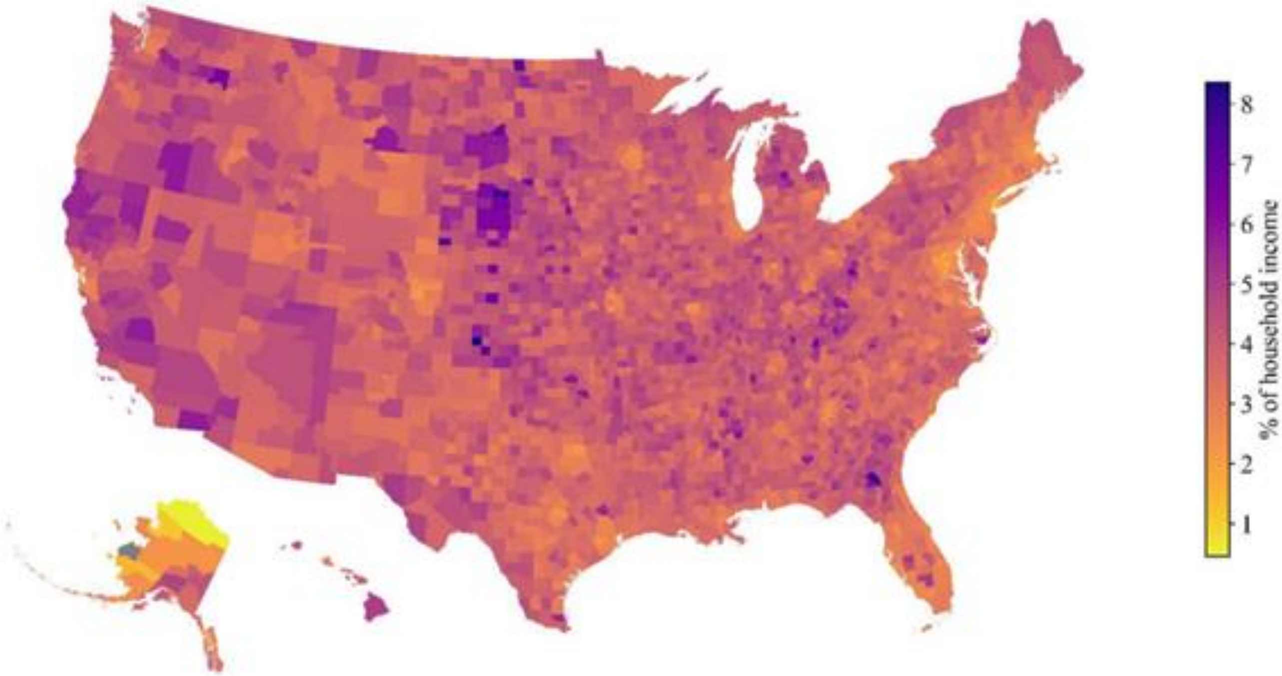
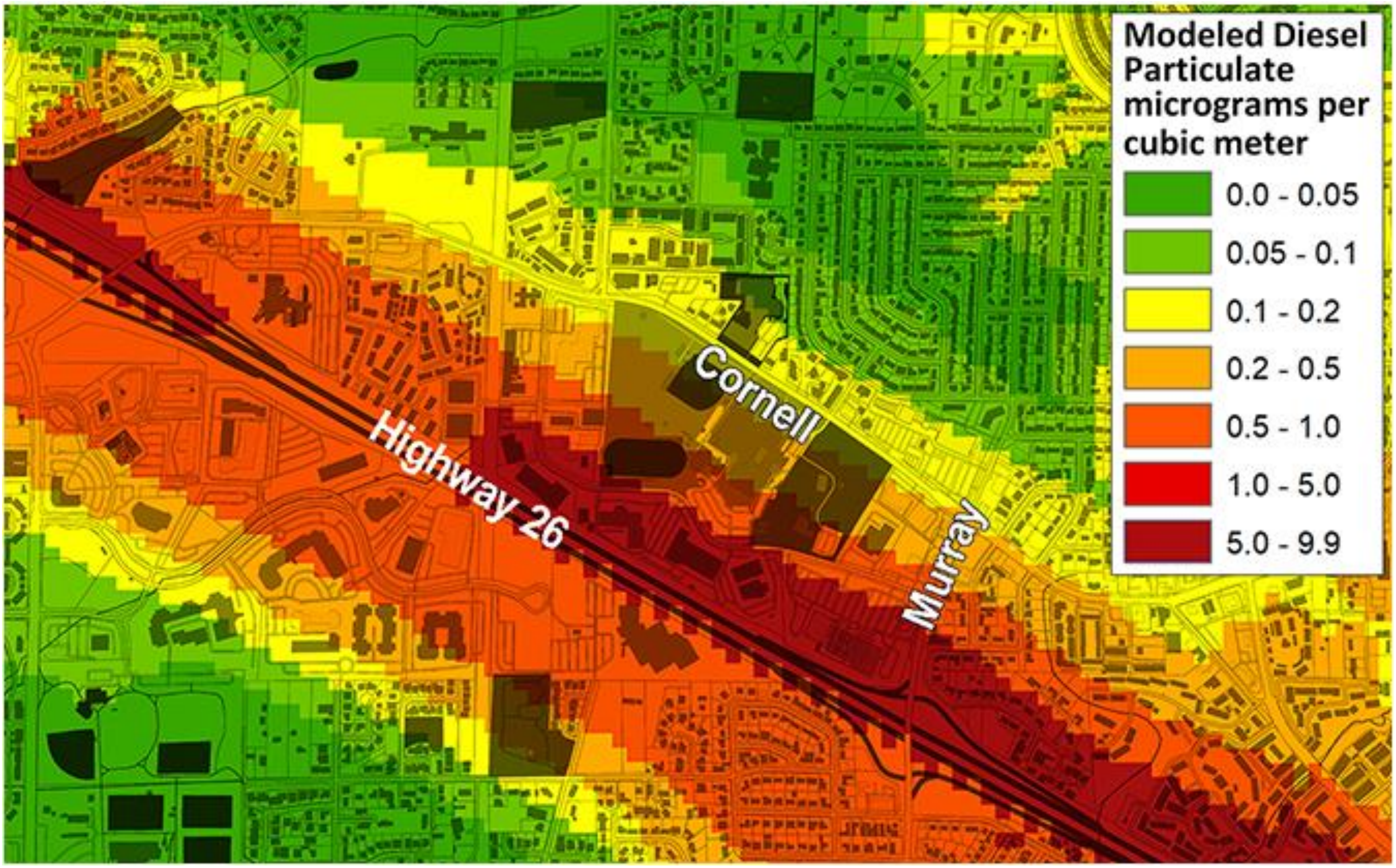


FIGURE ES-1 Transportation energy burden by county (grey area = no data)

There are health benefits associated with increased use of EVs for people living near busy roadways – often low-income communities and communities of color.[7] People living and/or working near busy traffic corridors are disproportionately harmed by vehicle-generated air pollution, including asthma, impaired lung function, premature death, and death from cardiovascular diseases and cardiovascular morbidity.[8] [9] Figure 3 below shows increased amounts of diesel particulate air pollution surrounding a portion of Highway 26 in Washington County. Because they produce no tailpipe emissions,[i] driving EVs improves air quality along traffic corridors and their surroundings.

[i] Plug-in hybrid electric vehicles may have some emissions from the combustion of fuel in addition to the battery operation, but emissions are likely to be significantly reduced than a comparable internal combustion engine vehicle.

Figure 3: Modeled Diesel Particulates on Highway 26 in Washington County, Oregon[ii] [10]



Demographics of Electric Vehicle Owners

Parsing out electric vehicle registrations by different demographic groups provides insight into which communities in Oregon are actively adopting EVs and where there is limited or no uptake. Lower adoption rates may indicate barriers to EV ownership for specific demographic groups. Where there are gaps, engagement with individuals in these communities can better identify priorities, needs, and challenges influencing their car-buying decisions, such as cost, access to charging, or the capabilities of the vehicle. Understanding these barriers can inform more equitable policy development to help Oregon meet its EV adoption and climate goals.

The information presented in this chapter is intended to provide insight into EV ownership patterns across Oregon, but it is important to note that there are some limitations to the data analysis. Address-level registration data from Oregon Department of Transportation's Driver & Motor Vehicle Services (DMV) is used to identify passenger EV ownership, and this analysis assumes registered owners are synonymous with buyers. Registration data was analyzed with U.S. Census Bureau data to better understand the state of EV adoption across different groups of people, including by income

[ii] Portland Clean Air modeled on-road diesel particulate distributed over roads using ODOT 24-hour truck counts and EPA's 2014 National Air Toxics Assessment data.

level, race, and housing characteristics. Census data are provided at the “block group” level,[iii] which means that ownership cannot be attributed to an individual but rather assessed against the characteristics of this smaller population unit. The data are illustrative of general trends and are useful for informing policy design that can improve equitable access to EVs and their benefits, but they cannot fully evaluate the diverse nuances and highly community-specific variables that influence an individual’s ability and desire to choose an EV.

Electric Vehicle Ownership by Level of Urbanization

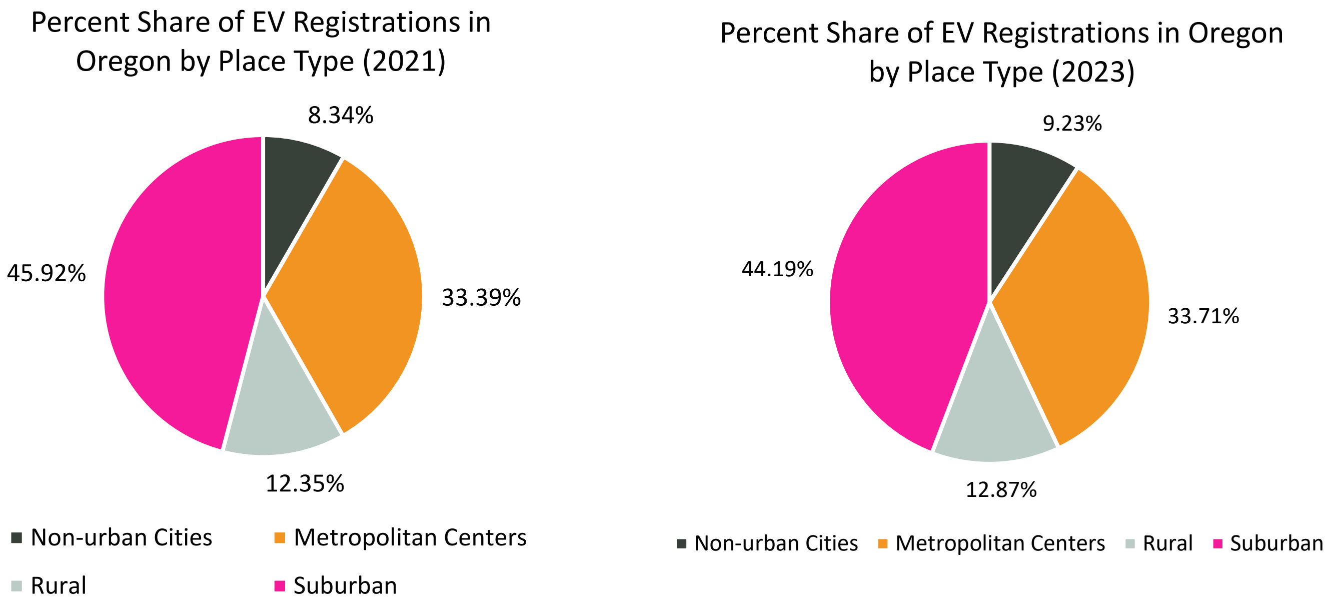
Rural EV adoption in Oregon is significantly lower than urban and suburban areas. While 35 percent of Oregonians live in rural parts of the state, only 13 percent of EV registrations are in these areas. Eighty-seven percent of EVs are registered in or near metropolitan areas.[12] This split has not changed significantly since 2021. Lower EV adoption rates in rural parts of Oregon may be due to a combination of factors, including EV range concerns, lack of preferred platforms like pickup trucks and large SUVs, skepticism about performance, limited public charging infrastructure, and lower average incomes.[13] Higher density living in urban and suburban neighborhoods also enables greater exposure to EVs and chargers, which is strongly correlated with the likelihood a person will purchase an EV (see the *Oregonians’ Awareness of EV Options and Benefits* chapter). Further, households in communities with low ownership of EVs are less likely to have access to them, experience them, or consider them as a viable vehicle option.[13] These factors perpetuate inequitable access to and ownership of EVs within Oregon’s rural communities.

Suburban areas have the greatest percentage of EVs registered in Oregon and non-urban cities have the lowest, but there have been modest increases in non-suburban areas of the state. In Figure 4, Oregon geographic data are characterized into distinct place types.[iv] These place types describe the physical characteristics and interdependencies of a population center and how it influences transportation choices. Rural refers to areas with relatively low population density that are far from densely populated urban centers and includes remote frontier areas (e.g. Lake County). Suburban refers to primarily residential communities near and within metropolitan areas (e.g. Beaverton). Metropolitan centers refer to dense, highly populated urban areas such as commercial and industrial areas, downtown city-centers, and mixed-use areas (e.g. the Portland metropolitan area). Non-urban cities are moderately dense areas relatively far and/or isolated from major urban centers (e.g. Newport). Figure 4 compares the percentages of EV registrations in 2021 and 2023, across these four categories. While the share of EV registrations increased for both rural and non-urban cities at 4.2 percent and 10.8 percent respectively, EV registrations remain more predominant in metropolitan centers and suburbs.

[iii] Census block groups are the smallest (lowest) level of geography published by the American Community Survey (ACS), the annual demographics survey conducted by the U.S. Census Bureau[11]

[iv] The tool utilized for this analysis (developed by ODOT and Oregon’s Department of Land Conservation and Development) initially categorized Oregon’s geographic area with nine place types.

Figure 4: EV Registrations by Level of Urbanization[14]



Rural drivers need access to a robust network of public charging stations, and rural chargers will need to meet a wide variety of needs, including long-distance light-duty vehicle travelers, vehicles that are towing other vehicles, specialized farming equipment, and other types of vehicles traveling across the state. Drivers in rural eastern and southern parts of the state need sufficient charging to accommodate lower ranges that can occur in extreme heat and cold, particularly in winter months. Consumer Reports tested EV ranges in different temperatures and "found that cold weather saps about 25 percent of range when cruising at 70 mph compared with the same conditions in mild weather."[15] (See chapter on *Availability and Reliability of Charging Infrastructure*.)

Rural Utilities Take the Reins

As electric vehicle ownership grows across the state, rural electric utilities are critical to developing infrastructure and community education to support the transition. Many of Oregon's rural electric utilities are investing in electric vehicles, charging infrastructure, and community engagement to build local exposure to the economic and environmental benefits of driving an EV. Emerald People's Utility District, Midstate Electric Cooperative, and Central Electric Cooperative launched EV carsharing programs to allow customers to borrow and experience driving an EV. Because there is less EV ownership in their territories, they also added EVs into their own fleets to increase community exposure. CEC created an education campaign, including videos, infographics, and virtual tours, to inform its customers about EVs, EV charging infrastructure, and related topics. These awareness-building efforts are important first steps in integrating electric vehicles in these rural communities.

Rural electric utilities are experiencing growth in EV ownership and increased loads in their service territories. Midstate Electric Cooperative and Central Electric Cooperative experienced a near 50 percent growth in the number of EVs in their territories from 2021 to 2022.[14] State transit corridors cross multiple electric utility territories and siting charging stations requires the cooperation of neighboring utilities. For example, Midstate Electric Cooperative and Emerald People's Utility District are working with state and local officials to add charging stations along Highway 58. Additional charging supports utility customers' charging needs and creates a highway charging network from the coast to the eastern region of the state for travelers.

EV Ownership by Income Level

There continues to be a correlation in Oregon between EV ownership and income. Most EV owners make more than the state's median household income of $70,084,[v] and ownership rates are even higher for Oregonians earning more than twice the median household income.[14, 16] Oregon counties with average household incomes less than the state median account for only 30 percent of registered EVs in Oregon.[14] In Figure 5 below, as average county household income increases, represented by the x-axis, the number of EV registrations also increases, represented by the y-axis. ODOE also assessed the correlation (represented by the r^2 values) between income and EV adoption in 2019 and

[v] Reported in 2021 dollars and calculated as the five-year average from 2017-2021

2022, shown in Figure 6. The correlation is slightly stronger, meaning that higher income counties were increasingly likely to have higher EV registrations.

Although there is a strong link between income and EV ownership, notable outliers in the data illustrate a constraint in the analysis. Some counties with average median incomes below the state median have higher EV adoption rates (greater than 10 EVs per 1,000), including: Lincoln (13.09), Tillamook (11.76), Clatsop (10.59), Lane (14 EVs), and Jackson (13.54).[14] This is likely due to limitations of comparing *countywide* median income averages to EV adoption rates. Although their median incomes are considerably lower than the other counties with similar EV adoption rates, they may have pockets of higher income communities that are not reflected at the county level. Overall, the counties that were highest above the trendlines were in large population centers and those furthest below represented some of the most remote areas of Oregon.

Figure 5: Registered EVs in relationship to Average Income in Oregon Counties[14]

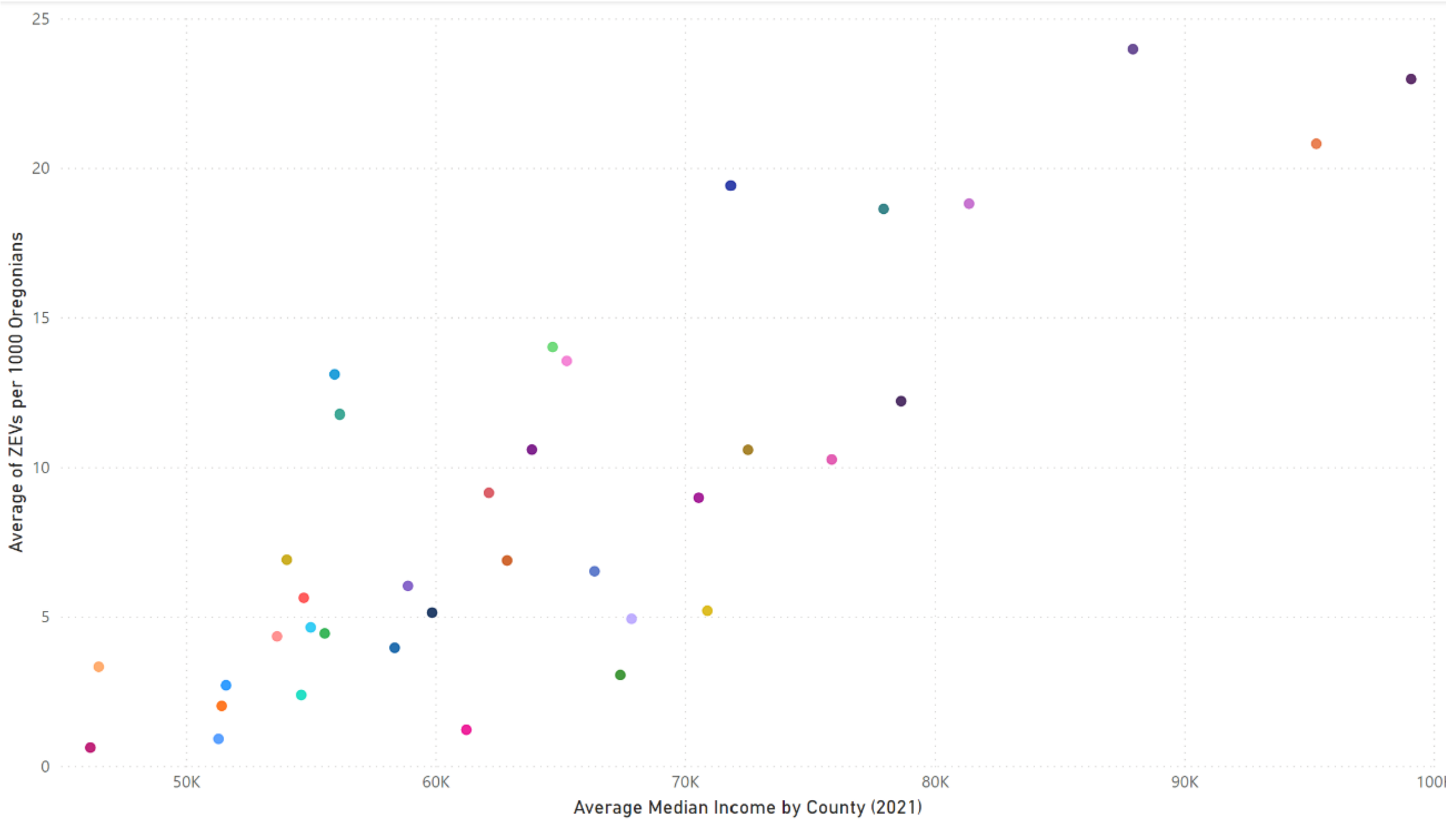
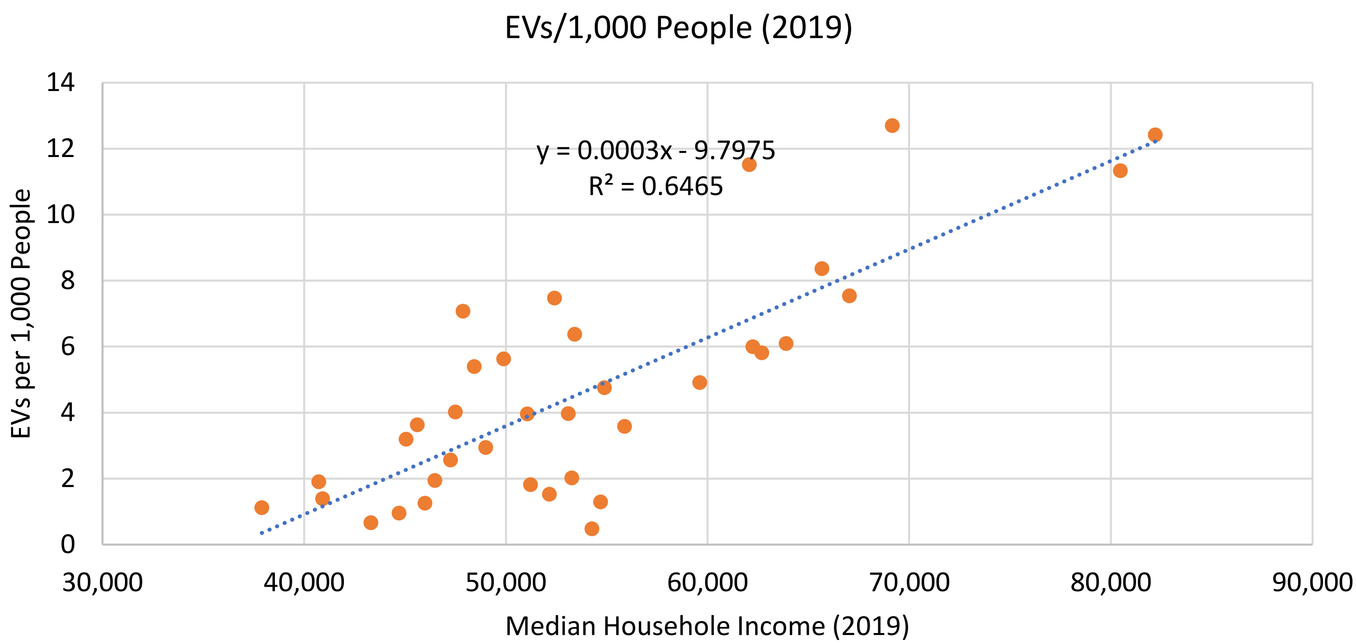
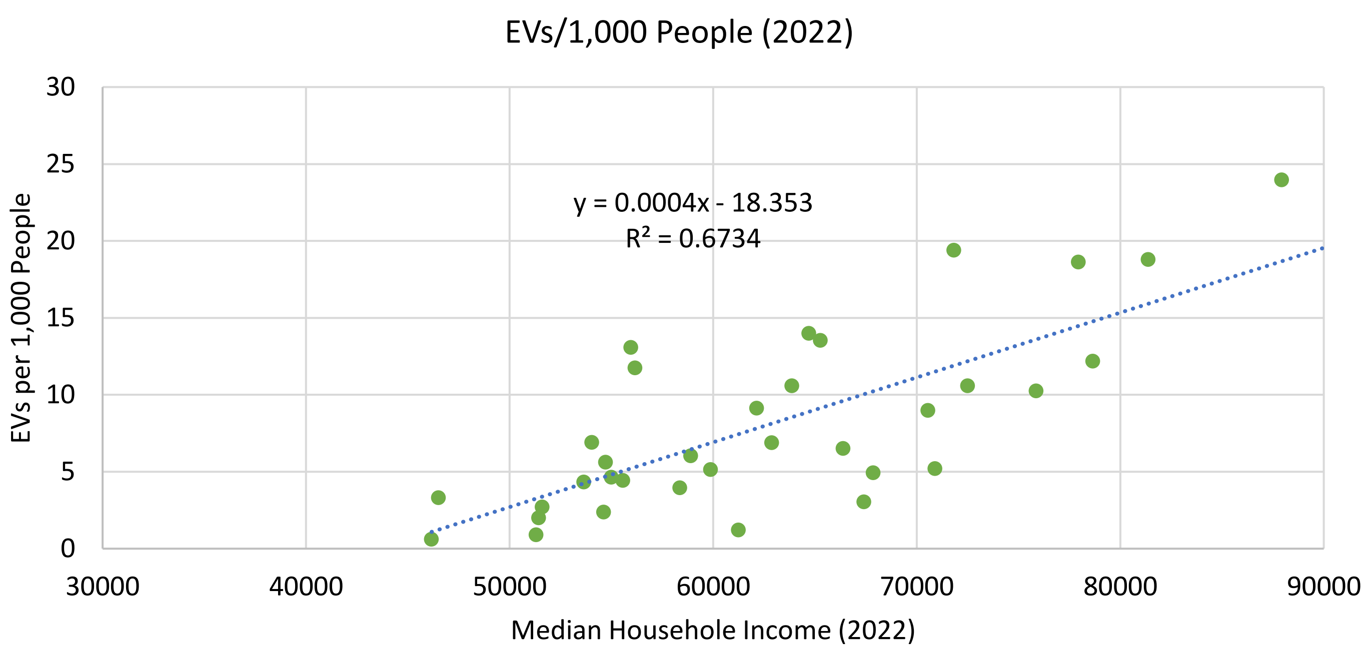


Figure 6: Correlation Analysis of EV Registration and County Income Data[14]



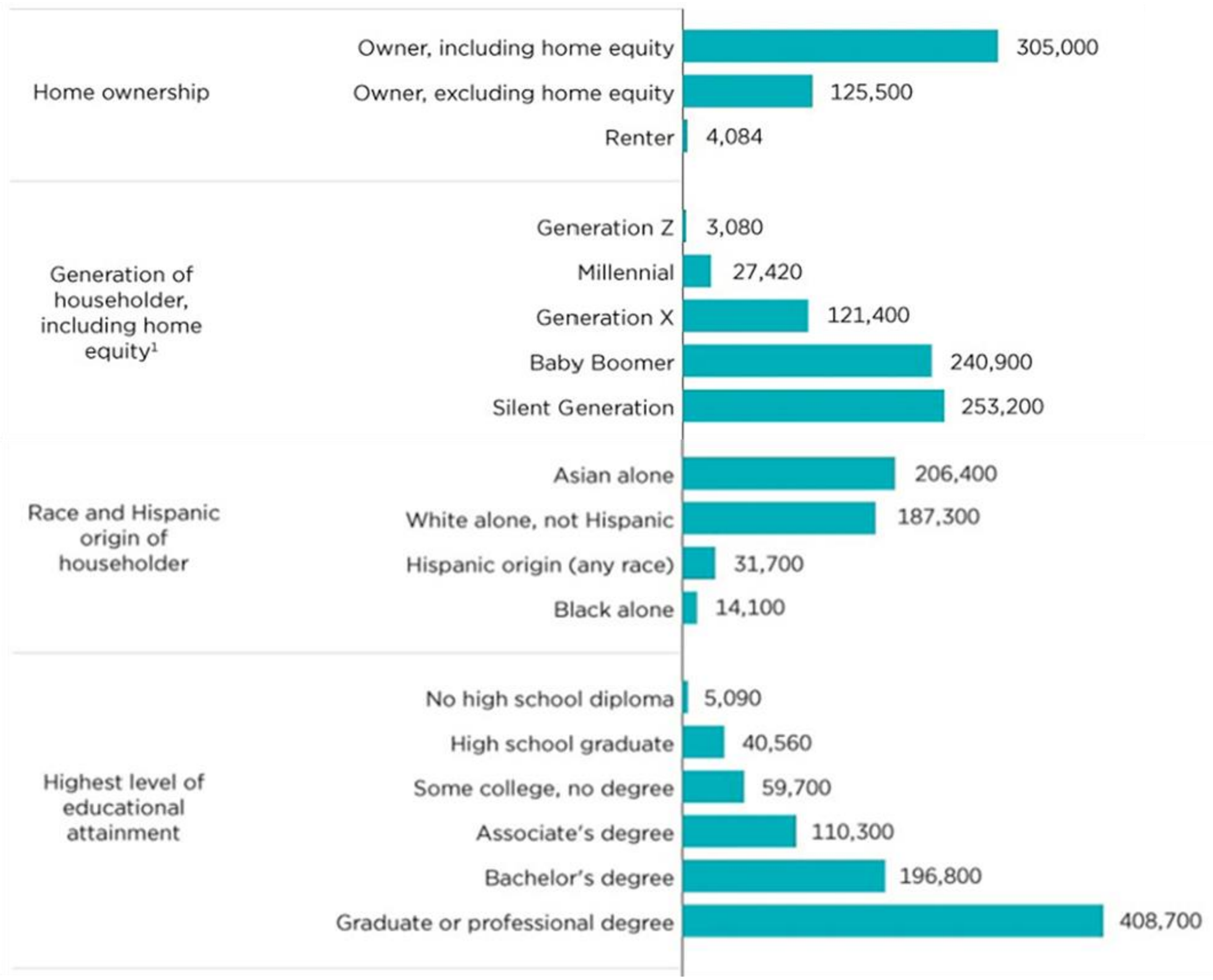


Systemic inequities across low-income families, communities of color, and renters have reduced their capacity to finance and pay for large purchases. While income level is associated with ability to purchase an EV, accumulated wealth[vi] also has an influence. Access to accumulated wealth can help buyers pay more for a down payment, receive a lower interest rate, or even pay for the vehicle outright. Figure 7 below shows significant national wealth barriers for renters, younger generations,

[vi] Accumulated wealth refers to the total value of assets, investments, savings, and other forms of wealth that a person or entity has acquired over time.[17]

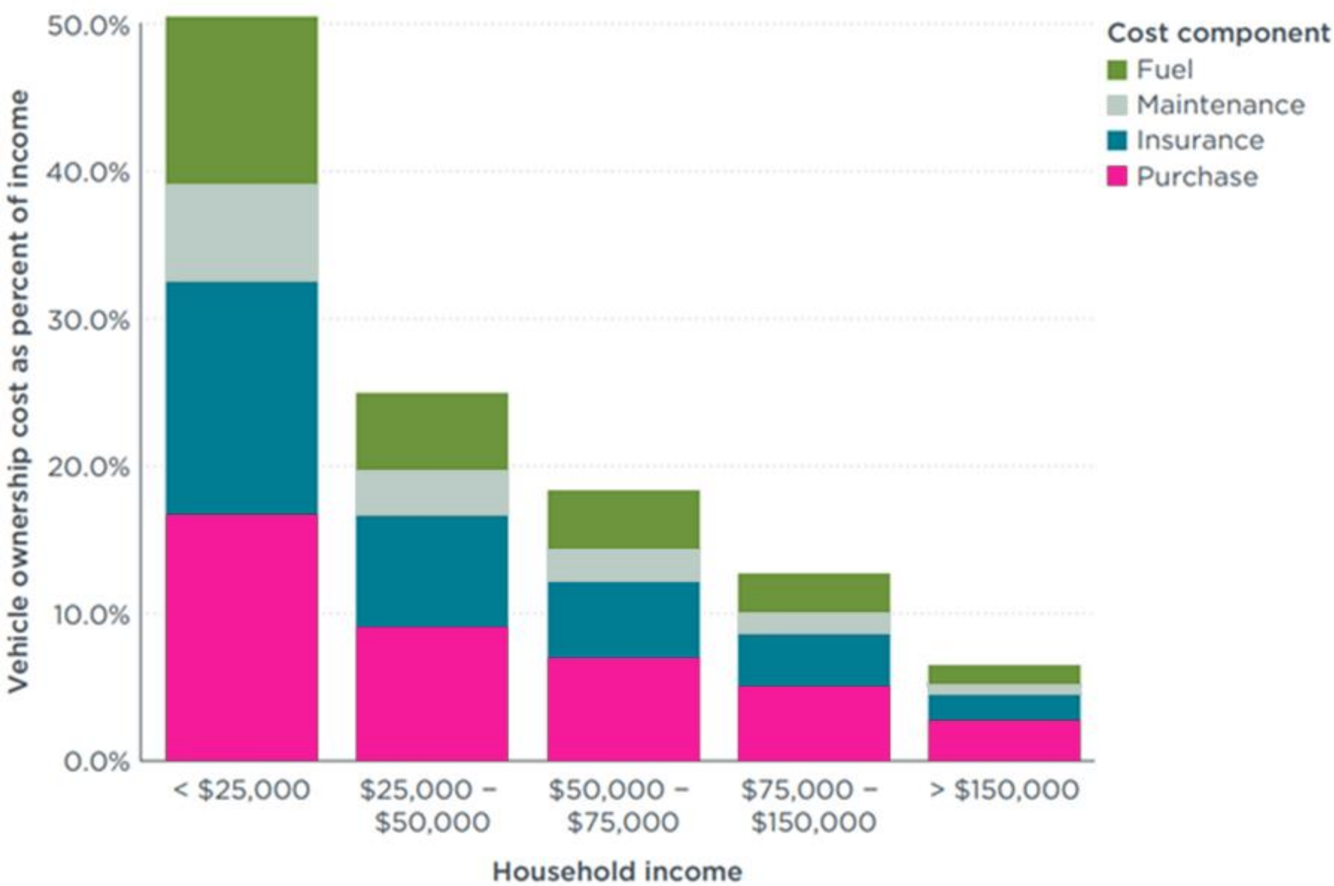
and black and Hispanic communities. These wealth disparities may become more exacerbated in the coming years if fossil fuel costs rise.[18] Market changes and greenhouse gas emission regulations could put upward pressure on petroleum costs, potentially increasing transportation energy burden in these communities, while wealthier EV owners would be insulated from these costs.[19]

Figure 7: Median Wealth by Household Characteristics: 2019 Census Data (In 2019 dollars)[19]



Total vehicle ownership costs, including fuel, maintenance, insurance, and the purchase cost are an increasingly higher proportion of household income as annual income decreases. Figure 8 shows that 50 percent of the average annual income for people making less than $25,000 per year is used for transportation, compared to drivers making between $75,000 and $150,000 (16 percent). The figure represents net cost of vehicle purchase after accounting for resale value, insurance, maintenance, and fuel costs. Switching to an EV can result in significant fuel savings for a similar type of vehicle.[vii] Savings largely come from lower costs to operate an EV compared with gasoline or diesel vehicles, and could go toward a monthly vehicle payment — though if the buyer must finance most or all of the costs, this amount is not likely to cover the entire payment. The higher up-front cost also often means higher insurance costs. Fuel and maintenance savings could offset the higher insurance costs or go toward the monthly car payment. (See the chapter on *Cost Differences Between EVs and Internal Combustion Engine Vehicles* for more.)

Figure 8. Total cost of vehicle ownership as percent of income, by annual household income[20]



Note: This analysis does not include costs from financing, licensing and registration, or parking. These items apply to all vehicles regardless of fuel; however, these costs also disproportionately affect low-income car-owners.[20]

Time investments are more closely linked to money for many low- and moderate-income communities, who have limited resources to pay for time-saving conveniences like restaurants, cleaners, and babysitters.[21] Until charging infrastructure becomes as ubiquitous and reliable as gas stations, driving an EV can require more planning and time flexibility to find an available charger. For drivers living in multi-unit homes or in houses that lack driveways or garages, there is a time investment to keep the vehicle fueled. Charging typically takes longer than the 2-3 minutes it takes to

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[vii] Based on 11,500 miles per year, $4.60/gallon gasoline and ¢12/kWh (assumes home charging) using the State of Oregon: DATA & REPORTS - Oregon Electric Vehicle Dashboard calculator

fill up at a gas station. A public DC fast charging station can take 20 minutes to an hour, depending on how much charge the battery requires.[22 23] Long-distance trips also need more planning and research to identify charging stations and more time to charge the vehicle along the route.[24] Regardless of other costs, this investment of time is more onerous for many time-constrained low- and moderate-income drivers.[20 25]

Electric Vehicle Adoption by Type of Home

In Oregon, single-unit homeownership continues to be a leading indicator of the likelihood of whether a driver will choose an EV. Charging at a single-unit home is convenient, affordable, and practical. An estimated 80 percent of charging occurs at home.[26] Most single family homes afford EV drivers the convenience of charging their vehicle when it is not in use and the low cost of paying to charge largely through their residential electricity bill.[27]

Multi-unit building residents are significantly less likely to own an EV.[14] While 37 percent of Oregonians reside in multi-unit homes, only 21 percent of EVs are registered in areas where more than half the residences are multi-unit, as shown in orange in Figure 9 below. Nearly 79 percent of Oregon EVs (shown in teal) are registered in areas where most residences are single-unit homes. This is largely reflective of what ODOE found in the 2021 report, but there are indicators this demographic distribution may be changing.

Figure 9: Comparison of Oregon EV Registrations in Areas that are Predominantly Single-Unit Homes or Multi-Family Homes[14]

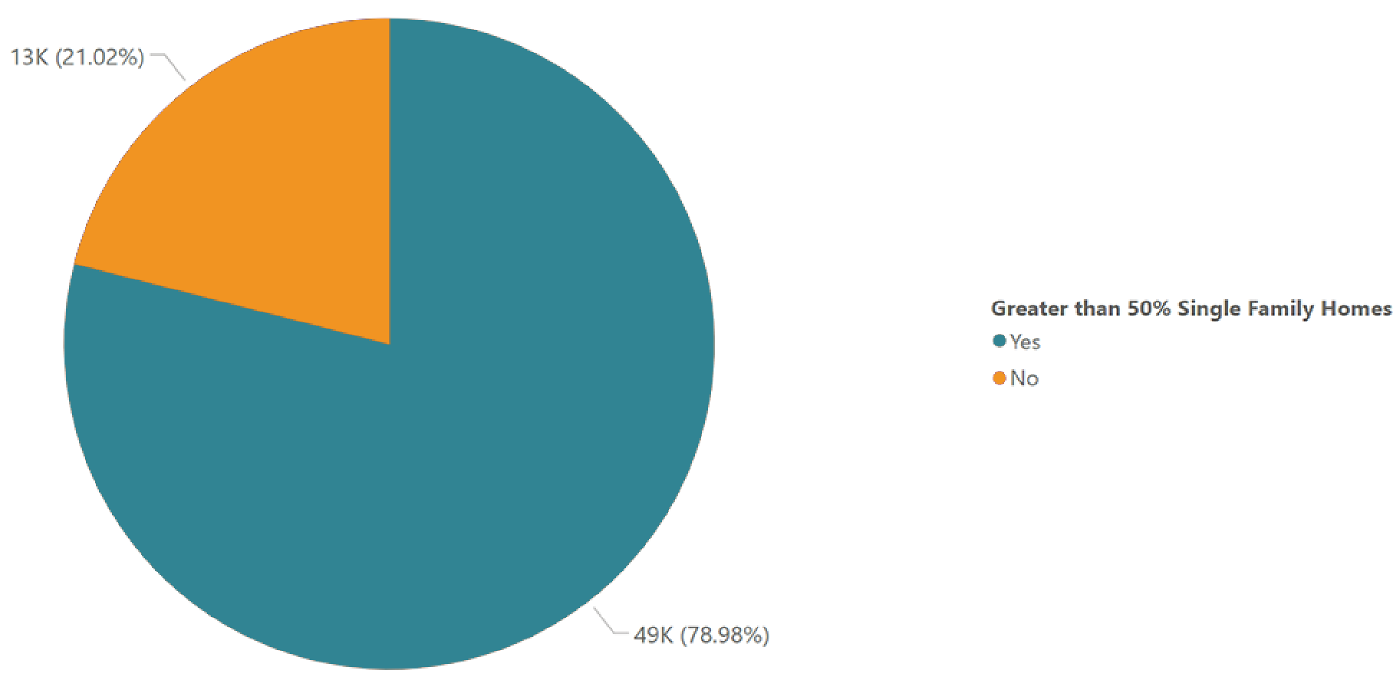


Figure 10 shows EV adoption across four distributions of housing types in Oregon, and EV ownership is highest in areas where 75 percent or more of the housing is single-unit homes. Although there are fewer EVs in other areas, Table 1 shows the highest growth rates in EV registrations occurred in areas where there was at least some multi-family housing. EV registrations in communities with only single-unit homes grew by 61 percent, but grew by about 75 percent in all other housing breakouts.[14]

Figure 10: Comparison of Oregon EV Registrations in Areas Broken Out Into Different Percentages of Single-Family Homes and Multi-Unit Homes[14]

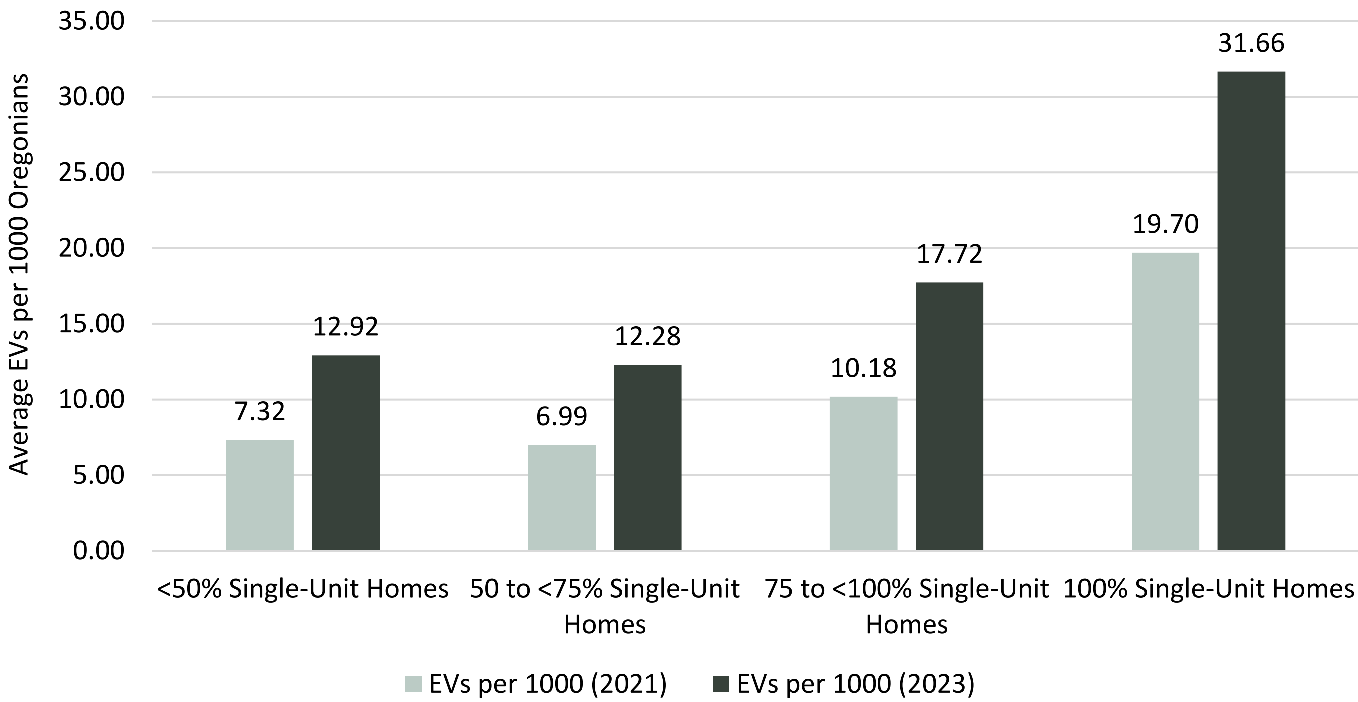


Table 1: EV Registration Growth Rate in Areas with Different Percentages of Single-Family Homes[14]

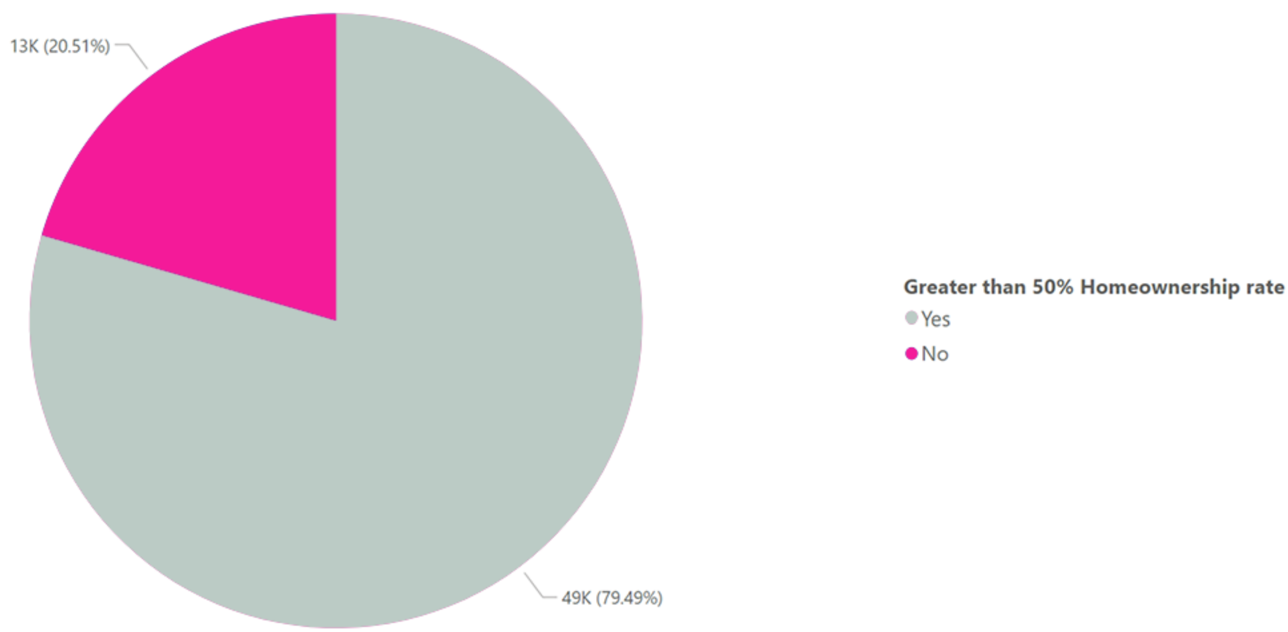
Percent Single-Family Homes	<50%	50 – <75%	75 – <100%	100%
Percent Increase in EV Registrations Since 2021	76.5	75.6	74.1	61

Further research is necessary to determine why the EV registration growth rate is higher in areas with lower numbers of single-family units. EV data are not specific to individual owners and do not indicate whether new EV owners live in multi-unit buildings or in single-family homes. The growth could reflect increased EV adoption from single-family homeowners within those areas. Continuing to collect, analyze, and expand on this data is important to informing EV-related policy development.

