2022 BIENNIAL ENERGY REPORT

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Executive Summary

In 2017, the Oregon Department of Energy, recognizing that the energy world has changed dramatically since the 1970s, introduced House Bill 2343 to the Legislature. The bill charged the department with developing a new Biennial Energy Report to inform local, state, regional, and federal energy policy development and energy planning and investments. The Oregon Department of Energy released reports in 2018 and 2020, which are available online: https://www.oregon.gov/energy/Data-and-Reports/Pages/Biennial-Energy-Report.aspx. This 2022 report – based on analysis of data and information collected and compiled by the Oregon Department of Energy – provides data and information on key energy resources, policies, trends, and forecasts, and what they mean for Oregon.

What You Can Expect to See in the 2022 Biennial Energy Report

The 2022 report is divided into several sections, walking through how Oregon is on the path to a cleaner, low-carbon future. Data and examples included in the report illustrate the many considerations and investments in new energy resources, system-wide planning, and responsible management. These efforts have positioned Oregon to successfully tackle today's energy challenges and needs, which are driven by a changing energy landscape bolstered by new statewide clean energy policies – and by Oregonians embracing cleaner energy, economic innovation, and emerging technologies.

The report begins by looking at **Energy by the Numbers** – detailed information on how energy flows through Oregon, from production and imports to use and exports, the state's overall and sector-based energy use, energy production and generation, energy expenditures, and the strategies Oregon has employed to meet growing energy needs.

Next up is a snapshot of the **Timeline of Energy History in Oregon**. This year, the Oregon Department of Energy developed the timeline into an online, interactive tool that provides an insightful and informative journey through Oregon's energy history and present. Photos, videos, and audio clips accompany the timeline events. View the history timeline online: https://energyinfo.oregon.gov/timeline

The **Resource and Technology Reviews** section covers the spectrum of traditional and innovative energy resources and technologies, from the basics about electricity generation to energy efficient building technologies and transportation fuels. The topics covered are some of the foundational elements of energy's landscape.

The **Energy 101** section aims to help readers understand the basics about how energy systems are planned and managed, along with innovative actions within communities and sectors. This information is meant to provide a foundation for those new to energy and those who are already steeped in the sector. Topics this year range from safety and resilience to resource planning and actions addressing climate change.

The final section includes more detailed **Policy Briefs** that dive into how Oregon could accelerate the transition to a clean energy future, a case study on the Oregon Clean Energy Opportunity Campaign that helped the state pass bold new clean energy policies and targets, workforce and supply chain challenges, and more. The primary purpose of the report – and these policy briefs – is to inform energy policy development, energy planning and energy investments, and to identify opportunities to further Oregon's energy policies.

The Biennial Energy Report wraps up with an overarching **Recommendation** that emerged as we analyzed the numbers, reviewed and researched existing and new technologies, and explored clean energy policies: *Oregon would benefit from a strong statewide energy strategy to align policy development, regulations, financial investments, and technical assistance*. A strong strategy, if done right, would optimize pathways to meet our clean energy goals, prioritize equity, balance tradeoffs, maximize benefits and minimize harms, and ultimately be used to make informed decisions and take action.

ODOE looks forward to sharing this report with Oregonians across the state to share lessons learned and hear feedback about what the agency should focus on over the next two years – and beyond.

The Biennial Energy Report may be found in its entirety at

https://energyinfo.oregon.gov/ber

or

https://www.oregon.gov/energy/Data-and-Reports/Pages/Biennial-Energy-Report.aspx

The Department of Energy welcomes comments, questions, and requests for presentations or webinars on report topics. Visit https://odoe.powerappsportals.us/en-US/ber-comment/.

LETTER FROM GOVERNOR BROWN

In my first *State of the State* address after being sworn in as Governor in 2015, I remarked that Oregon's way of life was being threatened by climate change. Six years later, the need to address the climate crisis is even more urgent. Our state has been ravaged in recent years by damaging floods, record ice storms, extreme heat waves, and devastating wildfires. Instead of these events feeling unexpected or unusual, they now feel like the new normal.

What is different? How we are responding. We've adopted landmark clean fuels legislation to improve air quality and reduce Oregon's carbon footprint. I issued executive orders to bolster electric vehicle adoption and improve energy efficiency in our built environment, and to direct state agencies to take actions to reduce and regulate harmful greenhouse gas emissions. In 2021, Oregon passed legislation that requires our largest electric utilities to provide 100 percent clean electricity to their customers by 2040. In 2022, Oregon's Climate Protection Program set a declining limit on greenhouse gas emissions from fossil fuels used throughout Oregon – which will reduce emissions over time while containing costs and promoting equity among Oregon's diverse communities.

We're already seeing results. Today, Oregon has more than 50,000 electric vehicles on our roads and our electricity mix is getting cleaner. The Oregon Global Warming Commission announced that thanks to Oregon's bold new policies, our 2035 greenhouse gas reduction goal is now within reach.

While we're on a better path, there is still much work to be done. As you'll see in the pages of this Oregon Department of Energy report, the transportation and energy sectors remain the largest contributors to the state's greenhouse gas emissions – but they are also evolving. New opportunities and technologies are emerging that could boost renewable electricity running through our transmission lines and reshape how Oregonians travel and move goods across the state.

I hope my successor in the Governor's office, my colleagues in the State Legislature, and my fellow Oregonians use this report – and the ODOE professionals who developed it – to better understand Oregon's current energy profile, outlook, and potential future. I encourage you to dive into the resource and technology reviews, energy 101s, and policy briefs on topics like energy storage, backup power, transportation fuels, energy efficiency, and more. Assess opportunities for Oregon's agricultural sector and review what drives energy costs for consumers.

Each of us can make a difference in meeting Oregon's climate goals. I encourage you to use the information in this report to make smart energy decisions for your home or business and for our state. Let's continue to move forward and forge a better path for the next generation of Oregonians. There is no time to waste.

Kate Brown

Governor Kate Brown

LETTER FROM ODOE'S DIRECTOR

Two years ago, when the Oregon Department of Energy last published this report, we featured a new energy history timeline to illustrate how historical events have shaped Oregon's energy landscape – and how Oregon's energy landscape has shaped history. As a former history major, it was my favorite addition to the report. In introducing the timeline in 2020, we asked, "What will be added by the time we publish the *2022 Biennial Energy Report*?"

As it turns out, a lot. The last two years have brought significant changes to energy in Oregon. The state's only coal-fired power plant was demolished. We celebrated reaching more than 50,000 electric vehicles on Oregon's roads – a 50-fold increase in just over a decade. ODOE launched new financial incentive programs for community renewable energy projects and energy efficient wildfire recovery. Portland General Electric's Wheatridge facilities – a first-of-its-kind set of energy facilities combining solar, wind, and battery storage – began operating in Morrow and Umatilla counties. Boardman-to-Hemingway, a 300-mile, 500-kilovolt transmission line, was approved by the Energy Facility Siting Council. NW Natural began pursuing contracts with renewable natural gas producers to add to the company's supply. The Oregon Department of Environmental Quality's Climate Protection Program launched, which sets a declining limit/cap on greenhouse gas emissions from fossil fuels used throughout the state. The Oregon Legislature passed House Bill 2021, a landmark bill that not only set one of the fastest timelines for emissions-free electricity in the country (100 percent clean by 2040 for most of the state's electricity), but also centers communities of color and rural, coastal, and low-income communities in the transition to clean energy.

There is no doubt that we are making history and moving toward a clean energy future. In July, the Oregon Global Warming Commission shared a new analysis that shows the state's greenhouse gas reduction goal is within reach, thanks to the state's bold energy and climate change policy advances. If Oregon successfully implements our policies, like HB 2021 and the Climate Protection Program, we could reach our goal of reducing emissions to at least 45 percent below 1990 levels by 2035.

It's amazing news, but getting there won't be easy. As Oregon makes this progress, it is essential that the clean energy transition moves forward in an equitable and affordable way – a way that doesn't leave Oregonians behind. In developing the 2022 report, an overarching recommendation emerged as we analyzed the numbers, reviewed and researched existing and new technologies, and explored clean energy policies: **Oregon would benefit from a strong statewide energy strategy** to align policy development, regulations, financial investments, community needs, and technical assistance. A strong strategy, if done right, would optimize pathways and leverage local solutions to meet our clean energy goals, prioritize equity, balance tradeoffs, maximize benefits and minimize harms, and ultimately be used to make informed decisions and take action. The Oregon Department of Energy ready to collaborate and make that energy strategy a reality.

In service of our mission, we provide a venue for problem-solving Oregon's energy challenges, and we act as a central repository for energy data, information, and analysis (or as Senator Lee Beyer once dubbed us: a Think Tank). We're proud to serve in this role – and to produce this biennial report to help keep Oregon on the leading edge of energy policies, technologies, and trends.

Within these pages, we hope elected officials, policymakers, advocates, and other Oregonians find useful information that builds on the foundation of our past reports. Once again, we begin with Energy by the Numbers – a section that lays out trends and indicators on where we are today in Oregon's energy landscape. Next, the energy history timeline provides important context (in a multi-media, interactive way) on how Oregon's energy systems, actions, and policies have evolved over time. Then our collection of Energy 101s, Resource and Technology Reviews, and Policy Briefs dive into more specific topics – including safety, resilience, energy efficiency, clean energy, and more.

In addition to this 2022 report, the Oregon Department of Energy has been building a digital reference library. In 2021, we published our inaugural Biennial Zero Emission Vehicle Report, which looks at data, trends, and challenges of electric and zero emission vehicle adoption in Oregon. We've also published studies identifying the opportunities, challenges, and barriers of emerging energy topics: potential formation of a Regional Transmission Organization in Oregon; integration of floating offshore wind facilities into the grid; and small-scale and community-based renewable energy projects. We'll also publish a study later this year on the potential benefits and barriers of production and use of renewable hydrogen in the state.

So dive in! We hope you use this information to engage in collaborative discussions and weigh options for addressing the energy challenges we face today – in our homes, farms, and businesses, and the way we travel. Reach out to the Oregon Department of Energy anytime to have a conversation, explore solutions, or request a workshop or presentation on an energy topic for your organization or community.

Together, we will continue forging the path to a safe, equitable, clean, and sustainable energy future.

Director Janine Benner
Oregon Department of Energy

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

Our Mission

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

Our Values

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

Our Position

On behalf of Oregonians across the state, we achieve our 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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ENERGY BY THE NUMBERS

Energy by the Numbers focuses on the metrics and data available to track how Oregon produces, purchases, and uses various types of energy.

This section includes energy use data on electricity, transportation energy, and direct fuels by resource and by sector. Where possible, data showing how Oregon's energy system has changed over time have been included to provide context and history. We also discuss energy production — where and what kind of energy Oregon produces, where and how we generate electricity, and what direct use and transportation fuels are produced in state.

Readers will find data on what Oregon spends on energy, how some Oregonians experience energy burden, and what the energy industry gives back to Oregon in terms of jobs. The section also demonstrates how energy efficiency continues to serve as an important resource for Oregon. It concludes with highlights on the four end use sectors: residential, commercial, industrial, and transportation, including energy use, expenditures, and GHG emissions – and how each sector uses energy to provide goods and services.

Trends and What's New:

- Oregon has vast energy efficiency potential, but the region hasn't been meeting the Northwest Power and Conservation Council's Power Plan goals for savings in electricity.
- Oregon exports more than half the wind power and over a third of the hydropower the state generates.
- Oregonians used less gasoline and jet fuel over the last two years but saw a small uptick in diesel use. Analysis indicates this is due to less personal travel during the COVID-19 pandemic and an increase in the delivery of goods.
- Oregonians spent less on energy in 2020 than in 2018. The variability in what we spend on energy is driven primarily by transportation fuel costs, which sees the largest swings in price.

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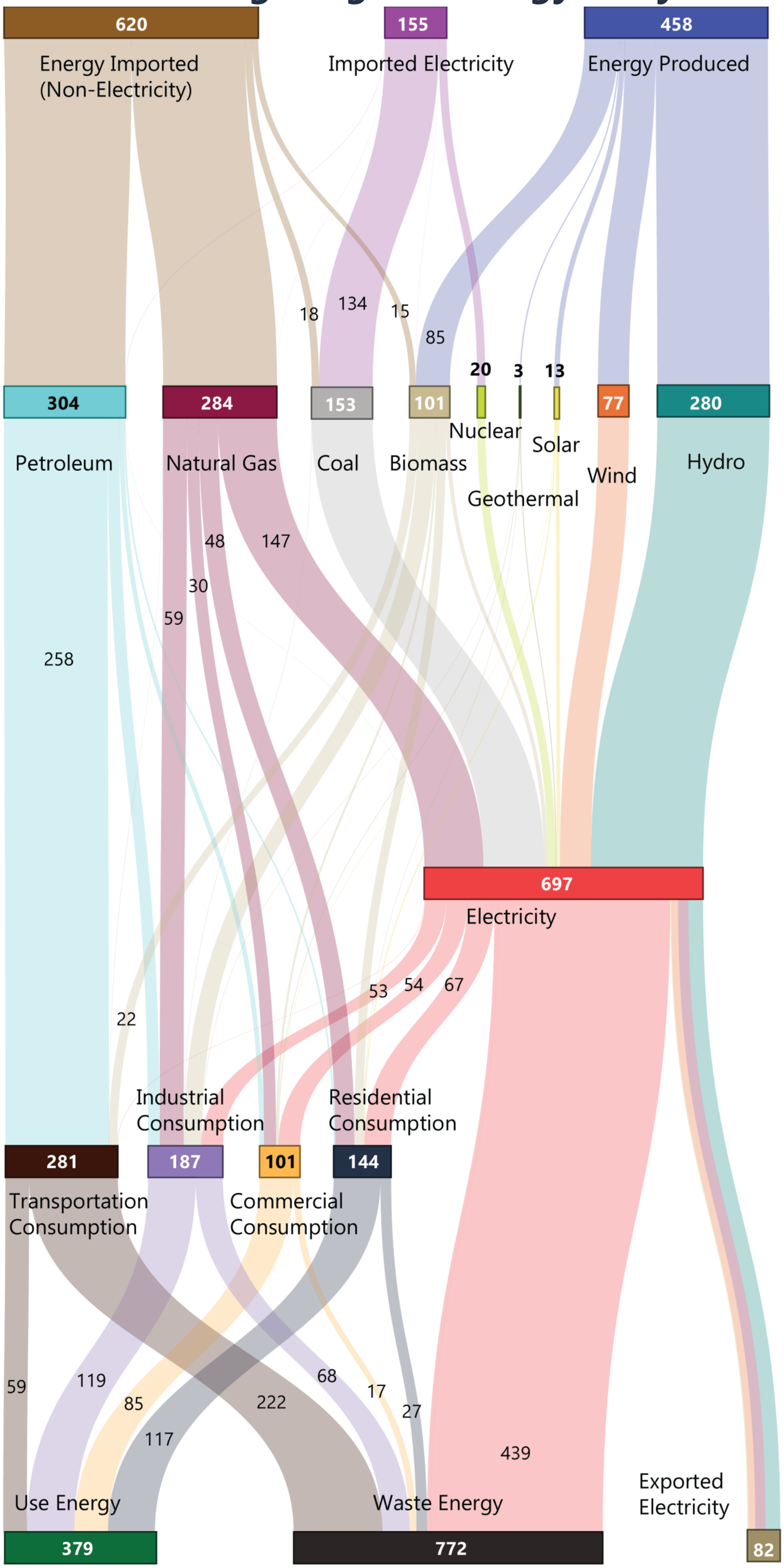
Understanding Oregon's Energy Story



Numbers represent trillions of Btu of energy.

Oregon's energy story has evolved over time to include new technologies, address changes in the availability of different generation resources, and to meet state energy goals. The Pacific Northwest has a long history of using hydropower resources, but 20 years ago, solar- and wind-generated energy was scarce.

Today, Oregon's energy resources are more diverse. In the chart at left, start at the top to see imported energy and energy produced in Oregon. **The numbers represent trillions of Btu of energy.** The energy lines flow through to show the different types of resources we use – including the energy we produce in Oregon and what we import as direct fuels or electricity – and where they end up in Oregon's energy story. The energy we produce and import helps meet various needs, from in-state electricity generation to transportation fuels to the natural gas and electricity that supply homes and businesses. Some energy ultimately goes unused due to system inefficiencies, and some is exported to other states.

Btu A **British Thermal Unit** is a measurement of the heat content of fuels or energy sources. Btu offers a common unit of measurement that can be used to count and compare different energy sources or fuels. Fuels are converted from physical units of measurement, such as weight or volume, into Btu to more easily evaluate data and show changes over time.

The chart provides a macro level look at the energy Oregonians produce, import, consume, and export. **Energy Produced** includes forms of energy that Oregon produces in-state, such as hydroelectric, wind, and biomass energy. **Electricity Imports** includes electricity that is generated in other states and brought in for use in Oregon. **Energy (non-electric) Imports** includes the other forms of energy brought into the state for various uses, such as gas to power transportation and fuels to heat Oregon homes.

The flow to **Waste Energy** includes all the energy that is not harnessed, from the point of extraction to the point of use. This includes energy lost as heat during combustion or transformation into electricity, transmission losses, and many other factors.[i]

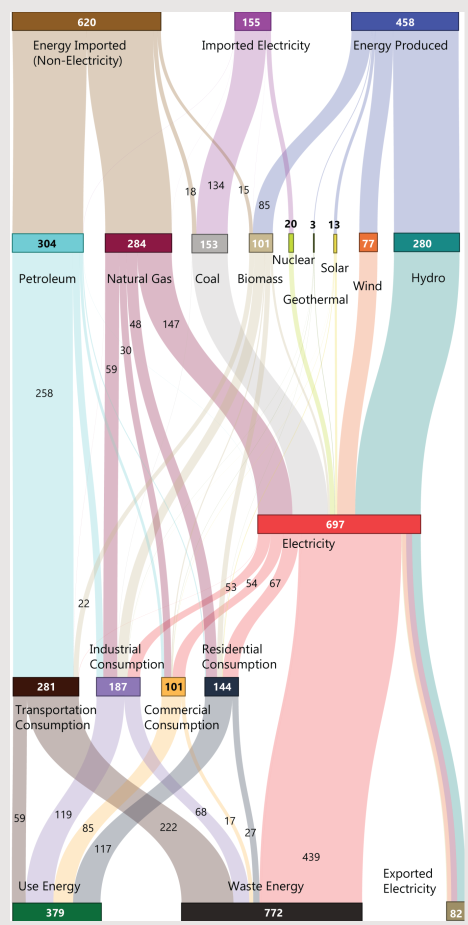
The coronavirus pandemic has affected many aspects of life in Oregon, including how Oregonians use energy. Between 2018 and 2020, the residential and commercial sectors experienced shifts in energy consumption. **Residential** sector energy increased from 141 to 144 trillion Btu, while **commercial** sector energy decreased from 104 to 101 trillion Btu as more people stayed home and many businesses shifted operations to adjust to the pandemic. Meanwhile, **industrial** sector energy consumption increased from 178 to 187 trillion Btu. **Transportation** energy consumption experienced the largest change, decreasing from 316 trillion Btu in 2018 to 281 trillion Btu in 2020, likely due to factors such as increased telecommuting and fewer travel opportunities.

Changes in the Energy Flow Chart Methodology and Design

In this report, Imported Electricity is illustrated as a separate energy flow. This change was made to show more clearly how electricity moves from generation to use (or waste). In the *2020 Biennial Energy Report,* energy related to imported electricity was grouped together with other energy types and labeled as Energy Imported.

Sector-based end-use efficiency estimates for non-electric energy have been updated to match the methodology used by Lawrence Livermore National Laboratory in its development of similar energy flow diagrams.[2] This report uses an end-use efficiency of 65 percent for the residential and commercial sectors, 49 percent for the industrial sector, and 21 percent for the transportation sector.

The electrical system losses associated with exported electricity are now included throughout the energy flows.



[i] Electrical system losses for various generation sources are estimated using methods that match with those used by the United States Energy Information Administration.[1]

Energy Sources Used in Oregon

Solar. Photovoltaic technology converts energy radiating from the sun into electricity. Solar systems are located on homes, businesses, and large utility-scale arrays. From 2012 to 2020, solar generation in Oregon increased from 6,400 megawatt-hours to over 1 million MWh.[3]

Nuclear. Generated electricity from a nuclear reactor where thermal energy is released from the fission of nuclear fuel. Oregon's nuclear power comes from the Columbia Generating Station in Washington State, and the electricity produced is marketed by the Bonneville Power Administration.

Hydropower. Electricity generation harnessed from the flow of water through dams. Oregon has 105 hydropower facilities of varying size, including four federal facilities on the Columbia River that span the Oregon and Washington border, and two facilities that span the Oregon and Idaho border.

Wind. Generation of electricity by the force of wind turning turbines. As of 2020, Oregon has 54 operating facilities in the state with a total capacity of 4,203 MW.[3]

Geothermal. Energy extracted from hot water or steam from natural underground sources can be used for water/space heating or the generation of electricity. Oregon has two geothermal electric generation facilities with a capacity of 24 MW.[3]

Natural gas. Fossil fuel extracted from beneath the earth's surface. Oregon has a single natural gas field located in Mist. Oregon imports most of the natural gas it consumes for electricity and as a direct fuel. There are 13 natural gas electricity generation facilities with a combined capacity of 4,354 MW.[3] Natural gas is used directly for residential, commercial, industrial and transportation uses.

Coal. Combustible rock is burned for industrial processes and to create electricity. Oregon had one coal-fired power plant, the 575-MW Boardman facility, which closed in October 2020 and was demolished in September 2022.[4] The state also imports coal-generated electricity from neighboring states.

Biomass. Includes all renewable biogas and biofuels derived from the energy of plants and animals. Wood and wood waste is Oregon's greatest source of biomass, which is used for space heating, cooking, electricity generation, and transportation. Oregon has 11 biomass and 30 biogas operating facilities converting waste products to electricity.[3] Oregon also produces plant-derived ethanol fuel and biodiesel from used cooking oil to be used as transportation fuels.

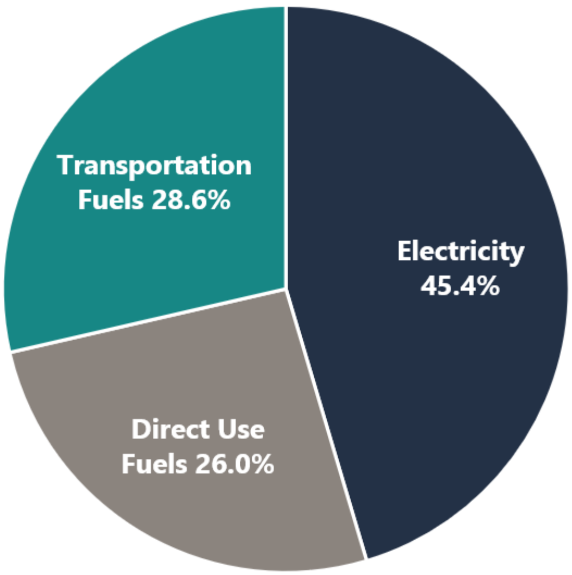
Petroleum. Fossil fuel extracted from beneath the earth's crust that includes gasoline, diesel, heating oil, lubricants, and other fuels we use for space heating, industrial equipment, and transportation. Oregon imports the petroleum that it uses.

Energy Use in Oregon

Consumption by Source

Oregon relies on energy from a variety of resources. We import energy like gasoline, natural gas, propane, and other fuels. We use electricity from both in- and out-of-state sources—including coal, natural gas, nuclear, hydropower, wind, and other renewable resources.[1]

For this introduction to Oregon's energy use, the report sorts energy into three main categories:



45.4%

of Oregon's 2020 energy consumption[2]

Electricity: this is where most people begin when thinking about energy—the critical resource that powers our day-to-day lives. The electricity Oregonians use comes from facilities across the western United States and in Oregon. This percentage also accounts for the energy in fuels that come from out of state, such as natural gas, but generate electricity in-state, as well as the energy losses associated with electricity generation.

26.0%

of Oregon's 2020 energy consumption[2]

Direct Use Fuels: this category includes fuel oil and natural gas used to heat homes and commercial spaces, fuels used for other residential purposes, such as gas stoves, solar thermal heating, and fuels used directly in industrial processes.

28.6%

of Oregon's 2020 energy consumption[2]

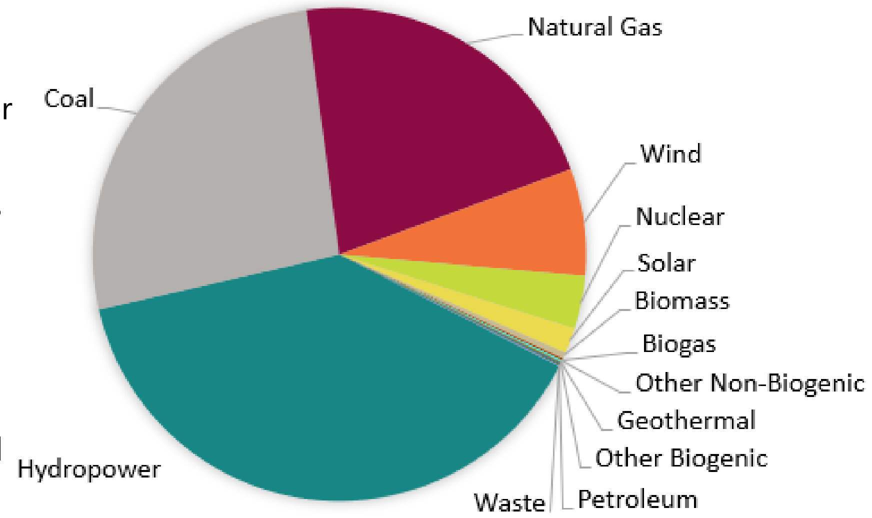
Transportation Fuels: this includes personal, passenger, and commercial vehicles, both on and off the roads, plus airplanes, boats, barges, ships, and trains. Nearly all transportation-related sources of energy are imported from out of state for in-state use.

Electricity

45.4%

of Oregon's 2020 energy consumption

38.9%	Hydropower
26.5%	Coal
21.5%	Natural Gas
7.0%	Wind
3.5%	Nuclear
1.7%	Solar
0.4%	Biomass
0.1%	Geothermal
0.1%	Biogas

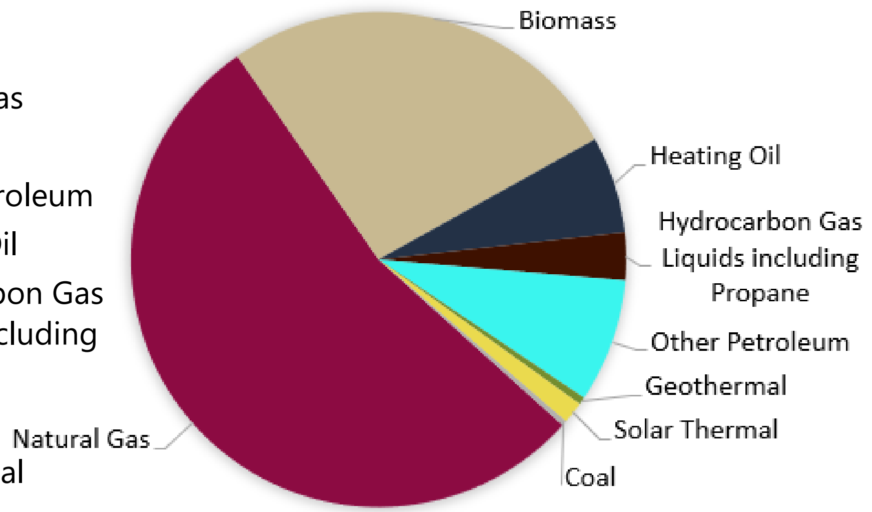


Direct Use Fuels

26.0%

of Oregon's 2020 energy consumption

53.7%	Natural Gas
26.6%	Biomass
8.1%	Other Petroleum
6.3%	Heating Oil
3.1%	Hydrocarbon Gas Liquids Including Propane
0.3%	Coal
0.5%	Geothermal

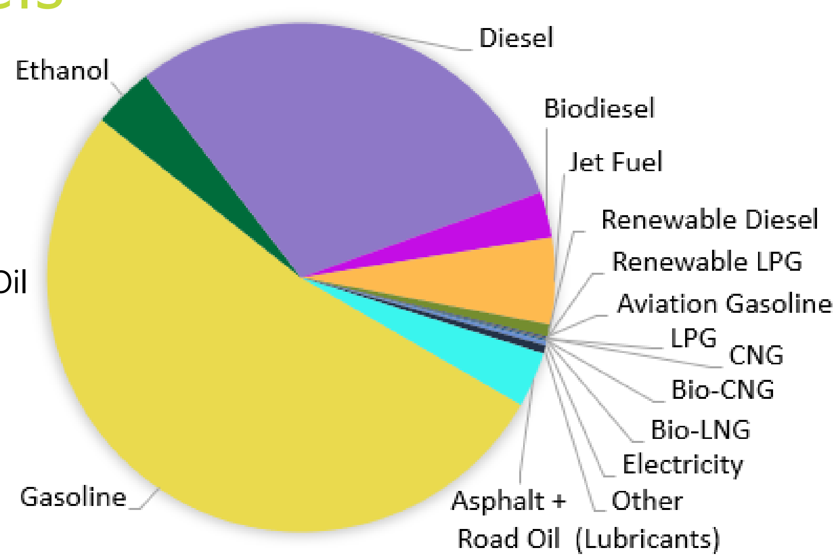


Transportation Fuels

28.6%

of Oregon's 2020 energy consumption

52.3%	Gasoline
30.0%	Diesel
5.5%	Jet Fuel
3.9%	Ethanol
3.5%	Asphalt/Road Oil
2.9%	Biodiesel
0.5%	Lubricants
0.1%	Aviation Gas
0.3%	Electricity



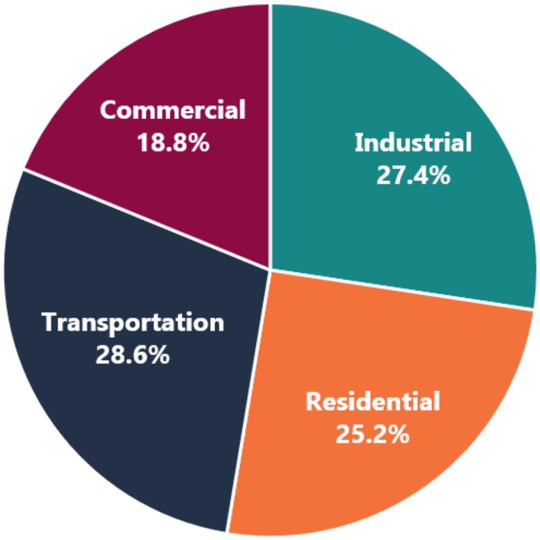
Note to readers: *Fuel percentages are rounded to the nearest tenth and not all are listed.*

Energy Use in Oregon

Consumption by Sector

Energy consumption is also tracked by how it is used among four main end-use sectors: Residential, Commercial, Transportation, and Industrial.

In Oregon in 2020, those four sectors combined consumed 983 trillion Btu of energy,[2] [3] including each sector's respective share of electrical system losses,[i] as discussed earlier in *Understanding Oregon's Energy Story.*



25.2% of Oregon's 2020 energy consumption[2]

Residential: this category includes single family, multi-family, and manufactured homes for Oregonians. Energy is used for lighting, to heat and cool living space, cooking, and appliances. Electricity is the most used energy resource in homes – with heat pumps, electric furnaces, and electric resistance heaters as examples of primary electric heat options.

18.8% of Oregon's 2020 energy consumption[2]

Commercial: this category includes businesses that provide goods and services, government and office buildings, grocery stores, and shopping malls. Energy is used to heat and cool spaces, power equipment, and illuminate facilities. It is Oregon's smallest energy-consuming sector, supported by the adoption of advanced energy codes, energy efficiency programs, and advancements in equipment and processes.

27.4% of Oregon's 2020 energy consumption[2]

Industrial: this category includes facilities used to produce, process, and manufacture products – including agriculture, fishing, forestry, manufacturing equipment, mining, and energy production. Energy powers industrial equipment and machinery to manufacture products. This sector has seen contractions in aluminum, forestry, and manufacturing – with improvements in efficiency of industrial facilities and equipment.

28.6% of Oregon's 2020 energy consumption[2]

Transportation: Personal cars, fleets, shipments, airline travel, and more make up Oregon's transportation energy use. Petroleum is the most used resource and the largest contributor of greenhouse gas emissions in Oregon. Alternative fuels like electricity and biofuels are a growing part of this sector.

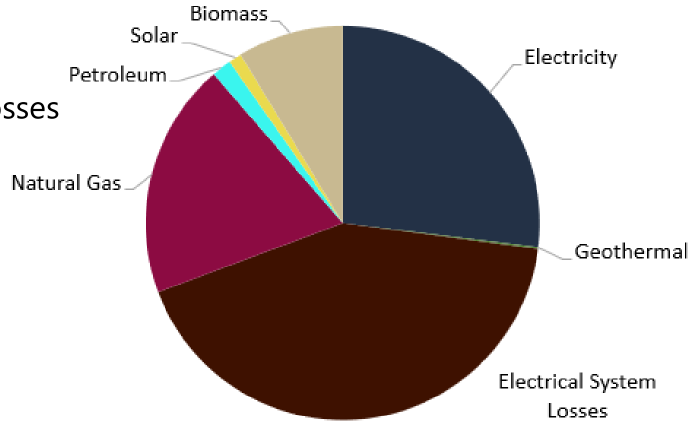
[i] Electricity generation and transmission result in energy losses that are estimated and included in EIA consumption data. Electrical system energy losses account for the amount of energy lost during generation, transmission, and distribution of electricity.

Residential

25.2%

of Oregon's 2020 energy consumption

42.2%	Electrical System Losses
26.9%	Electricity
19.3%	Natural Gas
8.7%	Biomass
1.6%	Petroleum
1.1%	Solar
0.2%	Geothermal

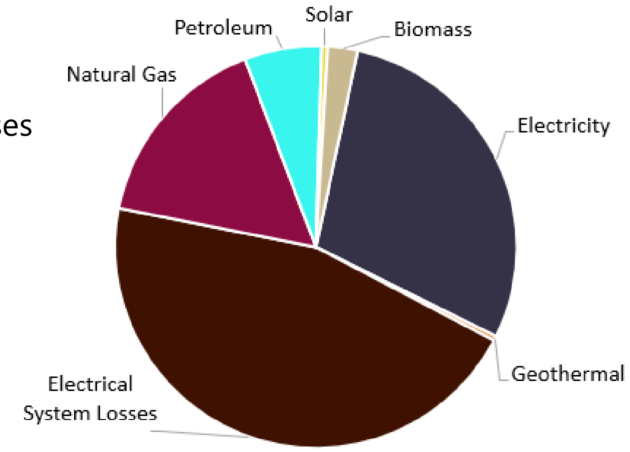


Commercial

18.8%

of Oregon's 2020 energy consumption

45.4%	Electrical System Losses
29.0%	Electricity
16.2%	Natural Gas
6.2%	Petroleum
2.4%	Biomass
0.4%	Geothermal
0.5%	Solar

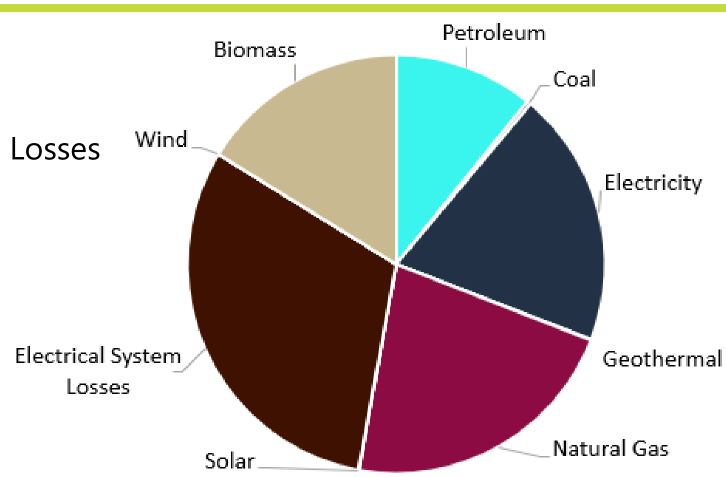


Industrial

27.4%

of Oregon's 2020 energy consumption

30.9%	Electrical System Losses
21.9%	Natural Gas
19.7%	Electricity
16.2%	Biomass
10.8%	Petroleum
0.3%	Coal
0.1%	Geothermal

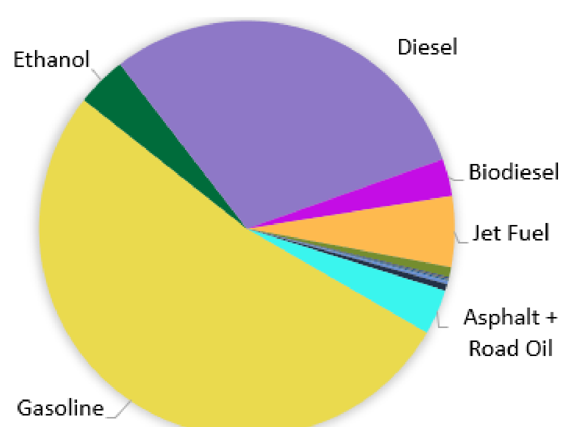


Transportation

28.6%

of Oregon's 2020 energy consumption

52.3%	Gasoline
30.0%	Diesel
5.5%	Jet Fuel
3.9%	Ethanol
3.5%	Asphalt + Road Oil
2.9%	Biodiesel



Energy Use in Oregon

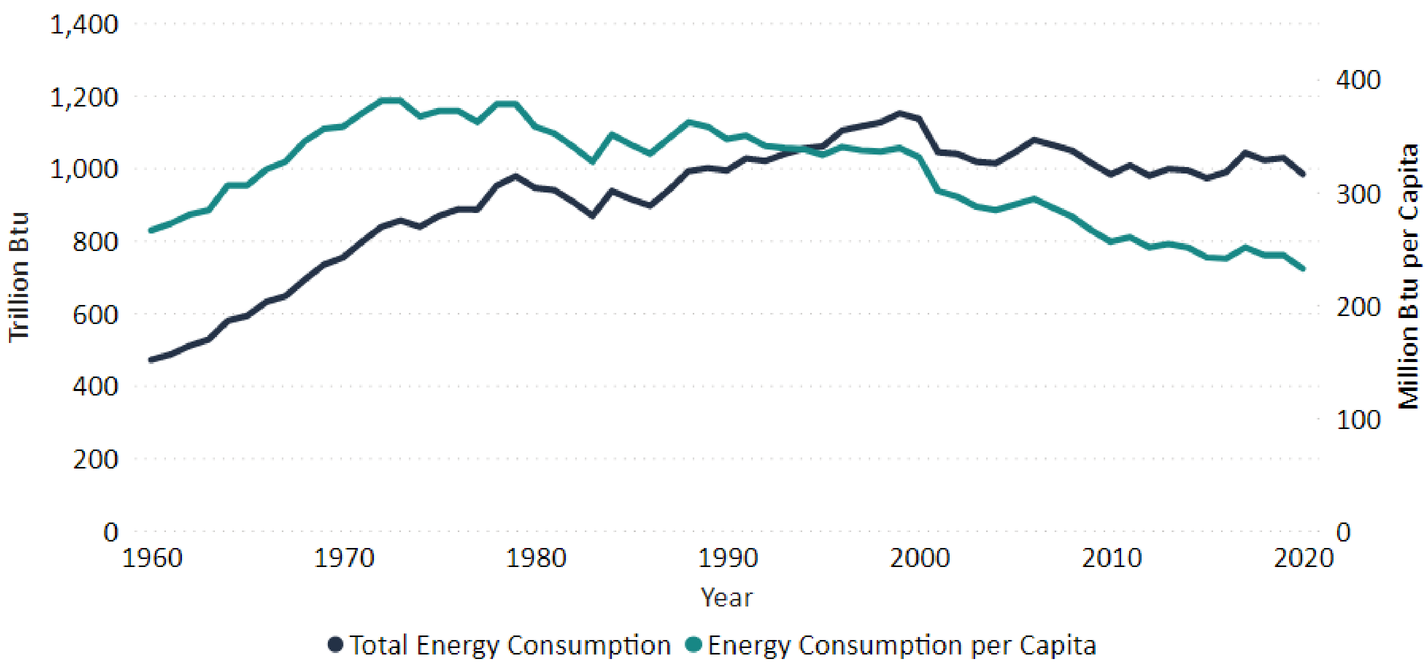
Oregon's Energy Consumption Over Time

15th

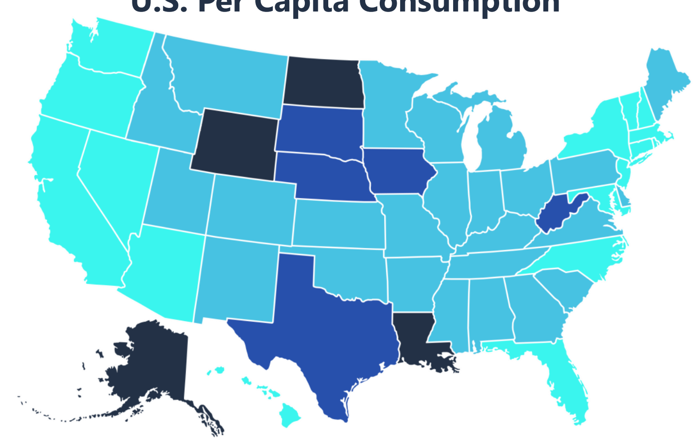
Oregon's rank for lowest per capita energy use among states in 2020.[4]

Oregon saw an overall trend of increased energy use for almost four decades—an average of 3.6 percent growth per year from 1960 to 1999.[2] During that time, the state shifted from a reliance on fuel oil and wood to an increased use of natural gas and electricity in homes and businesses. Oregon reached its highest consumption of energy in 1999 in both stationary and transportation uses. Since then, total energy use has been decreasing. The amount of energy used in Oregon declined by 13.4 percent between 2000 and 2020. Energy consumption per capita does not directly correlate with overall energy use. In the last 20 years, Oregon has had steady population increase during a period of slight decline in overall energy consumption. This translates to a steady decrease in energy consumption per capita.[2]

Oregon's Total Energy Consumption and Per Capita Energy Consumption Over Time[2]



U.S. Per Capita Consumption[4]



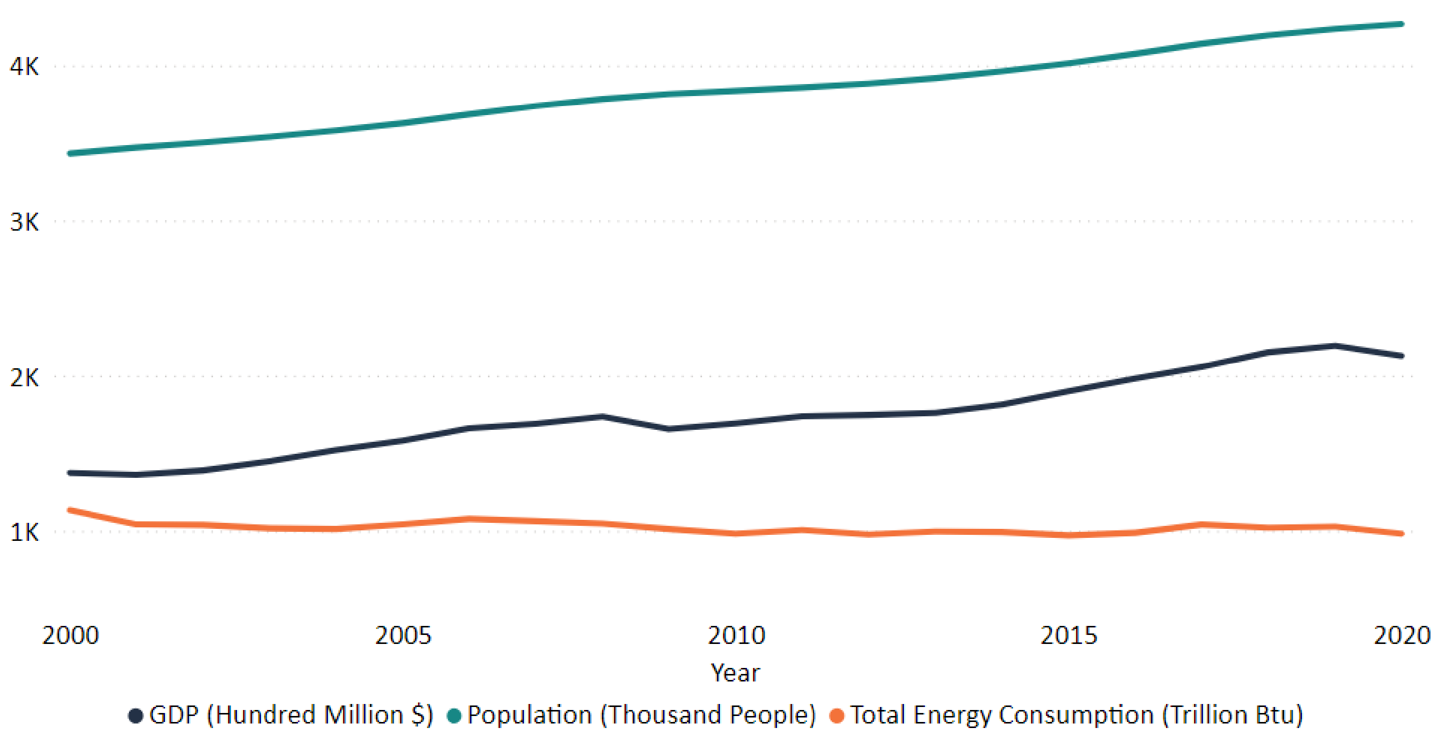
Energy Efficiency

While energy efficiency is not "consumed" like other resources, it is the second largest resource available in Oregon after hydropower. Efforts to increase energy efficiency effectively reduce overall energy consumption. Historically, Oregon has consistently met increased demand for electricity by implementing energy efficiency strategies.

Energy Consumption and Economic and Population Growth

Energy efficiency and changes in our economy have led to decreases in Oregon's total and per capita energy use over time. Oregon's emphasis on energy efficiency has helped reduce both total and per capita energy use despite an increasing population, thereby avoiding the need to build new electricity generation plants. The graph below shows that since about 2000, economic growth (measured by gross domestic product or GDP) does not correlate with increases in energy consumption. In fact, as the economy and our population have grown, our energy consumption has stayed relatively flat with a slight decline.[2]

Oregon's GDP, Population, and Energy Consumption by Year[2]



This displays all three data sets on the same axis; refer to the legend to find the units for each. This chart allows us to review the overall trends of population, energy consumption, and GDP in comparison to each other. The chart is not adjusted for inflation.

Consumption & Use

In the energy sector, *consumption* typically describes the amount of energy used. *Use* sometimes has the same meaning, but is often specifically applied when talking about the purpose of energy. For example, a home's annual electricity *consumption* goes toward a variety of *uses* like lighting, heating, and appliances. Or a furnace is *used* for heating but *consumes* electricity and natural gas. For this report, consumption and use are included in a wide variety of ways and sometimes interchangeably.

Electricity Use

Resources Used for Oregon's Electricity Mix

In 2020, Oregon used 53.7 million megawatt hours (MWh) of electricity from both in-state and out-of-state sources. Hydropower, coal, and natural gas make up the bulk of Oregon's electricity resources, commonly called the resource mix, although the share of each resource is constantly changing and evolving.

Renewable energy makes up an increasingly larger share of the mix each year. In 2021, the Oregon Legislature passed House Bill 2021, requiring Oregon's largest electric utilities, Portland General Electric and Pacific Power, to reduce greenhouse gas emissions to 80 percent below baseline emissions levels by 2030, 90 percent below by 2035, and 100 percent by 2040. The five largest sources of electricity are labeled below; the other resources not listed in the bubble chart are each under 2 percent.[1]

26%

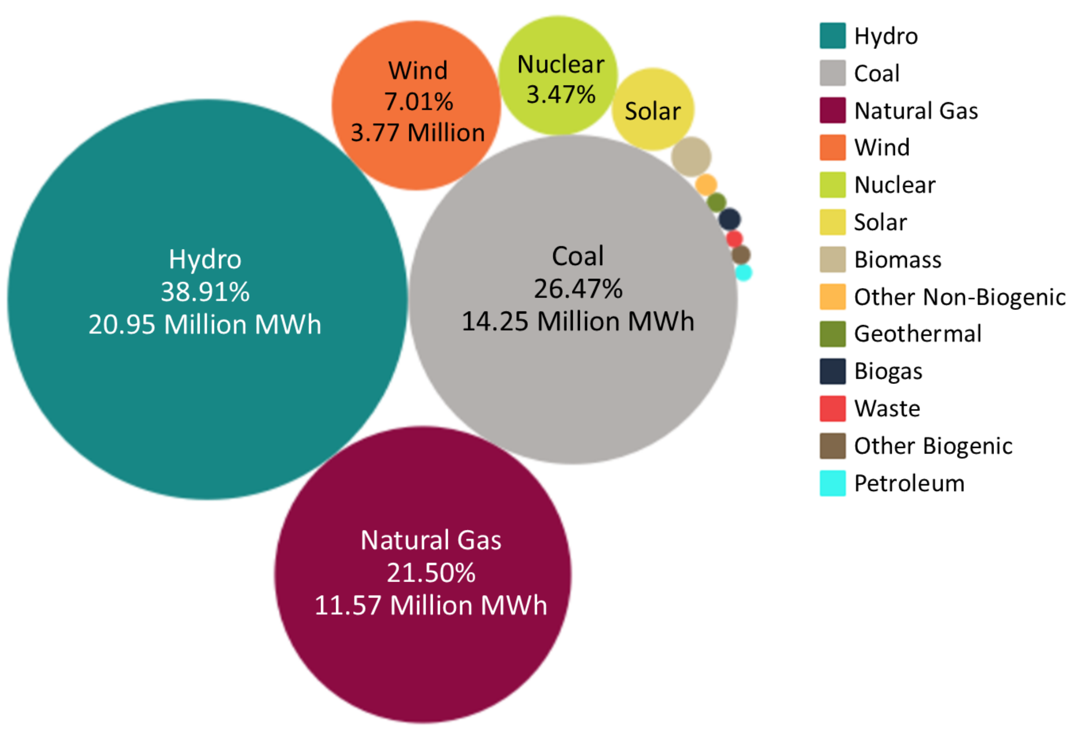
Percentage of Oregon's 2020 electricity mix that came from coal.[1]

2040

Year by which Oregon's two largest utilities and Electricity Service Suppliers will need to reduce emissions for electricity sold in the state by 100 percent below baseline emissions levels.[2]

Resources Used to Generate Oregon's Electricity[1]

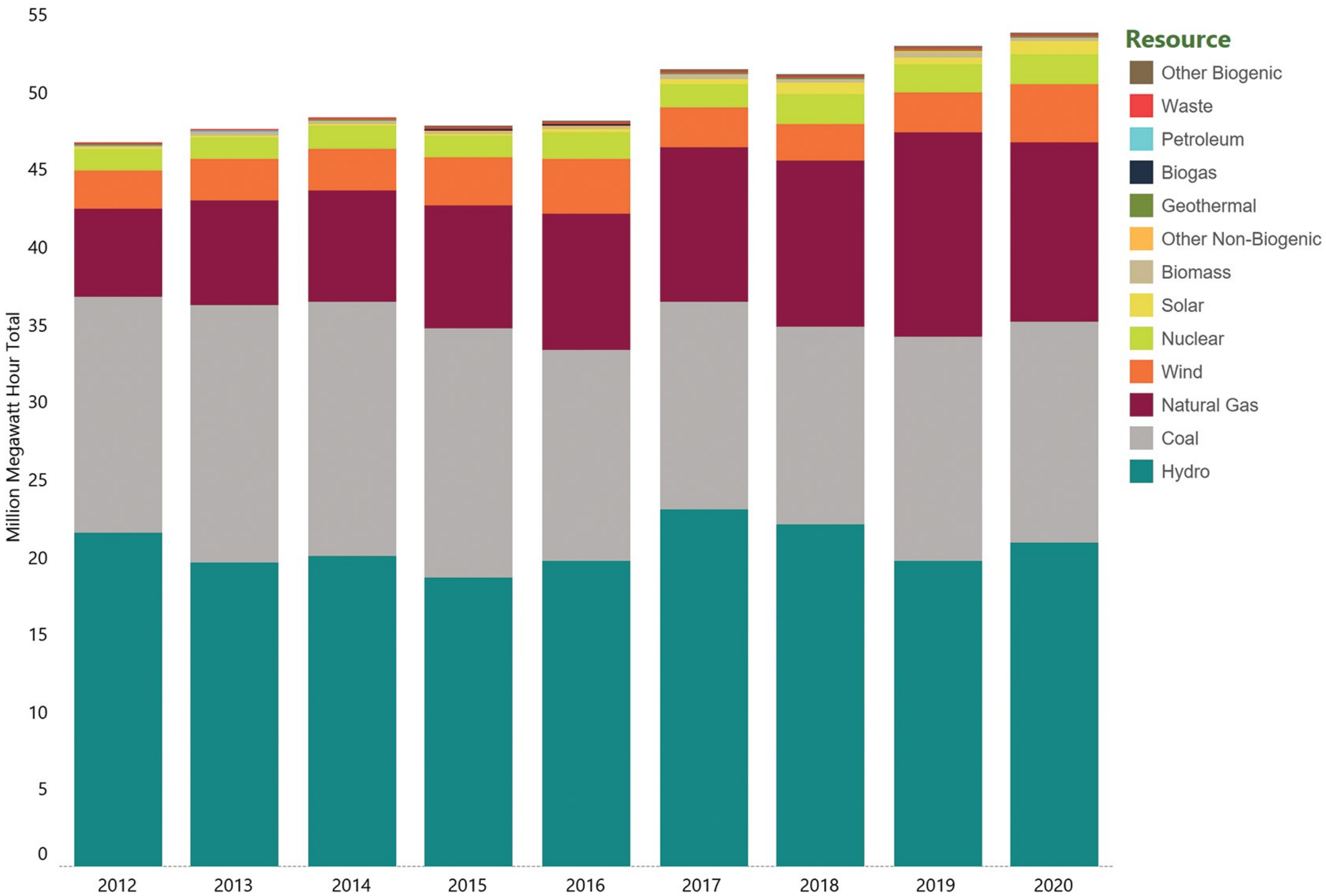
Based on 2020 data, this chart shows the energy resources used to generate the electricity that is sold to Oregon's utility customers.



Electric utilities are privately owned electric companies or consumer-owned utilities that distribute electricity to retail electricity consumers in Oregon. Oregon utilities generate their own electricity, purchase power from wholesale providers like BPA, or enter into short-term or long-term contracts to buy electricity from third-party owned power plants and the market.

Electric utilities in Oregon often generate electricity from plants they own for delivery to retail customers, and in many cases will also purchase electricity from **wholesale electricity providers**. Bonneville Power Administration is a federal power marketing administration that provides a significant amount of wholesale electricity to Oregon utilities, particularly consumer-owned utilities. Utilities also may purchase wholesale power from non-utility owned generators (Independent Power Producers) or directly from other utilities.

Oregon's Electricity Mix Over Time[1]



Oregon's electricity resource mix displays the proportion that each resource (solar, wind, hydropower, etc.) contributes to the total amount of electricity that Oregonians consume each year. The chart above presents Oregon's mix from 2012 to 2020 and shows two notable trends: First, total annual electricity consumption has increased from 47 to 53 million MWh between 2012 to 2020, driven by factors like economic and population growth and increased customer demand. Second, the percentage that each resource contributes to total electricity for Oregon consumption changes year-to-year. For example, between 2012 and 2020, coal's share of electricity consumed in Oregon steadily declined from 32 to 26 percent, while the share of natural gas increased from 12 to 21.5 percent. In the same period, hydropower's share went up and down according to annual precipitation patterns, with a high of 46 percent in 2012 and a low of 37 percent in 2019.

Fluctuations in the sources of electricity consumed in Oregon are the result of several factors, including the regional nature of energy markets, resource availability, market dynamics and utility contracts, public policy, and other factors.[1]

Hydropower availability drives year-to-year fluctuations in Oregon's electricity resource mix. Oregon and the Pacific Northwest are rich in hydropower, which is consistently a low-cost resource. In energy markets, utilities typically prioritize using the lowest cost generating resources, allowing them to meet customer demand at least cost. This often results in prioritization of hydropower, wind, and solar, which have low or zero marginal costs. These types of resources are used first when they are available, and then, if unmet customer demand remains, utilities will look to other types of units, such as natural gas power plants, to meet additional residual demand.

It is worth noting that the availability of renewable resources—such as wind, solar, and hydropower—vary over the course of a day, from season-to-season, and year-to-year based on natural cycles, weather patterns, and changing climate conditions. Utility electricity mixes include real-time supplemental market purchases of electricity that utilities make to meet demand; these purchases are called "unspecified" because the specific resources used to generate the electricity are not tracked nor accounted for in real-time.

Learn more about how Oregon's electricity generation may change as the state moves to a clean energy future in the Policy Briefs section of this report.

Learn more about Oregon's Electricity Resource Mix

The Oregon Department of Energy updates the state's electricity resource mix each year. On the agency's website, find the state's overall mix, a map of generation facilities, electricity mixes by utility, greenhouse gas emissions, and more.

www.tinyurl.com/OregonERM

Electricity Imports and Exports

Oregon is blessed with an abundance of renewable energy resources and is one of the leading producers of renewable energy in the country. This abundance is one of the reasons Oregon can export significant amounts of the renewable electricity it generates — particularly from hydropower.

Oregon imports all its petroleum and coal, and almost all of the natural gas fuels used to generate electricity at in-state facilities. Oregon does not have any coal mines and only extracts small amounts of natural gas at one facility in Oregon.

Oregon also imports electricity from all over the western U.S.; this imported electricity comes from various resources.[3]

Oregon 2020 Exports

57.0% of wind generation

34.4% of hydroelectric generation

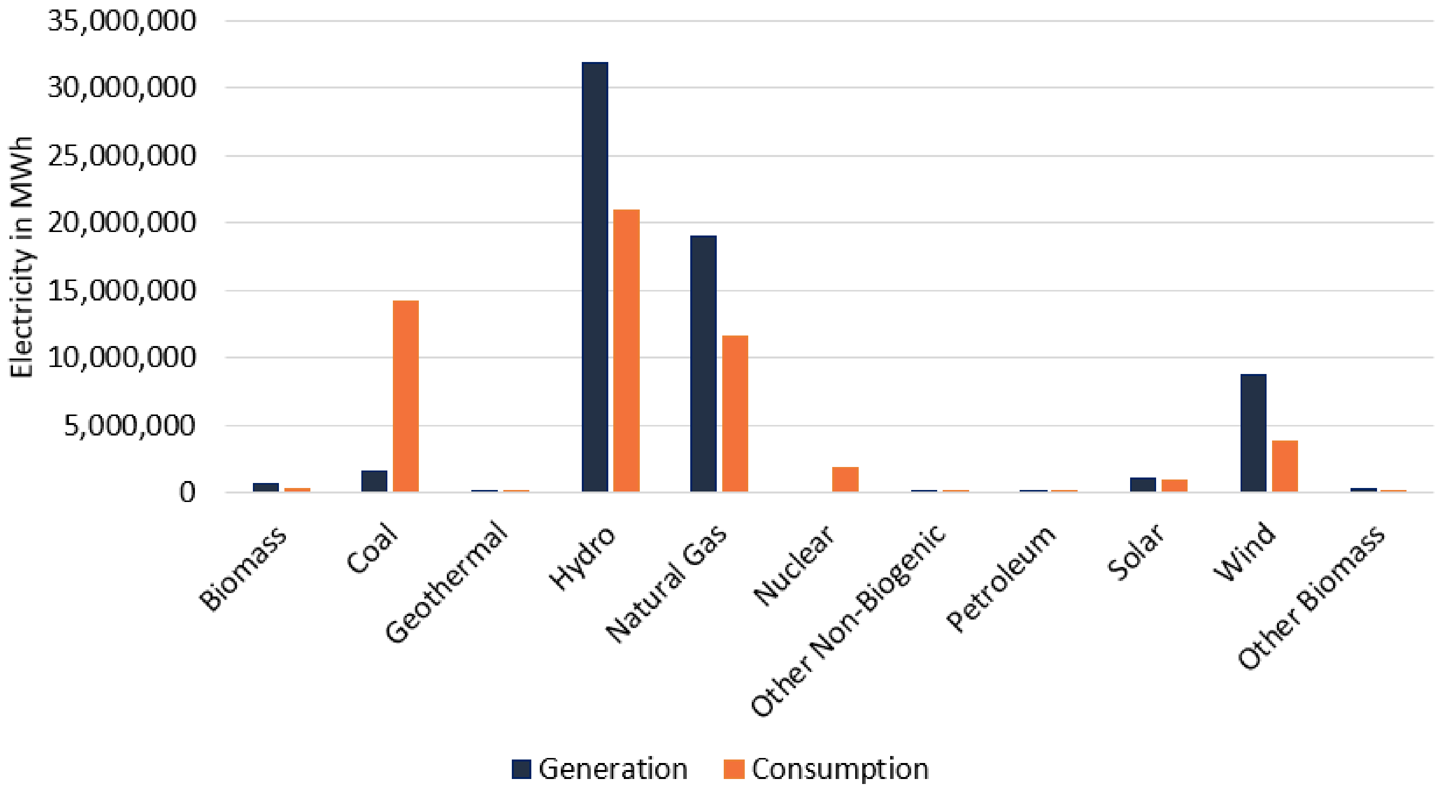
16.7% of solar generation[3]

Oregon 2020 Imports

88.6% of coal based electricity

100% of nuclear electricity

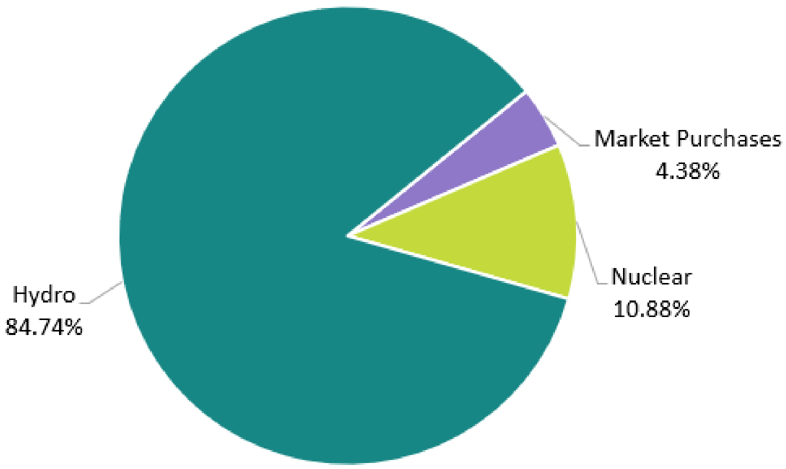
Oregon's Electricity Generation and Consumption (2020)[1 4]



Megawatt (MW): One million watts of electricity capacity—the equivalent of 1,340 horsepower, or enough power to simultaneously illuminate more than 100,000 standard 60-watt-equivalent LED lightbulbs. **Megawatt Hour (MWh):** A unit of measurement for energy output that represents the amount of energy supplied continuously by 1 MW of capacity for one hour. **Average Megawatt (aMW):** Represents 1 MW of energy delivered continuously 24 hours/day for one year, or 8,760 MWh.

Bonneville Power Administration and Market Purchases

Consumer-owned utilities in Oregon purchase most of their electricity from the Bonneville Power Administration, a federal agency that markets wholesale electric power from 31 federal hydroelectric facilities in the Northwest, a non-federal nuclear power plant, and several other small non-federal power plants. The dams generating the hydroelectric power are operated by the U.S. Army Corps of Engineers and the Bureau of Reclamation, while the nuclear facility is operated by Energy Northwest. BPA provides about 28 percent of the electricity used in the Northwest.[1]

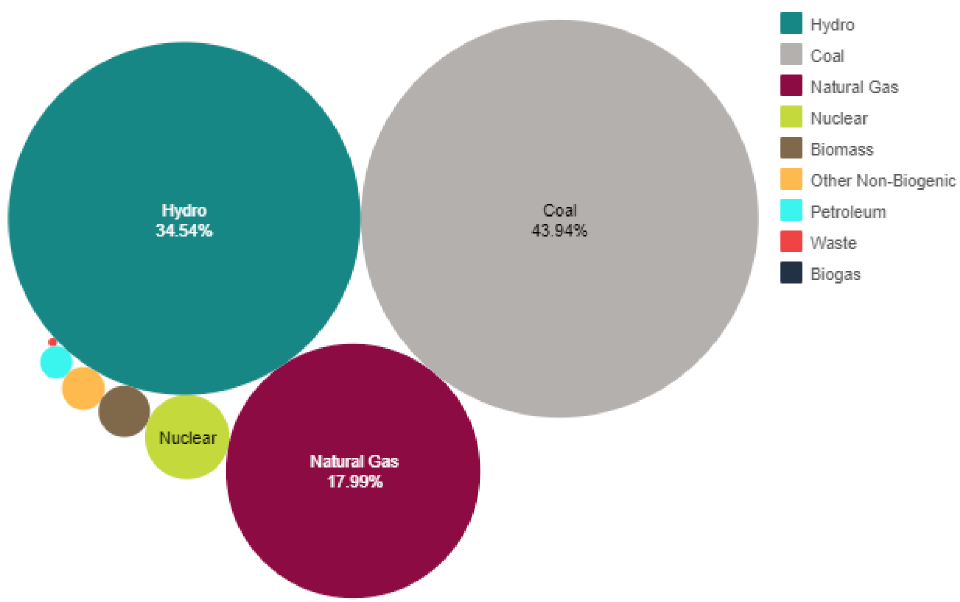


Bonneville Power Administration 2020

Oregon generation facilities sell electricity to Oregon utilities and the regional power market. Oregon electric utilities own facilities that generate power, but they also purchase power from the regional market to meet customer demand. The chart below illustrates the resources of 2020 market purchases.

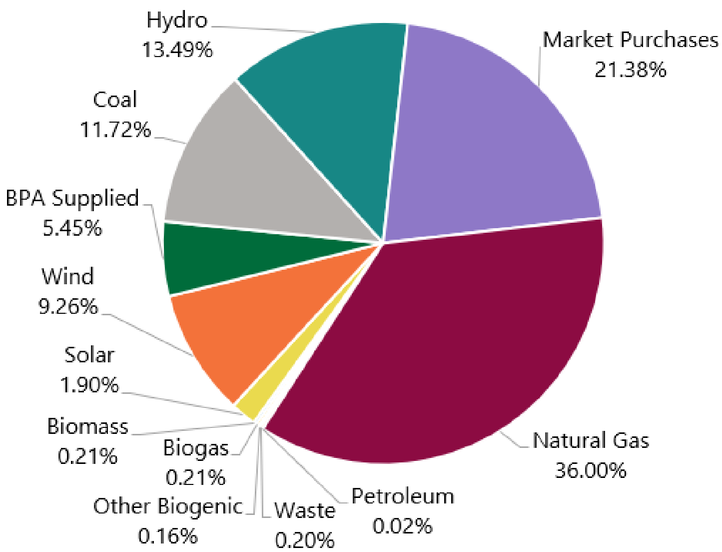
Some utilities make "unspecified" market purchases to meet demand. The utilities purchase the electricity on the power market and may not know the resource or facility that generated it. The mix shown here applies to all unspecified market purchases in Oregon, totaling 11.8 million megawatt hours in 2020.[1] This represents the annualized mix of generating resources available after all contracted use has been accounted for.

Electricity Market Purchases 2020

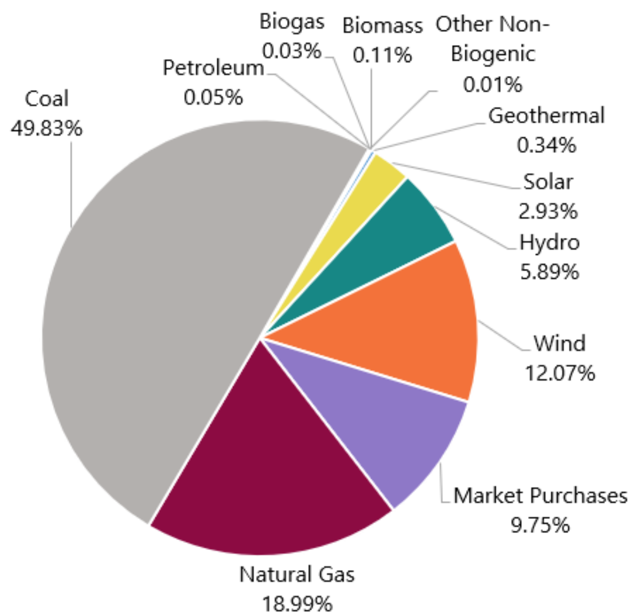


Investor-Owned Utility Resource Mix

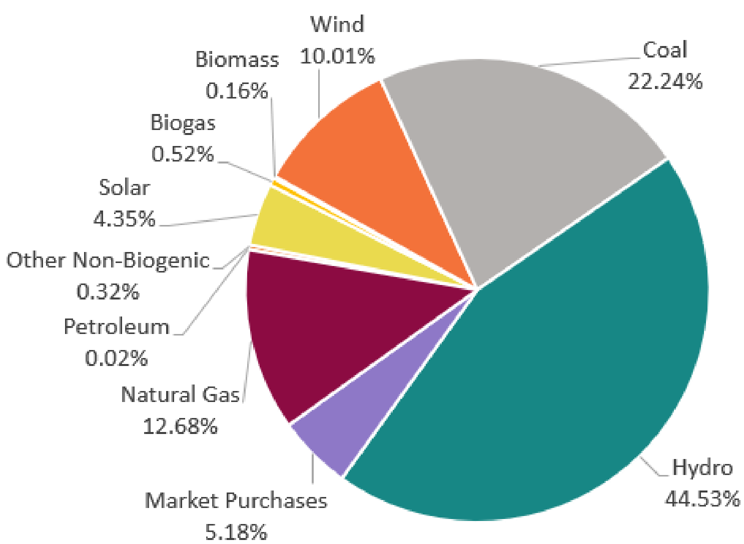
The resources utilities use to generate electricity consumed in Oregon vary depending on the utility provider. The electricity resource mixes for Oregon's three investor-owned utilities are shown below. Only 2020 data is shown for each utility; mixes will fluctuate over the years depending on the availability of certain resources like hydro or, increasingly, solar. The information below includes real-time supplemental market purchases of electricity that utilities make to meet demand.[1]



Portland General Electric 2020



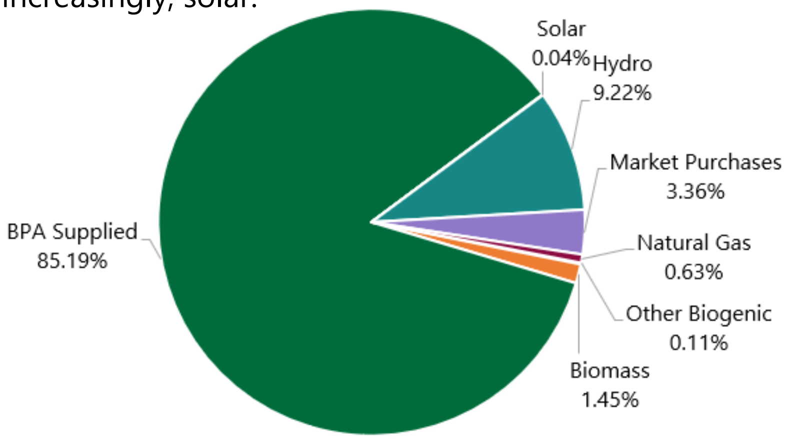
Pacific Power 2020



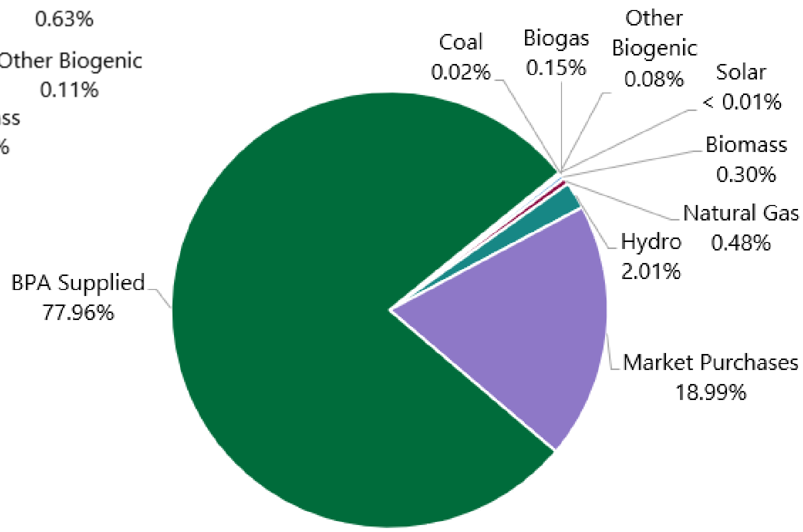
Idaho Power 2020

Consumer-Owned Utility Resource Mix

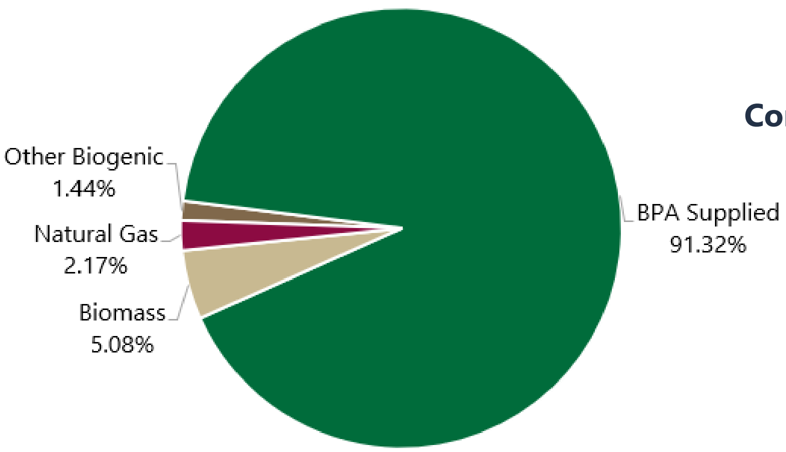
The electricity resource mixes for the Eugene Water & Electric Board (the largest consumer-owned utility by number of customers) and a composite of other COUs operating in Oregon are below. Clatskanie PUD is also included as an example. Only 2020 data is shown for the utilities; mixes fluctuate over the years depending on the availability of certain resources like hydropower or, increasingly, solar.[1]



Eugene Water & Electric Board 2020



Composite of Consumer-Owned Utilities (not including EWEB) 2020



Clatskanie PUD 2020

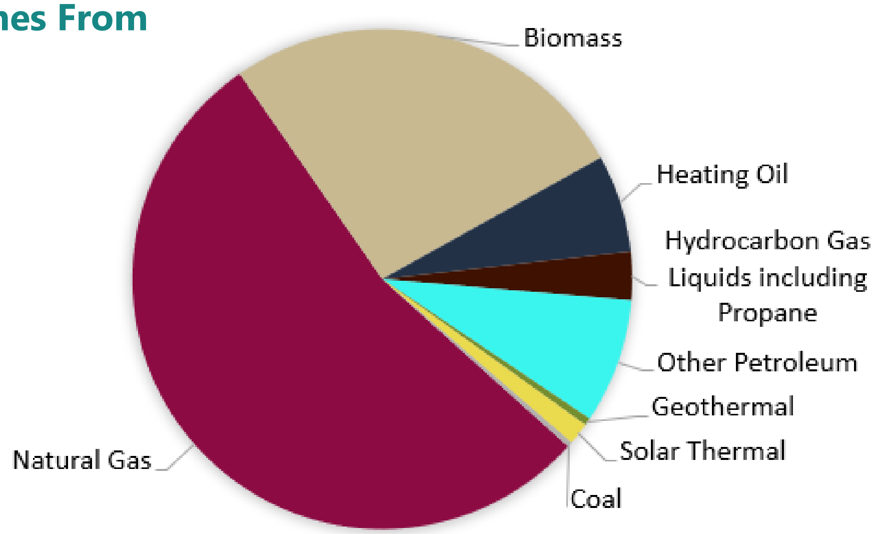
While the majority of power supplied by Oregon's consumer-owned utilities comes from the Bonneville Power Administration, **COUs have also invested in their own energy-generation sources**. For example, Clatskanie PUD supplements the electricity it buys from BPA with purchase agreements for natural gas, biomass, and biogenic facilities. Emerald PUD supplies some of its electricity from solar, biogas, and unspecified purchases from energy markets.

Thanks to the BPA-supplied power – which is mostly from federally owned dams – and their own resources, COU electricity mixes have very low greenhouse gas emissions.

Direct Use Fuels

What We Use and Where it Comes From

In 2020, Oregon used 255.7 trillion Btu of direct use fuels to cook, heat buildings, and support commercial and industrial processes.[1] Direct use fuels make up about 26 percent of the total energy consumption in Oregon.[2] These fuels are used on-site in the residential, commercial, and industrial sectors. They do not include fuels used to generate electricity or support the transportation sector.



Natural Gas. A gaseous mixture of hydrocarbon compounds, primarily methane, natural gas is a fossil energy source from beneath the earth's surface that is produced abundantly in the United States. Natural gas is used directly for space and water heating, cooking, and many agricultural, commercial, and industrial processes.

In 2020, Oregon used 137.2 trillion Btu of natural gas for direct uses — nearly all of it imported from Canada and the Rocky Mountain states.[1] The Pacific Northwest's only natural gas extraction facility is located outside Mist, Oregon and its resources go to NW Natural, one of three investor-owned gas companies serving the state.[3] The Mist field is primarily used for natural gas storage and produced only 0.34 trillion Btu of natural gas in 2020, representing 0.23 percent of Oregon's annual use.[1]

Natural Gas Consumption by Sector

Commercial Sector | 29.9 trillion Btu

Residential Sector | 48.0 trillion Btu

Industrial Sector | 59.3 trillion Btu[1]

Renewable natural gas, a low carbon-intensity alternative to fossil natural gas, is made by capturing methane biogas emitted from decomposing food waste, agricultural manure, landfills, and wastewater treatment plants. Biogas is processed to remove non-methane elements and can then be added to a pipeline or used onsite as natural gas. Oregon natural gas utilities are investing in RNG projects throughout the state. NW Natural currently has "options to purchase or develop RNG totaling about 3 percent of its annual sales volume in Oregon, enough to serve the gas needs of about 33,000 homes."[4] The Oregon Department of Energy inventoried current and potential RNG production quantities and estimated that 4.5 percent of Oregon's annual natural gas use (including power generation) could be replaced with RNG produced in the state — with the potential of reaching 17.5 percent of annual use with future technological advancements in collection and processing.[5] That additional 17.5 percent could meet about 31 percent of all direct gas use (not including power generation) in Oregon. NW Natural has also built interconnections for three facilities on its system, and at least one other RNG project is currently interconnected onto a large transmission pipeline in the state.

Biomass. Biomass is an organic material that comes from plants and animals that is burned to create energy. Biomass is considered a renewable source of energy, and comes from resources like wood, agricultural crops and waste, food or yard waste, and animal and human waste. Organic waste materials are collected and combusted to make energy that can be used on site or distributed to a facility instead of filling space in a landfill. While some biomass sources are the same as biogas, biomass also commonly refers to end-products such as wood chips, wood pellets, and charcoal that are used for thermal energy.

In 2020, Oregon consumed 70 trillion Btu of biomass as a direct use fuel.[1] Oregon has 15 wood and wood waste biomass-generating facilities. Biomass fuel feedstocks in Oregon are primarily wood and wood waste, but there are also 30 agricultural waste, landfill gas, and wastewater biogas generating facilities.[6] Many industrial facilities in Oregon burn woody biomass to generate electricity using waste products that would normally go to a landfill. Biomass is also used as a thermal energy source at commercial facilities, including schools and hospitals.[7]

Biomass Consumption by Sector

Commercial Sector | 4.5 trillion Btu

Residential Sector | 21.6 trillion Btu

Industrial Sector | 43.7 trillion Btu[1]

Heating Oil. Heating oil is a petroleum distillate fuel that is used primarily to heat buildings; some buildings also use it to heat water. Because space heating is the primary use for heating oil, demand is highly seasonal and affected by the weather. Most Oregon heating oil use occurs during the heating season: October through March.

In 2020, Oregon used 16 trillion Btu of heating oil for direct uses, and 2 percent of Oregon homes use fuel oil for heating.[1 8] It is also used to heat commercial buildings and for industrial applications. Oregon does not produce any heating oil in the state, so most of Oregon's petroleum supply comes from refineries in Washington.[7]

Biodiesel heating oil is becoming more readily available in Oregon. Biodiesel heating oil is a renewable fuel made from vegetable oils, like soy and canola, that are grown domestically. Biofuels are mixed with regular heating oil at 5 to 20 percent to create a cleaner burning alternative fuel. The mixes can be used by typical oil furnaces in homes, but increasing the portion of vegetable oils in the blends does require adjustments to home oil furnaces.

Heating Oil Consumption by Sector

Commercial Sector | 3.0 trillion Btu

Residential Sector | 1.3 trillion Btu

Industrial Sector | 11.8 trillion Btu[1]

Hydrocarbon Gas Liquids and Propane. HGLs are gases at atmospheric pressure and liquids under higher pressures, which can also be liquefied by cooling. Their versatility and high energy density in liquid form make them useful for many purposes, including as feedstock in petrochemical plants, as fuel for home space and water heating or cooking, and as transportation fuels, additives, or as a diluent. Propane is a hydrocarbon gas liquid that can be used to power farm and industrial equipment, backyard barbeques, and Zamboni machines at ice skating rinks. Propane remains a viable fuel over long periods of storage, making it a common backup fuel for essential facilities like hospitals and a potential resource in response to an emergency. Propane is a byproduct of natural gas production.[9] As U.S. natural gas production has increased, the supply of propane has followed, making it an affordable and attractive option for many Oregonians.[10]

Propane consumed in Oregon is imported. Based on the available data on propane production, imports, exports, and transportation, the Pacific Propane Gas Association estimates that more than 95 percent of the propane consumed in Oregon is sourced from natural gas processing plants in Alberta and British Columbia, Canada.[11]

Oregon consumed 8 trillion Btu of propane in 2020 as a direct use fuel, a 30 percent increase in consumption from 2010 to 2020.[1] Less than 1 percent of Oregon residents use propane to heat their homes; more use it for cooking.[8] While propane use on-road as a transportation fuel is a small segment of the total fuel usage in Oregon, school districts have embraced propane as a fuel for bus fleets.

Hydrocarbon Gas Liquids and Propane Consumption by Sector

Commercial Sector | 3.6 trillion Btu

Residential Sector | 2.6 trillion Btu

Industrial Sector | 1.8 trillion Btu[1]

Other Petroleum. These are petroleum fuels like kerosene or lubricants that are not propane or heating oil, and are used, for the most part, in Oregon's commercial and industrial sectors to fuel machinery and manufacturing processes. In 2020, Oregon consumed almost 20.7 trillion Btu of Other Petroleum fuels.

Other Petroleum Consumption by Sector

Commercial Sector 4.9 trillion Btu

Residential Sector 0.2 trillion Btu

Industrial Sector 15.6 trillion Btu

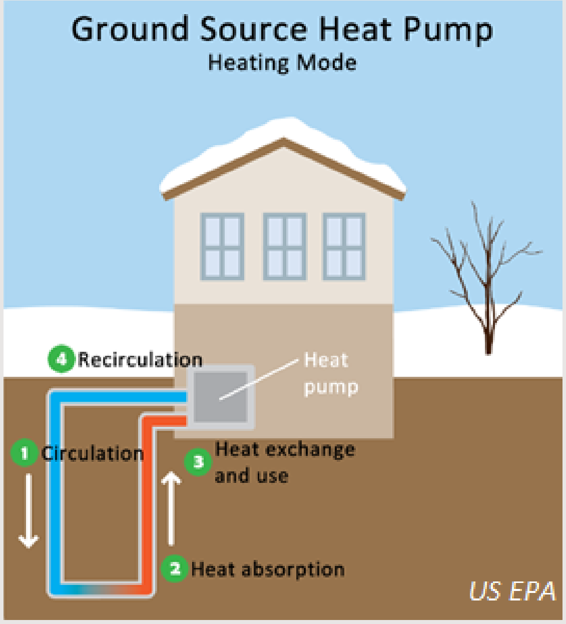
Solar Thermal. Oregon uses sunlight to produce solar energy to heat spaces and water in homes and businesses. Over 3.6 trillion Btu of solar thermal energy was consumed in Oregon in 2020. Solar thermal is most used as a direct use fuel in solar water heating systems in buildings. Solar water heating systems collect and transfer thermal energy to preheat water for the building, which reduces natural gas or electricity consumption.

Solar Thermal Consumption by Sector

Commercial Sector | 0.86 trillion Btu
Residential Sector | 2.65 trillion Btu
Industrial Sector | 0.14 trillion Btu[1]

Geothermal. In 2020, Oregonians consumed 1.2 trillion Btu of geothermal energy for heating and cooling residential, commercial, and industrial spaces.[1] Geothermal energy is a renewable fuel that comes from the internal heat of the earth and is produced in Oregon. While geothermal is often used to generate electricity, it can also be used for thermal energy applications such as heating spaces and keeping bridges and sidewalks from icing over.[12]

Geothermal or ground source heat pumps have been used in the U.S. since the 1940s and unlike air source heat pumps, they use the ground to exchange energy and keep buildings comfortable. A few feet below the earth's surface the ground remains at a relatively constant temperature (45-75 degrees Fahrenheit) even as the air temperature changes from winter to summer. These systems use that constant temperature to heat and cool homes and businesses. In the winter, geothermal heat pumps pull energy from the warm ground to heat buildings. In the summer, the process is reversed and energy from the building is taken and deposited in the ground, cooling the building. Installation prices of geothermal systems are greater than that of an air-source system of the same heating and cooling capacity but they are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air.[13 14]



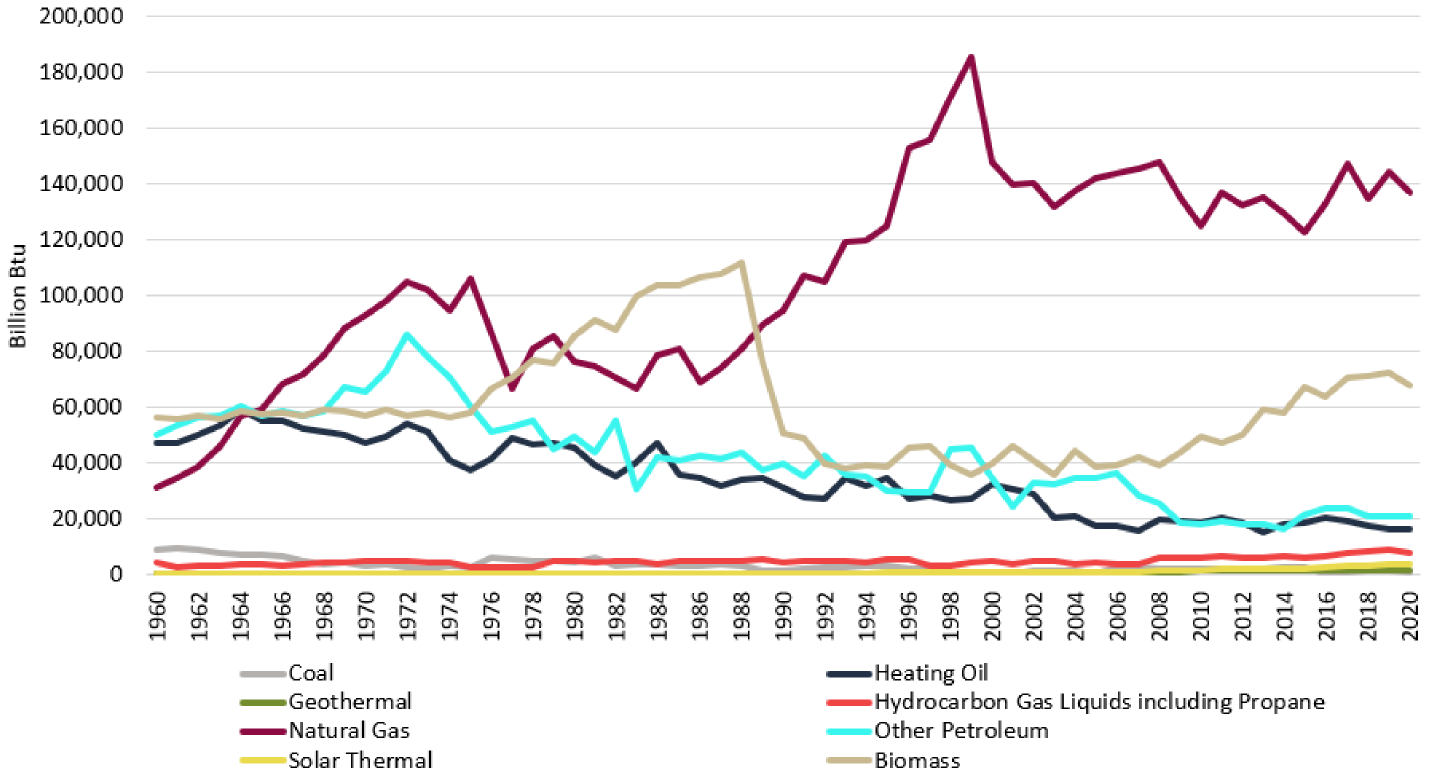
Coal. Coal is imported to Oregon to use as a direct fuel in the industrial sector. Oregon consumed 0.84 trillion Btu of coal from neighboring states in 2020, which does not include the coal used to generate electricity consumed in Oregon. Use of coal as a direct fuel in Oregon has declined by 91 percent since 1960.[1]

Geothermal and coal direct use fuels represent less than 1 percent of Oregon's direct use fuels.[1]

Direct Use Fuels Over Time

Oregon's energy consumption has evolved over time. For direct use fuels, that has meant decreasing wood and fuel oil use and an increase in natural gas. The chart below uses data from the U.S. Energy Information Administration to compare total consumption of direct use fuel types in Oregon's residential, commercial, and industrial sectors from 1960 to 2020. The chart does not include transportation fuels or fuels used to generate electricity used in those sectors.

Oregon Direct Use Fuels Consumption: 1960-2020 (Billion Btu)[1]



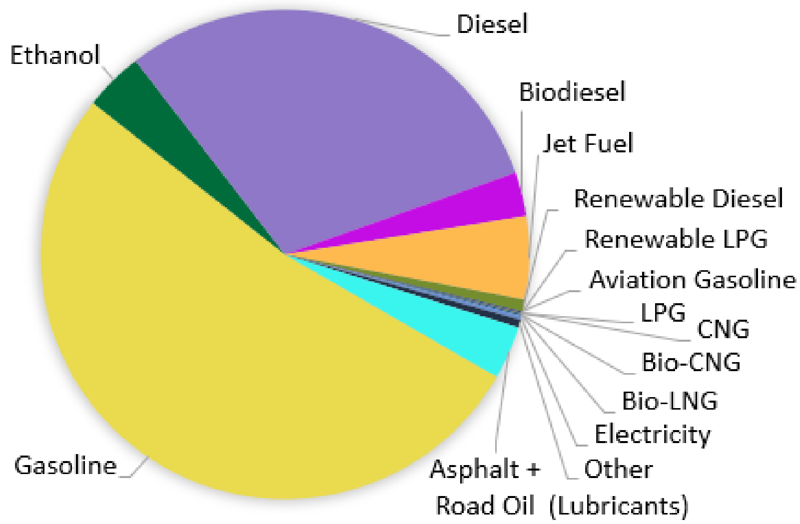
Natural gas has replaced distillate fuel oil and coal use in many Oregon buildings and industrial processes as a cleaner-burning alternative. Like distillate fuel oil and coal, natural gas exploration, extraction, production, and transportation has a negative effect on the environment. Drilling wells may disturb land, wildlife, and people in the surrounding area with air and potentially water pollution.[15] As Oregon reduces greenhouse gas emissions to meet state targets, the application and use of natural gas and other fossil-based direct use fuels may change as the state seeks lower carbon intensity alternatives. Learn more about the future of conventional gas fuels in the Policy Briefs section of this report.

Geothermal consumption is one of the smallest of Oregon's direct use fuels in the chart above. EIA began tracking geothermal consumption in 1989 with 0.38 trillion Btu. In 2020, Oregon consumed over 1.2 trillion Btu of energy from geothermal, an increase of 224 percent over that 30-year period.[1]

Oregon industry consumes a significant amount of biomass energy from secondary waste products, like lumber mill residue, logging slash, and animal manure. Biomass energy consumption has increased steadily since 2002, due almost entirely to increased demand for biofuels. Learn more about biofuels in the Transportation Fuels Energy Resource and Technology Review.

Transportation Fuels

What We Use



In 2020, Oregon's transportation sector used 28.6 percent — or 281 trillion Btu — of the energy consumed in Oregon. Transportation was the largest share of energy use among the sectors in 2020.[1] Oregonians consume many different types of transportation fuels:

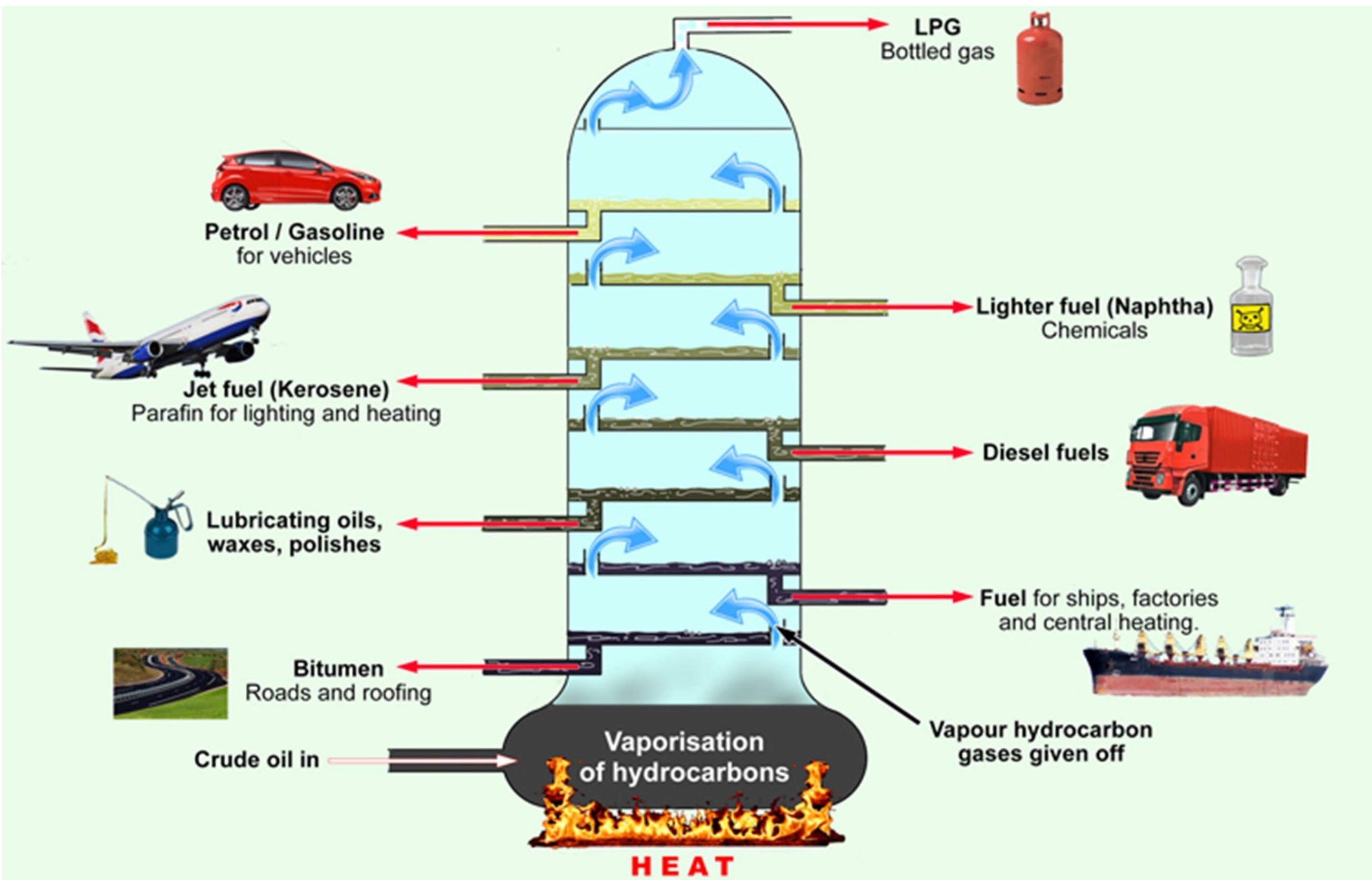
Petroleum-based products make up 92 percent of Oregon's transportation fuel use. They are processed by heating crude oil and separating components by weigh, sometimes referred to as fractionations (of the crude oil).

Gasoline. Lighter distillate of petroleum used by cars, motorcycles, light trucks, airplanes, and boats.

Diesel. Heavier distillate of petroleum used by trucks, buses, trains, boats, and ships.

Propane. A light petroleum hydrocarbon gas liquid fuel used to power cars, buses, trucks, and some non-road vehicles.

Uses for Petroleum Distillates in the Transportation Sector[2]



Alternative fuels (to petroleum) used in Oregon are produced by various means, often involving collection and processing of crops, byproducts, or waste streams.

Ethanol. Fuel produced from agricultural crops or wood that is blended with gasoline and used by cars and trucks.

Biodiesel. Fuel from organic oils and fats that can be blended with diesel fuel (up to 20 percent) and used by trucks, buses, trains, and boats.

Electricity. Fuel that powers some public mass transit systems and electric vehicles.

Natural Gas. Compressed and liquefied natural gas used by cars, buses, trucks, and ships.

Renewable Natural Gas. Biogas from agricultural waste, wastewater, or garbage is collected and refined to power natural gas cars and trucks.

Renewable Diesel. Fuel from organic oils and fats using a different production process than biodiesel to power diesel vehicles.[3,4]

The U.S. Energy Information Administration tracks transportation sector consumption. The Oregon Department of Energy also analyzes data from the Oregon Department of Environmental Quality's Clean Fuels Program and the Department of Transportation's fuel tax program to determine an estimate of the mix of transportation fuels consumed in Oregon. In 2020, petroleum-based products accounted for 92 percent of fuel consumed in the transportation sector; alternative fuels or biofuels like ethanol, biodiesel, and renewable diesel accounted for 8 percent; and electricity and natural gas accounted for 0.3 percent of the fuels consumed.[5]

Could Hydrogen Emerge as a Transportation Fuel in Oregon?

National Renewable Energy Laboratory (CC BY-NC-ND 2.0)

A potential emerging resource in Oregon and beyond is renewable hydrogen, which could be used as a direct transportation fuel, as storage for clean electricity generation, or other uses. The Oregon Department of Energy will publish a study on renewable hydrogen in 2022, including opportunities and challenges for using the resource in the state.

One potential renewable hydrogen use is as fuel for medium– or heavy-duty vehicles. At left, a zero-emission hydrogen fuel cell bus refuels in Irvine, CA.

ODOE's report will be published online:

tinyurl.com/ODOE-RH2-Study

Use Over Time

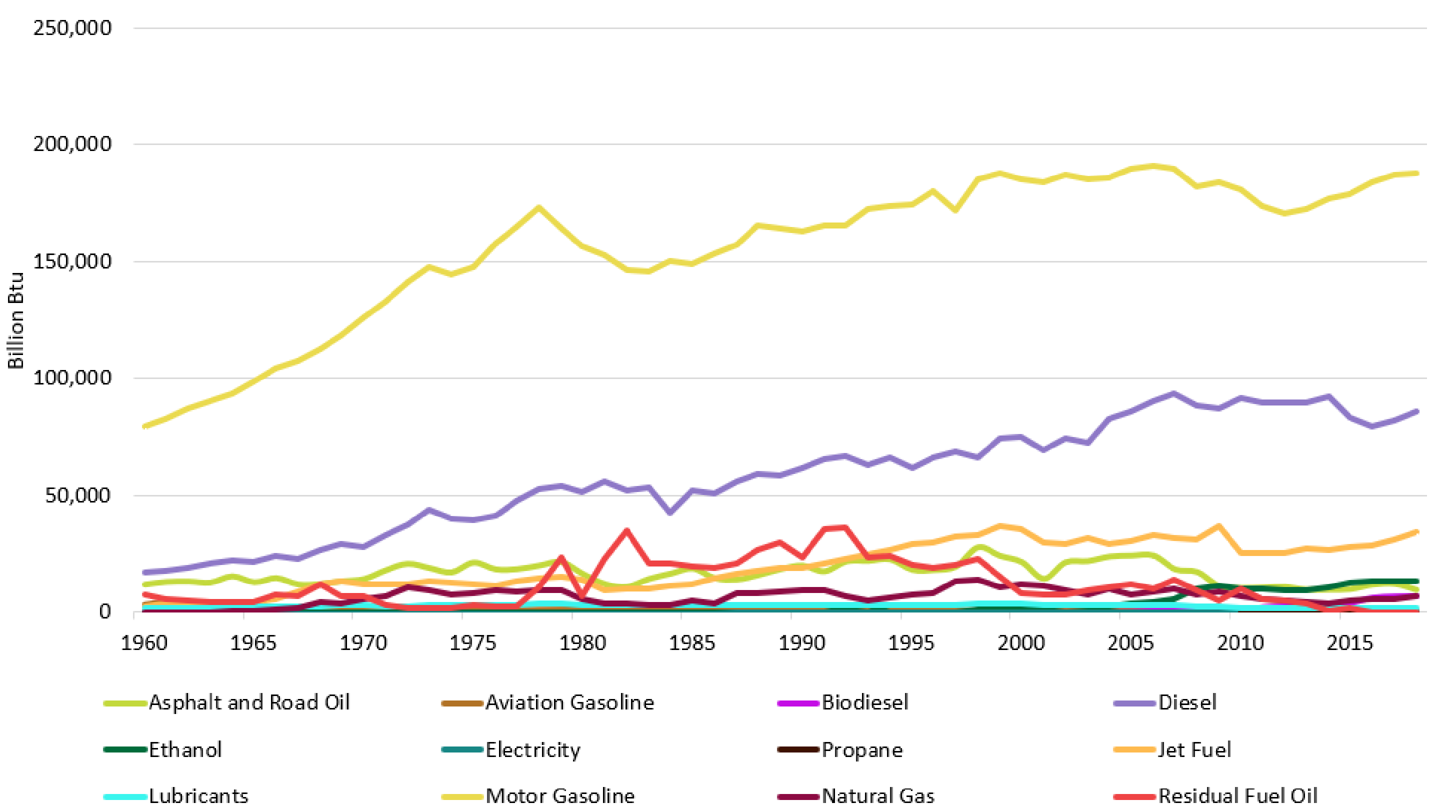
2.5%

Percentage of transportation fuel used in Oregon that was produced in state.[6]

The U.S. Energy Information Administration has tracked national energy consumption and individual state consumption since 1960. In Oregon and nationally, overall transportation consumption increased between 1960 to 2018. In 2019 and 2020 there was a 16 percent reduction in the use of gasoline and a 37 percent reduction in jet fuel, but a 3 percent uptick in the use of diesel. Analysis contributes this to less personal travel and increased delivered goods due to the COVID-19 pandemic. In 2020, Oregon's transportation sector consumed 281 trillion Btu of energy — an 11 percent decrease from 316 trillion Btu in 2018, the peak year of transportation energy consumption in Oregon.[5]

Except for 2019 and 2020, petroleum product consumption has steadily increased over time and still dominates transportation fuel use in Oregon. Nearly all transportation fuels are imported into Oregon. In 2020, just 2.5 percent of transportation fuel used in Oregon was produced in the state, including 8.2 trillion Btu of biodiesel and fuel ethanol.[6] Oregon electric utilities provided 0.75 trillion Btu of electricity to fuel zero-emission vehicles in 2020.[5] Oregon does not have crude oil reserves or refineries to process petroleum, so over 90 percent of the petroleum products delivered to and consumed in Oregon come from four refineries in Washington state.[7] Crude oil used at Washington refineries comes from Alaska, western Canada, and North Dakota.

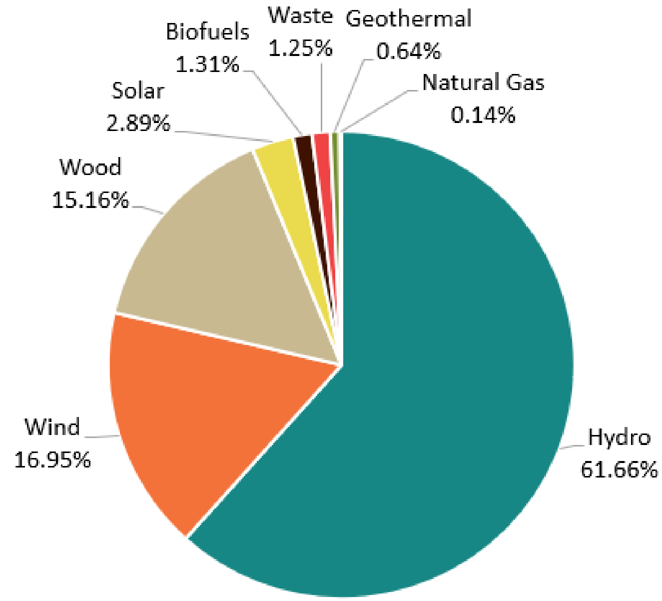
Oregon Transportation Sector Consumption: 1960-2020 (Billion Btu)



Energy Production

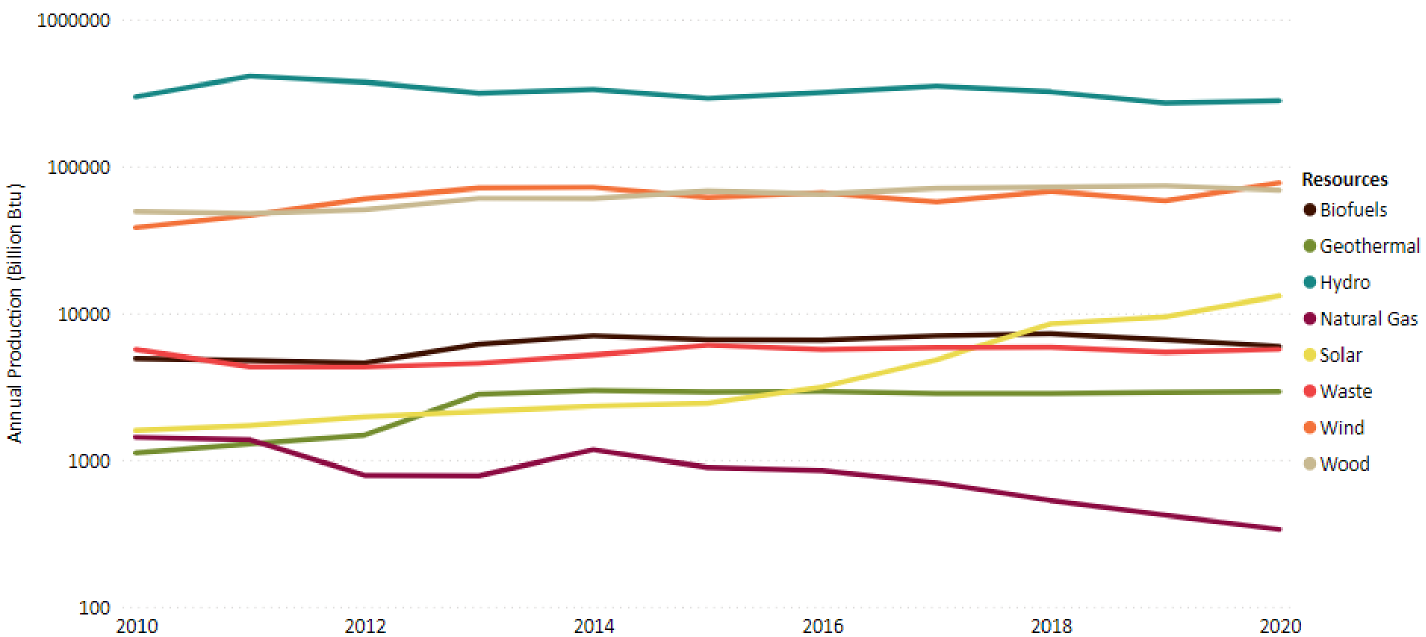
Overview

Energy production focuses on primary and secondary energy produced in Oregon. *Primary* energy represents energy that is collected from Oregon's natural resources — it does not include energy that is imported for consumption or electricity generated in Oregon. *Secondary* energy is consumed in real time, like electricity, or may be stored for later use, like wood pellets. This section includes consumption data and energy production context — such as how much of the electricity generated in Oregon comes from hydroelectric, wind, and solar compared to imported natural gas.



The chart above shows primary energy production in Oregon in 2020. Almost all the solar, wind, geothermal, and hydro primary energy is converted to *secondary* energy as electricity. Some of the biomass is used to make a variety of renewable fuels and some is combusted to produce heat and electricity.[1]

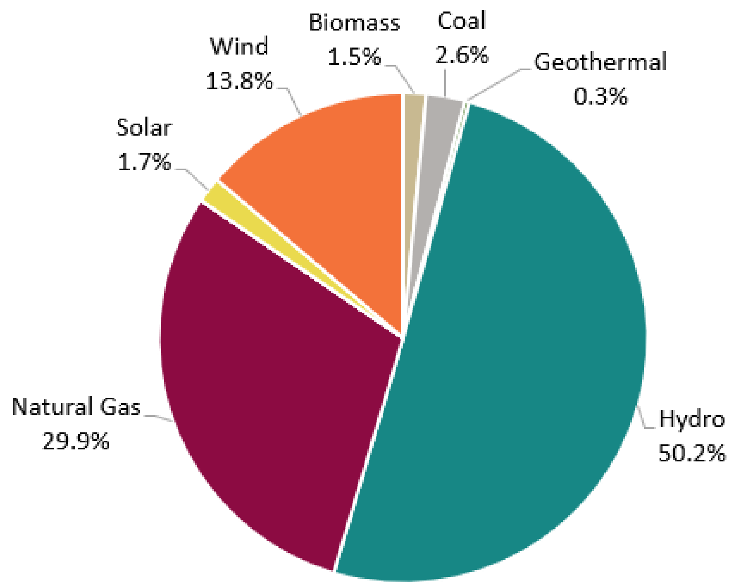
Oregon Primary Annual Energy Production Over Time[1]



The chart above uses a logarithmic scale to compare energy production. Without the logarithmic scale, the smallest contributors like natural gas and geothermal would be hard to see, as they would show along the bottom of the chart, and hydroelectric would dwarf all others except for wind. Hydro has been the largest primary energy source in Oregon over the chart's time period. Solar power has been steadily increasing since 2012, with faster increases starting in 2015. Wind energy has grown over the period at a slower rate, and in 2020 is now the second largest category. Since 2014, natural gas production has slowly been declining.[2]

Electricity

Oregon generates electricity from a variety of resources — hydropower, natural gas, and wind are the largest. In 2020, half of Oregon's electricity generation came from hydroelectric facilities.[1] Oregon has 105 hydro facilities.[3] The state's four largest electricity generating facilities are federally owned and operated dams on the Columbia River. They account for two-thirds of the generating capacity from the 10 largest power plants in the state.[4] Oregon is the second largest producer of hydroelectric power in the U.S. after Washington.[4]



Oregon's abundance of renewable electricity can be used in Oregon or sold on the energy market to utilities in other states. In 2020, 34 percent of Oregon's hydropower and 57 percent of its wind generation were exported.[5] Sixty-eight percent of electricity generated in Oregon in 2020 came from renewable resources. [1] Hydroelectric, wind and solar generation varies diurnally (over the course of a day) and seasonally.

Natural gas represented 30 percent of Oregon's 2020 electric generation. A little less than 3 percent[1] of electricity came from the Boardman coal plant, which shut down in October 2020.[1] Oregon natural gas facilities import all but a very small fraction of the natural gas they use. Oregon has a single site in Mist that produces natural gas, but is used primarily for natural gas storage. Oregon has no coal or petroleum resource extraction facilities.

Utility-Scale Solar in Oregon

In February 2018, Oregon's Energy Facility Siting Council approved its first EFSC-jurisdictional solar energy facility, the 75-megawatt Boardman Solar Energy Facility.

As of September 2022, there are more than a dozen EFSC-jurisdiction solar facilities under review, under construction, or operating in Oregon. The largest proposed facility to date is the 1,250-megawatt Echo Solar Project in Morrow County.

63.6 Million

Megawatt hours of electricity generated in Oregon in 2020.[1]

53.8 Million

Megawatt hours of electricity consumed in Oregon in 2020.[5]

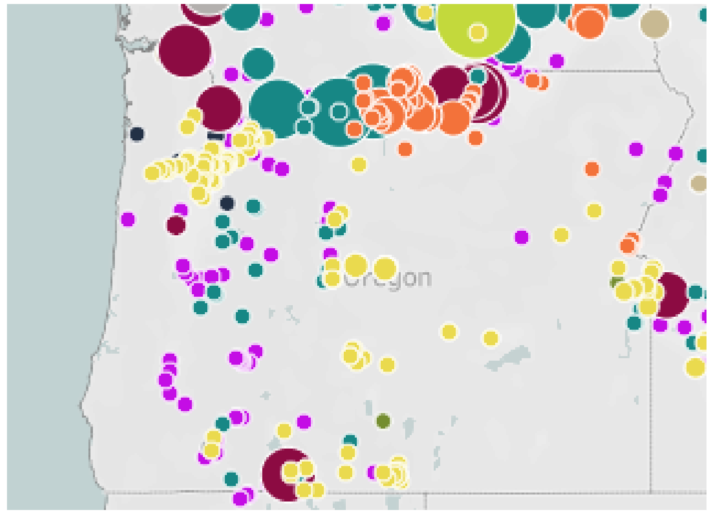
68%

Percentage of Oregon's electricity generation that comes from renewable resources.[5]

62%

Percentage of Oregon's electricity generation that is used in-state.[5]

Electric Facilities

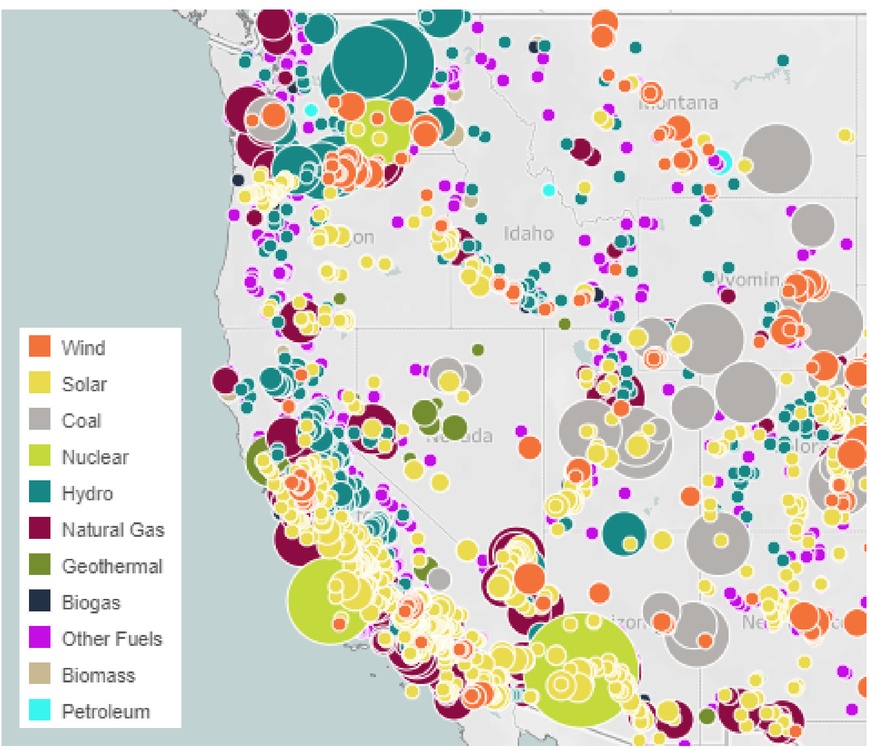


The map of Oregon at right shows where electricity generation sites are in the state. Facilities owned by Oregon utilities are included, as are third-party owned facilities, which can contract with utilities to provide power to Oregon consumers or sell their electricity on the open energy market. Note that the color of the circles corresponds to the resource used to generate electricity (see below), and the size of the circle is in relation to generation capacity of that facility.

Electricity used by Oregonians can come from facilities across the western United States. We rely on hydroelectric power produced on the Columbia River, nuclear power from the Columbia Generating Station in Washington, wind from turbines along the Columbia River Plateau, and electricity generated at coal-powered facilities located in several western states.[7]

The map below shows the various electricity generation sources in the Western Electricity Coordinating Council. The WECC is a nonprofit organization that focuses on systemwide electricity reliability and security across a geographic region known as the Western Interconnection. This diverse region includes Oregon and most of the intermountain west and parts of Canada.[6]

The map uses data from the U.S. Energy Information Administration and includes facilities with a nameplate capacity of 1 megawatt or greater.[7] According to the EIA, generator nameplate capacity is defined as the maximum rated output of a generator, prime mover, or other electric power production equipment under specific conditions designated by the manufacturer. Installed generator nameplate capacity is commonly expressed in megawatts (MW) and is usually indicated on a nameplate physically attached to the generator. Not all resources or facilities shown on the map contribute to Oregon's overall fuel mix, but many are available when Oregon utilities purchase electricity on the open market.

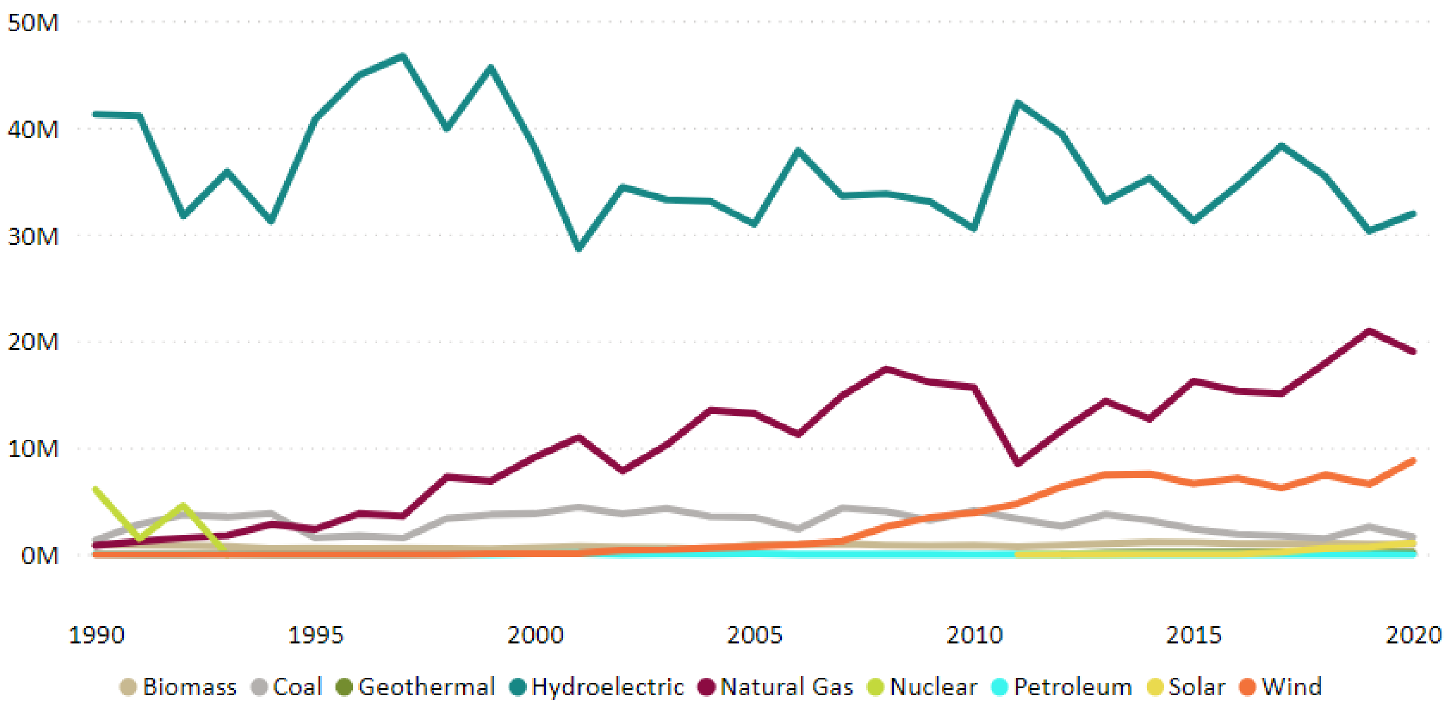


In the same way, electricity generated in Oregon may be sold through the energy market to support electricity needs in other states.

Electricity Over Time

Oregon's electricity generation has changed over the years. Hydropower, which is Oregon's largest electricity resource, varies year-over-year based on precipitation. Oregon hydropower reached a generation high of 46.7 million MWh in 1997. Wind and natural gas have both seen a gradual increase in generation over time. In 2020, natural gas is the second largest share of Oregon's electricity generation, at 19.0 million MWh. Coal generation has been steadily declining since 2010 and had declined to only 1.6 million MWh in 2020 when Oregon's last coal generating plant was closed.[1] Solar has increased each year since 2011, and is expected to continue growing with several proposed facilities in planning and review stages.[8]

Oregon Electricity Generation: 1990-2020 (MWh)[1]



Wind + Solar + Storage

As Oregon makes progress toward its clean electricity targets, the state will need more renewable energy resources to power Oregon homes and businesses.

Some renewable resources, like wind and solar, are variable since the sun doesn't always shine and the wind doesn't always blow. Adding utility-scale battery storage to renewable energy facilities allows renewable power to be generated and stored for later use on the electric grid. In 2022, Portland General Electric celebrated the completion of its Wheatridge Energy Facilities, which combine renewable wind and solar alongside battery storage in Morrow County.

Renewable Electricity

Renewable electricity generated in Oregon has grown due to customer demand, dramatic reductions in costs, and clean energy policies, like Renewable Portfolio Standards and HB 2021's 100 percent clean electricity by 2040 target. Demand for clean energy in California also spurred prior wind development in Oregon – 57 percent of wind energy in 2020 was exported.[5]

2012 Generation	2016 Generation	2020 Generation
6,400 MWh	40,900 MWh	1,077,900 MWh

17% of Oregon's solar generation was exported in 2020.[5]

Oregon has 726 MW of utility-scale solar facilities and 156 MW of net-metered solar installations on homes and businesses.

2012 Generation	2016 Generation	2020 Generation
6.3 Million MWh	7.2 Million MWh	8.8 Million MWh

57% of Oregon's wind generation was exported in 2020.[5]

Oregon has 4,203 MW of wind facilities in operation, with ODOE overseeing even more projects: 194 MW under construction, 421 MW approved but not yet built, and 340 MW under review.[8]

2012 Generation	2016 Generation	2020 Generation
39.4 Million MWh	34.6 Million MWh	31.9 Million MWh

34% of Oregon's hydropower generation was exported in 2020.[1]

In some Oregon utility territories, hydropower provides over 90% of consumers' electricity.[7]

Oregon's hydropower fluctuates from year-to-year due to changing precipitation and water conditions.

Direct Use Fuels

Aside from biomass produced in Oregon, most direct fuels – used in the residential, commercial, and industrial sectors – are imported from out of state. In 2020, Oregon used 255.7 trillion Btu of direct use fuels, representing about 25 percent of the total energy consumed in Oregon.[1] The majority of Oregon's primary energy production comes from energy sources like hydropower, wind, and solar used in electrical generation, but Oregon also produces some direct use fuels.

The table below shows the direct use fuels that are produced in Oregon in comparison to how much is consumed by the residential, commercial, and industrial sectors. If energy is produced in Oregon and not consumed in state, the assumption is that the energy was exported to support neighboring states' energy systems. Where more energy was consumed than produced, that means it was imported into the state for consumption.

Biomass is the most-produced direct use fuel in Oregon. In 2020, Oregon produced over 74 trillion Btu of energy from biomass while consuming an estimated 68 trillion Btu[1] and exporting 6 trillion Btu. The U.S. Energy Information Administration collects and shares these high-level energy production and consumption estimates to inform Oregon's understanding of state and federal energy systems — but the data does not show where each Btu of energy is consumed.

100%

Percentage of Oregon geothermal energy consumption that is produced in-state.[1]

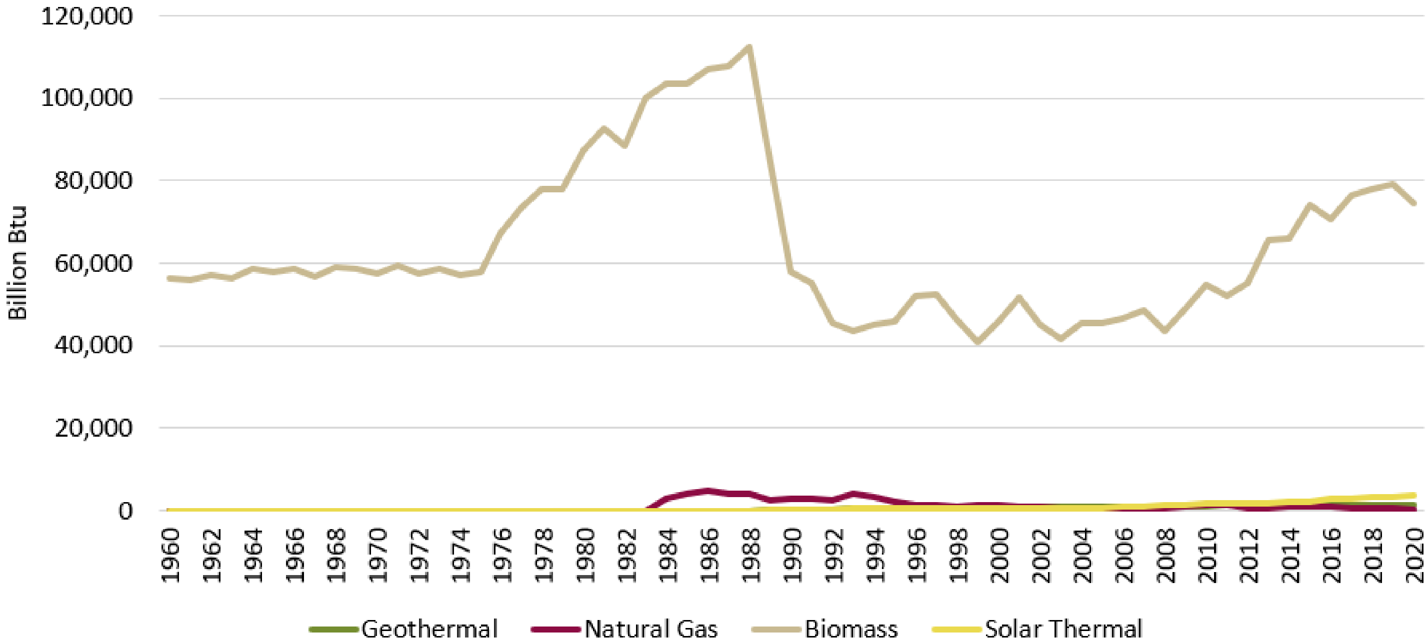
32%

Percentage of Oregon overall direct use fuels consumption that is produced in-state.[1]

Production & Consumption of Direct Use Fuels in 2020 (trillion Btu)

Resource	Consumption in Oregon	Oregon Production	Imported	% of Consumption Produced in Oregon
Geothermal	1.2	1.2	0	100%
Natural Gas	137.2	0.3	136.9	0%
Biomass	68.0	74.5	-6.5	110%
Other Petroleum	20.7	0	20.7	0%
Heating Oil	16.1	0	16.1	0%
Hydrocarbon Gas & Liquids/ Propane	7.9	0	7.9	0%
Solar Thermal	3.7	3.7	0	100%
Coal	0.8	0	0.8	0%
Totals	**255.7**	**79.8**	**175.9**	**31%**

Direct Use Fuel Energy Production in Oregon, 1960-2020[1] (billion Btu)



Natural Gas. In 2020, Oregon's residential, commercial, and industrial sectors consumed 51 percent of total[1] natural gas consumption as direct use fuels while the rest went to electricity generation. Oregon imports nearly all natural gas used, mostly from Canada and the Rocky Mountain states. The Pacific Northwest's only natural gas production is located outside Mist, northwest of Portland, and is owned and operated by NW Natural, one of three investor-owned gas companies serving the state. The Mist field produced about 320 million cubic feet of natural gas or 0.34 trillion Btu of energy in 2020, representing 0.2 percent of Oregon's natural gas used that year.[1] The facility hit a production peak of 4.7 trillion Btu in 1986.[1] The Mist facility is also used to store natural gas produced from outside of Oregon, for use in electricity generation as well as for customers within the natural gas distribution system. NW Natural pumps natural gas into the underground rock formations to store for later use during cold weather events, help balance additions and withdrawals to its pipeline system, and minimize costs for customers by purchasing gas at favorable prices throughout the year.

Renewable Natural Gas. RNG is biogas that has been purified to be a substitute for natural gas, often to meet specifications required for injection into a natural gas distribution pipeline. Biogas is collected from landfills where it is produced from decaying municipal waste streams like food and garbage, from anaerobic digesters at wastewater treatment plants (waste and food), and at agricultural sites that process waste streams like manure.

Four RNG projects are operational in Oregon with the capability to inject RNG into natural gas pipelines. Nine additional RNG projects are in development in Oregon.[11] In 2018, the Oregon Department of Energy conducted an inventory of current and potential RNG facilities and estimated 4.5 percent of Oregon's total annual natural gas use could be replaced with RNG produced in the state. Production capacity could reach as high as 17.5 percent of annual use with future technical advancements in collection and processing.[12] In November 2021, the Metropolitan Wastewater Management Commission in Lane County became the first public agency in Oregon to collect and inject RNG into NW Natural's gas line. The biogas was collected and processed from a regional wastewater treatment plant in Eugene, Oregon.[13]

Solar Thermal. In addition to solar radiation used to generate photovoltaic electricity, solar thermal energy is a resource used directly to provide heat in Oregon homes and businesses. Solar thermal systems capture energy from the sun to provide water heating and space heating in buildings. Most systems installed in Oregon are solar water heating systems that provide supplemental energy to residential water heaters, which can reduce water heating bills by 50 to 80 percent according to Energy.gov's Energy Saver.[14] In the last 10 years, residential solar water heating system installations have declined as photovoltaic systems have become less expensive and energy efficient heat pump water heaters have joined the market. It has become more cost effective for most homes to install a photovoltaic system with a heat pump water heater.

Geothermal Energy. Direct use geothermal energy uses hot water or steam from reservoirs below the earth's surface piped to end users for water or space heating. Oregon produced 2.9 trillion Btu of geothermal energy in 2020, and 1.2 trillion Btu of it was consumed as a direct use fuel.[1] For decades, the city of Klamath Falls has used geothermal heat sources to heat buildings, residences, pools, and even sidewalks. Schools and hospitals in Lakeview use a geothermal well system to heat some buildings.

This Klamath Falls greenhouse uses geothermal heat to keep plants warm.

Other examples of direct use of geothermal heat in the state include drying agricultural products, aquaculture (raising fish), heating greenhouses, and heating swimming pools. There are more than 2,000 thermal wells and springs delivering direct heat to buildings, communities, and other facilities in Oregon.[15]

Biomass, Wood Pellets, and Charcoal Briquettes. Biomass energy is from plants and plant-derived materials, including wood, wood waste, wood pellets, and charcoal briquettes. Residual material or waste from forest harvest and mill operations is converted into useful retail products. Wood and wood waste biomass has been Oregon's largest direct fuel production source since 1960. In 1988, wood and wood waste production hit a high of 113 trillion Btu. Thirty years later, Oregon's production was 75 trillion Btu — a 34 percent decrease.[1] In Oregon, the industrial sector is the largest producer and consumer of biomass energy. Eleven woody biomass facilities provide power in Oregon, primarily in the wood-products industry.[9] Wood is also produced and consumed as cordwood to heat homes – after industrial, the residential sector is the second largest consumer of wood energy in Oregon.[1]

Wood pellets are manufactured from timber waste and used for residential and commercial heating. Biomass Magazine lists six wood pellet plants in Oregon, producing 280,000 metric tons per year.[16] Charcoal briquettes and cooking pellets also use timber waste to create a fuel source for cooking; wood waste is burned in the manufacturing process as the products are heated up to remove moisture. Springfield, Oregon is home to one of Kingsford's five manufacturing plants in the U.S.[17]

Transportation Fuels

About 2.5 percent of the 281 trillion Btu of energy Oregonians consumed for transportation in 2020 was produced in state.[18] Oregon produces 34 percent of the biofuels the transportation sector uses, which makes up 7 percent of the state's total consumption of transportation fuels.[1]

Though still a small fraction of the total transportation fuels, electricity use for transportation is growing in Oregon. The state consumed 0.75 trillion Btu of electricity in 2020 or about 0.3 percent of total transportation consumption.[1]

5%

Biodiesel blend is used in nearly all heavy-duty vehicles both on and off the highway.

10%

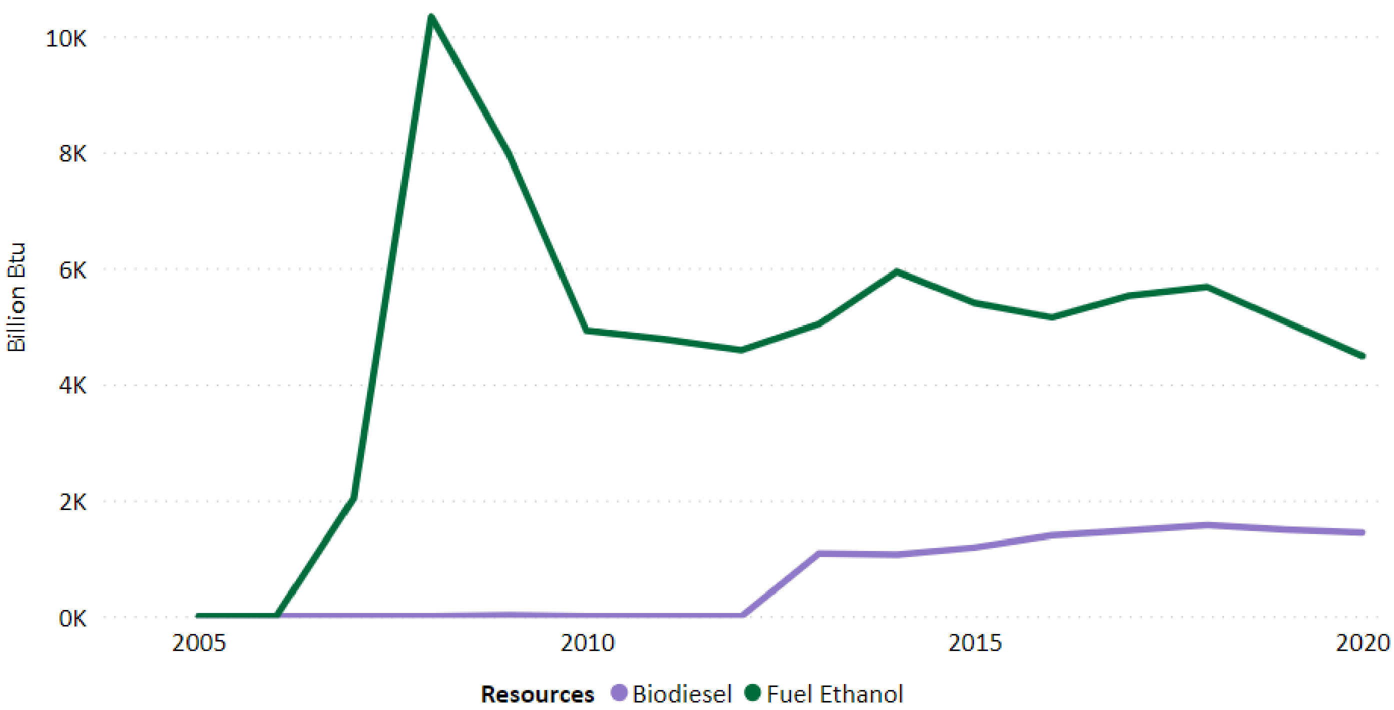
Ethanol blend fuel is used in a majority of light-duty vehicles in Oregon.

Production & Consumption of Transportation Fuels in 2020 (trillion Btu)

Resource	Consumption in Oregon	Oregon Production	Imported	% of Consumption Produced in Oregon
Biodiesel	8.16	1.495	6.67	18%
Fuel Ethanol	10.95	4.999	5.95	46%
Gasoline	146.90	0	146.90	0%
Diesel	84.35	0	84.35	0%
Jet Fuel	15.43	0	15.43	0%
Asphalt & Road Oil	9.85	0	9.85	0%
Lubricants	1.44	0	1.44	0%
Aviation Gasoline	0.30	0	0.30	0%
Electricity* (gge)	0.75	0.586	0.17	78%
LPG/Propane	0.06	0	0.06	0%
Compressed Natural Gas	0.05	0	0.05	0%
Bio-CNG	0.34	0	0.34	0%
Renewable Diesel	2.16	0	2.16	0%
LNG (Fossil)	0.00	0	0.00	0%
Totals	**280.75**	**7.08**	**273.67**	**2.5%**

**Specific electricity production is not known at the transportation level. The percentage used here is based on the ratio of electricity produced to electricity imported for 2020.*

Transportation Energy Production in Oregon, 2005-2020 (billion Btu)[1]



Ethanol. Oregon began producing fuel ethanol in 2007 and had its largest production year in 2008 with 10.3 trillion Btu of energy created. In 2020, Oregon produced 5.0 trillion Btu of ethanol.[1] Oregon has one commercial ethanol producer — Alto Ingredients' Columbia Dry Mill and Distillery in Boardman (previously known as Pacific Ethanol). Carbon dioxide emissions from the plant are captured and used by the food and beverage industry, turning emissions into a beverage-grade liquid used to carbonate soft drinks and make dry ice.[7]

Biodiesel. The U.S. Energy Information Administration began tracking Oregon biodiesel production in 2013. In 2020, Oregon produced 1.5 trillion Btu of biodiesel. SeQuential Pacific Biodiesel produces biodiesel from used cooking oil from local restaurants and businesses and is the second largest source of transportation fuels produced in Oregon (after ethanol).[19]

A Sequential Pacific Biodiesel truck fills up in Salem, OR.

Renewable Natural Gas. This emerging biofuel that captures methane from waste streams has potential to displace some fossil transportation fuels in Oregon.

Energy Facility Siting in Oregon

Oregon's Energy Facility Siting Council is a governor-appointed body that oversees the siting of energy facilities in the state, and is staffed by the Oregon Department of Energy. The types and sizes of energy projects subject to EFSC jurisdiction have changed over time. While the bulk of applications have been for electric generation projects, EFSC has also reviewed site certificate applications for electrical energy transmission, pipelines, nuclear research reactors, ethanol production, liquified natural gas storage, and many others. More recently, EFSC has reviewed battery storage as part of other energy projects, even though battery storage is not by itself state jurisdictional. EFSC also has ongoing responsibility for approved sites, including monitoring projects going into construction and operation, and reviewing site certificate amendment requests.

56

Total number of site certificates issued by EFSC — **40** are current.

19.5 Gigawatts

Capacity of EFSC-approved electricity facilities. Nearly **5.7 GW** is renewable.

7.4 Gigawatts

Capacity of renewable electricity generation under review, approved to begin construction, under construction, or operating.

Site Certificate — under ORS 469.300(26) — means the binding agreement between the State of Oregon and the applicant, authorizing the applicant to construct and operate a facility on an approved site, incorporating all conditions imposed by EFSC on the applicant.

Renewable Electricity EFSC Projects Summary (Megawatts)

Status	Wind	Solar	Geothermal	Hydro	Battery	Total MW
Active						
Operational	2,719	50	-	-	5	2,774
In Construction	194	362	-	-	-	556
Approved	421	812	-	-	463	1,696
Under Review	340	2,505	-	-	2,340	5,185
Subtotal	**3,674**	**3,729**	**-**	**-**	**2,809**	**10,211***
Inactive						
Approval Expired	640	-	35	-	-	675
Decommissioned	-	-	-	-	-	-
Denied	-	-	-	80	-	80
Withdrawn	2,445	300	180	200	1,100	4,225
Subtotal	**3,085**	**300**	**215**	**280**	**1,100**	**4,980**
TOTAL MW	**6,759**	**4,029**	**215**	**280**	**3,908**	**15,191**

**10,211/10,212 difference due to rounding.*

Non-Renewable Electricity EFSC Projects Summary (Megawatts)

Status	Coal	Nuclear	Natural Gas	Other	Total MW
Active					
Operational	-	-	3,237	51	3,288
In Construction	-	-	-	-	-
Approved	-	-	-	-	-
Under Review	-	-	-	-	-
Subtotal	**550**	**-**	**3,237**	**51**	**3,288**
Inactive					
Approval Expired	109	5,040	3,221	38	8,408
Decommissioned	550	1,130	415	-	2,095
Denied	-	-	-	-	-
Withdrawn	431	-	5,147	109	5,687
Subtotal	**1,090**	**6,170**	**8,783**	**147**	**16,190**
TOTAL MW	**1,090**	**6,170**	**12,020**	**198**	**19,478**

Non-Electricity Generation EFSC Projects Summary (Number) — Part 1

Status	Research Reactors & ISFSI*	Electric Transmission Line	Natural Gas Storage	Liquefied NG Storage	Total Projects
Active					
Operational	3	1	1	-	5
Approved	-	1	-	-	1
Under Review	-	1**	-	-	1
Subtotal	**3**	**3**	**1**	**-**	**7**
Inactive					
Withdrawn	-	1	-	2	3
Subtotal	**-**	**1**	**-**	**2**	**3**
Total MW	**3**	**4**	**1**	**2**	**10**

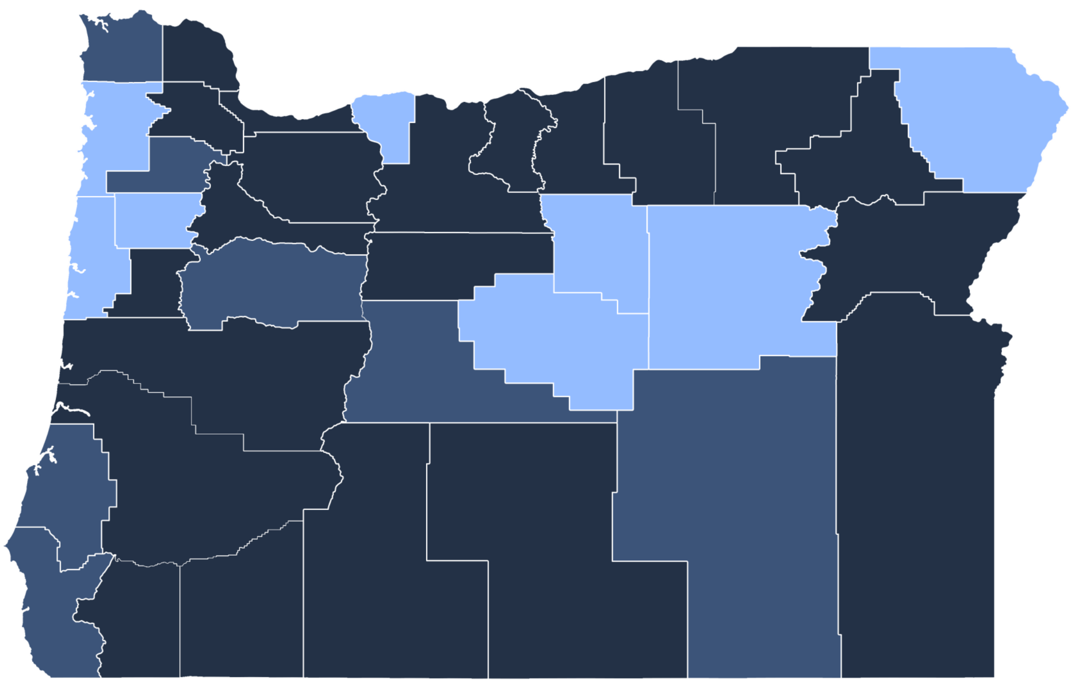
**Portland General Electric's Independent Spent Fuel Storage Installation Facility at decommissioned Trojan Power Plant.*
***This is an amendment to the existing in-service Eugene to Medford 500 kV transmission line.*

Non-Electricity Generation EFSC Projects Summary (Number) — Part 2

Status	Natural Gas Pipeline	Ethanol Production	Total Projects
Active			
Operational	2	1	3
Approved	-	-	-
Under Review	-	-	0
Subtotal	**2**	**1**	**3**
Inactive			
Withdrawn	-	1	1
Subtotal	**-**	**1**	**1**
Total MW	**2**	**2**	**4**

Total Projects (Parts 1 and 2)	**14**

Oregon Counties with State Jurisdictional Energy Projects



Counties with existing site certificates and/or applications

Counties with prior but not current site certificates and/or applications

Counties with no current or prior site certificates and/or applications

More information on Oregon's state-jurisdictional energy projects is available online:

tinyurl.com/EFSC-projects

Energy Costs & Economy

What We Spend

In 2020, Oregon spent $12.1 billion on energy, a drop from the recent peak of $14.2 billion in 2018.[1] This includes electricity and fuel for homes and businesses, industrial energy uses, and petroleum used in the transportation sector. Transportation accounts for about half of our state's energy expenditures and sees the largest swings in price. The variability in what we spend on energy is driven primarily by transportation fuel costs. In 2020, Oregonians sent about $5.7 billion in transportation dollars to other states and countries where extraction, processing, and refining of transportation fuels occurs.[2]

$12.1 billion

Oregonians spent on energy in 2020.[1]

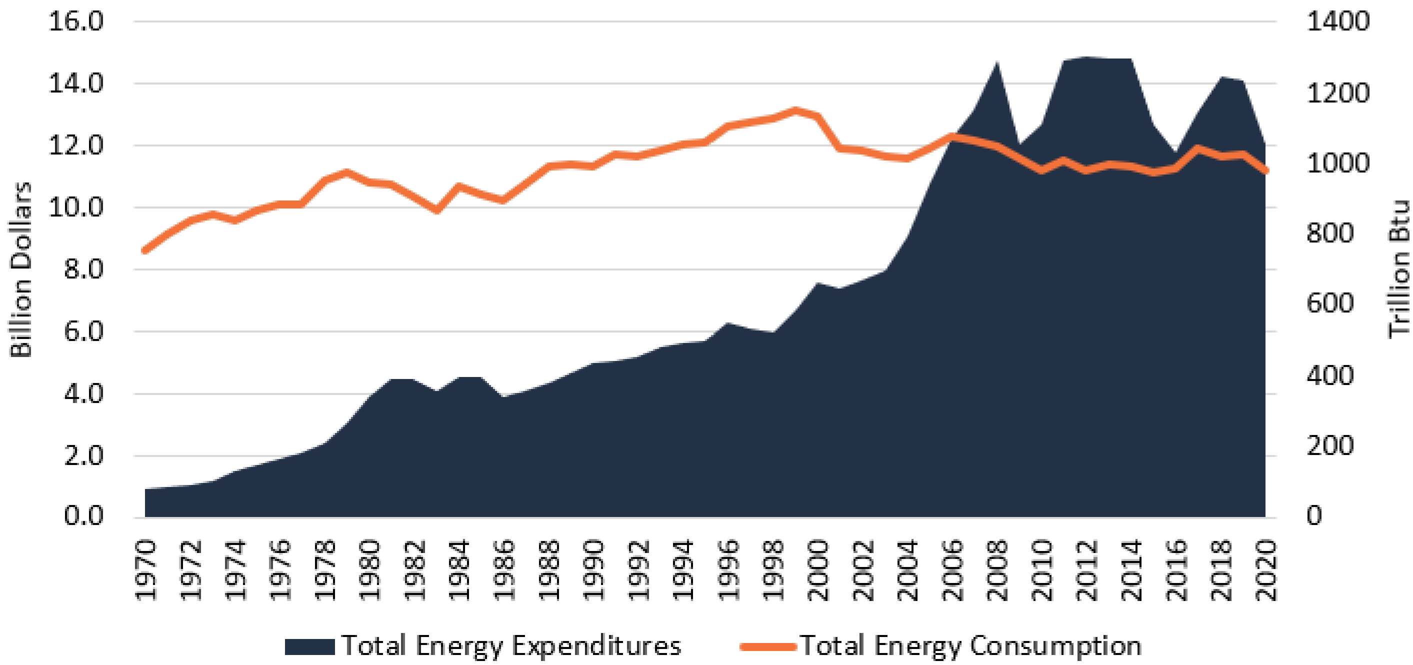
11.31 cents

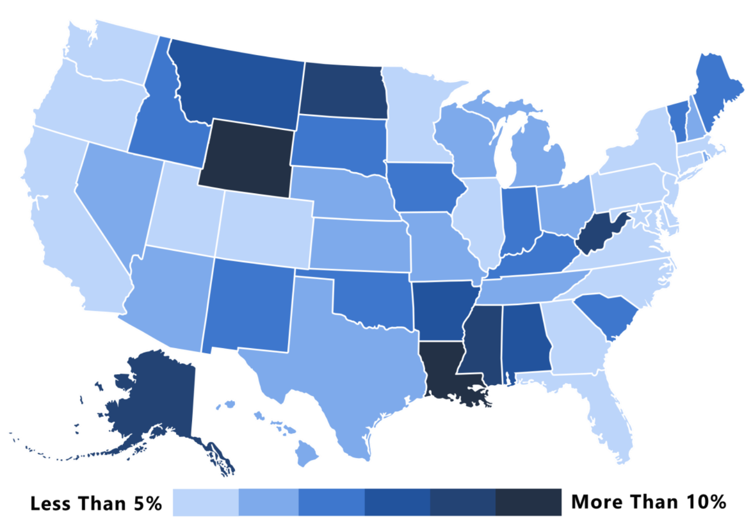
Oregon's average residential retail price per kilowatt hour of electricity for 2020.[14]

4.95%

Percentage of Oregon's GDP spent on energy in 2020.[1]

Oregon's Total Energy Expenditures vs. Total Energy Consumption[1]

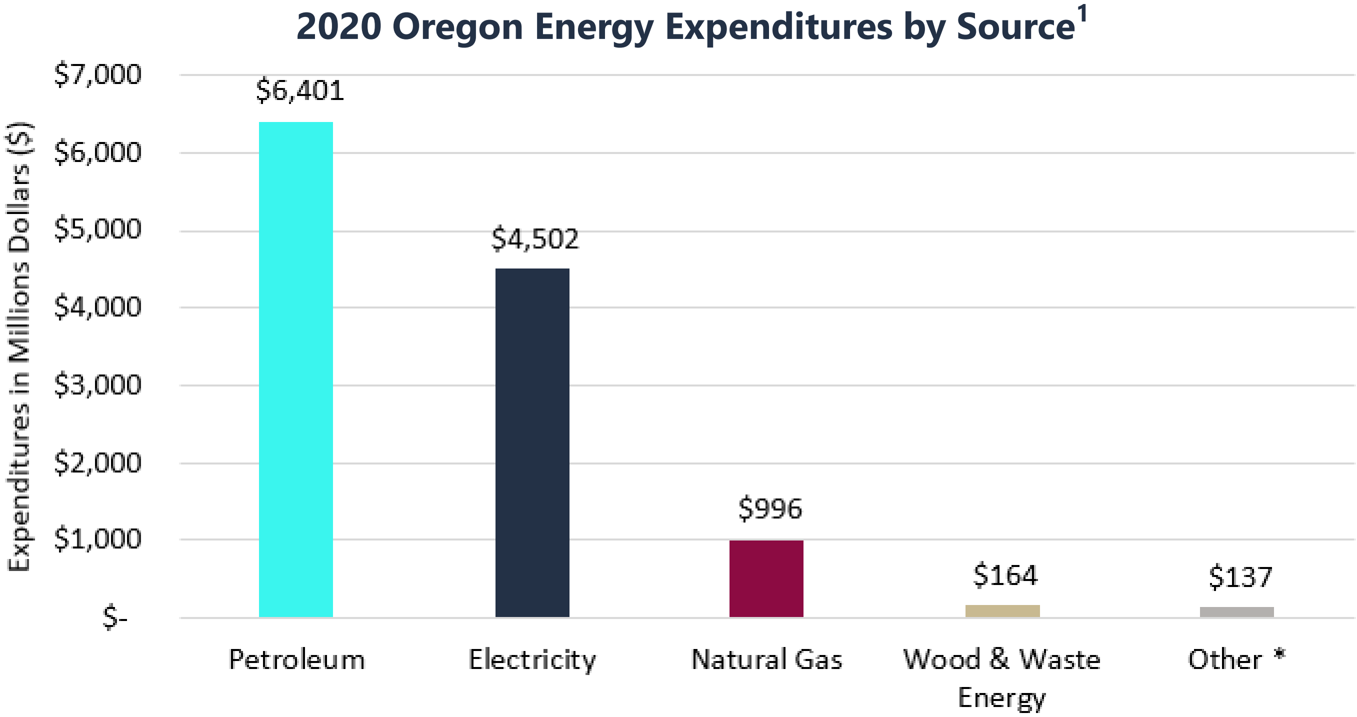




State Total Energy Expenditures as a Percentage of State Gross Domestic Product (2020)[1]

Oregon Energy Expenditures by Source

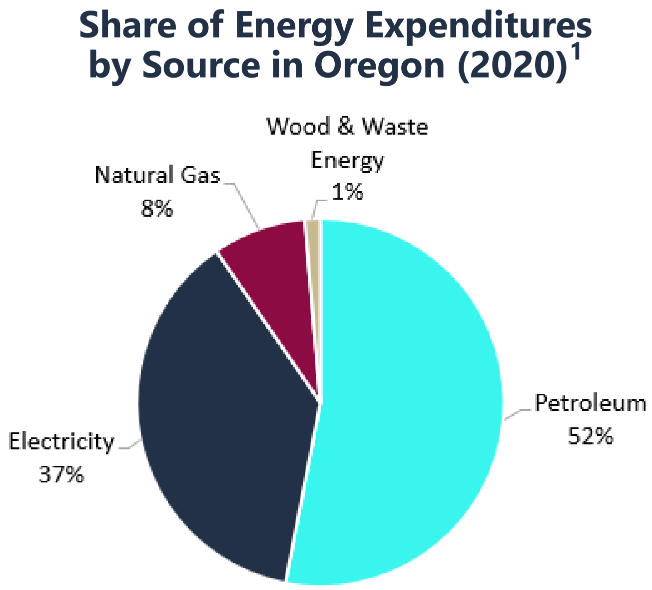
Oregon's industrial, commercial, residential, and transportation sectors spent over $12.1 billion on energy from petroleum, electricity, natural gas, wood, waste, and some coal.[1]



**Other* includes coal. *Other* is not included in the pie chart below, as it rounds to 0%.

The petroleum products category is dominated by transportation fuels. The transportation sector accounts for $5.7 billion in expenditures and includes some natural gas and electricity expenditures. As shown in the sector-based comparison later in this section, transportation energy use is the largest portion of Oregon's overall energy use.

The price of electricity has remained stable primarily because of the regulation of retail rates by the Oregon PUC and local governing boards of COUs. Natural gas retail prices are also regulated by the OPUC, and overall constitute a smaller portion of total consumer energy expenditures in Oregon. Petroleum product prices, however, are unregulated and experience a high level of price volatility with impacts from global market pressures and from localized taxes and storage and distribution costs. Despite a small drop in price per unit of energy in petroleum products in 2020, the petroleum category maintains an outsized portion of the annual energy expenditures.[1]



Energy Burden

Home energy burden is the percent of household income spent on home energy bills. Energy bills include electricity, natural gas, and other home heating fuels, and are compared to the total income of the people in that household. If a household is spending more than 6 percent of its income on home energy costs, it is considered burdened.[4] The energy affordability gap is the difference between a household's actual energy costs and an "affordable" energy burden level (6 percent of the household's income). With so many low-income Oregonians facing significant energy burden, Oregon's energy affordability gap is estimated to be about $289 million per year, or eight times the federal funding Oregon receives for energy assistance.[5]

The Oregon Department of Housing and Community Services has assembled county profiles for Oregon that provide a detailed look at population, poverty, income, homeownership, rental housing, and houselessness, which can provide additional context when discussing energy burden. See the dashboard online: **https://tinyurl.com/OHCS-County-Profiles**

3x

Nationally, low-income households spend three times more of their income on energy costs compared to the median spending of non low-income households.[4]

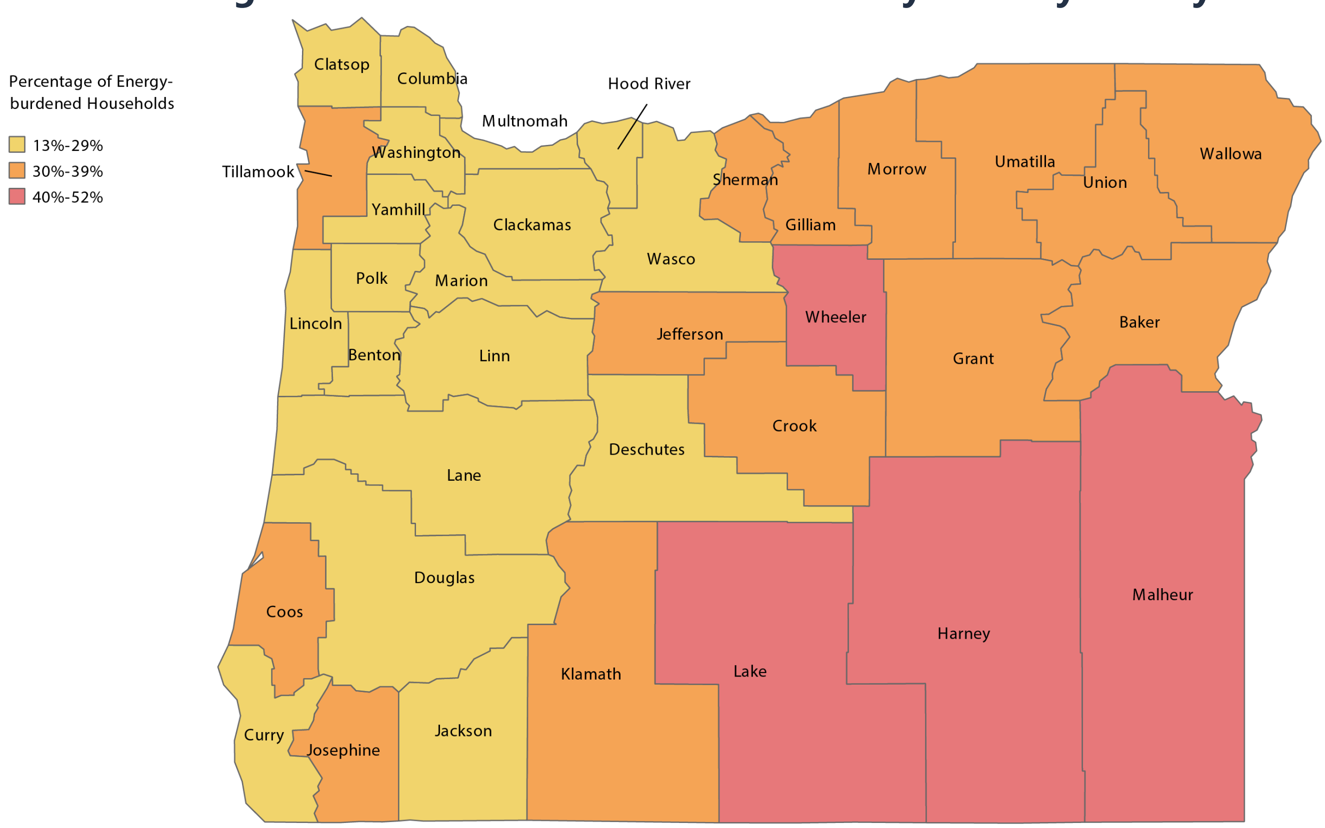
370,797

Number of Oregon households that were energy burdened in 2020, a small decrease from 2019.[5]

23%

Percentage of all Oregon households that were energy burdened in 2020,[5] a 2% decrease from 2019.