Electric Vehicle Adoption for Homeowners Compared with Renters

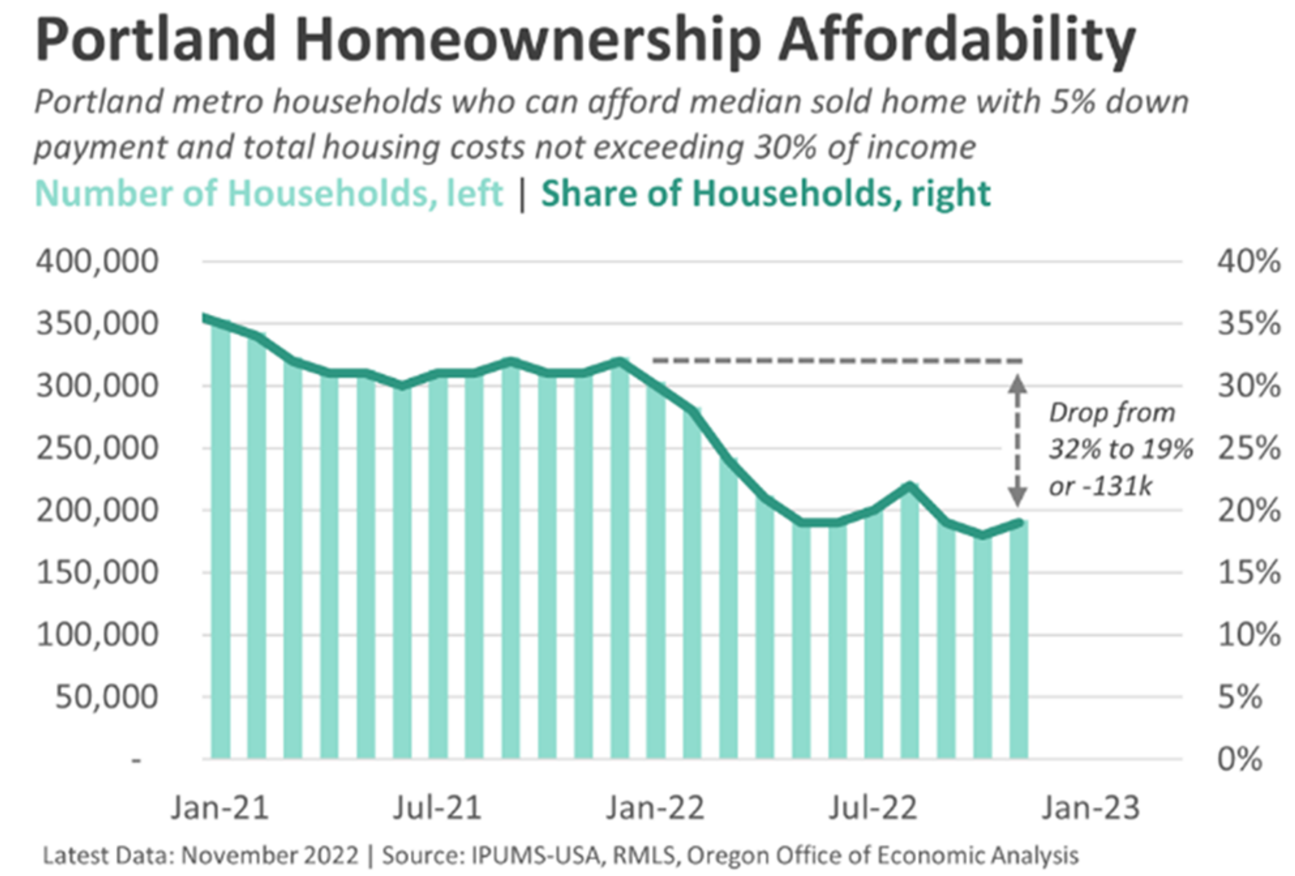
Nearly 80 percent of Oregon EVs are registered in census block groups where more than 50 percent of residents own their own home, compared with the roughly 65 percent of households that are owner-occupied statewide.[28] The 2023 demographic breakout for homeownership and renting is nearly the same as in 2021. Homeownership is often associated with single-unit homes and similarly, renters are often associated with multi-unit homes. While there is significant overlap in these categories, it should be noted that there are some multi-unit homes, including condominiums, that are occupant-owned, and some single-unit homes are occupied by renters.

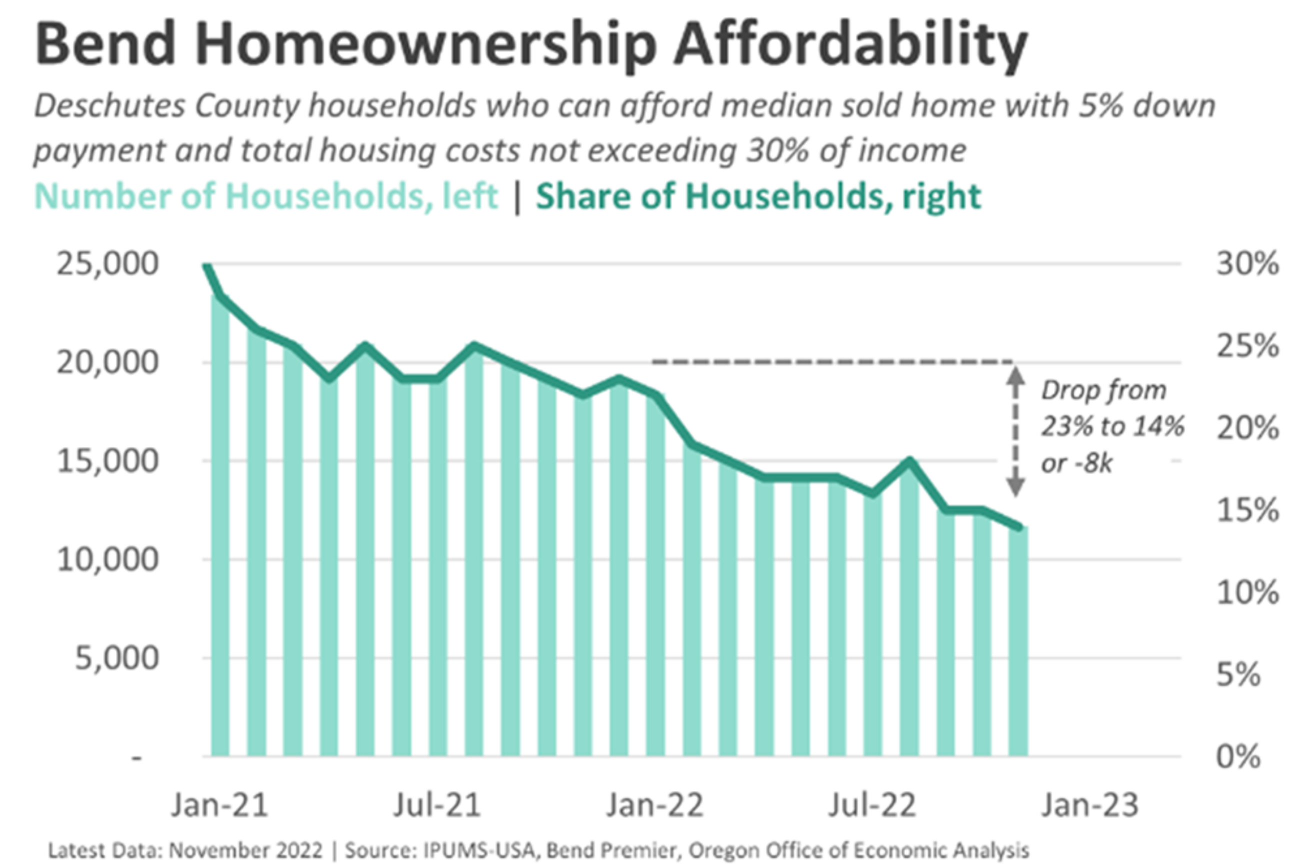
Figure 11: Comparison of EV Registrations in Areas with Different Homeownership Rates[14]

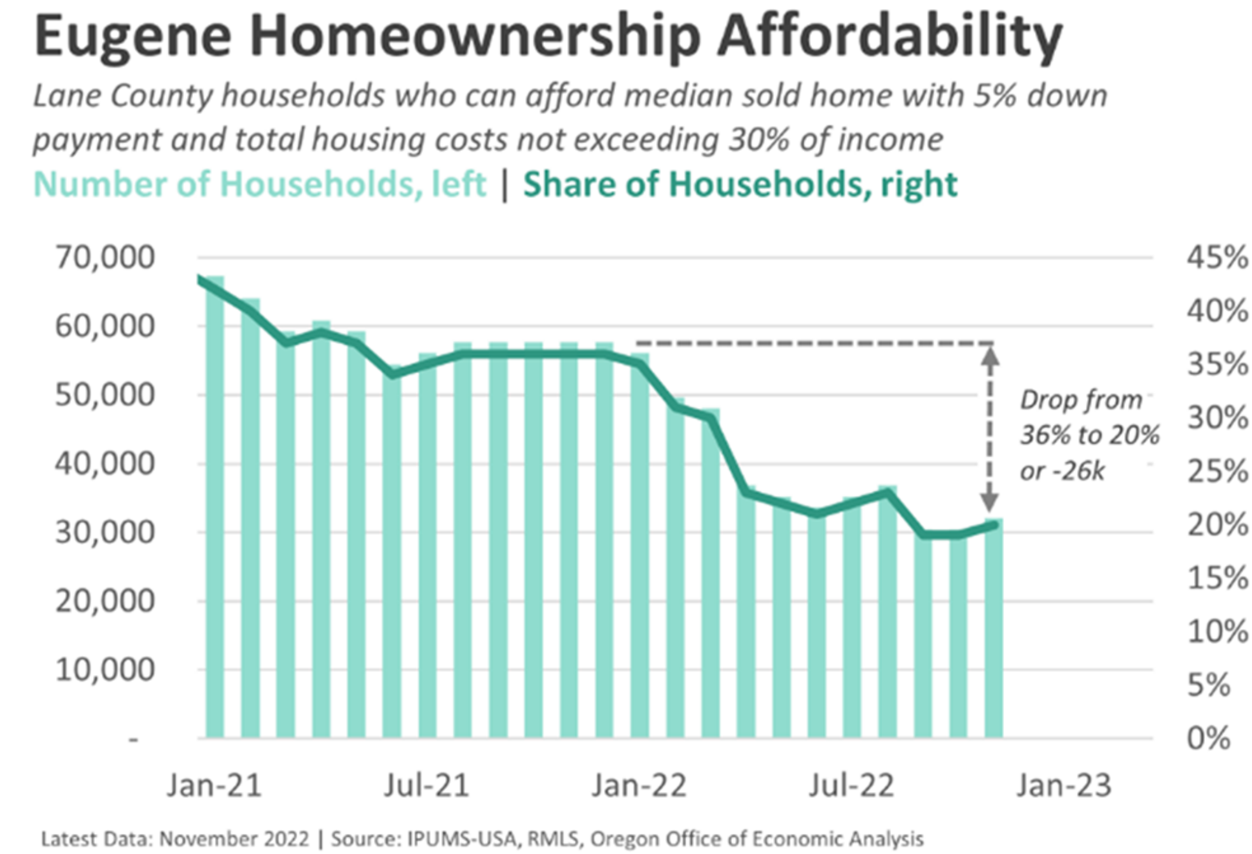


Homeownership has direct implications for EV adoption because of the lower cost and convenience of charging at home. In a 2020 customer survey of more than 600 residential Pacific Power customers, over 70 percent of respondents indicated that the ability to charge at home was a motivating factor to purchase an electric vehicle.[29] Oregon is currently in a housing supply and affordability crisis that puts homeownership out of reach for many households. The Portland, Bend, and Eugene areas all have a significant decline in the number of people that can afford to own their own home, as shown in Figure 12 below. This means increasing numbers of residents will need to rent their home, and renters – particularly those living in multi-unit homes – are less likely to have a dedicated or convenient parking spot with access to an electrical outlet or charger.[30]

Figure 12: Homeownership Affordability in Major Metropolitan Areas of Oregon[31]







Homeowners are much more likely to have the financial resources to bear the up-front cost of transitioning to an EV. While income level provides some insight into an individual's ability to pay for expenses like an EV, it is not comprehensive in explaining the economic stability of everyone within a specific income bracket. The Peter G. Peterson Foundation evaluated data on income and wealth and found that, "Households that owned their home had a median wealth of $305,000, substantially larger than those that rented who only have on average about $4,100. Even when home equity was excluded from total wealth, the median wealth of households that owned their home was $125,500, or over 30 times that of the median wealth of households that rented."[19] This additional wealth is a key factor in making the prospect of purchasing an EV much easier for homeowners than renters.

An equitable transition to EVs requires policies that address the unique challenges of renters, many of whom are members of Oregon's disadvantaged communities. An estimated 46.8 percent of renters in Oregon are cost burdened, which means their monthly housing costs exceed 30 percent of their income, limiting the amount of money they can spend on transportation.[32] Policies and programs are needed to address the high up-front costs of providing chargers for multi-unit buildings, supporting more cost-effective alternatives like workplace charging, and ensuring renters are not subject to higher electric fuel costs than homeowners. Tracking data on EV ownership for renters in the Biennial Zero Emission Vehicle Report is important to measuring the success of these policies and identifying where more efforts are needed.

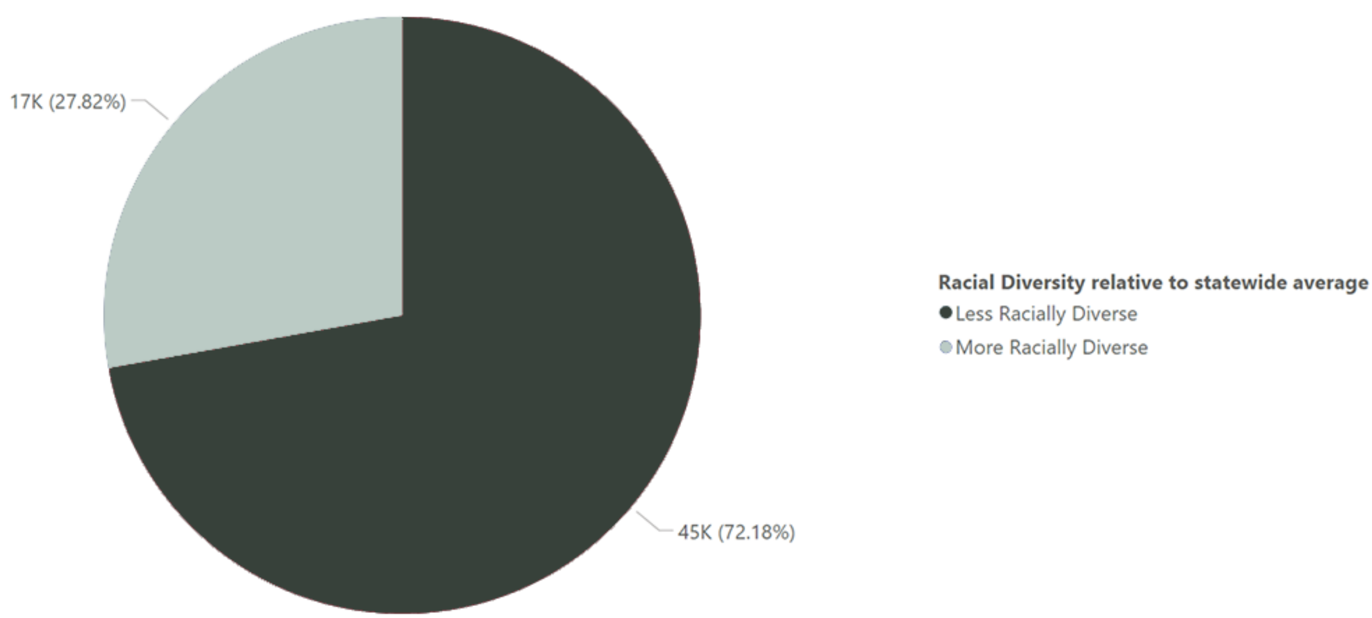
Electric Vehicle Adoption by Racial Diversity

Owner-specific demographic data of EV registrations is not available. To better understand the racial demographics of EV owners, ODOE looked at proxy data and correlations, such as homeownership, wealth, and census block group diversity.

Oregon's statewide racial diversity is about 75 percent white and 25 percent non-white, as shown in Figure 13 below.[16] The diversity of the state has not changed significantly since this was last evaluated in 2021. ODOE compared the 75/25 split against the diversity of each of the 2,970 census block groups in Oregon and assigned each as either more or less diverse than the statewide average. The data in Figure 14 represents whether an individual EV registration is in a more or less diverse census block group. The data show approximately 72 percent of registered EV owners live in census block groups that are less diverse than the state as a whole.[14]

Figure 13: Oregon Race & Ethnicity Demographics[34]

Figure 14: Comparison of EV Registration Shares in Areas with Different Racial Diversities[14]



Although this data does not conclusively show there is lower adoption in more racially diverse communities, known historical racial inequities indicate a disparity likely exists. Reduced wealth accumulation in non-white communities puts downward pressure on EV ownership, as described in the *EV Ownership by Income Level* and *Electric Vehicle Adoption for Homeowners Compared with Renters* sections of this chapter above. American Indian, Black, and Hispanic household incomes are consistently lower than white households, as shown in Figure 15.

Because there is a correlation between EV ownership and homeownership, some conclusions can be drawn about EV ownership among Oregonians who are black, Hispanic, and People of Color. Oregon housing data show that members of these communities are less likely to own single-family homes, which makes them less likely to own an EV.[35] There is a 24.6 percent gap in homeownership for households of color compared with white households, with white Oregonians 1.5 times more likely to own their home. In Oregon, homeownership rates are 15 percentage points lower in communities of color than in predominantly white communities (Tables 2 and 3). These disparities should be acknowledged when developing policies and programs to equitably increase EV ownership in Oregon.

"Lower rates of homeownership and higher rates of living in multi-unit dwellings for Black and Latino families often means charging at home is not an accessible option."

– Dave Cooke, Senior Vehicles Analyst in the Clean Transportation Program at the Union of Concerned Scientists[36]

Figure 15: Median Household Income for Different Races in Oregon[37]

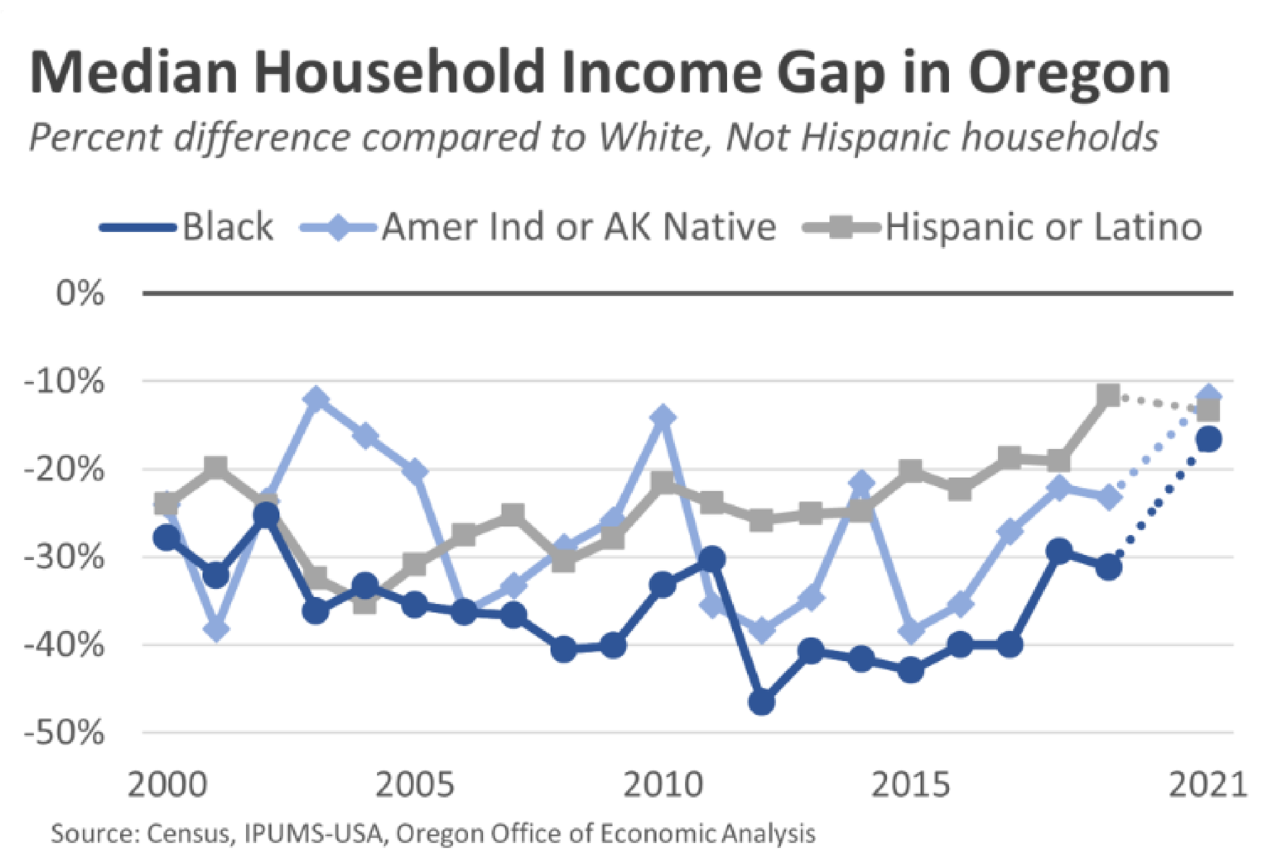


Table 2: Oregon Homeownership Rate and Homeownership Rate Gaps by Race/Ethnicity: 2015-2019[38]

Race/Ethnicity	Homeownership Rate Gap Relative to White Households (Percentage Point)	Homeownership Rate (Percent)
Black	30	42
Hispanic	25	47
Native American	15	57
Asian	12	59
Another Race	23	49
People of Color	25	47
White	null	72
All Households	null	64

Table 3: 2021 Oregon Homeownership Rates Across Race and Ethnicity[39]

	U.S.	Oregon	*Difference*
OVERALL	65.5%	64.0%	*-1.5%*
WNH	73.4%	67.3%	*-6.1%*
BIPOC	51.1%	52.3%	*1.2%*
Black	44.2%	40.9%	*-3.3%*
AIAN	59.3%	40.5%	*-18.8%*
Asian	62.6%	61.2%	*-1.4%*
Other	60.0%	68.1%	*8.1%*
Two or More	57.4%	57.1%	*-0.3%*
Hispanic	50.6%	47.9%	*-2.7%*

Share of BIPOC Households	U.S.	Oregon	*Difference*
Black	33%	7%	*-26%*
AIAN	1%	3%	*2%*
Asian	14%	18%	*4%*
Other	1%	3%	*2%*
Two or More	10%	22%	*13%*
Hispanic	40%	46%	*6%*

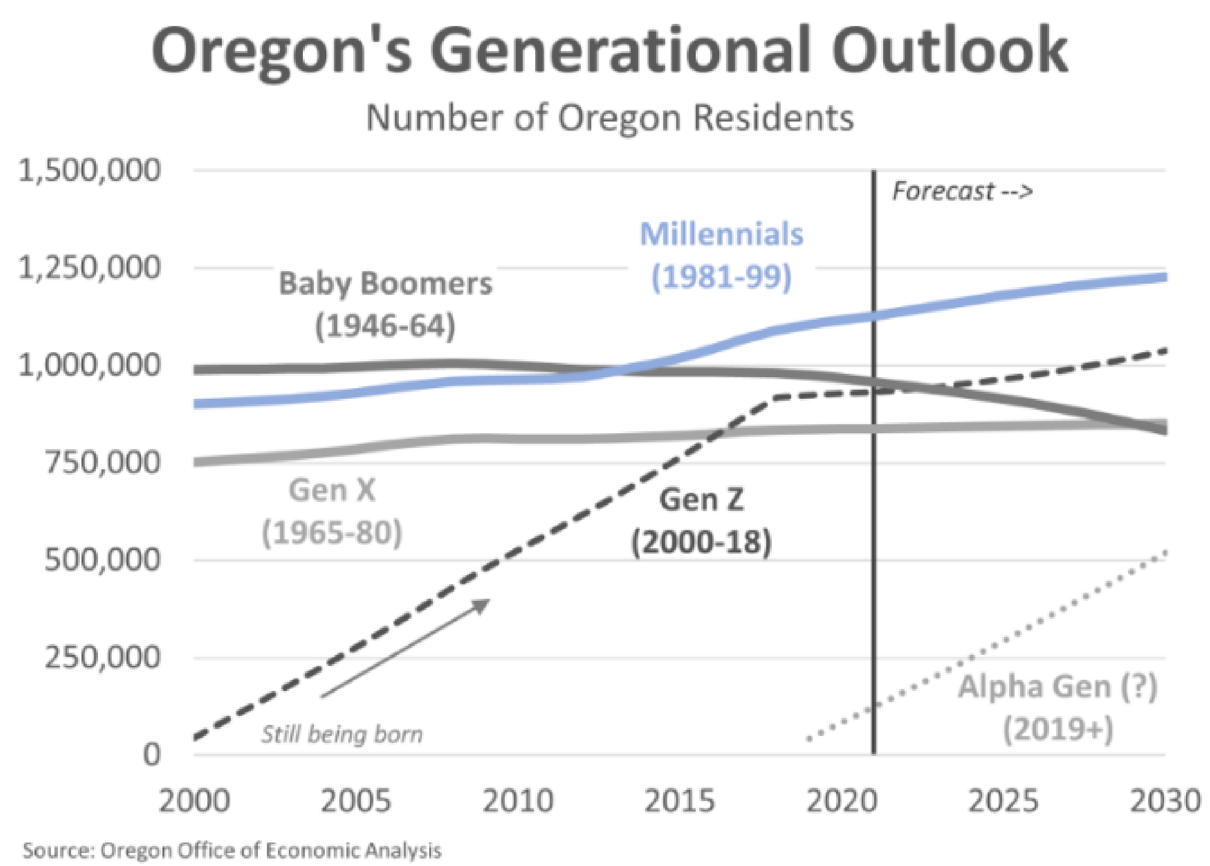
Source: IPUMS-USA, Oregon Office of Economic Analysis

EV Ownership and Transportation Sector Changes

Driving a personal car for work, school, shopping, and other activities is embedded in American and Oregon history and culture, and many cities have grown to meet the needs of individual drivers. While EVs offer the opportunity to address the emissions produced by vehicles, they do not address efforts to reduce total vehicle miles traveled. Oregon's larger metropolitan areas such as Portland, Salem, Eugene, Bend, and the Rogue Valley have public transportation services that provide the opportunity to travel without a personal automobile, but these are not adequately funded to meet the needs of *all* potential users. Rural public transportation in Oregon is much more limited in the number of trips and service hours available, meaning that owning a personal vehicle is the only viable transportation option for many rural Oregonians.[40] Even where public transit is available, it is not widely used. Most Portland area commuters drive alone — only 9 percent of workers carpool and 6 percent use public transportation.[42]

Recent trends, like the use of ridesharing and carsharing are changing the personal car model of transportation. As can be seen in Figure 16 below, Oregon's population increasingly consists of Millennials and Gen Z residents. Younger generations are buying fewer cars and using different mobility options, including public transportation, ridesharing, carsharing, and micromobility technologies.[43] Younger generations also earn less and have less disposable income than previous generations, making the cost of owning an EV a barrier.[44][45] Lack of a personal vehicle can limit access to a range of essentials like jobs, health care, and food.[20] EV ridesharing and carsharing programs can be cost effective alternatives to full ownership and increase exposure and experience with EVs to populations that may be new to them.[47]

Figure 16: Population by Generation Over Time in Oregon[46]



The growing availability of EVs and the push for greenhouse gas emissions reductions provides an opportunity to evaluate and build a more equitable transportation system in Oregon. Passenger EVs play a critical role in meeting Oregon's climate goals, but other transportation options are essential to ensure this energy transition is more equitable. Moving public transportation options to electric vehicles reduces exposure to diesel pollutants for drivers, riders, and neighborhoods. Programs that increase access to micromobility options (such as electric bikes and electric scooters) can also provide a cheaper, more sustainable transportation alternative for daily trips.[48] Evaluating current trends and behaviors can inform efforts to decarbonize the transportation sector while also creating a cleaner, more affordable, and convenient transportation system.

Medium and Heavy-Duty Fleets

The medium- and heavy-duty vehicle market is a few years behind light-duty adoption, but early adopters in Oregon are purchasing and learning about these new technologies.[49] These businesses can be a resource for other organizations interested in electrifying their fleets, and providing EV manufacturers with valuable feedback on vehicle performance. With only modest MHD electric vehicle adoption, there isn't yet demographic data that can be used to draw conclusions. To learn about commercial transportation electrification in Oregon, ODOE interviewed early adopters like the City of Roses to learn about their experience. In future reports, ODOE intends to evaluate the demographics of MHD EV adoption to identify barriers to ownership and determine if Oregon businesses can equitably access electric transportation technologies.

City of Roses Disposal & Recycling

City of Roses Disposal & Recycling (COR) is a minority owned B Corp with over 50 employees in the Portland metropolitan area with a focus on sustainability, reducing waste, and being a community leader. They have invested in an electric yard tractor, charging infrastructure, and have ordered a new electric garbage truck which is scheduled to arrive in August 2023.

COR spends close to $38,000 annually on fuel costs for each of their trucks. COR's CEO, Alando Simpson, says "The switch to electric will begin the process of not only reducing fossil fuel costs that negatively impact our bottom line and ecosystem but also enable us to use savings to expand a modern and lower emission fleet which will have minimal negative impacts to our community in the future." Driving an electric garbage truck will reduce their fuel costs by more than half, and they are looking forward to enjoying the benefits of a new quieter truck with lower emissions. However, they have also faced some challenges, including multiple delays on the delivery of their truck and the high expense of adding charging infrastructure to their facility.

City of Roses took advantage of utility and state programs to offset some of the costs of their transition:

- PGE's Fleet Partner Program built and paid for the infrastructure to bring electric service to the 120 kW dual-port charger that City of Roses purchased and installed.
- PGE's Drive Change Fund provided a grant to help purchase the electric garbage truck.
- Oregon Department of Environmental Quality helped fund the purchase of the electric yard tractor.[50]

City of Roses found for the price of one electric truck they could buy two diesel trucks with advanced emissions filtering systems. COR considers their electric garbage truck to be a pilot project, where they can learn more about the technology and how it could be incorporated into their fleet operations. Without incentives to address the high cost for the vehicle and charging infrastructure, COR would not recommend purchasing an electric truck.

Conclusion

Electric vehicle ownership is not equitably distributed across different demographic groups. Low-income drivers, People of Color, rural Oregonians, renters, and multi-unit housing residents have lower adoption rates than the state average. This indicates that EVs available today may not meet the needs of some Oregonians and that additional policies and programs may be necessary to sufficiently address the barriers these communities face. The state should do more to promote affordable and convenient charging options for multi-unit building residents, to increase charging infrastructure availability in rural and other underserved communities, to lower EV costs, and to reduce technology barriers. This historical transition in our transportation fuels and modes offers a unique opportunity to develop policies that make transportation cleaner, more efficient, more convenient, and more affordable for all Oregonians.

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Lion Electric Lion C school bus, Bend-La Pine Schools

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

EV Platforms Available in All Sectors

Key Takeaways

- The models available to light-duty consumers are growing rapidly, and growth is expected to continue as many manufacturers have plans for most — if not all — models to be electrified.
- Electric models of medium- and heavy-duty as well as specialty off-road vehicles are also becoming more available, with at least a few models in almost every configuration.

Introduction

The popularity of electric vehicles continues to increase, with the number of available models growing rapidly across on-road and non-road vehicles. More than 70 models of passenger vehicles are available for purchase, and there is an increasing variety of options, including sedans, crossovers, SUVs, and pickup trucks. Medium- and heavy-duty electric vehicles are also increasingly available, with electric transit and school buses, garbage trucks, delivery trucks, and even tractor trailers now operating in Oregon. There are many models of electric micromobility transportation options, including e-bikes and e-scooters, which are often used in urban areas to get to and from transit options. Industrial equipment, such as forklifts, gantry cranes, and some construction equipment, also come in electric formats.

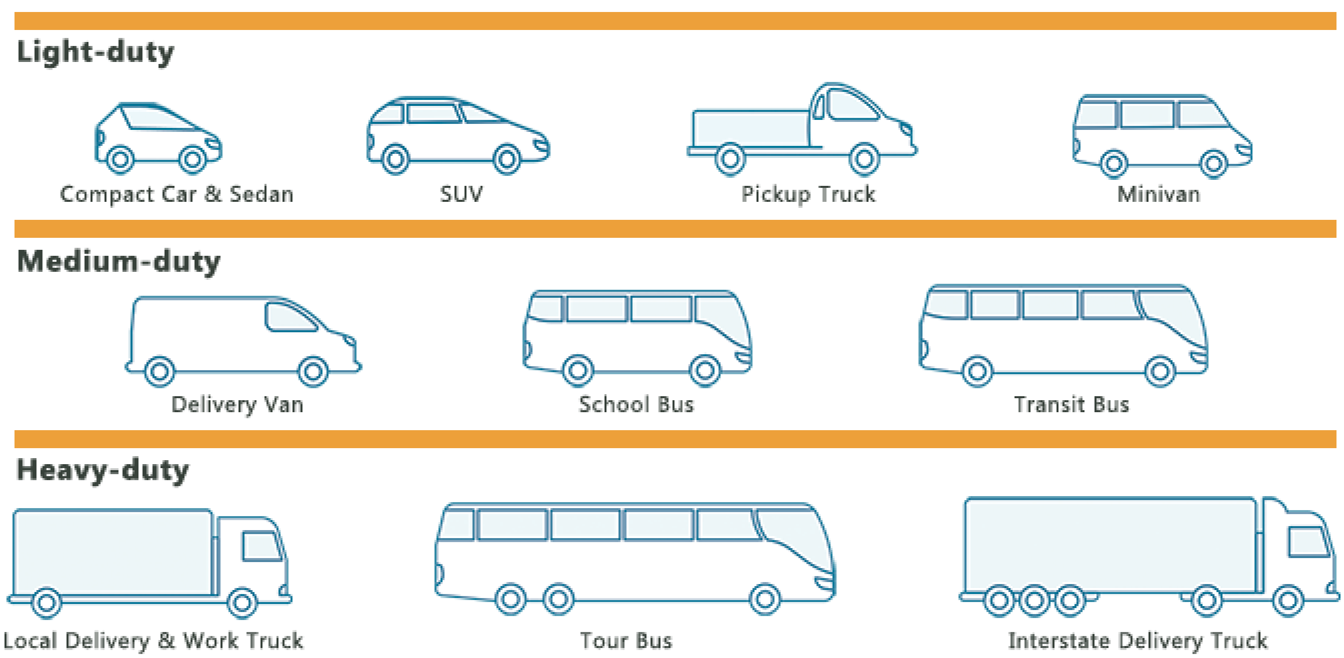
This chapter broadly describes available electric vehicle options across the transportation sector. The focus is on practical availability – commercially viable purchasing options – but will also include some information on vehicle types where an electric format has been manufactured but is not yet available for purchase. Table 1 highlights the different transportation modes which will be covered, along with the types of vehicles that fall into these categories.

Table 1: Different Modes of Transportation

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.			

Types of Vehicles by Sector



Light-Duty On-Road Vehicles

There are currently more than 40 battery-electric vehicles and 30 plug-in hybrid models registered in Oregon[1,2] Table 2 shows the EV models with the highest number of registrations in Oregon. There are more sedan and SUV EV options available for purchase today than vans or pickups, but manufacturer announcements for new EV models show more pickup models and larger SUVs will be available in the next few years.[3–5] Pickups and SUVs comprise over half of light-duty vehicles in Oregon, so there will be more EV options among vehicles Oregonians prefer.[6]

EV Pickups Boosting Transportation Electrification

The long-anticipated Ford F-150 Lightning electric pickup truck is now available, and its popularity is exceeding expectations. To meet customer demand, Ford temporarily shut down the plant that builds these vehicles to triple its production capacity. The plant's 2,000 workers will be able to produce 150,000 F150 Lightnings per year starting Fall 2023.[7]

Table 2: Top Models of Light-Duty ZEVs Registered in Oregon[6]

Make	Model	# Registered	Type	Format
Tesla	Model 3	10,074	EV	Car
Tesla	Model Y	8,507	EV	Car
Nissan	Leaf	6,295	EV	Car
Chevrolet	Bolt EV	3,292	EV	Car
Toyota	Prius Prime	2,937	PHEV	Car
Toyota	RAV4 Prime	2,810	PHEV	SUV
Tesla	Model S	2,647	EV	Car
Chevrolet	Volt	2,639	PHEV	Car
Tesla	Model X	1,823	EV	SUV
Volkswagen	ID.4	1,371	EV	Car
Ford	Mustang Mach-E	1,278	EV	SUV

Most major light-duty vehicle manufacturers have announced EV model production goals, with some indicating target dates at which all vehicle models will be electric.[8] Table 3 provides a list of manufacturer statements collected by Consumer Reports about electric model production.

Table 3: Aspirational EV Production Goals from Light-duty Auto Manufacturers[8]

Manufacturer	Statement
American Honda Motor Co.	aims for all its sales to be electrified vehicles by 2040
BMW North America	says it will bring roughly a dozen new EVs to market by 2025
Ford Motor Company	says it will produce more than 2 million EVs annually by 2026
General Motors	aims to have 20 EVs available in the U.S. by 2025 as it moves to an all-electric model lineup by 2035
Hyundai Motor Company	has committed to becoming carbon-neutral by 2045
Tata Motors	announced that all Jaguar and Land Rover models will have an electric version by the end of the decade
Kia Motors America	announced a road map with a target of 1.2 million annual BEV sales worldwide by 2030
Mazda Motor Company	will expand MX-30 availability to other states in 2022 (currently limited to CA)
Mercedes-Benz USA	announced that all newly launched vehicle platforms will be electric-only from 2025 onward
Mitsubishi Motors	plans to expand its electrified lineup to 50 percent of global sales by 2030, then on to 100 percent electrified by 2035
Nissan North America	will launch 23 electrified models, including 15 EVs, worldwide by 2030
Stellantis North America	aims to have its first battery electric vehicle by 2025 and to have an all-electric lineup by 2028
Subaru of America	made its entrance into the electric vehicle market in 2022 with an all-electric SUV called the Solterra
Tesla Motors	makes exclusively electric vehicles
Toyota Motor Sales	is promising to build 3.5 million battery-only electric vehicles per year, worldwide, by 2030
Volkswagen Group of America	says it will launch 70 pure electric vehicles and 60 hybrids by the end of the decade
Volvo Group North America	has a plan to build only pure electric vehicles by the end of the decade

In addition to battery and plug-in hybrid electric models, some manufacturers are making investments in fuel cell electric vehicles that run on hydrogen fuel. Toyota sells the Mirai and Hyundai sells the Nexo, but these are not currently available in Oregon.[9] For these vehicles to gain market share, there will need to be investments in hydrogen fueling infrastructure in Oregon and elsewhere. BMW, Toyota, Hyundai, and Honda are currently developing FCEV prototypes and/or concepts.

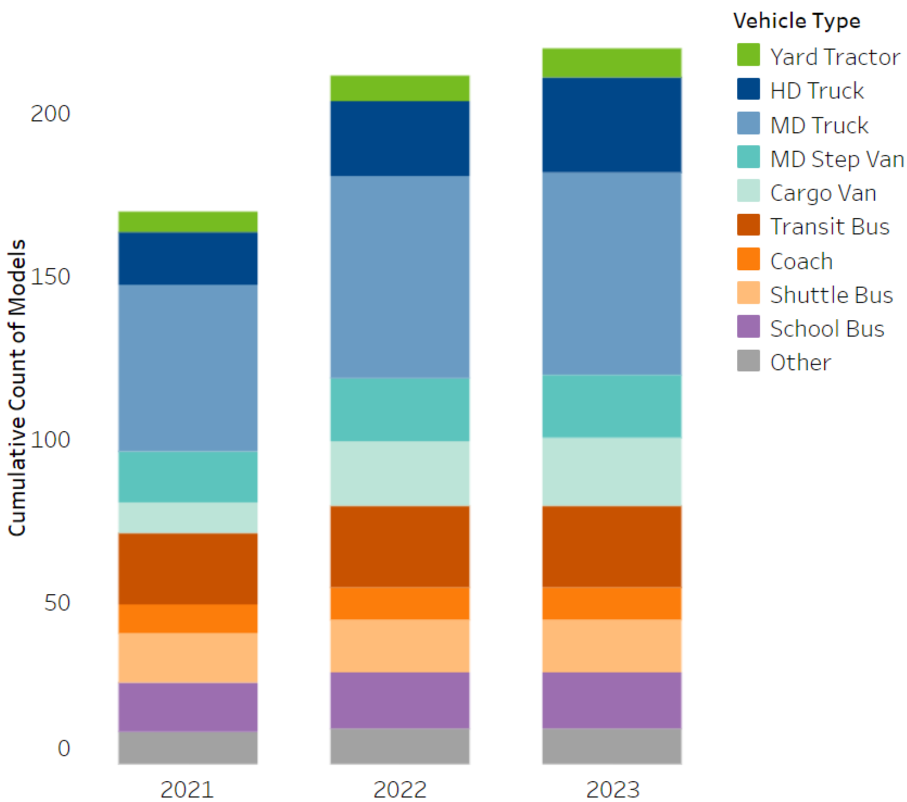
Medium- and Heavy-Duty On-Road Vehicles

Medium- and heavy-duty vehicles come in a wide variety of models for the same type of vehicles, and are often highly customized to meet a specific vehicle use case and duty cycle. For this reason, it can be challenging to accurately describe model "availability" in the same way this report approaches light-duty vehicles. For example, while electric versions of transit buses are commercially available today, electric buses may not be able to accommodate all bus routes, such as long-distance travel or mountainous terrain. This section of the report will provide information on what types of medium- and heavy-duty EVs are currently available, but it is important to note that these vehicles will not work for all potential vehicle needs.

The information provided in this section is largely based on information from CALSTART's Zero Emission Transportation Inventory tool. CALSTART, a national non-profit focused on accelerating cleaner transportation technologies and fuels, created the ZETI tool, an interactive online database where users can search for existing and upcoming medium- and heavy-duty EVs.[10] The tool also includes information about the weight/class, estimated payload/passenger capacity, driving range, and energy storage capacity for each vehicle.

There are 209 models of medium- and heavy-duty vehicle models available in the U.S. and Canada today, up from 161 in 2021.[11] Even more impressive is that the data provided in 2023 is only a partial year (through at least June 2023), but the number of models available is already larger than in 2022. Most are battery electric options, with about 13 fuel cell electric models. About half of existing models are medium- or heavy-duty trucks, shown as the dark and light blue portions of the bar chart in Figure 1. Electric buses make up the next largest group of vehicles, shown in red, orange, and yellow, at about a third of all vehicle types. Heavy-duty electric trucks showed the most growth, from eight manufacturers in 2021 to 18 in 2023.

Figure 1 Medium- and Heavy-duty Electric Vehicle Models Available in the U.S. and Canada by Vehicle Type[11]



The adoption of medium- and heavy-duty vehicles is expected to progress over time, starting with vehicles that have shorter routes and less power needs. Heavy-duty, long-haul vehicles will be some of the last to electrify. Figure 1 shows a visual of the expected timeline for EV adoption for different vehicle types, created from a study conducted by the California Air Resources Board. The study assessed anticipated market growth among non-passenger on-road and off-road vehicles from those most readily electrified to those that are hardest to electrify. This assessment, which is updated regularly, informs policy choices about EV investments in California, focusing funding on vehicles that can most readily electrify.

Buses and medium-duty trucks were expected to be some of the first on-road EVs adopted, as shown in Waves 1, 2, and 3 in Figure 2 — and in Oregon today, most medium- and heavy-duty EVs are transit and school buses and medium-duty trucks.[12] In Wave 4, CARB found that heavy-duty regional electric trucks and refuse trucks would begin to arrive. Oregon's first electric heavy-duty regional truck was deployed in 2023 and its first electric refuse trucks have been ordered.[13] Titan Freight Systems recently began using Oregon's first Class 8 semi-truck, and plans to add three medium-duty electric box trucks to its fleet later this year. City of Roses in Portland and Roseburg Disposal have both ordered electric garbage trucks to add to their fleets.

Electric School Bus Cost Assessment Tool

ODOE, in collaboration with the Oregon Department of Transportation and Department of Environmental Quality, created the Electric and Alternative Fuel School Bus Lifecycle Cost Analysis Tool and an accompanying Guide to School Bus Electrification. A school district can input information about its fleet and the tool will provide a summary of the estimated costs for different alternative fuel bus fleets, allowing them to screen options based on the lifecycle cost of different formats of buses.

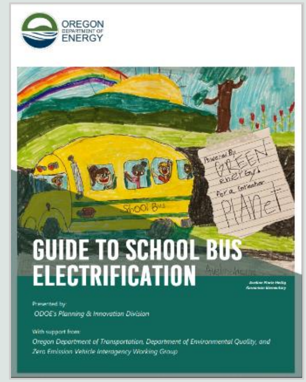
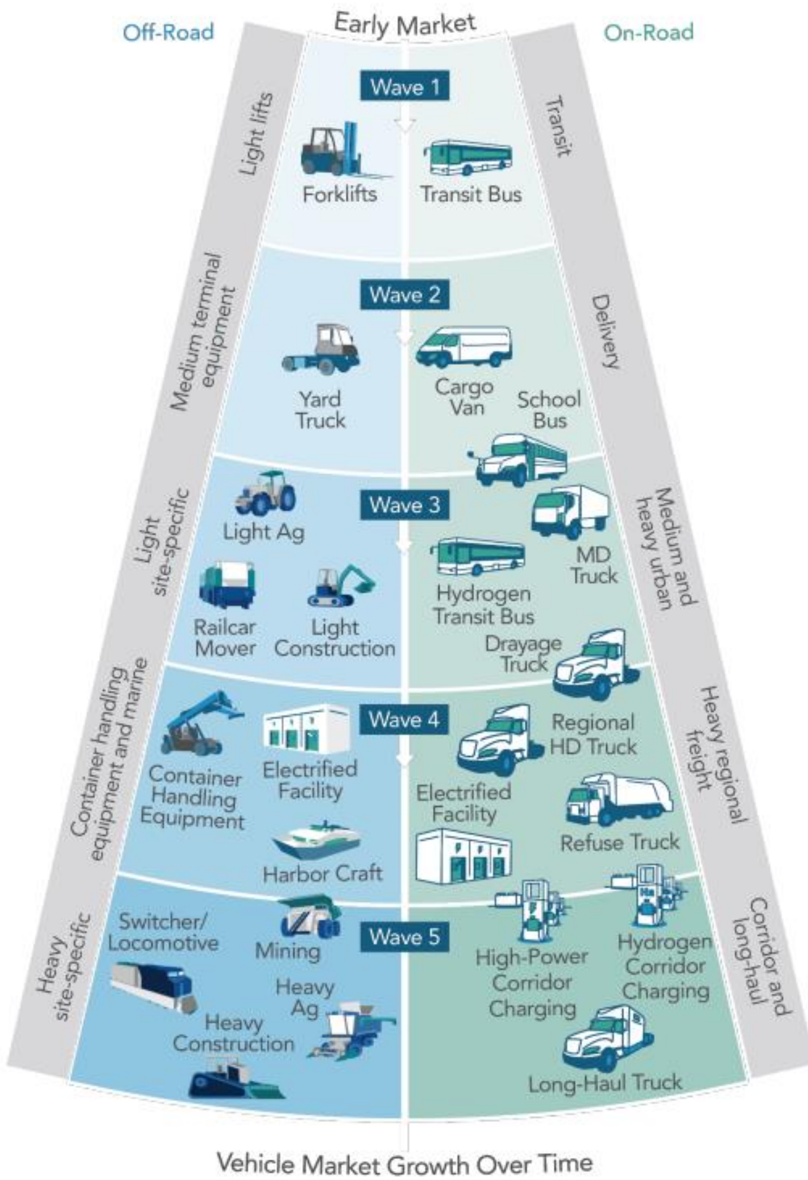


Figure 2: Expected Market Growth for Electric On-Road and Off-Road Medium- and Heavy-Duty Vehicles[11]



Leaders of the Pack – Roseburg Disposal

Roseburg Disposal Company has been providing waste management services in the community of Roseburg, Oregon for nearly a century. Today, the company has 16 employees and 14 trucks in operation. In 2024, they'll welcome a new member of the family — the company's first electric garbage truck.

It will take 18 months to build Roseburg's electric garbage truck, about six months longer than a conventional truck. When it arrives, Roseburg Disposal will be ready to put it into action, having already invested in and built the charging infrastructure. The company will be able to fully charge the new truck in about three hours, and the charging station can be upgraded to serve additional trucks in the future. The new truck will have a range of 80-100 miles, a good match for their 40- to 60-mile residential routes. Roseburg Disposal has also purchased a Ford F-150 Lightning electric truck as a work vehicle.

When considering the investment in an alternative fuel vehicle, Roseburg Disposal evaluated several fuel options, including some that have been adopted by others in the waste management industry, such as compressed natural gas (CNG). Ed Martin, the company's fleet manager, visited a waste management company in Boise, Idaho to do a ride-along in the company's electric garbage truck to get a first-hand experience. Ed found that the benefits of less vibration fatigue, heat, and noise, combined with better air quality and less maintenance, would benefit drivers and customers in residential neighborhoods. Roseburg Disposal determined that investing in electric vehicles made more sense to them as a long-term business solution with fewer barriers or risks.

Being an early adopter has presented them with challenges and lessons learned. Pacific Power conducted a feasibility study to install the charger for Roseburg Disposal's new electric garbage truck and determined that they would need to pay for a new transformer to support the charging power requirements for the truck. The upgrade and installation of the charging were completed on time, but truck delivery delays meant that Roseburg Disposal would have needed to start paying for this new electrical service even though it was not yet in use. This is an example of why utility partners are crucial to fleets because Pacific Power is now working with the company to address this issue. Financing can also be a challenge, since many banks are unfamiliar with these larger EVs, but Roseburg Disposal was able to work with Umpqua Bank to access financing.

Roseburg Disposal concluded that the benefits to their customers, the reduced emissions, and a reasonable payback of 6-7 years still gave them a strong business case. The company looks forward to expanding awareness by sharing their experience and new electric garbage truck with the Roseburg community and other Oregon waste management companies.

Electric transit buses are becoming some of the most widely adopted medium- and heavy-duty vehicles in Oregon. Lane Transit District purchased 30 battery electric transit buses, representing nearly a third of its fleet,[14,15] and Tri-Met is piloting several different formats of electric buses, including longer range buses like a 60-foot articulated bus and double decker variants that not only reduce emissions but also carry more passengers per trip.[16,17] Josephine County placed an order with Complete Coach Works for the purchase of two 35-foot, 100 percent electric-powered transit vehicles. Wilsonville's South Metro Area Regional Transit has deployed two electric transit buses and has another on order. Wilsonville also received a grant to purchase a mobile battery backup unit that can charge electric vehicles during power outages and to study the feasibility of using electric buses on long-distance routes.[18]

Off-Road Vehicles

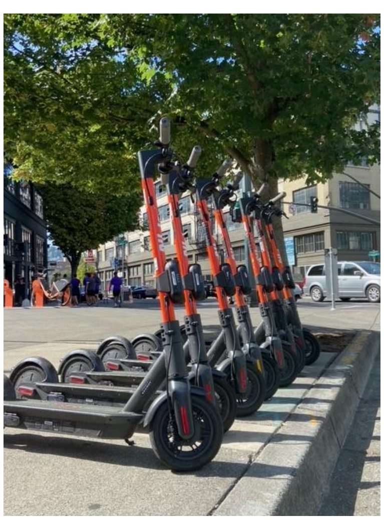
ZEV models of off-road vehicles like forklifts, scissor lifts, backhoes, and trenchers, are increasingly available in North America. Electric forklifts are the most common off-road warehouse vehicles in Oregon and are quickly becoming an industry standard. DEQ reported more than 3,500 electric forklifts registered for the Clean Fuels Program as of May 2023.[19] Electric versions of other warehouse equipment are becoming more commonplace as well, offering added value by also reducing indoor air pollution and improving worker safety. Other off-road vehicles eligible to generate credits for the Clean Fuels Program are shown in Figure 3.

Figure 3: Clean Fuels Program Eligible Off-road Vehicles

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

Electric versions of some agricultural equipment are also available for certain use cases. Wy'East partners with Forth, Sustainable Northwest, Bonneville Environmental Foundation, and Rusted Gate Farm to expand rural electrification and encourage a clean agricultural economy. They currently have six electric tractors and are rotating them to different locations around the Pacific Northwest to be tested at different types of farm operations, including orchards, vineyards, nurseries, greenhouses, and other smaller farms.[20] The recent availability of EV pickup trucks – some of which can fall into the medium-duty vehicle category – is expected to make major inroads in the agricultural setting, and some companies and startups are announcing work to bring battery electric utility terrain vehicles, such as the Polaris Ranger XP Kinetic, to market.

Electricity-fueled technologies are also better able to take advantage of precision agriculture approaches that incorporate remote sensing and communications technologies to more efficiently and effectively manage field and orchard crops. Researchers are developing and testing autonomous farm equipment, such as drones and robot "swarms," for agricultural operations like weeding; monitoring crops, livestock, and fencing; deterring birds from eating fruit in orchards and vineyards; and distributing beneficial insects to control pests.[21] Mobile power stations that carry large portable battery packs charged from grid electricity are new to the market and mainly marketed for their emergency response capabilities, but may also be useful in more remote farming or construction operations.[22]



Micromobility

Micromobility vehicles are important for commuting, local deliveries, or extending public transit services (the "last mile" concept). These include bicycles, scooters, skateboards, and one-wheels that provide transportation across relatively short distances within a town or city. Most E-micromobility options are widely available through online and retail outlets.

Row of e-scooters in Portland, Or

Marine

Marine craft are challenging to decarbonize, largely due to the large amounts of energy they use with fewer opportunities for charging. The International Maritime Organization is working on options to make ships more energy efficient, and the shipping industry has been evaluating how vessels could operate with fewer emissions. Ferries and other ships with short routes have been piloting electrification, and a startup named FleetZero is designing smaller cargo ships while rethinking the way cargo is moved around the globe to make electric ships more feasible.[23] This includes storing batteries in containers so that they can easily be picked up and swapped out when in port. However, overall battery electric alone is likely not sufficient to meet most ocean craft needs.

Washington State Ferries- the largest ferry fleet in the nation – is undertaking an initiative to electrify its fleet. The company envisions its future fleet to include plug-in hybrid-electric vessels. The conversion is necessary to help achieve Washington state decarbonization goals, and includes 16 new vessel builds, six existing vessel conversions, and the electrification of 16 terminals.[24]

Several operators are assessing hydrogen fuel cell electric as an alternative option to diesel. For example, in Norway, Norled's MF Hydra ferry is set to be the first hydrogen-powered vessel, and is designed to carry up to 300 passengers and 80 cars.[25]

Rail

Rail locomotives consume diesel to power an engine tied to a generator that creates electricity. The electrical energy is needed to produce the high torque at the wheels to get the vehicle and its load moving.[26] Because they are already electrically driven, locomotives are good candidates for electrification. Locomotives are used for two broad use cases in the rail industry, either to move trains and other vehicles around in railyards or to move trains across the country. Railroads have tested low-horsepower battery-electric locomotives that are used to switch freight cars in rail yards, but upgrades to support high-powered chargers and additional electricity capacity on site is needed for more railyards to adopt electrically -operated locomotives.[27]

Battery electric and fuel cell electric locomotives are also being tested as potential alternatives or support for cross-country locomotives. BNSF Railway and Wabtec partnered in the development and testing of a battery-electric high-horsepower road locomotive – the type that moves freight trains long distances. The FLXdrive was the first heavy-rail battery electric locomotive, and was used as part of a hybrid consist.[i] [28] In January 2022, Canadian Pacific built and tested the H2OEL, a hydrogen fuel cell-powered high-power locomotive. The locomotive was used to carry freight in October of that year, and Canadian Pacific expects to have three hydrogen locomotives in operation by the end of 2023.[29]

[i] Consists are two or more locomotives coupled together.

Aviation

Like marine craft and rail, electric aviation is nascent and is largely limited to smaller planes and shorter routes — but there are numerous efforts around the world, and many in the Pacific Northwest, to design and test both electric and hydrogen planes, as well as hybrids using both technologies. The first commercial electric flight was a plane developed by Washington state's Magnix, for Canadian commuter airline Harbour Air. The plane was a converted Air de Havilland DHC-2 where the piston engine was replaced by the Magnix-made magni500 electric propulsion system.[30] Electric aviation startup company Eviation chose Moses Lake, WA to conduct the maiden flight of an all-new, short hop airliner named Alice. The Alice also uses Magnix electric propulsion for power.[31]

In Oregon, HB 3257 — which was introduced but did not pass during the 2023 session — proposed an Electric Aircraft Task Force. The task force would have identified issues related to the facilitation of electric aircraft use in Oregon and proposed six airports to pilot EV readiness.

Conclusion

The availability of ZEV models for transportation platforms continues to widen, with commitments by nearly every major auto manufacturer for a large uptick in electric models. The first electric heavy-duty semi-truck is operating in Oregon, and electric bikes and scooters are helping to reduce congestion, noise, and air pollution in urban areas. Electric vehicles are 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 growing model options and the benefits of reduced pollution and often lower fuel costs, more Oregon individuals, businesses, and fleets are moving forward into the zero emission transportation sector.

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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 EVs and Internal Combustion Engine Vehicles

Key Takeaways

- More models of light-duty electric vehicles continue to approach cost parity with internal combustion engine vehicles, despite slower than expected declines in battery prices.
- High up-front costs are likely to remain a barrier to widespread adoption of medium- and heavy-duty EVs through at least 2030, when some analysts predict they may begin to reach cost parity with diesel counterparts.
- Government and utility incentives are necessary to make vehicles cost-effective in the near term.
- Flexible incentives that cover a variety of vehicle and charging infrastructure costs are key to supporting the zero-emission transition in Oregon and the region.
- Utilities play a critical role in supporting fleet managers in planning and implementing EV fleets.

Introduction

The 2021 edition of the Biennial Zero-Emission Vehicle report features a detailed total cost comparison between electric and internal combustion light-duty vehicles.[1] This analysis remains relevant in 2023. In general, light-duty electric vehicles continue to approach cost parity with internal combustion engine vehicles, with several models already achieving cost parity and many projections indicating most light-duty vehicles will reach cost parity within the next five years.[2,3] This section begins with a brief update on some key changes in the light-duty vehicle space since 2021 that affect the cost of electric vehicles. Specifically, it outlines key market trends and policy changes affecting EV costs in Oregon.

Following this update on LD vehicles, the chapter focuses on the costs of medium- and heavy-duty zero emissions vehicles. This chapter highlights the factors influencing lifetime costs of MHD EVs; presents a simplified total cost of ownership analysis of four common types of MHD vehicles; outlines indirect and non-financial costs of MHD vehicles; and gives an overview of policy progress in Oregon on this issue.

What’s That Acronym?

LD: Light-duty vehicles – generally passenger vehicles, including cars, vans, SUVs, and most pickup trucks.

MHD: Medium- and heavy-duty vehicles – larger trucks and buses, including freight, drayage, and delivery trucks, more powerful pickup trucks, and school and transit buses.

Light-duty Cost Update

Market Trends

For the first time since the data have been tracked, lithium-ion battery pack prices increased in 2022, according to BloombergNEF market data.[4] The average cost of a battery pack across all sectors rose to $151/kWh, up from $141 in 2021 (in real 2022 dollars). This rise is driven largely by increasing raw material and component prices, along with economy-wide inflation. Despite this increase, projections indicate battery pack prices will drop below $100/kWh, the threshold considered necessary to reach price parity, between 2025-2027.[5] This is later than BloombergNEF's projection from 2021, though it is in line with several of the analyst projections highlighted in the 2021 version of this report. While the slight increase in battery prices has slowed progress toward EV cost parity across all LD vehicle models, the lifetime cost of many models continues to be lower than gasoline and diesel vehicles thanks to the reduced operating costs over the lifetime of electric vehicles.

As the market for electric vehicles grows, the availability of used EVs also increases. Through Q1 of 2023, used EV retail sales had increased by 32 percent over the previous year.[6] Used EVs sold for an average price of $38,000 nationally and $36,193 in California. As the EV market continues to develop, used vehicles may provide a more affordable option for consumers interested in electrifying, particularly lower-income consumers who may struggle to cover the up-front cost of a new EV. (See the *Progress on Goals* and *Distribution of EVs by Demographics* chapters for more information).

Policies

As of May 1, 2023, the Oregon Clean Vehicle Rebate program has been temporarily suspended due to overwhelming demand and depletion of funding.[7] This demonstrates the program's success as many Oregonians have purchased electric vehicles using the incentive (as highlighted in the adoption section of this report). However, the temporary suspension also changes the economics of purchasing a light-duty vehicle in Oregon, at least until the program opens again in 2024 when funding is replenished. During the suspension, the up-front cost for an electric vehicle will be higher for households who would otherwise be eligible for the incentive, in particular the low- and moderate-income households who would be eligible to receive up to a $7,500 rebate. EVs remain cost competitive over their lifetimes thanks to their lower operating costs, but the lack of rebates could deter consumers who have limited up-front funds available or struggle to acquire financing at reasonable rates. This could further exacerbate the gap in EV ownership between low-income and higher-income households, further exclude low-income Oregonians from participation in the clean energy transition, and reduce access to vehicles that can help address transportation energy burden in these communities. The demographics section of this report features deeper discussion on this gap.

While the Oregon Clean Vehicle Rebate program has been suspended, a new federal EV incentive has been made available through the Inflation Reduction Act. Signed into law in 2022, the IRA created a $7,500 tax credit for new EVs, and removed the provision from the previous tax credit program that reduced or eliminated the available credit amount as manufacturers — like Tesla and General Motors — reached a certain number of sales.[8] The IRA-created program also includes specific rules around which models of vehicle are eligible based on the sourcing of the critical elements used in their production and where they are produced. (See the *Progress on Goals* chapter for more.)

This tax credit is expected to further lower the lifetime cost of owning an EV for consumers looking to switch from internal combustion engines. However, because it is a nonrefundable tax credit, it may not be effective at reaching low-income consumers who may have lower tax liability.[9]

Medium- and Heavy-duty Vehicles

Though light-duty vehicles account for the largest share of greenhouse gas emissions, they represent only a portion of the vehicles on the road. Medium- and heavy-duty vehicles are responsible for approximately 34 percent of transportation sector emissions in Oregon.[i] This makes finding zero-emissions alternatives for these vehicles an essential step to meeting the state's greenhouse gas emissions reduction goals. While recent advancements in vehicle technology have made EVs feasible across many types of MHD vehicles, primarily through electric drivetrains, cost presents a significant barrier to widespread adoption of these EVs. This section outlines the individual components that make up this cost and highlights opportunities for reductions in cost to make EVs more affordable over their lifetime.

Background

Medium- and heavy-duty electric vehicles vary widely in their design, use, and functionality, but are defined based on gross vehicle weight rating and encompass Class 2b and 3 (8,501 – 14,000 lbs) through class 8 (greater than 33,001 lbs) vehicles.[10] This includes everything from step vans to long-haul tractor trailers and heavy construction equipment. Table 1 outlines the different classes of medium- and heavy-duty vehicles and provides examples of the types of vehicles that fit into each class.

[i] Based on ODOE analysis of DEQ data. See "EV Progress Toward Reaching the State's Greenhouse Gas Emissions Reduction Goals" chapter for more.

Table 1: Medium- and Heavy-duty Vehicle Classes

Class	Gross Vehicle Weight Rating	Vehicle Examples	Percent of Total Oregon MHD Vehicle Fleet[11]
Class 2b and 3 Trucks	8,501 – 14,000	Heavy duty pickup trucks, SUVs, full-size vans, box trucks	84%
Class 4 and 5 Trucks	14,001 – 19,500	City delivery, conventional van, walk-in van, bucket truck	>1%
Class 6 and 7 Trucks	19,501 – 33,000	Buses, single axle vans	2%
Class 8a and 8b Trucks	> 33,001	Fire truck, refuse truck, dump truck	6%
Class 7-8 Tractors	> 33,001	Semi sleeper, heavy semi tractor	8%

Nearly all zero emission MHD vehicles currently available on the market rely on battery-electric or plug-in hybrid drivetrains (see *Electric Vehicle Platforms Available* chapter). While some fuel-cell electric vehicles exist in medium- and heavy-duty classes, this technology is less developed and has a lower market penetration at this stage. Accordingly, this chapter focuses mostly on BEV and PHEV MHD vehicles, with a brief discussion on how future non-electric zero emissions technologies could influence MHD vehicle adoption cost.

Total Cost of Ownership Analysis of Medium- and Heavy-duty Vehicles

The base purchase price of zero-emission MHD vehicles is higher than comparable internal combustion engine models of each vehicle. For example, a 2023 Ford E-Transit has a starting MSRP of $49,995 while the gasoline version starts at $44,455.[12] As vehicle size increases, the price difference tends to grow as well. Class 8 vehicles, like the Freightliner eCascadia, can cost two to three times their diesel vehicle counterparts.[13]

Despite the up-front cost difference, electric MHD vehicles have the potential for lower operating costs, in specific applications, that could lead to a lower lifetime cost. Similar to LD vehicles, this reduced operating cost is driven largely by reduced maintenance costs for EVs and the potential for reduced fuel costs due to the relative affordability of electricity over gasoline or diesel. However, unlike LD vehicles, reduced fuel costs are not a given due to the different structure of commercial and residential energy billing. While residential customers pay primarily for the volume of electricity consumed (measured in kWh), large electricity consumers, including many commercial and industrial customers, also pay for capacity,[ii] which ensures there is a sufficient supply of electricity on the grid

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[ii] Residential customers pay for capacity charges, but this is calculated across all customers and allocated as a fixed cost on all customer utility bills. For more information on capacity charges see "An Introduction to Demand Charges," August 2017, by the Clean Energy Group. https://www.cleanegroup.org/wp-content/uploads/Demand-Charge-Fact-Sheet.pdf.

during peak hours of consumption.[14] Table 2 highlights the differences between commercial and residential rate structures using examples from Portland General Electric rates.

Table 2: Residential vs. Commercial Electricity Rate Structures

Residential energy costs (Portland General Schedule 7 Time-of-Use option[iii])[15]	Commercial energy costs (Portland General Schedule 83)[16]
Basic charge Single-family home - $11 Multi-family home – $8 On-Peak Charge (per kWh) - ₵32.800 Transmission and related services - ₵1.8 Distribution – ₵15.500 Energy – ₵15.500 Mid-Peak Charge (per kWh) – ₵11.915 Transmission and related services - ₵0.520 Distribution – ₵5.315 Energy – ₵6.080 Off-Peak Charge (per kWh) – ₵7.43 Transmission and related services – ₵0.28 Distribution – ₵2.70 Energy – ₵4.45	Basic charge - $35 - $45 **Transmission and related services (per kW) - $1.77** **Distribution charges (per kW)** **The sum of:** **per kW of facility capacity** **First 30 kW - $4.75** **Over 30 kW - $4.65** **per kW of monthly on-peak demand - $1.47** Energy charge (kWh) On-Peak – ₵4.82 Off-Peak – ₵3.32 System usage charge (per kWh) – ₵1.031

Bolded text indicates charges that are based on capacity (as measured in kW).

For commercial fleets, capacity charges may be the largest component of the electricity bill. These charges are assessed on the highest electricity use at a given time during the billing month. High-power chargers, often used for charging medium- or heavy-duty vehicles, incur a higher peak electricity demand, which could potentially lead to higher electricity costs, especially if charging the vehicle takes substantially more instantaneous power than before the charger was added to the facility. For example, if a facility's highest electricity demand was 20kW before EV charging was added and the utility charges them $4.75 per kW, the total demand charge for the month would be $95.00. If a 50kW charger was added to the same facility, the business could see their demand charges grow to between $237.50 (if the highest demand was just 50 kW) to $332.50 (if the 50 kW was additional to the previous 20 kW of demand, for a total new demand of 70 kW). The more slowly a vehicle can charge, the less instantaneous electricity demand it will have, and the lower the associated demand charge. Utilities work with fleet managers to help them balance meeting fleet charging needs while reducing the impact to their electricity bill (see the *Charging Availability and Reliability* chapter).

[iii] Time of Use rate plans provide different rates based on when a household uses energy, on-peak, mid-peak, and off-peak.

To directly compare combined up-front and lifetime operating costs of MHD electric vehicles to internal combustion engine MHD vehicles, vehicle buyers or fleet managers utilize Total Cost of Ownership. TCO combines the up-front cost with the expected yearly operating costs across the life of the vehicle to compare how much it costs to own a particular vehicle for its entire lifetime. For organizations purchasing vehicle fleets, TCO is one of the key metrics used in determining which types of vehicles to buy. For widespread adoption of zero-emissions MHD vehicles to occur, the TCO of these vehicles will have to reach parity with internal combustion engine vehicles.

TCO analyses of MHD vehicles are more complicated than LD vehicles for two reasons: 1) it is a relatively emerging market, making specific cost data difficult to find; and 2) there is great variation in the application and design of MHD vehicles, requiring detailed analyses of each class of vehicle. Despite these challenges, there is a growing body of research that seeks to fully quantify the lifetime costs of zero-emissions medium- and heavy-duty vehicles by comprehensively enumerating all components of both up-front costs and vehicle operating costs, producing an estimated total cost for each vehicle class.[17,18]

Based on this research, there are four key cost categories that influence TCO of MHD vehicles. These can be further categorized into several subcomponents to better understand the individual costs that affect TCO. Table 3 provides an overview of each of these categories and their subcomponents, and they are described in further detail below.

Table 3: Factors Contributing to Lifetime Cost of a Vehicle.

Cost type	Category	Subcomponent
Up-front costs	Vehicle costs	Retail cost
		Depreciation
		Financing
		Incentives
		Tax and fees
	Infrastructure costs	EVSE acquisition costs
		"Make Ready" costs
		Site construction
Operating costs	Fuel costs	Volumetric electricity charges (kWh)
		Demand charges (kW)
		Gas or diesel costs
		Energy consumption
	Operations and maintenance	Insurance
		Maintenance
		Repair
		Taxes
		Registration
		Tolls and parking
		Payload capacity
		Labor

The differences in lifetime cost between internal combustion engine vehicles and EVs comes from the differences in individual cost components across both types of drivetrains. Additional detail about each category is provided below, highlighting the subcomponents with the largest differences in cost between EVs and ICEs.

Vehicle Costs

Vehicle costs are the up-front capital costs that a consumer pays to purchase a vehicle. The most significant difference in vehicle costs between MHD internal combustion engine vehicles and MHD EVs is the retail cost to purchase the vehicle. As highlighted above, retail costs of battery electric MHD vehicles are higher than their diesel counterparts, with this difference increasing in larger vehicles. This is due primarily to the cost of battery packs. Most projections indicate that MHD vehicle battery prices will follow a similar trend to LD vehicle batteries, and costs will decrease as the market matures.[19]

Table 4 highlights current estimated up-front retail costs of several key MHD vehicle classes.

Table 4: MSRP estimates[20]

Class	Vehicle type	Make	Model	MSRP
2b	Cutaway truck	Ford	F-150 Lightning Lariat Extended Range	$77,000
3	Cargo Van	Lightning eMotors	Electric Transit Cargo Van 105 kWh	$170,000
4	Box Truck	Motiv	EPIC E-450 Box Truck	$190,000
5	Shuttle Bus	Lightning eMotors	Electric F-550 Bus	$210,000
6	Cab & Chassis	BYD	6F ER	$218,000
7	City Delivery	Kenworth	K370E 282 kWh	$268,000
8	Trailer Truck	Freightliner	eCascadia	$380,000

Retail cost, however, is not the sole driver of up-front vehicle costs. Government and utility incentives can often be used to lower the price consumers pay for a vehicle, either up front or across the lifetime of a vehicle. Incentives can be structured in many different ways including tax credits, sales tax waivers, low interest loans, rebates, and point-of-sale voucher programs.[21] According to the Northeast States for Coordinated Air Use Management, point-of-sale incentives are most effective for driving adoption of EV MHD vehicles.

In December 2022, the Oregon Department of Transportation and Department of Environmental Quality published a report titled *Incentives to Support the Transition to Zero Emissions for Medium- and Heavy-duty Vehicles*.[22] In addition to summarizing the current state of MHD EV incentives in Oregon, it provides recommendations for policymakers and utilities in designing future incentive programs. It highlights the following components as important to successful incentive design:

- **Adaptable** – Implementing agencies need broad authority allowing for quick start-up and the ability to respond to changes.
- **Sustainable** – Incentives must have dedicated sources of revenue to support near-term and long-term fleet transitions.
- **Stackable** – State programs must be able to leverage federal and other funding opportunities.
- **Flexible** – Multiple, targeted incentive programs are necessary to enable private fleets to decide which combination of incentives are most useful.
- **Accessible** – Administrative and technical support is necessary to support fleet owners in transitioning to EVs. Incentive programs should provide this support to awardees with an emphasis on small businesses and fleets based in communities with higher levels of pollution.
- **Equitable** – New incentives should dedicate a percentage of funding to serving fleets that benefit environmental justice communities or that are located in areas disproportionately affected by high levels of air pollution.

Table 5: Oregon DEQ/ODOT Incentives Table

MHD ZEV Transportation Funding Mechanisms in Oregon (2022)									
Point Agency	Program	Eligibility	Incentive Levels	Coverage for Infrastructure	Small/Minority-Owned Fleets/Priority Communities	Scrappage	Stacking	Funding Source	Funding Amount
State Funding Mechanisms									
DEQ	Diesel Emissions Mitigation Grants	2010 or older diesel (Class 4-8)	25-100% of project costs	Yes	Yes	Yes	May stack with private funds	VW Settlement	~$8 million thru 2025
DEQ	Charging Pilot	Match support and commitment to ZEV Fleet	80-100% of project costs and 50-100% of planning costs	Yes	Yes	No	May stack with local or federal funds	State	$15 Million (one time)
Federal Funding Mechanisms									
DEQ	Diesel Emissions Reduction Act	2010 or older diesel vehicle (Class 4-8)	25-45% of project costs	Yes; limited to Battery Electric Vehicle charging units assoc. with vehicle replacement	No	Yes	May stack with local, private or non-VW state funds	Federal - EPA	~$530,000 per year@
DEQ/ODOT	Congestion Mitigation and Air Quality	Geographic/ Buy America Compliant/ Varies with project type	80% of project costs	Yes	Yes	Variable	May stack with State and private funds (including utility)	Federal - FHWA	$250,000 per year
ODOT	Low/No (Section 5339(c) grants)	Purchase or Lease of transit vehicles/infrastr.	80-90% of project costs	Yes	No preference indicated; ODOT or Transit agency applies	No vehicle or facility requirements	May stack with state funds	Federal - FTA	~$5.5 billion over 5 years (nationwide); varies by award
ODOT	National Electric Vehicle Infrastructure Act	Geographic/ Buy America Compliant/ Light Duty focus	80% of project costs	Yes	Justice40 communities to receive 40% benefits	Not applicable	20% non-federal match; May stack with state, local, or private funds	Federal - FHWA per IIJA	$52 million over 5 years
Utility Funding Mechanisms									
PGE	Business Charging Rebate	Installation of level 2 charger	$1,000/ charger	Yes	No	No	May stack with state, local, federal or private funds	Utility	Varies per year
PGE	Fleet Partner	Fleets adopting Electric vehicles	No incentive-technical and site assessment support	Varies	No	No	May stack with state, local, federal or private funds	Utility	Varies per year

For EVs to be cost competitive over their lifetime with internal combustion engine vehicles, vehicle costs will need to greatly decrease, either due to increased incentives or continued reduction in the cost of battery packs. Many analysts believe battery cost reductions will occur, and all classes of MHD EVs may reach cost parity with their diesel counterparts as soon as 2030.[23]

Infrastructure Costs

Vehicle costs are not the only component of up-front costs for purchasing an EV. Infrastructure costs refer to the fixed, up-front costs fleets must pay to procure the infrastructure and/or electricity upgrades necessary to operate their vehicles. MHDs have significant infrastructure requirements that increase up-front costs relative to internal combustion engine MHD vehicles, primarily due to charging needs. The diverse uses of MHD EVs, their high energy needs, and their unique schedules usually require more expensive forms of charging infrastructure than LD vehicles. However, not all fleets are the same. Different classes of MHD vehicles use different charging technology and the type of charger needed greatly affects the up-front infrastructure cost. While medium-duty vehicles can use Level 2 chargers ranging from 6.6 to 19.2 kW in power, heavier classes require Direct Current Fast Charging, or DCFC. For light-duty applications, DCFC charging capacity ranges in power level from 50 kW to 350 kW.[24] This technology is rapidly improving to increase capacity and accommodate medium- and heavy-duty vehicles with greater capacity demands.[25] More powerful chargers can reduce charging times but have a higher up-front cost. For fleets with predictable shifts, using low-power charging while off shift can reduce up-front infrastructure costs by 62-81 percent.[26]

Vehicle use patterns not only affect the type of charger that can be used, but the category of charging infrastructure available to the fleet. Table 6 outlines charging categories in the MHDV sector.

Table 6: Categories of EV MHD Charging Infrastructure

Depot Charging	Opportunity Charging	En-Route Charging
Depot charging is similar to home-charging for LD vehicles. Vehicles are charged at private locations using privately-owned infrastructure purchased by the fleet. Because about 87 percent of MHD vehicle trips are less than 200 miles, depot charging is a feasible solution for most fleets.[27] However, depot charging requires on-site charging infrastructure, which needs to be purchased by fleet managers and can substantially increase cost of fleet electrification.	Opportunity charging relies on publicly available charging infrastructure. Fleets would use opportunity charging to refuel and extend vehicle range during breaks or while loading and unloading. This is a lower cost option but is likely not feasible as a stand-alone solution for most fleets in the near-term due to lack of infrastructure. Opportunity charging could be most useful in extending the range of Class 3 through 6 vehicles using DCFC chargers.[28]	En-Route charging would use chargers located along common freight routes to serve long-distance MHD vehicles, such as trucks or transit. This would be primarily used for Class 6-8 vehicles and would make use of high capacity DCFC chargers. En-Route charging would be critical for long-haul applications of MHD EVs and could serve as a safety net for shorter trips.[29]

In addition to the infrastructure itself, utility costs associated with installing high-capacity charging stations can affect the up-front cost. These are often referred to as “make-ready costs” and refer to front-of-meter infrastructure that must be installed to provide adequate electricity to fleet chargers. These costs vary greatly depending on fleet size, charging infrastructure type, and location, and are difficult to estimate. Fleet managers pursuing electrification of MHD vehicles must work closely with their local utility to understand their charging needs and minimize up-front infrastructure costs.

PGE Fleet Partner

Oregon’s three investor-owned electric utilities – Portland General Electric, Pacific Power, and Idaho Power – all provide customized support for businesses interested in fleet electrification. This customized planning is essential to a successful transition, as it enables fleet managers to make informed decisions about vehicle models, charging infrastructure, and available incentives. For utilities, this type of planning is necessary to support system and infrastructure planning as more fleets make the decision to electrify. Utilities will need to continue scaling these types of technical assistance offerings and providing support for fleets in their territories.

PGE’s fleet transition planning is offered through its Fleet Partner program. PGE reports high demand for this program. As of April 2023, the program had received 90 site applications from 59 customers for electrification infrastructure. While the original pilot estimated 24 sites would be completed through the program, the utility plans to build at least 50 additional sites if the program budget and timeline expansion are approved by the Oregon Public Utility Commission.[30]

Fuel Costs

Fuel costs provide the greatest potential for EVs to become more affordable than internal combustion engine vehicles in the medium- and heavy-duty market thanks to the relative affordability of electricity over diesel. However, commercial electricity rate structures make this more complicated than a light-duty cost comparison. Because large commercial customers are charged not only for kWh of electricity used but for peak kW capacity, adding high-kW chargers could increase the demand charges fleet owners pay. These demand charges could be the difference in making EVs cost competitive relative to internal combustion vehicles, and fleet managers will need to work closely with utilities to understand the impact of charging infrastructure on their electricity bills.

Electricity rate structure is changing rapidly as clean energy adoption and increasing electricity demand force utilities and utility commissions to reconsider how to recover costs. Utilities and their large commercial customers will need to identify solutions together that remove the demand charge barrier for MHD vehicle electrification while allowing utilities to provide adequate grid capacity.[31]

In Oregon, these changes are already occurring. As part of its Fleet Partners program, Portland General Electric is supporting non-residential customers in planning for small-, medium- and heavy-duty vehicle electrification in a cost-effective manner. Through this program, PGE is gathering data that will help inform future commercial rate structures with the goal of with the goal of shifting load to off-peak and incentivizing charging behavior that benefits the grid.[32]

Operations and Maintenance

In general, TCO estimates indicate that yearly operations and maintenance costs for EVs are lower than internal combustion engine vehicles, even when accounting for potential payload reductions.[33] Operations and maintenance costs consist of the non-fuel costs necessary for daily operation, maintenance, and repair of a vehicle. Research from Argonne National Laboratory found reduced maintenance costs for hybrid, fuel-cell, and battery EVs relative to internal combustion engines over their lifetimes, with battery and fuel-cell EVs having the greatest savings.[34]

Because MHD EVs tend to be heavier than internal combustion engine vehicles, they may need to reduce their payload — the amount of cargo a vehicle can carry — to maintain an appropriate weight.[35] This could lead to increased operational costs by increasing the number of trips necessary to deliver an equivalent amount of payload or requiring more vehicles to deliver the same payload. This payload reduction varies greatly and depends on the vehicle type and payload. Some vehicles, like delivery trucks, are packed by volume instead of weight, meaning payload capacity reductions due to weight differences are negligible.[36] These capacity reductions are most relevant to long-range cargo shipping, where payload capacities directly impact revenues. To address this issue, California has enacted a weight exemption for zero and near-zero emission vehicles that allows EVs to exceed the weight limit by an amount equal to the difference in drivetrain weight, up to 2,000 lbs, of an EV and a comparable diesel system.[37] In Oregon, no such exemption currently exists. However, careful consideration would be necessary to ensure an exemption would not have unintended consequences for road safety and road maintenance.[38]

Total Cost of Ownership Estimates of Common MHDV Types

There are several tools available that simplify the TCO process and help fleet managers directly compare costs between electric vs. internal combustion engine vehicles to support purchasing decisions. This section uses a tool created by Portland General Electric to demonstrate the cost differences for four vehicle classes: Municipal buses, school buses, refuse trucks, and delivery vans.

Given the evolving nature of the MHD EV market, precise cost estimates can be difficult to find. Accordingly, the analysis in this section relies heavily on several assumptions about vehicle costs and usage patterns to produce an estimated TCO. Data sources for reference cases are cited and intended to serve as a best estimate of a current market for MHD EVs. Full assumptions are also outlined in the methodology section below. Assumptions are subject to change quickly with evolving market trends, which could significantly affect the 10-year TCO comparison. The assumptions in the reference case can be considered a best-case scenario, in which all rebates are accessible to the purchaser, the vehicle can be purchased at market value, and the appropriate model is readily available.

“Low-cost” and “high usage” cases for each vehicle type are also provided. In the low-cost case, vehicle price is decreased by 20 percent while the high usage case increases the daily miles driven by 20 percent. These cases are meant to illustrate the sensitivity of the TCO to up-front vehicle cost and miles driven.

Table 7: Total cost of ownership analysis of four MHDV classes.

	Daily Miles per Vehicle	Days Used per Week	EV Vehicle Price	Gas Diesel Price	Rebates/ Incentives	**10 Year TCO Gas**	**10 Year TCO Electric**	**Savings/Loss (electrification)**
Municipal Bus								
Reference	120	7	$785,000	$400,000	$62,650	**$1,093,623**	**$844,590**	$148,377
Low-cost	120	7	$628,000	$400,000	$62,650	**$1,093,623**	**$687,590**	$406,034
High Usage	144	7	$785,000	$400,000	$62,650	**$1,198,503**	**$837,525**	$360,978
School Bus								
Reference	46	5	$342,500	$100,000	$46,580	**$193,738**	**$322,623**	$(128,885)
Low-cost	46	5	$274,000	$100,000	$46,580	**$193,738**	**$254,123**	$(60,385)
High Usage	55	5	$342,500	$100,000	$46,580	**$206,415**	**$320,463**	$(114,048)
Refuse Truck								
Reference	80	6	$675,000	$350,000	$62,650	**$830,499**	**$804,432**	$26,067
Low-cost	80	6	$540,000	$350,000	$62,650	**$830,499**	**$669,432**	$161,067
High Usage	96	6	$675,000	$350,000	$62,650	**$882,559**	**$805,201**	$77,358
Delivery Van								
Reference	48	5	$65,000	$50,000	$14,080	**$142,526**	**$82,025**	$60,500
Low-cost	48	5	$52,000	$50,000	$14,080	**$142,526**	**$69,025**	$73,500
High Usage	57	5	$65,000	$50,000	$14,080	**$153,372**	**$81,183**	$72,188

In the table above, savings are the difference in 10 Year TCO between the gas and electric models. Positive numbers indicate a lower lifetime cost for the electric model.