Percentage of Oregon Households Considered Energy Burdened and Earning 200 Percent or Below Federal Poverty Level by County[6]



Transportation burden represents the total annual transportation costs of households in comparison to income of the household.[7] Home and transportation energy burdens are combined to discuss the whole energy burden of a household — and both are important indicators of affordability for Oregonians.

The Housing + Transportation Affordability Index was last updated in 2017 and provides more information on transportation energy burden by town: **htaindex.cnt.org/map/**

The Oregon Department of Transportation is developing public transportation solutions to increase the affordability for Oregon communities. Learn more about ODOT's innovative solutions in its Oregon Public Transportation Plan: **tinyurl.com/ODOT-OPTP**

Global Events Affect Energy Costs for Oregonians

Disruptions in demand for energy and price swings for petroleum products caused by the COVID-19 pandemic, record setting heat waves, and the war in Ukraine have contributed to a quickly changing and very challenging economic situation for all Oregonians — but especially for low-income households. Rising inflation and demand have contributed to shortages of certain goods, and many Oregonians struggled to pay for housing costs and utilities during the pandemic.

OREGONLIVE The Oregonian

Oregon gas prices soar to all-time high amid Ukraine invasion, possible Russian oil ban

Updated: Mar. 07, 2022, 11:24 a.m. | Published: Mar. 07, 2022, 11:06 a.m.

Gas prices hit a record Monday in Oregon amid concerns about the impact of a possible ban on Russian oil imports and the ongoing war in Ukraine. (File/The Oregonian) Faith Cathcart/The Oregonian

State and local jurisdictions have been working hard to ensure Oregon recovers from these challenges. For example, the Oregon Public Utility Commission and Oregon utilities came together to plan on making accommodations to ensure Oregonians and small businesses affected by the pandemic would still have access to electricity as they recovered.[8] Advocates are calling for utility assistance programs to operate year-round, rather than only during the winter due to life threatening heat waves.[9] The Oregon Legislature passed HB 2475, which allows the Public Utility Commission to consider energy burden and other factors affecting energy affordability in the rate making process. This allows for mitigation of energy burden through bill reduction measure or other programs like weatherization.[10]

The 2024 edition of this report will have access to 2021 and 2022 data that will provide further insight on how well Oregon navigated these challenges and whether any groups have been further disadvantaged.

Energy Jobs

Oregonians hold a number of jobs in the energy industry — from energy utility workers to wind turbine technicians to solar installers.

Energy employment is often sorted into energy efficiency, traditional energy, and motor vehicles jobs. In Oregon, most energy-industry employees work in energy efficiency, including high-efficiency and traditional HVAC, renewable heating and cooling firms, and others. Traditional energy jobs include energy extraction, as well as power generation, transmission, distribution, and storage. Motor vehicles jobs include both the manufacture and distribution of parts and vehicles for all industries from large scale industrial vehicles to small recreational vehicles such as golf carts.

90,543

Number of Oregonians employed in the energy industry in 2021.[11]

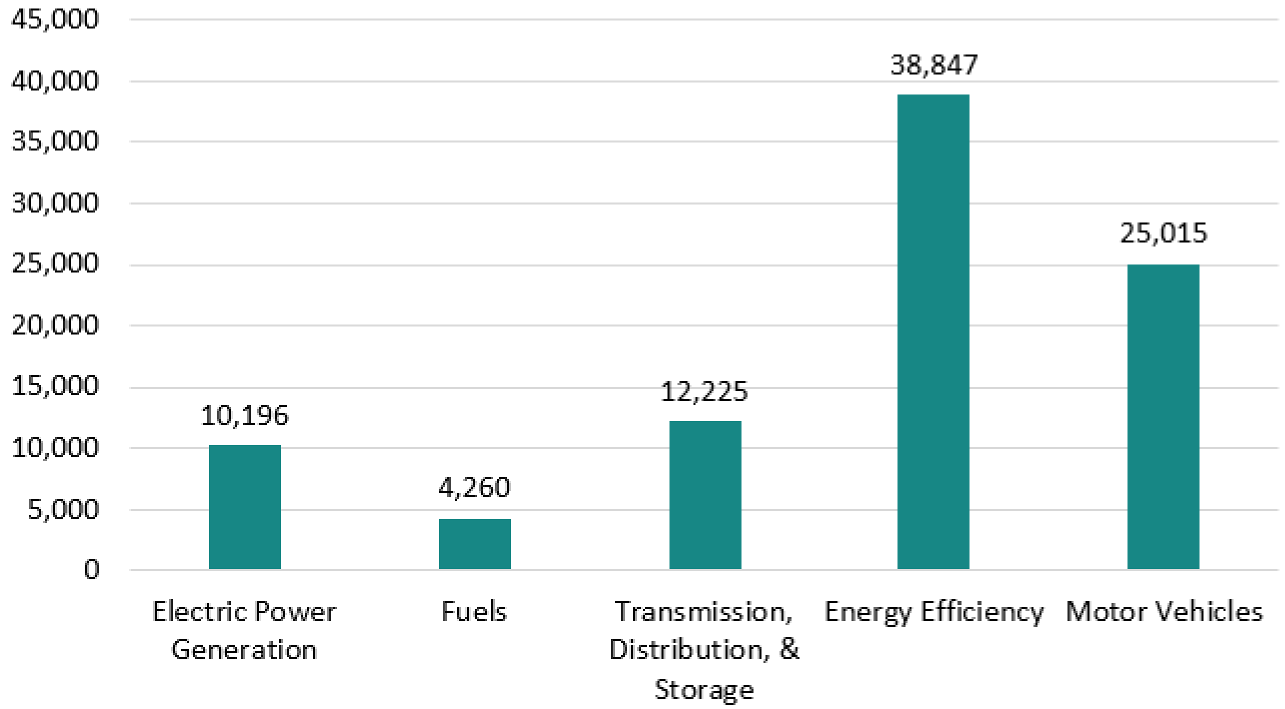
50,562

Number of clean energy jobs in Oregon in December 2020, a loss of 6,055 jobs during the pandemic.[12]

3,414

Number of clean energy jobs added in Oregon since May 2022 following the COVID-19 economic downturn.[12]

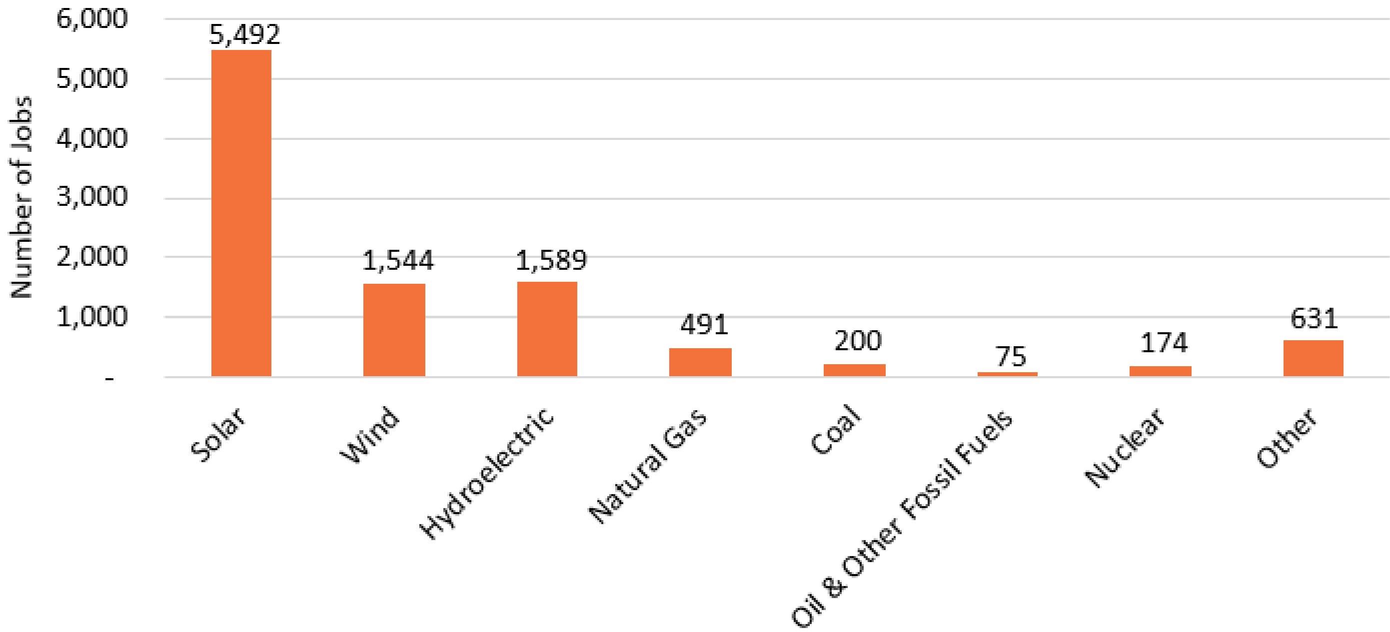
Number of Energy Jobs in Oregon by Type (2021)[11]



Nationally, 255,037 people work in the solar industry; Oregon makes up about 2.2 percent of those jobs, with 166 solar companies operating in the state. In 2021, 5,492 Oregonians worked on solar projects. The industry lost 267 solar jobs in Oregon in 2020.[13]

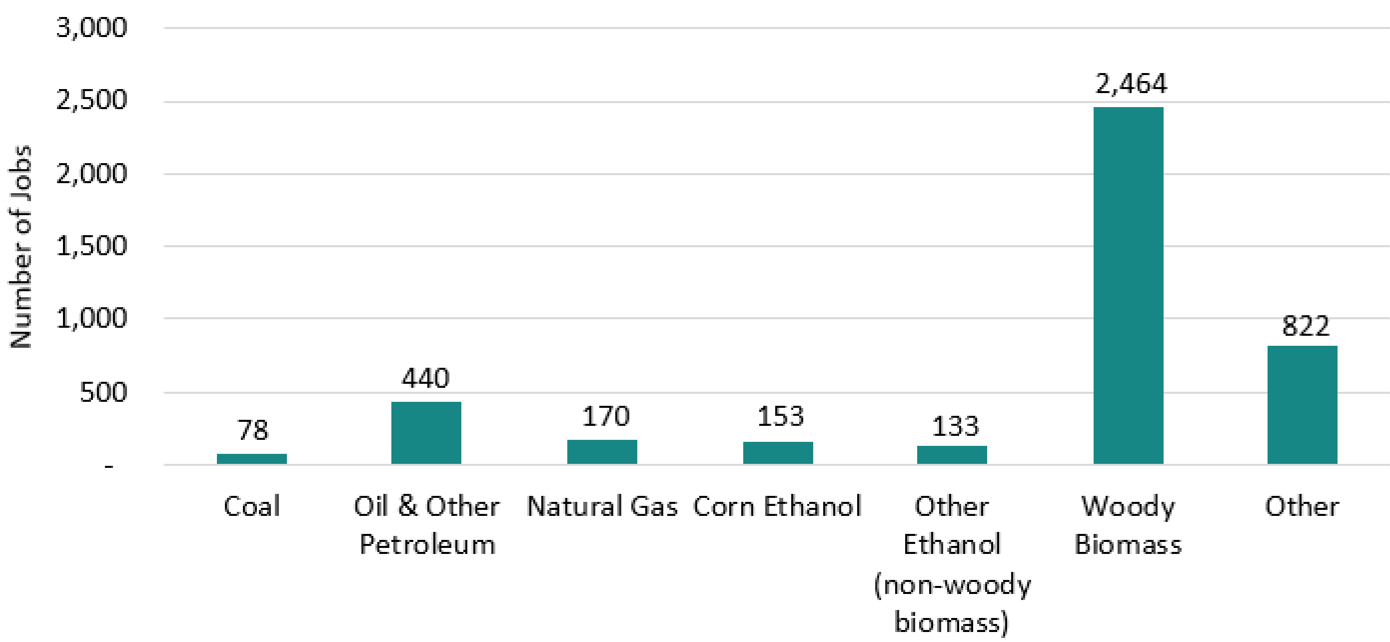
The electric power generation sector in Oregon employed 10,196 workers in 2021, and added 545 jobs over the previous year.[11]

Electric Power Generation Jobs in Oregon by Technology (2021)[11]



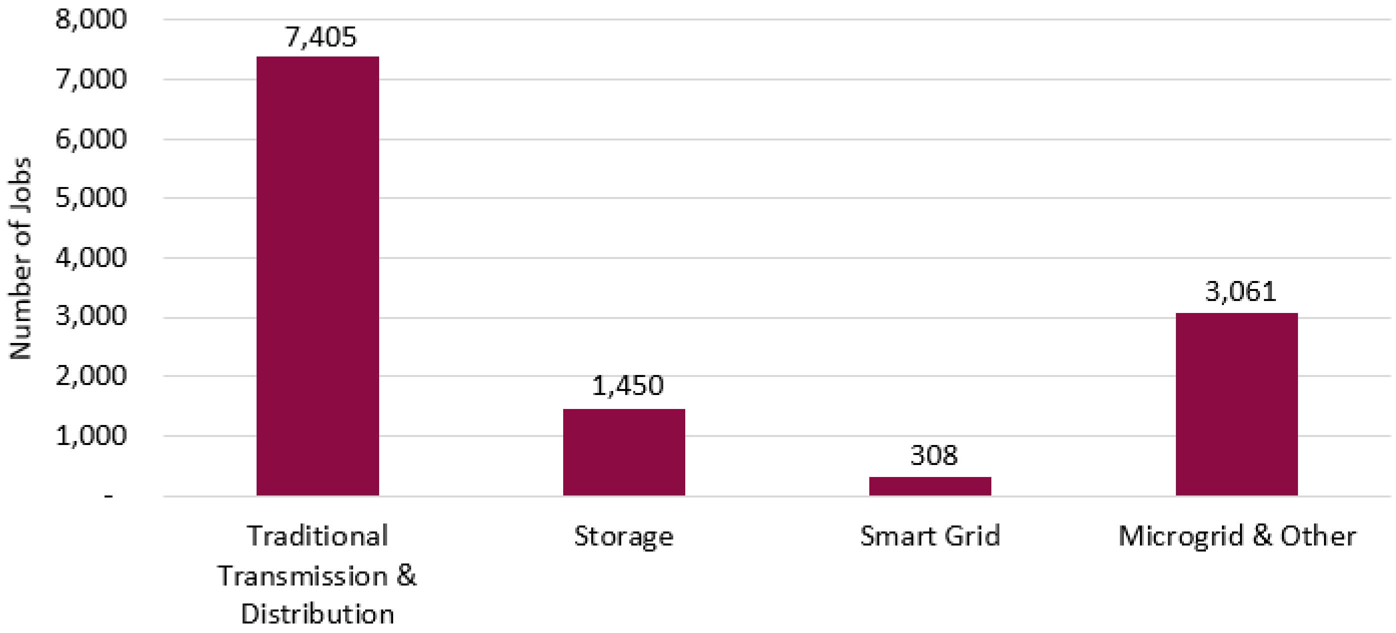
The fuels sector in Oregon employed 4,260 workers in 2021, and added 146 jobs over the previous year.[11]

Fuels Jobs in Oregon by Resource (2021)[11]



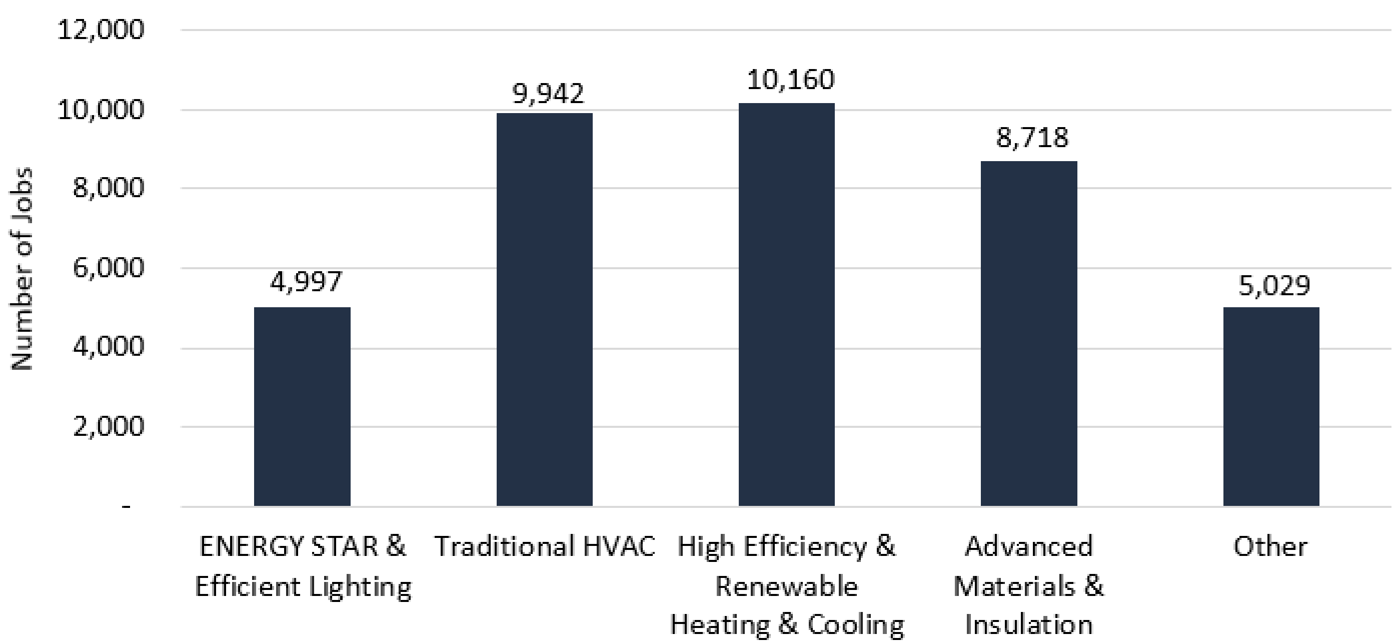
The transmission, distribution, and storage sector in Oregon employed 12,225 workers in 2021, a decrease of 661 jobs from the previous year.[11]

Transmission, Distribution, and Storage Jobs in Oregon (2021)[11]



The energy efficiency sector in Oregon employed 38,847 workers in 2021, and added 585 jobs from the previous year.[11]

Energy Efficiency Jobs in Oregon by Technology (2021)[11]



Turn to the Policy Briefs section of this report to learn more about local perspectives on Oregon's energy workforce and supply chain.

Energy Efficiency

Oregon's Second Largest Resource

9th

Oregon's 2020 rank among U.S. states for energy efficiency by the American Council for an Energy Efficient Economy.[3]

14

Years in a row that Oregon has landed in the top 10 most energy efficient states.[3]

Energy efficiency, the use of less energy to perform the same task or produce the same result,[1] plays a critical role in Oregon. It remains the second largest resource in the state after hydropower, and Oregon has consistently met increased demand for electricity by implementing energy efficiency strategies. The Northwest Power & Conservation Council reports that since 1978, the Pacific Northwest has produced about 7,200 average megawatts (aMW) of savings through efficiency programs and improvements.[2] That's more electricity than the whole state of Oregon uses in a year.

Over the past decade, Oregon reduced per capita energy use despite our state population growing, and energy efficiency is one reason why. Oregon's gains in energy efficiency have been helped by federal appliance standards, state policies and programs, natural gas and electric utility programs, Energy Trust of Oregon utility programs, and other nongovernmental organizations. For the region's cumulative savings, 60 percent comes from utility and Bonneville Power Administration programs.[2] Energy efficiency gains are cumulative and continue paying dividends for our region over time.

Energy Efficient Wildfire Recovery

In 2020, more than 5,000 structures and over 1 million acres were burned in 21 wildfires that devastated Oregon communities over the Labor Day weekend. Communities across Oregon lost homes and businesses under sky that was darkened by ash and smoke.

To help Oregonians recover, the Oregon Legislature allocated $10.8 million to the Oregon Department of Energy to incentivize energy-efficient rebuilding efforts. Building and homeowners can receive incentives to build to current building code or above code — incorporating these energy efficiency improvements help make buildings more comfortable and support long-term affordability thanks to lower energy bills. ODOE rolled out the program in early 2022.

Learn more: **www.oregon.gov/energy/Incentives/Pages/EEWR.aspx**

Oregon Electricity Savings

The Northwest Power & Conservation Council's 2021 Northwest Power Plan, published in March 2022, concludes that cost-effective efficiency can meet a large amount of new load growth in the region – allowing Oregon to grow without needing significant new electricity resources. The plan calls on the region to develop new energy efficiency programs equivalent to acquiring 2,400 average megawatts of power by the end of 2041.[2] Integrated Resource Plans from Oregon's large electric utilities also identify energy efficiency as a key strategy they will use to meet demand over their planning horizons.

The Regional Conservation Progress Report to the Northwest Power and Conservation Council in September 2020, however, demonstrates that there is significant cost-effective energy efficiency in the electric sector still available, but that regional energy efficiency achievement in the electric sector is on a downward trend – this means that each subsequent year of the Plan will deliver fewer savings. The COVID-19 pandemic affected the savings achievement in 2020 but was not the only factor. Program expenditures have been flat to declining over the last four years and the cost of savings has been increasing from $2 per aMW in 2016 to $2.75 per aMW in 2020.[4]

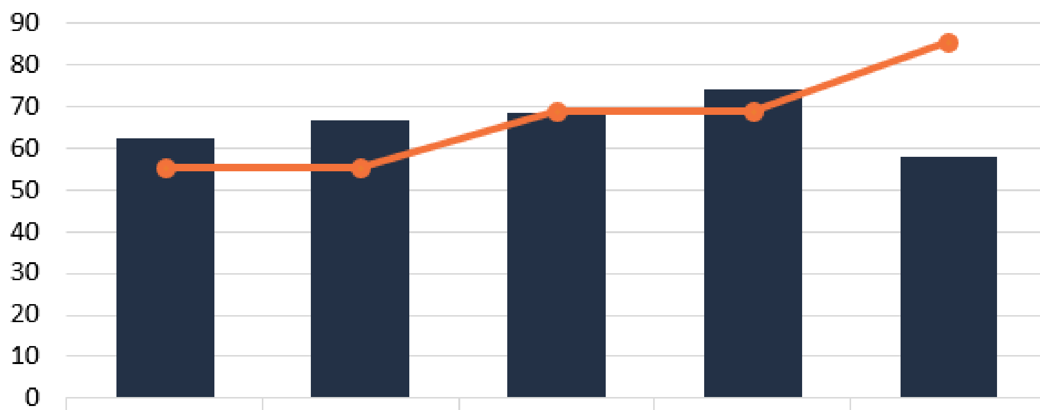
7,200

Average megawatts of regional electricity savings from energy efficiency (1978-2020).[2]

2,300

Average megawatts of Oregon electricity savings from energy efficiency (1978-2020).[2]

Oregon Electricity Savings & Estimated Share of Seventh Power Plan Goal (aMW)[2]



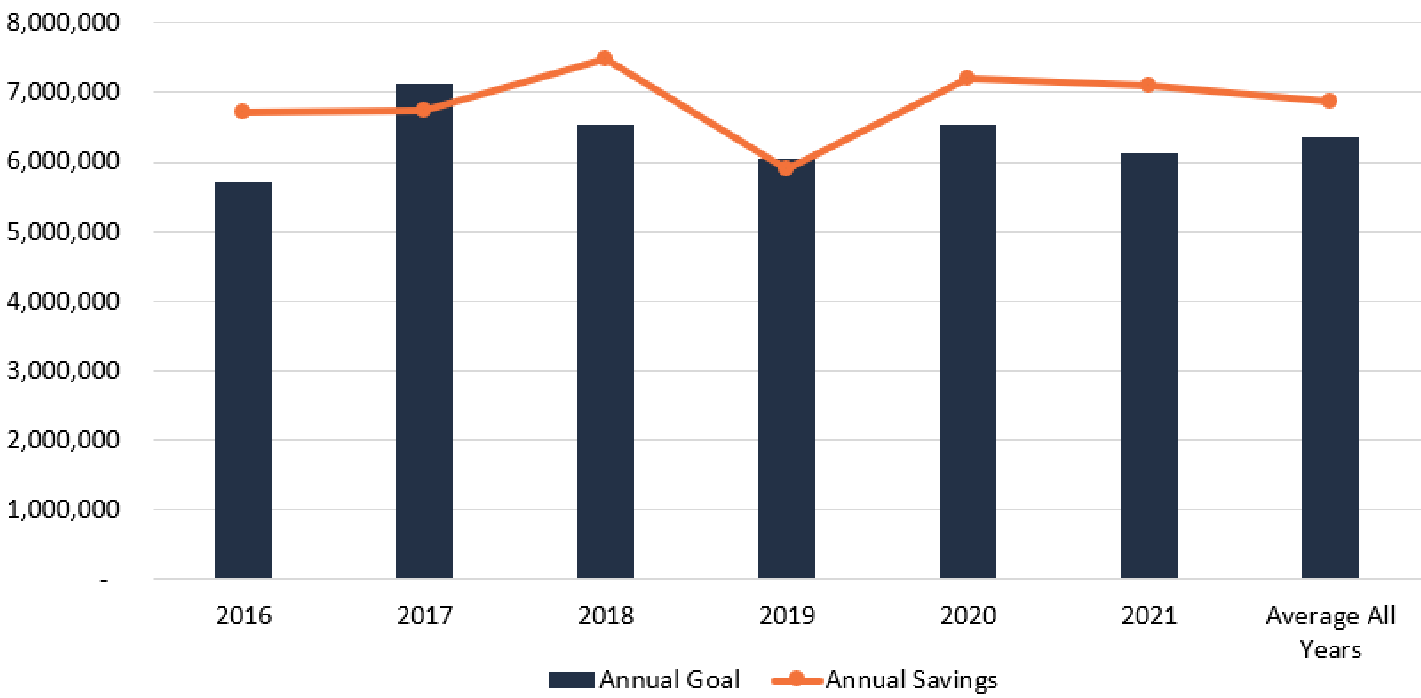
	2016	2017	2018	2019	2020
Energy Trust of Oregon	58.4	62.2	50.0	51.8	39.9
BPA	9.3	5.7	8.1	8.9	3.9
COU Utility Self-Funded	1.1	0.6	2.6	3.3	0.3
NEEA	9.0	7.9	12.4	16.8	15.0
Codes and Standards	0.0	0.5	1.9	2.4	3.4
Momentum	3.2	8.2	0.0	0.0	0.0
Market Adjustment	-18.7	-18.2	-6.6	-9.0	-4.6
Total Oregon Savings	62.37	66.85	68.38	74.24	57.81
Estimated Oregon Share of Goal	56	56	69	69	86

Oregon Natural Gas Savings

Natural gas efficiency goals are developed in each natural gas utility's Integrated Resource Plan submitted to the Oregon Public Utility Commission. The utilities' savings exceeded goals from 2016 and 2018 with a slight decline in 2019, then continued to exceed goals in 2020 and 2021.[5] Energy Trust of Oregon implements energy efficiency programs for natural gas utilities. Programs are funded by customer rates, and cost effectiveness tests of natural gas measures ensures that efficiency investments cost less than building new natural gas resources.

For more about cost-effectiveness, see Chapter 6 of the *2018 Biennial Energy Report.*

Oregon Natural Gas Savings Compared to Goals (Million Therms)[5]



Integrated Resource Planning

From the Oregon Public Utility Commission's website:

Oregon was one of the first states to require utilities to file integrated resource plans (IRPs). The IRP presents a utility's current plan to meet the future energy and capacity needs of its customers through a "least-cost, least-risk" combination of energy generation and demand reduction. The plan includes estimates of those future energy needs, analysis of the resources available to meet those needs, and the activities required to secure those resources. What began thirty years ago as a simple report by each utility has grown into a large, stakeholder-driven process that results in a comprehensive and strategic document that drives utility investments, programs, and activities.

Learn more: **www.oregon.gov/puc/utilities/Pages/Energy-Planning.aspx**

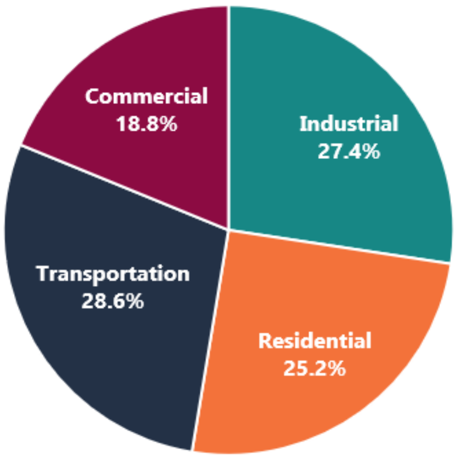
Energy End Use Sectors

Consumption

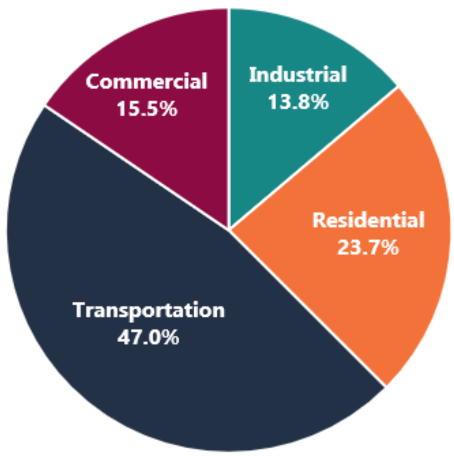
As noted earlier in this section, energy metrics are commonly divided into four end-use sectors: residential, commercial, industrial, and transportation.

Consumption and cost of energy vary across the sectors. In 2020, transportation accounted for 28.6 percent of energy consumption and 47 percent of expenditures due to higher per-unit cost of transportation fuels. The industrial sector used 27.4 percent of the total energy but accounted for only 14 percent of expenditures due to cheaper per-unit costs relative to the other sectors.[1]

Oregon Consumption by End-Use Sector (2020)[2 3]

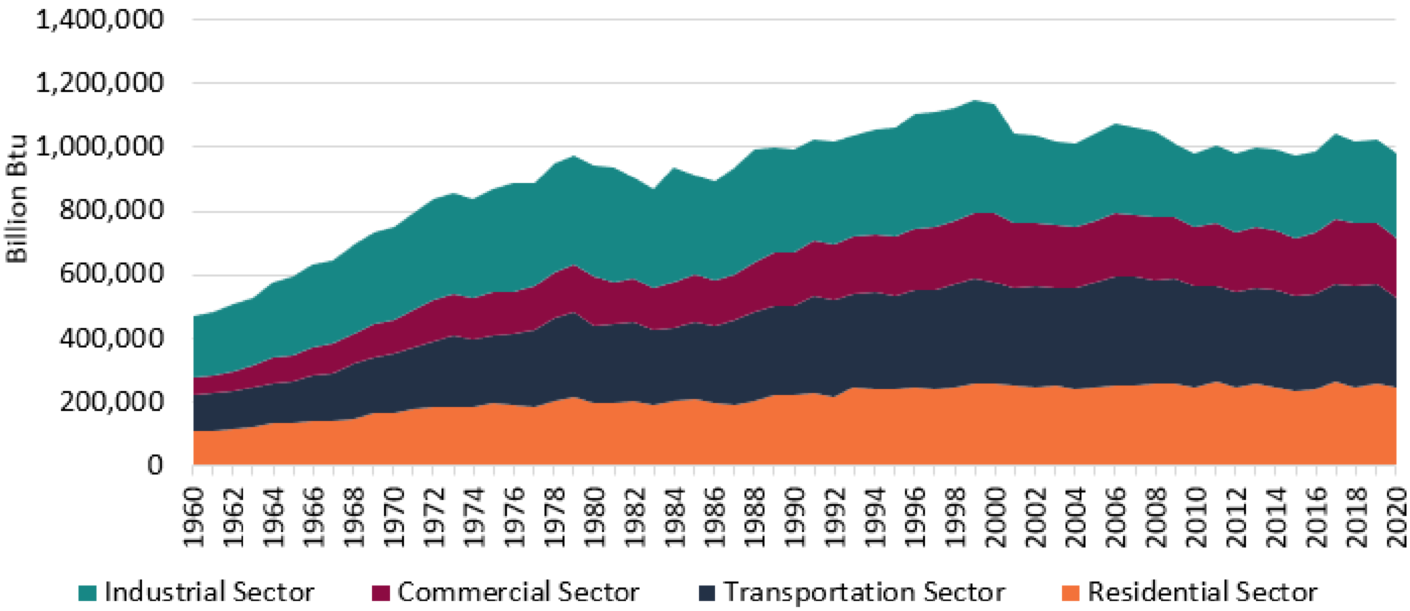


Oregon Expenditures by End-Use Sector (2020)[2 3]



Energy consumption across all sectors has remained relatively steady in recent years. Increased population, GDP, and vehicle miles traveled—which all increase energy use—have been offset by efficiency gains and a shift toward less energy-intensive industries, demonstrated in the downward trend of energy use in recent decades.

Oregon Consumption by Sector Over Time (Billion Btu)[2]



Expenditures

Oregonians' 2020 energy expenditures can be separated by sector. The transportation sector accounts for more than half of expenditures due to the much higher per-unit cost of transportation fuels. Because nearly all Oregon's transportation fuel is imported, most of this money goes out of state. While Oregon's residential, commercial, and industrial sectors have experienced gradual increases in spending through 2018, transportation sector expenditures reflect both increasing consumption and price volatility in the transportation fuels market. The variability in what Oregonians spend on energy is driven primarily by transportation fuel costs. Recent data show a drop in expenditures across all sectors for 2019 and 2020—a sharp drop in transportation and slight decreases in each of the other sectors. The start of the pandemic likely affected energy use and prices during this time frame, with individuals reducing their transportation use and increases in transportation of goods.

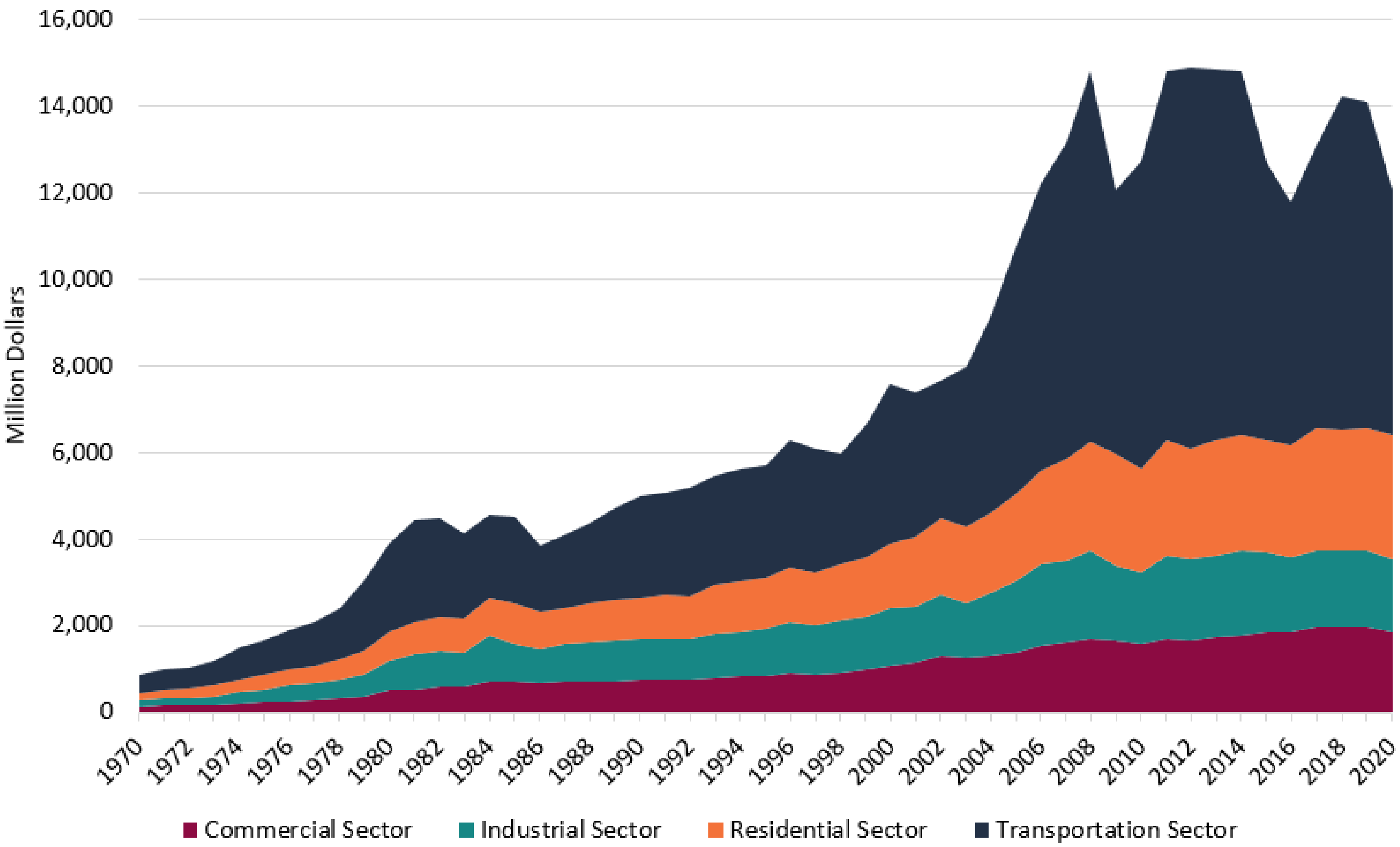
$2,845

Per capita (per person) energy expenditures in Oregon in 2020. The amount has dropped by 16% since 2018.[4]

39th

Oregon's rank in the U.S. for per capita energy expenditures.[4]

Oregon's Total Energy Expenditures by Sector Over Time[2]



The U.S. EIA reports prices in current dollars per million Btu and expenditures in current dollars — the chart is not adjusted for inflation.
Learn more: https://www.eia.gov/state/seds/

Greenhouse Gas Emissions

Most of Oregon's greenhouse gas emissions come from the energy we use every day. These GHG emissions contribute to climate change.

The Oregon Department of Environmental Quality (DEQ) collects data on GHG emissions in Oregon. DEQ publishes the data and uses it to create a sector-based GHG emissions inventory, which is updated annually. The data presented in this section is based on the emissions inventory.

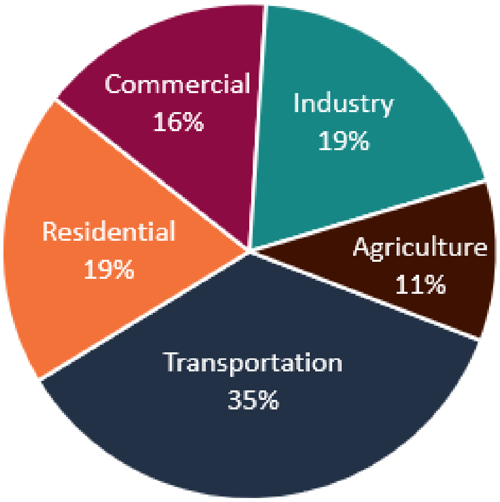
Greenhouse gas emissions can be categorized in multiple ways—by the productive use that creates emissions, by the sector that use falls within, and by the source of the emissions. DEQ provides a mixture of this data, As a result, when analyzing the data, various methods of categorization can reveal new insights. In this section, the data is first presented based on end-use sector, then by source, and then by a mixture of sector and source – presenting DEQ's usual sector-based inventory depiction and an expanded depiction based on further analysis of the data.

GHGs by Sector

Earlier in this report, data is broken out into four end-use sectors — transportation, residential, commercial, and industrial. For greenhouse gas emissions, data can also be broken out for the agriculture sector (in this report agriculture is included in industrial, unless it is shown separately, like here).

Each of the sectors' GHG emissions are summarized below and the pie chart shows the breakdown of emissions between sectors for 2019 – the latest data available. As seen in the chart, the transportation sector accounts for the most emissions.

Greenhouse Gas Emissions by Sector (2019)[5]



Agriculture GHGs. These emissions come from waste streams like methane and nitrogen-based fertilizers for soil management. This sector is distinct because emissions primarily come from methane and nitrous oxide, versus carbon dioxide.

Industrial GHGs. In addition to emissions from electricity generation and natural gas direct use, GHG emissions in the industrial sector come primarily from non-transportation petroleum combustion, industrial waste and wastewater, and manufacturing.

Commercial & Residential GHGs. In addition to emissions from electricity generation and natural gas direct use, GHG emissions in this sector stem primarily from fuel oil for heating and emissions from waste and wastewater.

Transportation GHGs. Transportation is the state's largest single source of GHG emissions, primarily from direct combustion of petroleum products, including emissions from on- and off-highway vehicles (like vehicles used in the industrial, agricultural, or commercial sectors). Of the emissions generated, about 55 percent are from gasoline used mostly in passenger vehicles, and about 35 percent are from medium- and heavy-duty diesel vehicle consumption.[3]

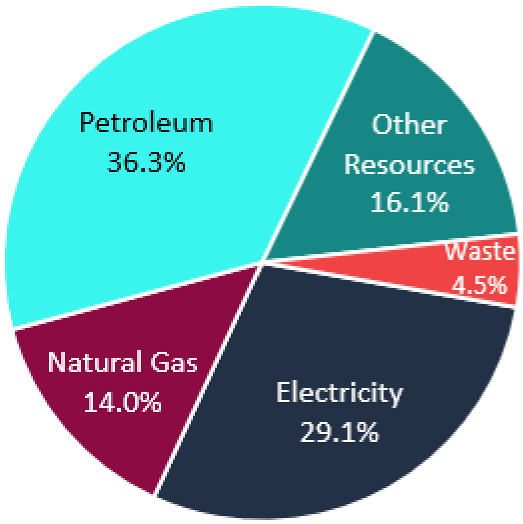
GHGs by Source

GHG emissions data can also be shown by source. Doing so can help illustrate the contribution of energy use to GHG emissions.

Earlier in this Biennial Energy Report, data is broken out into three main categories of energy — electricity, direct use fuels, and transportation fuels. For greenhouse gas emissions, data is broken out a little differently due to data availability and historical presentation practice. As a result, it is important to understand the categories detailed out below. In addition to energy-related items, a category on waste has also been called out as it is a substantial, identifiable source across the sectors.

As can be seen in the pie chart, petroleum products are the largest source of emissions. This correlates to transportation representing the largest sector source of Oregon's GHG emissions.

Greenhouse Gas Emissions by Source (2019)[5]



Petroleum. This represents transportation fuels including diesel, gasoline, and propane for on- and off-highway use, equipment use, and jet fuels.

Electricity. This accounts for electricity used in all sectors, which includes emissions associated with generation of electricity used in the state, regardless of where it is generated. Emissions from electricity generated in Oregon but used out of state are not included.

Natural Gas. This includes direct use of natural gas in all sectors, plus fugitive emissions from distribution. It does not include emissions associated with natural gas-fired power plants.

Other. This category includes uses specific to a sector's activity, such as fertilizer, cement and soda ash production and consumption, semiconductor manufacturing, use of refrigerants and solvents, etc.

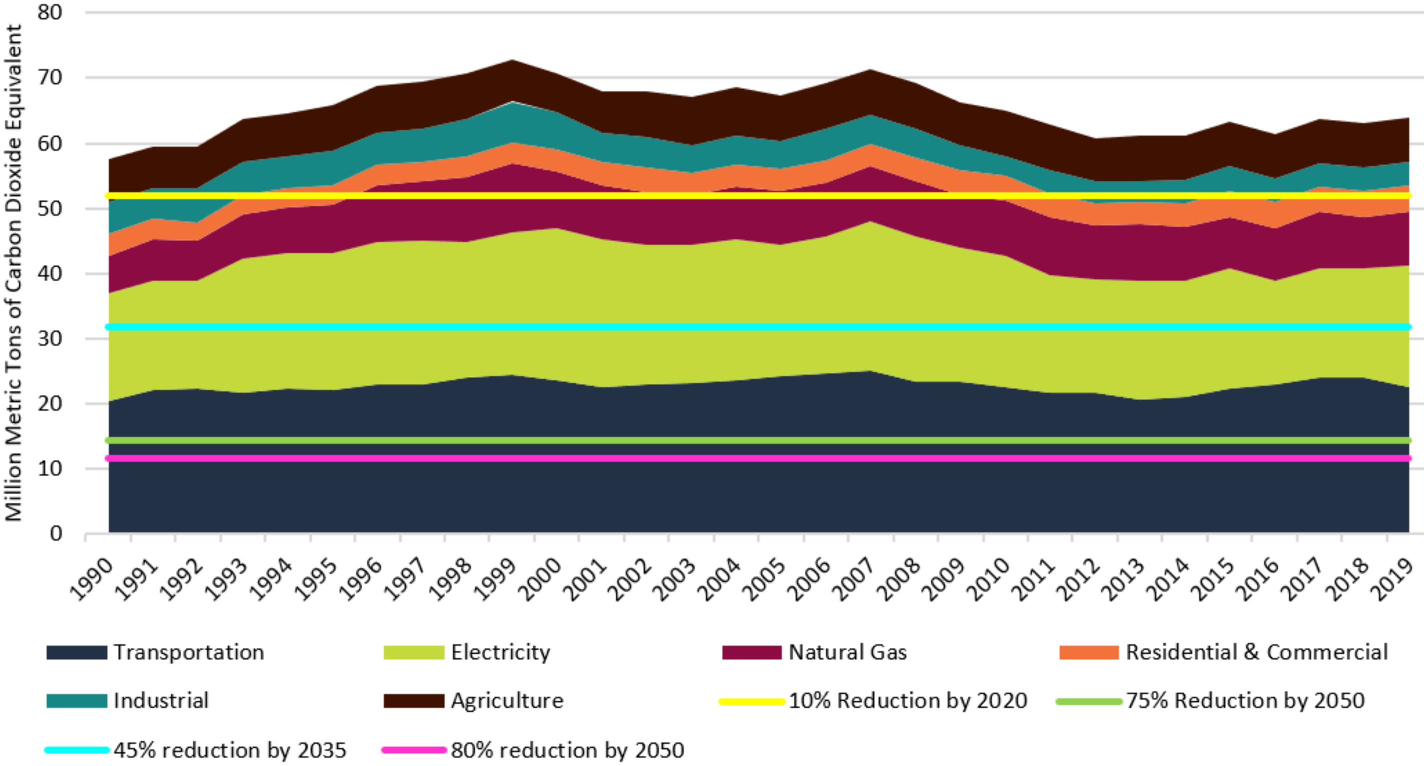
Waste. This includes treatment of waste products from the various sectors, including landfill waste and agricultural waste. Some of these emissions result from the combustion of waste.

GHGs by Sector and Source

Whether something is classified as a sector or a source can sometimes be blurred in GHG emissions data. For example, electricity can sometimes be considered a sector or source depending on who is doing the categorization. The sector and source distinction is not as important as the stories the presentation of the data can tell – particularly over time.

The chart below mirrors the sector-based inventory graphic DEQ provides. As can be seen, it includes six emissions wedges, including one for each of the sectors outlined earlier (residential and commercial are combined here), as well as ones for electricity and natural gas.

Oregon Greenhouse Gas Emissions Over Time[5]



Emissions from natural gas values include distribution and production losses, which differs slightly from DEQ methodology that only includes emissions from combustion in natural gas .

The values for the Electricity and Natural Gas wedges include use for each of the end use sectors: Transportation, Industrial, and Residential & Commercial (the data for the Agriculture sector does not specify electricity and natural gas use). The GHG emissions associated with each sector are lower in this emissions profile because that use is accounted for in the Natural Gas and Electricity Use values.

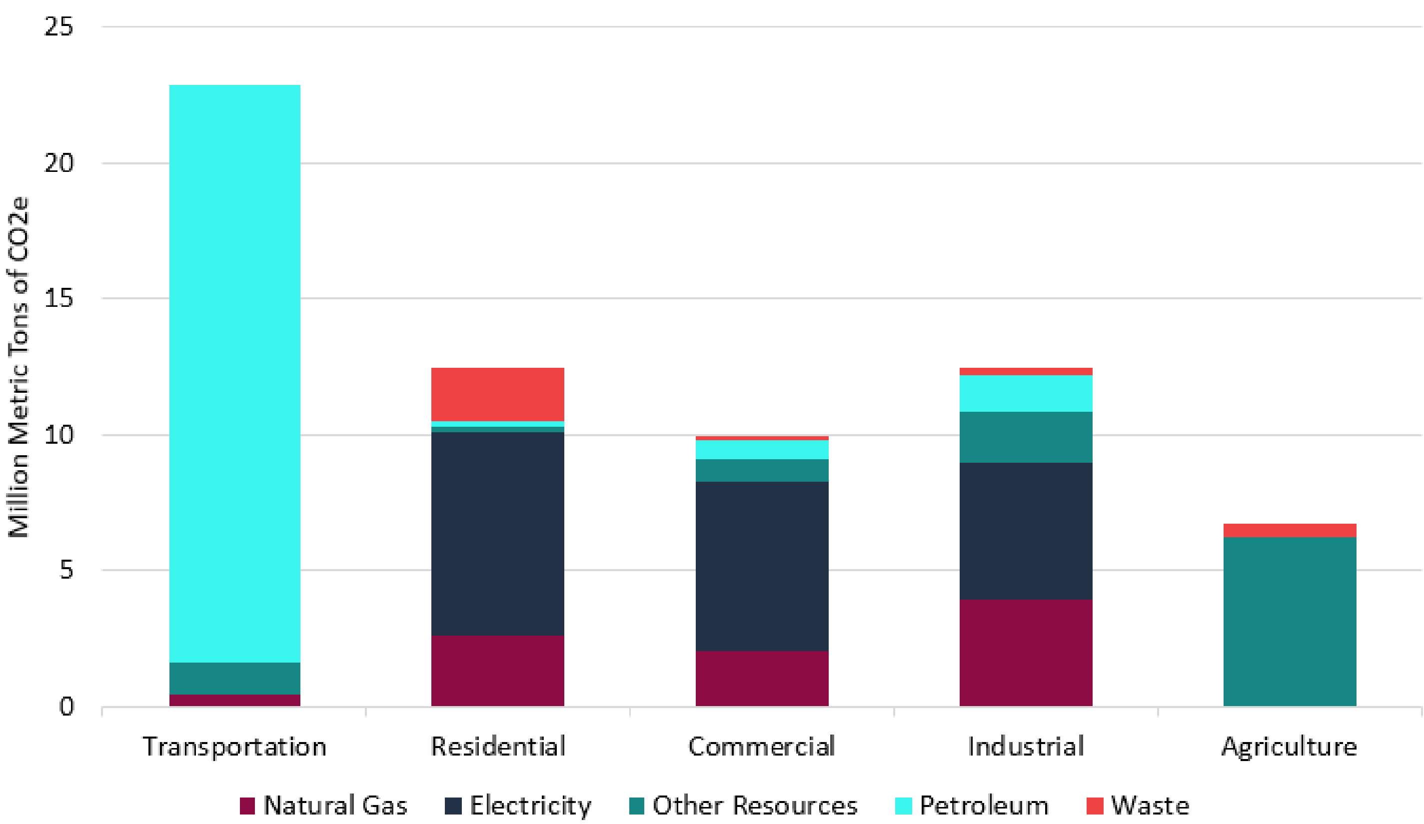
A look at the emissions over time, as provided in this chart, can be helpful in identifying trends. Electricity emissions increased from 1990 through about 2007, and then declined through 2016 and then trended back up. Transportation emissions have grown as a share of Oregon's statewide total GHG emissions in recent years, but the preliminary 2019 data indicates a decrease in transportation emissions. While total transportation emissions have fluctuated over the years, GHG emissions per vehicle have gone down thanks to improved fuel efficiency.[3]

The Oregon Global Warming Commission and others have used DEQ's sector-based inventory to track progress toward the state's greenhouse gas reduction goals. These goals are indicated by the horizontal lines on the chart on the previous page. As the chart shows, Oregon did not achieve its goal of 10 percent below 1990 levels by 2020 (yellow line). Oregon also has a statutory goal of 75 percent below 1990 levels by 2050 (green line).

In 2020, Governor Brown issued Executive Order 20-04, which established an updated 2050 goal of at least 80 percent below 1990 levels by 2050 (pink line) and a more near-term goal of at least 45 percent below 1990 levels by 2035 (light blue line). Recent analysis done by the Oregon Global Warming Commission indicates that the state may be able to meet the 2035 goal if the state is able to implement its current bold climate policies and programs.[6]

Using data from DEQ's Greenhouse Gas Inventory, ODOE assessed different breakdowns of the data and developed the following graphs – one showing only 2019 data and another with breakouts over time. These charts follow more of a bright line between sector and source as delineated earlier. These charts distinguish between residential and commercial and include more detail than just electricity and natural gas. In doing so, one can more clearly see the role that electricity, natural gas, petroleum, and other sources play in each of the sectors.

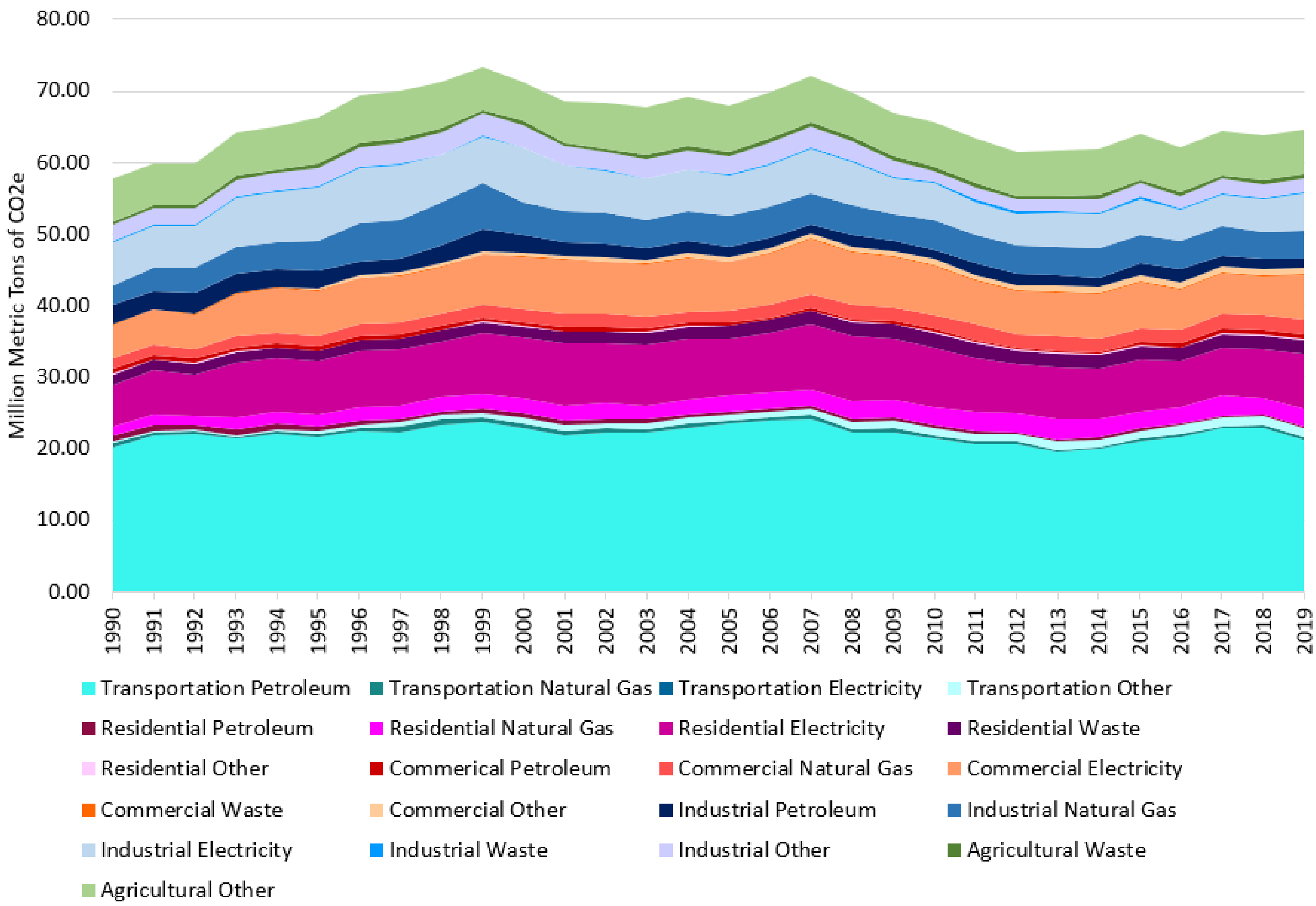
Oregon Greenhouse Gas Emissions by Sector and Source (2019)[5]



Viewing this data over time results in a complex chart that shows the variety of emission sources. This level of analysis can help policy makers identify the types of emissions and sectors to target that will most effectively meet emission reduction goals.

Data is grouped by sector, and then similarly shaded colors within those sectors identify the sources. For example, in the commercial, residential, and industrial sectors, electricity is the largest resource.

Oregon Greenhouse Gas Emissions by Sector and Resource Over Time[5]



The Social Cost of Carbon

Carbon dioxide and other harmful greenhouse gases that contribute to climate change also create costs for society, including economic damages that result from harming human health, interrupting business operations, damaging infrastructure and environmental resources, affecting agricultural production, and more. This *social cost of carbon* is an important consideration as Oregon continues its efforts to reduce GHG emissions and fight climate change. Learn more:

www.tinyurl.com/CostOfCarbon

Sector Profiles

Residential

25.2%

Residential sector's share of Oregon's energy use in 2020.[1]

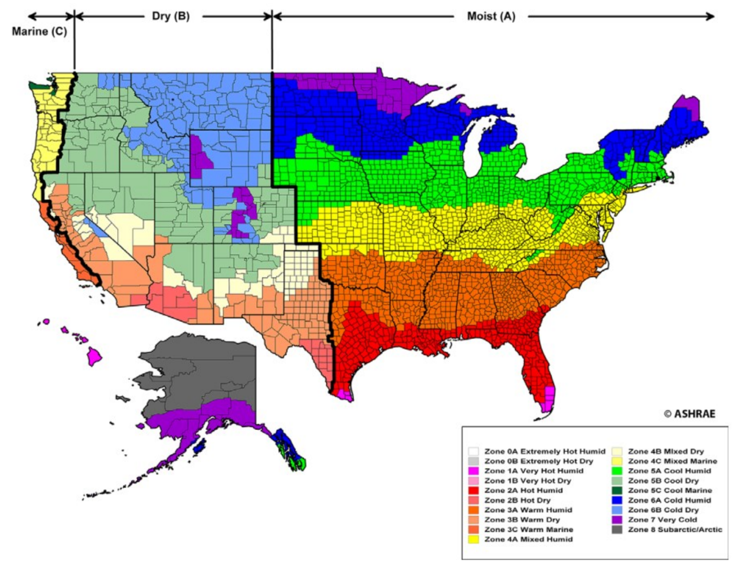
1.6 Million

Number of occupied housing units in Oregon in 2020.[1]

The residential sector consists of both single- and multi-family occupancies. Common uses of energy associated with this sector include space heating, water heating, air conditioning, lighting, refrigeration, cooking, and appliances. Residential energy use is closely tied to weather, housing vintage (decade a home is built), and type of housing.

Weather

Oregon is divided by two climate zones with different energy needs and weather patterns. The map to the right demonstrates the climates zones in the U.S.[3] In Oregon, west of the Cascade mountain range is a temperate mixed marine climate zone in yellow. East of the Cascade Mountain range in green, is a cool dry climate with more heating and cooling days, requiring more heating and cooling energy use. Buildings in Eastern Oregon have a higher average energy use index, meaning they typically use more energy per square foot.

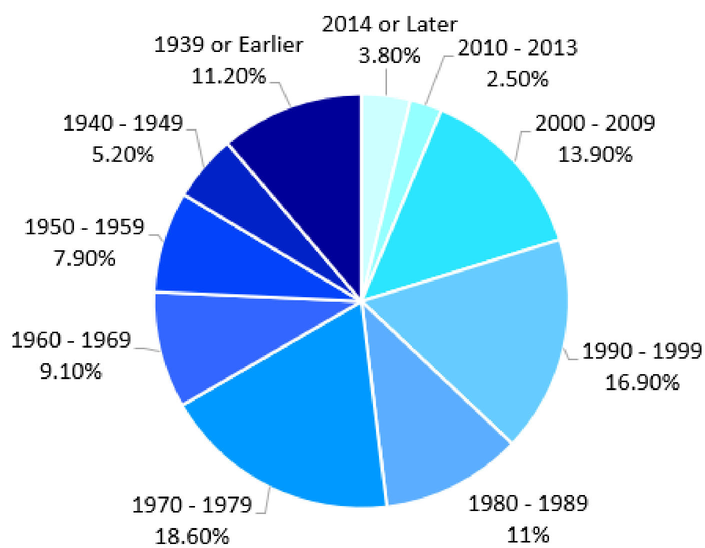


Vintage

The residential sector includes new construction and existing construction — and energy use can be very different between them, especially when comparing a newly built home to a decades-old home. Oregon's residential energy code has made significant performance increases since Oregon's first energy code in 1974.

Older homes with less insulation and older equipment use more energy for heating and cooling than newer, more efficient homes. Home vintage can indicate opportunities for updating heating and cooling equipment, water heating, insulation, windows, and house weatherization. About 63 percent of all homes in Oregon were built before 1990.[2]

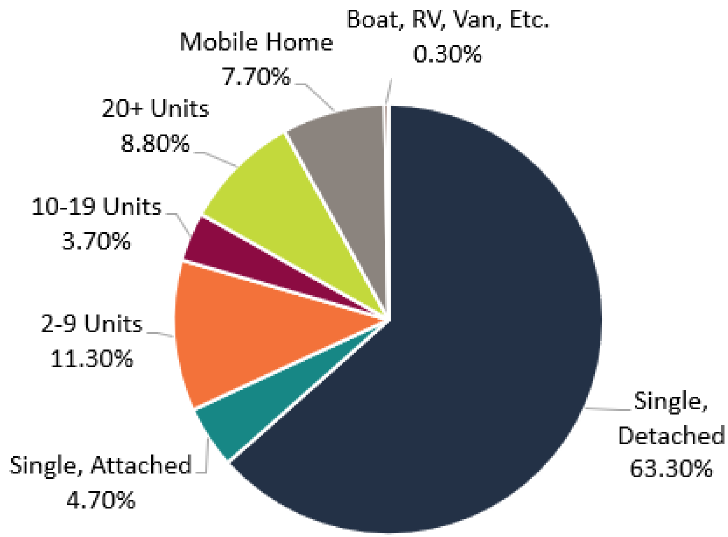
Oregon Homes by Vintage[4]



Type of Housing

Most housing in Oregon (63 percent) is detached single-family. Multifamily complexes with 20 or more units represent 8.8 percent of all housing, followed by mobile/manufactured homes at 7.7 percent. Other multifamily units (like those with fewer than 20 units) comprise the remainder.[2]

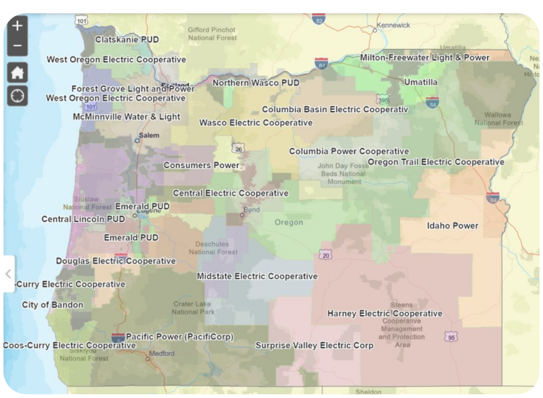
Oregon Housing Types[4]



Ownership and Vintage

Another way to look at housing stock in Oregon is by ownership and vintage across the region. Northwest Oregon has the most housing units, as well as the highest percentage of rental units. The distribution also shows nearly 80 percent of housing units were built prior to year 2000, with half being built prior to 1980.[2]

Region	Total Occupied Housing Units	Share of Units That Are Rental Properties	Share of Units That Are Pre-1980 Homes	Share of Units That Are Pre-2000 Homes
East Oregon	208,718	31%	51%	86%
NW Oregon	1,222,517	36%	53%	80%
SW Oregon	211,344	30%	52%	81%
All of Oregon	1,642,579	34%	52%	80%



Looking for your local utility? Use the Oregon Department of Energy's online lookup tool: **www.tinyurl.com/FindYourUtility**

Residential Energy Efficiency

Oregon's energy efficiency programs and policies save residential customers energy and money while increasing household comfort. The Northwest Power and Conservation Council estimates a total technical potential of 2,441 aMW across the regional residential sector in energy conservation in the 2021 Power Plan, representing about 27 percent of the projected 2041 residential sector load.

While there's been significant progress in residential energy efficiency, there is room for improvement when it comes to energy saving opportunities for homes. The NW Power and Conservation Council's 2021 Annual Regional Conservation Progress Report outlines opportunities:

Lighting. Lighting has historically been a significant energy efficiency opportunity, and the region has made great progress. Energy-efficient LED bulbs have increased from less than 1 percent of all installed bulbs eight years ago to nearly 70 percent.[4]

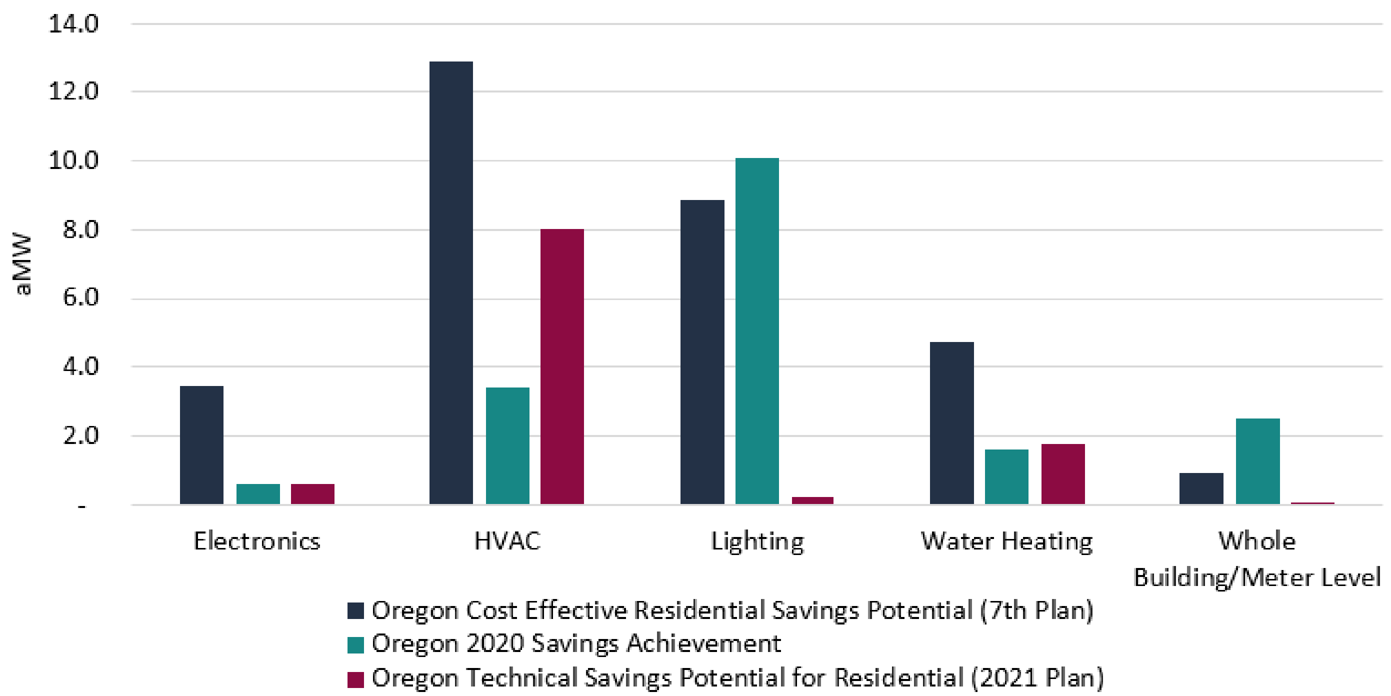
Heating, Ventilation and Air Conditioning. Upgrading an electric furnace to a heat pump can cut heating electricity use in half.

Electronics. Homes have a lot of electronic devices, and most of them are plugged in all the time. Simple controls that turn off equipment when nobody is in the room can significantly reduce energy use.

Water Heating. Just 2 percent of homes in the region have upgraded to a heat pump water heater, which can reduce the electricity used to heat water by half or better.[5]

The chart below shows residential savings potential in Oregon in average megawatts from the 7th Power Plan compared with achievements reported for 2020 and projected technical savings potential from the 2021 Power Plan.[6] [7] The chart shows a shift in potential savings, reduced across all categories and shifting away from lighting as the majority of light bulb sales are now LED.

Oregon Residential Savings Potential (aMW)
Change from NWPCC Seventh Power Plan to 2021 Power Plan[6 7]



Residential Heating and Cooling

More than half of Oregon homes heat with electricity.[2 8] Cooling types vary among Oregon homes, and the percentage of homes using air conditioning increased from 42 to 57 percent between 2012 and 2017.[8]

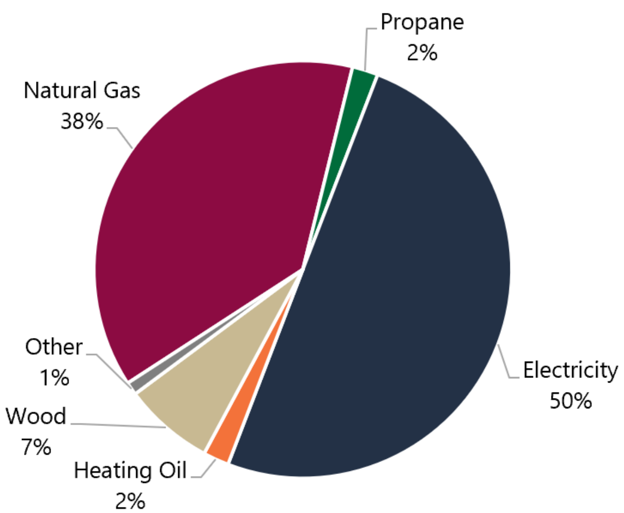
Average electricity use has increased slightly from 10,829 kWh in 2018 to 10,964 in 2020.[10] Average residential electricity use in consumer-owned utility territory is typically higher than in investor -owned territory. In 2020, the average annual COU customer use was 12,885 kWh, while for IOUs it was 10,304 kWh.[9] This may be partially due to higher prevalence of electric heating in more rural COU territories, and more homes that use gas as a heat source in urban IOU areas.

10,964 kWh

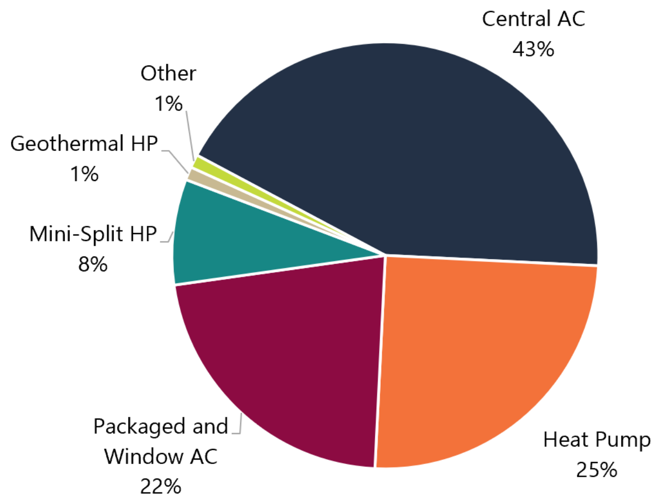
Average annual residential electricity use in Oregon in 2020.[9]

619 therms

Average annual residential natural gas use in Oregon in 2020, a slight increase from 605 therms in 2018.[11]



Average Heating Types Across Oregon Homes[12]



Average Cooling Types Across Oregon Homes[8]

Oregon County Profiles

The *2020 Biennial Energy Report* included county-by-county energy information in the web-based version of the report. Data used to populate the county profiles has not been updated since the 2020 report, but the profiles remains helpful for understanding how Oregon county energy use differs, including energy and transportation burden. View the 2020 profiles online:

energyinfo.oregon.gov/ber

Note: The data source for electricity (kWh) and natural gas (therm) use per residential customer has been updated to reference the Oregon Public Utility Commission "Oregon Utility Statistics" report. Previous versions of the Biennial Energy Report referenced a different data source, so values may not align between versions.

Commercial

The commercial sector is diverse and includes buildings of various types and sizes, such as offices and businesses; government, schools, and other public buildings; hospitals and care facilities; hotels; malls; warehouses; restaurants; and places of worship and public assembly. Total floor area of common commercial space types in the region is approximately 3.4 billion square feet, with an average annual growth of approximately 1.9 percent since 1990.[13] The commercial sector is distributed across buildings of various sizes, with buildings less than 5,000 square feet accounting for nearly as much total area as buildings greater than 100,000 square feet.[13]

18.8%

Commercial sector's share of Oregon's energy use in 2020.[1]

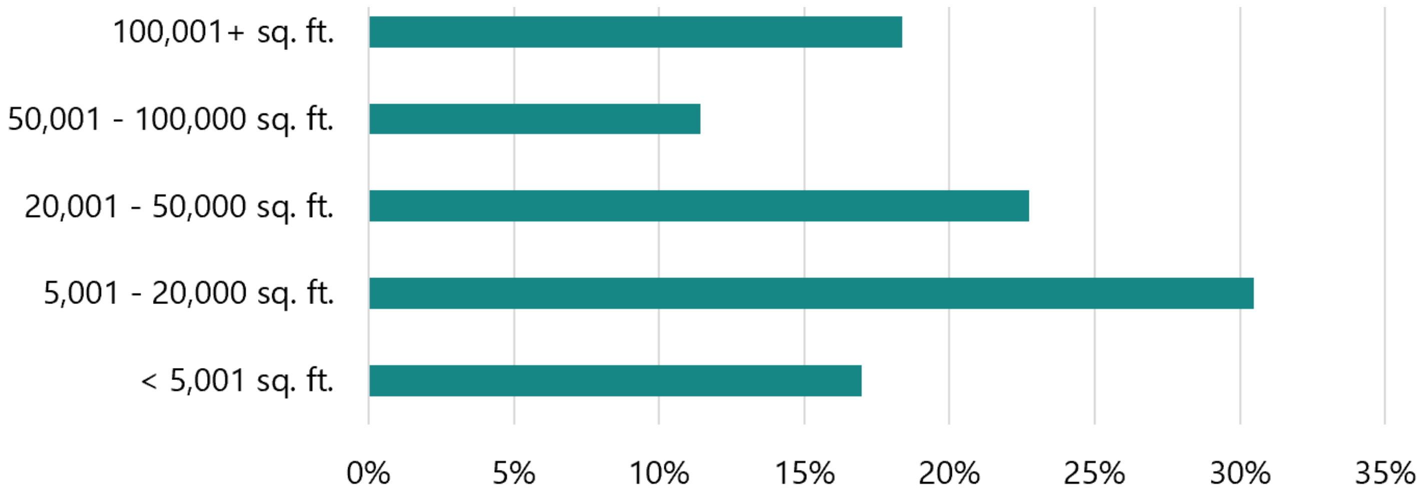
12.6%

Percent reduction in energy use by the sector since 2000.[1]

64%

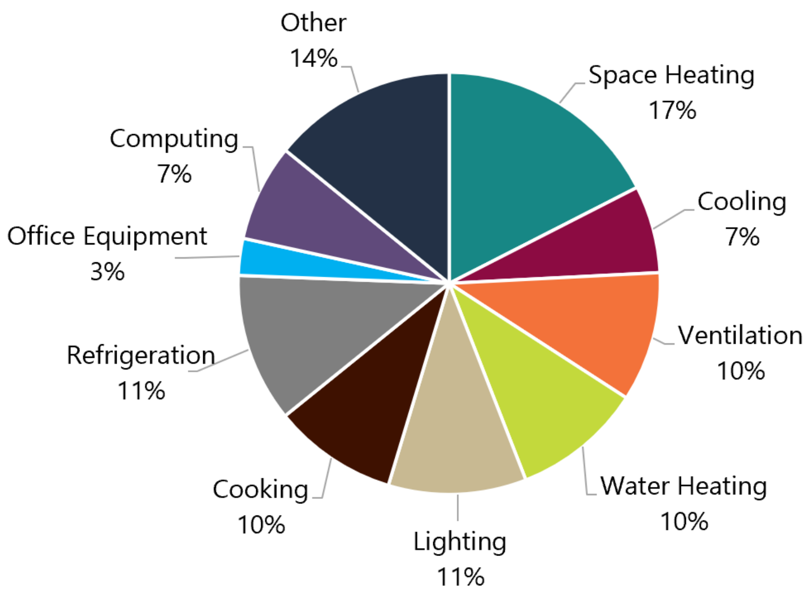
Percentage of northwest buildings that were built before 1990.[13]

Distribution of Regional Floor Space by Building Size in the Northwest



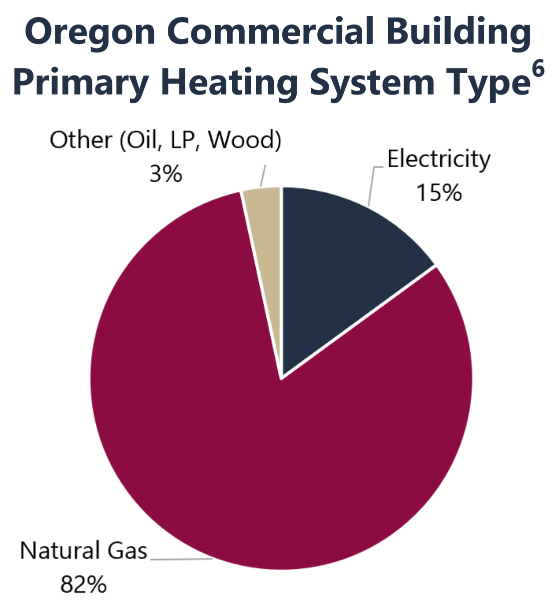
Regional Commercial Energy End Uses

In the Pacific NW, energy — from all sources, including electricity, natural gas, or other fuels — is used for HVAC, lighting, computing, and other commercial needs.[5]



Energy Use

Heating, cooling, and ventilation, which are responsible for the largest share of electricity and natural gas use in a commercial building, are provided through central systems, individual units, or a combination of both. The majority of commercial spaces in our region continue to use natural gas as a fuel source; however, recent studies suggest a shift toward a greater percentage of electrically heated spaces in new construction.[13] Ninety-seven percent of commercial buildings use electricity or natural gas for heating.

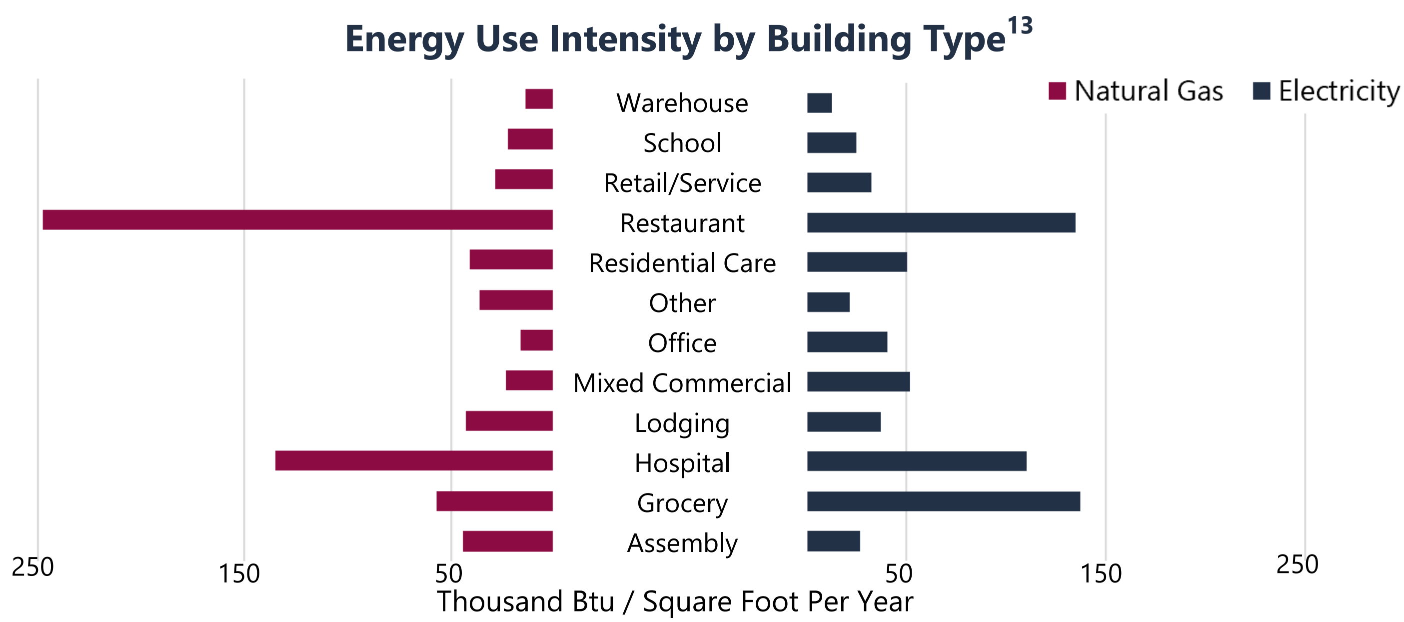


Lighting is the third largest share of energy use for commercial buildings. Efficiency and type of lighting are evolving as incandescent and fluorescent lighting is replaced with energy-efficient LEDs. Refrigeration and cooking use a lot of energy, with refrigeration accounting for about 18 percent of overall electricity use and cooking accounting for about 25 percent of natural gas use in commercial buildings in the Northwest.[15 16]

Energy Performance

Energy Performance is often measured by comparing a building's annual energy use to its size, and depends on a building's construction, equipment efficiency, operation, and location. This metric combines all energy consumption (like electricity and natural gas) into common units that are normalized to building area, and commonly uses units of kBtu (1,000 Btu) per square foot per year. This is often referred to as a building's EUI, or Energy Use Intensity. In commercial buildings, floor space, the type of building, and its activities drive energy use.

Financial incentives, improved building code and appliance standards, and energy efficiency programs are helping commercial buildings improve energy performance. The Portland Commercial Energy Performance Reporting policy requires buildings to benchmark and report annual energy.[17]



Industrial

27.4%

Industrial sector's share of Oregon's energy use in 2020.[1]

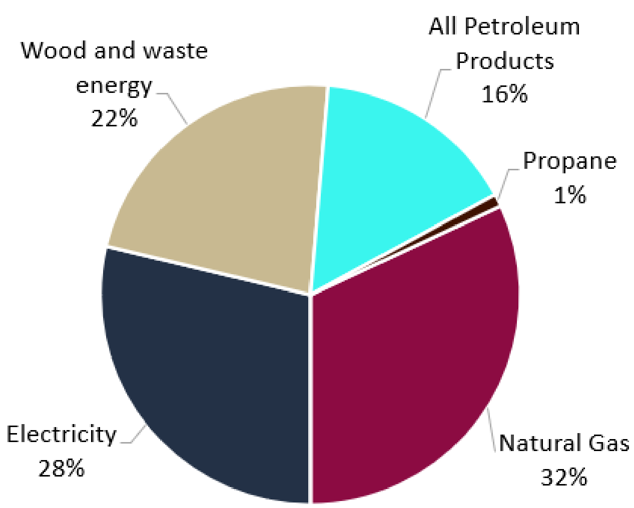
The industrial sector includes all facilities and equipment used for producing, processing, or assembling goods. The U.S. Energy Information Administration defines the industrial sector to include manufacturing, agriculture (including fishing and forestry), construction, and mining (which includes oil and natural gas extraction).[18]

At 81 percent in 2020, manufacturing uses by far the largest share of energy of any of the industrial subsectors nationally. The bulk chemical industry (the largest industrial consumer of energy), petroleum refining, and paper production use the largest shares of energy among the manufacturing segments and in 2018 represented a combined 70 percent, the latest year for which data was available.[19] Oregon's industrial manufacturing subsector includes paper and food processing, along with wood products, and computers and electronics.

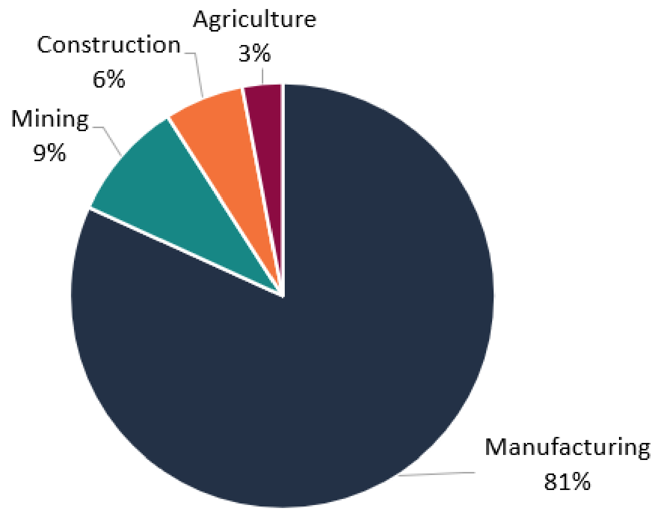
The industrial sector uses electricity to operate machine drives (motors), lights, computers and office equipment, and equipment for facility heating, cooling, and ventilation. Machine drives are the largest use of electricity by U.S. manufacturers.[20] Industry uses fossil fuels and renewable energy sources for heat in industrial processes and space heating in buildings, boiler fuel to generate steam or hot water for process heating and generating electricity, and feedstocks (raw materials) to make products like plastics and chemicals.[19]

According to the U.S. EIA, "Although the state's agriculture, food processing, and forestry activities, including the manufacture of forest products, are energy-intensive, most of Oregon's gross domestic product (GDP) comes from non-energy-intensive businesses. Computers and electronic products accounted for almost half of the state's manufacturing GDP in 2020, and Oregon's industrial sector per capita energy consumption is less than in two-thirds of the states."[21] Computer and electronic manufacturing have low energy intensity, especially relative to their high value. Many forest products/paper operations in Oregon offset natural gas for heat and electricity from the grid by using residual woody biomass/black liquor for cogeneration of electricity and steam for process heat.

2020 Oregon Industrial Energy Consumption by Fuel[1]



2020 U.S. Industrial Sector Energy Use Subsector Shares[1]



Transportation

The transportation sector covers the movement of goods, services, and people—including passenger and commercial vehicles, trains, aircraft, boats, barges, and ships. Fuel, mostly in the form of petroleum products, is used directly for transportation vehicles and to fuel equipment.

Transportation fuel costs tend to be higher in Oregon because of the region's distance from fuel supplies and refineries. The largest portion of the transportation sector's energy use comes from passenger vehicles — and in Oregon, passenger vehicles are older than the national average. The percentage of SUVs and pickup trucks registered in Oregon is greater than national average.

28.6%

Transportation sector's share of Oregon's energy use in 2020.[1]

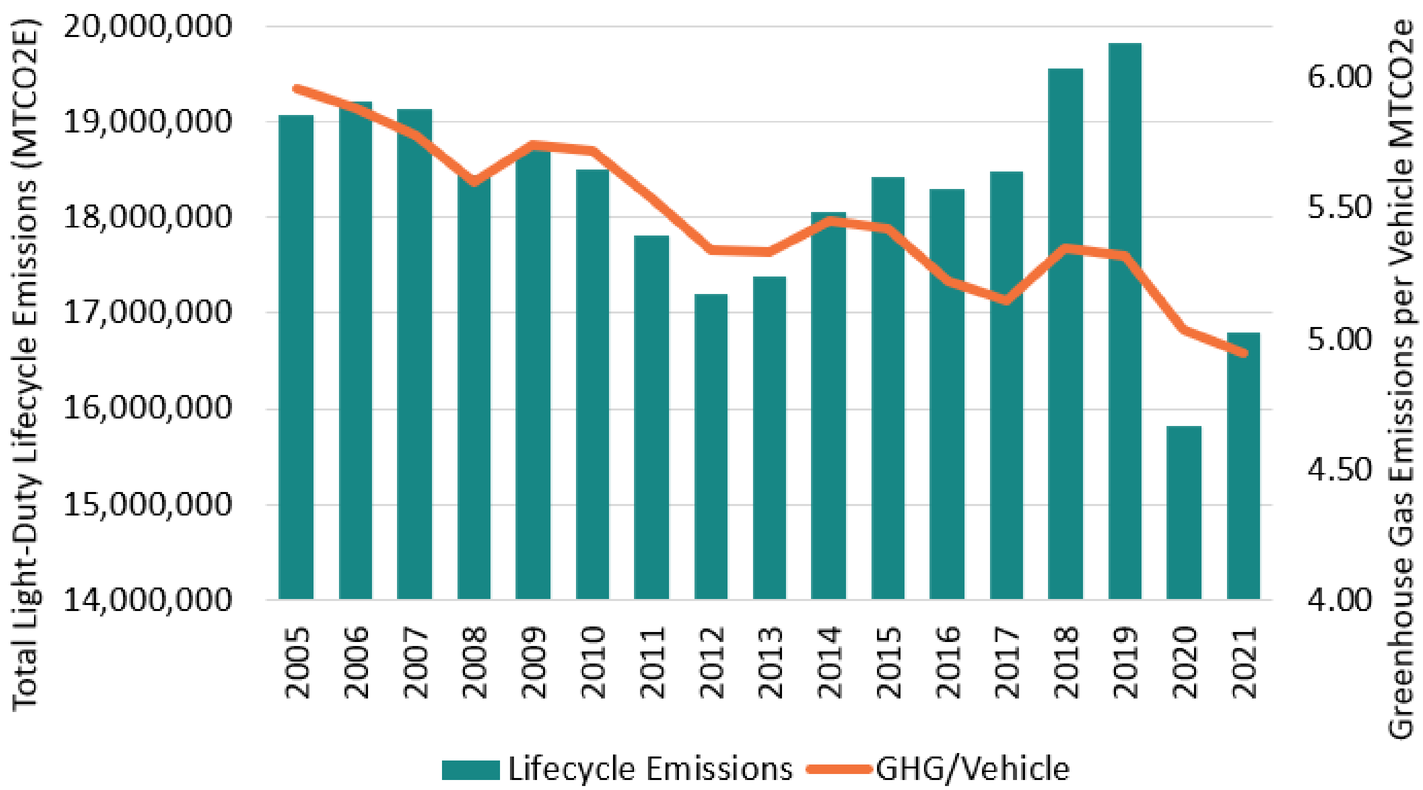
493 Gallons

Amount of fuel used by a 2005 typical model vehicle. It also emits about 5.93 metric tons of CO2 equivalent per year.[1]

425 Gallons

Amount of fuel used by a 2021 typical model vehicle. It also emits about 4.94 metric tons of CO2 equivalent per year.[1]

GHG Emissions Per Vehicle and Total Passenger Vehicle GHG Emissions in Oregon (Metric Tons of Carbon Dioxide Equivalent)[1]



Reader's Note: Lifecycle Emissions axis and Per Vehicle axis do not start at zero.

Of the transportation fuels used in Oregon, gasoline creates the largest amount of greenhouse gas emissions — over 15.5 million metric tons of carbon dioxide equivalent in 2020. Diesel is the second largest contributor of emissions at almost 9.8 million metric tons of CO2e.[22] Increased consumption of lower-emitting and renewable fuel sources such as electricity, biodiesel, renewable natural gas, and renewable diesel present an opportunity to reduce emissions from the transportation sector.

Transportation Fast Facts

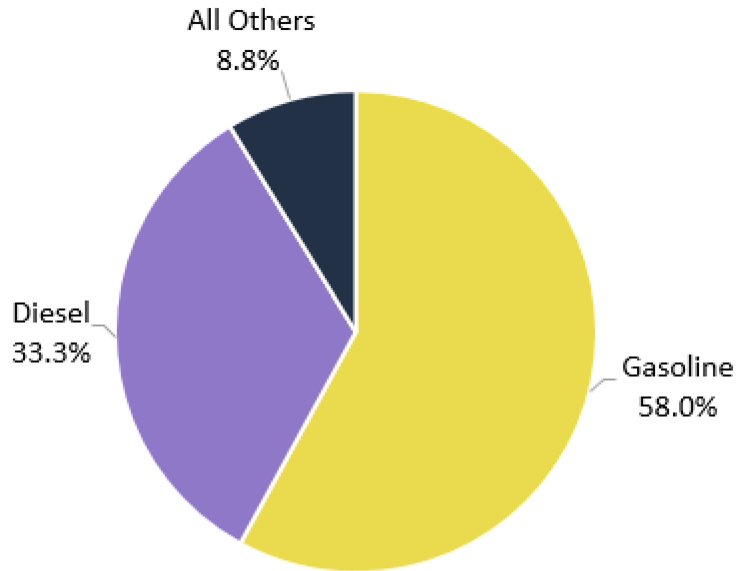
In 2020, nearly 1.3 billion gallons of gasoline powered vehicles on Oregon roads.[22]

That's over 296 gallons per Oregonian.

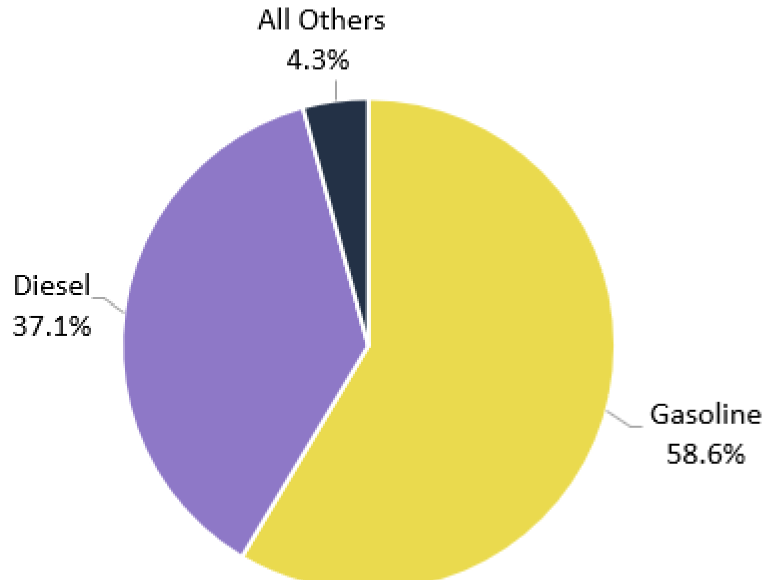
The typical Oregon household has at least two cars.

For electric vehicle drivers, no matter where a car is fueled in Oregon, drivers are reducing greenhouse gas emissions by 50 to 95 percent by fueling with electricity.[23]

Percent of On-Highway Consumption in Oregon (2020)[22]



Percent of On-Highway GHG Emissions Among Fuel Types (2020)[22]



Learn more about transportation in Oregon in the Technology Review section of this report.

Electric Vehicles

January 2011: **672 registered EVs**

May 2022: **52,033 registered EVs**[24]

More than 50,000 EVs added in just over a decade

Oregon's Zero Emission Vehicle Targets (Senate Bill 1044)

- 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.
- On Oregon, ZEVs are electric vehicles or EVs. Someday, other ZEVs could be on Oregon roads, such as clean hydrogen cars.

Oregon EVs by the Numbers

3,602,301 registered passenger vehicles[25]

52,033 registered electric vehicles

1.44% of registered vehicles are EVs

33,381 are battery EVs

18,172 are plug-in hybrid EVs

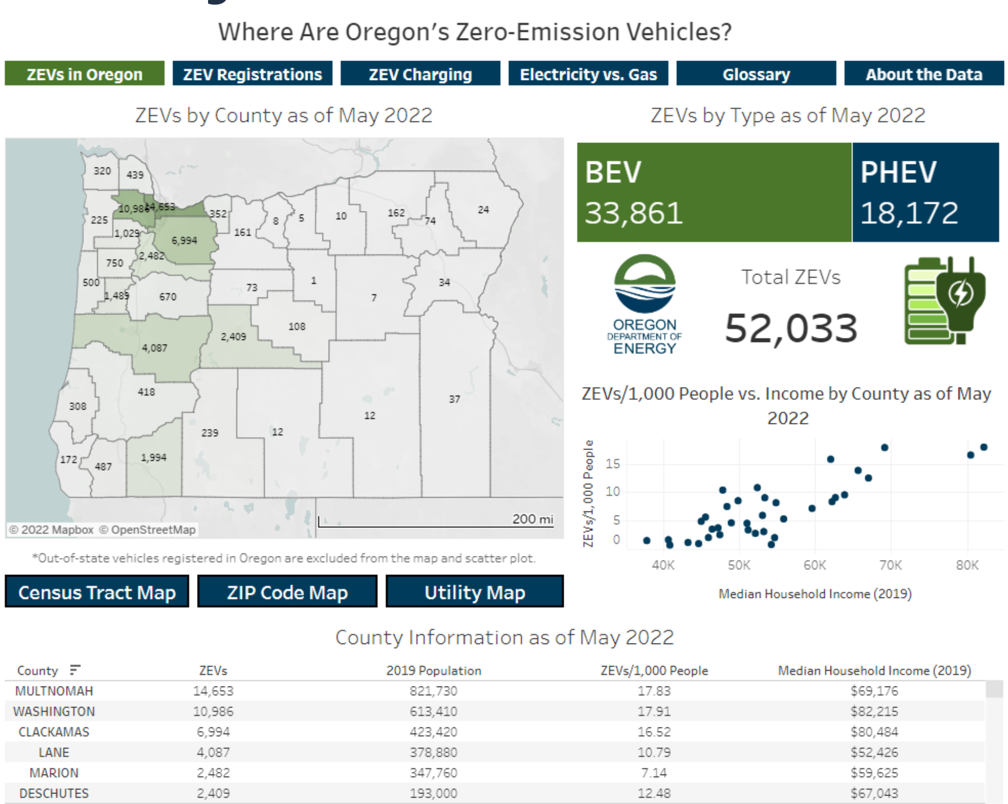
Oregon's EV Charging

9 charging networks[26]

2,171 public EV chargers

917 charging locations

Oregon Electric Vehicle Dashboard

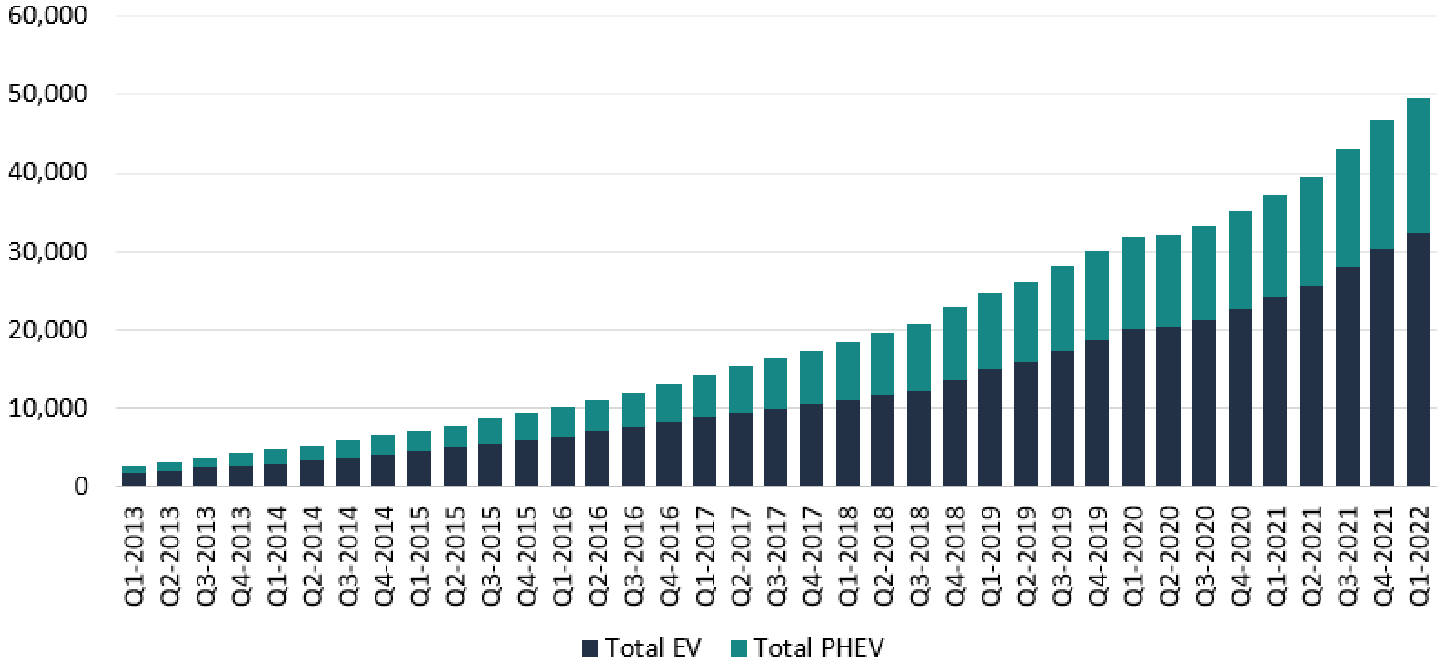


County	ZEVs	2019 Population	ZEVs/1,000 People	Median Household Income (2019)
MULTNOMAH	14,653	821,730	17.83	$69,176
WASHINGTON	10,986	613,410	17.91	$82,215
CLACKAMAS	6,994	423,420	16.52	$80,484
LANE	4,087	378,880	10.79	$52,426
MARION	2,482	347,760	7.14	$59,625
DESCHUTES	2,409	193,000	12.48	$67,043

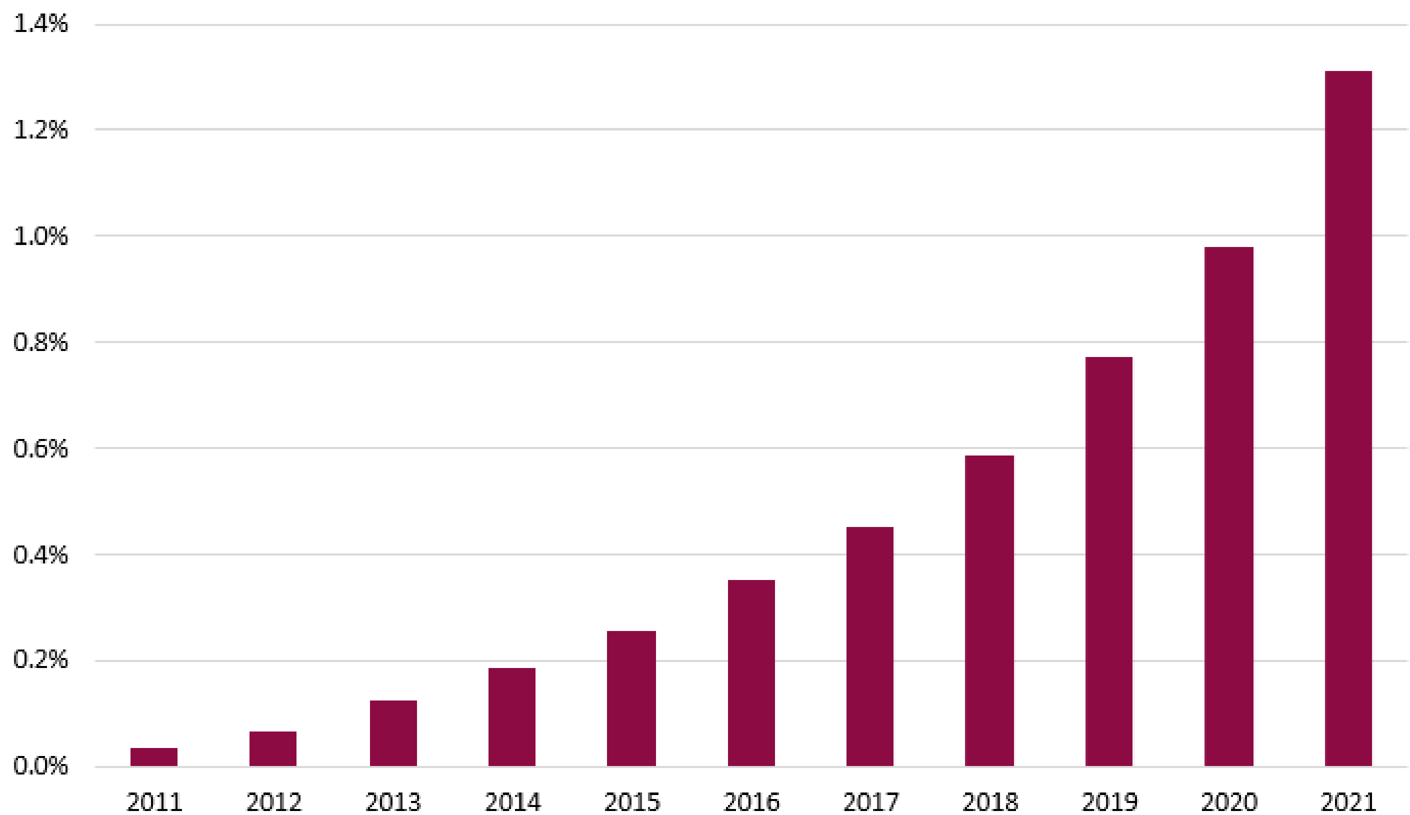
The Oregon Department of Energy developed an interactive Electric Vehicle Dashboard, which shows county-by-county EV adoption information, popular EV models, and other data. The dashboard also includes a calculator to show Oregonians estimated savings by making the switch to an EV.

www.tinyurl.com/OregonEVDashboard

Cumulative Oregon EVs and Plug-in Hybrid EVs by Quarter Year
(2013—Q1 2022)



EVs and PHEVs as a Percent of Total Fleet by Year



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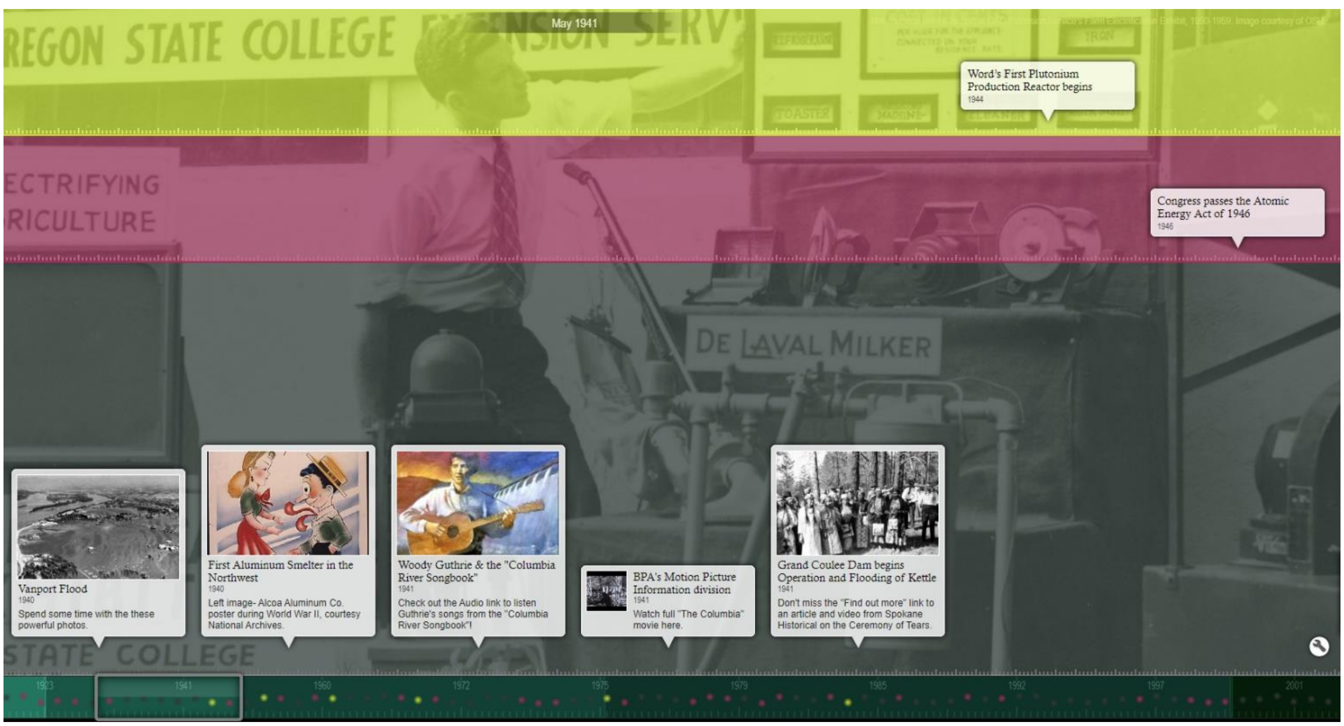
The 2020 edition of this *Biennial Energy Report* debuted an **Energy History Timeline** that aimed to show how Oregon's energy systems have evolved over time, from harnessing the state's various natural resources to human events like technology development and energy crises. The timeline also shared events that significantly affected Oregon's Tribes – the original inhabitants of this state. Among the many events along the timeline are actions and policy choices that Oregon's leaders and citizens have made in response to changing times, like stronger clean energy policies or a focus on electric vehicle adoption.

For this 2022 report, the agency evolved the timeline to create an interactive online tool and experience. The ODOE team collected dozens of photographs, stories, videos, and more to create a truly insightful and informative journey through Oregon's energy history and present.

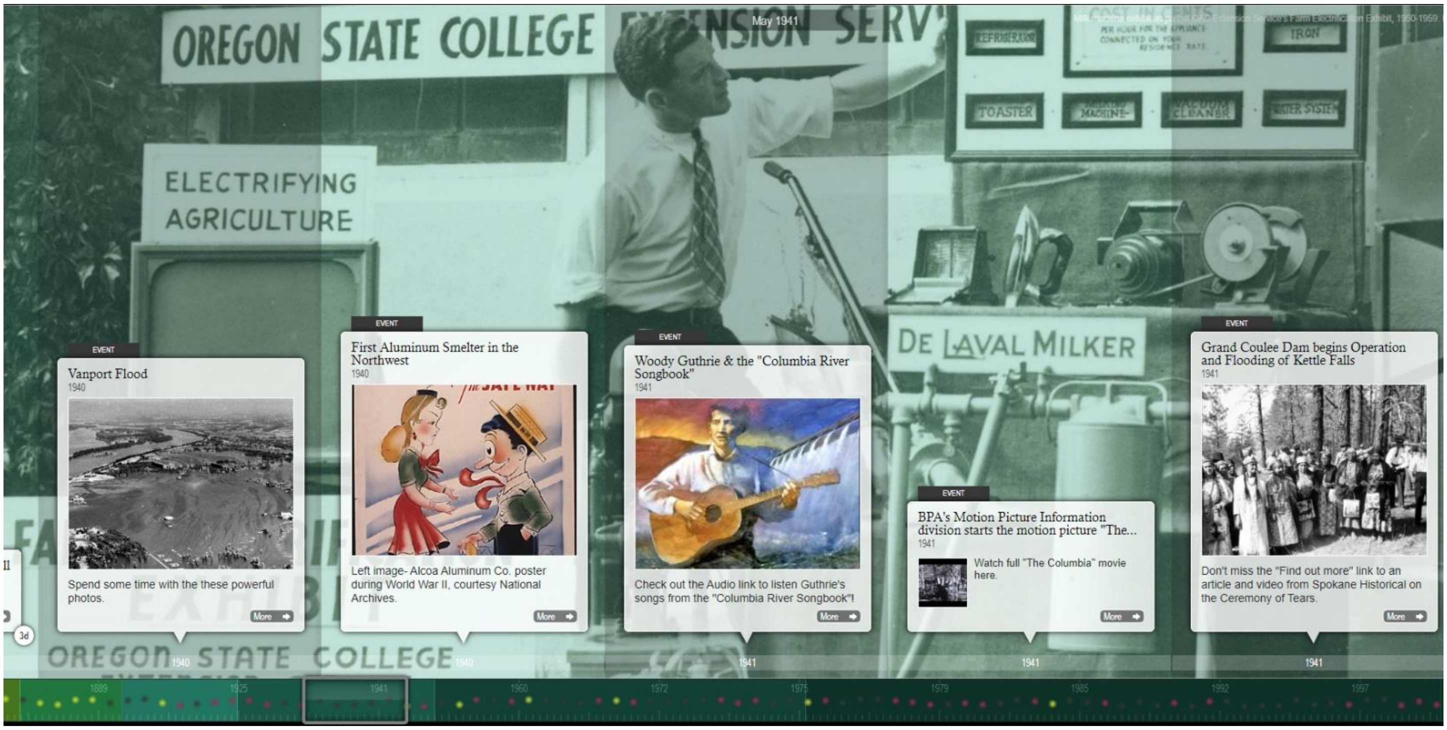
The interactive tool is composed of three timelines: an Energy Policy sub-timeline, an Energy Technology & Innovation sub-timeline, and the main events timeline. Each one showcases points in time that have shaped Oregon's energy landscape and the way we live today.

Be sure to visit often – we plan to add new media and events regularly.



Explore the new online tool: https://energyinfo.oregon.gov/timeline

Timeline Tool Tips



As you explore events, be sure to check for multimedia and links. Notice the left side of the Grand Coulee Dam event. There are multiple images to view.

Events may have video or audio features, like this entry that will play Woody Guthrie's love song to the Columbia River.

More user experience tips and instructions are available: https://energyinfo.oregon.gov/timeline

Rapid advancements in technology have responded to and pioneered changes in our state and across the world.

Often these resources and technologies are critical to the function of our society while also helping us work better and faster. Sometimes they also enable us to adapt — the COVID-19 pandemic made virtual meetings commonplace and changed how Oregonians conduct business. The resources and technologies presented in this section cover the spectrum of traditional to innovative, and demonstrate the breadth of technology that is integral to the production and management of our energy system.

There are trade-offs with these technologies. Some operate without emitting greenhouse gases or other air pollutants, but there are often emissions and environmental impacts associated with building and transporting them. Technologies like electric vehicles and rooftop solar can reduce energy costs or the effects of energy use for consumers, but not all Oregonians have access to these technologies — a significant equity issue to address in partnership with currently and historically underrepresented communities.

The technologies examined in the following pages are those that are prevalent in Oregon and of interest to stakeholders that ODOE heard from when putting together this report. Many of these technologies place Oregon and its communities on the forefront of a cleaner, more sustainable future. They help Oregon meet its climate and energy goals by enabling cleaner and more efficient fuels and resources. They offer opportunities to invest in Oregon's economy by creating energy-related jobs to maintain our energy system and develop new projects. They can make us more resilient by enabling us to maintain or restore our energy systems when disruptions occur.

And beyond these opportunities and benefits — they are just so cool.

TABLE OF CONTENTS

Energy Resource & Technology Review: Electricity-Generating Technologies

Timeline

- **1907** – The 6.2 MW Faraday hydropower facility on the Clackamas River opens. The facility remained in operation until 2019 when it was retired.[1]
- **1911** – The 6.6 MW River Mill hydropower facility on the Clackamas River opens. Today, it is the oldest electricity generator still operating in Oregon.[1]
- **1938** – The first two generators at the Bonneville Dam on the Columbia River are brought online. Together they generate over 100 MW of power.[1]
- **1949** – The first wood waste biomass facility begins operation in Springfield.[1]
- **1953** –The first generator at the McNary Dam is brought online. Four additional generators follow in 1954, bringing the total capacity at McNary to 350 MW.[1]
- **1957** – The first four generators at The Dalles Dam are brought online.[1]
- **1968** – The first four generators at the John Day Dam are brought online. Additional generators brought online through 1971 bring the total capacity at John Day to 2,160 MW, Oregon's largest.[1]
- **1974** – The Beaver natural gas facility in Columbia County, Oregon's first fossil fuel power plant, is installed.[1]
- **1980** – The 642-MW Boardman Coal facility begins operations.[1]
- **1998** – The 25-MW Vansycle wind facility in Umatilla County, Oregon's first commercial wind farm, begins operating.[1]
- **2011** – The Bellevue and Yamhill solar facilities, Oregon's first utility scale solar facilities with a combined capacity of 2.6 MW, begin operation in Yamhill County.[1]
- **2012** – The 4.4-MW Outback solar facility near Christmas Valley becomes the first utility scale solar project in Eastern Oregon.[1]
- **2017** – The Solar Star Oregon II facility near Prineville becomes the first solar facility in Oregon to exceed 50 MW of nameplate capacity.[1]
- **2020** – The Boardman coal facility closes operations.[1]
- **2020** – The first 300 MW of wind capacity comes online at the Wheatridge facilities, which combine wind, solar, and battery storage in Morrow County. An additional 50 MW of solar and 30 MW of battery storage capacity are added in 2022.[1]

Electricity Generation in Oregon

There are **459 utility-scale generators in Oregon** that provide electricity for homes and businesses throughout the Pacific Northwest.[1] These facilities use a variety of resources, including hydroelectric, natural gas, wind, solar, biomass, municipal waste, landfill gas, and geothermal resources. **Hydropower makes up 40 percent** of the electricity generated in Oregon, followed by natural gas at 21 percent and wind at 11 percent.

Are Batteries an Electricity Generation Technology?

While batteries do not directly generate electricity, they provide electricity to the grid by acting as a pass-through using stored energy that was previously generated by some other resource like wind, solar, or natural gas. Batteries, or other energy storge technologies such as pumped hydro, are charged during times of surplus generation on the grid and later discharged when needed. Charging and discharging energy storage devices results in some of the energy being lost. These losses are known as round-trip efficiency losses and are improving as battery technologies advance.

Figure 1: Total Technology Nameplate Capacity (MW) of Electricity Generation Facilities in Oregon[1][11]

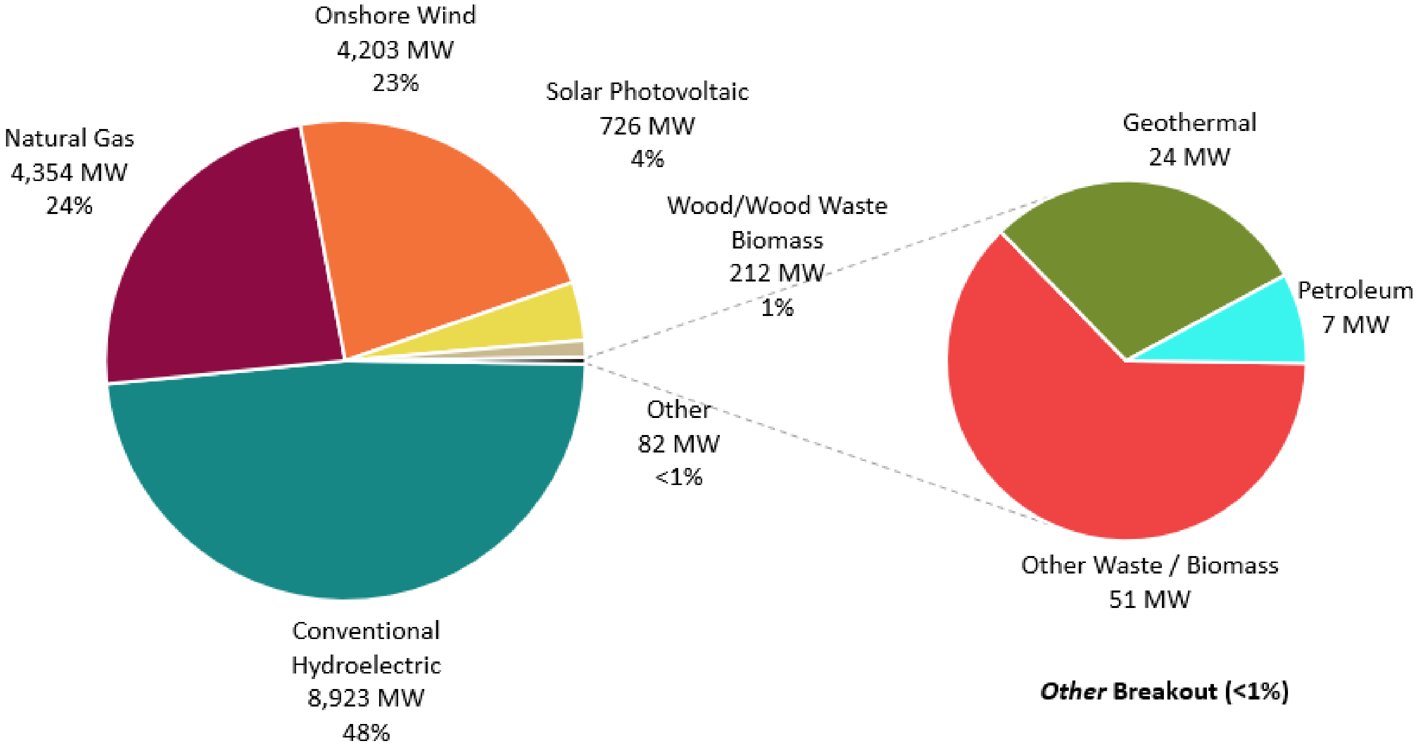
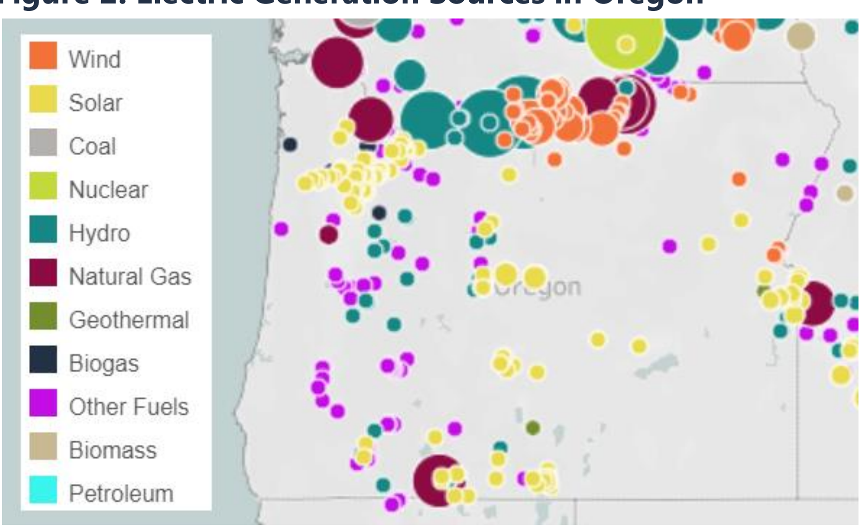


Figure 2: Electric Generation Sources in Oregon



Dot sizes correspond to the amount of energy generation, not physical size of facilities.

Megawatts, Megawatt-hours, and Average Megawatts

Megawatts. This section describes facilities according to their nameplate capacity, which is expressed in units of megawatts. Megawatts of nameplate capacity describes the amount of power a facility can generate under peak operating conditions. It is an indication of the size of a facility but not necessarily the amount of energy that it generates over the course of a year. For example, some natural gas facilities are referred to as "peakers" and only operate when needed to meet peak demand on the grid. Similarly, solar facilities may have large nameplate capacities but only operate during the daytime. To see the annual electricity consumption and generation from different facility types in Oregon see the *Energy by the Numbers* section of this report.

Megawatt-hours. Megawatt-hours (MWh) is a measure of energy produced by a facility. If a facility with a power rating of one megawatt operates continuously for one hour, it will generate one megawatt hour of energy. One megawatt-hour of electricity is about how much a typical Oregon home will consume in a month.

Average Megawatts. Like megawatt-hours, an average megawatt (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

Electricity generation in Oregon has evolved over the last century from a largely hydropower-based system, to one that included more coal and natural gas, followed by more carbon-free resources like wind and solar. From 1911 to 1949, hydroelectric dams were the sole source of electricity in Oregon, with new or upgraded generators added at existing dams to increase electricity generation over the years. The first biomass generation facility was added in 1949, and the first natural gas facility in 1974. In 1980, the Boardman power plant began operation in Morrow County, becoming the only coal fired electricity generator in Oregon. By the time the 585 MW Boardman coal plant was retired in 2020, there was already 3,772 MW of wind capacity operating in Oregon. Today, many different types of generation resources in Oregon contribute to the state's electricity resource mix. Figure 3 shows a timeline of electricity generation facilities in Oregon.

From 1911 to 1949, hydroelectric dams were the sole source of electricity in Oregon

Figure 3: Total Nameplate Capacity of Electricity Generators in Oregon – 1911-2019

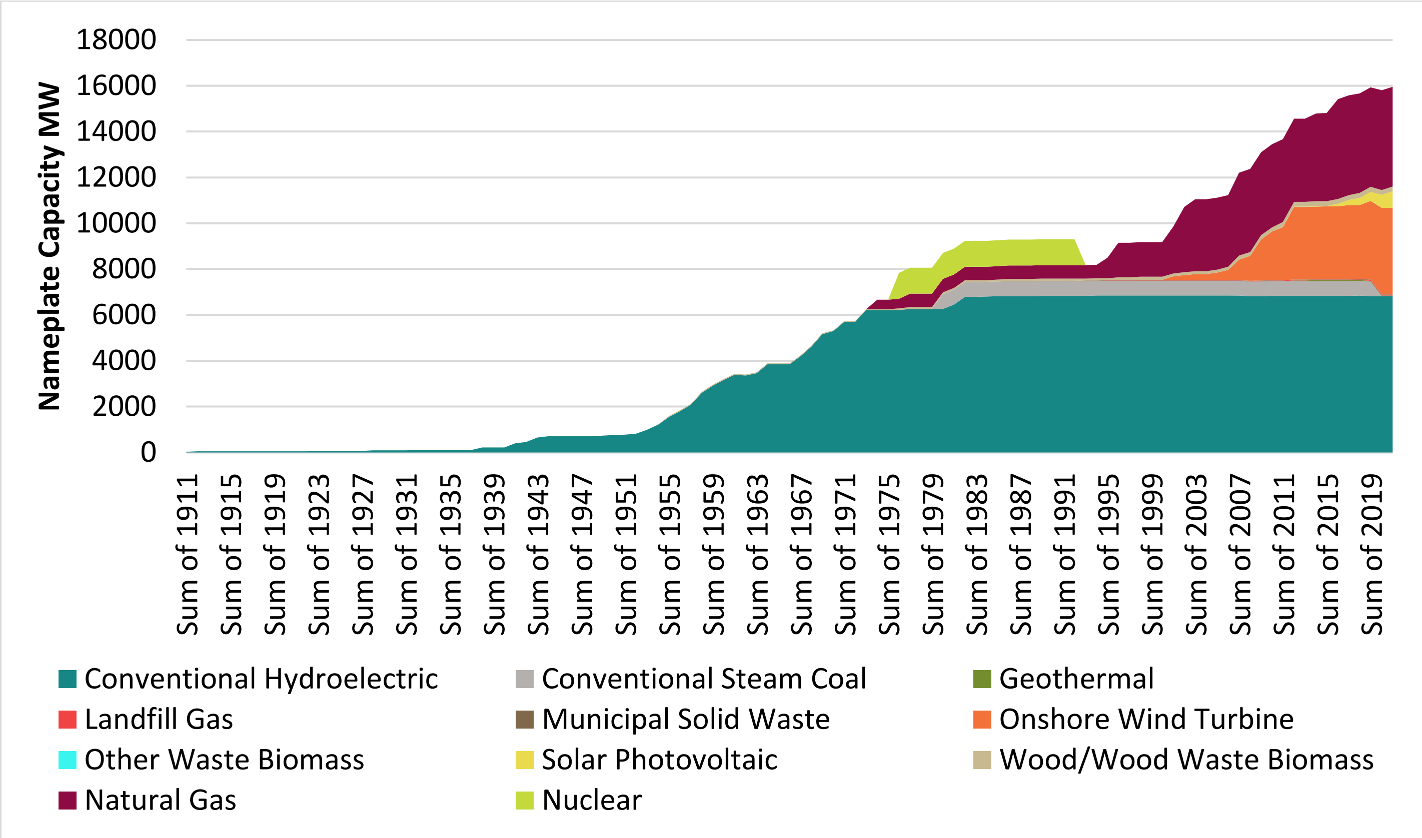


Table 1: Oregon Generator Type, Capacity, Generation, and Exports[1 11]

Generator Type	Nameplate Capacity (MW, 2021)	Generation (MWh, 2020)	Exports (MWh 2020)
Conventional Hydroelectric	8,923	31,920,643	10,972,309
Natural Gas	4,354	19,019,913	7,447,738
Onshore Wind	4,203	8,777,254	5,002,338
Solar Photovoltaic[i]	726	1,077,902	179,671
Wood/Wood Waste Biomass	212	631,206	413,898
Other Waste / Biomass	51	373,279	174,546
Geothermal	24	192,101	144,455
Petroleum	7	2,339	0
Coal[ii]	0	1,630,145	0

Trends and Potential

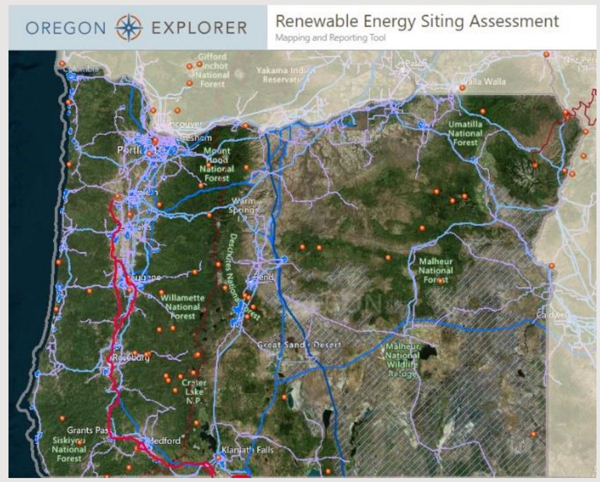
In 2021 the Oregon Legislature strengthened the state's clean energy goals, which will transform the makeup of energy facilities in Oregon. House Bill 2021 requires electric companies to reduce the greenhouse gas emissions associated with serving retail electricity customers by 80 percent by 2030

[i] EIA data contains 726 MW of utility-scale solar in Oregon through 2021. There is an additional 156 MWdc of net metered installations in Oregon that are not reflected in the generation or export data.

[ii] The Boardman coal plant closed in October 2020. This results in zero nameplate capacity in 2021 but significant generation in 2020.

and 100 percent by 2040 from a 2010-2012 average baseline.[2] Meeting this standard will require unprecedented development of renewable energy facilities over the next 20 years. Although PGE and PacifiCorp, with oversight from the OPUC, will determine the specific mix of electricity-generating technologies to meet their customers' demands, one 2021 study identified the need to develop 10,000 MW of new solar capacity and 20,000 MW of new offshore wind capacity to meet the state's 100 percent carbon free electricity target.[3] PGE and PacifiCorp are required to submit Clean Energy Plans (CEPs) to the OPUC.

The Oregon Renewable Energy Siting Assessment: A Resource for Renewable Energy Development



The Oregon Renewable Energy Siting Assessment (ORESA) project developed educational resources for users to explore data and information on renewable energy development in Oregon. The ORESA project goals were to develop baseline data and gather stakeholder perspectives to create a collection of information to support communities, policy makers, energy developers, tribes, and government agencies interested in potential projects or renewable energy policies. The key deliverables of this project (below) were developed to encourage early coordination and notification among cross-sector stakeholders, and to promote a better understanding of potential opportunities and challenges.

The ORESA Report summarizes key findings, data, stakeholder perspectives, and analysis on renewable energy siting opportunities across the state. The report acknowledged that renewable energy development to meet Oregon's clean energy and climate goals presents both opportunities and challenges. Sustainably accessing and developing renewable energy while avoiding or mitigating conflict with other important values requires careful consideration of a multitude of factors and acknowledgement that there may be trade-offs across these factors.

The Mapping and Reporting Tool includes data on renewable energy, military training areas, economic development, land use, natural and cultural resources, and other important considerations. Users can interact with and browse spatial data, create site-specific reports to support early coordination on potential projects, and review additional information such as regulatory process maps, reports, and tools that are not reflected in the spatial data.

The ORESA project was funded through a $1.1 million U.S. Department of Defense Office of Local Defense Community Cooperation grant awarded to the Oregon Department of Energy, working with the Department of Land Conservation & Development and Oregon State University's Institute for Natural Resources.

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

Wind and solar generation are expected to meet much of the Pacific Northwest's future energy demands. Wind is already a proven resource with more than 4,000 MW of in-state capacity online as of 2021 (for a complete accounting of energy consumed and generated in Oregon see the *Energy by the Numbers* section of this report). Utility-scale solar generation is rapidly increasing as well, rising from less than 100 MW in 2016 to 726 MW in 2021. Storage options are also becoming more prevalent, especially when combined with renewable generation because it can help store the energy from these resources at times when their full generation capacity is not needed. Oregon's Energy Facility Siting Council approved the state's first solar application, for the 75-MW Boardman Solar facility, in 2018. There are now more than 800 MW of solar approved with more than 2,500 MW under review.

Hybrid renewable energy facilities, which use more than one type of renewable energy resource, are also increasingly being planned and developed in Oregon. The Wheatridge renewable energy facilities in Morrow County, have combined 300 MW of wind, 50 MW of solar, and 30 MW of battery storage.[4] In February 2022, the Council approved the Obsidian Solar Center in Lake County, which will have a peak generating capacity of 400 MW and may include up to 50 MW of battery storage.[5]

Wheatridge Energy Facilities, Morrow County
Photo: Portland General Electric

Oregon's clean energy targets will affect the electricity generation resource mix in Oregon and other western states. Natural gas is currently the second largest electricity generation resource in Oregon, including 13 facilities with a combined generating capacity of 4,354 MW. These facilities generated a third of the electricity in Oregon in 2020 (for a complete accounting of energy consumed and generated in Oregon, see *Energy by the Numbers*). House Bill 2021's clean electricity requirements mean these facilities will no longer be able to serve Oregon markets beginning in 2040. The bill also prohibits the building of any new fossil fuel facilities or expansions of existing facilities that would result in a significant increase in carbon emissions. Oregon's natural gas plants may continue to operate beyond 2040 by exporting electricity to neighboring states that do not have the same clean energy targets as Oregon.

Energy storage facilities are also expected to play a large role in Oregon's energy future to help integrate increasing variable wind and solar resources. One of the challenges with resources like wind and solar is the variability in electricity generation output depending on the weather, the season, and time of day. One solution to variability is to install systems that can store surplus energy when it is plentiful and make it available when generation is limited or during periods of high demand. Oregon's Energy Facility Siting Council has approved applications for more than 400 MW of battery storage, with over 2,300 MW under review. In Klamath County, the proposed 400 MW Swan Lake pumped hydropower facility, which is under federal permitting jurisdiction, would use surplus electricity to pump water into an elevated reservoir, which could then be released through turbines to generate energy when needed. For more information on Electricity Storage, see the Electricity Storage Resource & Technology Review.

A diverse portfolio of energy generation facilities will be needed to meet the seasonal variation in Oregon loads. Batteries and pumped hydro facilities help solve short-term variability issues, but there are also longer-term seasonal variations in Oregon's renewable resources. Onshore wind resources are strongest in the spring but may be greatly diminished in late summer and mid-winter – on some days, production drops to zero. In the Willamette Valley, solar output is more than four times higher in July than in December. Seasonal variations may be partially addressed through a diverse regional portfolio of facilities. New technologies, such as floating offshore wind turbines and ocean wave energy generators, can provide more reliable winter generation and are being explored by utilities and electricity planners as long-term options to help balance renewable electricity generation in the region. Upgrades to electricity transmission infrastructure will be needed to deliver energy from remote generation facilities to load centers. Long-term storage, such as hydrogen generation and storage, may also play a role in seasonal variation. These new technologies and existing clean generation assets, like geothermal, will help Oregon meet clean electricity targets.

Beyond Energy

The development of any electricity generation resource has environmental, social, and economic effects on local and global communities. The effects may be positive, negative, or a combination of these, and their relative weight may be seen and felt differently by different communities. Positive effects include local construction and operations jobs, increased local property tax revenues, and in some cases community control of energy resources. Negative effects have traditionally included degradation to local air quality, other health and safety hazards associated with siting energy facilities near Oregon communities, and end of life recycling and disposal issues. Disadvantaged communities are often most affected by local environmental and economic effects of facility siting decisions. Additional financial risks are associated with investments in new facilities and technologies that may not result in good value for utilities and ratepayers.

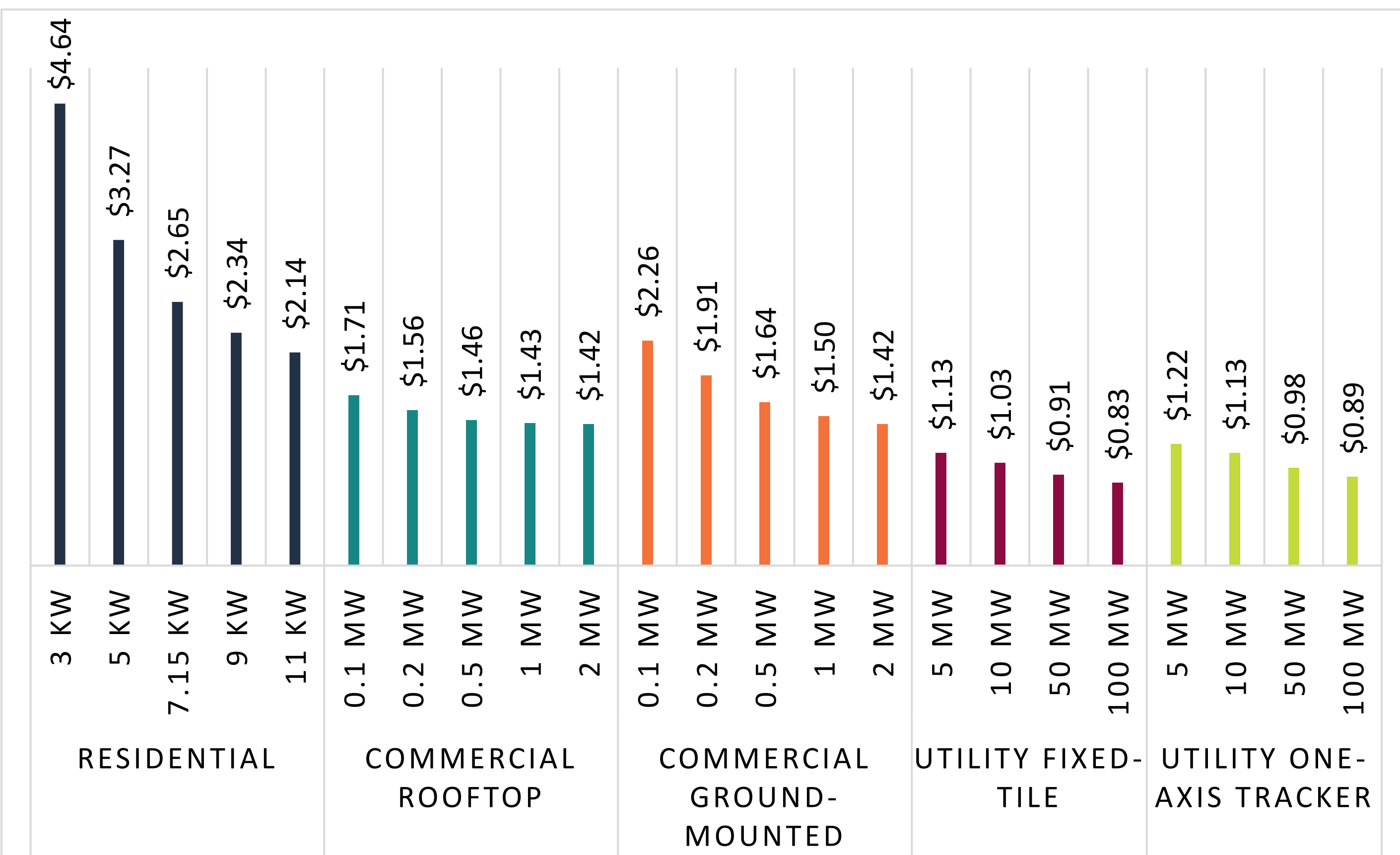
All electricity generation projects require some amount of land or water area for development. Some renewable resources such as hydropower, wind, and solar can have large geographic footprints. New transmission infrastructure, necessary to connect new resources to the grid, also has land requirements. Renewable energy facilities are not unique in requiring large development footprints. Extraction of coal and natural gas have significant land use impacts where they are extracted, transported, and refined. These negative effects are borne by local, often rural communities, many of which are located far from the large load centers that use most of the energy created.

Clean energy technologies can reduce the state's greenhouse gas emissions and demonstrate Oregon's commitment to mitigate climate change. Climate change directly affects Oregon communities by increasing the frequency and severity of extreme weather-related events, including the devastating wildfires of 2020, the unprecedented heat wave in June 2021, and the severe ice storms in February 2021. According to the National Atmospheric and Oceanic Administration, wildfires in Oregon resulted in an estimated $2 to $5 billion in damage costs in 2020[6] and $500 million to $1 billion in 2021.[7] Droughts in Oregon resulted in as much as $100 million in damages in 2020 and $100 to $250 million in 2021. Meanwhile, winter storms caused an estimated $250 to $500 million in damages in 2021.[7] Oregon may only represent a small percentage of global emissions, but combined with other states and countries taking action, greenhouse gas reductions can add up.

Distributed energy resources, like rooftop solar and residential battery storage, can reduce land impacts associated with large ground mounted systems but are higher in cost than utility-scale solar and storage projects. Chart 3 below demonstrates how solar costs are affected by economies of scale for residential, commercial, and utility-scale solar projects.[8]

Local solar and storage microgrids could improve community emergency preparedness by providing an electricity resource for critical operations when the main power system is not operating. Many of these projects are currently funded by home and business owners or local communities that provide much of the up-front capital costs. Programs like ODOE's Solar + Storage Rebate Program and the Community Renewable Energy Grant Program offer incentives that help offset this cost. Even with higher incentives, many low-income Oregonians may not have the financial resources to invest in these renewable projects.

Figure 4: Cost Per Watt DC of Solar Installations by Sector and Project Size (Derived from the NREL U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks: Q1 2021)[8]



Alongside economic, environmental, transmission, and geographic constraints, resource capacity constraints may also be an important factor in determining Oregon's future access to new electricity generation technologies. Presently, manufacturing of electricity generation technologies is highly dependent on foreign mineral resources. Copper and aluminum are critical resources needed to build solar panels, wind turbines, transmission lines, and batteries. Nickel, lithium, and cobalt are all essential to current battery technologies.[9] Most of these minerals have limited mining or refining operations in the U.S., and many of the countries that support the development of these resources do not have protections for communities and workers.[10] Where protections exist, they may not be applied consistently. The growing demand for these minerals is already prompting more international cooperation to ensure supply chains and policies address social and environmental equity, but continued efforts in this area are needed to help address these issues. Without domestic mines and refining operations, the U.S. will have to continue to rely on foreign materials to meet the demand for resources, and be subject to foreign environmental and labor practices.[10]

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Energy Resource & Technology Review: Transportation Fuels

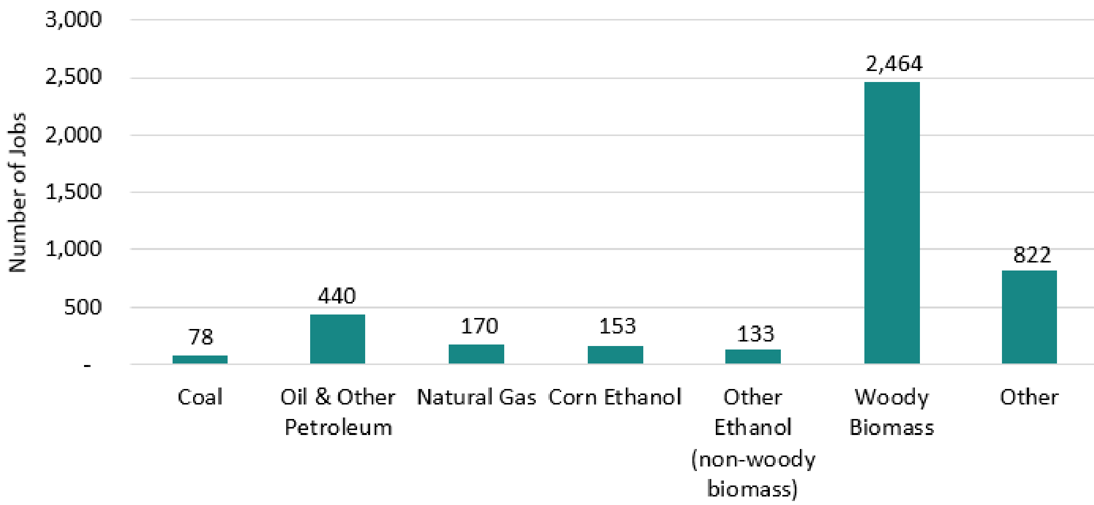
Timeline

- **1892** – With the invention of the automobile, gasoline was recognized as a valuable fuel.[1]
- **1899-1912** – Electric cars are popular in the United States, representing a third of the vehicles on the road. They are quiet, easy to drive, and don't emit pollutants compared to the gas and steam-powered vehicles available at the time.[2]
- **1920** – There were about nine million gasoline-powered vehicles in the United States, and gas stations were opening across the country to fuel the growing number of cars and trucks.[3]
- **1970** – Congress passes the first major Clean Air Act, requiring a 90 percent reduction in emissions from new automobiles by 1975.[4]
- **1971** – EPA begins testing the fuel economy of cars, trucks, and other vehicles, the first step toward informing consumers about the gas mileage of their vehicles.[4]
- **1983** – Portland Public Schools, one of the largest districts in the Pacific Northwest, converted its school bus fleet to propane power.[5]
- **1996** – Leaded gasoline was completely phased out of on-road transportation fuels in the U.S.[1]
- **2000** – Toyota launches the first mass-produced hybrid vehicle called the Prius.[2]
- **2005** – The U.S. Congress enacted a Renewable Fuel Standard that set minimum requirements for the use of renewable fuels, including ethanol, in motor fuels.[1]
- **2006** – The U.S. Environmental Protection Agency issued requirements to reduce the sulfur content of diesel fuel sold for use in the United States. Sulfur in diesel fuel produces air pollution emissions that are harmful to human health.[6]
- **2009-2013** – The U.S. Department of Energy invests in electric vehicle charging infrastructure, installing 18,000 chargers across the country.[2]
- **2016** – Oregon's Department of Environmental Quality launches its Clean Fuels Program.[7]
- **2016** – Clean Energy opens the first public natural gas station in Central Point, Oregon on September 22, which connects California to Washington with natural gas fueling.[8]
- **2016** – Oregon's Clean Fuels Program provides first credits for renewable natural gas as a transportation fuel.[9]
- **2017** – Oregon's Clean Fuels Program provides first credits for renewable diesel.[7]
- **2021** – On June 8, the Oregon Public Utility Commission issues the final rules for the large Renewable Natural Gas program under Senate Bill 98, which was passed in 2019 by the Oregon legislature and gave NW Natural the regulatory framework for procuring RNG for its customers and investing in RNG projects.[10] NW Natural has subsequently purchased RNG from multiple operating projects around the country as well as developed its own RNG projects utilizing waste methane resources.

Transporting people and goods made up about 26 percent of total U.S. energy consumption in 2020 – in Oregon, it was 29 percent.[11 12] Oregonians consumed 2.4 billion gasoline gallon equivalents of transportation fuels in 2020 and petroleum-based products accounted for 92 percent of the total.[11] These fuels provide power for the 3.2 million registered passenger vehicles and 8,930 trucking companies located in Oregon.[13 14]

As shown in Figure 1, Oregon employs 4,260 workers within the fuels sector; 440 workers supporting the distribution of petroleum fuels, 153 workers creating and distributing corn ethanol, and 133 workers in ethanol and other non-woody biomass alternative fuel manufacturing and distribution.

Figure 1: Oregon Fuels Jobs by Technology[15]



Woody biomass is the fuel that employs the most Oregonians at 2,464 people or 58 percent of the fuel sector.[15]

Oregon employs 4,260 workers within the fuels sector

What is a Gasoline Gallon Equivalent?

GGEs are a standardized way of comparing different transportation fuels. The energy content of all other fuels can be compared to the energy content of gasoline to produce the GGE or the comparable amount of that fuel that would move the same vehicle the same distance as a gallon of gasoline.

Oregonians spent almost $5.7 billion on transportation fuels in 2020, and because only 2 percent of transportation fuel consumed in Oregon is produced in Oregon, most of that money is sent to other states.[16] Alternative fuel options are growing, and many of these fuels could be produced in Oregon, offering an opportunity to capture greater economic benefit to the state.

Crude oil is a global commodity, and Oregon’s petroleum fuel prices are affected by worldwide events. In 2021, Egypt’s Suez Canal – a critical route for crude oil transport between the Middle East and Europe – was temporarily blocked by a container ship, slowing global trade. Crude oil prices rose by 4 percent in international markets leading to increased transportation fuel prices around the world.[17] In 2022, Russia invaded Ukraine, leading to dramatic increases in the cost of oil around the globe. Russia is the third-largest producer of oil in the world and the United States elected to ban the import of oil, natural gas, and coal as part of economic sanctions. This conflict and other petroleum supply factors led to Oregon fuel prices rising from an average price of $3.431/gallon for gasoline in June 2021 to $5.266/gallon in June 2022.[18] This was a 53 percent increase in the average price of gasoline in Oregon and demonstrated the risk in relying so heavily on imported fuels.

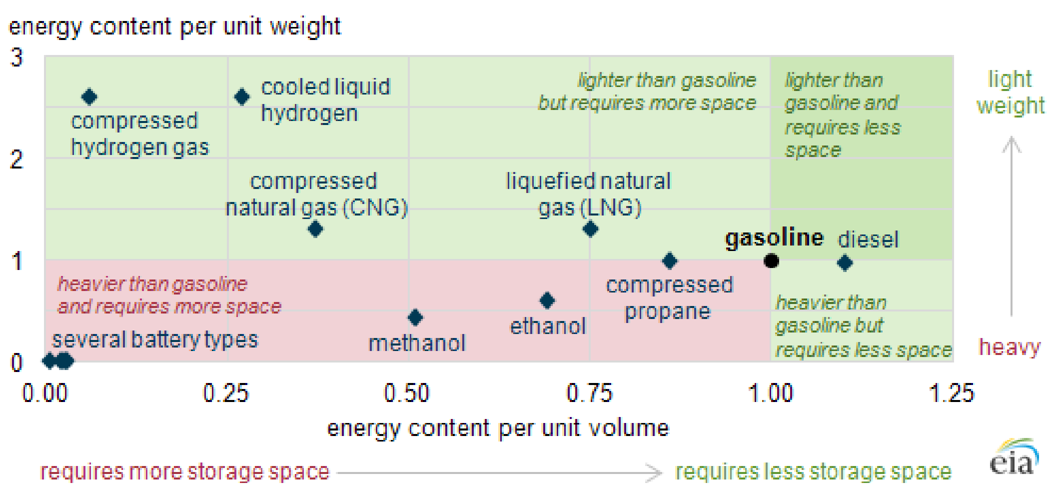
Transportation fuel use is the state's largest source of greenhouse gas emissions, primarily from direct combustion of petroleum fuels, including emissions from on- and off-road vehicles (construction, aviation, marine, rail, industrial, agricultural, or commercial). The transportation sector produced about 23 million metric tons of CO2 equivalent in 2019 – nearly 36 percent of total emissions.[19] About 62 percent of transportation emissions come from the combustion of gasoline in passenger cars and trucks, while about 27 percent are from diesel in heavy-duty vehicles.[20] In 2022, the Oregon Department of Environmental Quality began the Climate Protection Program, which established a declining cap on GHG emissions from petroleum fuels used in Oregon. This program will affect the future transportation fuel mix in the state by accelerating the transition from petroleum-based transportation fuels to lower carbon emission fuels.[21]

Energy content is the amount of energy released by combusting a fuel.[22]

Energy density is the amount of energy by a given mass or volume of fuel.[23] Transportation fuels have different energy densities, affecting the storage, weight, cost, and range of vehicles that use them.[24]

The use of alternative fuels – including electricity, renewable diesel, propane, and biofuels – is 8 percent of all transportation fuel use in Oregon. These fuels provide Oregonians with a variety of options and an increasingly more diverse landscape of transportation fuels. Alternative fuels generally have the benefit of lower greenhouse gas emissions and lower tailpipe emissions of other air pollutants. The energy density of transportation fuels varies. A fuel with a lower energy density means more of it would be needed to move a vehicle a certain distance than a high-energy density fuel. In some cases, reduced energy density is a trade-off for overall lower greenhouse gases. Some lower energy density fuels may need greater onboard fuel storage to achieve the same distances. Fuels such as ethanol and biodiesel are blended into most petroleum gasoline and diesel respectively, and are widely used in all vehicles and sectors. As shown in Figure 2, ethanol has less energy per unit volume than gasoline and is a little heavier, so the blended fuel is slightly less energy dense and heavier than pure gasoline, but ethanol supports gasoline burning more cleanly, reducing harmful emissions.[24] Compressed natural gas (CNG) is lighter than gasoline but requires more storage space to deliver the same amount of energy. Fuels that need greater storage capacity or have shorter ranges may have different applications and should be accounted for when comparing fuel options[24]

Figure 2: Energy Density Comparison of Transportation Fuels
(indexed to gasoline = 1)



Drop-in fuels are renewable fuels that can use existing fueling infrastructure and can be added to the tank of an existing fossil fuel vehicle without needing to modify it. Renewable diesel is an example of a drop-in fuel, it can be used in existing diesel engines and transportation infrastructure but can be challenging to find locally, especially in areas of Oregon outside the Willamette Valley. Some fuels, such as electricity and natural gas, require buying a new vehicle capable of using the fuel and may require new fueling infrastructure.

Transportation fuel choices are usually based on convenience, cost, and access. Gasoline and diesel fueling stations are everywhere. Most Oregonians own and are familiar with gasoline and diesel fuel internal combustion engine vehicles, vehicle replacements are easy to find, they are available in a wide variety of makes and models, and they can be the most affordable option. Electric vehicles have great potential for adoption because they are becoming increasingly available and fueling can be accessible at a driver's home or business. Renewable diesel and renewable gasoline offer ease of transition because they can use existing petroleum-based infrastructure and can be used directly by any fossil fuel vehicle, without changes to the vehicle. Alternative fuels, such as natural gas and hydrogen, require new transport and delivery infrastructure. Creating a network for fuel delivery with access for all Oregonians is potentially an expensive and challenging endeavor for new alternative fuels entering the transportation market. Hydrogen could be added to existing gasoline stations since the fueling process and infrastructure is quite similar (e.g., a storage tank, fuel pump, and nozzle) but retrofitting Oregon gas stations to include hydrogen would require significant capital.[25]

Oregon policymakers are increasingly assessing policy options that support the adoption of cleaner transportation fuels to meet state greenhouse gas reduction goals, and Oregonians are seeing more fuel and vehicle options available. This section evaluates and compares what the different transportation fuels are, where they come from, how they work, current and future benefits, and how they may play a role in Oregon's greenhouse gas emissions now and going forward.

Oregon Transportation Decarbonization Policies

- Oregon Department of Transportation's five-year Climate Action Plan to reduce greenhouse gas emissions from transportation, improve climate justice and make the transportation system more resilient. https://www.oregon.gov/odot/Programs/Pages/Climate-Action-Plan.aspx.
- Oregon Department of Environmental Quality's Climate Protection Program sets a declining limit, or cap, on greenhouse gas emissions from fossil fuels used throughout Oregon in transportation, residential, commercial, and industrial settings. https://www.oregon.gov/deq/ghgp/cpp/Pages/default.aspx
- 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. https://www.oregon.gov/deq/ghgp/cfp/Pages/default.aspx
- Oregon Department of Energy's Biennial Zero Emission Vehicle Report provides information on zero emission vehicle adoption in Oregon. https://www.oregon.gov/energy/energy-oregon/Pages/BIZEV.aspx

- Oregon Department of Transportation, Department of Land Conservation and Development, Department of Environmental Quality, and Department of Energy's Every Mile Counts Initiative is a multi-agency approach to reducing greenhouse gas (GHG) emissions and implementing the Statewide Transportation Strategy: A 2050 Vision for Greenhouse Gas Reduction. https://www.oregon.gov/odot/Programs/Pages/Every-Mile-Counts.aspx.

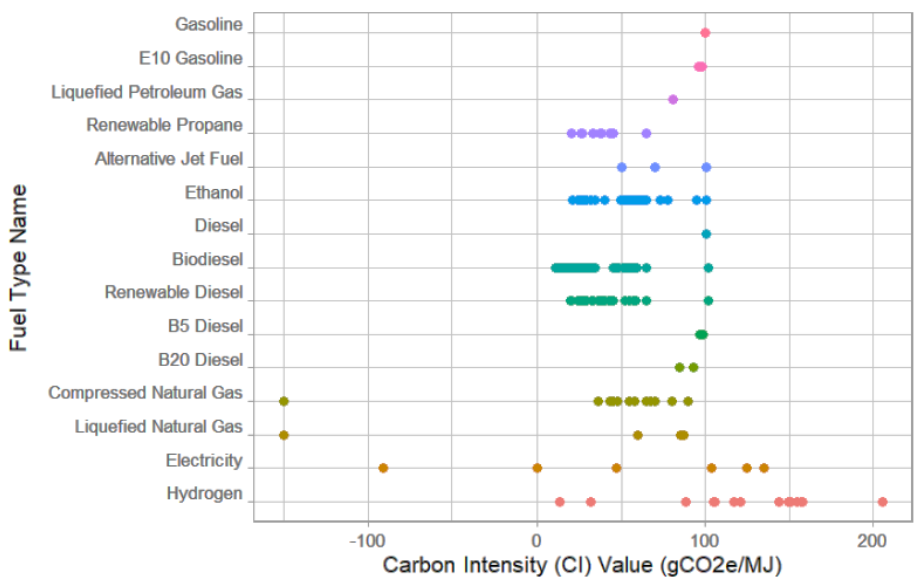
Carbon dioxide equivalent, or CO2e, is a standardized metric that converts all forms of greenhouse gases into an equivalent amount of metric tons of CO2 emissions, and therefore, the same global warming potential as one metric ton of CO2.

Megajoule is a unit representing the amount of energy – it is like calories, which represent the energy content of food.

There are two different ways to examine greenhouse gas emissions from transportation fuels. Measuring tailpipe GHG emissions refers to the emissions associated with using the finished fuel. If someone is driving around town burning gasoline to propel a vehicle, the exhaust contains emissions from that fuel combustion. An electric or zero-emission vehicle does not produce tailpipe emissions. Another method of measuring emissions is lifecycle analysis of transportation fuels, which is a more comprehensive evaluation and includes the associated emissions from the extraction, production, transportation, and use of the fuel. The example electric vehicle may not emit GHGs from its tailpipe, but resources used to create the electricity fueling the vehicle may have associated GHG emissions—although in Oregon these emissions are less than a comparable gasoline or diesel vehicle. Oregon DEQ's Clean Fuels Program assesses carbon intensities based on the lifecycle GHG emissions of transportation fuels.

One way to assess the effects on greenhouse gas emissions is to examine the carbon intensity of each fuel, which shows an apples-to-apples comparison of carbon emissions (represented in grams of carbon dioxide equivalent) compared to the amount of energy produced (represented in megajoules). Higher carbon intensities mean more greenhouse gas emissions are produced to move a vehicle the same distance than a fuel with a lower carbon intensity. The Oregon Department of Energy uses carbon intensity values set by DEQ's Clean Fuels Program.

Figure 3: Carbon Intensity Values of Transportation Fuels[80] *



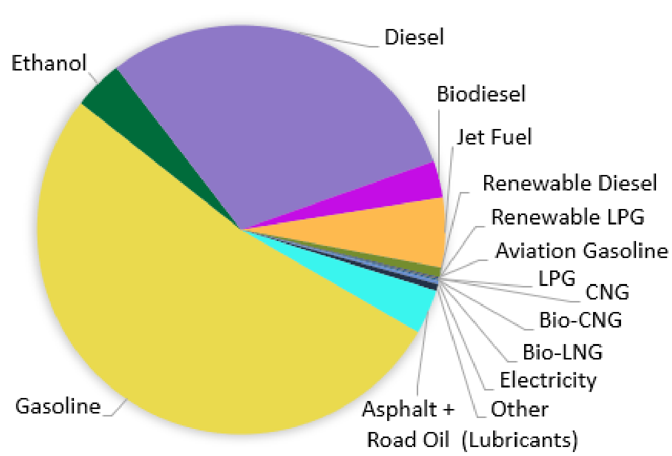
*Electricity and hydrogen CIs do not include the Energy Efficiency Ratio included in the calculation of CFP credits. Electricity's EER is 3.4 and hydrogen is 1.9 - 2.1. The CI of electricity after considering the EER is 3.4 times less and hydrogen is 1.9 – 2.1 times less.

Oregon's Transportation Fuels – Quick Facts[11 52 80 95]

Fuel	Total Estimated Consumption in Oregon GGE (2020)	Estimated Production in Oregon GGE (2020)	Average Carbon Intensity in gCO2e/MJ (2021)	Estimated No. Public and Private Fuel Stations in Oregon	Section Page Number
Gasoline	1,265,440,694	0	100.14	1,849	**92**
Diesel	726,634,560	0	100.74	1,352	**94**
Compressed Natural Gas (CNG)	407,359	†	79.98	15	**97**
Liquid Natural Gas (LNG)	84,880,477	†	86.88	2	**97**
Propane	549,102	0	80.88	44	**100**
Ethanol	94,340,735	43,062,160	53.72	4	**103**
Biodiesel	70,292,133	12,878,161	41.84	33	**107**
Hydrogen	0	0	74.68 - 82.54***	0	**111**
Electricity	6,495,585	63,624,782	25.35**	2,193	**113**
Renewable Gasoline	0	0	TBD	0	**118**
Renewable Diesel	18,617,155	0	36.98	43	**119**
Renewable Natural Gas	3,205,366	†	20.55	5	**125**
Renewable Propane	530,416	0	34.66	42	**128**

†*Comprehensive production data isn't available.*
***Includes the 3.4 Energy Efficiency Ratio*
****Includes the 1.9 to 2.1 Energy Efficiency Ratio*

Oregon Transportation Fuels Consumption (2020)



Petroleum Fuels	Blended Fuels	Zero Tailpipe Emission Fuels	Renewable Fuels
• Gasoline • Diesel • Natural Gas • Propane	• Ethanol • Biodiesel	• Hydrogen • Electricity	• Renewable Gasoline • Renewable Diesel • Renewable Natural Gas • Renewable Propane

This transportation fuel resource overview provides a variety of information on conventional fuels currently being used in Oregon, low carbon intensity alternatives, and some potential fuels that may come to Oregon in the future. The fuels are organized into four categories based on their use and value to Oregon's transportation sector:

- **Petroleum** fuels include petroleum-based fossil fuels like gasoline and diesel.
- **Blended fuels** are fuels added to petroleum fuels to reduce emissions like ethanol and biodiesel.
- **Zero tailpipe emission fuels** produce zero tailpipe emissions, though there may be emissions from the production of that fuel depending on how it is produced like electricity.
- **Renewable transportation fuels** are a lower carbon intensity version of commonly used petroleum fuels like renewable diesel.

Each transportation fuel description will include Oregon's consumption, production, carbon intensity, and available fueling locations to compare each fuel. Asphalt, road oil, lubricants, or other petroleum-based transportation fuels are not addressed. These fuels are similar to — and have many of the same benefits and environmental challenges as — gasoline and diesel fuels but are largely used in road construction and industrial processes rather than to fuel a vehicle. Jet and aviation fuels are also not included, but as new alternative fuels are more available to fuel aircraft, these fuels may be addressed in future versions of this report.

Petroleum Fuels

Petroleum is the most common energy resource used for transportation in the United States. Gasoline, diesel, natural gas, and propane are all petroleum fuels extracted from beneath the earth's crust as crude oil or natural gas.[12 20] In 2021, petroleum fuels represented 90 percent of fuel consumed by the transportation sector in the U.S., but gasoline and diesel fuel's combined share is expected to decrease to an estimated 74 percent in 2050.[12 26]

Oregon's geographic location affects the cost and carbon intensity of petroleum fuels consumed in the state. Oregon pays more for petroleum-based transportation fuels than most parts of the country due to its lack of regional petroleum resources. The Pacific Northwest has no crude oil resources and is located far from North America's major petroleum production regions in Texas, North Dakota, and Alberta, Canada. Over the last 10 years, the mix of crude resources that feeds northwest refineries has changed, resulting in changes to how Oregon's crude oil is transported and in the overall carbon intensity of the state's transportation fuels. Since 2011, Washington refineries have seen increased amounts of crude from the Canadian oil sands.[27 28] This crude has a much higher carbon intensity than other resources, meaning more greenhouse gas emissions are emitted per gallon of fuel because it requires more greenhouse gas-emitting energy to extract and process.[27]

Fuel spills associated with fossil fuel extraction, transport, and storage can be devastating to the environment. More crude is now delivered by rail, and most crude rail shipments travel through the Columbia River Gorge and Portland before moving up to Washington refineries. Trains carrying oil are a safety risk to Oregon communities, in 2016 an oil train derailed in the town of Mosier, three rail cars caught fire and four were found to be discharging oil.[29] Underground fuel storage tank systems used by service stations for public or private fleets corrode over time, and without proper maintenance leak fuel into the environment, possibly contaminating groundwater.[30] Sites with significant spills in communities have become brownfields – properties that are limited in use because of the presence of a hazardous substance, pollutant, or contaminant.[30] Cleaning up and reinvesting in these facilities can be an economic burden to communities. The U.S. Environmental Protection Agency determined that "of the estimated 450,000 brownfield sites in the U.S., about half are thought to be impacted by petroleum, much of it from leaking underground storage tanks at old gas stations."[31]

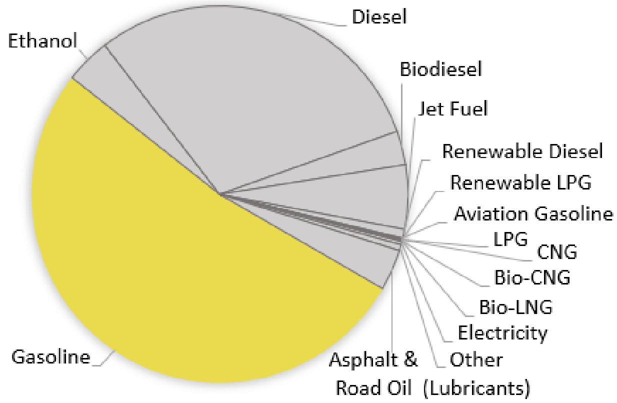

Mosier 2016 Oil Train Derailment[29]

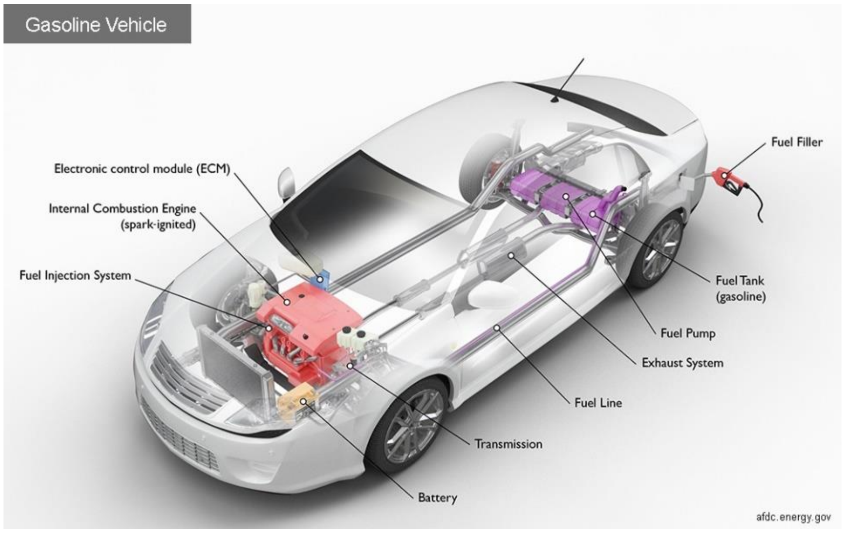
Gasoline

- **1,265,440,694** – Total gasoline consumed in Oregon (2020) GGE[11]
- **0** – Total gasoline produced in Oregon (2020) GGE[16]
- **100.14** – gasoline carbon intensity (2021) in gCO_2e/MJ[9]
- **1,849** – Public and private fuel stations in Oregon[32]

Gasoline is the most widely used transportation fuel in the United States and Oregon, powering cars, motorcycles, light trucks, airplanes, and boats. Gasoline accounts for fifty-two percent of Oregon's total transportation fuel consumption. Oregon's renewable fuel standard requires that nearly all commercially available gasoline for light-duty vehicles has a 10 percent ethanol blend, called E10. To learn about ethanol and how it is blended with gasoline, please visit

Figure 4: Gasoline Share of Oregon Transportation Consumption in 2020



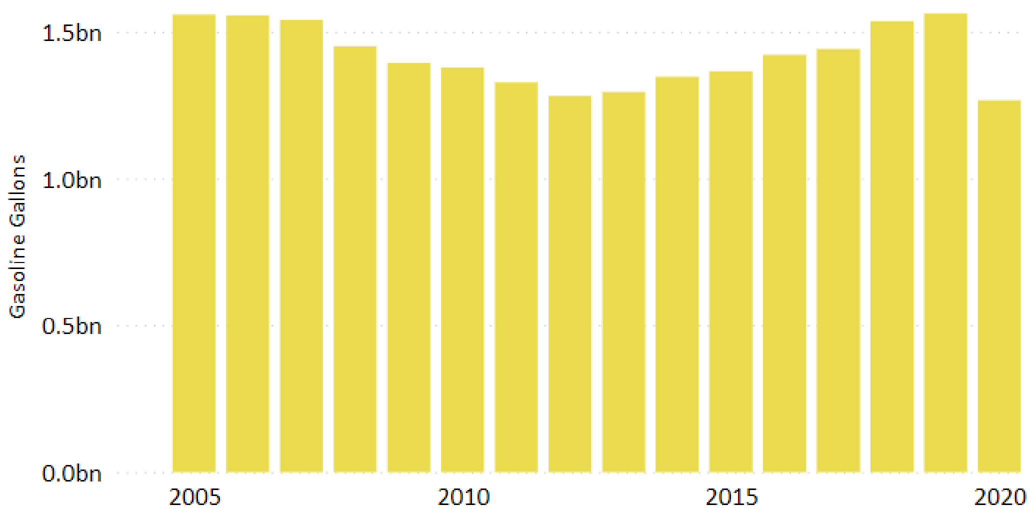


the ethanol section. Crude oil is refined through a process called fractional distillation in which a variety of petroleum fuels are created, including gasoline, distillate oil and many others.[20] U.S. petroleum refineries produce about 19 to 20 gallons of gasoline from a 42-gallon barrel of crude oil.[33] Petroleum refineries and blending facilities in Washington produce and transport 90 percent of motor gasoline for sale at retail gasoline fueling stations in Oregon.[27]

Trends and Potential

In 2020, nearly 1.3 billion gallons of gasoline powered vehicles on Oregon roads, or about 296 gallons per Oregonian.[11] Prior to the COVID-19 pandemic, gasoline consumption in Oregon had been steadily increasing since 2012, largely due to significant economic growth over the last 20 years. The state's population has increased by 23 percent and employment by 18 percent. The average vehicle-miles-traveled also increased by 13 percent.[34] There are more people doing more jobs and driving more per person, leading to greater use of transportation fuels. This is in spite of the growth of electric and other alternative fuel vehicles.[34] Oregon's aggressive EV mandates, coupled with state efforts to reduce overall vehicle miles traveled and improvements in the efficiency of gasoline vehicles, will eventually lead to steep declines in gasoline-powered vehicles and gasoline consumption longer term.[35] [36] In April 2022, the Oregon Department of Transportation completed a Passenger Vehicle Stock Forecast and estimated gasoline-powered vehicle registrations will peak in 2027 and then begin a steady decline.[37] The U.S. Department of Energy's 2022 Annual Energy Forecast indicates that gasoline consumption will not surpass 2019 levels going forward, potentially indicating that gasoline consumption is currently peaking with anticipated overall drops in consumption going forward.[38]

Figure 5: Oregon On-Highway Gasoline Consumption by Year[11]



Beyond Energy

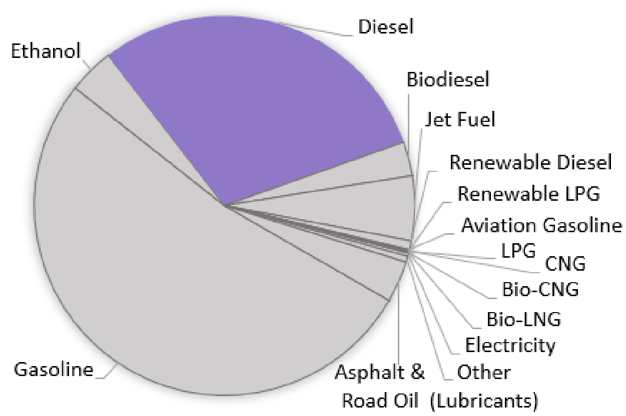
Crude oil products are a global commodity and events outside Oregon's and the United States' control can have a big impact on the price of gasoline. History and recent events confirm that the global crude oil market can be highly volatile. After Russia invaded Ukraine, the cost of gasoline in Oregon rose from $3.431/gallon in June 2021 to $5.266/gallon in June 2022.[18] This increased an average Oregonian's annual fuel costs by over $1,100 per year, a 53 percent increase[i]. Since most Oregon households use gasoline for their daily transportation needs, large changes in fuel costs like this can create additional financial hardships, especially for low-income Oregonians. In most parts of Oregon, particularly rural parts of the state, the costs for transportation exceed 30 percent of average income, and large increases in fuel costs may affect Oregonians' ability to pay for other household expenses.

Gasoline produces the largest amount of greenhouse gas emissions in Oregon — over 15.5 million metric tons of carbon dioxide equivalent in 2020.[11] Burning a gallon of gasoline without ethanol produces about 19 pounds of carbon dioxide. Gasoline exhaust also contains carbon monoxide, nitrogen oxides, particulate matter, and unburned hydrocarbons, which have been linked to substantial respiratory health effects and cancer.[41] This affects communities located in areas with high traffic usage, which are often low-income households and communities of color.[42]

Diesel

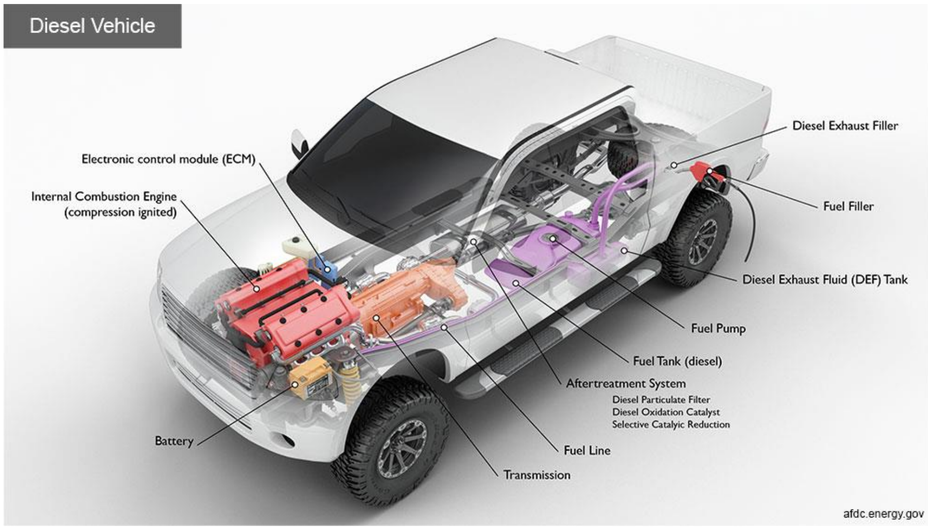
- **726,634,560** – Total diesel consumed in Oregon (2020) GGE[11]
- **0** – Total diesel produced in Oregon (2020) GGE[16]
- **100.74** – Diesel carbon intensity (2021) in gCO2e/MJ[10]
- **1,352** – Public and private fuel stations in Oregon[32]

Figure 6: Diesel Share of Oregon Transportation Consumption in 2020



Diesel fuel is second only to gasoline in fuel consumption in Oregon.[6] It is commonly used by trucks, buses, automobiles, and locomotives, as well as farm and construction equipment.[43] While both gasoline and diesel start as crude oil, they are separated into their component parts and blended with other fuels at a refinery. Diesel is typically blended with biodiesel at 5, 20, and 99 percent amounts. In Oregon, all diesel fuel that is sold or distributed must contain at least a 5 percent blend of biodiesel or renewable diesel called B5. A 20 percent blend, called B20, is also widely available in Oregon. Additional blends of petroleum diesel, biodiesel, and renewable diesel are used to cut lifecycle greenhouse gas emissions of diesel fuel consumption and are available in some parts of the state.[44] Learn more in the Biodiesel and Renewable Diesel sections below.

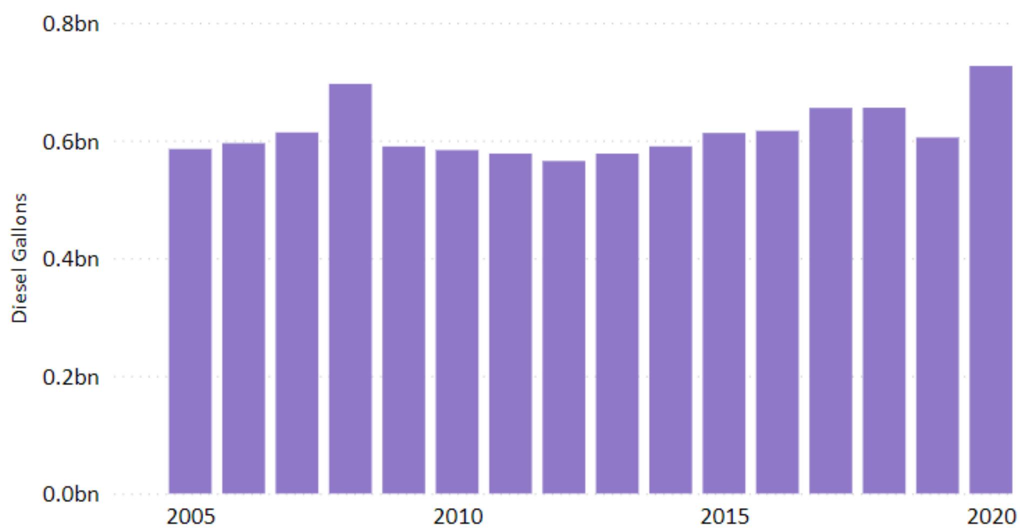
[i] Based on the average 14,032 Oregon vehicle miles traveled per year and an average passenger vehicle fuel economy of miles per gallon. [39,40]



U.S. petroleum refineries produce an average of 11 to 12 gallons of diesel fuel from each 42-gallon (U.S.) barrel of crude oil.[6] There are no petroleum reserves or crude oil refineries in Oregon, meaning all petroleum-based fuel must be imported into the state. Over 90 percent of diesel at Oregon service stations comes from refineries in Washington state. While it typically costs more, diesel contains more energy per gallon than gasoline, so a diesel engine requires less energy to accomplish the same amount of work.[45]

Trends and Potential

Figure 7: Oregon On-Highway Diesel Consumption by Year[11]

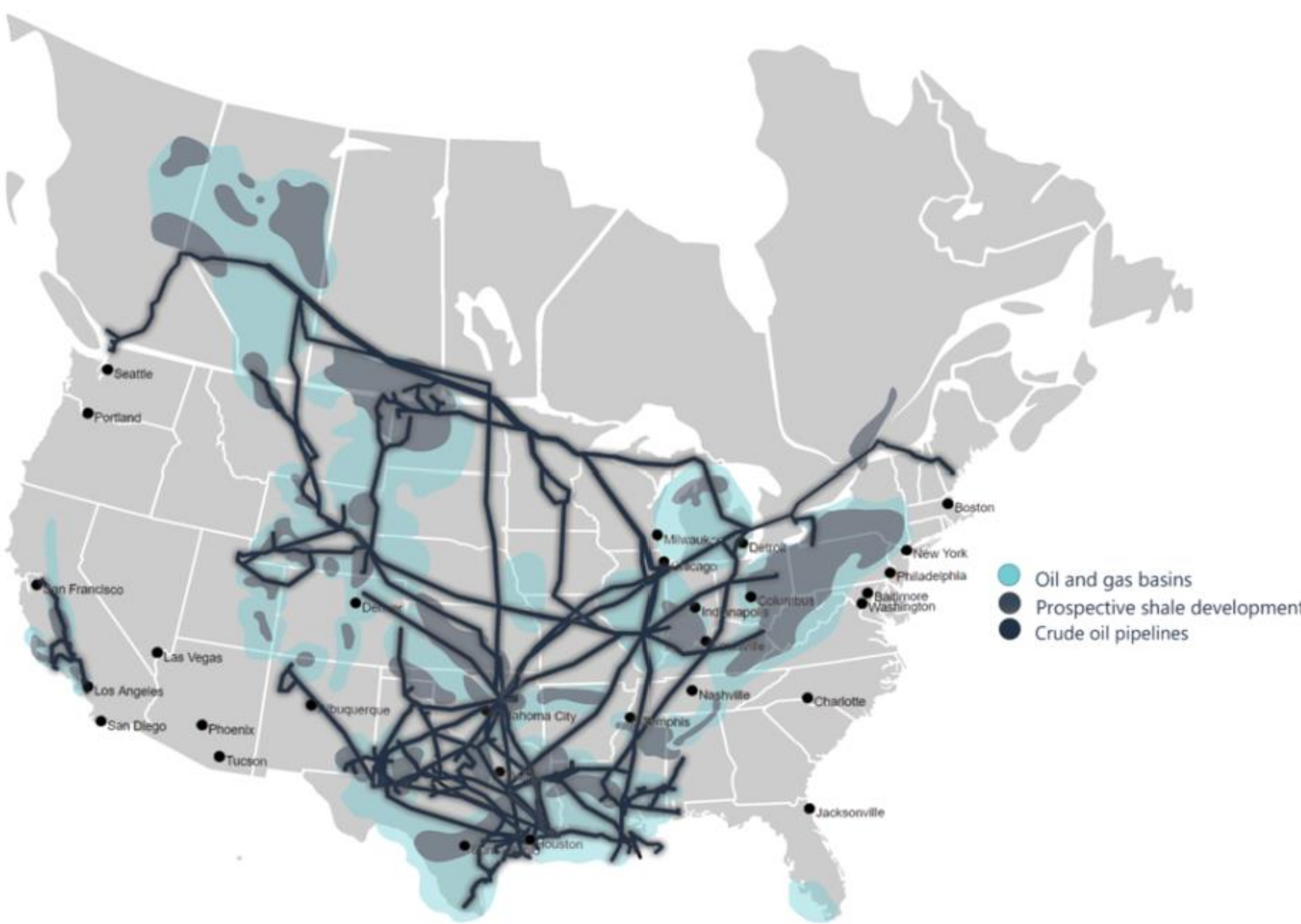


In 2010, Oregonians consumed 551 million gallons of diesel fuel and in 2020, consumption increased to 726 million, a 32 percent increase. Approximately 80 percent of all freight is moved by diesel engines in trucks, trains, and ships in the United States.[46] Some passenger vehicles also use diesel. The number of these vehicles using diesel is projected to continue to increase, depending on the effects of diesel prices on the market and the market penetration of alternatives, such as hybrid and electric vehicles.[43] The Oregon Department of Transportation's State Highway Fund Transportation Revenue Forecast in April 2021 found that diesel use by light and almost all medium-heavy vehicles increased in comparison to 2019. This was attributed to the use of diesel-powered delivery trucks and vans to support increased online retail shopping as a result of COVID-19.[47] Increased availability of diesel alternatives, such as renewable diesel and biodiesel, are increasingly a larger proportion of all diesel-type fuel consumption (see Renewable Diesel and Biodiesel sections below).

Beyond Energy

Diesel fuel consumption is one of the largest sources of greenhouse gas emissions in the state, creating almost 10 million metric tons of carbon dioxide equivalent in 2020. Black carbon particulate – about 70 percent of the particulate emitted by a diesel engine – also contributes to climate change by absorbing light and heat that warms the air and melts snow and ice.[46 48] Combustion of diesel emits more carbon dioxide than an equivalent amount of gasoline, as well as other tailpipe air pollutants, including nitrogen oxides and particulate matter.[49] Diesel exhaust is a known carcinogen that disproportionately affects the health of people in communities near heavily trafficked roads – often historically underserved and lower-income communities – leading to a higher likelihood of poor lung function.[50] Diesel air pollution in Portland, Oregon has been shown to be 10 to 20 times higher than the state's health-based air quality benchmarks.[51] Short and long-term exposure to diesel exhaust can lead to negative cardiovascular, respiratory, and nervous system effects.[50]

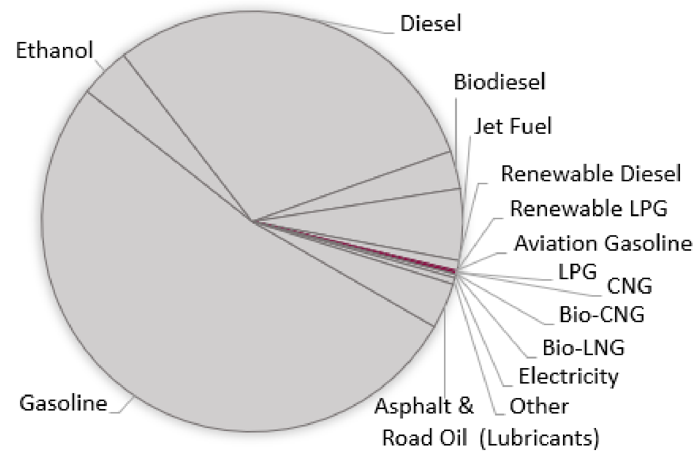
Figure 7: North American Oil and Gas Basins and Crude Oil Pipelines



Natural Gas: Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG)

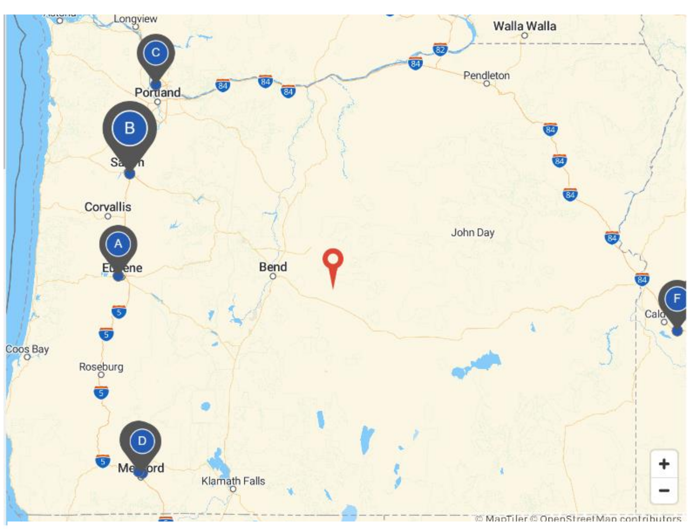
- **407,359** – Total compressed natural gas (CNG) consumed in Oregon (2020) GGE[11]
- **84,880,477** – Total liquefied natural gas (CNG) consumed in Oregon (2020) GGE[11]
- **0** – Total natural gas produced in Oregon for transportation (2020) GGE[16]
- **79.98** – natural gas carbon intensity (2021) in gCO2e/MJ[9]
- **4 CNG and 1 LNG** – Public and private fuel stations in Oregon[52]

Figure 8: Natural Gas/CNG/LNG Share of Oregon Transportation Consumption in 2020



Natural gas is an odorless, colorless gas that is largely comprised of methane but also includes many different compounds. Oregon imports most natural gas through pipelines from Canada and the Rocky Mountain states. Although more commonly used in Oregon to generate electricity and heat buildings, natural gas is also used as a transportation fuel.[53] About 2.6 percent of natural gas was consumed as a transportation fuel in Oregon.[54] There are two forms of natural gas currently used to fuel vehicles: liquefied natural gas and compressed natural gas. Natural gas vehicles exist for on-road and off-road vehicles, and many existing vehicles can be retrofitted to run on CNG and LNG.[55] Of the major auto manufacturers, only Ford offers light-duty CNG fueled vehicles, and these are retrofitted models of diesel pickups. There are few models available for the light-duty sector, and a limited number of models available in medium- and heavy-duty vehicles, such as garbage trucks, semi-tractors, and transit buses.[55]

A compressed natural gas vehicle gets about the same fuel economy as a conventional gasoline vehicle but with reduced greenhouse gas emissions.[56] CNG is produced by compressing natural gas to less than 1 percent of its volume. This means CNG has 100 times as much energy as the same volume of uncompressed gas, and this compression – up to 3,600 pounds per square inch – makes CNG fuel tanks compact enough to support adequate driving ranges for light-, medium-, and heavy-duty vehicle applications. Almost all natural gas consumed in Oregon is imported and there are only four public CNG fueling depots in the state.[52] Where available, the retail price of natural gas is generally much less than gasoline or diesel.[55]



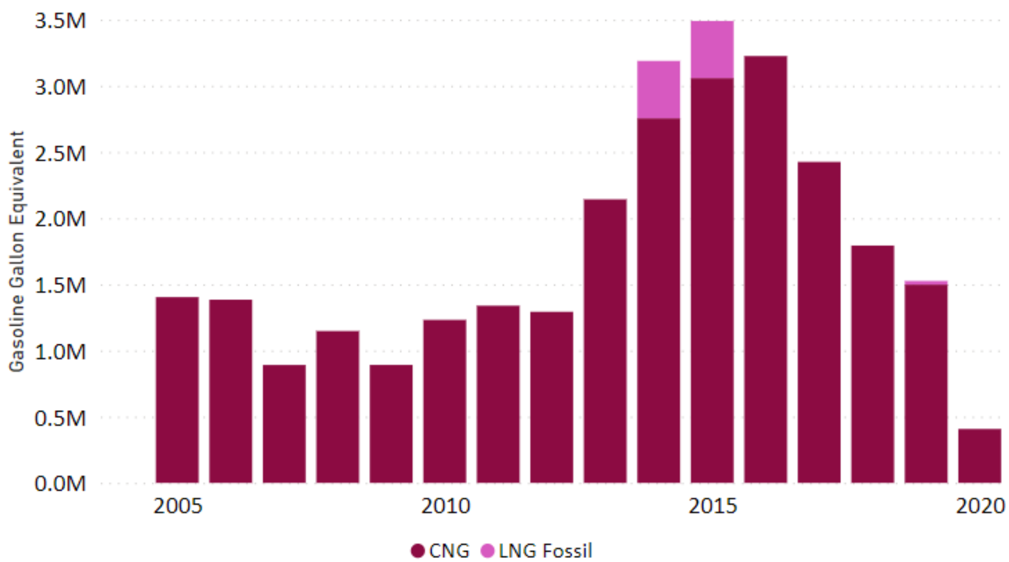
Oregon has four CNG fueling stations.[52]

LNG is natural gas that has been cooled to about -260° Fahrenheit, which converts the gas into its liquid state. More compressed than CNG, it is about 600 times smaller than in its gaseous state and therefore contains more energy per volume than CNG. LNG requires special containers to properly store the cold liquid, usually in double-walled and insulated tanks. Because of its higher energy density, it is more suitable for vehicles that require longer ranges, including ships, trucks, and buses.[58] However, the relatively higher cost to produce LNG has limited its use in commercial applications.[56]

Trends and Potential

In 2020, natural gas represented 0.2 percent of Oregon's total transportation fuel consumption. Natural gas use declined from 1.2 million GGE in 2010 to 407 thousand GGE in 2020 – a decrease of 67 percent. Renewable natural gas, a fuel created from biogas collected from waste, more than doubled natural gas use as a transportation fuel, Oregonians consumed over 3 million GGE in 2020. With the growth of renewable natural gas producing facilities in Oregon, DEQ's Clean Fuels Program has forecasted expected annual increases in the blend rates of renewable natural gas being used as a transportation fuel, replacing fossil natural gas.[7]

Figure 9: Oregon On-Highway Natural Gas Consumption by Year[11]



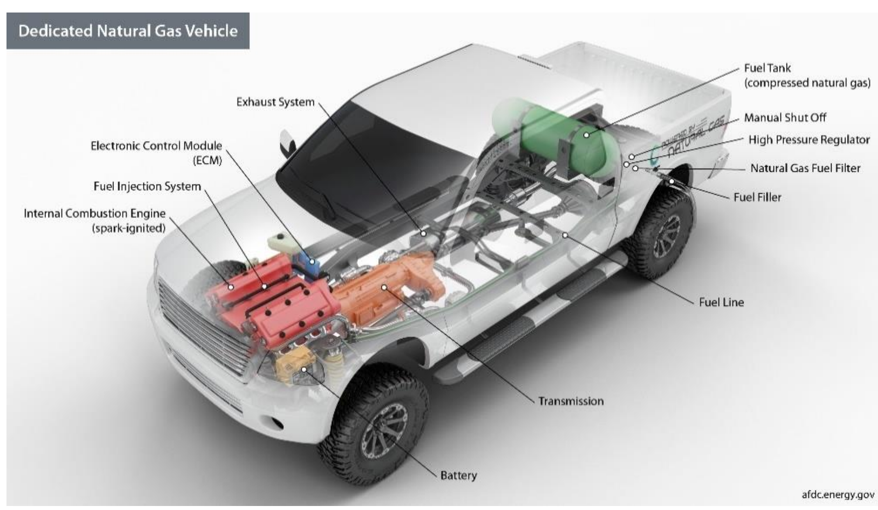
Oregon did not consume any fossil liquid natural gas as a transportation fuel in 2020, but it did consume 317 thousand GGE of renewable LNG. CNG has seen slightly greater adoption within Oregon with four fuel stations while there is only one LNG station.[52]

In 2018, more than 90 percent of the natural gas the United States consumed was produced in the U.S.[59] Oregon receives most of its natural gas from transmission pipelines from the Rockies, Northern Alberta, and Northern British Columbia, Canada. Overall, the United States is building more LNG export terminal infrastructure to support growing demand in Asia and Europe. As exporting capabilities increase, natural gas may become more of a global commodity, leading to domestic natural gas prices being subject to global supply and demand conditions, similar to crude oil. Oregon natural gas utilities can insulate themselves from potential price volatility with local natural gas storage and purchasing future contracts at lower market rates with domestic suppliers.[60]

Rogue Disposal & Recycling's hauling trucks are powered by Compressed Natural Gas.

With stronger regulations on fuel emissions, some shipping companies are adopting LNG as an alternative to residual fuel oil or diesel that are used as bunker fuels. Bunker fuel is any fuel used to power marine vessels.[61] In 2020, the International Maritime Organization implemented new regulations limiting the use of higher sulfur content maritime fuels such as bunker fuel, and low-sulfur marine fuels are significantly more expensive.[62] LNG meets these and other emission requirements for the shipping industry, and is being adopted by some shipping companies. Because using LNG requires new ships and fuel storage infrastructure, the up-front costs to convert may be a barrier for some applications despite lower fuel costs. However, LNG production and storage technology is developing quickly. The shipping industry is also investing in the design of more efficient ships, as it anticipated the potential of LNG as a long-term solution for reducing emissions.[56]

Adoption of natural gas as an alternative road transportation fuel in Oregon can be cost-effective depending on how frequently and how far the vehicles are driven. CNG- and LNG-fueled vehicles have similar power, acceleration, and cruising speeds to equivalent diesel-powered vehicles, but the driving range is lower because CNG and LNG are less energy dense than diesel.[24] Medium- and heavy-duty fleets with daily routes to and from a fueling hub such as a warehouse or bus fueling depot, are some of the best candidates for natural gas fuel adoption. Oregon fleets that have invested in natural gas vehicles and fueling include the City of Salem (Cherriots) and Medford's (Rogue Valley Transportation District) transit agencies, waste management companies like Gresham Sanitary Service, and Kroger.[63–66] The purchase price of new CNG vehicles is greater than a comparable gasoline- or diesel-powered version, and conversion of existing vehicles may cost $6,500 to $12,000. Limited existing fueling infrastructure in Oregon also requires a home or business fueling compressor, which costs $3,500 or more for a single personal vehicle. CNG storage tank costs and needs are dependent upon the size of the fleet and the needed speed of the fill-up.[67 68] Although CNG is 30 to 40 percent less expensive than gasoline or diesel, to offset the initial investment in the vehicle in a reasonable timeframe, fuel use must be relatively high.[69] Commercial fleets that are in continuous use and servicing local areas may be best positioned to take advantage of the lower costs of CNG.



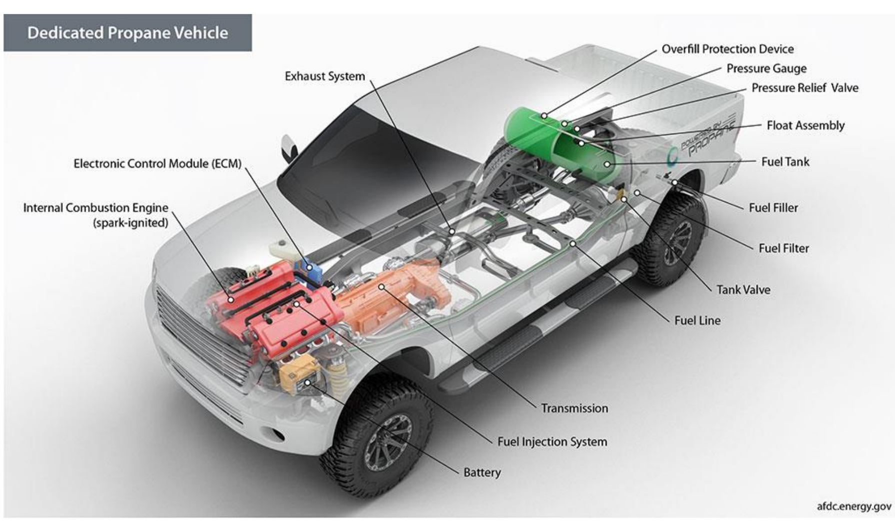
Beyond Energy

Natural gas has lower carbon emissions as a transportation fuel than gasoline and diesel, but its production and use do affect the environment. Carbon intensities for fossil natural gas vary depending on extraction and delivery methods, but on average lifecycle greenhouse gas emissions are approximately 20 percent less than gasoline or diesel.[7] Natural gas is predominantly methane, a powerful greenhouse gas that is the largest contributor to the formation of ground-level ozone, a hazardous air pollutant and greenhouse gas. Exposure to ground-level ozone can result in a variety of negative health outcomes and is estimated to be the cause one million premature deaths globally every year. Methane is 80 times more potent at warming the Earth than carbon dioxide over a 20-year period.[70] The U.S. Environmental Protection Agency estimates that in 2019, methane emissions from natural gas and petroleum systems and abandoned oil and natural gas wells were the sources of about 29 percent of total U.S. methane emissions and about 3 percent of total U.S. greenhouse gas emissions.[71] The EPA also estimates an average of 1.4 percent of natural gas is lost due to pipeline leaks as it travels from extraction to its end-use.[72] Extraction of natural gas, which includes hydraulic fracturing, may also negatively affect local wildlife, people, and water resources.[73]

Propane

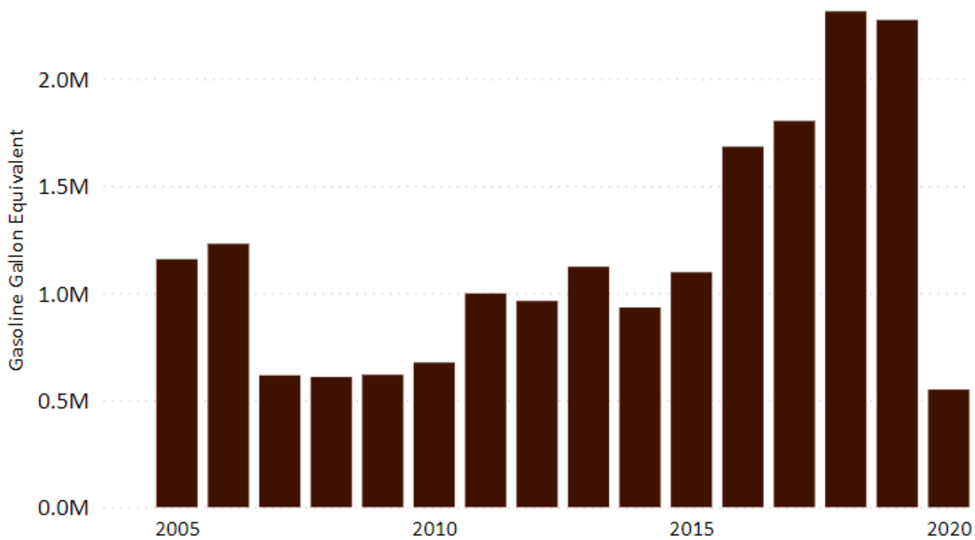
- **549,102** – Total propane consumed in Oregon (2020) GGE[11]
- **0** – Total propane produced in Oregon (2020) GGE[16]
- **80.88** – propane carbon intensity (2021) in gCO2e/MJ[9]
- **44** – Public and private fuel stations in Oregon[52]

Propane is a gas at atmospheric pressure and a liquid – called liquified petroleum gas or LPG – under higher pressures or cold temperatures. Its versatility and high energy density in liquid form make it useful for many purposes, including as a feedstock for petrochemical plants, as a heating or cooking fuel, and as a transportation fuel. New vehicles and conversion kits to retrofit existing vehicles are becoming increasingly available and vehicles can be built as dedicated propane vehicles or bi-fuel vehicles that can run on propane or gasoline.[74 75] Propane is used in Oregon to power buses, locomotives, forklifts, taxis, farm tractors, and Zamboni machines at ice skating rinks. The Pacific Propane Gas Association estimates that more than 95 percent of the propane consumed in Oregon is sourced from natural gas processing plants in Alberta and British Columbia, Canada.[76] Propane does not degrade as quickly as gasoline and diesel when being stored, making it a good transportation fuel for vehicles that are not in regular use.



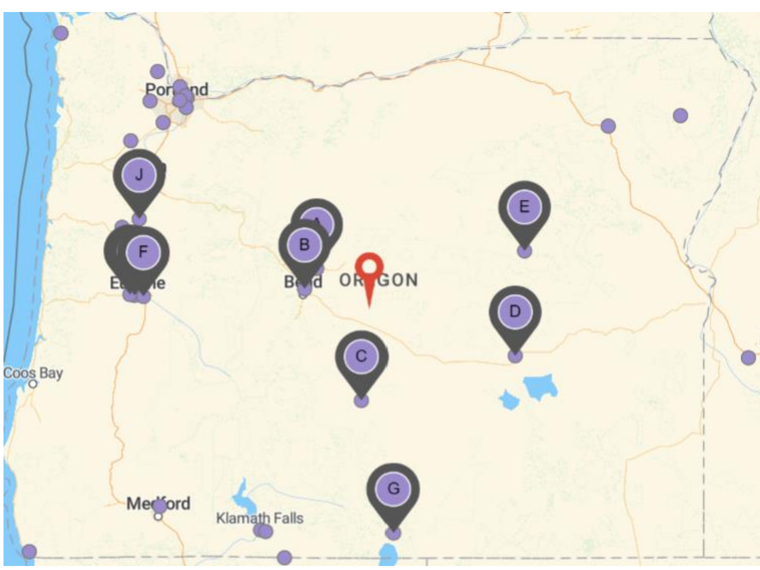
Trends and Potential

Figure 10: Oregon On-Highway Propane Consumption by Year[11]



Oregonians consumed 549,000 GGE of propane in 2020 as a transportation fuel, which was 0.02 percent of Oregon's total transportation consumption. All propane consumed in Oregon is imported.[77] As U.S. natural gas production increased, the supply of propane as a by-product of natural gas processing has followed, making it increasingly more available in the market. Total Oregon propane consumption was 6 trillion Btu in 2010 and 8 trillion Btu in 2020, a 30 percent increase. Although it is a small share of fuels reported to the Oregon Department of Environmental Quality's Clean Fuels Program, its use has steadily increased.[7]

Propane fueling infrastructure currently exists with 44 fueling stations in Oregon, largely supporting private and public fleets.[78] Propane is used by public and private local commercial fleets with light- or medium-duty trucks or delivery vans. Many Oregon school districts use propane as a fuel for bus fleets. In 1983, in response to rising fuel prices and air quality regulations, Portland Public Schools turned to propane as a fuel source for its fleet of buses.[79] There were an estimated 8,257 school buses in Oregon in 2019, and 1,159 — about 14 percent — were fueled by propane (the national average is 4 percent).[76] Using propane requires buying a new vehicle, but unlike many other fuels that require new fueling infrastructure, often the rental of a fueling pallet from a propane distributor is included in the price of the fuel. This reduces the initial investment burden on customers interested in adopting the fuel. Return on investment is reasonably fast without incentives and the fuel is available throughout Oregon.



Oregon has 44 propane fueling stations.[52]

Medium- and heavy-duty fleets with daily routes to and from a fueling hub such as a warehouse or bus fueling depot, are the most amendable to propane fuel adoption. In addition to some school districts, many other Oregon fleets have invested in propane vehicles and fueling, including Franz Bakery, Benton County, Polk County, and Jackson County.[74] For longer routes, most conversion systems allow for bi-fuel use, alleviating concerns about fuel availability. Long haul trucking fleets, however, have not adopted propane because of the greater fuel storage space needed. Propane is less energy dense than gasoline or diesel – one gallon of propane has 27 percent less energy than a gallon of gasoline. To achieve the same fuel range, fleet owners would need to expand each truck's fuel storage space, which would reduce overall cargo space.[75]

Beyond Energy

Propane production has similar air and land quality effects as other petroleum-based fuels because it is a byproduct of natural gas production and crude oil refining. Propane has lower tailpipe emissions than many older diesel and gasoline vehicles, reducing harmful air pollutants that negatively affect the health of Oregonians. Many Oregonians living or working near industrial areas or heavily trafficked areas are particularly vulnerable to the effects of diesel emissions and are disproportionately low-income communities and communities of color.[42] Propane has lower lifecycle greenhouse gas emissions in comparison to other petroleum transportation fuels. Oregon's Clean Fuels program estimated the carbon intensity of propane to be about 19 percent less than gasoline and diesel fuel.[80] Although propane is produced domestically, the propane consumed in Oregon is imported from Canada, meaning propane consumption in Oregon does not improve the state's or country's energy independence.[81]

Blended Fuels

In 2020, 2 percent of the transportation fuel used in Oregon was produced in the state, including 6.5 trillion Btu of biodiesel and fuel ethanol. Biodiesel and fuel ethanol are transportation fuels created from organic plant and animal material called biomass. Biofuels can be used on their own, but in Oregon and the U.S. they are more commonly blended with petroleum-based transportation fuels at varying concentrations. The federal Renewable Fuel Standard requires all transportation fuel sold in the United States to contain a minimum volume of renewable fuels with annual escalating amounts. Oregon adopted a state RFS in 2007; all diesel fuel sold in the state must be a blend with 5 percent biodiesel and all gasoline must be blended with 10 percent ethanol[82] Both federal and state standards increase the development and incorporation of biofuels to reduce total lifecycle GHG emissions of the fuels, reduce reliance on imported petroleum, and improve engine performance.[83]

City of Portland Renewable Fuel Standard

Many of Oregon's local governments have developed climate plans to reduce harmful GHG emissions in their communities. Oregon's transportation sector was responsible for almost 36 percent of GHG emissions in 2019 and communities are exploring local solutions to reduce the impact of transportation.[84] The City of Portland has a renewable fuel standard (Portland City Code Title 16.60) requiring all gasoline and diesel fuels sold in the city be blended with renewable fuels, reducing the carbon intensity and emissions of the fuel. In 2022, city staff proposed a code amendment to gradually increase the minimum renewable fuels blended with petroleum diesel fuel to support the city's climate and renewable energy goals. The draft was in public review at the time of printing, but if this amendment passes as proposed, in the first year of implementation, all diesel sold in the city would have a minimum blend of 15% biodiesel or renewable diesel starting in 2023. The blend percentage would increase each year until it reaches 99 percent four years after the effective date.

Staff proposal:

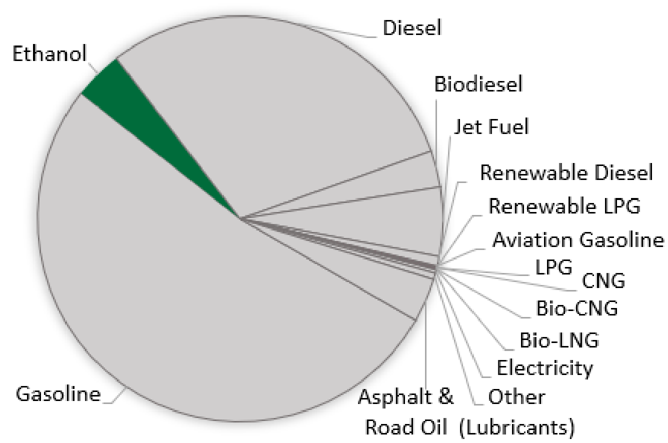
- 2023- minimum blend of 15 percent biodiesel or renewable diesel
- 2024- minimum blend of 35 percent biodiesel or renewable diesel
- 2025- minimum blend of 65 percent biodiesel or renewable diesel
- 2026- minimum blend of 99 percent biodiesel or renewable diesel

In addition to blend requirements, the proposed amendment limits the lifecycle carbon intensity of biodiesel and renewable diesel to 40 gCO2e/MJ, a value that most diesel substitutes in DEQ's Clean Fuels Program currently meet. A minimum carbon intensity is important because it creates a threshold that excludes feedstocks that are higher carbon across their lifecycle, especially feedstocks from agricultural products like soybeans and canola.[85]

Ethanol

- **94,340,735** – Total Ethanol consumed in Oregon (2020) GGE[11]
- **43,062,160** – Total Ethanol produced in Oregon (2020) GGE[16]
- **53.72** – Ethanol carbon intensity (2021) in gCO2e/MJ[9]
- **4** – Public and private E85 fuel stations in Oregon[52]

Figure 11: Ethanol Share of Oregon Transportation Consumption in 2020



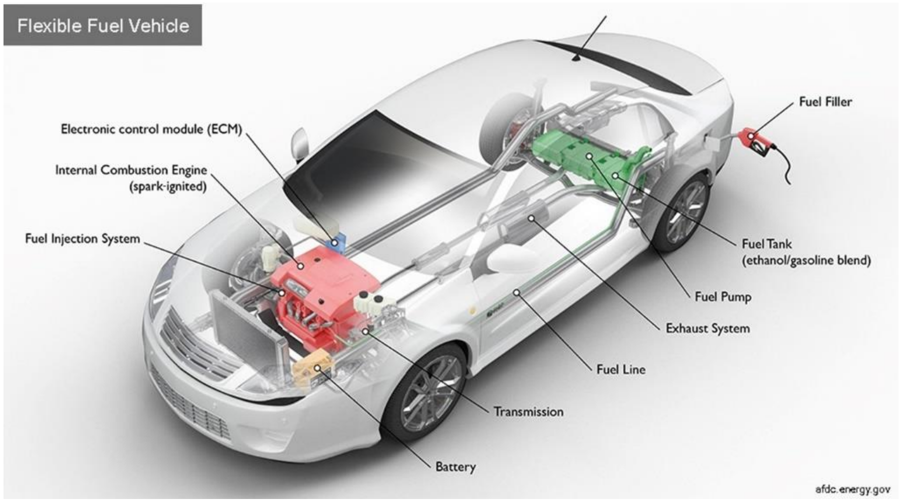
Ethanol is the most common gasoline substitute, with more than 98 percent of U.S. gasoline containing some amount of ethanol. It is a renewable, alcohol-based fuel, made by fermenting and distilling crops, such as corn, sugar cane, sorghum, and wheat. It can also be made by using some agricultural waste products which reduces the carbon intensity of the fuel even more[86] Ethanol oxygenates the gasoline, causing it to burn hotter and cleaner and reducing air pollution and greenhouse gas emissions. Ethanol contains about 30 percent less energy than gasoline per gallon.[ii] Ethanol's impact on vehicle fuel economy is dependent on the ethanol content in the fuel and whether an engine is optimized to run on gasoline or ethanol. [87]

[ii] Based on 98 percent denatured ethanol.

Why do we put ethanol in gasoline?

Ethanol was a replacement for methyl tert-butyl ether (MTBE), which was blended with gasoline from 1979 to 2005. Both ethanol and MTBE improve fuel octane ratings and support more complete combustion of gasoline. MTBE was itself a replacement for lead, added to gasoline by automotive engineers starting in the 1920s to reduce engine knock and improve performance. Health research in the 1960s determined vehicle engine exhaust was exposing the population to lead, leading to chronic negative health effects, particularly in children.[88] In 2005, fuel refiners switched from MTBE to fuel ethanol due to groundwater contamination concerns. [89,90]

Oregon's renewable fuel standard requires that nearly all commercially available gasoline for light-duty vehicles has a 10 percent ethanol blend, called E10. Ethanol is added to gasoline to help oxygenate the gas, causing the fuel to burn more completely. Thus, ethanol-infused gases produce cleaner emissions with less GHG emissions, leading to better air quality.[91]



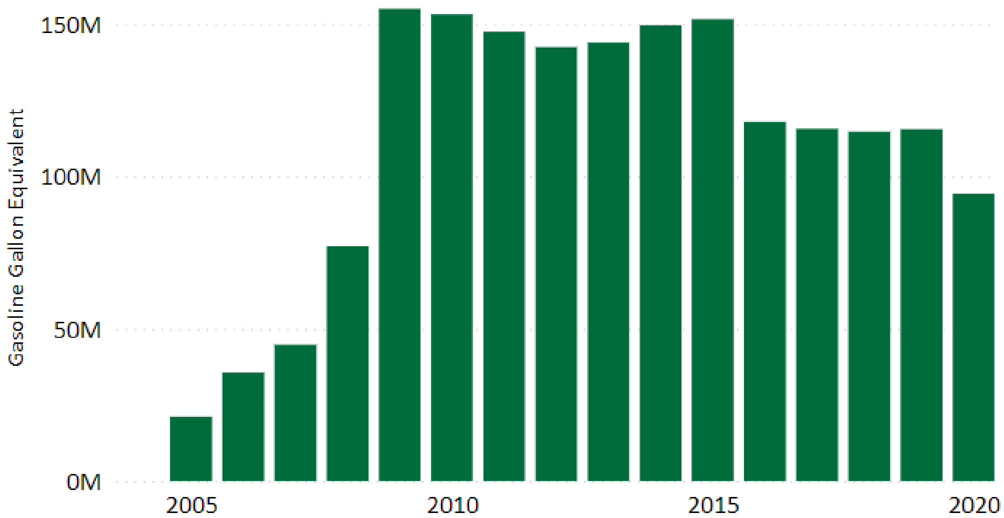
The most common use of ethanol is as a blending agent for gasoline. Oregon's renewable fuel standard requires most gasoline sold in Oregon to be a 10 percent ethanol and 90 percent gasoline blend called E10.[92] Ethanol is also available as E85 or flex-fuel, which is a gasoline blend with 51 to 83 percent ethanol. E85 can be used in flexible fuel vehicles, which are designed to operate on any blend of gasoline and ethanol up to 83 percent.[93] Another blend, E15 with up to 15 percent ethanol, was approved for use in passenger vehicle model years 2001 and newer.[86] The Oregon Legislature passed HB 3051 in 2021, allowing retailers to offer higher ethanol blends like E15 for commercial sale. In 2022, President Biden issued an executive order allowing E15 to be sold from June to September 2022 to reduce price pressures at the pump due to rising global crude oil prices resulting from the war in Ukraine.

Table 1: Comparing Carbon Intensities of Pure Gasoline vs. Ethanol Blends[9]

	gCO2e/MJ	CI Reduction from Gasoline	Percent Change
Pure Gasoline	100.14	-	-
E10	95.50	4.64	5%
E15	93.18	6.96	7%
E85 (51%)	76.46	23.68	24%
E85 (83%)	61.61	38.53	38%
Ethanol	53.72	46.42	46%

Trends and Potential

Figure 12: Oregon On-Highway Ethanol Consumption by Year[11]



Ethanol consumption and production have steadily increased in the United States, matching increased use of gasoline. In 2020, U.S. ethanol production reached 1,886 trillion Btu, a 3 percent increase from the 1,823 trillion Btu produced in 2010. Ethanol has lower tailpipe emissions than gasoline, but the lifecycle emissions of ethanol can vary widely depending on the feedstock and processing method. California, Washington and Oregon have enacted low carbon fuel standards for transportation fuels that encourage lower carbon ethanol production methods. To meet these standards, many first-generation production facilities are investing in energy and production efficiency improvements as well as carbon capture technologies to lower the carbon intensity of the ethanol they produce.[94]

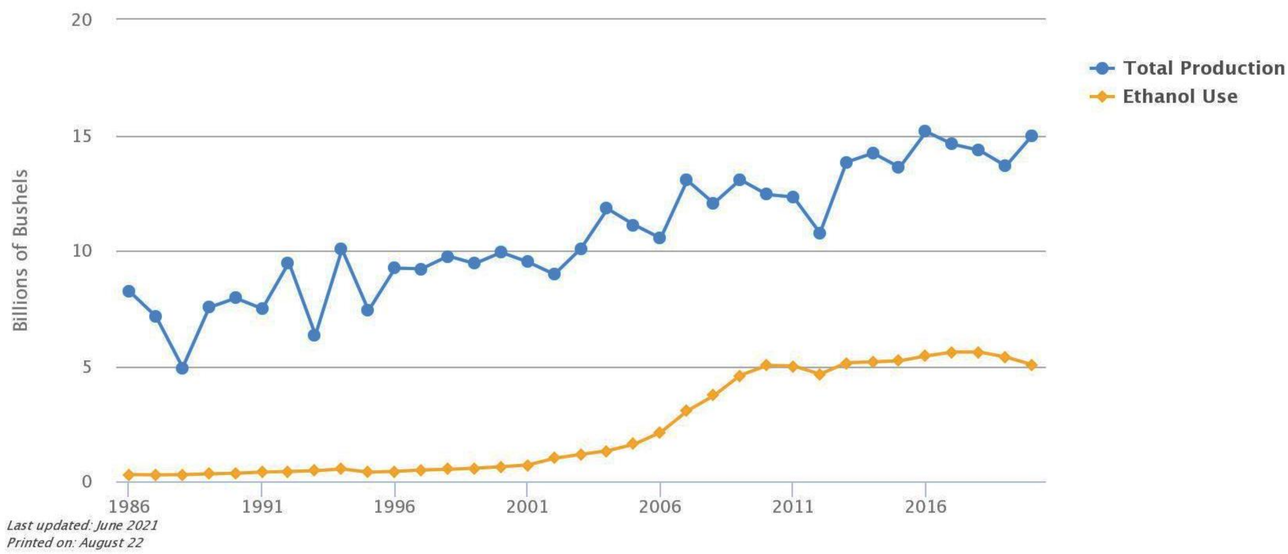
Ethanol plant in Clatskanie, OR.

A small amount of ethanol is produced in Oregon. Oregon began producing fuel ethanol in 2007 and had its largest production year in 2008 with 10.3 trillion Btu of energy created. In 2020, Oregon produced five trillion Btus or 43 million gallons of ethanol.[95] The Alto Columbia production plant in Boardman is the largest transportation fuel and commercial ethanol producer in the state. The plant uses corn as its feedstock and captures the associated carbon dioxide emissions for use by the local food and beverage industry. The carbon dioxide is used to create a beverage-grade liquid used to carbonate soft drinks and make dry ice.[96,97]

Beyond Energy

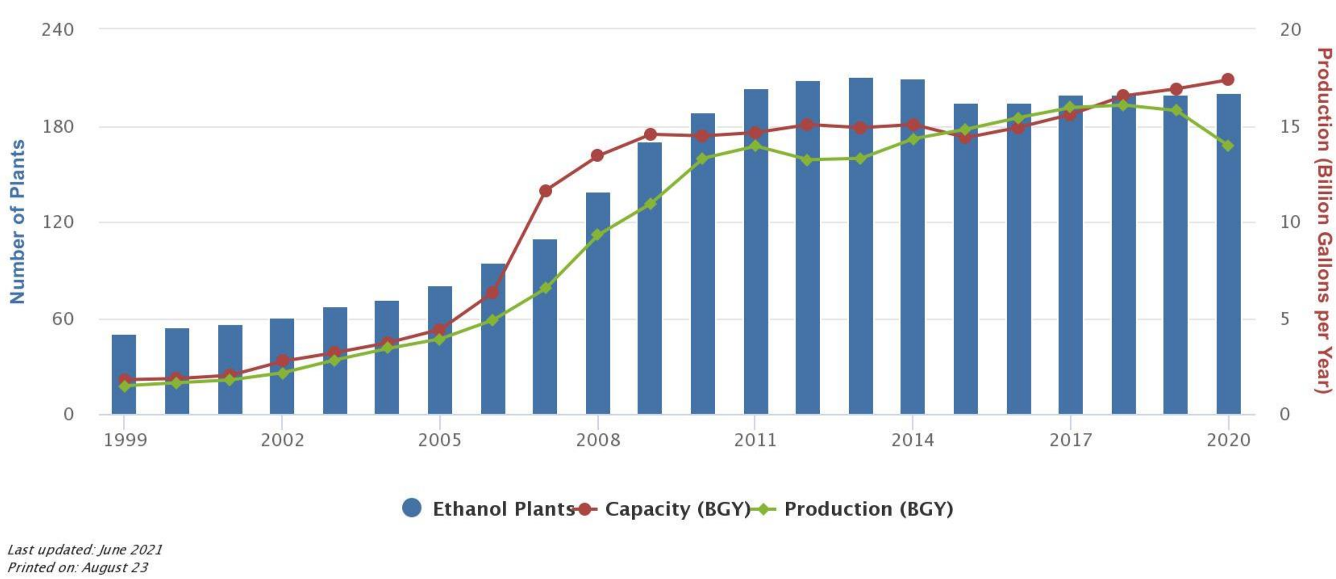
Ethanol production plants are commonly located in rural areas, offering local employment and economic opportunities. However, crop-based feedstocks such as corn and soybeans could compete for land resources that might otherwise be used for food crops. The U.S. Department of Energy estimates that 94 percent of ethanol currently produced in the United States is derived from domestically grown corn. This reduces the United States reliance on foreign crude oil and improves energy security but the tradeoff is that this agricultural land could have been used for food production.

Figure 13: U.S. Corn Production and Portion Used for Fuel Ethanol[98]



The United States Department of Agriculture chart above shows total U.S. corn production and the corn used to produce ethanol from 1986 to 2020. Corn used for ethanol production increased between 2001 and 2010, as nearly all gasoline was transitioned to a blend with 10 percent ethanol.[98] Analysis has found increased land used for ethanol and biofuel production in the U.S. may increase global GHG emissions, due to higher crop prices motivating farmers in other countries to convert forest and cropland. Deforestation releases carbon stored in vegetation, preventing the future storage of carbon in those plants. A potential solution may be to use more waste products to generate the fuel.[99] The United States agriculture sector has taken steps to address concerns around acreage attributed to corn as an ethanol feedstock by improving processing efficiencies to produce more ethanol per bushel.[100] Processing capacity is increasing while mitigating the acreage needed to keep up with domestic demand. The chart below shows the number of ethanol plants operational in the United States from 1999 through 2020. Plant capacity has increased while the number of operational plants has leveled off; average plant sizes are increasing and production is becoming more efficient.[101]

Figure 14: U.S. Ethanol Plants, Capacity, and Production[101]



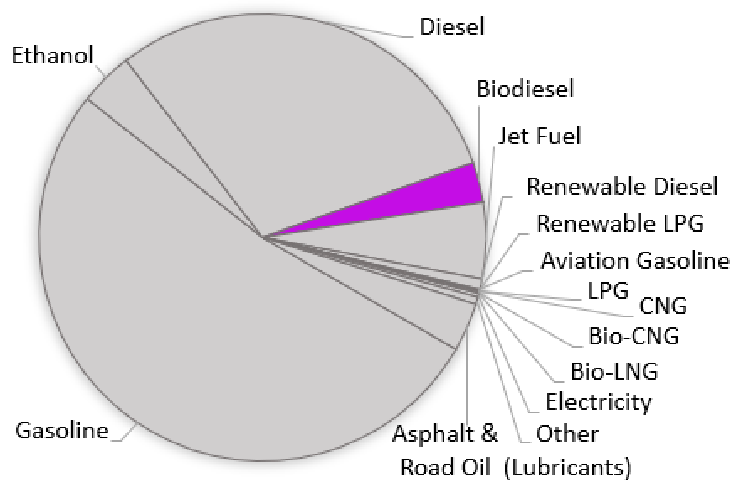
Increasing the amount of ethanol in a gasoline blend reduces the carbon intensity of the fuel. On average, corn-based ethanol produces 45 percent lower emissions than pure gasoline. Other feedstocks can support further lifecycle greenhouse gas emission reductions, improve the sustainability of ethanol as a transportation fuel, and reduce competition for agricultural land. Cellulosic ethanol—created using waste products such as wood or corn kernel fiber or from dedicated crops that need less water or fertilizers to grow like switchgrass or poplar and willow trees—is now available in commercial quantities. Cellulosic ethanol feedstocks are estimated to reduce GHG emissions by between 88 and 108 percent, compared with gasoline and diesel production and use.[86,102]

Biodiesel

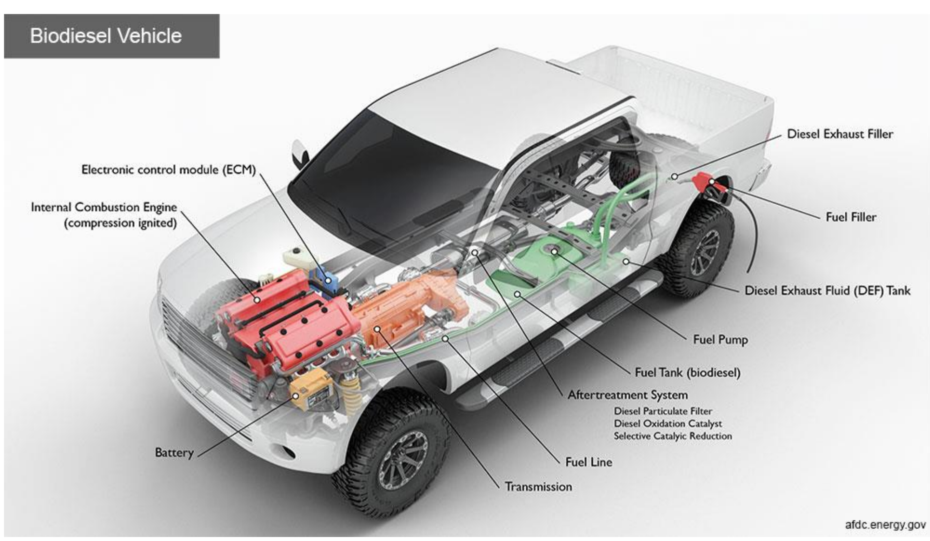
- **70,292,133** – Total biodiesel consumed in Oregon (2020) GGE[11]
- **12,878,161** – Total biodiesel produced in Oregon (2020) GGE[16]
- **41.84** – Biodiesel carbon intensity (2021) in gCO2e/MJ[9]
- **33** – Public and private fuel stations in Oregon[52]

Biodiesel is created from fats, oils, and greases and is currently the predominant form of biomass-based diesel. Rudolf Diesel, the inventor of the diesel engine, originally considered vegetable seed oil as the fuel to run his engine, an idea that eventually led to biodiesel production as an alternative to petroleum diesel fuel.[6] When blended with diesel fuel it can be used by standard diesel trucks, buses, trains, and boats. Oregon's Renewable Fuels Standard requires all diesel fuel sold in the state to include a 5 percent biomass-based diesel blend, known as B5. Similarly, a 10 percent biodiesel blend, B10, 20 percent biodiesel, B20, and any blend up to B99 are also offered in the state.

Figure 15: Biodiesel Share of Oregon Transportation Consumption in 2020



In 2020, Oregonians consumed 19 million gallons of B5 and 77,000 gallons of B20. Growth in B20 consumption in Oregon can be attributed to federal and state renewable fuels standards, Oregon's tax credit for in-state-produced B20 and the Clean Fuels Program. In some cases, retail B20 in Oregon costs less per gallon



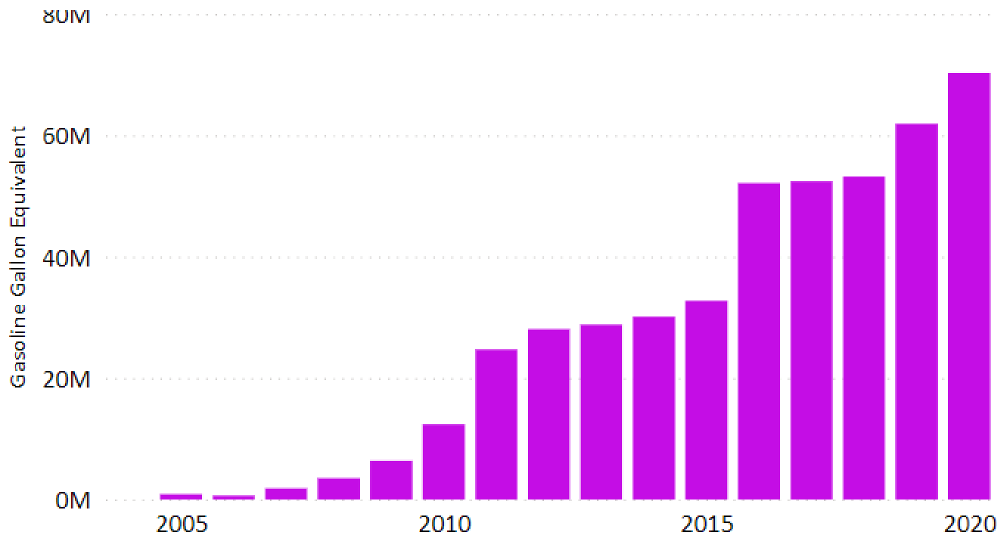
than B5 because Oregon Department of Environmental Quality's Clean Fuels Program reduces costs for fuel providers to below standard B5 costs.[7]

Biodiesel tends to gel at lower temperatures, so it is usually blended with renewable or petroleum diesel at a ratio of no more than 20 percent for use in most diesel vehicles. For this reason, biodiesel is not generally used as a full replacement for diesel unless the engine has been modified for higher blends, and most vehicle manufacturers recommend that their engines use up to a B20 blend. Biodiesels may also absorb water when stored, resulting in potential microbial growth in the fuel.[103] Not all petroleum product pipelines can transport biodiesel, but in Oregon the Kinder Morgan pipeline carries B5 to Eugene.[43]

Trends and Potential

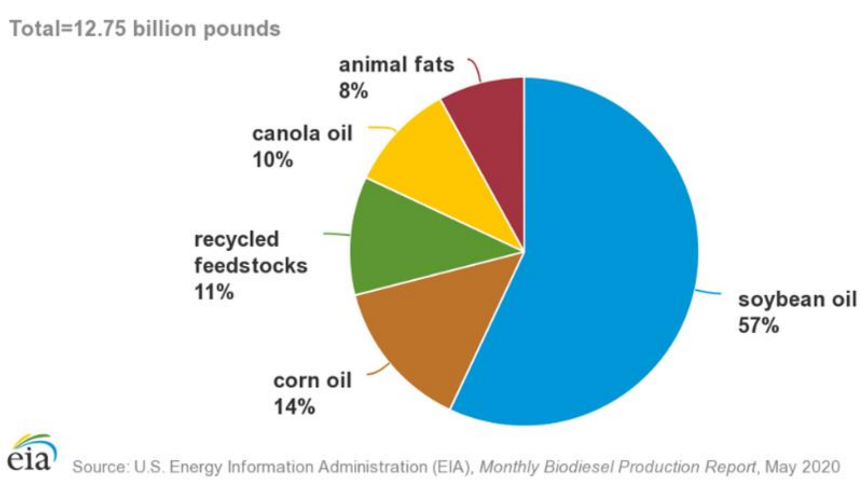
In 2020, Oregon produced 1.5 trillion Btu or almost 13 million gallons of biodiesel. SeQuential Pacific Biodiesel in Salem is the largest producer of biodiesel and the second-largest producer of transportation fuels in Oregon. SeQuential produces biodiesel from used cooking oil collected from local restaurants and businesses.[104] About 85 percent of the fuel SeQuential produces is sold in Oregon as part of a biodiesel blend, while the remainder is exported to regional neighbors Washington, California, Hawaii, and British Columbia.[105]

Figure 16: Oregon On-Highway Biodiesel Consumption by Year[11]



In the U.S., the production of biodiesel reached almost 235 trillion Btu in 2020. EIA estimates that 57 percent of the biodiesel in the United States is produced from soybean oil. Animal fats, used cooking oil, canola, and corn oil largely make up the rest of the feedstock.[106] Soybean production is projected to grow, but the biodiesel industry is hoping to achieve higher output through advanced technologies and new feedstocks such as algal oil from marine algae. The U.S. Department of Energy estimates that algae could produce 30 times more energy per acre than other biofuel crops.[107]

Figure 17: Feedstock Inputs to U.S. Biodiesel Production (2019)[106]



Biodiesel consumption has increased in Oregon. In 2015, Oregonians consumed 3.9 trillion Btu of biodiesel fuel and in 2020, Oregonians consumed 8.8 trillion Btu, an 122 percent increase over that span. Biodiesel consumption growth in Oregon may be affected by the production and supply of renewable diesel, an alternative petroleum diesel fuel that also qualifies under the federal and state renewable fuel standards. Oregon's Clean Fuels Program estimates regional production and available supply of renewable diesel will increase.

Beyond Energy

Producing biodiesel in Oregon can lead to retaining more transportation dollars in the state and reduce reliance on imported petroleum fuels. Greater production and storage of fuels in Oregon could improve energy security, support energy resilience during future catastrophic events, and create local employment and economic opportunities. Although biodiesel is flammable, it is safe to handle, store, and transport, potentially creating less damage than petroleum diesel if spilled or leaked into the environment.[108]

Blending biodiesel with petroleum diesel reduces the lifecycle greenhouse gas emissions compared to diesel fuel combustion—and where the fuel can be produced close to where it is consumed also reduces the carbon emissions associated with transporting fuel. In 2020, the Oregon Clean Fuels Program estimated biodiesel to have an average carbon intensity of 58 percent less than petroleum diesel.

Table 2: Comparing Carbon Intensity of Diesel, Biodiesel, and Blends[9]

	gCO2e/MJ	CI Reduction from Diesel	Percent change
Diesel	100.74	-	-
Biodiesel	41.84	58.90	58%
B5	97.79	2.95	3%
B10	94.85	5.89	6%
B15	91.90	8.84	9%
B20	88.96	11.78	12%
B50	71.29	29.45	29%

Because biodiesel is generally created from soybeans, canola, and other starch-producing crops, there is the potential for competition with food crops. If producing fuel is more lucrative than growing food, land historically used to produce food may transition to fuel crops. There is a risk that demand for more low-carbon fuels may increase deforestation in other countries to create arable land for fuel crops. In the United States, production yield of edible oils and animal feed have steadily increased with existing acreage, mitigating some land allocation concerns, as biofuel production facilities improve efficiency. There is also a greater potential for waste-based feedstocks such as used cooking oil and tallow to be a primary source of biodiesel. Several biofuel companies are looking at growing algae in brackish and saltwater to mitigate land-use effects. Although this feedstock is far from being available at a commercial scale, algal oil presents an opportunity to mitigate the land and resources needed to create biofuels as it can be grown on land not appropriate for farming and uses saltwater or brackish wastewater, although other potential environmental effects are not known.

Zero Tailpipe Emission Fuels

For the transportation sector to meet Oregon's clean energy goals, the state will need to transition to an entirely zero-emission fleet powered by hydrogen and electricity. These fuels have zero tailpipe emissions, though there may be emissions from the production of that fuel depending on how it is produced. For the entire lifecycle of these fuels to be zero emission, they would need to be produced from zero-emission resources such hydropower, wind, and solar. These resources are abundant and can be produced and supplied in Oregon. Fueling infrastructure, which will need to be operated and maintained, is also needed to support greater adoption of these fuels. The development of renewable energy and fueling supports more transportation fuel jobs in the state and retains more transportation fuel dollars. Producing more transportation fuels improves Oregon's energy security by reducing dependence on petroleum-based fuels that are extracted and processed outside the state. This can also reduce the volatility of transportation fuel costs due to global impacts on crude oil prices, such as the Russian war in Ukraine or OPEC crude production agreements.

Zero emission tailpipe fuels not only reduce greenhouse gas emissions, they also reduce other harmful air pollutants, such as small particulates and oxides of nitrogen. These pollutants are so small they can enter a person's bloodstream through the lungs, and lead to greater incidences of respiratory ailments, heart attacks, and premature death.[109] The effects of these pollutants contribute to increased hospitalizations and absences at work and school. Greenpeace Southeast Asia and the Centre for Research on Energy and Clean Air (CREA) quantified the annual economic costs of air pollution from petroleum fuels to be $600 billion for the United States alone.[110] Further, the health effects of poor air quality are not evenly shared, but more often affect children, the elderly, people of color, and people with lower incomes.[111]

Every Mile Counts

Zero-emission and renewable fuels are an essential piece of Oregon's plan to reduce greenhouse gas emissions in the transportation sector. Every Mile Counts is a collaboration of the Oregon Departments of Transportation, Energy, Environmental Quality, and Land Conservation & Development to develop and implement interagency actions that address greenhouse gas emissions. Agencies focus on three core strategies: supporting use of cleaner vehicles and fuels, reducing vehicle miles traveled per capita, and considering GHG emissions in state decision-making, with priority efforts focused on transportation electrification and cleaner fuels, in addition to supporting transportation options and local GHG reduction planning. Agencies coordinate on regulatory actions, planning activities, data collection, and developing metrics to track progress on GHG reductions.

Hydrogen

- **0** – Total hydrogen consumed in Oregon (2020) GGE[11]
- **0** – Total hydrogen produced in Oregon (2020) GGE[16]
- **156.83** – hydrogen carbon intensity (2021) in gCO2e/MJ[80]
- **0** – Public and private fuel stations in Oregon[7]

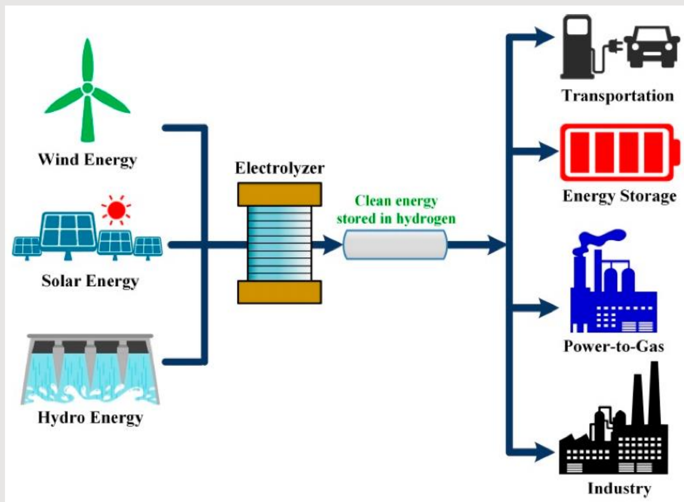
Hydrogen is the most abundant element on Earth, but extracting it efficiently from source materials can be challenging. Currently, about 95 percent of hydrogen produced in the United States is made from natural gas through a process called steam-methane reforming. This process is one of the most cost-effective for producing hydrogen, but also one of the most carbon intensive. There's growing interest globally in pairing steam-methane reforming with carbon capture and storage to produce low-carbon hydrogen. Hydrogen can also be produced using electricity to power an electrolyzer, which splits water into hydrogen and oxygen; when the electricity used is from renewable sources, the resulting hydrogen is also considered renewable.

What is a steam-methane reforming?

Steam-methane reforming is a process to produce hydrogen from natural gas. Methane, usually from natural gas, reacts with steam under pressure and in the presence of a catalyst to produce hydrogen, carbon monoxide, and a relatively small amount of carbon dioxide. Steam reforming can also be used to produce hydrogen from other fuels, such as ethanol, propane, or even gasoline.[112]

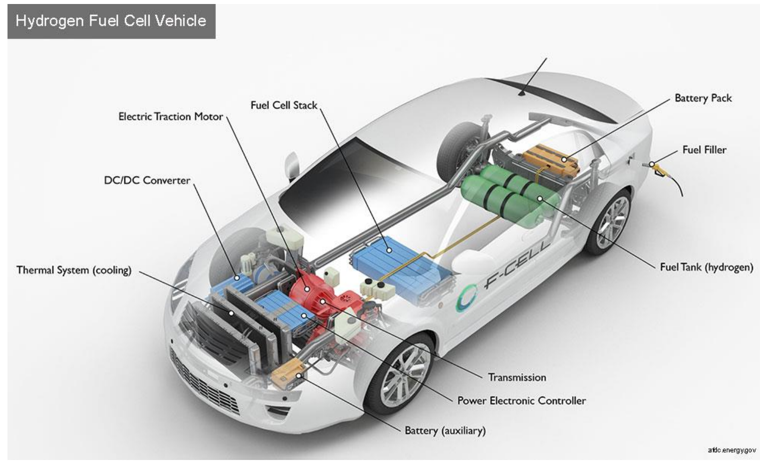
What is an electrolyzer?

Electrolysis is the process of using electricity to split water into hydrogen and oxygen. The reaction takes place in an electrolyzer. They range in size from small, appliance-size equipment for small-scale distributed hydrogen production to large-scale, central production facilities that could be tied directly to renewable electricity production like hydroelectric dams, solar or wind farms.



Today, most hydrogen is used for industrial applications such as oil refining, steelmaking, and production of ammonia and methanol.[113] However, low-carbon and renewable hydrogen are increasingly seen as important decarbonization options, especially for so-called "hard to abate" sectors where there aren't a lot of options to reduce emissions, like the industrial and transportation sectors.

Trends and Potential



It's unclear how large a role light-duty fuel cell electric vehicles (FCEVs) will play in reducing transportation greenhouse gas emissions in Oregon given the current strong adoption of electric vehicles and growing charging infrastructure. Currently, there are only a few models of light-duty FCEVs available, and they have higher upfront costs and maintenance costs than battery electric vehicles. However, hydrogen is more attractive as a fuel for medium- and heavy-duty applications, including transit buses and long-haul trucking. FCEVs offer longer ranges, quicker refueling times, and do not have performance issues in cold temperatures. The Portland metropolitan area's public transit system, TriMet, completed a feasibility study to consider hydrogen fuel cell buses. TriMet's Zero Emission Bus Transition Plan, completed for the Federal Transit Administration in May 2022, includes hydrogen fuel cell buses as part of the fleet transition plan, assuming a source of green hydrogen becomes available. Lane Transit District has also indicated interest in hydrogen fuel cell buses because of their extended range as compared to battery electric buses.

Two challenges associated with use of hydrogen as a transportation fuel in Oregon are the lack of fueling infrastructure and the lack of local hydrogen production. Oregon is working with the Federal Highway Administration to successfully designate its portion of I-5 as an alternative fuels corridor, which could support development of hydrogen fueling stations. Additionally, Oregon and Washington are collaborating on a joint application for up to $1 billion in funding from U.S. DOE for a regional clean hydrogen hub. A successful award would help finance additional production of hydrogen in the region, some of which would be available for transportation end uses.[114]

Hydrogen refueling station in Berkeley, CA.

Learn more about vehicles in Oregon using hydrogen in the Clean and Efficient Vehicles Technology Review.

Beyond Energy

Hydrogen presents new economic opportunities in Oregon,[iii] but the infrastructure development needed to produce and supply hydrogen around the state is a significant barrier to widespread adoption. Hydrogen production is not currently cost-competitive with petroleum fuel, but given the interest in hydrogen and renewable hydrogen in Oregon and new funding available from the federal government, it's likely that production will ramp up in the coming years.

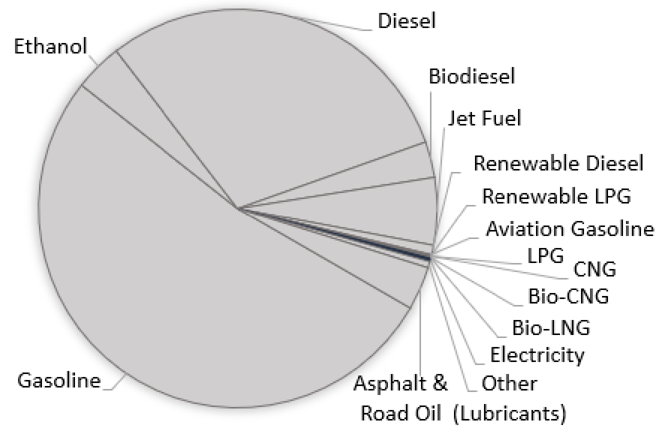
[iii] For more information, see the Oregon Department of Energy's *2022 Renewable Hydrogen Report* (Available November 15, 2022): https://tinyurl.com/ODOE-Studies

Hydrogen has the potential to reduce air pollution and lifecycle greenhouse gas emissions in Oregon. No matter how the hydrogen is produced, using hydrogen in a fuel cell electric vehicle creates zero local air pollution or tailpipe greenhouse gas emissions. Like many alternative fuels, however, the amount of lifecycle greenhouse gas reductions depends on the resources used to create the hydrogen. Where hydrogen can be produced from renewable or low-carbon electricity sources—such as producing renewable hydrogen using an electrolyzer powered by renewable electricity—the overall emissions are much lower.

Electricity

- **6,495,585** – Total electricity consumed for transportation in Oregon (2020) GGE[11]
- **63,624,782** – MWh of Total electricity generated in Oregon (2020)[115]
- **25.35** – electricity carbon intensity (2021) in gCO2e/MJ[9]
- **2,193** – Public and private fuel stations in Oregon[116]

Figure 18: Electricity Share of Oregon Transportation Consumption in 2020

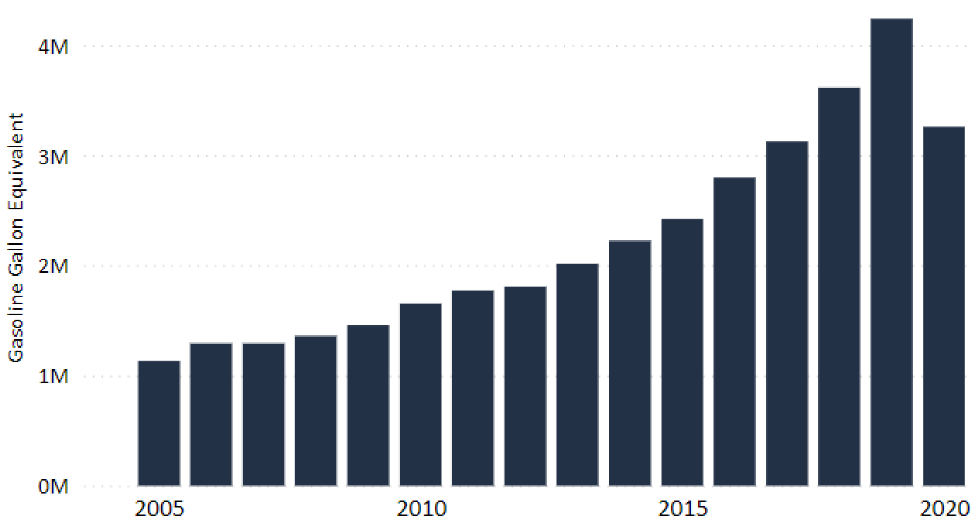


Electricity used as a transportation fuel is growing rapidly in the passenger vehicle sector and is increasingly used for medium- and heavy-duty trucks, port equipment, construction equipment, and other non-road vehicles. Electricity is produced from a variety of energy sources, including hydropower, natural gas, coal, nuclear, wind, and solar. Electric vehicles (EVs) use this electricity to charge battery packs on the vehicle that discharge the electricity to electric motors, which propel the vehicle.[117] Most EVs are charged at home or at a business, but chargers are increasingly available for the public to use across the state to fuel electric vehicles quickly when needed. To learn more about vehicles in Oregon using electricity, please visit the Clean & Efficient Vehicles Technology Review.

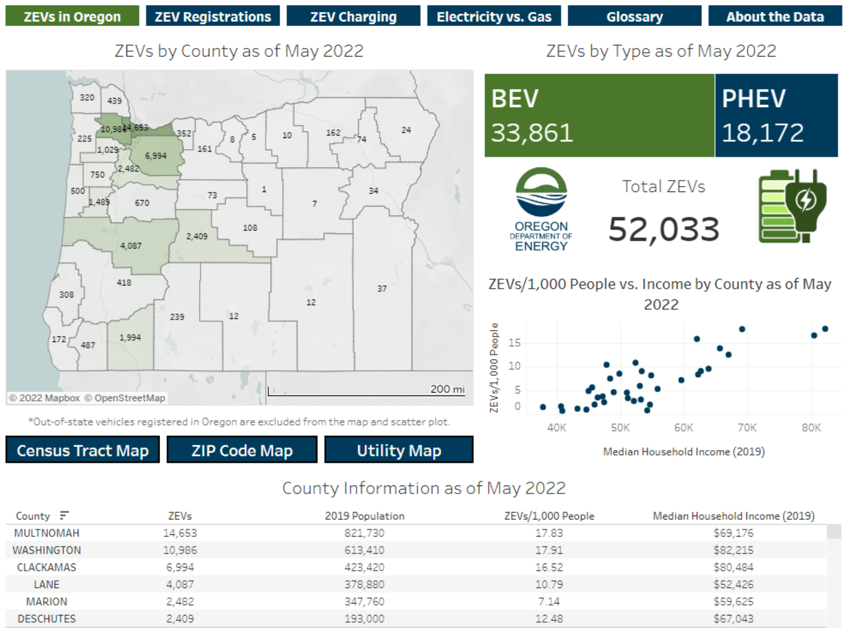
Trends and Potential

Electricity is expected to quickly become a larger portion of Oregon's transportation fuel mix. In 2010, only 0.08 percent of Oregon's transportation fuel consumption came from electricity. In 2020, 0.27 percent of Oregon's transportation fuel consumption came from electricity, demonstrating steady market growth. Electric charging stations are being installed

Figure 19: Oregon On-Highway Electricity Consumption by Year[11]



around the state, with more than 2,193 publicly available stations as of July 2022 to support the 50,000+ registered electric vehicles on Oregon roads.

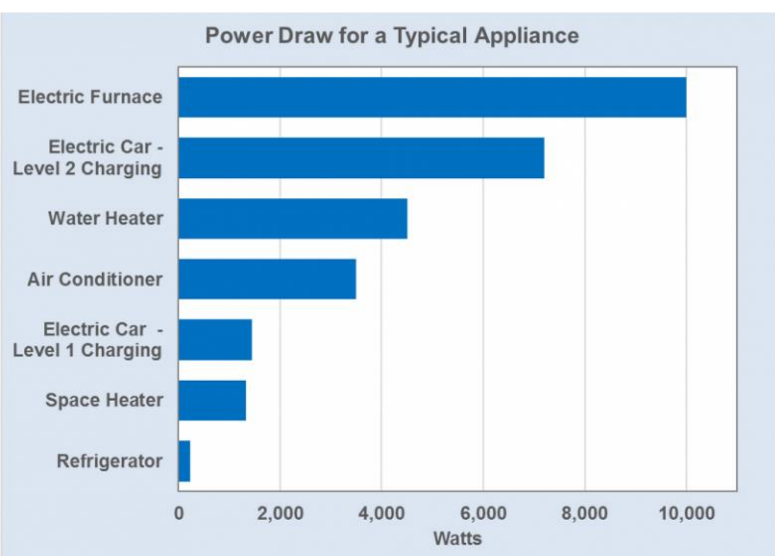


ODOE's Electric Vehicle Dashboard: https://tinyurl.com/ODOEEVDashboard

As electric vehicles become more popular, demand for electricity will increase and Oregon's electric utilities must plan to meet this market change. While the average electric passenger vehicle generally draws similar amounts of power as household appliances, widespread adoption of EVs will require utilities to plan for this growth in their forecasting of distribution system-level needs.

In its transportation electrification plans for Oregon, Pacific Power forecasts to have approximately 29,000 EVs in its territory by 2025, and Portland General Electric expects around 30,000 light-duty EVs by the end of 2025. Both utilities are preparing multiyear Transportation Electrification Plans for PUC acceptance, including programs to assist customers with installing EV charging while managing added load on the utility system. Utility plans include developing market transformation strategies to promote electric vehicle adoption while planning to manage the new load on their systems.[119]

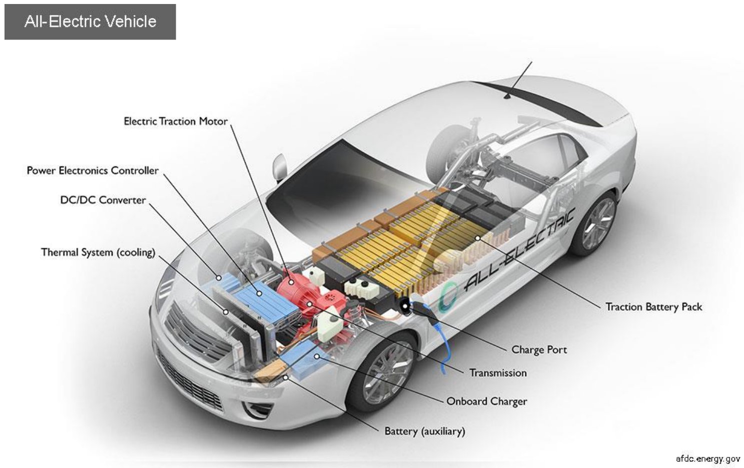
Figure 20: Power Draw for a Typical Appliance[118]



Many federal and state policies support increased EV adoption. The Inflation Reduction Act of 2022 expanded federal tax credits available for many individuals and businesses that purchase an EV, and businesses can get an additional tax credit for purchasing and installing chargers.[120,121] To learn more about EV incentives and the Inflation Reduction Act of 2022, please visit the Clean and Efficient Vehicles Technology Review. In 2021, President Biden signed an executive order directing the federal government to achieve 100 percent zero-emission vehicle[iv] acquisitions by 2035, including 100 percent zero-emission light-duty vehicle acquisitions by 2027.[122] At the state level, DEQ administers the low- and zero-emission vehicle standards which mandates an increasing percentage of sales be electric or fuel cell. This

[iv] Zero-emission vehicles may also include hydrogen fuel cell electric vehicles.

applies to both passenger vehicles and trucks. Oregon has established ZEV adoption goals for the state, including 250,000 registered vehicles by 2025 and 90 percent of sales by 2035.[123] DEQ also administers a rebate program for the purchase or lease of passenger electric vehicles: https://www.oregon.gov/deq/aq/programs/pages/zev-rebate.aspx.



Several state agencies have programs that support EV adoption such as DEQ's Clean Fuels Program, which is a market-based credit and debit system that helps reduce the carbon intensity of Oregon's transportation fuel mix. Electricity is lower in GHG emissions than gasoline, so using electricity as a fuel generates credits in the program providing an incentive to use less carbon intensive fuels. DEQ is also developing a pilot program to provide grants for medium- and heavy-duty vehicle charging infrastructure through a $15 million program funded by the 2022 Legislature.[124] The Department of Transportation is Oregon's lead agency for the National Electric Vehicle Incentive Program – a program designated in the federal 2021 Infrastructure Investments & Jobs Act. ODOT will be overseeing $100 million in federal and state funding to support EV charging throughout the state.[125] This new effort will be informed by ODOT's Transportation Electrification Infrastructure Needs Analysis, which delivers an overview of EV charging infrastructure needs and policy options to enable access to electric fuel for all Oregonians.[126]

Zero Emission Vehicle Interagency Working Group

Transportation electrification is such an important step the state needs to take towards achieving long-term climate goals, Governor Kate Brown established the "ZEVIWG" to ensure that efforts are coordinated. The ZEVIWG is a multi-agency team that coordinates and plans actions to support access to zero emission vehicles, fueling infrastructure, and providing education and outreach on their use, benefits, and costs. This engagement helps agencies increase awareness, coordinate efforts, leverage work, address barriers, and find solutions. An annual workplan guides individual actions and acts to keep track of efforts that have been implemented.

Beyond Energy

Oregonians driving EVs will have lower overall greenhouse gas emissions than driving a gasoline or diesel vehicle no matter where they charge their electric vehicle in the state. Using electric fuel coupled with the greater efficiency of an electric motor reduces greenhouse gas emissions by 50 to nearly 100 percent. Customers of consumer-owned electric utilities have some of the cleanest electricity because they receive power mainly from Bonneville Power Administration's nearly carbon-free resources – hydropower and nuclear.[127] As Oregon's utilities work to meet the state's 100 percent clean electricity targets by 2040, driving an EV will continue to get cleaner. The Clean Fuels Program also has a provision that allows charger owners to purchase and retire Renewable Electricity Credits

(RECs) to claim carbon-free electricity which makes it easier for Oregon's EVs to charge with renewable electricity.

EVs also have zero tailpipe emissions, reducing local air pollutants such as particulate matter and oxides of nitrogen, which can cause negative health effects, especially to communities near industrial and heavily trafficked areas. These are often historically disadvantaged communities, such as low-income, elderly, disabled, and communities of color.[42]

Charging an electric vehicle at home can cost less than 20 percent of the fueling cost of a comparable fossil fuel vehicle, and other operational and maintenance costs are about half.[128] The Oregon Department of Energy's Electric Vehicle Dashboard provides Oregonians with a tool to calculate electric vehicle costs in comparison to gasoline-powered vehicles: tinyurl.com/ODOEEVDashboard. Electricity rates, when home-charging, have less price volatility than other transportation fuels as they are regulated by Oregon's Public Utility Commission or the governing boards of consumer-owned utilities. Fueling costs for publicly accessible EV chargers tend to be much more expensive. Public charging companies have widely different rates, fees and may include a monthly subscription plan. ODOE evaluated one of the leading EV charging companies as an example and determined the costs to charge a vehicle at a public station were still lower than gas – about 35 to 50 percent – but were two to three times more than an average Oregonian would pay charging at home.[128]

The growth of electric vehicles has dramatically increased the demand for batteries and the minerals like lithium, cobalt and nickel needed to produce them. Acquiring the volume of minerals needed will be difficult but also labor, economic, and environmental concerns have been raised about the mining and processing of these metals. These difficult supply chain and geopolitical barriers may hinder the U.S. auto industry's ability to meet the demand for electric vehicles.[129] To learn more about batteries in electric vehicles, please visit the Clean & Efficient Vehicles Technology Review.

Equitable access to the lower costs and environmental benefits of EVs is a growing concern. Using electricity as a transportation fuel requires investment in a new vehicle, a significant financial barrier for low-income Oregonians and smaller businesses. Where someone lives and works affects how easy it is to charge an EV. Not all Oregonians have convenient access to home charging where they park their vehicles and public charging is significantly more expensive. This has implications for Oregonians living in multi-unit dwellings or other locations without access to home charging, who are more often low-income and communities of color. To learn more about electricity charging infrastructure and potential policy challenges, see the Oregon Department of Energy's 2021 Biennial Zero Emission Vehicle Report: https://www.oregon.gov/energy/energy-oregon/Pages/BIZEV.aspx.

Renewable Transportation Fuels

Renewable transportation fuels are biomass-based fuels that typically have lower carbon intensities than their petroleum-based versions, offering significant reductions in carbon emissions. Produced from biomass sources, these fuels are nearly chemically identical to petroleum-based fuels and can be used in existing conventional vehicles and fuel infrastructure.[130 131] In addition to lower greenhouse gas emissions, renewable fuels also have lower air pollutant emissions, including lower small particulate matter which can be a harmful air pollutant. Feedstocks for these fuels include fatty substances like vegetable oils, animal fats, greases, and algal products, or cellulosic materials such as dedicated energy crops, crop residues, and woody biomass.[131] Some of these feedstocks are waste that would otherwise end up in landfills, while others are created for the express purpose of providing a transportation fuel. These fuels could be produced in Oregon, offering the potential for local job creation and increased energy security.

Table 3: Comparing Carbon Intensities of Fossil-Based and Renewable Fuels

	Average Carbon Intensity (2021) in gCO2e/MJ	CI Reduction from Petroleum Fuel	Percent Change
Gasoline	100.14	TBD	TBD
Renewable Gasoline	TBD		
Diesel	100.74	63.76	63%
Renewable Diesel	36.98		
Compressed Natural Gas	79.98	59.43	74%
Renewable Natural Gas	20.55		
Liquid Natural Gas	86.88	66.33	76%
Renewable Natural Gas	20.55		
Propane	80.88	46.22	57%
Renewable Propane	34.66		

Often referred to as "drop-in" fuels, renewable fuels can use existing fueling infrastructure and can simply be added to the tank of an existing fossil fuel vehicle. Access to the fuels is largely driven by the availability of feedstocks, fuel processing facilities, and distribution points. Oregon's Clean Fuels Program provides a market that incentivizes lower-carbon fuels delivered into the state, making them more price competitive with petroleum fuels. This has led to increased availability and adoption of these fuels, particularly renewable diesel, in Oregon. Some renewable fuels, such as renewable propane, are blended with fossil propane by distributors because the supply is not yet consistent enough to sell separately to Oregon customers. Renewable diesel and renewable natural gas are more mature within the market and are created, distributed, and sold separately from their fossil counterparts, although they may still be blended in with petroleum fuels for transport and distribution.[132]

Even with the support of Oregon's Clean Fuels Program, the cost of some renewable fuels is greater than fossil counterparts due to the limited feedstock and production facilities of these relatively new transportation fuels—but as Oregon's market matures, the costs for these fuels are dropping.[7] California's Low Carbon Fuel Standard also provides credits to reduce the carbon intensity of transportation fuels used in that state. Many alternative fuel producers distribute their supply to

California and Oregon taking advantage of lucrative credit market prices.[133] Development of new or the expansion of existing renewable fuel production plants in the Northwest are increasing the availability of fuel supplies.[132] Other influences, such as world economies, oil prices, carbon markets, and the political climate play a role in determining renewable fuel prices, supply and demand.

Renewable Gasoline

- **0** – Total renewable gasoline consumed in Oregon (2021) GGE[11]
- **0** – Total renewable gasoline produced in Oregon (2020) GGE[16]
- **TBD** – renewable gasoline carbon intensity (2021) in gCO2e/MJ
- **0** – Public and private fuel stations in Oregon

Renewable gasoline is any fuel that is made from biomass and is compatible with and can be used by existing gasoline-fueled engines. There are no commercially available renewable gasoline alternatives that can fully replace gasoline in Oregon. Isobutanol, a renewable fuel that is similar to ethanol, can be blended with gasoline to reduce the carbon intensity of the fuel. Isobutanol has a higher energy content than ethanol, meaning isobutanol gasoline blends will power a vehicle further than ethanol gasoline blends.[134] In 2021, the U.S. Environmental Protection Agency approved the use of isobutanol as a blended fuel up to 16 percent of fossil gasoline.[135]

Trends and Potential

Renewable gasoline is not yet commercially available in Oregon but there is research and development currently going into potential production facilities.[130] Existing regional biofuel producers have expressed interest in developing a supply of renewable gasoline for the Northwest, but 2024 is likely the earliest Oregon would see commercially available product. Biofuel company Gevo began producing a renewable, corn-based isobutanol and fossil gasoline blend for the Seattle, WA area.[136] In 2019, Gevo was awarded a contract to supply at least 20,000 gallons per year of renewable isobutanol and 600,000 gallons per year of renewable isooctane to the City of Seattle to be used by its fleet of vehicles.[137]

Beyond Energy

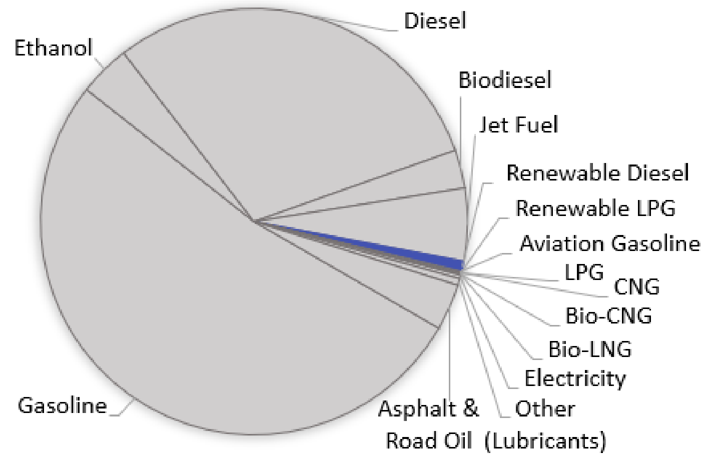
If a commercially viable renewable gasoline production method can be developed, there is potential for the product to be produced in Oregon or the Pacific Northwest from a variety of locally available biomass feedstocks. Regional production could offer increased energy security, job creation, and other economic benefits. Consumption of renewable gasoline, as an alternative to petroleum gasoline, would reduce greenhouse gas emissions because the carbon dioxide released from burning the renewable fuel is offset by the carbon dioxide captured by growing the feedstocks.[131] The EPA's lifecycle greenhouse gas analysis for the U.S. Renewable Fuel Standard program determined Isobutanol blends or renewable gasoline produce 65 to 130 percent fewer carbon emissions than gasoline, depending on the feedstock and production process.[138] Some of the feedstocks could be grown or collected in Oregon, supporting a transportation fuel economy in Oregon and increasing the state's energy independence.

Renewable Diesel

- **18,617,155** – Total renewable diesel consumed in Oregon (2020) GGE[11]
- **0** – Total renewable diesel produced in Oregon (2020) GGE[16]
- **36.98** – renewable diesel carbon intensity (2021) in gCO2e/MJ[9]
- **43** – Estimated public and private fuel stations in Oregon[139]

Renewable diesel fuel, sometimes called green diesel, is a low carbon intensity biofuel made from waste or renewable materials, including rendered tallow, fish waste, used cooking oil, inedible corn oil, soybean oil, canola oil, and other biomass resources.[140] It is chemically identical to petroleum diesel fuel and can be used in existing petroleum pipelines, storage tanks, and engines without modification or blending.[106] In 2020, the United States consumed over 960 million gallons, about a quarter of which was produced domestically and the rest is imported, mostly from Singapore-based refineries.[131]

Figure 21: Renewable Diesel Share of Oregon Transportation Consumption in 2020



While both renewable diesel and biodiesel are made from biomass feedstocks, they are produced using different manufacturing processes and create fuels with different characteristics. Renewable diesel production removes impurities and compounds that make the fuel cleaner and more stable than biodiesel.[103] These differences in production result in a colorless, odorless fuel that performs better at lower temperatures, reduces engine maintenance and costs, and improves overall vehicle performance.[140] Renewable diesel can fully replace fossil diesel in existing vehicles and fuel infrastructure, whereas biodiesel must be blended with petroleum diesel at no more than 20 percent to avoid engine performance and fuel degradation issues. It can also be stored for longer periods without the degradation in quality that can occur with other biofuels, making it a good option for backup fuel storage.[141] Renewable diesel is available as a standalone fuel called R100, or as a blend with petroleum diesel or biodiesel. A blend of 20 percent renewable diesel and 80 percent petroleum diesel is called R20, and a blend of 5 percent renewable diesel and 95 percent of petroleum diesel is called R5. A blend of 20 percent renewable diesel, 20 percent biodiesel, and 60 percent petroleum diesel is called RD20B20.[106]

Table 4: Renewable and Petroleum Diesel Blends

Blend	Name
Renewable Diesel	R100
Renewable Diesel 20% + Petroleum Diesel 80%	R20
Renewable Diesel 5% + Petroleum Diesel 95%	R5
Renewable Diesel 20% + Biodiesel 20% + Petroleum Diesel 60%	RD20B20

TriMet's Transition to R99 Renewable Diesel[172]

In December 2021, TriMet made the transition to renewable diesel (R99) for its fleet of 7,306 fixed-route buses after awarding a contract to Carson Oil Company, which partnered with Neste Renewable Diesel to secure a dedicated supply of R99 large enough to meet TriMet's operational requirements.

Five months later, TriMet announced a new contract for LIFT paratransit and WES commuter rail vehicles to switch to renewable diesel via a mobile fueling contract with Bretthauer Oil Company. Unlike the renewable diesel that is delivered for TriMet's fixed-route buses and stored in underground tanks at the garages, the fuel for TriMet's 265 LIFT vehicles and 6 WES trains comes directly from the delivery vehicles due to lack of on-site fuel storage at the LIFT and WES operations facilities. This fueling takes time for the truck driver to fuel each vehicle individually, and the fueling must be done overnight. This was a more challenging contract to procure due to the limited availability of additional, but not yet dedicated, renewable diesel in Oregon. Additionally, there is a persistent, severe national shortage of licensed HAZMAT-certified commercial truck drivers, making it impossible for most fuel distributors to be able to reliably meet TriMet's operational requirements on when fueling must be scheduled (365 nights per year, including weekends and all holidays) without exception.

The constrained supply of renewable diesel in Oregon limits the ability of other large users of diesel from taking this important step to reduce transportation emissions. Oregon state regulations lead to lower returns for renewable diesel manufacturers than California and Washington, so there is some risk of supply being diverted to those two states.

The move to renewable diesel in TriMet's fixed-route buses, and now LIFT vehicles and WES trains, combined with the shift to renewable electricity in June 2021 for MAX trains and all TriMet-owned facilities, reduces TriMet's greenhouse gas emissions by nearly 70 percent. TriMet estimates that with these climate actions, it will avoid more than 193 million pounds of greenhouse gas emissions each year. That is equivalent to taking almost 19,000 automobiles off the road, according to the Environmental Protection Agency.

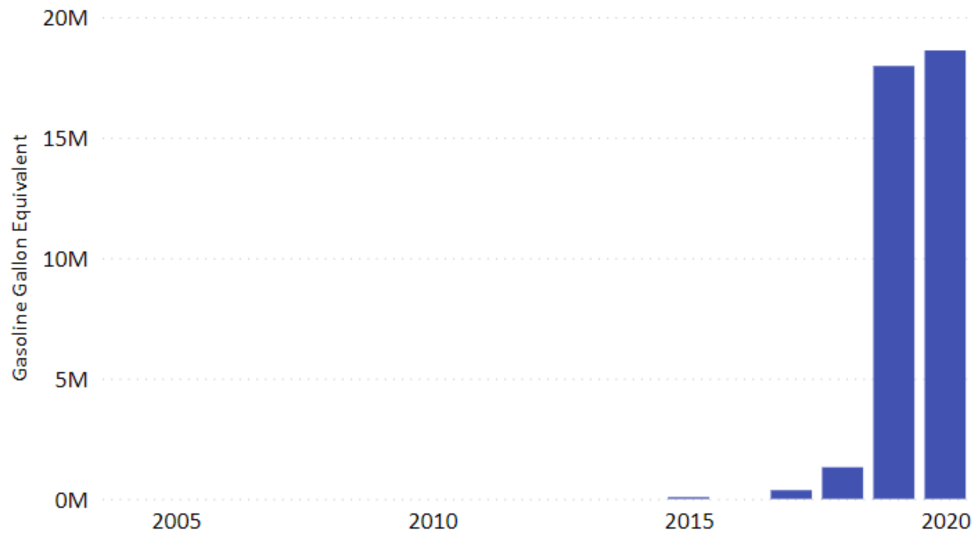
Transit service inherently reduces GHG emissions by providing an alternative to driving alone. Frequent transit service and high-capacity transit projects like light rail, streetcar, and bus rapid transit encourage transit-oriented development that supports more walking, biking, and shorter driving trips, all of which reduces emissions. Nationally, the benefit in emissions reductions due to transit is estimated to be six times what is emitted in providing the service.[v] However, this change is important to TriMet because the agency was the largest consumer of diesel in the Oregon prior to making the shift to renewable diesel. Making this change reduces carbon emissions and directly improves air quality in the communities that TriMet serves.

[v] https://nap.nationalacademies.org/catalog/26103/an-update-on-public-transportations-impacts-on-greenhouse-gas-emissions

Trends and Potential

Renewable diesel consumption is growing rapidly in Oregon as fleets that incorporate the fuel in their operations have positive performance results.[106] From 2018 to 2020, Oregon consumption increased from 1.2 million gallons to 17.6 million gallons or about 3 percent of all diesel fuel consumed in Oregon. The DEQ's Clean Fuels Program has driven this rapid growth, incentivizing delivery, and use of renewable diesel in the state. In CFP's 2022 program review to the Oregon Legislature, DEQ identified renewable diesel as the "primary drop-in fuel to generate credits and reduce deficits with the existing diesel vehicle fleet."

Figure 22: Oregon On-Highway Renewable Diesel Consumption by Year[11]



Oregon is an increasingly attractive market for renewable diesel distributors. Historically, California used nearly all the renewable diesel produced or imported into the U.S. because of the economic advantage provided by the California Air Resources Board's Low Carbon Fuel Standard. This program incentivizes the sale of lower-carbon fuels through a market-based credit and debit system, providing distributors with more revenue to offset the higher costs of selling lower carbon fuels in California. In 2016, Oregon became the second state to implement such a low carbon fuels standard – DEQ's Clean Fuels Program. Monetization of CFP credits helps offset the generally higher expense of providing lower carbon fuels such as renewable diesel, which is more expensive than petroleum diesel.[142,143]

Apart from ethanol and biodiesel, renewable diesel is the most widely adopted alternative transportation fuel in Oregon. CFP's forecast of 2022 fuel consumption in Oregon estimates consumption of renewable diesel will increase by 64.3 percent over 2020.[144] Renewable diesel demand in Oregon can exceed supply, and therefore many fleets must also have access to B5 and B20 diesel blends to supplement their fuel needs.[145] Access to renewable diesel outside of the Willamette Valley is limited due to additional delivery cost, demand volumes, and the number of storage tanks allocated to hold renewable diesel. Fleet demand for the fuel means renewable diesel is rarely available at retail stations, limiting access to the fuel, especially for smaller businesses that rely on commercial retail outlets for their fuel purchases, but availability is beginning to expand to other parts of the state.

Supply is largely constrained by limited production capacity in the U.S. and competition for global renewable diesel production. Five plants currently produce renewable diesel in the United States, with a combined capacity of over 590 million gallons per year, or just over 2 percent of all diesel consumed in the U.S. in 2020.[146,147] Production across the country is expected to grow with 2 billion gallons of capacity from six plants currently under construction and the expansion of three existing plants. The

BP Cherry Point plant near Bellingham, WA is the only renewable diesel refining facility operating in the Pacific Northwest. In October 2021, BP announced plans to invest $45 million in this refinery to double renewable diesel production capacity to an estimated 2.6 million barrels a year.[148] A renewable diesel production facility capable of processing up to 50,000 barrels per day is going through DEQ's air and water quality permit process in Port Westward, OR. It is likely that other domestic manufacturing facilities will be developed as demand grows.[149]

Increased use and storage of renewable diesel may improve Oregon's fuel resilience in response to an earthquake or other major disaster. Renewable diesel is chemically equivalent to fossil diesel and can fully replace fossil diesel in existing vehicles (patrol and fire trucks, heavy equipment, etc.), can be used in existing fuel infrastructure (storage tanks, pipelines, etc.), and can be mixed with fuels offering emergency responders valuable flexibility during an event. With a longer shelf-life than biodiesel, renewable diesel can support emergency preparation, response, and recovery activities. This will be important to keep in mind as state and local jurisdictions develop fuel storage capacity to improve Oregon's seismic disaster resilience as directed by SB 1567. The Oregon Department of Energy will be developing an Energy Security Plan for Oregon that will consider renewable diesel. The plan will be published in 2024.

Increased use and storage of renewable diesel may improve Oregon's fuel resilience in response to an earthquake or other major disaster.

Beyond Energy

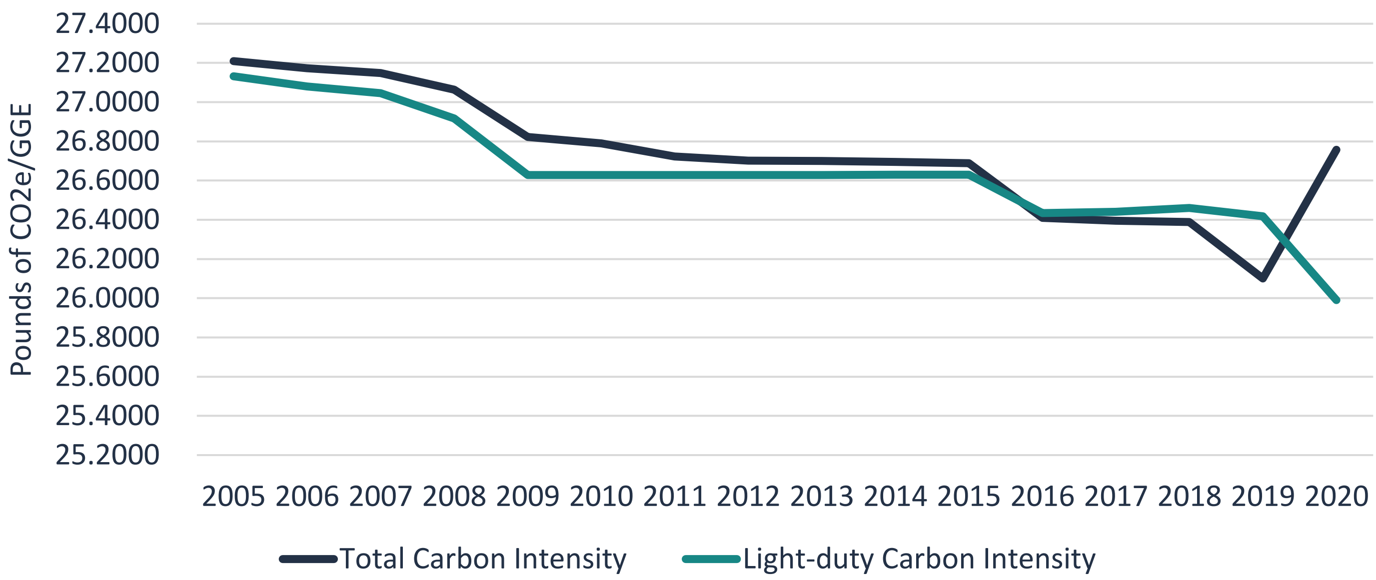
Renewable diesel can be created from a variety of feedstocks, so the resulting lifecycle of greenhouse gas emissions can vary widely. Emissions are calculated based on energy inputs to transport and process the feedstocks, transport the refined fuel, and final combustion. Greenhouse gas emissions are lower when renewable diesel feedstocks and processing is closer to the end-use and when the energy used to transport and process the feedstocks is cleaner, such as solar- or wind-generated electricity. Lifecycle greenhouse gas emissions of renewable diesel are up to 85 percent less than fossil diesel. Waste products such as tallow and used cooking oil offer the greatest reductions in emissions while vegetable oils are slightly less. Moreover, feedstocks such as animal fats and used cooking oil offer the benefit of producing renewable diesel from waste products that might otherwise end up in landfills or other waste streams.

The feedstocks used to produce renewable diesel can also have implications for land use and food production. Most renewable diesel produced today is created from animal fats or food waste as demand for the fuel has increased agricultural feedstocks like soy are being used. This could put transportation fuel crops in direct competition for land with food production.[150] In 2022, soy oil prices reached record highs, attributed to growth in renewable diesel and a constrained vegetable oil market resulting from the war in Ukraine (Russia and Ukraine are both leading grain suppliers).[151] Palm oil, another renewable diesel feedstock, may be grown in ways that contribute to unsustainable deforestation practices.[152] Deforestation practices can have greater negative environmental impacts than the benefits of producing renewable diesel from these sources. Palm oil plantations that do not meet EPA criteria for *existing* agricultural land do not qualify as renewable biomass for the federal

Renewable Fuel Standard because they cannot achieve a minimum 20 percent reduction in lifecycle emissions.[153]

Figure 23 shows that greenhouse gas emissions per gallon dropped more than 10 percent in Oregon from 2016 to 2019, largely driven by biodiesel and renewable diesel adoption in medium- and heavy-duty vehicles. The teal line shows relatively flat per gallon emissions in the passenger vehicle sector during that same period. In 2020, the trends reversed as transportation consumption changed due to the pandemic. Passenger vehicle use declined and medium and heavy-duty vehicle use increased.

Figure 23: On-Road Fuel Carbon Intensity (Pounds of CO2e/GGE) [154]



Combustion of renewable diesel produces less air pollution than fossil diesel because its chemical composition makes it burn more completely, reducing the particulate matter, nitrogen oxides, and carbon monoxide expelled from tailpipes. A blend of R50 – a 50 percent renewable diesel and 50 percent fossil diesel blend – reduces particulate matter from combustion by 15 percent. Using R100, or 100 percent renewable diesel, reduces particulate matter in emissions by 34 percent. This is significant because diesel fuel exhaust has been linked to various negative health outcomes including mortality, exacerbation of asthma, chronic bronchitis, respiratory tract infections, heart disease, and stroke.[155] Many vulnerable communities are located near high traffic areas and commercial and industrial facilities, causing greater exposure to diesel exhaust air pollutants.[42] A 2011 study of Portland air toxics discovered that, "In Multnomah County, census tracts with higher than average Black/African American, Asian/ Pacific Islander, and/or Latino residents have two to three times more exposure to diesel particulate matter than census tracts with 90 percent or more non-Latino white populations."[156]

Table 5: Pollutant and Reductions from Renewable Diesel Blends[157]

Pollutant	Pollution Reduction from R50 Blend	Pollution Reduction from R100
Particulate Matter (PM)	15%	34%
Nitrous Oxides (NOx)	5%	10%
Carbon Monoxide (CO)	8%	12%

Greenhouse Gas Emissions Study

In 2022, Oregon's Clean Fuels Program commissioned a study by University of California Davis' Policy Institute for Energy, Environment, and the Economy to evaluate potential fuel carbon intensity reduction targets that would need to be achieved by 2035. One modeled scenario expanded:

- The supply of renewable diesel to meet 25 percent of diesel market demand
- Passenger car electrification
- Adoption of other renewable fuels

This scenario demonstrated a robust 37 percent reduction in carbon intensity of transportation fuels in Oregon. The modeled air pollution reduction would decrease atmospheric carbon dioxide, ammonia, and sulfur dioxide from tailpipe emissions by 30 percent. The decrease in fossil diesel air pollution alone would have an economic value of over $19.5 million from avoided health impacts. Overall, the study determined Oregon's Clean Fuels Program targets will reduce pollutant emissions in Oregon and "reduce the incidence of air quality-related health impacts, thereby reducing anticipated premature mortality by around 12 deaths per year in 2035."[158]

Although the upfront cost of renewable diesel is more than petroleum diesel, vehicle maintenance cost savings and improved performance may offset or even overcome this higher cost.[10] The Eugene Water & Electric Board used renewable diesel in a portion of its fleet and determined it had less wear and tear on engines and particulate filter systems compared with fossil diesel, decreasing truck maintenance issues and costs.[159] In 2021, TriMet – Oregon's largest consumer of diesel – transitioned its entire bus fleet to renewable diesel. Although fuel costs increased by about $0.09 a gallon, TriMet anticipated renewable diesel would reduce bus maintenance labor and material costs by as much as $100,000 per year.[160] The 2020 Biennial Energy Report featured Titan Trucking, which converted its fleet and turned to 100 percent renewable diesel: https://energyinfo.oregon.gov/blog/2021/3/8/titan-freight-systems-goes-renewable-and-saves. Renewable diesel can also be blended with diesel at any ratio, allowing fleet owners the option to add renewable diesel in amounts that fit their budgets.

Development of new fuel production facilities within Oregon, even those focused on delivering renewable diesel, face significant barriers as they must address air and water quality, zoning, noise, traffic, and other concerns of the surrounding community. Renewable fuels produced at facilities may be used by fleets locally or shipped to other locations, so even if a facility produces a cleaner fuel, the local community may not realize the immediate air quality benefits.

ODOT and Renewable Diesel

In 2021, the Oregon Department of Transportation consumed 840,679 gallons of renewable diesel or 37 percent of the agency's total diesel use. ODOT started using renewable diesel in its fleet in 2016 and today it powers 10-yard semi-trucks, graders, loaders, tractors, sweepers, snow blowers, light trucks, and a variety of critical response vehicles. Consumption of renewable diesel has steadily increased and ODOT has discovered a variety of benefits without performance issues. The diesel engines require less forced regeneration, which occurs when emission particulates build up inside diesel engine filters to the point the vehicle is no longer operable. This leads to less maintenance needed from ODOT's technicians.

Renewable diesel can be stored for long periods like fossil diesel and does not separate over time or have the microbial growth that has been a challenge of some biofuels. Bulk storage tanks are cleaner, requiring less maintenance and cleaning of tanks, which is especially beneficial in remote locations that are used seasonally. ODOT uses renewable diesel even more in winter months as it performs better at colder temperatures with no gelling issues. Lower emissions and fuel odors have improved the air quality of service areas. The cost of renewable diesel to ODOT has been comparable to a winterized blend of B5, or an estimated $0.03 - 0.07 per gallon more, than standard non-winterized B5.

Greater adoption of renewable diesel has presented ODOT with logistic and supply challenges as not all locations are able to get renewable diesel. During some winter weather events, the demand of renewable diesel exceeds the amount allocated by the supply chain. ODOT staff have also needed to allocate time to training staff and vendors about renewable diesel. For example, technicians unfamiliar with the odorless and colorless fuel may mistake it for water in the fuel tank and misdiagnose engine problems. Overall, ODOT has discovered the benefits outweigh the challenges of incorporating a new fuel. The agency plans to use more renewable diesel as regional supply increases and work to get all of their locations access to it.[161]

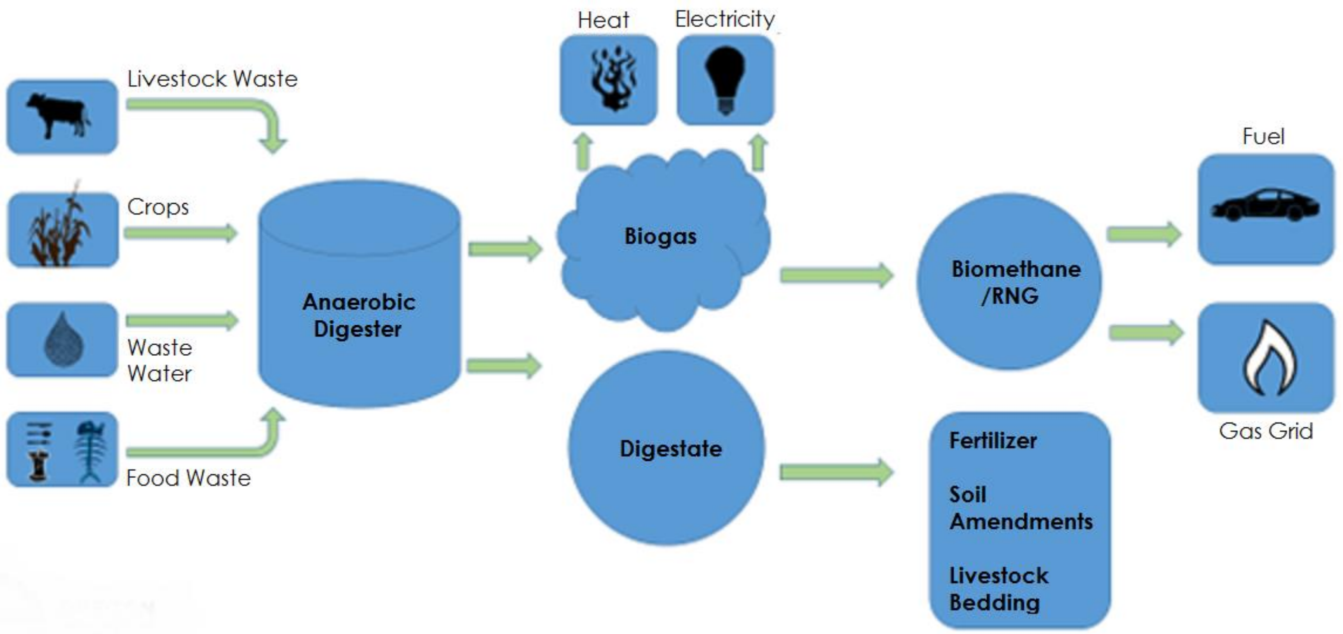
Renewable Natural Gas

- **3,205,366** – Total renewable natural gas consumed in Oregon (2020) GGE[11]
- **TBD*** – Total estimated renewable natural gas produced in Oregon (2020) GGE[16]
- **56.58** – renewable natural gas carbon intensity (2021) in gCO2e/MJ[9]
- **5** – Public and private fuel stations in Oregon[52]

**Comprehensive Oregon production data isn't available.*

Renewable natural gas, or biomethane, is a fuel derived from biogas, a methane byproduct of municipal waste streams such as garbage, wastewater, and waste food or agricultural waste streams like manure. Once collected, biogas can be processed to remove or reduce water, carbon dioxide, hydrogen sulfide, and other trace elements. This process, called conditioning or upgrading, results in a product that is referred to as renewable natural gas.[vi] RNG has a higher content of methane than raw biogas, making it comparable to conventional natural gas and suitable for vehicle applications. Like conventional natural gas, RNG can be used as a transportation fuel in the form of compressed natural gas (CNG) or liquefied natural gas (LNG) to power cars, trucks, or ships.[162]

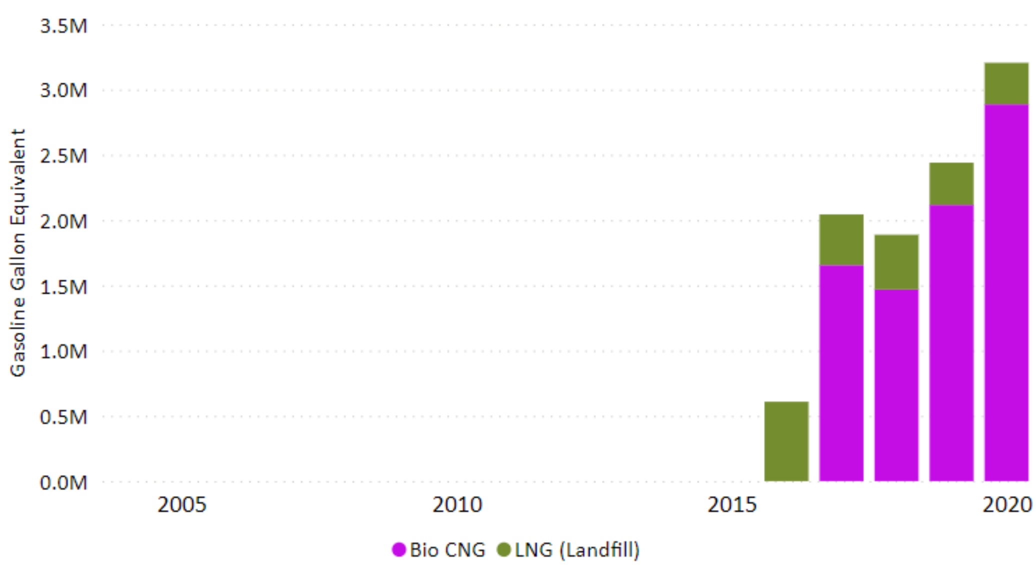
Figure 24: Potential RNG Pathways



Trends and Potential

Renewable natural gas consumption as a transportation fuel has grown in the last few years, with interest in RNG reducing greenhouse gas emissions and replacing natural gas. In 2017, Oregonians consumed 490 thousand GGE of renewable natural gas for transportation and in 2020, Oregon's consumption reached 3.2 million GGE, a 55 percent increase over that

Figure 25: Oregon On-Highway RNG Consumption by Year[11]



[vi] The differentiation between biogas and renewable natural gas is not clearly defined and is largely determined by the end-user needs and criteria.

span. Oregon is also a producer of renewable natural gas, with three projects operating in the state, one built but not yet operational, and five in development. The three operational facilities are converting the biogas they produce into RNG and injecting it into a natural gas pipeline.[163] Once in the pipeline, the RNG can be used as a transportation fuel, but may also be sold for other uses such as residential and commercial heating or industrial processing.

RNG availability is anticipated to increase as Oregon gas utilities invest in and contract for RNG production to reduce greenhouse gas emissions. RNG is a central pillar to these utilities meeting the requirements of the Oregon Department of Environmental Quality's Climate Protection Program, which establishes a declining cap on GHG emissions from petroleum fuels, including natural gas.[21] ODOE's 2018 Biogas and Renewable Natural Gas Inventory indicates about 4.5 percent of Oregon's natural gas needs could be met with renewable natural gas derived from commercially available technologies (anaerobic digestion) and an additional 17.5 percent from forest and agricultural residuals when advancements in gasification techniques become commercially viable.[167] The 17.5 percent from technological advancements could meet about 29 percent of all direct and transportation gas use (not including power generation) in the state.[54] As part of the *Vision 2050: Destination Zero Carbon Neutrality Scenario Analysis* report, NW Natural plans to invest $30 million annually to replace 5 percent of its fossil gas with renewable natural gas by 2024.[164] Avista and Cascade Natural Gas, Oregon's other two natural gas utilities, also plan to incorporate more RNG into their systems.[165] [166]

ODOE's 2018 Biogas and Renewable Natural Gas Inventory indicates about 4.5 percent of Oregon's natural gas needs could be met with renewable natural gas derived from commercially available technologies.

It is uncertain how much RNG will be available as a transportation fuel in Oregon. RNG can be used for fleets at fuel production sites, such as fueling garbage trucks with RNG derived from landfill biogas. ODOE's RNG inventory indicates significant financial incentives are available for the sale of RNG as a transportation fuel, largely provided through the monetization of credits received through state and federal clean and renewable fuels programs. However, lack of public accessibility to RNG limits the effectiveness of these incentives. ODOE's RNG inventory identified three major challenges for RNG to become widely available as a transportation fuel: the high cost of technologies necessary to clean and inject RNG into pipelines, the high cost to connect RNG resources to common carrier pipelines, and limited existing fueling depots. Few RNG production sites are located next to natural gas pipelines and building pipelines is expensive.[167] Biogas-to-electricity sites have been created in Oregon in locations where natural gas cannot be delivered directly into a truck fleet or pipeline. Biogas is collected and burned to generate electricity. The electricity produced can generate renewable energy credits and carry negative carbon intensities if the renewable electricity is used to charge electric vehicles. Biogas and renewable natural gas can also be stored and used as a renewable feedstock to create hydrogen, renewable diesel, or other fuels.

Beyond Energy

Renewable natural gas redirects existing methane waste streams into controlled processes for optimization, capture, and utilization of the biogas, offering economic, social, and environmental benefits.[168] Capturing and using RNG in Oregon's transportation fuels sector can provide local economic development opportunities. RNG production facilities could be located throughout the state at wastewater treatment facilities, landfills, large farms, and dairies. Local development of transportation fuels improves Oregon's energy security and helps retain more transportation-related dollars in the state, and as we decarbonize the economy, limited RNG may have a better use as a transportation fuel. Local production of RNG can also support transportation energy resilience by providing a local resource for transportation fuel in the event of fuel distribution disruptions. RNG combustion emits fewer air pollutants than petroleum-based fuels, improving local air quality in Oregon communities.[169]

Biogas facilities capture methane – a powerful greenhouse gas – from sources like landfills and animal waste, preventing them from being directly emitted into the atmosphere. Conversion to RNG and then combustion as a transportation fuel emits carbon dioxide, but lifecycle emissions for RNG (20.55 gCO2e/MJ) are considerably less than gasoline (100.14 gCO2e/MJ) and diesel (100.74 gCO2e/MJ). RNG created from the methane of confined animal feeding operations such as a dairy has a negative carbon intensity because capturing emissions at a facility far surpass the carbon emissions from producing the fuel. ODOE's Biogas and Renewable Natural Gas Inventory determined, "If the volume of RNG that could be potentially captured and utilized in Oregon displaced fossil fuel natural gas for stationary combustion, approximately 2 million metric tons of fossil fuel-based carbon dioxide would be prevented from entering the atmosphere."[167] Oregon's Department of Environmental Quality estimates that 64.5 million metric tons of carbon dioxide equivalent were emitted by Oregon in 2019.[19]

Renewable Propane

- **530,416** – Total Renewable Propane consumed in Oregon (2020) GGE[11]
- **0** – Total renewable propane produced in Oregon (2020) GGE[16]
- **41.95** – Renewable propane carbon intensity (2021) in gCO2e/MJ[9]
- **42** – Public and private fuel stations in Oregon[78]

Renewable propane is a lower carbon form of propane made from a mix of waste residues and sustainably sourced materials, including agricultural waste products, cooking oil, and animal fats. Renewable propane production is relatively new, with the first commercial production in the United States beginning in 2018. It is most often created as renewable diesel or sustainable aviation fuel is produced along with renewable naphtha and other co-products. Other methods for producing renewable propane are being studied and tested.[170] Imported into Oregon from production facilities in Los Angeles, California, it is currently available only in limited quantities and is typically mixed into existing propane supplies for distribution to propane vehicle fleets.

Trends and Potential

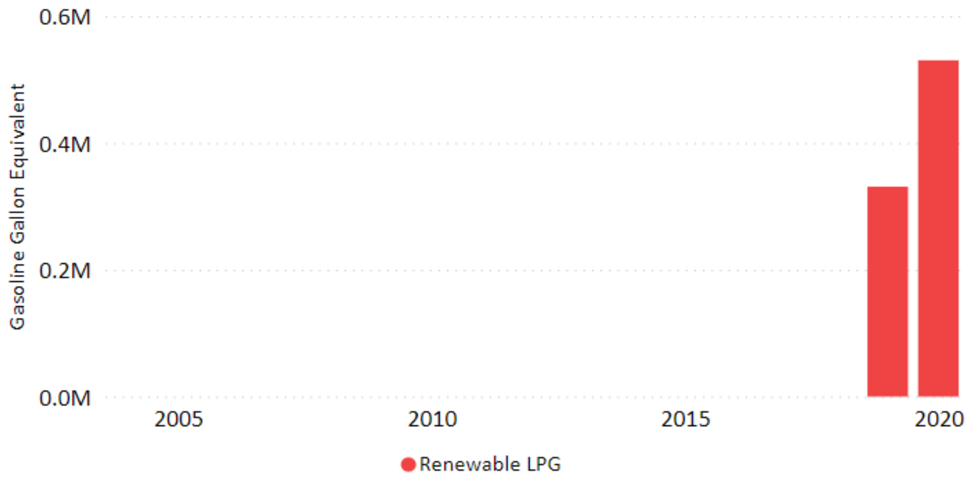


Figure 26: Oregon On-Highway Renewable Propane Consumption by Year[11]

As a byproduct of renewable diesel production, renewable propane supply will increase concurrently with renewable diesel production. Currently, only a fraction of the renewable propane is being delivered to the market because most of it is used on-site to fuel production plant operations.[38] Commercial availability is increasing, however, as low carbon fuel standards have created incentives for the fuel. U-Haul, the largest U.S. retailer of propane, procured one million gallons of renewable propane in 2020 and again in 2021 for retail sales at many of its California locations. U-Haul has indicated an interest in expanding this fuel to other states.[171] In 2020, Oregonians consumed 8 trillion Btu of propane for general use, .06 trillion Btu of this was renewable propane, about .77 percent. All renewable propane is imported into Oregon, but in-state production would occur if renewable diesel or sustainable aviation fuel production facilities are built.

Beyond Energy

Because of its relationship to renewable diesel production, renewable propane has many of the same economic and environmental benefits, in addition to the efficiencies of a single process to create both fuels. Production of renewable propane offers an opportunity to divert waste from landfills to be made into lower-carbon transportation fuels.[170] Renewable propane's average carbon intensity is 45 percent that of B20 diesel and fossil propane.[80] Oregon school districts or fleets who have already transitioned to use fossil propane in their school buses could transition to using renewable propane and reduce the carbon intensity of their fuels by another 45 percent.

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Energy Resource & Technology Review: Clean & Efficient Vehicles

Clean vehicles operate with fewer emissions than standard gasoline or diesel-powered vehicles, and ***efficient*** vehicles operate using less energy per mile. Zero-emission vehicles, such as battery electric, plug-in hybrid, and hydrogen fuel cell electric are the cleanest and most efficient vehicles available on the market today. Other vehicles with emissions lower than petroleum-fueled vehicles are also available, such as natural gas- and propane-fueled cars and trucks. In addition, standard internal combustion engine vehicles have largely become more efficient over time thanks to technological innovations spurred by regulations, such as the Clean Air Act.

Zero-emission vehicles, often called ZEVs, have no tailpipe emissions and are more than three times as efficient as internal combustion engine vehicles — meaning they can travel three times as far on the same amount of energy. As Oregon electric utilities decarbonize their systems to 100 percent clean by 2040, emissions associated with the electricity to fuel these vehicles will continue to go down.

Want to know more about zero-emission vehicle technologies, trends, and policies?

The *2020 Biennial Energy Report* included more background information on ZEVs and the *2021 Biennial Zero Emission Vehicle Report* includes deeper dives on ZEV trends and policies:

tinyurl.com/ODOE-Studies

Battery and Plug-In Hybrid Electric Vehicles

Timeline

- **1889** — William Morrison creates the first successful electric vehicle in the U.S. (Des Moines, Iowa).[1]
- **1935** — Electric vehicles have all but disappeared from use due to the discovery of cheap crude oil.[1]
- **1973** — The oil crisis spurs the next generation of electric vehicles (small, slow, and with limited range).[1]
- **1996** — GM introduces the EV-1, a two-seat aero-dynamic sports car with limited range. The car was discontinued in 2002.[2]
- **2008** — Tesla begins production of its first EV, the Roadster sports car, with a 245-mile range.[3]
- **2010** — Nissan releases the first modern battery electric vehicle by a major manufacturer.[1]
- **2022** — 50,000+ electric vehicle registrations in Oregon.

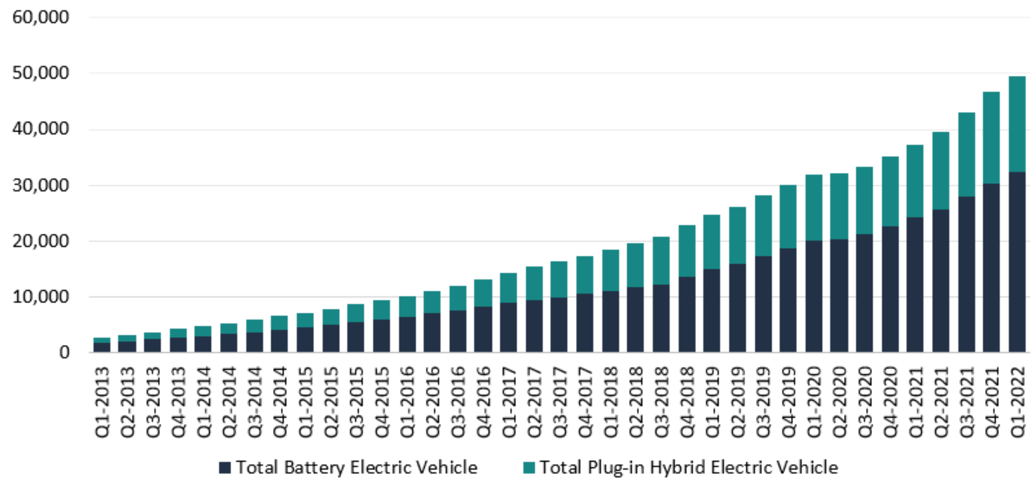
Electric Vehicles in Oregon

As of May 2022, there are **52,033 registered zero emission vehicles in Oregon**, including 33,861 battery electric EVs and 18,172 plug-in hybrids.

Battery electric and plug-in hybrid electric vehicles use batteries, either fully or in part, to supply electric fuel to the vehicle. The batteries power electric motors, which provide the force that propels the car. The vehicles are plugged into an outlet or EV charger to re-charge the battery. For more information on the technology, see the Electric Vehicles Technology Review from the *2020 Biennial Energy Report*.

Trends and Potential

Figure 1: Cumulative Registered Electric Vehicles in Oregon (2013-Q1 2022)[4]



Adoption of light-duty electric vehicles has been gaining traction in Oregon — and despite challenges of associated supply shortages due to the COVID-19 pandemic, electric vehicle adoption has continued to grow, achieving nearly 1.5 percent of total registrations as of May 2022.[4] While sales of all vehicles slowed overall during the pandemic, ZEV sales remained strong, taking over an increasingly larger market share of new vehicle purchases. At the end of 2021, ZEVs made up over 10 percent of all new vehicle sales in Oregon.[5] Much of the increase in ZEV adoption can be attributed to increased model availability, technological advancements that have increased vehicle range, and reductions in purchase cost.

In 2021, many vehicle manufacturers announced goals to produce more ZEV models, and in some cases pledged to go exclusively electric at a future date.[6] Oregon registered 14 new models of ZEV passenger vehicles in 2021 alone, including seven SUVs and the state's first registered electric pickup truck (see Table 1).[4] Technological challenges, such as microchip and other supply shortages, and control failures with battery management systems have caused delays in some models. Although demand for new electric pickup trucks was very high, delivery numbers for the two most prominent electric pickup manufacturers fell short of expectations.[7] There are also challenges for existing vehicle manufacturers to adjust their long-time business models to efficiently build and sell electric vehicles.[8] To address these issues, many auto manufacturers are committing to add their own battery manufacturing facilities, relying less on contracted subcomponents than they have for gasoline vehicles.[9] This trend will likely continue as federal funding slated for vehicle electrification requires American manufacturing and supply.[10]

EVs represent nearly 1.5 percent of total registrations in Oregon as of May 2022.

Learn more about electric vehicle models, costs, and incentives: **https://goelectric.oregon.gov**

Inflation Reduction Act Support for Zero Emission Vehicles

Tax Credits

The federal Inflation Reduction Act signed into law in August 2022 made changes to federal tax credits for electric vehicles.[11] The new law establishes a $7,500 tax credit[12] for new EVs and removes previous vehicle sales limits that had prevented Tesla and General Motors buyers from using the credit in the last few years. Tax credits are available to individuals with $150,000 taxable income or less, $225,000 for head of households, or joint households with $300,000. To be eligible, vans, pickups, or SUVs may not exceed $80,000 and all other vehicles may not exceed $55,000.[13] The law also allows for the tax credit to be made available at the point of sale beginning in 2024.[14]

One element of the new vehicle tax credit that has gained attention are requirements for sourcing supplies of minerals, locations of component processing, and workforce. To be eligible, final assembly of the vehicle must occur in North America.[12] For model year 2022, there are 26 models of EVs assembled in the U.S., including all Tesla models, Chevy Bolts, and Nissan LEAFs – the most popular models in Oregon.[15] The US DOE hosts a webpage listing qualifying models, and has a VIN tool for users to verify a vehicle meets the final assembly requirement.[i]

There are also requirements on the source of critical minerals used in the manufacturing of the EV battery. Through 2023, the battery must contain at least 40 percent of its critical minerals from domestic mines or from a country the U.S. has a free trade agreement with.[16] Resource sourcing requirements increase each year to a minimum of 80 percent by 2027. The bill also requires some domestic manufacturing of battery components. Through 2023, at least 50 percent of the *value* of battery components must be manufactured in North America. This percentage also increases by 10 percent each year until 2029, when all EV battery components must be manufactured in North America.[17] Failure to meet mineral resourcing or component manufacturing requirements will reduce the amount of the tax credit by $3,750 each.

The bill also created a tax credit of $4,000 or 30 percent of the vehicle price (whichever is lower) for used EVs. Income thresholds are $75,000 for a single filer, $112,500 for head of household, and $150,000 for joint filers. To be eligible, EVs cannot cost more than $25,000, and the used vehicle tax credit cannot be used more than once per vehicle, which must be sold by a dealership.[18] Used vehicles are not subject to the same battery and component manufacturing requirements as new vehicles.

The bill establishes a 30 percent tax credit for electric and other non-gasoline or diesel trucks. The credit for vehicles 14,000 pounds or more is capped at $40,000 or the incremental cost above the cost of a similar gas or diesel truck, whichever is lower. Vehicles under 14,000 pounds are capped at $7,500. Credits can be used by businesses through tax year 2032.[19] Tax exempt entities, such as state and local governments and many non-profit organizations are not

[i] https://afdc.energy.gov/laws/inflation-reduction-act

eligible. The bill also reestablished a 30 percent tax credit for businesses that invest in alternative fueling installations, including electric chargers.[20,21]

Other Incentives

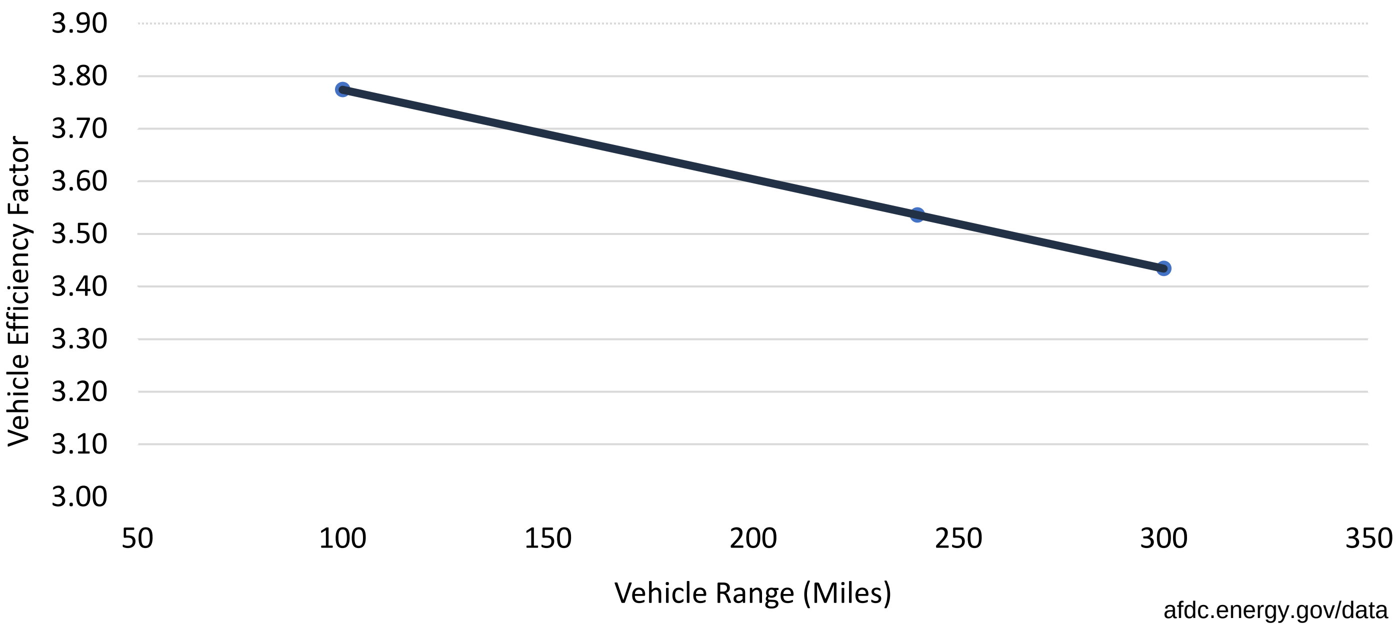
The IRA provides direct funding to support the conversion of clean heavy-duty vehicles. The new law provides $1 billion to the Environmental Protection Agency to award grants and rebates to cover the costs of converting existing gas and diesel vehicles to zero-emission vehicles. The funds can cover up to 100 percent of the incremental costs above and beyond the cost of a comparable diesel vehicle toward the purchase of a ZEV. 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 zero-emission vehicles, and planning activities to support vehicle deployment.[22] Funds will be awarded to states, municipalities, Tribes, or non-profit school transportation associations or specified contractors. $400 million of these funds are set aside to replace heavy-duty vehicles in areas that do not meet certain federal air quality standards known as nonattainment areas.

Table 1: New ZEV Models Registered in Oregon in 2021

Make	Model	EV or PHEV	Type
Audi	A7	PHEV	Car
Audi	e-tron GT	EV	Car
Bentley	Bentayga	PHEV	SUV
Chevrolet	Bolt EUV	EV	Car
Ferrari	SF90 Stradale	PHEV	Car
Ford	Escape Plug-in Hybrid	PHEV	SUV
Hyundai	Santa Fe Plug-in Hybrid	PHEV	SUV
Hyundai	Tucson Plug-in Hybrid	PHEV	SUV
Jeep	Wrangler Unlimited	PHEV	SUV
Lincoln	Corsair	PHEV	SUV
Polestar	2	EV	Car
Rivian	R1T	EV	Truck
Volkswagen	ID.4	EV	Car
Volvo	XC40	EV	SUV

Figure 2 shows the variability of ranges in typical light-duty EVs, from 100 miles to 300 miles, and highlights the overall average of 240 miles.[ii] In 2020, the weighted average range for a new battery electric vehicle was about 218 miles, up from 124 miles in 2015.[23] Increasing the battery capacity in an electric vehicle will extend the range of the vehicle but increases the weight, reducing its energy efficiency. This tradeoff is expected as larger electric SUVs and pickups enter the market.