This analysis demonstrates the variability in the cost effectiveness of electrifying medium- and heavy-duty vehicles. While the municipal bus, refuse truck, and delivery van are cost effective over a 10-year period in each scenario, the TCO varies greatly based on up-front cost and miles driven, with the refuse truck becoming significantly more cost-effective when the up-front price is reduced. In the reference case, the refuse truck is cost effective thanks to the estimated incentives. For each vehicle type, reducing the up-front cost has the greatest effect on total cost of ownership for the electric models. This highlights the value of policies that provide incentives for vehicle purchases and that support market-wide reductions in vehicle cost by providing certainty to manufacturers.

It is important to note that this analysis is meant to illustrate the ways individual cost components can affect a final TCO, not to be a definitive comparison of these vehicle types. Individual fleets will need to make their own decisions based on their specific circumstances and the cost factors discussed above, some of which are not feasible to model in a simple TCO. It is also possible that individual buyers will have specific vehicle needs that necessitate the purchase of more expensive vehicle models, with a higher price than the average cost used in this analysis. For example, TriMet recently finalized the purchase of 24 battery electric buses, with an average per bus cost of $1,111,418.[39] At this cost, the vehicles would not have been cost effective in the analysis. However, the purchase contract for these buses may include other benefits to TriMet, such as maintenance support, that are difficult to model using this tool. This highlights the challenges with generalized TCO analyses and the need for individual fleet managers to conduct their own analyses when making purchasing decisions.

Indirect and Societal Costs

While individual fleet managers and other buyers will make purchasing decisions driven primarily by lifetime costs of a vehicle, there are indirect costs associated with the purchase of diesel and gas MHD vehicles that could make EVs a preferable option even with a higher lifetime cost of ownership.

Greenhouse Gas Emissions

Greenhouse gas emissions are associated with a range of societal costs that are not represented in a traditional TCO analysis. As a mechanism for quantifying the societal externalities associated with burning fossil fuels, economists have developed the Social Cost of Carbon. The SCC is a measurement of the long-term economic costs associated with emitting an additional ton of carbon dioxide.[40] Incorporating the SCC into a TCO for medium- and heavy-duty vehicle fleets can radically affect the lifetime cost comparison between gas and diesel vehicles and EVs. This is especially relevant for government fleet managers, who must make decisions not only based on immediate financial analysis, but on the long-term impacts of their purchasing decisions on society.

Incorporating the SCC can make EVs much more cost competitive in the near term. However, the costs of avoided emissions are realized at the societal level, and do not result in tangible cost savings for individual businesses. This creates a major challenge for fleet managers who must make purchasing decisions with limited budgets. Policies that account for the societal costs of emissions into fossil fuel costs could help mitigate this challenge but would likely need to occur at the federal level.

Pollution, Air Quality, Health Impacts

In addition to GHG emissions, diesel medium- and heavy-duty vehicles release a range of air pollutants associated with poor air quality and adverse health impacts.[41] The medium- and heavy-duty sector accounts for 70 percent of on-road NOx emissions and 64 percent of on-road particulate matter in Oregon.[42] These contributions are highly disproportionate to the relatively small proportion of the state’s total vehicle population. Transitioning to EVs in the medium- and heavy-duty sector could have a range of health benefits for Oregonians, particularly those living near major trucking routes. Analysis by the American Lung Association estimated $1.1 billion in health-related savings and 103 fewer premature deaths in Oregon due to MHD EV adoption from 2020-2050.[43]

This pollution is not equally distributed. Communities of color and low-income communities face a higher burden due to air pollution and its associated health impacts. Mitigating emissions associated with MHD vehicles would help reduce this pollution and could contribute to Oregon’s broader environmental justice goals. This equity benefit is not realized by individual fleet managers but provides societal benefits that should be considered by policymakers in designing programs for MHD EVs. (See *Distribution of EVs by Demographics* chapter for further discussion.)

TITAN Freight Systems

Oregon-based TITAN Freight Systems is a leader in decarbonizing medium and heavy-duty vehicles. In July 2023, they became one of the first in the Northwest to put a heavy-duty all electric truck on the road.[44] Titan has added three battery electric Freightliner eCascadia Class 8 trucks to their fleet. The trucks were manufactured by Daimler Truck North America (DTNA), the nation’s largest manufacturer of Class 6-8 commercial vehicles, in their Portland Manufacturing Truck Plant.[45]

TITAN plans to replace a total of six of its current trucks with eCascadias in 2023. They will also be adding three Freightliner eM2 medium-duty electric box trucks to the fleet later this year. The eCascadias will replace trucks that provided deliveries to businesses in the Portland Metropolitan area and the eM2s will replace medium duty delivery vehicles that work downtown Portland routes. In spring 2023, the City of Portland was awarded nearly $2 million through the U.S. Department of Transportation Strengthening Mobility and Revolutionizing

Transportation (SMART) Grants program.[46] This funding is intended to enable Portland to pilot a Zero-Emission Delivery Zone, making it the first city in Oregon to implement a regulated area for zero-emission deliveries. TITAN plans on deploying their electric trucks to facilitate deliveries in the Zero-Emission Delivery Zone.

With the help of Portland General Electric, TITAN installed electric charging stations at their Portland area facility. Their new three 180 kW DC Fast chargers will be able to recharge their eCascadia trucks in about two hours and their three 60 kW chargers will be able to recharge an eM2 in four hours. Titan participated in PGE's Fleet Partner program to build the make-ready infrastructure at the Portland facility to support the new chargers.

Barriers and Challenges

In the immediate term, cost is the primary barrier to wider adoption of EVs in the medium- and heavy-duty sector.[47] EV technology is advanced enough to serve several use cases and provide a viable alternative to ICEs for many fleets. However, as outlined above, total cost of ownership of EVs remains higher for many use cases, making it difficult for fleet managers to justify electrification. Without policies that seek to lower the lifetime costs of EVs, such as incentives, tax credits, or low-interest loans, widespread MHD EV adoption may be delayed.

Availability of vehicles and supply chain constraints pose additional barriers to medium- and heavy-duty electrification. While some vehicle classes, such as school and municipal buses, are widely available, other classes of vehicles have not been widely deployed in the United States.[48] Fleet managers interested in purchasing electric vehicles currently face availability challenges and potentially long wait times. The unique manufacturing needs of some models have made scaling manufacturing difficult.[49] While these challenges are expected to be alleviated in the coming years as demand for these vehicles continues to increase and manufacturing processes for electric vehicles mature, they pose a near-term challenge to fleet managers interested in electrification.[50]

Beyond cost and availability challenges, battery range creates a barrier to widespread electrification of long-haul shipping applications. Fuel Cell Electric Vehicles, which rely on hydrogen as a fuel, may prove to be a viable technology for long distance shipping applications for which battery power is insufficient. FCEVs do not face the same payload reduction challenges, can be fueled faster than current batteries can be charged, and may provide much greater range.[51] However, the lack of an extensive network of hydrogen infrastructure poses a major barrier to wider adoption of FCEVs in the immediate term.[52] As technology progresses and more investment is made in hydrogen infrastructure, FCEVs have the potential to play a major role in supporting the zero-emission transition in harder-to-electrify MHDV applications.

FCEV costs

Fuel Cell Electric Vehicles share many of the same cost barriers as battery electric vehicles, with up-front cost being even higher for some models.[53] However, FCEVs face significant additional challenges due to the current lack of hydrogen fueling infrastructure and the challenges associated with building out a nationwide network of hydrogen infrastructure.[54] While battery electric vehicles can connect to the existing grid, the same type of network does not exist for hydrogen. As the market for hydrogen develops across sectors and the necessary infrastructure is built, FCEV may become a more viable option for zero-emissions medium- and heavy-duty vehicles.

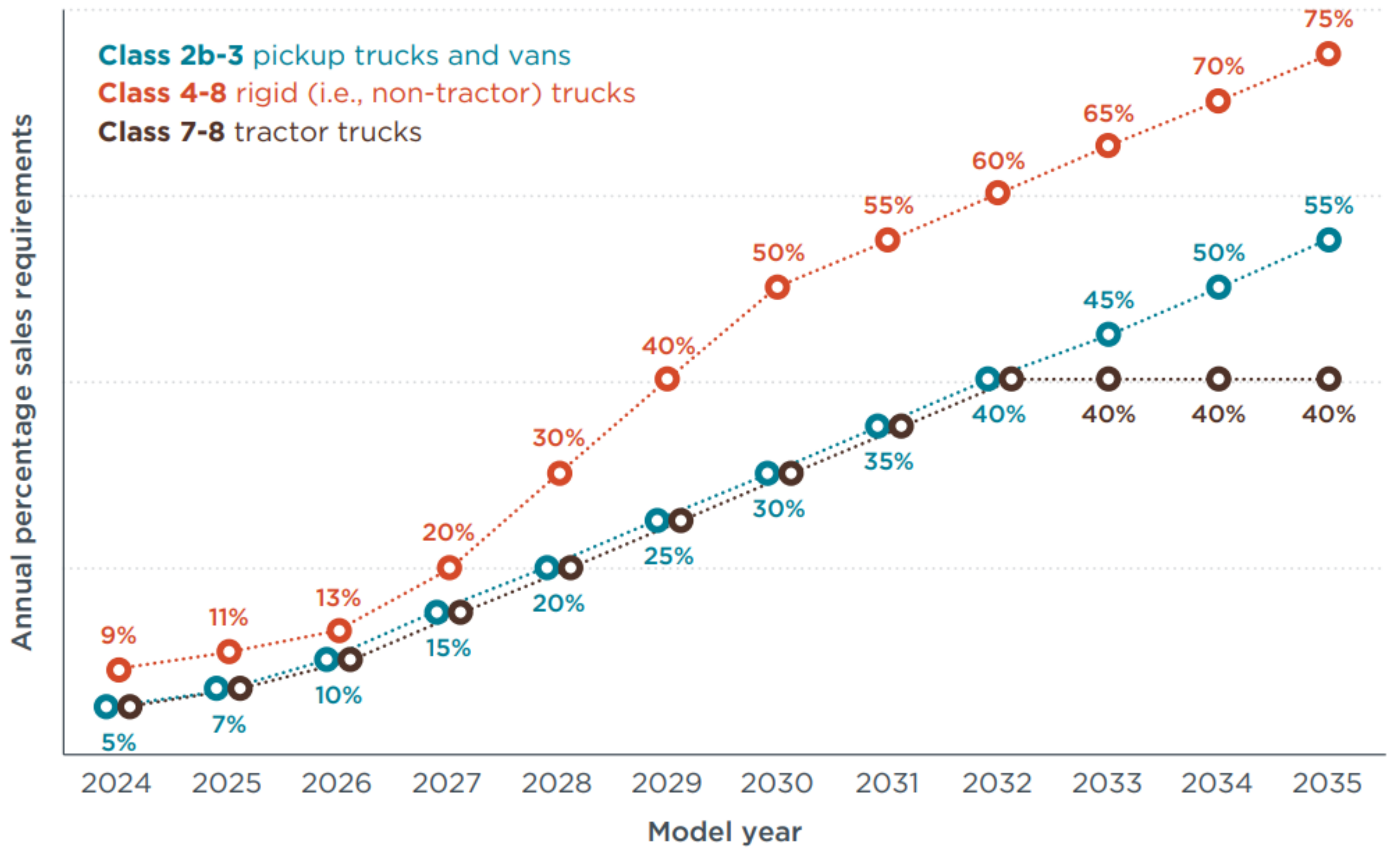
Policy

The policy landscape for zero emission medium- and heavy-duty vehicles is changing rapidly. Oregon is part of this change, including a commitment from the state to electrify the MHD sector. In 2020, Oregon joined 14 other states and Washington D.C. in signing a joint MOU that commits the state to working collaboratively to advance and accelerate the market for electric MHD vehicles, working toward a goal of 100 percent of all new MHD vehicle sales being electric by 2050, with an interim target of 30 percent of sales by 2030.[55] In order to achieve these goals and ensure a rapid and equitable transition to MHD electrification, the MOU states developed a Multi-State MHD Zero Emission Vehicle Action Plan, which provides a number of policy and program recommendations including zero-emission vehicle sales requirements, vehicle and infrastructure purchase incentives, and infrastructure planning and deployment. Oregon has already enacted a number of policies to support this transition. Policies are covered in detail in the Progress on Goals section of this report. For the purposes of this chapter, we highlight three types of policies influencing the costs and deployment of medium- and heavy-duty electric vehicles: 1) policies that reduce up-front costs through incentives; 2) policies that support a stronger market for EVs by making more vehicles available to purchasers; and 3) policies that support expansion of necessary vehicle charging and fueling infrastructure.

There are several incentives available to fleet owners for transitioning to electric MHD vehicles at the state, federal, and utility level. These incentives are outlined in Table 5 above and target vehicle purchase cost or up-front infrastructure cost. At the state level, two bills passed in 2022 (HB 4139 and HB 5202) created funds that will provide grants for up-front costs and charging infrastructure to support public and private entities, with priority given to projects located in communities disproportionately affected by diesel pollution or connected to transportation corridor projects.[56] [57] These funds are relatively flexible and can support a range of fleet owners in overcoming cost barriers of electrification. Continued investments in these flexible "cash on hood" incentive programs will be necessary to drive higher adoption of EVs in the MHD sector.

Also relevant to vehicle costs are policies that support market availability of new MHD EV models. These types of policies provide purchasers with assurance that there will be viable electric models to replace gas and diesel vehicles. Oregon is a Section 177 state and has opted into California's more stringent vehicle and truck emissions standards.[58] In 2021 the Environmental Quality Commission adopted the Advanced Clean Truck Rule, which requires manufacturers to ensure an increasing percentage of new sales of MHD vehicles in Oregon are zero-emission, beginning with model year 2025 vehicles. Figure 1 shows the required percentages by class manufacturers must provide over time.

Figure 1: Advanced Clean Truck Rule Manufacturing Requirements by Vehicle Class



This policy helps ensure there is a market for MHD EVs, requiring manufacturers to continue expanding their offering and investing in the MHD EV supply chain.

Policies that establish widespread adoption of charging infrastructure also help support the transition to electric vehicles in the medium- and heavy-duty sector. The Infrastructure Investments and Jobs Act included several funding opportunities for the development of charging and fueling infrastructure. The National Electric Vehicle Infrastructure program allocates $5 billion in funding for the development of LD vehicle DCFC stations along alternative fuel corridors within the national highway system. Oregon will receive $52 million in funding to develop charging stations along its network of AFCs.[59] ODOT expects to add 65 charging stations, totaling a minimum of 260 new DCFC ports, with NEVI program funding.

In addition to the NEVI program, the IIJA allocates $2.5 billion in funding for the development of charging and fueling infrastructure under the Charging and Fueling Infrastructure grants program. While the NEVI program focuses specifically on expanding access to charging infrastructure for LD vehicles, the CFI discretionary grant program is open for the development of hydrogen, natural gas, and propane fueling infrastructure, and the development of charging infrastructure. In addition, the CFI grants may be used to develop infrastructure for medium- and heavy-duty vehicles.[60]

Conclusion

The up-front costs of medium- and heavy-duty vehicles and the infrastructure necessary to operate these them are a barrier to widespread adoption of these vehicles. When incentives are available to reduce up-front costs, certain models of medium- and heavy-duty EVs are cost competitive with their gasoline or diesel equivalents. Without continued investment in and expansion of these and other incentives, MHD EV adoption will continue to be slow. In comparison, light-duty vehicle costs are closing in on cost parity with gasoline vehicles today.

By continuing policies that address up-front costs, offering innovative commercial electricity rates, and supporting the market for continued expansion of medium- and heavy-duty EV models, policymakers can further support the electric vehicle transition in Oregon and the region. The unique uses of these vehicles make general cost comparisons difficult, and fleet managers must work directly with their utilities to make purchasing decisions for their organizations that fully account for the lifetime costs of their fleets. Accordingly, incentives must provide flexibility to these consumers to ensure they can purchase vehicles and infrastructure that meets their needs.

Total Cost of Ownership Methodology

The TCO tool calculates a total cost of ownership by estimating the up-front costs for the purchase of the vehicle, and the yearly operating costs for the vehicle throughout a 10-year period for electric and diesel or gas models. The total amount represents the sum of the yearly costs over this 10-year period.

Several tools exist to estimate total cost of ownership for electric vehicle fleets, and these all rely on the same basic methodology, with some variation based primarily on electricity rates. Using any of the available cost analysis tools will provide similar results to what is presented in this report. Ultimately, the decision to use the Portland General Electric tool was based on the simplicity of the tool and the fact that many large Oregon fleets are served by PGE.

Key Assumptions

This tool relies on several assumptions to simplify the process of estimating a total cost of ownership. The most impactful assumptions are outlined below. For a detailed explanation of the calculation please refer to PGE's webpage.

Rate structure – The tool assigns a rate structure based on total site demand (kW) for chargers installed to meet projected vehicle charging needs. This means existing site demand is not included in the calculation and thus the total cost of ownership does not include increases in existing electricity bills due to increased capacity charges.

Vehicle costs – Up-front vehicles are estimated in the tool based on market rates. The analysis in this report uses these default values for the refuse truck and delivery van estimate. School and municipal bus estimates use the median cost of battery EV models published by Atlas EV Hub.

Incentives – The tool assumes several incentives will be realized. This includes carbon credits through the Oregon Clean Fuels Program, PGE's Business Charging Rebate, and the Federal EV Tax Credit. This represents a best-case scenario and may not be feasible for every fleet. However, there are several incentives that are not included in the tool that could be available to fleet managers, including the MHDV electrification fund and the grant program for charging infrastructure passed in the 2022 legislative session.

Charging infrastructure – The tool estimates necessary charging infrastructure based on the number of vehicles input and the battery size of the model of vehicle. The TCO employed in this report compares a single vehicle and thus does not get into the logistical challenges of planning charging infrastructure. This type of planning is not feasible for a generalized market wide TCO analysis. As discussed in the chapter, individual planning with utilities is crucial to successful fleet electrification and right-sizing of charging infrastructure.

Site upgrade/ "Make Ready" costs – Site upgrade costs – in front of the meter infrastructure needed to install high-capacity charging – are not included in the total cost of ownership estimates. This is because these costs are highly variable depending on location and may be reduced with participation in programs like PGE's Fleet Partner program.

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Youngster learning how to charge at an ODOT public event, Courtesy of ODOT

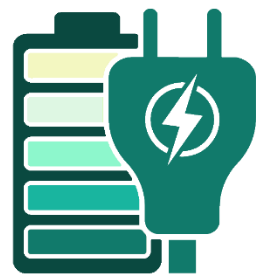
This section discusses the **availability and reliability** of the public and private electric vehicle charging infrastructure needed to support Oregon's targets for zero-emission vehicle sales and registration.

Availability & Reliability of Charging Infrastructure

Key Takeaways

- The availability and reliability of public EV charging infrastructure is one of the biggest barriers to wider EV adoption in Oregon.
- For Oregonians living in multi-unit homes and rural areas, widely available public EV charging infrastructure needs to be in place before driving an EV can be a viable transportation option.
- Existing public charging infrastructure is often seen as unreliable by users, and there is insufficient data available to the state to assess charger reliability.

Introduction



In the *2021 Biennial Zero Emission Vehicle Report*, this chapter focused on options for defining the terms "reliability" and "availability," along with quantitative and qualitative metrics to measure them. That report came on the heels of the Oregon Department of Transportation's *Transportation Electrification Infrastructure Needs Analysis* study, which included a wealth of information about gaps in charging infrastructure across the state as well as recommendations on improving reliability. In this 2023 edition, the chapter builds on the work of the TEINA study, providing an assessment of recent information about the overall reliability and availability of Oregon's charging infrastructure. Unlike TEINA, which modeled existing infrastructure and forecasted infrastructure needs, this chapter uses *existing* data and information (including TEINA) to assess the overall geographic availability of charging in Oregon and where there are gaps across the state. It discusses potential options to address charging infrastructure gaps, including an overview of costs, benefits, and challenges, and builds on the findings and recommendations provided in the TEINA study. The chapter also lists existing state and federal policies that seek to address charger availability and concludes with a high-level overview of charger reliability.

Defining Availability of Charging Infrastructure

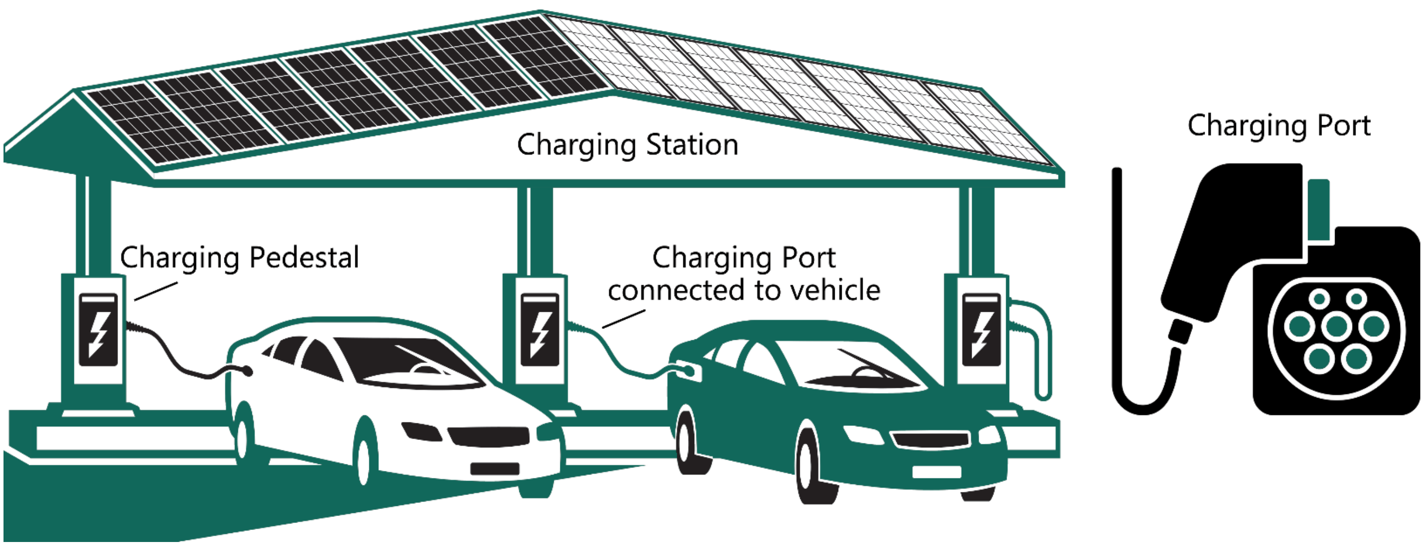
In its 2021 report, ODOE found that there is no standardized definition for "availability," but provided recommended categories to assess availability from the Northeast States for Coordinated Air Use Management, or NESCAUM. These included open access charging platforms[i], multiple payment options, pricing transparency, accessibility, and redundancy. In addition, ODOE heard from Oregon stakeholders that other considerations should be included, such as station locations and the density of the locations in a particular area, affordability of electric fuel, and a focus on equity. There are actions to address these considerations happening across several federal and state agencies. The

[i] Open access platforms allow non-members or non-subscribers the ability to access chargers without the need to sign up individually for each charging provider.

focus of this section of the report is the physical availability of charging infrastructure, including access in underserved communities.

Current State of Charging Structure Availability

Charging infrastructure is growing rapidly across the U.S., with about 142,000 public charging ports[ii] as of March 2023, an increase of about 50 percent since the beginning of 2021.[1] While most public charging points are Level 2 chargers, shown as the green portion of the bar in Figure 1, Direct Current Fast Chargers, or DC Fast Chargers, have the highest growth rate, as shown in the increasingly larger light blue portions. In that same timeframe, Oregon charging ports have more than doubled. As of August 2023, Oregon has 1,055 public charging stations with 2,636 ports – 1,922 Level 2 and 714 DC Fast Chargers.[2] New chargers are being added and some legacy chargers installed before 2017 have been decommissioned, but overall, charging infrastructure growth in Oregon is outpacing national growth.



[ii] Charging ports represent the individual physical cable that charges a vehicle and are the best representation of charging availability. A charging unit may have anywhere from one to four charging ports associated with it, like how most gas pumps have two separate nozzles for dispensing gasoline.

Figure 1: U.S. Quarterly Growth of Public EV Charging Ports[3]

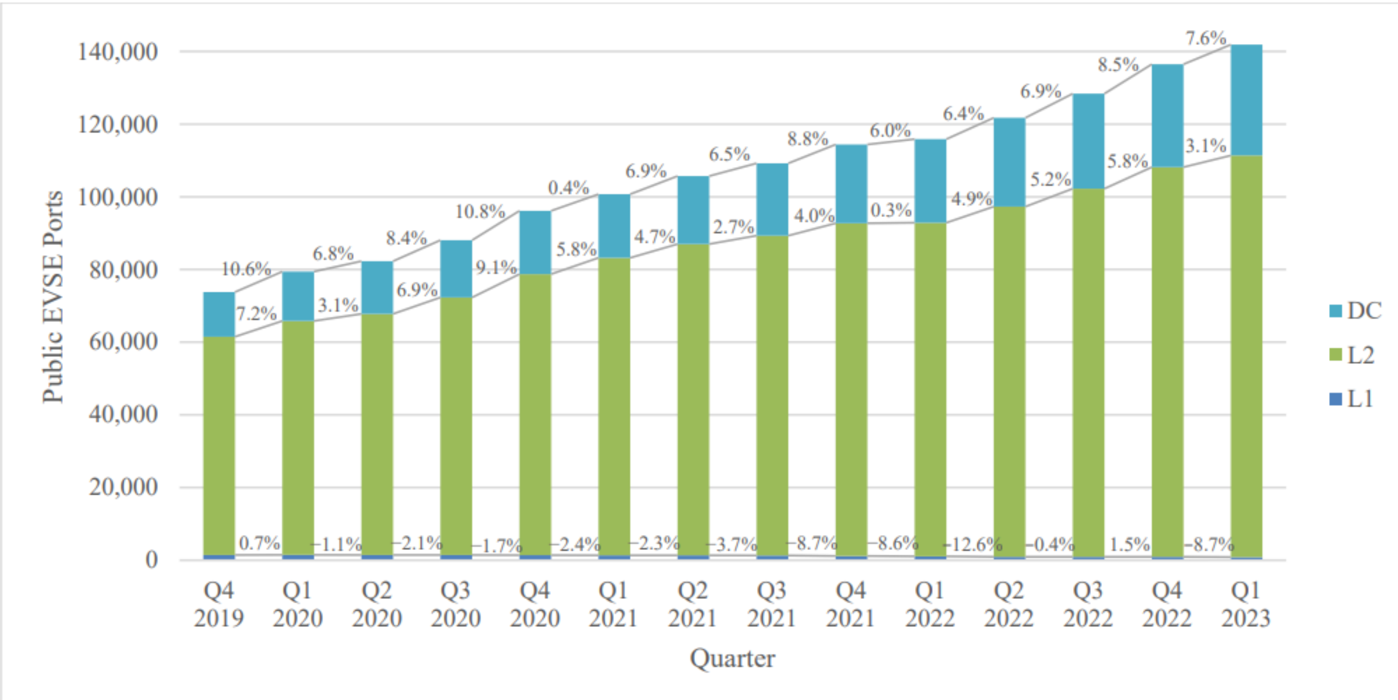
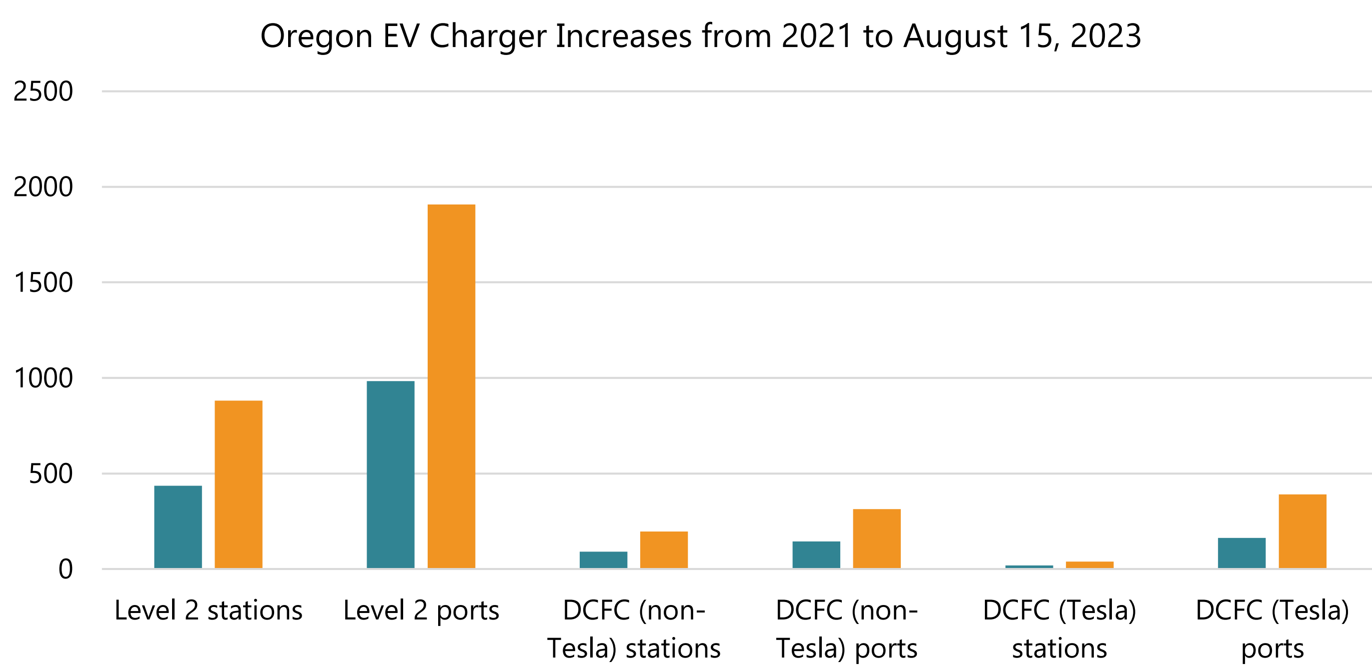


Figure 2: Oregon Growth of Public EV Charging Ports and Stations[4]



As of August 2023, Tesla has the most charging ports available in the state, but there are more non-Tesla stations than Tesla stations. About 55 percent of DC Fast Chargers are Tesla-only chargers located in 38 unique places. Non-Tesla DC Fast Chargers comprise 45 percent of charging points, located in 199 specific locations. Many companies support the non-Tesla chargers in Oregon, and therefore there are more overall stations.

The need for charging depends on whether a vehicle can be charged at home or at work, how far the vehicle needs to travel before its next charge, and whether the vehicle is compatible with a charger. EV buyers can purchase a charging cord that plugs directly into a 110 V outlet, and some manufacturers also sell 220 V charging cords. This facilitates charging at home or on the road where standard outlets are available. Charging is slower, but usually this is sufficient when the vehicle can charge all day or all night.

Public charging is a more complex issue, where EVs and chargers must be compatible. Incompatibilities exist for Level 2 charging as well as DC Fast Charging. All non-Tesla vehicles use one format of Level 2 charging, called J1772, and Tesla vehicles use a Tesla-designed format called the North American Charging Standard. For DC Fast Chargers, there are three formats, including Tesla's NACS, CCS,[iii] and CHAdeMO[iv], although almost all new non-Tesla EVs now come with the CCS format. Until recently, charging sites were either Tesla or non-Tesla, and EV drivers would need to ensure the charger they selected was compatible with their vehicle. Tesla drivers can purchase adaptors so their vehicles can use CHAdeMO and CCS chargers, but non-Tesla drivers have not been able to use the Tesla charger network.

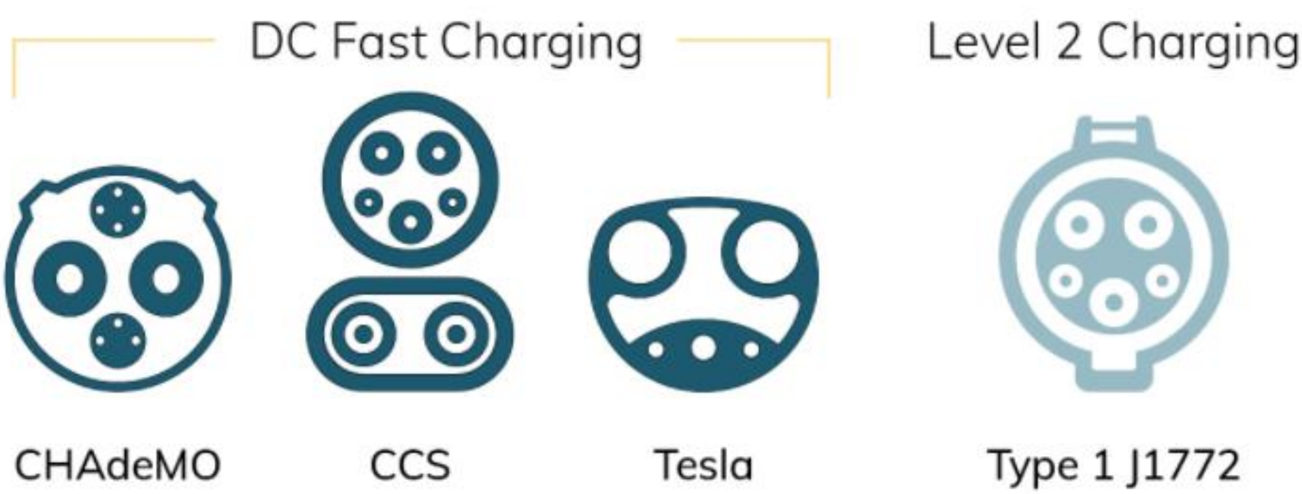
Charging providers are in the initial phases of making all three charger formats available at their stations, especially at DC Fast Chargers. In 2022, Tesla announced they would open their charging network to other manufacturers and networks, and in 2023 many charging networks, including Tesla, have begun adding other charging standards to a few existing locations.[5] While widespread availability is still in the beginning stages, there are some design and software challenges that will need to be addressed in the rollout. Overall, this converging of all three DC Fast Charger standards will create more charging station locations for

VW e-Golf, Hyundai Ioniq, and a Ford F-150 Lightning Using Tesla "Magic Dock" Superchargers.
Photo: MotorTrend

[iii] Combined Charging System chargers can provide up to 350 kW of charging and are currently the standard for most EVs apart from Tesla.
[iv] CHAdeMO chargers in the U.S. generally provide up to 50 kW of charging and had been the preferred standard for vehicles from Asian vehicle manufacturers.

all drivers. In addition, there is some indication that the Tesla NACS standard may soon become the most widely adopted EV charging standard. Ford, General Motors, Nissan, Honda, Rivian, Mercedes-Benz, Polestar/Volvo, and Fisker announced they had signed an agreement with Tesla that would allow their existing EV owners to access the Tesla charging network with an adaptor, and would add the Tesla NACS charge port starting with their 2025 model year EVs.[6, 7, 8, 9 10 11]

It is uncertain when or if all various charging formats will coalesce on a single standard. CHAdeMO fast charging is the most likely to become obsolete in the future. The only vehicle produced in 2023 with a CHAdeMO fast charging port is the 2024 model year Nissan LEAF, and Nissan's other new EV model, the Ariya, is equipped with a CCS charging port.[12] Even if CHAdeMO connectors will no longer be installed on new vehicles in the U.S., the CHAdeMO chargers will need to remain for some time to accommodate legacy vehicles. The average age of a light-duty vehicle in Oregon is 16 years, so CHAdeMO fast charging will likely still need to be available for at least two decades after the last model year of CHAdeMO cars are produced.[13] CCS and Tesla are both in wide use at this time. Although many manufacturers have committed to the Tesla NACS standard, there is no indication from other manufacturers that they will do the same.



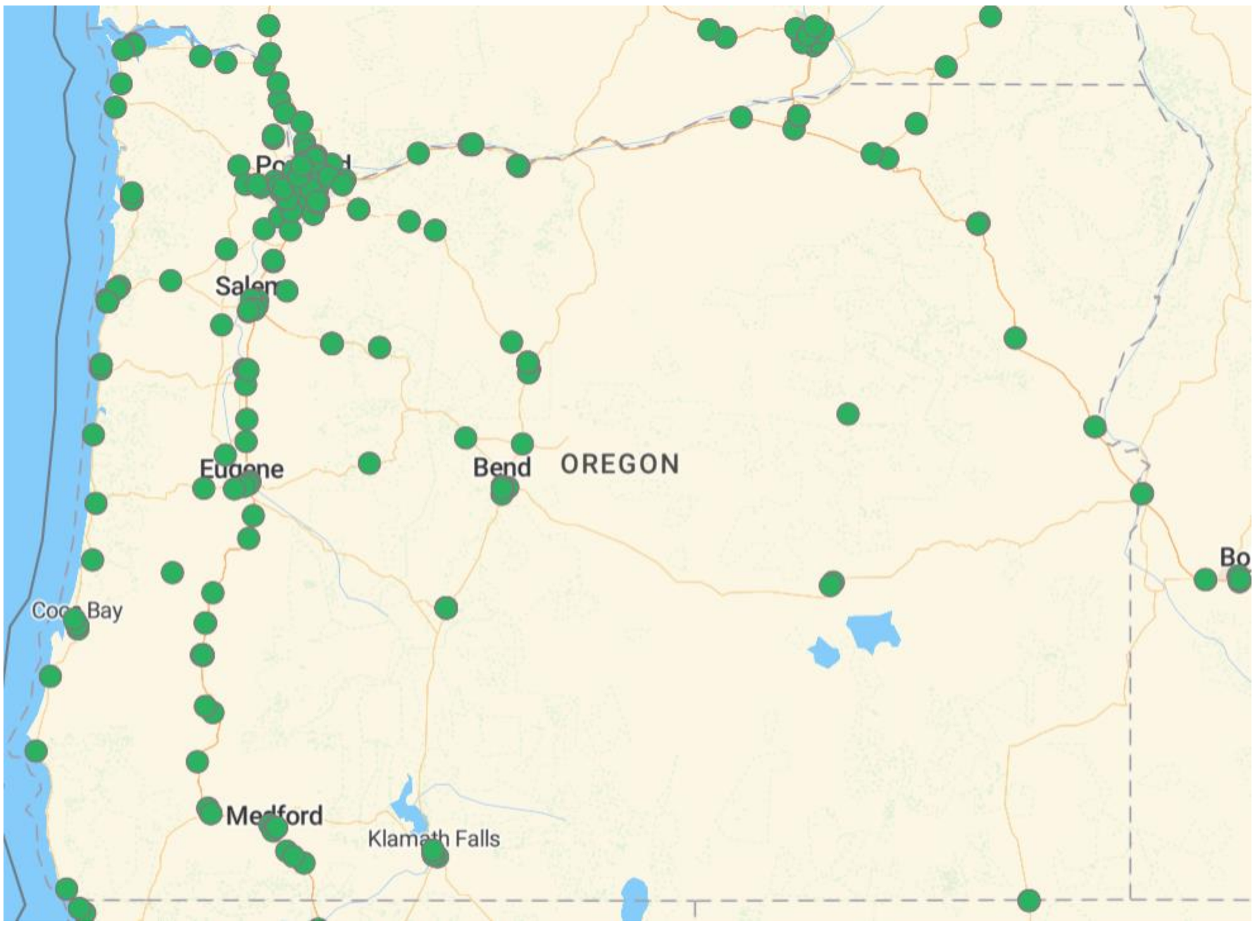
Level 2 and DC Fast Charging Connectors for EV Charging in North America

Gaps in Charger Availability

Lack of available chargers is the biggest reason consumers choose not to purchase an EV. The EV charging experience consistently ranks low in J.D. Power EV customer surveys.[14] In their 2023 Electric Vehicle Consideration Study, they found 49 percent of car buyers indicated they would not purchase an EV due to lack of available charging stations. Portland General Electric found that 63 percent of EV purchasers indicated the inability to charge at home was a major barrier in its 2022 EV customer survey.[15] Lack of chargers affects many people, from drivers who lack access to charging at home and people who need public charging to meet their travel needs.

In most cases, rural drivers have fewer public charging options to meet their charging needs. The map below shows fast charging locations throughout the state, which are largely concentrated in the Willamette Valley, along the coast, and along Interstates 5 and 84. Large swaths of eastern and southeastern Oregon have only one or two charging options in the whole county. For example, the only DC Fast Chargers in Malheur County are located at one Tesla site in Ontario, while in Harney County there is one CHAdeMO charger in Burns and a bank of Tesla Superchargers in Hines. There are no DC Fast Chargers in Lake County.[2] Where chargers are available in these areas, they tend to be along major travel routes, such as I-84, U.S. Highway 20, and U.S. Highway 97. These are designed to meet the needs of travelers but may or may not meet the needs of local drivers.

Figure 3: DC Fast Chargers Available in Oregon[16]



Charging infrastructure placement is important to guarantee useability and equitable access to EVs for Oregon communities. The overall cost and expectations for return on investment mean that private EV charging companies will build in locations where usage is expected to be higher. This generally means chargers have been built in higher-income metropolitan areas or along major highway travel corridors. Government supported networks, like the West Coast Electric Highway, have been successful in providing public charging for some rural areas of the state, as shown in the map below. The construction and operation of these chargers was supported by federal and state funding, which is not as dependent on a fast return on investment. The availability of chargers in rural areas can give residents more confidence that EV charging will be available where they need it, potentially supporting more rapid EV adoption. For example, Curry County located in the far southwestern corner of the state – where WCEH chargers are the only DC Fast Chargers available – the EV adoption rate is 9.61 EVs per 1000 residents, or about the same as Marion County.[16] In comparison, Lake, Malheur, and Harney counties all have EV adoption rates under 3 per 1,000 residents.[16]

Figure 4: West Coast Electric Highway Charger Location Map[17]

In general, Oregonians living in multi-unit buildings and low-income areas have fewer charging options than others. A 2021 study from the National Renewable Energy Laboratory indicated that only about 33 percent of *all* existing light-duty vehicles are regularly parked near an electric outlet.[18] While metropolitan areas have more public chargers available, there tend to be fewer publicly accessible DC Fast Chargers or Level 2 chargers in and near low-income neighborhoods. In the map of the Portland metropolitan area below, each dot represents existing DC Fast Charger or Level 2 public charging locations. Most of the chargers are in higher income areas of Beaverton, Hillsboro, Tigard, and west Portland, with fewer options in east Portland, Gresham, and much of Clackamas County. When compared against the maps in Figure 6, there is little to no DC Fast Charging near areas where there are more multi-unit homes, shown in dark purple on the left. These areas also mirror portions of the Portland area where the median income is below twice the federal poverty level, shown as white in the map on the right. This means that people living in these multi-unit homes and who are low-income must travel further to access DC Fast Charging than many other people living in the Portland area.

Figure 5: Public EV Charger Sites in the Portland Metropolitan Area[2]

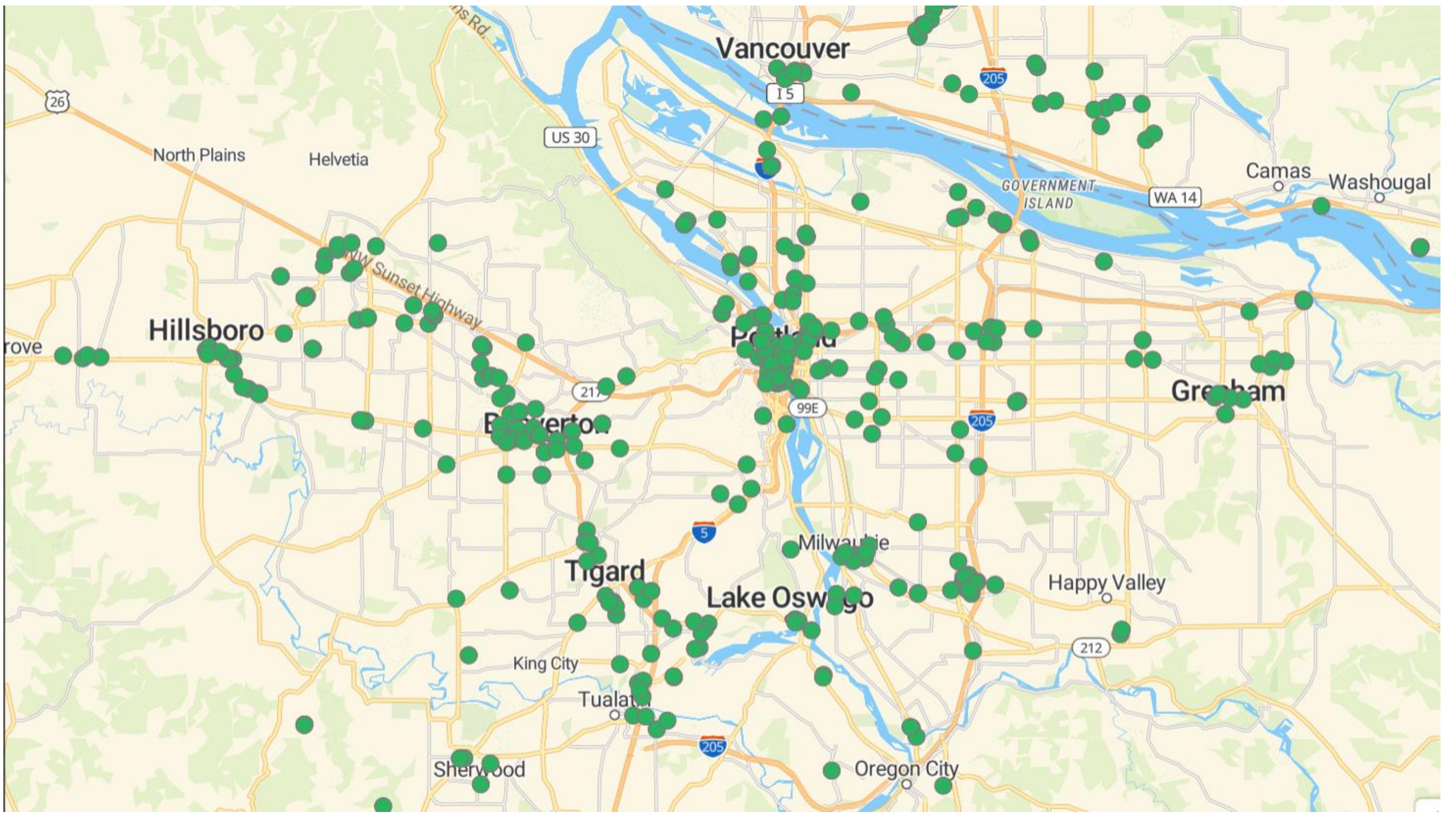
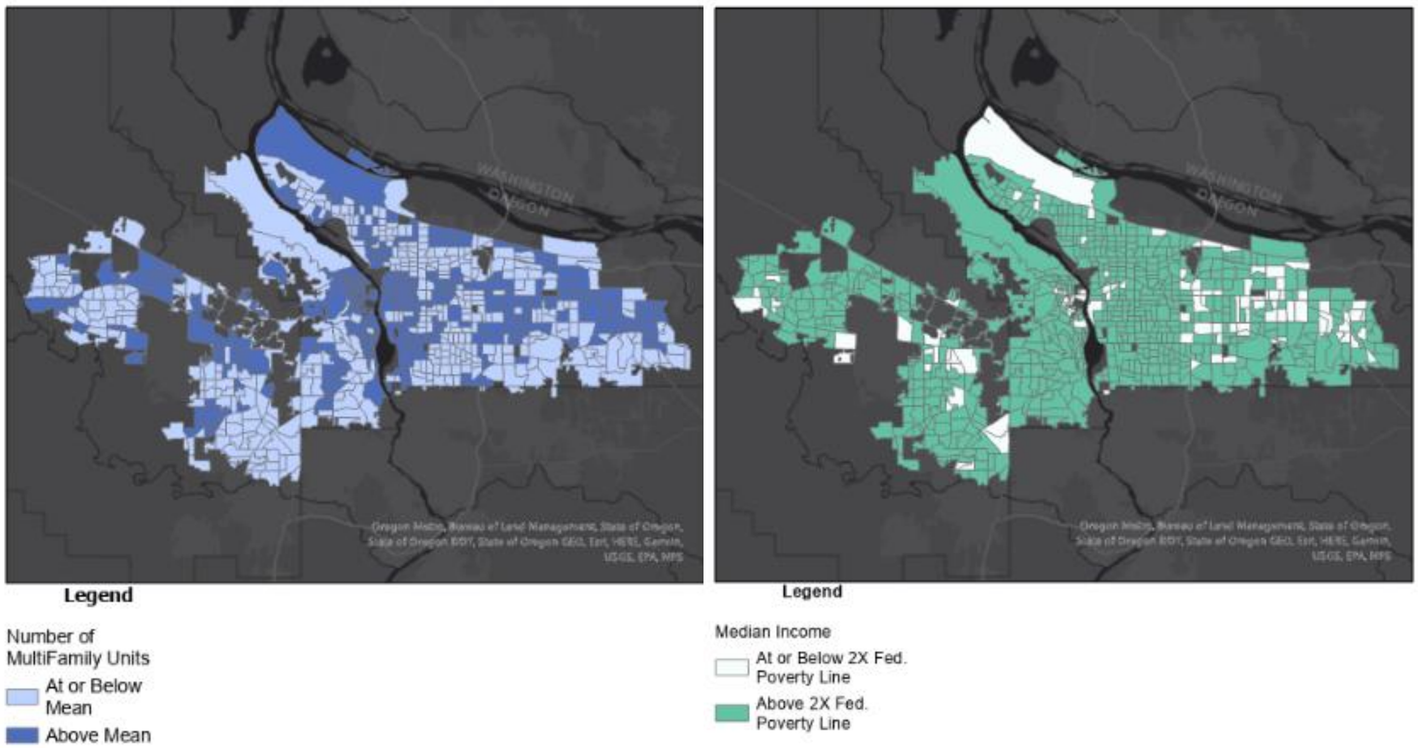


Figure 6: Areas with Multi-Unit Buildings and Areas with Low-Income Residents in Portland



Because there are fewer charging options in many low-income communities, reliability is more crucial for these chargers. Charger locations are determined based on existing or anticipated market demand, with fewer investments in other areas – especially in communities where EV adoption is slower. One U.S. study ranked counties from least to most distressed – an assessment of nine criteria that help identify counties with higher proportions of disadvantaged communities – and found 33 percent of charging ports are located in the upper quintile (least distressed) of counties, while less than 20 percent are located in the lower quintile, and less than 12 percent were in the second-lowest quintile.[19]

Options for Addressing Charger Availability

There are several charging options to support EV drivers beyond home charging, including private workplace charging, public Level 1 and 2 charging, and public DC Fast Charging. There are a range of trade-offs associated with these different charging solutions. Figure 7 below shows how cost and time investment change with different charger availability solutions. Home charging is the least cost and least time-consuming form of consumer charging, whereas intra- and intercity DC Fast Chargers are more expensive and can require more of a time investment. The following section includes a high-level overview of each type of charging option and highlights the relative benefits and challenges of these options. Each section includes a box indicating the anticipated need for the type of charging as found by ODOT in its Transportation Electrification Infrastructure Needs Analysis study.

Figure 7: Relative Cost and Time Investment for Different Consumer Charging Options[20]

Workplace Charging

ODOT's Transportation Electrification Infrastructure Needs Analysis Study Findings for Oregon's Workplace Level 2 Charger Needs in the Business-as-Usual Scenario[21]

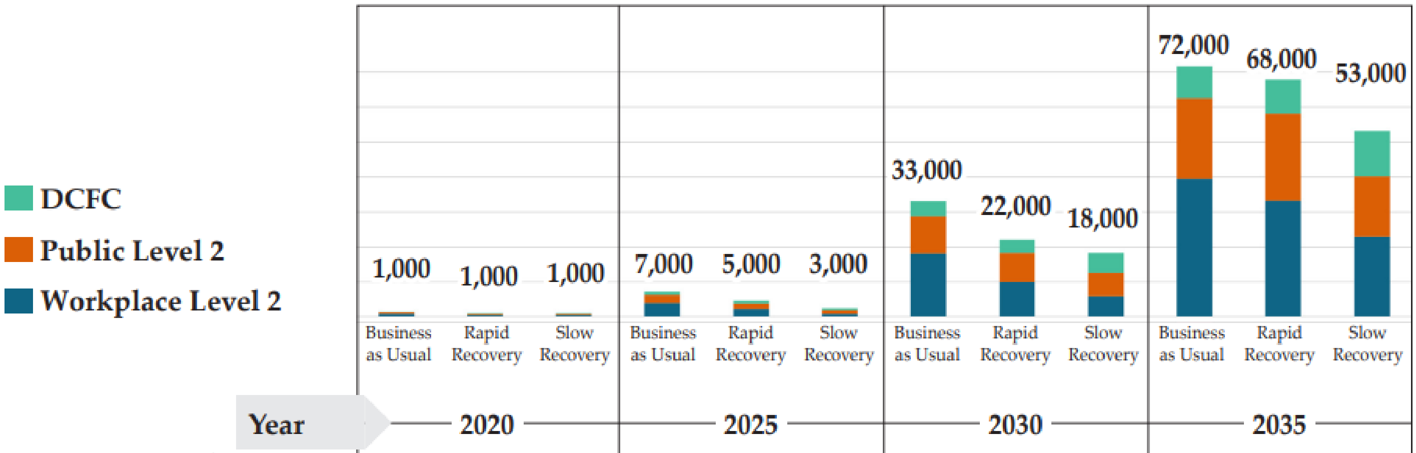
7,220 by 2025

33,304 by 2030

72,379 by 2035

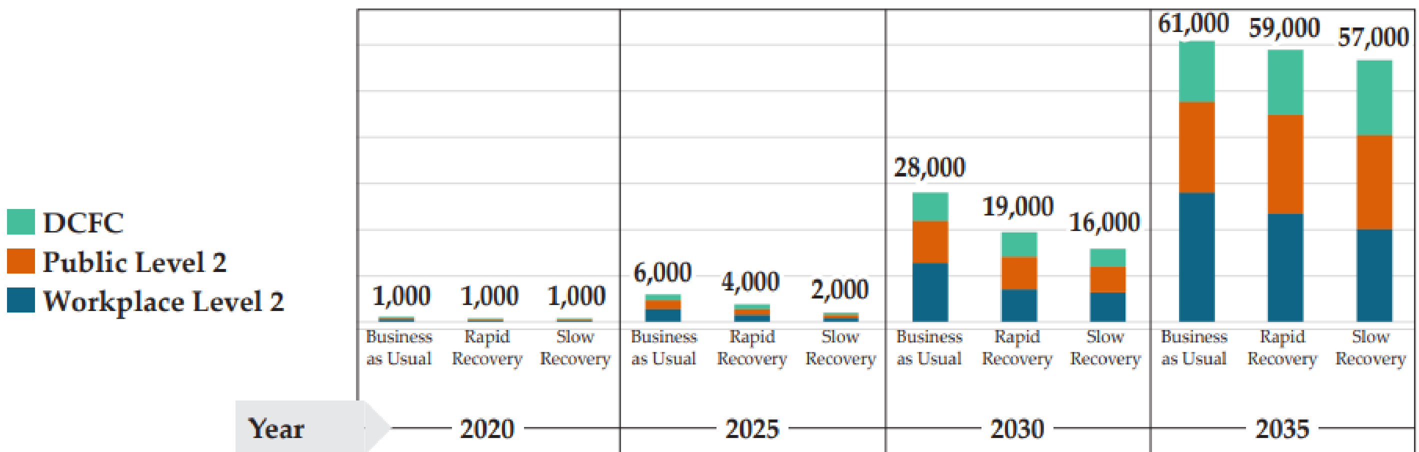
In the Oregon Department of Transportation's TEINA study, they found workplace charging is a major consideration for drivers that cannot access charging at home.[22] For each of the business-as-usual scenarios, workplace Level 1 or 2 chargers make up more than half of the needed charging in urban areas (Figure 8) and about a third of charging needs in rural parts of the state (Figure 9).[23] [24] There are different options for businesses to support this type of charging, from a common set of chargers available to all employees to reserved employee parking spaces with chargers.[25] Employers could choose to offer charging as part of a benefits package, charge a monthly fee for use, or purchase a software system that enables users to pay for fuel directly. Workplace chargers could also help increase charger availability for nearby residents, if standard business hours allow for use of the chargers in the evenings and overnight.[26] For example, *Communities in Charge*, a program in California, offers technical assistance and funding to businesses that install charging, with a focus on also enabling local community access to those chargers.[27]

Figure 8: TEINA Study Total Number of Charing Ports for Urban Light-Duty Vehicles[23]



Business as Usual Optimized Scenario	2020	2025	2030	2035
DCFC		971	4,259	9,150
Public Level 2		2,337	10,653	23,106
Workplace Level 2		3,946	18,150	39,420
Total Charging Ports		**7,254**	**33,062**	**71,676**

Figure 9: TEINA Study Total Number of Charing Ports for Rural Light-Duty Vehicles[24]



Business as Usual Optimized Scenario	2020	2025	2030	2035
DCFC		1,316	6,063	13,178
Public Level 2		1,945	9,069	19,748
Workplace Level 2		2,776	12,856	27,966
Total Charging Ports		**6,037**	**27,988**	**60,892**

It is less expensive for a business to install level 1 and 2 charging than DC Fast Charging, but adding any chargers requires businesses to take on oversight of the project and develop a system for driver access.[28] Software to manage payments increases the up-front cost of the charger, but this would reduce the need for businesses to manage payments and costs.[29] Businesses and organizations may also need charging policies, including employee charging etiquette and systems for sharing charger use among several EV drivers throughout the day.[22] Data collection from the chargers is also an important aspect of charger management, because it can help identify when additional charging may be necessary.[30]

The economics of installing chargers at existing locations can be affected by numerous factors. For instance, adding electrical infrastructure, digging up existing parking areas to add electrical conduit, and adding an internet connection can increase costs. Some businesses can access federal tax credits for EV charging infrastructure.[31] There may be other opportunities to help reduce costs such as: making investments in employee charging at the same time the business installs charging for its own vehicles, planning to add charger conduit during the next planned parking renovation, or taking advantage of economies of scale by upgrading all parking to be charger ready. However, certain opportunities to mitigate costs may be more amenable for larger companies with more economic resources than smaller businesses, and more applicable to larger parking areas that can benefit from economies-of-scale when adding charging infrastructure.

State of Oregon Leading in Workplace Charging

Oregon's Department of Administrative Services Fleet & Parking Services offers employee workplace charging at some state building parking facilities. State employees wishing to use the space must apply for a parking space equipped with a charger, and in addition to paying the cost to rent the spot, they will pay an additional $10 – $20 per month for use of the charger, depending on the size of the vehicle's battery. Smaller battery vehicles have the option to reserve the spot for half a day instead of the full day.[32]

Workplace charging also has the potential to be beneficial to the electric grid, especially as more solar resources are added to Oregon's electricity mix. Solar is plentiful during the middle of the day when most workplace charging would occur, allowing utilities the ability to utilize low-cost solar energy to fuel a large portion of Oregon's EV fleet.[33]

Other Level 1 and 2 Charging Options

ODOT's Transportation Electrification Infrastructure Needs Analysis Study Findings for Public Level 2 Charger Needs in the Business-as-Usual Scenario [21]

4,512 by 2023

20,784 by 2030

45,162 by 2035

Level 1 and 2 charging near where people live and work could provide beneficial public access.[34] An EV parked at a Level 2 charger for two hours can add about 44 miles or more, which is more than the average number of miles Oregonians drive on a daily basis.[35] [36] Charger locations could include multi-unit buildings, park-and-rides, business districts, educational facilities, restaurants, movie theaters, grocery stores, and shopping centers. These types of charging locations allow drivers to charge while they complete errands, eat at local restaurants, or attend events, while also helping to support local businesses.[37]

The costs to install this type of fueling infrastructure vary and depend on the charger's location and the individual needs of the users. A typical Level 1 charger can cost anywhere from $300 – $1,500 per charger unit, and a Level 2 from $1,300 – $4,900 or more per unit.[38] While the cost of the charger is known, the cost for installation can vary depending on how much effort is needed to install the charger, whether any additional electricity service is needed, and how many chargers are being installed.[39] Where properties exist with individual garages, existing 110 V or 220 V outlets could support driver needs, potentially in conjunction with public DC Fast Charging. In other cases, where outlets are not readily available, the costs to install charging are affected by the charger location, whether electrical upgrades are needed, and whether the charger needs networking capability.[29]

A 2019 study[v] reviewed the costs to install 1,294 charging units at 637 individual charging sites, including labor, materials (other than the charger), permitting costs, and taxes, and found that installation costs ranged from $2,305 – $2,836.[40] Although this study was conducted before the COVID-19 pandemic created supply shortages that affected costs, the study showed that cost reductions can occur when adding six or more chargers at the same time. When located in disadvantaged and rural communities, property owners can utilize the federal EV charger tax credit to help offset the charger and installation costs.[41] Some state programs, such as the Oregon Department of Transportation's Community Charging Rebates Program, allow funds to be used for equipment and installation costs, as well as other planning and design elements, such as signage.[42]

Table 1: Charger Installation Costs from ICCT and EPRI Study[40]

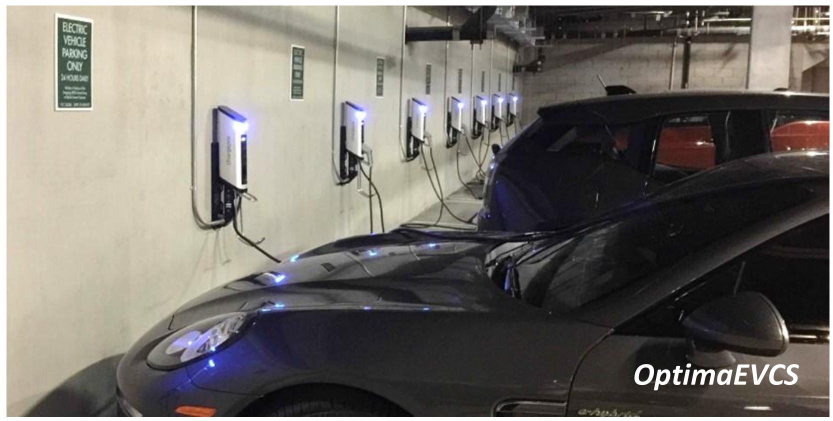
	1 Charger per Site	2 Chargers per Site	3-5 Chargers per Site	6+ Chargers per Site
Labor	$1,544	$1,827	$1,647	$1,316
Materials[vi]	$1,112	$1,039	$1,272	$874
Permit	$82	$62	$59	$38
Taxes	$96	$89	$110	$75
Total[vii]	$2,836	$3,020	$3,090	$2,305

[v] The initial study was conducted by the Electric Power Research Institute, and numbers were revised by the International Council on Clean Transportation using cost data from Idaho National Laboratory.[40]

[vi] Materials does not include the cost of the charger.

[vii] Totals do not match exact sums of numbers above due to rounding errors.

Locating Level 1 or 2 chargers at or near multi-unit residential buildings offers a convenient option for residents, but the cost to install can often be a significant barrier. Oregon has laws providing residents at multi-unit homes the right to install a charging station for their use, but the costs to install would likely fall to individual EV owners.[43] Residents in multi-unit homes tend to have lower average incomes than people living in single-family homes, and EV adoption is lower in areas where multi-unit buildings are more prevalent.[44 45] (See the chapter on *Distribution of EVs by Demographics*.) The cost for the vehicle coupled with additional charging costs make the economics of owning an electric vehicle for many multi-unit building residents more challenging.[46 47]

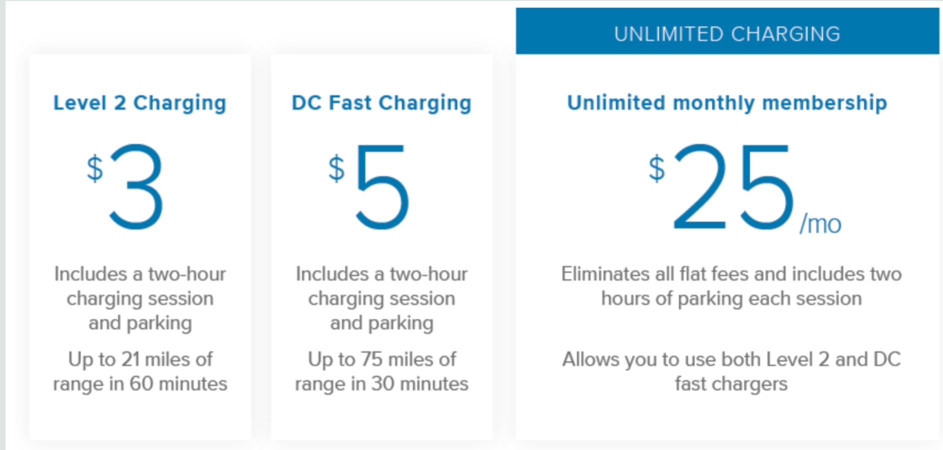


Consumer costs for fueling at these types of chargers varies depending on the charger owner and the type of charging provided. Providers sometimes charge for the use of the space, use of the charger, or both, and electricity costs can vary from pricing per kWh, pricing per time used, a combination of these, and in some cases membership with a specific company discounts the cost or sets a single membership fee for unlimited charging access.[48] Some providers charge a higher rate during peak usage times.[49] Because of this variability, the overall affordability of this charging option is highly specific to each situation.

Utilities Supporting More Equitable Access to Chargers

Portland General Electric built seven charging stations – called Electric Avenue – throughout the metropolitan area of their service territory, including downtown Portland, Beaverton, East Portland, Hillsboro, Milwaukie, Salem, and Wilsonville. The total number of chargers across all stations is 26 DC Fast Chargers and 14 level 2 chargers, which equates to about four Level 2 charging ports and about twelve DC Fast Charger ports per site.[50] Many stations are located in or near the downtown areas of these cities, where people go to restaurants, entertainment venues, and to shop. They are also often near some of the highest density living areas in each city. PGE offers specific fees for one-time users or a monthly membership rate for unlimited charging. They also run a pilot program in SE Portland, where EV drivers can use charging installed on utility poles in the neighborhood.[51] Users scan a QR code on the utility pole, and pay $3.00 for four hours, with an additional fee during peak electricity demand hours. PGE specifically selected the Clinton neighborhood because it is near many multi-unit residences.

Level 2 chargers can also be an important charging option for rural drivers. Pacific Power is providing many of the rural cities and towns they serve with Level 2 chargers (and DC Fast Chargers), including Bend, Klamath Falls, Madras, Mill City, and Otis.[52] The sites have two Level 2 charging ports and 4 DC Fast Charger ports, and pricing plans are built on the amount of electricity provided, measured in kWh. There are lower cost options for users who charge during off-peak electricity hours.



Direct Current Fast Charger Options

ODOT's Transportation Electrification Infrastructure Needs Analysis Study Findings for Public DC Fast Charger Needs in the Business-as-Usual Scenario [21]

4,048 by 2023

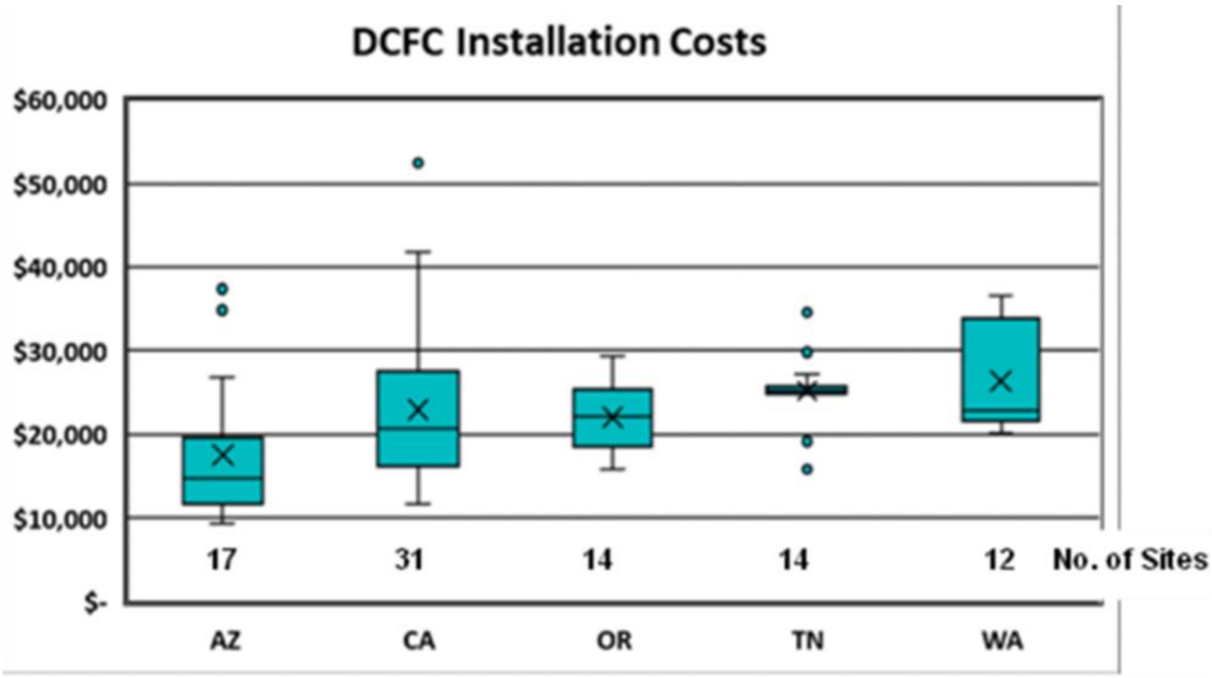
13,166 by 2030

26,453 by 2035

Direct Current Fast Chargers, or DC Fast Chargers, are the fastest method to refuel an EV, and offer the advantage of being able to host multiple users over a short period of time.[53] A DC Fast Charger works like a gas station, where the driver waits with or near the car as it is fueling. DC Fast Chargers can fully power an EV in a relatively short period of time, often less than an hour. Many people use them when traveling long distances, but they can also support EV charging in cities and neighborhoods, especially for people that have no other charging options. Sites tend to be located along busy travel routes, including in metropolitan areas. DC Fast Chargers are almost exclusively installed by EV Service Providers, most of whom pay for the installation, operation, and maintenance of the chargers.

The cost to install a DC Fast Charger depends on the specific equipment and the installation needs, with installation the most variable portion of overall cost. DC Fast Chargers can range from $22,000 for a 50kW charger to as much as $180,000 for a 350 kW charger.[54] Most charger installations today are for 150 kW chargers, which average about $100,000 for the equipment, but increasingly 350 kW chargers are also being installed. Installation costs for DC Fast Chargers range from an average of $45,500 for 50 kW chargers to $66,000 for 350 kW chargers.[55] Idaho National Laboratory conducted a study of DC Fast Charger installations across eight states, including Oregon. The 14 charger installations in Oregon cost around $22,000, as shown in Figure 10. However, average costs do not illustrate the variability between charger installations. This same study also provided the installation costs for a *single* charger across all states, and Oregon had both the lowest and highest installation costs.[56]

Figure 10: DC Fast Charger Project Installation Costs by State[56]



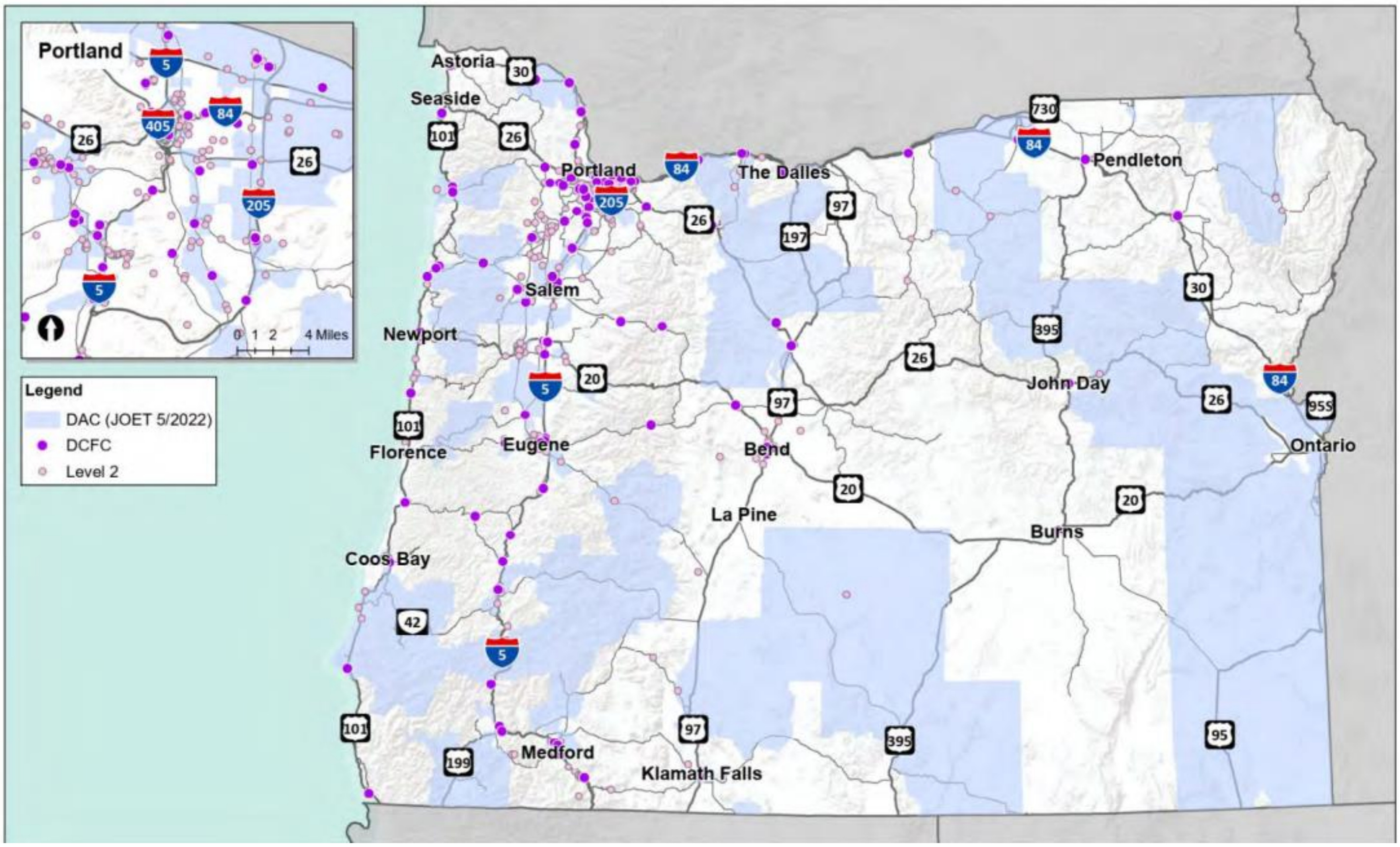
DC Fast Charger installation costs are affected by the type of charger, the existing electrical capacity at the site, the type of surface that will need to be breached to install the conduit and wiring, electricity service costs, labor, materials, permits, and taxes.[57] In the INL study, adding new electrical service was the single largest cost driver for a DC Fast Charger installation, on average increasing the total cost by 29 percent. The second largest driver was the breaching and replacement of the surface material where the electrical wiring would be installed, with costs being, on average, 21 percent higher if the site was on concrete or asphalt.

The passage of the Infrastructure Investments and Jobs Act in 2021 – often referred to as the Bipartisan Infrastructure Law – is beginning to help address some of these market gaps. The IIJA created the National Electric Vehicle Infrastructure program, which provides $5 billion in formula grant funding over five years to support public EV charging along major thoroughfares across the U.S., and $2.5 billion in discretionary grant funding to support public charging and fueling in communities and along corridors that help address climate change, support EV charging in rural and disadvantaged communities, and increase transportation energy resilience.

The Oregon Department of Transportation is leading the NEVI program work for Oregon, with a focus on charging in rural and disadvantaged communities. The deployment of these chargers will support Justice40 initiative goals, which require 40 percent of the benefits of federal investments in climate clean energy infrastructure accrue to disadvantaged communities.[58] The map below was produced by

ODOT for the development of its state plan to utilize NEVI funding, and it identifies significant gaps in charging infrastructure (purple dots) for disadvantaged communities (highlighted in blue).[59] Large swaths of rural Oregon have little to no charging infrastructure, and in urban areas there is less infrastructure in disadvantaged communities than in other parts of the metropolitan area. ODOT's work implementing the NEVI state plan plays a crucial role in bringing EV charging to many of these communities.

Figure 11: Oregon Department of Transportation Map of EV Charger Locations and Disadvantaged Communities[59]



Transportation Network Companies like Uber and Lyft could serve as a focal point for investments in charging infrastructure for some low-income communities. Data from Lyft indicates that 44 percent of Lyft rides start or end in low-income communities, meaning demand for TNC ridesharing is high in these areas.[60] Investments in charging could provide convenient fueling infrastructure for drivers while also providing access to charging for the local community. As a result of California's *Clean Miles Standard*, which requires electrification of TNC fleets, RMI estimated that the charging network in Los Angeles would need to grow three to six times its current amount just to support TNC drivers.[61] In the 2021 Oregon Legislative session, HB 2614 would have required TNC companies to meet certain levels of EV miles driven, starting at 5 percent in 2024 and increasing to 100 percent by 2031.[62] Although the bill did not pass, if a future version were to pass, investments in charging stations in the communities where drivers live and tend to operate will become more essential.

Medium- and Heavy-Duty Charging Infrastructure

Electric vehicles can meet the needs of many medium- and heavy-duty vehicle use cases, particularly for buses, delivery trucks, refuse trucks, drayage trucks, and other locally operating vehicles. For this reason, medium- and heavy-duty vehicle adoption is progressing in a similar way to the light-duty sector, where the first adopters largely, if not exclusively, charge their vehicles where they are garaged. In many cases, fleet operators with vehicles that can complete their duty cycle without the need for publicly available charging could potentially convert to an electric version of that vehicle. However, there are large cost hurdles for fleet owners to manage as they consider switching to electric medium- and heavy-duty vehicles.

The most common form of charging for medium- and heavy-duty EVs is depot charging, where the vehicles are plugged into lower power chargers for extended periods of time.[63] This is a cost-effective charging method because the electricity provided is slow but sufficient to meet the needs of the vehicle's duty cycle, while limiting additional electricity bill charges that can accrue with the higher energy demand needed for more powerful chargers. (See the *EV Costs* chapter.) Depot charging works well for vehicles that have periods of downtime, such as school buses, some transit buses, and garbage, drayage, and delivery trucks. Unsurprisingly, these are the types of vehicles for which medium- and heavy-duty EV adoption is growing.[64]

There are many vehicle types where electric models are currently commercially available and could meet the vehicle duty cycle requirements. A study by M.J. Bradley & Associates found that electric models could meet the vehicle duty cycle needs for 40 – 60 percent of all medium- and heavy-duty vehicles, and the expected improvements in battery energy density in the next five years will increase this percentage.[65] Table 2 shows the types of charging necessary to meet different vehicle use case needs. Home base charging refers to vehicles that generally do not require publicly available charging. Level 2 refers to 220 V charging that can be relatively inexpensive to add, while Level 3 charging (or DCFC) has higher power requirements and would necessitate the addition of a high-powered charger or bay of chargers. Vehicles listed under "public" would likely require public charging infrastructure to be a viable option.

Table 2: Medium- and Heavy-Duty Charging Needs by Vehicle Type

Home Base, Level 2	Home Base, Level 3	Public
• Heavy-duty Pickup & Van	• Heavy-duty Pickup	• Long Haul Tractor
• School Bus	• *Regional Haul Tractor*	• *Regional Haul Tractor*
• Delivery Van	• Transit Bus	• *Box Truck (Class 6 – 7)*
• Service Van	• Shuttle Bus	• *Box Truck (Class 8)*
• Service Truck	• Delivery Truck	
• Box Truck (Class 3 – 5)	• Refuse Hauler	
• Stake Truck (Class 3 – 5)	• *Box Truck (Class 6 – 7)*	
• Stake Truck (Class 6 – 7)	• *Box Truck (Class 8)*	
	• Dump Truck	

Medium- and heavy-duty EVs with duty cycles that allow for several hours of charging a day usually only need a Level 2 charger, which costs about $1,100 - $7,000. Level 3 (DCFC) chargers can cost between $32,000 - $180,000, and are generally used for vehicles that tend to operate most hours of the day or have higher mileage requirements.[66] Table 3 below shows a basic overview of costs for different types of chargers, including amount of time they take to charge a vehicle and their voltage needs. More volts may require additional circuits on-site, a new electric panel, or potentially more utility upgrades. In general, the faster the charge, the higher the cost.

Table 3: Average Costs for Different Types of Commercial EV Chargers[54]

	L1	L2	DCFC - 50 kW	DCFC - 150 kW	DCFC - 350 kW
Equipment Costs	Up to $350	$1,100 to $7,000	$22,000 to $50,000	$80,000 to $120,000	$150,000 to $180,000

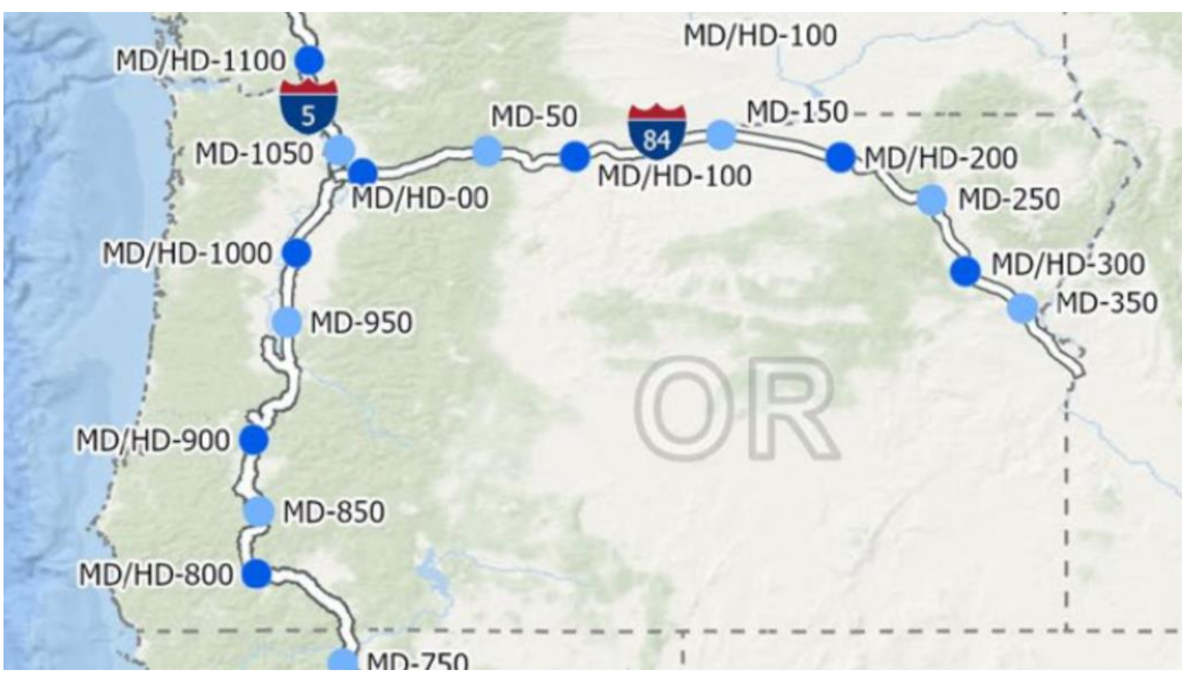
Costs for installing medium- and heavy-duty EV chargers also vary depending on what type of charging is needed, where the chargers will be installed, whether other building upgrades will be needed, whether on-site electric upgrades are required, and whether the utility may need to upgrade local distribution system equipment.[67] The costs to install Level 2 chargers can range from $1,100 - $7,000, and Level 3 chargers from $22,000 - $180,000, and per charger costs generally drop for additional charger installations.[54] Because many of these costs are affected by the electricity service, the local electric utility is a critical partner who can help ensure siting of the charger(s) is cost-effective while also considering the potential future electrification needs for the fleet.[68] Other costs may accrue if there is a need for building upgrades, signage, or other construction necessary to the efficient operation of fueling the fleet.

Medium- and heavy-duty-specific publicly available charging infrastructure is necessary to meet the needs of commercial fleets that travel longer distances. Commercial charging infrastructure to support these vehicles does not yet exist, largely because utilities and manufacturers are still working to better understand the logistics of building this type of charging and how best to integrate it into the electric grid.[69] Some medium-duty vehicles with a compatible charging port or adaptor could potentially charge on existing DC Fast Chargers, but the length of time to charge them may be prohibitively long. Also, because medium- and heavy-duty vehicles are generally larger than light-duty vehicles, they could take up more than one light-duty vehicle charging spot while charging.

Oregon companies are leading efforts to begin the development of medium- and heavy-duty charging. Portland General Electric partnered with Daimler Truck North America to build the first publicly accessible group of chargers capable of fueling different types of EVs, including heavy-duty trucks.[70] The site, called Electric Island, is located on Swan Island near DTNA's vehicle production facility in Portland. PGE and DTNA are using the chargers at the site to research this high-power form of charging and its effects on the grid. While the site does not have MW-level charging yet, it was designed with a 5 MW capacity, which allows for upgrades to include this high-powered charging that is the anticipated future standard for medium- and heavy-duty EVs.[71]

Electric Island was developed in part to support the work of the West Coast Clean Transit Corridor Initiative, a collaboration of electric utilities serving the major freight corridors in the west coast states.[72] The WCCTI discussed many of the unique travel needs of medium- and heavy-duty EVs that will need to be considered in the development of charging stations, with particular focus on local electric distribution system needs.[73] These conceptual sites were located every 50 – 100 miles along all roadways, including through Pacific Power and PGE territories as shown in the map below.[74] Pacific Power noted in the report that some of the mountainous locations in their territories may need stations more frequently due to higher fueling needs in those areas.[75] While this report was conceptual in nature, the WCCTI is continuing to do studies and engage with states and utilities to assess and prepare for the eventual buildout of a medium- and heavy-duty vehicle charging network.

Figure 12: WCCTI Report Conceptual Sites for Medium- and Heavy-Duty Charging Sites in Oregon[76]



Like light-duty DC Fast Charger costs, medium- and heavy-duty vehicle charging costs are highly uncertain, depending on many variables including the number of chargers to be sited, the amount of land needed, and power requirements.[77] These in turn come with other variables. For example, the cost to deliver power to the site depends on the distance from the nearest utility interconnection, the available electric circuit capacity, and any distribution system upgrades needed to support the new load. Some federal and state programs exist to offset infrastructure costs, particularly the Inflation Reduction Act Alternative Fuel tax credit, which allows for states and other tax-exempt organizations to receive a direct pay – rather than a tax credit – for charging and other alternative fuel infrastructure.[78] [79] This funding provides an opportunity for states to collaborate on charging along interstate roadways.

Transforming the medium and heavy-duty transportation sector to electric vehicles will require the development of public fast charging along all major traffic corridors. This sets up a chicken-and-egg scenario in which charging infrastructure viability is dependent on long-range medium- and heavy-duty EVs operating, which are in turn dependent on large scale commercial EV charging availability. Trucking representatives are concerned that regulations and state targets requiring manufacturers to sell heavy-duty EVs are not supported by the necessary charging infrastructure.[80] Even where states make significant investments in medium- and heavy-duty charging, this may not translate across state lines. Interstate freight operators will need certainty that charging will be available in all states in which their vehicles travel.

Other technological solutions are being evaluated to provide power quickly to electric medium- and heavy-duty vehicles, such as battery swapping and electric road systems. Electric road systems can transfer power to a truck either via inductive coils in a road, or through conductive connections between the vehicle and road, or via catenary (overhead) lines.[81] There are no known plans to implement battery swapping or road based charging in Oregon at this time, but these are potential solutions that could enhance the capability of existing public charging solutions and reduce charging times for vehicles.