Figure 2: Relationship Between Average Range and Efficiency of U.S. Electric Vehicles[24]



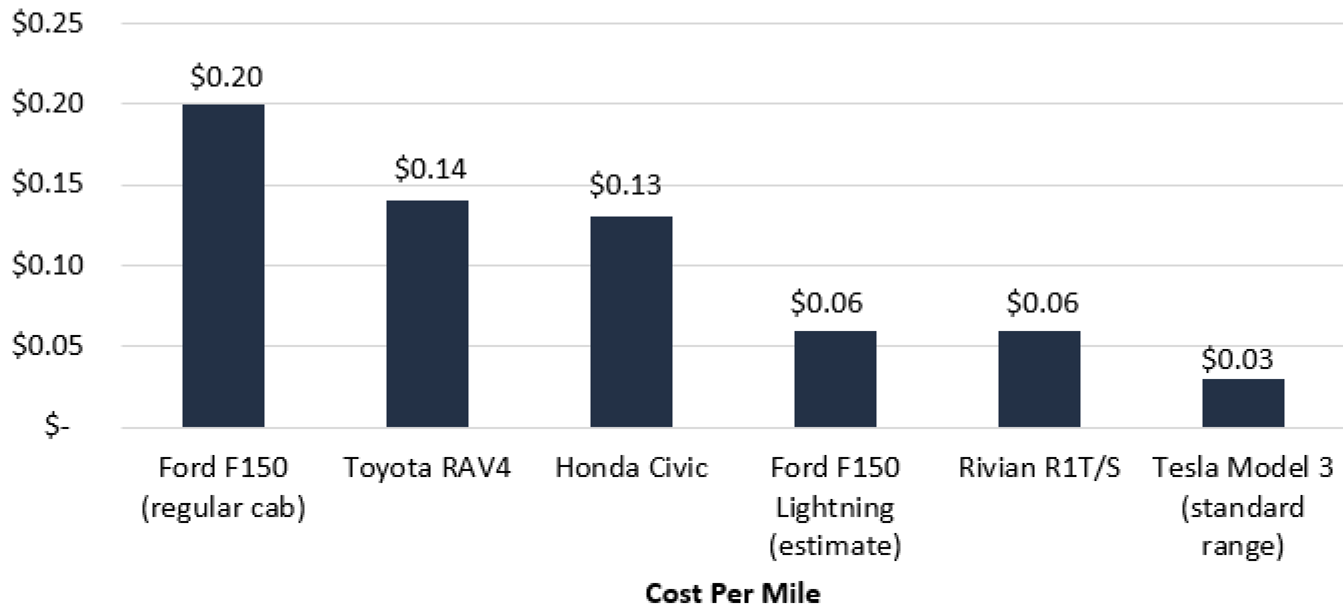
New battery chemistries are being studied today that may improve overall efficiency in future models. Solid-state batteries – so called because the material in the batteries is solid rather than the liquid used in today's EV lithium-ion batteries – are actively being developed and tested in a wide range of businesses and research settings, offering more charge per weight and per square inch of battery space.

Most studies and industry experts predict that passenger EVs will reach cost parity with internal combustion engine vehicles in the next few years. However, high global demand for EVs coupled with lagging raw material production capacity may create higher costs in the short term. The cost to produce EV batteries dropped from $1,200 per kWh in 2010 to about $130 per kWh in 2021.[25] Constraints on the availability of raw materials may push the cost to produce batteries up in 2022, and the exact timing of cost parity will depend on how quickly new mineral resources can be developed and brought to market. Oregon's EV rebates coupled with federal and other incentives reduce the initial up-front costs of an EV, in some cases to less than a comparable gasoline vehicle.[6]

While the upfront cost (without incentives) of an EV is currently higher than a comparable gasoline vehicle, much of this cost can be offset by the significantly lower cost to fuel and maintain an EV. On average, Oregonians will pay approximately 78 percent less for fuel when they can charge their vehicles at home.[6]

[ii] Average range is higher in the U.S. (240) than the global EV range (218).

Figure 3: Comparing the Total Operating Cost of Electric Vehicles vs. Gas-Powered Vehicles per Mile[26]



Maintenance costs are also lower for EVs, at approximately 60 percent of the cost to maintain a comparable gasoline-powered vehicle.[27]

The growth in publicly available charging stations is expected to spur EV adoption. Oregon will benefit from $52 million in federal investments (with a $13 million match) for public fast charging stations along Oregon's major corridors, as well as other incentive programs for EV charging offered by utilities and state agencies.

Medium- and heavy-duty zero emission vehicles are also becoming more widely available, and the adoption of California's Advanced Clean Truck Rule by the Oregon Department of Environmental Quality in 2021 will ensure that an increasing percentage of electric medium- and heavy-duty vehicles will be available for sale in Oregon. EV adoption has increased in the medium- and heavy-duty sector. More than four Oregon transit authorities and six school districts in Oregon have already deployed or are in the process of procuring electric buses.[28] Lane Transit District purchased 30 battery electric transit buses, representing nearly a third of its fleet,[29] [30] and Tri-Met is piloting several different formats of electric buses, including longer range buses, such as 60-foot articulated and double decker variants that not only reduce emissions but also carry more passengers per trip.[31, 32]

Procuring electric medium- and heavy-duty vehicles is more expensive than traditional diesel vehicles and requires additional expenditures to install the necessary charging infrastructure. Many utilities support electric medium- and heavy-duty adoption by providing technical assistance on cost effective charging installation and/or make-ready programs for fleets that cover some or all utility upgrades needed to accommodate charging infrastructure. In addition, through competitive grant programs, some Oregon utilities offer incentives for light-, medium- and heavy-duty vehicles as well as for charging infrastructure. For example, Oregon's two largest utilities, Portland General Electric and Pacific Power, offer EV charging station technical assistance to businesses that are electrifying fleets, offering workplace charging, or adding charging to multifamily properties.[33] [34] PGE also has a grant program to help pay the incremental cost of replacing a diesel school bus with an electric school bus.[35] The U.S. Department of Energy's National Renewable Energy Laboratory predicts that medium- and heavy-duty vehicles will achieve cost parity over the lifetime of the vehicle by 2035.[36]

Beyond Energy

Driving an electric vehicle offers many environmental and health benefits. In Oregon, the transportation sector accounts for nearly 40 percent of all greenhouse gas emissions. Driving an electric vehicle anywhere in Oregon reduces greenhouse gas emissions by 50 to 100 percent compared to driving a fossil fuel vehicle. Electric vehicles have no tailpipe emissions, and the associated emissions from the electricity generated will continue to decrease as utilities decarbonize their generation mix. Further, because much of Oregon's electricity is generated in state, more transportation dollars will remain in Oregon's economy. Driving an EV also improves local air quality, especially near busy roadways and places where vehicles may spend time idling. These communities are often low-income communities and communities of color that have been disproportionately affected by transportation pollutants and the effects of climate change. [37]

Because much of Oregon's electricity is generated in state, driving an EV means more transportation dollars will remain in Oregon's economy.

The raw materials to produce electric vehicle batteries are largely mined outside the U.S. For example, the U.S. produces only about 1 percent of lithium and 0.3 percent of cobalt, both critical minerals for EV battery production.[38–40] China supplies 85 percent of these and other rare earth minerals, and the mining practices have significant environmental impacts as well as human rights concerns.[41] Lower labor costs and fewer environmental regulations in China make it challenging for a critical mineral industry in the U.S. to compete. In June 2021 the Biden Administration released the National Blueprint for Lithium Batteries, which provides guidance on developing domestic battery supply chain components, domestic processing and manufacturing of battery components, and increased research on recycling and repurposing of these components. The blueprint is intended to reduce dependence on foreign mining and manufacturing, increase domestic jobs associated with the renewable energy sector, and further enable domestic decarbonization.[42]

The Oregon Department of Energy has an all-electric Chevrolet Bolt and a plug-in hybrid Chevrolet Volt in its small fleet.

Fuel Cell Electric Vehicles

Timeline

- **1998** — Chicago Transit Authority and BC Transit (Vancouver) each deploy three Ballard-powered fuel cell buses in revenue service for a two-year demonstration and testing program.[43]
- **2000** — Ballard Power Systems presents the world's first production-ready fuel cell for automotive applications at the Detroit Auto Show.[44]
- **2015** — Retail sales of the Toyota Mirai in the U.S. (California only) begin in August.[45]
- **2015** — FirstElement opens the first pipeline-fed, publicly accessible hydrogen fueling station in the U.S. in December (located in California).[46]

Fuel Cell EVs in Oregon

Oregon does **not yet have any registered fuel cell vehicles** in the state, nor does it have fueling infrastructure.

FCEVs are classified as zero-emission vehicles along with battery electric and plug-in hybrid electric vehicles. Rather than using batteries, the fuel cells in these vehicles convert hydrogen fuel to electricity when the vehicle is operating. Like other ZEVs, FCEVs have no tailpipe emissions, and any lifecycle greenhouse gas emissions are contributed by how the hydrogen is produced and transported. For more information on the technology, see the Electric Vehicles Technology Review in the *2020 Biennial Energy Report*.

Trends and Potential

There are no registered FCEVs and no dealerships sell them in Oregon, largely because there are no hydrogen fueling stations in the state. The capital cost to build a light-duty hydrogen fueling station is approximately $1.9 million, making investments in the fueling infrastructure significantly higher than for battery electric vehicles.[47 48] However, a single hydrogen fueling station can service far more vehicles in one day than an EV charging station.

There are 61 retail hydrogen fueling facilities operating in the U.S., 60 of which are located in California and all of which support light-duty hydrogen fuel cell vehicles.[iii 49] The catalyst for this hydrogen transportation economy in California was the California Energy Commission's sizable funding of retail hydrogen fueling stations ($20 million per year to fund up to 100 stations) and the magnitude of legislative, regulatory, incentive, procedural and structural efforts to support the hydrogen economy in the state. Washington has also committed funding to fuel the transition to hydrogen fuel cell vehicles: in 2021 the Washington State Legislature approved $2.55 million for the development of the state's first hydrogen fueling facility to be built along I-5 in Chehalis in 2023.[50]

[iii] The remaining facility is located in Hawaii.

They also created a hydrogen fuel cell electric vehicle pilot program to apply a partial sales and use tax exemption through SB 5000.[51]

The development of the Chehalis fueling site will likely generate more interest in Oregon hydrogen fueling stations that could link Washington and California and create a "Hydrogen Highway," similar to the West Coast Electric Highway that was foundational to EV adoption along the West Coast in the 2010s. Hydrogen fuel is significantly lighter and can be condensed into a smaller space than batteries. Because weight and range requirements for long-haul and heavy-duty trucking may limit the extent to which battery electric trucks can replace diesel vehicles, hydrogen fueling facilities along major freight routes may spur investments in hydrogen fuel cell vehicles.

The Oregon Department of Transportation completed a Hydrogen Pathway Study in May 2022, looking at potential hydrogen fueling needs and investments if hydrogen fuel cell vehicles represent a portion of ZEVs in the light-, medium- and heavy-duty sectors in Oregon by 2035.[52] If hydrogen fuel cell vehicles on the road mirror the assumptions outlined in the report, Oregon will need 47 public hydrogen fueling stations to serve hydrogen vehicles in the light-duty vehicle sector and 19 fueling stations to serve medium-duty and heavy-duty vehicles by 2035.

Beyond Energy

Driving an FCEV has lower associated greenhouse gas emissions than a comparable diesel or gasoline vehicle. Like other zero-emission vehicles, FCEVs have no tailpipe emissions, although there are often emissions associated with the production of hydrogen fuel. Currently 95 percent is made from natural gas, often as a byproduct of petroleum and fertilizer production.[43] The DEQ Clean Fuels Program carbon intensity for all fossil-derived hydrogen is higher than that of gasoline or diesel — but because FCEVs are 2.5 times more efficient than internal combustion engine vehicles, their use results in fewer overall emissions in most cases.

FCEVs can also be fueled with renewable or low-carbon hydrogen. Renewable hydrogen is created by splitting water molecules using electricity, and when the electricity used is zero-emission – like solar and wind power – the lifecycle emissions associated with the production of the hydrogen can be less than 10 percent that of gasoline and diesel. In 2021, the Oregon Legislature passed SB 333, which directed the Oregon Department of Energy to produce a study on the opportunities and challenges of producing renewable hydrogen in Oregon.[55] The study includes information on renewable hydrogen use and options for the transportation sector.[iv] Low-carbon hydrogen can be produced from fossil fuels paired with carbon capture and storage technology or from low-carbon sources of electricity that may not be considered renewable, such as nuclear power.

FCEVs can also be fueled with renewable or low-carbon hydrogen.

Switching to zero-emission vehicles can improve air quality, bringing health benefits to local communities, and helps address climate change, which disproportionately affects low-income communities and communities of color.

[iv] For more information, see the Oregon Department of Energy's *2022 Renewable Hydrogen Report* (Available November 15, 2022): https://tinyurl.com/ODOE-Studies

Electric Vehicle Chargers

Timeline

- **2008** — First publicly accessible level 2 electric vehicle charger installed in Oregon.[56]
- **2011** — First publicly accessible DC Fast Charger (level 3) electric vehicle charger installed in Oregon[56]
- **2012** — The West Coast Electric highway opens, providing CHAdeMO DC Fast Charging and level 2 charging with a frequency no more than 50 miles apart on major corridors in WA, OR, and later joined by CA.[57]
- **2021** — Daimler Trucks North America opens "Electric Island," the first heavy-duty vehicle charging station in Oregon.[58]
- **2022 - 2024** — Oregon and WA are updating 56 legacy West Coast Electric Highway chargers to offer both CCS and CHAdeMO fast charging capability.

EV Chargers in Oregon

Oregon has 917 public and proprietary EV charging locations or stations[56] with 2,177[56] charge ports. 1,705[56] are Level 2 chargers, while 472[56] are Level 3 DC Fast Chargers.

Chargers are the electric fueling infrastructure to support battery electric and plug-in hybrid electric vehicles. Currently, over 80 percent of charging is done at home, either through a standard outlet (Level I) or an installed Level II charger. At-home charging is more challenging at multi-unit dwellings — a recent study by nonprofit Forth found that only 5 percent of at-home charging occurs at multi-unit dwellings.[59] Additional public charging infrastructure is needed to support Oregonians living in those multi-unit dwellings and for those needing to travel and charge away from home. A study by the National Renewable Energy Laboratory estimates that 3.4 DC Fast Chargers and 40 Level 2 charging ports are needed for every 1,000 EVs.[60]

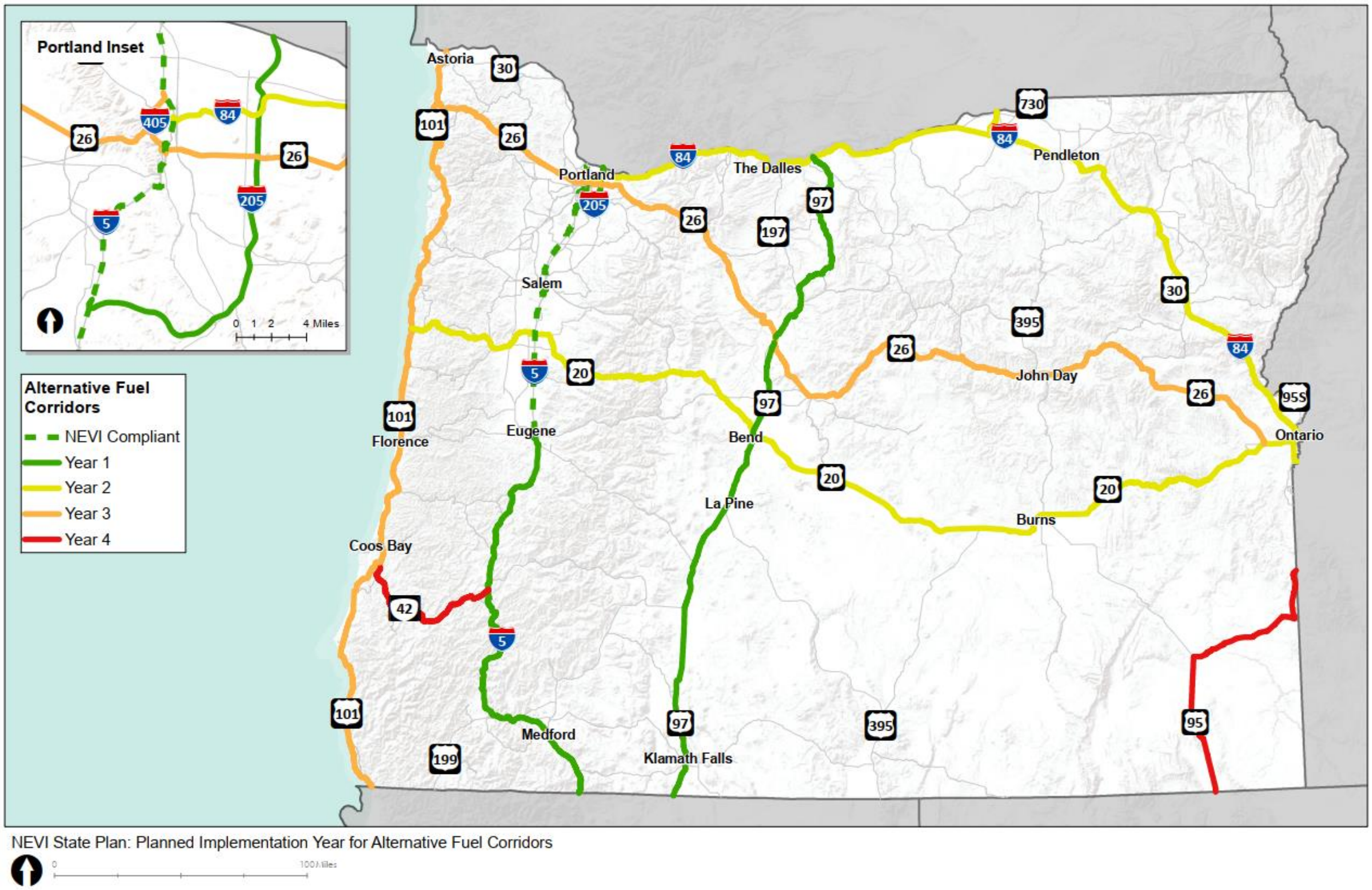
Trends and Potential

It is anticipated that EV charger availability will expand rapidly in the next five years. The Infrastructure Investment and Jobs Act passed by Congress in Fall 2021 includes $5 billion through the National EV Incentive program to support EV charging infrastructure along specific, high-travel corridors. The Oregon Department of Transportation will receive $52 million over five years to deploy DC fast chargers along Oregon's eleven electric Alternative Fuel Corridors.[v] The bill also includes billions of dollars across other programs that could provide funding for EV charging in private or public settings.[61] ODOT's Transportation Electrification Infrastructure and Needs Analysis – a statewide

[v] As of 2022, Oregon has 11 electric Alteranative Fuel Corridors: I-5, I-84, I-82, I-405, I-205, US 101, US 97, US 20, US 26, US 95, and OR 42.

assessment published in 2021 of where chargers are most needed in Oregon – provides a strong foundation for optimizing charger deployment programs.

Figure 4: Oregon's Alternative Fuel Corridors (ODOT)



Charging done at home can often be completed overnight, and for many Oregonians, charging on a standard 110 V outlet is sufficient to meet most daily driving needs. For longer trips or for those who cannot charge at home, faster charging is necessary. The first wave of DC Fast Charger stations generally powered up to 50 kW. Today, the faster and more powerful 150 kW is becoming the standard and 350 kW are increasingly common. While older models of vehicles may only be able to charge at the 50 kW level,[vi] most new models today can accept up to 150 kW, and many auto manufacturers are competing to provide EVs that can charge at increasingly faster speeds using higher-powered chargers.

There are three types of connectors used on DC Fast Chargers: CCS, CHAdeMO, and Tesla. CCS chargers can charge most electric vehicles on the road today, while Tesla chargers can only be used for Tesla vehicles and CHAdeMO chargers can only be used with a small number of vehicle models. In recent years, North American and European vehicle manufacturers began coalescing around the CCS standard, so most vehicles available and on the road today accept this connector, with the exception of the popular Nissan LEAF. CHAdeMO chargers in the U.S. are rated only to 50 kW, and a new standard that would enable higher powered CHAdeMO chargers was released in 2020. CHAdeMO

[vi] Vehicles capable of only 50 kW charging can still charge at the higher-powered stations, as the chargers will recognize the capacity of the vehicle and provide the right amount of charge.

remains the primary standard in Japan, because it offers bidirectional charging – the ability to charge the battery as well as discharge the battery back to the grid.[62] In the U.S., CHAdeMO chargers will remain to support LEAFs and are required to be included for many publicly funded programs to support older generation electric vehicles.

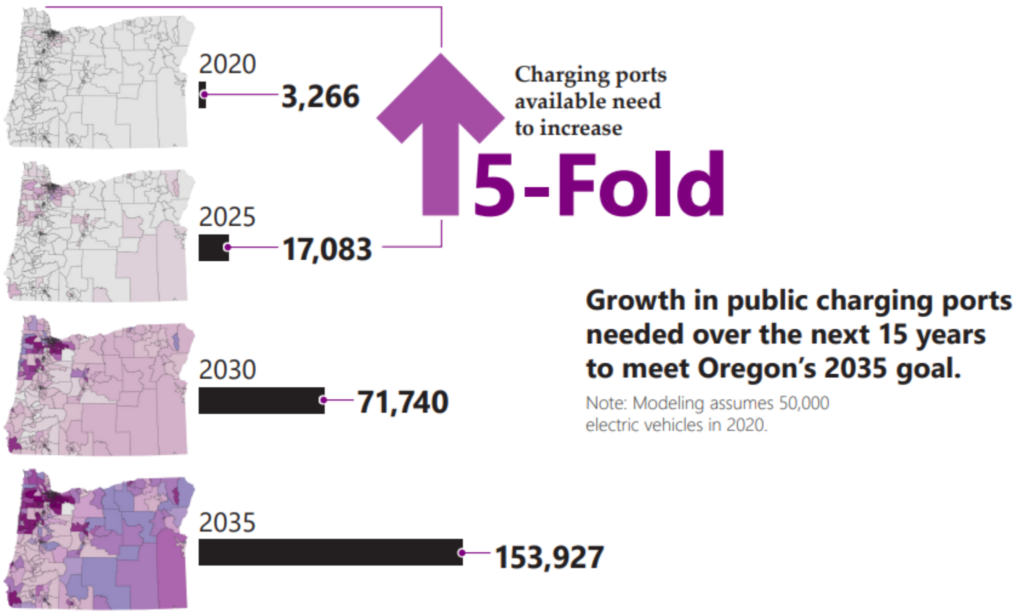
"Electric Island," a joint project by Portland General Electric and Daimler Trucks North America is a first-of-its-kind electric fueling station capable of charging everything from light-duty passenger vehicles to electric freight trucks.[62]

Oregon is also leading in the formative stages of medium- and heavy-duty vehicle charging infrastructure development. A joint project with Portland General Electric and Daimler Trucks North America developed a first-of-its-kind publicly available electric fueling station capable of charging everything from light-duty cars to electric freight trucks. Located on Swan Island in north Portland, the site can host up to 5 MW of charging infrastructure and is being used by PGE and Daimler to study how utilities and fleet owners can optimize charging for larger vehicles.[58 63]

Beyond Energy

Adoption of electric vehicles is a central pillar of Oregon's strategy to reduce greenhouse gas emissions in the transportation sector, and the rapid deployment of charging infrastructure is critical to accelerate EV adoption in the next five years. To support this, the Oregon Department of Transportation, supported by the Oregon Department of Energy, developed the Transportation Electrification Infrastructure Needs Analysis study in 2021 to study and identify charging gaps and needs across the state.[64] The study points out the magnitudes of growth in charging required to meet Oregon's EV adoption

Figure 5: Growth in Public Charging Ports Needed Over the Next 15 Years[64]



goals.[65] ODOT is also committing more than $100 million in funding over the next five years to support EV charging infrastructure deployment along key travel corridors and within Oregon communities, provided through a mix of state and federal funds.

Ensuring that EV charging infrastructure is equitable and accessible to all Oregonians (including all communities, income levels, housing types, and geographic locations) has become a guiding principle in infrastructure deployment. A UC Davis study on the Air Quality Impacts of Oregon's Proposed Clean Fuels Program Changes clearly signals that the health of Oregonians will benefit from the expansion of the carbon reducing program.[66] The study shows clear air quality improvement in the vicinity of major roadways and that disadvantaged communities, including lower-income and Black, Indigenous, and People of Color populations, are more likely to live near major roadways and be exposed to vehicle pollution.

Access to charging and the ability to pay for electric fuel through a home or business utility bill affect how much drivers pay to fuel their EV. For example, someone who can charge at home may save as much as 80 percent compared to a gasoline car, while relying on public charging could reduce this savings to approximately 50 percent.[vii] This varies depending on several factors, especially volatility in gasoline prices. EV drivers who rent or live in multi-family dwellings, or who otherwise cannot charge at home, may pay more for electric fuel that must be purchased at publicly available EV chargers.

Rural Oregonians have more limited charging resources than metropolitan areas. There can be more than 50 miles between publicly available chargers on some Oregon highways, which may limit the use of older EV models with shorter driving ranges. When charging is available, rural drivers may have to make an additional investment of time to charge the vehicle when they travel. This additional time could be further inflated if only slower Level 2 chargers are available. In some rural areas of Oregon there is insufficient electrical capacity to support DC fast chargers without costly upgrades to the distribution system. The "sunk costs" of time waiting for charging might outweigh the fuel cost savings for some drivers.

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Siting and installing a significant number of EV chargers offers increased jobs and economic benefits for Oregon. Professional electrical installers and ongoing operation and maintenance needs are necessary to support the charging infrastructure, and the siting of chargers can have economic benefits for nearby businesses, such as restaurants and hotels, which may see increased traffic from drivers using the chargers. The consumption of electric fuel also retains more of Oregon's transportation dollars in state, supporting local utilities and energy developers. The U.S. Energy Information Administration estimates that in 2020, Oregon spent about $5.7 billion on transportation energy, which is mostly paid to businesses out of state.[67]

EV chargers are largely composed of metals and alloys, including copper, stainless steel, carbon steel, aluminum, nickel, chrome, and titanium. These components are necessary to meet charger design and operational standards, as well as for parts like charging cables that must be replaced over time, due to

[vii] Calculation assumptions: 25 MPG car, $4-$5 dollar/gal gas, Home charging at ¢11/kWh, Public charging at ¢30/kWh

expected wear and tear. The rapid deployment of EV chargers will rely on global supply chains for these metals and alloys, some of which are strained due to COVID-related supply chain challenges. Global adoption of EVs and chargers will create high demand for these resources in the next decade or more, with the market for these materials increasing by 34 percent by 2028.[68] Similar to raw materials for the batteries that fuel EVs, the extraction, refinement, and transport of these raw materials has the potential for negative social and environmental effects, and the economic effect of the rapid upswing in demand for these materials could create increases in costs for equipment suppliers and EV owners.[68]

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Energy Resource & Technology Review: Energy Efficient Building Technologies

Energy use in buildings across the residential and commercial sectors makes up 25 and 19 percent of Oregon's 2020 overall energy use respectively, and produces 35 percent of Oregon greenhouse gas emissions. While adoption of energy efficiency measures continues to rise in Oregon, there remains significant potential to further reduce building energy use in new and existing buildings with new or improved energy efficiency measures,[1] including construction techniques, efficient equipment and appliances, and equipment controls that reduce the monthly consumption of utility-provided energy. These measures also provide many non-energy benefits for both the building owner/operator and the community, such as: saving money, reducing energy burden,[i] reducing greenhouse gas emissions and other pollutants, increasing jobs, reducing demand for future infrastructure, enhancing distributed energy resources, increasing local reliability, and supporting a more resilient energy system (for more information on this topic see the *Beyond Energy Savings* Policy Brief).

In Oregon, there are many drivers of energy efficient technology adoption. In addition to the benefits above, for individual businesses and homeowners it can be a desire for energy savings (and financial savings) or other benefits like improved indoor air quality, comfort, support for a clean energy system, or progress toward corporate sustainability goals. Drivers at a regional or market-scale include policies and programs that promote energy efficiency, such as those that improve energy building codes and energy efficiency standards; provide utility incentives and finance energy efficiency measures; provide tax incentives; address appliance labeling efforts like ENERGY STAR; fund research and development; and enable market transformation for new products through programs developed by the Northwest Energy Efficiency Alliance.[1] [2]

The region has made impressive strides acquiring energy efficiency. The Northwest Power and Conservation Council estimates that the Pacific Northwest has, as of 2018, cumulatively saved over 7,200 average megawatts of energy – making the energy efficiency resource second only to hydroelectric power – and saves ratepayers over $4 billion per year and reduces GHG emissions by over 22 million MTCO2 per year.[3] Yet there remain numerous challenges to acquiring more energy efficiency. One challenge is access to capital for energy efficiency investments, especially in existing buildings where goals require replacement of functioning equipment. While incentives or tax credits can help with these investments, they are not applicable in all situations. The Northwest Power and Conservation Council's *2021 Power Plan* discusses additional challenges, including decreased investment in cost-effective energy efficiency and the recent drop in the cost-effectiveness threshold that energy efficiency must meet. Energy

Energy efficiency saves Pacific NW ratepayers over $4 billion and reduces GHG emissions by over 22 million MTCO2 each year.

[i] Energy burden is the percentage of household income spent on energy and transportation costs, and anyone paying more than 6 percent of their household income on energy is considered energy burdened.

efficiency has long been the lowest cost resource for the region, but is now facing competition from low-cost renewable solar and wind resources.[3] Other challenges to adoption include limited availability of technologies, lack of consumer familiarity with efficiency products, and recent supply chain and shipping delays related to the COVID-19 pandemic.

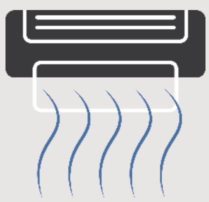
This Technology Review provides more information on energy efficient equipment, including heat pumps, water heaters, and smart devices and appliances.

Heat Pumps

Timeline

- **1834** — Refrigeration was a precursor to heat pumps, as Jacob Perkins filed the first patent in England for mechanical refrigeration to make ice. [7]
- **1855** — Peter Von Rittinger developed the first heat pump (heating only) at an Austrian Salt mine. A Swiss fuel shortage drove development for commercialization in the late 1930s and early 1940s).[7]
- **1968** — Mitsubishi releases a wall-mounted split-system room air conditioner, also called a ductless heat pump.[8]
- **1970s** — U.S. adoption of the technology starts to increase.[9]
- **2000s** — Widespread incentives became available for heat pumps, including the first tax credits in 2006-2007.[10] Local utility incentive programs and market transformation efforts focusing on promoting heat pumps picked up in the late 2010s and early 2020s.[11]
- **2022** – SB 1536 passed in Oregon establishing two statewide heat pump programs, one for incentives for homeowners and one rebate program for rental homes.
- **2022** – Federal Inflation Reduction Act created large scale investment in energy efficiency and clean energy including a tax credit and rebate program for residential heat pumps.

Heat Pumps in Oregon and the Northwest



In 2017, about **15 percent of single-family households in the Northwest used a heat pump** as the primary heating system (11.3 percent air source heat pump; 3.4 percent mini-split heat pump; and 0.7 percent geothermal (or ground source) heat pump).[4]

Research from Washington state showed an **increase in the number of households using electricity for heating** — from approximately 20 to 90 percent of surveyed respondents — indicating an increase in homes using electric technologies like heat pumps.[5]

Oregonians could **save about 50 percent on home heating costs** with a heat pump compared to electric resistance heat, like cadet or baseboard heaters.

Heat pumps move heat rather than create it. In heating mode, heat pumps collect heat from ambient outdoor temperatures, concentrate it, and transfer that heat inside the building — even on cold days. In cooling mode, heat pumps operate like regular air conditioners and refrigerators, moving heat from inside the building or refrigerator to outside. Heat pump technology is essentially the same as refrigeration technology, except that heat pumps have a reversing valve that allows operation in two directions for both heating and cooling.

What Makes a Heat Pump Efficient?

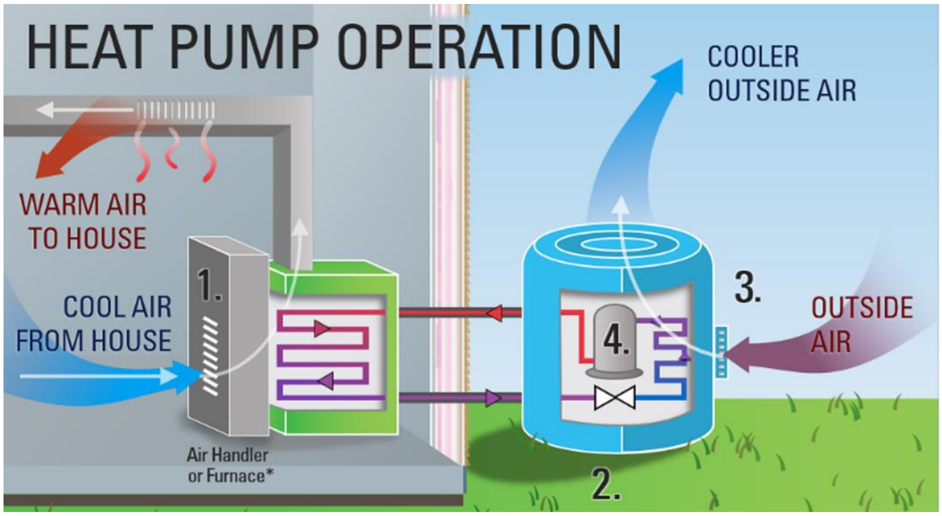
Heat pump efficiency is generally expressed using standard metrics, such as the Seasonal Energy Efficiency Ratio (SEER), Energy Efficiency Ratio (EER), Heating Season Performance Factor (HSPF), or Coefficient of Performance (COP). For these metrics, higher values indicate greater efficiency.

SEER or EER measures a heat pump's efficiency in cooling mode, and HSPF measures the heating mode efficiency. Heat pump incentive programs often require minimum SEER and HSPF ratings.

The Coefficient of Performance measures the overall efficiency of a heating or cooling technology. Measured in kilowatts, it is calculated as the amount of heating or cooling provided by the technology compared to the kilowatts of power consumed by the technology. A COP of 3 means that three units of beneficial energy (for heating or cooling purposes) are delivered for every one unit of electricity energy that is input into the system. Put another way, a COP of 3 would mean that equipment is 300 percent efficient.

To qualify as ENERGY STAR-rated, heat pump models need to have: a minimum 8.5 HSPF, a minimum 15 SEER, or a minimum 12.5 EER for air source split systems.[6]

Figure 1: Air Source Heat Pump Operation[12]

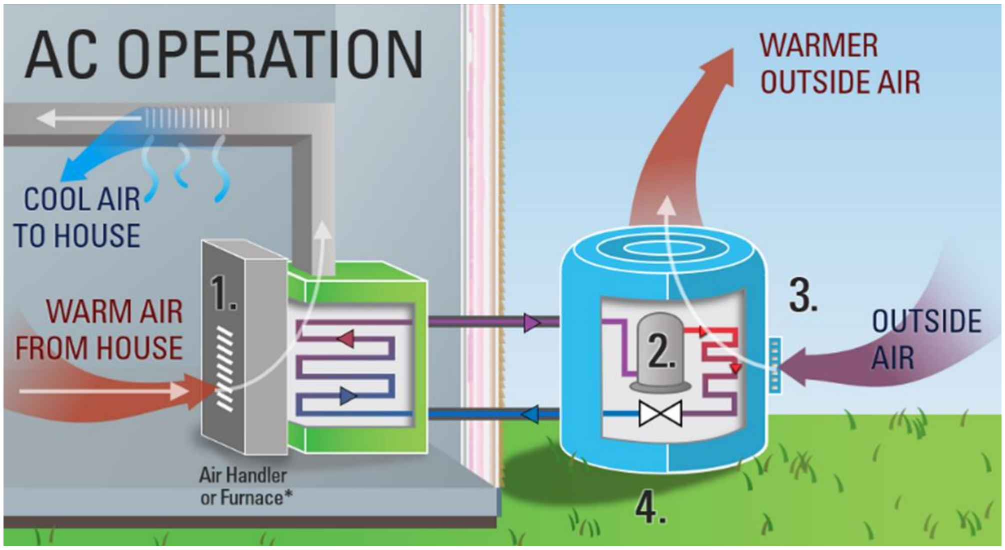


1. Cold air from inside the home is passed across the high-temperature, high-pressure gas refrigerant in the indoor coil, which transfers heat to the cold air. The refrigerant condenses to a liquid, and warm air is circulated through the home.

2. Warm liquid refrigerant is passed through an expansion valve, which relieves pressure. As the pressure is reduced, the temperature of the liquid is reduced, and the cold refrigerant passes through the outdoor coil.
3. Heat energy transfers from the outside air to the low-pressure, low-temperature, liquid refrigerant.
4. The low-temperature gas refrigerant goes through a compressor, which raises its temperature and pressure and passes it back to the indoor coil.

Ductless units operate similarly, except the fan is built into the indoor unit and blows warmed air directly into the room.

Figure 2: Air Conditioner Operation[12]



1. Warm air from inside the home is passed across a cool refrigerant coil, and the heat is absorbed by the liquid refrigerant, which evaporates into a low-temperature gas. The cooled air is ducted back through the house.
2. The low-temperature gas refrigerant goes through a compressor, which raises its temperature and pressure.
3. Hot, high-pressure refrigerant gas is passed through the outdoor coil. The refrigerant passes heat to the outdoor air and condenses to a high temperature liquid.
4. Warm liquid refrigerant is passed through an expansion valve, which relieves pressure. As the pressure is reduced, the temperature of the liquid is reduced. The low-temperature, low-pressure liquid refrigerant is then piped back into the house.

Ductless units operate similarly except the fan is built into the indoor unit and blows cool air directly into the room.

Types of Heat Pumps:

Air Source Heat Pumps

- Use electricity to operate a compressor to transfer heat between the air inside and outside of the building
- Most common type of heat pump system
- Often the least expensive heat pump option
- Can be ducted or ductless (some ductless versions are called mini-splits)

Ground Source Heat Pumps (sometimes referred to as geothermal heat pumps)

- Use the relatively constant underground temperature near the building instead of air for heat transfer
- Typically higher in capital costs to install
- More efficiently transfer heat than air source heat pumps
- Tend to have lower operating costs than air source heat pumps

Water Source Heat Pumps

- Use a pumped closed water loop from a nearby surface or groundwater source instead of air for heat transfer
- Typically higher in capital costs to install
- More efficiently transfers heat than air source heat pumps
- Tend to have lower operating costs than air source heat pumps

Gas-fired or Absorption Heat Pumps

- Use the combustion of natural gas or propane to generate the heat source for transfer to the building, rather than mechanical energy used in air source or compression heat pumps
- Absorption heat pumps are not reversible and do not create cooling or air conditioning
- More efficient than traditional gas furnaces
- Relatively new type of heat pump that is not yet commercially available

Trends and Potential

Currently, heat pump technology enhancements are focused on improving cold weather capabilities, efficiency, and suitability for retrofitting large commercial buildings in a cost-effective manner. In cold climates, traditional air source heat pumps tend to provide less heating capacity and operate at lower efficiency levels, but advances in the technology such as variable speed fans and two-speed compressors have greatly improved effectiveness and efficiency in cold environments. Heat pumps operate at a lower supply air temperature than traditional fuel-based heating systems; therefore, in large-scale installations replacing a central heating system with a heat pump often requires extensive updates. Heat pumps are being effectively deployed to save energy (and reduce GHG emissions) across the United States, from cold climates such as Alaska and Maine all the way to the hot and humid south.

Senate Bill 1536 (2022) requires ODOE to create a $10 million statewide Community Heat Pump Deployment Program that prioritizes assistance to: environmental justice communities, individuals who rely on bulk fuels (e.g., LPG, propane, coal, and wood) or electric resistance heating, or individuals who reside in a home or structure that does not have a functioning heating or cooling system. In addition, it requires ODOE to create a $15 million Oregon Rental Home Heat Pump Program, working through contractors installing heat pumps for owners of a rental home, manufactured home, or recreational vehicle that provides housing for low-income residents. ODOE expects to launch the program in 2023.

> **Incentives**
>
> Learn more about the Oregon Department of Energy's incentive programs and save:
>
> **www.oregon.gov/energy/Incentives**

Beyond Energy

Contemporary heat pumps that operate solely on electricity are more efficient than electric resistance heat, and play an important role in achieving decarbonization goals. Depending on the proportion of renewable energy in the utility's electricity generation source, installing new heat pumps can reduce greenhouse gas emissions created from heating and cooling buildings. Heat pumps also have no site emissions; coupled with increasingly clean power grids, this can support better air quality for Oregonians especially when compared to other heat sources like wood and propane. However, heat pumps do often use hydrofluorocarbons as the medium to transfer heat; these gases have a high global warming potential (GWP), and the prevalence of their use may have wider environmental impacts. High-GWP refrigerants are being phased out through federal mandates, reducing their effect in the future. This phase-out will decrease the production and import of HFCs in the United States by 85 percent over the next 15 years (by 2036). In cases where heat pumps replace an existing inefficient heating system, the units add cooling without the need for additional pieces of equipment that will need maintenance. The savings from the winter months can help offset the cost of the added summer cooling.


OREGONLIVE The Oregonian

Oregon's heat wave death toll grows to 116

Updated: Dec. 01, 2021, 12:18 p.m. | Published: Jul. 07, 2021, 12:42 p.m.

Salem Fire Department paramedics and employees of Falck Northwest ambulances respond to a heat exposure call during a heat wave, Saturday, June 26, 2021, in Salem, Oregon. Nathan Howard | AP Photo

Following the June 2021 Oregon heat dome event, which led to more than 100 heat-related deaths,[13] access to cooling has become an important topic to address when planning for Oregon's changing climate. The dual heating and cooling benefit that heat pumps provide can help people stay safe during extreme weather events. SB 1536 required ODOE to contract with the Energy Trust of Oregon to create a $2 million Community Cooling Spaces program for landlords to provide community cooling spaces for tenants. It also required ODOE to study the cooling and electrical needs of publicly supported housing, manufactured dwelling parks, and RV parks, focusing on: the prevalence of cooling facilities, the need for cooling facilities, the barriers to transitioning housing and parks to include cooling facilitates, and where possible, specific scenarios for properties in development or preservation to add cooling facilities.

Oregon is not only predicted to face record heat waves, but also record cold snaps and inclement winter weather. This increases the need to consider resilience in home heating systems. Depending on the type of heat pump and size, this could force older heat pump models to use electric resistance heating more often during extreme cold, increasing costs to the homeowner and demand on the electricity grid. Newer heat pump technology can operate more efficiently in colder temperatures without use of a secondary heating system. Heat pumps, when paired with a backup system such as on-site renewable generation with battery storage or a wood or natural gas fireplace, can also be part of a redundant system that provides flexible, efficient heating during normal operation and emergency backup during power outages.

Water Heaters

Timeline

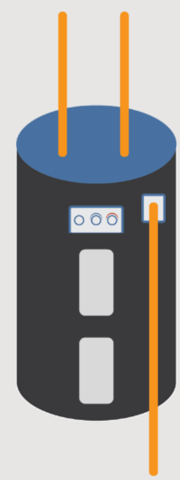
- **1890s** — Edwin Ruud designed automatic storage tank-type natural gas water heater, which were safer for use in homes.[17,18]
- **1889** – Edwin Ruud invented the electric water heater with automatic storage in Philadelphia.[19]
- **1897** — First natural gas-fueled, tankless hot water patented in Philadelphia by Edwin Ruud.[17]
- **1937** — Heat pump water heaters were first patented by G. Wilkes and F.M. Reed.[20 21]

Energy-Saving Water Heaters[14]

Oregonians can see a **50 percent reduction in annual electricity use**, on average, for switching from an aging electric resistance water heater to an electric heat pump water heater.

Households can also see an **8 percent reduction in natural gas use** when swapping a standard water heater model to an ENERGY STAR-rated gas fired water heater. Savings are further increased by about 10 percent when swapping from a storage tank style to a direct vent tankless gas water heating unit.[14,15]

Oregonians could **save about $330** per year for a family of four when switching from an aging electric resistance storage water heater to a highly efficient heat pump water heater.



Water heaters are a standard appliance in all sectors. They provide hot water for the taps and showers in occupied residential and commercial spaces, and directly to processes and equipment in commercial and industrial applications. There are multiple types of water heater technologies that serve these markets. These common technologies include electric storage water heaters (which are available in both electric resistance and heat pump models), natural gas storage water heaters, and tankless (or instantaneous) water heaters (which are available in both natural gas and electric models). Solar thermal water heaters and propane-fueled water heaters also represent a small percentage of the overall market.

What Makes a Water Heater Efficient?

UEF is the Uniform Energy Factor, a measure of water heater overall efficiency determined using a USDOE test method. The higher the value, the more efficient the water heater. SUEF is the Solar Uniform Energy Factor, or the energy delivered by the total system divided by the electrical or gas energy put into the system. Again, the higher the value the more efficient the system.

The Coefficient of Performance (COP) is 3.0 for heat pump water heaters, and about 1.0 for high efficiency storage water heaters (both gas and electric).

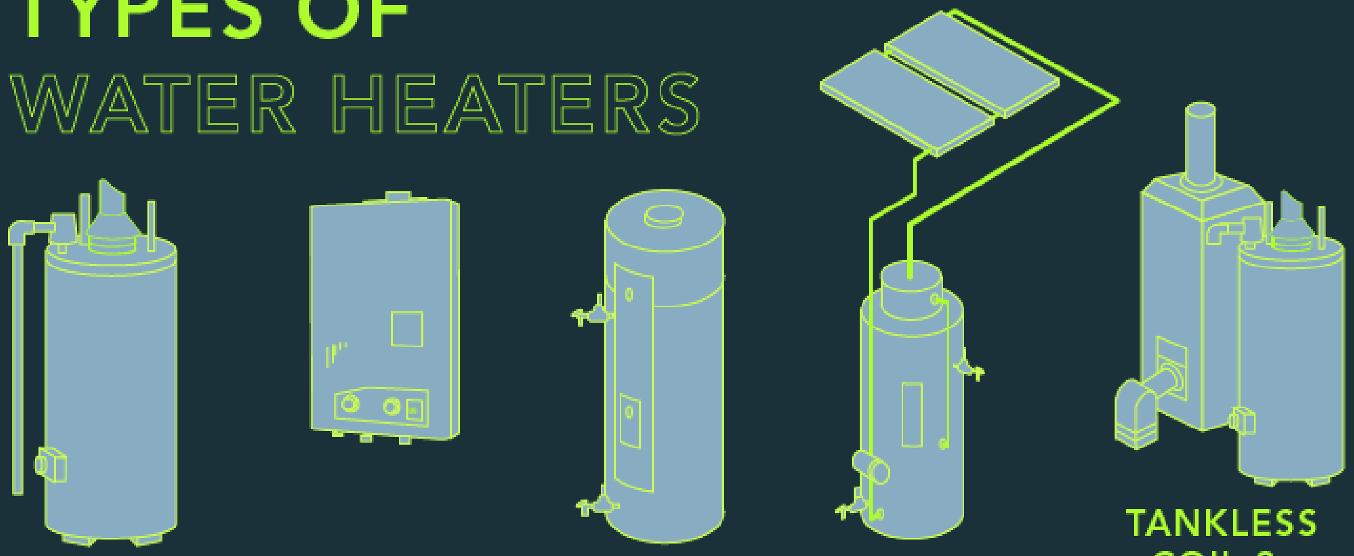
To qualify as an ENERGY STAR model, water heaters need to meet these factors:[16]

- Hybrid Heat Pump/Electric Storage water heaters
    - Integrated Heat Pump Water Heater UEF 3.3 min
    - Integrated Heat Pump Water Heater, 120 V UEF 2.2 min
    - Split System Heat Pump Water Heater UEF 2.2 min
- Gas Storage water heaters
    - < 55 gal UEF 0.64 min
    - > 55 gal UEF 0.78 min
- Gas instant water heaters EF 0.87 min
- Solar water heaters
    - SUEF 3.0 for those with electric backup
    - SUEF 1.8 for those with gas back up

Like many products and appliances, water heaters are available in varying levels of energy efficiency.

Figure 3: Types of Advanced or ENERGY STAR-Certified Water Heaters[22]

TYPES OF WATER HEATERS



	STORAGE	TANKLESS	HEAT PUMP	SOLAR	TANKLESS COIL & INDIRECT
COST	$	$$	$$	$$$	$$
LIFE EXPECTANCY	10-15 years	20+ years	10-15 years	About 20 years	10-11 years
PRO	Lower purchase cost	Provides a constant supply of hot water, and is 8-34 percent more energy efficient than a storage water heater. Depending on the amount of hot water your home uses daily, you could save at least $100 a year.	2-3 times more energy efficient than a storage water heater and lower operating costs. Energy Star heat pump water heaters can save homeowners almost $300 a year on their electric bills	50 percent more efficient than gas or electric water heaters	Lower installation and maintenance costs
CON	Standby heat loss – energy can be wasted to keep the water in the tank heated to the set temperature.	Limited flow rate of hot water means simultaneous, multiple uses of hot water can stretch a tankless water heater to its limit, and some times the energy savings don't pay for the cost of purchase and installation.	Performance is dependent on the installation location, and heat pump water heaters exhaust cold air -- increasing the load on space conditioning appliances during heating months.	Solar water heaters may require a backup system for cloudy days and times of high demand.	Inefficient choice for many homes, especially for those in warmer climates.
SOLUTION	Look for an insulated tank to reduce heat losses and lower operating costs.	Install two or more tankless water heaters connected in parallel or separate ones for appliances that use a lot of hot water.	Switching the heat pump water heater to regular resistance mode will stop cold air exhaust but also reduce the appliance's efficiency.	Make sure you buy a solar water heating system that includes a storage water heater as part of the system package.	

High efficiency gas storage water heaters. These water heaters are similar to standard efficiency gas heaters, but offer increased insulation, more efficient burners, and other improvements to increase the overall energy efficiency. Models known as "condensing" gas water heaters include a secondary heat exchanger that recovers additional energy from the combustion exhaust stream and lead to increased energy efficiency.

Heat pump water heaters. These units operate using a similar cycle to typical refrigerators, air conditioners, or heat pumps. This technology captures heat from the surrounding area and transfers it to the water in the tank. High efficiency units, such as ENERGY STAR certified water heaters, can use 50 percent less electricity compared to standard electric resistance water heaters. Heat pump water heaters typically also include a traditional electric resistance heating element to enable the heater to operate in heat pump mode or as a standard electric water heater in the case the heat pump is not able to meet the demand for hot water. This increases flexibility and offers a balance between performance and energy efficiency.

Solar thermal water heaters. This type of heater offers a variety of technologies and configurations to provide hot water. The configurations all have a common aspect of using solar energy to heat the water through solar energy collectors and storage tanks. Solar thermal water heaters can operate in conjunction with standard water heater technology as a backup to provide consistent hot water to the end user.

Tankless (or instantaneous) water heaters. These can come in natural gas or electric models and operate using the same concept as typical water heaters, but they do not contain a storage tank. These models use a sensor to activate the heater when needed and heat the water as it flows through, meaning that they must heat the water much faster than a storage water heater to be able to supply sufficient hot water to meet user demand (such as a shower). By only heating water on demand, these units save energy by eliminating the heat loss from a storage tank during standby operation; not having a pilot light also reduces gas use. In addition, tankless water heaters have direct venting which reduces the risk of carbon monoxide poisoning and limits exposure to cold outdoor air from a constantly open-air vent. To serve a building with multiple simultaneous hot water uses (such as a home with a kitchen and multiple bathrooms), these units typically require increased electricity or natural gas supply infrastructure.

Trends and Potential

In Oregon and nationally, building energy codes and appliance standards help to ensure that newly installed water heaters and hot water systems meet minimum efficiency standards. This work, combined with ENERGY STAR labeling and regional- and utility-run energy efficiency programs, helps incentivize, reduce costs, and drive adoption of leading water heater technology in Oregon and the region. In addition, building hot water storage tanks represent a potential avenue for thermal storage that, in combination with Oregon's new rule for demand response controls for water heaters,

Building energy codes and appliance standards help to ensure that newly installed water heaters and hot water systems meet minimum efficiency standards.

could reduce peak demand from building energy use and help offset future demand growth, and reduce reliance on fossil fuels for generation.

Most single-family homes in Oregon have a storage water heater (water heaters that have a water tank), which are typically fueled either by electricity or by natural gas (about 50/50 split). About 1 percent are fueled by propane. In the Pacific Northwest, approximately 2 percent of homes use an electric heat pump water heater as of 2017. Data and distribution of water heaters types for the northwest can be seen in the following table from NEEA's Residential Building Stock Assessment.[4]

Figure 4: Distribution of Water Heaters in the Northwest by Detailed Type[4]

Detailed Type	Water Heaters		
	Percent	Error Bounds for the Analysis	Number of Homes in Sample
Instantaneous-Electric Resistance	0.8%	0.7%	6
Instantaneous-Fossil Fuel Condensing	3.0%	1.1%	31
Instantaneous-Fossil Fuel Non-Condensing	2.0%	1.1%	19
Storage-Electric Heat Pump (Packaged)	1.8%	0.9%	20
Storage-Electric Resistance	46.3%	3.1%	551
Storage-Fossil Fuel Condensing	4.1%	1.3%	38
Storage-Fossil Fuel Non-Condensing	41.3%	3.2%	390
Storage-Indirect Water Heater	0.5%	0.3%	10
Total	**100.0%**	**0.0%**	**1,048**

Smart Devices and Appliances

Timeline

- **1620** — Origin of the thermostat: Cornelius Drebbel invents an egg incubator with a mercury thermostat-based air and temperature control.[24]
- **1830** — Andrew Ure invents the modern-day application and what we currently refer to as a thermostat to keep boilers warm.[24]
- **1880** — Professor Warren Johnson invents first electrical thermostat to control room temperature in buildings.[24]
- **1906** — Mark Honeywell builds on previous patents and develops the first programmable thermostat.[24]
- **1962** — Imperial Chemical Industries invents Direct Digital Controls.[25] DDC controls would become more commercially available and popular in the 1970s and 1980s.
- **1975** — Smart home technology is invented, which uses radio frequency bursts onto existing electrical wiring to control appliances. [26]
- **2010** — Nest Learning Thermostats are introduced.[26]
- **2014** — Amazon Alexa is introduced and accelerates the trend toward connected home devices.[26]

Smart Devices in Oregon

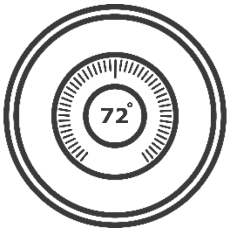
As of 2017, **10 percent of households in Oregon** use smart devices or appliances and the adoption rate continues to increase.[4]

Smart thermostats can save between 10 and 15 percent of heating and cooling costs when operated correctly, and offer more convenience compared with the level of effort required to achieve similar savings with a programmable thermostat.[23]

Smart devices and appliances cover a broad category of Wi-Fi enabled or otherwise connected devices that can be programmed to reduce energy use, collect information about energy use habits of building occupants, and receive and respond to signals from the owner, grid, or utility. This can range from a fully integrated automated building energy management system in a commercial building—where multiple appliances and pieces of equipment can be monitored and controlled by a central computer—down to a single smart appliance such as a refrigerator that sends a mobile alert. Smart devices and appliances are designed to use automation and connectivity to conveniently achieve energy savings while reducing the amount of time that building occupants need to actively engage in energy management practices. This combination of advanced technology and convenience are the main attractions of smart technology. These devices can also be part of utility demand reduction or demand response programs where participants voluntarily agree to have the utility control the device and turn it off or change settings to reduce peak loads and operate the system more cost-effectively, thereby helping to keep rates as low as possible.

Technology/Resource Overview (What is it and How Does it Work?)

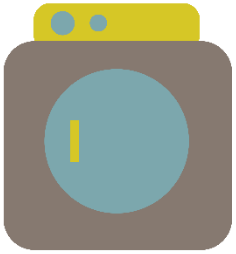
Smart Thermostats[23]



Smart thermostats are Wi-Fi enabled devices capable of connecting to a smartphone or similar device. They differ from programmable thermostats in that they are easily controlled remotely. Smart thermostats can be programmed to use a phone's location and Wi-Fi connection to track occupancy to change room temperature settings. These thermostats can use machine learning to predict when occupants will come home and can raise or lower temperature to ensure the home is comfortable upon arrival. In addition to energy savings, the benefit of this type of convenience for homeowners is saved time. Smart thermostats can also be connected and respond to grid and utility conditions to manage systemwide load, reduce outages, and minimize peak demand.

Smart Appliances[27]

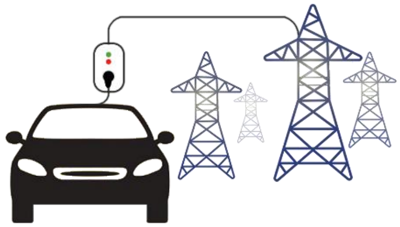
Smart Appliances don't have to be Wi-Fi enabled and controllable by a smartphone, but many are. Refrigerators, water heaters, heat pumps, furnaces, washers, dryers, and even tea kettles or coffee makers can come with this added level of control and connectivity. The primary components are integrated features that save energy and add convenience (and sometimes increase safety). An early example of this type of appliance are programmable coffee pots, where a timer can control when the coffee pot starts brewing coffee and how long afterward the warming plate turns off. Other features common in smart appliances are maintenance alerts and other monitoring features to help ensure the appliance is running at peak efficiency, and energy saving convenience features like programmable delays (for example allowing you to set your dryer cycle to begin at a certain time so laundry is ready to be folded when you arrive home from work, reducing the number of times you use the de-wrinkle cycle).



Another layer to smart appliances is grid connected devices that, when demand is high, can allow the utility provider to make minor adjustments to equipment settings to reduce peak demand, potentially in exchange for reduced rates or incentives. Adjustments are generally minimal and imperceptible to the occupant, and users always have the option to override if needed. These demand response programs can help utilities meet short duration peak electricity demand periods while delaying or removing the need for more expensive new generation assets.

Smart Electric Vehicle Chargers[28]

Electric vehicles (EVs) are expected to create load growth for electric utilities as adoption increases. Utilities can meet this anticipated growth through a variety of options, including smart EV chargers that can regulate when and how fast an EV charges. Wi-Fi enabled or programmable chargers allow a smart phone or timer to program EVs to charge at times when energy demand and/or costs are lower. Many utilities offer a lower EV-specific rate during off-peak hours, often overnight. A smart charger could be programmed to run during these hours or set to enable the utility to communicate with the charger to help balance EV fueling needs with grid demand. Like the demand response programs for appliances described above, smart EV chargers can enable utilities to control EV charging to help reduce peak loads. The ability to regulate charging is a critical component for utilities managing increasing numbers of EVs on their systems, and some Oregon utilities provide rebates to incentivize installation of smart charging infrastructure. Electric vehicles with smart charging technology also present a unique opportunity for small scale energy storage, when paired with bi-directional flow and grid integration. Excess electricity generation from on site or the grid can be directed to the chargers for storage in vehicle batteries, and if desired can be used to provide energy on site during peak demand or electric system outages.



To learn more about grid interactive smart chargers and utility planning for increased ZEV charging demand, see ODOE's *2021 Biennial Zero Emission Vehicle* report.

Controllable Lighting

Lighting controls come in various forms, the simplest being occupancy detectors that turn off lights in an area after a certain amount of time if no movement is sensed. Additional types of controls automatically dim lights by using daylight sensors to change the lighting based on how much natural light is coming through the windows in relation to a required minimum light level setting. Outdoor lighting can be controlled using motion detection and/or daylight sensors. More advanced lighting controls can include Wi-Fi connectivity and control in combination with the sensors listed above, which allow for the convenience of remote control while also using automated sensors to passively save energy. In Oregon, for new commercial construction and retrofits, energy codes include requirements for occupancy and scheduling controls.

Conclusion

Advances in energy efficiency have helped utilities manage regional demand and reliability for energy, improved energy bills and thus reduced energy burden for many Oregonians and contributed to progress toward state and local climate goals. There remains significant energy efficiency potential to continue to provide these benefits. Advanced technology adoption rates vary according to many factors, but costs and barriers can leave some groups behind. Incentives and market transformation efforts that focus on closing these gaps will help achieve regional and local goals.

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Energy Resource & Technology Review: Electricity Storage

Timeline

- **1800** – Allessandro Volta, Italian physicist, builds the first electrochemical battery. Named the voltaic pile, it is a stack of copper and zinc plates separated by brine-soaked paper disks that can produce a steady current over time.[1]
- **1838** – William Grove develops the first *fuel cell* — a device that converts the chemical energy of a fuel into electricity through a chemical reaction with an oxidizing agent.[1]
- **1907** – Pumped storage hydropower is first used at a facility near Schaffhausen, Switzerland.[2]
- **1923** – Hydrogen is first discussed as an energy storage medium in a paper by John Haldane titled: "Daedalus or Science and the Future."[3]
- **1930** – The Connecticut Electric and Power Company creates the first large-scale pumped-storage facility in the United States near New Milford, Connecticut. It pumps water from the Housatonic River to a large storage reservoir 70 meters above.[4]
- **1985** – The Bath County Pumped Storage Station begins operating and is described as the "largest battery in the world." It is located in Bath County, Virginia and it remained the largest pumped-storage power station in the world until 2021 when it was surpassed by the Fengning Pumped Storage Power Station in northern China.[5]
- **1987-1991** – Akira Yoshino, Japanese chemist, patents the first commercial lithium-ion battery. Four years later, Sony starts selling the world's first rechargeable lithium-ion batteries based on Yoshino's design.[6]
- **2013** – Portland General Electric opens a 5-megawatt energy storage facility in Salem, Oregon. The Salem Smart Power Center was an industry-first in its use of lithium-ion battery technology in a large, utility-scale application.[7]
- **2018** – Wheatridge Energy Facility is the first state-jurisdiction approved battery-storage facility in Oregon.
- **2021**- The U.S. Department of Energy invests $27 million dollars in battery storage technology. It aims to support domestic manufacturing of next-generation flow batteries and increase equitable energy storage access.[8]

Electricity Storage in Oregon

There are more than **600 small-scale battery storage systems in Oregon**. Together these systems provide more than **8 megawatt-hours of backup power** for Oregon homes and small businesses. Many larger systems, co-located with solar and wind facilities, are planned or under construction. Oregon's Energy Facility Siting Council has approved applications for more than **400 MW of battery storage**, and nearly 3,000 MW of storage is in the application process.

Most energy we use directly can be stored in some form, like gasoline tanks on vehicles and at gas stations, or in natural gas and propane storage tanks. Electricity is unique because it must be used as it is created. The *fuel* (e.g., water, coal, or natural gas) used to generate electricity can be stored in many circumstances and used at the necessary time, and in other cases the fuel (e.g., wind, sunshine) cannot be stored. To store electricity once it is created, it must be converted into some other form of energy. There are four different categories of storage mediums used to store energy from electricity: electrochemical, chemical, mechanical, and thermal. Each of these categories includes different technologies. For example, lithium-ion batteries are a form of electrochemical storage, and pumped hydropower is a form of mechanical storage.

There are trade-offs for each type of storage, including varying levels of energy conversion efficiency, energy capacity, discharge time, lifetime, and physical space requirements. Conversion efficiency refers to the overall measure of how much energy is lost throughout the input and output cycle — for all storage technologies there is necessarily more energy input than energy output. It requires energy to convert electricity into another form of energy, and all forms of potential energy are subject to natural processes that slowly reduce the amount of energy stored.[i] There are also energy losses that result from the physical conditions of the storage medium. For example, lithium-ion batteries can lose more of their stored energy in colder weather, and pumped hydropower can lose more stored energy on hot and windy days due to evaporation.

Each type of storage technology results in greenhouse gas emissions, including from the extraction and processing of source minerals, production of components, transportation of source materials, components, and final products. These greenhouse gas emissions are not provided in this technology review, but instead discussions of climate effects focus on emissions associated with the electrical energy that is stored in each of these technologies.

Common Energy Storage Measurement Terms

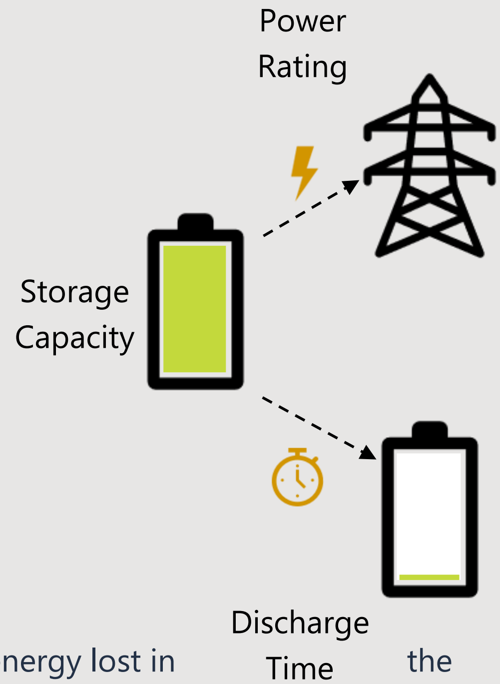
Storage capacity refers to the maximum amount of electrical energy that can be stored in a particular technology, expressed in megawatt-hours or kilowatt-hours. The maximum amount of electricity a technology can supply to the grid at any given moment is referred to as **power**, or in the case of batteries, the **power rating**, and is expressed in kilowatts or megawatts. The **discharge time** refers to how much time it would take for a storage technology to discharge electricity before it has spent all its stored energy. Discharge time may be constant for some types of technologies, such as flywheels, or it may be dynamic, such as batteries which can be discharged at varying rates.

For example, excluding inevitable energy losses, a 5-kWh capacity battery with a 1 kW power rating could discharge 1 kWh of electricity for five hours, or a battery with a power rating of 5 kW could discharge the same 5 kWh of electricity for one hour. For electric vehicles, the rate of charge and discharge for a battery is determined by the driver's needs. Utility-scale batteries, however, are

[i] The second law of thermodynamics states that as energy is transferred or transformed, more and more of it is wasted or lost.

often optimized to charge and discharge in a way that preserves the battery lifetime while also supporting grid services.[ii]

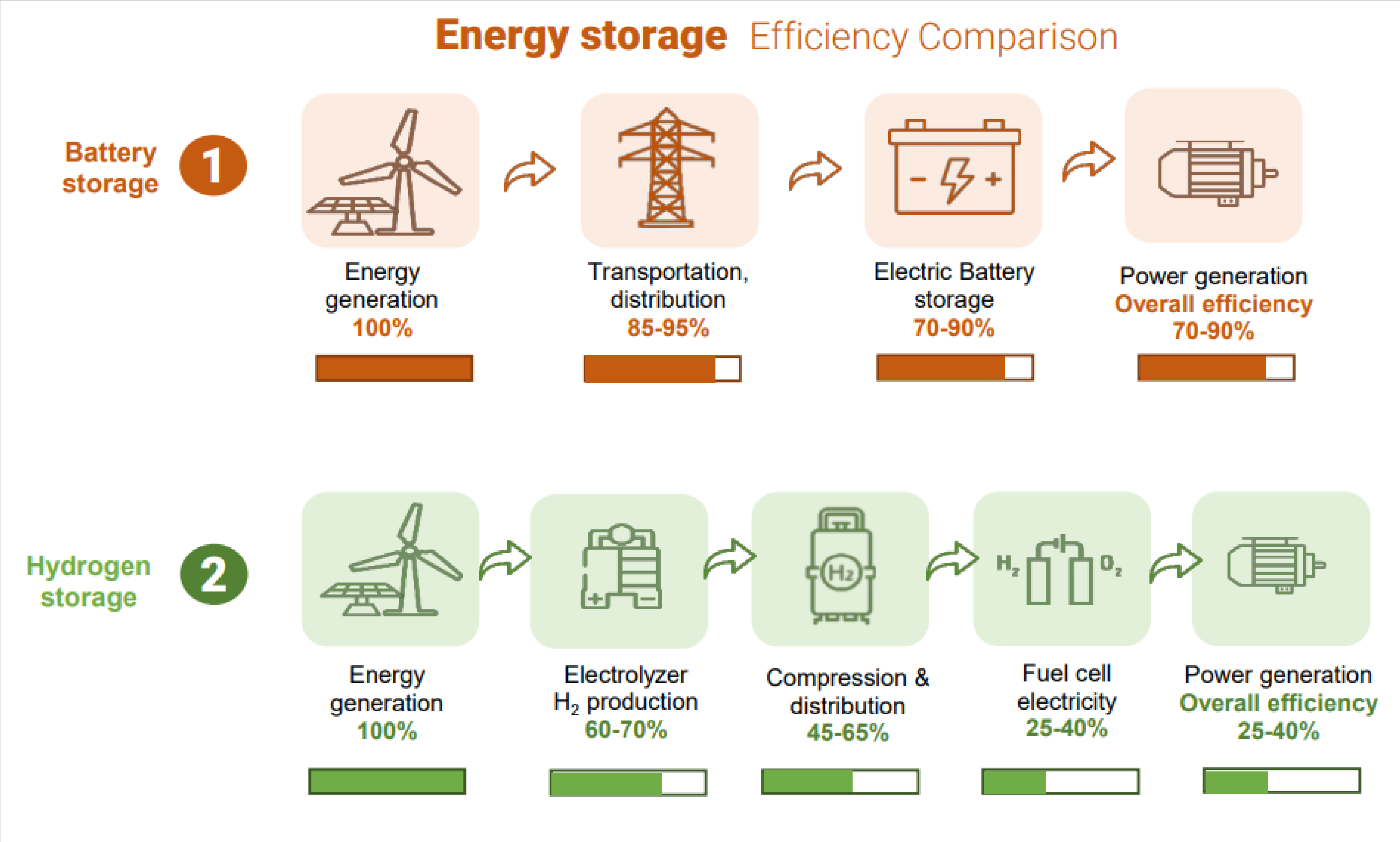
- **Storage Capacity or Energy Rating:** A measurement of the maximum volume of stored energy, in megawatt-hours (MWh) or kilowatt-hours (kWh), within a given storage technology.
- **Power or Power Rating:** A measurement of how much energy, in megawatts (MW) or kilowatts (kW), can flow out of a battery device and onto the power grid in a given instant.
- **Discharge Time or Duration (seconds to days):** A measurement of the energy-to-power ratio of the storage technology expressed as the amount of time that the technology can discharge at its maximum power rating until it has exhausted its energy supply.
- **Energy Density (watt-hour per liter):** The amount of energy stored in a given technology per unit volume.
- **Efficiency Rating (percent):** The amount of usable energy lost in the process of converting electricity to and from the storage technology.



The efficiency of a storage technology refers to how much energy is consumed or lost in the process to convert electricity to the storage medium and then convert it back into electricity. All electricity storage devices are net consumers of usable energy, meaning the amount of electricity delivered back to the grid will be less than the amount of electricity initially sent to the storage technology. Lithium-ion batteries are very efficient, returning about 85 to 98 percent of the energy they store back to the grid, whereas storing electricity by converting it to hydrogen requires large amounts of energy inputs and returns only about 25 to 45 percent of the electricity back to the grid.

[ii] Grid services are functions that help maintain a reliable electricity grid. They include maintaining the proper flow of electricity, addressing imbalances between supply and demand, and helping the system to recover after events like blackouts.

Figure 1: Efficiency Comparison of Different Storage Technologies[9]



Source: Company data, Goldman Sachs Global Investment Research.

Storage mediums also have limited lifetimes during which they can effectively store and release energy. The lifetime of the technology depends on different factors. Mechanical storage, such as pumped hydropower, tends to have longer lifetimes because limitations are based on mechanical and structural wear and tear, which generally can be maintained to last for a long time. Lithium-ion batteries are dependent on chemical processes that eventually degrade the chemistry of the battery terminals – much like rust accumulating on exposed metal – which diminish the capacity of the battery over time. Refurbishing batteries is generally not commercially available, so when batteries reach the end of their useful lifetimes for their original purpose, they are typically repurposed for another application.[10]

The physical space requirements, often referred to as energy density, can vary widely between different storage types. Electrochemical storage technologies tend to be very energy dense, which means more energy can be stored in relatively small spaces. Electrochemical storage devices like batteries are also scalable, meaning users can size the number of storage devices to meet specific storage needs. This modularity enables users to easily add to a site's total storage capacity. Other forms of storage, such as pumped hydropower, are less energy dense, requiring more space to store a similar amount of energy.

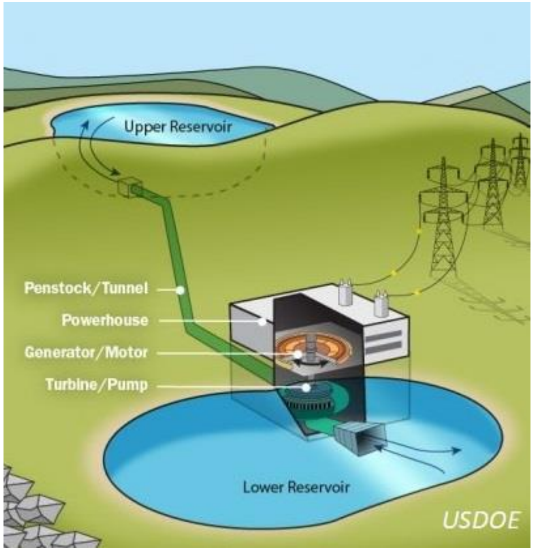
This technology review covers the four different types of storage forms, focusing largely on three specific technologies: pumped hydropower, battery storage, and hydrogen. These are the most common types of storage in the U.S., or in the case of hydrogen, have potential as a companion technology for renewable energy development.

Table 1: Comparison of Different Storage Technologies[1]

Storage Form	Storage Type	Power (MW)*	Discharge Time	Energy Density (Watt-hour /Liter)	Maximum Lifetime	Efficiency
Mechanical	Pumped Hydropower	100 - 1000	4 - 12 hours	0.2 - 2	30 - 60 years	70 - 85%
	Flywheels	0.001 - 1	10 – 20 milliseconds	20 - 80	20K - 100K cycles	70 - 95%
	Compressed Air	10 - 1000	2 – 30 hours	2 - 6	20 - 40 years	40 - 75%
Electro-chemical	Lithium-Ion Batteries	0.1 - 100	1 min - 12 hours	200 - 400	1000 - 10,000 cycles	85 - 98%
	Flow Cell Batteries	1 - 100	2 – 10 hours	20 - 70	12,000 - 14,000 cycles	60 - 85%
Chemical	Hydrogen	0.01 - 1	mins - weeks	600 (at 200 bar)	5 - 30 years	25 - 45%
Thermal	Molten Salt	1 - 150	hours	70 - 210	30 years	80 - 90%

** Power rating is based on typical storage devices today. Devices like batteries and physical mediums like hydrogen are easily scalable, meaning a particular site may have a much higher power rating.*

Mechanical Storage Technologies



Mechanical storage devices use kinetic or gravitational means to store energy. The most common form of mechanical electricity storage is pumped hydropower, which uses two bodies of water at different elevations to store potential energy[iii] in the water at the higher elevation. When electricity is needed, the water is allowed to flow downhill through an energy-generating turbine to the lower elevation reservoir. When electricity is plentiful (and often lower-cost), the water is pumped back up to the higher reservoir.[12]

There are other forms of mechanical energy storage, but they generally have limited applications. For example, flywheels convert electricity into stored potential energy by spinning a rotor that can release that energy to generate electricity. Flywheels are more amenable to high-power, low-energy storage needs, generally used to respond to

[iii] Potential energy is the energy stored in a physical body relative to its surroundings. For example, water at higher elevations has potential energy that can be captured when it flows downhill, or a coiled spring has energy that is released when it is allowed to uncoil.

minor fluctuations in the electrical grid.[13] There are only four flywheel energy storage sites operating in the U.S., none of which contribute to Oregon's electric grid.[14]

Trends and Potential

In 2019, pumped hydropower accounted for 93 percent of all utility-scale energy storage in the U.S.[12] The U.S. currently has the second highest proposed capacity of new pumped storage hydropower projects in the world after China.[7] The Grand Coulee Dam in Washington State – the largest hydropower generator in the U.S. – has an associated pumped hydropower project that can supply as much as 314 MW of capacity when fully operated.[16 17] In addition, projects in California, Colorado, and Arizona can also contribute to the electricity consumed in Oregon.[14]

There are no existing pumped hydropower systems in Oregon, but there are two proposed sites at different stages of permitting and development.

There are no existing pumped hydropower systems in Oregon, but there are two proposed sites at different stages of permitting and development.[18] The Swan Lake Energy Storage Project proposed in Klamath County received Federal Energy Regulatory Commission licensure in 2019, and is currently in the pre-construction phase.[19] As proposed, the project would have over 3,500 MWh of storage capacity.[20] A second, even larger, pumped hydropower facility has been proposed in Malheur County using Lake Owyhee as the lower reservoir. This project would link to the grid using the approved Boardman-to-Hemingway transmission line that will run within 10 miles of the proposed project substation.[21]

Development of pumped hydropower facilities involves extensive capital needs and complex permitting processes. These facilities generally have large capacities, from dozens to hundreds of megawatts, and require large land areas that necessitate environmental and cultural impact assessments. Like a conventional hydropower system, they can be highly flexible to meet changing power needs, such as balancing variable renewable energy resources like wind and solar. There are also high costs and permitting requirements if the owner/operator wants to expand the reservoir to provide additional storage capacity.[11]

Pacific Northwest Pumped Storage Hydropower Development Act[23]

Enacted as a part of the Infrastructure Investment and Jobs Act, signed by President Biden on November 15, 2021, a new law streamlines permitting processes for pumped storage projects. The bill assigns sole permitting authority to the Bureau of Reclamation for non-federal pumped storage development at federally owned reservoirs in the Pacific Northwest. Introduced by members of Congress from Washington State, the new law may encourage pumped storage development at some of the Federal Columbia River Power System dams in the region.

Beyond Energy

Pumped hydropower requires large areas of land to be converted to water reservoirs. This conversion of land can reduce biodiversity through impacts on existing freshwater habitats and land, including effects on fish species.[24] There is also an initial release of methane (a greenhouse gas) when reservoirs are first created due to the decomposition of organic material in the inundated areas. Pumped hydropower projects also require water. This is a concern in arid areas with limited water supply, and particularly where water to supplement the project comes from underground aquifers.[25] These effects are highly variable based on the surrounding landscape and biodiversity, and would require environmental analysis to effectively understand site-specific impacts.[26]

Any form of hydropower can affect lands and natural and cultural resources. In particular, tribal lands and sacred sites and resources have the potential to be damaged or destroyed. Many areas of Oregon have sites that are sacred to Tribes, including archaeological sites and areas where traditional foods and medicines are available and harvested. Previous inequitable policy decisions to flood sacred and productive tribal lands for hydropower use led to the submersion of important cultural resources, such as the Celilo Falls fishing community after the construction of The Dalles Dam.[27] Tribes have indicated that they must be included in discussions around projects like pumped hydropower to ensure their recommendations are incorporated into all project development and planning discussions and processes.[28]

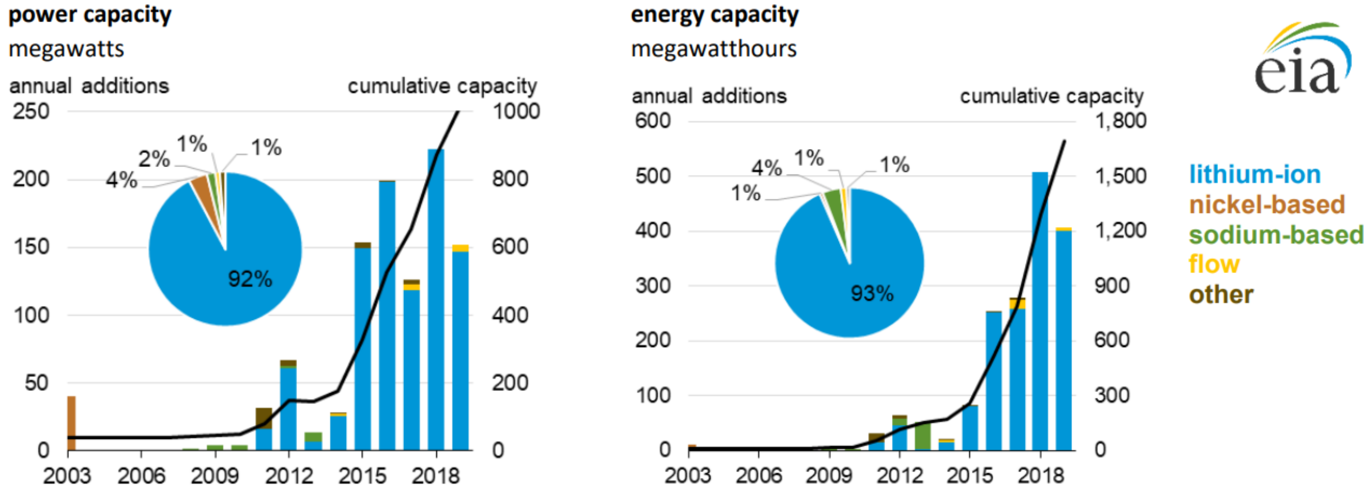
Tribes must be included in discussions around projects like pumped hydropower to ensure their recommendations are incorporated into all project development and planning discussions and processes.

Electrochemical Storage Devices

Electrochemical storage uses electricity to cause a chemical reaction that can be reversed later to generate electricity. The storage technologies for electrochemical reactions are called batteries. There are many types of batteries used for a wide variety of applications.[29] Lithium-ion batteries account for 98 percent of utility-scale battery use[30] and are the most commonly used in residential storage systems.[31] Compared to other battery types, lithium-ion are more energy dense, weigh less, are more energy efficient, perform better in higher temperatures, and maintain charge better when not in use.[29]

Other battery chemistries used by U.S. electric utilities include nickel, sodium, and lead acid. These chemistries have been used for a long time in the industry and accounted for about 6 percent of battery storage in 2019. These legacy storage batteries are often replaced with better-performing lithium-ion when upgrading facilities.[32] Redox flow batteries – a type of battery where the electricity-conducting fluid is contained in a separate tank until the battery is activated – are a relatively new technology that is largely used in pilot and demonstration type projects.[33]

Figure 2: Large-Scale Battery Storage Capacity by Chemistry (2003-2019)[32]



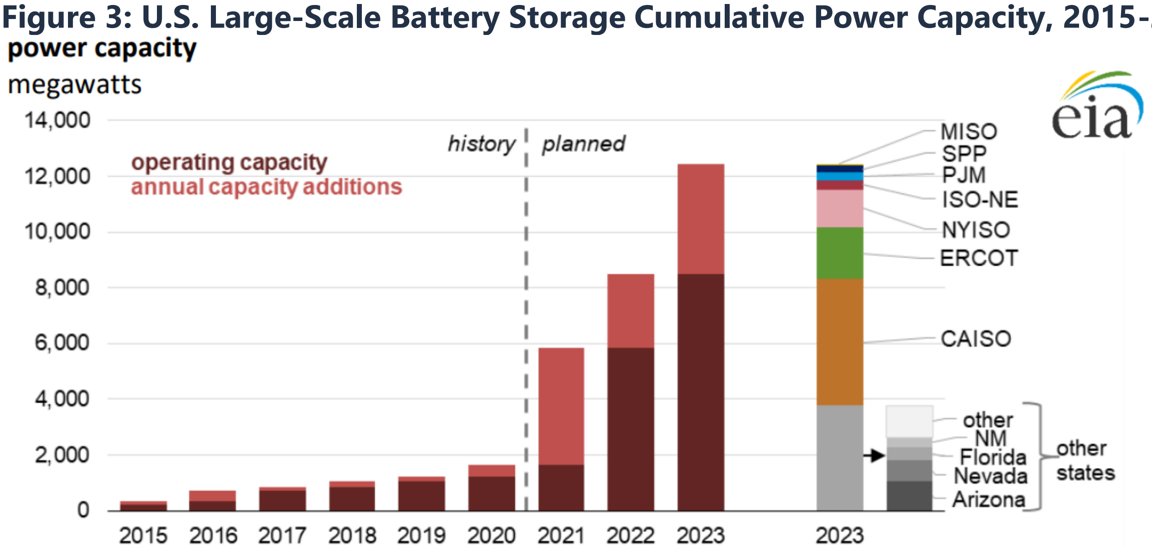
Source: U.S. Energy Information Administration, 2019 Form EIA-860, *Annual Electric Generator Report*

The ability to store electricity that can be dispatched at a later time can provide several different services to the grid. Batteries can support critical grid management functions on a second-by-second basis, shift supply to meet peak demand needs, enable better and more efficient use of variable renewable technologies, support more efficient and reliable transmission and distribution systems, and reduce energy costs by deferring large investments in infrastructure or taking advantage of minute-to-minute fluctuations in electricity generation costs.[34] Some battery types and configurations may be optimal for a specific function, but most utilities opt for lithium-ion batteries because they can meet all electric utility battery use case applications.[32]

Trends and Potential

Lithium-ion battery storage production is expected to continue its rapid increase in the next five years to meet demand for electric vehicles, consumer electronics, and increasingly for utility-scale and small-scale battery storage.[35] Lithium-ion battery costs have fallen 89 percent in the last decade, from over $1,200 per kWh in 2010 to $132 per kWh in 2021.[36] Global demand is expected to grow rapidly in the next decade, and lithium-ion batteries will likely dominate the storage market through 2025.

Figure 3: U.S. Large-Scale Battery Storage Cumulative Power Capacity, 2015-2023[37]



Source: U.S. Energy Information Administration, Dec 2020 Form EIA-860M, *Preliminary Monthly Electric Generator Inventory*

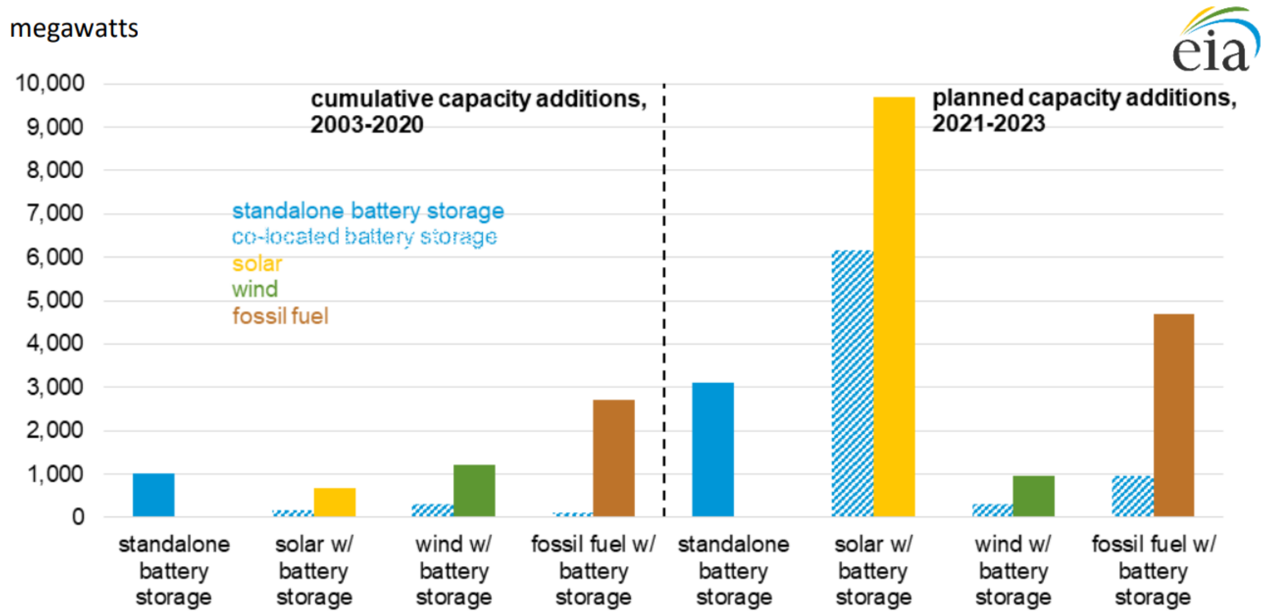
Utility-Scale Battery Storage

Lithium-ion battery use in the electricity sector is also expected to increase in the U.S. by more than 500 percent over the next five years, from 1,500 MW in 2020 to 7,800 MW by 2025.[38] In California alone, the California Independent System Operator anticipates more than 6,000 MW of battery storage will be online by 2024.[39] To date, most battery storage has been used to maintain second-to-second grid stability by charging and discharging in small amounts, and integrating solar and wind generation is expected to be one of the biggest drivers for utility-scale batteries in the years ahead.[40] They store energy at times when wind and solar are plentiful and electricity supply exceeds demand; the batteries then discharge their stored energy back to the grid as electricity when renewable generation resources are limited.

Batteries can also lower costs for utilities by reducing the need to purchase expensive electricity on the market when demand is high, or by deferring the need to build infrastructure to meet growing electricity demand. They can also address transmission line congestion by storing energy so it can be transmitted at times when there is more capacity, reducing the need for transmission expansions or upgrades. Batteries are especially useful to address daily electric load patterns, such as storing energy when solar production is high in the middle of the day and then supplying energy to the grid in the early evening when electricity demand is high and the solar resource is waning.[34]

Most utility-scale storage in the U.S. are standalone sites, which provide general grid support, but increasingly batteries are being sited with renewable energy facilities. This trend is driven by lower costs for battery production and incentives that require co-locating with renewable resources. By 2023 it is expected that 60 percent of batteries will be co-located with wind and solar projects, as shown in Figure 4.[41] In Oregon, Portland General Electric's Wheatridge Renewable Energy Facility is one of the first facilities in North America to site wind, solar, and battery storage at one site.[42]

Figure 4: U.S. Large-Scale Battery Storage Power Capacity Additions, Standalone and Co-Located[37]



Source: U.S. Energy Information Administration, Dec 2020 Form EIA-860M, *Preliminary Monthly Electric Generator Inventory*

Note: Solid yellow, green, and brown bars indicate generating total capacity of solar, wind, and fossil fuels that have battery storage on-site.

Inflation Reduction Act Support for Storage

In August 2022, the Biden Administration signed into law the Inflation Reduction Act, providing funding for programs and actions across multiple sectors, including clean energy development.[43] The IRA extends the Investment Tax Credit for renewable energy projects, including both standalone battery storage projects and renewable energy generation co-located storage systems. The tax credit starts at 6 percent of the project development cost but increases to 30 percent if certain labor practices are used in the development of the project, and can increase an additional 10 percent if the project meets domestic content requirements. It can be applied to battery, thermal, or hydrogen energy storage projects with at least 5 kWh nameplate capacity. The new law also allows for cash payment options in lieu of tax credits that can be used by tax-exempt organizations, including state and local governments, Tribes, and others.

Batteries can mitigate transmission and distribution line issues, such as congestion on segments with heavy usage or to manage voltage levels at the ends of long lines.[44] Electricity can be stored in batteries to be transmitted when the lines are less congested. That power would then be available when demand is high and without the need to transmit the electricity across congested lines. Similarly, batteries can store energy at the ends of long distribution lines, which can help to maintain grid.

Although lithium-ion batteries are the predominant battery chemistry used today, new battery chemistries have the potential to improve upon capabilities. Solid-state batteries are one of the most discussed and potentially market-altering new types of battery, which have the potential to become commercially available in the next few years.[45] Unlike the lithium-ion batteries in use today, which use liquid electrolytes, solid state batteries use electrolytes made of a solid material. This innovation could make batteries safer, more affordable, and improve overall battery performance, including faster charging times. Many solid-state chemistries have been demonstrated as viable, with businesses and U. S. Department of Energy laboratories working toward commercialization pathways.[46] Other types of batteries may be necessary for advancements in long-duration storage (see the Long-Duration Storage Energy 101).

Small-scale Battery Storage

The residential and commercial sectors in the U.S. account for about 41 percent each of total small-scale[iv] storage installations, with the industrial sector at about 14 percent.[v] The remaining 4 percent is directly connected to the grid, usually for utility-run small-scale storage. There were 402 MW of small-scale battery storage capacity in the U.S. in 2019. California accounted for 83 percent of that, largely due to state incentives that support small-scale storage installations and state requirements for 325 MW of customer-sited storage capacity to be installed by 2024.[47]

[iv] Small-scale battery storage systems are defined as those that have less than 1 MW of generating capacity.

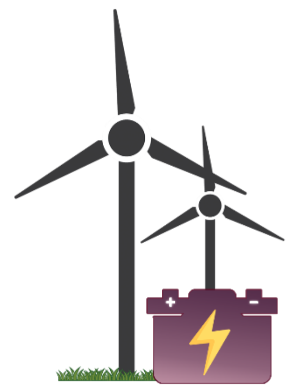
[v] This includes only small-scale storage reported to the U.S. Energy Information Administration. Small-scale storage that has been added on the customer side of the meter and not reported to the local utility may not be included.

There are more than 600 small-scale energy storage systems in Oregon totaling more than 8 MWh of energy storage. The adoption of small-scale storage is limited in the Pacific Northwest by high up-front costs coupled with low electricity costs. This makes them less cost-effective than in parts of the country where retail electricity prices are higher. Battery storage can be particularly economical for customers that have time of use electricity rates, where the retail cost for electricity varies at different hours of the day. The option to store low-cost electricity for use at times when costs are higher makes an energy storage investment pay for itself more quickly.

The Oregon Department of Energy runs the Oregon Solar + Storage Rebate Program, which issues rebates for solar electric systems and paired solar and storage systems for residential customers and low-income service providers. To date, the program supported the installation of more than 200 small-scale storage projects in Oregon homes. The 2022 passage of the federal Inflation Reduction Act will also provide tax credits for small-scale storage. See ODOE's *2020 Biennial Energy Report* for more information on residential-scale battery storage.

Beyond Energy

Batteries that supply electricity to the grid are not inherently zero-carbon but take on the emissions of the type of electricity used to charge them. In theory, this would mean that a battery charged with solar or wind power would have zero emissions, whereas a battery charged with electricity generated by natural gas would have the same amount of carbon as that natural gas source. In practice, the emissions profile associated with batteries is more complex, largely driven by when and where batteries are charging and discharging. At any given point in time, grid electricity is a mixture of both non-emitting and carbon-emitting resources, which contribute to the charging of the battery.



Batteries can be co-located directly with zero-emission generating resources, like wind or solar projects. The identification of the carbon emissions impact of this, however, is not straightforward and is not zero by default. For example, if a solar project could export energy to the grid and displace the use of carbon-emitting energy in real-time, then co-locating a battery to otherwise store that solar energy could result in more carbon emissions on the system than if the solar project had been allowed to discharge directly to the grid. In other circumstances, a co-located battery could enable using more solar output than would have otherwise occurred. In addition, batteries can also be used to optimize the operation of carbon-emitting resources, which would have the effect of reducing its overall emissions. For example, Portland General Electric added battery storage to their Port Westward natural gas plant, allowing that plant to operate more efficiently, reducing fuel use and emissions at the plant.[48]

Lithium-ion batteries are made of raw materials such as lithium, cobalt, nickel, and graphite.[49] These minerals are largely mined and refined in foreign countries. Domestic reserves of these and other minerals often constitute less than 5 percent of the total world capacity, as shown in the table below.

Table 2: Comparison of U.S. Mineral Reserves and Manufacturing Capacities vs. the World[50]

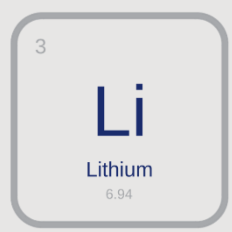
Element	U.S. Reserves (1,000 Metric Tons)	Percent of U.S. Reserves	World Reserves (1,000 Metric Tons)	Total Manufacturing Capacity w/ US. Reserves (GWh)*	Total Manufacturing Capacity w/ World Reserves (GWh)*
Lithium	750	3.6%	21,000	7,470	209,163
Cobalt	53	0.7%	7,100	703	94,164
Nickel	100	0.1%	94,000	167	156,510
Manganese	230,000	17.7%	1,300,000	3,271,693	18,492,176

**Reflects the estimated total capacity of batteries that could be produced with this element.*

Although new technologies are being developed to reduce dependence on certain minerals, the expected dominance of lithium-ion batteries in the near future means the U.S. is dependent on foreign nations for raw material supply unless new domestic mines are developed and begin production. In many countries where mining provides a large share of national revenue, the practices at the operations may have negative effects on local communities due to environmental damage, human rights abuse, and inadequate safety and health standards.[51] The USDOE has collaborated with the Federal Consortium for Advanced Batteries to develop a *National Blueprint for Lithium Batteries* for the next decade, which provides guidance on supporting the development of domestic resources, materials processing, battery manufacturing, and end-of-life recycling strategies.[30] The 2022 Inflation Reduction Act included incentives for the development of domestic resources and component manufacturing as well as requirements that a percentage of minerals come from North America or a country that has a free trade agreement with the U.S. The act provides an additional 10 percent investment tax credit for projects using 100 percent U.S. steel and iron, and a percentage of the total costs of the project from components that are mined, manufactured, or produced domestically. The percentage is set at 40 percent initially and increases every year beginning in 2025 to 55 percent by 2028.[43]

Potential Lithium Resources in Oregon

The Oregon Department of Geology and Mineral Industries approved three applications for HiTech Minerals to explore lithium deposits located in southern Malheur County near the Nevada border. HiTech's parent company, Jindalee, estimates that the site has over 10 million metric tons of lithium, or more than 13 times the total amount of current U.S. lithium reserves.[52]



The U.S. Department of Energy estimates that by 2031 there will be 2 million tons of end-of-life *electric vehicle* batteries alone. Recycling batteries can reduce reliance on foreign raw materials and component production, lower overall battery manufacturing costs, and reduce waste and waste disposal costs.[53] Currently, recycling batteries is expensive, largely driven by costs to appropriately handle and transport the batteries for recycling and disposal. The National Blueprint for Lithium

Batteries includes a goal to "enable U.S. end-of-life reuse and critical materials recycling at scale and a full competitive value chain in the United States," which calls for incentives for battery recycling and the development of federal policies to require the use of recycled material in battery cell manufacturing.[54]

The U.S. Department of Energy's ReCell Center conducts research and development on advanced battery recycling techniques and leads multiple programs to support more efficient and cost-effective battery recycling.[55]

Lithium-ion batteries have the potential to cause fires or explosions when they fail or are mishandled. When batteries malfunction or are damaged, the internal temperature of the battery rises. Rising temperatures inside the battery can lead to the release of toxic and explosive gases, which can cause fires. This can cause a cascading reaction as one cell in a battery explodes, damaging adjacent cells that subsequently also catch fire and potentially explode. Batteries that are stored and maintained properly are at low risk for failure, but battery owners can also reduce their risk by: regularly inspecting batteries for damage or failure, including fire suppression systems and explosion protection devices in the storage facility design, following National Fire Protection Association standards, and designing an emergency operations plan in coordination with the local fire department.[56]

Increased use of batteries can support jobs across many economic sectors, including mining, raw materials processing, manufacturing, and transportation of materials and goods. As the U.S. identifies and supports raw materials production and processing, as well as battery manufacturing and recycling opportunities, new economies will be created to support the increased demand for batteries. Some of the jobs will be driven by geographic availability of raw materials, while manufacturing and recycling may be driven by proximity to raw material streams, the availability of low-cost and renewable forms of electricity, or the availability of a trained workforce.

Chemical Storage Technologies

Chemical storage involves storing energy in chemicals that can be later used to generate electricity.[57] Natural gas, coal, and diesel fuel are examples of chemical energy storage until they are combusted to produce large amounts of energy. This energy was "stored" hundreds of millions of years ago from decaying plant matter that eventually formed these hydrocarbons. In addition to energy stored by the earth's natural processes, energy can be stored in chemicals made specifically for this purpose. One form of chemical energy storage today is creating hydrogen from natural gas or water – the resulting hydrogen can then be combusted to spin turbines or run through a fuel cell to generate electricity. Other technologies and processes can be used to store energy from electricity by creating ammonia, methanol, and methane.[57]

Hydrogen can be used to fuel combustion turbines that generate electricity, either blended with ammonia or natural gas or as pure hydrogen. In some parts of the industrial sector, such as steel mills, refineries, and petrochemical plants, hydrogen – a byproduct of these industrial applications – has been used for on-site electricity generation for more than 20 years.[58] Most existing natural gas turbines can run on low blends of hydrogen with minimal changes to the turbine, although upgrades to the plant are necessary to be able to store and blend the hydrogen.[59] To utilize higher blends of hydrogen, turbines must be retrofitted to account for physical differences between natural gas and hydrogen to ensure turbines are not damaged and can operate as effectively. Manufacturers are also developing turbines capable of using up to 100 percent hydrogen that could be installed at existing natural gas plants.

Trends and Potential

ODOE is not aware of any commercially operating sites in Oregon to create and store chemicals using electricity that can be used later to provide electricity back to the grid. Electrolyzers have existed for more than a century, but the practice of using these to store energy is not widely adopted today — though several projects are in development. The Advanced Clean Energy Storage hub is expected to go online in 2025 with an 840 MW turbine that will be capable of using renewable hydrogen stored in a salt cavern in Delta, Utah.[60] In Washington State, Douglas County Public Utility District held a ground-breaking ceremony on March 12, 2022, for a 5 MW hydrogen production facility that will help that utility provide more flexible electricity operations.[61] NW Natural filed an application at the Oregon Public Utility Commission for approval to build an electrolyzer project that would use electricity from the Eugene Water & Electric Board to generate clean hydrogen that will subsequently be mixed into the natural gas supplied to a small number of customers in the Eugene area. This project will help NW Natural confirm that its system standards, procedures, and equipment, along with downstream appliances, will be able to accommodate a 5 percent or higher blend of hydrogen.[62] The company is now testing hydrogen blends at its training facilities to assess the effect of blending hydrogen up to 20 percent in its distribution system.

NW Natural and the Eugene Water & Electric Board plan to partner on a project that will generate renewable hydrogen. The H2 will be mixed into the natural gas supplied to a small number of customers in the Eugene area.

There are many benefits associated with chemical storage, most notably the higher total energy capacity and longer lifetime than many other forms of storage.[57] Chemical storage systems can store energy for much longer periods of time – provided an appropriate containment vessel – than can electrochemical or thermal storage systems. However, powering the grid with non-petroleum derived chemicals costs more than simply combusting natural gas or coal because the infrastructure needed to safely create, store, transport, and handle the hydrogen – or other chemicals – is not yet fully developed.[63] Converting electricity to hydrogen, ammonia, or other chemicals to store the energy also has lower round-trip energy efficiencies (meaning it loses more energy as waste) than other forms of storage, which increases the plant size necessary to achieve equivalent storage capacity.[57]

Beyond Energy

Chemicals that store energy can have uses beyond electricity generation. Hydrogen and ammonia can be used as transportation fuels or in industrial applications, creating more potential revenue streams beyond energy storage.[57] For example, hydrogen sold as a transportation fuel can have a higher rate of return because it can benefit from revenues derived from participation in the federal Renewable Fuels Standard or Western states' low carbon fuels standards, such as the Oregon Department of Environmental Quality's Clean Fuels Program. For more on hydrogen, see the Hydrogen Energy Resource & Technology Review.

Storage of any chemical comes with safety risks. Combustible chemicals like hydrogen, methane, and methanol must be handled and stored correctly to avoid fires and explosions. Chemicals like ammonia[64] and methanol[65] can be harmful in large doses, requiring safe handling to avoid damaging the environment in case of accidental release. Without physical adjustments to the mechanical combustion mechanism on the turbine, hydrogen fuel has the potential to emit more oxides of nitrogen – an air pollutant that can lead to smog – than natural gas.[66] [67] Other forms of storage chemicals, such as methane and methanol, also have associated greenhouse gas emissions when burned, and potential emissions if leaks occur during transport.

Thermal Storage Technologies

Thermal energy storage uses surplus energy – excess electricity or waste heat – to store energy for later use by heating or cooling a medium (a solid, liquid or gas) that can be used at a later time.[68] This generally involves storing heat from solar radiation or industrial processes by heating water, which can be used later as the building's hot water supply or to help provide ambient heating. Waste heat from the cooling of buildings can also be captured and used for the same purpose, making more efficient use of the heating and cooling needs in a building or a collection of buildings connected via district heating. In addition to heating, excess electricity can be used to freeze water that provides cooling to the building.[69] Water is the most common storage medium, but solid mediums like rock can also be used.[70]

Concentrating solar-thermal power plant. Photo: U.S. Department of Energy

Concentrating solar-thermal power plants[vi] are the only form of utility-scale thermal energy storage in use in the U.S. These plants use a large array of reflectors (mirrors) to concentrate solar rays at a receiver that captures the thermal energy.[71] A molten salt tank that is capable of soaking up and retaining the heat can be added to this system to store some or all of the heat for later use.[72] Like other thermal generation plants, such as natural gas and coal, the captured heat is used to create steam to spin turbines. The heat stored in the

[vi] Concentrating solar-thermal power plants, which use large mirrors to concentrate solar energy to heat up a substance, differ from photovoltaic solar, which collects photons of solar energy to generate electricity.

molten salt enables the plant to run the generator even after the sun goes down.[73] This effectively reduces the variability of solar-based energy production by enabling operators to choose when to dispatch electricity generated. Only direct sunlight can be effectively concentrated, so concentrating solar thermal plants work best in areas with high direct solar irradiance, such as the southwestern United States.[73] The only concentrating solar-thermal plants with thermal storage operating in the U.S. are in California and Arizona,[74] but thermal energy storage could be coupled with any heat-producing electricity generation unit, such as nuclear power.

Thermal Energy Storage and Nuclear Power

Nuclear electricity generators generally provide a steady supply of electricity to meet the constant and ongoing electrical power needs. However, nuclear technology does not have the ability to easily ramp up or down to meet changing demand needs for the grid. Pacific Northwest-based TerraPower received USDOE Advanced Reactor Demonstration Program funds to develop a new type of nuclear reactor with a molten salt thermal storage component.[75] The storage piece can boost the reactor's energy capacity from 350 MW to 500 MW for over five and half hours. The storage can also be used to boost and lower the electricity output, making it a more flexible generator than today's nuclear technology. TerraPower estimates that the new reactor and storage system will be commercially available at the end of the decade.

Trends and Potential

Utility-Scale Thermal Energy Storage

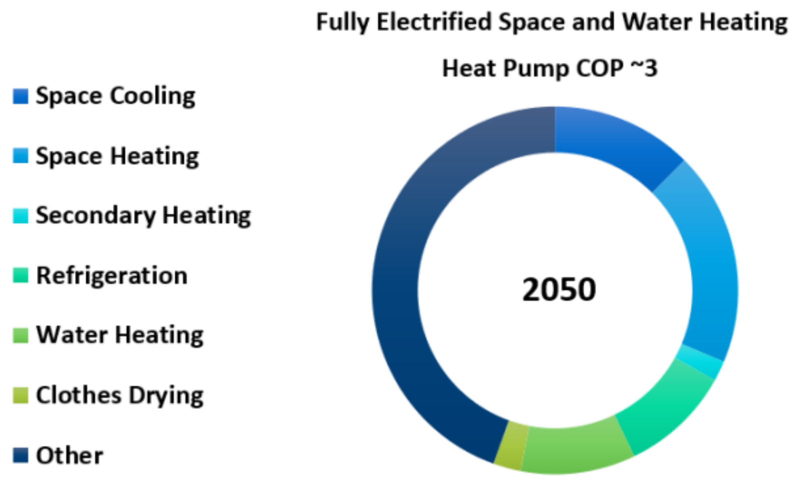
Concentrating solar-thermal generation accounts for 1.7 GW of electricity capacity in the U.S., and of that, only 360 MW has associated thermal storage capacity.[73] [74] No concentrating solar-thermal plants have been brought online since 2015, largely due to the dramatic cost reductions for solar PV and lithium-ion batteries that have made these solar-thermal plants look much less cost-effective by comparison. It may be possible, however, to add more thermal storage capacity to existing concentrating solar-thermal plants to increase the value of these existing facilities. In 2022, solar-thermal generation plants coupled with thermal storage are not cost competitive with other generation resources, such as natural gas, wind, and photovoltaic solar.[76]

Thermal energy storage deployment with concentrating solar generation plants increases the cost effectiveness of the solar plant because it enables the plant to provide electricity to the grid outside daylight hours. Although the total capacity of the plant is not changed by adding thermal energy storage, its capacity factor – the percentage of actual energy output compared to the maximum potential energy output – is increased.[73] This is particularly useful in the southwestern U.S., where electricity loads tend to ramp up in the evening at the same time the sun is setting and solar power generation is waning. The higher overall costs of this type of electricity generation have stalled further construction of concentrating solar thermal plants. However, the associated storage may have applications with other heat-generating resources.

Building-Scale Thermal Energy Storage Systems

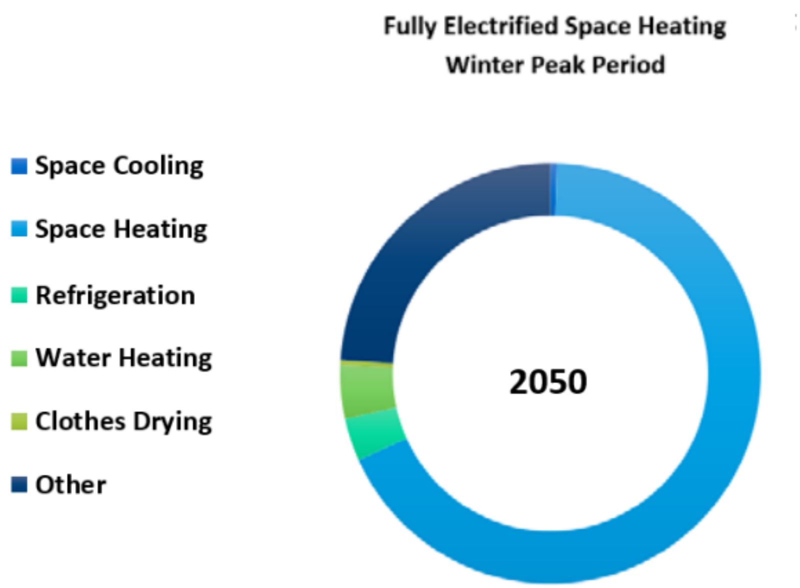
Thermal energy storage systems in buildings have the potential to help better manage building energy use, including reducing the building's peak energy load and providing grid reliability benefits.[77] The residential, commercial, and industrial sectors account for nearly 70 percent of all energy consumption in Oregon, much of which is spent to heat or cool a building or drive industrial processes. On average, heating and cooling loads account for 45 percent of annual electricity consumption in residential and commercial buildings, which is reflected in Figure 5. This percentage can increase when demand is higher due to heat waves and cold snaps. Building thermal energy loads are expected to grow by 2050, increasing to more than 50 percent of building electricity consumption and exceeding 75 percent during peak electricity demand times as shown in Figure 6.

Figure 5: Annual Electrical Energy Consumption in Residential and Commercial Buildings for Space and Water Heating[78]



Graphic modified from its original.

Figure 6: Peak Period Electrical Energy Consumption in Residential and Commercial Buildings for Space and Water Heating[78]



Graphic modified from its original.

Thermal energy storage is not adopted at the levels of lithium-ion electrochemical battery storage. For on-site storage in buildings, lithium-ion storage accounts for about 500 times more overall energy storage than thermal energy storage.[79] Thermal storage systems could operate in concert with battery storage systems to store energy and support heating and cooling activities at times when electricity is plentiful, while thermal energy storage technologies could further reduce the need for electricity to support heating and cooling.

Beyond Energy

Thermal energy storage options can help reduce greenhouse gas emissions from buildings. Buildings are overwhelmingly the largest consumer of electricity during peak loads.[78] Increasing storage capacity to shift building energy loads could reduce greenhouse gas emissions. Thermal energy storage could be a valuable tool for utilities to more effectively integrate and utilize variable renewable energy resources.

Building thermal energy storage has the potential to reduce energy costs. For example, ice storage systems can be set to operate overnight and provide cooling energy and lower energy use during the heat of the day during peak load periods. Other thermal storage, like water heaters, can supplement the electricity needed to create hot water, reducing the overall costs for the home or building owner. There is limited information on the costs of installation and operation for these technologies. In 2021, the U.S. Department of Energy hosted a workshop focused on priorities and pathways to the widespread deployment of thermal energy storage in buildings. A survey of those in attendance indicated that the main barriers to adoption are a lack of awareness of system costs, performance metrics, and value addition, followed by a lack of incentives.[80] More information is needed to fully understand the potential value of thermal energy storage systems for building owners and utilities.

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Energy Resource & Technology Review: Hydrogen

Timeline

- **1800** – English scientists, William Nicholson and Sir Anthony Carlisle, discover how to produce hydrogen and oxygen gases by applying an electric current to water. This process would later be known as "electrolysis."[1]
- **1807** – François Isaac de Rivaz constructs the first wheeled vehicle with an internal combustion engine in Switzerland. The engine is powered by a mixture of hydrogen and oxygen for fuel.
- **1923** – J.B.S. Haldane proposes a hydrogen-based renewable energy economy in a speech delivered at Cambridge University entitled: "Daedalus or Science and the Future."[2]
- **1956-1958** – The United States Air Force funds the development of a hydrogen-fueled reconnaissance aircraft. Although eventually cancelled, the project would lead directly to the first rocket engine powered by hydrogen.[3]
- **1959** – Francis T. Bacon, at Cambridge University, builds first practical hydrogen-air fuel cell. Named the "Bacon Cell", it is the fuel cell that would provide power to supply electricity to operate and power the Apollo missions.[4]
- **1970** – Electrochemist John Bockris coins the term "hydrogen economy" during a talk at the General Motors (GM) Technical Center in Warren, Michigan. It refers to the use of hydrogen to decarbonize "hard-to-abate" economic sectors such as cement and steel production, long-haul transportation, etc.
- **2021** – The United States Department of Energy launches its "Hydrogen Shot" through the Energy Earthshots Initiative. The goal of the project is to reduce the cost of clean hydrogen by 80 percent so that it costs $1 per kilogram by the end of the decade.

Hydrogen is the lightest element in the universe, and the most abundant. On Earth, it is found in the greatest quantities within water molecules, and is present as a gas in the atmosphere only in tiny amounts – less than 1 part per million by volume. It does not exist freely in nature and must be extracted from other sources like water and fossil fuels.[5] It is considered to be an energy carrier, not an energy source, in part because energy is required to separate, or extract, hydrogen from these sources.[6] The most common pathway to produce hydrogen today uses steam to separate the hydrogen from methane in natural gas (known as steam methane reformation, or SMR).[7] Hydrogen created from fossil fuels like natural gas is responsible for about 700 million metric tons of CO2 emissions per year globally — roughly equivalent to the total annual greenhouse gas emissions of the United Kingdom and Indonesia combined.[8]

Lower-carbon and zero-carbon hydrogen – often referred to as clean hydrogen – can be produced through several pathways, including electrolysis of water with renewable electricity or natural gas/renewable natural gas coupled with carbon capture and sequestration technology, among others. Renewable hydrogen is produced using renewable feedstocks. There's no single definition for renewable hydrogen – some limit its use to only electrolysis using renewable electricity while others may include biogenic pathways that use biomass or microorganisms.

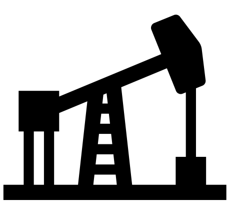
The industry describes hydrogen based on its carbon intensity, such as *clean* or *low carbon*.

Hydrogen is sometimes described using different colors to denote the feedstock used to produce it: "gray" for fossil fuel-based feedstock, "green" for renewable sources like solar or wind, and "blue" for fossil fuel-based feedstocks using carbon capture and sequestration technologies.[9] While the color label can give some idea of the environmental impact associated with the production of hydrogen, it does not provide quantitative specifics on the associated greenhouse gas emissions. For this reason, the industry is quickly moving to instead describe hydrogen based on its carbon intensity with terms like "clean" or "low carbon."

Assessing hydrogen *strictly* according to carbon intensity describes only the associated carbon content, and some environmental advocates have indicated a distinction should continue to be made between renewable and non-renewable hydrogen because using fossil fuel feedstock would support continued reliance on these fuels and slow down decarbonization efforts. Others counter that the road to full decarbonization is expensive and hydrogen produced from fossil fuels with carbon capture and sequestration is a critical intermediate step to building a hydrogen economy that will move closer toward zero emissions over time.[i]

Hydrogen Use

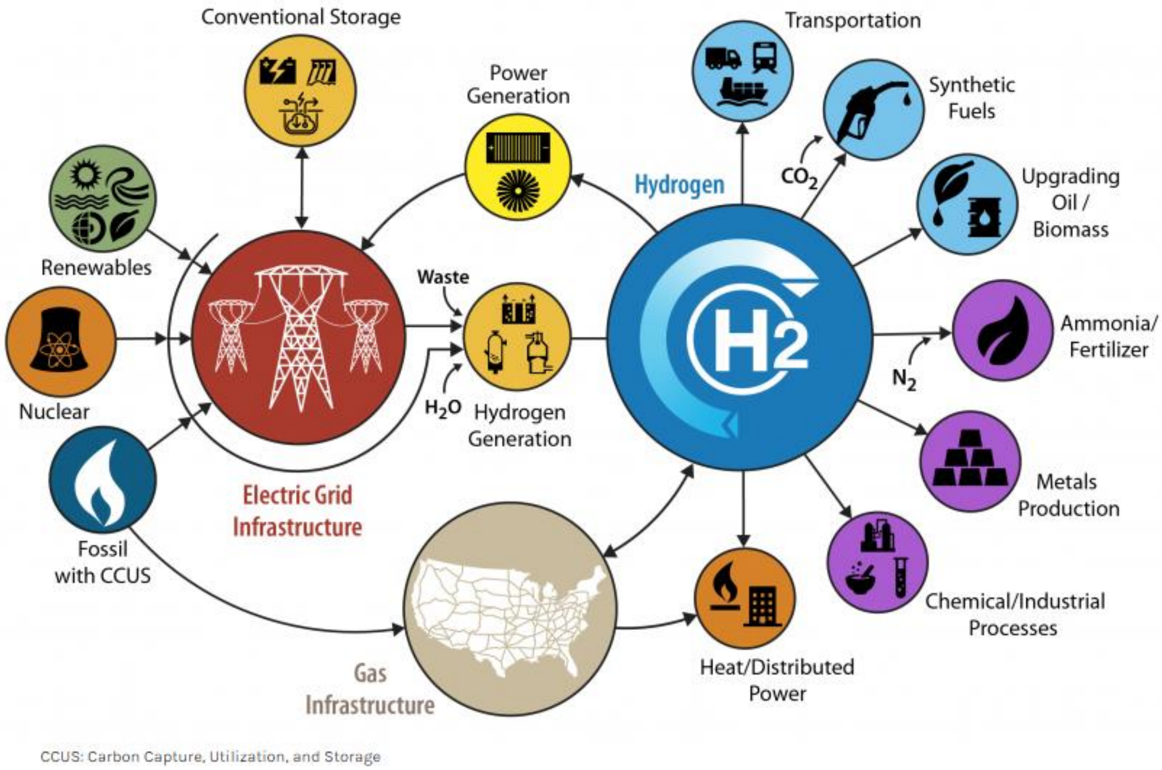
Hydrogen is used predominantly in industrial applications, such as petroleum refining, production of steel and other metals, food processing, and chemical production.[10] It is the primary feedstock for the production of ammonia, about 80 percent of which is used to manufacture fertilizers.[11] Oil refining accounts for about 33 percent of total global demand for hydrogen, where it is used in the refining processes to reduce the sulfur content of petroleum fuels and to transform heavier, low-quality crude oil into lighter, higher-value petroleum products.[12] The refinement process generates some hydrogen, which is typically captured on site to be used in the sulfur removal and other refinement steps. On average, about a third of the hydrogen used by refineries comes from this on-site hydrogen byproduct. The remaining hydrogen is provided by hydrogen production facilities, usually owned and operated by the refinery, and from suppliers.[13] Commercial supplies of hydrogen are also mostly produced from natural gas.[14]



In addition to its current uses, hydrogen is increasingly considered as an option to reduce greenhouse gas emissions in sectors where the option to electrify is either too costly or not technologically feasible. Potential new end uses of hydrogen include as fuel for medium- and heavy-duty transportation, rail, and aviation; long-duration energy storage; or as a substitute for natural gas combustion in high-heat industrial processes, among others.

[i] For more information, see the Oregon Department of Energy's *2022 Renewable Hydrogen Report* (Available November 15, 2022): https://tinyurl.com/ODOE-Studies

Figure 1: Hydrogen Uses[37]



Hydrogen can be used to power fuel cell electric vehicles, which convert the hydrogen to electricity that powers the vehicle (see the Clean and Efficient Vehicles Technology Review for more). Hydrogen offers several advantages compared with battery powered vehicles, including faster refueling times, longer ranges, less sensitivity to cold temperatures, and the ability to maximize payload for heavy-duty trucks because of its lightweight and high energy density. Most of the hydrogen fueling stations in the U.S. are in California, which has provided state investments and support to establish hydrogen fueling infrastructure.[15] This initial support has driven FCEV adoption and increased the demand for and development of more hydrogen fueling stations.[16]

Hydrogen could be used to power turbines that generate electricity; however, there are no existing all-hydrogen electricity generators operating in the U.S. It can also be mixed into the natural gas pipeline at volumes of up to about 20 percent, based on information from projects in Europe and pilot projects in the U.S. The physical properties of hydrogen differ from natural gas, which is the limiting factor in how much hydrogen can be blended into existing natural gas infrastructure.[17] In particular, hydrogen can corrode and embrittle some metals, meaning infrastructure such as pipelines, pumps, plumbing, and appliances may need to be upgraded or replaced to carry or combust high concentrations of hydrogen. These effects are minimized when hydrogen is blended with natural gas at lower concentrations.

Trends and Potential

Hydrogen use is expected to grow through 2030, largely due to increasing demand for methanol and ammonia to support agricultural needs, iron and steel production, and crude oil refinement.[18] Beyond 2030, hydrogen demand will remain high, but continued growth will depend on global policy choices and strategies to decarbonize industrial and transportation end uses. Demand for hydrogen could continue to rise over the next several decades if policies and programs are instituted that heavily support the uptake of hydrogen-fueled vehicles.

Clean hydrogen production is also anticipated to increase in the next decade, but the rate of growth is dependent on the cost to produce clean hydrogen compared to natural gas steam reformation. The infrastructure and equipment to generate hydrogen from natural gas are largely in place today, whereas producing clean hydrogen would require capital investments to build electrolyzers. Policy supports for this development, such as the production tax credit included in the Inflation Reduction Act, are necessary for clean hydrogen to be cost competitive.[19] Goldman Sachs forecasts that renewable hydrogen could reach cost parity with hydrogen from fossil fuels as soon as 2025 in some regions.[20]

U.S. Department of Energy Hydrogen Shot – The "1 - 1 - 1 Goal"[21]

Hydrogen Shot is a program that seeks to reduce the cost of clean hydrogen by 80 percent to $1/kilogram in 1 decade. Currently clean hydrogen costs about $5/kilogram, and reducing costs by 80 percent would open up new end-use markets for this fuel. If achieved this could revolutionize hard-to-decarbonize industries like steel manufacturing, ammonia production, heavy-duty freight, and long-term energy storage. Hydrogen Shot was launched on June 7, 2021 and is the first US DOE Energy Earthshot program to address the most challenging barriers to reducing greenhouse gas emissions.

Crude Oil Refining

Hydrogen is a key resource for the oil refineries that provide gasoline, diesel, and other fossil fuels to Oregon. Although global oil demand is likely peaking today, the demand for lower sulfur and lighter distillate crude oil products – which require hydrogen as a feedstock – is expected to rise through 2030. Even as many vehicles are converted to zero emission options, there are some vehicle types that will be more challenging to decarbonize, including many long-distance shipping vehicles, such as freight trucks, airplanes, ships, and trains. These transportation vehicles will need other options to address emissions, including using lower sulfur, higher-distillate fuels that require hydrogen for refinement.[22] In addition, the most likely zero emission options for these vehicles are fuel cell electric vehicles or synthetic biofuels, which both require hydrogen.

Transportation Fuel

A zero-emission hydrogen fuel cell bus refuels in Irvine, CA.
Photo: NREL (CC BY-NC-ND 2.0)

Fuel cell electric vehicles may be the first widely adopted commercial use of hydrogen as a transportation fuel in Oregon. The vehicles are available in other countries and in California, but are not sold in Oregon because there are no publicly available hydrogen fueling stations to support them. If hydrogen fueling infrastructure becomes available, adoption of fuel cell electric vehicles could ramp up rapidly, leading to increased market demand for more hydrogen fuel. Support for adoption is largely driven by decarbonization benefits, and would therefore require the development of renewable hydrogen resources.[23] Since 2000, about 40 percent of publicly supported hydrogen-generating electrolyzer projects around the globe were built to support vehicle fleets. While FCEVs are not as widely adopted as other types of electric vehicles, several countries have deployment targets for these vehicles and the fueling infrastructure needed to support them.[24]

Hydrogen is also a potential precursor for the production of synthetic hydrocarbons, often referred to as biofuels.[25] It is used in the processing of biomass feedstocks to create renewable diesel, a fuel that is available and used in Oregon as a substitute for petroleum-based diesel.[26] There is growing interest in using hydrogen to create other fuels like ammonia, synthetic methane, and other synthetic fuels as lower carbon substitutes for existing fuels like diesel, natural gas, and aviation fuels. Synthetic fuel production is very nascent, and consequently has high production costs. Producing hydrogen using electrolysis is an energy intensive process – the amount of energy needed is more than half the amount of energy that is being stored. More research and technological advancements are needed to make biofuel production from renewable hydrogen a cost-effective energy resource.

Electricity

Electrolyzers can serve as flexible loads to help manage increasing amounts of renewable energy generation on Oregon's electric grid. Hydrogen can serve as a long-duration energy storage medium, converting electricity to hydrogen that stores the energy for later use. Using hydrogen to store electrical energy when it is plentiful and provide it back to the grid when it is limited can help balance electricity supply with demand. It is also particularly useful for longer-term seasonal electricity generation needs. For example, the Pacific Northwest generally has ample supply of hydropower in the spring months, when energy demand tends to be lower, but less supply in late summer when cooling energy demands tend to be higher. Hydrogen could play a future role in supporting Oregon's goal to achieve a 100 percent clean electric grid by 2040 by helping balance renewable energy supply and demand (learn more in the Electricity Storage Technology Review).

Hydrogen could play a future role in supporting Oregon's goal to achieve a 100 percent clean electric grid by 2040 by helping balance renewable energy supply and demand.

Demand for clean hydrogen may increase as Oregon and other western states work to add more clean energy resources. Electrolyzers operate most cost effectively when the price of the electricity used to power the process is very low. The Pacific Northwest currently has limited circumstances when surplus carbon-free electricity is available, mostly during the spring season when wind may be curtailed.[27] However, as Oregon's largest electric utilities work to meet the state's 100 percent clean electricity goal by 2040, hydrogen could be an increasingly cost-effective option to help manage higher quantities of renewable resources supplying the grid.

Direct Use Fuel

Using hydrogen as a blended fuel to supplement the natural gas system is another area of potential growth, but it comes with challenges. The impetus for doing this would be to reduce greenhouse gas emissions in the natural gas sector. Because hydrogen is less dense than natural gas and requires increased pressure to move it through pipelines, adding 20 percent hydrogen by volume (the assumed maximum safe limit for blending) only results in a 6 to 7 percent reduction of GHG emissions. For this reason, blending renewable or low-carbon hydrogen into a natural gas pipeline may not be a cost-effective end-use for hydrogen if greenhouse gas emission reductions are the primary goal.

Energy Resilience

Hydrogen can support energy resilience, especially near clean electricity generation resources, where excess electricity could be used to create hydrogen that can be stored on site. In the case of events where traditional energy supplies are limited, stored hydrogen could provide a valuable energy resource for nearby communities. The hydrogen can also support a more reliable grid, as a method to store energy when demand is low and provide energy when demand is high. For example, there is interest in siting electrolyzers in coastal communities that could be used to create hydrogen from offshore wind resources[ii] to help balance grid needs and provide more energy resilience to those communities.

Beyond Energy

Hydrogen production today accounts for 700 million metric tons of CO2 per year, roughly 10 percent of total greenhouse gas emissions in the U.S. in 2020.[28] [29] Hydrogen combustion itself does not generate greenhouse gas emissions, but most hydrogen is produced from natural gas and coal, which creates about 10 metric tons of CO2 per 1 metric ton of hydrogen produced. There are existing technologies that can capture up to 90 percent of the emissions, but use of these technologies increases overall costs – adding about 50 percent for capital investments and 10 percent to power plant fuel costs[30] (for more information on carbon capture and storage, see the *2020 Biennial Energy Report*). Another option to reduce emissions is to generate renewable hydrogen.

[ii] Read more on renewable hydrogen and offshore wind in the Oregon Department of Energy's *2022 Floating Offshore Wind Study*: https://tinyurl.com/ODOE-Studies

Hydrogen could be generated using any form of electricity, but for it to be renewable it must use renewable electricity sources like solar and wind. Without CCS, fossil-generated electricity, such as natural gas and coal, would have similar emissions as hydrogen produced as a byproduct of refining these fuels. The Infrastructure Investment and Jobs Act passed in November 2021, requires the Secretary of Energy, in consultation with the Environmental Protection Agency, to develop an initial standard for the carbon intensity of clean hydrogen production.[31] It initially defines clean hydrogen to mean hydrogen produced with a carbon intensity equal or less than 2 kg of carbon dioxide equivalent produced at the site of production per kilogram of hydrogen produced. The USDOE considers a number of feedstocks that could be eligible to produce hydrogen within that carbon intensity, including renewable electricity, electricity or thermal energy from nuclear reactors, and fossil fuel inputs coupled with carbon capture and storage.[32]

Hydrogen could be generated using any form of electricity, but for it to be renewable it must use renewable electricity sources like solar and wind.

The electrolysis process to generate renewable hydrogen requires large amounts of water. Water consumption would double if all existing hydrogen generation resources (mainly created from natural gas) were converted to electrolysis generators.[33] Areas where water availability is limited may not be ideal locations for this type of hydrogen generation. There is interest in potentially siting renewable hydrogen electrolyzers near offshore wind installations, where seawater is readily available. The water would need to be desalinated to avoid corrosive damage to the equipment. The desalination process itself does take energy, but it is a minimal amount compared to the electricity output ultimately gained from the hydrogen produced.

Hydrogen presents health and safety considerations, as it is a combustible fuel. Hydrogen is non-toxic, but like other combustible fuels, handling and storage are important to reduce the potential for fires or explosions.[34] Hydrogen molecules are very small, which allows them to more easily seep through seals and linings, particularly through infrastructure designed for other gases. Special equipment is required to properly store and transport high concentrations. Because it is small and light, hydrogen disperses quickly in an open environment meaning the risk of ignition or explosions could be less than natural gas or gasoline vapors. However, like all volatile gases, the physical environments and conditions of hydrogen use must be tested and understood to fully characterize safety protocols for all anticipated commercial applications. [35]

Safety standards are critical for any industry to grow smoothly and efficiently, and such standards already exist across the current hydrogen production and delivery pathway. In addition, safety protocols are in use for hydrogen users.[36] As the industry grows more standards will be needed to ensure public safety. Organizations such as the Center for Hydrogen Safety and the Compressed Gas Association work to develop, update and promote these standards globally. Currently, the general public has limited interaction with hydrogen fuel, but this interaction will grow in the future as the industry expands. Public interactions with hydrogen fuel are most likely to occur at fueling stations for hydrogen fuel cell vehicles. Deliberate and clear communication about safety measures for hydrogen fueling stations and other new hydrogen end uses is essential to address safety concerns and ensure the safe handling and use of this fuel.

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Just about everything involves energy. It's part of our daily lives – from driving our cars and heating our homes to turning on our computers and firing up the grill after a long day.

This section builds the foundation of the energy story: how energy is produced, used, and transformed. These Energy 101s were developed for people new to energy or specific energy topics, along with those looking for a resource to help tell the story of how energy systems affect their work and interests. Energy policy is complex and, without being armed with technical information and understanding, it is sometimes difficult to be part of the conversations.

101s this year touch on a variety of topics. We dive into how utilities plan for future energy needs – including long-duration energy storage, an emerging technology. We share insights on electrifying the agricultural sector and provide a history lesson on the Public Utility Regulatory Policies Act (PURPA). You'll find information on Oregon's Fuel Action Plan, which outlines how we'd ensure fuel delivery to critical services in the event of an emergency, and the basics on Oregon's radioactive waste management activities. We also provide background information on the Infrastructure Investment & Jobs Act and what it will mean for energy in Oregon, and captured a list of climate programs and actions in Oregon State government.

We hope these 101s continue to build foundational knowledge so readers can make informed choices about the energy resources, uses, and investments that can change our work, lives, and communities.

TABLE OF CONTENTS

Energy 101: Oregon’s State Government Energy Landscape

Many of Oregon’s state agencies have a role to play on energy issues in the state. This Energy 101 highlights state agencies that do the most energy-related work, as well as a few associated organizations that work closely with Oregon’s state government. Understanding which agency has which responsibilities is sometimes hard to decipher. This piece helps to answer questions like: What’s the difference between the Oregon Department of Energy and the Oregon Public Utility Commission? Which agencies provide energy incentives? Who supports energy education and data analysis?

After a brief description of the roles of the Governor, Legislature, and Oregon Department of Energy, each agency or organization is listed in alphabetical order. For each agency or related organization, you will find basic information about their roles and responsibilities, followed by examples of their work in the energy landscape. Each agency or organization is connected to Oregon’s energy landscape in a different way through their missions, programs, and activities. Not every energy-related task of each agency is captured, but rather a snapshot of their work, as it relates to energy, is provided. Relatedly, not every agency with a role in energy is mentioned here; for example, for several agencies, their primary nexus to energy is as a reviewing agency for energy facility siting (see call-out box on page 210 below).

Adapted from the National Association of State Energy Officials, five categories provide examples of energy-related work occurring across agencies and organizations, and related icons are used in the narrative.[1]

Energy Programs to support shifts in behavior around energy consumption and production, which can include clean energy and clean fuel financial incentives, implementation programs, energy efficiency programs, contractor licensing, energy audits, home energy scoring, and public energy education.

Regulation to create and enforce standards and rules in the energy industry, which can include siting and permitting energy facilities and infrastructure; environmental regulations; economic regulations; consumer protection requirements; and oversight, monitoring, and compliance of other requirements.

Energy Policy Analysis and Education to support decision-makers in enacting policy changes, which can include developing legislative and budget proposals, conducting administrative rulemaking, engaging with energy industry and advocacy groups during policy development, and sharing data and analysis to inform the Legislature, Governor, and other decision-makers.

Safety and Resilience to protect public health and the environment from the impacts of the energy system, which can include safety regulations, energy security and resilience planning, nuclear and hazardous waste clean-up, emergency preparedness and response to shortages and disruptions in energy or fuel supply and delivery.

Energy System Planning to analyze and plan for future energy needs and policies to support them, which can include integrated resource plans, resource adequacy, transmission planning, and other energy resource analysis.

Oregon's Governor

The Governor is the leader of the executive branch of state government and uses convening powers to set priorities and solve problems. In addition to being responsible for vetoing or signing each bill passed by the Legislature, the Governor selects the director of many state agencies and appoints members to oversee 300 policymaking, regulatory, and advisory boards and commissions.[2] This includes appointing directors and commissioners for several agencies with a strong nexus to energy. It also includes hiring policy advisors who advise the Governor on energy policy and engage with state agencies to advance the Governor's vision and priorities. The Governor also exerts significant control over the function of the government by proposing two-year budgets, with input from agencies, for approval by the Legislature, as well as introducing bills to recommend policy changes.[3] This includes budgets and bills affecting the state agencies and related organizations below. The Governor can also manage the actions of state agencies by issuing executive orders, which are directives from the Governor on the focus, priorities, and operations of state government. Many state agency energy initiatives and programs are in response to an executive order, such as Executive Order 20-04, directing state agencies to reduce greenhouse gas emissions.[4]

Regional Solutions is a program within the Oregon Governor's Office.[5] Created via executive order by Governor Kitzhaber in 2014 and later enacted through the Legislature, Regional Solutions focuses on promoting economic and community development for each region in Oregon. Regional Solutions staff work locally to set priorities, identify roadblocks, and develop collaborative interagency approaches to accomplish statewide and regional goals. Regional Solutions takes advantage of community resources of all types, public, private, and civic, to develop sustainable communities and support Oregon's economy.[6]

Oregon's Legislative Assembly

Oregon's Legislative Assembly is bicameral, consisting of the House of Representatives and the Senate. The Senate includes 30 members elected to four-year terms, with half of the Senate seats up for election every two years. The House of Representatives includes 60 members elected to two-year terms. Oregon's legislators are elected from single member districts, meaning that each Oregonian is represented by one Senator and one Representative. The Legislature is responsible for enacting new laws and revising existing laws, and these laws have created agencies, funded them, and directed them to do much of the work described below. The Oregon Legislature deliberates and make changes to legislation at the committee level. As of October 2022, the following committees address energy issues and energy-related agencies: Senate Energy and Environment, Senate Natural Resources and Wildfire Recovery, House Environment and Natural Resources, House Wildfire Recovery, House

Veterans Emergency Management, Senate Veterans and Emergency Preparedness, Joint Ways and Means, and Joint Ways and Means Subcommittee on Natural Resources.

Equity and Justice: Both the Governor and the Legislature have directed state agencies to focus on equity. For the agencies that work on energy and natural resource issues, this started with the establishment of the Environmental Justice Task Force with Senate Bill 420 in 2007 and continues with new requirements for equity impact statements for agency budgets and rulemaking with House Bills 2167 and 2353 in 2021. Each state agency has their own equity-related goals and programs, and each state agency works to better engage with communities traditionally excluded from decision-making.

Oregon Department of Energy, Energy Facility Siting Council, and Oregon Hanford Cleanup Board

The Oregon Department of Energy (ODOE) acts as a central hub for energy-focused activities and is Oregon's dedicated state energy office. The Energy Facility Siting Council, staffed by ODOE, is a seven-member, Governor-appointed and Senate-confirmed council responsible for certifying and overseeing the development of large electric generating facilities, high voltage transmission lines, gas pipelines, radioactive waste disposal sites, and other projects. The Oregon Hanford Cleanup Board is a 20-member, Governor-appointed advisory group that represents Oregon's interests in the Hanford Nuclear Site cleanup project by acting as a watchdog and ensuring that the cleanup process is progressing.[7]

Examples of Work in the Energy Landscape

Programs: The Oregon Department of Energy manages and administers statutorily authorized energy programs to save energy, support the state's decarbonization efforts, make communities more resilient, and position Oregon agencies to lead by example. Recently, the agency has launched new financial incentive programs to support renewable energy and energy efficiency, such as such as the Community Renewable Energy Grant Program, Oregon Solar + Storage Rebate Program, Rural & Agricultural Energy Audit Program, and Energy Efficient Wildfire Rebuilding Incentive.[8] Two heat pump incentive programs will open in 2023.

Energy System Planning: ODOE managed the Oregon Renewable Energy Siting Assessment (ORESA), a collaborative project and online mapping tool that supports data-driven approaches and early coordination for renewable energy development.[9] The Department's planning work also includes providing Oregon's perspectives in other energy system planning processes, such as regional energy planning.[10] Finally, the Department helps policymakers assess pathways to meeting Oregon's energy and climate goals, including tradeoffs associated with various policy choices that could be made. For an example, please see the Charting the Course for Oregon's Energy Future Policy Brief.

Energy Policy Analysis and Education: The Department serves as a repository for energy research and data by generating reports, analyses, and tools, such as the Biennial Energy

Report, Oregon Electric Vehicle Dashboard, Electricity Resource Mix, renewable hydrogen study report, and floating offshore wind study report. The Oregon Hanford Cleanup Board helps hold the federal government, its contractors, and the state of Washington accountable by advocating for an increased budget and commenting on USDOE actions related to the Hanford Site cleanup.[11] ODOE provides input to policymakers, the Legislature, and the Governor on energy policy and program development and seeks input through advisory and stakeholder groups, such as the Energy Advisory Work Group. ODOE can advocate for energy bills proposed by the agency or supported by the Governor during even-year, long sessions, and is working on two legislative concepts for the 2023 session.[12] Finally, the agency provides information and analysis on energy-related bills as requested.

Safety and Resilience: One of ODOE's main responsibilities is ensuring that Oregon's energy systems are resilient, so that they can better withstand and recover quickly after a disruption such as a natural disaster.[13] The department developed and manages the Oregon Fuel Action Plan, which outlines how Oregon's emergency services and essential service providers would maintain access to necessary fuels in the face of a disruption to normal supply.[14] In preparation for an emergency at nearby nuclear sites, ODOE has developed a Nuclear Emergency Preparedness program, outlining how to keep Oregonians safe.[15] The Oregon Hanford Cleanup Board has a direct focus on protecting the health and safety of the Columbia River from radioactive waste located upstream at the Hanford Nuclear Site.[16]

Regulation: ODOE serves as staff for the Energy Facility Siting Council, which is responsible for overseeing the review of large electric generating facilities, high voltage transmission lines, gas pipelines, radioactive waste disposal sites, and other projects. Developers of these types of energy facilities must have their project proposal approved by the Energy Facility Siting Council and obtain a site certificate before they can build or operate the facility, which can influence where proposed facilities will be located.

The Role of Agencies and Other Entities in Energy Facility Siting

State agencies are critical partners to the Energy Facility Siting Council when it comes to siting energy facilities within state siting jurisdiction. Providing specialized analysis as part of the comprehensive energy facility permitting process, the following agencies review each application:

- The Department of Environmental Quality
- The Water Resources Department
- The Oregon Department of Fish and Wildlife
- The Department of Geology and Mineral Industries
- The Department of Forestry
- The Public Utility Commission of Oregon
- The Oregon Department of Agriculture
- The Department of Land Conservation and Development
- The Oregon Department of Aviation
- The Northwest Power and Conservation Planning Council
- The Office of State Fire Marshall

- The Department of State Lands
- The State Historic Preservation Office

Through the siting process, the Energy Facility Siting Council consults with Tribes identified by the Legislative Commission on Indian Services, as affected by the proposed facility. Nearby cities and counties, as affected by the proposed facility, are also consulted. If a proposed site is on federal land, federal land management agencies are included in the siting process. More information on the procedures used for the siting of renewable energy can be found here: https://oe.oregonexplorer.info/externalcontent/renewable/2022-ORESA-Procedures-Report.pdf.

Bonneville Power Administration

The Bonneville Power Administration (BPA) is a nonprofit, federal power marketing administration housed within the U.S. Department of Energy.[17] BPA was created by the U.S. Congress in 1937 to market electric power generated by the Bonneville Dam and to build the necessary transmission infrastructure to do so. Today, BPA markets electric power from 31 federally-owned dams and controls around 75 percent of the high voltage transmission lines in the Northwest – including Oregon, Washington, Idaho, and part of Montana. BPA uses analysis and plans from the Northwest Power and Conservation Council to inform its energy and transmission system plans.

Examples of Work in the Energy Landscape

Programs: In addition to power marketing,[18] BPA has invested millions of dollars into its Environment, Fish, and Wildlife Program, intended to reduce and mitigate the impact of hydropower dams.[19] Other programs and initiatives at BPA include wildfire mitigation, community education, pollution prevention, and cultural protection and preservation.[20]

Energy System Planning: BPA analyzes on power generation, transmission, and energy efficiency inform a wide range of decisions related to energy resources and rates.[17] For example, BPA establishes rates to be charged for power and transmission services in a rate proceeding, a formal evidentiary hearing process. Prior to the rate proceeding, BPA determines its spending levels through a public process, the Integrated Program Review (IPR). BPA's initial rate proposal is then prepared based on the outcome of the IPR. BPA's rates must be set so that BPA will be able to recover its total costs, including obligations to repay its debt to the Federal Treasury. BPA's initial rate proposal is then evaluated in a rate proceeding during which BPA staff presents its rate proposal to customers and other parties for review. At the conclusion of the rate proceeding, the Administrator issues a Final Record of Decision, which includes BPA's final proposed rates. BPA then files its rates proposal with the Federal Energy Regulatory Commission for confirmation and approval.

Safety and Resilience: BPA's wildfire mitigation plan includes a mix of vegetation management and asset management programs to mitigate the risk of wildfire. The wildfire mitigation plan also focuses on resilience, outlining BPA's protocol for restoring service following a wildfire.

The Federal Government in Oregon's Energy Landscape

The federal government is also a major player in Oregon's energy landscape. The Bonneville Power Administration works especially closely with the state's consumer-owned utilities and provides most of the transmission capacity in the state. BPA is listed here as one of the organizations working closely with state agencies but many other federal agencies also have a role. For instance, the U.S. Departments of Energy, Transportation, and Agriculture are critical partners in funding projects and programs – and this is increasingly true with the recent passage of the Infrastructure Investments and Jobs Act and the Inflation Reduction Act. The U.S. Department of Defense funded and worked in close partnership with state agencies on the recent Oregon Renewable Energy Siting Assessment.[9] The U.S. Environmental Protection Agency administers the well-known ENERGY STAR program, which helps Oregonians access more efficient appliances, and regulates pollution that comes from many energy generation facilities. The Federal Energy Regulatory Commission and the Bureau of Ocean Energy Management also have jurisdiction over energy facility siting in certain cases. And of course, federal legislation and executive orders can direct climate and energy policy from coast to coast.

Building Codes Division, Construction Energy Industry Board, and Other Industry Boards

The Oregon Building Codes Division (BCD) within the Department of Consumer and Business Services is responsible for administering Oregon's Statewide Building Code – a set of uniform standards to ensure that newly-constructed residential and commercial structures are safe to occupy.[21] BCD also participates in the Built Environment Efficiency Working Group, an interagency effort to implement Executive Order 17-20 and increase the energy efficiency of Oregon's built environment, including residential, commercial, and public buildings. Seven Governor-appointed boards assist BCD, including the Construction Industry Energy Board that evaluates and approves or disapproves proposed state building code standards and administrative rules relating to the energy use and energy efficiency aspects of the electrical, structural, prefabricated structure, and low-rise residential specialty.[22]

Examples of Work in the Energy Landscape

Regulation: Oregon's Statewide Building Code includes energy efficiency standards for residential and commercial structures. Two major energy efficiency standards, the 2021 Oregon Energy Efficiency Specialty Code (OEESC), and the 2021 Oregon Residential Specialty Code (ORSC), outline energy efficiency requirements for windows, insulation, lighting, and other equipment.[23] Proposed standards evaluated by the Construction Industry Energy Board may include energy-conserving technology, construction methods, products, and materials.

Business Oregon and Oregon Business Commission

Business Oregon is the economic development agency for the State of Oregon. The agency works with communities and businesses and uses its programs and expertise to help businesses grow, add jobs, diversify the economy, and increase Oregon prosperity. It works with communities to enhance and expand infrastructure and community safety with projects such as water and wastewater systems, seismic rehabilitation for schools, or rural broadband development. This work also sets the stage for future business development. The agency's mission is to invest in Oregon's businesses, communities, and people to promote a globally competitive, diverse, and inclusive economy, all carried out with an agency strategic plan.[24]

Examples of Work in the Energy Landscape

Programs: Two of Business Oregon's incentives programs are involved in Oregon's energy landscape: the Rural Renewable Energy Development (RRED) Zone program and the Strategic Investment Program (SIP). Energy is an essential component of most businesses, even more so in rural areas that may not have the access to necessary infrastructure. Recognizing this, Business Oregon has assisted in the development of the RRED Zone Program, which offers eligible rural businesses a 100 percent tax abatement from local property taxes associated with a renewable energy project for the first three-to-five years of project operation.[25] Renewable energy projects can increase the value of a property, leading to more revenue from property taxes over the life of a project. Renewable energy development can also be eligible for the SIP, which is a tax exemption that applies to the portion of the project's real market value that exceeds a particular cut off. The size of the initial taxable portion depends on the total value and location of the project.[26]

Department of Administrative Services

The Department of Administrative Services is the central administrative agency of Oregon state government. DAS works to effectively implement the policy and financial decisions made by the Governor and the Oregon Legislature. The department also sets and monitors high standards of accountability to ensure that state government uses tax dollars productively. To fulfill its mission, DAS supports state agencies by providing a strong and stable management infrastructure. As part of this effort, DAS works with private enterprise, citizens, and other government entities to develop an efficient service delivery system.[27] The Department of Administrative Services leads state government by providing an array of services that include asset management (fleet and buildings), budget development, procurement, human resources, IT support, surplus property management and many others.[28]

Examples of Work in the Energy Landscape

Programs: As the central administrative agency for state government operations, DAS develops energy-related policy and practices, helps implement energy-related executive orders, and supports enterprise-wide energy management efforts. DAS developed the statewide Energy and Resource Conservation Policy[29] to direct agencies in managing energy in existing buildings, and a Fleet Policy[30] to provide agency direction on use of fleet vehicles, including electric vehicles (EVs). DAS Procurement Services also provides guidance on procurement of energy efficient equipment, from appliances and IT equipment to vehicles and fuels, through statewide policy and technical specifications in statewide price agreements with vendors. DAS also actively manages energy in its portfolio of state-owned buildings, most of which are leased to tenant agencies, and staffs an energy technical team to oversee energy-related operations and maintenance, as well as capital improvement projects to increase energy efficiency in new construction and major renovations. The DAS Office of Sustainability, along with the Oregon Sustainability Board, supports agency energy management efforts through sustainability planning, resources and technical support, and communications and education.

Department of Environmental Quality and Environmental Quality Commission

Oregon's Department of Environmental Quality (DEQ) is the state's main regulatory agency responsible for restoring, maintaining, and enhancing the quality of Oregon's air, water, and other natural resources.[31] The responsibilities of DEQ are numerous and include collecting and analyzing environmental data, monitoring and enforcing compliance with environmental regulations, as well as the restoration of valuable property. When DEQ proposes rules and policies, they must be adopted by the Environmental Quality Commission (EQC) before they take effect. The EQC, DEQ's policy and rulemaking board, is a five-member, Governor-appointed panel that adopts rules, establishes policies, issues orders, judges appeals of fines or other DEQ actions, and appoints the DEQ director.[32] Recently, through rulemaking, the EQC played a central role in defining Oregon's Climate Protection Program, the state-wide emissions reduction program.[33]

Examples of Work in the Energy Landscape

Regulation: One of DEQ's major responsibilities is running Oregon's Climate Protection Program, which sets a declining limit on the greenhouse gas emissions from the use of fossil fuels in transportation, residential, commercial, and industrial settings. Under the policies and regulations within the Program, DEQ aims to achieve a 90 percent reduction in the greenhouse gas emissions from fossil fuels over the next 30 years.[34] Additionally, DEQ is responsible for issuing certain permits that would be needed for energy infrastructure, such as the Title V Air Permits and 401 Water Quality Certification permits.[35]

Energy Policy Analysis and Education: Policies created and passed by the Legislature typically include broad policy mandates, and individual agencies and their rulemaking boards, such as the Environmental Quality Commission, develop detailed rules and policies to accomplish those broad policy mandates set by the Governor or Legislature.[36]

Safety and Resilience: Large quantities of oil are shipped along the Columbia River and along the coast. Hazardous materials are shipped along the highways and by rail. DEQ's Emergency Program focuses on collaborating with other agencies and industry officials to prevent and respond to spills.[37] DEQ also focuses on the reduction and elimination of toxic materials and substances, including efforts to reduce air toxics from transportation fuels such as diesel soot, benzene, and polycyclic aromatic hydrocarbons.[38]

Programs: DEQ's Clean Vehicle Rebate Program offers Oregon drivers a cash rebate for purchasing or leasing an electric vehicle.[39] DEQ's Vehicle Inspection Program, initially created to help Oregon comply with the federal Clean Air Act, continues to ensure vehicles driven in Oregon meet emissions standards.[40] The Greenhouse Gas Reporting Program requires major emitters of greenhouse gases, such as electricity and natural gas providers, to report their annual emissions to DEQ which is then audited and made publicly available.[41] DEQ's Clean

Fuels Program reduces the carbon intensity of transportation fuels used in Oregon. As of fall 2022, the reduction targets are 10 percent below 2015 levels by 2025, 20 percent lower by 2030, and 37 percent lower by 2035. From 2016 to 2022, the Clean Fuels Program supported the reduction of 7.3 million tons of greenhouse gas emissions and has displaced nearly 1.5 billion gallons of fossil fuels with cleaner options.[42]

Department of Land Conservation and Development and Land Conservation and Development Commission

The Oregon Department of Land Conservation and Development (DLCD) is responsible for administering Oregon's land use planning program, established through Senate Bill 100 (1973), which recognizes the importance of planning in protecting farm, forest, and coastal areas, conserving natural resources, managing urban growth, and creating livable communities. DLCD also assists cities and counties in adopting and maintaining comprehensive plans and zoning codes that adhere to Oregon's 19 planning goals.[43] The Land Conservation and Development Commission (LCDC), staffed by DLCD, is a seven-member Governor-appointed, Senate-confirmed board. LCDC adopts state land-use goals and rules, assures local plan compliance, and oversees the coastal zone management program.[44]

Examples of Work in the Energy Landscape

Energy Policy Analysis and Education: DLCD helps set goals, targets, and policies for the cities and counties they assist in the development of comprehensive plans, which often outline energy plans and goals, including the provision of renewable energy resources.[45]

Regulation: DLCD developed and LCDC adopted rules for the siting of wind and solar energy projects to help balance land uses involving agriculture and conservation. Intended to direct renewable energy development toward areas with limited value to wildlife and agriculture, rules limit local approval of photovoltaic solar energy projects larger than 12 acres on high-value farmland or 20 acres on arable lands through a conditional use proceeding, which is commensurate with rule provisions for siting most energy generation projects on lands protected for agricultural purposes. LCDC's agricultural lands rule also provides a conditional use opportunity for photovoltaic solar projects of up to 320 acres on nonarable lands.[46] On lands protected for forest uses, the threshold for all energy generation projects is 10 acres. Projects exceeding the acreage thresholds identified for agricultural or forest lands that remain subject to local jurisdiction may be considered through a post acknowledgement plan amendment process.

Energy Trust of Oregon

Energy Trust of Oregon is an independent nonprofit organization that administers energy efficiency and renewable energy incentive programs in the service areas of Portland General Electric, Pacific Power, NW Natural, Cascade Natural Gas, and Avista. Following the establishment of the Public Purpose Charge in Senate Bill 1149, Energy Trust has been responsible for investing ratepayer funds in cost-effective electric and natural gas efficiency resources, paying the above-market cost of small-scale renewable energy system installations, and supporting market transformation that promotes the development, availability, and adoption of energy-efficient products and practices, primarily through the Northwest Energy Efficiency Alliance.[47] Energy Trust's activity is reported in quarterly and annual reports to the Oregon Public Utility Commission (OPUC) and in a biennial report to the Legislative Assembly on Public Purpose Charge Receipts and Expenditures.

Starting in 2022, House Bill 3141 changed how ratepayer funds administered by Energy Trust are collected and expanded what qualifies for renewable energy funding to include projects that improve reliability and resiliency of the electric grid. The law requires at least 25 percent of Energy Trust's renewable energy revenues flowing from a public purpose charge paid by PGE and Pacific Power customers be used to serve low- and moderate-income customers, and it requires the OPUC to set equity metrics for all funds invested by Energy Trust. Lastly, it requires Energy Trust continue jointly planning and delivering programs in coordination with the aforementioned utilities.[48]

Examples of Work in the Energy Landscape

Programs: Energy Trust administers services and programs to help customers and communities save energy and benefit from renewable energy. This scope includes residential, commercial, industrial, and agricultural customers of the five participating utilities.[49] Energy Trust offers incentives for homes including heating and cooling systems, windows, and insulation; business incentives include operations and maintenance changes, lighting, heating and cooling, irrigation, industrial equipment, and custom projects. Incentives are also provided for above-code construction of residential and commercial buildings. Solar incentives are available to residential and commercial projects, including community solar, and project development assistance and installation incentives available for small-scale in-conduit hydropower, biopower, geothermal and small-scale, municipally owned wind projects. Contractor coordination and training help enable a skilled workforce to install energy-efficient equipment and renewable energy systems in Oregon**.**

Energy System Planning/Analysis: Energy Trust contributes program data and analysis in OPUC dockets and proceedings to inform utility resource and system planning. It coordinates with participating utilities to develop energy efficiency supply estimates, savings scenarios, targets and funding for annual energy savings that provide customers with reliable, low-cost energy. Energy Trust offers incentives for feasibility studies and the construction of renewable energy projects, such as hydropower and biopower, to help reduce barriers to renewable energy development in the state.

Safety and Resilience: Energy Trust staff supports community energy planning for cities and counties and helps identify strategies and actions that can increase the resilience of communities and the entire energy system. These include developing microgrids that can continue to function without the main grid, further promoting energy efficiency, and expanding access to distribution-system connected technologies and distributed energy resources.[50]

Environmental Justice Council (EJC)

Since its creation in 2007, the Environmental Justice Taskforce has advised the Governor and Oregon's natural resource agencies on environmental justice, which is defined as "equal protection from environmental and health hazards, and meaningful public participation in decisions that affect the environment in which people live, work, learn, practice spirituality, and play."[51] In 2022, the Legislature passed HB 4077, renaming and codifying the existing Environmental Justice Taskforce as the Environmental Justice Council. HB 4077 provides the Environmental Justice Council with additional resources, including staff support from Department of Environmental Quality, to enable further outreach and meaningful engagement with environmental justice communities across the state. The Environmental Justice Council is responsible for working with natural resource agencies to identify minority and low-income communities that are likely to be impacted by the work done by the agencies.[52]

Examples of Work in the Energy Landscape

Energy Policy Analysis and Education: The Council meets directly with environmental justice communities to understand the perspectives and concerns of these communities firsthand and to advise the Governor's Office, policy makers, and the state's natural resource agencies on environmental justice. This role includes working with natural resource agencies to address community concerns and improve the public participation process as well as developing policy recommendations. In the near-term, this work also includes developing an equity mapping tool to aid state agencies in their work.