Policies Addressing Charger Availability

EV charger availability is expected to increase significantly in the coming years. Private companies, such as Tesla, Electrify America, EVgo, and Chargepoint regularly add chargers to their networks to meet customer demand. Federal and state programs are also investing in charging infrastructure, and governments play a critical role filling gaps. This is especially important for communities where the choice to purchase an EV may be dependent on existing charging infrastructure. Public charging is especially important for multi-unit building residents and Oregonians who need to travel long distances. The following is a description of current policies and programs that support charging infrastructure development in Oregon.

Federal Policies and Programs

Federal programs supporting EV charging infrastructure range from tax credits for residential or business installations to more expansive programs administered across a variety of federal agencies. These programs are generally funded by the federal government, while implementation is conducted by the states. These programs will be addressed in the State Policies and Programs section below. This section will focus on tax credit incentives that help offset costs for charger installations.

The passage of the 2022 Inflation Reduction Act expanded tax credit programs to cover costs for installing EV chargers.[82] [41] Beginning in the 2023 tax year, businesses that install chargers in low-income or rural areas are eligible for a tax credit of 30 percent of the cost of the hardware and installation, not to exceed $100,000. For charging infrastructure subject to depreciation, the eligible costs are up to 6 percent of the costs. However, if businesses meet certain prevailing wage and apprenticeship requirements, they may be able to receive the full 30 percent (not to exceed $100,000). There are property ownership and usage requirements, and permitting and inspection fees are not covered. The IRA also expanded qualifying hardware to include charging stations for 2- and 3-wheeled vehicles that operate on public roads. Consumers are also eligible to receive a tax credit of 30 percent of the cost of qualifying EV charger hardware and installation, up to $1,000. Chargers must be installed at a person's primary home, and the credit cannot exceed the total tax liability.

State Policies and Programs

Alternative Fuel Corridor Designations

The Oregon Department of Transportation applies for alternative fuel corridor designation of the state's major thoroughfares with the Federal Highway Administration.[83] To date, ODOT has secured 11 EV corridors and 2 hydrogen corridors, and may consider future applications for other roadways.[84] Designations are often a prerequisite of federal funding opportunities to support charger or hydrogen installations, particularly those from the Infrastructure Investments and Jobs Act.

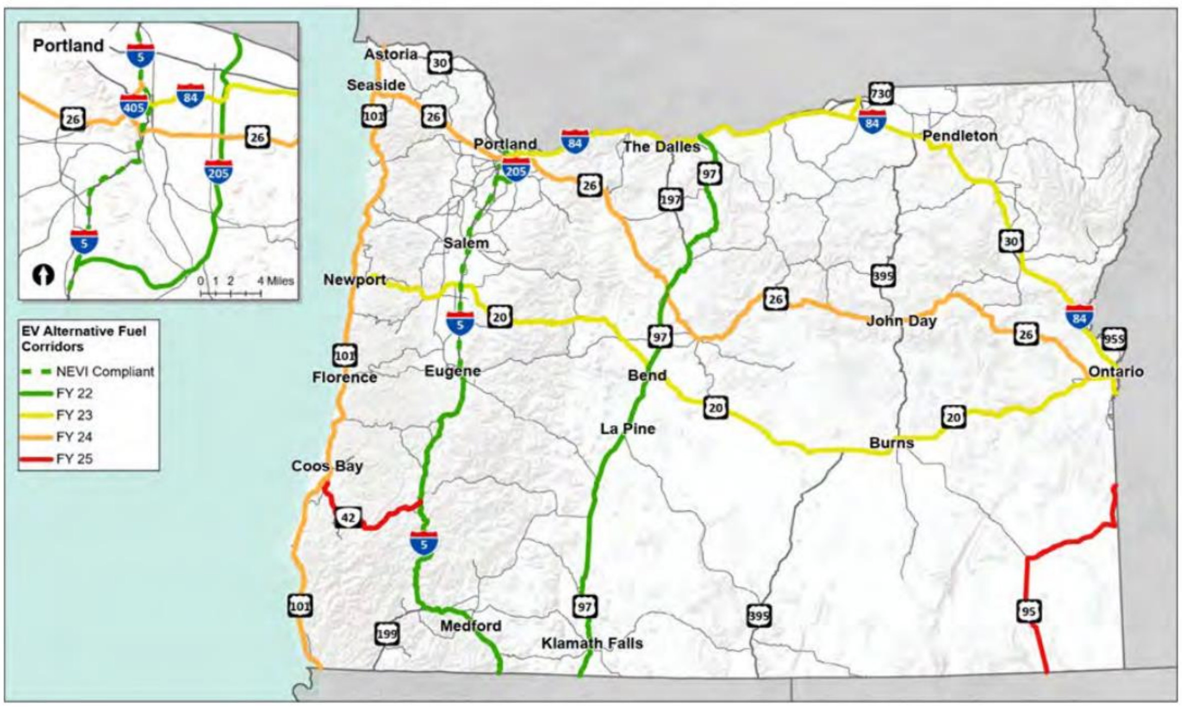
National Electric Vehicle Infrastructure (NEVI) Formula Program

Implemented by the Oregon Department of Transportation, the NEVI Program provides grant funding for up to 80 percent of the project costs associated with deploying EV charging infrastructure and establishing an interconnected network that will facilitate data collection, access, and reliability.[85] The NEVI Formula Program is a $5 billion investment by the Federal Highway Administration of the U.S. Department of Transportation, and supports development of a nationwide network of EV chargers that are convenient, affordable, reliable, and equitable.[86] The program aims to add 500,000 chargers in the U.S. by 2030, with at least 40 percent of program benefits accruing to disadvantaged communities.[87] Oregon will receive $52 million from the fund for chargers along designated EV alternative fuel corridors.[88] To receive funds, ODOT developed a state plan and the private sector provided a state cost match of $13 million.

In 2022, ODOT submitted its 5-year Oregon National Electric Vehicle Infrastructure Plan outlining the strategies and actions to guide deployment of EV charging infrastructure throughout the state.[89] U.S. DOT subsequently allocated the use of fiscal year 2022 funds. The plan was developed collaboratively through engagement with interested parties, including EV drivers, EV charging companies, local governments, electric utilities, and environmental justice and advocacy groups. ODOT submitted an update to their plan in July 2023, which provides information on fiscal year 2023 activities and expects to publish the update this fall, once U.S. DOT approves.[84]

On June 2, 2023, ODOT opened *a request for statements of qualification* for vendors interested in developing proposals to invest in EV charging stations for the NEVI program, other future light-duty EV charging programs, and anticipated medium- and heavy-duty charging infrastructure investments.[88] ODOT anticipates awarding contracts in winter 2024, and construction will begin in 2024 for year one of their NEVI plan, which includes installations along Interstate 5 south of Eugene, Interstate 205, and U.S. Highway 97.[90] ODOT will release more solicitations for future years of the plan that will include additional approved corridors. Figure 13 highlights existing EV alternative fuel corridors, which are color-coded to show the sequence of corridor development.

Figure 13: Oregon Electric Vehicle Alternative Fuel Corridors[90]



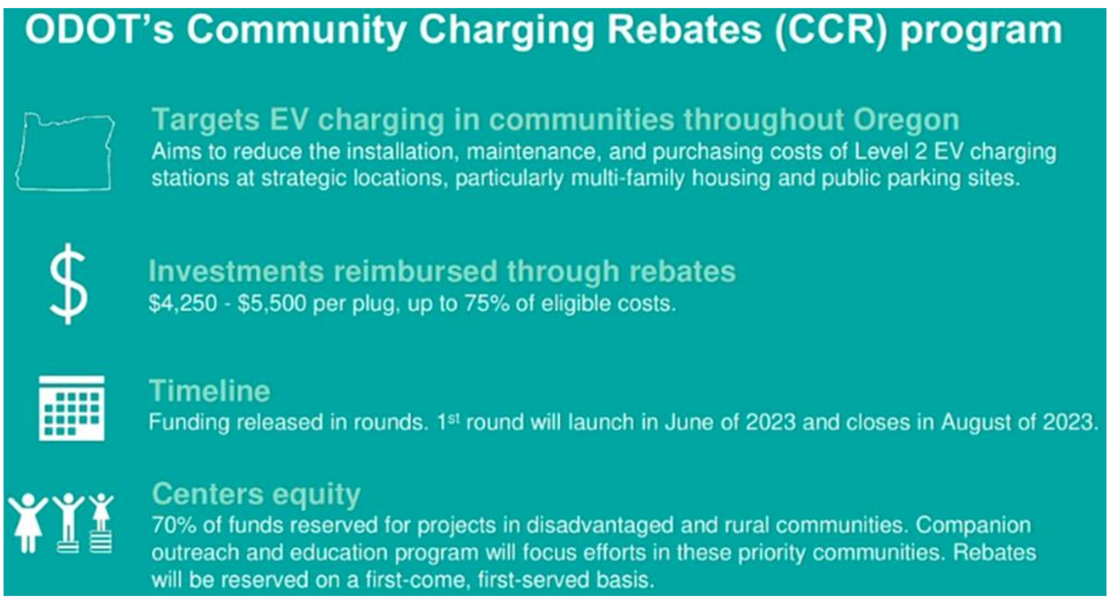
Charging and Fueling Infrastructure Discretionary Grant Program

The Infrastructure Investment and Jobs Act included $2.5 billion for the Charging and Fueling Infrastructure Discretionary Grant Program, beginning in FY 2022 with allocations expected over five years.[91] Half of the funding is available for traffic corridors and half is allocated for community grants, with the intent of filling geographic gaps beyond the NEVI plan. The program puts a focus on locating projects in urban and rural underserved and disadvantaged communities. The CFI is also administrated by the Federal Highway Administration and is a competitive grant program that supports not only EV charging infrastructure, but also other alternative fuel installments, including hydrogen fueling stations.[viii]

Community Charging Rebates Program

In 2023, ODOT established the Community Charging Rebates program to support local charging infrastructure needed to meet community EV charging needs.[42] This program reimburses investments in the purchase, installation, and maintenance of qualified Level 1 or 2 chargers, and is designed to support charging for Oregonians who are not able to charge at home. Chargers must be publicly accessible and/or installed at multi-family housing. Funding will be released over multiple years, and a minimum of 70 percent of funding is reserved for projects in disadvantaged and rural communities.[83] As of August 24, 2023, 75 percent of Year 1 funds had been allocated, and the remaining 25 percent is reserved for disadvantaged and rural communities.[92] ODOT developed an interactive map, which applicants can use to determine if they are eligible to apply as a disadvantaged or rural community.[93] Community Charging Rebates Program - Priority Type Locator

Figure 14: Oregon Department of Transportation Community Charging Rebates Program Overview[94]



Project Type	Charger Type	Maximum Rebate per Port (Min. 2 port/site)
Publicly accessible parking, including right-of-way parking	Level 2	$4,250, up to 75% of eligible project costs
Multi-family housing (can be private)	Level 2	$5,500, up to 75% of eligible project costs
Multi-family housing (can be private)	Level 1	$750

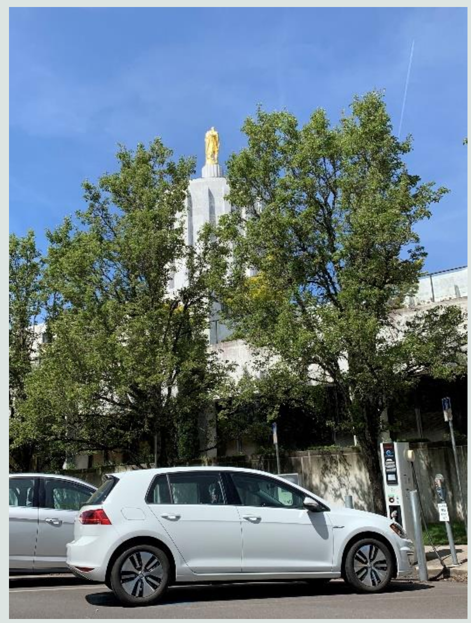
[viii] Hydrogen fueling would support fuel cell electric vehicle adoption.

Carbon Reduction Program

The Carbon Reduction Program was created by the Infrastructure Investment and Jobs Act and provides funding to states to support reductions in greenhouse gas emissions from transportation. The program brings $82 million to Oregon, and ODOT will use $24 million to fund alternative fuel projects in areas of the state with fewer than 200,000 residents. The other $58 million will be used to fund projects in urbanized areas of Portland, Eugene, and Salem, as well as statewide projects overseen by ODOT. The $24 million alternative fueling funds can be used for public EV charging, as well as other alternative fuels, including hydrogen. ODOT opened applications for $13 million of this fund from February – May 2023, and selected projects will be announced in fall 2023. The remaining $11 million will be available in 2024.

Oregon Department of Transportation Online Tools for Electric Vehicle Charging Projects

The Guide for Oregon EV Charging Deployment is a "one stop shop" offering information and tools to interested parties planning for EV charging infrastructure projects. It includes EV charging basics, best practices in station design and equitable site selection, general cost information, funding opportunities, and other information for planners of EV charging projects.



ODOT also developed the EV Infrastructure Planning Map, where users can explore potential sites for EV charger development. The map incorporates data on travel habits, demographic information, and equity criteria. Users can rank potential project areas by selecting different criteria, including equity and access, filling gaps in existing charging networks, and expected site popularity.

A separate tool estimates future charging infrastructure needed throughout Oregon. The TEINA Dashboard uses data from ODOT's Transportation Electrification Infrastructure Needs Analysis study to help local planners determine annual EV charging needs through 2035. Users can select specific areas to assess, such as counties, cities, and census tracts.

Charging Installations at Oregon State Parks

The Oregon Parks and Recreation Department and nonprofit Adopt a Charger have installed 18 EV chargers at seven state parks in 2023, with an additional four chargers at another park expected later in the year. A private donation is covering charging costs at all Oregon State Park locations through 2025. The Oregon Department of Parks & Recreation will assess the usage data collected from these chargers to better understand how they can continue to meet EV driver needs.

Table 4: Level 2 Chargers Planned for Oregon State Parks[95]

State Parks	Charging Location & Quantity	Status
Silver Falls State Park	4 stations in the South Falls day-use parking lot	Live
Banks-Vernonia State Trail	2 stations in the Banks Trailhead parking lot	Live
L.L Stub Stewart State Park	3 stations in the Welcome Center parking lot	Live
Rooster Rock State Park	4 stations in the main parking lot	Pending
Cape Lookout State Park	2 stations in the day-use parking lot	Live
William M. Tugman State Park	2 stations in the day-use parking lot	Live
Prineville Reservoir State Park	2 stations in the side parking lot near the day-use lot	Live
The Cove Palisades State Park	2 stations in the Crooked River day-use parking lot	Live

Oregon Zero-Emission Fueling Infrastructure Grant Pilot Program

The Oregon Legislature established the Oregon Zero-Emission Fueling Infrastructure Grant pilot program in 2022 to fund EV charging for medium- and heavy-duty trucks, buses, and equipment.[96] Approximately $13.3 million in competitive grants to fund charging equipment and installations was awarded to 14 businesses and local governments in March 2023.[97] Funding was awarded in two categories: Capital Improvement Grants for projects ready to make structural alterations or repairs, and Technical Assistance Grants for projects requiring funds for research and planning for future construction. DEQ designed the program to fund a diversity of Oregon fleets and locations, and the information collected from the projects will inform future work transitioning medium- and heavy-duty vehicles to electric. Awardees included a diverse range of Oregon fleets and fueling locations, including public work fleets, buses, shipping yards, drayage vehicles, refuse trucks, and electric snow groomers in the Portland metropolitan area, Salem, Bend, Douglas County, Wasco County, Hood River, and Newberg.

Oregon Clean Fuels Program

The Oregon Clean Fuels Program has played a role in supporting electric vehicle charging since the program began in 2016.[98] [99] Program participants are eligible to receive CFP credits for electricity used to charge vehicles, and those credits can be monetized to help pay back costs for the charger and installation. Oregon electric utilities are eligible to receive credits from electricity they provide to residential customer EV chargers, and many utilities have used the funds generated from sales of the credits to fund charging infrastructure. Some utilities have funded grant programs that offset charger and installation costs for residential and commercial customers, and in some cases, they used funds to provide charging for their EV fleets.

In 2022, the program was updated to allow public entities and certain private entities[ix] to apply for a loan of CFP credits, which can be monetized to pay for the up-front costs of charging infrastructure and installation costs.[100] The loan is for the expected electric consumption to charge on-site EVs over the next five years. The credits generated are deducted from those owed for up to six years, until the credit loan is fully paid back. Once paid, per program rules the owner can begin receiving CFP credits for the electricity used by the charger. This program has been particularly helpful for medium- and heavy-duty fleet electrification to provide capital for purchasing and installing chargers (and EVs). DEQ provides helpful tools for fleet operators interested in a CFP credit loan, including an advance credit calculator and fact sheets for electric transit buses, school buses, and garbage trucks.

Public Purpose Charge Schools Funds Supporting EV Infrastructure

Oregon K-12 schools in PGE or Pacific Power territories can access public purpose charge funds to pay for EV charging equipment and installations.[101] Facilitated by the Oregon Department of Energy, eligible schools conduct a fleet audit to assess the energy use in their fleets, which then enables them to use the funds for EVs and charging infrastructure. Bend-La Pine Schools used these funds to add a Level 2 charger for its newly acquired electric school bus in 2021, and in 2022 the Beaverton School District used funds to install four Level 2 chargers for its electric buses.

Artwork courtesy of Beaverton School District third grader, Aveline Heilig

[ix] An example of this is private entities under franchise agreements with public entities or that are on contract to provide a public service such as garbage trucks.[100]

Oregon Public Purpose Charge Funds Support First Electric School Bus East of The Cascades

Students are enjoying a new kind of ride to school after Bend-La Pine Schools acquired its first all-electric school bus — it's the first public electric school bus in use east of the Cascades.

The electric school bus was also the first bus supported, in part, with Public Purpose Charge funds. The Public Purpose Charge program, administered by the Oregon Department of Energy, is funded through the state's two largest electric utilities, Portland General Electric and Pacific Power. The funds support energy and fleet audits, energy efficiency improvements, and, as of 2020, zero-emission vehicles and chargers for Oregon schools.

Bend-La Pine's electric bus is a LionC model, manufactured by Lion Electric, that can fit up to 71 passengers with a 125-mile battery range. The bus will be assigned to a regular route in the district and will serve several elementary and secondary schools on a two-week rotation to give different route drivers the opportunity to experience driving it. The district also used Public Purpose Charge dollars to install a charger for the bus.

The Public Purpose Charge program was first established in 1999 through Senate Bill 1149 to support energy efficiency, renewable energy development, and low-income weatherization. A portion of the funds collected is distributed to school districts in Portland General Electric and Pacific Power territory for energy efficiency improvements. In January 2020, the program guidelines were updated to include school fleet audits and the purchase of zero-emission vehicles and charging infrastructure.

Building Codes and Local Ordinances

In 2021, the Oregon Legislature passed House Bill 2180, which established standards for EV charging in building code requirements.[102] The law requires building developers to include EV charging make-ready infrastructure for Level 2 chargers to a minimum 20 percent[x] of parking spaces in new buildings, such as multi-unit homes and commercial buildings. This requirement was included in Oregon's July 1, 2022 commercial building code update, and it allows local jurisdictions to create ordinances with higher make-ready requirements.[103] Building codes and ordinances play a critical role in ensuring that *new* multi-unit building developments are better prepared for increasing numbers of EV owners residing in these buildings. While Oregon's building code does not require chargers themselves, this new code will make the installation of future chargers easier and significantly more affordable.[104]

[x] The bill included exceptions for commercial buildings under private ownership, multi-unit buildings with less than five residential units, or mixed-use buildings with both these exceptions.[102]

What is "make-ready" charging infrastructure?

Make-ready installations include all the infrastructure needed to support a charger, but not the charger itself. This includes all electrical and conduit necessary to provide power to the charger.

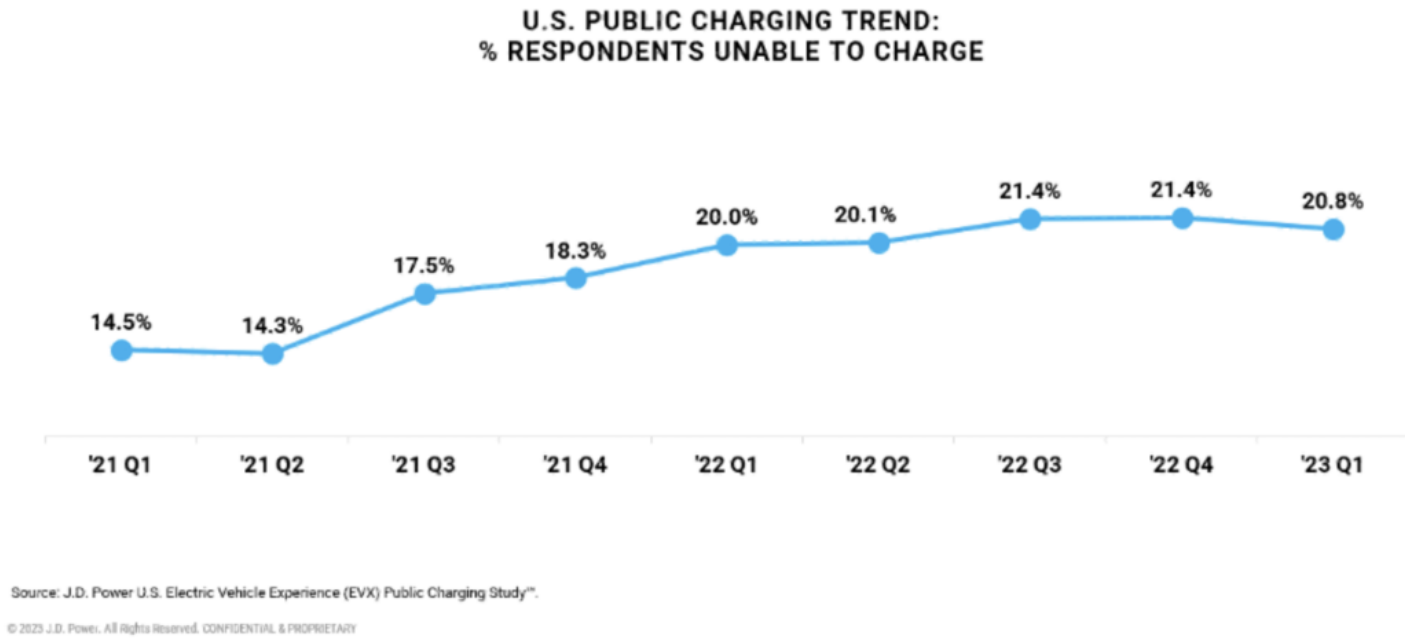
Electric Vehicle Charger Reliability

The National Charging Experience Consortium has set a goal for public charging stations nationwide – that they charge vehicles the *first* time, *every* time. To accomplish this, US DOE national labs are collaborating with industry over the next two years to measure and significantly improve the customer experience with public EV charging infrastructure in the United States.[105]

Reliable charging infrastructure is foundational to greater adoption of EVs, especially in the near-term when there are a limited number of charging options for drivers.[105] [106] There are no official overarching federal or State of Oregon definitions of EV charger reliability, nor are there regulations requiring charging providers to meet certain reliability standards. 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.[107] In the last Biennial Zero Emission Vehicle Report, ODOE looked at different ways reliability can be assessed, including measuring uptime, or the share of time a charging port or station is operational, and total time for malfunctioning chargers to be repaired.

Despite lacking specific charger data, there is survey data that showing consensus that EV charging is not reliable. A 2021 Plug In America survey found that over 50 percent of EV drivers have experienced a malfunction when using public charging, and this was higher specifically for non-Tesla owners.[108] A study evaluating the functionality of charging systems in California's Bay Area found 23 percent of equipment were non-functioning.[109] An ODOT survey of 227 EV drivers in Oregon found that more than half of respondents indicated they rarely or never found EV chargers in good working order, and few responded that they always found chargers to be in good working order.[110] In Figure 15 below, quarterly surveys conducted by J.D. Power since 2021 show that an increasing percentage of EV drivers who use public charging have experienced charging failures or equipment malfunctions that left them unable to charge their vehicles.[111]

Figure 15: EV Charging Infrastructure Reliability Over Time[111]



Development of charger reliability standards can be challenging because they must include effective measurements of reliability that cover a wide variety of interconnecting considerations, including charger types, driver needs, and malfunction types. Figure 16 below includes four key considerations recommended by The International Council on Clean Transportation for entities working to define reliability standards for chargers.[112] Defining reliability is prerequisite to developing metrics, because the metrics must be designed to adequately measure and assess the definitional requirements. Standards should address the types of malfunctions covered, the type and format of data to be reported, the quality of the data, the frequency of the reporting, the accessibility of these data, and the responsible parties. Working with interested parties, especially EV charging companies, is critical to developing reliability definitions and metrics that are effective while limiting cost burdens on companies to provide the data.

Figure 16: Key Steps for Defining EV Charger Reliability Standards[112]

1. Decision on the chargers targeted

Questions to be answered
- Which chargers should the reliability standard target?

Key actions
- Identify which chargers drive users' dissatisfaction
- Understand what can legally be done

2. Definition of the reliability concept

Questions to be answered
- What falls behind the reliability concept? i.e. What types of failures are considered?

Key stakeholders to work with
- CPOs, to understand what data they can come up with and the cost burden that a tight definition would imply
- Consumers to understand the most significant causes of dissatisfaction

3. Decisions on the metrics to be reported, actions to be required, and responsibilities

Questions to be answered
- What should be reported?
- What preventative actions should be taken?
- Who is responsible for reporting and acting?

Key actions
- Development of standardized metrics
- Requirements on data type and quality
- Discussions around responsibilities
- The AFIR (European Union), DoT and FHWA standards (United States), and the AFIREV (France), presented below, can provide some examples

4. Design of a framework

Question to be answered
- How should data be reported?

Key decisions
- Frequency of the reporting
- Ownership, location, quality, and accessibility of the data

EV chargers fail due to mechanical, software, and payment issues. Mechanical breakdowns can be due to normal wear and tear, equipment misuse, and vandalism. Software issues, including payment systems, can include glitches that require a system reboot, disruptions in connectivity, and communication issues between the vehicle and charger. Failures in any of these systems can make the charger inoperable. EV charging stations do not have onsite attendants, but companies usually have a phone number to call for assistance.[111] However, if the issue cannot be addressed via a software reboot, the time for someone to come and service the equipment can take hours, days, or even weeks.[113]

Figure 17: Top Six Causes of DC Fast Charging Unreliability[112]

Cause of DC fast charging unreliability	Explanation
Hardware reliability	This includes the failure rate of hardware components and the time it takes to replace them. The responsibility to improve this mostly falls on charge point manufacturers. This can be monitored through uptime data.
Vehicle interoperability	Standardization of vehicle plugs and charging connectors across makes and markets is inconsistent and can lead to charging failure. This can be monitored through an assessment of charge success rates.
Global supply chain disruptions	This results in industry-wide parts shortages and increased lead time to replace non-functioning parts.
Service operations	There is a need for enhanced real-time remote monitoring diagnostic capabilities and a decrease in repair time.
Network IT management systems	These systems allow charge point operators to communicate with and manage the charge points. The rapid growth of charger utilization and the customer base can put stress on the IT structure.
Payment authorization	This can be internal or external payment system failure and remains a top driver of unreliability.

The charger manufacturer is not always the site owner and operator, which can create confusion about who is responsible for charger maintenance and repair.[114] This is more frequently encountered with Level 2 chargers, where site hosts could be the responsible party. Site users may become frustrated when no responsible entity can help them address charging issues, especially when there are no other nearby charging options. Site hosts may choose to address charger issues on a case-by-case basis, or they may contract with another company for site maintenance and service. Site hosts may forget the charger exists, especially while the charger continues to function, or staff turnover could lead to oversights on charger responsibilities. In these instances, warranty and maintenance contracts could potentially run out before issues arise, which could mean higher costs to complete a repair. Lacking a plan to serve and upgrade the equipment, the charger may be left in disrepair.

Ensuring chargers are maintained and dependable is equally as important as charger availability, and reliability may be more critical in lower usage areas, where charging options are more limited.[115] Most charger owners do not provide publicly available data on charger performance, and often consider this information to be proprietary. Customer surveys indicate there are considerable reliability issues with chargers — lacking data, there is little visibility into charger reliability in Oregon. This is particularly challenging for disadvantaged communities, where relatively fewer numbers of chargers means any malfunctioning charger will have a disproportionate effect on users. Unless reported data is consistent and comparable for chargers across all communities, it is difficult to assess equity in charger reliability.

Recognizing the critical role charger reliability plays in increasing EV adoption, the U.S. Joint Office of Energy and Transportation announced the creation of the National Charging Experience Consortium in May 2023.[105] [105] [116] The consortium is a collaboration of organizations from the EV industry tasked to address specific EV charging reliability issues. Led by three of the U.S. DOE laboratories – Argonne

National Laboratory, Idaho National Laboratory, and the National Renewable Energy Laboratory – the Consortium will work together to identify solutions to payment processing and user interface issues, vehicle-charger communications, and diagnostic data sharing. Over two years, these entities will share data and information with the EV industry that address these issues to ensure EV charging experiences are reliable, as well as affordable, convenient, equitable, and safe.

The National Charging Experience Consortium is building on national reliability standards established by the U.S. Department of Transportation and Federal Highway Administration for federally funded EV chargers.[112] This includes supporting the development of a data sharing platform that will help inform ongoing network reliability assessments. ODOT includes these standards in its NEVI and Community Charging Programs.[113] [117] Contracts often include requirements that help ensure chargers are consistently reliable, especially for chargers located in disadvantaged communities.[118] [119] EV charging overall would benefit from the Consortium's plan to broaden sharing of data, including what types of failures occur most frequently, how charging companies assess reliability metrics, and what barriers exist to improving reliability.[120]

Oregon National Electric Vehicle Infrastructure Plan[113]

As the Oregon Department of Transportation works to implement its NEVI state plan, the agency is focusing on reliability to ensure reliable access to EV charging for all Oregonians. Charging ports at funded stations will need to meet a minimum uptime requirement of 97 percent, and to default to charging if internet connectivity is lost.[119] ODOT is also monitoring the work of the National Charging Experience Consortium to better inform investments and improve reliability.

Mandating EV charger reliability standards to ensure positive consumer experiences may increase up-front and maintenance costs, slow deployment, and increase the costs of electric fuel for consumers.[112] State policy will have to balance the tradeoffs of consumer protection and rapid development of EV charging stations. As the market evolves and more charging stations are available, consumers will have the ability to choose more reliable charging stations. Today, drivers rarely have the luxury of choice, and underserved communities in Oregon have even less access to public charging and need consumer protections to guarantee access. Availability and access to reliable public fast charging is crucial to broader customer acceptance and trust in the transition to EVs.

Urgency to Address Reliability

There is perhaps no charging infrastructure topic more urgent at this moment than ensuring that all new installations going forward are designed and supported over the long term with reliability front of mind.[115]

-U.S. Department of Energy's National Renewable Energy Laboratory (NREL)

Conclusion

More publicly available EV charging infrastructure is necessary to meet the needs of the growing light-duty market. This is most important for Oregonians who are not able to regularly charge their vehicles at home. Significant charger growth is anticipated in the next few years as federal funds are made available and approved, and several state programs are set up to address critical infrastructure gaps in many disadvantaged communities. More support is needed to ensure drivers living in multi-unit residences, low-income communities, and those traveling long distances can conveniently and affordably fuel an EV, and more funding is needed to address the high costs businesses and organizations face when considering transitioning their fleets to electric.

Multiple consumer surveys find that the existing public charging infrastructure is seen as unreliable. There are no agreed-upon charger reliability standards at the federal or state level, and, lacking access to charger data, it is not possible to assess the state of charger functionality in Oregon. Consumer confidence in the dependability of EVs depends on widely available, affordable, and reliable public EV charging infrastructure. Prioritizing state efforts to support a dependable charging network for electric vehicles is crucial to ensure that EVs are increasingly the vehicle of choice for Oregonians.

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Grassland Switchyard, Boardman, OR

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 EVs on the Electric Grid

Key Takeaways

- Oregon electric utilities, and the broader western grid, are not expecting resource adequacy issues associated with adoption of electric vehicles over the next five years.
- Grid impacts associated with increased loads from electric vehicles are likely to be limited to local distribution system upgrades in the near term, requiring coordination and planning with local utilities, especially for the larger loads expected from medium- and heavy-duty vehicles.
- Utility programs can mitigate the effects of EVs on the grid and enable higher penetrations of EVs to be served by Oregon utilities.

Introduction

Electric vehicles represent a new load on the electric grid, which has implications for utility generation and distribution planning, as well as utility ratepayer costs. There are already more than 69,590 EVs on the road in Oregon with many more expected in the coming years.[1] Other electric loads, such as data centers, are also expected to increase electricity demand as much if not more than EVs.[2] At the same time, Oregon utilities will be decarbonizing the energy sold in the state to meet Oregon's clean electricity goals. The effects of electrification will be systemic, with electric utilities adding significant new electric resources by acquiring more cost-effective energy efficiency, managing loads, adding renewable energy generation (e.g., wind and solar), utilizing energy storage to ensure generated electricity is available when and where it is needed, and planning for distribution system upgrades to support new local loads. These technologies have the potential to bring widespread benefits to Oregonians and re-shape Oregon's electric grid and will have to be thoughtfully managed to minimize the economic impacts to Oregon ratepayers.

Several factors must be considered when planning for resource and distribution system needs associated with transportation electrification. These include:

- **Effects on load growth, peak load, and resource adequacy**: How will vehicle electrification impact load growth and peak electricity demand, and how is this expected to interact with other major electrification trends?
- **Local effects on utility distribution systems**: How will vehicle electrification impact localized peak loads, and in turn how will that affect utility distribution systems?
- **Load management**: What policies or programs can utilities use to manage and mitigate the effects of transportation electrification, especially during peak load?

Utilities balance these considerations through resource and distribution system planning. Oregon's investor-owned utilities complete this planning with oversight from the Oregon Public Utility Commission through Integrated Resource Plans, Distribution System Plans, and Transportation Electrification Plans. These plans forecast load growth and local system impacts associated with transportation electrification and propose solutions to balance the benefits and costs to ratepayers.

Consumer-owned utilities conduct their planning through local boards and councils in partnership with the Bonneville Power Administration, including planning for future resources and energy procurement contracts, as well as upgrades to their electricity distribution systems.

Effects on Load Growth, Peak Load, and Resource Adequacy

Utility system operators forecast anticipated EV load growth and develop resource adequacy plans to ensure there are adequate electricity resources to meet future electricity demand. Resource adequacy goes beyond Oregon's borders. The western electric grid shown in Figure 1, is an interconnected system across 10 states, 2 provinces, and portions of Texas and Mexico. These entities and utilities work together to ensure there will be adequate resources across the entire region.

Figure 1: The Western Electric Grid[3]

There are enough existing and planned electricity generation resources to meet electricity load in the next five years, even when considering high EV adoption forecasts. In 2020, Pacific Northwest National Labs conducted a study to assess western resource adequacy using three different EV adoption scenarios.[4] The study concluded that even under a high penetration scenario – more than 9.3 million EVs on the western grid in 2028 – no resource adequacy issues are expected under normal operating conditions. Further, if utilities implement load management strategies to shift EV loads during peak demand times, the number of electric vehicles on the western electric grid could be more than doubled to 19.6 million EVs without triggering resource adequacy concerns.

Oregon utilities also find that there are adequate generation resources to accommodate anticipated EV load over the next five years, and that the anticipated load growth from EVs and other electric loads may not create a significant resource adequacy issue even in the next decade. EV-related load growth will occur in parallel with other electric load growth, including data centers, electric heat pumps, and other electric end uses. There will also be energy savings from the implementation of new programs and technologies, including rooftop solar and additional energy efficiency savings.

Table 1 below shows Portland General Electric's load forecasts through 2030, broken out into baseload energy load growth, EV and building electrification loads, and energy efficiency savings.[i] PGE projects new EV loads to be approximately 177 average megawatts by 2030, or about 6.5 percent of the 2,691 aMW of total annual energy delivered on its system.[5] [6] To put this in perspective, this is 70 percent of the 247 aMW of energy *savings* expected from energy efficiency measures shown in the Energy Efficiency column. In each of the years through 2030, PGE is estimating substantially more energy savings from energy efficiency than new load growth from electric vehicles and building electrification combined.

Average Megawatts and Megawatt-hours

Average Megawatts (aMW) is a unit of energy. If a facility with a power rating of one megawatt operates continuously, 24 hours a day, for a whole year, it will generate one average megawatt of energy. Because there are 8,760 hours in a year, an average megawatt is equal to 8,760 megawatt-hours.

Megawatt-hours (MWh) is a measure of energy produced by a facility. One megawatt-hour of electricity is about how much a typical Oregon home will consume in a month.

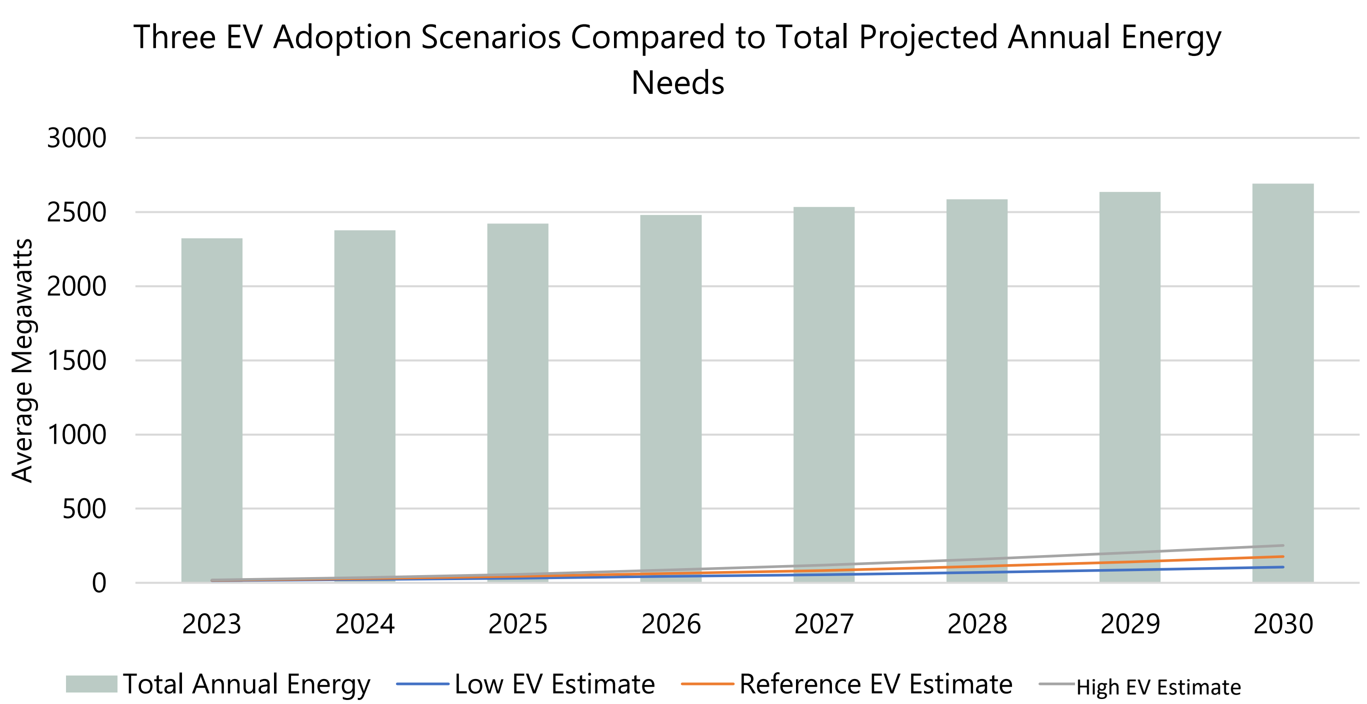
[i] The base load, building electrification, and energy efficiency load forecasts are from PGE's updated 2023 Clean Electricity Plan and Integrated Resource Plan filed with the Oregon Public Utility Commission on June 30, 2023.[5] The transportation electrification load forecasts are from PGE's 2023 Transportation Electrification Plan, which was filed with the Oregon Public Utility Commission on August 25, 2023.[6]

Table 1: Portland General Electric's Reference Case Load Growth Forecasts 2023-2030 in aMW[5] [6]

Year	Base Load[5]	EV Loads[6]	Building Electrification[5]	Energy Efficiency[5]	Total Annual Energy[5] [6]
2023	2,334	17	4	-31	2,323
2024	2,402	29	7	-61	2,376
2025	2,463	43	10	-91	2,422
2026	2,530	63	13	-121	2,480
2027	2,594	83	17	-151	2,535
2028	2,649	110	20	-181	2,586
2029	2,703	141	23	-214	2,635
2030	2,759	177	27	-247	2,691

PGE forecasts show that EV growth is expected to grow, but it is not anticipated to grow larger than 10 percent of overall energy use. Figure 2 shows PGE's projected overall load through 2030, represented by the green bars. The three modeled EV load growth scenarios (low, reference, and high) are shown in the blue, orange, and gray lines. In all scenarios EV load growth is forecast to be less than or about the same as energy savings from energy efficiency measures, ranging from 4.3 percent to 9 percent of the utility's total load in 2030.[6] [7]

Figure 2: Comparison of Portland General Electric's Projections of EV Load to Total Annual Load[7]



PacifiCorp also developed a load forecast through 2032 in its 2023 Oregon Transportation Electrification Plan and Integrated Resource Plan.[8 9] Transportation electrification is not broken out as a separate load, but it is included in the forecast and is expected to be 3 to 4 percent of the total load (650,000 to 850,000 MWh). While lower than PGE's forecasted percentage of load, it is consistent with slower EV adoption rates in rural areas, which includes much of PacifiCorp's territory in Oregon.[9]

There is less data available for projected transportation electrification loads in Oregon's consumer-owned utility service territories. Most consumer-owned utilities acquire most or all of their power from Bonneville Power Administration, which is informed by energy forecasting from the Northwest Power & Conservation Council's power plans. The 2021 Northwest Power Plan forecasted three EV load growth scenarios for the Pacific Northwest region ranging from 733 aMW to 904 aMW by 2041.[2] Based on the Plan's total load forecasts of 20,580 to 25,895 average megawatts, transportation electrification would represent approximately 3.5 percent of total load in 2041.This would indicate even lower load growth than the PacifiCorp and PGE models.

The transition to electric vehicles can deliver widespread benefits to Oregonians with reasonable cost increases to ratepayers, even with the need to manage this new electric load. In 2021, the Oregon Legislature passed HB 2165, which enables electric utilities serving more than 25,000 customers to fund EV infrastructure improvement measures through electricity rates. In their 2023 Integrated Resource Plans, PGE and PacifiCorp assessed the challenges associated with growing electric vehicle adoption and other anticipated end-use electrification, such as heat pumps, and concluded that with proper planning, load management programs, and energy efficiency acquisitions, they could meet these new loads at reasonable cost.

Electric vehicles are not the only new load growth on the western grid, and in some cases, new commercial developments like data centers are considerably larger than the current loads associated with electric vehicle adoption. For example, the 2021 NW Power Plan estimated electricity use associated with electric vehicles to be 67 average megawatts in 2021 compared to 657 average megawatts for datacenters.[2] In future years this trend is likely to continue. The 2041 medium load forecast in NW Power Plan anticipates 1179 average megawatts consumed by data centers compared to 816 for transportation. While the future of EV adoption and data center development in Oregon is not certain, to date data centers have had a much larger effect on load growth than EVs.

Transportation electrification will be occurring in parallel with data center development, indoor cannabis grow-operations, building electrification and other changes in residential, commercial, and industrial loads. So far, Oregon utilities and the broader western grid have been able to meet these loads with minimal costs to consumers. While short-term planning does not indicate major hurdles for Oregon utilities, longer term load growth, combined with decarbonizing the electricity sector, will require thoughtful planning to control costs and maintain reliable grid operations.