Federally Recognized Oregon Tribes

There are nine federally recognized Tribes in Oregon; these Tribal governments have been in what is now Oregon since time immemorial: 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. Village sites and traditional ways are known to date back many thousands of years. Tribal governments are separate and unique sovereign nations with powers to protect the health, safety, and welfare of their enrolled members and to govern their lands. This tribal sovereignty predates the existence of the U.S. government and the State of Oregon. Most Oregon Tribes are "confederations" of three or more Tribes and bands. Each Tribe's area of interest may extend far beyond its Tribal governmental center or reservation location.[53]

Examples of Work in the Energy Landscape

Regulation: Many tribal governments have authority for permitting on their reservation lands as well as land use planning and building requirements.

Energy Policy Analysis and Education: Some tribes have worked with U.S. Department of Energy, Office of Indian Energy Policy and Programs and the National Labs to develop Energy Visions or Strategies to help pursue their goals.[54] There are also regional collaborations among tribes to develop energy strategies, as illustrated in the 2022 CRITFC Energy Vision: https://critfc.org/energy-vision.

Local Governments

There are 241 incorporated cities in Oregon. Among the services that city governments typically provide are fire and police protection, streets and street maintenance, sewer and water treatment and collection systems, building permit activities, libraries, parks and recreation activities, and other numerous social services that are determined locally. Cities also have considerable responsibilities for land use planning within their city limits and urban growth boundaries. City councils serve as the highest authority within city government in deciding issues of public policy.[55] There are 36 counties in Oregon. Twenty-eight counties, including nine with charters, are governed by a board of commissioners comprised of three-to-five elected members. The remaining eight, less populated counties are governed by a “county court” consisting of a county judge and two commissioners. Nine counties have adopted “home rule” charters, wherein voters have the power to adopt and amend their own county government organization. Counties provide a range of important public services, including, land-use planning, building regulations, refuse disposal, air pollution control, economic development, and urban renewal.[56] In addition to cities and counties, several other forms of local government exist in Oregon such as Regional Governments, Metro, Port Districts, and Special Service Districts.[57]

Examples of Work in the Energy Landscape

Regulation: Local governments have, for example, a role to play in energy siting and energy efficiency through their land use planning and building regulation authorities.

Programs: Some cities, such as City of Portland, have financing programs like the Portland Clean Energy Fund. Also, some cities have instituted home energy scoring to help potential homeowners better understand the energy use and cost associated with a home before buying.

Energy Policy Analysis and Education: Several local governments have developed clean energy, climate, or sustainability plans that prioritize actions that they can take within local authorities and jurisdiction to pursue goals around affordable energy, energy resilience, and clean energy (among others). More examples can be found in the Community Energy Planning in Rural Oregon Guidebook - https://tinyurl.com/BPCEP

Northwest Power and Conservation Council

The Northwest Power and Conservation Council was created in 1980 when the United States Congress passed the Pacific Northwest Electric Power Planning and Conservation Act.[58] The council represents a compact unique in the nation among Idaho, Montano, Oregon, and Washington to address the Pacific Northwest’s energy and environmental needs. The Power Act requires the Council to develop a long-term energy plan for the region and to develop a fish and wildlife program to address the impacts of the hydroelectric system on fish and wildlife populations. The Council’s work acknowledges and analyzes the many changes in the planning environment: the evolving science about the Columbia

Basin ecosystem; the Northwest's economy; the availability of BPA funding for fish and wildlife restoration; the cost and availability of generating resources; the availability and cost-effectiveness of energy efficiency measures; the engagement of the public; and the operation of the Columbia River power system.

Examples of Work in the Energy Landscape

Energy System Planning/Analysis: The Northwest Power and Conservation Council is required to produce an electric power plan for the region every five years, outlining projected energy demand, evaluating electricity resources and their costs, and analyzing new technologies and strategies.[58] Information in the power plans guide how the Pacific Northwest will meet its future electricity needs and acts as an early warning system – alerting the region of any potential energy shortfalls.[59] The power plans typically include a major focus on demand response and energy efficiency as tools to meet future load growth and reduce emissions.[60] These power plans are a valuable resource for electric utilities to use when conducting their own resource planning, offering a regional perspective and providing technical modeling of how various resources will perform.[61]

Oregon Department of Emergency Management

The Oregon Department of Emergency Management coordinates and maintains a statewide emergency services system for emergency and disaster communications. OEM awards grant funding to local governments, coordinates search and rescue efforts, and manages the state 9-1-1 Program. The Drought Readiness Council and Oregon Seismic Safety Advisory Commission (OSSPAC) also operate out of OEM.

Examples of Work in the Energy Landscape

Energy System Planning/Analysis and Safety and Resilience: Working with the Public Utility Commission and the Oregon Department of Energy, OEM coordinates energy-related planning ahead of potential disasters to mitigate issues related to power outages or lack of access to fuel. In the event of an actual disaster, OEM leads state government efforts in a coordinated response to the disaster, which would include coordinating with ODOE, OPUC, and private sector partners related to energy needs.

Oregon Department of Fish and Wildlife and Oregon Fish and Wildlife Commission

The Oregon Department of Fish and Wildlife (ODFW) is a regulatory agency working to protect and enhance Oregon's fish and wildlife as well as their habitats for use and enjoyment by present and future generations.[62] ODFW's regulatory role involves the take of state-managed species – for example, hunting or fishing. ODFW also serves an advisory role within many permitting arenas, working directly in support of agencies and departments responsible for project permitting. ODFW is structured with three divisions, the Fish Division, the Wildlife Division, and the Habitat Division. Species and habitat conservation can shape the type and location of energy systems. The Oregon Fish and Wildlife Commission consists of seven members appointed by the Governor, appoints the ODFW director, formulates general state programs and policies concerning management and conservation of fish and wildlife resources, and establishes seasons, methods, and bag limits for recreational and commercial take.

Examples of Work in the Energy Landscape

Regulation: ODFW sets regulations related to hunting and fishing as well as wildlife and habitat conservation. ODFW generally serves an advisory role in energy development actions, working directly with responsible regulatory agencies regarding potential impacts of a proposed action, including energy production and transmission on fish, wildlife, and habitats. At the early stages of project development, ODFW advises developers on siting and helps determine what impact studies should be conducted to help avoid, minimize, and mitigate potential impacts from a project.[63]

Oregon Department of State Lands and State Land Board

Since statehood in 1859, the Land Board has been composed of the Governor (chair), Secretary of State, and State Treasurer. Oregon's Constitution directs the Land Board to manage lands under its jurisdiction to obtain the greatest benefit for the people of Oregon, consistent with resource conservation and sound land management. The Land Board oversees the Common School Fund and state lands dedicated to providing revenue for the fund. On behalf of the State Land Board, the Department of State Lands manages Oregon's school lands and other resources that contribute revenue to the Common School Fund. Additionally, the state owns the submerged and submersible land underlying all navigable and tidally-influenced waterways. DSL is responsible for management of these publicly owned submerged and submersible land and for the protection of wetlands and waters of the state.

Examples of Work in the Energy Landscape

Regulation: DSL has primary jurisdiction for leasing land within state waters, waters within 3 miles of shore, for projects such as offshore transmission cables or other infrastructure related to marine-based energy development. In addition, DSL has responsibility over removal-fill permits that can be required for energy infrastructure projects.

Oregon Department of Transportation and Oregon Transportation Commission

The Oregon Department of Transportation (ODOT) helps ensure that Oregon’s transportation system is safe and reliable, and acts as the central agency for planning the future of Oregon’s transportation systems. ODOT is responsible for the licensing of vehicles and operators in Oregon, as well as the maintenance of the state’s transportation system including bridges, highways, and public transportation.[64] The Oregon Transportation Commission is a five member Governor-appointed and Senate-confirmed board that establishes state transportation policy, oversees ODOT’s activities, and guides the planning, development, and management of a statewide integrated transportation network.[65]

Examples of Work in the Energy Landscape

Regulation: Within ODOT, the Fuels Tax Group is responsible for collecting various fuel taxes, including Motor Vehicle Fuel Taxes and Use Fuel Taxes.[61] This tax revenue is used to further update and improve Oregon's transportation infrastructure, including efforts to reduce congestion and therefore, greenhouse gas emissions. ODOT's Rail Division inspects freight railroad activities, including hazardous material transportation, in order to ensure compliance and prevent spills and leaks.

Energy System Planning: Around 35 percent of greenhouse gas emissions in Oregon come from the transportation sector. As the overall manager of the transportation system, ODOT works continuously to reduce those emissions. Strategies include supporting public transportation and other alternative ways to travel; making it easier to own and use an electric vehicle; using and encouraging use of clean fuels; and helping local governments identify ways to reduce emissions. Additionally, the agency regularly performs energy audits in its facilities around the state, making improvements to conserve resources.

Safety and Resilience: ODOT works with the Oregon Department of Environmental Quality and the Federal Railroad Administration to manage hazardous substances and materials. ODOT's Hazardous Materials Group also ensures agency compliance with environmental regulations during the use of hazardous materials, water discharges, site cleanups and more.

Oregon Global Warming Commission

The Oregon Global Warming Commission, created through HB 3543 (2007),[66] is a 25-member advisory group.[67] The Governor appoints 11 voting members to the commission. The commission is directed in statute to submit a biennial report to the Legislature describing Oregon's progress toward achieving the state's greenhouse gas emissions reduction goals. The commission can also make recommendations for additional actions to reduce emissions, which often relate to energy given the carbon intensity of Oregon's current energy systems. The commission's key priorities include decreasing greenhouse gas emissions, protecting the health and wellbeing of Oregonians, and ensuring that Oregon's economy remains vibrant and healthy.[67] Oregon Department of Energy provides energy expertise and staff support for the commission.

Examples of Work in the Energy Landscape

Energy Policy Analysis and Education: In 2010, the Oregon Global Warming Commission published the Roadmap to 2020 report, outlining a ten-year plan to combat climate change. Currently the Oregon Global Warming Commission, with ODOE staff support, is developing a Roadmap to 2035 – outlining additional actions the state could take to further decarbonize Oregon's economy.

Oregon Housing and Community Services

Oregon Housing and Community Services (OHCS), the state's housing finance agency, administers programs that aim to increase access to stable housing by preventing homelessness, assisting with utility payments, preserving and financing the building of affordable housing, and encouraging homeownership.

Examples of Work in the Energy Landscape

Programs: The Oregon Low Income Weatherization Program (WAP) provides weatherization and energy conservation services at no cost to qualified households. OHCS also directly administers the Oregon Multifamily Energy Program (OR-MEP), which facilitates energy-efficiency in affordable multifamily housing through design assistance, cash incentives, coordination with other regional energy programs, as well as contractor and public educational opportunities.[68] OHCS also provides funding and program support through two billing assistance programs. The federally-funded Low Income Home Energy Assistance Program (LIHEAP) includes bill payment assistance, energy education, case management, and home weatherization services. The ratepayer-funded Oregon Energy Assistance Program (OEAP) provides assistance to low-income households at risk of having their electricity service disconnected. These services are delivered by local community-based organizations, including Community Action Agencies (CAAs), senior centers, and housing authorities.[69]

Oregon Public Utility Commission

The Oregon Public Utility Commission (OPUC) is responsible for rate regulation of Oregon's investor-owned electric utilities (Portland General Electric, Pacific Power, and Idaho Power), natural gas utilities (Avista, Cascade Natural, and NW Natural), telephone service providers (landline only), as well as select water companies. The OPUC also enforces electric and natural gas safety standards and handles utility-related dispute resolution on behalf of Oregon residents. In the event of an emergency, the OPUC is part of the Oregon Emergency Response System to coordinate and manage state resources. OPUC consists of three full-time commissioners that are appointed by the Governor and confirmed by the Senate, and is supported by staff with a wide range of utility, financial, legal, and energy expertise.

Examples of Work in the Energy Landscape

Regulation: The OPUC regulates investor-owned electric and natural gas utilities providing service to Oregon residents to ensure they offer safe and reliable energy at reasonable rates. The rates charged by investor-owned utilities must be approved by the OPUC and cannot be changed without going through the quasi-judicial rate case process. During this process, the OPUC examines the utility's operating expenses to determine whether the proposed rate change is warranted, and consumer protection is a central element of the process. The OPUC also regulates Oregon's power system by creating and enforcing safety and reliability standards, conducting field inspections and vegetation audits, and analyzing outage events as well. The OPUC also works with the Pipeline and Hazardous Material and Safety Administration to enforce the Pipeline Safety Act by conducting inspections of natural gas pipelines in Oregon.[70]

Safety/Resilience: The OPUC requires investor-owned utilities to proactively manage emerging safety and reliability risks such as earthquakes, wildfire, or cybersecurity threats, as well as offer reliable and secure operation of electric power and natural gas supply infrastructure. As an economic regulator of these utilities, the OPUC ensures that the utility has sufficient revenue to pay for reasonable costs to operate and maintain its systems in a safe manner. This includes costs for infrastructure, vegetation management, and facility maintenance. The OPUC also conducts inspections and provides general safety oversight for the 38 consumer-owned utilities (Cooperatives, Peoples' Utility Districts, and Municipal Utilities). OPUC works with Oregon Utility Notification Center (Call 811 Before You Dig) to coordinate and avoid damaging underground utilities, Oregon Utility Safety Committee (OUSC) made up of public and privately-owned utility service providers to propose recommendations on utility safety-related issues, and Oregon Joint Use Association an industry advisory group established by the Oregon Legislature to advise the OPUC on safety issues related to utility poles. In 2021, Oregon passed SB 762 to address the impact and increased risk of wildfires. SB 726 requires OPUC to convene workshops focused on helping both investor-owned and consumer-owned utilities develop wildfire protection plans.[71]

Energy System Planning: Oregon IOUs are required to file Integrated Resource Plans, outlining the utility's expected upcoming demand and its plan for meeting that demand. Integrated Resource Plans describe the utility's plan for procuring additional energy resources and are used to help inform future decisions whether to approve a rate change for a utility. Integrated Resource Plans are intended to help the utility determine their "least-cost/least-risk" combination of energy generation, demand-side management, and purchased energy to meet future energy needs and legal requirements. The OPUC oversees Energy Trust operations (as required by SB 1149) through a funding Grant Agreement (2005) and sets annual performance goals. The Energy Trust provides energy efficiency services for customers of Portland General Electric, Pacific Power, Northwest Natural, Cascade Natural Gas, and Avista, which are part of energy efficiency resource acquisition in integrated resource plans. Additionally, OPUC is responsible for reviewing and approving the "Clean Energy Plans" submitted by utilities outlining their plan to comply with the House Bill 2021.[72] These Clean Energy Plans require PGE and Pacific Power to work with the Community Benefits and Impacts Advisory Group to ensure that community considerations are part of their Clean Power Plans.[73]

Energy Policy Analysis and Education: The OPUC conducts policy analysis through an inclusive stakeholder process to evaluate differing viewpoints on key issues, such as an on-going investigation about potential bill impacts that may result from limiting the GHG emissions of regulated natural gas utilities. The OPUC's stakeholder processes and analysis also provide an understanding of how changes in the electricity sector, such as an increase in distributed generation, storage, and smart grids, will impact how the electric grid is regulated.

Oregon Sustainability Board

The Oregon Sustainability Board was created in 2001 and encourages activities that best sustain, protect, and enhance the environment, economy, and community for the present and future benefit of Oregonians. The Legislature adopted the Oregon Sustainability Act (ORS 184.421-435), which established the state's overall sustainability policy. The legislation created the OSB and established legislative goals for the Board, and more generally for state government around sustainability. Appointed by the Governor, eleven members represent a variety of stakeholders across the State of Oregon.

Examples of Work in the Energy Landscape

Energy Policy Analysis and Education: Subsequent executive orders and communications from the Governor directed the Board to oversee, review, and approve sustainability plans developed by state agencies, all of which address energy used by state agencies in their operations. The Board, which meets quarterly, is actively involved in the oversight of agency sustainability plans and initiatives, as well as statewide projects working to enhance the environment, economy, and community.

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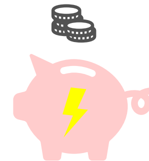
Energy 101: Consumer Energy Cost Drivers



Oregonians spent more than $12 billion on energy in 2020—from electricity and natural gas used in homes and businesses, to the fuels that run our vehicles.[i] The methods of production and delivery of energy to consumers varies widely. Depending on the type of energy, there are varying levels of state and federal price regulation and opportunities for policymakers to affect end-use costs to consumers. This brief describes the production-to-consumption supply chains for electricity, natural gas, and gasoline, and identifies opportunities where policymakers can affect various elements of these supply chains. It also summarizes the regulatory processes for establishing the retail rates that consumers pay for electricity and natural gas service.

There are three main types of energy that most Oregonians typically use daily: electricity, natural gas, and gasoline. Each varies significantly in its physical characteristics, industry composition, and regulatory structure. These differences have an impact on the extent to which state policymakers can influence retail prices for Oregon consumers. A little talked-about benefit of electrification and electric vehicles is moving consumers from gasoline—a fuel whose price is unregulated—to electricity, a fuel whose retail price is regulated either by the Public Utility Commission or by local elected boards. Unlike with gasoline, state regulators and elected boards play a central role in setting retail prices for electricity, which can provide a valuable safeguard for consumers.

Energy as a Commodity

Energy is the power derived from the use of physical or chemical resources, especially to provide light and heat or to work machines.[1] In the case of gasoline or natural gas, that fuel is delivered to the consumer as chemical potential energy. Until you start your car's engine, or turn on your gas stove, that fuel is there holding that energy until a spark ignites the fuel, breaks its chemical bonds, and creates useful energy. Electricity, on the other hand, *is* energy—no physical or chemical conversion is required by the consumer to derive useful energy from electricity. Instead, the conversion into usable energy generally occurs at electric power plants, and that energy is transmitted over the grid directly to end-users.

Geographical Influences

Energy supply chains play a big role in overall energy costs and have implications for what can influence consumer prices. The physics of electricity generation and transmission necessitate an electric sector that is more local in nature and built nearer to end-use consumers, which lends itself to state regulation. On the other hand, oil (and its liquid fuel derivatives) and natural gas (to an increasingly similar but still much lesser extent) can be transported as fungible physical commodities. This has resulted in the development of global commodity markets, the prices of which are unregulated.

There are three main types of energy that most Oregonians typically use daily: electricity, natural gas, and gasoline.

[i] Learn more about energy costs and Oregon's economy in the Energy by the Numbers section of this report.

Supply Chains

Gasoline	
Extraction	Crude oil is extracted from underground.
Transport	Crude oil is transported, often via tanker or pipeline, to refineries that produce end-use fuels of various kinds. In some cases, crude oil may cross long distances (and oceans) from its site of extraction to a refinery.
Refining	There are approximately 130 oil refineries in the United States, with most refining capacity located east of the Rocky Mountains and more than 40 percent of national capacity along the Gulf of Mexico.[2] For most Oregonians, the nearest refineries are located in the Puget Sound region in Washington. Oil refineries distill crude oil into various types of end-use fuels, including gasoline, diesel, kerosene, and jet fuel.[3]
Transmission	Refined gasoline is distributed regionally across the U.S. by pipeline or tanker.
Distribution	Gasoline is then often transported the final stage to retail gas stations by truck, where it is stored underground in tanks until pumped into cars.

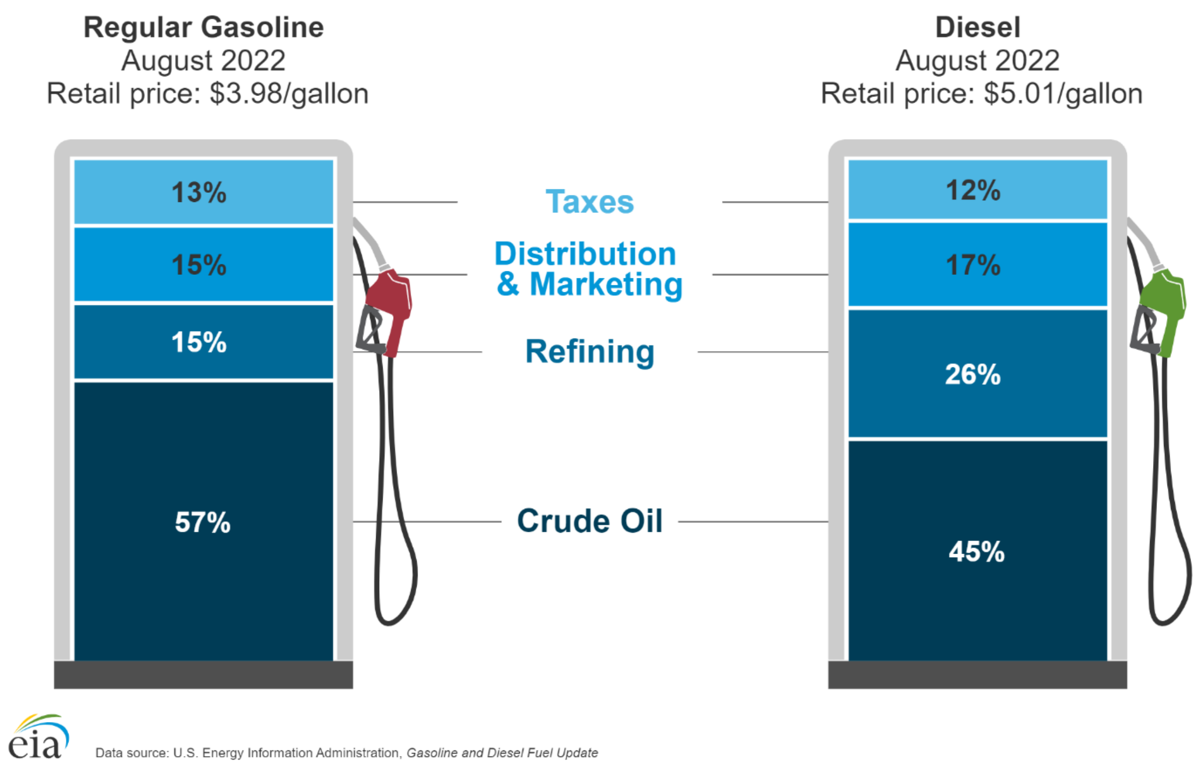
Natural Gas	
Extraction	Natural gas is extracted from underground, sometimes as a byproduct of oil extraction. In recent years, the use of hydraulic fracturing (fracking) has been more widely used to extract natural gas from underground shale formations.
Transport	Raw natural gas is transported via pipeline, often a relatively short distance, to a natural gas processing plant near the wellhead.
Processing	Most of the natural gas processing plants that produce natural gas used in Oregon are located in the northern Rocky Mountains region of British Columbia and Alberta, Canada.[4] These plants process and clean raw natural gas to remove water and other contaminants.
Transmission	Processed natural gas moves through a network of interstate gas pipelines from processing plants to wholesale purchasers, like local gas distribution companies.[5]
Distribution	Local gas distribution companies maintain a network of gas distribution pipelines to deliver natural gas to end-use consumers in Oregon.

Electricity	
Extraction	Many types of electricity generation, such as coal, natural gas, and nuclear (uranium), require the extraction of natural resources.
Transport	Some fuels, like coal, natural gas, and uranium, must be transported from the site of extraction to a power generation facility. Resources like solar, wind, and hydropower do not require the transport of fuels, but are dependent on the availability of these resources in a particular location.
Generation	Conversion of the primary energy source (wind, solar, coal, natural gas, uranium, water) into electricity occurs at a power plant.
Transmission	Electricity is delivered from the source of generation to a retail provider over the electric transmission system.
Distribution	Electricity is delivered from the wholesale transmission system over the distribution grid to reach end-use consumers.

Market Influences

The price that Oregonians pay for energy varies by type of fuel, by time of day or year, and by location in the state. This variability across time is particularly true with gasoline and diesel, where a significant portion of the consumer end-use cost is driven by global crude oil commodity markets. Changes in global oil markets are more likely to result in volatility in retail prices because of the lack of policies and retail price regulation. For example, in early March 2022, gas prices jumped 49 cents in just over a week as Russia attacked Ukraine, disrupting global markets.[6] One year earlier, a large container ship became stuck in the Suez Canal—a major thoroughfare that handles 12 percent of seaborne trade.[7] Even in the midst of the COVID-19 pandemic, which had globally depressed oil prices, this event caused a small, but noticeable, spike in oil prices. More recently, the consortium known as the Organization of the Petroleum Exporting Countries, along with non-OPEC partners, agreed to cut oil production, driving oil futures prices up.[8] As shown in Figure 1 below, crude oil prices typically account for more than half the end-use consumer cost of gasoline, and 45 percent of diesel.[9]

Figure 1: Distribution of Costs for Gasoline and Diesel[43]



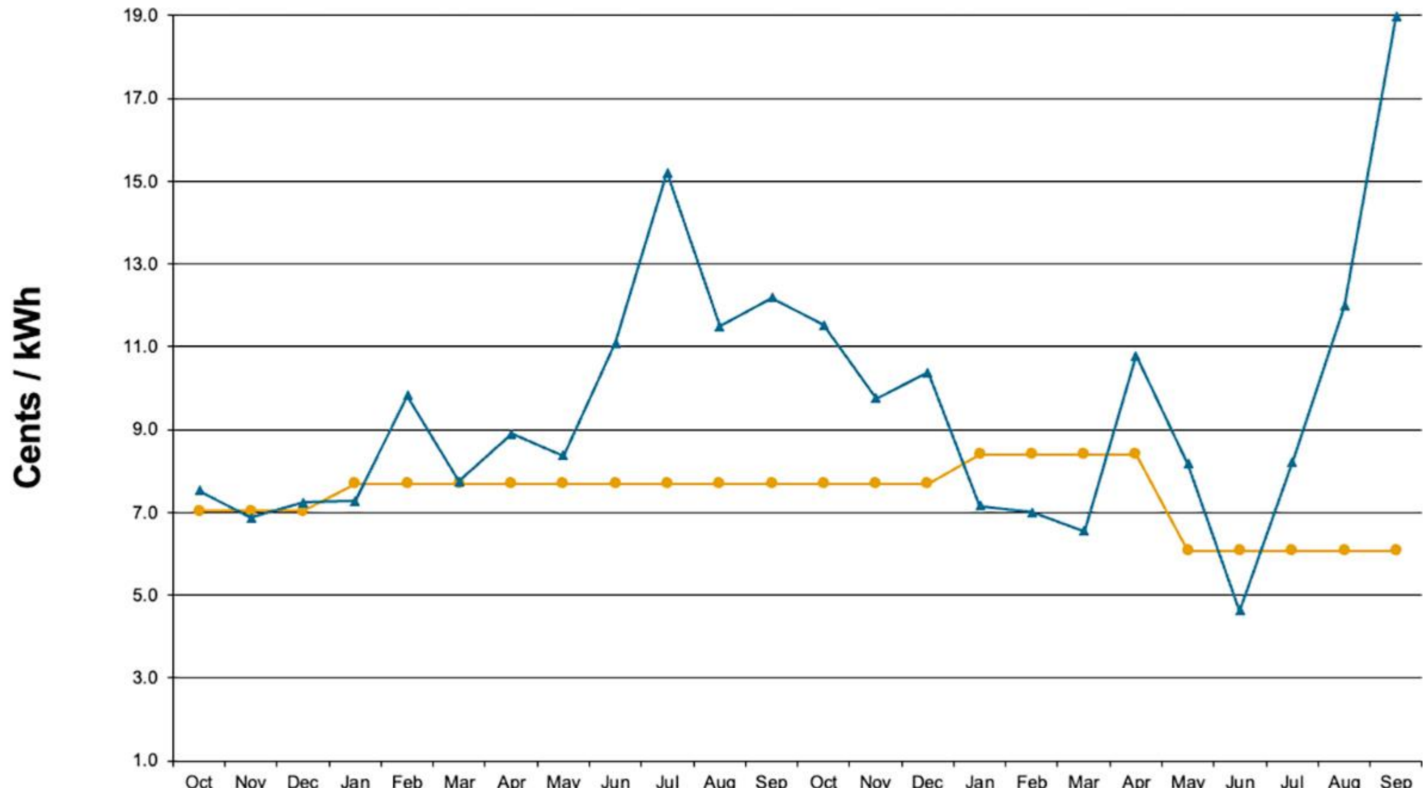
Regulatory Influences

For both electricity and natural gas, wholesale rates are subject to federal regulation while retail rates are subject to state regulation, which allows for some degree of public input on how end-use consumer prices are determined. Investor-owned natural gas and electric utilities are regulated by the Oregon Public Utility Commission, and the utilities participate in retail ratemaking cases that provide insight on utility costs that ultimately lead to setting the retail natural gas and electricity rates paid by

Oregonians. The OPUC commissioners must approve utility retail rate changes.[10] Costs of doing business are taken into account, including costs to plan for, build, and maintain utility systems, and the wholesale rates—which are subject to regulation by the Federal Energy Regulatory Commission—that utilities must pay to acquire bulk quantities of natural gas or electricity for delivery to retail customers.[11] Consumer-owned utilities are regulated by their elected governing boards. Global issues like supply chain disruptions for parts and equipment can also have an effect on rates, but these are rigorously assessed by the OPUC to be investments that are least-cost and least-risk for the utility and its ratepayers before they can be included in the rates that end up on a customer's bill.

Retail electricity and natural gas costs are more stable for retail consumers even when the costs for the utility may be more volatile. Figure 2 shows the relatively stable costs for retail electricity compared to more volatile wholesale electricity costs.[12] Over the course of the two-year period, customer retail rates in yellow stayed relatively flat, from 5.4 to 7.1 cents per kWh, even as wholesale costs in blue varied by nearly 10 cents over the same time period. The ability to maintain stable retail rates for consumers through retail price regulation is an advantage of the electric and natural gas sectors as compared to the gasoline sector.

Figure 2: Comparison of Wholesale and Retail Electricity Rates[44]



	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22
Cost of Service	7.0	7.0	7.0	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	8.4	8.4	8.4	8.4	6.1	6.1	6.1	6.1	6.1
Daily Pricing	7.5	6.9	7.2	7.3	9.8	7.7	8.9	8.4	11.1	15.2	11.5	12.2	11.5	9.8	10.4	7.2	7.0	6.6	10.8	8.2	4.6	8.2	12.0	19.0

Establishing Consumer Prices for Electricity and Natural Gas Through the Utility Ratemaking Processes

Electricity and natural gas energy costs are passed on to consumers through retail rates for utility services provided by regulated monopolies. Utility rates for electricity and natural gas services are established through public, transparent processes for both investor-owned and consumer-owned utilities. Investor-owned utilities are private electricity or natural gas companies. Three electric and three natural gas investor-owned utilities have their retail rates approved by the Oregon Public Utility Commission. Consumer-owned utilities are formed as municipal utilities, people's utility districts, and rural electric cooperatives.[13] For the 38 consumer-owned utilities that operate in Oregon, oversight is provided by publicly elected local boards.

Oregon Investor-Owned Utilities

Electricity:

- Idaho Power Company
- Pacific Power
- Portland General Electric

Natural Gas:

- Avista
- Cascade Natural Gas
- NW Natural

Oregon Public Power

In addition to the investor-owned electric utilities regulated by the Oregon PUC, there are 38 consumer-owned, not-for-profit electric utilities that also serve Oregonians. These utilities have been organized pursuant to authorities granted by the Oregon State Legislature.[45 46 47]

The first municipal utilities in Oregon were established in 1889: McMinnville Water & Light and the City of Milton-Freewater.[14 15] There are now 12 municipal electric utilities that are overseen by Oregon city governments or city-affiliated boards. There are also six people's utility districts and 18 rural electric cooperatives in Oregon that have locally elected boards—plus two additional cooperatives located out of state that have service territory in Oregon.[16] Formed in 2001, the Umpqua Indian Utility Cooperative is the first utility in the Northwest both owned and operated by a Tribe.

Together, consumer-owned utilities and investor-owned utilities provide universal electric service to all Oregonians and have public processes to establish fair rates for consumers.

Ratemaking Process for Regulated Investor-Owned Utilities

The Oregon Public Utility Commission is responsible for ensuring that investor-owned utilities provide safe and reliable electricity or natural gas service to consumers at just and reasonable rates.[17] In accordance with this directive, the OPUC applies a specific regulatory framework to calculate the retail rates that these utilities may charge to customers for electricity or natural gas service. The OPUC determines rates through complex and technical ratemaking proceedings.

Revenue requirement and operating expenses. In the investor-owned utility context, the ratemaking process is designed to enable a utility to recover the total costs it incurs in providing service to its customers and to earn a reasonable rate of return for the utility's shareholders. To establish a utility's retail rates, the OPUC first calculates the utility's "revenue requirement," which reflects the total cost to the utility of providing service to its customers. These costs may vary by utility due to differences in the type of load, distances between loads, and other service territory characteristics. Within the revenue requirement, a utility's costs and expenditures fall into one of two general categories: operating expenses and capital expenditures. Operating expenses include costs the utility expects to incur in providing service to customers. The OPUC allows utilities to recover a variety of operating expenses from ratepayers, including fuel, operations, and maintenance costs; administrative costs, taxes, and fees; and staffing and labor costs, including wages, salaries, and benefits. Depreciation and amortization expenses are also categorized as operating costs within the revenue requirement. Utilities may recover operating expenses from ratepayers, but may not earn an additional profit from these expenditures. Utilities are also not entitled to recover every kind of cost they may incur in the course of their operations. The OPUC may prohibit a utility from recovering certain operating expenses from ratepayers or require a utility's shareholders to cover a portion of those costs. For example, utility shareholders have been held responsible, in whole or in part, for expenses that are not necessary and prudent for serving ratepayers, such as executive incentive pay, lobbying costs, employee gifts and travel expenses, promotional costs, or trade association dues.[18]

Rate base. The second category of costs included in the revenue requirement is referred to as the utility's "rate base." The rate base includes prudent investments in capital projects that are used in service to ratepayers (known as the "utility plant in service"). To recover capital expenditures through the rate base portion of its revenue requirement, a utility must demonstrate that a project is "used and useful." This means the project must be in service during the entire period it is included in the rate base (*i.e.,* "used"), and that the project is needed to provide safe and reliable service to customers (*i.e.,* "useful"). The used and useful requirement is particularly important because a utility is entitled to earn an additional rate of return on capital expenditures in its rate base. Under the regulatory compact between investor-owned utilities and state regulators, utilities are entitled to earn a reasonable rate of return on their rate bases to maintain their financial integrity, attract capital, and compensate investors.[19]

Ratemaking for Consumer-Owned Electric Utilities

In addition to the three investor-owned electric utilities that serve Oregonians, there are also 38 consumer-owned utilities that serve Oregonians—including municipal utilities, rural electric cooperatives, and people's utility districts.[ii] Each of these utilities is self-governed by a locally elected board that sets retail rates separately for the customers it serves.

While each COU ratemaking process is separate, there are common elements involved across all of them. As not-for-profit entities, COUs are not driven by a profit motive, instead reinvesting accrued revenues back into the utility itself and/or the communities they serve. According to the American Public Power Administration, COU ratemaking involves the following core steps:[48]

(1) Identify the utility's **cost of service** across power supply, transmission, distribution, and customer-related expenses to determine the utility's revenue requirement

(2) **Divide the utility's revenue requirement by customer class** to identify the amount to be recovered from each class

[ii] See the utilities serving Oregonians using the Oregon Department of Energy's interactive Find Your Utility tool: www.tinyurl.com/FindYourUtility

(3) Factor a **rate adjustment strategy** into a financial plan that takes input from utility management and the governing board to develop a rate implementation strategy for three to five years

(4) **Balance the proposed rate structure** after seeking input from the governing board and the public to align the proposal with the needs of the community and the utility's revenue requirement

(5) Publish the draft rates and **seek customer feedback at a public hearing** before the board approves the rates

Most COUs serving Oregonians purchase most (100 percent in many cases) of their power supply from the Bonneville Power Administration. The low-cost, low-carbon power supplied by BPA is the primary reason that Oregon COU retail rates are among the lowest in the nation.

Customer class. Rates are set based on the cost to provide electricity or natural gas service to residential, commercial, and industrial customer classes that have similar usage and cost profiles for the utility system. After the OPUC approves a utility's revenue requirement, it divides the revenue requirement by the utility's estimated retail sales to determine the rates the utility may charge each customer class to recover its operating expenses and earn a rate of return for its shareholders. The ratemaking process aims to allocate total costs across a utility's customers in a just, reasonable, and non-discriminatory manner.[20] The cost of providing electricity or natural gas to customers can vary depending on how different customers receive and use energy. Because of these distinctions, the OPUC and utilities design different rates for residential, commercial, or industrial customer classes. In addition to retail rates, which are levied on each unit of energy consumed during a billing period, there are several other charges on a consumer's bill, such as a fixed basic customer charge that represents the minimum cost of service and reflects the cost to connect a customer to the distribution system. Commercial and industrial rates also include a charge—referred to as a demand charge—for the largest amount of power consumed at a given time over the course of the billing period.[21]

Wholesale purchase costs. Because wholesale electricity and natural gas prices fluctuate in response to market conditions, a customer's retail rates may not reflect the utility's wholesale costs on a month-to-month basis. Both investor-owned electric and natural gas utilities pass through the cost of wholesale purchases of electricity and natural gas to consumers without any associated rate of return for the utility. In addition, to enable these utilities to recover their wholesale electricity and gas costs without imposing additional costs onto consumers, the OPUC applies an adjustment to retail rates on an annual basis based on changes in wholesale purchase costs. For electric utilities, this is referred to as a power cost adjustment, while for gas utilities it is referred to as a purchased gas adjustment.[25] These adjustments allow utilities to update their annual revenue requirements without filing a general rate case, but through a public process that is still subject to prudency review by the OPUC. [26]

Energy efficiency. Recognizing that energy efficiency investments help reduce consumer energy bills, provide public health, environmental, and economic benefits, and reduce reliance on imported fuels, the Oregon legislature took action to support utility energy efficiency investments through the adoption of SB 1547 in 2016.[49] SB 1547 specifically aimed to ensure utilities make prudent investments in energy efficiency before acquiring new electric generating resources. To achieve this, the bill directed electric utilities to "[p]lan for and pursue all available energy efficiency resources that are cost effective, reliable and feasible." The bill also directed the OPUC to "plan for and pursue the acquisition of cost-effective demand response resources."[49] In requiring utilities to plan for and acquire cost-effective energy efficiency resources before investing in new generating resources, SB 1547 made it easier for utilities to recover the value of energy efficiency investments through the ratemaking process. Allowing utilities to include energy efficiency investments in their rate bases removes an inherent financial disincentive for utilities to conserve electricity, which has the effect of reducing revenues from electricity sales. Though the OPUC has worked to "decouple" utility profits from electricity sales for more than a decade by spreading the revenue requirement out over a utility's customer base, SB 1547 created a new financial incentive for utilities to reduce electricity sales through energy efficiency improvements.

Differential rates. In 2021, the Oregon legislature adopted HB 2475, known as the "Energy Affordability Act," which was designed to support a just and equitable clean energy transition by incorporating additional social justice considerations into the ratemaking process. The Act authorized the OPUC to consider differential energy burdens and other economic, equity, and environmental justice factors affecting energy affordability when approving electric and gas rates.[22] This authorization enables the OPUC and regulated utilities to design differential rates that account for ratepayers' ability to pay for electricity and gas services. For example, utilities may now offer discounted rates for "income-qualified" customers.[23] Utilities are required to file interim differential rate proposals prior to January 2023.[24]

The Oregon Citizens' Utility Board

Many proceedings at the OPUC, including ratemaking proceedings, involve complex technical and legal processes. The Oregon Citizens' Utility Board is a nonprofit created in 1984 by ballot initiative to advocate on behalf of and protect the rights of residential customers of investor-owned electric and natural gas utilities. CUB intervenes in regulatory proceedings before the OPUC and advocates on behalf of these customers.

Taxes and Other Charges

Local, state, and federal taxes may be included in electric and natural gas utility bills and are added to the price of transportation fuels at the pump. Tax rates vary by location. For example, current state gasoline taxes in Oregon are $0.38 per gallon and federal taxes are $0.184 per gallon.[27] Some cities also set local tax rates for gasoline, which range from $0.01 to $0.10 per gallon. In Oregon, taxes on transportation fuel are used almost exclusively to fund road and bridge improvements and maintenance. This is because the state constitution requires gas tax revenues to be used for highway-related purposes, such as constructing or repairing roadways or highway rest areas.[50]

Electric and natural gas utilities may also incur local taxes and fees, such as utility franchise fees or license fees, that they pass on to customers.[30 31] Investor-owned utility revenues are also subject to

Oregon's commercial activity tax, though certain fees and surcharges collected from utility customers are exempt from taxation, including charges that support energy conservation, renewable energy, and low-income assistance programs.[28] If a utility's gross revenues do not exceed $1 million, it is exempt from the corporate activity tax.[29]

In Oregon, Portland General Electric and Pacific Power are required to add a 1.5 percent Public Purpose Charge to customers' bills.[32] This is used to fund programs for low-income weatherization, renewable energy, low-income housing, and school investments in energy efficiency and transportation electrification. The utilities must also collect a 0.25 percent surcharge from their retail customers to support transportation electrification.[51]

Addressing Consumer Energy Costs

When energy prices increase, consumers often wonder how state government intervention could help to alleviate costs. As discussed above, global commodity prices contribute significantly to the retail prices paid by consumers, particularly for gasoline and diesel. In the immediate term, state policymakers have few ways to affect these prices. State and local governments set tax rates, and therefore can increase or reduce fuel taxes, but such actions do not tend to have much of an immediate effect on price increases.[33] As shown in the Figure 1 above, taxes generally account for less than 15 percent of retail gasoline and diesel fuel prices, which limits the extent to which a reduction in taxes would lower transportation costs.[34]

Wholesale natural gas prices also affect retail customer costs, but the effects of month-to-month price volatility are somewhat ameliorated by annual Oregon Public Utility Commission proceedings that oversee fuel cost assessments on ratepayers. The OPUC must ensure that retail rates for electricity and natural gas services are "just and reasonable" for both utilities and consumers. This directive does not ensure that utility ratepayers are insulated from cost increases; if wholesale prices rise, utilities are entitled to pass the higher costs onto consumers through annual retail rate adjustments. But retail rate regulation by the OPUC provides an added level of transparency and oversight over retail electric and natural gas prices that does not exist in the petroleum fuels markets.

In conjunction with transportation electrification, retail rate regulation also offers an opportunity to address transportation energy burden. When consumers shift from a fuel type with unregulated prices that are strongly influenced by volatile global commodity markets (like gasoline) to a fuel type that has regulated prices (like electricity), this shift will almost certainly reduce and stabilize transportation energy costs for Oregonians. Up to 30 percent of low-income households in Oregon are transportation burdened.[42] When charging at their residence or business, consumers that drive electric cars typically pay 70 to 80 percent less than those who drive gasoline cars. Electrification of the transportation sector presents a long-term opportunity for the state to have more influence than the status quo on managing the adverse effects of wholesale energy price volatility on Oregon consumers. Differential rates authorized by HB 2475 will further reduce energy burden associated with transportation electrification.

Global events and environmental factors can also put upward pressure on consumer energy prices that are difficult to address at the state level. Recently, there have been many outside events influencing gasoline and natural gas prices. The examples below describe several events and their effect on energy prices.

COVID-19

Demand for gasoline plummeted in Spring 2020 following stay-at-home orders as the global COVID-19 pandemic emerged.[35] As a result, the price for crude oil plummeted from approximately $60 to less than $20 per barrel in about two weeks, as shown in Figure 3.[36] Given the significant role that crude oil prices play in retail gasoline prices, the average national retail price also fell from about $2.50 to $1.80 per gallon.[37] Following the initial downturn in demand for oil and gas, the recovery caused prices to rebound starting in late 2021.[38] For more information on the effects of COVID-19 on the energy sector, see the COVID-19 Response and Effects of the Energy Sector Policy Brief from the *2020 Biennial Energy Report.*

Figure 3: Crude Oil Prices per Barrel Reported from Brent Market[52]

War in Ukraine

Russia is one of the top three crude oil-producing countries in the world (alongside the United States and Saudi Arabia).[39] As a result, the global instability in crude oil markets created when Russia invaded Ukraine in early 2022 contributed to the national average gasoline price spiking from about $3.35 to over $5.00 per gallon between January and June 2022.[37] A price for a barrel of crude jumped from approximately $75 to over $125 in the same period.[36]

Enbridge Natural Gas Pipeline Rupture

A rupture of a gas transmission pipeline between British Columbia and Washington state in October 2019 sent local natural gas prices skyrocketing as the supply of natural gas sharply decreased. Average next-day prices at the Sumas Hub were in the range of $2 to $3 per million British thermal units but rose to $9.55 per million Btu in the weeks following the rupture.[40]

Summer 2021 Pacific Northwest Heatwave

During June 2021, the Pacific Northwest suffered through an unrelenting heatwave that set records for both its severity and length. Portland recorded a temperature of 115 degrees at the heatwave's peak. During this record heat, wholesale electricity prices in the region climbed 435 percent.[41] The large increase in prices was driven by higher demand for electricity, largely from the widespread and prolonged use of air conditioning. Consumers were spared the real-time increase in price, as retail rates help to insulate consumers from this type of volatility in wholesale prices.

Conclusion: An Opportunity for Less Volatility

Oregon policymakers have oversight of the electric and natural gas sectors through the OPUC and COU governing boards, and this has helped keep electricity and natural gas costs relatively stable for retail ratepayers over the years. In no small part due to the region's robust hydroelectric system, Oregon has some of the lowest retail electricity prices in the country, which has made the state attractive to businesses that require large amounts of electricity. However, wholesale electricity prices in Oregon are still subject to price fluctuations, primarily from natural gas, which fuels 20 to 25 percent of the generation used to meet Oregon's electricity demand. As Oregon utilities move toward using 100 percent emissions-free resources, including solar, wind, and hydroelectricity, the price fluctuations of fossil fuels like natural gas will have an increasingly smaller effect on electricity prices.

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Energy 101: Oregon Fuel Action Plan

Learn more about how energy has contributed to Oregon's history on ODOE's interactive history timeline: ***energyinfo.oregon.gov/timeline***

The nationwide gasoline shortage of the early 1970s helped lead to the creation of the Oregon Department of Energy in 1975. At that time, ODOE began collaborating with the Federal Energy Administration,[1] other state energy offices, and the private sector to implement strategies to control traffic congestion and reduce panic buying at the pumps resulting from the supply shortages nationwide.

Originally, ODOE's fuel planning efforts focused on supply issues resulting from international geopolitics. Since the 1970s, the agency's fuel policies and procedures have evolved and adapted to the changing threats to the region's petroleum supply and distribution system. In 2017, ODOE developed an Oregon Fuel Action Plan,[2] which identifies strategies for addressing a variety of potential events that could trigger supply disruptions and distribution problems.

The U.S. Department of Energy is Born

For the three-year period between 1974 and 1977, the Federal Energy Administration implemented federal oil allocation and pricing regulations. An independent agency, the Federal Energy Administration was the successor of the Federal Energy Office, a short-term organization created to coordinate the government's response to the Arab oil embargo. By October 1977, when it became a part of the newly established U.S. Department of Energy, the Federal Energy Administration had also assumed the tasks of promoting energy conservation, collecting energy supply and demand information, managing the nation's strategic petroleum reserve, and promoting the development of new energy resources.

Threats to the Pacific Northwest's Fuel Infrastructure

The petroleum industry occasionally experiences supply and distribution problems, but in general is extremely resilient to short-term disruptions. A "just-in-time" business strategy – which means having the minimum amount of inventory available to meet demand – creates an efficient, but tight, supply chain under normal conditions.

Oregon's primary fuel terminals in Portland and Eugene are on a six-day refueling cycle, meaning the state has less than one week's supply of reserves on hand at any given time. Oregon faces additional challenges because all the refined petroleum products used in Oregon are imported from outside the state and any significant disruption to pipeline or refinery operations can quickly become problematic.

Oregon's Petroleum Supply and Distribution System

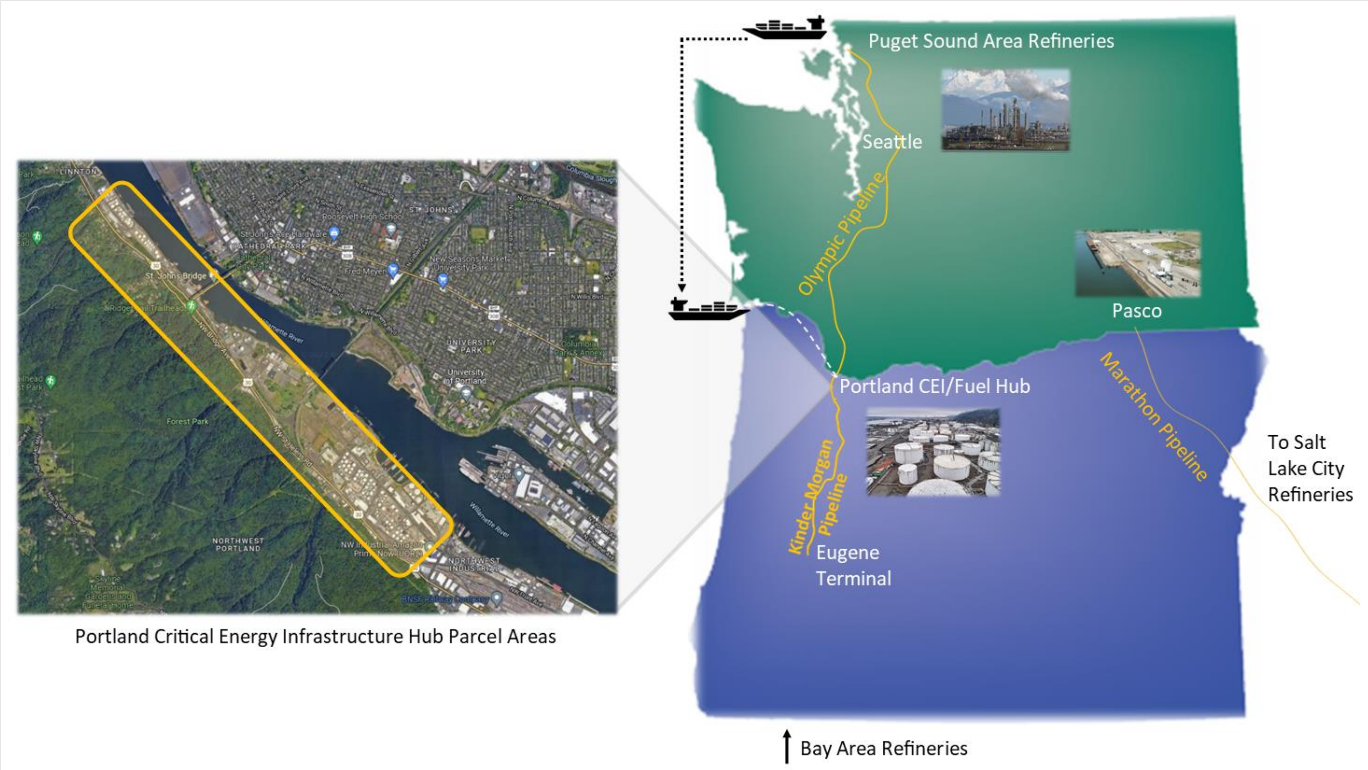
More than 90 percent of transportation fuels used in Oregon are produced in refineries in Washington and delivered via the Olympic pipeline and barge to seven Portland-area terminals. From these terminals, some of the product flows via pipeline south to Eugene, and via another pipeline to the Portland International Airport. The Eugene distribution terminal serves southern, central, and eastern Oregon. Tank barges also carry some refined petroleum up the Columbia River to Pasco, Washington to service eastern Oregon communities. Additionally, an estimated 1,500 tanker trucks deliver fuel from the Portland-area terminals to about 2,400 fueling locations throughout the state. [3]

Less than 10 percent of the refined petroleum products used in Oregon originate from refineries in Salt Lake City and the San Francisco Bay Area.[4] From Salt Lake City, the Marathon Pipeline transports product to a distribution terminal in Pasco, Washington. From the Pasco facility, trucks deliver fuel to eastern Oregon communities.

San Francisco Bay Area refineries supply small quantities of fuel to a Chico, California terminal from which trucks deliver supply to southern Oregon communities.

Learn more about where Oregon gets its petroleum fuels in our *2020 Biennial Energy Report.*

Figure 1: Map of Oregon and Washington Fuel Supply and Distribution System



Threats to the region's fuel infrastructure include natural hazards, intentional acts, equipment failures, and pandemics. Examples of natural hazards include earthquakes, winter storms, wildfires, heat waves, floods, and droughts. Cyberattacks, physical security breaches, mechanical breakdowns, terrorism, and war are examples of intentional acts. Pandemics like COVID-19 and H1N1 also pose risks to the critical workforce at refineries, terminals, pipelines, delivery companies, and retail fueling outlets. A workforce reduction could affect the fuel supply chain and distribution system. As the climate changes, many of these natural hazards are intensifying in frequency and magnitude, posing increased risks to energy systems.

The Pacific Northwest's greatest natural threat is a Cascadia Subduction Zone earthquake and tsunami. Seismic studies show a CSZ event would likely devastate the region's petroleum infrastructure. Widespread damage to refineries in the Puget Sound area of Washington, the Olympic Pipeline, and the Portland-area terminals is anticipated – shutting down the region's fuel infrastructure for weeks to months, if not longer.[5] Oregon can expect to lose most, if not all, of the fuel supply to the terminals due to earthquake damage.[6] The earthquake also has the potential to affect northern California and disrupt the small amount of fuel deliveries from Bay Area refineries to southern Oregon communities. Additionally, with damage to roads and bridges, it may be difficult to transport what supply Oregon does maintain to affected communities.

Fuel Planning Authority, Roles, and Responsibilities

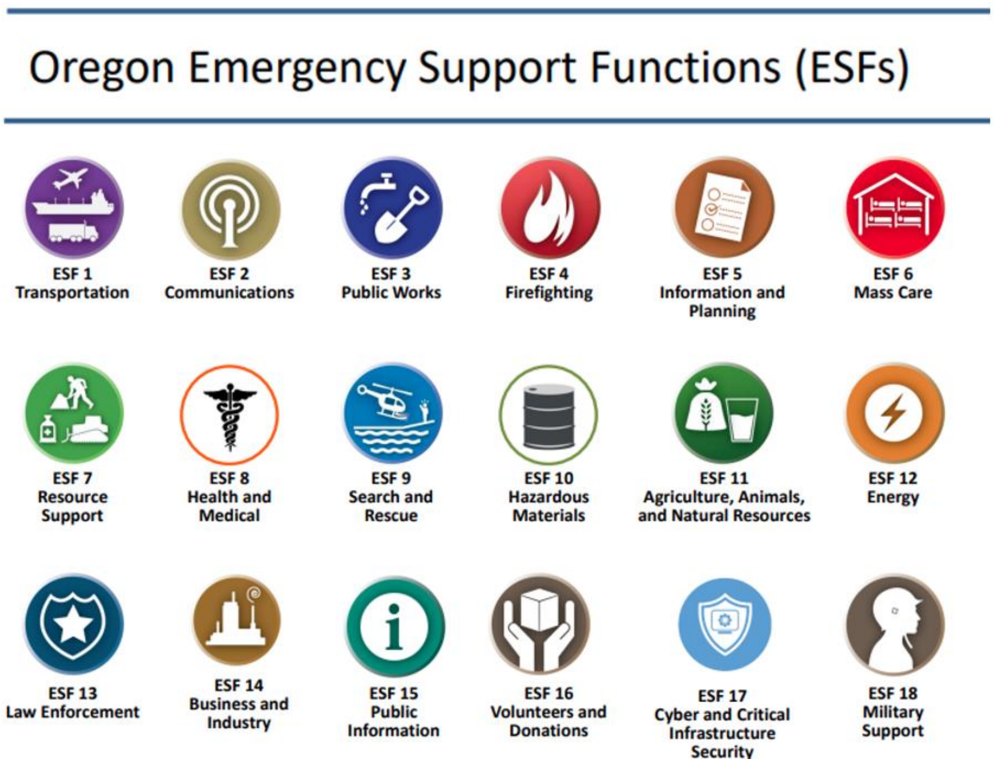
Oregon Revised Statute 401 grants the Governor broad authority to protect the public by declaring a State of Emergency when a disaster occurs.[7] ORS 401.188 provides additional powers to the Governor to control, restrict, or regulate the use, sale, or distribution of fuel and other commodities to support the state's response and recovery activities.[8]

The Oregon Department of Emergency Management (OEM) developed a coordinated response structure identifying 18 Emergency Support Functions or ESFs[9] that ensure if critical lifelines and services are disrupted, vital capabilities and resources can be provided by emergency response agencies. Oregon's ESF structure mirrors the federal framework and ESF 12 addresses the energy subsectors. At the federal level, the U.S. Department of Energy is the lead for ESF 12.

At the state level, OEM designated the Oregon Department of Energy and the Oregon Public Utility Commission as lead agencies for ESF 12.[10] ODOE is responsible for the petroleum, liquified natural gas, and radiological issues and the PUC has the lead for the electricity and natural gas sectors in planning for, responding to, and recovering from a disaster. ODOE works closely with the U.S. Department of Energy (USDOE) to ensure the federal ESF 12 plans integrate and align with state strategies in preparation for responding to and recovering from fuel disruptions affecting Oregon.

In the event of an emergency or natural disaster, the Oregon Department of Energy is responsible for the petroleum, liquified natural gas, and radiological issues.

Figure 2: Oregon's 18 Emergency Support Functions



ORS 176.750-785 authorizes ODOE to develop and maintain a statewide contingency plan and strategies to ensure that adequate fuel supplies are available to maintain emergency services, transportation systems, the economy, and public health and welfare while an emergency exists.

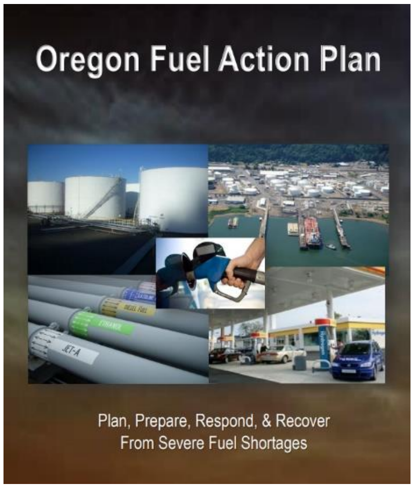
Oregon Fuel Action Plan

As the designated state lead for ESF 12 overseeing petroleum emergency preparedness, planning, response, and recovery, ODOE developed the Oregon Fuel Action Plan in 2017. The plan identifies priority actions the agency would take to direct the state's overall response to petroleum disruptions. This includes establishing scalable procedures for:

- Plan activation and notifications within ODOE and to external partners and key stakeholders.
- Monitoring and assessing the severity, scope, and other consequences of supply shortages and distribution problems.
- Federal, state, local, tribal, and petroleum industry collaboration and coordination in emergencies.
- Issuing voluntary and mandatory fuel conservation measures.
- Securing waivers to ensure timely fuel deliveries.

- Developing and disseminating fuel information and protective actions to the public and news media.
- Fuel allocation to emergency and essential services providers when supplies are limited.
- Designating distribution sites for receiving emergency fuel supplies.
- Coordinating and implementing regional response measures with western states if event conditions warrant joint state actions.

In the event of a CSZ earthquake, ODOE actions include working with federal agencies and the petroleum industry to create new temporary fuel supply chains into Oregon until the region's petroleum infrastructure is restored. ODOE would continue to collaborate with federal partners to identify new delivery systems into the affected communities following a Cascadia earthquake. This would include bringing fuel into staging areas in central Oregon, expected to be located at the Redmond and Klamath Falls airports, before moving the product into communities along the I-5 corridor when possible. Small amounts of fuel could also be transported by air, but these missions would be limited. To support coastal communities, fuel supplies could be delivered by tanker ships, as it is anticipated that roads and bridges will be severely damaged and coastal communities may be inaccessible via road.



The Oregon Fuel Action Plan was developed in coordination with federal, state, local, tribal, and petroleum industry partners. Each strategy and procedure identified by the plan can be scaled up or down as needed to address different levels of supply disruption severity.

Oregon Emergency Response Structure and ODOE Responsibilities for Fuel

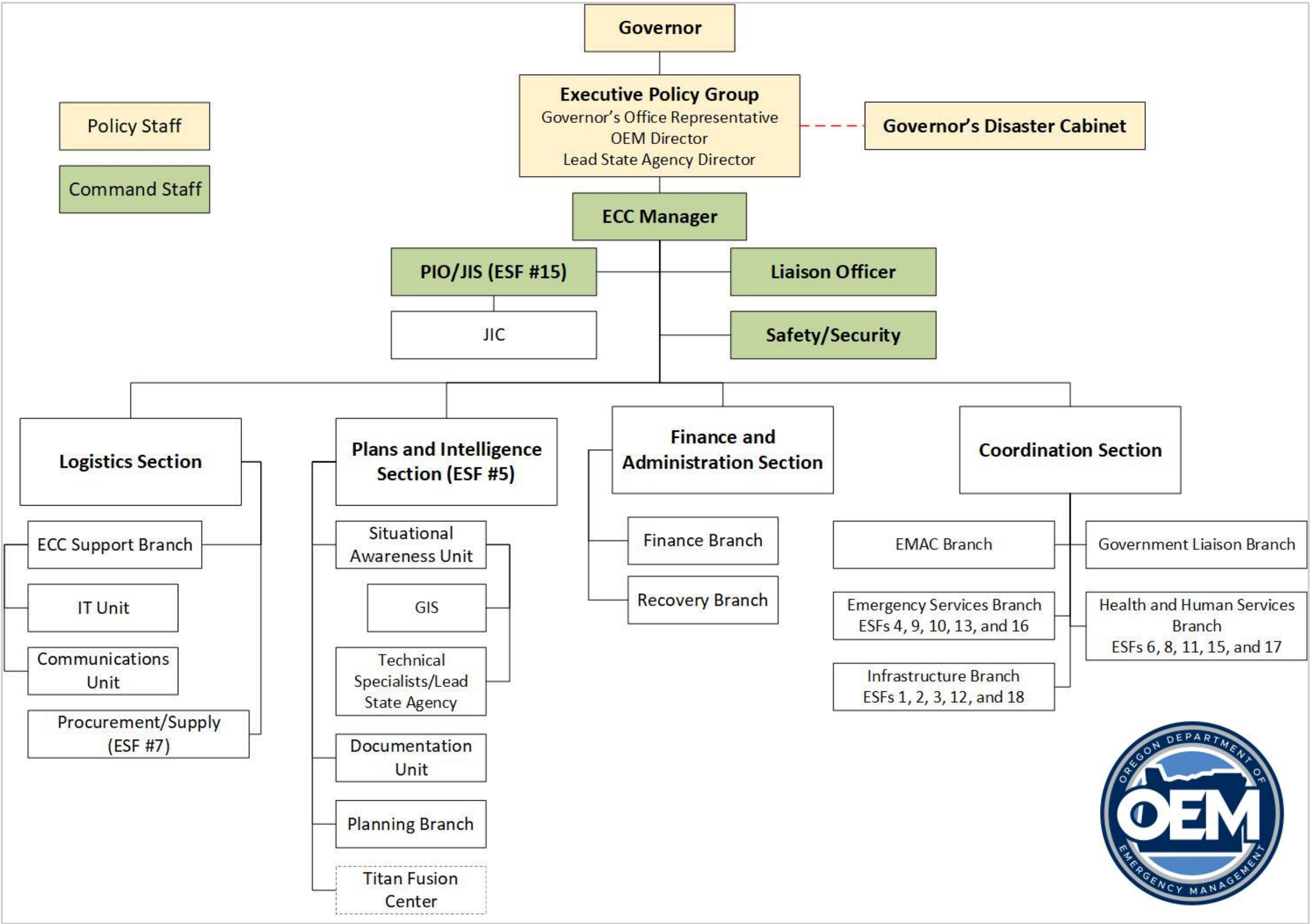
During state-declared emergencies, OEM may activate the State Emergency Coordination Center to direct and coordinate the state's overall response to an event. During State Emergency Coordination Center activations, ODOE and other state agencies with emergency response duties report to the State ECC virtually[i] or in person to support the state's overall response and recovery effort.

- ODOE's Director guides and advises state leadership on policy issues and concerns surrounding fuel disruptions. ODOE's Director reports to the Governor's Disaster Cabinet.[11]
- ODOE emergency preparedness staff works with petroleum industry partners to assess the severity of supply disruptions, determine risks to public health and safety, and identify solutions to mitigate supply and distribution concerns. ODOE emergency preparedness staff report to the ECC to coordinate with other ESF agencies to ensure interdependencies are addressed among all critical lifeline services.[12]

[i] The current plan has been updated with OEM to include virtual reporting since the onset of the COVID pandemic, but this is not currently reflected in the online plan.

- ODOE's Public Information Officers develop and disseminate emergency fuel information and protective action instructions and provides support to the state's Joint Information Center (JIC).[13]

Figure 3: Oregon State Emergency Response Structure



ODOE Response to Events

The Oregon Department of Energy has activated the Oregon Fuel Action Plan when the Governor issued state emergency declarations in response to events that affected the fuel supply and distribution system. Following are some recent examples:

2020 Wildland Fires. The Labor Day 2020 windstorm resulted in five simultaneous "megafires"– fires greater than 100,000 acres in size – in Oregon. These fires started September 7 - 8, 2020, and in a matter of days burned more than 1 million acres. While Oregon's fuel supply and distribution system was not directly impacted, there were limiting factors affecting fuel access. Fire suppression and utility crews responding to affected areas lacked fueling capabilities for their trucks within the response area. ODOE coordinated with fuel cardlock facilities to secure fuel cards for fire fighters and utility crews. Without ODOE's support, these first responders would have had to drive more than an hour away to fill their tanks before returning to continue critical life safety work. ODOE also coordinated a mission to reprogram fuel pumps in a fire-impacted area to ensure first responders could access fuel.

2021 Wildland Fires. Starting in June 2021, a sudden increase in commercial air travel as the COVID pandemic waned, coupled with an early wildfire season in late spring, resulted in jet fuel supply and distribution problems for smaller airports in southern and northeast Oregon to support wildland firefighting missions. While there was no shortage of jet fuel in Oregon, there were logistical challenges connecting available supplies with fuel haul trucks and drivers to get the much-needed fuel to those local airports where the demand for jet fuel exceeded local supplies. ODOE worked with state, local, and federal partners, as well as with the private sector, to ensure firefighters had the fuel they needed to continue to fight wildfires. This included establishing procedures in coordination with the Oregon Department of Forestry and the Oregon Department of Aviation for requesting and meeting fuel needs in future wildfire seasons.

2021 Winter Storm. In February 2021, the Governor declared a state of emergency after freezing rain and snow blanketed nine Oregon counties, causing treacherous conditions. Because roundtrip fuel deliveries from Portland to central Oregon and to some coastal communities average ten hours under normal conditions, ODOE coordinated with the Oregon Department of Transportation to secure an Hours-of-Service (HOS) waiver to allow fuel truck drivers to exceed the 11-hour limitation, if needed, to make timely deliveries without penalties. Oregon HOS laws limits drivers to 11 hours of drive time within a 14-hour window after 10 consecutive hours off-duty. ODOE also worked with suppliers and distributors to coordinate fuel deliveries to first responders and critical infrastructure facilities like water and wastewater treatment facilities for powering backup generators.

COVID-19 Pandemic. ODOE worked with the petroleum industry to assess personal protective equipment needs and was able to secure 14,000 masks and other PPE requests from FEMA for fuel terminal operators and gas station attendants. The reduction of travel caused by COVID resulted in a surplus of winter grade gasoline and diesel fuels, making it difficult for industry to meet the annual May 1 deadline to transition to summer grade fuels. At the request of industry, ODOE facilitated discussions with the Department of Environmental Quality, Department of Agriculture, and the City of Portland to lift the regulation that requires fuel distributors to change their blends of gasoline and diesel by that May 1 date. This allowed fuel companies more time to sell their remaining winter grade fuels before transitioning to summer

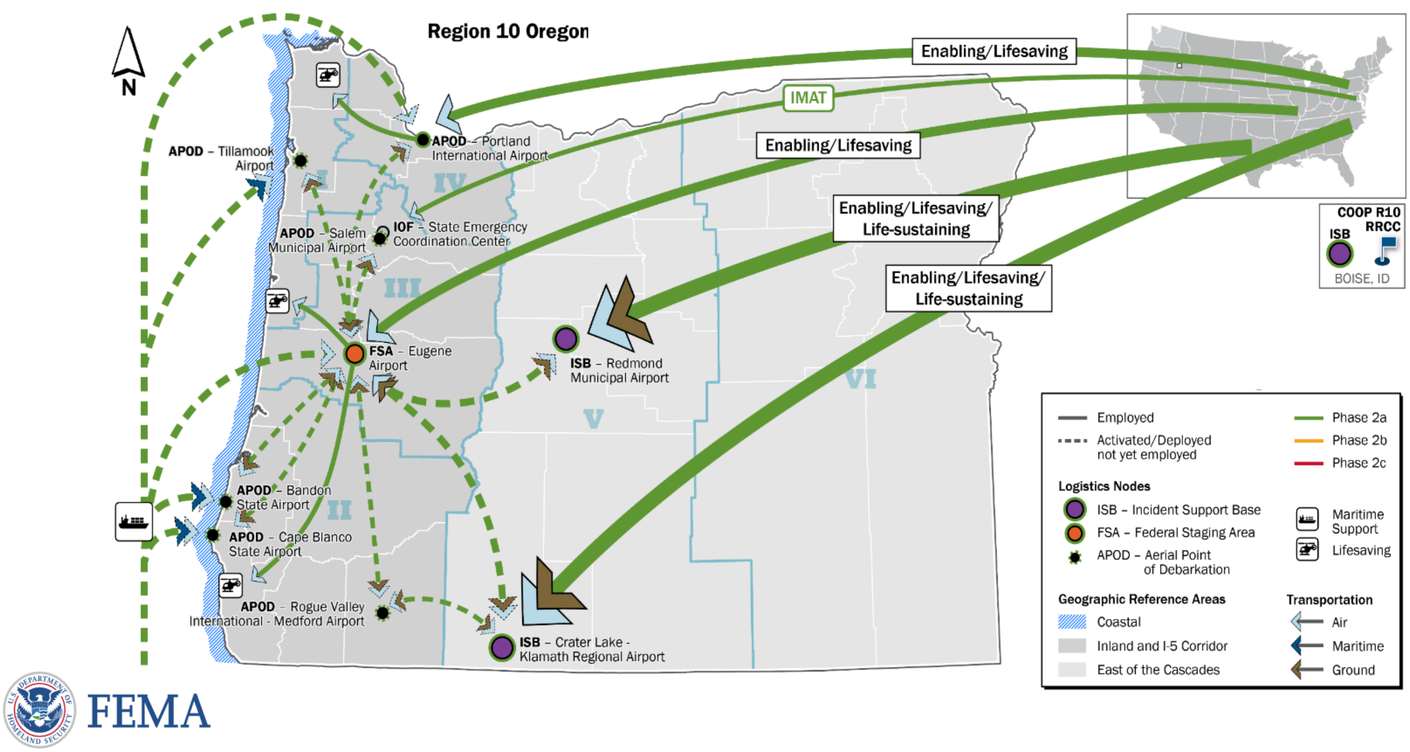
grade fuels without penalty. ODOE also supported the Joint Information Center by developing public messaging about the temporary suspension of the self-serve gas ban to allow gas station owners the option to let customers pump their own gas. This allowed gas stations to continue operations with fewer staff. The Oregon Fuels Association reported that COVID caused a temporary 50 percent reduction in the state's gas station workforce due to illness, childcare issues, and safety concerns.

Ensuring Program Readiness

ODOE routinely participates in national, regional, state, and local level exercises to ensure program readiness. These training opportunities provide ODOE staff the ability to validate the Oregon Fuel Action Plan to ensure that strategies and procedures established remain current and relevant to address present threats to the petroleum sector. Exercises and tabletop drills also allow ODOE staff to maintain their response capabilities by working through the complexities involved in the establishment and coordination of an emergency fuel management system with key federal, state, local, and petroleum industry partners following a CSZ earthquake and tsunami.

In February 2022, for example, ODOE staff participated in FEMA's CSZ Supply Chain Logistics Management Tabletop.[14] In the three-day discussion-based exercise, ODOE staff increased its understanding of protocols for road clearing and reopening to support fuel movement into the affected communities, security measures needed to protect and support fuel distribution, and logistical requirements to establish fuel storage and distribution points. ODOE staff also discussed leveraging surviving private sector capabilities to support fuel missions. Figure 4 below demonstrates the proposed routes that would be used by FEMA to bring resources, including fuel, into Oregon in the event of a CSZ earthquake.

Figure 4: FEMA-Proposed Concept of Operations for Oregon – Cascadia Event



As another example, ODOE staff took part in USDOE's Clear Path IX Fuels Tabletop in September 2021.[15] The purpose of the exercise was to improve the overall understanding of the federal resources and capabilities available to support fuel operations in Oregon and Washington in the aftermath of a CSZ event. ODOE staff validated federal protocols for states requesting fuel assets, identified lead federal agencies tasked to carry out specific fuel missions, and confirmed logistics coordination requirements for receiving fuel resources in Oregon post CSZ. The exercise also provided federal agencies an opportunity to understand ODOE expectations concerning fuel priorities and strategies in a major disaster.

ODOE staff also regularly participate in private sector training and emergency exercises. In October 2022, Kinder Morgan invited ODOE staff to join the company's Worst Case Disaster Exercise. The scenario involved a pipeline failure resulting in a spill of nearly 60,000 gallons of jet fuel into the Willamette River. As a result, the pipeline from the Kinder Morgan terminal to the Portland International Airport (PDX) would have been shut down for months. During the Exercise, ODOE worked with the company, PDX, Port of Portland, City of Portland, and the Oregon Department of Environmental Quality to address jet fuel supply disruptions that would have occurred at the airport.

All lessons learned from responding to actual emergencies, exercises, and training will be incorporated as appropriate in a forthcoming revision of the Oregon Fuel Action Plan.

Regional Coordination

With the increase in cyberattacks, extreme weather events, and the threat of a CSZ event and associated risks to the fuel infrastructure, regional coordination is increasingly important since fuel emergencies often have regional impacts crossing state lines. Oregon also relies exclusively on importing the finished petroleum product from refineries in other states.

Western States Petroleum Collaborative. In March 2020, the WSPC[ii] was created to facilitate the coordination and development of a regional fuel response framework with 11 state energy offices and emergency management agencies.[16] The western states recognized the need to work together and share resources to address regional petroleum shortage preparedness and response needs. This effort was built off the existing network of State Energy Emergency Assurance Coordinators originally established in 1996 to encourage information sharing in energy disruptions. The WSPC expands the coordination beyond information sharing to include coordinated response actions.

[ii] This group was originally named the Western Petroleum Shortage Response Collaborative, or WPSRC. The 11 participating states agreed to shorten the name and acronym to Western States Petroleum Collaborative, or WSPC.

Staff from ODOE and the Oregon Department of Emergency Management co-chaired the 18-month effort sponsored by the USDOE's Office of Cybersecurity, Energy Security, and Emergency Response (CESER), the National Association of State Energy Officials (NASEO), and the National Emergency Management Association (NEMA) to establish the framework for the WSPC beginning in March 2020. As co-chairs, ODOE and Oregon Emergency Management[iii] staff provided guidance and worked to ensure project goals and objectives reflected the need for regional coordination to manage fuel disruptions affecting multiple states.

The WSPC Framework was finalized in September 2021, with ODOE hosting and facilitating the initial WSPC quarterly meetings in 2021, Washington hosting the 2022 meetings, and California hosting in 2023. The meetings allow the 11 western states to collaborate on fuel planning, preparedness, response, and resilience efforts during non-emergency conditions. During emergencies, any state could activate the WSPC to share information, provide situational awareness, or to discuss implementation of regional measures if needed in response to the fuel situation in two or more states. USDOE, NASEO, and NEMA participate and support the WSPC as needed.

NASEO Energy Security Committee. ODOE staff also participates in NASEO's monthly Energy Security Committee virtual meetings to discuss, learn, and collaborate in the areas of energy data and analysis, intra-state and inter-state communications and training, and public-private sector coordination. The committee collaborates with relevant federal partners and industry stakeholders to promote the roles, responsibilities, and capabilities of State Energy Offices to manage comprehensive energy sector security.

Energy Security Planning

In November 2021, the Infrastructure Investment and Jobs Act was enacted, authorizing USDOE to provide financial and technical assistance for state energy offices to develop what is now called a State Energy Security Plan. State Energy Security Plans must include an assessment of potential hazards to all energy sectors and cross-sector interdependencies as well as proposed methods to strengthen the state's ability to have reliable, secure, and resilient energy infrastructure.[17] The federal law also requires states to engage in regional coordination and provide an annual letter of certification from the Governor to USDOE to ensure a state's State Energy Security Plan complies with federal requirements. ODOE staff will lead and coordinate the development of Oregon's Energy Security Plan.

Likewise, Oregon legislators passed a bill in the 2022 session with similar energy security provisions.[18] SB 1567 directs ODOE to develop an Energy Security Plan that evaluates the state's ability to recover quickly from natural disasters and intentional acts, including cyber risks, to Oregon's energy systems overall. This includes assessments of the state's electricity network, natural gas system, and liquid fuels. SB 1567 also directs ODOE to evaluate strategies to increase fuel storage capacity throughout the state to provide a safety net for local communities following major disasters. ODOE's ongoing planning with federal agencies shows that the greatest challenge following a CSZ event will be the widespread damage to the state's transportation systems, which will limit the ability to deliver fuel to

[iii] On July 1, 2022, the Oregon Office of Emergency Management became the Oregon Department of Emergency Management.

affected communities in western Oregon. It could take weeks to deliver fuel to some communities due to the lack of access, and will likely take longer in the more remote areas of the state.

Developing the plan will be a major effort for ODOE and require close coordination with key state agencies, local governments, tribal governments, Environmental Justice Council, and the public. ODOE will also consult with private-sector partners in the petroleum industry, electric and natural gas utilities, and other qualified technical experts in disaster resilience. ODOE expects that developing the Energy Security Plan will take about 18 months. SB 1567 requires ODOE to complete the plan by June 2024.

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Energy 101: Backup Power

Backup power systems provide emergency onsite energy generation in the event of a power outage. These systems use generators or battery storage to provide emergency backup power. Fossil fuel generators have traditionally been used for industrial or institutional uses, such as at hospitals, as well as for residences. These systems may use diesel, gasoline, propane, or natural gas to generate onsite electricity. Recently, however, technology advancements and price reductions have increased the use of solar energy systems paired with battery storage to provide backup power in residential and small commercial applications. Solar plus storage systems may also be installed with conventional fossil fuel generators to extend run times and improve system performance. Regardless of the type of system used for backup power, energy efficiency measures and careful operations are necessary to reduce loads and ensure maximum system benefits.

The Oregon Department of Energy office in Salem has a 300-gallon diesel backup generator that can provide power to critical agency equipment for about 24 hours in the event of an outage or emergency.

Most of the backup power systems serving commercial and industrial loads are diesel-fueled generators. There are no recent studies analyzing backup generators in Oregon, but a 2021 study conducted in California found that nearly 90 percent of existing commercial and industrial backup generators are fueled with diesel, 6 percent from natural gas, and the remainder from other fuels, such as propane.[1] Permits for new backup generators also indicate a strong preference for diesel-fueled systems. In Crook County, Oregon, the Apple and Facebook data centers together hold permits to operate 222 diesel generators totaling more than 600 MW of capacity.[2] The 2021 California study found that 84 percent of backup power generators permitted since April 2020 are diesel-fueled.

Battery storage paired with onsite renewable energy systems is an emerging backup power technology in Oregon. These systems typically use rooftop solar to charge wall-mounted battery storage packs. Solar plus storage systems can be continuously recharged without the need to store or procure fuel during a natural disaster but must be sized appropriately and rely on variable solar resources for recharging. In Oregon, battery storage systems are becoming more commonly used in residential applications; on a larger scale, solar plus storage systems may be used to power microgrids, providing power to critical infrastructure and making Oregon communities more resilient. However, there are limitations to the amount of power that can be generated and stored with onsite solar-plus-battery storage systems. For providing backup power to larger systems, and

This residential battery storage system stores energy generated by rooftop solar panels.

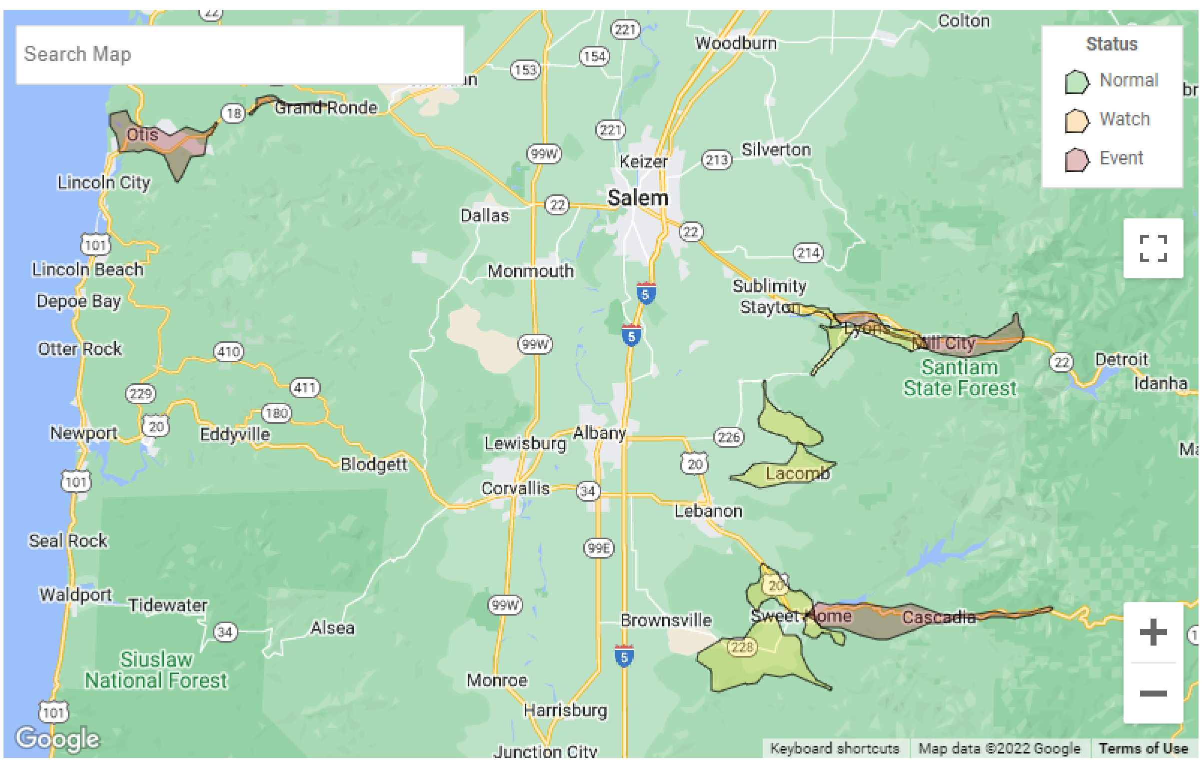
for many other applications, solar plus storage systems are still more expensive than fossil fuel-based generators and may be seen as cost prohibitive for some consumers.

Function and Importance

Escalating frequency and severity of extreme weather events may increase interest in backup power systems. For example, the catastrophic Oregon wildfires of 2020 and their corresponding widespread power outages showed how changes in the climate may increase the need for backup power. Wildfire risk to grid infrastructure may result in utilities implementing proactive Public Safety Power Shutoffs, or other protective measures to ensure public safety. In California, these shutoffs have increased demand for backup power — the 2021 California study found that total capacity of backup generators increased by 34 percent from December 2018 to 2021.[1]

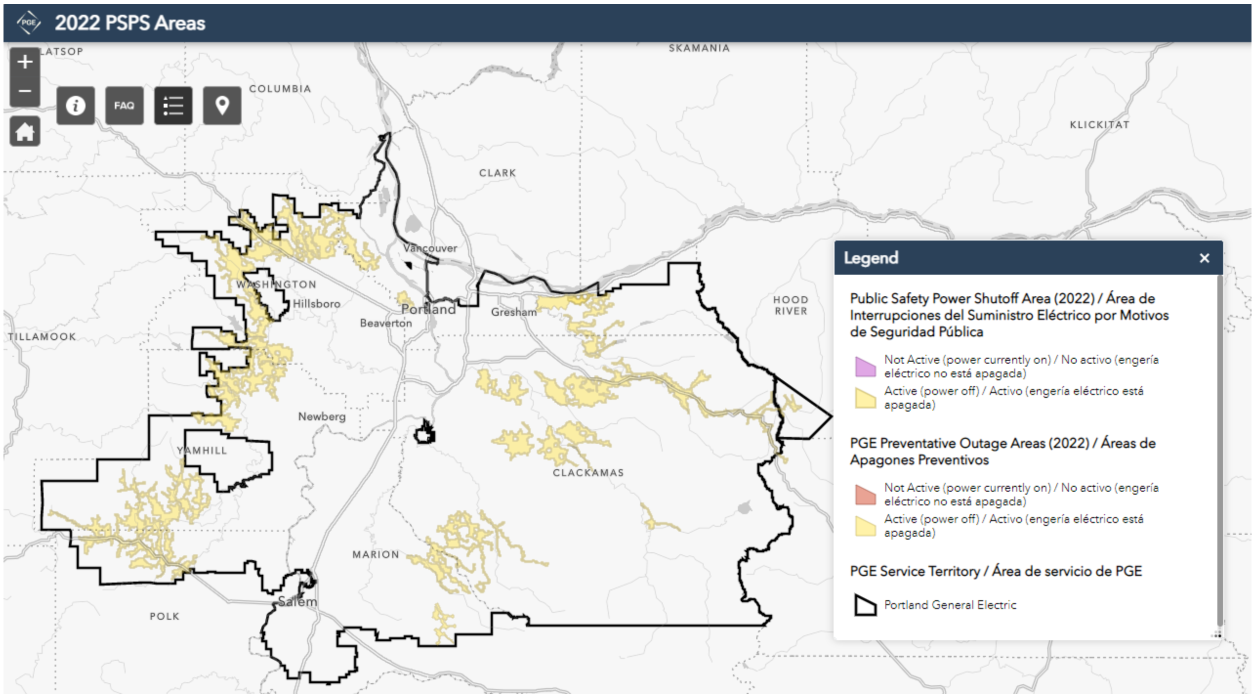
In May 2022, the Oregon Public Utility Commission adopted rules establishing protocols for Public Safety Power Shutoffs (PSPS) for Oregon utilities.[3] Pacific Power and Portland General Electric maintain web pages where customers can get up-to-date information regarding potential power shutoffs. On September 9, 2022, Portland General Electric and Pacific Power initiated Public Safety Power Shutoffs to mitigate the risk of wildfire during an extreme fire hazard weather event. The shutoffs affected over 40,000 customers.[4] Figures 3 and 4 below indicate some of areas affected by the shutoffs. The maps published by PGE and Pacific Power are updated throughout the wildfire season.

Figure 3: Areas affected by the Public Safety Power Shutoff implemented by Pacific Power to mitigate wildfire risk during an extreme fire hazard weather event on September 9, 2022.[5]



Power was cut off to the areas tinted red.

Figure 4: Areas affected by the Public Safety Power Shutoff implemented by Portland General Electric to mitigate wildfire risk during an extreme fire hazard weather event on September 9, 2022.[6]



Power was cut off to the areas tinted yellow.

Critical Facilities

Some facilities and building systems are required by Oregon Building Codes to have backup power to ensure public safety. For example, facilities where interruption of the primary power could result in loss of human life or serious injuries, such as hospitals, are required to have emergency backup generators. Facilities that are not required to have backup generators may still be required to have emergency power systems on some building systems, such as exit lighting and smoke detectors. The 2019 Oregon Structural Specialty code defines emergency power systems as "a source of automatic electric power of a required capacity and duration to operate required life safety, fire alarm, detection and ventilation systems in the event of a failure of the primary power."[7]

Limitations

Limitations of Diesel Generators

Fuel Storage. During a natural disaster, fossil fuel generators are likely to be limited by the amount of fuel that is stored on site. A Cascadia subduction zone earthquake is expected to devastate Oregon petroleum supplies and distribution.[8] As a result, many facilities across the state may be limited to the fuel stored on site with refueling postponed weeks or months following a natural disaster.

Backup fuel storage requirements are set forth in Oregon Building Codes for critical facilities. The Oregon Structural Specialty Code references NFPA Standard 110 published by the National Fire Protection Association.[9] Fuel storage requirements vary depending on facility type and local seismic classifications. For example, a hospital in a high seismic risk area may be required to store fuel for up to 96 hours of generator operation with storage tanks sized at 133 percent of expected full load fuel consumption.

The fuel consumption rate of fossil fuel generators depends on the generator size and to a lesser extent the electrical load being served. For example, a 400-kW diesel generator operating at 25 percent load will consume about 7.9 gallons of fuel per hour and operate at a fuel conversion efficiency of 31 percent. The same generator operating at 100 percent load will consume 24.2 gallons per hour and operate at a fuel conversion efficiency of 41 percent.[10] Under full load conditions, the 400 kW generator would need about 3,000 gallons of on-site fuel to meet the 96-hour run time requirement in Oregon Code.

Diesel generators and fuel storage tanks. Photo: Portland General Electric

Maintenance. NFPA-110 also describes requirements for maintenance and operations of fossil fuel generators.[9] Facility operators are required to do weekly inspections of the generators and conduct monthly operational testing. Operation tests must be conducted under full load for a period of at least 30 minutes. Liquid fuels that are stored on site must remain within manufacturers specifications. For example, NFPA 110 requires that diesel fuel must undergo regular testing if stored for more than 12 months.

Even with routine maintenance and inspections, diesel generators are prone to mechanical failures during an emergency. During Hurricane Sandy in 2012, generators failed at several hospitals in New York and New Jersey.[11] More recently, in 2021, a backup generator at Thibodaux Hospital in New Orleans failed during Hurricane Ida, requiring Intensive Care Unit patients to be moved.[12] The causes of diesel generator failures have included equipment flooded in basements, failed switchgear, overheating, and fuel shortages.[11]

Limitations of Solar Plus Storage

Size. Solar plus storage systems have significant limitations for use as stand-alone backup power systems —especially in facilities with high electrical loads like hospitals. For example, the 400-kW diesel generator described above was assumed to run for 96 hours at full load and consume 3,000 gallons of fuel. This run-time represents 38.4 MWh of electricity provided to the site over four days, or 9.6 MWh of energy per day. If this system were located in Portland, and the backup power were required in December, it would take about 8 MW of solar PV to provide a similar amount of daily energy. Eight MW of solar with battery storage would require about 50 acres of space and be cost prohibitive as a backup power system. Solar plus storage systems may be used to supplement large facility backup operations as described for large hybrid systems below.

Opportunities

Residential and Small Commercial

While solar plus storage systems may not be viable for large facilities with limited space, there is an opportunity to use them in residential and small commercial applications. Systems may be configured to power limited essential loads or, in off-grid applications, serve as the sole power source in a home. Many systems are designed to operate indefinitely during a power outage, utilizing daytime solar to recharge the battery packs. Discharge rates will depend upon the loads being served in the home (additional information regarding battery storage systems can be found in the *Electricity Storage* Energy Resource and Technologies Review section of this report). Rooftop solar tied to wall-mounted battery packs are now in use in hundreds of homes in Oregon. The Oregon Solar Plus Storage Rebate program has supported installation of these systems in more than 200 Oregon homes including 23 systems for low- and moderate-income residents.

Table 1: Oregon Solar + Storage Rebate Program – Storage Overview as of September 2022

Number of battery storage systems installed	217
Average cost of batteries	$20,853
Average size	11.2 kWh
Number of projects in low-income homes	23
Number of projects for low-income service providers	0

Critical Facilities with Moderate Loads

On-site solar and storage systems can be used to power critical facilities to increase the energy resilience of Oregon communities. There are now several examples in Oregon of local on-site solar and battery storage systems that can power critical community services such as emergency shelters, potable water delivery and first responder communications, in the event of a prolonged power outage. The Beaverton Public Safety Center uses battery storage to ensure emergency services are available in the community in the event of a natural disaster.[13] Similarly, the Eugene Water & Electric Board developed the Grid Edge Demonstration project, which uses solar and battery storage to power a microgrid, including a potable water fill station and emergency shelter.[14]

Large Hybrid Systems

There are also opportunities to use solar plus storage systems in conjunction with diesel generators to improve system performance. These hybrid systems use solar and/or batteries to improve system performance and extend fuel supplies. Consider the 400-kW diesel generator described in the limitations section above. The generator has an efficiency (kWh per gallon of fuel) of only 31 percent when operated at one-quarter load compared to 41 percent at full load. Lower load ratios would result in even lower operational efficiencies (taking more fuel to create a kWh of electricity). Building systems do not operate at a steady state; building systems cycle on and off, resulting in changing electrical loads. Batteries have the advantage of being able to track building loads instantaneously with no reduction in efficiency. In a hybrid system, the batteries can be configured to serve building loads to minimize run time of the fossil fuel generator. If the generator is needed, it can be run at full capacity, and therefore maximum efficiency, for as long as necessary to charge the batteries. These systems can be further optimized by ensuring energy efficiency measures are in place to reduce loads to extend backup power capabilities.

Additional Benefits

Backup power systems can provide value to Oregon utilities during day-to-day utility operations. For example, Portland General Electric operates a Dispatchable Standby Generation program that enables utility operation of customer-owned generators during emergency conditions, such as unplanned loss of generation.[15] In this program, output from the generators is used to provide emergency support to the electric grid. The owners of the generators receive maintenance, fuel, and equipment upgrades from PGE in exchange for the option to call upon the resources should the grid need them. PGE and ratepayers benefit from 135 MW of dispatchable generation, deferring the need to build new generation resources to deliver replacement power when critical grid issues arise.

Solar and battery storage systems can also support utility operations. In addition to supporting the community in the event of a natural disaster, the Beaverton Public Safety Center's solar and storage system also supports day-to-day grid operations.[13] Similarly, Portland General Electric and Pacific Power are both piloting battery storage programs where distributed batteries can be aggregated and operated by the utility.[16] [17] These distributed storage systems will reduce the need to run fossil fuel power plants and will support Oregon's clean energy transition.

Electric Vehicles and Backup Power

Electric vehicles are an emerging potential source of residential backup power. In 2022, Ford released the F-150 Lighting, an electric pickup truck that provides automatic backup power in the event of a power outage. The base model includes a 98 kWh battery pack, and the extended range model a 131 kWh battery.[18] Ford estimates that the extended range option could provide up to 10 days of backup power to a residence, and touts this benefit in one of its TV commercials. Ford has partnered with the solar company SunRun to provide integrated solar charging systems for the Lightning and is developing a home integration system.[19]

Ford F-150 Lighting Pro.[20]

Electric vehicles are unique in that they may serve as a standalone backup power system at a residence or serve as mobile power units in the event of an emergency. In 2018, Nissan launched the Blue Switch program in Japan. The program creates partnerships between Nissan and local government or commercial partners to leverage fleets of Nissan LEAFs as mobile power units.[21] In the event of an earthquake or other natural disaster, the fleets of vehicles are deployed as versatile power packs to assist recovery efforts. Nissan reports that the 62 kWh battery in a Nissan LEAF can power an average Japanese home for four days, charge more than 6,000 phones, or provide power to an elevator to conduct 100 round trips in a 43-story apartment building.[22] Closer to home, Snohomish County Public Utility District in Washington has completed the Arlington Microgrid Project, which includes an electric vehicle fleet that can be used to power the facilities in the event of a power outage.[23]

While some electric vehicles can provide backup power during a natural disaster, they also represent a potential source of emergency transportation during periods of constrained liquid fuel resources. It is expected that a Cascadia Subduction Zone earthquake would devastate Oregon petroleum supplies and distribution, as well as Oregon's power grid. Even if some roads and bridges are damaged, electric vehicles tied to solar charging systems could provide critical local transportation options during disaster recovery. The table below demonstrates the potential for a 10-kWdc solar PV system to charge an electric vehicle in three climate zones: Astoria, Portland, and Bend. A 10-kW solar PV system would require about 600 square feet of roof space.

Table 2: A 10-kWdc Solar PV System Charging an Electric Vehicle in Three Oregon Location

Oregon Location	Avg Daily PV Output December (kWh)[1]	EV Miles[2]	Avg Daily PV Output July (kWh)	EV Miles
Astoria	13	42	43	144
Portland	12	39	50	165
Bend	22	73	55	183

As seen in Table 2, an electric vehicle in Portland could be expected to get about 39 miles of range from an average single day of charging with a 10 kWdc PV system in December. The 10 kWdc system size is arbitrary and values can be scaled up or down for larger or smaller PV system sizes. In a disaster recovery scenario, an electric vehicle fleet would likely need to alternate days of operation and days of solar charging to ensure that some vehicles are always available for use.

Policy Considerations

The increased frequency and severity of natural hazards (e.g., wildfires, flooding, ice storms, etc.) and society's reliance on reliable and resilient electric service have resulted in public policies supporting community energy resilience. Federal, state, and local governments are likely to implement policies to support backup power systems to improve community energy resilience and deliver critical services during and following disruptive events. The Oregon Department of Energy will continue to work with

[1] Average kWh per day values are from the PVWatts Calculator developed by the National Renewable Energy Laboratory.[24] Output is based on a 10kWdc system, facing south, at a fixed 30-degree slope. The table also assumes 14 percent system losses, which is the default value in PV watts for a PV system utilizing a DC to AC inverter. Electric vehicle charging systems may be configured with direct DC charging that could improve system efficiency.

[2] EV miles are calculated at 3.3 miles per kWh of battery use in an electric vehicle. This value is typical of the Nissan LEAF and Chevrolet Bolt, which are both used in the State of Oregon motor pool.[25]

the Oregon Legislature and regional stakeholders to support adoption of backup power systems and statewide energy resilience planning.

In March 2022, ODOE launched the $50 million Community Renewable Energy Grant program to provide funding for community renewable energy resilience projects across the state. Grants of up to $100,000 are available for planning projects and up to $1,000,000 for construction projects. Priority is given to projects that support community energy resilience and that serve rural and traditionally underserved communities. Grants are available outside a city with a population of 500,000 or more (Portland), regardless of utility service territory.[26] Thirty-five applications for energy resilience projects, representing communities across Oregon, were successfully submitted in the first round of funding, which closed on July 10. Additional rounds of funding will follow in the fall of 2022 and in 2023.

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Energy 101: Radioactive Waste in Oregon

Oregon has contended with radioactive waste as part of its history since World War II. In the 1970s, Oregon first developed laws, rules, and programs to prohibit the disposal of radioactive waste within the state. Oregon has long had a presence in the cleanup of former uranium mining residuals in Southern Oregon and of radioactive and chemically hazardous waste at the Hanford Nuclear Site. Located along the Columbia River in southeast Washington, Hanford is one of the largest nuclear waste cleanup sites in the world.[1]

Radioactive waste includes more than spent nuclear fuel (non-useful remnants of nuclear power plant fuel[2]) or other waste products from nuclear power plants. Virtually all materials contain some radioactivity, so it is necessary to define the level of radioactivity in waste that constitutes an unacceptable health risk to the public or the environment.

Naturally occurring radioactive materials (NORM) are everywhere, for example: fertilizer material production facility,[3] waste material from natural gas fracking,[4] pipe scale buildup,[4] and bananas, bricks, and granite countertops can all have low levels of radioactive materials. [5] [6]

The Oregon Department of Energy's Nuclear Safety and Emergency Preparedness Division, serving as staff to the Energy Facility Siting Council, is responsible for determining whether a waste material meets the state-specific definition of "radioactive waste" consistent with the rules contained in OAR 345-050. These rules are intended to help identify materials that could be disposed of or are exempt from the rule, such as slightly radioactive materials that present minimal health hazards.

This section describes the history of radioactive waste management in Oregon, the present-day challenges associated with managing radioactive waste and Oregon's role, and a look ahead to potential future management challenges.

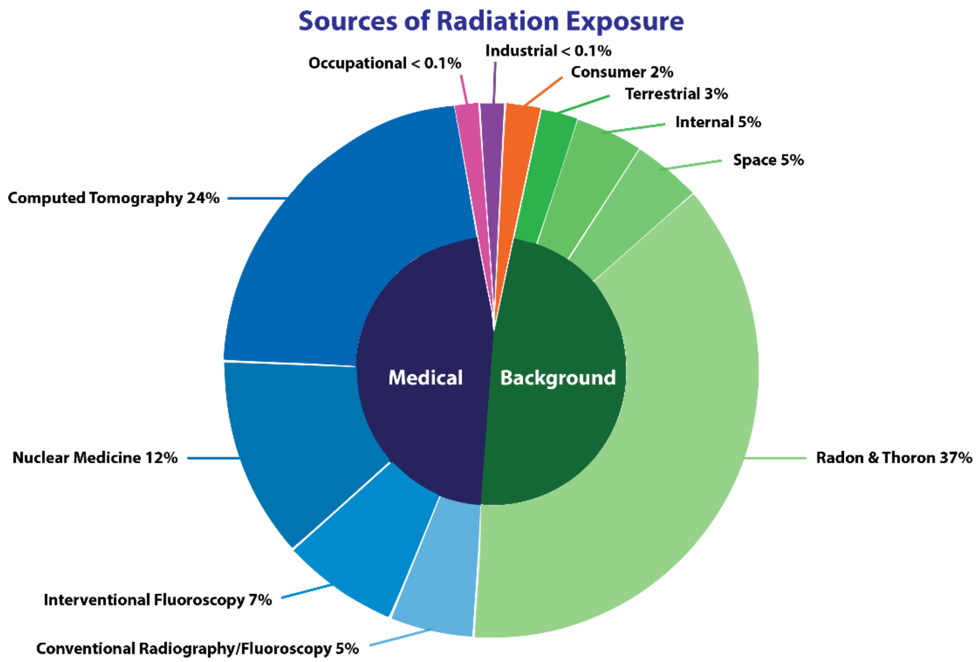
Management Challenges of Radioactive Waste

Many forms of radioactive waste remain unsafe for very long periods of time and require additional safety protocols to ensure safe storage for the duration of time the waste remains hazardous. The decay half-life of radioactive materials can range from just a few minutes to thousands of years, depending on the *radionuclide* in question. This means that permanent waste disposal sites must have safeguards in place that will stand the test of time – some longer than the span of human history to date.

Half-life is the time taken for the radioactivity of a specified isotope to fall to half its original value. It takes about 10 half-lives before a radioactive substance will fully decay.

Radioactive waste is a human and environmental health concern. While high dose exposure to radioactivity can present acute health risks, such exposures are not expected outside of nuclear emergency events. More likely scenarios involve chronic lower dose exposures to waste handlers or other members of the public who might frequently come into contact with material. This type of exposure can present long-term cancer risks for exposed individuals. As is shown in Figure 1, most radiation exposure to most people comes from either radon gas, which occurs naturally in soil in some parts of the world and can accumulate in building basements if not properly managed, or from medical diagnostics or treatments.

Figure 1: Sources of Radiation Exposure[7]



Average Annual Radiation Dose

Sources	Radon & Thoron	Computed Tomography	Nuclear Medicine	Interventional Fluoroscopy	Space	Conventional Radiography/ Fluoroscopy	Internal	Terrestrial	Consumer	Occupational	Industrial
Units mrem (United States) mSv (International)	228 mrem 2.28 mSv	147 mrem 1.47 mSv	77 mrem 0.77 mSv	43 mrem 0.43 mSv	33 mrem 0.33 mSv	33 mrem 0.33mSv	29 mrem 0.29 mSv	21 mrem 0.21 mSv	13 mrem 0.13 mSv	0.5 mrem 0.005 mSv	0.3 mrem 0.003 mSv

(Source: National Council on Radiation Protection & Measurements, Report No. 160)

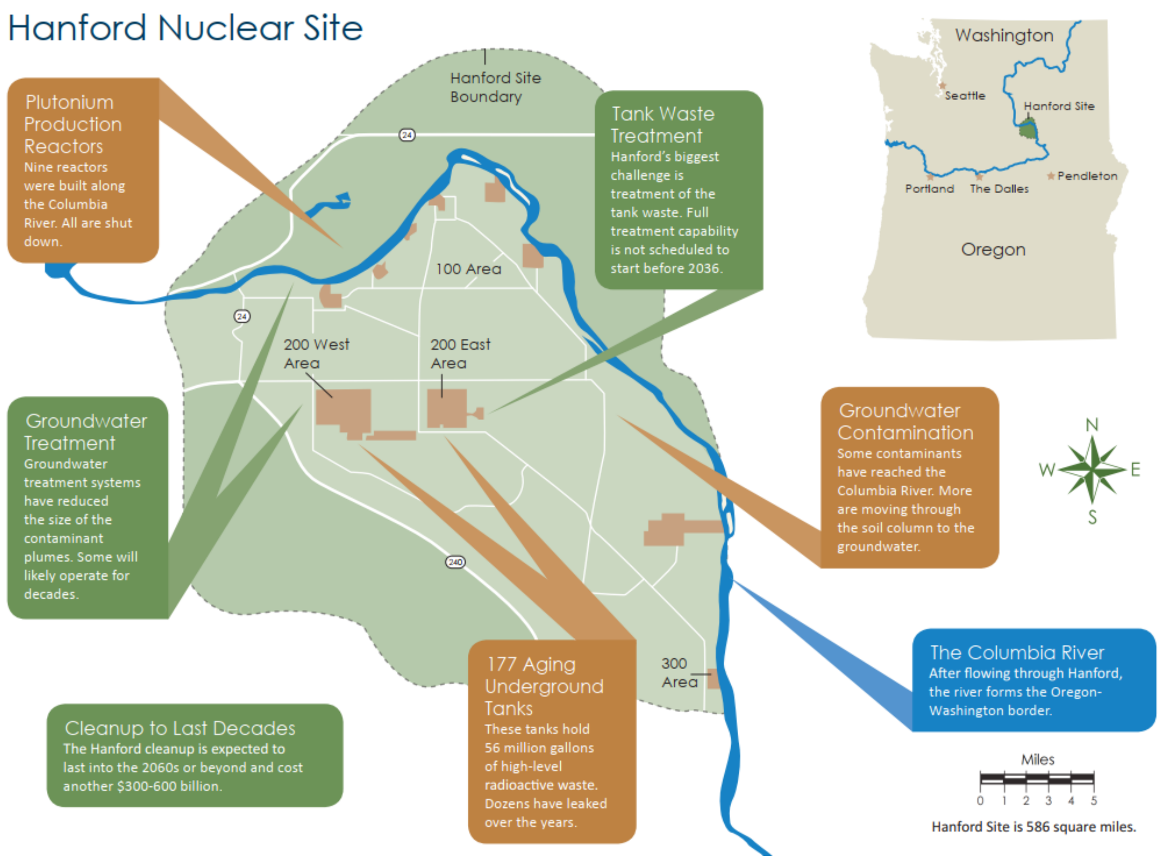
Public perception of radioactive waste and its management includes considerations for the environment and the economy of local communities. Even when potentially radioactive materials have been disposed of safely in a landfill, people may be concerned about the stigma of associating their community with radioactive waste. For example, online search results for towns near waste disposal sites may leave a negative impression on potential visitors or developers. Residents and businesses may fear this will have a detrimental effect on property values and the attractiveness of that community to visitors or new residents. Perceived risk also has the potential to affect natural resource value, such as the water that supplies agricultural products or fish and wildlife from affected environments, even if the products or water are safe to consume.

History of Radioactive Waste Management in Oregon

Hanford

Oregon's – and the nation's – nuclear waste legacy starts in Washington State, at the Hanford Site. Hanford was a foundation of the Manhattan Project, operating from 1943 to 1989 and ultimately producing 65 percent of the plutonium for America's nuclear weapons.[8] [9] During Hanford's operation, large amounts of radioactive materials were discharged into the air and soil at the site and, for a period of time early in site operations, directly into the Columbia River. Radioactive isotopes from this waste were later found in coastal shellfish, river fish, and even whales offshore.[10] Plutonium production at Hanford ended in 1989, and the focus has shifted to waste cleanup.

Figure 2: Sources of Radioactive Waste at the Hanford Nuclear Site[11]



Oregon has a tremendous stake in the safe and timely cleanup of Hanford. The Hanford site is located just 35 miles upstream of Oregon's border. From Hanford, the Columbia River flows through prime Oregon farmlands and fisheries, and unchecked radioactive and chemical contamination would pose a potential long-term threat to these important resources. Accordingly, the Oregon Department of Energy's primary role in representing Oregon in the ongoing cleanup is to advocate for cleanup decisions that are protective of the river and surrounding resources.

Today, the legacy contamination at Hanford does not enter the river at levels that would negatively affect Oregonians, but many risks still remain.[12] Fifty-six million gallons of high-level radioactive waste currently reside at the site in degrading underground storage tanks. Large volumes of waste still exist in the soil at Hanford due to past leaks, spills, or because of intentional disposal in purpose-built burial sites. Hundreds of contaminated buildings remain, and groundwater that flows to the Columbia River still has plumes of chemical and radiological contamination.[13] [14]

While Oregon has no regulatory authority at Hanford, the federal government recognizes ODOE as a critical, objective voice in technical reviews and policy discussions related to the cleanup. The U.S. Department of Energy owns and operates the Hanford site and has made significant progress on several Oregon cleanup priorities. Because the extent of the contamination is so widespread, and some of the challenges so difficult, the USDOE expects cleanup to continue for another 40 years or more. [15] ODOE's engagement advocates for cleanup actions that are protective of Oregon's interest in the safety and value of the Columbia River, today and in the future.

Oregon Legislature Bans Radioactive Waste Disposal

Through the 1970s and 80s, as the nation was searching for a location to site a permanent deep geologic repository for spent nuclear fuel and high-level radioactive waste. Oregon passed a law that would prohibit such a site within the state. The 1977 legislature instituted a strict ban: "Notwithstanding any other provision of this chapter, no waste disposal facility for any radioactive material shall be established, operated or licensed within this state."[16] Responsibility for enforcing the ban on disposal was charged to the Nuclear and Thermal Energy Council, which became the Energy Facility Siting Council and the Oregon Department of Energy.[17]

Implementation of the new law proved to be challenging because while it had the intended effect of restricting the disposal of radioactive waste from nuclear weapons and nuclear power, it also had the unintended effect of banning waste from some established industries in Oregon. Industries such as metals processing and fire-resistant brickmaking produce naturally occurring radioactive materials, often referred to as NORM, as byproducts of their operations. If these materials were defined as "radioactive waste" under the law, then these industries would face a lack of disposal options for their waste.

Many wastes contain **Naturally Occurring Radioactive Materials (NORM) or Technologically Enhanced NORM (TENORM)** – and may qualify as radioactive waste that cannot be disposed of in Oregon

Natural radioactivity is present in trace amounts in the earth's crust and waters. Many industrial processes that use or come in contact with natural raw materials, such as water, soils, rock, or sand, may generate TENORM. In high enough concentrations, the resulting wastes that contain NORM or TENORM can present health and safety hazards to humans and the environment if they are not handled and disposed of properly. [29]

In 1978, in coordination with the legislature, the Nuclear and Thermal Energy Council and ODOE initiated a rulemaking to define radioactive waste based on a material's threat to public health and the environment.[18] Adopted on December 12, 1978, the rules defined exemptions based on quantities, concentrations, type of material, and human exposure pathways for waste materials containing NORM.

Most of the exemptions developed were based on U.S. Nuclear Regulatory Commission regulations, but because the NRC claimed no authority over NORM, additional exemptions were needed for these materials. NORM occurs in many different chemical forms, and depending on the physical and chemical characteristics, a given concentration or quantity may or may not pose a disposal risk. Human exposure pathway tests were created in part to account for these different characteristics and provide certain exemption pathways for NORM. [19]

Oregon's radioactive waste disposal law is unique compared to some other states. The state's risk-based definition of radioactive waste does not allow a petitioner to "take credit" for the natural radioactive shielding and other protections that normal landfill disposal would provide. The waste itself must be benign enough that if it were spread on the ground and a house built on top, it would be able to meet protectiveness standards. Figure 3 illustrates the Oregon rules compared to some states that allow for licensed waste facilities.

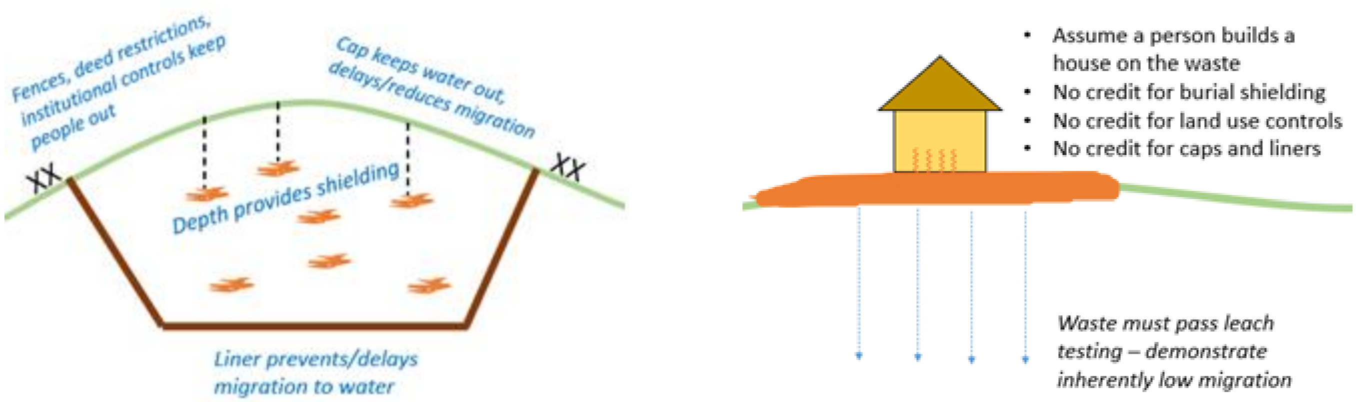
Figure 3: Oregon Radioactive Waste Disposal Comparison

Some states allow disposal in permitted facilities with certain safety features.

(Supported by predictive environmental model.)

Oregon ORS 469.525 prohibits radioactive waste disposal facilities.

(*Radioactive waste* is defined by its risk properties.)



Oregon has a limited part to play in the future of spent fuel and high-level waste disposal in the United States. The statewide ban on radioactive waste disposal—coupled with the moratorium on new nuclear power development (until a final repository exists and Oregon voters agree to allow construction of the power facility)—means that Oregon is not a likely location of a future waste repository.[20] However, because the Hanford Site was once considered a top candidate location for a nationwide repository,[21] the Oregon legislature established the Oregon Hanford Cleanup Board and empowered them in statute to act as the lead point of contact between the Federal Government and the State of Oregon regarding the establishment of a high-level waste repository, either at Hanford or in Oregon.[22] ODOE provides staff support to the Oregon Hanford Cleanup Board. Today, the OHCB and ODOE regularly work with the U.S. Department of Energy and its regulators to represent Oregon's interests at Hanford, as well as represent Oregon's interests in establishing a national permanent spent nuclear fuel and nuclear waste repository.

Trojan – Oregon's Former Commercial Nuclear Power Plant

Trojan's cooling tower was imploded in 2006.

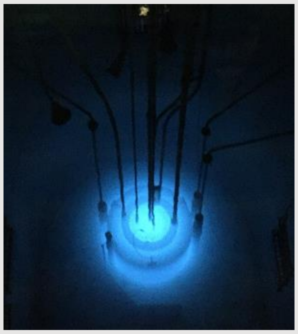
Developed and built prior to the 1978 statutes on nuclear power generation, the Trojan Nuclear Power Plant was Oregon's only commercial nuclear power plant, located in Columbia County about 40 miles northwest of Portland along the Columbia River.[23] Trojan began generating power on May 20, 1976, with a capacity of 1,130 megawatts. From the outset, the plant was plagued by design flaws and other problems that led to temporary closures and expensive repairs. During this time, several failed legislative efforts to close the plant were presented by anti-nuclear groups.

The Trojan nuclear power plant ceased operations in 1993, requiring the safe and proper decommissioning of the entire plant and the storage of the spent nuclear waste – a process that took 10 years to complete.[23] The containment building was demolished and the cooling tower imploded. Most of the radioactive waste was hauled to the U.S. Ecology landfill located on the Hanford Site for burial, and the reactor vessel and steam generators were shipped by barge up the Columbia River to the Hanford site. Today, Trojan's spent nuclear fuel is stored in 34 passive-cooled containment vessels on a concrete pad at the former plant site. The spent fuel will remain there until the federal government establishes a national spent fuel repository or interim consolidated storage facility. The site is managed by Portland General Electric with oversight by the Nuclear Regulatory Commission and engagement by ODOE staff. In this regard, the Trojan site is not unique; across the nation, nearly all spent nuclear fuel from operating and legacy nuclear power plants is stored at the site where it is generated.[24] Despite repeated efforts, the federal government has not been able to establish a deep geologic repository for the nation's spent nuclear fuel or high-level nuclear waste. The nation is far from operating such a centralized repository.

Trojan's spent nuclear fuel is now stored in 34 passive-cooled containment vessels at the former plant site.

Oregon Research Reactors

Two small-capacity nuclear reactors currently operate at Reed College (photo at right) and Oregon State University. Built in the late 1960s, these reactors are used to support education and research activities. The very limited wastes from these reactors, including the small quantities of spent fuel produced by their operation, are stored at the Hanford Site pending final disposal in a permanent spent fuel repository. [25] [26]



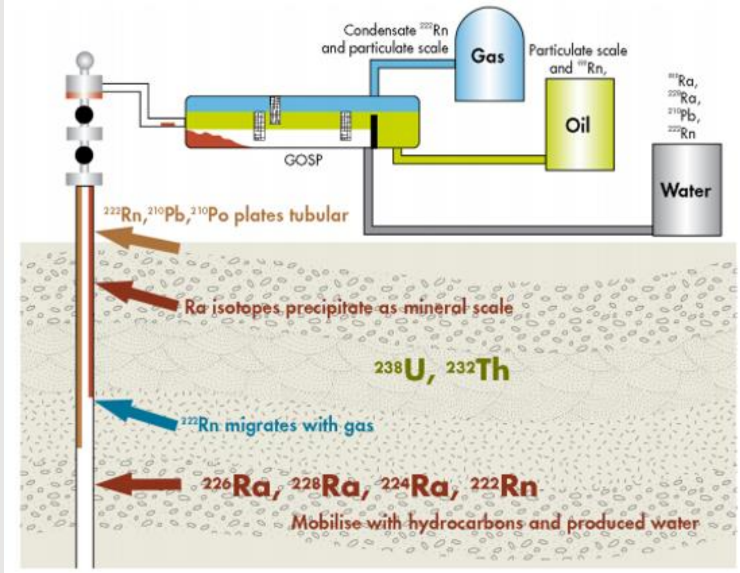
Uranium Mining and Milling Residuals

Oregon had two uranium mining sites in operation during the late 1950s and early 1960s.[27] Uranium was discovered outside of Lakeview, Oregon in 1955, which resulted in uranium production at the White King and the Lucky Lass mines. A uranium processing mill was constructed on the northern edge of Lakeview to process the mined ore and operated from late 1958 until 1961.[28] Located about 17 miles northwest of Lakeview and about a mile apart, the open pit mines produced a low grade of ore, which was used in the nation's nuclear weapons program – meaning Lakeview uranium likely was used in the Hanford reactors to produce plutonium. Mining at White King and Lucky Lass stopped around 1965.

In 1976, areas of elevated radioactivity were discovered in the uranium tailings pile (residue from ore) next to the mill, which was subsequently covered with about two feet of dirt.[28] Between 1968-1988, the mill tailings and contaminated soil were excavated and moved to a disposal cell about seven miles outside of Lakeview. A compacted soil layer was added to limit the escape of radon – a byproduct of uranium radioactive decay – and to restrict water percolation into the tailings. A rock cover was added to protect the soil from erosion. Today, ODOE conducts annual inspection visits to ensure that the site mitigation work remains protective, that the cover over the mill tailings does not erode, and that periodic water sampling from the mill site does not indicate the presence of unanticipated radiation.

The mines sat for several decades – the pits filling with acidic water and containing elevated levels of radioactive materials. Contamination threatened nearby Augur Creek. In 1995, the U.S. Environmental Protection Agency added the two mines to its cleanup priorities list. Cleanup occurred through 2005, with an ODOE resident site inspector to oversee the cleanup. The U.S. EPA, Oregon Department of Environmental Quality, ODOE, and the U.S. Forest Service work collaboratively to monitor the mine sites and ensure that the remediation continues to be protective.

2020 Notice of Violation



Origins of TENORM and Where It May Accumulate

Source: International Assoc. of Oil & Gas Producers, Report No. 412 (2008)

In 2019, ODOE was alerted to waste that was being illegally disposed in Oregon. The waste was primarily associated with oil and gas extraction, which generates technologically enhanced naturally occurring radioactive material, or TENORM. As shown in this figure, TENORM is NORM that has been "concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing."[29] The agency issued a Notice of Violation in 2020, followed by a risk assessment to ensure that there was no risk to workers or the surrounding environment.[30] In the 2021 legislative session, the Oregon legislature passed Senate Bill 246 granting ODOE and EFSC additional investigative and punitive authority to evaluate compliance with state rules.[31]

Since 2019, ODOE has been evaluating waste streams from waste disposal companies and from industries that commonly dispose of NORM or TENORM in the state. No other waste streams which meet the definition of "radioactive waste" have been identified during this ongoing evaluation, which includes review of pathway exemption reports for suspect waste streams from more than 15 facilities. ODOE continues to work with its partners at the Oregon Health Authority's Radiation Protection Services and the Oregon Department of Environmental Quality to develop robust programs to minimize the chance of future illegal disposal of radioactive waste.

Present-Day Management Challenges for Radioactive Waste

Oregon's prohibition on the disposal of radioactive waste created a challenging regulatory environment because virtually everything contains some amount of radioactivity. Subsequent state rules created strict definitions and exemptions for materials the state will accept, but new technologies, raw material productions, and pathways for new economic development may knowingly or unknowingly lead to potential radioactive material waste production in Oregon. Because sources of radioactive waste are so diverse, ODOE is expanding its efforts to work with industry partners, landfills, transportation companies, trade groups, and other state and local government agencies to provide both awareness of Oregon's rules and technical support to maintain compliance.

Landfills around the state periodically encounter radioactive materials during normal operations. Often the material is medical waste from therapies or diagnostic procedures that contain radioactive elements and are usually safe for disposal after they have been isolated for a week or two to allow for radioactive decay. Other commonly encountered items include older scrap metals that contain higher proportions of certain radioactive metals, heat exchangers or pipes that have accumulated naturally-occurring radioactive build-up over years of use, the occasional consumer item, or family heirloom that contains a small amount of radioactive material.[29] In these cases, the common solution is to separate the waste for disposal outside Oregon at licensed low-level radioactive waste disposal facilities. Guidance on radioactive material disposal is provided by the Oregon Health Authority's Radiation Protection Services division. On some occasions, these items may qualify for disposal in Oregon based on a determination of low public hazard due to their total quantity or concentration of material, or via a specific risk-based exemption in consultation with ODOE. Some landfills around the state have installed radiation portal detectors, which screen incoming waste loads for radiation. If radiation is detected, the portal will alert landfill staff to further investigate the waste and contact state partners at ODOE and Oregon Health Authority.

In 2021, the Chemical Waste Management facility near Arlington, OR installed a radiation detection portal system, which screens all incoming hazardous waste loads to check for potential radiation.

NORM and TENORM represent a class of radioactive material that has long been a management challenge in Oregon and across the nation.[29] These materials can occur as a byproduct of several types of industrial processes, including oil and gas production, metals refinement and metal casting, fertilizer production, activities where refractory bricks are used, scrap metal recycling, geothermal power production, or even simply residues from water and sewer pipe cleaning. One industrial process that is gaining increased national attention is the management of water associated with hydraulic fracturing for oil and gas, and some oil and gas producing states have recently implemented regulations to safely manage disposal of TENORM waste.

The system of waste transportation, transfer, and disposal involves many different places and players around the state. Radiation portal detectors are used in key locations where potential radioactive waste may occur, typically at certain landfills, recycling facilities, and waste transfer stations. Awareness of the Oregon laws concerning radioactive waste has also grown in recent years. ODOE and its stakeholders are working to make sure the people who are a part of this system know about and are equipped to comply with state law.

Looking Ahead: What is Oregon Doing to Address the Challenges of Radioactive Waste?

The establishment of regulations for radioactive waste in other states and at the federal level has implications for the future of radioactive waste management in the state. Historically, Oregon was a leader in promulgating standards for radioactive waste disposal, including NORM and TENORM, while most states and the federal government had no regulations in place for these waste products. Since 2015, at least five states (Montana, Pennsylvania, North Dakota, Texas, Colorado) have conducted rulemaking efforts to set disposal standards for TENORM.[32] [33] [34] [35] [36] As other states begin to establish their own definitions of acceptable waste, it is important for Oregon to review and potentially update its rules to ensure the state keeps in step with advancing science around radiation safety.

The State of Oregon will continue working to assess the risks and rules associated with radioactive waste and protect Oregon interests and values. The state has already strengthened its enforcement capabilities and is currently engaged with stakeholders to update Oregon's radioactive waste definition rules. ODOE is also engaging in a statewide effort to grow and strengthen its radioactive waste disposal prevention program. The Trojan spent fuel continues to be safely stored in Oregon until a national repository becomes available and ODOE is ready to engage with the federal government if the high-level waste repository conversation returns to the Pacific Northwest. Finally, Oregon will remain a strong voice for the cleanup of the Hanford site and the protection of the Columbia River for many decades to come.

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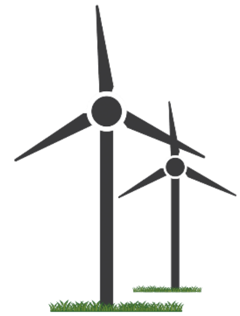
Energy 101: Public Utility Regulatory Policies Act of 1978 (PURPA)



The Public Utility Regulatory Policies Act of 1978 (PURPA) has played an important role shaping energy markets and encouraging renewable energy nationally—and in Oregon—for more than 40 years.[1] This section is designed to provide Oregonians a better understanding of current perspectives on the policy and the potential effects of PURPA reform on Oregon's evolving electric sector, and includes a summary of key aspects of PURPA, its role in renewable energy development, and a high-level overview of current discussions about potential policy reform.

History of PURPA

In 1978, Congress passed PURPA as a legislative response to the energy crises of that decade. In its passage, Congress aimed to reduce dependence on imported fossil fuels and increase diversity in energy resources by encouraging development of alternative energy resources. At the same time, the legislation encouraged conservation of electric energy and increased efficiency in the use of generation facilities and resources by electric utilities while ensuring equitable retail rates for electric consumers.[2]

One of the ways that PURPA was designed to accomplish its goals was through the creation of a new class of generating facilities known as "non-utility generators," or as they are now more commonly known: qualifying facilities. Qualifying facilities are often called "QFs" and fall into two groups:[1]

1. **Small power production facilities.** Generating facilities of 80 MW or less whose primary energy source is renewable (hydropower, wind, solar, biomass, or geothermal); and
2. **Cogeneration facilities.** Generating facilities that produce both electricity and another form of useful thermal energy (such as heat or steam) in a way that is more efficient than the separate production of both forms of energy.

To encourage the development of QFs by independent power producers, PURPA authorized the Federal Energy Regulatory Commission to adopt rules to determine the eligibility of QFs for special rates and exemption from certain regulatory requirements.[4] According to FERC, small power producers seeking to connect to the utility grid before PURPA was enacted often faced three "major obstacles."[4] First, utilities were not required to purchase the output from power projects owned by IPPs. Second, some utilities charged high rates to IPPs for back-up grid service for their projects. And third, in many cases, an IPP exporting wholesale electricity to the utility grid could actually be considered an electric utility itself, and therefore would be subject to considerable federal and state regulation.[4] To overcome these three barriers, PURPA created certain rights for QF projects that fall into three categories:[5]

> **Independent Power Producer or IPP:** A corporation, person, agency, authority, or other legal entity or instrumentality that owns or operates facilities for the generation of electricity for use primarily by the public, and that is not an electric utility.[3]

1. **The right to sell electricity or capacity to a utility at the utility's avoided cost rate.** PURPA imposes a mandatory purchase obligation on utilities, requiring utilities to purchase electricity from QFs at either an avoided cost rate or a negotiated rate. The avoided cost rate is intended to represent the incremental cost to the electric utility of electric energy or capacity which, but for the purchase from the QF, the utility would have to generate itself or purchase from another source. An avoided cost rate is somewhat analogous to the marginal wholesale price for a utility to acquire another kilowatt-hour of energy.
2. **The right to purchase certain services from utilities.** PURPA gives QFs the right to interconnect to a utility's transmission or distribution system by paying a fair price for upgrade costs on a non-discriminatory basis. PURPA also gives QFs the right to purchase supplementary power, back-up power, maintenance power, and interruptible power from utilities as needed at rates which are just and reasonable.
3. **Relief from certain regulatory requirements.** Federal and state laws define an electric utility and subject entities falling within such definitions to significant regulation and oversight. PURPA exempts QFs from obligations under the Public Utility Holding Company Act of 1935 and provides an exemption from certain state laws and regulations regarding the rates and financial organizational aspects of electric utilities.

Since its inception in 1978, PURPA has undergone several changes as energy markets have evolved in the United States. During the 1990s and into the early 2000s, federal legislation, combined with regulatory action at FERC aimed at increasing competition, led to substantial restructuring of wholesale electricity markets across the country.[i] In particular, these actions led to the development of competitive, centralized markets for buying and selling wholesale electricity in much of the country. These markets were and remain administered by independent system operators or regional transmission organizations.[ii] As a result of these changes, there were several efforts to modify or repeal PURPA. Elements of the original legislation were increasingly viewed by some stakeholders as being unnecessary, particularly given the development of competitive, centralized markets where QFs could sell power.

Energy Policy Act of 2005

In 2005, Congress amended PURPA through the Energy Policy Act of 2005 (EPAct 2005) to account for changes in wholesale electricity markets, such as the development of organized wholesale dispatch markets, among other changes in the industry.[6] Significantly, EPAct 2005 created a procedure to relieve utilities of their must-purchase obligation from certain renewable QFs, provided the utility seeks such a waiver from FERC, and that the Commission finds that such QF projects in the utility's service territory have non-discriminatory access to competitive electricity markets. In implementing this provision through Order 688, FERC found that some organized markets (but, notably, not CAISO at the time as it had not yet launched its Day-Ahead Market) offered sufficient, non-discriminatory access to renewable QFs between 20 MW and 80 MW in size and thus utilities operating in those

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[i] For example, see: the Energy Policy Act of 1992 and FERC Orders 888 (creating the Open Access Transmission Tariff), 889 (creating the Open Access Same-time Information System), and 2000 (encouraging the formation of Regional Transmission Organizations).
[ii] For more on Regional Transmission Organizations, see ODOE's 2021 report on RTOs: www.oregon.gov/energy/energy-oregon/Pages/RTO.aspx

markets were relieved of their must-purchase obligations for those projects pursuant to PURPA.[7] In 2011, FERC found that California's three large investor-owned utilities also qualified for this waiver.[8] Notably, in Order 688, the Commission also established a rebuttable presumption that projects equal to or smaller than 20 MW do *not* have non-discriminatory access and thus the must-purchase obligations of utilities remained unchanged. This change for renewable projects larger than 20 MW lessened the effect of PURPA in some states, while the core elements of PURPA remained essentially unchanged in Oregon and the Pacific Northwest.

FERC Order 872

In 2020, FERC further revised its regulations implementing PURPA. In Order 872,[5] FERC reduced the minimum size of a renewable QF that is presumed to have non-discriminatory access to power markets from 20 MW to 5 MW for projects located within certain ISO or RTO markets. This provision essentially relieves utilities operating within these markets of their must-purchase obligations for renewable QFs sized between 5 MW and 80 MW (the maximum size of a renewable QF pursuant to PURPA). The order also granted additional flexibility to state regulatory authorities to establish avoided cost rates for QF projects. This change affected state regulatory authority regardless of whether the QF was located inside an ISO or RTO market.

Role of the State

Though FERC has broad authority to prescribe rules for PURPA implementation throughout the nation in many instances, Congress reserved discretion to state regulators (public utility commissions in the case of investor-owned utilities, and governing boards in the case of consumer-owned utilities) to determine implementation in others. This allows states to tailor elements of PURPA implementation to the specific market and industry conditions in their state, which can vary significantly in terms of existing resource mix, prevailing power rates, and interconnection considerations. The following are core elements of PURPA implementation over which states exercise significant authority, including some indication of the range in how different states exercise this authority:[9]

- **Avoided Cost Pricing**. States have wide discretion to define what is reasonable and non-discriminatory when establishing avoided cost rates that utilities must pay for the energy and the capacity delivered from QF projects. The intention of PURPA is that utilities should pay QFs for the power output of their projects at a rate that represents the "avoided cost" to that utility of having to otherwise procure or purchase that amount of energy and capacity elsewhere, in the absence of the QF project existing.

  Historically, many states have developed avoided cost pricing based on market prices for purchasing a marginal MWh of power, which in recent decades would often be set by a natural gas plant. Other states, meanwhile, have looked to market pricing for renewables, specifically, to set the avoided cost rates paid to renewable QFs. There is significant diversity in how states develop avoided cost pricing. Nationally, avoided cost pricing for QFs varies widely with some states offering higher or lower rates for output during different times of the year.

  For a summary of PURPA implementation by state, including avoided cost pricing, the National Regulatory Research Institute maintains the following online database: https://www.naruc.org/nrri/nrri-activities/purpa-tracker/

- **Fixed vs. Variable Energy Rates**. Pursuant to FERC Order 872, states acquired the authority to offer either fixed-price energy contracts or to offer variable-price energy contracts to QFs based on the time the energy is delivered. To determine a fair variable price, the purchasing utility can rely upon market pricing from an ISO or RTO market, where one exists, or from another wholesale bilateral market trading hub (such as the Mid-Columbia, or Mid-C, in the Pacific Northwest) in areas that operate without an ISO or RTO. In either case, QF projects retain the ability to opt for fixed-price capacity payments.
- **Contract Terms and Conditions**. State regulators have authority to adopt standard terms and conditions for QF contracts, or to require bilateral negotiations between individual QF projects and the utility obligated to purchase the output.
- **Contract Duration**. The duration of contracts offered to QF projects varies widely across the country. Most states offer contract durations in the 10- to 20-year range, with some exceptions as short as 2-year and as long as 25-year contract terms.
- **Interconnection Agreements.** States also exercise authority over the type of interconnection agreements required for QF projects in their state and the associated fees that utilities can charge for interconnection.

PURPA Implementation in Oregon

Since the inception of PURPA, Oregon has taken numerous actions to implement the legislation, including enacting its own complementary legislation in ORS 758.505-555.[10] Oregon's PURPA implementation legislation was designed to fulfill the state's goal of promoting "the development of a diverse array of permanently sustainable energy resources" while ensuring that the rates paid to PURPA QFs are "just and reasonable."[9] For the state's consumer-owned utilities, each governing board has adopted its own rules for administering its PURPA obligations, including the establishment of pricing and contract durations.[9]

Meanwhile, for the state's IOUs, the Oregon Public Utility Commission is responsible for regulatory oversight of PURPA.[9] The OPUC aims to implement the legislation such that it encourages the economically efficient development of QFs, while protecting ratepayers by ensuring that utilities pay rates equal to what they would have incurred in lieu of purchasing power from a QF project.[11] While there have been numerous regulatory proceedings at the OPUC related to PURPA implementation, there are three groups of decisions that shape how PURPA is implemented today:

- **Order No. 05-584 (2005)**:[12]
  - Established standard contracts for QFs smaller than 10 MW with uniform terms and conditions, 20-year contract duration, and 15-year fixed prices.
  - Established a process for calculating avoided cost pricing and required utilities to develop several pricing options.

- QFs larger than 10 MW would receive avoided cost rates via negotiated contracts rather than standard offers.[iii]

- **Order No. 14-058 (2014)**:[12]
  - Reconsidered the provisions adopted in Order No. 05-584.
  - Reaffirmed decision to maintain 10 MW eligibility cap for standard contracts with a 20-year contract duration and 15-year fixed prices, in addition to provisions intended to reduce transaction costs for QF development.
  - Modified avoided cost method to: (1) account for the capacity contribution of different QFs, and (2) to incorporate wind integration costs.
  - Committed to revisit solar integration costs in the future after more solar QF development occurs.
- **Orders No. 16-129 (2016),**[13] **No. 16-130 (2016),**[14] **and No. 19-016 (2019):**[15]
  - Reaffirmed its decision to maintain 20-year contract durations with 15-year fixed prices.
  - Identified that some solar developers were able to circumvent the 10 MW threshold to qualify for standard contracts by developing multiple, smaller projects.
  - Reduced the size threshold for standard contracts, as adopted in Order No. 05-584, for solar QFs (but *not* for non-solar QFs) from 10 MW to 3 MW for Idaho Power (Order No. 16-129), PacifiCorp (Order No. 16-130), and PGE (Order No. 19-016).

Effects of PURPA on Renewable Development in Oregon

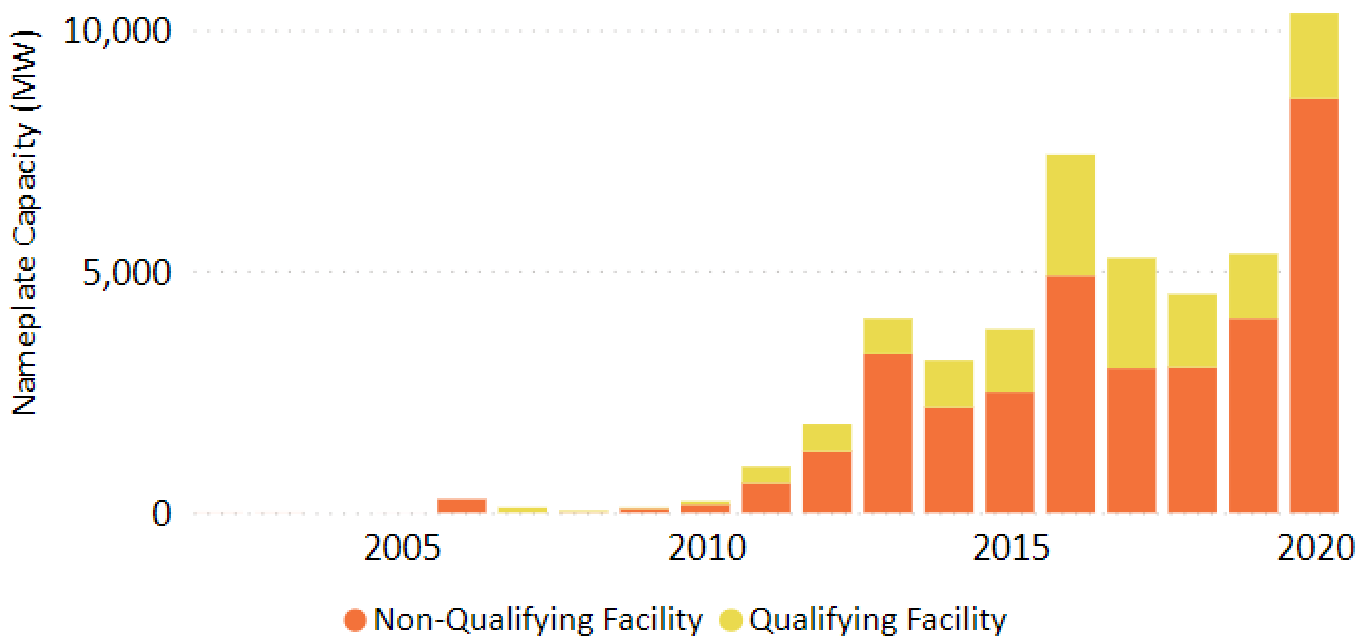
According to data from the U.S. Energy Information Administration, more than 169 gigawatts (GW) of renewable generating capacity became operational in the United States between 2000 and 2020. Of that total, PURPA QF projects account for 21 GW (or approximately 12 percent). Solar PV projects account for nearly two-thirds of those QF projects (approximately 13.5 GW of capacity), driven by significant reductions in solar technology costs in recent years. By contrast, wind energy projects account for less than one-quarter of those QF projects (approximately 5 GW of capacity).[16]

More than 169 GW of renewable generating capacity became operational in the U.S. between 2000 and 2020. Of that total, PURPA projects account for 21 GW (about 12%).

Figure 1 shows the national growth in solar capacity since 2000, with QFs continuing to account for a significant share of total projects through 2020.

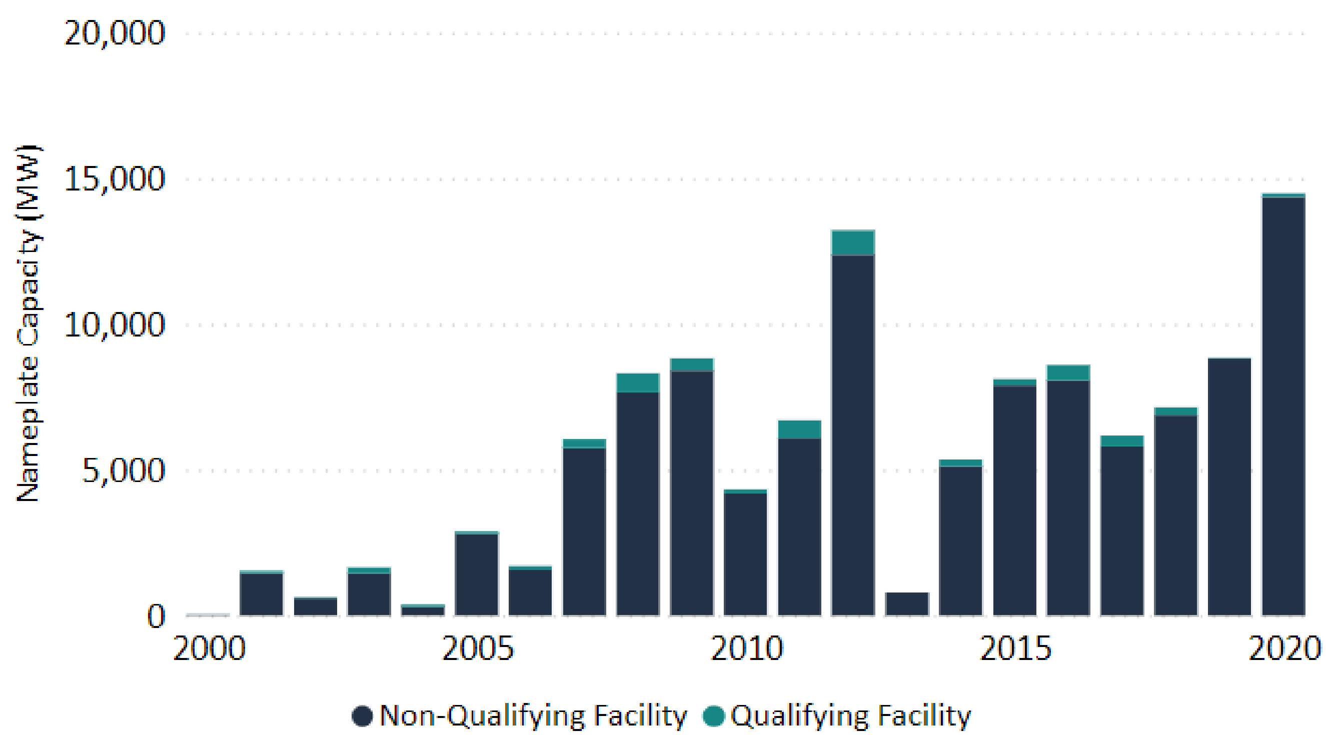
[iii] OPUC Order No. 07-360 established guidelines for determining negotiated rates for large QFs consistent with 18 CFR 292.304(e). For more information: https://apps.puc.state.or.us/orders/2007ords/07-360.pdf

Figure 1: U.S. Solar Nameplate Capacity (MW) by Year and QF Status[16]



Meanwhile, Figure 2 illustrates the deployment of wind energy capacity since 2000, which tells a different story. Major deployments occurred earlier (by the mid-2000s) and the contribution of QF projects is noticeably smaller than with solar.

Figure 2: U.S. Wind Nameplate Capacity (MW) by Year and QF Status[16]



Between 2000 and 2020 in Oregon, approximately 4.5 GW of renewable generating capacity became operational, of which PURPA QFs accounted for approximately 650 MW (or approximately 14 percent of all renewable projects). Solar QF projects account for 420 MW of that capacity (or roughly two-thirds of all QFs in Oregon). By contrast, wind QFs account for 143 MW of that capacity (or less than one-quarter of all QFs in Oregon).

Figure 3: Oregon Solar Nameplate Capacity (MW) by Year and QF Status[16]

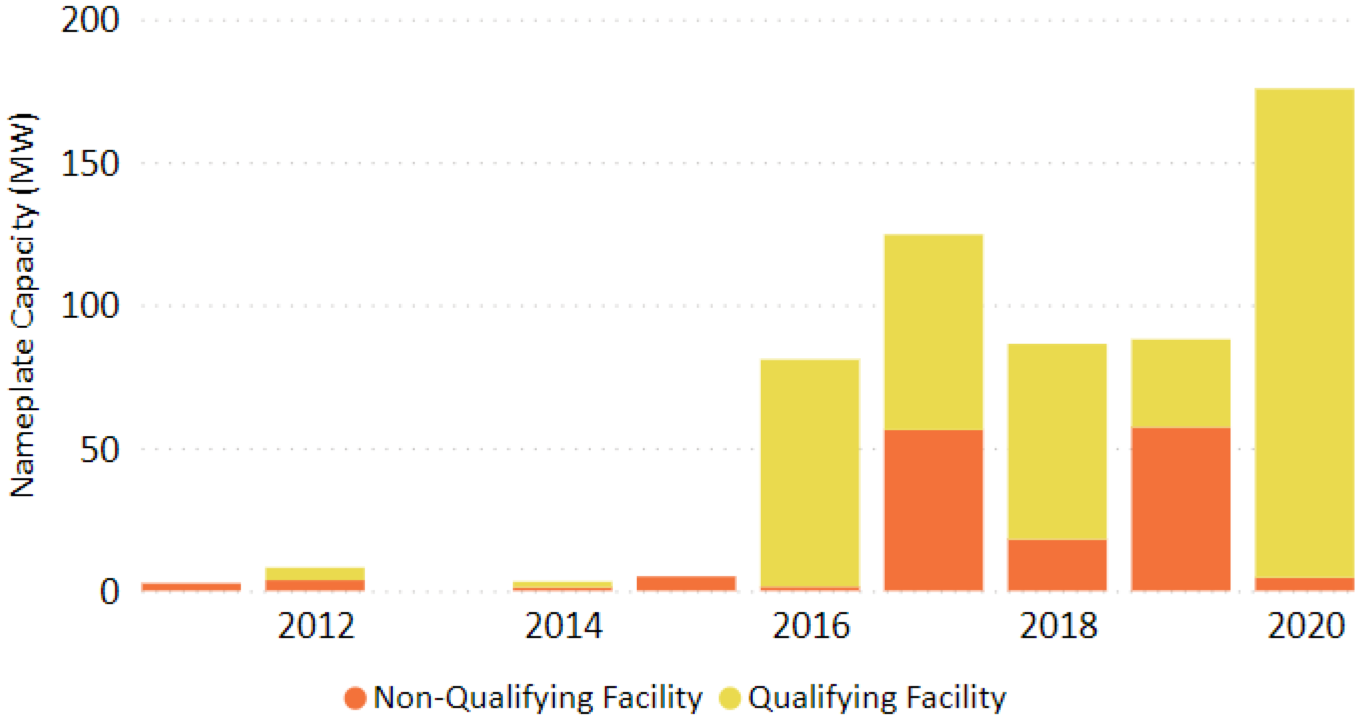
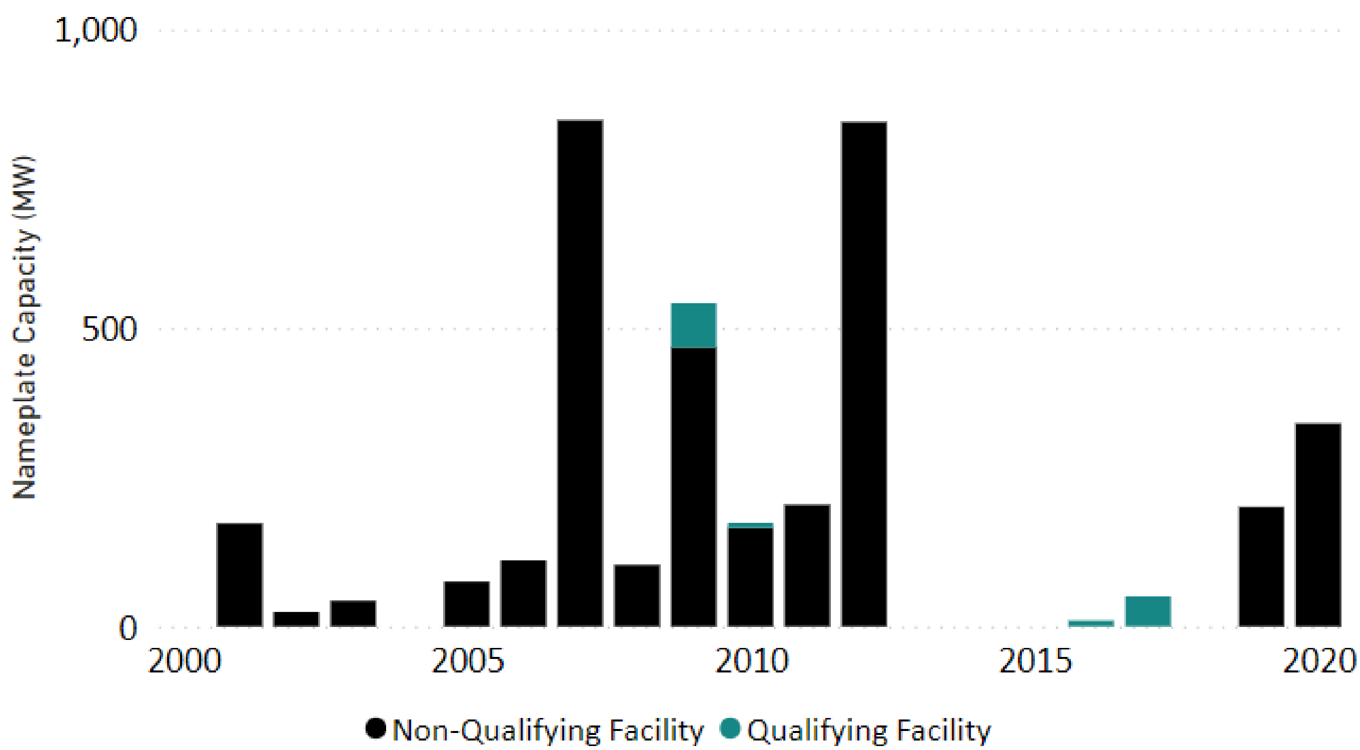


Figure 4: Oregon Wind Nameplate Capacity (MW) by Year and QF Status[16]



Next Steps: The Future of PURPA

The electric utility sector has changed dramatically since the adoption of PURPA in 1978. As shown above, the deployment of utility-scale renewables has grown significantly in the last two decades. This has been driven by state policies responding to an increased awareness of the threat posed by climate change combined with technology advancements and cost reductions. As of 2022, renewable projects of all sizes are increasingly cost-effective in the power sector. And recent actions taken by FERC in Order 872—such as reducing the must-purchase obligation for utilities from renewable QFs larger than 20 MW to those renewable QFs larger than 5 MW in certain RTO markets, and giving authority to states to adopt variable-priced avoided costs at the time of delivery—reflect these fundamental changes to the competitiveness of renewables in the marketplace. While PURPA has driven meaningful development of renewable projects in the past, there are divergent perspectives about the continued role of PURPA in helping Oregon to meet its clean energy goals in the decades ahead.

As of 2022, renewable projects of all sizes are increasingly cost-effective in the power sector.

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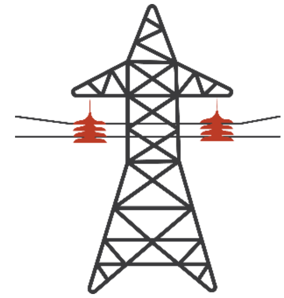
Energy 101: Electric Sector Resource Planning and Acquisition



The electric utility sector lacks significant capability to store its generated electricity.[i] As a result, electric utilities must ensure that they have sufficient electricity available to serve the demands of their customers in real-time, all the time. But not all resources need to be electric generating resources (e.g., power plants), as utilities can also meet these demands by investing in energy efficiency measures or developing incentives to shift customer demand patterns from times of higher to lower demand. To do this, utilities must continually evaluate what types of resources are available to them now and in the future, and correspondingly what they expect their customer demand to look like in the future, and then acquire the least-cost, least-risk portfolio of resources to meet demand.

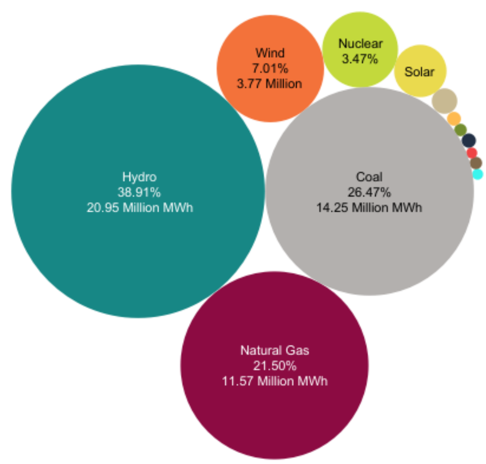
This section provides foundational information on:

Resource Planning. How do electric utilities in Oregon identify a need to develop or acquire new generating resources to serve customer demand in the future?

- *Investor-Owned Utilities:* How do investor-owned utilities (Portland General Electric, PacifiCorp, and Idaho Power) engage in this type of planning? What role does the state play?
- *Consumer-Owned Utilities:* How do consumer-owned utilities (e.g., rural electric cooperatives, municipal utilities, and People's Utility Districts) engage in this type of planning? What role does the Bonneville Power Administration play? What role does the state play?

Resource Acquisition: Once an electric utility has identified a need to acquire a new resource to meet customer demand in the future, it has several different mechanisms available to procure the additional necessary resources, including:

- *Spot market purchases:* Historically, electric utilities in Oregon have looked to engage with neighboring utilities in bilateral transactions to acquire resources to meet customer needs over short-term time intervals.
- *Long-term contracts:* In other instances, a utility might project a persistent future deficit that warrants signing a long-term contract (typically ranging from several years to 20 years) to purchase a resource from a third-party on an ongoing basis.
- *Utility-owned projects:* And the final major mechanism involves a utility developing and owning its own resource(s) to meet projected future long-term needs.



Learn about Oregon's electricity resource mix:
www.tinyurl.com/OregonERM

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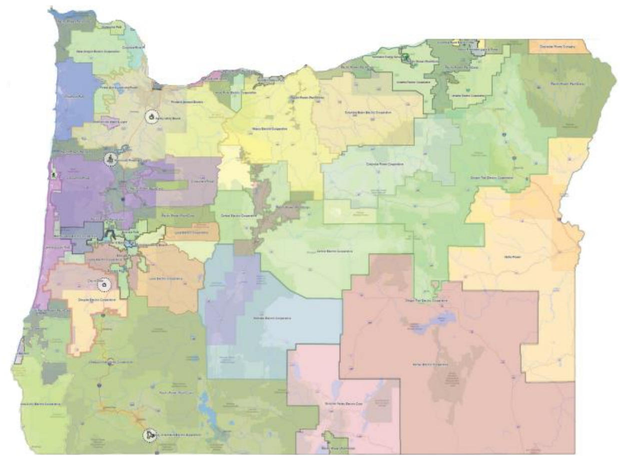
[i] While limited amounts of battery storage are beginning to deploy onto the power grid, this foundational reality of the electric sector has not changed.

Electric Resource Planning

Two types of electric utilities serve Oregon customers: private investor-owned utilities (IOUs) and not-for-profit, consumer-owned utilities (COUs). The regulatory construct is significantly different between IOUs and COUs, including around utility resource planning and the involvement of the state in that process.

The primary mechanism for IOUs to engage in resource planning occurs through the development of integrated resource plans (IRPs) with oversight from the Oregon Public Utility Commission (OPUC). Meanwhile, the 38 COUs serving Oregonians are governed by local boards, with significant variations in how each COU engages in resource planning.



An interactive map of Oregon utilities is available online: **www.tinyurl.com/FindYourUtility**

Investor-Owned Utilities: Integrated Resource Planning

In the 1980s, Oregon became one of the first states in the country to require state-regulated electric utilities—Portland General Electric, PacifiCorp, and Idaho Power—to develop least-cost plans, later called integrated resource plans (IRPs).[1] An IRP is designed to identify a utility's need for resources in the future. Development of a plan is typically led by specialists that deploy sophisticated computer modeling tools to evaluate a range of possible future scenarios. Important inputs to this process include a forecast of future customer demand based on expected population and economic growth, the adoption of new electric technologies (such as electric vehicles), and variable weather conditions. The state's three IOUs develop IRPs for submission to the OPUC about every two to three years. According to the OPUC:[1]

> *The IRP presents a utility's current plan to meet the future energy and capacity needs of its customers through a **'least-cost, least-risk'** combination of energy generation and demand reduction. The plan includes estimates of those future energy needs, analysis of the resources available to meet those needs, and the activities required to secure those resources.*

Public Participation

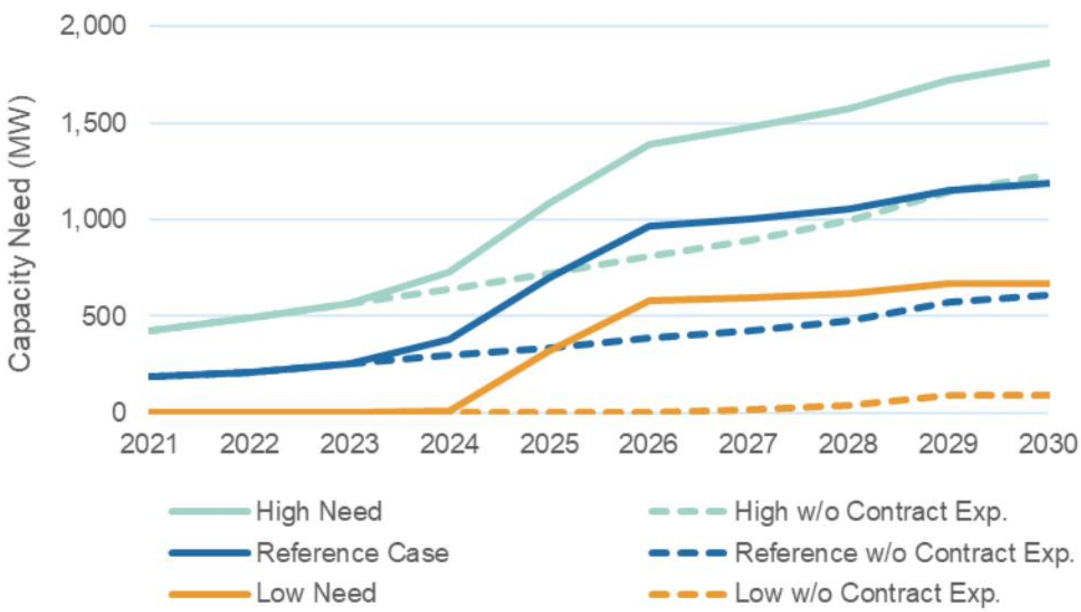
The development of IRPs is an ongoing, iterative process that presents opportunities for stakeholder engagement and feedback. Public meetings are held by the utilities several times a year, as often as monthly, where stakeholders are encouraged to provide information, feedback, and input that can influence how the IRP is shaped. These meetings are also often used as opportunities for the IOUs to share new modeling and forecast information with stakeholders as it becomes available. Public participation can also occur at the OPUC after the utility submits its IRP to the Commission for acknowledgement. ODOE recognizes, however, that the time required to engage in, and the technical nature of, these processes can be a substantial barrier to the meaningful participation of many stakeholders.

Identifying Resource Needs

As a utility engages in the development of its IRP, it is common for the utility to identify a projected future resource deficit—that is, a point of time perhaps several years into the future when it expects to have insufficient generating resources available to meet what it expects its customer demand for electricity to be. This might occur when the utility makes the decision to retire an existing power plant (e.g., such was the case when PGE retired the Boardman coal plant), or due to the expiration of an existing long-term contract to purchase power from a third-party, or simply due to a projected increase in customer demand for electricity.

As an example, the following graph from PGE's 2019 IRP shows how this type of a deficit can be illustrated as part of a utility IRP. The graph forecasts PGE's anticipated future capacity need under a reference case scenario, and across both a low need and a high need scenario. In addition, PGE has also reflected here how that deficit would change if it assumes that its existing contracts for power delivery do *not* expire but were renewed (the dotted lines).[2]

Figure 1: PGE Future Capacity Needs Under Various Scenarios[2]



These types of deficits appear frequently as a routine part of the IRP process. When they occur, the utility will develop an action plan to acquire resources to lower the risk of that future projected deficit materializing. The following section addresses how utilities can acquire resources once a projected future deficit has been identified.

State Role

In addition to the OPUC requiring IOUs to develop and file IRPs on a regular schedule, state agency staff from several agencies (including the Oregon Department of Environmental Quality, OPUC, and the Oregon Department of Energy) engage directly with IOU staff throughout the IRP development cycle. After a utility submits its IRP with the OPUC, the OPUC Commissioners will vote on whether to "acknowledge" the plan. Acknowledgment of the actions in an IRP does not constitute pre-approval by the OPUC of an investment for which the utility may later seek to recover the costs via rates charged to its customers.[1] Instead, the OPUC reviews the prudency of utility investments through a rate case proceeding after investments have been made.

More Information

More information on current Integrated Resource Planning efforts underway in Oregon, including information to track and sign-up for information on public meetings:

PGE: https://portlandgeneral.com/about/who-we-are/resource-planning

PacifiCorp: https://www.pacificorp.com/energy/integrated-resource-plan.html

Idaho Power: https://www.idahopower.com/energy-environment/energy/planning-and-electrical-projects/our-twenty-year-plan/

Track the regulatory dockets at the Oregon PUC related to IOU IRPs: https://www.oregon.gov/puc/filing-center/Pages/Key-Cases.aspx.

The NW Power & Conservation Council: Regional Power Plan

Individual electric utilities engage in their own resource planning, identify their own needs, and develop their own action plan to acquire resources when necessary. Meanwhile, the Northwest Power and Conservation Council, pursuant to the 1980 Northwest Power Act,[ii] develops a regional power plan every five years "to ensure an adequate, efficient, economical, and reliable power supply for the region."[3]

The regional power plan includes several key provisions, including:[4]

- a regional electricity demand forecast;
- electricity and natural gas price forecasts;
- an assessment of cost-effective energy efficiency potential;
- identification of a least-cost portfolio of generating resources.

While the regional power plan guides resource decision-making by the Bonneville Power Administration, it has no regulatory effect on the electric utilities that serve retail customers in Oregon. Instead, the regional power plan is relied upon by Oregon utilities mostly as an informational resource that helps them better understand the regional landscape when engaging in their own planning efforts.

The most recent five-year regional power plan, the 2021 Northwest Power Plan, was published in February 2022: **https://www.nwcouncil.org/2021-northwest-power-plan/**

[ii] Passage of the Northwest Power Act was in part a reaction to the lack of an accurate plan and electricity forecast, which led to an overbuilding of resources known as WPPSS (see the History Timeline section of this report). The Act created the Northwest Power and Conservation Council and directed the Council to give priority to cost-effective energy efficiency followed by cost-effective renewable resources. This was the "first time in history that energy efficiency was deemed to be a legitimate source of energy, on par with generating resources" (NWPCC 7th Power Plan Summary Brochure). The Northwest continues to see benefits from this approach, as energy efficiency is the region's second largest resource behind hydropower.

Consumer-Owned Utilities: Resource Planning

As noted above, COUs are self-governed by local elected boards and not subject to OPUC oversight when it comes to resource planning activities. Some of the state's larger COUs, such as the Eugene Water & Electric Board,[5] engage in integrated resource planning to consider potential future need for resources. Resource planning for most of the state's smaller COUs, however, looks quite a bit different for the reasons described below.

Role of BPA

In all cases, Oregon's COUs have a long history of contracting with the Bonneville Power Administration (BPA) for significant amounts of the power supply necessary to serve their retail customers. COUs are currently engaged in 20-year Regional Dialogue Contracts with BPA that are due to expire in 2028.[6] BPA recently initiated a series of public workshops to address the development of the policies and contracts that it will offer to its customers to meet their evolving needs post-2028.[7]

Under the current contracts, some of the state's COUs receive a ***fixed amount*** of BPA's power output, while that utility supplements the electricity delivery from BPA with output from its own generating resources or from other power contracts. The majority of the COUs that serve Oregonians, however, are ***full requirements*** customers of BPA, meaning that they "generate no power, relying instead on BPA for all of the power needed to meet their total load requirements."[8]

In the case of these full requirements customers, while they could elect to secure and apply non-federal resources to meet their current and future customer needs, their full power needs are currently handled by BPA. If BPA's existing federal resources are insufficient to meet these customer loads, it will procure additional resources (typically through market purchases) to deliver adequate supply to these customers. An important step in this process occurs through the establishment of each utility's Rate Period High Water Mark every two years, which allows for a recurring feedback loop between BPA and the utilities to account for changes to customer demand for electricity.[9]

These utilities were served 100% by BPA in 2021:

- City of Bandon
- Canby Utility
- City of Cascade Locks
- Clearwater Power Company
- Columbia Basin Electric Cooperative
- Columbia Power Cooperative
- Columbia River PUD
- Coos-Curry Electric Cooperative
- Douglas Electric Cooperative
- City of Drain
- Harney Electric Cooperative
- Hermiston Energy Services
- Hood River Electric Cooperative
- Midstate Electric Cooperative
- Monmouth Power & Light
- Oregon Trail Electric Cooperative
- Salem Electric Cooperative
- Springfield Utility Board
- Surprise Valley Electrification Corp.
- Umpqua Indian Utility Cooperative
- Wasco Electric Cooperative
- West Oregon Electric Cooperative

State Role

Resource planning by COUs is not regulated or overseen by the state, but instead by locally elected boards. Staff from the Oregon Department of Energy, however, engages on an informational and regular basis with BPA, and with individual and groups of COU General Managers and other representatives on a wide range of issues.

More Information

Bonneville Power Administration – Resource Planning: https://www.bpa.gov/energy-and-services/power/resource-planning
Bonneville Power Administration – Regional Dialogue (Post-2006) Contracts: https://www.bpa.gov/energy-and-services/power/regional-dialogue
Bonneville Power Administration – Provider of Choice (Post-2028) Contracts: https://www.bpa.gov/energy-and-services/power/provider-of-choice
Eugene Water & Electric Board – Integrated Resource Plan: https://www.eweb.org/about-us/power-supply/integrated-resource-plan

"Prediction is difficult—particularly when it involves the future."
— Mark Twain

It is important to recognize that electric utilities are required to forecast the future when they engage in resource planning. Because of the need to generate power in real-time to meet customer demand at all times, there is little margin for error in the power system. As a result, there is a long history of the utility sector working to proactively identify potential future resource deficits several years in advance to allow for resource acquisition to occur before a significant deficit ever materializes.

Of course, this type of future-looking planning involves a significant amount of uncertainty. Utilities must try to answer questions to inform their planning, such as:

- **Demand growth:** Will the population increase or decrease? Will the economy grow, and by how much? How rapidly will consumers adopt electric vehicles? Are there expected to be large new industrial customers moving to the area? What type of weather extremes should be anticipated?
- **Supply availability:** Are any existing power plants expected to retire or need maintenance? How much power will be available to import from other utilities and other regions at different times of the year? What new resources are planned and when will they become available? Will extreme weather (e.g., drought) affect power generation from resources like hydropower? How much can demand be reduced through investments in energy efficiency measures?

Answering any one of these questions introduces variables into the resource planning process for an electric utility. If the output of the answers to these questions results in having too few resources available, the risk becomes that the utility cannot keep the lights on. To avoid this downside, utilities often err on the side of staying ahead of projected future deficits to maintain some level of surplus resource availability or reserves. While this minimizes risk, it also comes at a cost to ratepayers. How much risk is too much risk to accept? And at what cost? These questions are central considerations when utilities engage in resource planning based on uncertain future conditions.

Electric Resource Acquisition

As noted above, both IOUs and COUs engage in resource planning to identify potential deficits and the need to acquire new resources to meet future customer demand. There are several mechanisms commonly used by utilities to acquire new resources to meet these needs.

Long-term Resource Acquisition

If a utility's resource planning identifies a persistent future need for more resources to meet customer demand, the utility generally has two primary options to acquire such a resource: to develop the resource itself or to enter a contract to purchase output from a resource owned by a third party. And in some cases, if the utility believes sufficient market supply will be available, a utility may opt to meet this type of future need through ongoing spot-market purchases.

Supply-side and Demand-side

It is important to note that these long-term resources are not limited to electricity generating resources (i.e., power plants). Utilities may also find that acquisition of demand-side resources, such as energy efficiency or load flexibility[iii] measures, could more cost-effectively address the need. In the context of an IOU IRP, utilities will evaluate a range of different resource portfolios, including both supply-side and demand-side actions, under different future scenarios to identify an optimal least-cost pathway forward on resource acquisition.

Energy Storage

As noted above, there is a historic lack of storage capabilities in the power system. But this is beginning to change. In some circumstances, utilities may identify energy storage as the optimal resource to meeting a specific future need. For example, this could occur in a circumstance where more solar or wind power is available for generation than what is needed to meet current demand. With conventional resources, like a gas plant, the utility could simply turn off the plant, stop physically burning more gas, and then turn the plant back on later and resume burning that gas physically stored on-site. The solar and wind resource, by its nature, requires the utility to use it when it is available or lose it. Energy storage systems can capture this otherwise wasted (or curtailed) energy for use later. This is one example of the type of scenario that is expected to drive more energy storage onto the power grid to help meet utility needs in the years ahead. See the Energy Storage Technology Review for more.

Risk

Utilities and their regulators will consider not only the cost of various resource portfolio pathways, but also the risk of choosing one pathway over another. For example, are there particular risks associated with future costs for a certain technology increasing? Or are there risks of a specific type of resource

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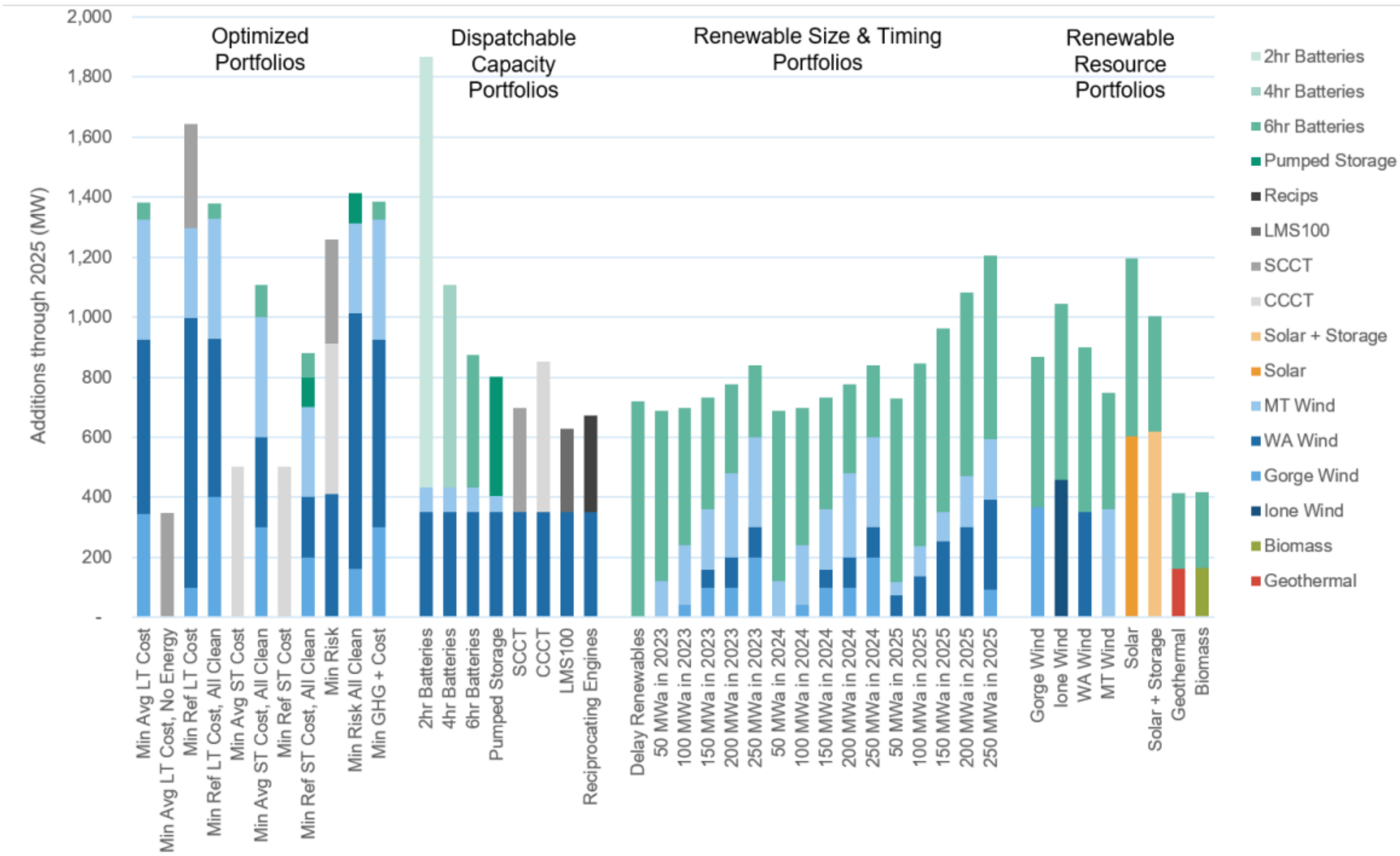
[iii] Load flexibility, or demand response, refers to the ability of a utility to incentivize customers to shift their demand patterns to better align with the needs of the power system. For example, offering a rebate to customers who voluntarily reduce demand (e.g., a residential customer turning up their thermostat, or an industrial customer shifting into standby mode) on hot summer afternoons. The reduction in power demand that can result serves the same purpose for the utility as acquiring a power generating resource.

failing to perform? Are there risks associated with developing a new power plant with an operational life expected to last for several decades versus relying on contracts to purchase power from a third party? Utilities will also use sophisticated modeling to test how different resource portfolios perform under a variety of scenarios that capture a range of potential future conditions.

The following visual from PGE's 2019 IRP illustrates the types of resource portfolios that utilities will evaluate as part of their planning. This graph displays different types of resource additions through 2025 across the different resource portfolios evaluated.[2]

Figure 2: PGE Resource Additions Through 2025 Across the Portfolios



Resource Strategy

Once a strategy for long-term resource acquisition has been selected, the utility may take direct action itself (e.g., to invest in energy efficiency or develop load flexibility programs for its customers), enter directly into negotiations to purchase a targeted resource, or develop a Request for Proposals to solicit bids from third parties for the amount and type of resources it seeks. Depending on the type of resource the utility identifies as being necessary, the lead-time required to acquire the resource could be several years (or more) in the case of a large-scale power plant.

Utility-Scale Power Plants: Project Development Process

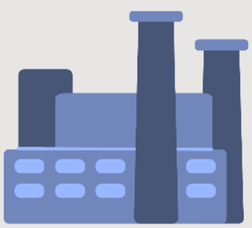
Significant resource planning and work to identify an optimal resource strategy will occur before a utility reaches a decision to either move forward with building a new power plant or signing a long-term contract to buy the output from a new plant developed by a third-party. Planning activities can take several years.

Because both the planning process and the project development process for a specific power plant take several years, often projects begin the development process long before the utility finalizes its resource planning and acquisition strategy.

What are the key steps involved in the project development process?

- Assembly of a capable project team
- Identification of suitable project site
- Acquisition and/or control of the site
- Identification of target project size and technology selection
- Siting and permitting
- Interconnection study process
- Secure a power offtake arrangement (e.g., Power Purchase Agreement or PPA)

Learn more about Oregon's energy facility siting and permitting process in the 2020 Biennial Energy Report: **www.tinyurl.com/SitingPermitting**



Often, once a utility makes the decision to acquire a project it will issue a Request for Proposals (RFP) and solicit bids. In certain circumstances, IOUs may need to comply with OPUC competitive bidding requirements for the RFP. Many projects that have achieved some or all of the project development milestones identified above may submit bids, even though only one or a few of the projects may ultimately be selected to execute a PPA, proceed to development, and become operational.

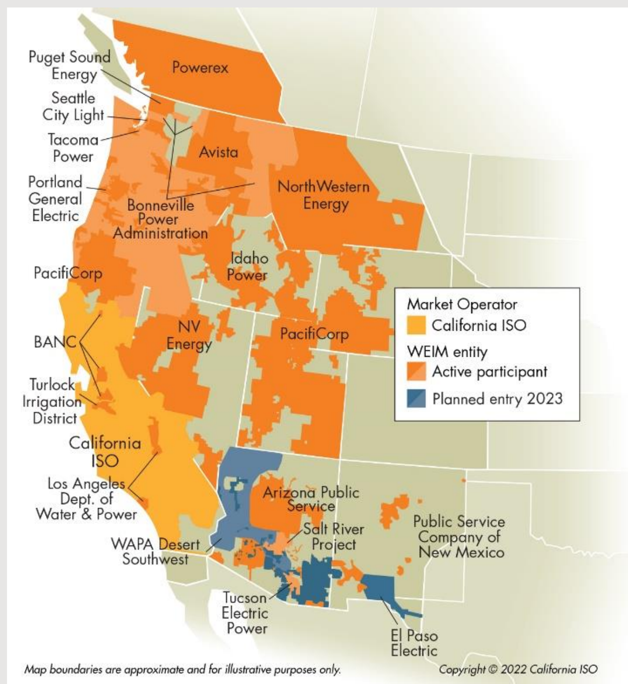
Short-term Resource Acquisition

Resource planning is an ongoing, iterative process designed to identify medium- to longer-term needs (typically three to five years or more in the future) so that utilities have ample time to take action to acquire resources before a resource deficit materializes. That said, short-term resource deficits still occur for a variety of reasons. For example, this might occur if extreme temperatures drive customer demand higher than what was planned for, or if a power plant goes offline for an unplanned reason. Sometimes the utility may need to acquire additional resources for a season, for several weeks, or even several hours.

When these types of short-term needs arise, utilities can buy and sell power directly with other utilities through negotiated deals, generally referred to as bilateral transactions. In most parts of the country, utilities participate in centralized markets administered by a Regional Transmission Organization (RTO) or Independent System Operator (ISO). Where these types of centralized markets exist, utilities are often able to meet short-term needs through the market. This is the type of structure that exists, for example, in California through the markets administered by the California Independent System Operator (CAISO). Because Oregon utilities are not currently members of an RTO or ISO, the Oregon Department of Energy published the *Regional Transmission Organization Study: Oregon Perspectives* in December 2021 that identifies current stakeholder perspectives on the benefits, challenges, and risks of Oregon entities participating in an RTO or ISO. The full report is available online: https://www.oregon.gov/energy/energy-oregon/Pages/RTO.aspx.

What role does the Energy Imbalance Market (EIM) play?

In recent years, all three IOUs operating in Oregon have joined the Western EIM, and BPA joined earlier in 2022. The EIM is an extension of the real-time centralized market platform used by the California Independent System Operator to entities across the west outside of California.



The EIM has been designed to minimize costs to utilities by optimizing the dispatch of participating resources. However, the EIM has been designed specifically to preclude participants from relying on that market to meet short-term resource deficits. This is accomplished by imposing strict resource sufficiency tests on market participants every hour before they are able to participate in the EIM. If a utility has insufficient resources available, then its participation in the EIM will be restricted.

For more information on the impact of the EIM on Oregon entities, see the Policy Briefs section of this report.

What's Next

The electric utility sector continues to undergo transition as the economy moves from a reliance on fossil fuels to clean energy. Following the passage of HB 2021 in 2021, Oregon's IOUs will need to transition to 100 percent clean energy by 2040.[10] This will require a transition away from fossil-fuel resources and the development of a significant amount of new clean energy resources—notably wind and solar.[iv] This is occurring at a time when overall demand for electricity is also likely to increase due to expanded electrification, such as through the adoption of electric vehicles. At the same time, COUs are entering a potential period of transition as their existing long-term contracts with BPA expire in 2028. This is also occurring against a backdrop of large-scale retirements of coal power plants across the western United States, and a changing climate that is increasing pressures on hydropower resources.

As a result of these changes, it is likely that utility resource planning efforts will become even more dynamic, complex, and consequential in the years ahead. Utilities will need to balance the costs and risks associated with different pathways to decarbonize the power system. The scale of fossil fuel retirements will be large, but the scale of clean energy development will be even larger, especially as demand for electricity rises due to increased electrification. Continued momentum toward increased regionalization of energy markets combined with changes in technology—from new types of generation, like floating offshore wind, to new opportunities for incentivizing load flexibility—will create new opportunities and challenges for electric sector resource planning and acquisition.

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[iv] A key element of this implementation will occur through the development of Clean Energy Plans submitted to the Public Utility Commission. For more information, see: https://www.oregon.gov/puc/Documents/HB2021-Summary.pdf

Energy 101: Long-Duration Energy Storage

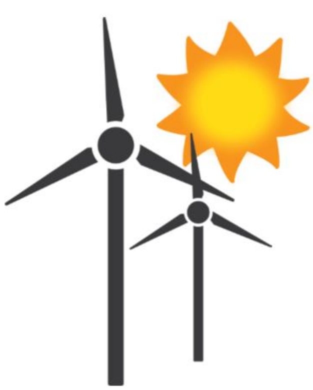
Technical studies in the power sector increasingly identify the need for significant volumes of energy storage to achieve deep decarbonization policy objectives. Most storage systems deployed in recent years have been lithium-ion batteries designed to completely discharge their stored energy to the grid over timescales ranging from two to four hours, which could be referred to as **short-duration energy storage**. These types of battery storage systems can provide significant benefits to consumers and to grid reliability.

Some grid planners and utilities, however, have started to identify a need for storage resources that can discharge energy to the grid for longer durations. These types of storage assets are increasingly referred to as **long-duration energy storage** or **LDES**. For example, the California Public Utilities Commission, which develops a statewide reference system plan as part of its integrated resource planning proceeding, recently identified a statewide need for 973 MW of long-duration energy storage by 2026.[1] However, there is a lack of clarity around what long-duration energy storage in the power sector really means—how to define it, what technologies can deliver it, what the capabilities are or could be, and how much will be needed to cost-effectively decarbonize the power sector.

Renewable Energy and Storage

Consumer demand for electricity is variable throughout the course of a day, over different days of the week, and across different months of the year, and the electric power system has been developed over the last century to accommodate this variability. This has been achieved primarily through the development of large dispatchable power plants – such as those powered by coal or natural gas – that can modulate their power output to correspond to variability in demand.

Wind and solar generation projects, on the other hand, have variable output dependent on the natural availability of the winds and the rising and setting of the sun, respectively. Hydropower resources similarly have variable output based on the availability of water flows driven by precipitation patterns, seasonal runoff from snowmelt, and other factors. While the variability of hydropower tends to be most pronounced over months, seasons, and years, the variability of wind and solar power occurs on daily and hourly timescales while also displaying seasonal variability. This presents a new challenge for grid planners tasked with matching supply availability with consumer demand in real-time. The challenge is one characterized by a mismatch in timing, for which energy storage presents a solution.



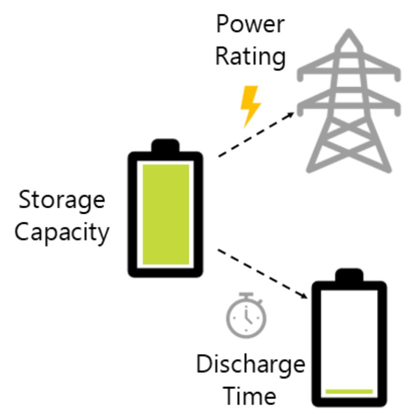
As a result of the anticipated large-scale deployment of wind and solar in the years and decades ahead, the power system's need for energy storage is expected to increase. In some respects, this might result in the power system more closely resembling other sectors, for which large volumes of centralized and distributed storage are ubiquitous. The gasoline and natural gas sectors, for example, have the equivalent of two to three weeks' worth of end-use fuel in storage at any given time. The electric sector by contrast currently has less than three hours' worth of electricity in storage (the vast majority of which is stored in pumped-storage hydro projects).[2] It is highly unlikely that the electric sector would ever approach the volume of storage that exists in the gasoline and natural gas sectors, but given the need for a decarbonized power sector to rely on large amounts of variable output resources, like wind and solar power, it is highly likely that more grid-connected storage will be valuable in the years and decades ahead.

Defining Long-Duration Energy Storage

The Basics of Measuring Energy Storage

In recent years, lithium-ion batteries have become the most common new type of energy storage technology deployed on the power grid. These batteries are flexible power resources that can serve a multitude of grid needs, but they need to be charged with power from the grid. The contribution that these storage assets can make to the grid is largely dependent upon the total capacity of the battery to store energy, how much energy can flow out of that battery back onto the power grid, and for what duration. Those projects are typically reported with the following metrics: [3] [4]

- **Storage Capacity or Energy Rating:** A measurement of the maximum volume of stored energy, in megawatt-hours (MWh) or kilowatt-hours (kWh), within a given storage technology.
- **Power or Power Rating:** A measurement of how much energy, in megawatts (MW) or kilowatts (kW), can flow out of a battery device and onto the power grid in a given instant.
- **Discharge Time or Duration (Hours):** A measurement of the energy-to-power ratio of the storage technology expressed as the amount of time that the technology can discharge at its maximum power rating until it has exhausted its energy supply (typically measured in one-, two-, four-, or six-hour increments).

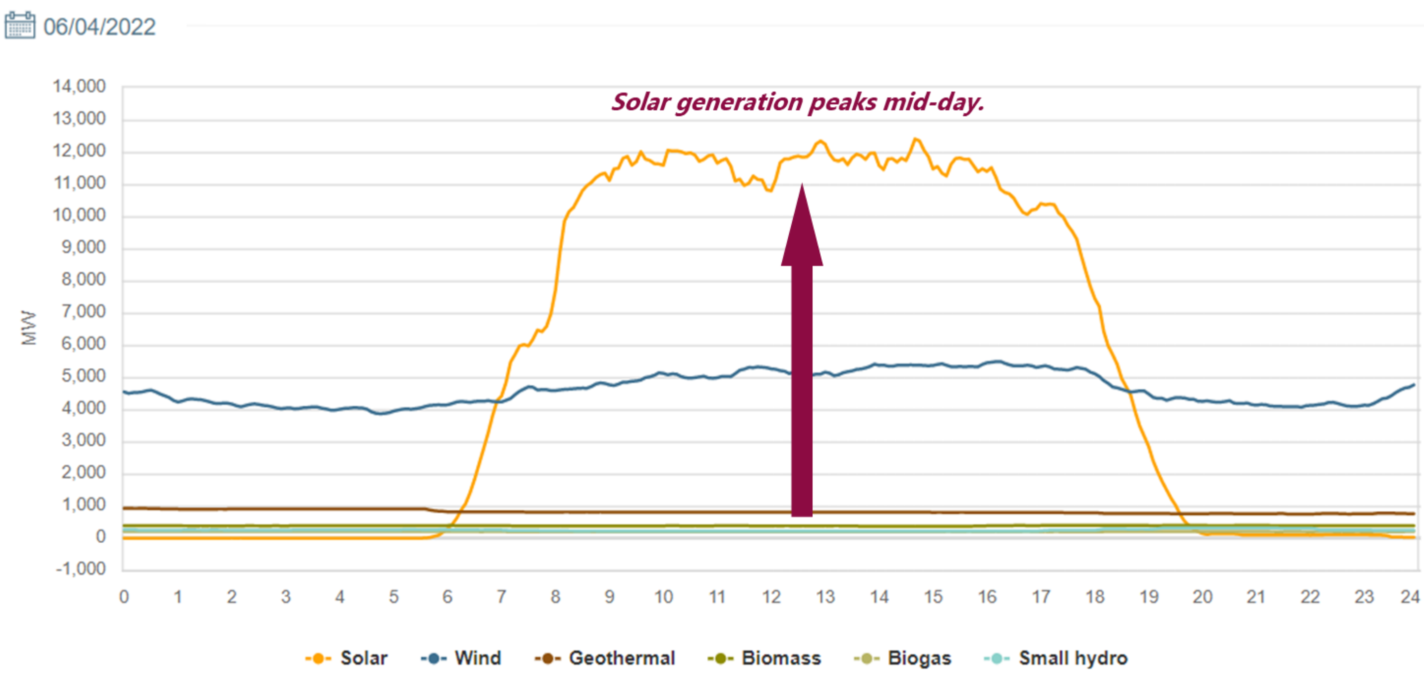


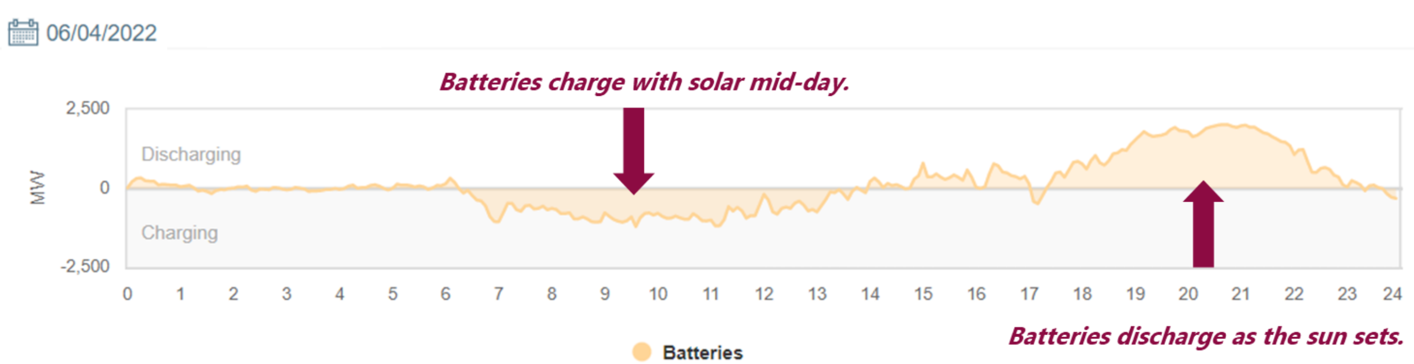
According to the National Renewable Energy Laboratory, battery storage systems with a duration of two to six hours are currently sufficient to provide reliable peaking capacity in most parts of the country until renewable penetrations exceed 25 percent.[5] For this reason, it is common to see grid-connected battery systems reported as having a duration in this range. NREL anticipates future phases of storage deployments greater than eight-hour durations as renewable penetration levels exceed 50 percent.[5] Note, however, that a battery with a fixed power rating and battery capacity can theoretically operate for different durations, while the economics of doing so may vary across different use cases. Consider the following hypothetical 10 MW / 40 MWh battery system:

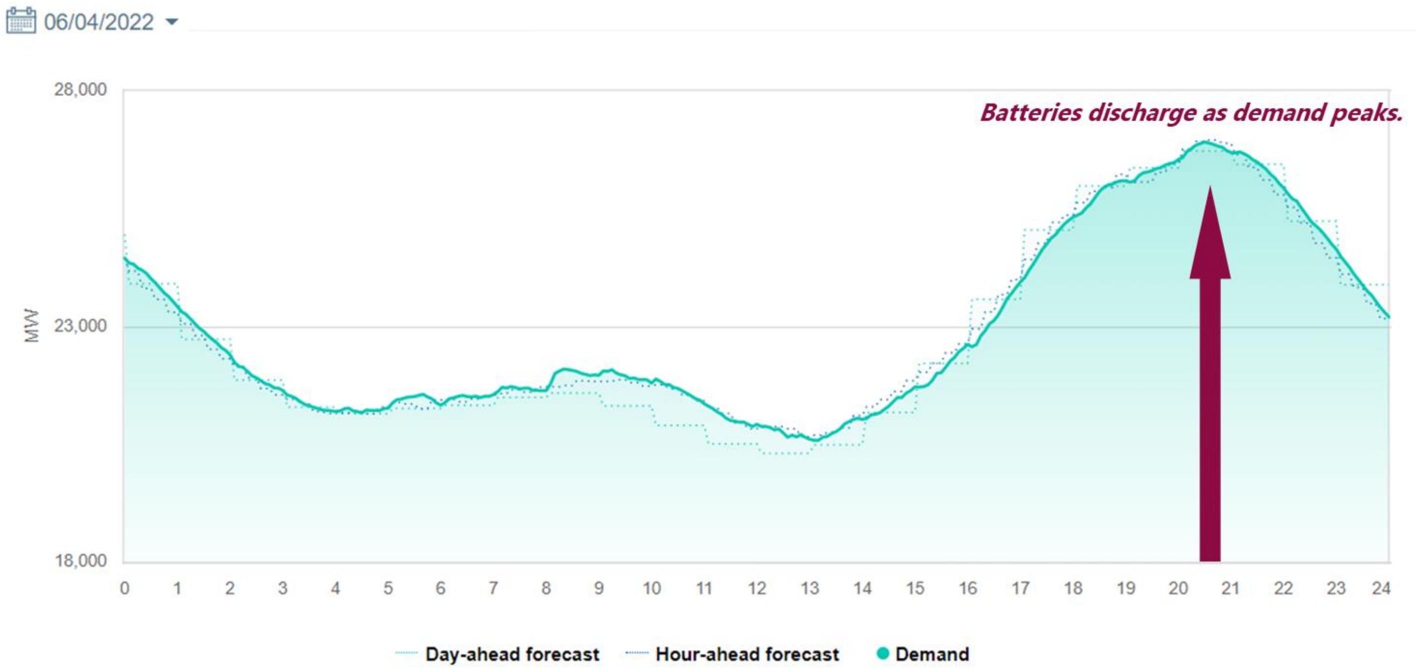
Power Rating	Battery Capacity	Power Output	Duration
10 MW	40 MWh	100% of max	4-hour
		50% of max	8-hour
		25% of max	16-hour

Depending on the use case and the corresponding economics of operating a battery a particular way, a utility may choose to dispatch a storage device in a variety of ways. The following visuals from the California Independent System Operator illustrate one potential use case for grid-connected batteries – storing excess solar generation during mid-day hours and shifting that output to later in the evening as the sun sets and power demand increases: [6] [7]

Figures 1-3: Solar Generation and Battery Charging and Discharging Data from California ISO on June 4, 2022







These figures show that the bulk of the battery discharge currently occurs over a 4-hour time interval, from about 6 to 10 p.m. As the cost of lithium-ion batteries continues to fall, it may become more economical to operate batteries at lower power output to achieve longer durations, or to "stack" 4-hour duration batteries at max power output to achieve effective, longer durations. For example, one scenario could have two 10 MW / 40 MWh batteries operating at max output for four hours, with the first discharging from 4 p.m. to 8 p.m., and the second one discharging from 8 p.m. to midnight.

Defining Long-Duration Energy Storage

Utilities across the country are beginning to procure long-duration energy storage (LDES) projects. As noted above, the California PUC identified a need for 973 MW of long-duration energy storage by 2026.[1] Meanwhile, a coalition of community choice aggregators in California recently issued a request for proposals to solicit bids for long-duration energy storage projects, requiring the projects to be 50 MW or larger, able to discharge at that power output for eight hours or more, and able to become operational by 2026.[8] An electric utility in Minnesota has signed a contract with an LDES project developed by Form Energy that promises to deliver 1 MW of power output for 150 hours by 2023.[8]

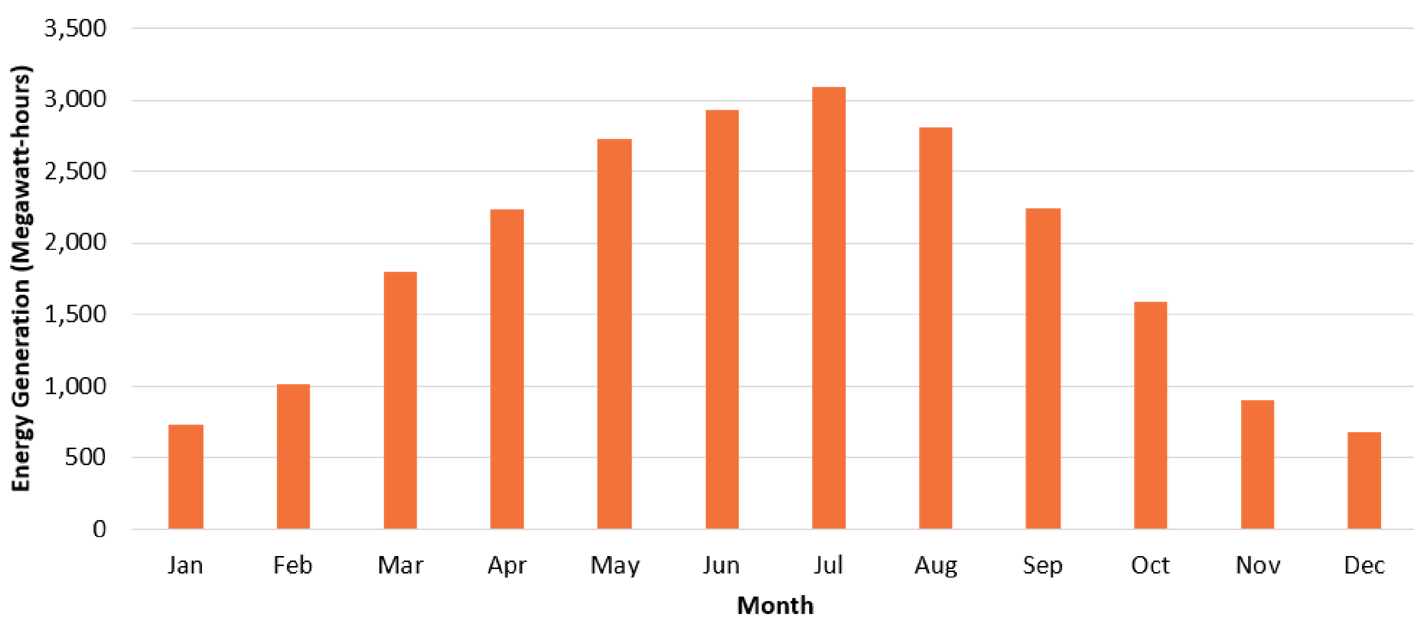
How then does the industry define long-duration energy storage? Despite these emerging efforts to procure LDES resources, no definitive technical definition of LDES exists, as found by the National Renewable Energy Laboratory in a paper published in November 2021 titled, *Storage Futures Study: The Challenge of Defining Long-Duration Energy Storage*.[9] In that study, NREL reviewed recent literature to survey the range of definitions used across the industry. According to NREL, despite the "large range in definitions, there appears to be at least some justification for considering ≥10 hours as a consensus duration" required for a storage device to qualify as LDES.[9] They settled on this threshold for two primary reasons: (1) it was the most often cited number in the literature reviewed, and (2) it is consistent with the definition adopted by the Advanced Research Projects Agency-Energy (ARPA-E) of 10-to-100 hours, which was also referenced by the U.S. Department of Energy's Long-Duration Storage Shot initiative described below.[9]

Table 1: Storage Technologies and Economical Durations of Max Output

Storage Type	Primary Technology	Economical Duration of Max Output
Standard storage	Lithium-ion batteries	2-hour, 4-hour, 6-hour
Long-duration energy storage	Pumped-storage hydro, hydrogen, flow batteries, gravity storage, compressed air, derated lithium-ion batteries, etc.	10- to 100-hour
Seasonal storage	TBD – hydrogen a likely candidate	More than 100-hour

That said, NREL also pointed out that while the literature does identify a lower-end threshold (10 hours), there is very little discussion of the upper-bound number (100 hours) included in the ARPA-E definition.[9] This point may be relevant to the extent it allows us to distinguish long-duration energy storage (10-to-100 hours) from an even longer-duration form of energy storage which might better be conceptualized as "seasonal energy storage" (which might be measured across weeks or even months). For power systems with up to 80 percent penetration of variable output wind and solar, however, NREL contends that 10- to 100-hour LDES systems should be sufficient, and that in the near-term, four-hour storage systems will be sufficient in most regions of the country for most applications.[9] In the long term, consider the visual in Figure 4, which shows modeled power generation output from a hypothetical 10 MW solar project located in Lakeview, Oregon. As this visual illustrates, solar systems in Oregon generate significantly more power during the summer months than the winter months. As the state moves to higher levels of renewable energy, and approaches 100 percent, it may become necessary to consider solutions to effectively store solar energy generated during the spring and summer months to be able to use during other seasons.[10]

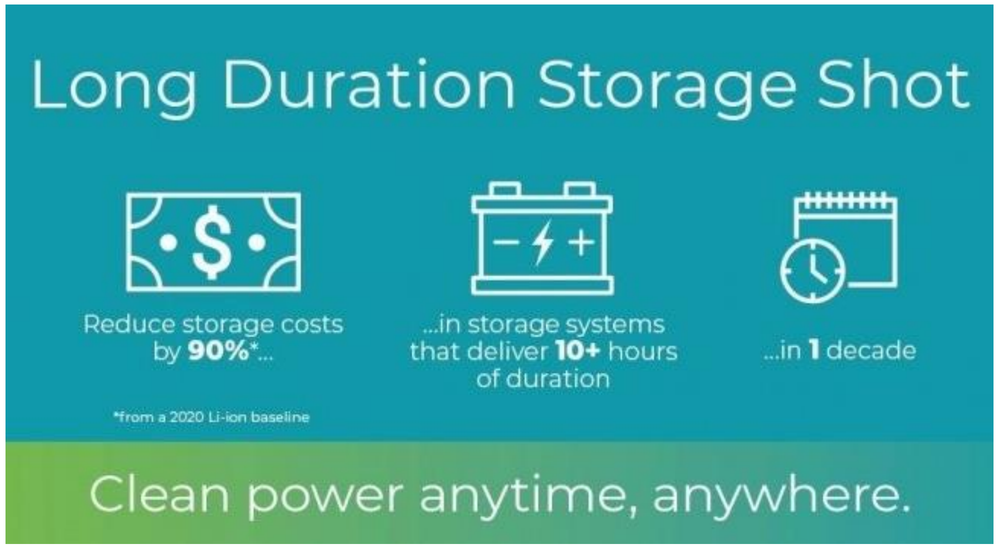
Figure 4: Modeled Power Generation Output from Hypothetical 10 MW Solar Facility in Lakeview, OR



Potential Technology Solutions

Two technologies have dominated energy storage deployments in the power sector to date: pumped-storage hydropower and lithium-ion batteries. Pumped-storage hydropower projects have been in operation for several decades, while the commercial deployment of lithium-ion batteries for energy storage is a recent development over the last several years. Both technologies deliver energy storage to the grid, but both have limitations. Pumped-storage hydropower projects can only be developed in locations with highly specific site characteristics, while lithium-ion batteries may not be cost-effective in delivering the capabilities sought from long-duration energy storage.

In 2021, the US Department of Energy launched the "Long Duration Storage Shot" initiative. The initiative is open to any storage technology, or combination of technologies, that can achieve the following three objectives: (1) reduce costs by 90 percent from a 2020 baseline for lithium-ion batteries, (2) deliver 10+ hours of duration, and (3) can achieve these objectives within 10 years.[11]



There is a range of technologies that might compete in this initiative, including:[12] [13] [14] [4]

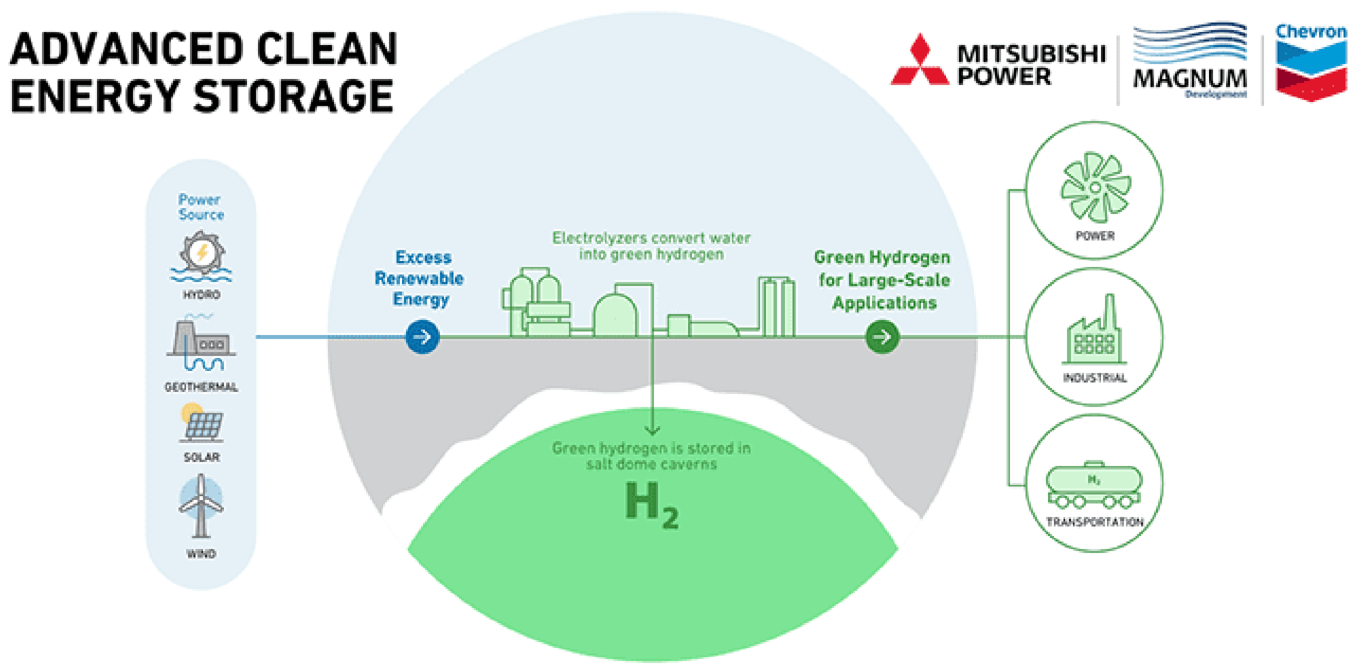
- **Pumped-storage hydropower:** Using low-cost electricity to pump water to a reservoir at elevation, before leveraging gravity to let the water descend from the reservoir to generate electricity at a time of higher need.
- **Mechanical gravity storage:** Similar to the concept of leveraging gravity with pumped-storage hydropower, but instead using cables or other mechanical systems to elevate large masses (e.g., large concrete blocks) using low-cost electricity before letting the masses descend at a later time to generate electricity.
- **Electro-thermal storage:** Converting electricity into thermal energy that can be stored as heat (e.g., in molten salt) or cold (e.g., in a chilled liquid), before using a heat engine powered by a temperature differential to convert back into electricity for the grid.
- **Liquefied air:** Using low-cost electricity to supercool and liquefy air in pressurized above-ground tanks that can be dispatched to power a generator and generate electricity when needed.
- **Underground compressed air:** Injecting large volumes of compressed air into underground geologic formations, then releasing the pressurized air to generate electricity when needed.
- **Flow batteries:** A type of battery technology that uses electricity to circulate liquid electrolytes that can charge or discharge electrons.

- **Virtual storage:** Aggregating many distributed resources (e.g., rooftop solar systems, or residential batteries) across a wide area to provide virtual storage capabilities that can either absorb (by increasing demand for power from flexible loads) or generate (by dispatching distributed batteries or rooftop solar systems) power like a large-scale storage system.
- **Hydrogen:** Using an electrolyzer powered by excess renewable energy to separate hydrogen from water that can be stored as a gaseous or liquid fuel, and then either used in a fuel cell or combustion engine to generate electricity when needed.

These technologies each exist at different levels of commercial readiness, with numerous companies actively working on research and development. For example, trade press reports that significant investment funds have recently flowed to companies working on long-duration energy storage systems based on gravity-based energy storage, nickel-hydrogen batteries, an electro-thermal pumped heat energy system, and an iron-air battery.[14] Given the range of different technologies that may be suitable for long duration energy storage, and their varying levels of technological readiness, it is difficult at this point to characterize a single cost of long duration energy storage.

Meanwhile, a consortium of companies is actively developing a long-duration energy storage project—the Advanced Clean Energy Storage Project—at the site of a retiring coal plant in Utah. The project intends to use a 220 MW electrolyzer to convert renewable power into hydrogen, which can be stored in large volumes in salt caverns (each one approximately the size of the Empire State Building) located beneath the site of the power plant. The retiring coal plant will be repowered as an 840 MW gas plant with turbines capable of combusting the renewable hydrogen stored on site. Project sponsors expect that the caverns can store enough renewable hydrogen (labeled "green hydrogen" in the graphic below) to generate 150 GWh of clean energy.[i]

Figure 5: Illustration of Underground Hydrogen Storage Design for Advanced Clean Energy Storage Project[15]



[i] Note that 150 GWh (150,000 MWh) is equivalent to the 840 MW gas plant operating at its theoretical maximum output consecutively for seven days.

While many technologies are expected to compete, it is not yet certain which technology, or combination of technologies, might prove most cost-effective to deliver the kind of long-duration energy storage at-scale that the power sector may require in the decades ahead.

Oregon-Based ESS, Inc. Forging a Path for Long-Duration Energy Storage

ESS Inc. is ready to bring more long-duration energy storage to the market – and further accelerate the clean energy transition. The Wilsonville-based company's mission is to provide clean and sustainable long-duration energy storage options through its environmentally friendly iron flow batteries that use earth-abundant iron, salt, and water to store energy.

The chemistry also means the batteries are safer and non-toxic – which means they are easier to permit and site and significantly reduce the need for fire suppression or containment preparations. At the end of a battery's 25-year life, it can also be recycled to keep materials out of landfills.

ESS has storage solutions for different customer types, including utilities, commercial businesses, and industries. The company's *Energy Warehouse* product is designed to store up to 400 kilowatt-hours of electricity, providing storage durations of four to 12 hours. ESS's *Energy Center* model is designed for utility-scale needs, providing megawatts of power with a duration of six to 12 hours. Energy Center capacity varies depending upon site design and customer needs, but a one-acre footprint can support approximately 8 megawatts, and 64 megawatt-hours.

As Oregon and other states work toward clean energy goals, including 100 percent clean electricity by 2040, long-duration energy storage solutions like these can support variable renewable energy resources, like wind and solar, to strengthen overall grid reliability and provide power when Oregonians need it.

Learn more about ESS online: https://essinc.com/

In August 2022, Oregon Department of Energy Director Janine Benner joined U.S. Department of Energy Secretary Jennifer Granholm, Oregon Senators Ron Wyden and Jeff Merkley, Oregon Governor Kate Brown, and others on a tour of ESS, Inc.'s Wilsonville campus.

Long-Duration Energy Storage as a Tool for Decarbonization

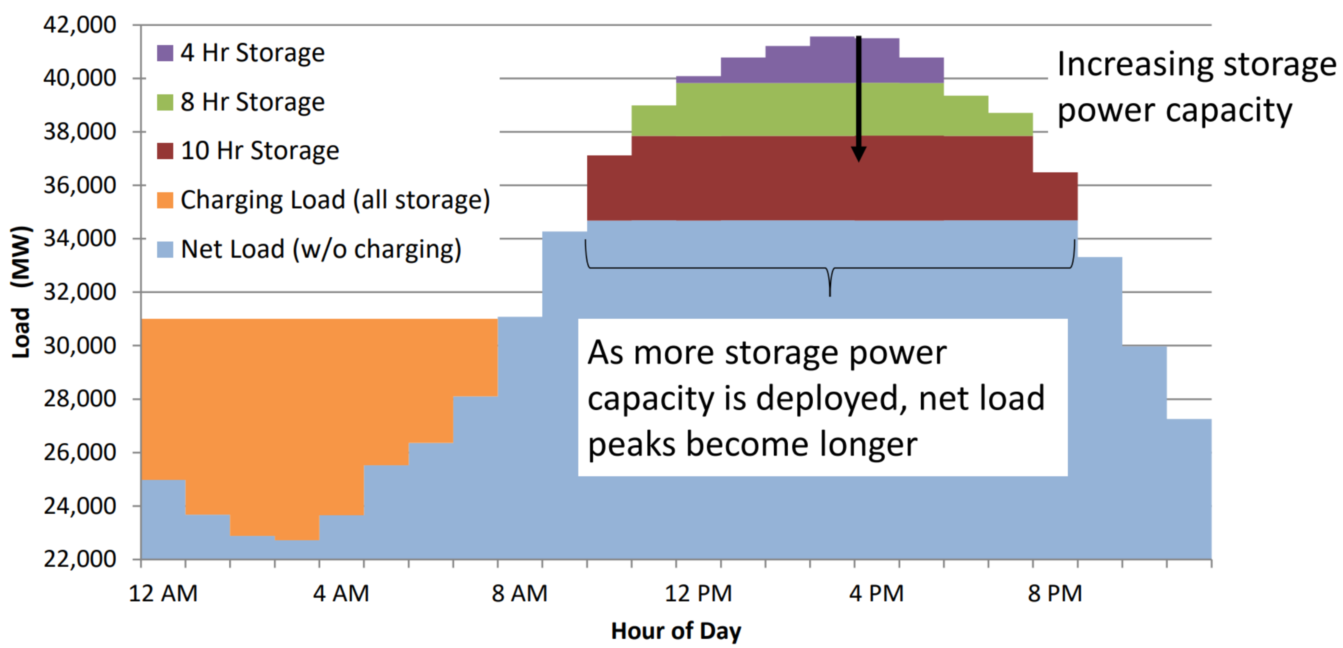
The potential need for LDES solutions to support a deeply decarbonized power system in Oregon and the Pacific Northwest is not yet certain. To reach extremely high levels of decarbonization in the economy, the power system will require some combination of the following solutions to manage the variability in the output of wind and solar generation:[4]

- Dispatchable electricity that can be powered by zero- or low-carbon resources (hydropower, nuclear, fossil fuels with carbon capture, bioenergy, geothermal, or renewable hydrogen);
- Negative emissions technologies that can offset the GHG emissions of fossil fuel resources;
- Significant transmission expansion to facilitate transfers of variable wind and solar across large geographic areas; and/or
- Energy storage systems that can mitigate the imbalances that occur between variability in consumer demand for power and the availability of wind and solar output.

To a large extent, these types of solutions (and others, such as flexible loads that can respond to grid conditions) will be in competition with one another in the decades ahead. It is too soon to know which specific technology pathway will prove the most cost-effective in helping our state and region to achieve our climate objectives. LDES may play a role in supporting a cleaner electricity grid, but recent technical studies do not provide a consistent picture of a definitive need for LDES to support a future grid with large amounts of variable, clean energy generation resources. This means that the power system's need for long-duration energy storage is challenging to define today. The following examples illustrate the diversity of results on the need for LDES provided in two recent studies.

A 2021 study by the National Renewable Energy Laboratory indicates that larger deployments of standard storage (two- to six-hour storage devices) on the grid will affect the potential need for LDES systems.[9]

Figure 6: Effect of Storage Deployment on Duration Needed[9]



As illustrated in Figure 6, four-hour storage systems can offset the apex of peak load where the peak is less than the four-hour output of the battery. Below the apex, the duration of peak load need exceeds four hours, necessitating a longer-term solution to meet this portion of peak demand. The NREL paper indicates this 'longer-duration' need is not unique and could be met by appropriately de-rating a four-hour storage system.[9] For example, in Figure 6, a system manager could operate a four-hour storage system at 50 percent of maximum output to achieve eight hours of duration, or at 25 percent of maximum output to achieve 16 hours, etc. NREL summarizes this dynamic (emphasis added): [9]

> *…the need for durations of more than 4 hours is lessened by the increased deployment of solar PV and the ability to derate shorter-duration storage (if sufficiently cost-effective),* ***making the need for technologies with specific durations as much of an economic issue as a technical one****. Therefore, the need for storage with durations of 10 or more hours largely hinges on a future grid with a specific set of conditions including regional load patterns, renewable energy deployment, previous storage deployments, and the economics of competing storage options.*

Alternatively, a study published in November 2021 by McKinsey finds that, while technically feasible to use derated lithium-ion batteries to sustain output for longer durations, it will not be economical to do so at-scale. The study suggests that long-duration energy storage will become "the lowest-cost flexibility solution" for power systems once the penetration of wind and solar reaches 60 to 70 percent, which may occur in some countries as soon as 2025 to 2035.[16] As a result, McKinsey expects 1,500 to 2,500 GW of LDES to be deployed globally on the power grid by 2040.[16] [4] The study notes, however, that as costs continue to decline for lithium-ion batteries and as grid-connected battery installations increase, LDES systems may be less cost-effective.

Next Steps

As explored in this report's *Charting the Course for Oregon's Energy Future* Policy Brief, the scale of solar and wind energy development necessary in the decades ahead to achieve mid-century policy objectives is substantial. There is also consensus in the literature that a significant deployment of grid-connected energy storage technologies will add value in helping to mitigate supply and demand imbalances that result from this buildout of variable wind and solar generation. That said, grid planners and utilities do not yet have certainty about the extent to which dedicated ***long-duration*** energy storage solutions (as opposed to ***short-duration*** energy storage solutions, such as the two-hour and four-hour batteries that are beginning to proliferate in the power sector) may be required to cost-effectively decarbonize the power system in Oregon and the region. And to the extent that grid planners and utilities do identify a clear need for long-duration energy storage, it is not yet certain what technology, or suite of technologies, will be best positioned to meet that need in the decades ahead.

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Energy 101: Electrification Options in the Agricultural Sector

Electrifying equipment and vehicles in the agricultural sector can reduce pollution and greenhouse gas emissions from fossil fuels and save energy costs for farmers and ranchers.[1] [2] Oregon farmers and ranchers are already taking advantage of options to reduce fossil fuel use by making their buildings and equipment more energy efficient, practicing reduced-till and no-till farming, and installing renewable energy generation.[3] Increasingly, agricultural producers will also have options to electrify the tools and equipment they use on their farm or ranch.

Oregon agricultural producers rely more heavily on electricity as an energy source than those in other regions of the U.S.[4] Oregon farms, like farms in many other western states, are more likely to irrigate and more likely to power their irrigation pumps with electricity compared to farmers in other regions.[5] According to ODOE analysis for the 2020 Biennial Energy Report, Oregon agriculture gets about 60 percent of its power from electricity with the remaining 40 percent coming from a variety of fossil fuels, while the U.S. agricultural sector as a whole gets about 24 percent of its power from electricity.[6] [4] Oregon agriculture uses about 8,900 billion Btu of energy yearly, which is about 3.5 percent of the total energy used by the Oregon industrial sector.[6]

While electric tractors have so far received the most legislative discussion in Oregon, there are several other important on-farm fossil fuel uses that could be electrified now and in the near future.[7] In some cases, electric equipment is already available, like electric heat pumps for space heating, electric forklifts, and robotic dairy feeders. Electric vehicles like pickup trucks, utility vehicles, and small tractors are new to the market with long waiting lists of potential customers despite higher upfront costs than gas- or diesel-powered versions. Electric and hybrid versions of heavier farm vehicles are still in the research phase and not yet commercially available, while researchers are also exploring options for post-harvest crop processing using electricity. The pace of technological innovation and development in the sector has accelerated in recent years, with researchers developing precision agricultural techniques and autonomous equipment incorporating sensors, wireless communications, and in some cases battery-powered devices such as robots and drones.

This Energy 101 will explore the possible benefits and challenges of electrification for farmers and ranchers, as well as the factors that are likely to affect whether and when agricultural operators will adopt electric equipment. Next, this piece will describe the status of technological and commercial development for different types of electric farm equipment and consider lessons from an innovative Oregon electric tractor demonstration project. Finally, this Energy 101 will consider existing incentives that could promote agricultural electrification and issues that on-farm electrification will raise for rural electric systems.

Electrification of farm and ranch operations, like the electrification of other aspects of our economy such as transportation, and cooking and heating for homes and commercial businesses, is complex and raises several issues relating to sustainability and social impacts. The mining of materials and manufacturing of equipment, as well as the practical and economic challenges of recycling at the end-of-life for batteries, will be important topics for research and innovation. (See the Policy Briefs section of this report for more information)

Current Uses of Fossil Fuels on Oregon Farms and Ranches

Oregon farmers and ranchers increasingly have electric options for many types of equipment and vehicles to support the many different tasks they perform in their agricultural operations. Oregon's diverse mix of landscapes and climates supports a similarly diverse mix of agricultural products. Not surprisingly, Oregon farmers and ranchers use a wide array of production methods and equipment, while relying upon a variety of energy resources including electricity, diesel, gasoline, natural gas, LP gas/propane, biomass, and biofuels.[3] Table 1 lists types of agricultural equipment that currently use fossil fuels and could be candidates for electrification.

Table 1: Current Agricultural Fossil Fuel Uses That Are Candidates for Electrification[8] [9] [10]

Equipment	Agricultural Uses	Fuels Used	Commercialization And Adoption Status of Electric Options
Water pumps	Irrigation, wells, stock watering	Diesel, electricity, solar	Available; irrigation pumps largely already electrified; solar increasingly used for stock watering pumps and small-scale irrigation
Water heating	Process heat, sanitation	Natural gas, propane, electricity	Available; early/low adoption
Small mobile specialty equipment: forklifts, dairy barn equipment, pruning and harvesting platforms	Moving feed, hay, and other materials in farmyards and enclosed or semi-enclosed buildings; dairy feed mixers, alley scrapers for dairy barns	Diesel, propane, electricity	Available; early but growing adoption of electric forklifts and dairy barn equipment
Hand tools and small-scale motorized tools: pruning saws, loppers, trimmers, chainsaws	Pruning orchards, vineyards; trimming weeds; removing downed trees	Diesel, propane, electricity	Available; growing adoption
Space heating (heat pumps, heat exchangers, radiant heating)	Heating greenhouses, workshops, offices, livestock barns	Natural gas, propane, electricity	Heat pumps available, early/low adoption; Heat exchangers under development, limited availability and adoption; Radiant heaters available for small-scale applications, both plug-in and hardwired common in some service territories

Equipment	Agricultural Uses	Fuels Used	Commercialization And Adoption Status of Electric Options
Construction equipment: skid steers, excavators, backhoes	Earth moving, trenching, and digging	Diesel	New to market: limited availability
Small tractors (under 100 horsepower)	Mowing, rototilling, moving fruit bins, tending orchards and vineyards; indoor agricultural operations such as greenhouses and livestock barns	Diesel	New to market: limited availability
Pickup and medium-duty trucks	On-road and off-road transportation; hauling hay, fertilizer, other materials	Gasoline, diesel	New to market: limited availability, wait lists for purchase
Utility vehicles, all-terrain vehicles	Off-road transportation, moving tools and small goods	Gasoline, diesel	New to market: limited availability, wait lists for purchase
Mobile power sources (generators)	Wind machines for crop protection, mobile chilling units, mobile irrigation pump stations	Diesel, gasoline, propane, electricity	New to market: limited availability; field equipment such as wind machines are already plugged into electric service where available
On-farm processing equipment	Drying (thermal/forced air, radio wave), distilling; specialized equipment tailored for individual crops	Natural gas, propane, diesel, biomass	Research phase; early commercial models available for drying grains, alfalfa; low adoption
Medium and large tractors, combines, harvesters: fully electric, hybrid diesel-electric	Field operations including tilling, planting, spraying, harvesting	Diesel	Research phase: not commercially available

Potential Benefits and Challenges for Agricultural Electrification at the Farm/Ranch Level

One of the primary benefits of electrification for farmers and ranchers is reduced energy use. Taking tractors as an example, agricultural tractors in the U.S. consumed 4.3 billion gallons of diesel fuel in 2020, producing 44 million metric tons of CO2 emissions. Only 20 percent of the diesel consumed by tractors is translated into useful work, with most of the energy content wasted either by idling or in the form of heat. On average, electric tractors use 50 percent less energy to do the same amount of work due to the increased efficiency of electric motors.[1]

In addition to more efficient use of energy, **potential co-benefits** at the farm or ranch level include:

- Reducing fuel costs and lowering total costs of equipment ownership over time.[2 11 12]
- Avoiding exposure to fossil fuel price volatility.[13 14]
- Reducing costs and labor time to maintain vehicles (for example, eliminate the need to change oil and coolant or clean the engine compartment for electric tractors and other vehicles).[15 8]
- Reducing or eliminating on-site exhaust fumes and overall greenhouse gas emissions from equipment operations.[2 12]
- Reducing need for engine lubricants and coolants that can pollute water and crops, and reducing or eliminating need to transport and store fossil fuels on-site.[8 16]
- Improving operator safety from reduced exposure to: moving parts within the engine compartment, exhaust, vibration, and noise that can cause hearing loss.[16 2 8]
- Increasing functionality of electrical equipment: precision, remote control and communications capability, interoperability with other precision agriculture technologies, possibilities for autonomous operation, such as self-driving tractors, field and dairy barn robots, and drones.[16 17 14]
- Increasing ability to meet energy needs using on-farm electricity generation from solar, wind, hydropower, and/or biodigesters with battery backup.[16 14]
- Specific to electric tractors: no idling required to operate auxiliaries and implements; maximum torque available starting at zero RPM; regenerative braking adds to battery run-time; for smaller tractors the additional weight of batteries aids with traction and eliminates or reduces the need to attach metal or concrete weights for this purpose.[18 12 8]

Converting from equipment powered by fossil fuels to electric equipment will present **potential challenges** at the farm/ranch level, including:

- Higher upfront cost for electric equipment compared to fossil fuel powered equipment, varying by type of equipment.[2 11 14]
- Limited initial availability of electric versions of some equipment, especially for specialty crops and large field equipment.[10 2]
- Performance concerns for early adopters due to uncertainty about battery life, downtime for charging, and durability and operational capabilities under farm conditions like extreme temperatures, dust, and mud.[9 8 14 19]

- Maintenance and troubleshooting learning curve for owners; concerns about availability of spare parts and trained repair and maintenance professionals in the early phases of adoption.[2]
- Limited knowledge about and trust in the startup companies that manufacture many early models of electric equipment, compared to farmers' long experience with established brands and associated distributors.[2, 19]
- Upfront costs to upgrade on-farm electrical service and/or install a charging station for some types of equipment.[16]
- Lack of electrical service or inconvenient location of existing electrical service to charge electrical equipment in remote fields and pastures.[8] (See *Issues for Further Study* below for additional information about utility service in rural areas and issues raised by agricultural electrification).
- Uncertainty about ability to install on-farm generation, mainly solar, due to lack of a suitable on-site location, lack of experience with permitting requirements, or limitations under land use laws.[8]
- Limitations on stockpiling electric power in the event of grid disruptions, compared to the ability to store diesel and propane on-farm.[9]

Oregon Agrivoltaics Continue to Show Promise

Oregon State University researchers and students have been studying Oregon farming approaches that can blend solar energy (photovoltaics) and agriculture into *agrivoltaics* for mutual benefit. According to OSU's research, agrivoltaics are showing promise, with potential co-benefits for farmers and the environment — including more food, better food, less water use, and more energy.

Plants need light to grow — but it turns out, they don't always need that light from the direct sun, and in certain cases can actually thrive in low-light conditions. OSU's research shows that some plants are less stressed when they have partial shade and produce higher quality crops with less water. And it's not just about crops – an OSU study published in April 2021 showed that partial shading by solar panels allows flowers to delay blooming, giving pollinators more options later in the season.

A 2020 study by the university team showed that co-developing just 1 percent of American farmland with solar energy and agriculture could have a significant economic effect, providing about 20 percent of the total electricity generation in the country with an investment of less than 1 percent of the U.S. budget. The cost would be paid for in energy savings within 14 years. Agrivoltaics could also reduce greenhouse gas emissions by 330,000 tons and create more than 100,000 jobs in rural communities.

Learn more about OSU's agrivoltaics research and five-acre sustainable farming system model: https://agsci.oregonstate.edu/newsroom/sustainable-farm-agrivoltaic

Factors Influencing Rate of Adoption for Electric Agricultural Equipment

Researchers and industry experts expect that many factors will influence the rate at which farmers and ranchers adopt electric equipment, and that the transition from fossil fuels to electric farm equipment will take place over a generation. Electrification of equipment will happen more quickly when it clearly simplifies farmers' work and saves time and money;[1] in these cases electrical equipment will become the industry standard as has already occurred with irrigation pumps in Oregon. The level of investment required to purchase different types of equipment, as well as the risks associated with a transition to unfamiliar equipment with new fueling and maintenance requirements, will also affect decisions about electrification on the farm. Electrification in agriculture is likely to follow similar patterns as electrification in other sectors, although adoption on the farm may be slower than adoption in the transportation and construction sectors. This section will consider the factors that affect whether and when electrification is an attractive option for various agricultural uses, while the next section will discuss the state of technological and commercial readiness for various types of electrical farm equipment.

Electrification of equipment will happen more quickly when it clearly simplifies farmers' work and saves time and money.

Table 2. Characteristics Affecting Rate of Adoption for Different Types of Electric Farm Equipment

Strong Candidates for Early Electrification	Equipment Likely to Be Electrified Later
• Used indoors or near farm buildings with electrical service • Small size • Charges on 110V or 220V outlet • Low differential in upfront cost compared to internal combustion version • Large fuel savings/short payback time • Used daily for routine tasks • Saves time and/or labor • For electric tractors: equipment needed for three to four hours per day; farm operations with light-duty tasks	• Used in remote fields/pastures • Large and mobile, requiring heavy batteries • Requires special charging infrastructure and/or electrical system upgrades • Large differential in upfront cost compared to internal combustion version • Long payback time based on fuel cost savings • Used in time-sensitive farm operations such as planting and harvesting

Characteristics Affecting the Timing of Electrification for Different Types of Equipment

The strongest candidates for early electrification will be relatively small equipment that farmers and ranchers use daily "in the farmyard" or close to the geographical center of the operation, where electric service for charging is already available and the equipment has short payback times due to fuel cost savings.[16 1 8 9] Oregon examples of equipment used in the shop or barn that are likely to be adopted early include electric forklifts and dairy barn equipment (which save time, labor, and fuel) and heat pumps for space and water heating.

The strongest candidates for early electrification will be relatively small equipment that farmers and ranchers use daily.

The next tier of electric equipment for early adoption includes equipment that farmers use in the field or pasture that returns to the barn or shop every night, especially equipment that can be charged using existing 220V plugs. Examples in Oregon include utility vehicles, small tractors, and pickup trucks. As discussed below under the sections on the E-Tractor Demonstration Program and current incentives for electrification, several Oregon organizations are finding creative ways to make these electric vehicles available for trials in the field as they start to come on the market.

In agricultural settings, it is common to use a diesel generator or idle a diesel truck or tractor out in the field to provide power for a variety of purposes, such as unloading grain or running cooling units to extend the shelf life for just-picked fruit. Electrification of those field tasks could occur in parallel with adoption of electric farm vehicles. Electric tractors and pickup trucks can be used as a mobile power source for welders, drills, chainsaws, and other hand tools out in the field or pasture, while larger tools and implements can be powered by electrically charged mobile power stations. Mobile power stations could also run wind machines to provide frost protection in orchards where electrical service is not available,[20 21] charge small tractors or utility vehicles to keep them running all day out in the field during critical times,[22] or provide backup power for farm operations during outages.[9]

Electric and hybrid versions of high-horsepower tractors, combines, and harvesters are likely to be adopted later than other electrical farm equipment.[8 2] This category of equipment includes some of the most expensive equipment used by farmers and ranchers, meaning that replacing internal combustion versions with electric versions will involve significant investments. Large field equipment is used for many time-sensitive operations like planting and harvesting, leaving little down time for recharging, and with large financial risks for delays due to machine breakdowns or missing components.

Another limiting factor for electrification for large farm equipment is the need to develop suitable charging infrastructure near where the machinery is used, since this equipment is generally not returned to the shop or barn each night. Large agricultural operations that farm scattered parcels are most likely to own such equipment. The owners frequently store large field machinery away from the shop or barn rather than bringing it in from the fields every night, as these vehicles travel at low speeds and use agricultural tires that break down rapidly when driven on hard road surfaces. Farmers may have concerns that remotely stored electric equipment like large tractors and harvesters would be vulnerable to weather and theft, particularly to being stripped of wiring and electronic components depending upon market value.[8]

Electric space heating for large agricultural buildings and electric-powered crop drying are also likely to be adopted later than other on-farm uses, if at all, due to cost considerations. Greenhouses in Oregon are mainly heated with propane or natural gas where it is available; the efficiency of natural gas heating for greenhouses has improved over recent decades, and natural gas is likely to remain the most cost-effective method for greenhouse heating for the foreseeable future.[23 9]

Crop drying and other processing commonly occurs on-farm after harvest. As discussed below in the section on technological development and commercial availability, researchers are investigating methods to substitute electricity for fossil fuels in commodity-scale crop drying, but electric drying methods are not currently cost-competitive. Oregon farms produce several niche crops requiring a variety of specialized processing equipment, such as hops, mint, and meadowfoam. An east coast example suggests that at least some agricultural processing in Oregon could be electrified where suitable and cost-competitive technologies are available: the Vermont Electric Co-op has run a successful incentive program to encourage its members to electrify their maple syrup evaporators, with electric evaporators using 22 times less energy than oil-fired evaporators.[1]

Oregon hops growers use specialized processing equipment.

Sector-Wide Factors Affecting Timing and Rate of Agricultural Electrification

Given the capital-intensive nature and seasonal timeframe of agriculture, producers are typically able to make only a limited number of capital improvements each year between the harvest and next season's planting. Electrification of equipment is one among many potential capital improvements that farmers could make in the off-season and will compete with other potential cost-saving investments.[16] Farmers tend to make large capital investments after a profitable harvest for tax reasons, which means that a few strong economic years for the sector could bring a large wave of investment in electrification if suitable equipment, installers, and supporting infrastructure are available at the right time.[2] However, as noted below, Oregon farmers report net cash incomes below national averages, which could be a barrier to electrification.[24]

Experts studying agricultural and environmental sustainability expect that food manufacturers will increasingly seek to bolster their sustainability credentials and will in turn put pressure on commodity growers to implement practices that reduce greenhouse gas emissions and other negative environmental impacts. This pressure from commodity buyers, along with public and utility incentives to reduce fossil fuel use and farmers' own interests in sustainability, will also figure into farmers' and ranchers' investment decisions about whether to adopt electric equipment and/or undertake other improvements offering verifiable and quantifiable environmental benefits.[16]

Overlap with Other Economic Sectors

Electrification of agriculture is likely to follow similar patterns as the electrification of on-road vehicles and off-road construction vehicles, with earliest adoption occurring for: smaller vehicles; vehicles that operate within a limited range of electrical service for charging; and applications with high potential to reduce pollution, vibration, and noise. For example, terminal tractors or "yard trucks" are easier for freight companies to electrify than tractor-trailers that operate primarily on highways.[25] [18] For large highway vehicles, diesel-electric hybrid solutions, including conversion kits for existing tractor-trailers, are likely to be market ready before fully electric trucks;[26 27] this dynamic could apply to large field tractors as well.[28 29] The adoption of electric landscaping equipment is following a similar pattern as industry experts' expectations for agriculture: homeowners and commercial landscapers have been relatively quick to adopt smaller and handheld tools and equipment, which now dominate retail shop floors, while larger equipment like electric riding mowers with sufficient battery life for commercial landscapers currently have high upfront costs that are not made up by fuel savings.[9 30]

Agricultural electrification proponents expect that many general challenges for electrification will be ironed out as markets for electric equipment expand and mature in other sectors. Agriculture will benefit from advances in battery technologies and equipment design in the transportation and construction sectors, as battery prices decline and farmers and ranchers become more accustomed to using electric tools and vehicles.[16 9] On the other hand, as more farm operations adopt electric equipment, prices for used diesel- or gasoline-powered farm equipment could fall, prolonging the life of older fossil-fueled equipment. This dynamic has been seen in the diesel heavy-duty truck market when some states adopt stricter emissions regulations than neighboring states.[31] In response, recent diesel emissions reduction programs require that older engines be disabled in order for recipients to receive an incentive for newly-purchased diesel equipment.[32 33]

Electrification of other economic sectors is often a higher priority for policy makers than electrification of agriculture, given the greater volume of fuel used and the noise and pollution associated with diesel-powered equipment used on and near ports, highways, and construction sites in urban environments.[32] For a sense of scale, Oregonians consumed 76.12 trillion Btu of diesel fuel for transportation in 2018 while Oregon agriculture consumed approximately 1.34 trillion Btu of diesel, making agricultural diesel consumption about 1.75 percent of consumption by the transportation sector.[34] Considering these various factors, electrification of agricultural vehicles could take off slowly in the near term, but the sector could ultimately electrify quickly after electric options mature and reach greater market share for automobiles and diesel equipment in other sectors.[16]

Technological development and commercial availability

Commercially Available Electric Equipment

Electric equipment options to meet on-farm needs are in several phases of development, commercialization, and adoption. In some cases, electric technology has been commercially available for some time. For example, farmers and ranchers in Oregon have largely switched from diesel **irrigation pumps** to electric versions, with USDA surveys indicating that 96 percent of agricultural irrigation pumps in Oregon are powered by electricity.[5] Many of the remaining irrigation pumps are located in areas where extending utility infrastructure is expensive, and where irrigation upgrades are economically feasible only as part of larger water projects receiving conservation funding.[9] Farmers and ranchers continue

About 96 percent of agricultural irrigation pumps in Oregon are electric. Photo: Wy'East RC&D

to make additional irrigation improvements using utility incentives to install variable frequency drives and water- and energy-saving irrigation hardware upgrades.[35] Many irrigation districts in Oregon are implementing and/or planning irrigation modernization projects, replacing open canal/ditch systems with piped, pressurized water delivery to farms. Irrigation modernization projects have allowed farmers receiving pressurized water to reduce the size of their pumps or forego pumps altogether, saving energy and associated expenses for pumping, while allowing irrigation districts and some farms to generate hydroelectricity.[36]

Electric heat pump technology has improved in recent years, and their improved cold weather performance now makes heat pumps a better fit for space and water heating in colder environments like central and eastern Oregon in wintertime.[37 38] While not yet common on farms and ranches, heat pumps could provide cost-effective and efficient heating and cooling for rural residences, farm workshops, and horse barns, especially if combined with weatherization improvements.[9] Other electric heating technologies, such as radiant heating and heat exchangers, show promise for large scale poultry and hog operations, which are most common in the midwestern and southeastern U.S.[1]

Agricultural and industrial users are adopting electric **forklifts**[18] for multiple work tasks, while many Oregon dairy operations are adopting specialized electric **dairy barn equipment**, including equipment like alley scrapers, hay pushers, and robotic feeders to replace small diesel tractors and skid steers.[39 40 41 42] Forklifts and dairy barn equipment mostly operate in enclosed and semi-enclosed environments, making electric equipment beneficial for indoor air quality.[43 44 45]

Agricultural and industrial users are embracing electric forklifts.
Photo: Toyota (CC BY-NC-ND 2.0)

Electric Equipment New to Market

Electric versions of several types of vehicles commonly used on farms and ranches are coming online and sparking interest, with utility terrain vehicles, tractors, and pickup trucks the most high-profile examples. Early offerings in the **electric tractor** market are in the under-40 horsepower and 40-100 horsepower categories — a size suitable for small acreages, orchards and vineyards, and light tasks such as mowing on larger operations.[2] (See "Oregon E-Tractor Demonstration Program" section below for more information about the market status for electric tractors).

At the time of publication, wait lists for **electric pickup trucks** are long and these vehicles are just starting to make their way into consumers' hands.[46 47 48 49] Meanwhile, both established companies and startups are announcing progress on **electric utility terrain vehicles**, with initial sales of a Polaris utility terrain vehicle (UTV) announced for 2022, and UTV prototypes by other startup companies in the works.[50 51] As industry observers note, the early models for electric UTVs are following a similar pattern as for electric cars, with higher-priced premium versions coming to market first, while lowerpriced, mid-market, and entry-level versions — which may be most attractive to many farm operations — are to be released later.[51]

Established companies are developing electric versions of construction equipment that create zero exhaust and low amounts of noise and vibration, largely to meet concerns in urban environments.[52] [53] [54] Construction equipment such as **backhoes, excavators, and skid steers** are commonly used on farms and ranches as well, and agricultural producers may find electric versions increasingly attractive as costs come down and farmers and ranchers gain experience and comfort with incorporating electric equipment into their operations.[9] **Mobile power stations** that carry large portable battery packs charged using grid electricity are new to the market, and mainly marketed for their emergency response capabilities, such as running heavy equipment for debris cleanup.[22]

Electric Agricultural Equipment in Research and Development

Established farm equipment companies are researching non-fossil fuel powered and hybrid diesel-electric alternatives for **large, high-horsepower field machinery**, and have presented concept vehicles and prototypes at farm shows over the past two decades.[55] [56] [57] [58] As noted above, some researchers expect that hybrid diesel-electric tractor-trailers for highway use will be adopted more quickly than fully-electric versions, a dynamic that could also carry through for large diesel-powered field equipment in the agricultural sector.[26] However, companies developing diesel-electric hybrid tractors have not yet started producing these vehicles for the commercial market.[58] Electric powered options for this class of tractors also remain largely in the research stage of development with very few units sold,[59] and many experts anticipate that additional advances in battery technologies will be needed for large electric tractors to succeed commercially.[60] Manufacturers of heavy duty trucks, tractors and construction equipment are also researching and testing hydrogen-powered versions.[61] [62] [63]

Diesel-electric hybrid tractor technologies promise to reduce fuel consumption while preserving the power and efficiency benefits of diesel. One approach is to boost a tractor's diesel engine with an electric motor when additional power is needed to negotiate hills or rough ground, allowing the diesel engine to run more efficiently at a constant speed and avoiding wear and tear on the engine.[8] Other approaches include using a diesel-powered generator to power electric motors that drive the front axle,[64] or pairing a diesel engine for propulsion of the tractor with electric motors to run implements and/or auxiliaries such as fans and conditioning of the occupant cab. Decoupling the diesel engine from implements and auxiliaries allows each component to run at the most efficient speed for the task at hand and means that a diesel-electric hybrid could use a smaller diesel motor. This approach could allow implements such as unloading augurs to run for some time on battery capacity without requiring the diesel engine to idle, while also taking advantage of electric motors' ability to operate at precisely controlled speeds ranging from zero to 100 percent capacity.[16] [65] [66]

Researchers are also exploring alternatives to reduce or replace fossil fuel use for **grain drying**. Farmers in Manitoba, for example, are interested in switching from fossil fuels to electricity to dry corn after harvest. Switching to electricity for grain drying as much as possible will help farmers minimize the impact of carbon pricing because, like many parts of rural Oregon, electricity in Manitoba is almost entirely generated from renewable sources, mainly hydroelectric.[67] Current crop-drying approaches combine electric fans and conveyors with propane or natural gas as a thermal source. Studies in Canada and Europe indicate that heat pumps could provide thermal energy for drying, as well as cooling the grain at the back end of the process; however, heat pump grain drying equipment is more expensive than current crop-drying equipment and may require farmers to make electrical service upgrades.[68] Similar analysis would be needed to assess how feasible and cost-effective electric crop drying would be in Oregon, taking into account Oregon-specific fuel and electricity prices, utility tariff structures, crops, and drying methods.[69] (See *Issues for Further Study* below for more discussion about possible needs to upgrade electrical service to incorporate electric equipment.)

Another potential electric-powered approach would use radio waves to evaporate the water from grain kernels.[68] [70] This technology could also be used to dry nuts, fruits, alfalfa, biomass like wood chips, and manure, according to a midwestern company offering commercial radio wave drying equipment.[71] [72] [69] Radio frequency crop drying may prove to be a more cost effective option in the long run, but is still in very early commercial development and only likely to be available in the near-term for a subset of Oregon's commodity crops.

Electricity-fueled technologies are 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.[16] Researchers are developing and testing autonomous farm equipment, including **small autonomous and remote-controlled devices**, 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.[73] [8] [74] [75] [76] [14] [77] Their usefulness will increase as battery longevity improves and battery weight decreases. Electric tractor manufacturers, including the company that makes Monarch tractors, are testing **self-driving tractors**.[17] Finally, researchers and early adopters are testing **electrostatic weeding machines** in Europe and locally in Oregon[78] [79]

Oregon E-Tractor Demonstration Program

Oregon is home to a pioneering "tractor share" program, giving farmers and ranchers around the state an opportunity to try out an electric tractor on their property. The program is a joint effort by four local organizations: Sustainable Northwest, Forth, Bonneville Environmental Foundation, and Wy'East Resource Conservation and Development Area Council, and has received funding from USDA as well as other private donors. To date, the program has five tractors on hand with plans to acquire an additional five or six electric tractors, as well as electric pickup trucks and UTVs and possibly a small excavator or skid steer. The initial tractors purchased under the program are equivalent to diesel tractors in the 30-40 HP range, suitable for mowing and other light duty

An electric Soletrac tractor in use in Oregon. Photo: Wy'East RC&D

tasks; the program also has 70 HP units on order. [80 81 19]

Before sending them out into the field, project partners are outfitting the electric tractors with sensors to record operational data and allow researchers to compare field performance and fuel costs with that of diesel-powered tractors. An Oregon State University study using data collected by sensors during the program's first season compared the estimated total cost of ownership of a 30 HP Solectrac tractor with the cost to own and operate a 32 HP John Deere diesel tractor. Researchers commonly calculate the "total cost of ownership" when comparing electric vehicles with internal combustion engine vehicles to account for differences between the initial purchase price and other costs over the life of the vehicle, including financing, fuel, and maintenance costs. Like EVs, electric tractors are currently more expensive to purchase but have lower expected fuel and maintenance costs over the life of the vehicle.

The electric tractor model in the OSU study costs approximately $3,000 more to purchase than an equivalent, similarly equipped diesel model ($28,398 for the electric model versus $25,345 for the diesel model). Taking into account fuel and maintenance costs over an assumed tractor life of seven years, the OSU study found the electric and diesel tractors close to parity on total cost of ownership when assuming that each machine is operated for 250 hours annually. According to the study authors, a more realistic assumption is that a farm would use a tractor in this size category for about 750 hours per year. Assuming 750 hours annual use, the electric version would save between $4,400 and $18,000 in total cost of ownership, with greater savings associated with heavier, more energy-intensive use under the study's "workhorse scenario." Solectrac estimates that its 25 horsepower electric tractor costs $0.78 per hour to run, while an equivalent diesel version would cost around $5.00 per hour to run, depending on fuel prices.[12] The OSU analysis used a diesel price of $3.20 per gallon, meaning that fuel savings would be higher when diesel prices are higher than assumed in the study; the study author notes that the lifetime savings associated with an increase in diesel prices are compounded as annual operating hours of an electric tractor increase. Additionally, the OSU analysis used conservative assumptions that likely overestimated maintenance costs for electric tractors, while also assuming four percent financing for the electric tractor compared to zero percent financing for the diesel model. [11]

Project partners also commissioned a report by the Cadeo Group studying barriers to adoption of electric tractors in the Pacific Northwest. Significant challenges to initial adoption include higher up-front costs and the current sales and financing structure — electric tractor manufacturers are still building their distribution networks to sell their wares directly to farmers, while most diesel tractors and associated implements are sold by local distributors who have longstanding relationships with producers and can offer zero percent financing.[2 82]

Wy'East RC&D

Despite these challenges, Oregon is one of the states that researchers have identified as most promising for electric tractor adoption.[1] The Cadeo Group study authors suggest several factors that could make electric tractors a good fit for agricultural operations in the region: the preponderance of small acreages and specialty crops, including orchards and vineyards; higher-than-average diesel prices versus lower-than-average electricity prices; and higher-than-average age of existing tractor stock.[2] Oregon farms are smaller than farms in the rest of the region on average — two-thirds of Oregon farms are under 50 acres in size, with less than 10 percent over 500 acres. There are nearly 5,000 farms in Oregon growing fruit, tree nuts, and berries — some of the operations that researchers expect will find small electric tractors most attractive.[83] Many of the specialty crops in Oregon are also grown in Europe, where companies are leaning heavily into electric and hybrid diesel-electric tractor development; for example, the Landini brand from Italy, which is popular in specialty orchard applications in Oregon, has announced a new diesel-electric hybrid model.[64] The study authors note that electric tractor companies are targeting the growers of high value crops and hobby farmers as being the most likely early adopters of the technology.[2] However, as noted above, Oregon farm incomes are lower than the national average, with many small farms making no or low profits, which may outweigh the otherwise attractive fit between electric tractor's characteristics and Oregon's topography and mix of crops.[24]

Current Incentives for Agricultural Electrification

Electrification of internal combustion equipment used in agriculture is one of many actions that policy makers could promote to reduce fuel use, pollution, and greenhouse gas emissions in the sector. Incentives may be effective to promote purchases for various types of electric agricultural equipment as that equipment becomes more widely available over the next few years and as farmers need to replace existing equipment. For example, the OSU study of early Oregon E-Tractor Demonstration Program results, described above, finds that relatively small incentives could help overcome the higher upfront purchase and financing costs for small electric tractors compared to diesel alternatives, and provide a boost to purchases.[11]

While there are no federal or state programs available in Oregon that are explicitly designed to electrify the agricultural sector, investments in several types of electrical equipment used on farms are eligible to receive funding assistance under existing programs. USDA assistance includes grants and low-interest rate loans that can be applied toward purchases of stationary electric equipment in some cases, while owners of mobile electric equipment can generate credits for electric charging under the Oregon Clean Fuels Program. Pickup truck purchases may be eligible for state rebates and/or federal electric vehicle tax credits, although tax credits will be of limited use for operations with little profits.[84] [85] On the other hand, mobile power sources are not eligible for energy storage incentives[9] and agricultural vehicles and equipment are not eligible for state diesel emission reduction incentives. Such programs offer incentives to replace or repower diesel engines in school buses, construction

The Oregon Rural and Agricultural Energy Audit program, funded by USDA and administered by ODOE, can help agricultural producers identify investments that are REAP-eligible and provide documentation of potential energy savings needed for a successful REAP application.

equipment, delivery trucks and tractor-trailers, and equipment operating in and near ports, like barges.[33]

Several USDA programs offer assistance that could support electrification of agricultural equipment. The USDA Rural Energy for America Program offers competitive grants and loan guarantees to agricultural producers for renewable energy and energy efficiency projects. Electric farm vehicle purchases are not eligible for REAP funds, but other stationary electrical equipment that achieves energy efficiency gains compared to internal combustion equipment could qualify.[86] The Oregon Rural and Agricultural Energy Audit program, funded by USDA and administered by ODOE, can help agricultural producers identify investments that are REAP-eligible and provide documentation of potential energy savings needed for a successful REAP application.[87] Under the Rural Energy Savings Program (RESP), rural electric cooperatives are eligible to apply for zero percent loans from the USDA that cooperatives can in turn loan to their customers at below market rates for energy efficiency projects, which could include electrical equipment that achieves energy savings.[88] Few Oregon utilities have participated in the RESP program to date, however, due to the administrative burden or perceived lack of need.[69] The USDA Natural Resource Conservation Service also offers financial assistance for projects that conserve resources, including energy; two electric tractor projects in Oregon have received USDA NRCS Conservation Innovation Grant awards: the E-Tractor Demonstration project and an autonomous electric tractor demonstration project on an Oregon blueberry farm.[89]

Owners of charging stations in Oregon can generate Clean Fuels Program credits for the electricity used to charge farm vehicles, including tractors, utility vehicles, pickup trucks, forklifts, excavators, backhoes, and skid steers. Medium- and heavy-duty diesel-electric hybrid tractors would qualify, similarly to plug-in hybrid electric vehicles, as would agricultural vehicles like small tractors and utility vehicles that are charged on a 220V outlet. Vehicle owners will need to be able to document the charging activities by using a directly metered outlet or by providing charging information generated by the vehicle itself.[90] [91]

Utilities that aggregate Clean Fuels Program credits could use proceeds from credit sales to fund electric tractor adoption. For example, Pacific Power has distributed grants using Oregon Clean Fuels Program funds to the Crook County Fairgrounds for an electric tractor demonstration and to the Oregon Environmental Council for a rural EV pilot project. The OEC project put electric utility terrain vehicles into the hands of field staff and installed electric chargers at three Oregon irrigation districts where they are proving to be nimble and useful for maintenance and other tasks.[92] [93]

An electric utility terrain vehicle in use in Oregon. Photo: Oregon Environmental Council

A few other states are offering incentives for electric agricultural equipment. For example, California is dedicating part of the revenues from its cap-and-trade program to the Funding Agricultural Replacement Measures for Emission Reductions or FARMER Program, offering funding through local air districts to replace high emission agricultural equipment with low- or no-emitting versions, including electric equipment. Local air districts can choose to fund replacements for agricultural trucks, irrigation pump engines, tractors, harvesters, and/or agricultural UTVs.[94] The Colorado Clean Diesel Program offers grants to assist with purchases of electric or hybrid electric equipment to replace certain diesel equipment, including agricultural tractors as well as terminal tractors, construction equipment, transportation refrigeration units, airport ground support equipment, and snow groomers. The Colorado program requires that the diesel equipment be rendered inoperable and gives priority to the northern Colorado non-attainment zone.[95] [96]

Issues for Further Study: Rural Electric Service and Utility Planning

One study estimates that agricultural electrification will increase electric cooperative sales by 12 to 15 percent at the national level.

The degree to which agricultural electrification will affect electrical loads and infrastructure needs for rural Oregon utilities is uncertain and will differ by utility given the diversity among Oregon's rural electricity providers and their service territories. A 2018 study sponsored by the National Rural Electric Cooperative Association estimated that electrification of agricultural equipment currently powered by fossil fuels would increase electric sales in the U.S. by 55,000 to 67,000 GWh annually, with half of the increase due to adoption of electric tractors. The study estimated that agricultural electrification would increase electric cooperative sales by 12 to 15 percent at the national level.[1]

For investor-owned and large consumer-owned utilities with substantial industrial and commercial loads, agricultural electrification will likely have minimal effect on their overall customer demand. Smaller utilities with loads dominated by agricultural users could experience more substantial increases in demand as a percentage of their current loads, as well as significant changes in timing of loads, which in the long term may require acquisition of additional generation resources and/or investments in infrastructure. Further study is needed to quantify the potential for load growth due to agricultural electrification and the impacts for rural utilities, including the timing of potential new agricultural loads in relation to the seasonal peaks in generation by existing and expected resources like hydroelectric, solar, and wind.

Planning for increased loads due to electrification of vehicles, appliances, and other equipment is part of the regular planning that Oregon electric utilities undertake to reliably serve their residential, commercial, industrial, and agricultural customers. Utilities consider likely demand growth, including beneficial electrification, when sizing transformers and substations as they build out and update their distribution systems. In early stages of adoption, existing generation resources and distribution infrastructure will likely be capable of meeting any increased demand due to agricultural electrification with some limited and localized need for infrastructure investments. Future infrastructure investment needs will depend on how much new load is added, the extent to which new loads are staggered or overlap with the timing of existing agricultural loads, and the age, condition, and capacity of a utility's existing distribution infrastructure.[69] Some rural utilities will need to increase their load management capacity to handle the increasingly complicated daily and seasonal patterns of demand for electricity as their customers adopt new electrical equipment that is used at times and in volumes that differ from current demand patterns. On the other hand, increased electrical use on farms and ranches could help some rural utilities to even out their loads on a daily and/or seasonal basis.[69]

At the farm level, most agricultural operators will be able to accommodate the equipment most likely to be adopted first using existing service and outlets. Most farm and ranch properties have at least one 220V outlet to power a welder or other tools; these outlets can also charge small electric tractors, electric pickup trucks, and electric UTVs.[9] Central Electric Cooperative, for example, indicates that the utility's existing distribution systems can absorb the addition of 220V outlets into many existing customer accounts to charge these smaller vehicles without any need for a utility equipment upgrade.[69] Additionally, electric service is already available in dispersed locations in fields and pastures to power electric irrigation pumps; farmers and ranchers may be able to add charging infrastructure at these dispersed sites for electric farm vehicles used in the field.[69]

Some electric agricultural equipment, including large processing equipment currently and in the future fast chargers for electric farm vehicles, may require three-phase power service while many farms and ranches currently receive single-phase power service (See call-out box for an explanation of three-phase versus single-phase power and the significance for agricultural producers).[68 16] Depending on how far the farm or ranch is from the nearest three-phase power connection point and the type of equipment that the farm or ranch wishes to install, an onsite phase converter may be a cost-effective and workable option rather than extending three-phase power to the shop or barn.[97 98] Given that many farms are now using more powerful equipment than they did when rural areas were first electrified last century, several companies design and sell high-powered equipment like irrigation pumps that is specially designed to operate on single-phase power.[97] However, specialty equipment for on-site processing, which in Oregon could include larger scale wine-making, crop drying, malting, and sawmill equipment, will likely require three-phase power.[99 100]

Farms and ranches may also consider installing renewable energy generation onsite to meet all or part of their electricity needs, as well as implementing energy efficiency measures to offset a portion of any increase in electrical use due to electrification. Some examples of cost-effective energy efficiency measures on Oregon farms include installing LED lighting, insulating agricultural buildings, installing variable frequency drives for the motors powering pumps and other equipment, and implementing water-saving irrigation upgrades.[101] Agricultural producers interested in increasing energy efficiency in their operations are eligible to receive an energy audit with 75 percent of the cost covered by a USDA grant administered by ODOE under the ORAEA program; rural electric utilities and the Energy Trust of Oregon also offer energy assessments and energy efficiency incentives for agricultural operations.[87 101 102]

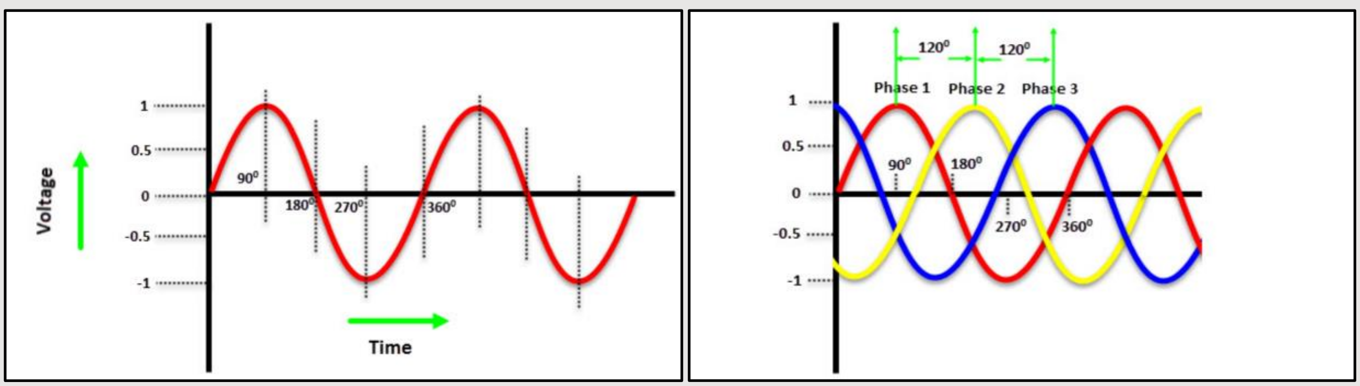
Agricultural producers may be able to shift their electrical use to different times of day to lower their electric bills; irrigators in particular are already experienced with timing their electricity use to balance costs and potential productivity gains, taking advantage of cheaper rates at certain times of day or avoiding demand charges where applicable.[69] Utility representatives stress that they are eager to work with their customers who are considering electrification to provide information about the best times to charge and to make sure that conversions to electric equipment occur smoothly,[69] while researchers also emphasize the need for utilities to gain in-depth understanding of the potential value and the practical considerations of electrification for farmers and ranchers.[1]

Single-Phase Vs. Three-Phase Power

In a single-phase alternating current (AC) power supply, power is distributed using two wires, one that carries the electric current and one that is neutral. AC power takes the form of a wave, meaning that power supplied oscillates and is equal to zero at some point with each oscillation of the wave, between 50-60 times per second. While single-phase power supply is suitable for most residential and small business applications and for small motors up to about five horsepower, single-phase power supplies are less efficient in transfer of power than three-phase. In single-phase circuits some motors may require specialized start up equipment.[103] [104]

Figure 1: Pattern of Alternating Currents for Single-Phase Versus Three-Phase Power Supply[103]

Single-Phase Power Supply *Three-Phase Power*



In a three-phase AC power supply using three wires, the power takes the form of three waves staggered by 120 degrees, which means the peak level of power never drops to zero. Three-phase power supplies can deliver more power and are more efficient at transferring power compared to single-phase power supplies. Larger motors, including those used in many types of agricultural processing equipment and fast chargers for electric vehicles, require three-phase electrical power to ensure consistency of power supply.[103]

Implications for Agricultural Electrification

Some agricultural producers wishing to electrify additional equipment may be able to meet their needs using phase converters tailored to the specific size and type of equipment that requires three-phase power. Such equipment, including static, rotary, and digital phase converters, is commercially available and useful for equipment that operates at a constant frequency.[105] [97] [98] Variable frequency drives or VFDs are also able to convert single-phase power supply to three-phase power, and are a better option for small motor applications where it's beneficial to vary the frequency and motor speed. VFDs change single-phase power into direct current, and then invert the direct current to three-phase power.[98]

Agricultural producers who perform large-scale processing on-farm may need to upgrade the utility infrastructure serving their operations. Extending three-phase power to a shop or barn can be costly depending upon the distance for new wiring, and customers who upgrade to three-phase power or install digital three-phase converters on site may incur demand charges on their electric bills that they did not incur previously. Some Oregon rural utilities charge demand charges for three-phase power service (with no demand charges for single-phase) due to the increased demands that the inductive motors cause for utility infrastructure,[68] while other utilities charge demand charges for all irrigation loads regardless of whether those loads are powered by single-phase or three phase service.[69]

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Energy 101: Oregon State Climate Programs and Actions

In March 2020, Governor Kate Brown issued Executive Order 20-04 directing Oregon state agencies to take a series of significant actions to reduce emissions of greenhouse gases and help prepare for the effects of climate change in Oregon. EO 20-04 further advanced the State's GHG reduction goals by setting targets of at least 45 percent below 1990 levels by 2035, and at least 80 percent by 2050.[1] While some of the directives in EO 20-04 were explicit, many were broadly defined.

To promote understanding of what work is underway and help identify gaps to advance climate policy, the Oregon Department of Energy and the Oregon Global Warming Commission took stock of major ongoing climate change-related programs and projects led by various state entities (agencies, boards, and commissions). The following tables summarize entities' major initiatives related to four main categories:

- **Greenhouse Gas Emissions Reductions and Sequestration**: Programs or policies *directly* resulting in GHG emissions reductions or carbon sequestration (the capturing and storage of carbon dioxide).
- **Assessment of Climate Risks and Vulnerabilities**: Assessment projects and ongoing monitoring of climate change-related risks and associated vulnerabilities emerging in a variety of contexts/sectors in Oregon.
- **Preparing for Climate Change**: Policies and programs facilitating measures to increase resilience to climate change-related risks, as well as policies and programs to transition to a cleaner (low-carbon) economy. This can include *indirect* efforts to reduce GHG emissions and efforts to increase the sustainable use of resources.
- **Educating Oregonians About Climate Change**: Publications, resources, and outreach directed toward educating Oregonians about climate change (including schools and the general public).

Many initiatives are collaborative among several agencies; these initiatives are cross-referenced and are colored in **orange text** below. For mitigation programs/policies, where estimated, the expected GHG emissions reductions resulting from a project/program are noted. Emissions reduction estimates for many programs in this topic will be available in the Oregon Global Warming Commission's forthcoming Roadmap to 2035 report. Such information is helpful to monitor and advance progress toward reaching our state goals.

Business Oregon (Oregon Business Development Department)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Rural Renewable Energy Development Zone Program • Provides businesses tax abatement from local property taxes (for 3-5 years) for generating renewable electricity or producing, distributing, or storing biofuels[2] **Solar Development Incentive Program** • Provides businesses incentives for developing qualified solar projects ($0.005/kWh for up to 150 MW of capacity; sunsets Jan 2023)[3]	*No activities in this category*	**Oregon Renewable Energy Siting Assessment (ORESA) – See ODOE** **Oregon's Climate Change Adaptation Framework – See DLCD** **Climate Equity Blueprint – See OHA**	*No activities in this category*

Department of Administrative Services

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Sustainable Procurement Services Program • Integrates consideration of sustainability and GHG reduction in procurement[4] **Conversion of state fleet to zero-emission vehicles** • 100% of new light-duty vehicles by 2025[5] • Installation of new electric vehicle charging infrastructure **Agency Climate Action Toolkit - Lead** • Provides tool and guidance for agencies to reduce GHGs in their operations **Zero Emission Vehicle Interagency Working Group - See ODOT** **Built Environment Efficiency Working Group - See ODOE**	**Assessment of climate hazards to inform leases, construction, and land purchases** • Inclusion of mid- and long-term climate risk (e.g., from floods and fires) and resilience benefits in decision-making processes[6]	**Building design/retrofit (in progress)** • Incorporates climate change projections and hazard analysis into building design and retrofit plans and statewide policy[7] **Oregon's Climate Change Adaptation Framework – See DLCD** **Climate Equity Blueprint – See OHA**	*No activities in this category*

Department of Consumer and Business Services (Building Codes Division, Division of Financial Regulation, and Oregon Occupational Safety and Health)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Oregon Energy Efficiency Specialty Code • Improves Oregon's energy efficiency requirements for new buildings and renovations to achieve 60 percent decrease in energy use by 2030 (relative to 2006)[8] **Oregon Reach Code** • Optional energy efficiency construction standard for builders, consumers, and contractors beyond the state building code[9] **Built Environment Efficiency Working Group - See ODOE**	**Assessment of insurance & climate risk** • Analysis of climate risks (e.g., damage from wildfires), insurance premiums, and mitigation costs to engage insurance industry and account for climate risks in financial risk assessment[10]	**Fire Hardening Grant Program** • Grant for fire hardening in repair or replacement of structures damaged or destroyed in 2020 wildfires[11] **New heat and smoke exposure rulemaking** • Updated existing OSHA rules to better reflect changing hazard conditions and ensure protection for vulnerable workers[12] **Building Codes:** • New residential: fire hardening for construction in high wildfire risk areas by 4-1-23[13] • New residential: Zero energy ready by 10-1-23 • Commercial: irrigation via water recapture by 10-1-25 **Oregon's Climate Change Adaptation Framework – See DLCD**	**Mandatory training for new heat and smoke exposure rules** • Oregon OSHA implementation of risk-mitigation training requirements for exposed/vulnerable workers[14] • Audience: employers/ employees **Public communication campaign about heat and smoke hazards** • Ongoing education outreach on climate-related work hazards in English and Spanish[15] • Audience: general

Department of Land Conservation and Development (DLCD)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Climate-Friendly and Equitable Communities • Program to meet climate goals though improved transportation options, more walkable neighborhoods and services in urban areas (with pop. of 50k+)[16] • Requires Eugene-Springfield and Salem-Keizer to develop regional strategy to meet GHG targets **Transportation and Growth Management Program** • Coordinates land and transportation planning to improve transportation efficiency[17] • Supports development of walking/biking opportunities **Every Mile Counts – See ODOT**	**Natural Hazards Mitigation Planning** • Supports state, local, and tribal governments in assessing how climate change will affect natural hazards; identifying vulnerable assets and populations; and assessing overall risk to natural hazard events[18] • Develops Oregon's Natural Hazard Mitigation Plan • Leads the Hazard Mitigation Team for the Office of Emergency Management **Oregon Coastal Management Program** • Supports coastal communities in assessing natural hazards and vulnerabilities specific to the coast[19] • Supports coastal communities in developing and implementing actions to reduce	**Coordinates implementation of FEMA's National Flood Insurance Program in Oregon** • Connects participants with federal program and resources[21] **Interagency Working Group on Climate Impacts to Impacted Communities** • Development of guidance for climate actions for impacted communities with equity focus[22] **Oregon's Climate Change Adaptation Framework – Lead** • Identification of adaptation needs and strategies across Oregon's economy[23] **Climate Equity Blueprint – See OHA** **Oregon Renewable Energy Siting Assessment (ORESA) – See ODOE**	**FEMA National Flood Insurance Program (NFIP) training** • DLCD-hosted training on a range of NFIP-related topics[24] • Audience: local gov/general **Resources on DLCD website** • Information and links for program information, toolkits, local planning, reports, etc.[25] • Audience: general

	vulnerability and risk from natural hazards **Oregon's Climate Change Vulnerability Assessment – Lead** • Assessment of how climate change is affecting the well-being, livelihoods, and cultural identify of Oregonians[20]		

Environmental Quality Commission and Department of Environmental Quality (DEQ)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Climate Protection Program • January 2022 program that establishes GHG emission limits on fossil fuel providers/suppliers and large industrial sources (mitigating 25.1 MMTCO2e by 2050)[26] **Clean Fuels Program** • Reduces lifecycle GHG emissions from fuels used in transportation sector by 10% by 2025, 20% by 2030, and 37% by 2035[27] • Resulted in 6.5 MMTCO2e emissions savings through 2020[28] **Oregon Clean Vehicle Rebate Project** • Rebate program to incentivize purchase/lease of new/used zero emission vehicles[29] • Charge Ahead Rebate incentive for low- and moderate-income households to acquire an EV	**Assessment of environmental health cost of carbon-based fuel use** • Identified health outcomes and healthcare cost savings associated with pollution reduction[32] **Ongoing environmental monitoring** • Continued investment in monitoring capabilities, including effect of wildfire smoke on air quality[33] **Material Recovery Programs** **See:** Preparing for Climate Change category	**Wildfire smoke hazard resilience** • Significant investment in air quality monitoring; facilitating wildfire smoke monitoring and reporting • Support for community preparedness and response for associated public health risks[34] **Food Waste Reduction Strategy** • Identifies and funds food waste reduction and outreach[35] • Targets social benefits and lifecycle GHG savings[36] **Built Environment Strategic Plan** • Reduces lifecycle GHG impacts of built environment through voluntary programs, capacity building, grants and more • Centers equity and environmental justice	**Resources on DEQ website** • Information on climate change, DEQ programs, and other state programs and resources[37] • Audience: general **GreenState Podcast** • Explores environment and environmental quality in Oregon[38] • Audience: general **Air, Land & Water Blog** • Covers environmental quality and climate change topics[39] • Audience: general **Bad Apple Campaign** • Statewide marketing campaign educating consumers to reduce food waste and lifecycle emissions from food production • Audience: general

Zero Emission Vehicle Standards[iii] • Advanced Clean Truck Regulations, which requires medium- and heavy-duty truck manufacturers to produce and deliver increasing percentages of zero-emission vehicles[30] • ZEV standards for light-duty vehicles, requires manufacturers to produce and deliver increasing percentages of zero-emission vehicles and reduce GHG emissions from conventional vehicles. DEQ is in rulemaking to adopt California's Advanced Clean Cars II rule requiring all new light-duty vehicle sales to be zero-emission by 2035[31] **Zero Emission Vehicle Interagency Working Group - See ODOT** **Every Mile Counts – See ODOT**		**Material Recovery Programs** • Plans, regulates, and provides assistance for local recovery programs statewide • Incorporates lifecycle impacts of material recovery **Oregon's Climate Change Adaptation Framework – See DLCD** **Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD** **Climate Equity Blueprint – See OHA** **Oregon Renewable Energy Siting Assessment (ORESA) – See ODOE** **Natural & Working Lands Proposal – See OGWC**	

Oregon Department of Agriculture (ODA)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Research into carbon sequestration through changing land use practices • Identifying strategies to improve soil health and carbon sequestration potential[40] • Integrating expertise on soil health throughout ODA programs with new Soil Health Position	No activities in this category	**Advancing water management practices** • Improving the quality of groundwater management areas • Improving agricultural water quality rules that increase watershed resilience • Engaging in Place-Based Planning for water resources, focused on adapting to the impacts of changing water regimes across Oregon **Advancing the resilience of native species** • Changing climate conditions can favor invasive species, helping them to out-compete native species and expand their populations rapidly • Implementation of an Early Detection and Rapid Response (EDRR) strategy to protect native species habitat	No activities in this category

		Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD **Oregon's Climate Change Adaptation Framework – See DLCD** **Oregon Renewable Energy Siting Assessment (ORESA) – See ODOE** **Natural & Working Lands Proposal – See OGWC**	

Oregon Department of Energy (ODOE) and Energy Facility Siting Council

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Solar + Storage Rebate Program • Rebate program for installation of solar panels and storage capacity[41] • 684 projects completed in 2021[42] **Energy Efficient Schools Program** • Provide technical support and connect schools with resources for energy efficiency projects[43] **Energy Efficiency Appliance Standards** • Advancement of standards from HB 2062[44] • Appliance efficiency improvements could achieve 2.5 MMTCO2e in emissions savings through 2035[45] **Energy Facility Siting Council Carbon Standards** • Monetary Offset rate for excess facility emissions raised from $2.85 to $4.27 per ton of CO2 in 2022 (the maximum increase allowed by current statute), update emissions standards, and implement HB 2021	**Energy Sector Climate Vulnerability Assessment** • Identifies and evaluates climate change related vulnerabilities and risks facing energy infrastructure and services[49] • Explores opportunities for risk mitigation and resilience, and provides a guide for others to conduct climate vulnerability studies[50] **Biennial Energy Report** • Overview of climate change risks and impacts to energy use and infrastructure[51]	**Community Renewable Energy Grant Program** • Grants for community renewable energy generation and storage projects[52] • Improves energy resilience[53] • 50% of funding dedicated to environmental justice communities[54] **Energy Efficient Wildfire Rebuilding Incentive** • Provides grant incentives for energy efficient rebuilding of destroyed structures[55] **Research into development of alternative energy resources** • Renewable Hydrogen Study (expected 2022)[56] • Floating Offshore Wind Energy Study[57] • Small-Scale and Community-Based Renewable Energy Projects Study[58]	**Biennial Energy Report** Reports in 2018, 2020, and 2022 include analysis and resources on climate change including: • Statewide GHG emission data and statistics • Goals and climate commitments • Risks and impacts • Deep decarbonization pathways • Clean energy and renewable standards • Energy efficiency and net-zero buildings • Energy sector climate vulnerability assessment • Electric vehicles and chargers • Hydrogen fuel cell vehicles • Renewable and zero-emission vehicle standards • Truck fuel efficiency • Alternative fuels assessments • Transportation fuels assessments • Carbon capture and storage

requirements.[46] [47]

Heat Pump Program[139]

- $25M provided in SB 1536 (2022) for grants and rebates to replace mainly bulk fuel based and electric resistance heating systems with heat pumps to provide both cooling and more efficient heating to residents

Built Environment Efficiency Working Group - Lead

Tasked with reducing energy consumption and emissions related to the built environment[48]

Renewable Portfolio Standards for Investor-Owned Utilities and Energy Service Suppliers – See PUC

Zero Emission Vehicle Interagency Working Group - See ODOT

Every Mile Counts – See ODOT

Roadmap to 2035 – See OGWC

Biennial Energy Report

- Evaluation of current GHG reduction targets and projected impacts[59]
- Findings used to inform future GHG reduction strategies[60]

Oregon's Climate Change Adaptation Framework – See DLCD

Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD

Oregon Renewable Energy Siting Assessment (ORESA) – Co-Lead

- Developed a mapping tool to help inform the siting of new renewable energy resources[61]

Natural & Working Lands Proposal – See OGWC

- Wildfire mitigation planning
- Agriculture sector GHG emissions analysis
- Renewable energy resource and technology reviews
- Overview of effects of energy development and consumption on climate, opportunities to mitigate emissions through energy efficiency and clean energy development, and climate change risks and impacts to energy use and infrastructure[62]
- Audience: general

Resources on ODOE website

- Electric Vehicle Dashboard[63]
- Solar Dashboard[64]
- Links to reports/publications[65]
- Program information[66]
- Audience: energy industry/general

Educational outreach on energy efficiency and clean energy

- Direct school engagement[67]
- Activities and

			materials on ODOE website[68] • Audience: children and students **Grounded Podcast** • Exploration of energy landscape in Oregon[69] • Audience: general **Roadmap to 2035 – See OGWC**

Oregon Department of Fish & Wildlife

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
ODFW wildlife area carbon sequestration • The approximately 200,000 acres of wildlife and recreation lands managed by ODFW sequesters 61,000 MTCO2e per year[70] **ODFW GHG Emissions Reduction Plan** • The ODFW GHG Emissions Baseline Assessment (2019-2020) estimated agency operations generate 9,280 MTCO2e per year[71] • The ODFW GHG Emissions Reduction Plan will be released by the end of 2022, identifying goals and targets for reducing agency GHG emissions	**Oregon Connectivity Assessment and Mapping Project (OCAMP)**[140] • High resolution habitat connectivity mapping effort for 60 species[72] • Data used for species and ecosystem conservation and protection[73] **Strategy Species List** • Identifies Oregon's species of greatest conservation need, highlighting species particularly vulnerable to climate change **Aquatic habitat prioritization** • Assessing climate resilience of aquatic habitat across the state • Focuses on instream water conservation and fish passage efforts **Ongoing environmental monitoring** • Re-aligned monitoring of aquatic species and	**Climate and Ocean Change Policy** • Incorporating a climate lens in programs, policies, and expenditures (as directed by OAR Chapter 635, Division 900) **Thermal Angling Sanctuaries** • Creation of protected cold-water refuges during warmest months to protect migrating species from high water temperatures[76] • Developing consistent guidelines for modifying angling regulations to protect fish during climate-driven downturns (such as warmer than average water temperatures) **Oregon Ocean Acidification and Hypoxia Report** • Identified opportunities for all state agencies to reduce ocean acidification and	**Drought Outreach Campaign via Oregon Conservation and Recreation Fund** • Large investment in targeted marketing campaign highlighting the impacts of drought on fish and wildfire, ongoing drought being driven by climate change, and opportunities for the public to help fish and wildlife persist. • Audience: General **Climate and Ocean Change Communications Plan** • Developing comprehensive communications to educate the public on the impacts of climate and ocean change on fish, wildlife, and their habitats • Audience: General **Ocean Conservation Strategy** • Oregon's State Wildlife Action Plan identifies climate change as one of the seven Key

	habitat conditions and change over time[74] **Assessment of climate vulnerability for the hatchery system** • Identification of increased risks to hatchery infrastructure from wildfire, flooding, hypoxia, drought, etc.[75]	hypoxia **Conservation Opportunity Areas** • Focusing investments and conservation efforts on locations across the state to support the highest number of species of greatest conservation need, providing intact habitats, act as climate refugia, and connect vital landscapes **Oregon's Climate Change Adaptation Framework – See DLCD** **Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD** **Oregon Renewable Energy Siting Assessment (ORESA) – See ODOE**	Conservation Issues in Oregon, providing background information and identifying priority goals and actions for Oregonians • Audience: General

Oregon Department of Forestry (ODF)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Adapting forest management to reduce wildfire risk • Reduces biogenic carbon emissions from fires[77] **Carbon sequestration in wildland forests** • Works to avoid net reduction in sequestered carbon (relative to 1974)[78]	**Assessment of forest health and composition in a changing climate** • Collaborative effort with U.S. National Forest Inventory Program to inventory and measure changes in tree species distribution, range, etc.[79]	**ODF Climate Change and Carbon Plan (2021)** • Identifies opportunities and goals for wildfire management, mitigation, and adaptation[80] • Explores incentives and rulemaking for appropriate stewardship of private forestland[81] • Expands resources for urban and community forests[82] **Oregon's Climate Change Adaptation Framework – See DLCD** **Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD** **Climate Equity Blueprint – See OHA** **Natural & Working Lands Proposal – See OGWC**	**Resources on ODF website** • Climate Change and Carbon Plan information and webinar[83] • Blogs on wildfire and carbon sequestration in harvested wood products[84] • Audience: wood products industry/general

Oregon Department of Transportation (ODOT) and Oregon Transportation Commission (OTC)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
West Coast Electric Highway • West Coast regional corridor of charging stations for zero emission vehicles[85] • 1.3 million kilowatt-hours of charging to date[86] • Upgrades in 2022-2023 expanding access **Piloting road user charges, tolls, and other pricing tools** • Market incentives to reduce driving[87] • Potential for large-scale implementation later this decade[88] **Intensification of investment in no-/low-emission transportation infrastructure** • $55 million funding increase for walking and biking transportation infrastructure[89] **EV charging infrastructure plans and investments** • National EV Infrastructure (NEVI) program provides $52 million federal/$13 million non-federal match funding over 5 years to build fast	**Transportation infrastructure climate vulnerability assessment** • Evaluation of risks associated with sea level rise, coastal erosion, landslides, flooding, and wildfire hazards and impacts on transportation infrastructure, as well as condition assessment of current infrastructure assets[92]	**Active Transportation Needs Inventory** • Data collection on pedestrian/bike infrastructure deficiencies[93] • Will be used to target funding of future infrastructure development[94] **Statewide Climate Change Adaptation and Resilience Plan** • Identification of needs, goals, and strategies to contend with projected future climate conditions and hazards[95] **Net-Zero Transit Pilot Project** • Assessing options to reduce emissions from public transit through lower carbon fuel use and zero-emission vehicle adoption **Oregon's Climate Change Adaptation Framework – See DLCD**	**Resources on ODOT Climate Office website** • General information, reports, program information, climate hazard factsheets, etc.[96] • Audience: general

charging stations on corridors • Community EV Charging Rebate program (2022) for Level 2 charging investments, largely in disadvantaged communities • Section 11401 of Bipartisan Infrastructure Law (2021) establishes $2.5 billion competitive grants for fueling infrastructure in communities and corridors, over 5 years • Transportation Electrification Infrastructure Needs Analysis (TEINA) (2021; 2022 update) identifies charging gaps and needed investments in charging infrastructure in rural, underserved, and urban areas throughout Oregon, with goals and deployment strategies **Statewide Transportation Improvement Program** • Planning includes evaluating GHG emissions resulting from transportation projects • $55 million increase for walking and biking transportation infrastructure in 2024-27 cycle		**Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD** **Climate Equity Blueprint – See OHA**	

Operations and Maintenance GHG Inventory • Assessment of GHG inventory for emissions associated with agency maintenance and construction operations for the development of reduction strategies **Zero Emission Vehicle Interagency Working Group - Lead convener** • Increases the rate of adoption of electric vehicle use through regulation, investment, and infrastructure development[90] **Every Mile Counts - Lead convener** • Identification, prioritization, and implementation of opportunities to reduce GHG emissions from transportation[91] **Transportation and Growth Management Program – see DLCD**			

Oregon Health Authority

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Healthy Homes Grant Program • Grant supporting weatherization and retrofits for reduced energy consumption and climate resilience[97]	**Climate and Health in Oregon - 2020 Report** • Assessment of current/projected health risks associated with climate hazards[98] • Exploration of cross-cutting effects of climate change (e.g., on livelihoods, housing, mental health, etc.)[99] **Climate Change and Social Resilience (2020)** • Analysis of impacts of climate change on social/community health[100] **Research on effects of climate change on youth depression** • Participatory, community-based study, with emphasis on intersectionality, especially for youth of color and Indigenous youth[101] **2021 State Modernization Investment ($37.9 million) to Local Public Health Agencies (LPHAs) and Tribes**	**Oregon Climate and Health Resilience Plan (2017)** • Identifies needs and makes recommendations to modernize and equip healthcare community to manage climate related health hazards[102] **Oregon ESSENCE (Electronic Surveillance System for the Early Notification of Community-Based Epidemics)** • Statewide public health monitoring system of incidences of climate change-related health hazards leading to visits to medical treatment centers[103] **2021 State Modernization Investment ($10 million) to Community-Based Organizations (CBOs)** • OHA awarded funds to 35-40 individual CBOs across the state to lead local climate resilience	**Climate Change Resilience Planning Toolkit** • Tools and resources to prepare for changing healthcare needs related to climate change[105] • Audience: healthcare community **Resources on OHA website** • Reports, presentations, handouts, videos, local adaptation plans, training materials, etc.[106] • Audience: healthcare community/general **Culturally Responsive Climate and Health Curricula** • OHA is funding Oregon Community Health Workers Association (ORCHWA) to develop and deliver a culturally responsive climate and health curricula, for Community Health Workers across the state. ORCHWA will also be available to

	• LPHAs are asked to protect communities from environmental health threats from climate change through public health interventions that support equitable climate adaptation. The LPHA will demonstrate strategies toward developing a local or regional climate adaptation plan or incorporate into community health assessment. • Tribes are asked to perform Environmental Health, climate change and emergency preparedness activities, technical assistance, and training	projects. **Building Resilience Against Climate Effects (BRACE)** • This federal grant supports the Climate and Health program to advance equitable climate adaptation through collaboration across all levels of government and with community partners serving priority populations **Climate Equity Blueprint - Lead** • Provides agencies with guidance on how to design and implement programs to advance equity[104] **Oregon's Climate Change Adaptation Framework – See DLCD** **Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD**	consult smaller organizations planning community education interventions through Public Health Modernization Audience: community health workers

Oregon Water Resources Department (OWRD)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Water conservation programs • Reduction of energy use as a co-benefit of programs to increase water efficiency[107]	**Oregon's Integrated Water Resources Strategy (2017)** • Analysis of water needs and pressures, including climate change-related impacts[108] **2015 Statewide Long-Term Water Demand Forecast** • Projection of the future water needs of the state with consideration of climate change scenarios[109]	**Use of incentives and place-based water resource planning to reduce water use** • Increased resilience to water scarcity[110] • Reduction of energy use related to efficiency improvements and the energy-water nexus[111] **Oregon's Climate Change Adaptation Framework – See DLCD** **Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD** **Climate Equity Blueprint – See OHA**	**Resources on OWRD Website** • Curated resources for "Drought" and "Wildfire Recovery" topics • Audience: general[112] **See also:** publications in assessment category

Oregon Watershed Enhancement Board

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Riparian reforestation and wetland restoration grant programs • Sequestering 5 to 10 MTCO2e per hectare per year[113] **Grants that support prevention of land use change (preservation of forest, grassland, etc.)** • Avoiding release of 16 to 300 MTCO2e per hectare per year[114]	No activities in this category	**Climate Resolution:** • Directs the agency to integrate emissions reductions, carbon sequestration and storage, and adaptation and resilience in their budgeting, investing, and policy-making decisions **Land management strategies eligible for OWEB grant funding:** • Use of forest conservation and restoration practices designed to reduce/mitigate fire risk[115] • Riparian restoration efforts designed to mitigate effects of drought and heat on fish/wildlife[116] • Management of wetlands and floodplains for mitigation of improved filtration and storage of surface runoff[117] **Oregon's Climate Change Adaptation Framework – See DLCD**	**Climate-Related Technical Resources for OWEB Grant Applicants (2021)** • Projected climate impacts and hazards related to watersheds, water quality, native species, habitats[118] • Information on external tools/resources[119] • Audience: OWEB grant applicants/general

		Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD **Natural & Working Lands Proposal – See OGWC**	

Oregon Public Utility Commission (PUC)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Energy efficiency investments through Energy Trust of Oregon • Reduction of 4.3 MMTCO2e from 2016 to 2020[120] **Regulate 100% clean electricity by utilities** • Requires 80% GHG emissions reductions (below baseline emissions) by 2030, 90% by 2035, and 100% by 2040[121] • Projected reduction of 12 MMTCO2e from 2021 to 2030[122] **Oversight of 90% GHG reduction from gas utilities by 2050[iv]** • Ensure gas utilities meet targets set by DEQ in Climate Protection Program in least-cost, least-risk manner **Enforce Renewable Portfolio Standards for Investor-Owned Utilities and Energy Service Suppliers** • Requires at least 20% of electricity sold by the electric utility or electricity service supplier in 2020 be 'qualified' renewable energy	**Hosted Wildfire Dialogue of West Coast Utility Commissions** • Collaborative discussion/ assessment of wildfire hazards to utilities[123] **Established requirement for utilities to assess climate risks** • Requires utilities to include assessment of climate risks posed to generation and distribution capacity in their integrated resource plans (IRPs)[124] • Update approach to avoided costs across all technology planning and acquisition that prices in value of GHG reduction and reduces climate risk • Require best available climate science in IRPs including weather forecasting and hydroelectric availability • All gas and electric IOUs employ the use	**Wildfire rulemaking (AR 638)[141]** • Per EO 20-04 and SB 762, rulemaking to reduce/mitigate hazard risk to utilities from wildfires and other extreme weather events (e.g., modification to vegetation management rules)[125] **Exploring resiliency to climate change events in utility planning and investing** • As part of HB 2021,[142] explore utility planning and future investing in grid resiliency • Increased direction to gas and electric IOUs to produce climate vulnerability and/or adaptation sections in their long-term planning documents	**Oregon Wildfire & Electric Collaborative - Wildfire Mitigation Workshop Series** • Workshop series to develop and share best practices to reduce wildfire risk and damage[126] • Audience: energy utilities

• Requirement increases incrementally every five years to 50% by 2040 **Enable procurement of Renewable Natural Gas by natural gas utilities** • Supports qualified renewable natural gas investments up to 5% in each calendar year 2020-2024, increasing every 5 years up to 30% for years 2045-2050 **Implement utility Transportation Electrification investment framework and updated approach to TE planning** • Per HB 2165 and EO 20-04, developed with stakeholders an enhanced approach to utility investing and planning that supports more rapid electrification of transportation **Zero Emission Vehicle Interagency Working Group - See ODOT** **Built Environment Efficiency Working Group - See ODOE** **Roadmap to 2035 – See OGWC**	of the social cost of carbon when assessing portfolios of resources to meet energy needs • Conducted Natural Gas Fact Finding to explore with stakeholders the regulatory tools that could be employed by the Commission to encourage/ support gas utilities to meet GHG reduction targets and mitigate associated customer risks.	**Oregon's Climate Change Adaptation Framework – See DLCD** **Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD** **Oregon Renewable Energy Siting Assessment (ORESA) – See ODOE**	

Environmental Justice Council[i]

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
No activities in this category	**Development of an Environmental Justice Mapping Tool as described HB 4077, passed by the Oregon Legislature in 2021** • The tool will include environmental, health, socioeconomic, and other factors and will help define EJ communities in Oregon • Uses for the tool can include informing benefits while diminishing burdens for EJ communities • Provide GIS map layers that will be compatible with other mapping tools at state agencies to enable more specific data analysis and comparisons	**Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD** **Climate Equity Blueprint – See OHA**	**Environmental Justice Task Force Handbook** • Best practices guidebook for state natural resource agencies to integrate environmental justice concerns, including effects of climate change into agency programs, actions, and decisions • Audience: State natural resource agencies, boards, and commissions

[i] Formerly the Environmental Justice Task Force, which was renamed in the passage of HB 4077 in 2022.

Oregon Climate Change Research Institute (OCCRI)

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
No activities in this category	**Oregon Climate Assessments** • Biennial assessment of current and projected effects of climate change in Oregon[127] **Assessing Climate Risks for Oregon Counties** • Developing county-level natural hazard mitigation plans that include climate change-related hazards (in partnership with DLCD) **Oregon's Climate Change Vulnerability Assessment – See DLCD** • Producing content and graphics for visuals that will be used in 12 regional workshops	**Provision of technical support for the development of policies and programs responding to effects of climate change** • Local, state, and regional levels, in partnerships with utilities and other groups[128] **Oregon's Climate Change Adaptation Framework – See DLCD**	**Media contributions on climate change (local-national)** • Local and national contributions to climate change-related journalism[129] • Presentations on climate change and its effects at the invitation of diverse governmental, nongovernmental, educational, and civic groups. • Audience: sector-based, general. **Publication of peer-reviewed papers** • Contributions to scientific literature related to climate change in Oregon[130] • Audience: academic **See also:** Oregon climate assessments in assessments category

Oregon Global Warming Commission

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
Roadmap to 2035 • Develop an economy-wide, Oregon-specific model that forecasts expected emission reductions from state programs and regulations[131] • Provide decision-makers with recommendations for future actions the state should take to reduce Oregon's greenhouse gas emissions[132]	*No activities in this category*	**OGWC Biennial Report to the Legislature** • Economy-wide and sector-based recommendations for government response to mitigate emissions and increase resilience in Oregon[133] • Assessment of the efficacy and progress of current goals/ programs/policies[134] **Natural & Working Lands Proposal – Lead** • Development of carbon sequestration and storage goals for Oregon's natural and working lands[135] **Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD**	**Resources on OGWC website** • Publications, reports, links to state and local government climate change resources, links to non-government resources[136] • Audience: general

Oregon Sustainability Board

Greenhouse Gas Emissions Reductions and Sequestration	Assessment of Climate Risks and Vulnerabilities	Preparing for Climate Change	Educating Oregonians About Climate Change
No activities in this category	*No activities in this category*	**Review and approval of agency sustainability plans** • Collaboration with state entities to develop plans that meet state and entity goals[137] **Interagency Working Group on Climate Impacts to Impacted Communities – See DLCD**	**Sustainability support and outreach** • Assistance for consumer/industrial product environmental impact assessment[138] • Audience: industry/general

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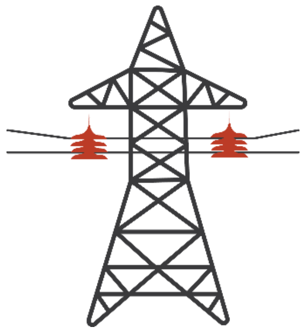
Energy 101: Infrastructure Investment and Jobs Act of 2021



The Infrastructure Investment and Jobs Act (PL 117-58)[i] will fund the building and repairing of roads and bridges, deployment of broadband internet, strengthening of the electric grid and water systems, and much more. The initial bill was introduced by Oregon Representative Peter DeFazio on June 4, 2021. Following months of negotiations, the bill passed in Congress with bipartisan support and was signed into law by President Joe Biden on November 15, 2021. The law authorizes $1.2 trillion in infrastructure spending across more than 380 federal programs. Of that, approximately $650 billion reauthorizes existing funding, while another $550 billion adds new funding to support the nation's infrastructure needs.[1] [2]

The Biden-Harris Administration is working to implement this funding across multiple federal agencies. With such a variety of programs funded, the Infrastructure Investment and Jobs Act funds are anticipated to be dispersed from the federal government to recipients at different times, depending on the complexity of the program and the individual grantmaking and/or procurement processes associated with aspects of each program. The Biden-Harris Administration has established the following priorities across programs in administering these funds:

(a) investing public dollars efficiently, working to avoid waste, and focusing on measurable outcomes for the American people;

(b) increasing the competitiveness of the United States economy, including through implementation of the Act's Made-in-America requirements and bolstering United States manufacturing and supply chains;

(c) improving job opportunities for millions of Americans by focusing on high labor standards for these jobs, including prevailing wages and the free and fair chance to join a union;

(d) investing public dollars equitably, including through the Justice40 Initiative, which is a government-wide effort toward a goal that 40 percent of the overall benefits from federal investments in climate change and clean energy flow to disadvantaged communities;

(e) building infrastructure that is resilient and that helps combat the crisis of climate change; and

(f) effectively coordinating with state, local, Tribal, and territorial governments in implementing these critical investments.[ii]

With all these distinct programs, it is challenging to precisely identify at the time of this report's publication how this law will affect energy-related infrastructure in Oregon. However, below are highlights of anticipated funding that will support energy-related investments nationwide, including Oregon.

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[i] The Inflation Reduction Act of 2022 was passed after the drafting of this section, but prior to publication. Please see ODOE's website using the link at the end of this article to follow updates pertaining to the funding opportunities under the Inflation Reduction Act.

[ii] Exec. Order No. 14052 as of Nov. 15, 2021, 86 Fed. Reg. 64335 (Nov. 18, 2021).

State Energy Program

Purpose	National Funding Level	Oregon Agency Anticipated to Receive Funds
Provides funding to states to support electric transmission and distribution planning as well as planning activities and programs that help reduce carbon emissions in all sectors of the economy — including the transportation sector, by accelerating the use of alternative transportation fuels and vehicle electrification. This funding will also support improvements to a State Energy Security Plan as directed by Oregon SB 1567. This allocation is in addition to the existing annual state allocation of State Energy Program funding.	$500 Million	Oregon Department of Energy
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	Approximately $5.6 Million	To Be Determined

Energy Efficiency Revolving Loan Fund Capitalization Grant Program

Purpose	National Funding Level	Oregon Agency Anticipated to Receive Funds
Provides capitalization grants to states to establish a revolving loan fund under which the state shall provide loans and grants for energy efficiency audits, upgrades, and retrofits to increase energy efficiency and improve the comfort of buildings.	$250 Million	Oregon Department of Energy
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	Approximately $1.3 Million	Loans and/or grants will be made to commercial or residential property owners

Energy Efficiency and Conservation Block Grant

Purpose	National Funding Level	Oregon Agency Anticipated to Receive Funds
Assists states, local governments, and Tribes in reducing energy use, reducing fossil fuel emissions, and improving energy efficiency.	$550 Million	Oregon Department of Energy will receive the state allocation
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	Unknown	Cities and/or counties with lower populations will be eligible to apply for a portion of the state allocation

Preventing Outages and Enhancing the Resilience of the Electric Grid (IIJA Section 40101(d))

Purpose	National Funding Level	OR Agency Anticipated to Receive Funds
Provides grants to States and Tribes to prevent outages and enhance the resilience of the electric grid.	$2.3 Billion	Oregon Department of Energy will receive the state allocation
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	Approximately $50 million	Electric Grid Operators, Electricity Storage Operators, Electricity Generators, Transmission Owners and Operators, Distribution Providers, & Fuel Suppliers

Preventing Outages and Enhancing the Resilience of the Electric Grid (IIJA Section 40101(c))

Purpose	National Funding Level	OR Entities Anticipated to Receive Funds
Provides competitive grants to eligible entities to prevent outages and enhance the resilience of the electric grid.	$2.3 Billion	Electric Grid Operators, Electricity Storage Operators, Electricity Generators, Transmission Owners and Operators, Distribution Providers, and Fuel Suppliers
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	Unknown	N/A

Energy Auditor Training Grant Program

Purpose	National Funding Level	OR Agency Anticipated to Receive Funds
Provides grants to "eligible states" to train individuals to conduct energy audits or surveys of commercial and residential buildings to build the clean energy workforce, save customers money on their energy bills, and reduce pollution from building energy use.	$40 Million	Oregon Department of Energy anticipates preparing a competitive application
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	Estimated funding to Oregon unknown; Awards cannot exceed $2 million	To Be Determined

Building Codes Implementation for Efficiency and Resilience

Purpose	National Funding Level	OR Agency Anticipated to Receive Funds
Creates a competitive grant program to enable sustained, cost-effective implementation of updated building energy codes to save customers money on their energy bills.	$225 Million	To Be Determined
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	Unknown	To Be Determined

National Electric Vehicle Infrastructure Formula Program

Purpose	National Funding Level	OR Agency Anticipated to Receive Funds
Creates a five-year program to strategically deploy high-powered, fast electric vehicle charging infrastructure on federally-approved EV Alternative Fuel Corridors and establishes an interconnected charging network to facilitate access, reliability, and data collection. Sets aside 10 percent of funding for discretionary grants to state and local governments that require additional assistance to strategically deploy EV charging infrastructure. The State of Oregon will provide additional information about the deployment of funds as it becomes available on ODOT's NEVI webpage.	$5 Billion	Oregon Department of Transportation
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	Approximately $52 Million in federal funds over five years; 20 percent non-federal match required	N/A

Weatherization Assistance Program

Purpose	National Funding Level	OR Agency Anticipated to Receive Funds
To increase energy efficiency in low-income households to reduce their total residential energy costs and improve health and safety, especially for older adults, people with disabilities, and children.	$3.5 Billion	Oregon Housing and Community Services
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	$30,603,866	Will be administered by community-based organizations

Low-Income Home Energy Assistance Program

Purpose	National Funding Level	OR Agency Anticipated to Receive Funds
Additional funding for the Low-Income Home Energy Assistance Program (LIHEAP), which assists eligible low-income households with their heating and cooling energy costs, bill payment assistance, energy crisis assistance, weatherization, and energy-related home repairs.	$500 Million	Oregon Housing and Community Services
	Estimated Funding Amount to Oregon	**Anticipated Subrecipients (if applicable)**
	$1,081,558	Will be administered by community-based organizations

A complete list of programs funded through the Infrastructure Investment Act can be found at: https://www.whitehouse.gov/wp-content/uploads/2022/01/BUILDING-A-BETTER-AMERICA_FINAL.pdf.

Rural communities may also want to consult the Rural Playbook, a guide released by the White House intended to help rural communities strategize the potential uses of IIJA funds. https://www.whitehouse.gov/wp-content/uploads/2022/04/BIL-Rural-Playbook-.pdf.

The Rural Playbook highlights several energy-related investments under the Bipartisan Infrastructure Law, including $700 million to upgrade existing hydropower dams and $1 billion to improve resilience, safety, reliability, and availability of energy in rural and remote communities with a population under 10,000. The law also includes grants to invest in: electric vehicle charging networks in rural areas and low- and moderate-income neighborhoods; zero-emission school buses; cybersecurity for rural and municipal electric utilities; and weatherization assistance to improve energy efficiency for low-income families.

Other important funding opportunities for rural communities under the bill include improving high-speed internet access; cleaning up abandoned mines, Superfund sites, and brownfields; improving transportation infrastructure including bridges, roads, and transit; strengthening drinking water and wastewater systems; developing and implementing community wildfire protection plans; reducing risks to local infrastructure from disasters and natural hazards; and extending the existing Secure Rural Schools program.

Oregon Department of Energy staff have heard from stakeholders that communities with fewer resources may be disadvantaged in seeking these much-needed funds. Many environmental justice communities in Oregon lack the resources and capacity to adequately plan for, apply to, and subsequently manage these federal dollars. While solutions to this problem are likely not one-size-fits-all, the agency is exploring options to provide assistance and reduce these barriers.

The State of Oregon will provide additional information about the deployment of these funds as it becomes available. You can follow the implementation of Infrastructure Investment and Jobs Act funds across all agencies online: https://www.oregon.gov/odot/IF/Pages/default.aspx.

Specific updates from the Oregon Department of Energy are available from ODOE's website: https://www.oregon.gov/energy/energy-oregon/Pages/IIJA.aspx.

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POLICY BRIEFS

The primary purpose of the Biennial Energy Report is to inform local, state, regional, and federal energy policy development, energy planning, and energy investments, and to identify opportunities to further the state's energy policies.

In service of ODOE's role as the central repository within state government for the collection of data on energy resources, the report collects and analyzes critical data and information to provide a comprehensive and state-wide view of the energy sector. The term "energy" includes many intersecting systems that generate and distribute electricity to end-users, and that store and distribute fuels for home-heating, industrial processes, and transportation. It also includes the critical infrastructure, facilities, planning, and energy management that support these systems. A key consideration in analyzing the energy system is effects that it has on public health, the environment, the economy, and communities across the state – as well as the equitable distribution of benefits and burdens to Oregonians.

This section of the report provides insights on select emerging energy trends, opportunities, and barriers in the energy sector. These policy briefs can be read as standalone documents, and there are cues in each discussion to point the reader to information and data found in other parts of this report or others that can provide additional background and insight.

In addition to this Biennial Energy Report, ODOE published several studies over the last two years on other emerging topics – including zero emission vehicles, Regional Transmission Organizations, renewable hydrogen, floating offshore wind, and small-scale and community-based renewable energy projects.

Learn more: **www.oregon.gov/energy/Data-and-Reports/Pages/ODOE-Studies.aspx**

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Policy Brief: Charting a Course for Oregon's Energy Future

Part I: Introduction

States across the U.S. have adopted increasingly **aggressive clean energy and climate change policies** in recent years.[1] Local governments – from Portland, Bend, and Ashland to other cities in Oregon[i] – are also adopting such policies, sometimes with even more aggressive timelines and goals than those adopted by their respective states. In almost all cases, these policies are intended to achieve significant **reductions in economy-wide greenhouse gas emissions by 2050**.

While state policies vary in specifics, recent technical analyses find that achieving these targets will require an "unprecedented transition"[2] and "substantial investments"[3] to effect "a transformation of the energy system."[4] This transformation – sometimes referred to as deep decarbonization – has the potential to boost Oregon's GDP in 2050 by as much as $4 billion,[5] driven primarily by indirect economic and health benefits, but also by taking the billions of dollars that Oregonians currently send out of state for fossil fuels and redirecting to in-state investments in clean energy.

Many of the technical analyses align in their findings that this energy system transformation to meet policy objectives is achievable by focusing on four core pillars of decarbonization:

- **Energy efficiency**
- **Electrification of end uses**
- **Decarbonizing the electric sector**
- **Developing low-carbon fuels**

Important decisions remain, however, for state policymakers on whether, and to what extent, to encourage or discourage specific technology pathways within this transition to a clean energy economy by mid-century.[6] [7] [4]

This Policy Brief series will review recent technical analyses that identify the scale of the actions required to achieve clean energy and decarbonization policies and will identify common themes and strategies from that literature. It will also frame some of the questions that Oregon policymakers will need to consider when determining how to achieve the state's 2050 climate goals and identify how the state can engage more intentionally in identifying its own priorities in the clean energy transition.

The sections of this brief that follow will explore in greater detail some of these policy decisions facing the state across the following subtopics:

- Transformation of the electric sector
- The role of conventional and alternative gaseous fuels
- Decarbonization of the transportation sector
- Trade-offs among different clean energy pathways

[i] For information on local jurisdictions within Oregon taking climate change actions see: https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Policy-Briefs.pdf#page=13

Oregon's Policy Landscape

Two recently adopted policies play a central role in defining Oregon's clean energy and climate policy landscape: Executive Order 20-04 and HB 2021. Both policies, particularly when considered in combination, commit Oregon to deep decarbonization of the state's economy by mid-century that is similar to the types of policies modeled in the technical analyses reviewed for this Policy Brief series.

Executive Order 20-04: Directing State Agencies to Take Actions to Reduce and Regulate Greenhouse Gas Emissions[8]

Governor Brown signed EO 20-04 in March 2020.

While the order imposed requirements on several state agencies, one of the most consequential outcomes has been the establishment of the Climate Protection Program by the Department of Environmental Quality. The CPP is a regulatory program launched in 2022 designed to dramatically reduce economy-wide greenhouse gas emissions by 2050. The program adopts a cap on emissions from fossil fuels—including the direct use fuels and transportation fuels sectors—used throughout the state, with an interim target of a 50 percent reduction by 2035 and a 90 percent reduction by 2050.[9]

House Bill 2021 (2021) [10]

The most relevant element of this law for purposes of this brief is the 100 percent clean electricity standard. The law requires the state's largest retail electricity providers (investor-owned utilities and electricity service suppliers) to eliminate greenhouse gas emissions from the electricity they provide to consumers by 2040, with interim targets of an 80 percent reduction from baseline levels by 2030 and a 90 percent reduction by 2035.

Technical Studies: Charting the Course to 2050

In response to the adoption of more aggressive clean energy and climate policies, many states, energy providers, and other industry stakeholders have commissioned technical analyses to identify broad strategies and potential technology pathways for achieving these policies in the decades ahead. For this series of briefs, the authors have reviewed 20 of these technical studies published since 2018.[ii]

Some of these studies were focused on individual utility service areas or on specific states, some focused on the Pacific Northwest as a region, and others evaluated these types of policies nationwide. Table 1 illustrates the breadth of the regions and policies considered by these studies.

[ii] In October 2022, Portland General Electric published an update to the 2017 Deep Decarbonization Study used for this brief. The 2022 study explores potential decarbonization pathways across PGE's service territory considering the goals established in HB 2021. https://portlandgeneral.com/about/who-we-are/resource-planning

Table 1: Summary of the Range of Scope of the Studies Reviewed

Geographic Areas	**Regional:** Pacific Northwest, United States **States:** Oregon, Washington, Montana, California **Service Areas:** NW Natural, Portland General Electric, Eugene Water & Electric Board, Seattle City Light, SoCalGas, Los Angeles Department of Water and Power
Areas of Focus	**Sectors:** Electrification effects on electric system, evaluation of effects on gas infrastructure, heating loads **Broader:** Electricity system, economy-wide
Policy Targets	**Targets:** Carbon neutrality, net-zero emissions, 100% clean electricity, 100% electrification of buildings and transportation, economy-wide decarbonization, 80 to 100% reduction in greenhouse gas emissions from 1990 levels
Dates	**Dates:** Load growth through 2024, achieving GHG targets by 2045-2050, carbon neutrality by 2045-2050, 100% clean electricity by 2035

Despite this variation in geographic scope, sectoral focus, and range of the specific clean energy or decarbonization targets evaluated, these studies coalesce around the identification of several common strategies, or pillars of decarbonization, necessary to achieve these policy objectives in the decades ahead.

Common Strategies: Pillars of Decarbonization

Many of the technical studies reviewed identified some combination of the four pillars of decarbonization identified above. And as noted explicitly by multiple studies, a portfolio of solutions will be required to achieve clean energy and carbon policy objectives, while a pursuit of any one of these strategies alone would be insufficient.[11 12 13 14]

- **Energy efficiency:** Continued investments in energy efficiency is a core strategy to achieve decarbonization policy objectives.[15 11 13 16 17 6 18 12] This strategy helps to reduce the overall amount of clean energy necessary to power the economy. In this context, energy efficiency refers both to improving the efficiency of using a particular fuel (e.g., converting home heating from electric resistance heating to a high-efficiency electric heat pump), but also to converting an end-use from one fuel type to another in certain cases (e.g., converting from a gasoline vehicle to an electric vehicle or from a vehicle to walking or biking, which use energy much more efficiently).
- **Electrification of end uses:** Converting end-uses from fossil fuels to electricity is another core decarbonization strategy.[15 11 19 20 16 13 17 21 18 12] In particular, many studies identify the need to electrify the transportation sector and space and water heating in buildings to varying degrees.[11 19 20 16] The extent to which these sectors need to be decarbonized to achieve climate targets depends upon how ultimately stringent the targets are. In Oregon, for example, one study found

that an 80 percent reduction in GHG emissions from 1990 levels by 2050 could be achieved "without decarbonizing significant quantities of liquid fuels," but that would change if the target were increased to 100 percent.[22] Expansive electrification has the potential to drive a significant build-out of the electric sector, potentially doubling the amount of installed generating capacity by 2050 compared to today.[23]

Clean electricity supply: The next strategy requires a significant increase in the availability of clean electricity supply compared to the mix on today's grid.[15 11 19 13 24 23 25 26 17 6 18 12] Many of the studies reviewed identify the retirement of coal resources as a critical component, while also emphasizing the need to develop new clean electricity generation resources. Wind and solar generation are consistently identified as the primary resources needed to provide clean electricity,[3 23 25] while at least one study identified a scenario where wind and solar projects are constrained, and advanced nuclear and/or gas plants with carbon capture technology are necessary.[25]

Low-carbon fuels: Some end-uses – such as certain industrial processes, heavy duty transportation, and aviation fuels – are more challenging to decarbonize with electricity than others. Identifying a decarbonization strategy of other end-uses, such as space and water heating in the building sector, may require balancing trade-offs between broader electrification and the use of low-carbon fuels in existing gas infrastructure. In any case, the technical analysis finds that the development of large volumes of low-carbon fuels (e.g., biofuels or electrolytic fuels such as renewable hydrogen) are a fourth strategy to achieving decarbonization objectives.[15 11 22 13 27 17 28]

Several of the studies also identify one or both of the following additional strategies, neither of which will be focused on in this policy brief for the reasons described:

- **Carbon capture:**[iii] Some studies identify carbon capture, usage, and/or sequestration as another strategy.[29 11 21 25] Carbon storage can be categorized in two ways: one, capture and storage of carbon in the creation of energy, such as carbon capture technology paired with a conventional natural gas; or two, carbon capture in the natural environment, as in the planting and growth of trees. Storing carbon in the process of producing energy has been identified as one potential pathway available to developing sufficient volumes of clean electricity (strategy 3 above) or low-carbon fuels (strategy 4 above). Examples of carbon capture are incorporated in this report and potential pathways. Some of the studies, however, also include carbon sequestration in working and natural lands as a component of achieving economy-wide decarbonization policy objectives, which is distinct and apart from the scale of clean energy development necessary to achieve clean energy and climate policy objectives.[iv] This paper is focused on the clean energy needs for achieving policy objectives. For these reasons, carbon capture is not included in this paper as a *distinct* strategy for achieving clean energy and climate policy objectives. However, ODOE recognizes that carbon capture and carbon

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[iii] For more information on carbon capture, see *Technology Review: Carbon Capture and Storage* from the 2020 Biennial Energy Report: https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=101

[iv] While some crops can be grown specifically to create fuels, which has implications for net greenhouse gas emissions, for the purposes of this report, these types of crops are not a consideration.

sequestration in natural and working lands can be an important component of an overall strategy for managing and reducing carbon emissions.

- **Emissions reductions not related to energy:** While most of the emissions that need to be reduced to achieve economy-wide climate policy objectives originate with the energy sector, reductions are also necessary in other sectors of the economy, including the agriculture, industrial, and waste sectors. For this reason, at least two of the studies reviewed called out the need to reduce these emissions as another strategy.[29] [18] Given that this strategy does not directly implicate the development of clean energy resources to achieve policy objectives, it is also left out of this paper as a distinct strategy.