Load Management: Utility Programs to Minimize Grid Impacts

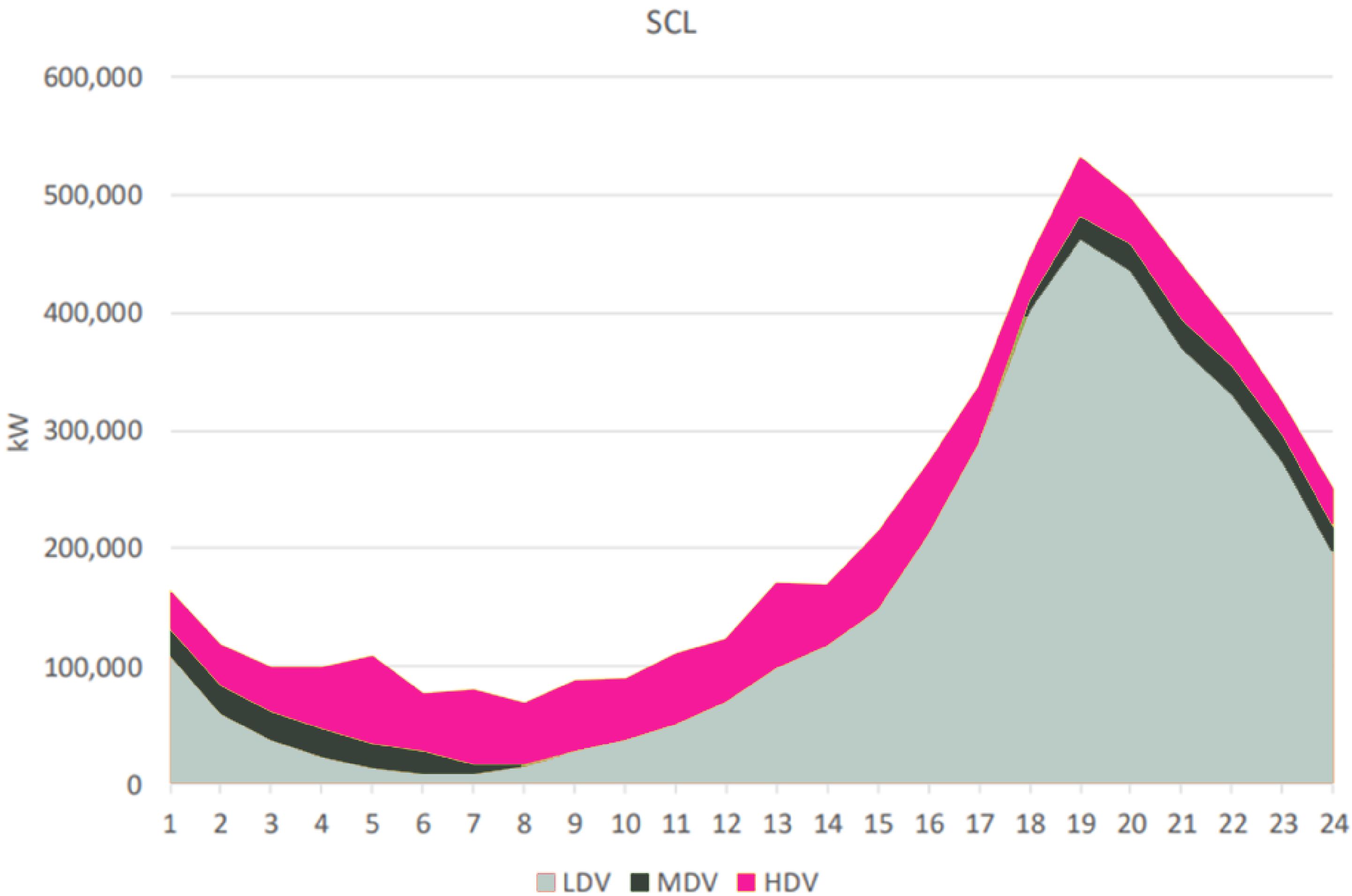
> ***"Managing TE load is an important aspect of controlling costs to serve TE load and extracting system benefits."***
>
> – From PGE's 2023 Transportation Electrification Plan

Utilities must manage peak load to maintain a reliable grid and keep their costs – and the costs to their customers – low. During periods of peak demand, utilities need to purchase additional electricity generation via electricity markets. When demand is high across multiple utilities, the market value for additional resources spikes. If utilities consistently need to pay high market prices to meet load, the costs may be passed on to utility customers through annual electricity rate increases called power cost adjustments. If peak demand exceeds the capacity of all available generation resources, there may be rolling blackouts or other service disruptions.

Load management strategies provide utilities with more options to manage electric vehicle charging, and can not only reduce charging during peak load times but also help to better manage the overall grid. Strategies are designed to shift specific loads, such as EV charging, away from periods of peak electricity demand. This is important because electric utilities build generation resources to accommodate peak electricity load. By managing when vehicles are charging, utilities can accommodate increasingly larger numbers of EVs without the need to purchase expensive energy on the market or build new generation resources. For example, the Pacific Northwest National Laboratory study mentioned earlier found that existing western grid resources can accommodate double the number of EVs when using managed charging than without managed charging.

Without managed charging, EV loads could significantly contribute to overall system peak load, which could trigger a need for more electricity generation capacity. Figure 3 below shows modeling results of an unmanaged EV load profile for Seattle City Light in 2028.[14] The EV load peaks at roughly the same time of day as grid-wide peak load, largely driven by light-duty charging, represented in sage. Light-duty charging peaks in the early evening hours when drivers are expected to arrive home and plug in their vehicles to begin charging. Light-duty EV charging wanes after 8 p.m. when cars reach their battery capacity and stop charging. Medium-duty charging, shown in dark green, is also expected to occur in the evening and the morning, when vehicles are switched out for different duty cycles. Heavy-duty vehicles, represented in pink, are expected to be charging regularly and at a consistent level throughout the day.

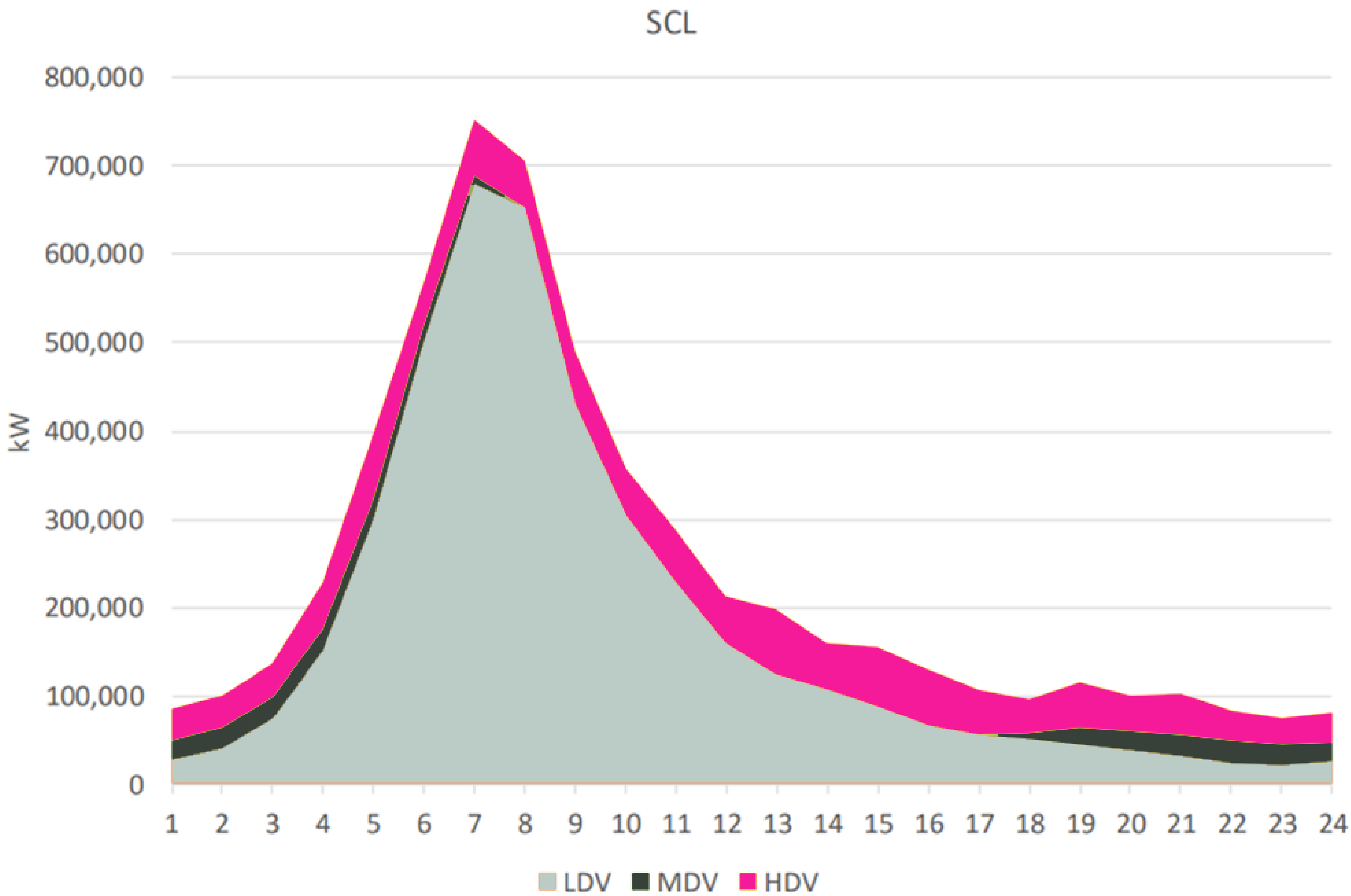
Figure 3: Stacked 24-hour Unmanaged EV Charging Profile for Seattle City Light in 2028[14]



Managed charging can move the EV load profile so that it does not coincide with the normal electricity peak load time. PNNL modeled the same scenario for Seattle City Light but included a delayed start to EV charging.[14] In this instance, the peak load is delayed until about 7 a.m., when overall system load is usually lower. This enables utilities to use their existing resources to charge the vehicles when they are available, reducing the need for market purchases and potential impacts to ratepayers. This specific delay may not work in practice, because many vehicles would be charging at the time people are ready to use them in the morning. A slightly shorter delay could peak charging at midnight instead of 7-8 a.m., avoid the early evening peak, and still have vehicles fully charged by morning.[ii]

[ii] This assumes average daily travel needs, which would not require a 100 percent recharge of the battery. Some vehicles may require longer charging to meet mileage or duty cycle requirements.

Figure 4: Stacked 24-hour Managed EV Charging Profile for Seattle City Light in 2028[14]



Utilities have several load management strategies, including demand response and managed charging. Demand response enables the utility to throttle back EV charging at select moments of high-capacity need, meaning all EV chargers enrolled in the program may have slower charging rates during the peak electricity demand times. Customers retain the option to override the utility, and the reduced charging rate is not likely to be noticed by or affect the customer's needs. The incremental effects to individual EVs will decrease as more EVs are available on the system, because the utility can spread the slower charger rate across more EVs. Managed charging allows the utility to schedule when a vehicle starts to charge to avoid peak demand times, often initiating charging later in the evening when there are generally more electricity resources available to meet that load. PacifiCorp and PGE are piloting programs to manage EVs charging on their systems.[4] PGE has both a demand response and a managed charging program, and PacificCorp is currently launching a managed charging program for residential customers.

In their 2023 transportation electrification plans, PGE and PacifiCorp both identify load management strategies as key objectives to mitigate the impacts of EVs on the grid. While there are options described for specific program designs, they generally propose to offer EV owners financial incentives to charge during periods of low demand. These incentives create opportunities for utilities to manage

EV charging loads but also increase the volume and speed of EV adoption by providing a rebate for a home charger. This demonstrates that utilities see co-benefits associated with EV adoption and discretionary load timing. Increasing loads and electricity sales during periods of low demand can help utilize low-cost energy, such as surplus wind and solar, and even reduce overall costs for rate payers.

In addition to utilities managing smart chargers to schedule when or how fast a vehicle is charging, EVs can be programmed by drivers to charge at a specified time, and Smart Chargers, whether they connect with the utility or not, can also be used by the driver to schedule charging times. The ability to schedule charging enables utility customers to take advantage of lower cost time-of-use rates.

PGE's 2023 Transportation Electrification Plan describes its process for studying and adopting load management programs designed to meet specific customer and charging use cases.[15] The report describes two categories for managed charging programs: passive managed charging and active managed charging. Passive programs create incentives to change customer behavior, while active programs give a utility direct control of charging equipment and data collection from vehicles through telematics. Table 2 provides examples of passive and active managed charging strategies under consideration at PGE.

Table 2: Portland General Electric Managed Charging Programs[15]

Passive Managed Charging	Active Managed Charging
EV time-varying rates, including Time of Use and hourly dynamic rates	Direct load control via the charging device
Communication to customer to voluntarily reduce charging load (i.e., Behavioral Demand Response event)	Direct load control via automaker telematics
Incentive programs rewarding off-peak charging	Direct load control via a smart circuit breaker or panel
Good fit for residential, fleet, workplace, and public charging	Good fit for residential, fleet, and workplace charging

PacifiCorp's 2023 Transportation Electrification Plan also includes efforts to mitigate EV charging loads.[9] The report identifies four main strategies:

- Conduct ongoing planning studies to understand future grid impacts.
- Deploy innovative pilots that support management of future load.
- Develop resiliency strategy to support EV charging infrastructure and future grid impacts.
- Create internal and external tools to understand grid impacts and build reliability.

PacifiCorp's plan includes different programs to manage EV load, including encouraging active managed charging programs to increase off-peak charging, time-of-use rates that incentivize voluntary off-peak charging, and demand response programs.

Oregon's consumer owned utilities are not required to develop transportation electrification plans but many of them are proactively taking steps to manage EV loads. There are currently at least 16 consumer owned utilities in Oregon that offer financial incentives related to EV adoption. Most of the incentives are in the form of rebates for level two chargers that can be programmed to charge during off-peak hours. Some utilities reference charging equipment qualified by the Bonneville Power Administration, including ENERGY STAR Certified, 240-volt, Level 2 models with networking capability.[iii]

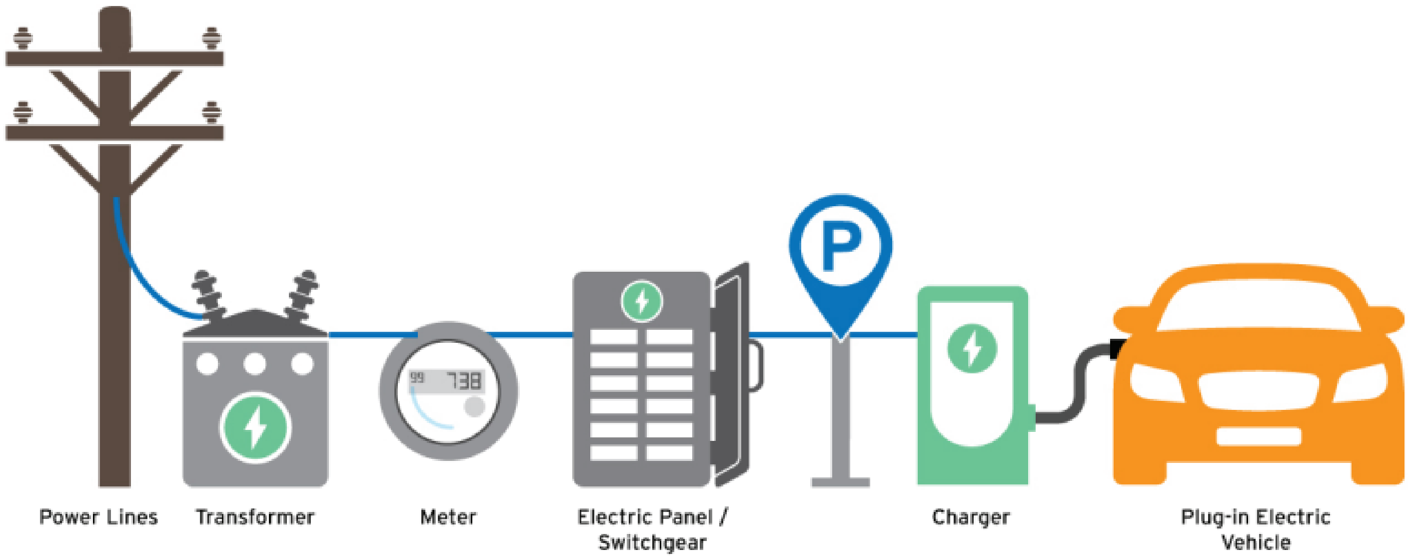
Utility programs to manage increasing EV charging loads must also be flexible enough to change and accommodate future grid management strategies. As utilities transition the grid to use more variable renewable energy resources, they may be able to take advantage of the vast energy storage resource available across a large fleet of electric vehicles. EV batteries could serve as a virtual power plant – where utilities can discharge energy from this large collective at peak demand periods to support grid operations. Flexible load management programs and communication platforms where vehicles and grid operators can exchange information are precursors to utilizing EVs as a grid resource, and not just another load. Many electric utilities are actively engaged in load management strategies to ensure EV adoption does not become disruptive to future grid operations, and to ensure they and their customers can continue to realize the benefits of transportation electrification.

Local Effects on Utility Distribution Systems

Electric vehicle charging and other electrification measures represent significant new loads on local utility distribution systems and can trigger the need for upgrades, usually in the form of a utility service transformer replacement. As shown in Figure 5 below, the utility service transformer is the last piece of equipment in a utility distribution system before the electricity enters a customer's electric meter. The electric utility maintains all equipment up to the meter, including lines and transformers. From there, the electricity goes to the building's electric service panel where it is dispersed to individual circuits throughout the structure. Like a customer's electric service panel, transformers are designed to operate up to a certain peak load, so drawing more than the transformer can accommodate leads to failures. This can happen when relatively large loads, such as EVs and other major appliances, are added in residences and businesses.

[iii] Networking capabilities are bi-directional data transfers between the EV charger and the utility or another external partner engaged in EV load management.

Figure 5: Flow of Electricity from Utility Distribution System to an Electric Vehicle[16]



Transformers may be located on poles in areas served by overhead power lines or on pads for underground lines. In residential areas, a transformer may support multiple houses (typical in urban neighborhoods) or a single house (typical in more rural areas).

Residential service transformer capacity is determined by utility engineers based on the expected loads to be served. In a residential setting, transformer sizes are determined based on the number of homes being served, the type of heating system in the homes, and the number and size of electrical appliances. Homes with gas heating systems will normally have smaller transformers than homes heated with electricity. Table 3 shows typical loads in Oregon homes that affect the sizing of utility service transformers. EV charger loads typically fall between an electric heat pump and an electric water heater in terms of size of load and annual energy consumption.

Table 3: Load Profiles for Large Electric End Uses in Typical Homes

Device	Estimated Peak Demand (kW)	Estimated Annual Electricity Consumption (kWh)
Electric Furnace	10 to 20+	13,695
Electric Baseboard	10 to 20+	10,396
Electric Heat Pump	10 to 20 (Includes electric resistance backup element)	6,182
Electric Vehicle Charger (level 2)	6 to 20	3,800
Electric Water Heater	4.5 (typical)	3,030
All other Major Appliances	NA	3,145
Gas Furnace	< 1	1,054

Most existing service transformers were installed before EVs and other electrification measures became popular. When new electrical loads are introduced in a home, they have the potential to overload the existing service transformer, triggering the need for a transformer upgrade. A utility will evaluate new loads on its systems, and replace the old transformer with a new, larger transformer when there is the potential to overload an existing service transformer.

While the infrastructure needs of EV charging installations are very site-specific and there are many scenarios that can require service line or transformer replacement, these utility-side upgrades are not expected to be a regular problem for home and small business level 2 charging installations. Large medium- or heavy-duty truck charging sites are likely to require upgrades to the distribution network. Early engagement between the utility and the customer can also help identify whether distribution system upgrades can be avoided by incorporating solutions into the design of electrical infrastructure at the site (e.g., right-sizing charging, battery storage, load management, or other methods of avoiding upgrades to wires and transformers). For example, PGE and Daimler Truck North America are planning to bring battery storage to their Electric Island heavy-duty electric vehicle charging site in North Portland later this year to better understand how batteries can help support distribution system needs for higher power charging.

Transformer Upgrade Costs

The costs associated with transformer upgrades are borne by utility customers, either through rates or specific customer billing. The costs for normal distribution system upgrades and equipment are typically passed on to all utility customers through their electricity rates. In 2021, HB 2165 directed PGE and PacifiCorp to implement a rate increase of one quarter of 1 percent to support and integrate transportation electrification. Apart from planned replacements and upgrades, existing policies for some utilities (including many consumer-owned utilities in Oregon) require the customer who triggers the need for a new transformer to pay for the full cost of the upgrade. This policy can be relatively straightforward when a single home is served by a single transformer. However, there are other considerations, such as the age of the existing transformer and the projected date of when the utility would replace the transformer through normal operations.

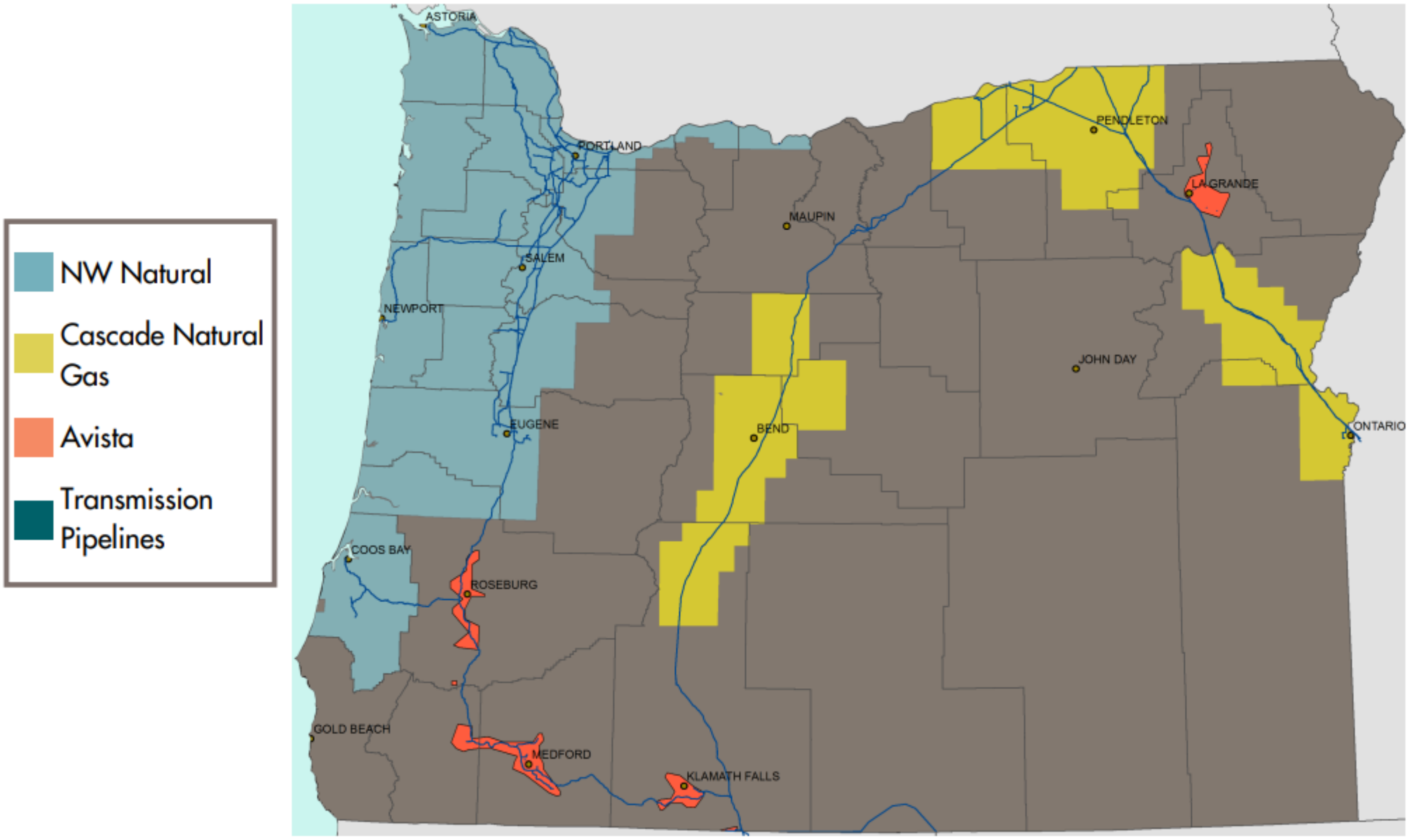
When a single transformer serves multiple homes, the question of who pays becomes more complicated. If an existing transformer serves four homes, and all four homes conduct electrification measures, it is likely that the transformer will need to be replaced at some point when the sum of new electric load end-uses pushes the local transformer over its limit. This could occur with the first homeowner installing an electric car charger, or years later when the last homeowner converts a gas furnace to an electric heat pump. If the upgrade is triggered by the last homeowner installing the heat pump, they could potentially bear the cost of the transformer upgrade, despite the added electric load from all the previous upgrades conducted by the other homeowners. These policies may prove to be difficult to implement as more customers adopt electrification measures, and utilities may need to update policies to ensure a more equitable distribution of the financial burden.

Differences in Urban and Rural Distribution System Needs

Electric vehicle adoption, and adoption of other electric end-uses in general, may be easier and cheaper in rural parts of Oregon that are not served with natural gas. Distribution system impacts will vary depending on existing infrastructure, which was designed to meet local electricity needs, as well as the combined effects of heating and transportation electrification. Rural electricity is more frequently designed with service transformers serving one or two end-users and with larger transformers to accommodate electric heating. In urban areas, many homes often share a transformer and heating loads are more often supplied by natural gas. Because adoption of electric vehicles is occurring in parallel with other electrification efforts, homes and businesses that embrace more electrification – such as replacing natural gas furnaces, water heaters, and dryers with electric options – will see more effects on local distribution systems.

Natural gas use in Oregon's residential sector may correlate to customer costs associated with distribution system upgrades. In the past, the relatively low electric loads associated with gas-heated homes provided an opportunity for utilities to install smaller service transformers, which reduced costs for their ratepayers. As shown in Figure 6, natural gas is largely available in more urban parts of the state in the Willamette Valley, along the coast, and in areas around larger cities in central, southern, and eastern Oregon. Many rural areas do not have access to natural gas service, and therefore have larger residential service transformers that may be able to accommodate EV charging without the need for an upgrade.

Figure 6: Oregon Natural Gas Utility Service Territories



While the total amount of energy consumed in a year is important, the instantaneous peak load has stronger implications for local transformer capacity. As shown in Table 3 above, a typical gas furnace has a peak demand of less than 1 kW compared to a peak demand of 10 kW to 20 kW for an electric heat pump. The increase in peak demand is what determines the need for a transformer upgrade. For example, in urban neighborhoods where homes are more likely to share a transformer for multiple houses, if two gas-heated homes were to install heat pumps and electric vehicle chargers, it could add more than 40 kW of load to the existing shared service transformer. To put this in perspective, a typical residential transformer for four homes may have a capacity of 50 kW, so this could add more than 80 percent to the total capacity of that transformer. In this case, the utility would likely upgrade to a 75 kW or larger transformer.

In contrast, replacing a heating system in a rural home will likely involve changing from one electric end-use to another electric end-use, such as replacing electric resistance baseboards or an electric resistance furnace with an electric heat pump. The new heat pump will likely have a similar peak demand as the old electric baseboards and would not increase the overall load on the transformer—potentially allowing for the addition of EV charging without the need for a transformer upgrade.

Homes that do not use natural gas may also have a cost advantage with adding an electric vehicle because the energy savings from switching to a more energy efficient heat pump may completely offset the additional energy consumption to charge a vehicle. Switching from baseboard or electric furnace heating to an electric heat pump will save about 4,000 kWh over the course of the year, and a typical electric vehicle in Oregon uses about 3,100 kWh annually.

EV Grid Effects Beyond the Service Transformer

In some cases, the effects of transportation electrification on peak loads may extend beyond individual service transformers. Electric utility system planning must account for peak loads associated with each feeder in a distribution system, as well as for the system as a whole. The 2020 Pacific Northwest National Laboratory study found that there is little short-term concern regarding system-wide resource adequacy, but there is concern that some local feeders within utility distribution systems may be strained by increased EV adoption.

PGE completed a system-wide analysis to identify feeders that may be subject to overloading from new EV charging loads.[17] The study considered existing grid conditions as well as projections of EV adoption rates in different parts of the distribution system. PGE describes two ways in which load growth from EV charging can affect distribution system planning. First, concentrated adoption of EVs may put more strain on already heavily loaded feeder lines, accelerating the timeframe for system upgrades. Second, for feeder lines currently below planning thresholds, incremental EV growth could add additional feeder lines to the “watch list” that will trigger a more in-depth planning review. The study concluded that light-duty EVs will have minimal system impacts and will likely only affect local service transformers. However, there were eight feeder lines out of 622 total that are expected to make the watch list. All eight feeder lines triggered the planning threshold under summer peak load conditions, but only by 3 to 7 percent.

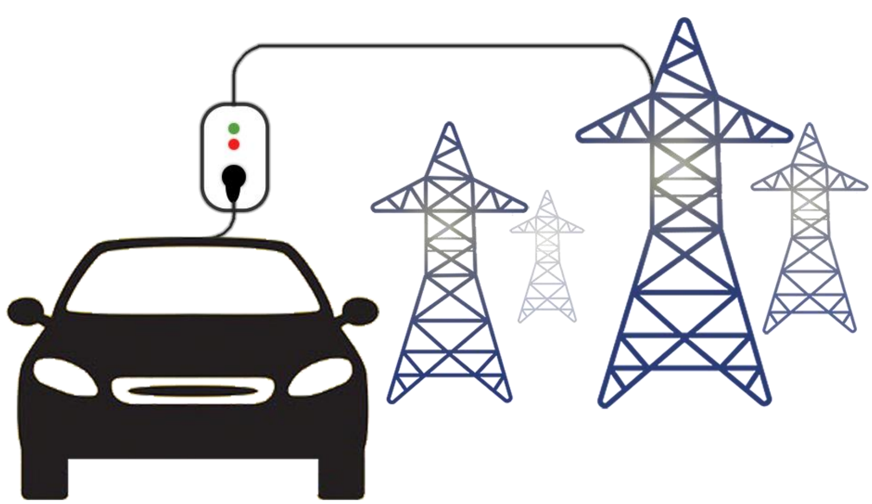
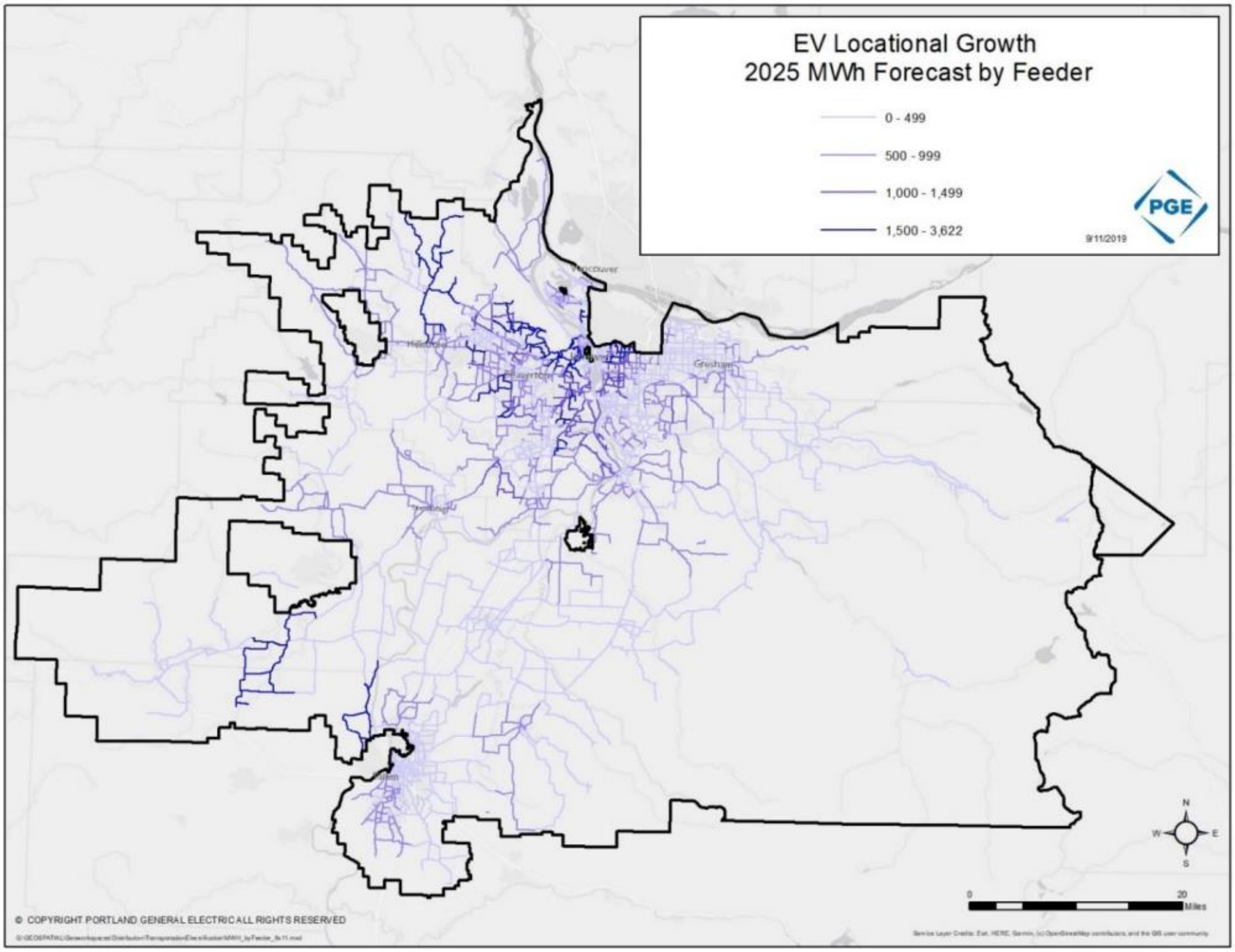


Figure 7: Portland General Electric Expected Substation Feeder Load Growth by 2025[17]



Mapping EV Charging to Inform Distribution System Planning

The Oregon Department of Energy works with consumer-owned utilities to map where EVs are charging on their systems. EV registrations tend to grow near areas where one or more EVs are already in use, which could affect local distribution systems. ODOE links EV registration data to specific areas, substations, or sometimes local transformers, and provides that information in a map or table for the utility. Utilities can then use the information to identify where system upgrades related to EVs may be needed.

Commercial Sector: Fleet Vehicle Charging Effects on the Grid

Commercial electric vehicles will have variable effects on the grid, largely dependent on the use case and duty cycle of the vehicles in the fleet. Commercial fleets can include light-duty, medium-duty, or heavy-duty vehicles, or a mixture of some or all of these. There are currently more than 6 million fleet vehicles in the U.S., ranging from conventional light-duty automobiles to cargo vans, buses, local delivery trucks, and long-haul trucks.[18]

Commercial fleets have a more diverse set of charging use cases compared to individual consumer vehicles. For example, a school bus fleet may be able to slow charge overnight to accommodate short duration trips the following day. In contrast, transit buses used by a municipality may run nearly continuously throughout the day, and benefit from more frequent high-speed charging. In either scenario the charging infrastructure to support the fleet will represent larger localized loads compared to consumer vehicles charging at home. While the localized grid impacts from medium- and heavy-duty charging are expected to be higher, the overall grid loads will be much lower. In its 2023 Transportation Electrification Plan, PacifiCorp estimates that medium- and heavy-duty vehicles will represent only 1 to 2 percent of the overall load impact associated with EVs in the next three years.[19]

Fleet charging infrastructure is more complex and has the potential for greater effects to local grid management, so the electric utility is an essential partner to businesses looking to add charging capacity to their facilities. Coordinating with the utility not only reduces potential negative impacts to the grid but can also help businesses optimize their EV fleet planning. For example, a level two charger will draw around 20 kW.[20] A fleet of 40 vehicles would have a total connected charging load of up to 800 kW. The electric utility can help determine the best locations and charging strategies that minimize local grid impacts and maximize fleet operations.

In many cases, electric system upgrades to accommodate new fleet charging capabilities will mirror upgrades in the residential market (i.e., service transformer upgrades). In other cases, utility distribution system upgrades may go beyond the transformer. PGE estimates larger fleet EV sites to start at around 1.5 megawatts and some may expand to 20 megawatts in the next five years.[21] These larger loads may result in feeder line upgrades and even new substations, which will have much higher costs and require careful cost considerations by the utilities and regulators.

Private Sector Driving Medium-Duty and Heavy-Duty EV Adoption

Many of the companies operating commercial fleets see electrification as an important step to meeting corporate clean energy targets. In 2021, FedEx announced that its entire parcel pickup and delivery fleet will be zero-emission electric vehicles by 2040 – that's more than 200,000 vehicles.[22] UPS and Amazon have made similar fleet electrification commitments. In 2020, UPS announced the purchase of 10,000 electric delivery vehicles.[23] In 2019 Amazon announced a partnership with Rivian to bring 100,000 electric delivery vehicles on the road by 2030.[24] These commitments also mean significant increases in private – and potentially public – charging infrastructure to fuel these vehicles.

Fuel Cell Electric Vehicles and the Electric Grid

Fuel cell electric vehicles use hydrogen as a fuel to generate electricity that powers the vehicle. Because these vehicles do not plug into the grid, they are often discussed as a potential option to limit the effects of increasing EVs on the electricity system. Today, 95 percent of the hydrogen produced in the United States comes from natural gas reformation, a process that requires electricity.[25] This method for creating hydrogen is carbon intensive, especially if the electricity used to produce it is made with coal or natural gas.

Electrolyzer technologies exist that create hydrogen by using electricity to "crack" water into its oxygen and hydrogen components, and there is great interest in deploying these to supply clean hydrogen and help manage the electric grid. Electrolyzers would be an additional load on the electric grid but could potentially be easier to manage than hundreds of thousands of vehicles. If a hydrogen economy develops in Oregon, and electrolyzers become more cost effective, they could act as a "flexible load" for the grid, soaking up excess renewable energy when available and shutting down when demand is high.

Hydrogen fuel cell electric vehicles are not widely used outside of California, mainly because fueling infrastructure has not been developed in other parts of the country. But these vehicles and the electrolyzers that make the hydrogen fuel may play an important role in the future electricity grid. For more information on Fuel Cell Electric Vehicles and Hydrogen, see the 2022 Biennial Energy Report.

Portland General Electric has developed a fleet electrification program to better help fleets plan, build, and pay for the infrastructure associated with electrification.[26] The program benefits fleet owners by identifying least cost options to add their charging infrastructure, and it benefits PGE by allowing the utility to identify and manage any potential distribution system impacts from the specific charging use cases, including charging locations.

Another technology that will support the development of fleet charging stations is telematics, which enable real-time GPS location and tracking data collection from vehicles. Telematics could play a central role in planning for medium- and heavy-duty charging needs across Oregon and the U.S. One of the strategies identified by PGE in its 2023 Transportation Electrification Plan is to utilize vehicle telematics to inform ideal locations for future charging infrastructure. PGE collaborated with Daimler Truck North America to assemble data that could be used to plan heavy-duty charging infrastructure in the Portland metropolitan area. Telematic vehicle tracking data was collected from existing gas and diesel engine fleets to map vehicle routes. In the future, telematics could enable real time tracking of EV battery charge level, so that utilities can better predict fleet charging needs and manage fleet charging to maximize vehicle performance and minimize grid impacts.

Conclusion

The adoption of electric vehicles represents a new load on the electric grid that will affect Oregon utilities and ratepayers. EV adoption will occur in parallel with other new loads, such as data centers and heat pumps. While there are not immediate concerns regarding resource adequacy or widespread grid impacts, there may be local instances where EV adoption requires significant grid upgrades, especially for charging stations that serve medium- and heavy-duty EV fleets. Oregon electric utilities will need to continue their careful planning to ensure grid infrastructure keeps up with new electric loads, while maintaining affordable energy costs for their customers.

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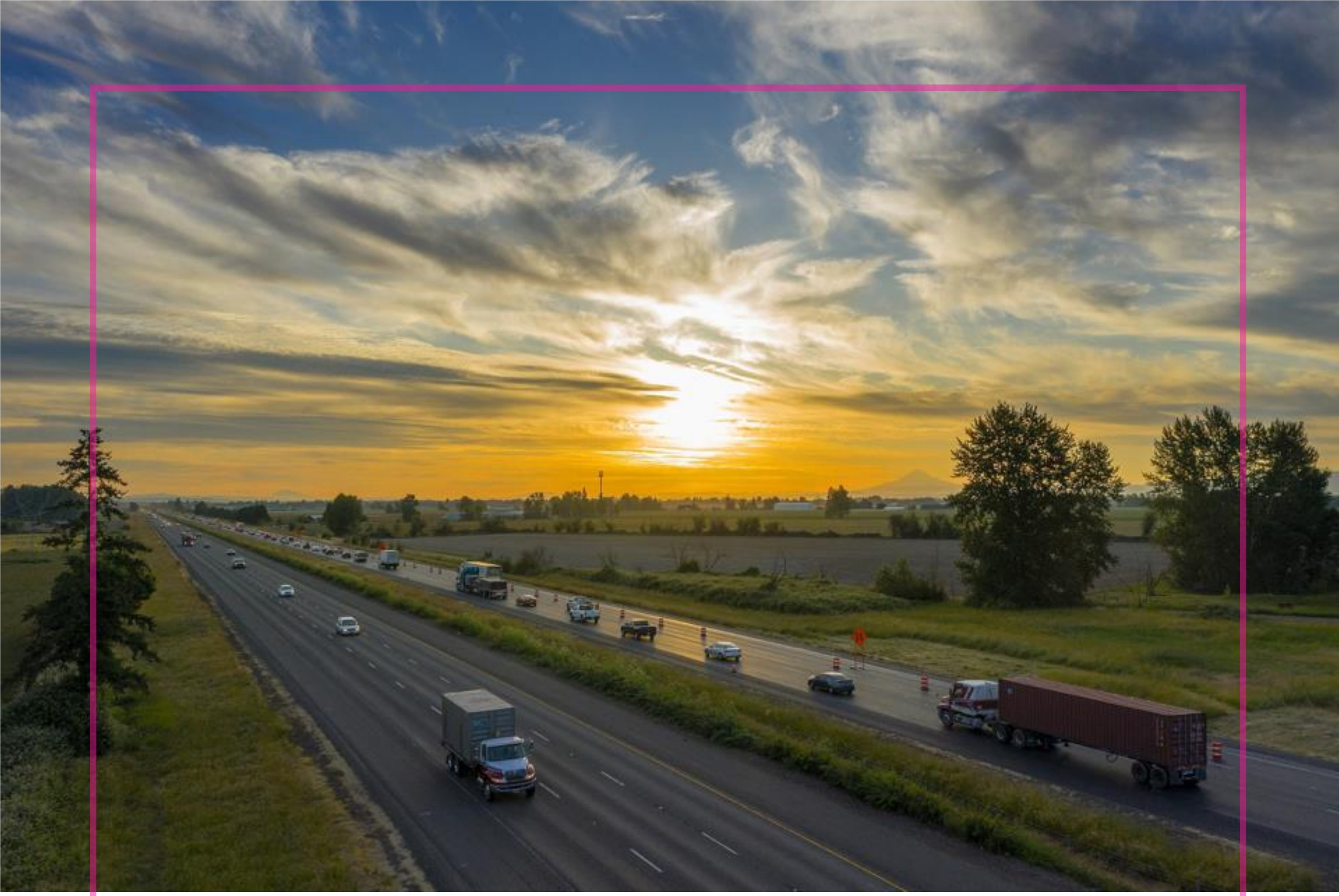


Photo credit: Rob Stevens, ODOT

This section of the BiZEV report helps address the agency directive from SB 1044 (2019)[1] to evaluate, 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.