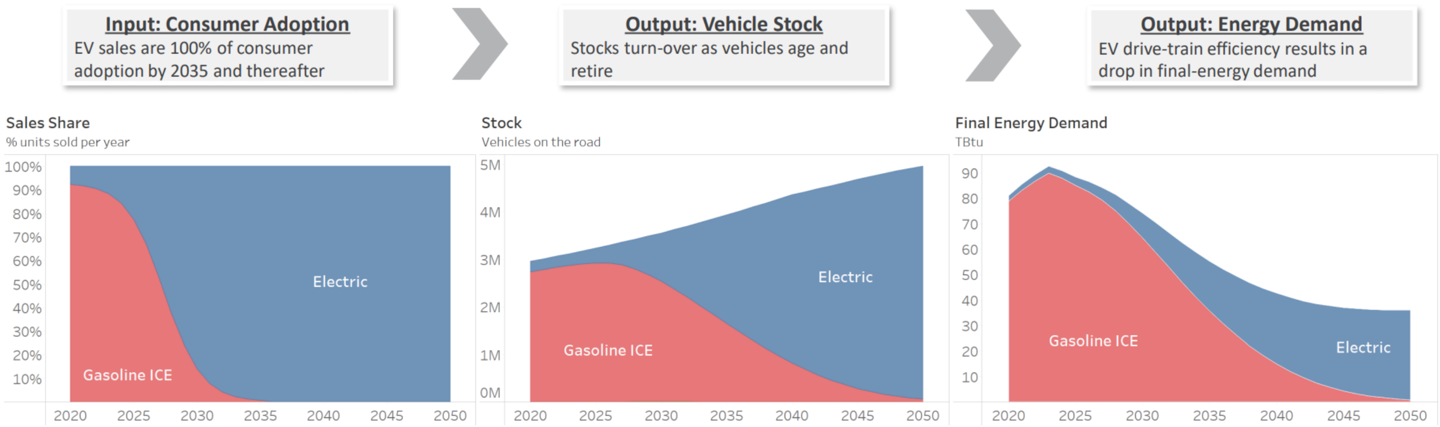
Scale and Pace of Change

A striking conclusion common across much of the analysis is the *scale* and *pace* at which clean energy development must occur in the years and decades ahead to achieve 2050 policy objectives. Take the electric sector as an example. In the *Oregon Clean Energy Pathways* study, the core decarbonization scenario projects a **90 percent increase** in electric sector demand between 2020 and 2050.[22] Depending on the scenario evaluated, the studies reviewed tended to identify increased electric demand in the range of **50 to 100 percent by 2050**.[30] [31] [26] [32] [33]

The range of expected growth in electric demand varies across these studies for several reasons, from different starting positions (e.g., the percentage of heating loads already served by electricity instead of natural gas), to different modeled policy targets (e.g., 80 percent versus 100 percent reduction in emissions), to the breadth of analysis (e.g., economy-wide versus only certain sectors). In any case, the directionality of the findings is similar, with an expectation of significant growth in electric demand in the decades ahead, and with transportation electrification specifically identified in several studies as the primary driver.[34] [35]

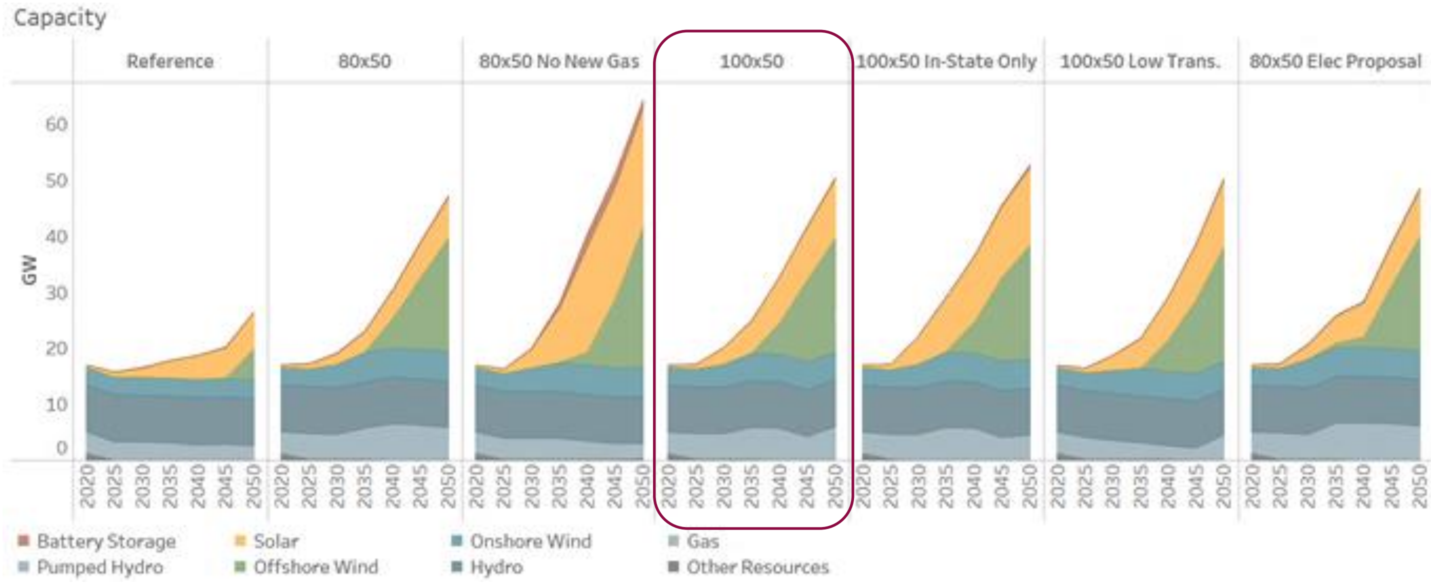
The *Washington State Energy Strategy* highlights the challenge presented by these changes: "The twin challenges of decarbonization in Washington are pace (to reach 2030) and scale (to reach 2050). Rapid change across all sectors of the economy is required to meet the 2030 challenge."[36] The identification of a need for near-term, dramatic action appears across much of the literature: "The decade ahead, between now and 2030, will be critical. . ." to establish technology deployment, market transformation, and investment trends "necessary to put the country on a realistic path" to achieving its clean energy and climate policy objectives by mid-century.[37] The long operating lifetime of appliances, vehicles, and heavy machinery results in a wide "turning radius" for the energy sector, and is a primary reason why the analysis identifies a need for rapid, near-term action.[38] [39] For example, given the estimated operating lifetime of a new light-duty vehicle, the share of electric vehicles among new sales needs to increase significantly by 2030, and likely requiring all new light-duty vehicles sales to be electric by 2035, in order to achieve 2050 objectives.[40] Figure 1, from the core decarbonization scenario of the *Oregon Clean Energy Pathways* study, illustrates what this transition will need to look like in order to phase-out gasoline powered light-duty vehicles by mid-century.[41]

Figure 1: Illustration of Model Inputs and Outputs for Light-Duty Vehicles[41]



The necessary large-scale deployment of renewable energy projects – like wind and solar facilities or the infrastructure to support biofuels or renewable hydrogen – further contributes to this wide "turning radius"[38] and the need to take near-term action to achieve mid-century policy goals.[42] [23] [43] Figure 2, from the *Oregon Clean Energy Pathways* study, for example, illustrates what its modeling identified for different renewable energy resource builds across various scenarios.[44]

Figure 2: Scenario Models to 100 Percent Clean Electricity and Deep Decarbonization by 2050



The 100 percent clean energy by 2050 scenario evaluated in the study above (circled in red) identified a need to develop the following renewable electricity generation resources in Oregon through 2050 to achieve its policy objectives:

- **Solar:** From 500 MW in 2020 to 10,550 MW by 2050 (2,000 percent growth)
- **Onshore wind:** From 3,210 MW in 2020 to 4,970 MW in 2050 (55 percent growth)
- **Offshore wind:** From 0 MW in 2020 to 20,250 MW by 2050

In total, this scenario would require a **nearly 10-fold increase** by 2050 in the amount of renewable generating capacity currently installed in Oregon through 2020. Put another way, this would require more than 1,000 MW of new renewable energy capacity to become operational in Oregon every single year, on average, between 2020 and 2050. This compares to about 2,000 MW of total utility-scale wind and solar capacity deployed over a decade in Oregon, from 2010 to 2020.[45] The annual pace of deployment would need to accelerate by approximately five times through 2050 compared to the rate of deployment last decade.

How Much Will It Cost?

There will be up-front costs associated with transitioning Oregon's energy resources, and there will also be long-term offsetting co-benefits for the state. Co-benefits will include jobs and trades, improved health, energy savings, and retention of more of the state's energy dollars that flow out of Oregon. For example, the transportation sector today largely relies on petroleum fuels that are extracted and refined outside of Oregon, which means that Oregonians send more than $5 billion each year out of the state to import these liquid fuels. Electric vehicles will use fuel that is largely supplied and delivered by local utilities or the Bonneville Power Administration and will support local, well-paying jobs in the electric sector and in the development of renewable energy and EV charging infrastructure. Further, electrification of technologies that currently use fossil fuels is likely to result in lower operating costs for consumers. Current analysis shows that fueling an EV at residential retail rates costs about one-fifth of the cost to fuel a similar vehicle with gasoline, and drivers are not subject to the volatile prices swings of the global crude oil market. Similarly, operators of wind and solar projects don't have to pay for variable fuel costs, as has been the case when operating coal and natural gas fleets.

It is also critical that policymakers consider the effects of this transition on low-income communities, which are disproportionately communities of color, rural areas, and people with disabilities.[46] Although the costs of transitioning to cleaner technologies can often more than pay for themselves over the lifetime of ownership, the up-front costs can be a barrier to adoption in these communities. Further, as Oregonians with higher incomes take more ownership of their energy resources—through on-site distributed energy resources, investments in community renewable energy projects, and energy management technologies like home battery storage—Oregonians with lower incomes may be left behind. This dynamic can result in a greater share of the cost of maintaining the energy system falling on the ratepayers who can least afford it. It is imperative that decisionmakers have the data and analysis to better understand these challenges and robust policy options to avoid an inequitable energy transition.

While there are up-front costs associated with decarbonizing the energy sector, they must be compared to the costs of not addressing climate change.

While there are up-front costs associated with decarbonizing the energy sector, these up-front costs must be compared to the costs of not addressing climate change – which will be substantial. If the world fails to address the impacts of climate change, Oregonians will face significant impacts, including:[47]

- Significant detrimental effects on public health and the state's economic vitality, natural resources, and the environment;
- A disproportionate effect on the wellbeing of impacted communities; and
- An increase in the frequency and severity of wildfires.

Oregon Governor Brown identified that these effects would worsen "if prompt action is not taken" to reduce emissions and that the "executive branch has a responsibility . . . and moral imperative to reduce GHG emissions and to reduce the worst risks of climate change . . . for future generations."[47]

The technical studies reviewed in this brief identify the scope and scale of the types of investments the state can make to do its part to help avoid these costs to Oregonians. Several of the studies reviewed not only modeled strategies and specific technology pathways to achieve deep decarbonization policy objectives, but also estimated the costs of making the necessary investments.

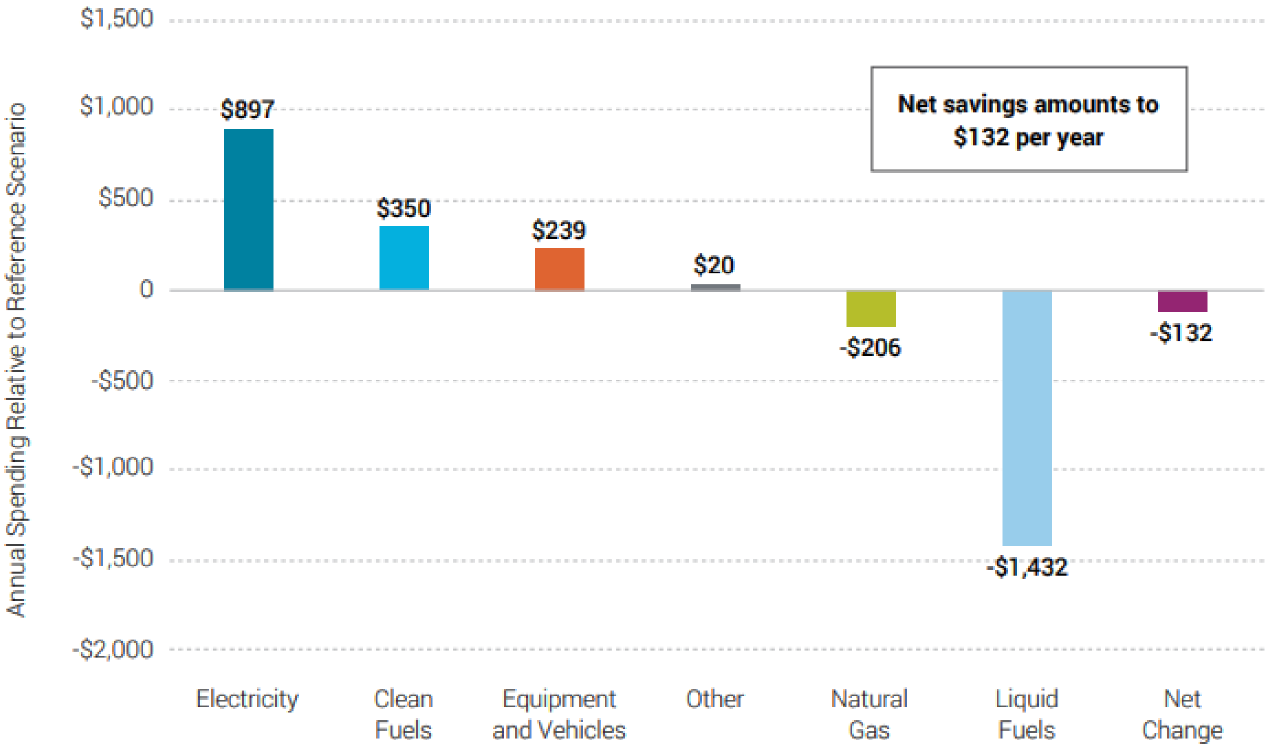
Pathway Choices. Many of the studies identified multiple technology pathways to meet mid-century policy goals, often with divergent costs to achieve the same policy objectives. For example, an aggressive electrification strategy may require a costly overbuilding of wind and solar projects to meet winter demand, while resulting in high levels of curtailments other times of year (i.e., needing to turn off power generators when there is too much power and not enough demand).[48] [18] Alternatively, if additional transmission is built in this same scenario, total costs for overbuilding renewable power projects could be partially offset by exporting more of that otherwise curtailed output.[49] Meanwhile, retaining significant volumes of liquid or gaseous fuels for the transportation or building sectors would require investments in technologies to produce low-carbon fuels and the infrastructure to move those fuels.[50] Two studies in the Pacific Northwest identified 40 to 90 percent higher total costs in 2050 when modeling scenarios where the use of fossil gas is completely prohibited, even in rare circumstances, from meeting peaking needs in the power system.[51] [52] In short, the specific technology pathways pursued to achieve mid-century goals matter, and different pathways come with different costs.

The Final 10 Percent. The preceding point about the retention of some fossil gas to meet (relatively infrequent) peak demands for power echoes an important finding identified in NREL's *LA100* study.[53] That study found similar total cost increases until approximately 80 to 90 percent of energy needs were supplied by renewable energy. The final 10 to 20 percent was identified as the most challenging and expensive, with an identification of "the cheapest option [being] storable renewable fuel used in a combustion turbine." The current challenge with this strategy, however, is that the development of renewable biofuels or hydrogen at-scale is not yet commercially viable. A similar result was found in the *Pacific Northwest Zero-Emitting Resources* study, which identified a much higher cost (requiring a much larger build-out of renewables) to achieve 100 percent clean energy compared to 95 percent clean energy, which allows for some remaining natural gas generation to meet peak demands.[54]

Total Net Costs. The analysis of the total costs to achieve mid-century clean energy and decarbonization policy goals must be considered in the context of several important caveats. First, as noted above, the specific technology pathway selected – and there are myriad options – to achieve the state's policy goals will ultimately affect total costs to Oregonians. In 2022, it remains challenging to forecast future costs for the types of technologies (such as renewable hydrogen deployed at-scale) that may be necessary to cost-effectively achieve the final 5 to 10 percent of decarbonization beyond 2040. The third and final caveat is that, while the capital investments required – in wind and solar generation, the electric grid, electric vehicles, and a range of other end-use technologies – are significant, they must be considered holistically against the reductions in expenditures for energy elsewhere in the economy. Several of the studies reviewed conducted this type of net cost analysis on achieving mid-century clean energy and deep decarbonization policy goals.

A key finding that is repeated across several studies is captured by the *Washington State Energy Strategy*: "Additional equipment costs for decarbonization are largely offset by savings from the avoided purchase of fossil fuels."[55] Figure 3 from that study illustrates annual spending per consumer in 2050 in the electrification scenario compared to the reference case.[56]

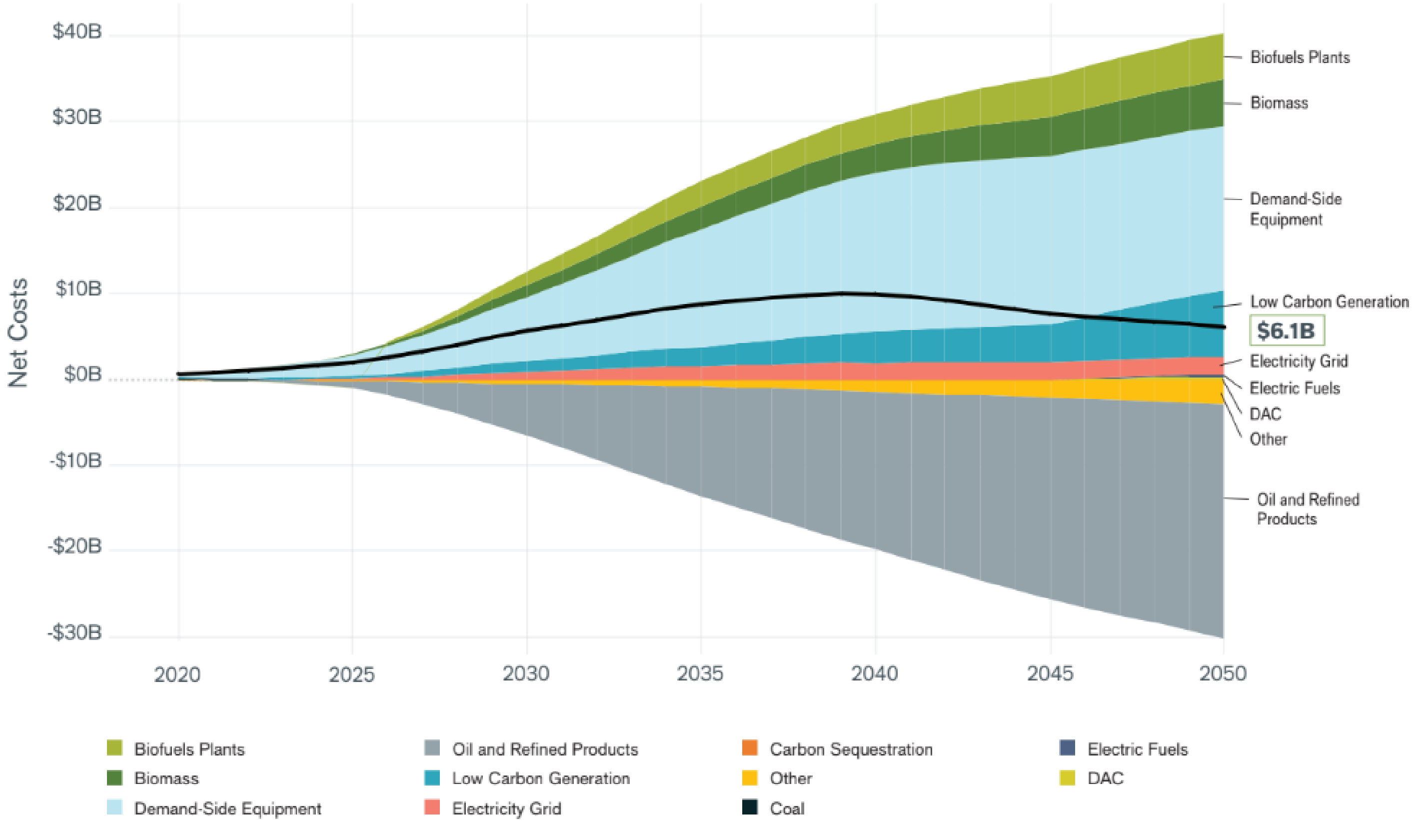
Figure 3: Change in Average Spending per Person in the Electrification Scenario (2050)[56]



Source: Appendix E – Economic Impacts of Decarbonization Modeling, December 31, 2020 (p. 16).

This visual helps illustrate how the increase in per person costs for electricity – nearly $900 annually or about $75 per month – are offset by an even larger reduction in annualized costs for liquid transportation fuels. An analysis for the Pacific Northwest, meanwhile, found cumulative costs to decarbonize by mid-century result in an increase of total annual spending on energy expenditures of approximately 1 percent of GDP.[57] That study shows how these costs are projected to unfold over the next three decades, again showing costs driven by electrification (i.e., demand side equipment and low carbon generation) being largely offset by a reduction in spending on petroleum products (Figure 4).[58]

Figure 4: Annual Net Energy System Costs for the Central Case Relative to the Business-as-Usual Case (2020-2050)[58]



Source: Northwest Deep Decarbonization Pathways Study, May 2019, Evolved Energy Research, page 106.

"Increased costs in a decarbonized system consist primarily of biofuel feedstocks and infrastructure, demand-side electrification and efficiency investments, and renewable power plants and supporting electricity infrastructure. **These costs are mitigated by the savings from reduced spending on fossil fuels**, **primarily liquid petroleum products such as gasoline, diesel, and jet fuel.**"

— Pathways to a Clean Energy Future for the Northwest: An Economy-wide Deep Decarbonization Pathways Study [52]

Technology Pathway Decisions and Balancing Trade-Offs

As described previously, the technical studies reviewed largely agree on some combination of the four pillars of decarbonization to achieve mid-century clean energy and deep decarbonization policy goals: energy efficiency; electrification of end-uses; clean electricity supply; and low-carbon fuels. Important policy decisions remain, however, in identifying the specific technology pathways that are preferable for Oregon to achieve its objectives.

Identifying Different Pathways

The briefs that follow will explore the range of pathways available to the state across the transportation, natural gas, and electricity sectors to achieve mid-century policy objectives. Oregon will need to consider several issues in the decades ahead when contemplating potential pathways:

- **Heating loads in buildings:** How should Oregon balance its strategy to decarbonize buildings between electrification and the development of low-carbon fuels? Are there greater risks with one approach over another?
- **Medium- and heavy-duty transportation:** What role can the state play in encouraging or discouraging the decarbonization of the medium- and heavy-duty transportation sector through electrification, renewable hydrogen, or biofuels?
- **Renewable generation:** Can the state identify a preferred resource development pathway for renewables that balances multiple objectives, such as land use impacts, fish and wildlife impacts, the need for transmission development, local economic development, resilience benefits, and total costs of energy?
- **Creating space for innovation:** The optimal technology solutions to achieve the most aggressive climate targets may not yet be commercially available. To what extent should Oregon develop policy flexibility to allow for a range of solutions, such as gas power plants with carbon capture, gas turbines that use renewable hydrogen, large-scale development of biofuels, or some type of long-duration energy storage?

The state's mid-century policy goals can be achieved with a combination of different answers to these questions, and will have significant effects on the state's electric, natural gas, and transportation sectors. More importantly, how these questions are answered will have important implications for equity and for the cost to Oregonians to achieve a clean energy transition.

How these questions are answered will have important implications for equity and for the cost to Oregonians to achieve a clean energy transition.

Some solutions might have higher up-front capital costs, but net savings over time. Some solutions would have greater or lesser effects on land use, fish and wildlife, and other natural environments in the state. Some solutions might bolster community resilience more than others. Some solutions might have a bigger indirect impact on in-state jobs and economic development. And in all cases, priority consideration must be given to how the trade-offs among different pathways to 2050 affect environmental justice and low-income communities in the state.

Conclusion

Oregon has taken a critical first step in recognizing the seriousness of the climate crisis by adopting aggressive mid-century policy objectives. This transition is achievable, but it is imperative that more collaboration among Oregon stakeholders occur in the near-term to inform the development of an equitable, balanced clean energy pathway for the state over the decades ahead.

As outlined here, and as described in greater detail in the briefs that follow, Oregon policymakers have important questions still before them. Convening diverse stakeholders from across the state to understand varied perspectives can help Oregon become more equitable as it defines a pathway to achieving its mid-century clean energy and climate policy objectives in a manner that considers:

- **Equity:** The upfront costs required to adopt some clean energy technologies can create a disproportionate burden for some customers. In addition, in many cases, historic investments in large-scale infrastructure have failed to adequately consider the perspectives of environmental justice and low-income communities. **How can Oregon identify a pathway to 2050 that centers the concerns of historically marginalized communities?**
- **Land use:** Solar and onshore wind development both have significant land use impacts. The development of high-voltage electric transmission can also have effects that span large areas and multiple jurisdictions. Offshore wind development, meanwhile, can avoid many of these land use impacts, but comes with potentially adverse impacts to marine wildlife and the environment, coastal communities, and fishing industries. **Can Oregon identify a pathway to 2050 that balances the different land use and wildlife impacts of renewable energy development?**
- **Cost:** Technical analyses identify a multitude of pathways that can achieve mid-century clean energy and climate policy objectives, but each pathway has different costs and benefits. In some cases, those cost differences play out over various timescales and affect different customers in different ways. For example, if higher income customers are early adopters of transitioning from natural gas heating to electric heat pumps, lower income customers may be forced to disproportionately bear the costs of maintaining the natural gas system. **What policy solutions can help mitigate the costs of the clean energy transition across sectors and types of customers, particularly for the state's most energy burdened residents?**
- **Resilience:** Given the scale of clean energy necessary to achieve policy objectives, a significant amount of large-scale development will be required. In some instances, however, smaller-scale projects or a diversity of project types – which may come at a cost premium – located closer to population centers may be able to improve the energy resilience of Oregon communities. **Is there a pathway to 2050 that balances the scale and total cost of the clean energy transition with a secondary objective to improve community energy resilience across the state?**
- **Fuel choice:** Technical analyses find that climate policy objectives can be met in many cases by either electrifying existing end-uses of natural gas, or by continuing to use the existing gas system but with increasing volumes of low-carbon fuels instead of conventional gas. In the latter case, large amounts of new electric generation would still be required to produce clean, electrolytic fuels at scale. **Is there a pathway to 2050 that balances maintenance of existing gas infrastructure with an increasing electrification of end-uses?**
- **Regionalization:** The energy system in many respects already operates on a regional basis. In the electric sector, for example, excess Pacific Northwest hydropower in the spring has long been sold to utilities in California. Increasingly, Oregon utilities are importing low-cost solar power from the south. There are both benefits and challenges to pursuing more localized or more regionalized approaches to the energy system. **Is there a regionalization strategy that**

can balance interests in developing in-state clean energy resources with the benefits that might accrue from increased regionalization?

The state has adopted bold policies, and it is assembling the technical analysis necessary to understand the range of choices yet to be made. In the years ahead, Oregon has a unique opportunity to control its own destiny by intentionally engaging with stakeholders to identify Oregon's preferred pathway to 2050.

It's the Oregon way.

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Policy Brief: Charting a Course for Oregon's Energy Future
Part II: Electric Sector

This section is part of a Policy Brief exploring the pathways available to Oregon in the decades ahead to achieve its clean energy and climate change policy objectives, and is based on a review of 20 technical studies published in recent years.

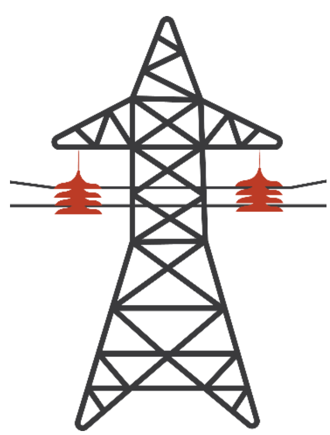
Those studies coalesce around four common strategies, or pillars of decarbonization, required to achieve these policies: energy efficiency, electrification of end-uses, clean electricity supply, and low-carbon fuels. While these pillars provide the foundation for achieving policy objectives, policymakers must consider the trade-offs among a range of specific technology pathways to transform the state's energy systems by 2050.

There is wide agreement among the studies reviewed that demand for electricity will grow in the decades ahead if mid-century clean energy and climate policy objectives are to be achieved. The electrification of end uses – one of the four pillars of decarbonization – is the primary reason that demand is expected to increase, even though that growth will be tempered to some extent by savings from energy efficiency, another of the four pillars.

> "Energy efficiency plays a crucial role in all pathways, and total energy demand *[for electricity, gasoline, natural gas, etc.]* in 2050 is approximately 10 to 20 percent below today's level, while the population grows by more than 40 percent. **Despite overall energy demand decreasing, electricity consumption increases in all pathways** . . . As a result, electricity's share of overall energy demand is projected to increase in a deeply decarbonized future."
>
> — *Exploring Pathways to Deep Decarbonization for the PGE Service Territory* [1]

This brief will explore the range of potential electric load growth scenarios modeled in the studies and will identify the anticipated drivers of that growth after accounting for expected savings from energy efficiency. In addition, the brief will consider the impacts of that growth on peak demand, not just annualized or average energy, and will then examine the multitude of pathways available to serve this expected increase in demand across the following three areas:

- **Transmission development:** The technical literature identifies the need for a large buildout of renewable generating capacity, much of which will be large-scale projects interconnected to the high-voltage transmission system. Depending on the scenario, this buildout may require the development of a lot of new transmission capacity.
- **Distribution system:** Distribution-level solutions will also play a role in achieving mid-century policy objectives. These solutions include investments in energy efficiency, load flexibility, small-scale renewables, batteries, and in the distribution grid itself.



- **Emerging solutions:** There is also a range of emerging solutions that could play a meaningful role, including evolving regionalized markets, widespread use of energy storage technologies, and new types of renewable generation resources, such as offshore wind or other innovative generation technologies, like small modular nuclear reactors.

In short, this brief will explore what this projected growth in electric demand might mean for Oregonians, and what pathways are available so the state can intentionally choose the portfolio of clean energy solutions that makes the most sense for Oregon.

Growth in Electric Demand

The reviewed studies anticipate significant growth in electric demand—after accounting for savings from energy efficiency—by mid-century to achieve deep decarbonization policy objectives. There is a range of increased electric demand found across several of the studies:

- **Oregon Pathways:** In its core decarbonization scenario, electric sector demand is expected to increase by 90 percent between 2020 and 2050 [2]
- **Portland General Electric:** 60 to 75 percent increase in total retail electricity sales between 2018 and 2050 [1]
- **Eugene Water & Electric Board:** High electrification of buildings and light-duty vehicles (heavy-duty vehicles and industrial loads not evaluated) is expected to result in a 20 to 30 percent increase in annual load by 2050 [3]
- **Washington Energy Strategy:** Electric sector demand expected to increase by 90 percent from 2020 levels by 2050 [4]
- **Seattle City Light:** In its aggressive electrification scenario, annual electric sector loads are expected to increase by 116 percent between 2020 and 2042 [5]
- **Montana Pathways:** Electrification scenario finds total loads increase by 56 percent from 2018 levels by 2050 [6]

The range of expected growth in electric demand varies across these studies for several reasons, from different starting positions (*e.g.*, the percentage of heating loads already served by electricity instead of natural gas), to different modeled policy targets (*e.g.*, 80 percent versus 100 percent reduction in emissions), to the breadth of analysis (*e.g.*, economy-wide versus only certain sectors).

> "By 2045, electricity demand (both annual consumption and peak demand) is likely to grow. High levels of energy efficiency can offset this growth in the buildings sector due to hotter climate, population growth, and electrification. **It is the electrification of the transportation sector that propels overall growth in electricity demand**."
>
> *— LA100: The Los Angeles 100% Renewable Energy Study* [7]

Many studies identify electrification of the transportation sector as a primary driver of this projected growth in demand in the decades ahead. Electrifying industrial processes and heating loads in the building sector are often cited as additional significant drivers.[5] [8] [9] [10] [4] [1] [11] [12] [13] In some scenarios, however, mid-century policy objectives can be met by relying on a greater use of low-carbon fuels (*e.g.*, renewable hydrogen) in the industrial and building sectors rather than on electrification.[1] [14] [15] These scenarios still have the potential to increase electric demand—for example, the production of electrolytic clean hydrogen to decarbonize conventional fuel use in buildings. In these cases, large-scale electrolysis to produce hydrogen could ramp production during times of plentiful renewable output and could lower production during times of constraint, actually helping to balance the grid and maintain reliability while contributing to the overall increased demand for electricity.[15]

Key Considerations for Electric Load Growth through 2050

In addition to the traditional drivers of electric load growth, such as population and economic growth, the answers to key questions specific to the clean energy transition will affect expected growth in electric demand.

Transportation:

- How quickly will the state's fleet of light-duty vehicles transition to electric?
- What percentage of light-duty vehicles will ultimately convert to electric by 2050?
- Will the heavy-duty transportation sector (e.g., trucking, buses, aviation, marine) transition to electric or to another low-carbon alternative, such as hydrogen?
- To what extent will the production of electrolytic fuels, like renewable hydrogen, increase demand for electricity?

Heating and Cooling:

- What percentage of residential and commercial customers in Oregon will convert from gas to electric for heating?
- How many customers will continue to use gas heating systems but source the gas from low-carbon sources, some of which (like electrolytic hydrogen) will still drive an increase in electric demand to produce those fuels?
- How many customers that currently have electric heating will upgrade to more efficient electric systems?
- With hotter summers driven by climate change, how many Oregonians will install electric air conditioning technologies?

Industrial Processes:

- How many energy-intensive industrial processes will convert from direct-use of fossil energy to electricity?
- How many of these energy-intensive industrial processes will seek to use renewable hydrogen, the production of which would also drive an increase in electric demand?

There are not inherently 'right' or 'wrong' answers to these questions, and many combinations of answers can enable the state to achieve its policy goals. Some answers may make it easier or harder to achieve decarbonization policy objectives, and some answers may involve a different set of trade-offs (including costs) than others. But how Oregon answers these questions will likely have a profound effect on the state's pathway to 2050.

Peak Demand

An important consideration of the electrification of end uses is not simply how much total energy these end uses will consume over the course of a year, but also the potential that these end uses will contribute to higher local or system peaks in demand. Primarily because of the historic difficulty in storing electricity at scale, the power system has necessarily been designed to be able to simultaneously generate and deliver enough energy to meet the highest customer demands for electricity at a given moment. For more information on this, and how peak demands have a disproportionate effect on total system costs, see the Resource Adequacy 101 from the *2020 Biennial Energy Report*.[16]

In some respects, projecting future *peak* demand is more challenging than projecting future energy demand overall.

In some respects, projecting future *peak* demand is more challenging than projecting future energy demand overall. Consider, as an example, an electric vehicle: it is easy to calculate how much energy it takes to charge a particular vehicle (based on the size of the battery) and how much energy it will consume annually (based on estimates of miles driven). But assessing the same vehicle's potential contribution to peak demand is driven by what time the owner of the vehicle will charge the car – and that is much harder to project. This concept of flexible demand is discussed more later in this section.

The following highlights from the technical literature identify the potential challenges associated with increased peak demand driven by electrification, but also indicate that the development of strategies to influence *when* new loads, like vehicles, use the grid can mitigate these potential impacts to peak demand:

- **Pacific Northwest:** Particularly in scenarios with high levels of building electrification, "significant new investments"—including upgrades to the distribution system and building new winter peak capacity generating resources—may be required to address winter peak demand from heating loads.[17]
- **Eugene Water & Electric Board:** The cumulative impacts of high levels of electrification of vehicles and buildings could "add between 50-70% to peak load during colder, less frequent (1-in-10) weather events," [3] but that this can be mitigated, particularly with vehicles, through "managed or diversified charging behavior."[18]
- **Portland General Electric:** Widespread adoption of electric vehicles is expected to drive increases in total energy demand, which, if unmanaged, would increase peak demand. However, "charging off-peak, such as when renewable generation is high or during the middle of the night can mitigate peak load impacts."[1]
- **Seattle City Light:** The electrification of space and water heating could result in "significant increases in system peak" unless "peak mitigation strategies" are employed.[19]

Exploring Pathways to 2050

Given the expected increase in electric demand, combined with the need to replace existing emitting resources with clean energy resources, it is perhaps unsurprising that the studies reviewed find the need to develop a significant amount of new renewable generation.

> "**The scale of renewable resource development present in all scenarios highlights the need for proactive planning to ensure that these resources are available to come online in a timely fashion.** This includes identifying promising areas for resource development, possible transmission network upgrades to ensure renewable generation is delivered to load, and operational considerations to balance a highly renewable grid."
>
> — *Exploring Pathways to Deep Decarbonization for the PGE Service Territory* [20]

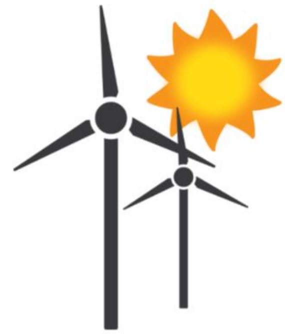
Nearly all the studies reviewed identify the need to develop a substantial amount of new wind and solar generation in the years ahead:

- **Oregon Pathways:** Modeling deep decarbonization of the Oregon economy by 2050 found the need for "significant investment" in new renewables that "should begin in the 2030s," with investments first in onshore wind and solar followed by a "large and rapid investment in offshore wind" beyond 2035.[8] The same study found a wide range of potential resource builds, from a couple GW of offshore wind to as much as 20 GW of offshore wind, and between 7 GW of solar and dozens of GW of solar in cases where no new gas is permitted. [21]
- **Washington Energy Strategy:** In its state energy strategy, Washington acknowledges that its electric supply is already 69 percent clean because of the state's existing hydropower resource, but assumes there is "no opportunity to expand" that supply in the future.[15] As a result, its modeling of an electrification scenario finds the need to deploy 12 GW of in-state solar and 4 GW of offshore wind by 2050. Those numbers increase (to 18 GW and 10 GW, respectively) in a scenario where new transmission (and the ability for more imports) is constrained.[15]
- **Pacific Northwest:** A study evaluating the elimination of greenhouse gas emissions in the Pacific Northwest by 2045 and exclusive reliance on renewables and storage found the need to develop 57 GW of wind and 42 GW of solar. The same study, however, found these projections dropped dramatically—to between 5 and 10 GW of solar, and between 7 and 11 GW of wind—in scenarios where other innovative sources of dispatchable, clean generation are available (e.g., small modular reactors or renewable gases)[22] and in scenarios where the target is a 95 percent (rather than 100 percent) reduction in emissions.[23]
- **Montana Pathways:** Modeling a 100 percent clean economy by 2050 shows the need to approximately double the amount of installed power-generating capacity in place today in the state. Assuming the elimination of coal and gas generation and stable output from hydropower results in needing approximately 8 GW of new wind and solar by 2050.[24]
- **Los Angeles 100 Study:** Given the low costs and access to high-quality resources, the LA100 study finds that "wind and solar resources are responsible for providing the majority of the energy" (accounting for between 69 and 87 percent) required to achieve a 100 percent clean

power system.[25] The same study found that up to one-third of residential homes would adopt on-site solar, up from 6 percent in 2020.[26]

- **National:** In a compendium that reviewed multiple studies from across the country there was identified a "dramatic increase in wind and solar capacity" combined with a phase out of coal by 2030 as a core strategy to achieve aggressive mid-century policies.[27]

Transmission Development

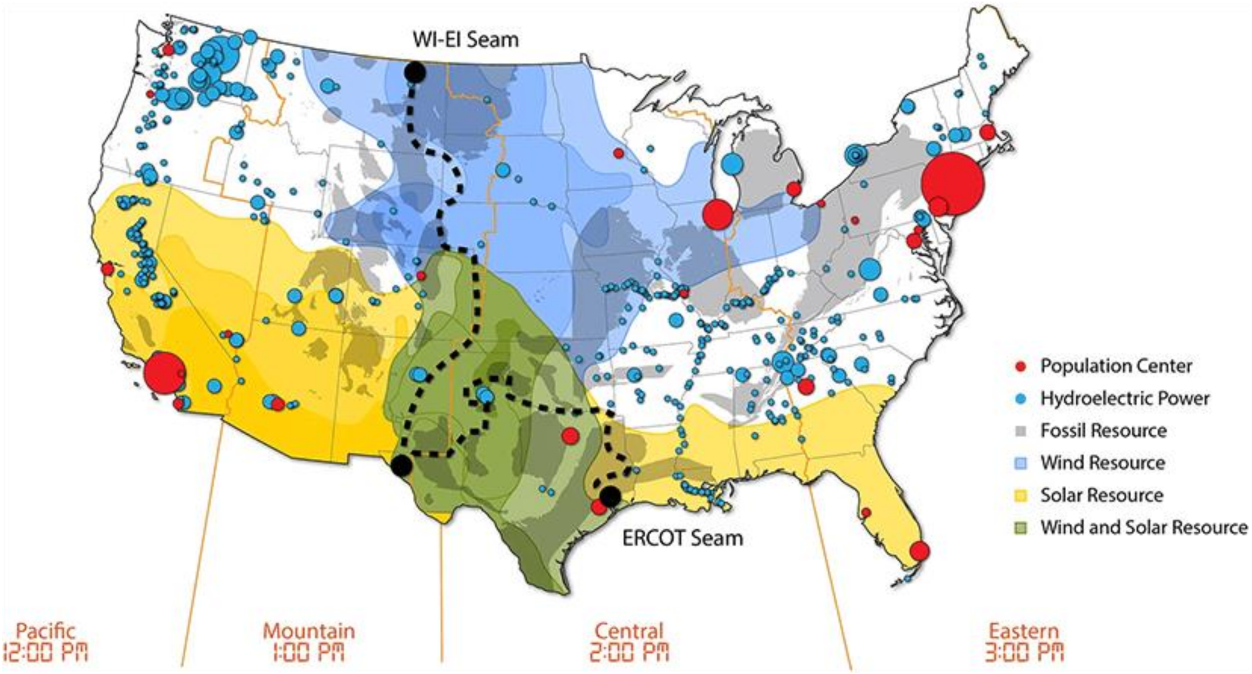


Technical studies evaluating mid-century clean energy and deep decarbonization policy objectives identify a need to develop substantially more wind and solar capacity than exists today. Renewable energy projects are most effective at generating electricity when they are located where the wind and solar resources are the highest quality—the strongest and most consistent. It is largely for this reason that the same technical analyses generally identify the development of new high-voltage transmission as a component of the least-cost decarbonization pathway, because transmission lines allow customers to access the highest quality renewables. Transmission projects themselves, however, are large infrastructure projects with potential adverse effects on private property, wildlife, cultural resources, open space, and other resources, and often have long, complex development timelines. Policymakers will have to balance the need for new transmission to support the highest quality, least-cost renewable resources with its potential adverse effects and often long development timelines.

> "**A regionally integrated power grid is critical to enabling Oregon to take advantage of out-of-state clean energy resources, export power to other states, and efficiently plan for grid reliability.** Regional grid integration will also be key to efficient decarbonization throughout the West. Early action is needed to identify how regional coordination can facilitate increasing clean energy transmission and construction of new transmission lines."
>
> — *Oregon Clean Energy Pathways Analysis* [28]

Figure 1, produced by the National Renewable Energy Laboratory (NREL), broadly illustrates the relative strength of different renewable resources across large geographic areas. Note, for example, the amount of hydropower (blue circles) in the Pacific Northwest, the strong onshore wind resources in Wyoming and Montana (shaded blue), and the strong solar resources in California and the desert southwest (shaded yellow). Note also that this map, while illustrative, is not perfect and it does not indicate, for example, the exceptional offshore wind resource located off the southern Oregon and northern California coast.[29]

Figure 1: Renewable Resources Available Across the United States[29]



Identified Need for Transmission Development

Many of the technical studies identified transmission expansion as an essential component of achieving mid-century policy objectives:

- **Oregon Pathways:** To achieve 100 percent clean energy by 2050, "a large expansion of transmission connections between Oregon and surrounding states" will be required. Specifically, the study found that Oregon would benefit from increasing transmission connections to Idaho to import onshore wind resources from the Rocky Mountain states, while increasing transmission connections to California would allow Oregon to import low-cost solar and export offshore wind.[30]
- **Washington Energy Strategy:** The state's energy strategy found that a power system that relies on solar and wind resources to meet load "will require a more robust and flexible transmission network" compared to the one that exists today, and that modeling across all scenarios points to the importance of expanded transmission across western states to lower overall decarbonization costs.[31] As a result, the state's clean energy strategy identifies investing in new transmission as a key action.[32]
- **Los Angeles 100 Study:** A study by NREL of 100 percent clean energy for the City of Los Angeles found that, across all scenarios, there is a "need for new transmission to accommodate future growth in both electricity supply and demand."[7]
- **National:** Analyses of deep decarbonization scenarios nationally "show significant increases in long distance transmission post-2030," particularly when the grid is modeled with large amounts of wind and solar that benefit "greatly from optimizing . . . over a wide geographic region."[33]

- **National:** A review of multiple national and regional studies evaluating what is required to achieve mid-century policy targets identified transmission expansion as a "priority focus area for clean electricity."[34]

Transmission projects are large infrastructure investments that require substantial capital to finance. Multiple studies not only identified a need for significant transmission development, but explicitly found those investments to be part of a least-cost pathway to achieving mid-century policy objectives in the Pacific Northwest. [35] [36] [37]

Bonneville Power Administration: 2022 Transmission Cluster Study

Bonneville POWER ADMINISTRATION

The Cluster Study process is the primary mechanism that BPA uses to process and offer service in response to customer requests for long-term firm transmission over BPA's transmission system. In 2022, BPA's Cluster Study—its largest to date—evaluated 144 requests for service representing 11,118 MW of capacity. The bulk of these requests were from solar, wind, and storage projects mostly seeking "to move renewable energy from east of the Cascades and the Mid-Columbia area to Portland and Seattle."[38]

Of those requests, BPA awarded service to 11 of them (totaling 1,046 MW) that would not require system upgrades. Another 59 (3,161 MW) would require BPA upgrades, while the remaining 74 (6,911 MW) would require BPA upgrades and third-party mitigation. [39]

The 2022 study represents a significant increase from just one year earlier in 2021. That Cluster Study only saw 116 transmission service requests filed representing 5,842 MW of capacity. The jump in requests seen in 2022 was likely driven by the adoption of aggressive clean energy policies in both Washington and Oregon. [39]

Transmission service requests to be considered in BPA's 2023 Cluster Study were submitted in August 2022. That study is expected to begin in early 2023.[38]

Process for Developing Transmission

New transmission lines can increase access to the best renewable resource areas across the western U.S. and could allow Oregon to import more low-cost solar from the south and to export more hydropower or other abundant renewables, such as offshore wind. The challenge comes not just from the cost of financing and developing these types of large, multi-state projects but also from the complicated and lengthy processes for identifying which projects are needed, siting and permitting those projects, and determining how costs will be allocated.

> "Expanding transmission . . . is a long, difficult process with many hurdles to overcome. **Early planning and determination of feasible projects and project costs should begin now to prepare for transmission in the future**. . . The needed expansion of transmission capacity will require coordination among utilities, planning agencies and governments."
>
> — *Washington 2021 State Energy Strategy: Transitioning to an Equitable Clean Energy Future* [40]

Multiple studies identified that the long development timelines for large transmission investments require near-term regional coordination and action to ensure needed projects are operational by the 2030s and beyond. [27] [36] In addition to regional coordination to identify high priority projects, stronger support will also likely be required at the state and federal level, particularly regarding streamlined permitting.[41] [42]

Traditionally, most transmission development occurs to maintain the reliability of the power system and to deliver power from individual generation projects. An additional mechanism has been used in some states to drive transmission development for policy reasons, such as to access broad geographic areas where strong renewable resources exist. Two such examples:

- **Renewable Energy Transmission Initiative (California):** In response to the adoption of clean energy and climate goals, the California Independent System Operator and multiple state agencies developed the Renewable Energy Transmission Initiative, or RETI, in 2009 to examine "where potential new renewable energy generation could be developed and assess what transmission may be needed" to deliver that power to customers. The first RETI process occurred in the late 2000s, and RETI 2.0 was designed as an update in 2016-17 following the passage of California's SB 350, which adopted more stringent policies.

  RETI 2.0 was designed to explore the emerging transmission implications of "accessing a diverse and balanced renewable energy portfolio" and the "diverse transmission system needed" to build a future grid based on renewable energy. The process was not a regulatory process, but rather a scoping exercise to identify significant transmission resources needed to achieve clean energy policies and "an overview of the potential energy, environmental, and land-use issues" that may need to be addressed if those resources are developed.[43]

- **Competitive Renewable Energy Zone (Texas):** The Texas State Legislature introduced the CREZ concept in 2005; it was approved by the Public Utility Commission in 2008 as "a means of connecting areas with abundant wind resources to more highly populated parts of the state." The concept called for developing a robust network of high-voltage transmission to "bring wind power generated atop remote western mesas to cities" in eastern Texas. Once completed in 2013, the CREZ projects included more than 3,500 miles of transmission lines capable of delivering more than 18,000 MW of power.[44]

U.S. Department of Energy: National Transmission Planning Study

In support of implementation of the Infrastructure Investment and Jobs Act, the USDOE has initiated, in collaboration with NREL and the Pacific Northwest National Laboratory, the development of a National Transmission Planning study. The NTP is designed to:

- Identify new transmission that will provide broad-scale benefits to electric customers;
- Inform regional and interregional transmission planning processes; and
- Identify interregional and national strategies to accelerate decarbonization while maintaining system reliability.

USDOE is expected to release interim results of its study in Fall 2022 before publishing its final results in Fall 2023.[45]

Different Pathways for Transmission Development

There is no single pathway to expand the transmission system to enable achievement of clean energy policy objectives. In many cases, there will be options in terms of broad strategies for transmission expansion, each with disparate impacts on individual states and stakeholders:

- **In-State vs. Out-of-State Resources:** In some cases, the best quality, lowest cost renewable resources will be located out of state, requiring transmission to deliver the power to in-state customers. The extent to which a state commits to developing this transmission could have a substantial impact on whether more or less of the renewable capacity needed to meet policy objectives is located in-state or out-of-state. **To what extent does Oregon want to identify pathways that support the in-state development of clean energy resources?**
- **Net Import vs. Net Export:** Oregon is currently a net exporter of electricity at most times of year on account of the region's abundant hydropower. As the need to develop new renewable capacity to achieve policy targets increases, this import-export balance could shift. For example, Oregon may find it cost-effective to develop more transmission to import solar from California and the southwest states during certain months, and to export a resource like offshore wind during other times of year. **Does the state have a preference about the extent to which it seeks to use clean energy exports as an opportunity to generate revenue for the state and its utilities?**
- **Distributed vs. Large-Scale Resources:** Developing distributed renewable resources can reduce the need for new transmission to deliver power from large-scale renewables. For example, as more electric vehicles are adopted in the Portland metro area, PGE may be faced with a choice of building more transmission to access large-scale renewables that can charge those vehicles, or it may have opportunities to deploy more distributed renewables and reduce the need for as much new transmission and large-scale renewables. There are, however, limitations on how much distributed resources can contribute to meeting the overall scale of system needs—due to land use constraints, challenges deploying projects on existing built structures, and conflicts with existing urban development—and this will be exacerbated as demand increases due to the electrification of end-uses. **Can the state identify a role for the contribution of distributed resources that balances the potential trade-offs (e.g., higher costs) with its benefits (e.g., resilience, avoided transmission)?**
- **Type of Renewable Technology:** Decisions about new transmission investments will be a critical factor in determining which types of renewables can be used to serve Oregon customers in the years ahead. In some cases, transmission investments can simply make it more cost-effective to deliver power from a renewable resource located in a specific area. In other cases, significant transmission investments might be a prerequisite to delivering power from a particular resource, which is likely the case with Oregon's sizable offshore wind resource. **Can Oregon stakeholders reach consensus around preferences for developing particular types of renewable resources that balance trade-offs, such as in-state land use impacts?**

For more information on the opportunities and challenges for the development of renewables and transmission in Oregon, see the Oregon Renewable Energy Siting Assessment.[46]

- **Role of Gas-Based and Thermal Resources:** The need for new transmission development will also be affected by the extent to which the state's clean energy strategy incorporates thermal power resources (e.g., gas plants powered by conventional gas or an alternative like renewable hydrogen, or nuclear power plants) and its approach to decarbonization of the fuels sector. For example, varying levels of new transmission and new renewable generating capacity may be required depending on the extent to which the transportation sector relies upon electrification versus the development of electrolytic fuels, like renewable hydrogen. A finding in a study by PGE was revealing on this point: "*Although the low electrification pathway has the lowest retail energy deliveries* [in the electric sector] *by 2050, the pathway requires the highest levels of transmission-connected renewable generation due to electric loads from producing hydrogen and synthetic natural gas.*"[1] **What role does Oregon seek for gas-based resources (using either conventional gas or renewable gas) in achieving its mid-century policy objectives?**

The state can achieve its aggressive mid-century clean energy and climate policy objectives across a range of transmission development pathways. The examples described above characterize some of these choices and their broad respective impacts. In each case, the policy objectives can be achieved, but pursuing one path over another may come with different overall costs and benefits to Oregonians and varying levels of land use impact in the state.

The state can achieve its aggressive mid-century clean energy and climate policy objectives across a range of transmission development pathways.

The Distribution System as a Resource

This section considers the contribution of resources located within the distribution system (and nearer to customers), along with an identification of the high-level trade-offs.

Identified Need for Solutions within the Distribution System

The technical studies identified a range of solutions within the distribution system that can make a meaningful contribution to achieving clean energy and decarbonization targets, including: energy efficiency, upgrades to the distribution grid, flexible demand, and distributed renewables.

Energy Efficiency

Identified as one of the four pillars of decarbonization, continued investments in energy efficiency are an important component of achieving clean energy and decarbonization policy goals. The realization of savings from efficiency, however, can result in some counterintuitive outcomes. For example, electrification of the transportation sector can result in significant *economy-wide* gains in energy efficiency because electric engines are more efficient than internal combustion engines, yet this can still result in a significant overall increase in demand for electricity. The energy efficiency savings in this case come from a reduction in societal consumption of another fuel – gasoline. These types of savings from energy efficiency will play an important role in achieving policy objectives, as will continued savings from traditional energy efficiency investments within the built environment to use electricity more judiciously. For more information on the evolution of the cost-effectiveness of energy efficiency within the electric sector, see the Policy Brief on Co-Benefits of Energy Efficiency.

Within the electric system, savings from efficiency in the building sector are expected to help offset increased electric demand elsewhere (such as from the electrification of transportation):

- **Washington Energy Strategy:** The state energy strategy recommends "deep levels of efficiency for new and existing buildings." [47] The same strategy, however, acknowledges that the "pace of stock rollover to new efficient technologies limits action" that can deliver savings by 2030, pointing to the "value of early and aggressive action to improve energy efficiency" that can reduce or avoid the need for other infrastructure investments.[48]
- **Pacific Northwest:** Continued investments in energy efficiency will be a "key strategy to reduce costs and meet goals," and can reduce the need for "new energy supply and associated infrastructure." [49] This will require significant investments in buildings – including building shell improvements and retrofits – to minimize increases to peak demand, in particular.[50] [51]
- **National:** Two broad ways to categorize sub-sectors on the demand-side are among those where decarbonization will occur through fuel switching (e.g., from using natural gas for heating to using electricity) and those where energy efficiency will be the primary mechanism. "Non-heat applications in buildings" are likely to be the areas where energy efficiency contributes the most in the building sector.[52]
- **Montana Pathways:** Savings from energy efficiency investments will offset "most of the increase in demand" associated with the electrification of space and water heating in the building sector.[53]
- **Los Angeles 100 Study:** In its study of deep decarbonization for Los Angeles, NREL found that "high levels of energy efficiency can offset" growth in electric demand in the building sector "due to hotter climate, population growth, and electrification."[7]
- **California:** One study in California compared the amount of renewable electricity required to deliver 1,000 Btu of heat to a residential customer across two different scenarios. Using an electric heat pump, about 0.1 kWh of renewable electricity would be required. But using a gas furnace to deliver the same amount of heat from synthetic clean gas would require about 1.0 kWh of renewable electricity.[54]

Distribution Grid

There are also potential investments needed in the electric distribution grid itself to accommodate the expected increase in demand for electricity from electrification. Depending on the technology pathway pursued to achieve decarbonization policy goals, the stresses on the electric distribution grid may vary. For example, a pathway that includes the production of a significant volume of electrolytic renewable hydrogen may require deploying high amounts of renewable generation and associated transmission infrastructure – but it would be unlikely to have much effect on the electric distribution grid. On the other hand, aggressive electrification of end uses, such as residential heating and transportation, would likely have more of a direct effect on the electric distribution grid.

Few of the studies reviewed explicitly considered the potential impacts on the electric distribution grid itself, but examples included:

- **Northwest:** A key challenge in the Pacific Northwest will be ensuring the winter peak demand for electricity can be met if building heating loads are increasingly electrified. This will require "significant new investments" including "an expansion of the electricity system in the form of upgraded distribution systems" in addition to more winter peak capacity generating resources.[17]
- **Seattle City Light:** The electric distribution grid of Seattle City Light "has significant capacity available for electrified load" but there will be certain times where that system may be constrained if the growth in electric demand is unmanaged.[19]
- **Los Angeles 100 Study:** The LA100 study expects that up to one-third of customers (up from 6 percent today) in single-family homes will install rooftop solar systems. The study found that "the distribution grid can manage this growth in local solar – along with the projected growth in electricity demand" from electrification. This would require "a modest number of equipment upgrades" to the distribution grid, representing only a "small fraction of the total cost of the clean energy transition."[7]

Flexible Demand

Flexible demand strategies are concerned with *when* energy is consumed.

Given the stresses that peak demands place on the power grid, technical analyses increasingly identify flexible demand as an important component of the clean energy solution. Energy efficiency investments are focused on reducing the amount of total energy consumed, while flexible demand strategies are more concerned with *when* energy is consumed. For example, the electric grid today tends to be most stressed during times of extreme weather – such as when home heating demands are high on cold winter mornings, or when air conditioning demands are high on hot summer afternoons. These conditions have always presented a challenge for the electric grid and driven the need to deploy additional capacity to accommodate these peaks. As the grid relies more on variable wind and solar output, however, these challenges are expected to become more pronounced. Deploying flexible demand technologies and strategies, particularly with large new loads (such as charging electric vehicles) added to the electric grid, can help to cost-effectively minimize increasing peak demands as more end-uses are electrified.

- **Los Angeles 100 Study:** A study of deep decarbonization scenarios in Los Angeles identified the high "value of energy efficiency and demand flexibility," finding an 8.5 percent reduction in total annual energy consumption and a 17 percent reduction in peak demand in the scenario that pursued significant efficiency and demand flexibility. In addition, the energy savings also "reduces the cumulative (2021-2045) costs of that scenario by 13 percent."[55]
- **Portland General Electric:** The shift in operational paradigm to a power system built upon variable output wind and solar "necessitates a transition to new forms of balancing resources" to integrate renewables. In particular, new sources of flexible demand will be needed,

including (a) flexible end-use loads, such as smart EV charging, and (b) flexible transmission-connected loads, such as facilities for the production of electrolytic hydrogen.[56]

- **Washington Energy Strategy:** In its state energy strategy, Washington identified a need for "structural changes" to ensure that electric resources can replace fossil fuels across the economy. Among the changes identified is the need to develop distributed resources and consumer appliances with "smart grid capabilities . . . to ensure reliability and flexibility."[32]
- **Montana Pathways:** Identified a significant increase in peak demand flexibility in its electrification scenario compared to its business-as-usual scenario – from 842 MW to 1,400 MW – driven by a conversion of water and space heating loads from natural gas to electricity.[57]

Distributed Renewables

The scale of the clean energy transition is going to require the development of a large amount of new renewable capacity. While much of this buildout will come from transmission-connected, large-scale renewable projects, there will also be a role for smaller-scale projects connected to the utility distribution grid – often called "distributed renewables." In some cases, these smaller projects have the potential to deliver unique benefits to Oregonians, including improvements to local energy resilience, avoiding land use and other environmental impacts associated with large-scale projects, providing grid services including a reduction in net demand, and creating local economic opportunities.[i] These projects may come with higher costs, however, as they will not be able to take advantage of economies of scale compared to large-scale projects. There are also likely to be physical constraints that serve as a barrier to the development of distributed renewables and limit the scale of their ultimate contribution to the clean energy transition.

The following examples illustrate the findings of the technical studies:

- **Portland General Electric:** Rooftop solar "can play a key role" in meeting clean energy targets, but its ultimate share of the generation mix in a "deeply decarbonized energy system is limited by the resource quality in Northwest Oregon" combined with anticipated increases in electric demand from electrification. Distributed solar, therefore, "reduces the need for" but does not replace the need for large-scale, transmission-connected renewables.[1]
- **Montana Pathways:** The co-optimization of distributed renewables in one of the scenarios modeled reduces peak load by 3 percent, which helps defer some distribution system upgrades and reduces total system costs.[58]
- **Los Angeles 100 Study:** In a city known for its abundant sunshine and mild weather, the LA100 study projects that between 22 and 38 percent of all existing single-family homes in Los Angeles will have rooftop solar by 2045 (up from 6 percent in 2020).[26] The contribution

[i] For more information on the benefits and opportunities associated with small-scale and community-based renewable energy projects, see ODOE's 2022 study on Small-Scale and Community-Based Renewable Energy Projects: www.oregon.gov/energy/Data-and-Reports/Pages/SSREP-Study.aspx

of these systems will still fall far short of what's required to decarbonize the Los Angeles economy.

- **Los Angeles 100 Study:** The LA100 study also evaluated the potential for developing ground-mount solar resources within the LA Basin (in addition to on rooftops in the built environment). While the study identified 4.8 GW of additional potential in this category, the model selected "only a fraction of this potential due to the overall lower costs and higher performance" of siting large-scale, transmission-connected solar projects elsewhere in the state.[59]

Why can't Los Angeles just rely on lots of rooftop solar and battery storage to reach 100%?

"The solar resource in LA is great. But putting solar on every available rooftop in LA would not be enough – even accounting for future energy efficiency upgrades. Solar is only available during daylight hours, and even if it is paired with batteries for energy storage, it remains insufficient to meet load reliably."

— *LA100: The Los Angeles 100% Renewable Energy Study*[60]

Process for Developing the Distribution Grid as a Resource

In many respects, there are already robust processes in place (or being developed) that can evaluate the need for resources located within the distribution grid to contribute to achieving policy goals. In other instances, such as with the role of distributed renewables, the process may not be as clear.

Energy Efficiency as a Resource

The Pacific Northwest has long been an industry leader in identifying energy efficiency as a resource to meet customer demand. That is, rather than investing in a new power plant, utilities have looked first to make investments in energy efficiency to reduce consumer demand. Only after achieving all cost-effective savings from energy efficiency will the utility sector look to develop new sources of generation.

The Pacific Northwest has long been an industry leader in identifying energy efficiency as a resource to meet customer demand.

According to the Northwest Power and Conservation Council, the region has realized more than 7,000 average megawatts (or more than 60,000,000 MWh) of savings from investments in energy efficiency since 1978.[61] In other words, the region's cumulative investments in efficiency offset annually the need for more energy than the entire state of Oregon consumes in a year (approximately 50,000,000 MWh in 2020).[62]

The results of the studies presented here all account for expected future savings from energy efficiency. The scale of buildout of wind and solar capacity called for in the technical analyses provides a strong reason for Oregon and the region to redouble efforts on energy efficiency in the years ahead. Every MWh saved through investments in efficiency means one less MWh of renewable generation, and its associated trade-offs, that will need to be developed to achieve clean energy and climate policy objectives.

Launching Energy Efficiency as Service in Seattle

Seattle City Light launched its Energy Efficiency as Service (EEaS) pilot with an aim to unlock deep energy efficiency in commercial buildings within its service territory. The program is a potential solution to the “split-incentive” problem. For example, a building owner might pay for the energy efficiency upgrades but they do not benefit directly from the savings as they are passed on to the tenants in the form of decreased energy bills. As a result, there is often a lack of motivation by building owners to make the necessary improvements in energy efficiency because they are not directly benefitting from their investment in these green initiatives.

SCL created the Energy Efficiency as Service pilot to directly address the issue by paying measured electricity savings over time, instead of paying up-front incentives. As a pilot, it allows the utility to test how it could lessen the split-incentive between owners and energy users to encourage greater energy efficiency. It also gains the added value of continuing to grow and learn in this space while building upon lessons gleaned from the innovative MEETS™ prototype project at the Bullitt Center.

The EEaS program’s initial goal is to execute agreements for up to 30 buildings up to the next 20 years with hope to sign 15 agreements in the initial phase of this pilot program. City Light works with participants who wish to invest in deep energy efficiency upgrades. Participants recoup their investment through the value of the energy savings from tenants who pay the energy bills as if the building had not received an energy improvement. This occurs via an energy efficiency service fee placed on the building’s energy bill. City Light uses a power purchase agreement to transfer the financial value of the energy savings to the entity responsible for financing the energy improvements.

To be eligible for the EEaS program, an existing structure much be a commercial, master-metered building that is greater than 50,000 square feet. Only exclusively electric new construction projects that pursue total building performance standard compliance with Seattle Energy Code are considered. In both cases, projects should target at least 25 percent electricity savings relative to existing operations or code expectations for new buildings. Energy efficiency service fees and PPA payments commence once more than 10 percent savings are achieved for existing buildings.

To date, the Energy Efficiency as Service program has enrolled one participant with two more applicants. Projects are targeting 30 percent of electricity savings on average. City Light looks forward to further expanding the program as building efficiency technology and initiatives continue to flourish.

Integrated Resource Planning

In the 1980s, Oregon became one of the first states in the country to require state-regulated electric utilities – Portland General Electric, PacifiCorp, and Idaho Power – to develop least-cost plans, later called integrated resource plans.[63] Some of the state's consumer-owned utilities, like the Eugene Water & Electric Board, also develop IRPs. An IRP is designed to identify a utility's need for resources in the future. Development of a plan is typically led by specialists that deploy sophisticated computer modeling tools to evaluate a range of possible future scenarios. Important inputs to this process include a forecast of future customer demand based on expected population and economic growth, the adoption of new electric technologies (such as electric vehicles), and variable weather conditions. The state's three IOUs develop IRPs for submission to the Oregon Public Utility Commission every two years. According to the OPUC:

> *The IRP presents a utility's current plan to meet the future energy and capacity needs of its customers through a* ***'least-cost, least-risk'*** *combination of energy generation and demand reduction. The plan includes estimates of those future energy needs, analysis of the resources available to meet those needs, and the activities required to secure those resources.*

The IRP process allows for utilities to better understand how a diverse suite of resources, including those located within the distribution grid can contribute to meeting the utility's future needs. The IRP process can incorporate evaluation of a wide range of potential solutions, from investments in energy efficiency or to enable flexible demand (e.g., smart thermostats), to the deployment of battery storage systems or distributed renewables.

For more information on utility resource planning, see the Resource Planning and Acquisition Energy 101.

Distribution Resource Planning

Oregon's electric utilities have always evaluated their systems to make necessary investments to maintain the operation of safe, reliable, affordable distribution systems to serve customers. Typically, these types of investments would be focused on routine maintenance or upgrades, or extension of distribution service to new customers (e.g., a new industrial load or a new residential neighborhood).

Oregon's electric utilities have always evaluated their systems to make necessary investments to maintain the operation of safe, reliable, affordable distribution systems to serve customers.

In recent years, however, technology advancements have created new opportunities for utilities to consider other types of investments within the distribution system that can optimize system efficiency and maximize customer value to contribute to meeting broader system needs. Examples include whether utilities can:

- Make more data available about where on their distribution grids there is excess capacity that could accommodate more distributed resources.

- Identify strategic investments in the distribution system that could accommodate more distributed renewables in a particular location.
- Identify a suite of non-wires alternatives (e.g., energy efficiency, storage, distributed renewables, flexible loads) that, if deployed within a particular area of the distribution grid, may allow the utility to delay or eliminate the need for some other large-scale investment, like a new transmission line.

These types of more granular planning processes focused on the distribution system are still evolving. For more background on distribution system planning, see 2020 BER – Distribution System Planning 101. [64]

For more information on the evolving distribution system planning processes of the state's investor-owned utilities, see the Oregon PUC's website: https://www.oregon.gov/puc/utilities/Pages/Distribution-System-Planning.aspx

Pathways to 2050

As with the development of new transmission and large-scale renewables, there are multiple pathways available to Oregon and the region as they consider the optimal role for resources located within the distribution grid to achieve policy objectives. For example:

- **Commitment to Energy Efficiency:** While the Pacific Northwest has long been a leader in achieving savings from energy efficiency, the Northwest Power and Conservation Council identified that savings have slowed in recent years.[65] There is an increasing interest, however, in reconsidering how the value of energy efficiency investments are assessed, including a consideration of the climate, capacity contributions, resilience, and other benefits of such investments in addition to kWh savings of energy. **How much will the region increase its efforts to maximize savings from energy efficiency in the years ahead?**

  For more information on emerging efforts to explore the diversity of benefits provided by energy efficiency investments, see the Policy Brief on Co-Benefits of Energy Efficiency.

- **Role of Distributed Energy Resources (DERs):** As identified above in the transmission pathways discussion, here again at issue will be the extent to which distributed energy resources are developed to contribute to meeting system needs. Pursuing a pathway with more or less reliance on DERs will have implications on the need to develop the distribution grid. In many cases, cost-effective development of the resources necessary to achieve policy objectives will require the deployment of large-scale resources that can capture economies of scale. In other cases, however, DERs can deliver a suite of unique benefits, such as local energy resilience and mitigation of the land use impacts of large-scale projects. **Can Oregon identify a role for DERs that can inform the need for future investments in the distribution grid?**

  For more information on the benefits and challenges associated with small-scale and community-based renewables, see the Oregon Department of Energy's 2022 study on Small-Scale and Community Based Renewable Energy Projects.

- **Competing Sources of Flexibility:** Given the changing nature of the power grid with increasing penetrations of variable wind and solar power, studies identify the need for more flexibility to manage the grid. There are numerous sources of flexibility that could contribute to meeting this need, from participation in broader regional markets, to developing more grid-connected battery storage, to incentivizing customer load flexibility programs. Depending on the relative emphasis on one flexibility solution over another will have disparate impacts on the distribution grid. **Can Oregon identify a role for different sources of flexibility to achieve its policy objectives?**

Emerging Solutions in the Electric Sector

The previous subsections addressed the anticipated growth in electric demand to meet clean energy and climate policies and explored different pathways across the transmission and distribution systems to achieve those policies. Several of the studies reviewed by ODOE also identified a need for solutions that are not currently deployed at scale, at least in Oregon, as of 2022. These emerging solutions in the electric sector include: battery energy storage, certain innovative technologies, and expanded regional energy markets.

> "The 2021 State Energy Strategy avoids reliance on yet to-be-invented technologies, but it embraces many solutions that are not yet widely deployed, such as electric and hydrogen vehicles, advanced building techniques, green hydrogen production and intelligent grid devices. **The emphasis on advanced technology is unavoidable given the ambition of the state's emissions reduction limits.** It presents an opportunity to make even more and faster progress through research and innovation, and to boost the state's economy. These efforts might yield efficiency gains or cost reductions for energy storage, nuclear power generation, geothermal energy, offshore wind, power grid control or many other technologies."
>
> — *Washington 2021 State Energy Strategy*[66]

Identified Need

An important consideration for many of these emerging solutions involves the potential complementarity of some solutions with others, but also the extent to which some solutions may compete with one another. For example, increasing the deployment of solar generation can result in surplus amounts of clean energy during certain times of the day and year. The deployment of battery storage can be a valuable complement in this circumstance, allowing the grid to maximize the use of low-cost solar power. Batteries can also be used for a multitude of other use cases, such as providing ancillary services to maintain grid stability or serving as a capacity resource to help meet periods of extreme demand. Meanwhile, flexible demand solutions can provide many of the same grid services, and several of the studies identified the competitive nature of the deployment of these resources.[67] For example, in scenarios where battery costs are assumed to be lower, the modeling selects less of a deployment of flexible demand solutions because of the overlap in the values and grid services that each technology delivers. Similarly, scenarios that model an increase in regional transmission connections can make it more cost-effective to import surplus solar power from other regions and may undercut some of the value of deploying more batteries for that purpose in Oregon.

Most the studies reviewed rely heavily on geographically diverse wind and solar projects, electric vehicles, and battery storage as core elements of achieving clean energy and decarbonization policies. But will those technologies be enough? One study reviewed found that "at least one reach technology that is not yet commercially proven is needed" to achieve 2050 policy goals, particularly in sectors that are more difficult to electrify (such as trucking and heavy industry).[68]

> "Emerging technologies will play a critical decarbonizing role. . . **it is likely that a range of technological developments will emerge to solve some of the most challenging deep decarbonization problems in the years beyond 2030.** These technologies, which include electrolysis, direct air capture, hybrid boilers, hydrogen, synthetic fuels, and carbon capture, will provide economic value for excess renewables, displace conventional gas and liquid fuels, and help balance the grid."
>
> — *Pathways to a Clean Energy Future for the Northwest: An Economy-wide Deep Decarbonization Pathways Study*[37]

Innovative Technologies

As the analysis presented earlier shows, a large amount of renewable energy requiring significant capital investment will need to be deployed to achieve policy goals. The challenge, including the costs, of supplying clean energy will vary depending on the time of year and hour of the day. For example, one megawatt of solar capacity might be able to deliver least-cost power during a sunny, mild spring afternoon. But it will be much more costly to generate and deliver the same amount of power from that one megawatt of solar capacity in the overnight hours in January. To do this would require pairing that solar with storage capabilities, and potentially building additional solar capacity, to deliver the same amount of energy.

The challenge of providing clean energy across 8,760 continuous hours of the year – 24 hours a day, 365 days a year – may necessitate the deployment of innovative technologies. Examples identified in the studies include:

- **Clean Firm Resources:** Several studies identify a need, particularly as the power system approaches higher levels of clean energy (typically beyond 80 or 90 percent), for innovative clean firm capacity[ii] resources that can maintain reliability during times of high demand and/or during times of low availability of wind and solar output. Oregon, and the Pacific Northwest, may have less of a need for these types of resources than some parts of the country on account of the scale of its existing, flexible, carbon-free hydropower system that can help to integrate large amounts of wind and solar.

[ii] Firm capacity refers to the capability of a generating resource to guarantee its availability to produce a certain amount of energy at a specific time. Most firm capacity in the northwest has historically been provided by hydropower and fossil power plants.

The following examples were identified as possible clean firm solutions that may play a role in achieving 2050 policy objectives:

- *Advanced Nuclear*: A major breakthrough in costs is likely needed,[69] but advanced nuclear (such as small modular reactors, of the type developed by Oregon-based NuScale Power) is one potential source of clean firm capacity.[34 70]
- *Renewable Gas*: Another option is the use of renewable gas (e.g., biofuels or renewable hydrogen) in combustion turbines.[70 34 55] These technologies could operate much like the conventional, dispatchable gas power plants in operation today except that their fuel source would be renewable. In its *Vision 2050*, NW Natural identified its facility in Mist, Oregon as providing "20 billion cubic feet of underground storage capacity . . . [or] 6 million MWh of renewable energy storage capability" that could be used to store renewable gas.[71]

> "Today, the cheapest option for this peaking capacity *[in a 100 percent clean energy power system]* is storable renewable fuel used in a combustion turbine. . . *[Los Angeles]* can produce its own clean fuel in the form of hydrogen (produced from renewable electricity). This option is not yet commercially available at scale, so building the necessary infrastructure **could represent a significant portion of total costs associated with the clean energy transition**."
>
> — *LA100: The Los Angeles 100% Renewable Energy Study*[55]

- *Fossil Gas with Carbon Capture*: Another low-carbon firm capacity solution identified in some studies is the continued use of natural gas power plants paired with carbon capture and sequestration.[69 70]

> "Despite the declining costs of variable renewable energy (VRE) and short-duration battery storage, multiple studies have concluded that some amount of firm energy and capacity will be necessary to reliably meet load and maintain stable grid operations in a deeply decarbonized power system. Where a small amount of gross emissions are allowed in the power sector, firm energy needs are typically met with natural gas combustion turbines. **When a zero emissions constraint is applied, firm capacity needs are met with technologies that are not yet commercial at a large scale today if available in the model.** These include advanced nuclear, natural gas with carbon capture and sequestration (CCS), combustion turbines fueled with renewable natural gas or hydrogen, and multi-day, or seasonal energy storage resources."
>
> — *Pathways Toward Carbon Neutrality: A Review of Recent Mid-Century Deep Decarbonization Studies for the United States*[72]

- **Offshore Wind:** The offshore wind resource off the southern Oregon coast is among the highest quality wind resource areas in the world. But to capture that renewable resource for the power grid requires further development of innovative floating offshore wind turbines because of the ocean depths off the Oregon coast. Two of the more recent studies reviewed – *Oregon Clean Energy Pathways* (2021)[73] and the *Washington State Energy Strategy* (2021)[74] – both identified the need to deploy offshore wind resources beyond 2040 to achieve policy goals. One of those studies noted that the level of offshore wind deployment that would be beneficial to achieving policy targets "would require a rapid scale-up of new supply chains and production capacity."[75]

For more information on the challenges and opportunities associated with floating offshore wind in Oregon, see ODOE's 2022 report on Floating Offshore Wind.[76]

- **Automated Load Flexibility:** Flexible loads were identified above as a potential clean energy solution within the distribution system. Maximizing the effectiveness of these strategies may require the flexibility to be automated to align with dynamic grid conditions. This will likely require "investments in information and communication technologies"[77] and market transformation to support flexible load integration.[34] One potential large source of flexible loads is likely to come from electric passenger vehicles and trucks charged at home.[67]
- **Advanced Transmission Technologies:** One of the studies reviewed specifically identified a need to develop "advanced transmission technologies, such as flexible AC transmission systems," that can maximize the use of existing transmission assets.[77]
- **Long Duration Energy Storage:** Most battery storage systems currently being deployed in the power sector can discharge power at full output over 2 to 8 hours of duration. Some studies have identified a need to develop and deploy long-duration energy storage technologies to achieve policy goals as the power system approaches 100 percent clean energy.[69] [27] [70] Typically, this refers to technologies that can discharge energy over a duration of 10 to 100 hours, but sometimes is used to refer to storage technologies that operate on a seasonal timeframe (e.g., storing excess solar power from the summer months so that it can be used in the winter months).

  Learn more about long-duration energy storage in the Energy 101 section of this report.
- **Continued Wind & Solar Advancements:** Across most of the studies reviewed, there is an expectation of a significant deployment of wind and solar technologies. One study focused on the need for innovation to achieve clean energy policies and cautioned that ongoing research & development "should not be deprioritized" around those technologies simply because cost reductions have already occurred. The study continues: "In a low-carbon economy, a large portion of energy services are ultimately provided by renewable electricity, which means that even modest cost reductions have large impacts on total costs."[78]

Battery Storage

Battery storage is being deployed rapidly on the power grid in some parts of the country (like California), arguably taking it out of the category of an emerging solution in the electric sector. But battery storage has yet to be deployed at scale in Oregon and the Pacific Northwest. The deployment of battery storage systems alongside wind and solar generation has been identified as a "near-term, no-regrets option" to help achieve aggressive clean energy goals.[77] The following are examples of the identified need for battery storage in the studies reviewed:

- **National:** A review of multiple studies nationally identifies a dramatic increase in wind and solar capacity "accompanied by the deployment of 4-hour and 8-hour battery storage capacity in order to avoid curtailment" of renewables and to balance the grid.[27] Short duration storage is identified as a focus area for deployment.[34]
- **Los Angeles 100 Study:** Wind and solar resources will be "fundamental to providing the majority of energy required" to meet future energy demand and will be "enabled by storage."[79]
- **National:** By 2050, the average duration of energy storage deployed on the grid is 6 to 7 hours and modeled scenarios "build more storage early" when wind and solar are deployed at a faster rate. The amount of battery storage on the system, however, is "extremely sensitive to the amount of flexible end-use load" that is assumed to be available, while an elimination of flexible demand "approximately doubles the amount of storage" necessary.[80]
- **Portland General Electric:** In its deep decarbonization analysis, PGE found that the shift to a power grid dominated by wind and solar "necessitates a transition to new forms of balancing resources," including energy storage which can complement traditional sources of flexibility. The study notes, as do others, that the exact portfolio of available balancing options will depend upon specific pathways chosen to develop a clean energy economy.[56]

Siting Snapshot

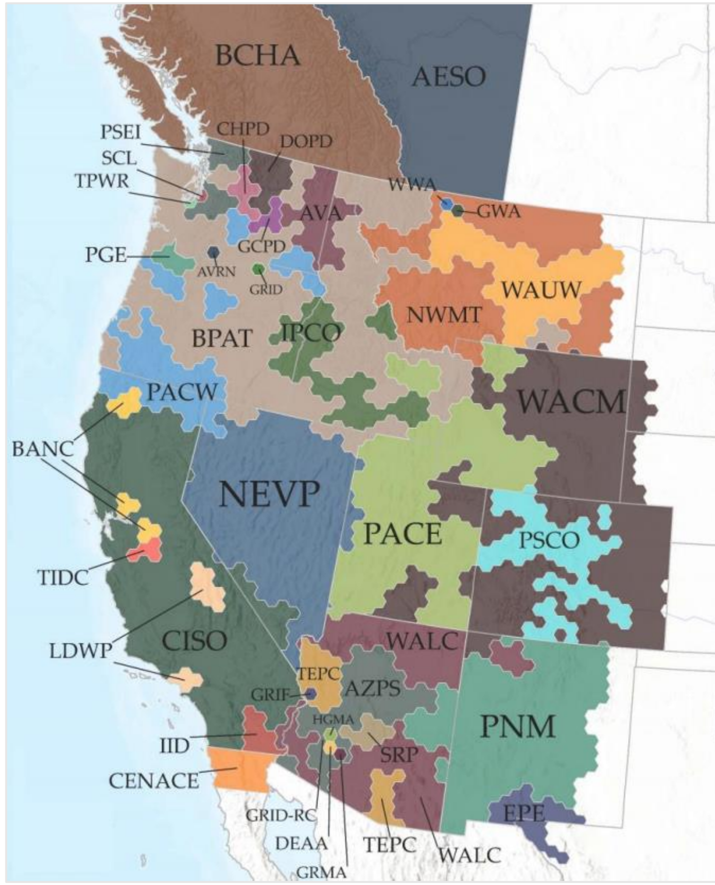

Wheatridge Facilities (PGE)

The Energy Facility Siting Council, staffed by the Oregon Department of Energy, plays a role in approving utility-scale storage when batteries are proposed for major natural gas, wind, solar, or wind and solar projects. So far, storage has been proposed as an addition to existing EFSC-approved facilities and as part of new applications.

The first project proposed to include storage was Obsidian Solar Center in Lake County, whose developers included storage in the Notice of Intent in January 2018. That project was approved in February 2022 and is not yet operational. The first project to be approved with storage was Wheatridge Wind Energy Facility in 2018 – an existing facility that has since become four separate facilities. Three of the now-four facilities have been approved to add a total of 150 MW of storage.

Regional Energy Markets

Currently, most electricity in the Pacific Northwest is exchanged through bilateral markets between utilities or Balancing Authorities (BAs). Similarly, the region's transmission system is operated by individual transmission owners, requiring projects to pay separate charges (often referred to as "wheeling" charges) to deliver power across each transmission system. There are approximately three dozen BAs currently operating across the western United States, with each responsible for balancing supply and demand within their footprint:[81]



BPAT: Bonneville Power Administration
PACW: PacifiCorp
PGE: Portland General Electric
IPCO: Idaho Power
CISO: California ISO

Most of the studies reviewed, whose scopes were statewide or regional in nature, note that the technical models used to conduct the study assumed that these separate BAs did not exist. Instead, as described by the *Oregon Clean Energy Pathways* study, "the modeling examines how the electricity grid could be decarbonized at lowest cost if existing resources were dispatched and new resources were built optimally within a single balancing area across the western United States."[82] The *Washington State Energy Strategy* similarly assumed "efficient dispatch [of generators], akin to a single balancing authority for the western grid."[36] With the status quo, each BA on the map balances supply and demand within its footprint. If the BA anticipates a deficit, it will enter into a bilateral agreement with another BA to purchase power – or to sell power in cases of surplus. This process of using bilateral agreements cannot capture the maximum economic efficiencies that would be possible to achieve through a centralized economic dispatch that optimizes supply and demand across multiple BAs.

The *Oregon Pathways* study continued by describing the need for regional grid integration as a "critical requirement" for "achieving the lowest cost regional decarbonization portfolio."[83] A regionally integrated grid would enable Oregon to better take advantage of low-cost out-of-state renewables (e.g., solar from the desert southwest), to export its own power to other states across the west, and to efficiently plan for a reliable decarbonized power grid.[28]

> "Increased grid integration and transmission between the Northwest and California is cost-effective. **Significant cost savings can be realized if the Northwest and California electric grids are expanded and operations are better integrated.** Building additional transmission lines between the Northwest and California electricity grids could reduce the costs of decarbonization by an estimated $11.1 billion in net present value over the 30-year study period accrued to the combined California and Northwest region."
>
> — *Pathways to a Clean Energy Future for the Northwest: An Economy-wide Deep Decarbonization Pathways Study* [37]

Steps toward increased regionalization have been occurring, and are continuing to develop, in the Pacific Northwest. The *Washington Strategy* concludes that, while some stakeholders "advocate for creation of a regional transmission organization," the owners of the region's transmission resources (e.g., BPA and various electric utilities) are "in the best position to advance this work and build on recent progress."[40]

For more information on regional transmission organizations and an overview of Oregon stakeholder perspectives on the same, see ODOE's *Regional Transmission Organization Study: Oregon Perspectives*.[84]

Update: Evolving Wholesale Electricity Markets

In the 2020 Biennial Energy Report, ODOE published a policy brief on *Evolving Wholesale Electricity Markets*.[85] Those markets have continued to evolve over the last two years, with highlights including:

- **BPA joins the Energy Imbalance Market (EIM):** After engaging with its customers for several years, BPA joined the EIM in May 2022. According to BPA, it anticipates that its participation will help to "optimize surplus capacity and load service, providing operational and economic benefits for surplus power and savings on short-term purchases."[86]
- **Benefits of the EIM:** In 2020, ODOE reported on the cumulative gross benefits through Q3 2020 (total gross benefits at the time had just recently exceeded $1 billion). Through Q3 2022, the EIM now reports the following benefits:[87]

Table 1: EIM Participants and Cumulative Gross Benefits (Through Q2 2022)

EIM Participants	Cumulative Gross Benefits ($ Millions)
PacifiCorp (Oregon + Non-Oregon)	$537.53
Portland General Electric	$175.96
Idaho Power	$160.80
Bonneville Power Administration	$13.43
Non-Oregon Participants	$2,024.44
TOTAL BENEFITS SINCE 2014:	**$2,912.16**

- **Extended Day-Ahead Market:** As discussed in the 2020 BER, this would extend the California Independent System Operator's day-ahead market to EIM participants. According to CAISO, EDAM will "improve market efficiency by integrating renewable resources using day-ahead unit commitment and scheduling across a larger area." The current schedule for implementation of EDAM follows:[88]
  - **September 2022** – Draft EDAM Tariff framework published
  - **November 2022** – Draft EDAM Tariff published
  - **December 2022** – Final EDAM proposal published, and a vote is expected by the joint CAISO Board of Governors and EIM Governing Body

  After the creation of EDAM, current participants of EIM will be able to choose whether to voluntarily participate in EDAM or not.

- **SPP Markets+:** The Southwest Power Pool, based in Little Rock, Arkansas, is another regional transmission organization, like CAISO, that also operates day-ahead and real-time markets for the wholesale transaction of electricity. In February 2021, SPP extended its real-time market – named the Western Energy Imbalance Service (WEIS) market – to entities in the west (primarily to utilities located in Colorado, Wyoming, and portions of northern Montana).[89]

  In addition to the WEIS market, SPP is also offering what it calls Markets+. Markets+ is a conceptual bundle of services that would "centralize day-ahead and real-time unit commitment and dispatch" and "provide hurdle-free transmission service" across its footprint. SPP describes this suite of services as delivering some of the value of expanded regionalization for those utilities not "ready to pursue full membership in a regional transmission organization."[90] SPP released its Draft Service Offering for Markets+ on September 30, 2022.

  At this time, no utility operating in the Pacific Northwest is participating in either SPP's WEIS market or in Markets+.

- **Western Resource Adequacy Program:** While the maintenance of resource adequacy does not suggest an evolution of wholesale electricity markets, per se, an adequate power system is a foundational pre-requisite for the operation of healthy wholesale markets.

  At the request of several stakeholders across the west in 2019, the Western Power Pool (formerly the Northwest Power Pool) initiated development of the Western Resource Adequacy Program to address the "urgent and immediate challenge" of maintaining resource adequacy across the west.[91] It has since been designed to deliver a region-wide approach for "assessing and addressing resource adequacy" to ensure regional reliability of the power system. By working together, the intention is to find opportunities for savings and using fewer resources compared to each Balancing Authority across the west maintaining resource adequacy on its own.

  The Board of the Western Power Pool approved the WRAP's Tariff in August 2022 and filed it with the Federal Energy Regulatory Commission for approval.[92] It is anticipated the FERC will make a decision on approval by the end of the year. Meanwhile, in September 2022, current participants in WRAP made their first non-binding filings of data, including Winter 2022-2023 and Summer 2023 forward-showing submittals.[93]

Process for Pursuing Emerging Solutions

The range of emerging solutions that could make a meaningful contribution to achieving Oregon's clean energy and climate policy objectives are likely to be developed through numerous processes. In some cases, additional research and development of a particular technology may still be required, perhaps necessitating involvement by the federal government. This is likely the case with several of the innovative technologies identified, such as clean firm resources or long-duration energy storage technologies.

In other cases, such as increasing regional coordination, utilities have already taken steps in recent years and other efforts are currently being explored. A combination of utility interest, combined with stakeholder advocacy and state policies, is likely to continue to encourage increased regional collaboration in the years ahead.

And in yet other cases, such as with some types of innovative generation, like offshore wind, or with battery storage, utility planning efforts are likely to identify the need for these types of resources. In some cases, there may be opportunities for state policies (such as HB 2193,[94] which mandated the procurement of battery storage by PGE and PacifiCorp) or regulators to require the pursuit of particular solutions, though customer cost impacts are an important consideration.

One of the near-term challenges will be to clearly identify the required emerging solutions to optimally achieve the state's policies objectives by mid-century, and then to work backwards to define processes and timelines that ensure those resources can be planned for and developed in alignment with those policy objectives. Depending on the type of emerging solution that is identified as necessary, policymakers may have options to advance those solutions through regulation, incentives, or stakeholder and public education.

Depending on the type of emerging solution that is identified as necessary, policymakers may have options to advance those solutions through regulation, incentives, or stakeholder and public education.

Pathways to 2050

At this juncture, it is not yet certain which emerging solution (or solutions) might be required for Oregon to achieve its mid-century clean energy and climate policy objectives. But, as several of the studies noted, it is probable that at least one of these solutions will be necessary.

As Oregon considers potential pathways to achieve its policy objectives, it must evaluate these types of issues when assessing emerging solutions:

- **The Role of Dispatchable Gas Generation:** Some of the studies find that the most cost-effective, deeply decarbonized energy system relies on some residual amount of gas power generation (which could be fueled by conventional natural gas or a renewable gas alternative) to maintain system reliability during extreme conditions. **Given these types of findings, how should the state view the need for gas infrastructure in the near-term?**

- **Need for Innovative Technologies:** Particularly in scenarios where gas generation is phased out or severely limited, Oregon may be reliant on the development of one or more innovative technologies to maintain power system reliability. **What role should the state play in supporting or pursuing the development of these types of innovative technologies?**
- **Sources of Flexibility:** Several studies identified that both battery storage and flexible demand may be necessary elements of the clean energy transition, but that they also compete with one another in certain respects to help provide system flexibility to integrate large amounts of wind and solar generation on the grid. Developing more transmission can also provide increased flexibility through greater use of regional transfers. **How should the state balance its support for the development of different types of flexibility?**
- **The Effects of Increased Regionalization:** Multiple studies identify increased regionalization as a critical requirement to achieving the most cost-effective decarbonization of the electric grid. This may incur trade-offs, however, such as less development of certain types of energy resources in Oregon. **How should the state balance support for increased regionalization against potential trade-offs that regionalization may incur?**

Conclusion

The studies reviewed by Oregon Department of Energy staff universally find that an increasingly clean electric sector will play a dominant role in achieving mid-century clean energy and climate policy objectives. The scale and pace of the investments required are enormous, they must accelerate now, and they must be sustained for decades.

Oregon has significant opportunities to develop an intentional pathway to achieve its policy objectives in a way that balances trade-offs and meets the needs of Oregon stakeholders and communities.

But importantly, Oregon has significant opportunities to develop an intentional pathway to achieve its policy objectives in a way that balances trade-offs and meets the needs of Oregon stakeholders and communities. The state has opportunities, for example, to evaluate the extent to which it seeks to rely on distributed resources, whether to maximize the development of a particular type of renewable or to develop a diverse portfolio of resources, and to identify which innovative technologies may be required.

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Policy Brief: Charting a Course for Oregon's Energy Future

Part III: Natural Gas Sector

This section is part of a Policy Brief exploring the pathways available to Oregon in the decades ahead to achieve its clean energy and climate change policy objectives, and is based on a review of 20 technical studies published in recent years.

Those studies coalesce around four common strategies, or pillars of decarbonization, required to achieve these policies: energy efficiency, electrification of end-uses, clean electricity supply, and low-carbon fuels. While these pillars provide the foundation for achieving policy objectives, policymakers must consider the trade-offs among a range of specific technology pathways to transform the state's energy systems by 2050.

Conventional gaseous fuels, including natural gas and propane, play important roles in Oregon's energy system. In the electric sector, natural gas-fired power plants provide needed flexibility to the grid and help to maintain reliability. Natural gas is also delivered to consumers across the state for "direct use" in buildings and industrial processes. Many homes and businesses rely on natural gas (and to a lesser extent, propane) for space and water heating, cooking, and to fuel other gas appliances and systems. Industrial facilities often use natural gas to generate heat and/or power for industrial processes. But while natural gas has historically served as a reliable and affordable energy source, it is primarily comprised of methane, a potent yet relatively short-lived greenhouse gas that has more than 80 times the warming potential of carbon dioxide (CO_2) over a twenty-year period. (Methane's global warming potential declines to about 25 times that of CO_2 over a 100-year timeframe, though individual methane molecules only survive in the atmosphere for around 12 years.) When combusted, natural gas emits CO_2 and other harmful air pollutants.[1] In 2019, natural gas combustion produced 14 percent of Oregon's annual greenhouse gas emissions.[2]

To achieve its mid-century climate goals, Oregon must substantially reduce emissions from natural gas combustion. Two recently adopted state policy frameworks—the 100 percent clean electricity standard established by HB 2021, and the Climate Protection Program administered by the Oregon Department of Environmental Quality—require steep reductions in emissions from electricity generation and direct use natural gas in the coming decades. Achieving these mandatory emissions reductions in a manner that ensures all Oregonians have equitable access to reliable and affordable energy will require coordinated action by regulators and utilities, with guidance and input from consumers, stakeholders, and community members.

To achieve its mid-century climate goals, Oregon must substantially reduce emissions from natural gas combustion.

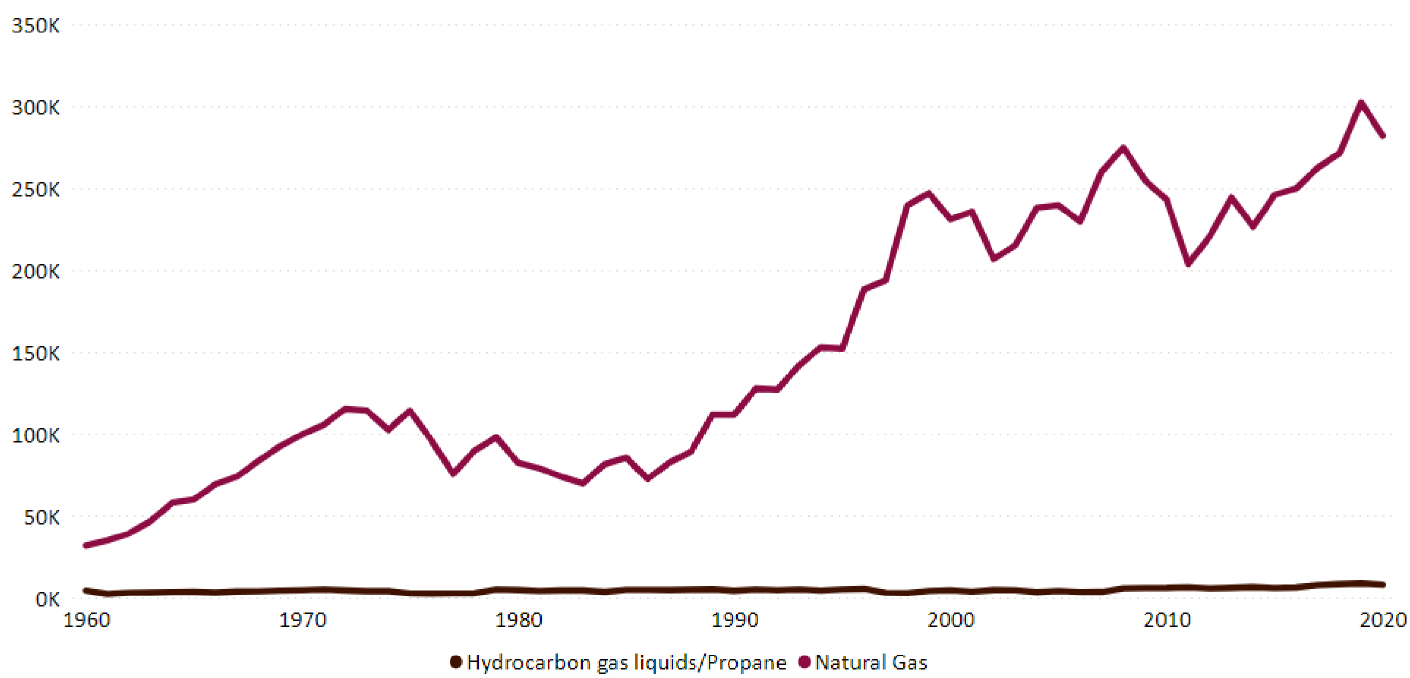
The studies reviewed for this policy brief series commonly identify three key strategies for reducing emissions from natural gas: 1) decrease the quantity of gas consumed through conservation and energy efficiency improvements, 2) reduce reliance on direct use gas through electrification of building systems and components, and 3) transition from fossil gas to low- or zero-carbon alternative fuels. Each of these strategies presents unique challenges, opportunities, trade-offs, and uncertainties. Moreover, it is likely to be more difficult to electrify some uses of dispatchable gaseous fuels, and in those circumstances the most cost-effective pathway to decarbonization may be through using existing gas infrastructure to carry low-carbon gaseous fuel like renewable natural gas.

Oregon has an opportunity to engage the public to find the right balance between replacing gas end uses and continuing to use existing gas infrastructure in innovative ways to achieve its clean energy and climate policies. Drawing from recent studies, this policy brief describes the role that natural gas currently plays in Oregon's energy system; explores pathways to decarbonizing natural gas through a combination of energy efficiency, electrification, and low-carbon alternative fuels; discusses the cost and equity implications of these decarbonization strategies; and explores key policy considerations and tradeoffs associated with these strategies.

The Role of Natural Gas in Oregon

Natural gas is the primary focus of this brief, but most of the decarbonization strategies reviewed could also apply to propane. Natural gas consumption volume and applications far outpace propane, as shown in Figure 1. Total natural gas consumption (in billion British thermal units) in the chart includes fuels used for electricity generation, and the residential, commercial, industrial and transportation sectors.

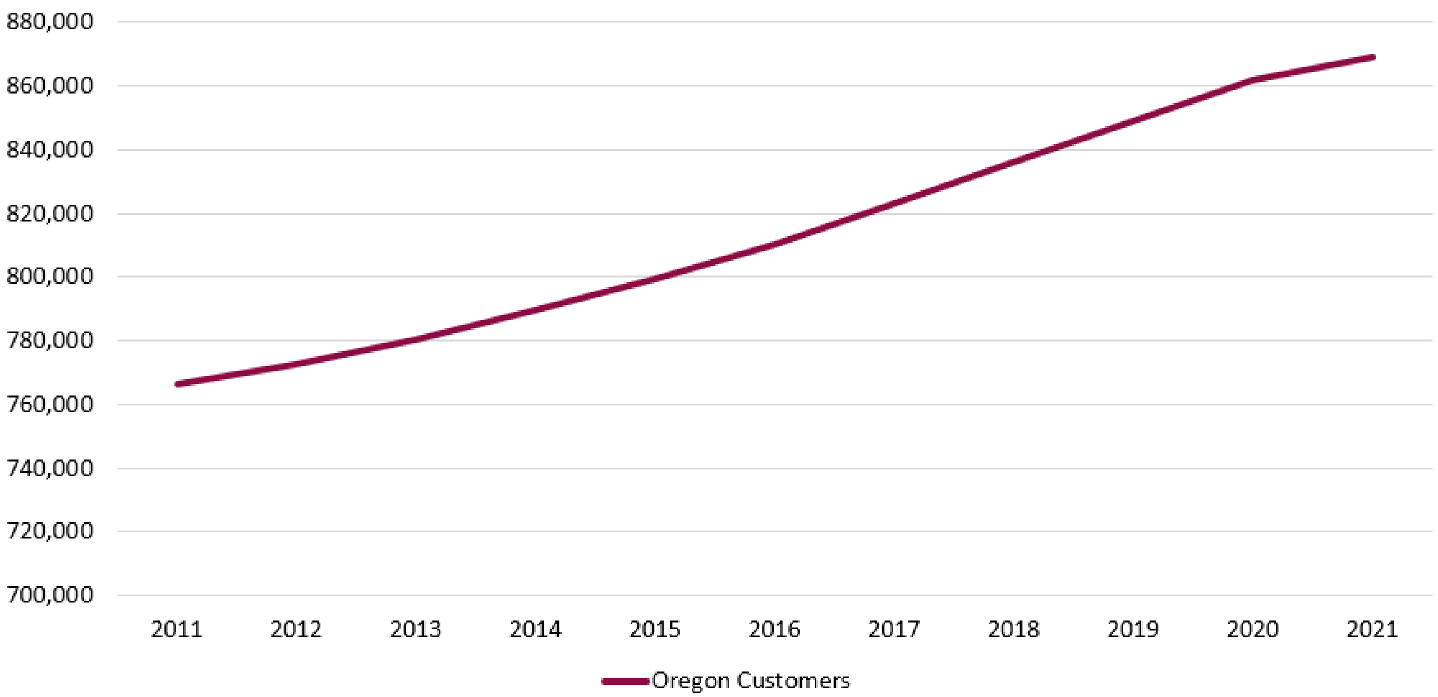
Figure 1: Total Natural Gas and Propane Consumption 1960 – 2020 (Billion Btu)[3]



Consumption of natural gas in Oregon has increased significantly in recent decades. Figure 1 shows Oregon's aggregate consumption of natural gas and propane from the electricity, residential, commercial, industrial, and transportation sectors between 1960 and 2020. Oregon consumed 282 trillion Btu of natural gas as a direct use fuel in 2020, an increase of three percent from the 275 trillion

Btu Oregon consumed in 2008.[3] In 2019, natural gas use produced an estimated 9 million metric tons of CO_2 equivalent emissions ($MTCO_2e$), or 14 percent of Oregon's total emissions.[2] Figure 2 shows that the total number of natural gas retail customers in Oregon has steadily increased over the last decade; in 2021, there were approximately 870,000 retail gas customers in the state. Learn more about natural gas and propane consumption in Oregon in the Energy by the Numbers section of this report.

Figure 2: Total Natural Gas Retail Customers in Oregon 2011–2021[4]



Electric utilities are also using more natural gas. Total consumption by Oregon's electric power sector increased from 119 trillion Btu in 2008 to 137 trillion Btu in 2020, an increase of 15 percent.[3] Natural gas has been a low-cost generation resource that helps utilities meet load growth with fewer greenhouse gas emissions and other air pollutants than coal. Natural gas plants are also able to play different roles in grid management, including serving as steady baseload power generators and acting as highly flexible generators that can ramp up and down quickly to meet constantly changing electricity demand.

Recent Trends: Natural Gas Consumption for Electricity Generation

- Economic and population growth have driven Oregon's total annual electricity consumption to increase from 47 million MWh in 2012 to 54 million MWh in 2020.[5]
- Electricity generation from coal plants decreased from 33 trillion Btu in 2011 to just under 17 trillion Btu in 2020.[3]
- Natural gas demand varies year to year because demand is highly dependent on natural fluctuations in the Pacific Northwest's annual precipitation and corresponding hydropower production.
- Flexible natural gas generation is often used to respond quickly to increases in electricity demand and support the variability of renewable energy resources such as solar and wind.

Oregon Natural Gas Facts

- The natural gas industry supports an estimated 46,100 jobs in Oregon[6]
- In 2020, Oregon consumed 59 trillion Btu of natural gas in the industrial sector, second only to electricity generation.[3]
- Industry uses gaseous fuels for process heat, combined heat and power, and as a feedstock for fertilizer.[7]
- In 2020, Oregon consumed 7 trillion Btu of natural gas as a transportation fuel.[3]

The Natural Gas Market

Oregon is highly dependent on natural gas resources from other states and Canada. In 2020, the state's only natural gas resource, the Mist facility in Columbia County, produced the equivalent of 0.12 percent of Oregon's total natural gas consumption.[3] Most of Oregon's natural gas is imported from the U.S. Rocky Mountain region, northern Alberta, and Northern British Columbia. (Learn more in the Transportation Fuels 101 in the *2020 Biennial Energy Report*.)

The rapid development of liquid natural gas export terminals around the world has implications for the future of low-cost natural gas, as the commodity will be subject to the effects of a more global marketplace. Global trade of LNG increased 4.5 percent in 2021 and more growth is expected, with the United States as the world's largest exporter and China as the largest importer.[8 9] Oregon natural gas utilities have contracts with producers, but increased demand and capacity to distribute natural gas globally will influence future prices. The Russian invasion of Ukraine in 2022 lead to European policies that limit or prohibit purchases of Russian natural gas, resulting in an increasing demand for LNG from the United States.[10] Global supply and demand will have an increasingly larger effect on the affordability of natural gas in Oregon.[11 12]

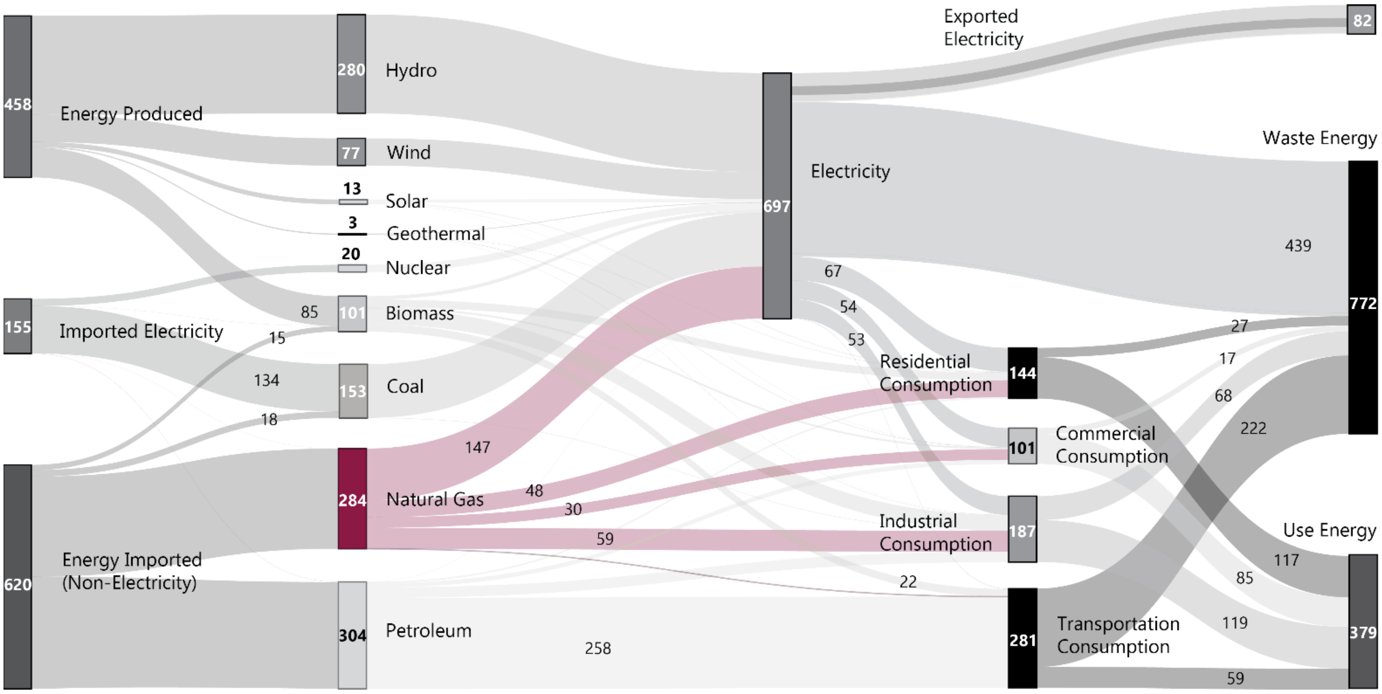
Natural Gas Alternatives

As Oregon seeks to meet its climate and energy goals, there is interest in identifying alternatives to natural gas in both direct use applications and electricity generation. Strategies for reducing emissions from natural gas used in commercial or residential spaces largely focus on either electrifying the end uses or supplementing or replacing natural gas with lower carbon fuels, such as renewable natural gas or hydrogen. Similar options exist in many industrial sectors, including using waste process heat to generate electricity, heat water, or conserve energy through other mechanisms. Electrification, the replacement of existing natural gas equipment with electric equipment, is another strategy identified in the analyses.

Through the adoption of HB 2021 in 2021, Oregon legislators signaled a shift away from new natural gas electricity generation, prohibiting the siting of new gas plants in the state. Replacing the flexibility and low-cost of natural gas for electricity generation will be a challenge. While utilities are beginning to invest in battery storage to help balance variable renewable energy generation and meet system load needs, most of the reviewed studies concluded that some dispatchable capacity will still be needed to meet demand and maintain stable and reliable electrical grid operations.[13] Alternative fuels like renewable natural gas and hydrogen are also being investigated as potential alternative fuel replacements for fossil natural gas in the electricity sector. Many of the studies reviewed conclude natural gas will be replaced or supplemented by increasing volumes of alternative low-carbon gaseous fuels by 2050.

Exploring Pathways to 2050

Figure 3: How Natural Gas Moves Through Oregon's Energy Flow[i]



Numbers are in trillions of British thermal units.

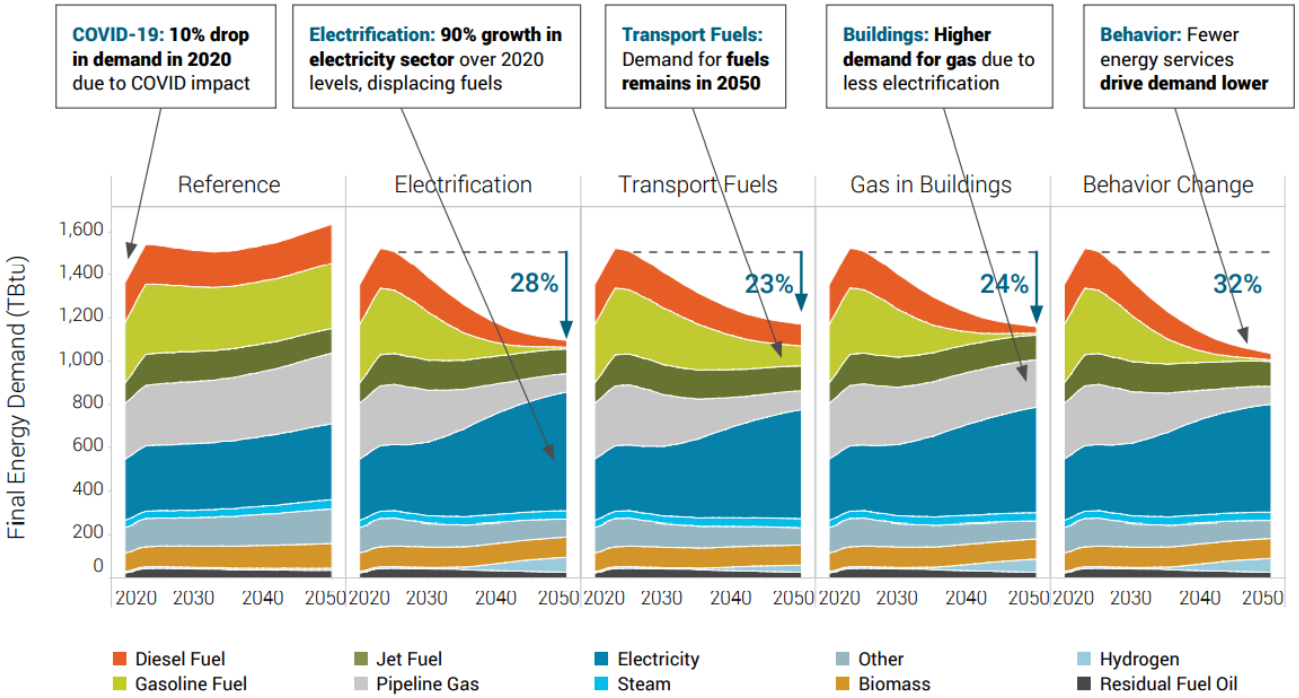
There are many pathways to reduce emissions in the natural gas sector, including increasing energy efficiency, converting natural gas end uses to electricity, or transitioning to lower carbon alternative fuels. Energy efficiency improvements to buildings and industrial applications can reduce emissions by decreasing the amount of natural gas needed to fuel building systems and processes. Electrifying appliances and building systems, such as replacing natural gas furnaces with high-efficiency electric heat pumps, can reduce emissions by eliminating the need for natural gas as a direct use fuel. Low-carbon alternative fuels, such as renewable natural gas and hydrogen, and potentially new carbon capture and sequestration technologies, can reduce emissions while continuing to use existing natural gas infrastructure. A combination of some or all of these strategies is necessary for Oregon to achieve its mid-century climate policy goals.

Decarbonization studies consistently identify the need to address emissions from natural gas use but vary on their recommendations of which strategies to use and to what degree. The National Renewable Energy Laboratory modeled the resources needed for Los Angeles to meet a 100 percent renewable electricity target by 2045, and many of the scenarios modeled included replacing natural gas for electricity generation with hydrogen and renewable natural gas.[14] The Washington State Department of Commerce modeled several scenarios for decarbonizing the state's economy by 2050,

[i] Learn more about Oregon's energy flow in the Energy by the Numbers section of this report.

including a scenario in which overall energy demand is reduced through energy efficiency improvements and electrification. The results of Washington's decarbonization scenario analysis are illustrated in Figure 4. The state's "Gas in Buildings" scenario retained the most continued use of conventional gas fuels, with a greater use of low-carbon alternative fuels for transportation and increased use of renewable natural gas in buildings. While the scenario achieved the state's GHG reduction goal, its projected costs were higher than the costs of other scenarios modeled. However, the gas in buildings scenario offered some added benefits by allowing for continued use of existing conventional natural gas infrastructure.[15]

Figure 4: Washington Energy Strategy Decarbonization Scenarios, Final Energy Demand 2020-2050[15]



In most studies reviewed for this brief, continuing to use some amount of gas power plant capacity—whether powered by natural gas (with or without carbon capture) or by lower carbon fuels—is an essential tool for maintaining a reliable power system and supporting high amounts of renewable energy. Studies differ on the amount of natural gas remaining in the system by 2050, whether and how much renewable natural gas or hydrogen will be needed, and the cost effectiveness of different actions, but for many studies the most cost-effective scenarios include continued use of existing gas infrastructure to some extent.

> "**[N]o Energy and Environmental Economics, Inc. (E3) study has yet identified a strategy that eliminates the use of pipeline gas altogether**, since zero carbon gas alternatives can replace natural gas in the pipeline. Every scenario leaves residual gas demands in industry, while others allow gas usage in the buildings or transportation sector."
>
> — The Challenge of Retail Gas in California's Low-Carbon Future[16]

Energy Efficiency

Reducing consumption of gaseous fuels through improved efficiency is one of the simplest and most cost-effective decarbonization solutions available. Natural gas and propane are used for space and water heating and cooking in Oregon's built environment, as well as for a variety of industrial applications. Improving the thermal envelope of buildings and the efficiency of appliances reduces the amount of gas needed to support building functions, while also reducing energy costs and preserving occupant comfort benefits.[ii] [17] All natural gas utilities in Oregon have identified reductions in natural gas consumption that can reduce overall system demand through 2040.

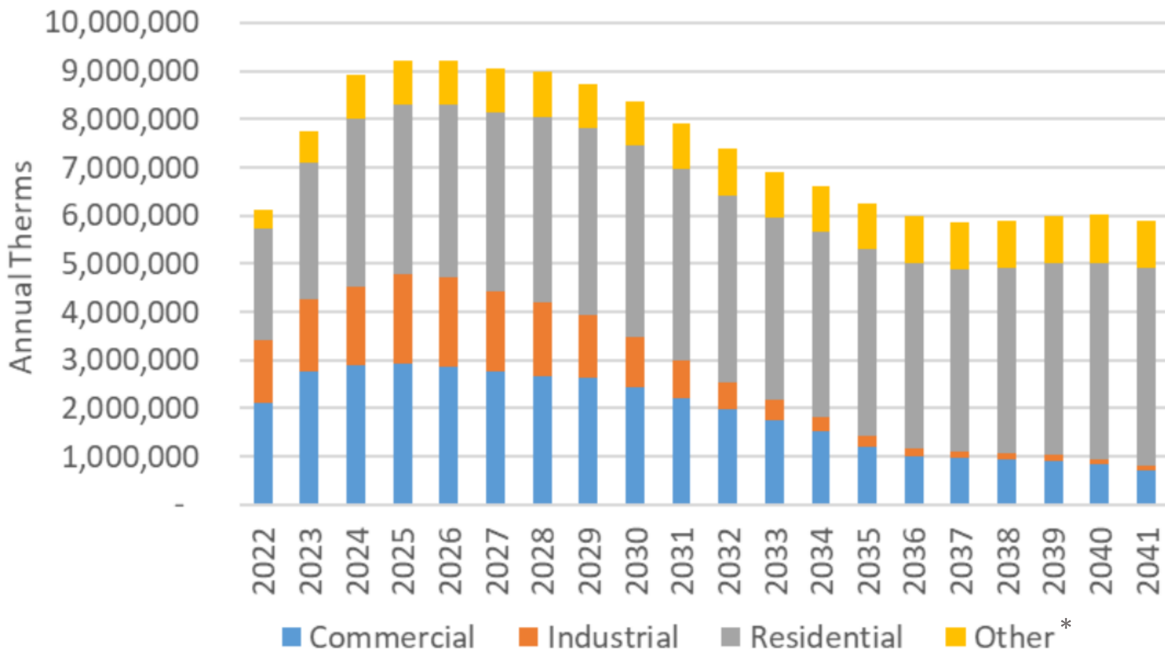
Table 1: Energy Trust of Oregon Energy Savings Projections for Oregon Natural Gas Utilities

Utility	Natural Gas Delivered in 2020 (million therms)	Energy Efficiency Savings Projections (million therms)	Timeline	Source
Cascade	318.9[4]	12.1	2020-2039	2020 Integrated Resource Plan[18]
Avista	130.9[4]	14.8	2021-2040	2021 Natural Gas Integrated Resource Plan[19]
NW Natural	1,044.8[4]	147.1	2022-2041	2022 Integrated Resource Plan[17]

Energy efficiency gains in the near-term will lead to immediate fuel and carbon savings, reducing the need for additional natural gas production resources, and addressing potentially limited quantities of available alternative fuels.[15] In Figure 5 below, NW Natural's most recent integrated resource plan projects that between 2022 and 2025, energy efficiency improvements will conserve approximately 50 percent more gas than is currently conserved, largely due to increased savings in the industrial and residential sectors.[17]

[ii] Learn more in the Energy Efficiency Options for Existing Buildings Policy Brief.

Figure 5: Modeled Future Cost-Effective Energy Efficiency Savings for NW Natural's Portfolio[17]

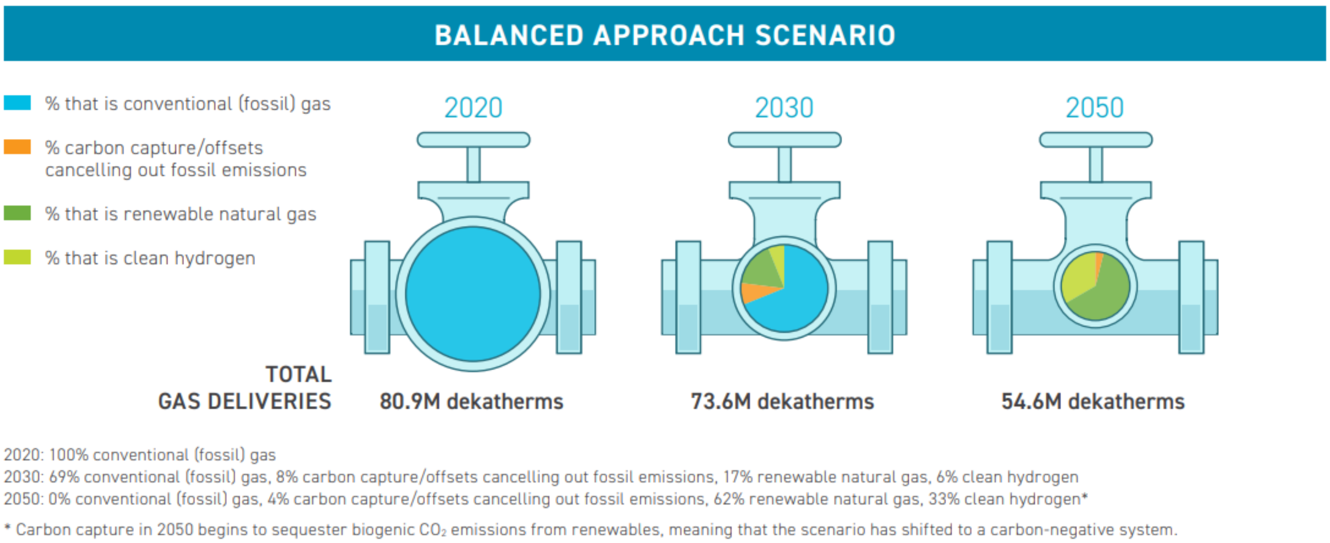


**Other includes energy efficiency gains from building codes and market transformation.*

Reducing Greenhouse Gas Emissions with Energy Efficiency

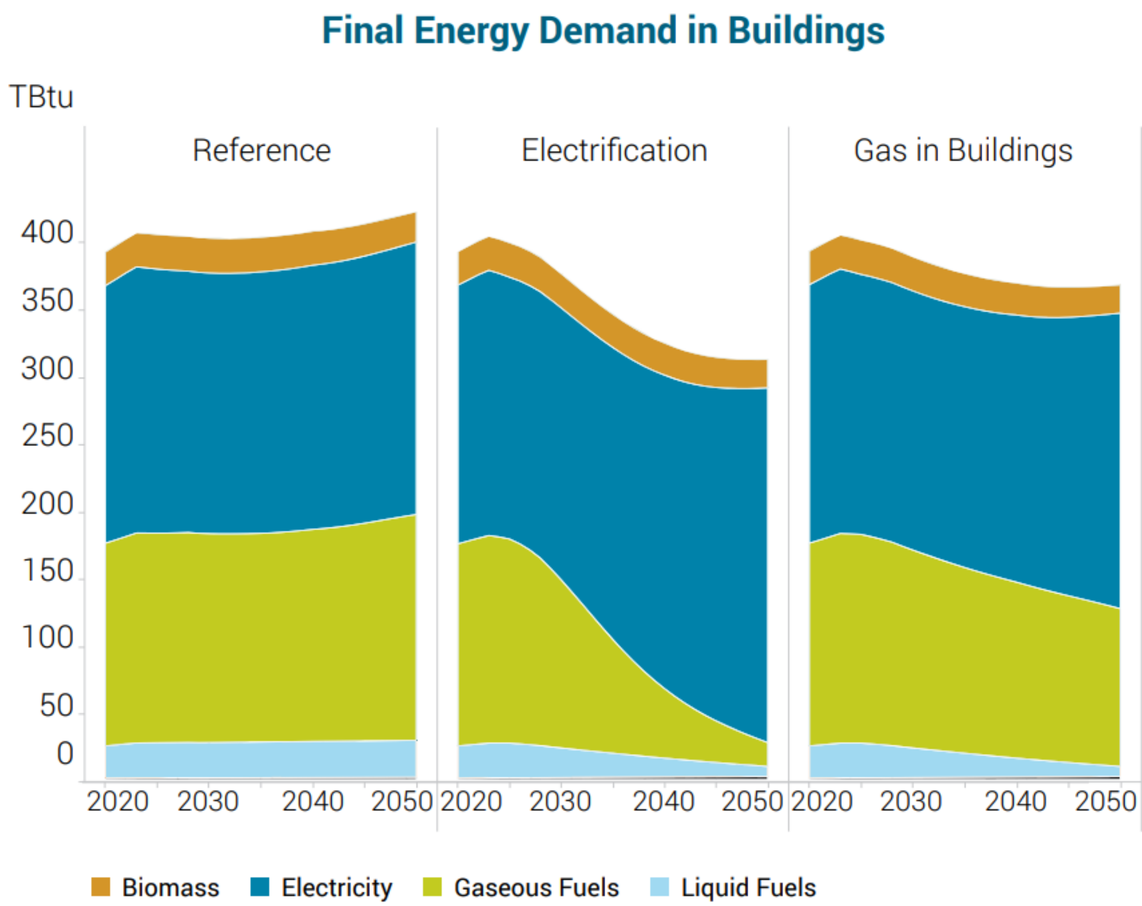
Energy efficiency savings are projected to achieve direct greenhouse gas reductions. For example, as illustrated in Figure 6, NW Natural modeled a scenario in which its total gas deliveries were reduced by more than 25 dekatherms, reflecting an approximately 30 percent reduction in deliveries, from to 2020 to 2050. While most of the emissions reductions in the scenario resulted from electrification of some end uses and transitioning pipeline gas to low-carbon gas, savings from energy efficiency were expected to account for roughly a quarter of these reductions.[20] In 2021, Energy Trust of Oregon, which administers energy efficiency programs for NW Natural, Cascade Natural Gas and Avista, invested $2.66 million to acquire 7.1 million therms of natural gas efficiency savings.[21]

Figure 6: NW Natural Modeled Natural Gas Demand Reductions [20]



To achieve decarbonization objectives in the gas sector, the studies reviewed found that savings from increased energy efficiency will be complimented by increased electrification of end uses in buildings and the availability of alternative fuels by 2050. In Figure 7, for example, Washington's *2021 State Energy Strategy* projected a significant reduction in gaseous fuel use in buildings by 2050 in its high electrification scenario. Similarly, studies that focused on reducing natural gas demand to achieve GHG targets also relied on high levels of energy efficiency adoption in buildings.[22] In scenarios where lower-carbon alternative gaseous fuels replaced natural gas, gaseous fuels continued to support a significant amount of building energy needs, as shown in the "Gas in Buildings" scenario depicted in the figure. It is important to note that non-fuel-specific energy efficient building technologies and designs will provide benefits under any scenario by reducing overall demand for energy irrespective of the fuel source.

Figure 7: Energy Use Reductions Required to Meet Washington State's Net-Zero Emissions Targets[15]



Barriers

The studies reviewed generally concluded that reducing energy consumption through building energy efficiency improvements is necessary to achieve aggressive clean energy mid-century policy targets. However, acquiring the amount of energy efficiency savings needed to dramatically reduce demand will require more efficient building codes and operating practices, programs to engage hard-to-reach customers, and significant capital investments. It is also difficult to predict when new, efficient technologies (*e.g.,* natural gas heat pumps) may become commercially available, and what the associated costs, emissions impacts, and deployment rates will be for new technologies once they enter the market.

Energy efficient building designs and technologies are most cost-effective when incorporated into buildings during initial construction, and efficiency retrofits in existing buildings are most cost-effective when undertaken during major upgrades or when appliances and equipment fail. Builders are required to meet minimum efficiency designs and standards during construction and renovation, but Oregon does not require independent additional efficiency investments in existing buildings. There are multiple mechanisms to drive energy efficiency improvements in existing commercial buildings.

Deep energy efficiency retrofits in existing buildings would likely require significant capital investment. For projects to be cost-effective, they must provide sufficient energy savings to offset their up-front costs within a reasonable time period. Therefore, unless natural gas dramatically increases in price, the cost-effectiveness of energy efficiency retrofits will likely continue to be a barrier to adoption. This challenge with the cost-effectiveness of energy efficiency retrofits in the gas sector makes it more difficult to serve low-income and other hard to reach communities. These customers may require additional resources and policy support to help them improve the energy efficiency of gas usage in their buildings and appliances.

In addition to a shortage of regulatory tools and high upfront costs that may deter efficiency upgrades, there is uncertainty around the timing, availability, and impacts of new, high-efficiency technologies. For example, there are innovative natural gas technologies under development that aim to achieve greater efficiency rates than currently available technologies. However, these technologies are not yet commercially available in Oregon, making it challenging to predict the timing of their availability, cost, and potential market penetration. Dual fuel appliances, natural gas heat pumps, natural gas heat pump water heaters, and new efficient furnaces are expected to provide improved energy efficiency benefits once they become available. The unknown viability and availability of these technologies creates some uncertainty about how much achievable natural gas savings from efficiency investments is possible, and if they will have implications for achieving mid-century clean energy policies.

Electrification

Most of the studies reviewed concluded that in addition to energy efficiency, the least-cost, least-risk decarbonization strategies rely heavily on electrification of building end uses. Electrification is the process of converting appliances and building systems currently powered by natural gas to comparable technologies powered by electricity. HB 2021 requires Oregon's large investor-owned utilities and electricity service suppliers to eliminate carbon emissions from electricity sold in Oregon by 2040, which will make electricity an even cleaner alternative to the direct use of conventional gaseous fuels than it is today. Most of the studies reviewed identified an increasing share of total energy consumption coming from the electrification of end-uses through 2050, driven by transitioning to electric vehicles, and by converting many current end-uses of natural gas to electricity.

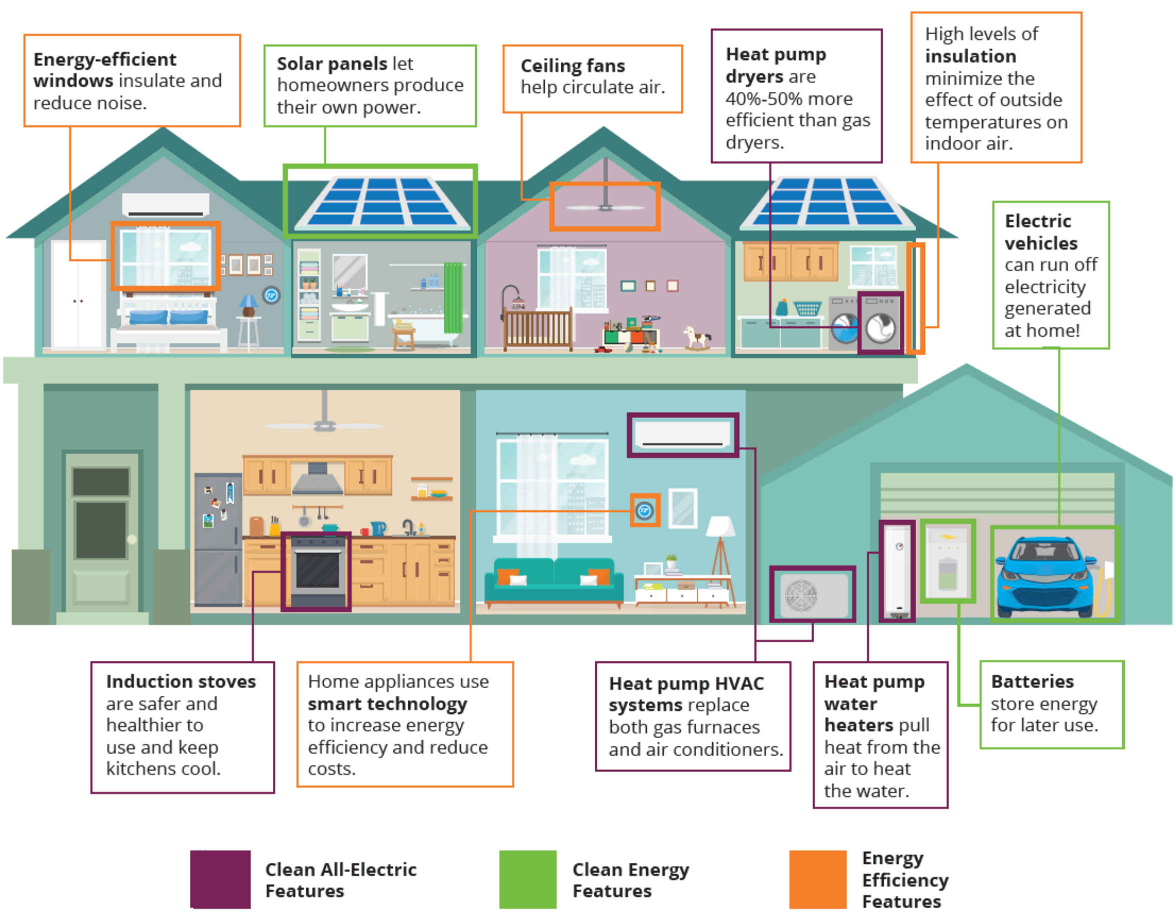
> "Efficiency and electrification are **low-cost and low-risk pillars** of energy decarbonization."
>
> — The Role of Electricity in Decarbonizing California's Energy System[23]

Reducing Greenhouse Gas Emissions with Electrification

Electrification of many current natural gas end uses will likely play an important role in reducing emissions from the natural gas sector. For example, SoCalGas—a large investor-owned gas utility in California—found that 55 to 95 percent of building space heating could be cost-effectively electrified by 2050.[24] Evolved Energy Research similarly found that "aggressive electrification of demand and development of clean electricity could meet 80 percent of Oregon's decarbonization targets."[25]

Electric options are readily available in many sectors, but some end uses lend themselves to electrification more easily than others. There are electric versions of heating, drying, cooking, and other technologies that are used in residential and commercial buildings. Other sectors that have historically relied on natural gas, such as drying equipment in agricultural operations, also have increasingly more electric options (see more in the Electrification Options in the Agricultural Sector Energy 101). Other end uses may be harder to electrify, at least in the near-term, including industrial applications that use high-heat processes, such as those used in the steel and chemical processing industries. Further, the gas sector may be able to help other sectors decarbonize, such as by providing renewable natural gas or renewable hydrogen to fuel heavy-duty trucks, ships, or trains.

Figure 8: Home Electrification Opportunities[26]



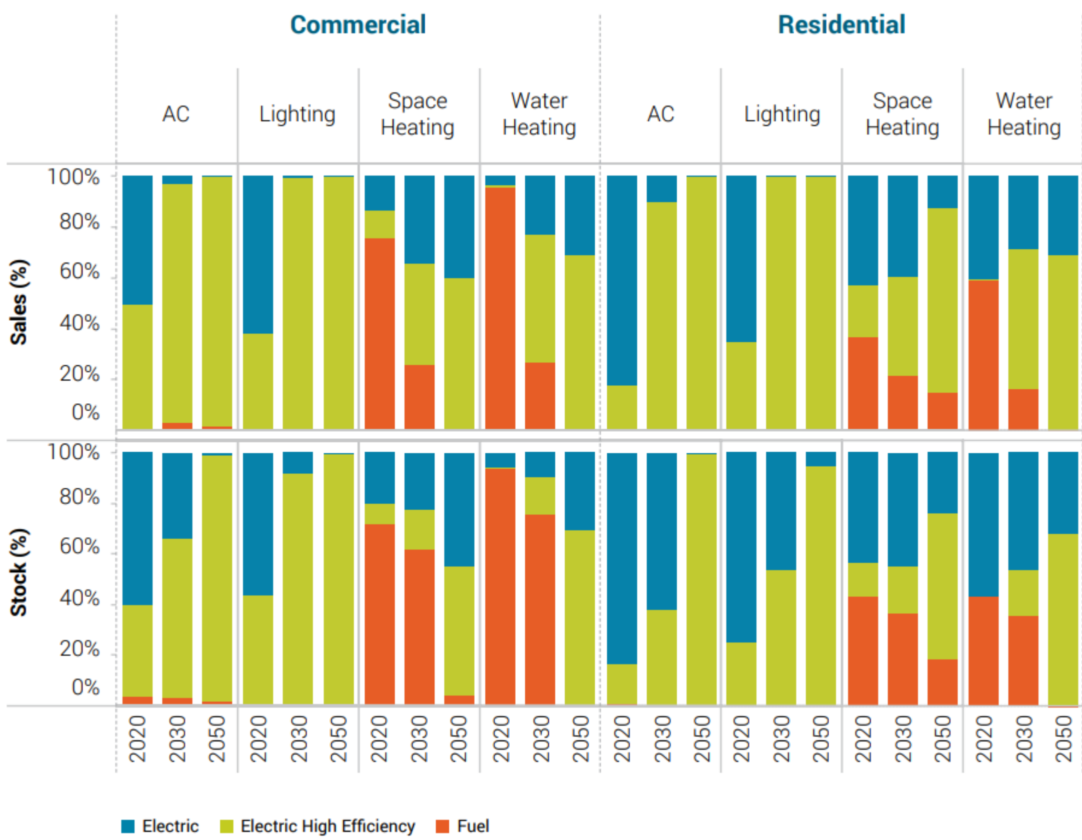
Barriers

Widespread electrification will likely take time to accomplish without policy and market intervention. As noted above, some end uses, such as heavy-duty transportation and some industrial processes, are expected to remain more difficult or costly to electrify than others. In many studies, several end uses are not expected to fully electrify until 2050, and the success of electrification as a decarbonization strategy is dependent on widespread changes to construction practices, as well as consumer adoption of electric appliances.

Retrofitting buildings and switching from natural gas space and water heating systems to electric options can potentially present a net cost over equipment lifetimes using current natural gas utility prices.[27] In addition, electrification of residential heating demand, in particular, has the potential to contribute to increases in electric system peaks, which could cause cost increases as well if new generating resources are needed to meet peak demand. If natural gas prices rise substantially in the future, however, the economics around electrification could change.

Figure 9 illustrates the pace in which building equipment must electrify to achieve Washington State's decarbonization targets under an electrification-oriented scenario. The bar graphs in the top row show the percentages of newly sold equipment that are electric, high-efficiency electric, or powered by direct use fuels in 2020, 2030, and 2050. The bar graphs in the bottom row show the composition of installed building equipment in those same years. The graphs help illustrate the rate at which building equipment must be electrified and become more efficient between now and 2050 to achieve Washington's decarbonization goals.

Figure 9: Building Equipment Sales and Stock Shares in Washington's 2021 State Energy Strategy Electrification Scenario[15]



Technologies like ductless heat pumps can support the efficient electrification of buildings.

The pace of consumer adoption of electric appliances may also present a challenge for electrifying natural gas end uses. Relying on consumer markets to change absent policy intervention may take too long, given the pace and scale of change required. Consumer behavior and preferences may be slow to change. For example, many Oregonians may currently prefer gas ranges, but also may be unfamiliar with the effectiveness, potential cost savings, improvements to indoor air quality, and climate benefits of electric ranges. Slow consumer adoption of electric technologies thus has the potential to be one of the greatest barriers to electrification.[16]

Widespread building electrification could also require a significant buildout of the electric grid. Large, rapid increases in demand for electricity occurred several times in the last century in the U.S., most notably during the wave of in-home electrification that occurred from the 1930s through 1960s, and again with the adoption of home air conditioning in parts of the country in the 1980s. Electrification of large portions of the direct fuel and transportation sectors has the potential to drive growth in electric demand as much as, if not exceeding, those periods of rapid growth seen in the twentieth century.

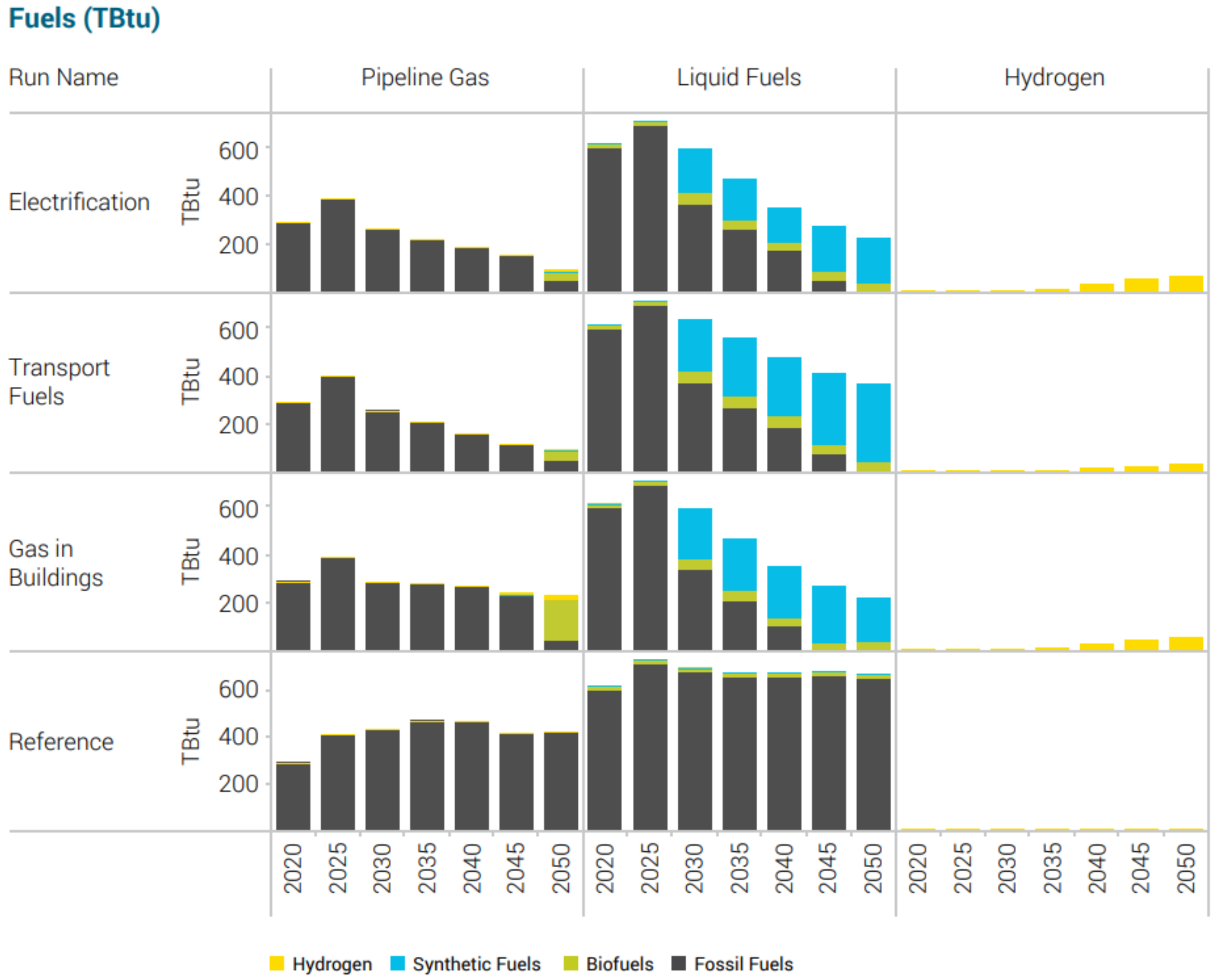
Electric stoves offer cost, efficiency, and performance benefits.[28]

For more information on what the studies identified in terms of potential growth in electric demand and the need to develop substantial amounts of new wind and solar generation, see the Electric Sector section of this Policy Brief.

Low-Carbon Alternative Fuels

Many studies concluded that some degree of alternative fuel adoption would be needed to provide direct use fuels to hard-to-decarbonize end users and to support the electric grid during extreme peak events such as major heat waves or cold snaps. Energy and Environmental Economics, Inc., in a study for the California Energy Commission, concluded that there are no viable decarbonization strategies for California's energy system that completely eliminate the need for a dispatchable gas fuel.[16] Washington's *2021 State Energy Strategy* reached similar conclusions. Figure 10 below illustrates the rate and pace at which Washington's energy mix must transition to cleaner fuels to achieve the state's mid-century decarbonization targets.[15] Washington's analysis indicated that pipeline gas will likely play a reduced yet not insignificant role in the state's energy system in 2050, though biogas is projected to replace a large portion of the fossil-based natural gas consumed in the state.

Figure 10: Fuel Decarbonization in Washington's 2021 State Energy Strategy[15]



Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020 (p. 42).

One Oregon-specific study found that to meet a 100 percent clean energy target by 2050, most gas usage remaining in the economy would need to be decarbonized with low-carbon alternative fuels.[25] Similar to renewable electricity production, these low-carbon fuels could be made in Oregon, creating new economic, resilience, and energy security opportunities. Local production of fuels would reduce the effects of the global natural gas marketplace on energy prices in Oregon and retain more energy dollars in state. Local energy resources also afford opportunities to support local community energy resilience because they can provide a fuel source during extreme events, ensuring access to direct fuels for first responders and other critical needs.

Reducing Greenhouse Gas Emissions with Alternative Fuels

Alternative gas fuels include renewable natural gas and renewable hydrogen, which have lower carbon intensities than fossil natural gas. Each of these fuels (and others that are being researched today) have benefits and challenges involving the total amount of fuel that can be produced, the development and deployment of infrastructure and production facilities, and infrastructure to transport the fuel. In some cases, end users may need to retrofit or replace existing gas equipment to be able to use alternative fuels. In this section, the term "alternative fuels" is used when describing the range of natural gas alternatives, and individual fuels will be referenced by name when describing attributes specific to that fuel.

Low-carbon alternative fuels offer a decarbonization strategy that allows for continued use of existing gas equipment and infrastructure and provides a potential bridge to future electrification. These fuels can either be blended with existing natural gas or serve as a clean replacement for it. Many studies found that even with high rates of electrification, achieving decarbonization targets will require scaling up production and supply of alternative fuels.[15 24] Producing and using low-carbon alternative gas fuels would allow some building, transportation, and industrial applications that are more challenging or more costly to electrify to continue to use gaseous fuels and existing infrastructure. This approach would require significant investment to develop new production facilities and feedstocks, and potentially new infrastructure and end-use technologies. Most studies reviewed identified low-carbon fuels as one of the pillars of decarbonization, and many of those studies found it most beneficial to prioritize the use of low-carbon fuels for end uses that are most difficult to electrify.[15 22]

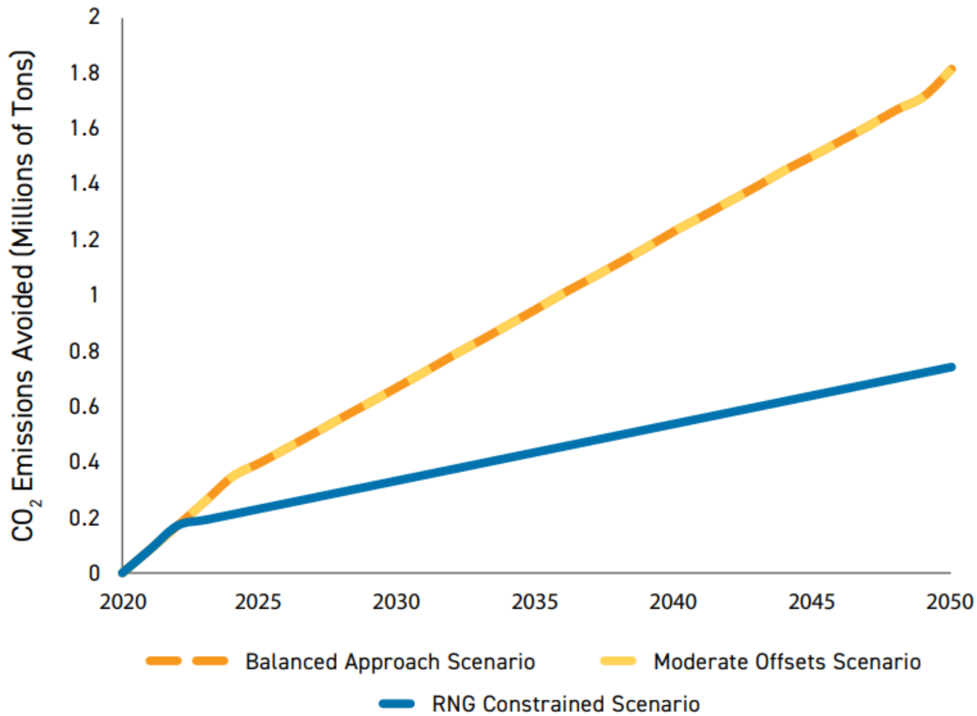
Renewable Natural Gas

Renewable natural gas (RNG), or biomethane, is a fuel derived from biogas, a methane byproduct of municipal waste streams such as garbage, wastewater, and waste food or agricultural waste streams like manure. Once processed, it can replace fossil natural gas without the need for upgrades or replacement of existing natural gas infrastructure. Opportunities to produce renewable natural gas exist around the state, but investments in the development of biogas capturing and processing facilities in addition to transmission infrastructure to connect to the larger natural gas transmission and distribution system are necessary to bring this fuel to customers.

The amount of RNG able to be captured today in Oregon could replace up to 4.5 percent of Oregon's total annual natural gas use (including gas used to generate electricity and gas used directly in buildings and industrial processes), and could rise to as much as 17.5 percent if future technical advancements in collection and gasification become commercially available.[iii] [29] NW Natural estimates RNG, with imports from other parts of the country, could displace between 14 and 34.2 million dekatherms by 2050, 17.5 to 43 percent of its 2020 volume. In Figure 11 below, NW Natural estimates the associated emission reductions could be between 0.6 and 1.8 million metric tons of carbon dioxide, or roughly 11.1 to 35 percent of the utility's reported 2020 emissions.[20 30] Because natural gas use in the electric sector is expected to decline significantly to comply with the 100 percent clean energy standard established by HB 2021, the anticipated supply of RNG could meet a greater percentage of Oregon's gas demand in the future.

[iii] See ODOE's 2018 RNG Inventory Report: https://www.oregon.gov/energy/Get-Involved/Pages/Renewable-Natural-Gas-Inventory.aspx

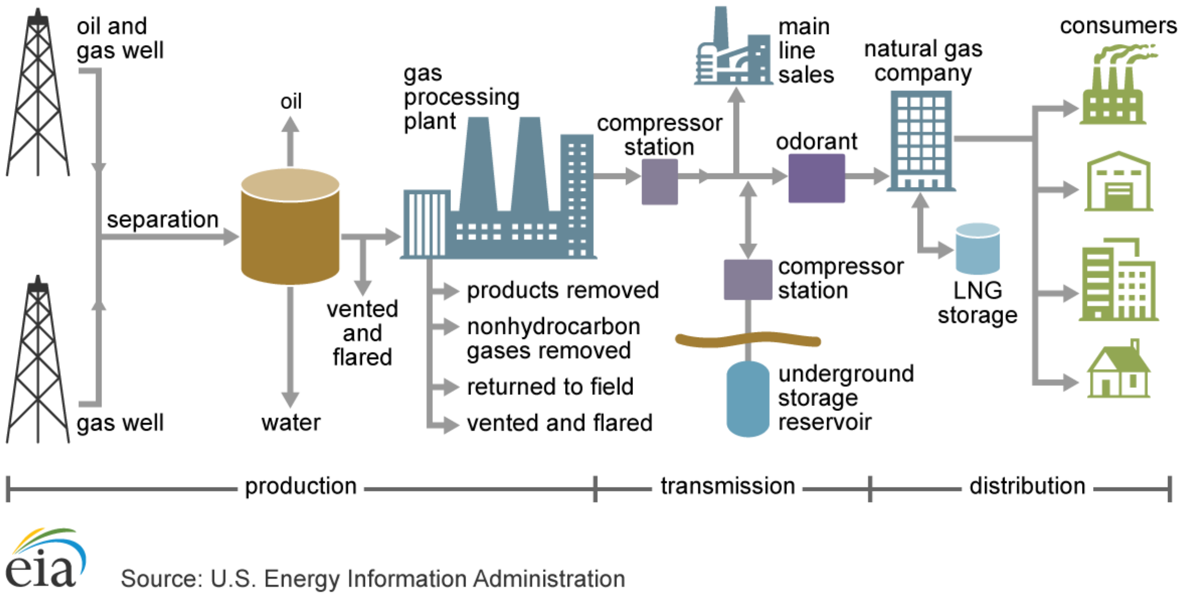
Figure 11: Potential Emission Reductions Resulting from RNG in NW Natural's Vision 2050 Modeling Scenarios[20]



Natural gas—both fossil and renewable—consists almost entirely of methane, a potent greenhouse gas, the rapid reduction of which is important to address climate change. Depending on how RNG is produced and processed, it generally has a lower carbon intensity attributed to it than fossil natural gas. RNG derived from manure is considered to have the lowest emission intensity, often with a negative value, because it captures large amounts of methane that would otherwise end up directly in the atmosphere.

Like fossil natural gas, there are associated fugitive emissions of methane from transporting and combusting RNG, although combustion emissions are 21 times less potent than methane released directly into the environment.[31] [32] As shown in Figure 12 below, the large and complex production and transmission system for natural gas provides the fuel to many parts of Oregon and the rest of the country, but also offers multiple opportunities for methane leaks. (In contrast, the local gas distribution networks in Oregon have been upgraded to reduce leakage.) These fugitive emissions can be limited by consuming the gas close to where it is produced to avoid long-distance transmission. One major opportunity with RNG development is that it can provide fuel in many parts of Oregon and reduce the distance gas must travel before being used. Many farms, landfills, and wastewater treatment plants already use the gas they generate on site to supplement their energy needs.

Figure 12: Natural Gas Production and Delivery Pathway[33]



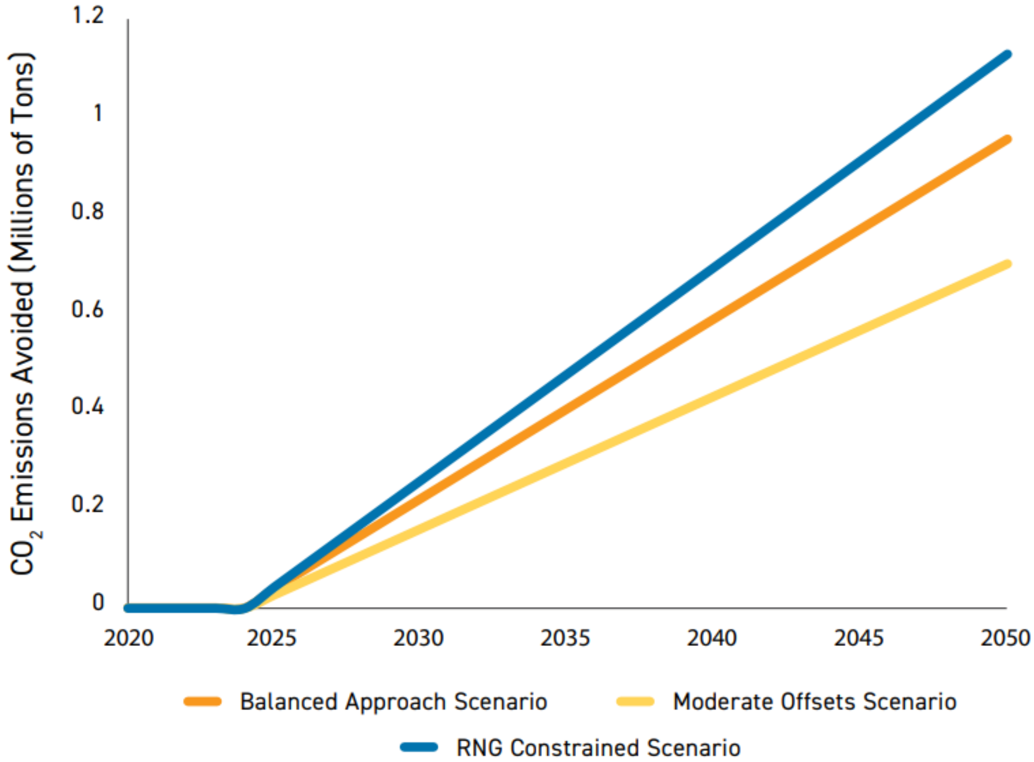
One barrier to greater use of RNG is lack of a cost-effective means to inject the gas into the existing gas pipeline system. This is largely due to high costs to process biogas to remove contaminants to meet pipeline quality standards, and the costs to interconnect biogas production facilities to transmission or distribution systems. Gas pipelines cost about $250,000 to $1.5 million per mile to build, meaning even relatively short distances to interconnect would be very costly.[34] This could be particularly challenging for landfills and animal operations, which in many cases can only produce relatively small volumes of gas and which tend to be located in less densely populated areas that may be further from existing infrastructure.

Renewable Hydrogen

Renewable hydrogen can be produced in several ways. The least-carbon-intensive method for producing renewable hydrogen involves using electrolyzers powered by renewable electricity to split water into hydrogen and oxygen. Hydrogen, like natural gas, can be combusted in a turbine to generate electricity. Using this fuel in its pure form as a direct use fuel would require replacing or significantly upgrading existing infrastructure and end use appliances or technologies. However, it can be blended into natural gas at 10 to 20 percent concentrations without the need for any changes to equipment or infrastructure.[35] There are currently no hydrogen electrolyzers operating in Oregon, although one pilot project is in the initial stages of development in Eugene (for more information on renewable hydrogen, see the Energy Resource & Technology Reviews section of this report).

NW Natural estimated renewable hydrogen could displace between 13.2 million and 21.2 million dekatherms of natural gas, or 16.3 to 26.2 percent of the utility's 2020 gas volume. As illustrated in Figure 13 below, the utility estimated this would result in emission reductions of 0.7 to nearly 1.2 million metric tons of CO_2, or about 12.9 to 22.1 percent of NW Natural's reported 2020 emissions.[20 30]

Figure 13: Potential Emission Reductions Resulting from Clean Hydrogen in NW Natural's Vision 2050 Modeling Scenarios



Renewable hydrogen can be produced at any site where water and renewable electricity are available, so hydrogen development, like RNG, could help to increase Oregon's energy security and support clean energy jobs. In addition, electrolyzers could use renewable electricity to produce hydrogen for storage, which could be used later in a turbine or fuel cell to generate zero-carbon electricity to support the grid or provide a local energy resource.[15]

Blending renewable hydrogen into a natural gas pipeline may not be a cost-effective end use for hydrogen if greenhouse gas emission reductions are the primary goal. Hydrogen is less dense than natural gas and requires increased pressure to move it through pipelines; adding 20 percent hydrogen by volume (the assumed maximum practical and safe limit for blending) only results in a six to seven percent reduction of GHG emissions. For this reason, many studies find that hydrogen may initially be more cost-effective as a transportation fuel.

The cost of renewable hydrogen infrastructure is a major barrier to development of the technology. Even in scenarios where buildings are not largely electrified, the volume of low-carbon fuels needed to meet demand leads to higher gas costs for consumers, further bolstering the cost-effectiveness of building electrification as an alternative to decarbonization of the gas sector.[16] For example, Energy + Environmental Economics found that 1 kWh of renewable electricity could generate 10 times as much heat by powering a high efficiency electric heat pump than that same 1 kWh of renewable electricity could generate in heat if used to power an electrolyzer to produce renewable hydrogen for delivery through the gas system to provide end-use heat to a customer.[23] Given these challenges, policymakers must take into account the various pathways available to decarbonize the natural gas sector and identify an optimal role for the use of hydrogen as part of the solution to achieving mid-century policy goals.