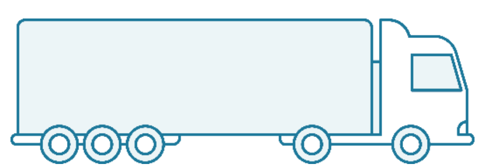
Impacts of EV Sales on the State Highway Fund

Key Takeaways

- As the number of zero-emission vehicles in the statewide fleet of light-duty vehicles increases, the overall contribution of the fuels tax to the State Highway Fund decreases. Although zero-emission vehicle adoption will affect State Highway Fund revenues, the specific revenue change depends on the fuel economy of the vehicle that is replaced and how much that vehicle is driven. Depending on how many miles a vehicle is driven during the year, the reduced motor fuels tax contribution is usually only partially offset by the higher registration fee.
- Switching from an internal combustion vehicle to an EV does not always lead to reduced highway fund revenue, but it becomes more likely for a driver with higher VMT that has switched from a vehicle with a lower fuel economy. A driver of a 40+ MPG EV who drives the equivalent of the statewide VMT average would actually contribute more to the State Highway Fund because the higher fixed EV registration fee contributes more to the fund when compared with the 40+ MPG registration and taxes from fuel purchases.
- Effects on the State Highway Fund may have been minimal up to this point. However, Oregon is facing a shifting model for highway maintenance and construction funding. Factors such as increasing EV market share, decreasing vehicle-miles-traveled, decreasing vehicle registrations, increasing inflation, and fleetwide fuel economy improvements place downward pressure on State Highway Funding that cannot be easily offset by registration fee or fuel tax increases. However, options do exist that can ameliorate the downward pressure on revenues.

Introduction

State Highway Fund revenues are affected as electric vehicles gain popularity because EVs use no gasoline or diesel fuel, and do not contribute the associated fuel tax to the State Highway Fund. Oregon funds the maintenance and construction of its roadways through a combination of revenue from the federal government and state sources. State sources include the state fuels tax (gas tax, diesel, and other fuel tax), taxes on heavy trucks (weight-mile tax and truck registrations), and driver and motor vehicle fees (licenses and vehicle title and registration). The state funding sources contribute to the State Highway Fund, which the Oregon Constitution declares must be spent on roads, including bikeways and walkways within the highway right of way. State funds can be used for both construction projects and the day-to-day maintenance and operations of the state's roads.[2]



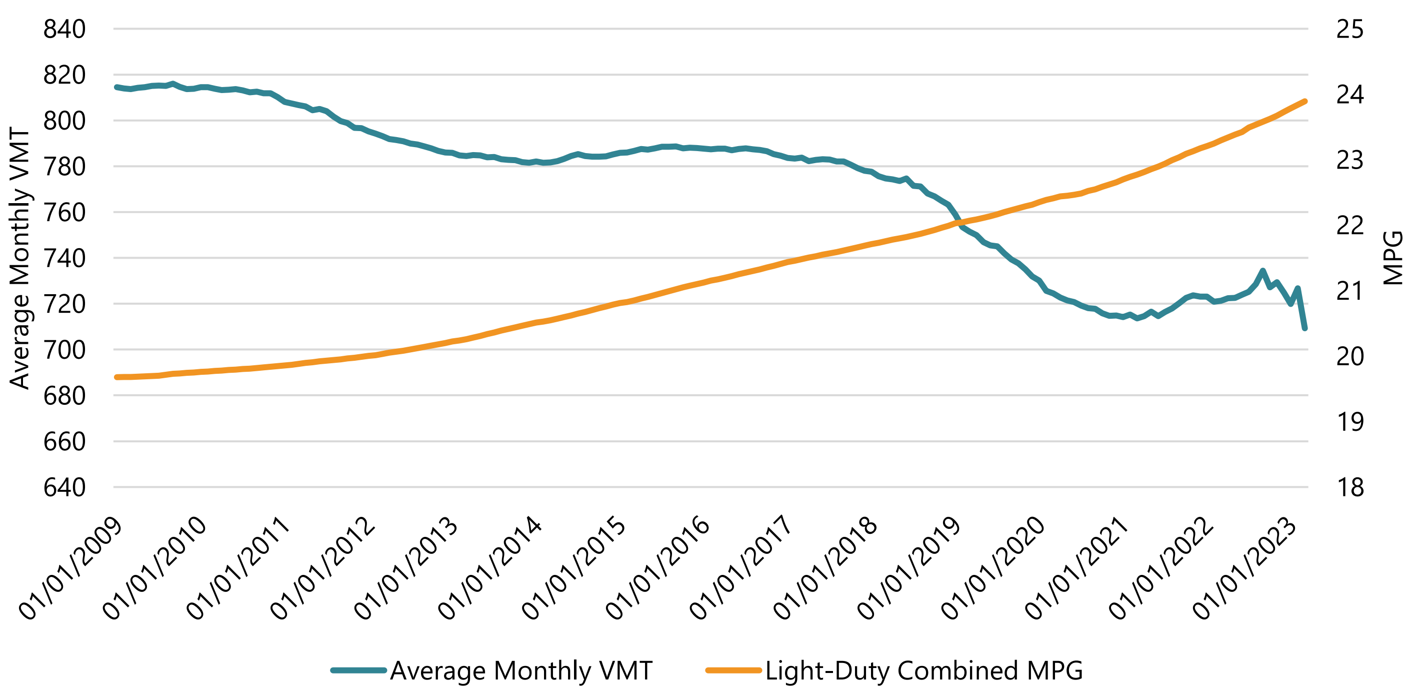
Oregon has historically based the financing of its highways on the principle of cost responsibility – the idea that road users (light and heavy vehicles) should pay for their respective share of road costs based on some measure of roadway usage. For vehicles 26,000 pounds or lighter, the largest revenue source for roads and bridges has traditionally been tied to vehicle fuel consumption, which serves as a proxy for road usage. For commercial vehicles with a registered weight greater than 26,000 pounds, this is mainly in the form of a weight-mile tax that is paid based on distance traveled in Oregon and the weight of the vehicle.

For light-duty passenger vehicles, this cost share has been met through a motor fuels tax levied on every gallon of fuel sold in the state. The point of taxation along the supply chain varies for fuel types – motor vehicle fuels like gasoline are taxed at the point of first sale (when the dealer or distributor purchases the fuel from the terminal) and are incorporated into the price a consumer later pays. Fuels like diesel, biodiesel, and fuels other than gasoline are known as “use fuels” that are taxed at the retail level when fuel is placed into the tank of the vehicle. As of July 2023, all motor vehicle fuels are taxed at $0.38 per gallon by the state.[3] These fuel and weight-mile taxes, along with DMV fees for titling and registration, are the primary contributors to the State Highway Fund. There are also local gas taxes that contribute to local road maintenance that will be adversely affected by a decrease in gasoline and diesel sales, but they are not analyzed here.

Presenting the Data

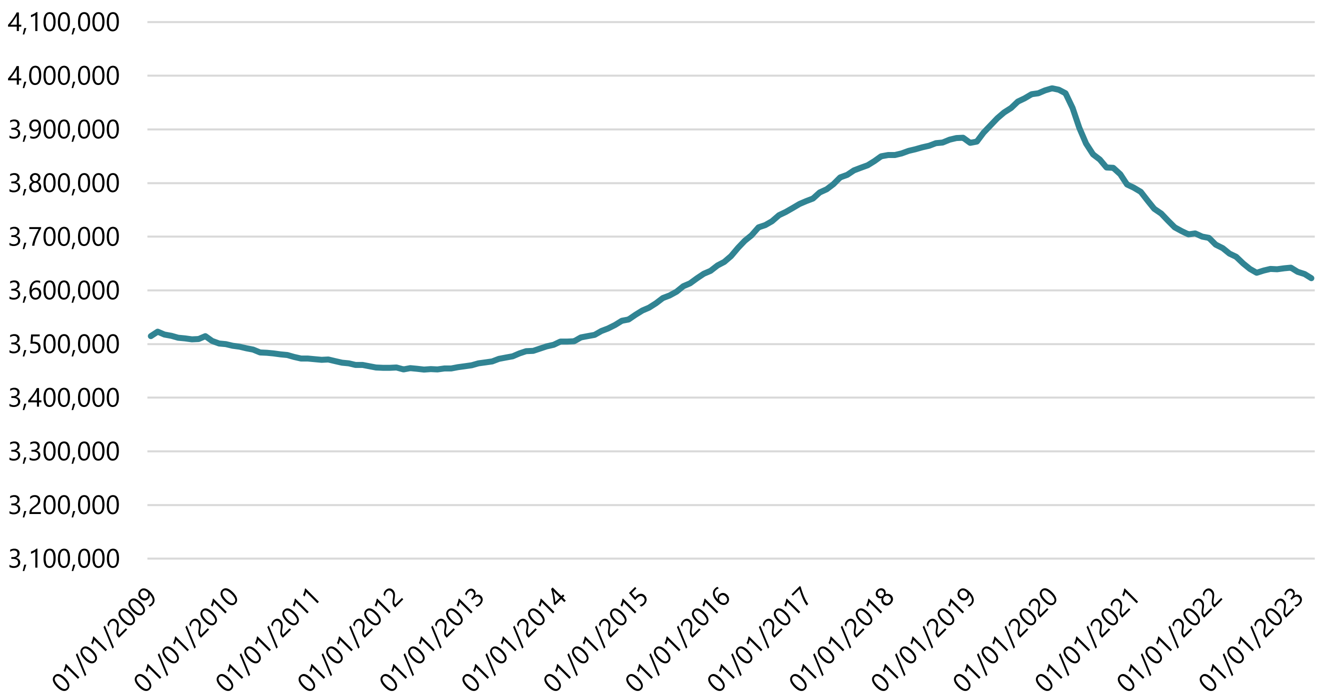
There are many variables that can affect State Highway Fund revenues. Also, inflation in the price of construction materials can be a significant factor in State Highway Fund spending, but is not addressed in this report. Revenues associated with light-duty vehicles are largely dependent on how much fuel is consumed and how many vehicles are registered in Oregon, along with the specific tax rate and the amount of fees. Factors that influence fuel consumption include Oregon population, number of vehicles, average vehicle miles traveled (VMT), overall profile of Oregon’s fleet and its associated fuel efficiency, and other micro- and macro-economic contributions. This section of the report primarily looks at the isolated effect of EV adoption on the State Highway Fund, and does not attempt to consider the other broader economic variables.

Figure 1: Vehicle Miles Travelled (VMT) and Light-Duty Combined MPG Over Time [4]



Factors currently placing downward pressure on highway fund revenues include a decrease in VMT 2009-2021 (the green line in Figure 1) and general improvement of fuel efficiency across Oregon's fleet (orange line in Figure 1). This MPG gain is the result of older, less efficient vehicles being replaced by newer vehicles with improved fuel economy, and as hybrid and electric vehicles gain market share. Figure 2 shows that the total count of vehicles with valid registrations peaked in early 2020 and has generally declined since, which has also reduced the contributions to overall State Highway Fund revenues in recent years.

Figure 2: Vehicles with Oregon Registrations[4]



Factors placing upward pressure on highway fund revenues include an increasing Oregon population (Figure 3) and increasing fees and taxes for fuels and registrations (Figure 4). 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. This action was deemed necessary to offset the effects of the trend toward lower VMT and higher fuel efficiency that would lead to a decrease in State Highway Fund revenue. Also, ODOT's taxes and fees are not indexed to inflation, so these increases helped to address increasing prices for roadway maintenance over time.

Figure 3: Oregon Population Over Time [5] [6] [i]

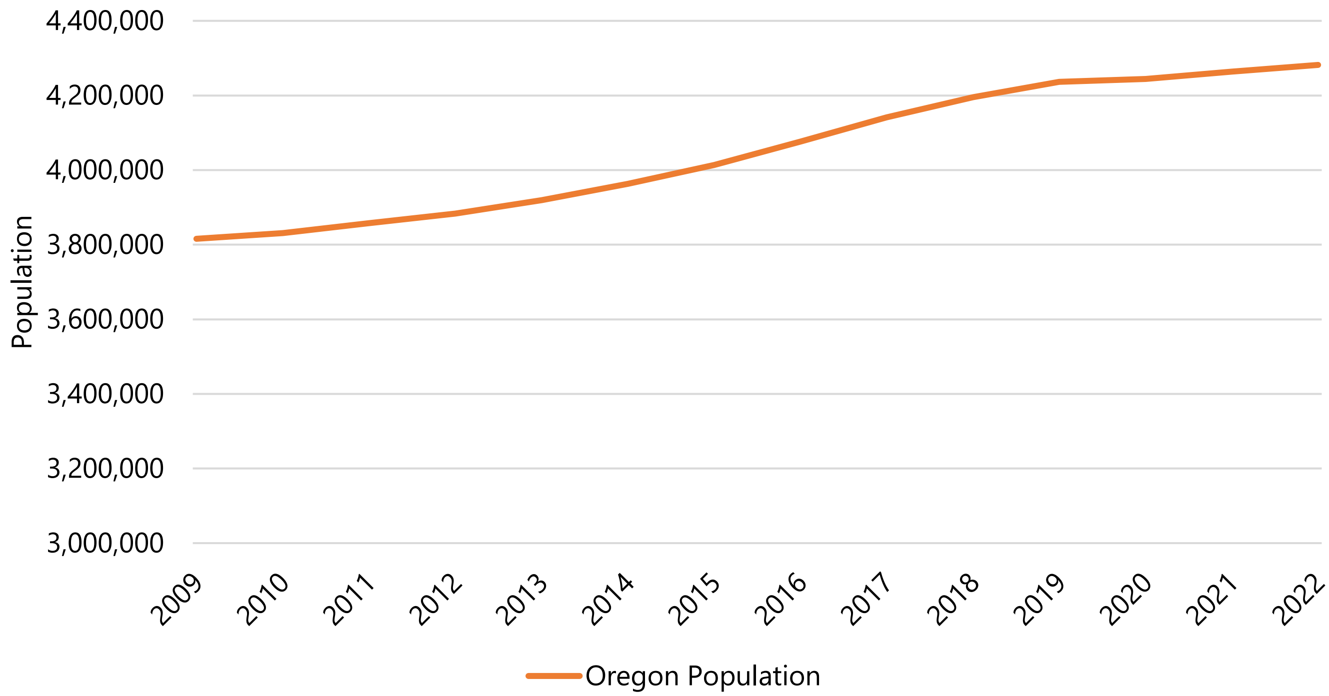
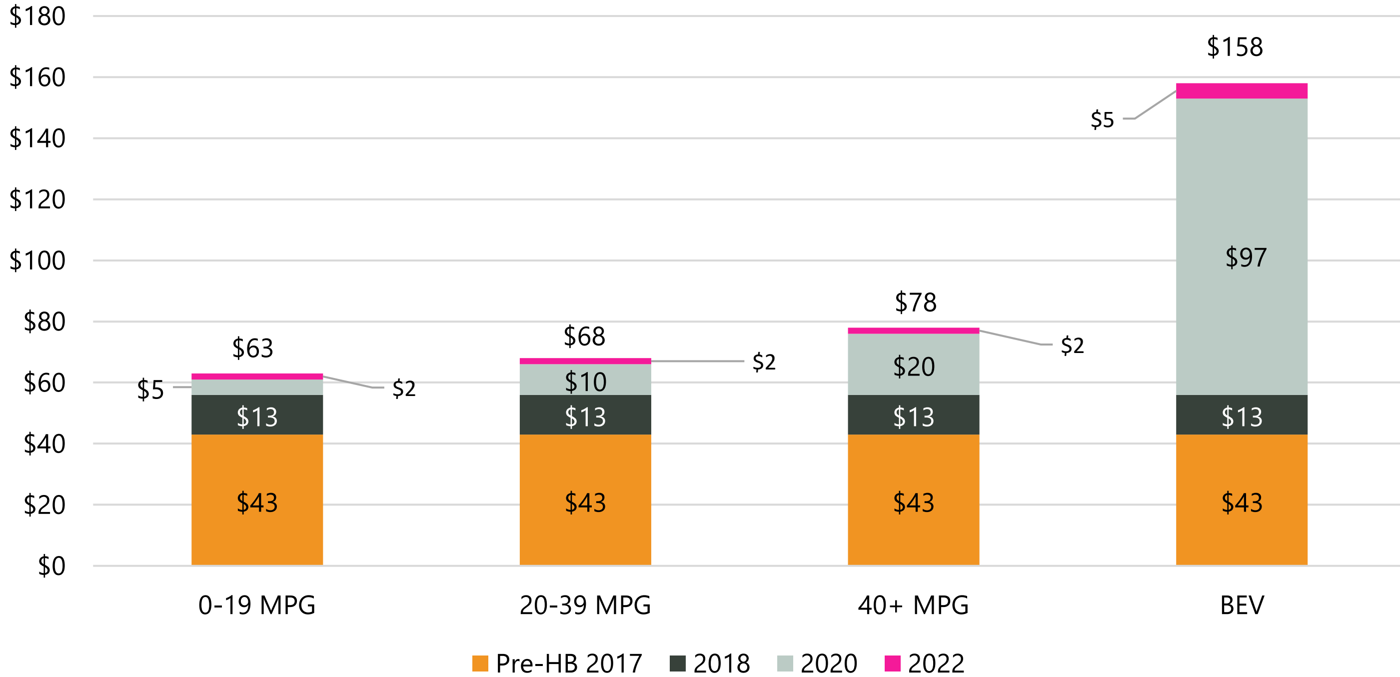


Figure 4: Passenger Vehicle Annual Registration Fees, with Increases from HB 2017 [7] [8]

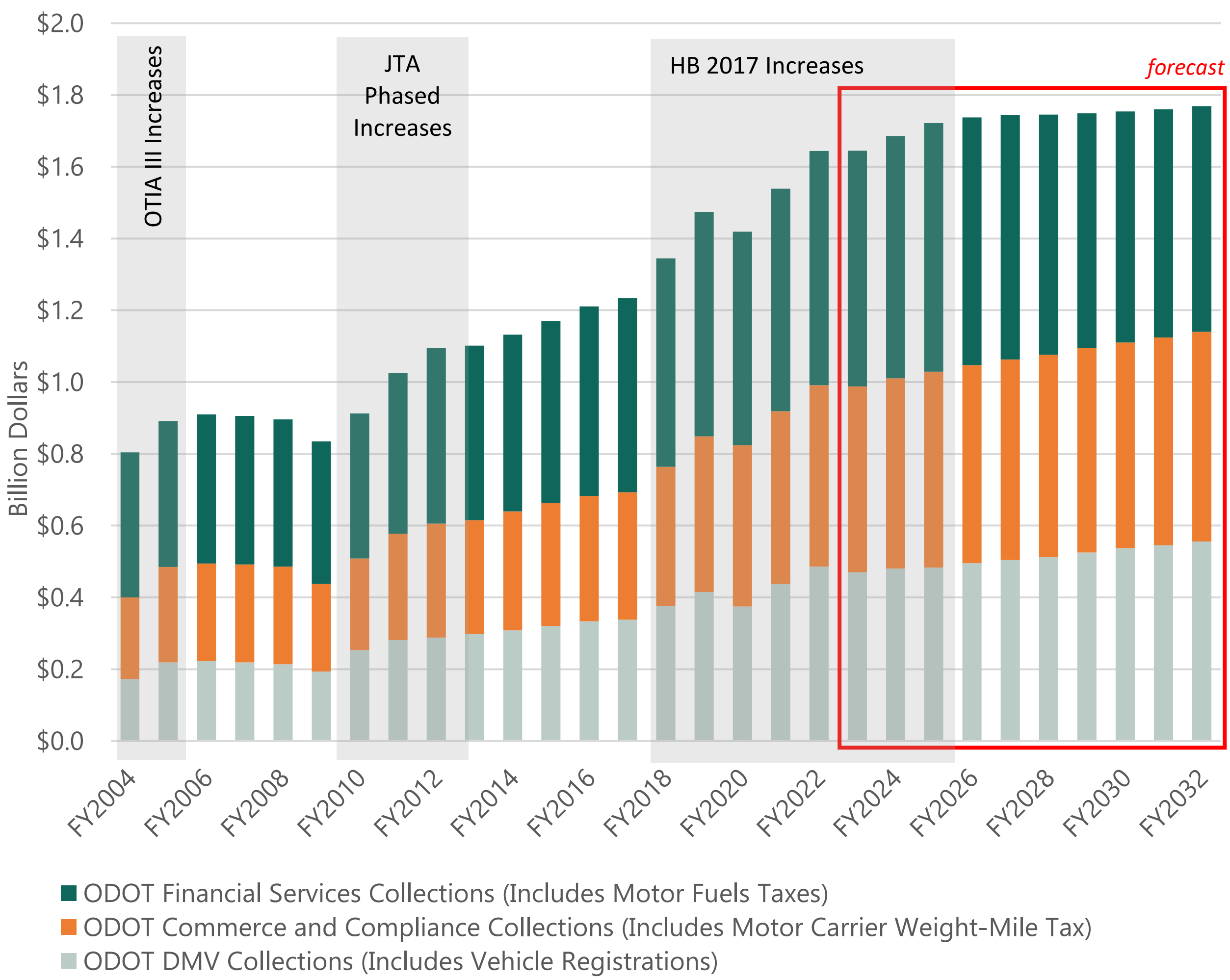


[i] Population values for 2011 through 2019 are from the 2020 Annual Population Report Tables (April 15, 2021). Revised estimates to be consistent with Census 2020 were not yet available at the time of 2023 BiZEV publication.

Highway Fund Revenue

Figure 5 shows the State Highway Fund revenues over the previous two decades, as well as ODOT projections through 2032. Revenues have increased steadily in the past due to increasing vehicle registrations and increases in the taxes and fees associated with registration and fuel usage. ODOT's forecast through 2032 shows relatively flat revenue projection.[9] As expected, the contribution from the motor fuels tax shows a decrease as more high-MPG vehicles and EVs make up Oregon's fleet of passenger vehicles. This is balanced, however, by projected increases in the DMV registration revenues as well as weight-mile tax revenues from commercial vehicles. In Figure 5, vehicle registrations are a portion of the DMV collections, the weight-mile tax on motor carriers is part of ODOT Commerce and Compliance Division collections, and motor fuels taxes are part of ODOT Financial Services.

Figure 5: Total Gross State Highway Revenues by Fiscal Year (Source: ODOT) [ii] [10]



[ii] In Figure 5, 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 2023-2031 is meant to show that these years represent forecasts.

Oregon Vehicle Portfolio Profile

ODOT provided ODOE with data that include (as of December 2022) registered light-duty vehicle counts; average MPG; and estimated annual vehicle miles traveled (VMT) by vehicle type (cars, pickup trucks, sport utility vehicles or SUVs, and vans) and by registration group where EVs are separate from all other vehicles (Table 1). Standard hybrid vehicles and plug-in hybrid vehicles are included in their respective DMV MPG registration group. Table 1 also includes a percent change comparison to the data that was included in the 2021 Biennial Zero Emission Vehicle Report (as of February 2021).

Table 1: ODOT Data on Oregon Light-Duty Fleet [11]

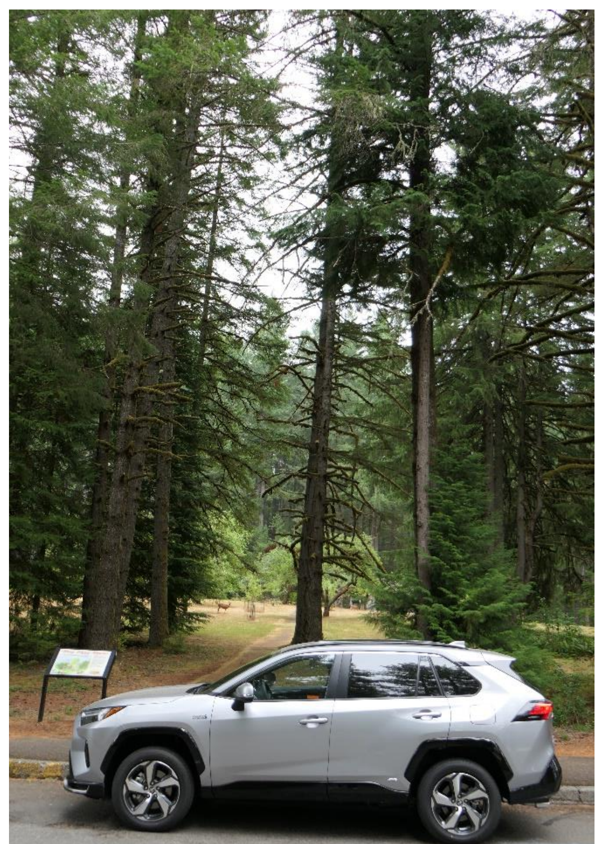
Vehicle Type	Registration Group	Total Count and Percent Change from 2021 BiZEV		Average MPG and Percent Change from 2021 BiZEV		Estimated Annual VMT and Percent Change from 2021 BiZEV *	
Car	EV	35,575	73%	116	1%	7,850	2%
Car	MPG 0-19	428,308	-7%	18	-1%	6,990	1%
Car	MPG 20-39	953,279	3%	27	0%	8,921	-3%
Car	MPG 40 +	88,461	11%	55	2%	10,057	-7%
SUV	EV	4,783	132%	96	2%	10,174	-16%
SUV	MPG 0-19	482,837	0%	16	1%	8,734	-6%
SUV	MPG 20-39	487,044	22%	24	0%	9,884	-5%
SUV	MPG 40 +	21,947	164%	51	15%	11,176	1%
Truck	EV	555	9150%	69	N/A	5,696	4940%
Truck	MPG 0-19	788,130	7%	15	3%	9,028	-4%
Truck	MPG 20-39	70,732	43%	21	1%	10,603	22%
Van	EV	92	2967%		N/A	5,193	250%
Van	MPG 0-19	143,242	2%	16	2%	9,381	-3%
Van	MPG 20-39	55,982	14%	22	1%	10,560	-5%
Van	MPG 40 +	1,121	97%	82	-1%	11,463	12%

* Five-year average VMT (2018-2022), derived from records with available odometer readings

Analysis

As the number of zero-emission vehicles in the statewide fleet of light-duty vehicles increases, the overall contribution of the fuels tax to the State Highway Fund decreases. Most EVs do not consume liquid fuel,[iii] and therefore drivers do not pay state, federal, or local motor fuels taxes. PHEVs will also affect State Highway Fund revenues, but these vehicles have even more complexity because they can be driven on battery only, gasoline only, or in hybrid mode, which means drivers of these vehicles may pay some fuel taxes, but likely not as much as a standard gasoline vehicle. Depending on how many miles a vehicle is driven during the year, the reduced motor fuels tax contribution is usually only partially offset by the higher registration fee.

Although zero-emission vehicle adoption will affect State Highway Fund revenues, the specific revenue change depends on the fuel economy of the vehicle that is replaced and how much that vehicle is driven. Figure 6 illustrates the combined registration and gasoline fuel tax contribution to State Highway Fund revenue for a single vehicle, based on annual vehicle miles travelled. EV contributions (shown in yellow) stay flat no matter how much the vehicle is driven, because drivers only contribute a fixed amount to the State Highway Fund through their annual registration fees. Gasoline vehicles (represented by orange, blue, and gray lines) have both a fixed registration fee and a variable fuel tax, which means the more they drive (higher VMT) the more they contribute to the fuel tax portion of the fund. The figure shows that at low annual VMT, EVs actually contribute more to the State Highway Fund than gasoline vehicles because of their significantly higher fixed registration fee that is not dependent on VMT. However, as annual VMT increases, the revenue from a gasoline vehicle overtakes revenue from an EV. This occurs at a faster rate for vehicles with low fuel economy because they consume more fuel (and pay more fuel tax) for each mile travelled. The break-even point occurs at approximately 4,000 annual VMT for vehicles in the 0-19 MPG registration group, 6,000 annual VMT for the 20-39 MPG group, and 11,000 annual VMT for the 40+ MPG group.

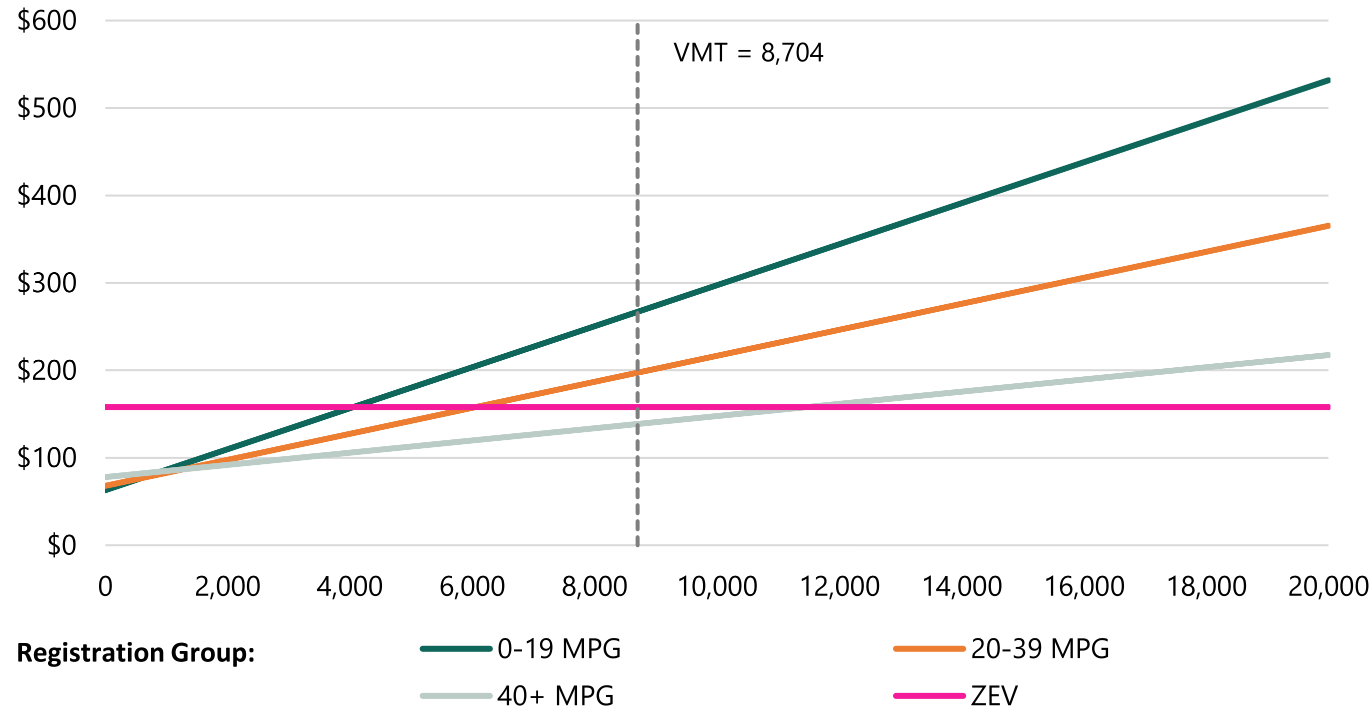

Oregon Department of Energy's Hybrid RAV4

Switching from an internal combustion vehicle to an EV does not always lead to reduced highway fund revenue, but it becomes more likely for a driver with higher VMT that has switched from a vehicle with a lower fuel economy. Oregon's average VMT for light-duty vehicles in 2022 was 8,704 miles.[4] On average, a driver switching

[iii] Some ZEVs, such as Plug-In Hybrid Electric Vehicles, can consume gasoline and will pay into the State Highway Fund depending on how much liquid fuel the vehicle consumes.

from a low MPG vehicle to an EV is very likely to lead to reductions in revenue — the higher registration for an EV in these cases is not significant enough to offset the reduction in motor fuel tax revenue. However, a driver of an EV who drives the equivalent of the statewide average would actually contribute more to the State Highway Fund because the higher EV registration fee contributes more to the fund when compared with the 40+ MPG registration and taxes from fuel purchases.

Figure 6: Annualized Highway Fund Revenue Per Vehicle (Registration + Fuel Tax) [3 7 12]



There is limited data to show which cars are being traded for zero emission vehicle purchases, but anecdotal evidence suggests that it is unlikely that many of the low fuel efficiency vehicles are *currently* being replaced. Most of the 0 – 19 MPG vehicles are SUVs and pickup trucks, but these categories also show the fewest numbers of EV registrations. Also, EV SUVs only became a growing portion of the market in the last few years and the first EV pickup trucks have only been available since late 2021 — so there have been few options for drivers who want this type of vehicle. (See the *Model Availability* chapter for more.) This means that the effects on the State Highway Fund may have been minimal up to this point. However, as more EV versions of these types of vehicles come to market, the effects on revenues may become more pronounced.

Forecasts

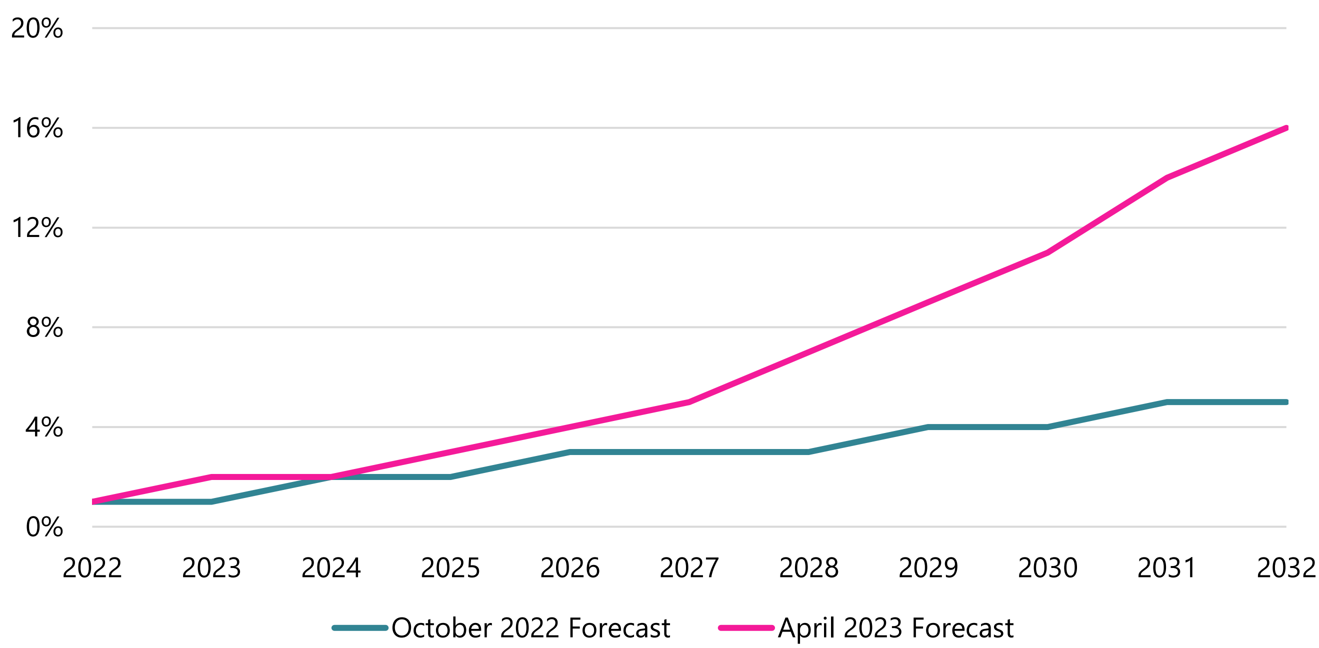
The pace at which EVs are adopted will influence the State Highway Fund revenues. The Oregon Department of Transportation forecasts the electric vehicle share in total passenger stock and has recently revised its projections to include Oregon DEQ's adoption of the Advanced Clean Cars II (ACCII) rule. Among other things, the rule will require 100 percent of new car sales to be EVs by 2035.[9] This will accelerate the transition to electric vehicles, particularly beginning in 2027. As shown in Figure 7 below, ODOT's April 2023 forecast[9] shows a considerable jump in projected EV registrations since the previous forecast. This will create more significant downward pressure on the State Highway Fund, and the degree of pressure will depend on what types of vehicles are being replaced as described above. ODOT's April 2023 forecast projects approximately 3 percent EV market share of total vehicle stock by 2025 and 11 percent by 2030, which translate to approximately 110,000 and 400,000 registered EVs respectively. These projections are less than the goals in SB 1044 (2019), which target 250,000 EVs by 2025 and 25 percent (approximately 875,000) EVs by 2030.

Oregon's ZEV Adoption Targets: SB 1044

In 2019, Senate Bill 1044 outlined new Zero Emission Vehicle adoption targets for Oregon:

- 50,000 registered ZEVs on Oregon roads by 2020
- 250,000 registered ZEVs on Oregon roads by 2025
- At least 25 percent of registered vehicles and at least half of the new vehicles sold annually are ZEVs by 2030
- At least 90 percent of new vehicles sold annually are ZEVs by 2035.

Figure 7: Comparison of ODOT 2022 and 2023 Forecasts of Electric Vehicle Share in Total Passenger Stock [9]



As of April 2023, Oregon had nearly 70,000 EVs registered.[13] Table 2 shows the effect on the State Highway Fund revenues of increasing EV adoption from the March 2023 registration levels under two future rates of growth: ODOT-forecasted EV growth and the more aggressive growth to meet SB 1044 goals. Four scenarios were run for each growth rate using the state average VMT. Each scenario (scenario 1 through scenario 3) assumed that all of conversions to EVs would come from only one vehicle fuel efficiency registration group (MPG group). However, future adoption rates will most certainly involve a mixed profile of all the vehicle registration MPG groups as estimated in scenario 4. For both scenario 1 (0 – 19 MPG group) and scenario 2 (20 – 39 MPG group) the State Highway Fund would experience a loss in revenue. In scenario 3 (high fuel efficiency vehicles in the 40+ MPG group), revenues would increase. However, since only 3 percent of registered vehicles in the current statewide light-duty fleet are in the 40+ MPG group, this scenario is unlikely. In scenario 4 with replacements happening in a mix of MPG groups the State Highway Trust Fund would also experience a loss of revenue.

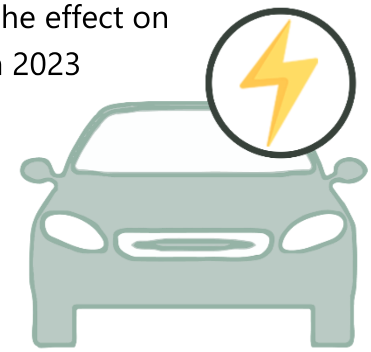


Table 2: Revenue Change for One-to-One Replacement with an EV

Annual Revenue Change for a 1-to-1 Replacement with an EV
(using ODOT Forecast for EV Adoption Projections)

EV Replacement Scenario if each new EV replaced a vehicle in the following MPG Registration Group	Revenue Increase or Decrease in 2025	Revenue Increase or Decrease in 2030
Scenario 1: replace from 0-19 MPG group	-$4,516,548	-$34,766,245
Scenario 2: replace from 20-39 MPG group	-$1,631,474	-$12,558,314
Scenario 3: replace from 40+ MPG group	+$801,308	+$6,168,093
Scenario 4: replace from a mix of groups (52% 0-19 MPG; 45% 20-39 MPG; 3% 40+ MPG)	-$3,036,816	-$23,375,968
ODOT Registered EV Forecast (for reference)	*Approx. 110,000*	*Approx. 400,000*

Annual Revenue Change for 1-to-1 Replacement with an EV
(using SB 1044 Goals for EV Adoption Projections)

EV Replacement Scenario if each new EV replaced a vehicle in the following MPG Registration Group	Revenue Increase or Decrease in 2025	Revenue Increase or Decrease in 2030
Scenario 1: replace from 0-19 MPG group	-$19,946,289	-$88,274,890
Scenario 2: replace from 20-39 MPG group	-$7,205,028	-$31,886,784
Scenario 3: replace from 40+ MPG group	+$3,538,793	+$15,661,389
Scenario 4: replace from a mix of groups (52% 0-19 MPG; 45% 20-39 MPG; 3% 40+ MPG)	-$13,411,394	-$59,353,864
SB 1044 EV Registration Goals (for reference)	*250,000*	*Approx. 875,000*

Plug-in hybrid electric vehicles are also likely to drive revenues down. While PHEVs can use gasoline for fuel, it is reasonable to assume that the electric battery motor will be used to offset some of that fuel. Electric fuel is less expensive than gasoline, creating an incentive to utilize the electric fuel as much as possible. Further, PHEVs may be seen as a better option for replacing pickup trucks and SUVs, where range and power are attributes that many drivers want. These types of vehicles are more prevalent in the 0-19 MPG category, which means the battery will more quickly offset fuel consumption.

Options to Address Effects from Electric Vehicle Adoption to the State Highway Fund

State fuel taxes were originally instituted to correlate the amount drivers pay to maintain roads and bridges to the amount they drive. Taxing fuel consumption served as a proxy for road usage with a goal of equitable cost-share responsibility. However, this fuel tax model does not translate to EVs. Taxing the electricity used for EV fuel would be an option to address EV contribution to the State Highway Fund, but this introduces challenges because most EV drivers fuel at home and the submetering and infrastructure to do this could be cost-prohibitive. Another option is to pay taxes based on the number of miles driven. The technology to do this exists for most cars today, which have telematics capabilities (often via a report from a vehicle's on-board diagnostics). Telematics allow for vehicle information, such as odometer readings, to be reported and shared via internet connections. This information can be used to assess taxes based on the miles driven over a specified period of time. Several states, including Oregon, are investigating this as a potential replacement for taxing fuel at distribution or at the pump.[14]

Oregon is a leader in developing a road usage tax program to address the effects of transportation electrification on revenues to maintain roads and bridges. Oregon launched a road usage charge program, called OReGO, in July 2015.[15] OReGO is a voluntary program and many registered light-duty vehicles in Oregon are eligible for enrollment in the program.[15] Participants are sent a device to self-install in their vehicle that collects data on mileage and fuel consumption (if applicable). They are provided a nonrefundable tax credit for fuel taxes paid at the pump,[iv] and instead pay 1.9 cents per mile as assessed by their vehicle interface device. Enrolling in OReGO also reduces registration costs for drivers of zero-emission vehicles (battery electric or plug-in hybrid electric) and high-MPG (40 MPG or better) vehicles. For example, EV drivers would normally pay $316 for a two-year registration fee and PHEV drivers would pay $156, but if they enroll in OReGO they pay only $86 for a two-year registration.[v] The program is currently operating effectively on a voluntary basis with about 700 drivers and 2,100 vehicles enrolled to date.[15] The voluntary nature of the program presents a challenge because a driver is more likely to enroll in a voluntary program if it saves them money, which conversely decreases State Highway Fund revenue. However, the OReGO program presents a valuable model that shifts the contribution of an EV or high-MPG vehicle from a fixed fee to a per-use fee that is more aligned with Oregon's traditional cost responsibility, where drivers contribute their share toward the highway fund based on a measure of how much they use Oregon's roadways.

There are also national efforts to create a mileage fee pilot program.[16] The 2021 Infrastructure Investment and Jobs Act includes funding through the U.S. Department of Transportation for two mileage-based pilot programs. The first provides continuing and additional support for state and local pilot programs, while the second establishes a new nationwide motor vehicle per-mile user fee pilot program. The IIJA directs the USDOT to solicit participants from each state and includes both commercial and passenger vehicles in the pilot program. Technologies such as smart phone applications, telematic data analysis, and manual reporting may be incorporated into this national pilot program as a means for tracking vehicle mileage. Advanced state-level programs such as OReGO will certainly inform this national pilot program, and the national attention on this issue demonstrates the broad nature of the challenges for transportation infrastructure across all states.

[iv] Battery electric vehicles do not consume gasoline and would not participate in this part of the OReGO program.

[v] Registration fees are double for new vehicles.

Other Options

There are other options to address wear and tear on Oregon's roads that could play a role in assessing costs to maintain them. The amount of fuel consumed or miles driven does not always reflect how much a driver causes wear on Oregon's roadways. Other considerations play a role — vehicle weight, towing, studded tires, offroad driving, and even driver behavior can create significant variances in the degree to which a vehicle affects roadways. Some states charge taxes or fees for specific technologies, such as trailers and studded tires.[17] [18] In Oregon, many heavy-duty vehicles are assessed taxes based on the number of miles driven and the weight of the vehicle.[19] Modern technology may afford more options to understand the effects of different technologies on roadways, and provide policy options to maintain a State Highway Fund that supports safe, affordable, and convenient travel for all Oregonians.

Conclusion

Many states, including Oregon, are facing a shifting model for highway maintenance and construction funding. Factors such as increasing EV market share, decreasing vehicle-miles-traveled, decreasing vehicle registrations, increasing inflation, and fleetwide fuel economy improvements place downward pressure on State Highway Funding that cannot be easily offset by registration fee or fuel tax increases. In the absence of other policies, State Highway Fund revenue is projected to slow or flatten in the coming years, even as Oregon's total population is expected to grow. However, Oregon is leading to address this through pilot programs like the OReGO Road Usage Charge program, and state officials are actively working to ensure a sustainable model for future funding of Oregon's State Highway Fund.

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