Carbon Capture and Storage

Carbon capture and storage (CCS) is a process of capturing carbon dioxide (CO2) emissions at the source of fossil fuel combustion such as at electricity generating power plants or industrial facilities creating steel or cement (learn more in the *2020 Biennial Energy Report*). Once CO_2 is captured, it is compressed and transported to a site, and injected deep underground into rock formations for long-term storage. CCS has the potential to collect and remove existing carbon from the atmosphere to help address global warming. CCS has been used in the U.S. since 1972 and several natural gas plants in Texas have captured and stored more than 200 million tons of CO_2 underground.[36]

Incorporating CCS into gas power plants would allow continued use of conventional gas fuels in electricity generation and industrial applications while mitigating some of the emissions of natural gas without using low-carbon fuel as a replacement. Carbon captured from industrial processes could be used as a feedstock to produce synthetic fuels, and while the carbon would still be released into the atmosphere at combustion, the potential of using the gas twice would reduce the overall emission intensity. Two of the studies reviewed identified a potential role for CCS:

- **Washington State** highlighted the potential of carbon to be collected from industrial smokestacks and the need to provide technical assistance to industry as CCS is evaluated.[15]
- **NW Natural** incorporated various levels of CCS in the modeling of its Vision 2050 approaches to decarbonization to demonstrate how it could be used as a supply-side solution. [20]

CCS is an emerging solution that remains an expensive process. As Oregon transitions electricity generation to more renewable resources, natural gas will likely be used less frequently and at lower capacity to maintain grid reliability under extreme conditions. With modest and inconsistent utilization, building CCS infrastructure for the remaining natural gas plants that are being operated less frequently may not be a cost-effective, long-term solution.[37] Advancements in CCS technology may make this a more viable solution in the decades to come.

Costs

The potential pathways for decarbonizing the natural gas sector each have unique cost profiles. Ultimately, it is likely that a combination of the following different pathways will be required to cost-effectively achieve the state's decarbonization objectives for the sector.

Energy Efficiency. Energy efficiency investments are one of the least-cost options available to reduce greenhouse gas emissions today. All of the natural gas utilities serving Oregon project significant savings from energy efficiency improvements supported by financial assistance from Energy Trust of Oregon. Energy Trust-funded efficiency investments are required to be "cost-effective," meaning the total cost of an energy efficiency investment cannot exceed the utility's avoided costs—the costs the utility would otherwise incur to meet the same demand with other supply-side energy resources. Energy Trust of Oregon's cost effectiveness determination assigns an economic value to energy savings that accounts for both the energy and some of the non-energy benefits of an efficiency investment. To some degree, the cost of carbon is included in the calculation as an avoided regulatory expense. For more information on cost-effectiveness of energy efficiency, and the inclusion of non-energy benefits see the Co-Benefits of Energy Efficiency Policy Brief.

Oregon's Ten-Year Plan: Reducing the Energy Burden in Oregon Affordable Housing

Oregon Housing and Community Services recommends energy efficiency as one of the best tactics to reduce the low-income population's energy burden.[38]

Electrification. Once cost-effective savings from energy efficiency have been realized, the studies reviewed find that electrification of many end uses is often the least-cost option to reduce greenhouse gas emissions from the building sector. In all cases, electrification was broadly more cost-effective than widespread adoption of alternative fuels, largely due to the costs to develop and make these fuels commercially viable, and the costs to upgrade pipelines and other infrastructure specifically to accommodate hydrogen development. Several studies found that expected natural gas cost increases in the future would create a feedback loop that will make electrification even more cost-effective by comparison in the years ahead.[15] [16]

> "Converting building end uses to electricity is **less expensive and more energy efficient than a strategy focused on creating synthetic pipeline gas**, even if buildings convert to high-efficiency gas equipment."
>
> — Washington 2021 State Energy Strategy[15]

Energy planning and policies that complement each other across all energy sectors are needed to achieve decarbonization goals.[24] Promoting fuel switching and encouraging Oregonians to transition homes and businesses from natural gas to electricity would be a significant shift for the state, natural gas and electric utilities, as well as customers. Electric utilities would need to prepare for a large increase in electric load coupled with a transition to largely renewable energy generation assets, while natural gas utilities may have to maintain a system with reduced demand while developing infrastructure to access and deliver lower carbon alternative fuels.

Alternative Low-Carbon Fuels. The use of gaseous fuels will continue to be a necessary resource for electricity generation and hard-to-electrify sectors in the near- to medium-term. Over time the reliance of this smaller group of end users on these gaseous fuels will make them more vulnerable to changes in gas prices. Most studies anticipate natural gas prices to rise in the future, largely due to increased demand from overseas markets for liquefied natural gas.[11,12] Future decarbonization actions, particularly those that send price signals to disincentivize fossil fuel consumption, will likely also create upward pressure on natural gas prices. Costs to comply with these emission reduction programs may increase natural gas rates across all customer classes,[39] but those increases will be in part offset by the energy savings from energy efficiency. As natural gas rates increase, low-carbon fuels will become more attractive as an alternative for utilities and customers.

However, substantial public and private investment would be required to create the necessary infrastructure to produce RNG or renewable hydrogen at-scale. Given the likely cost, it may be more cost-effective to electrify the end-uses of certain customers. This would make it easier to allocate the limited supply of RNG or renewable hydrogen to transportation, industry, or other hard to decarbonize customers.

Consumer Costs and Equity

Decarbonizing the natural gas sector will require significant investment and create unique equity challenges. How costs are allocated, and the equity implications of those allocations, will be important considerations in future policy development. Many Oregonians already suffer from disproportionately high energy burdens and are highly vulnerable to energy cost increases. Transitioning to electric appliances may not currently be an option for many households due to cost barriers or a lack of control over building systems or investments (which is often the case for rental households). At the same time, growing interest in building electrification could reduce the number of customers reliant on natural gas service, which could in turn cause bill increases for remaining gas utility customers. State policy solutions will be necessary to address and mitigate adverse equity impacts that could arise from the clean energy transition.

How costs are allocated, and the equity implications of those allocations, will be important considerations in future policy development.

Oregonians experiencing low incomes often must devote a much higher percentage of their income to their energy bills than higher-income households. The percentage of household income devoted to energy bills represents a household's "energy burden." When a household's energy costs exceed six percent of the household's income, the household is considered to experience a high energy burden.[40] A recent analysis of home energy affordability found that "Oregon households with incomes of below 50 percent of the Federal Poverty Level pay 23 percent of their annual income simply for their home energy bills."[41] An increase in fuel costs could increase the energy burden for vulnerable Oregonians, many of whom may already be forced to choose between paying for food, medicine, or their energy bills.[40] At the same time, many households lack the financial resources to invest in high-efficiency electric appliances and efficiency retrofits. These households are at risk of being left behind by a clean energy transition in which higher-income households embrace building electrification and disconnect their homes from the gas system. Under this scenario, a shrinking pool of natural gas utility customers would be forced to cover the remaining fixed costs associated with the gas system, with each remaining customer responsible for a higher share of those costs.

Oregonians that rent their homes are also at risk of incurring rising energy costs during the clean energy transition, because many renters have limited options to decarbonize. Landlords have a disincentive to invest in energy efficiency retrofits or efficient electric appliances due to the high upfront costs, which forces renters to bear the financial burden of higher energy bills.[42] Renters also often lack control over the types of energy they consume in their units. In 2021, approximately 21 percent of Oregon renters heated their homes with natural gas.[41] Many of these renters may not have the option of electrifying their heating systems. And rental units heated by inefficient electric baseboard heaters may not have the option to install efficient electric heat pumps. The relative lack of control that many renters have over the type and amount of energy they consume in their residences puts them at greater risk of incurring higher energy burdens if fuel costs increase. This risk is even more pronounced for low-income renters.

The Oregon legislature took action to address disproportionate energy burdens through the adoption of HB 2475 in 2021. HB 2475 directed the Oregon Public Utility Commission to consider "differential energy burdens on low-income customers and other economic, social equity or environmental justice factors that affect affordability for certain classes of utility customers" when setting retail rates for electric or natural gas service. The bill allows the OPUC to develop new utility bill rate structures based on customer needs or characteristics, such as income or equity factors.[43] The OPUC and the retail electric and natural gas utilities it regulates are in the process of developing differential rates that could help mitigate disproportionate energy burden impacts moving forward.[43]

All the decarbonization studies reviewed projected reductions in natural gas demand by mid-century, which may lead to price increases that could disproportionately impact low-income gas customers. At an economywide level, several studies estimated that increases in gaseous fuel prices will be largely offset by cost savings elsewhere in the energy economy, such as savings from reductions in fuel consumption and from a transition to lower-cost electrified end-uses. How these shifting costs impact individuals is likely to vary, however, and a key challenge will be to manage this transition to protect those who may not be able to adapt quickly and equitably share in the benefits of this transition. The following paragraphs briefly summarize the findings from three recent studies analyzing the potential cost impacts from decarbonizing natural gas sectors in California, Oregon, and Washington.

California Energy Commission Analysis. In 2020, the California Energy Commission published a study evaluating decarbonization scenarios to achieve the state's mid-century GHG reduction targets, with a focus on identifying and evaluating impacts to gas customers and the gas system as a whole. The study concluded that building electrification represented the least-cost strategy for reducing emissions from the natural gas sector, but cautioned that absent policy intervention, the cost savings from electrification would likely accrue to households that can afford to electrify, and could cause costs to increase for low-income gas customers. The study estimated that demand for natural gas will likely decline in California over time, and declining demand would put upward pressure on gas prices. This decline in demand and associated cost increase would create a feedback loop in which rising gas prices make electrification a more appealing and economical option for consumers who can afford to switch, causing gas demand to drop and prices to increase even further. Recognizing that residential customers pay most of the fixed costs to maintain and operate the gas distribution system, the study projected that the reduction in gas customers resulting from electrification would cause those fixed costs to be shared by a smaller number of customers. Lower-income customers that cannot afford to electrify could be forced to shoulder a disproportionate share of these fixed system costs, in addition to higher gas rates. The study concluded that a well-managed transition from gas to electricity would help mitigate these impacts, while also supporting the financial viability of gas utilities to ensure customers continue to receive safe and reliable service at just and reasonable rates. State building electrification policies, incentives, and support for low-income or vulnerable communities may also be needed to provide consumer protection from future fuel price increases.[16]

Oregon Public Utility Commission Investigation. Following the adoption of the Oregon Department of Environmental Quality's Climate Protection Program (CPP), the OPUC launched a natural gas fact finding investigation to identify the actions natural gas utilities plan to take to comply with the CPP and evaluate the associated cost impacts on the utilities and their customers. Following an extensive public stakeholder process, the OPUC issued a draft report describing its preliminary findings. The draft report found that natural gas utilities will need to take significant near-term actions to meet their future greenhouse gas emissions reduction obligations under the CPP, and that these decarbonization actions will likely increase natural gas costs. Table 2 shows the estimated bill impacts resulting from the utilities' compliance activities in 2025, 2035, and 2050. The utilities' decarbonization models and cost estimates varied significantly due to differences in utility characteristics and future uncertainties. The utility modeling was also constrained by uncertainties around the viability of certain decarbonization pathways, because some of the alternative fuels or technologies utilities are planning to implement are not currently available in the market.[39] The draft report concluded that while most, and potentially all, of the utilities' CPP compliance strategies would carry additional costs and risks that must be tracked and addressed, "the transition to a decarbonized gas sector can create benefits and long-term cost savings for customers and the Oregon economy."[39]

Table 2: Estimated Bill Impacts from Gas Utility Compliance with the Oregon Climate Protection Program[39]

	2025			2035			2050*		
	Res	Com	Ind	Res	Com	Ind	Res	Com	Ind
Avista	1%	7%	14%	21%	53%	60%	26%	162%	72%
Cascade Natural Gas	13%	15%	16%	27%	28%	32%	43%	26%	50%
NW Natural	9%	17%	22%	9%	17%	35%	-2%	12%	39%

**Avista and Cascade modeled compliance costs through 2040, so those values were used in place of 2050*

Washington State Energy Strategy. In 2020, the Washington State Department of Commerce updated Washington's State Energy Strategy to align it with the state's climate and energy targets. The Department conducted a deep decarbonization pathway analysis to determine the lowest cost path for reducing emissions. This analysis modeled potential cost impacts to consumers under several scenarios, including electrification. The analysis found that although the average annual cost of electricity, clean fuels, and equipment would likely increase under a high-electrification scenario, the savings from reductions in liquid fuel and natural gas costs would lead to an overall net reduction in energy expenditures for consumers by 2050.[15] Figure 14 below shows the projected net costs and savings under the analysis's electrification scenario.

Figure 14: Change in Average Spending per Person in the Electrification Scenario (2050)[15]

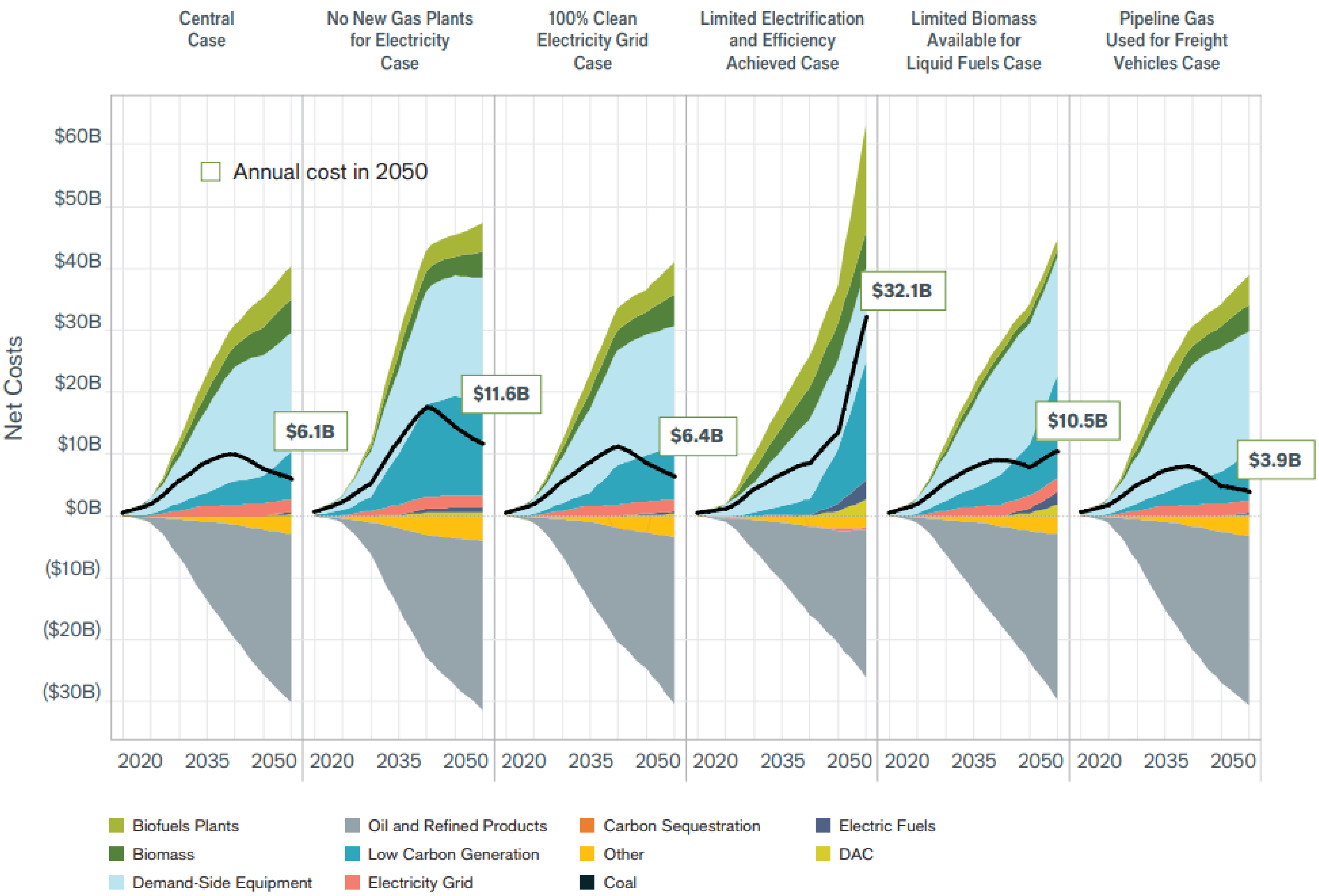
Source: Appendix E – Economic Impacts of Decarbonization Modeling, December 31, 2020 (p. 16).

Energy System Costs

Most of the evaluated studies modeled potential costs and trade-offs between different deep decarbonization pathways across the entire energy economy. Examples include:

- **Clean Energy Transition Institute** evaluated decarbonization pathways in the Northwest, including Idaho, Montana, Oregon, and Washington. Figure 15 below illustrates the results of six different decarbonization scenarios that were modeled through 2050 as part of that study. The costs to deploy clean energy resources are shown above the x-axis, while the modeled reduction in costs associated primarily with using smaller volumes of fossil fuels are shown below the x-axis. This visual illustrates how expenditures on clean energy solutions are expected to be mitigated, to varying extents, by reductions in expenditures on fossil fuels—this net cost figure is represented on the visual by the bolded black line. One notable finding illustrated here is that the scenario with the highest net cost in 2050 ($32.1 billion) is the scenario with limited electrification of end uses, and which results in the greatest demand for biofuels and electric fuels (e.g., renewable hydrogen). On the other hand, the scenario with the lowest net cost ($3.9 billion) is shown at far right and incorporates the use of pipeline gas to decarbonization the heavy-duty transportation sector.

Figure 15: Annual Net Energy System Costs Under Six Decarbonization Scenarios[25]



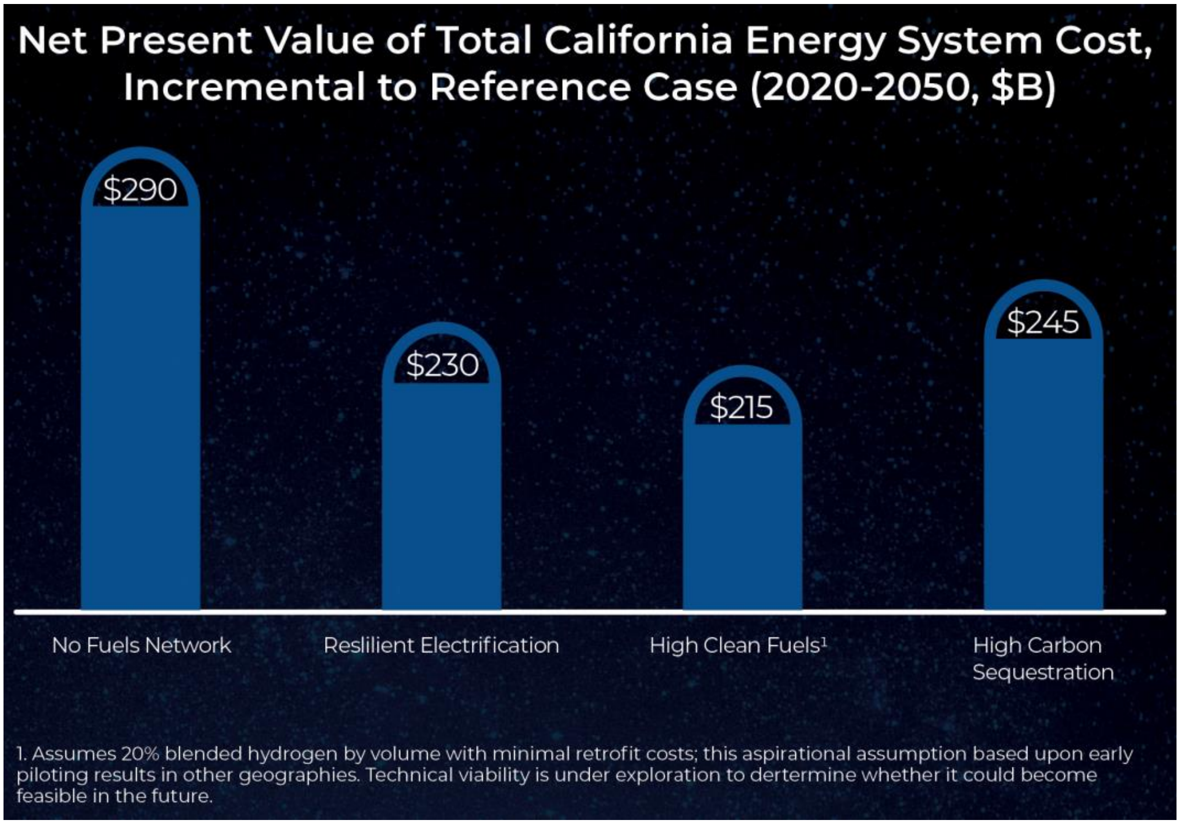
Source: Northwest Deep Decarbonization Pathways Study, May 2019, Evolved Energy Research, page 107

- **Evolved Energy Research's** Oregon Clean Energy Pathways study estimated that meeting emission targets of 80 to 100 percent reduction from 1990 levels will require additional state spending of 0.2 percent GDP per year. But if there is low adoption of electrification in the built environment and transportation sectors it would lead to greater alternative energy demands and decarbonized fuels, making decarbonization approximately 0.4 percent of state GDP more expensive between 2040 and 2050.[25] This finding illustrates the potential downside of pathways that rely more on decarbonized fuels versus electrification.
- **SoCalGas'** technical analysis of California's clean energy future also evaluated the total estimated costs of across four modeled scenarios to achieve 2050 policies:[24]
  - *No Fuels Network:* Modeled a scenario in which all of the gas utility's existing customers (commercial, industrial, and residential) convert to electrification to meet their energy needs by 2045. This eliminates any remaining need for a gas fuels network.
  - *Resilient Electrification:* This scenario modeled most residential and commercial end-users (but not industrial) electrifying their gas end uses by 2045.

- *High Clean Fuels*: This scenario modeled the use of low carbon fuels to decarbonize transportation (100 percent of long-haul heavy duty, and 50 percent of medium duty and short-haul heavy duty) and replaced residential and commercial gas demand with low carbon fuels (20 percent hydrogen blended in the pipeline, plus extensive use of biogas) without requiring major upgrades to gas infrastructure.
- *High Carbon Sequestration:* This scenario modeled continued use of primarily conventional natural gas with direct carbon capture or indirect offset by carbon capture. This scenario assumed limited hydrogen blending in the pipeline, and the creation of a hydrogen hub to deliver hydrogen directly to specific end users that require it.

SoCalGas' modeling found that full electrification, with complete elimination of the existing gas fuels network, would be the most expensive pathway. As Figure 16 illustrates, the three scenarios that rely upon continued use of gas infrastructure are lower cost, with the least-cost scenario being the *High Clean Fuels* scenario:

Figure 16: SoCalGas Incremental Costs by Scenario, 2020–2050[24]



Policy Considerations

To reach Oregon's decarbonization targets, intentional policy choices will need to guide the role of conventional and alternative gas fuels in the state.

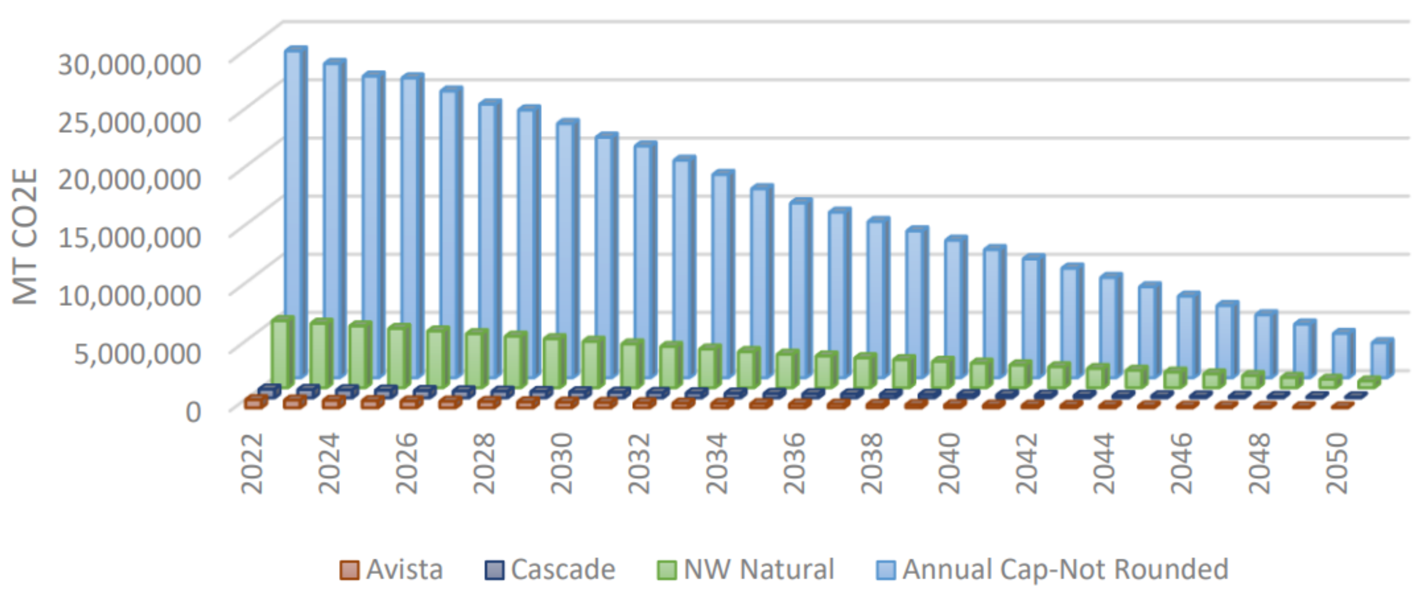
Existing Policy

Oregon has two key regulatory programs in place to reduce carbon emissions from natural gas and direct-use fossil fuels consumed in the state. The Oregon Climate Protection Program establishes a declining cap on the *quantity* of carbon emitted from natural gas consumed in Oregon, and the Oregon Clean Fuels Program requires reductions in the average *carbon intensity* of transportation fuels sold in Oregon, including natural gas. In addition to these two statewide regulatory programs, some local governments have taken steps to reduce natural gas emissions within their jurisdictions.

Oregon has two key regulatory programs in place to reduce carbon emissions from natural gas and direct-use fossil fuels consumed in the state.

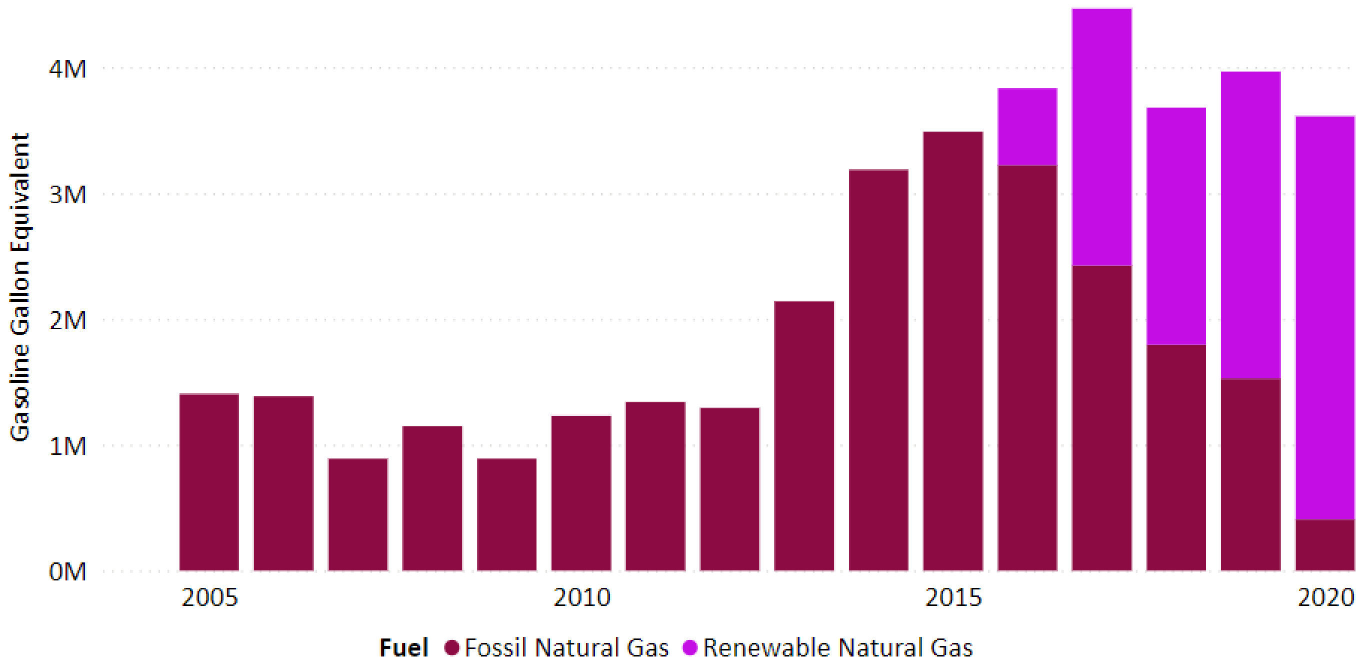
The Oregon Department of Environmental Quality's Climate Protection Program (CPP) sets a declining limit, or cap, on greenhouse gas emissions from fossil fuels used in Oregon, including natural gas.[44] The CPP has a requirement to reduce GHG emissions 90 percent by 2050 with an interim target to reduce emissions 50 percent by 2035. These requirements are designed to drive fuel suppliers, natural gas utilities, and industrial facilities to invest in low-carbon alternative fuels and other decarbonization strategies over time.

Figure 17: Oregon Climate Protection Program Emission Caps[39]



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 requires reductions in the average carbon intensity of Oregon's transportation fuels over time. The program was updated in 2022 to require a 37 percent reduction in average carbon intensity by 2035. Natural gas sold as a transportation fuel in Oregon is subject to regulation under the Clean Fuels Program. Figure 18 shows the quantities of natural gas and renewable natural gas sold as transportation fuels in Oregon from 2005 to 2020. Gaseous fuels that have lower carbon intensity values than gasoline or diesel generate credits under the program, while gasoline and other high-carbon intensity fuels earn deficits under the program. The clean fuels standards gradually increase in stringency over time, requiring a 10 percent reduction in carbon intensity by 2025, a 20 percent reduction in 2030, and a 37 percent reduction in 2035. As the carbon intensity reduction targets rise, fuels with carbon intensity values below the current standard (and therefore receive compliance credits under the program) may exceed the carbon intensity standard in future years (and generate deficits under the program). Fossil natural gas is an example of a fuel that generates compliance credits under the current standard, but will become a regulated fuel that generates deficits when the carbon intensity target rises after 2025. (Liquified natural gas became a regulated fuel in 2022.) Low-carbon intensity alternatives like renewable propane and renewable natural gas will continue to generate credits that will likely increase in value as the standards increase.

Figure 18: Oregon On-Highway Natural Gas Consumption 2005–2020[45]

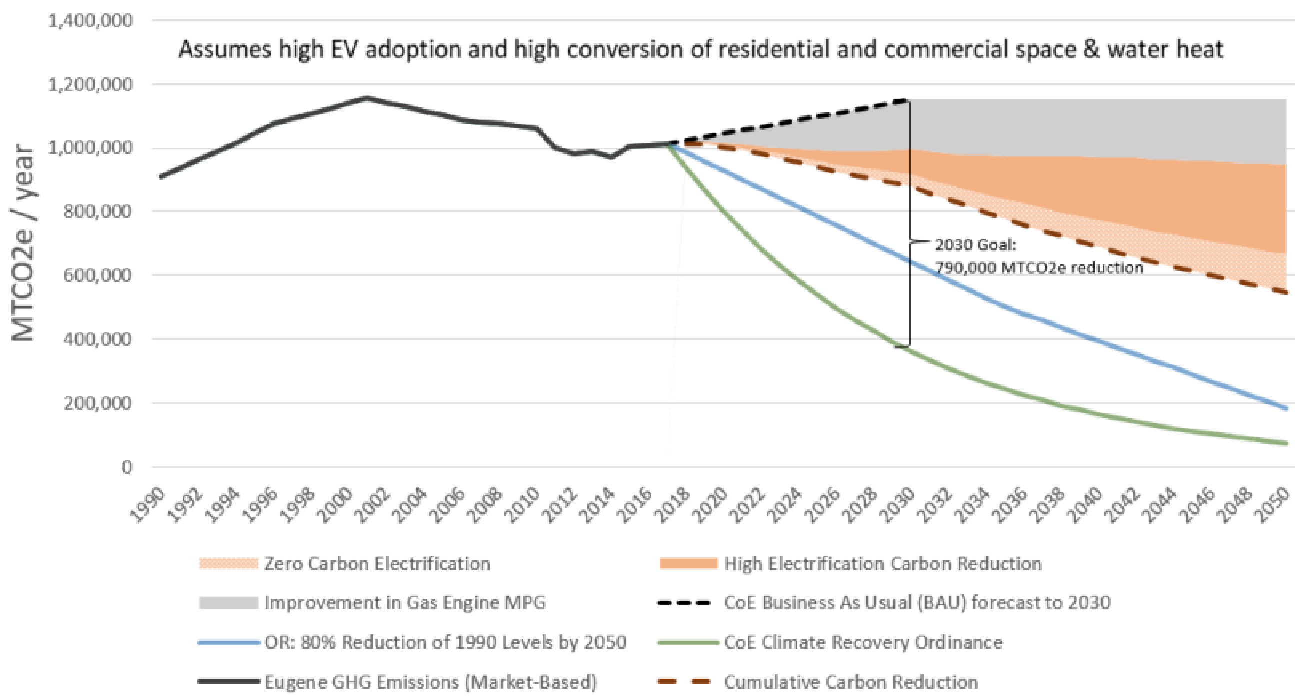


Recent Trends: Natural Gas Consumption for Transportation

- Oregon's transportation sector consumed 4.7 million gasoline gallon equivalent of natural gas and propane in 2020, which is 0.19 percent of all transportation fuels consumed in Oregon.[45]
- In 2020, 89 percent of natural gas used as a transportation fuel in Oregon was renewable natural gas and 49 percent of propane consumed as a transportation fuel was renewable propane.[45]

Oregon jurisdictions are also developing local climate action plans with decarbonization targets, leading to their own evaluation of the role of natural gas and gaseous fuel consumption within their communities. The **City of Eugene** is exploring limiting new natural gas infrastructure development in favor of electrification as part of their climate change mitigation strategy. The Eugene City Council is engaged in talks with its local utility, NW Natural, and is evaluating adding a new section to their health and environmental code prohibiting natural gas infrastructure in newly constructed buildings. Seventy-six cities throughout the country have placed various restrictions on natural gas use, including limiting natural gas in new construction and encouraging the electrification of buildings.[46]

Figure 19: Eugene Carbon Reduction Goals (MTCO2e)[27]



Conclusion

In working to achieve its mid-century clean energy and decarbonization policy targets, Oregon will need to determine the continued role of natural gas within that future. The development of a statewide energy strategy would empower the state to better guide gas decarbonization policy, provide clearer direction to utilities and fuel suppliers, and set appropriate expectations for the market and consumers.

Review of recent studies evaluating deep decarbonization pathways identified four pillars of decarbonization and multiple pathways available to accelerate Oregon's clean energy transition. Decarbonizing Oregon's natural gas will likely not come from one strategy but through a combination of energy efficiency investments, electrification, and the development of low-carbon alternative fuels like RNG and renewable hydrogen. The approach and scale of Oregon's investment in the clean energy transition will vary depending on technical innovations, market changes, costs, and timelines. A comprehensive state energy strategy could support a transparent, fair, and cost-effective clean energy transition that meets the needs of Oregon stakeholders.

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Policy Brief: Charting a Course for Oregon's Energy Future

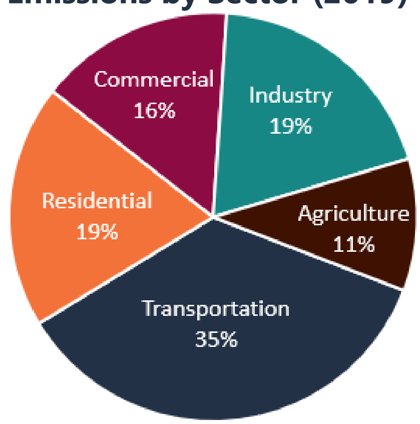
Part IV: Transportation Sector

This section is part of a Policy Brief exploring the pathways available to Oregon in the decades ahead to achieve its clean energy and climate change policy objectives, and is based on a review of 20 technical studies published in recent years.

Those studies coalesce around four common strategies, or pillars of decarbonization, required to achieve these policies: energy efficiency, electrification of end-uses, clean electricity supply, and low-carbon fuels. While these pillars provide the foundation for achieving policy objectives, policymakers must consider the trade-offs among a range of specific technology pathways to transform the state's energy systems by 2050.

The transportation sector[i] is responsible for the largest share of greenhouse gas emissions in Oregon, 35 percent in 2019, or 22.8 million metric tons of carbon dioxide-equivalent emissions.[1] These emissions come from the combustion of fossil fuels in a wide variety of vehicles that are the backbone of the state's economy. Oregon's transportation sector consumes 29 percent of all energy used in the state, with most of it coming from imported petroleum fuels, like gasoline and diesel.[2] [3] Emissions in the sector continue to rise, largely due to Oregon's growing economy and an increasing population, but they have been growing more slowly than would otherwise have occurred due to state and federal renewable and clean fuels programs. The U.S. Department of Energy projects that economic and population growth will spur continued growth in all areas of the transportation sector.[4]

Figure 1: Greenhouse Gas Emissions by Sector (2019)[1]



Oregonians spend about $5.7 billion on transportation fuels each year. Oregon imports approximately 98 percent of its transportation fuels, with domestic supplies largely coming from electricity, biodiesel production, and ethanol production. Most of the money Oregonians spend on transportation fuels is sent to other states that extract, transport, and refine the petroleum fuels that keep Oregon moving. In-state fuel production is anticipated to grow as more Oregonians purchase vehicles that are fueled with electricity from Oregon utilities. Increasing interest in renewable biofuels may also contribute to more in-state fuel production.

Recognizing this large challenge of reducing transportation emissions in the state, the Oregon Department of Transportation developed the Statewide Transportation Strategy in 2013. The STS is a broad overview of actions to achieve emissions reductions in Oregon's transportation sector.[5] This brief will focus on two elements of the State Transportation Strategy: adopting cleaner fuels and making vehicles more efficient. It will also explore the pathways identified in recent technical analyses for how the state and region can reach decarbonization goals in the transportation sector.

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[i] Learn more about Oregon's transportation sector in the Energy by the Numbers section of this report.

Current State Policies

Oregon has several programs across multiple agencies supporting decarbonization of the transportation sector. These programs inform policy discussions, reduce vehicle miles traveled, make lower carbon fuels more widely available, lower the up-front costs to purchase zero-emission vehicles, and support widespread availability of charging infrastructure. Two key programs that reduce emissions in the transportation sector are the Clean Fuels Program and the Climate Protection Program.

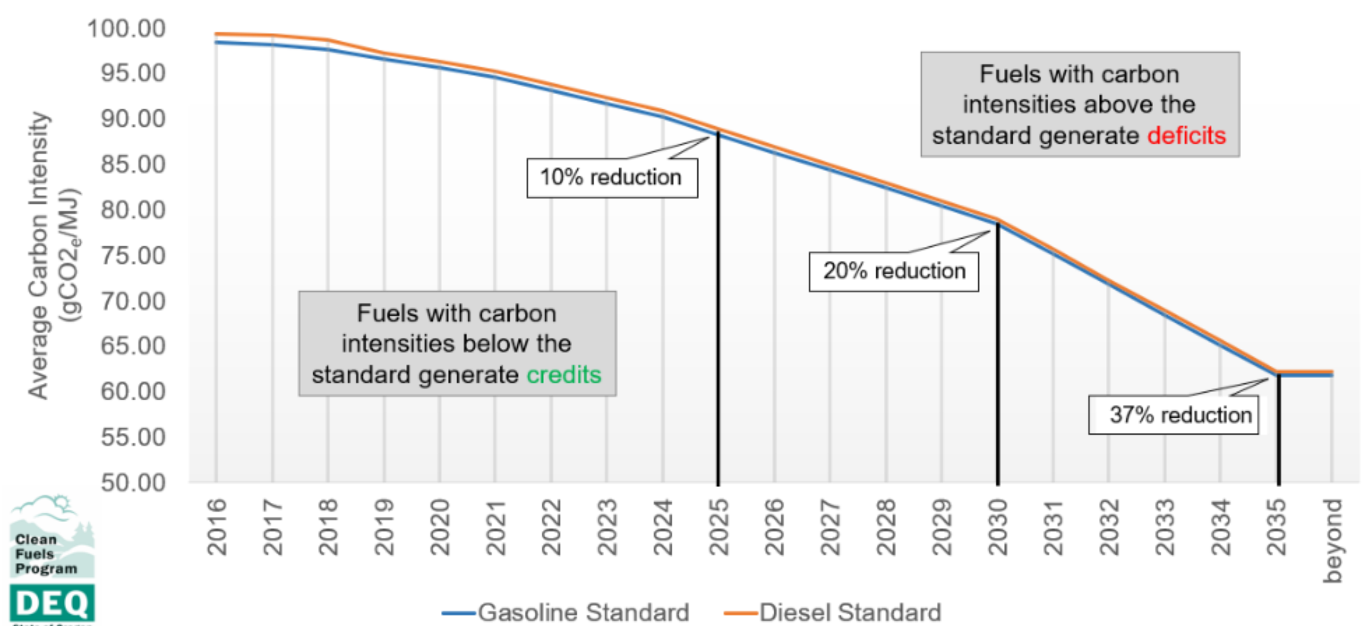
Oregon's Zero Emission Vehicle Goals[6]

In 2019, the Oregon legislature established the following ZEV targets in SB 1044:

- 50,000 registered ZEVs by 2020
- 250,000 registered ZEVs by 2025
- 50% of vehicle sales and 25% of registered vehicles by 2030
- 90% of vehicle sales by 2035

The **Clean Fuels Program**, managed by the Oregon Department of Environmental Quality, drives lower-carbon alternative fuel availability in the state.[7] The program establishes carbon intensities for all types of fuel consumed in Oregon, and it incentivizes lower carbon fuel consumption through a credit/deficit system. As shown in Figure 2, the program has a goal to reduce the average carbon intensity of Oregon fuels 37 percent by 2035 compared to 2015.[8] Carbon intensities represent the *lifecycle* of the fuel, including emissions from the extraction, generation, transportation, refinement, and combustion of each fuel. A particular fuel will generate credits or deficits based on its carbon intensity. Higher carbon intensities mean more greenhouse gas emissions are produced to move a vehicle the same distance as a fuel with a lower carbon intensity.

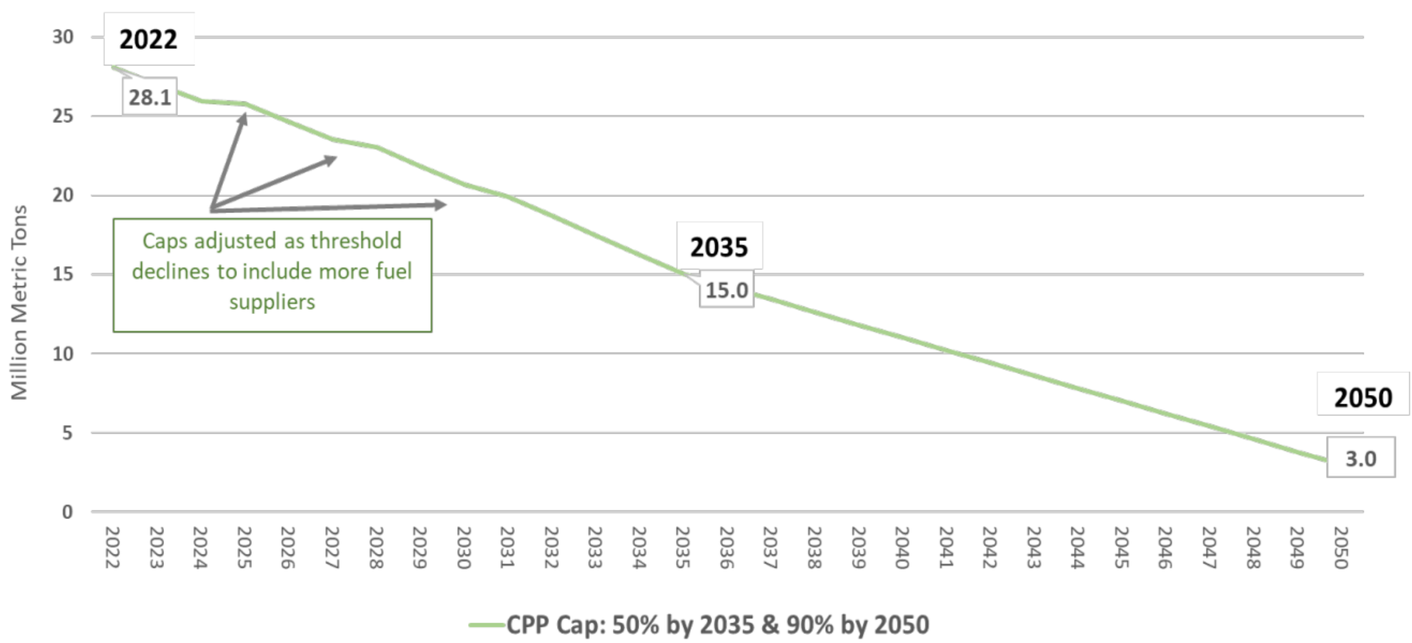
Figure 2: Clean Fuels Program Carbon Intensity Targets for Gasoline and Diesel Fuels and Alternatives[9]



The program does not have specific greenhouse gas emissions targets, but it will result in emissions reductions by lowering carbon intensity. DEQ estimates that achieving a 37 percent reduction in carbon intensity by 2035 will reduce tailpipe emissions by 50 percent.[8] All gasoline, diesel, ethanol, biodiesel, and renewable diesel fuel importers must comply with the program.[7] Other fuels developers or importers, such as aviation fuel and other renewable fuels, can voluntarily register to participate.

The Oregon **Climate Protection Program**, also administered by DEQ, aims to reduce emissions from transportation fuels 90 percent by 2050, compared to the 2017-19 average, and 50 percent by 2035.[10] It sets a declining limit on greenhouse gas emissions from fossil fuels used throughout Oregon including gasoline, diesel, natural gas, propane, and aviation fuels. The program mandates reductions in emissions but allows the market to choose how the reductions will occur. Transitioning to biofuels and zero-emission vehicle technologies like battery electric and fuel cells are two strategies to achieve these reductions.

Figure 3: Climate Protection Program Greenhouse Gas Emissions Reduction Goals[10]

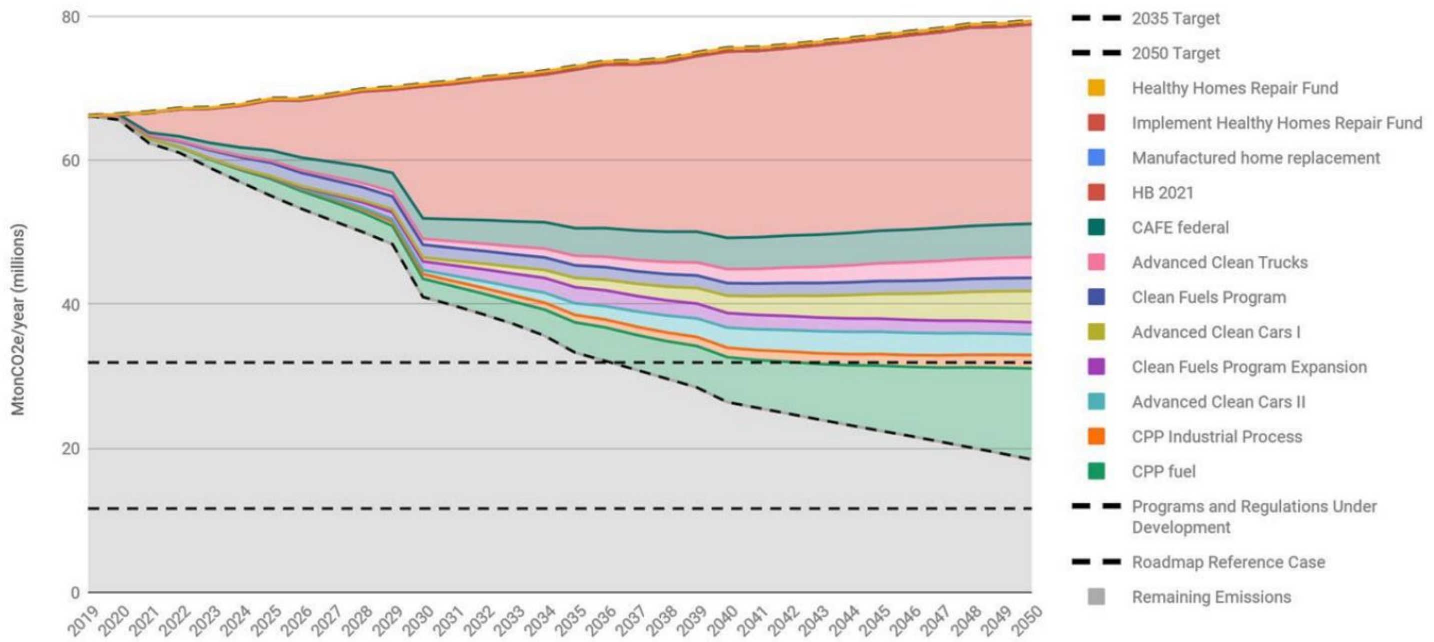


In addition to DEQ, several other state agencies also administer programs to reduce greenhouse gas emissions from the transportation sector. Agency collaboration is conducted through the *Every Mile Counts* initiative, led by the Oregon Department of Transportation.[11] ODOT, ODOE, DEQ, the Oregon Public Utility Commission, and the Department of Administrative Services also collaborate and cooperate specifically on clean vehicles through the Zero Emission Vehicle Interagency Working Group to support transportation electrification. Figure 4 below shows the array of work that ZEVIWG member agencies engage in to support transportation electrification.

Figure 4: Zero Emission Vehicle Interagency Working Group Member Agency Actions[11]

These programs and policies are making progress on reducing emissions. In 2021 and 2022, the firm SSG conducted a study for the Oregon Global Warming Commission that assessed greenhouse gas emissions reductions that can be achieved through existing and planned state programs.[12] The Transformative Integrated Greenhouse Gas Emissions Reduction (TIGHGER) Study included anticipated transportation emissions reductions from the adoption of federal fuel efficiency standards, the Clean Fuels Program, the Climate Protection Program, and other DEQ zero-emission vehicle programs, including the Advanced Clean Cars I program and the Advanced Clean Trucks program.[13] SSG also assessed the Advanced Clean Cars II rule, which is currently in rulemaking at DEQ but has not been adopted as of the publication of this report. Figure 5 below shows that the combined reductions of all these programs and others applying to buildings and electricity, have the potential to achieve Oregon's 2035 interim greenhouse gas reduction goal of 45 percent below 1990 levels. Successful implementation of each of the programs in the chart below is needed to achieve this 2035 goal, and more actions are needed to achieve the 2050 goal.

Figure 5: Modeled GHG Reductions from Oregon Programs[14]



> *"No sector is* ***as important as transportation*** *to achieving decarbonization, nor as complex in its operation and governance."*
>
> — 2021 Washington State Energy Plan[15]

Exploring Pathways to 2050

Pathways to cleaner transportation begin with extensive electrification of as many vehicles as possible.

The studies reviewed for this brief were consistent in their findings for the transportation sector: Pathways to cleaner transportation begin with extensive electrification of as many vehicles as possible. This largely depends on the availability of electric models and the charging infrastructure needed to support them.[16] Where vehicles cannot be electrified, low- and zero-carbon replacement fuels are needed. As new vehicle models are electrified, the need for these alternative fuels may go down. However, as discussed below, some vehicles will be difficult or impossible to electrify in the near to mid-term, and these vehicles will need zero-carbon fueling options to achieve full sector decarbonization.

Electrification

Electrifying road vehicles – passenger vehicles, trucks, and buses – is a key element of most deep decarbonization studies.[17] All types of electric vehicles[ii] are more energy efficient than gasoline internal combustion engine vehicles, and this, combined with the state's relatively clean electricity

[ii] Electric vehicles include battery electric, plug-in hybrid electric, and fuel cell (hydrogen) vehicles. Oregon currently has no hydrogen vehicles, so unless otherwise noted, the term electric vehicles indicates BEVs or PHEVs.

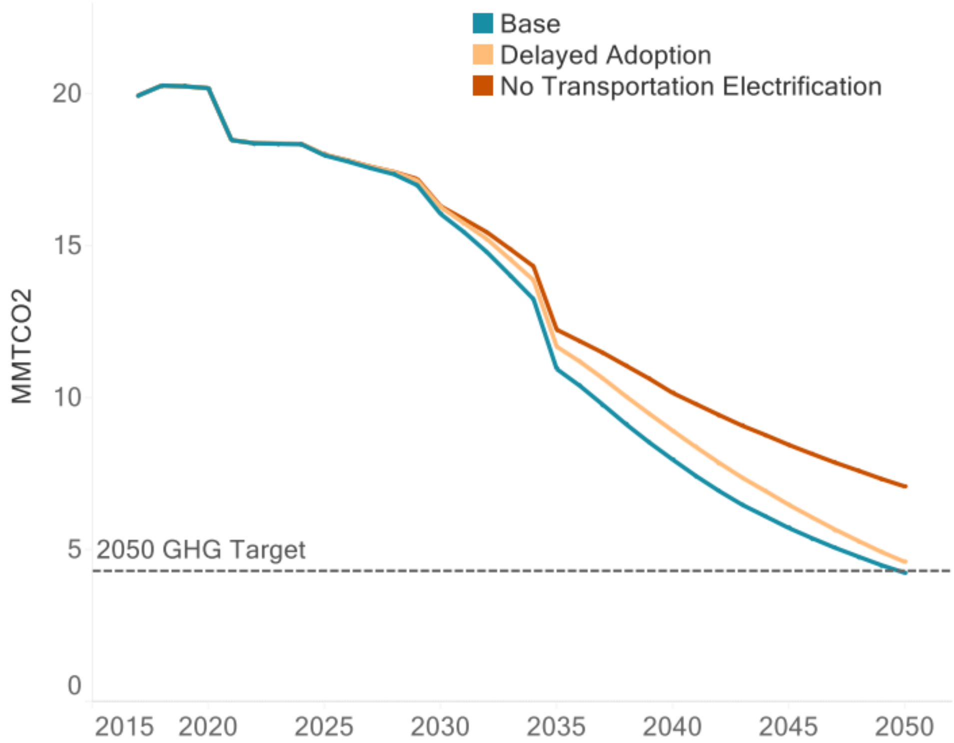
resource mix, means that switching to an electric vehicle in Oregon will immediately result in greenhouse gas emissions reductions.[18] Further, as Oregon's investor-owned electric utilities move toward 100 percent clean by 2040, electric vehicles in the state will become cleaner over time.[18] Electrifying the light-duty passenger vehicle sector alone could achieve a 19 percent reduction in *overall* state emissions.[19] Many studies indicate that sales of new passenger vehicles will need to be all electric by 2035 to achieve significant decarbonization by 2050.

- **Washington 2021 State Energy Strategy**: "For passenger cars to be fully zero-emissions by mid-century, nearly all new car sales will need to be EVs by 2035."[20]
- **Exploring Pathways to Deep Decarbonization for the Portland General Electric Service Territory**: "Electrification of passenger transportation is a critical component of decarbonizing the energy system, and passenger vehicles are at least 90 percent BEV by 2050 across all pathways. To ensure these vehicles are on the road by 2050 requires consumer adoption to be near 100 percent of vehicle sales during the mid-2030s. Delays in adoption increase the likelihood of missing the 2050 target."[21]
- **SoCalGas – The Role of Clean Fuels**: "All scenarios assume that 85% of light duty vehicles sales are battery electric vehicles (BEVs) by 2035 and 15% of light duty vehicles sales by 2035 are fuel cell electric vehicles (FCEVs)."[22]
- **Princeton Net-Zero America Project: "**We assume battery electric vehicles dominate the transition in the light duty sectors with fuel cell vehicles playing a larger role in medium- and heavy-duty vehicles."[23]
- **Oregon Clean Energy Pathways Analysis**: **"**Early electrification is key to avoiding large decarbonization costs in the future. Oregon should strive to reach 100% electrification sales of light-duty vehicles and building appliances by 2035."[24]

Figure 6 below from Evolved Energy Research's *Exploring Pathways to Deep Decarbonization for the Portland General Electric Service Territory* demonstrates how the timing of electrification matters. It shows a sensitivity analysis[iii] of different vehicle electrification options. The base case represented by the line in blue shows the anticipated reduction in greenhouse gas emissions with 100 percent of new passenger vehicle sales and 50 percent of medium- and heavy-duty sales being electric by 2035. Changing this date to 2050, as shown in the yellow "Delayed Adoption" line, increases total emissions in 2050 by 8 percent because over 10 percent of on-road vehicles have not been electrified. The "No Transportation Electrification" scenario shown by the red line removes all sales requirements, resulting in significantly higher emissions in 2050. This increase occurs despite the higher uptake of renewable diesel that was included in both scenarios.

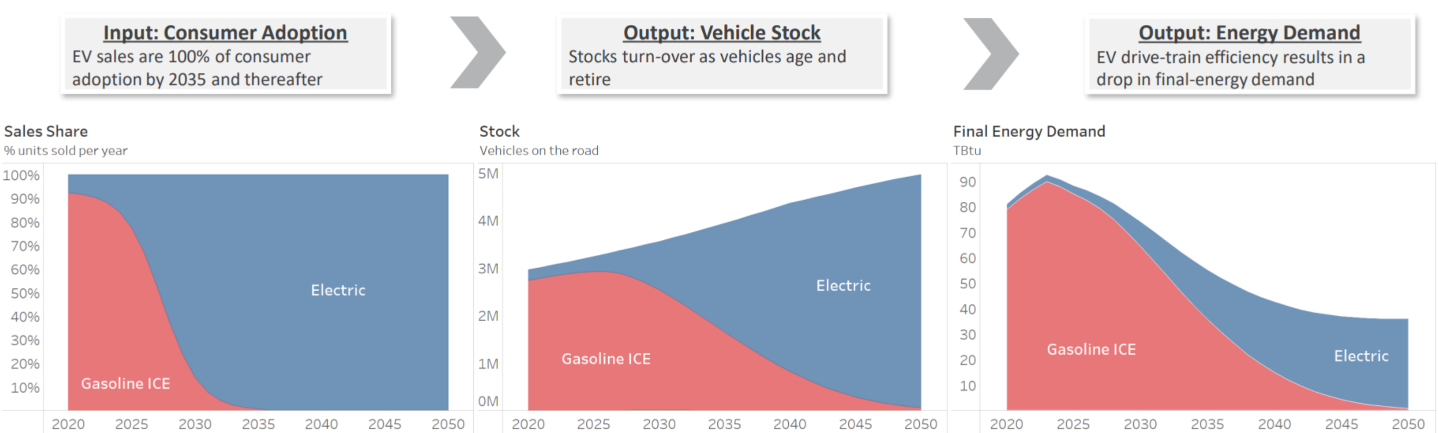
[iii] A sensitivity analysis is a modeling technique where one or more variables is adjusted while everything else remains constant to assess the effect of that variable on modeling results.

Figure 6: Modeled Effects of Reduced Electric Vehicle Sales Requirements[25]



Electrifying the transportation sector will eventually require replacing the non-electric vehicles in use today. This involves ensuring that electric vehicles are available, accessible, affordable, and meet consumer needs. Most vehicle replacements occur when a current vehicle stops working or at planned replacement cycles. Passenger vehicles tend to stay in the fleet for 15 to 16 years,[26] which means turning over a significant portion of the fleet will take time. In 2021, new electric vehicles were 7.8 percent of all passenger vehicle sales.[27] Figure 7 below from the *Oregon Clean Energy Pathways* report shows the rate of new vehicle sales in the first graph, followed by the expected rate of change in the overall passenger vehicle fleet, or stock, in the second graph.

Figure 7: Illustrative Example of Vehicles Sales and Existing Stock Turnover[28]



The reviewed studies indicate that medium- and heavy-duty vehicle electrification will also contribute to decarbonization. Due to the challenges associated with weight and range limitations of current battery technology, it is likely that other options, such as hydrogen fuel cells, will also be necessary for these vehicles.[22 29] Medium- and heavy-duty vehicles that can charge at centralized warehouses (e.g., fleets of delivery vehicles) may be easier to electrify. The amount of electrification will depend on technological advancements in vehicle models and batteries as well as the potential development of clean hydrogen infrastructure. Like passenger vehicles, there is a significant lag in timing for converting these larger vehicles due to how long they tend to remain in operation. For example, in a statewide fleet survey, DEQ found that 22 percent of medium- and heavy-duty trucks on the road in 2020 were 20 years or older.[30]

22% of medium- and heavy-duty trucks on the road in 2020 were 20 years or older.

- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Northwest**: "Widespread transportation electrification (100% of light-duty, 60% of medium-duty, and 40% of heavy-duty vehicles in the study's Central Case) will be crucial to reduce emissions at least cost and avoid using either scarce biofuel supplies or relatively expensive electric fuels [such as clean hydrogen] for transport."[31]
- **Washington 2021 State Energy Strategy**: "For heavy-duty trucks, we assume demand for hydrogen for long-distance hauling by 2050, including electric trucks. This drives the need for hydrogen refueling and delivery infrastructure. Whether hydrogen fuel cells are favored for some transportation applications in the future will depend on the relative development of propulsion technologies. For short-haul trucks, we assume a transition to 100% electric."[32]

Continued Use of Liquid Fuels

In addition to some medium- and heavy-duty vehicles, marine vessels, trains, aircraft, non-road construction, agriculture, warehouse, port, and forestry vehicles have limited electric options today, and some of these are likely to be very difficult to electrify even in the long-term. These will continue to rely on fossil gasoline, diesel, aviation fuel, or lower-carbon alternatives until zero-emission fuels become commercially available.

- **Washington 2021 State Energy Strategy**: "Not all segments of the transportation sector can be readily electrified through onboard battery storage. As the deep decarbonization modeling results suggest, long-haul freight trucks, some off-road vehicles, and long-distance rail, shipping and aviation will likely need to rely on liquid or gaseous fuels for the foreseeable future."[33]

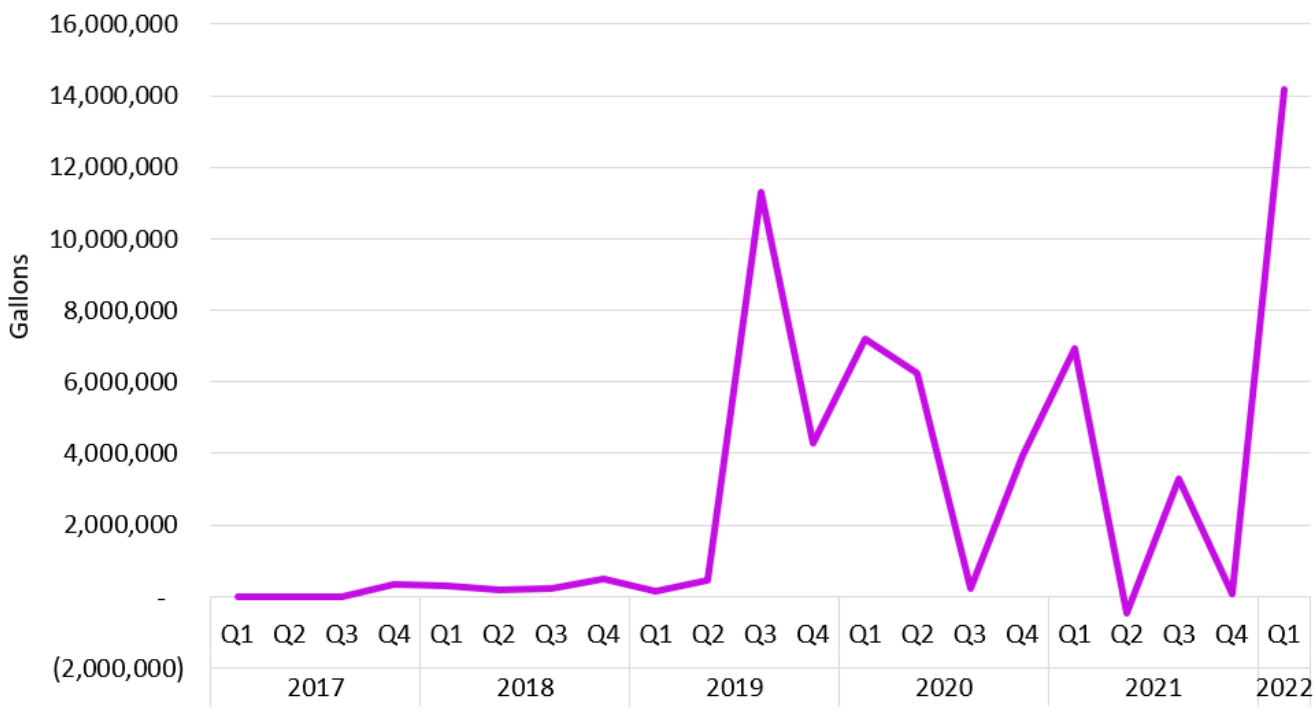
Lower-carbon liquid fuels, such as renewable versions of diesel, natural gas, and aviation fuel, can reduce emissions today and over the next 30 years.[34 35] For example, renewable diesel has 42 to 80 percent fewer emissions than fossil diesel. These fuels can be substituted directly, without the need for a new vehicle or retrofit, and stored and transported in existing fossil fuel infrastructure. This makes them easier to adopt in the near-term and an important transitional fuel until zero-carbon options are commercially available. Often referred to as "drop-in" fuels, they are increasingly available, although not currently in sufficient amounts to replace *all* existing diesel and aviation fuel use.[9]

The most widely available drop-in fuel is renewable diesel, which has seen growth in Oregon since 2018, although it remains challenging to procure outside of the Willamette Valley.[9] The fuel is in high demand because it performs better than fossil diesel.[36 37 38] The Clean Fuels Program is the main driver of renewable fuel supply in Oregon because it makes the production of these fuels more cost-effective. Figure 8 shows renewable diesel was largely unavailable until 2019, and supply has been somewhat inconsistent. This occurred in part because Oregon markets compete with California, where a more mature Low Carbon Fuel Standard offers a higher credit price for suppliers. As Oregon's Clean Fuels Program continues to mature, credit values for suppling renewable diesel will help create a better business case in Oregon markets. COVID-19 has also affected fuel supply and demand. (See the Transportation Fuels Energy Resource and Technology Review for more information.)

Renewable Diesel in the Pacific Northwest[39]

In 2018, BP began producing renewable diesel at its Cherry Point petroleum refinery in Washington State and became the only producer of this fuel in the Pacific Northwest region. It has since made additional investments to expand its renewable diesel production capacity, which BP says will reduce carbon emissions from the plant by 400,000 – 600,000 tons per year.

Figure 8: Deliveries of Renewable Diesel into Oregon in Gallons[72]



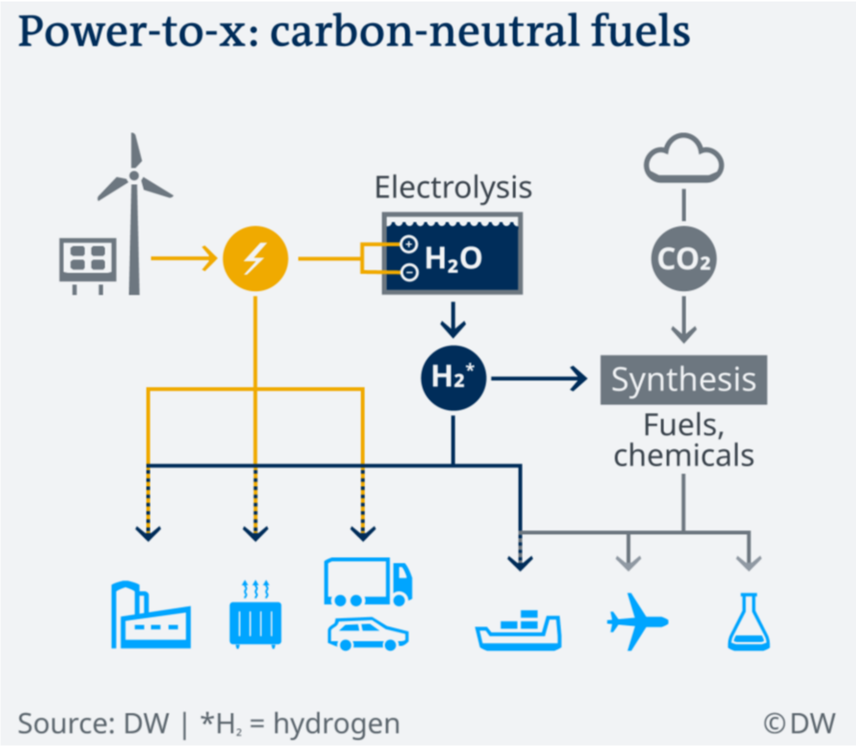
"In all decarbonization scenarios, liquid fuels are not eliminated, but they are **fully decarbonized by 2050** with a combination of synthetic fuels, biofuels and hydrogen."

— *Washington 2021 State Energy Strategy*[34]

While lower-carbon fuels like renewable diesel can drive immediate emissions reductions, zero-carbon liquid fuels like hydrogen produced with renewable electricity will be necessary to achieve near 100 percent reductions in the transportation sector. In its *Oregon Clean Energy Pathways Study,* the Clean Energy Transition Institute found that it may be feasible for Oregon to meet its 2050 greenhouse gas reduction target of 80 percent below 1990 levels without significant investments in zero-carbon fuel development; to meet a target of 100 percent reduction will require the production and use of zero-carbon fuel for hard-to-electrify sectors.[29] Other studies point to the need to consider and prepare for which vehicles are most likely to be difficult to electrify and what zero-carbon liquid fuel options are the most opportune alternative. Clean hydrogen could be an alternative for freight vehicles, and biomass-based fuels and synthetic fuels as zero-carbon alternatives where hydrogen is not an option.

- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Northwest**: "Sustainable biomass is best used for jet and diesel fuel. The best use for sustainable biomass is creating liquid fuels to power the hardest-to-electrify subsectors within transportation, namely aviation and long-distance freight shipping."[35]
- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Northwest**: "For energy-dense transportation, such as aviation, long-haul trucking, and some industrial heat processes, carbon-beneficial biomass and synthetic fuels may be used."[40]

Figure 9: Potential Future Energy Pathways Using Clean Electricity[41]



The processing and transportation infrastructure for these low-carbon fuels is not commercially available today.[42] While hydrogen is a commodity that is produced and delivered around the world, more than 95 percent of it comes from natural gas, which means it is not currently a zero-emission fuel.[43] Hydrogen electrolyzers are needed to produce hydrogen from water, and to make it clean, those electrolyzers must be powered by zero-emission electricity (see the Hydrogen Energy Resource and Technology Review for more). Similarly, synthetic biofuels are not commercially produced today, and would require infrastructure to produce the fuels at scale and deliver them to customers.[44]

Opportunities and Challenges

Infrastructure

Successful transportation electrification depends on the efficient deployment of charging infrastructure that is as ubiquitous and convenient as fueling with gasoline or diesel.[45] The Oregon Department of Transportation conducted a statewide gap analysis for EV charging necessary to meet the state's zero-emission vehicle adoption goals. Figure 10 shows the future need for different vehicles and charger types, including a 4,700 percent increase in charging infrastructure by 2035.

Figure 10: Oregon State Charger Needs to Meet Battery Electric Vehicle Adoption Targets[46]

Number of Charging Ports Needed by Use Case (Business as Usual Scenario)	2020	2025	2030	2035
Urban Light-Duty Vehicles (LDVs)	1,489	7,254	33,062	71,676
Rural LDVs	1,176	6,037	27,988	60,892
Corridor LDVs	406	1,614	2,104	2,713
Local Commercial and Industrial Vehicles	10	371	949	1,836
Transit and School Buses	15	893	3,318	7,407
Transportation Network Companies (TNC)	0	23	183	207
Long-Haul Trucking	0	39	219	690
Disadvantaged Communities	171	852	3,917	8,506
Total Number of Charging Ports	3,267	17,083	71,740	153,927
Increase Over 2020 Level		523%	2,196%	4,712%

Note: Modeling assumes 50,000 electric vehicles in 2020. Projections reflect optimized Business as Usual results.

Light-Duty Vehicle Charging Ports Needed by Type of Charging Port (Business as Usual Scenario)	2025	2030	2035
Workplace Level 2	7,220	33,304	72,379
Public Level 2	4,512	20,784	45,162
Public Direct Current Fast Charge (DCFC)	4,048	13,166	26,453

Note: LDV includes the Urban, Rural, Corridor, TNC, and Disadvantaged Communities Use Cases

The infrastructure need is significant, and includes not only addressing gaps in charger availability, but also highlights other challenges, such as local electric distribution system availability and upgrade costs. Once charging infrastructure is in place, ensuring that infrastructure is reliable will be key to consumer confidence.

- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Pacific Northwest**: "The level of transportation electrification called for by 2050 requires immediate attention to accelerating the widespread adoption of electric vehicles, investing in the essential charging infrastructure, and determining how the grid will handle the additional load required to serve this new demand."[47]
- **Washington 2021 State Energy Strategy**: "Infrastructure must be widely available, affordable and accessible to communities and the full range of vehicle classes. Rural areas outside the reach of mass transit systems will require BEV and FCV options to achieve low-carbon transportation."[20]

Electricity Demand

All transportation decarbonization options will increase electricity demand. More electricity is needed to support charging electric vehicles, and it is also needed to refine renewable diesel, produce clean hydrogen, or to produce synthetic biofuels.

- **Eugene Water & Electric Board's Electrification Impact Analysis Phase I**: "A high level of EV adoption, could increase EWEB's 'average system load [energy] up to 15% and increase peak demand [capacity] up to 30%.'"[48]
- **Montana Deep Decarbonization Pathways**: "Electrification of transportation is the largest contributor to demand growth in the electrification scenario."[49]
- **Seattle City Light**: "In 100% electrification scenario - electricity needed for transportation sector is 90x greater than it is today."[50]

In some cases, particularly for passenger vehicles, utilities have tools available to manage the demands from this new electric load in ways that can limit the need for major investments in grid infrastructure. These focus on demand-side management actions, such as programming vehicles to charge during off-peak hours and enabling the utility to control vehicle charging in ways that optimize the grid while still meeting drivers' needs.

- **Eugene Water & Electric Board's Electrification Impact Analysis Phase II**: "Phase 2 of the study estimates a lower coincident peak of EV charging (1 kW per EV) compared to Phase 1 of the study due to increased levels of off-peak workplace and public charging in the future. The electric peak impact, while still significant, can be mitigated with managed or diversified charging behavior."[51]
- **Exploring Pathways to Deep Decarbonization for the Portland General Electric Service Territory**: "Widespread adoption of electric vehicles (EVs) is projected to be the largest source of increased electricity consumption, and, left unmanaged, would increase peak demand. However, the fleet of EVs across PGE's service territory can employ smart charging by shifting their demand to more efficient times of day. Charging off peak, such as when renewable

generation is high or during the middle of the night can mitigate peak load impacts while ensuring that passengers complete all of their intended trips."[21]

Electrification of vehicles can also offer opportunities for utilities to use the vast future network of electric vehicle batteries to better manage the electric grid. Electric vehicles can be charged at times when there is low-cost renewable electricity on the grid, and may eventually be able to operate as flexible demand resources, shifting electricity use to better match the needs of the grid. In Figure 11, a sensitivity analysis conducted for Portland General Electric shows that if 75 percent of available electric vehicles could be used as flexible demand, it would allow for increased use of available renewable energy (a reduction in curtailments[iv] by 7 percent) and thus reduce carbon emissions compared to not using EVs as a flexible load.

Figure 11: Sensitivity Analyses for EV and Electrolysis Flexible Load Options[53]

Sensitivity	Curtailment (MWa)	Curtailment (%)	Emissions ($MMTCO_2$)	Emissions (%)
Flexible End-Use Load				
None	+54	+9%	+0.21	+5%
Flexible EV Load Only	+14	+2%	+0.05	+1%
Flexible WH Load Only*	+36	+6%	+0.14	+3%
Flexible Electric Fuel Production				
Add Electrolysis Facilities	-78	-12%	-0.08	-2%
Energy Storage				
Increase 8-hr energy storage	-31	-5%	-0.07	-2%
Add 24-hr PHS*	-68	-11%	-0.15	-4%

Notes: values for 2050 and relative to High Electrification pathway base assumptions.

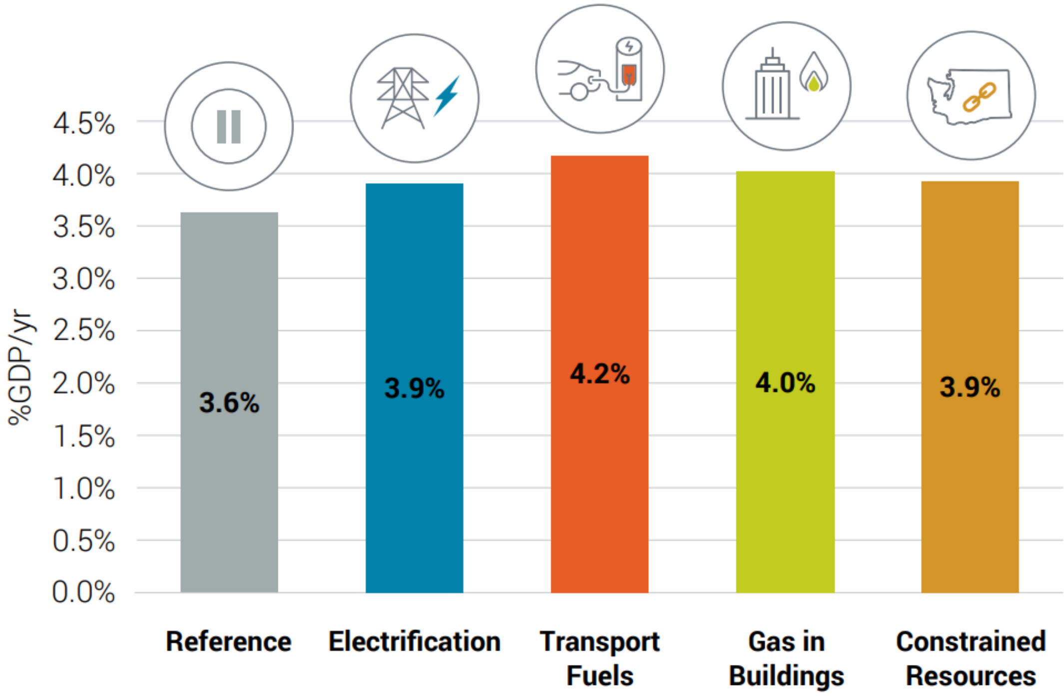
**WH stands for water heater and PHS for pumped hydro storage, which reflect other sensitivity analyses performed by Evolved Energy Research, but are not applicable to this topic.*

Costs

Studies found that scenarios with higher levels of electrification generally had lower costs than scenarios that relied more heavily on zero-carbon fuels like hydrogen and synthetic biofuels. Figure 12 below reflects annual energy spending in Washington State, represented as a percentage of Gross Domestic Product over the 2020 – 2050 timeframe. The blue bar represents the anticipated costs for a high electrification decarbonization scenario compared to the reference case – it is the lowest cost of the different scenarios. This contrasts with the "Transport Fuels" scenario, which is the highest cost to decarbonize because vehicles and buildings require more zero-carbon fuel alternatives.

[iv] Curtailment is the reduction of output of a renewable resource below what it could have otherwise produced.[52]

Figure 12: Average Annual Energy Expenditures in Washington 2021 State Energy Strategy[54]



- **Oregon Clean Energy Pathways Analysis**: "Rapid adoption of electric vehicles, electric appliances, and electric space/water heating enable lower cost economy-wide decarbonization by 2050."[55]
- **Washington 2021 State Energy Strategy**: "The Transport Fuels Scenario, where fewer vehicles are electrified or transition to hydrogen, requires more clean fuels, which drives higher costs."[56]
- **Meeting the Challenge of Our Time: Pathways to a Clean Energy Future for the Northwest**: "Widespread transportation electrification (100% of light-duty, 60% of medium-duty, and 40% of heavy-duty vehicles in the study's Central Case) will be crucial to reduce emissions at least cost and avoid using either scarce biofuel supplies or relatively expensive electric fuels for transport."[31]

While adoption of new technology can be expensive, transitioning to fuels produced in-state like electricity or biofuels can lower overall transportation expenditures by reducing Oregon's dependence on imported fossil fuels. Electricity use could also reduce transportation fuel price volatility for Oregonians, allowing businesses and families to better budget for these costs.[33] See the Consumer Energy Cost Drivers 101 for more information.

Funding Roadways

Oregon finances state highways on the principle of cost responsibility – the idea that road users should pay for their share of road costs. Currently, drivers pay for roads when they pay for gas; the state assesses a tax on each gallon of fuel sold. These tax revenues go into the State Highway Fund, which pays for state highway, county road, and city street construction and maintenance. As zero emission vehicles, which don't run on gas, become a greater portion of the passenger vehicle fleet, annual fuel tax revenues are likely to decline. Yet, the roads still need to be maintained. The Oregon Department of Transportation is exploring an alternative method for funding roadway maintenance and construction that could solve this problem. The OReGO program charges a tax on mileage instead of at the pump, allowing ZEV owners who opt in to the program to pay 1.8 cents per mile.[57]

Equity

In addition to the challenges outlined above, pathways to decarbonize the transportation sector need to consider equity. Electrification strategies should ensure that the benefits are felt in every corner of the state and shared by all drivers, communities, and businesses. Policies should be intentionally designed to avoid exacerbating historical inequities. This is particularly important as Oregon moves forward with electrification, for which the availability and accessibility of both vehicles and charging infrastructure are critical.

- **Washington 2021 State Energy Strategy**: "Experience tells us and data confirm that the costs and benefits of our energy future will not be shared equitably without intentional action. Policy makers must embed equity, resiliency and inclusivity into policy design and implementation."[58]

Charging Availability

While home electricity supplies have been designed to accommodate standard appliances, some homes – particularly older ones – may require electrical upgrades to accommodate an EV. Some upgrades can be expensive, particularly if a new electrical panel is required. People who live in homes that don't have garages or driveways may need alternative charging options. Some electric utilities are providing outlets on streetlights and utility poles where EV owners can access charging near their homes.[59] [60] Other options for these consumers include public or workplace charging.

About 38 percent of Oregonians do not have access to home charging because they live in multi-unit buildings.[61] Oregon's commercial building code requires new multi-unit dwellings to be EV-ready, but it may be expensive for existing building owners to bring charging to their residents, and some apartment buildings do not have associated parking lots. Public charging options are not yet available everywhere in Oregon, and generally electric fuel at public chargers costs more than residential electricity rates. Workplace charging offers the convenience of charging during the workday, but employers may not want to bear the costs of installing the infrastructure.

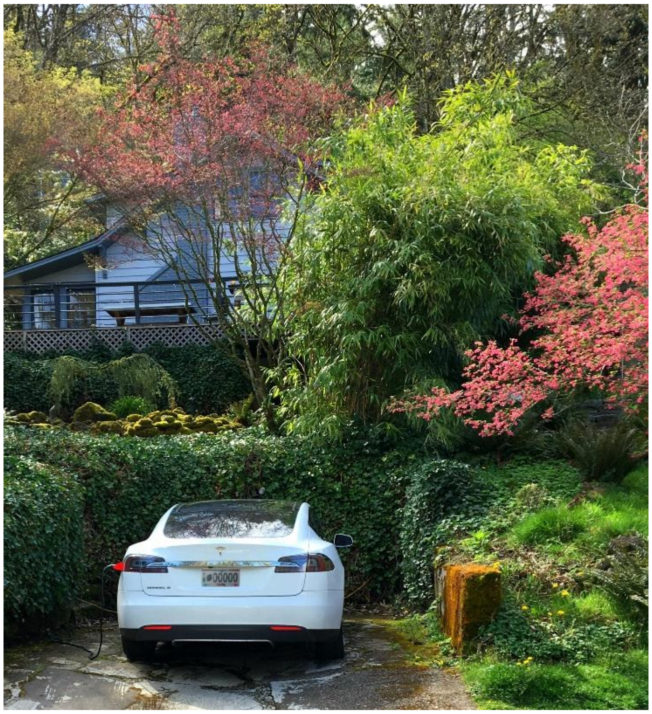
About 38% of Oregonians do not have access to home charging because they live in multi-unit buildings.

Businesses interested in electrifying their fleets may face high costs for charging infrastructure, including the cost to purchase and install charging equipment and potentially to upgrade electricity delivery to the site. Slow fleet turnover can also be a barrier for businesses; when a diesel vehicle reaches the end of its useful lifetime, buying an electric model may be significantly more expensive than a new diesel model. Once purchased, trucks can remain in service for more than two decades, which means vehicle electrification actions are needed in the next decade to achieve a significant fleet turnover by 2050.[30]

The type of charger available is likely to become a bigger issue as certain electric vehicle models proliferate. Today there are three charging standards for fast charging EVs (CCS, Tesla, and CHAdeMO) and two standards for Level 2 charging (Tesla and J1772). CHAdeMO, which supports many older models of EVs, including the popular Nissan LEAF, is rapidly becoming an obsolete standard in the U.S.[62] CHAdeMO chargers are necessary to support these vehicles until they cycle out of the fleet. Many of the early low-cost EVs use CHAdeMO, so availability of this charging platform may be particularly critical for low-income drivers.

Vehicle Availability

Although state and federal incentives can bring the cost of some EVs close to parity with gasoline vehicles, costs are still high.[63] Low-income households are more likely to purchase a used vehicle.[64] Nearly three-quarters of 2021 U.S. passenger vehicles sales were used vehicles.[65] [66] However, with demand exceeding supply for used EVs, there is indication that used car prices are also trending higher.[67] Electric vehicles are anticipated to reach cost parity across all vehicle classes by the mid-2020s, but policies to address the higher costs, like the state's EV rebates, can be helpful until this occurs.[68]



A potential unintended consequence of passenger vehicle electrification is that older gasoline vehicles may ultimately end up in environmental justice[v] and low-income communities, exacerbating current inequities. As more Oregonians buy electric cars, used gasoline vehicles may become a lower-cost option for Oregonians with low incomes. Many low-income communities are in areas that are disproportionately affected by poor air quality resulting from local transportation emissions. Concentration of gasoline vehicles in these communities will slow local air quality improvements that will result from electric vehicle adoption.

[v] Environmental justice communities include communities of color, communities experiencing lower incomes, tribal communities, rural communities, coastal communities, communities with limited infrastructure and other communities traditionally underrepresented in public processes and adversely harmed by environmental and health hazards, including seniors, youth, and persons with disabilities.[69]

Policy Considerations for Oregon

Most of the studies reviewed for this brief conclude that there are three major pathways to decarbonize the transportation sector:

1. Electrify as many vehicles as possible as soon as possible.
2. Use lower-carbon liquid fuel alternatives for vehicles that cannot be electrified in the near-term.
3. Plan for zero-carbon liquid fuel alternatives to decarbonize vehicles that cannot be electrified.

Each strategy has trade-offs that must be weighed. There is also an opportunity to build a more equitable transportation system from the ground up. Energy transitions have not historically benefitted everyone. Often, key benefits are out of reach for those who are most in need due to high up-front costs of new technologies or geographic disparities. Inequitable access to the benefits of electric vehicles already exists: cost savings are highest for Oregonians who can charge their vehicles at home, and investments in charging infrastructure in low-income or rural communities often lag because the economics don't pencil out soon enough.[70] [71] Policies may be needed to address these issues and other equity considerations.

There is an opportunity to build a more equitable transportation system from the ground up.

A transition to clean transportation requires thoughtful deliberation and robust engagement with industry, communities, drivers, and governments. The following questions could help frame transportation decarbonization policy discussions.

Electrify as many vehicles as possible as soon as possible:

- Is the market trajectory of passenger zero-emission vehicle sales, coupled with existing programs and policies, sufficient to achieve the state's greenhouse gas emissions goals, or are additional policies necessary to transition the fleet by 2050?
- Is Oregon's used ZEV market sufficient to ensure affordable vehicles are widely available in the state?
- How can Oregon support timely charging infrastructure development sufficient to meet anticipated battery electric vehicle adoption rates?
- What options are there to provide charging for electric drivers who can't charge at home? Are incentives necessary? What are the most cost-effective and convenient alternatives to at-home charging? Is there a role for workplace charging or centralized charging depots?
- What policy levers exist to make ZEVs available in environmental justice communities?
- How can the state use its resources to support chargers for passenger vehicles along travel routes? Should the state consider the use of state-owned lands, resources, and operations for public charger installations? If so, what policies or policy changes are needed?
- How can the state address the high up-front costs for businesses interested in electrifying their medium- and heavy-duty fleets? Is there a need to design programs specifically for small businesses?

- What policies or policy changes are needed to ensure sufficient revenue is collected to fund Oregon's roads and bridges?
- How can the state work with utilities to ensure sufficient electricity is available and take advantage of opportunities for transportation electrification to benefit the electric grid?

Use lower-carbon fuel alternatives for vehicles that cannot be electrified in the near-term:

- What options does the state have to facilitate the availability of renewable diesel, and other lower-carbon liquid fuel alternatives, in all parts of Oregon?
- What is the optimal use of limited supplies of lower-carbon liquid alternative fuels to support decarbonization?
- How can state policies help balance the need to support lower-carbon liquid alternative fuels in the next few decades while preparing for an economy where the demand for these fuels may ultimately diminish?
- Should the state prioritize the development of in-state production to support a clean transportation sector in Oregon?

Plan for zero-carbon liquid fuel alternatives to decarbonize vehicles that cannot be electrified:

- What fuel options enable Oregon to retain more transportation fuel-related dollars in the state?
- What are neighboring states considering for zero-fuel development? How much influence could they have on future fuel decisions in Oregon?
- What role should the state play in supporting the production of biofuel feedstock crops and the development of biofuel and clean hydrogen production facilities?
- Are there opportunities to use existing infrastructure to support zero-carbon fuel development? For example, could gas stations be repurposed to provide clean hydrogen?
- As Oregon moves toward a 100 percent clean electric grid, what options exist to develop zero-emission fuel production operations that can act as flexible demand to help optimize grid management?

Conclusion

As identified previously in this policy brief series, there is an emerging consensus in technical studies that energy efficiency, electrification of end uses, decarbonization of the electric sector, and the development of low-carbon fuels are necessary strategies to achieve a decarbonized energy future. The studies were equally consistent in the strategies needed to reduce emissions in the transportation sector. While there are challenges in navigating this transition for transportation in Oregon, it's necessary to make these changes to meet our state's energy goals – ideally with the thoughtful deliberation and balanced approach of a statewide energy strategy charting the course.

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Policy Brief: Charting a Course for Oregon's Energy Future

Part V: Pathway Trade-Offs

This section is part of a Policy Brief exploring the pathways available to Oregon in the decades ahead to achieve its clean energy and climate change policy objectives, and is based on a review of 20 technical studies published in recent years.

Those studies coalesce around four common strategies, or pillars of decarbonization, required to achieve these policies: energy efficiency, electrification of end-uses, clean electricity supply, and low-carbon fuels. While these pillars provide the foundation for achieving policy objectives, policymakers must consider the trade-offs among a range of specific technology pathways to transform the state's energy systems by 2050.

Other briefs in this series describe common strategies identified in recent studies to achieve clean energy and climate change policy objectives. These strategies include pathways to meet those targets by taking different actions across the electricity, natural gas, and transportation sectors. This brief focuses on how those different pathways will require intentional consideration of trade-offs – in terms of total costs, effects on disadvantaged communities, land use impacts, and more – as investments are made to deploy needed clean energy projects to achieve Oregon's mid-century policy objectives, including HB 2021 and the Oregon Department of Environmental Quality's Climate Protection Program.

The studies characterized in the earlier briefs in this series illustrate how these aggressive policies can be achieved, but they also reveal the multitude of pathways available to do so. Oregon has the opportunity at this juncture to consider the technical findings and explore the range of trade-offs for different pathways. In so doing, the state can engage with the public to identify an intentional pathway for Oregon that optimally balances these trade-offs.

Key Considerations in the Transition to Clean Energy

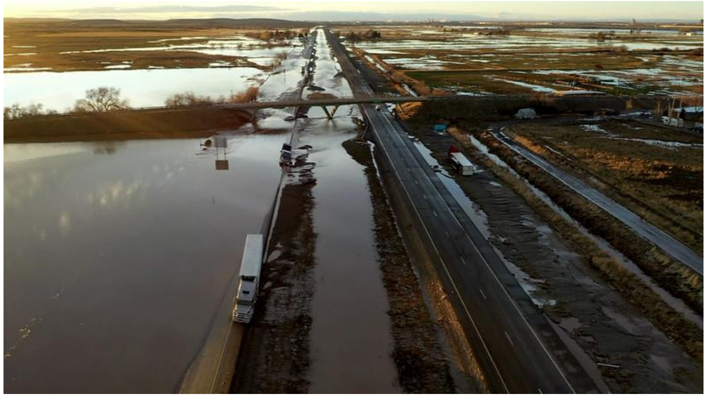
? *What are the risks in continuing the status quo and not meeting our greenhouse gas reduction policy targets in time?*

First, it is important to acknowledge the option of maintaining the status quo. While Oregon has adopted aggressive policy targets to address climate change, significant investments – many involving complex processes and decision-making with long development timelines – are required to ensure sufficient clean energy is in place to meet those requirements. Continuing to emit greenhouse gas emissions from energy infrastructure will exacerbate the real risk that communities across Oregon, and the world, will continue to experience worsening effects resulting from climate change. While action by Oregonians alone will not stop climate change, it is important the state does its part to reduce emissions and support people through the energy transition. The IPCC's Sixth Assessment Report includes five scenarios that consider how humanity will respond, or not, to climate change and what effects may result – including inundation of coastal communities on a regular basis, significant drop in global food production, far more extreme heat, and more devastating flooding.[1]

USEPA recently published an analysis that focuses on the disproportionate and unequal risks that climate change is projected to have on communities that are least able to anticipate, cope with, and recover from the adverse climate change effects.[2] For example:

Flooding:

- "Areas with both high flood exposure and high social vulnerability **occur predominantly in rural areas**. . ."
- "**Hispanic and Latino individuals are also 50 percent more likely** to live in coastal areas with the highest projected increases in traffic delays from climate driven changes in high-tide flooding."
- "**[I]ndividuals in . . . socially vulnerable groups . . . [are more likely to live]** in areas where the highest percentage of land is projected to be inundated due to sea level rise."



In early 2020, severe flooding closed Interstate-84 in north-central Oregon for several days. Photo: Oregon Department of Transportation

Increased Mortality Rates:

- "**Black and African American individuals are 40 percent more likely** than non-Black and non-African American individuals to currently live in areas with the highest projected increases in mortality rates due to climate-driven changes in extreme temperatures."

Childhood Asthma Diagnoses:

- "**Black and African American individuals are 34 percent more likely** to live in areas with the highest projected increases in childhood asthma diagnoses due to climate-driven changes in particulate air pollution."
- "**[I]ndividuals in . . . socially vulnerable groups are approximately 15 percent more likely** to currently live in areas with the highest projected increases in childhood asthma diagnoses due to climate-driven increases in particulate air pollution."

Labor Impacts:

- "**Hispanic and Latino individuals are 43 percent more likely** than non-Hispanic and non-Latino individuals to currently live in areas with the highest projected labor hour losses in weather-exposed industries due to climate-driven increases in high-temperature days."
- "**Those with low income or no high school diploma are approximately 25 percent more likely** than non-low-income individuals and those with a high school diploma to currently live in areas with the highest projected losses of labor hours due to increases in high-temperature days with 2°C of global warming."

Oregon communities already experience the effects and costs of climate change. The Oregon Health Authority's *2020 Climate and Health in Oregon* report found that climate change is negatively affecting Oregon's natural and human environments and intensifying public health crises in the state.[3] For example, between 2015 and 2020, Oregon set several ominous records that were exacerbated by climate change: [3]

- **High temperatures:** The single hottest year in state history occurred in 2015 and three others (2016, 2018, and 2020) over that timespan all rank in the top 10 hottest years on record. Since the publication of the OHA Report, 2021 also ranked in the top 10 hottest years on record.[4]

> "A new study finds the Pacific Northwest's extreme heat wave last summer was a freak event that should only happen once in 10,000 years and **it was even hotter because of climate change**. Records were broken across the region in June of 2021, as temperatures soared as high as 118 degrees Fahrenheit. . . Hundreds of people died across the Northwest, and at least 96 people died in Oregon."
>
> — *Pacific Northwest heat wave was a freak, 10,000-year event, study finds.* OPB (September 2022)[5]

- **Snowpack:** The lowest snowpack ever recorded in the state was in 2015.
- **Wildfire:** The most severe wildfire seasons in modern history have occurred since 2015, including the 2020 wildfire season that burned more than 1 million acres and destroyed or severely damaged more than 4,000 homes. By comparison, Oregon's next most severe wildfire year, 2015, saw 56 residences lost to conflagration fires. Not only do wildfires harm communities, they also result in harmful air pollution, exacerbate climate change by emitting greenhouse gas emissions, and impact wildlife habitat.[6]
- **Water Supply:** The municipal drinking water system for the City of Salem was contaminated with cyanotoxins (2018) resulting from algal blooms.

> "Scientists are anticipating even **more harmful algal blooms with the warmer water temperatures that come with climate change**."
>
> — *Researchers identify toxin that tainted Salem's drinking water in 2018.* OPB (June 2022) [7]

- **Disasters:** Areas of the state were declared national disaster areas multiple times for damage caused by extreme storms, floods, and landslides (2016, 2017, 2019, 2020).
- **Drought:** Drought emergency declarations were issued in 25 of 36 counties in the state in 2015. Meanwhile, 11 counties declared drought emergencies again in 2018 and then 15 counties did so yet again in 2020.

OHA's report also found that climate change affects each community differently and requires the state to acknowledge and address racial and economic inequities in Oregon. It also found that Oregonians working on the frontlines, including those working outdoors in smoke and extreme heat, are at increased risk of illness and death.[3] For example, OHA found that farmworkers in Oregon (the majority of whom are Latino and Latina immigrants) are "particularly vulnerable" to the cumulative effects of climate change, which can exacerbate existing disparities.[3]

As identified in the previous briefs in this series, recent studies find that the current pace and scale of clean energy deployment needs to accelerate in Oregon and across the world in the years and decades ahead in order to reduce these types of risks.

Trade-Offs in Focus: Achieving Clean Energy and Climate Policy Goals

Policy Goal: Reducing greenhouse gas emissions and producing clean electricity

Key Policy Question: What are the trade-offs involved with failing to achieve the state's clean energy and climate change policies?

Framing the Trade-Offs: Maintaining the status quo trajectory of the world's energy systems would continue reliance on resources that emit greenhouse gas emissions. While Oregon has made progress in reducing emissions, more can be done to accelerate progress. The adverse effects of unmitigated climate change on the health and well-being of humanity and on natural ecosystems are well documented, some of which have been described above.

The primary alternative to the status quo, as outlined in this series of briefs, requires accelerating the clean energy transition in Oregon to reduce the state's contribution to climate change. This will require significant investment in clean energy and all development pathways will involve some degree of adverse impacts. The state has an opportunity to identify an intentional approach to deploying clean energy to ensure that Oregon reduces its emissions while balancing the respective trade-offs involved in a way that is optimized for Oregonians.

In the clean energy transition, how can Oregon lower overall costs, balance benefits, and mitigate rather than exacerbate energy burdens?

The clean energy transition requires building significant new infrastructure to power homes, businesses, and modes of transportation – and customers will ultimately pay for the associated costs through utility bills, fuel costs, and the embedded cost of energy in goods and services. While the costs of clean energy generating technologies have fallen dramatically and the fuel itself – such as the sun and the wind – is free, there are still substantial costs associated with the necessary infrastructure to transition to a clean energy economy. As described in the introduction to this policy brief series, several studies show that the capital investments required to support the clean energy transition – such as investments to deploy renewables and to purchase EVs – will be largely offset by reductions in expenditures elsewhere in the economy. For example, the *Washington State Energy Strategy* found that savings from avoided purchases of gasoline and, to a lesser extent, natural gas, can substantially offset the costs of increased expenses in the electric sector and on clean fuels.[8]

One of the four pillars of decarbonization identified in the studies arguably has fewer trade-offs than the others in most cases: energy efficiency. For example, using a more efficient electric appliance results in lower energy consumption and thereby reduces the need for the development of additional power plants and the associated impact to the environment. Investments in energy efficiency also tend to result in a direct reduction in customer energy bills. In recent years, savings from energy efficiency in the Pacific Northwest have slowed.[9] Importantly, the studies reviewed for this policy brief series identify a need to redouble efforts to invest in energy efficiency to help mitigate the scale of the buildout of clean energy resources that will be required to achieve aggressive mid-century policy targets. For more information on the evolution of evaluating the cost-effectiveness of energy efficiency investments, see the Policy Brief on Co-Benefits of Energy Efficiency.

In some cases, the most energy efficient pathway to achieving decarbonization goals may require using more electricity.

In some cases, however, the most energy efficient pathway to achieving decarbonization goals may require using more electricity. Electrification of end uses will lead to an increase in electricity use. But this transition in the transportation sector – from vehicles that use gasoline or diesel in internal combustion engines to vehicles powered by electric drive trains – will be more energy efficient. As referenced in the introduction to this policy brief series, the *Oregon Clean Pathways* study found that converting light-duty vehicles in Oregon from gasoline powered internal combustion engines to electric would cut energy consumption (on a Btu basis) by more than half.[10]

Analyses of household energy burden focus on the high energy bills that challenge income-constrained U.S. households. Energy burden refers to the portion of a household's income spent on electricity, natural gas, and other home heating fuels – a household that spends more than 6 percent of its income on energy is considered energy-burdened.[11] Energy burden analyses rarely consider the cost of transportation energy, which is unfortunate given that a broader energy scope would likely spotlight even larger affordability challenges and would lay a foundation for projecting the positive impacts on energy burden that would likely result from expanding the market share of electric light-duty vehicles.[12] For example, the average price for a gallon of gasoline in Oregon in 2022 has been about $4.50/gallon, while the equivalent cost for charging a similar model of EV is $0.81.[i] Assuming the average number of miles driven per year, that would equate to a savings of $2,084 per year.[13]

There are also costly health consequences associated with the energy infrastructure that is typical in affordable housing in the U.S. Outdated space conditioning equipment and poorly insulated roofs, walls, and foundations characterize this building stock, all of which can cause or exacerbate the health problems of occupants. Exposure to carbon monoxide poisoning and other indoor air pollution, in addition to higher energy costs, can result from inefficient, unvented, and poorly serviced heating equipment. Other health issues include lead exposure, thermal discomfort, and aggravation of respiratory problems such as asthma. Respiratory illnesses and thermal discomfort are also associated with older HVAC systems. Living with energy insecurity represents the consequences of stressors, fears, and even mental health related to the inability to pay energy bills and the real potential of disconnection of electricity and gas heating utility services. These effects are amplified for groups vulnerable to additional underlying health issues combined with financial limitations.[12] As described in the policy brief on the Co-benefits of Energy Efficiency, targeted energy efficiency investments, if done right, can not only reduce energy burden but help mitigate some of these other challenges.

Targeted energy efficiency investments, if done right, can reduce energy burden and help mitigate other challenges.

[i] Assumes gasoline and electric vehicle models are similar and driving habits are the same.

The Oregon Department of Energy offers rebates for solar and solar plus storage projects.

Policies and programs to subsidize improvements in energy efficiency and investments in renewable energy include rebates and credits for smart thermostats, efficient appliances, and tax credits for rooftop solar systems. However, such subsidies are often inaccessible to low-income households – they are not "inclusive" – due to affordability barriers and limited tax liability against which tax credits can be credited.[12] Nationwide, residential rooftop solar systems have been installed disproportionately on owner-occupied, single-family housing owned by middle- and upper-income families.[14] Because they have less disposable income, low-income households often find it more difficult to invest in on-site solar energy. In addition, these same customers are more likely to live in older housing, which often makes their rooftops less suitable for hosting solar. Federal solar tax credits have historically[ii] been a poor fit for households that do not have large tax liabilities.[12] Oregon's solar tax credit programs were discontinued several years ago, and a solar and storage rebate is now available in the state to help address this tax liability incentive issue.[iii]

Cost is another input to consider when evaluating clean energy pathways – including how much the processes and timeline to build those resources would cost – and how those costs are ultimately passed down to Oregonians through utility bills and fuel costs over time. Large-scale renewable energy projects can take advantage of economies of scale and can be sited in locations with the strongest resources and optimal transmission access. This can help deliver the lowest cost renewable power, to the benefit of all utility ratepayers, regardless of income or proximity to the project. For example, the 120 MW Jackpot Holdings solar development near Twin Falls, Idaho is contracted to deliver energy to Idaho Power for less than 2.2 cents per kWh, which is below conventional avoided cost rates for Northwest utilities.[15] However, large-scale energy facilities can have negative effects on natural resources and the communities in which they are sited, and the benefits don't necessarily accrue to the most affected communities.

An alternative to large-scale renewable energy development are small-scale and community-based renewable projects.

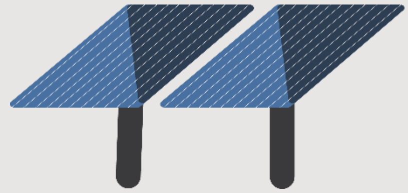
An alternative to large-scale renewable energy development are small-scale and community-based renewable projects. In addition to delivering clean energy, these projects also have the potential to deliver additional co-benefits, including local energy resilience and economic development in communities. In Oregon, there are financial incentives to support small-scale projects with local community benefits.[iii] The Community Renewable Energy Grant

[ii] The Inflation Reduction Act of 2022 (H.R. 5376) made changes to the federal tax credit, including extending the credit to participants of community solar projects, and making the tax credit refundable to tax exempt entities, which may increase low and moderate-income participation in the program.

[iii] Learn about Oregon Department of Energy incentive programs: www.oregon.gov/energy/Incentives

Program administered by the Oregon Department of Energy provides construction grants of up to $1 million to support small-scale community projects with an emphasis on such projects that deliver local energy resilience benefits. The program is designed to support the development of many valuable community-based projects.[iv]

ODOE Community Renewable Energy Grant Program



In October 2022, the Oregon Department of Energy selected 21 recipients for a total of $12 million in Community Renewable Energy Grant Program dollars for the first round of funding.[16] The program supports planning and construction of renewable energy or energy resilience projects for Tribes, public bodies, and consumer-owned utilities. ODOE will make additional rounds of funding available through 2024.

More information on the projects selected: https://tinyurl.com/C-REP-Round1

Trade-Offs in Focus: Minimizing Energy Burden

Policy Goal: Minimize energy burden

Key Policy Question: How do different clean energy deployment pathways affect energy burdened, low-income Oregonians? Can some pathways minimize those burdens more or less than others?

Framing the Trade-Offs: Supporting the development of small-scale and community-based projects within low-income and disadvantaged communities could help to promote local economic development and support other community benefits (e.g., resilience) within those communities. This strategy may result in higher overall costs, however, as these projects likely would not benefit as much from economies of scale or be able to site in optimal locations with regard to resource quality and transmission access.

Policies could also be designed to support the development of the least-cost portfolio of renewables – including any associated transmission development and siting and permitting support – to deliver the lowest cost clean energy to maintain lower electricity rates for all utility ratepayers. Pursuing a strategy that results in the lowest electric rates, particularly given the expected increase in the reliance on electricity to meet more consumer energy demands in the future (such as from EVs), could help to alleviate energy burdens on low-income Oregonians. This type of strategy may miss opportunities to provide non-energy or co-benefits to those same communities.

[iv] For more information on the benefits and opportunities associated with small-scale and community-based renewable energy projects, see ODOE's 2022 study on Small-Scale and Community-Based Renewable Energy Projects: www.oregon.gov/energy/Data-and-Reports/Pages/SSREP-Study.aspx

What are the considerations in workforce, supply chain, and innovation through continued research and development?

The energy sector is a capital- and workforce-intensive industry. As identified elsewhere in this brief, significant investment will be required to deploy clean energy in the years ahead to achieve policy goals. Different clean energy pathways will have different effects on issues related to workforce, supply chain considerations, and the potential need for research and development to support innovative solutions.

In recent years, workforce and supply chain issues have created problems for a range of industries, including in the electricity, transportation, and natural gas sectors. Given the scale and pace of the clean energy development necessary – and not just in Oregon, but also in other regions of the country at the same time – these issues could become a bigger challenge in the years ahead. See the Policy Brief on Local Energy Perspectives on Workforce and Supply Chain for more.

The USDOE *Solar Futures* study found that continued technological progress in solar – as well as wind, energy storage, and other technologies – is critical to achieving cost-effective grid decarbonization and greater economy-wide decarbonization. Continued research and development is key to keeping these technologies on current or accelerated cost-reduction trajectories. For example, a 60 percent reduction in PV energy costs by 2030 could be achieved via improvements in photovoltaic efficiency and lifetime energy yield. Further advances are also needed in areas including energy storage, load flexibility, generation flexibility, and inverter-based resource capabilities for providing grid services. With the requisite improvements, solar technologies may proliferate in novel configurations associated with agriculture, waterbodies, buildings, and other parts of the built environment.[17] The anticipated growth in solar deployment will yield broad economic benefits in the form of jobs and workforce development. The solar industry already employs around 230,000 people in the United States, and with the level of growth envisioned in the *Solar Futures* study's scenarios, it could employ 500,000 to 1,500,000 people by 2035.[17]

There are also significant differences in the supply chains, and the potential susceptibility of those supply chains to disruption, associated with the development of different types of clean energy resources. For example, most solar PV modules in recent years have been manufactured in Asia and imported into the United States.[18] Other clean energy technologies may be more readily manufactured domestically, or even in state. And in some cases, this may be a necessity. Floating offshore wind turbines, given their immense scale, must be manufactured near a port for final deployment into the ocean.[19]

Trade-Offs in Focus: Supply Chain

Policy Goal: Achieving clean energy and climate policies while minimizing susceptibility to supply chain disruptions

Key Policy Question: Are some pathways to achieving mid-century policy goals more conducive than others to avoiding supply chain disruptions of the type that have plagued the global economy in the last several years?

Framing the Trade-Offs: Supporting policies that drive a buildout of a single type of clean energy technology (e.g., solar PV), even if that path may offer the least-cost option, could make Oregon's energy sector more dependent on global imports more susceptible to supply chain disruptions.

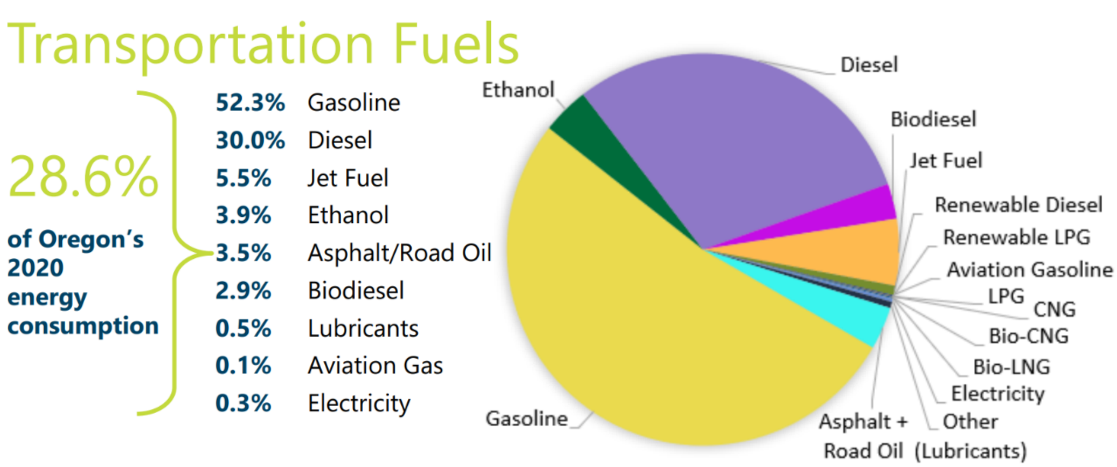
Developing an intentional strategy that relies upon a diverse portfolio of clean energy resources (e.g., solar, offshore wind, hydropower, robust transmission buildout, etc.), even if it may not be the least-cost option, could help mitigate the risks of supply chain disruptions disproportionately impacting one technology more than another. Sourcing certain technologies, like solar PV panels, from domestic manufacturers could also help to mitigate these concerns.

All energy resources and related infrastructure incur some level of adverse effects and trade-offs: what are they and how can we avoid, minimize, mitigate, and compensate for them?

The development of any energy resource comes with some associated trade-offs. Below are some examples of the types of broad trade-offs that must be considered as investments in clean energy are made to meet mid-century policy targets. It is important to acknowledge these trade-offs and to understand how these trade-offs may adversely and inequitably affect certain communities, depending on the type and location of the resource being developed.

Transportation Sector Examples

The transportation sector includes personal, passenger, and commercial vehicles, both on and off the roads, plus airplanes, boats, barges, ships, and trains. As of 2022, nearly all transportation fuels are imported from out-of-state for consumption in Oregon. Currently the transportation sector primarily uses gasoline and diesel, while the studies reviewed find the need to rapidly transition to electrification and low-carbon fuels, like renewable hydrogen, to achieve mid-century policy targets.



While decarbonizing the transportation sector will reduce the negative effects associated with petroleum use, there are also challenges associated with the low-carbon alternatives, including the extraction of lithium for EV batteries, the need to develop more renewable generating capacity to fuel electric cars or produce renewable hydrogen, the charging and fueling infrastructure to support new technologies, and the affordability of these new technologies for some customers. Examples include:

- **Renewable hydrogen** is an option for decarbonizing the transportation sector sited in the studies reviewed. As an end-use technology, the use of hydrogen has some unique appeal for the transportation sector, as customers would be able to travel a similar distance on a tank of fuel and could refuel in a similar amount of time compared to gasoline cars. But new infrastructure would be required to produce, store, and deliver renewable hydrogen at-scale to fuel a substantial portion of the transportation sector.[v] For example, a significant amount of renewable electricity would be necessary to power the electrolyzers to produce renewable hydrogen, and, as discussed below, there are trade-offs involved with the large-scale buildout of renewables.
- **Lithium-ion batteries** are used to power electric cars, as well as to store grid-scale electricity – and they are also used in smartphones and laptops. In the U.S. alone, stationary battery energy storage (to support renewable energy generation) is expected to grow from 523 megawatts annually to 7.3 gigawatts in 2025, and U.S. roads are projected to see 46 million passenger electric vehicles (EV) by 2035.[20] Critical minerals (e.g., cobalt, lithium, nickel, graphite, manganese) used in batteries are finite and mined in only a few regions around the world. Moreover, these minerals are often found and refined in countries with less stringent environmental, labor, and public health regulations. The demand for graphite, lithium, and cobalt is expected to increase by nearly 500 percent by 2050 with the potential for shortages of some minerals by the end of this decade if current trends for mobile and stationary batteries persist.[20] Lithium can be extracted through open-pit mining, like many other minerals, as well as methods that involve taking superheated, mineral-rich brine found underground and pumping it up to the Earth's surface. Lithium is extracted from that brine and then the brine is reinjected back into the earth. Both of these methods have large land footprints, are often very water intensive, and can create contamination and waste. Right now, most of the commercially harvested lithium comes from Australia and some countries in South America, namely Chile. Some companies have explored a method of extraction that involves geothermal energy that could have less environmental impact. The California Energy Commission estimates that there's enough lithium in the Salton Sea area to meet all of the United States' projected future demand and 40 percent of the world's demand, and there are at least 10 geothermal plants and lithium extraction projects in progress there.[21] Also, extending the useful life of batteries through reuse and recycling lowers lifecycle environmental impacts by reducing energy output and the costs of obtaining, transporting and refining virgin materials required to manufacture new batteries.[20] There are also efforts underway to develop novel battery technologies that avoid or minimize the use of rare earth minerals and instead rely on more abundant materials.

[v] For more information, see the Oregon Department of Energy's *2022 Renewable Hydrogen Report* (Available November 15, 2022): https://tinyurl.com/ODOE-Studies

Trade-Offs in Focus: Zero-Emission Vehicles

Policy Goal: Reducing greenhouse gas emissions in the transportation sector by accelerating a transition to zero emission vehicles

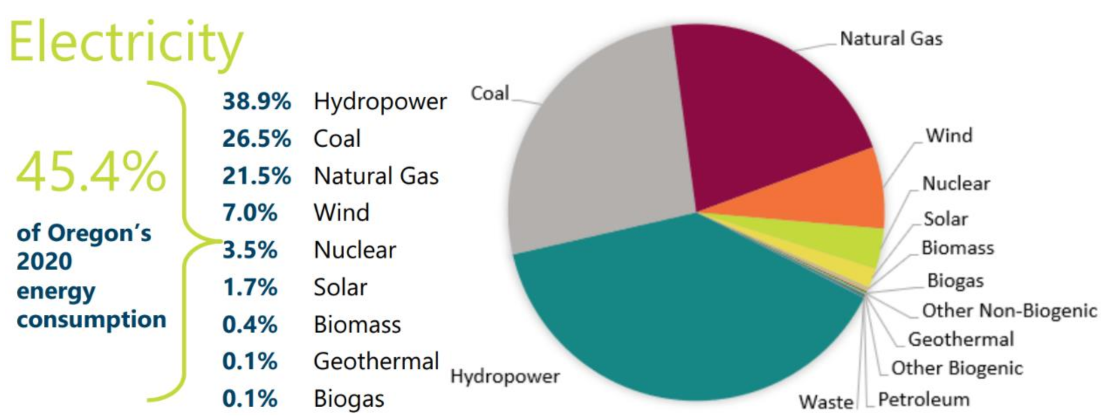
Key Policy Question: How much will electric vehicles with lithium-based batteries drive the decarbonization of the transportation sector?

Framing the Trade-Offs: Decarbonizing the transportation sector is a critical component of achieving mid-century clean energy and climate policies, but the options for doing so involve potential adverse effects.

For example, policies to support current electric vehicle technology—which is becoming significantly more cost effective—will require the mining of large volumes of lithium. As with other zero-emission vehicle technologies, these adverse effects will be mitigated in some ways by a reduced need to extract petroleum products and a reduction in GHG emissions associated with fossil-fuel powered vehicles, but localized impacts will likely be distributed unevenly.

As an alternative, policies could support additional research and development of other alternative zero-emission vehicles (such as EVs with innovative batteries that avoid the need to mine for lithium and other rare earth minerals, or production of low-carbon fuels like renewable hydrogen), but these technologies may be more expensive and/or lack commercial viability on the timeline required to achieve policy objectives. These technologies will also have other potential adverse effects, such as the need to develop additional renewable generation (along with the associated land use and fish and wildlife impacts) to produce renewable hydrogen.

Electricity Sector Examples



The electricity Oregonians use comes from facilities located in the state and across the western United States. Some of the in-state facilities also import fuel from out-of-state, which is the case with natural gas plants. The largest source of electricity comes from the hydroelectric dams on the Columbia River and its tributaries. As of 2022, solar and wind facilities make up a relatively small percentage of the electricity that Oregonians consume on an annual basis. But their contribution, particularly from solar, has grown in recent years as costs have fallen over the last decade. As discussed earlier, the studies reviewed find the need to deploy substantial amounts of new wind and solar capacity in the years and decades ahead. While these renewable energy resources do not emit greenhouse gas emissions, they do have other negative effects that policymakers should consider when evaluating tradeoffs associated with the clean energy transition. Examples of the negative effects of clean energy generation resources include:

- **Hydropower** is the largest existing energy resource in the region – and it is carbon free. However, there are significant and documented fish and wildlife impacts, particularly for threatened salmon and steelhead species within the Columbia River Basin. In some places, like the Grand Coulee and Chief Joseph dams in northeast Washington, fish passage is impossible, and the native salmon populations upriver from those dams have been eliminated. The remainder of the federal dams on the Columbia and Snake Rivers – including those along Oregon's border – have fish passage structures that allow returning adult salmon to pass over the dams, but these dams still take a toll, such as when juvenile salmon and steelhead pass through the powerhouse at these hydropower projects. These fish species can also suffer adverse effects in the warmer, slower moving waters impounded behind these hydropower projects. And they can fall prey to predators like sea lions and certain avian species, which have thrived in the conditions the dams created. Fish biologists have also identified that the stressors placed on these fish that survive passage through multiple reservoirs and dams can have adverse effects on longer-term survival.[22] Many Tribal Nations in the Pacific Northwest signed treaties in the 1850s with the U.S. government ceding land. A critical element of those treaties was preservation of the rights for Tribal Nations to continue to fish and to gather foods as they always have since time immemorial. They preserved the right to fish on Tribal lands and at usual and accustomed places, which has been interpreted over the years as the need to have sufficient fish in the rivers for Tribes to be able to catch, in order to honor those treaty rights.[23] At the same time, electricity marketed from the Bonneville Power Administration from the federal hydropower system can provide as much as 22,000 MW of carbon-free power,[24] and in recent years has provided about 40 percent of the electricity that Oregonians consume on an annual basis. This provides an important, existing base of carbon-free power for the Pacific Northwest, which results in the region having among the cleanest electricity mix in the United States. The climate benefits of this clean electricity are also important for the survival of salmon, which are threatened by decreasing freshwater flows and increases in temperature associated with climate change.[25]

- **Solar** facilities can occupy a large amount of land and can have adverse effects on natural and cultural resources. Large-scale projects in Oregon also tend to be concentrated in the eastern portions of the state. It takes approximately 6 acres of land to support 1 MW of ground mounted solar PV, which would mean 500 MW of solar would require about 3,000 acres (or 4.7 square miles). A 500 MW solar facility would produce approximately 140 aMW of energy output annually, assuming a 28 percent capacity factor.[26] And while rooftop solar can avoid these land use impacts and make a meaningful contribution, there are limitations on how much those systems can contribute to the scale of the need identified in the studies reviewed. For more information, see the excerpts from the *LA100* study included in the Electricity section of this Policy Brief. There are also concerns with the energy used in the production of PV panels, particularly when manufactured in countries that still use significant quantities of coal power.

Siting Snapshot

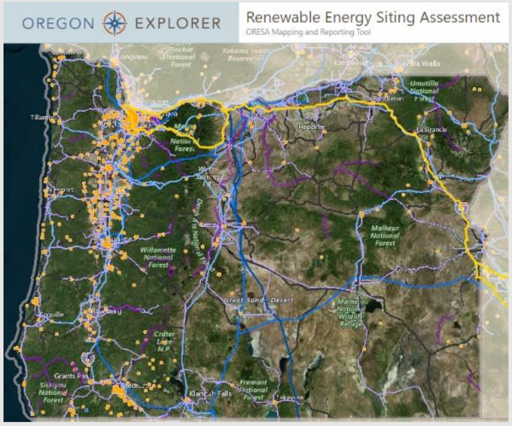
Oregon's Energy Facility Siting Council, which is staffed by the Oregon Department of Energy, has established requirements for what happens to both land where facilities are sited and equipment like wind turbines and solar panels when they are decommissioned.

During the application process, the Council ensures that project developers have the expertise to not only construct and operate a project, but also retire the facility and restore a site to a useful, non-hazardous condition. It is also requires that a certificate holder retire the facility if construction or operation is permanently ceased.

In order to prevent a certificate holder from getting out of this obligation later, the Council also requires a bond or letter of credit to be in effect at all times until the facility is retired. The Council determines the amount for that bond or letter of credit, called the retirement cost. For example, the largest permitted solar project in Oregon, the Obsidian Solar Center, has a retirement cost of $28.3 million to ensure that resources are available to restore the site.

One frequently asked question involves what happens to wind turbines, solar panels, and batteries when they are no longer operational. Oregon Revised Statutes direct the Energy Facility Siting Council to adopt standards for the reduction of solid waste. The Council requires a materials analysis during the application process and has a waste minimization standard. The Council also recommends conditions that applicants must agree to, including – as applicable – the development of a project solar panel recycling plan, a requirement to use reused or recycled wind turbines to the extent practicable, or annual reporting on the quantities of removed wind turbine components and how they were disposed.

Oregon Renewable Energy Siting Assessment (ORESA)



A thoughtful approach to deploying renewable energy sources at the scale required to achieve policy goals should seek to minimize or avoid conflicts, and will require close coordination and careful consideration of a wide range of factors. Published in June 2022, the Oregon Renewable Energy Siting Assessment project developed a comprehensive, online Mapping and Reporting Tool and report to explore and better understand the opportunities and constraints of future renewable energy development in Oregon. This project confirmed that there is enough renewable energy potential in the state to meet Oregon's energy and climate goals, while acknowledging that there are tradeoffs related to impacts and benefits with development that need to be evaluated through sustainable and responsible processes. In the tool, users can interact with more than 250 spatial datasets and explore key themes from the report related to energy planning, military coordination, siting and permitting, and inter-agency collaboration, coordination, and community engagement.[27] Learn more, read the report, and access the tool online: www.tinyurl.com/ORESA

- **Wind** projects have been deployed on land in Oregon for decades, with more than 3,500 MW of capacity installed as of 2022. Siting and permitting the development of these projects required avoiding, minimizing, and mitigating adverse effects on existing land uses and wildlife, such as bird strikes. Meanwhile, Oregon has access to one of the strongest offshore wind resources in the world – a large ocean area located in federal waters off its southern coast – where floating offshore wind projects could be deployed. There is strong interest in the potential to develop this resource to contribute to Oregon and the region's clean energy goals, with exploratory activities and studies currently in process.[28] Offshore wind projects, if deployed at scale, could occupy large areas of the ocean off Oregon's southern coast, with the potential for adverse effects on fisheries and other existing industries that rely on the ocean. On the other hand, because offshore winds are stronger, more consistent, and more abundant than land-based winds, developing this resource could make a critical contribution to achieving mid-century clean energy policies, while also offsetting the need to develop other clean technologies on land and creating significant new economic development opportunities for coastal Oregon. According to NREL, one square mile of ocean can accommodate approximately 7.5 MW of installed offshore wind capacity.[29] As a result, a 500 MW offshore wind project would require approximately 65 square miles of space in ocean and could generate about 250 aMW of energy output (assuming 50 percent capacity factor[30]).

Trade-Offs in Focus: Natural Resource Impacts of Clean Energy Generation

Policy Goal: Achieving Oregon's statutory target of 100 percent clean electricity by 2040, while also supporting more zero-emission vehicles

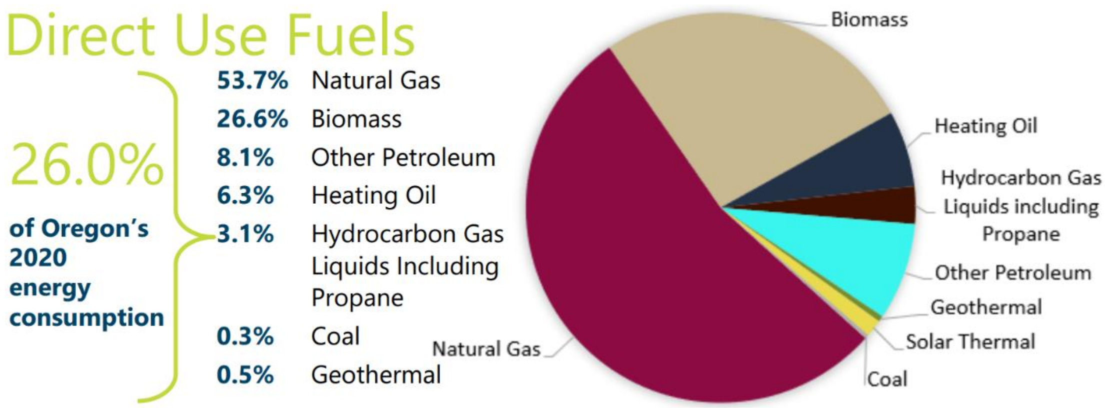
Key Policy Question: A portfolio of clean electricity resources will be required to achieve mid-century clean energy and climate policies. Can the state identify an optimal portfolio design that balances the trade-offs associated with the scale of clean energy development necessary to achieve policies?

Framing the Trade-Offs: The existing hydropower resource is immense in scale and is the primary reason that the state currently has some of the cleanest electricity in the nation. But there exist few opportunities to develop new hydropower resources at-scale. Additionally, some in the region have advocated exploring a pathway that would lead to removal of the four Lower Snake River Dams,[31] which account for approximately 1,000 aMW of clean energy annually in the region, to restore threatened salmon and steelhead species within the Columbia River Basin. While this could help to restore fish populations, it would result in the loss of a valuable, flexible carbon-free power resource that would need to be replaced with other carbon-free resources that also have potential adverse effects on the natural environment and wildlife.

As noted above, solar resources can occupy a significant amount of land. The studies reviewed to develop this series of briefs finds that tens of gigawatts of new wind and solar capacity is likely to be needed in Oregon to achieve policy goals. To put this land use footprint in perspective, the Oregon Zoo occupies 64 acres, which means that an area that size that is suitable for hosting solar could accommodate approximately 10 MW of installed solar capacity. It would require a land area 100 times the size of the Oregon Zoo to accommodate 1 GW of solar capacity.

Developing the state's offshore wind resource offers a potentially valuable tool to minimize the land use impacts of solar and the adverse effects of the hydropower system on threatened salmon and steelhead. However, the development of offshore wind resources will also incur trade-offs. As noted above, large areas of coastal waters would be required for developing this resource at scale and this development has the potential to harm fish, marine life, and other ocean users.

Natural Gas Sector Examples



Direct use fuels include fuel oil and natural gas that is used to heat homes and commercial spaces, fuels used for other residential purposes, such as gas stoves, and fuels used directly in industrial processes. The primary direct fuel used in Oregon is natural gas. Electric utilities will need to phase out the use of fossil gas in the generation of electricity to comply with HB 2021. Meanwhile, pursuant to Oregon's Climate Protection Program, natural gas utilities will need to develop strategies to reduce carbon emissions from their gas supply by 90 percent from an average of 2017-2019 levels in the decades ahead (by 2050). This is reflected in NW Natural's *Vision 2050* which was reviewed as part of this policy brief series. Most studies reviewed point to electrification as a primary means of decarbonizing current natural gas end uses. In addition, the use of renewable natural gas (such as captured methane from wastewater treatment plants or from dairy farms) or renewable hydrogen produced from wind and solar powered electricity have also been identified as pathways available for decarbonizing this supply of gas for direct-use applications.[vi]

Trade-Offs in Focus: Decarbonization of the Natural Gas Sector

Policy Goal: Reducing emissions from the direct use of natural gas

Key Policy Question: Can Oregon identify an optimally balanced pathway to decarbonize the natural gas sector?

Framing the Trade-Offs: Pathways are available for developing low-carbon fuels (like RNG and RH2) at scale that could use existing gas infrastructure to supply clean energy to Oregonians.

[vi] For more information on potential feedstocks, see ODOE's 2018 RNG Inventory Report and 2022 Renewable Hydrogen Report (coming November 15, 2022): www.tinyurl.com/ODOE-Studies

This would have the advantage of leveraging existing investments in gas infrastructure to deliver large volumes of clean energy to customers to replace the direct use of natural gas, such as for space and water heating applications. That said, there are challenges associated with the production of these low-carbon fuels at scale. For example, a significant amount of additional renewable electricity generation would need to be developed to produce large volumes of renewable hydrogen. There are significant trade-offs involved with the scale of renewables buildout anticipated to decarbonize the electric sector already which would be exacerbated by needing to develop even more renewables to produce renewable hydrogen. One of the drivers of this has to do with the efficiency losses that would occur when converting renewable electricity to hydrogen using an electrolyzer, a technology whose efficiency ranges from about 50 percent to 80 percent depending on type and size.

Electrification of current direct-use natural gas applications, meanwhile, is another potential pathway to decarbonization of the sector. While this would also require the development of additional renewable generating capacity, the renewable electricity generated could be used directly by electric end-use appliances without having to first be converted into hydrogen, thereby avoiding the costs and efficiency losses of that conversion process. On the other hand, electrification of these end-uses would require new investments in electric end-use appliances to replace existing gas appliances and has the potential to result in substantial stranded assets in the form of existing gas infrastructure.

Conclusions and Considerations to Chart a Path Forward

The studies reviewed as part of this policy brief series identify that there is no single pathway to achieving the state's clean energy and climate policies, but rather there are multiple pathways – each with its own unique cost profile and associated trade-offs for Oregon's natural resources and its people. This brief focuses on select examples of these types of tradeoffs facing the state as it charts its path to achieving mid-century policy objectives. A combination of regulation and standards to *require* specific actions as well as programs and incentives to *encourage* other actions could help resolve some of these policy choices.

The state would be well-served to engage a broad group of stakeholders to design intentional technical analysis that is responsive to the interests of Oregonians to identify Oregon-specific pathways to achieving mid-century clean energy and climate policies. This type of analysis and intentional planning to understand the potential tradeoffs of different pathways can help the state to minimize or mitigate potential adverse effects, while maximizing community and economic benefits across the state. It would also provide a critical foundation for development of a comprehensive state energy strategy that best positions Oregon to achieve its policy goals in a manner that is optimized for Oregonians. Such a strategy could be developed to address the types of core questions identified throughout this policy brief series, including:

- **Equity.** How can Oregon identify a pathway to 2050 that centers the concerns of historically marginalized communities?

- **Land Use.** How can Oregon identify a pathway to 2050 that balances the different land use and wildlife effects of clean energy developments?
- **Cost:** How can Oregon identify policy solutions to help mitigate the costs of the clean energy transition across sectors and type of customer, particularly for the state's most energy-burdened residents?
- **Resilience:** How can Oregon identify a pathway to 2050 that balances the scale and total cost of the clean energy transition with a secondary objective of seeking to improve community energy resilience across the state?
- **Fuel Choice:** How can Oregon identify a pathway to 2050 that balances maintenance of existing gas infrastructure with an increasing electrification of end uses?
- **Regionalization:** How can Oregon identify a pathway to 2050 that balances interests in developing in-state clean energy resources with the benefits that might accrue from increased regionalization?

Several states have conducted this type of analysis to inform the development of energy strategies that can guide investment, regulation, and project development in the energy sector. For example:

- **Wisconsin** developed and published a clean energy plan in April 2022.[32] It provides a framework to help ensure that Wisconsin businesses, communities, and people are well-positioned to share in the work of this plan and to take advantage of the large influx of federal dollars for clean energy and environmental justice initiatives. The Wisconsin plan objectives include all electricity consumed within the state to be 100 percent carbon-free by 2050, reducing the disproportionate impacts of energy generation and use on low-income communities and communities of color, and improving reliability and affordability of the energy system (among others). The Wisconsin plan identifies areas where further analysis will be needed to inform new legislation, programs, or changes in policies and procedure, while also identifying core strategies and actions, including: accelerating clean energy deployment, maximizing energy efficiency, modernizing buildings, supporting transportation innovation, prioritizing equity, and fast-tracking workforce development.
- **Washington** developed and published a state energy strategy – one of the studies reviewed for this policy brief series – that offers a blueprint for how the state can nearly eliminate the use of fossil fuels by 2050 while continuing to maintain and grow a prosperous economy.[33] It is informed by detailed technical analysis and modeling and covers transportation, buildings, industry/workforce, equity, electricity, and decarbonization modeling. The strategy identifies key actions in the following areas: communities, transportation, buildings, and industry.

Oregon policymakers have responded to the clear and present risks of climate change by committing the state to transition its economy away from fossil fuels and toward clean energy. Achieving these policy commitments will require substantial new investments by 2050, as identified by the studies reviewed for this policy brief series. The state has an opportunity over the next several years to engage stakeholders to develop an intentional strategy for how Oregon can accelerate this transition in a way that is equitable, that considers the respective of trade-offs between different clean energy pathways, and that defines a path forward for Oregonians.

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Policy Brief: Oregon Clean Energy Opportunity Campaign Case Study

- A coalition led by environmental justice communities—the Oregon Clean Energy Opportunity Campaign—**developed and passed major energy legislation** in 2021.
- The groundwork for the Oregon Clean Energy Opportunity Campaign **included environmental justice principles** developed in the 1990s, deep engagement with communities around the state, and successful leadership on local initiatives.

2021 was a landmark year for Oregon when it comes to energy. With the passage of House Bill 2021, Oregon joined a growing list of states with a 100 percent clean electricity standard, a policy that requires a minimum share of electricity to be generated from eligible "clean" sources.[1] The bill did much more than that, though, and is viewed by many as both a big step forward toward meeting the state's energy goals and as a model example of a bill that centers equity. The bill was the cornerstone of an agenda developed by a new coalition led by environmental justice organizations called the Oregon Clean Energy Opportunity Campaign. This case study will cover the formation, agenda development, and advocacy strategy of the Oregon Clean Energy Opportunity Campaign — and how it resulted in the centering of equity and justice in three pieces of energy legislation.

Background

Just one year prior to the passage of HB 2021, the legislative session had ended in a stalemate over climate policy.[2] Senate Bill 1530 was the latest iteration of a policy sought since 2009[3] that would have placed an economy-wide cap on greenhouse gas emissions and established a market mechanism to raise funds for clean energy projects. Enough legislators denied quorum (the minimum number of legislators required to hold a vote) for the remaining days of the 2020 session to prevent a vote on SB 1530. Only three bills passed both chambers and many bills that would have otherwise passed never came up for a vote.[4] Among them was House Bill 4067,[5] which would have allowed the Oregon Public Utility Commission to set more affordable rates for low-income Oregonians in investor-owned utility territories. That bill passed the House and was up for a vote in the Senate on the very day the 2020 session fell apart. Environmental justice organizations, led by Verde, were spearheading work on that effort.[6]

As that legislative session closed, environmental justice organizations in Oregon were coming off a string of recent successes on behalf of their communities. They had come together as the Oregon Just Transition Alliance in 2017[7] and in 2019 crafted an Oregon version of the Green New Deal,[8] a federal policy proposal introduced by Rep. Alexandria Ocasio-Cortez that had gained traction with many climate activists. That effort fed into a successful campaign and ballot measure to establish the Portland Clean Energy Fund.[9] Oregon Just Transition Alliance member organizations also opposed the proposed Jordan Cove Liquefied Natural Gas Terminal near Coos Bay; just prior to the 2020 legislative session the terminal had failed to secure an important permit.[10] Some members of the Oregon Just Transition Alliance were skeptical of SB 1530 and the "cap and invest" strategy at its core.[11] It was clear to many advocates that Oregon needed a different approach on

Environmental justice organizations in Oregon came together as the Oregon Just Transition Alliance in 2017.

greenhouse gas reductions in the wake of the 2020 legislative walkout. As that session ended, environmental justice leaders were frustrated, but also realized that there was a chance to reset the table around climate and energy policy in Oregon with environmental justice principles in mind.

Defining Principles

To understand environmental justice principles, it is helpful to look back to the roots of the environmental justice movement. For example, the Jemez Principles for Democratic Organizing[i] were developed at a meeting hosted by the Southwest Network for Environmental and Economic Justice in Jemez, New Mexico in 1996.[12]

Jemez Principles

Be Inclusive	Emphasis on Bottom-Up Organizing	Let People Speak for Themselves
Work Together in Solidarity and Mutuality	Build Just Relationships Among Ourselves	Commitment to Self-Transformation

These principles, which are more fully articulated on the website in the *i* footnote below, are referenced alongside the Oregon Just Transition Alliance's Core Principles.[13]

With all of these principles in mind, the Oregon Just Transition Alliance carried out a "Frontline Community Listening Tour" in the summer of 2020.[14] The organizations involved included PCUN, Rogue Climate, Verde, APANO, Unete, Beyond Toxics, NAACP Eugene Springfield, Euvalcree, Imagine Black (formerly PAALF), and SEIU 503.

Members of the alliance shared a 2019 Oregon Green New Deal policy platform, heard feedback, and asked these questions:

1. What issues are you most concerned with in your lives and why?
2. What kind of future can you imagine might be possible for us to achieve in one decade?
3. What do you want to see in an Oregon Green New Deal?

10 Pillars for an Oregon Green New Deal

Given constraints of the COVID-19 pandemic, the Oregon Just Transition Alliance members used online surveys, virtual listening sessions, and phone interviews to hear from 200 frontline community leaders.

[i] https://www.ejnet.org/ej/jemez.pdf

This work resulted in the alliance identifying 10 Pillars for an Oregon Green New Deal:

Oregon Just Transition Alliance: 10 Pillars for an Oregon Green New Deal[14]

January 2021

1. **Invest in Resilient Communities and a Just Recovery**
   - Recover from and Prepare for Disasters like Wildfires, Droughts & Floods
   - Support Workers and People hit Hardest by the Global Pandemic
2. **Dismantle Racism and White Supremacy in Oregon**
   - Denounce White Supremacy and Decolonize Education
   - End Police Brutality
   - End the Prison Industrial Complex
   - Welcome Immigrants and Refugees
3. **Ensure Housing Justice**
4. **Build Healthy Communities**
   - Ensure Access to Healthcare
   - Ensure Access to Healthy Air
5. **Create Jobs that Center Workers and the Environment**
   - Advance Workers Rights, Safety and the Equitable Distribution of Jobs
   - Center Workers in a Transition to a Low-Carbon Economy
6. **Advance Clean Energy Opportunity**
   - Stop Fossil Fuel Infrastructure
   - Transition to Renewable Energy
7. **Advance Transportation Justice**
8. **Protect Water**
9. **Ensure Thriving Forests**
10. **Grow Sustainable and Equitable Food Systems**
    - Advance Farm Justice
    - Ensure Access to Health, Affordable and Culturally Appropriate Food

Oregon Clean Energy Opportunity Campaign

The alliance's 2020 listening tour and the 10 pillars provided the policy foundation for what came next as the 2021 legislative session approached. Core to the Jemez Principles is the idea that leadership should come from organizations led by Black, Indigenous, and People of Color, and others who have experienced historical discrimination, to create balance and to shift power dynamics. While Oregon's environmental justice groups were part of coalitions with more traditional climate advocates – and had formed their own coalitions, the Oregon Just Transition Alliance and the Portland Clean Energy Fund Coalition – they decided to build a new group called the Oregon Clean Energy Opportunity Campaign.[15] This new endeavor included environmental justice groups, labor organizations, social justice advocates, mainstream environmental groups, and local governments. It also included leadership and an organizational structure that reflected the Jemez Principles.

For example:

- The coalition's steering committee was comprised of groups led by people of color or others who have experienced inequities.[16]
- A conscious decision was made to include rural communities in both leadership positions and as a vital constituency in the new coalition because rural communities are becoming increasingly racially diverse,[17] and rural Oregonians of all races experience the highest energy burden[ii] in the state.[18]
- At meetings, if someone identifying as historically underrepresented wanted to share a perspective, they could move to the head of queue to speak.[19] This is called a "progressive stack" approach, which was a practice first popularized during the community meetings of the Occupy Wall Street movement.[20]
- The new coalition also organized from the ground up by recruiting new voices from communities around the state as part of the Energy Justice Leadership Institute.[16]

Oregon Clean Energy Opportunity Campaign Steering Committee[16]	**Oregon Clean Energy Opportunity Campaign Advocates**[16]
• Adelante Mujeres • Asian Pacific American Network of Oregon (APANO) • Beyond Toxics • Causa • Coalition of Communities of Color • Euvalcree • Lake County Resources Initiative • NAACP Eugene Springfield • Native American Youth And (NAYA) Family Center • Oregon Just Transition Alliance • OPAL Environmental Justice Oregon • Pineros y Campesinos Unidos del Noroeste (PCUN) • Rogue Climate • Verde	• 350 PDX • Bonneville Environmental Foundation • City of Milwaukie • City of Portland • Climate Solutions • Columbia Riverkeeper • Community Energy Project • Ecumenical Ministries of Oregon • The Environmental Center • Multnomah County • Oregon Coast Energy Alliance Network (OCEAN) • Oregon Environmental Council • Oregon League of Conservation Voters (OLCV) • Oregon Physicians for Social Responsibility • Sierra Club

[ii] Energy burden is the percentage of household income spent on energy and transportation costs; anyone paying more than 6 percent of their household income on energy is considered energy burdened.

2021 Legislative Session

More than 5,000 structures were lost in the Labor Day 2020 wildfires.

While the coalition was forming and learning to work together, Oregon experienced a catastrophe predicted by climate scientists.[21] Record wildfires, fanned by unusually high winds on a hot day,[22] swept through many regions of the state over Labor Day weekend in 2020 and destroyed more than 5,000 structures.[23] The majority of the structures lost were manufactured homes owned or rented by lower-income Oregonians. Smoke filled the skies as the fires persisted for days, creating some of the worst air quality conditions in the world.[24] For leaders of the Oregon Clean Energy Opportunity Campaign, climate change had very literally hit home; member organization Rogue Climate, headquartered in Phoenix in Southern Oregon, lost its office in one of the fires.[25]

With a framework and policy platform in place – and with potent, heart-wrenching evidence of how climate change will hit low-income communities hardest – the Oregon Clean Energy Opportunity Campaign prepared for the 2021 session. The Governor issued Executive Order 20-04 in March 2020, which outlined many new initiatives for state government to address climate change.[26] In a win for environmental justice organizations, the order established an Interagency Workgroup on Climate Impacts to Impacted Communities to develop strategies to guide climate actions. In the wake of George Floyd's murder and the resulting demonstrations in the summer and fall of 2020, the Governor was embracing recommendations of the Oregon Racial Justice Council on how to incorporate racial justice into state budget and policy decisions. The table was set for equity issues to be prioritized – but conventional wisdom was that the Governor's Executive Order and the abrupt end to the 2020 session over climate legislation would make energy legislation a challenge. The Legislature would also be meeting virtually, and leaders were focused on the ongoing pandemic. Into this context, the coalition put forward three priority bills for 2021.

First, the new coalition picked up where the Oregon Just Transition Alliance had left off when the 2020 session ended early. They wanted to bring back the energy affordability bill.

HB 2475[25] was drafted to give the Oregon Public Utility Commission the ability to consider "differential energy burdens on low-income customers and other economic, social equity or environmental justice factors that affect affordability for certain classes of utility customers" in the ratemaking processes for electric and natural gas utilities. In addition to the use of rates and bill credits, the PUC would be able to mitigate energy-burdened customers through bill reduction measures or programs such as demand response or weatherization.

The coalition put forward three priority bills for 2021.

This bill also required electricity consumers purchasing electricity from electricity service suppliers (ESSs) to pay the same amount to address the mitigation of energy burdens as retail electricity consumers that are not served by ESSs (i.e. investor-owned utilities).

Finally, in line with social justice principles, the PUC would be directed to provide up to $500,000 in financial assistance, in aggregate, to organizations that represent residential utility customers that are either low-income or members of environmental justice communities in regulatory proceedings conducted by the PUC. This would allow these groups to have a seat at the table with more resourced organizations and businesses.

Portland General Electric: Income-Qualified Bill Discount Program

During the 2021 Oregon Legislative Session, lawmakers passed HB 2475, the Energy Affordability Act. This Act gives the Oregon Public Utility Commission the authority to allow utilities to provide income differentiated rate designs, such as bill discounts, that help reduce energy burden for low-income customers.

On April 18, 2022 Portland General Electric launched its Income-Qualified Bill Discount program, a new offering that provides a 15-25 percent discount on household energy use. The first of its kind for investor-owned utilities in Oregon, PGE developed this program in partnership with the OPUC and community stakeholders. The program is designed to result in a reduction of energy burden for income-qualified customers, alleviating hardship and providing easier, more affordable access to reliable power.

"As an essential service provider, it's imperative that we meet our customers where they are," says Sunny Radcliffe, director, Government Affairs. "Almost 17 percent of Oregonians live in households with incomes that are below the federal poverty level. This new program provides a meaningful bill decrease that recognizes the level of need of income-qualified customers. I'm proud of the work we are leading to address our customers' needs as their trusted energy partner."

Ease of enrollment is central to the program's design, meaning no income documentation is needed during enrollment. Eligible customers can sign up via PGE's website at: portlandgeneral.com/IQBD or by calling PGE's Customer Service at 503-228-6322. Information and support are available for non-English speaking customers.

Next, the coalition brought back another concept that several member organizations had pursued in the past. House Bill 2842 would establish a Healthy Homes Program at the Oregon Health Authority.[27] The program would provide grants to entities that provide financial assistance to low-income households to repair and rehabilitate their residences and to landlords to repair and rehabilitate properties inhabited by low-income households. *Repair and rehabilitate* was defined in the bill and included: energy efficiency; radon, lead, and mold abatement; air filtration systems; and measures to improve fire and seismic resilience. The bill also would also establish the Interagency Task Force on Healthy Homes to consider ways to improve the health and safety of homes.

Finally, the coalition would pursue a clean electricity standard for Oregon. House Bill 2021 known as the "100% Clean Energy for All" bill, introduced a broad range of targets, programs, and studies to transition Oregon to a clean, resilient, equitable electricity grid, including:[28]

- **100 Percent Clean Electricity Targets.** Oregon's large investor-owned utilities (IOUs) and electricity service suppliers would reduce greenhouse gas emissions associated with electricity sold in Oregon compared to a 2010 baseline – 80 percent emissions reductions by 2030, 90 percent by 2035, and 100 percent by 2040 – effectively requiring emission-free electricity by 2040. The legislation provided exemptions from meeting those goals if compliance would affect system reliability or lead to excessive rate increases.
- **Community Benefits and Impacts Advisory Group.** Clean energy plans required by the bill would include equity measures, and utilities must have advisory committees focused on community benefits and impacts to help guide their clean energy work.
- **Natural Gas Plant Restrictions.** The bill would prevent the Oregon Energy Facility Siting Council, which is staffed by the Oregon Department of Energy, from issuing new or amended site certificates for fossil-fueled energy facilities that emit greenhouse gases into the atmosphere.
- **Community Renewable Energy Grant Program.** The bill would create a $50 million fund at ODOE to provide competitive grants for planning or developing community renewable energy projects less than 20 megawatts in capacity that promote energy resilience, increase renewable energy generation or storage capacity, and provide economic or other benefits to communities. The program would include a 50 percent carve-out for environmental justice communities.
- **Responsible Contractor Labor Standards.** The concept would require renewable project developers and contractors to document and meet specific labor standards when constructing renewable energy generating or storage facilities with capacity of 10 megawatts or greater.
- **Study on Small Scale Renewable Energy Development.** The bill would direct ODOE to convene a work group to develop and publish a study on the barriers, opportunities, and benefits of small-scale renewable energy projects by September 30, 2022. The study would also require a look at diverse ownership models; one aim of many energy justice groups is to spread the benefits of ownership to the community level.
- **Green Energy Tariffs.** The bill would permit IOUs to collaborate with local governments to develop PUC-approved green electricity rates in alignment with local government renewable or clean energy goals.
- **RPS Community-based Renewable Energy Project Target Changes.** HB 2021 would increase the RPS community based renewable energy target from 8 percent of aggregate electrical capacity by 2025 to 10 percent of aggregate electrical capacity by 2030 for Oregon's large IOUs.

With these three bills as the agenda, the Oregon Clean Energy Opportunity Campaign continued to build its work on environmental justice principles as the coalition developed strategies for getting the bills passed. One component was having Energy Justice Leadership Institute (EJLI) participants not only meet and communicate with their own legislators, but also to support the voices of communities themselves by providing testimony at committee hearings. Organizing efforts led by the Oregon

Clean Energy Opportunity led to 116 Oregonians meeting with two-thirds of legislators, 450 people submitting testimony in support, volunteers making 5,000 calls to community members and getting 250 of them to urge their legislators in support of all three bills, and 680 postcards mailed to lawmakers.[19]

Meanwhile, some legislative leaders also embraced the Oregon Clean Energy Opportunity Campaign's approach. Newly elected State Representative Khanh Pham, who had been the director of the Oregon Just Transition Alliance prior to her election, was a chief sponsor of HB 2021.[28] Representative Pam Marsh, as the Chair of the House Energy and Environment Committee and co-chief sponsor of the bill, worked hard to bring rural voices to the negotiating table, which was a challenge given hard feelings about climate policy in the year prior. This work led to the inclusion of the Community Renewable Energy Grant Program, the study on small-scale and community energy projects, and the increase to existing community-based renewable energy project targets. In the end, all three priority bills of the Clean Energy Opportunity Campaign passed into law. Final passage of HB 2021 happened to fall on the hottest day ever in Salem (it was hotter still the next day and the day after that)[29]; the legislative session also started just before a record ice storm cut power to the capital city for days.[30]

Governor Brown signed HB 2021 in July 2021.

What's Next

Since the 2021 session, Oregon Clean Energy Opportunity Campaign leaders have been working to address concerns related to siting and tribal resources, preventing fossil fuel infrastructure and cryptomining, promoting programs and policies to support cooling and human safety in extreme heat, and focusing on implementation and processes to ensure state agencies are incorporating feedback from communities. As climate impacts have come to Oregon, this unique coalition reflects the idea that those most likely to be adversely affected by climate change can and will lead the way in developing policy ideas and passing legislation to help Oregon meet its emissions reduction goals.

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Policy Brief: Energy Efficiency Policy Opportunities in Existing Buildings

- Existing buildings hold **the greatest potential** for reducing energy consumption and associated greenhouse gas emissions in the building sector.
- Successful existing voluntary energy efficiency programs have **made Oregon a leader** in energy efficiency and greenhouse gas (GHG) reductions, but more is required to access the large pool of potential energy efficiency and GHG reductions in the existing building stock.
- There are multiple strategies and programs that can **support higher adoption** of energy efficiency technologies for existing buildings.
- Policy design should be informed by robust data and new programs should establish specific targets and goals to **ensure programs are efficient and effective**.

This policy brief will explore policy and program options for reducing energy use and greenhouse gas emissions in the existing buildings sector. Energy consumption in buildings is responsible for approximately 22.4 million metric tons, or nearly 35 percent of annual Oregon greenhouse gas emissions.[1] Reducing greenhouse gas emissions in the built environment is a priority for Oregon and a focus of recent executive orders and legislation. While building energy codes are a successful policy for addressing energy efficiency in *new* construction, there are few regulations that focus on existing buildings – which represent most emissions in the building sector.

Energy efficiency reduces both energy use and GHG emissions. It is now the second largest resource in the Pacific Northwest, behind hydropower.[2] The Northwest Power and Conservation Council reports that from 1978 through 2020, the region acquired 7,530 average megawatts (aMW) in energy efficiency, including about 2,200 aMW in Oregon alone.[i] [3] These accomplishments save ratepayers more than $4 billion per year on their electricity bills and have reduced emissions by over 24 million metric tons of carbon dioxide.[4] Building efficiency is a big part of these overall energy savings.

Building Codes for New Buildings

Oregon's building energy codes apply to newly constructed buildings; application to existing buildings is limited to only renovations. Building codes cover many aspects of construction, including: insulation, windows, and heating and cooling options that affect the building's overall energy consumption. Once occupied, updates to existing equipment and building elements are not required; and building energy performance is not regulated once construction is complete. Newly installed equipment, however, is required to meet the current code.

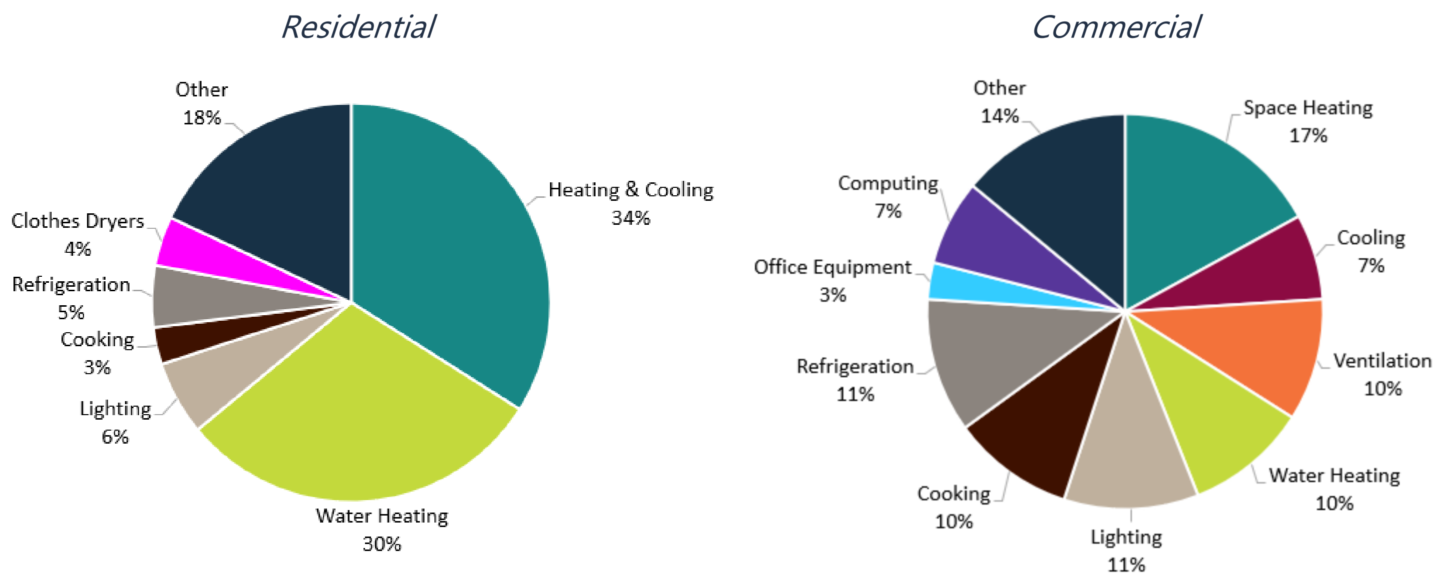
Oregon's commercial and residential building codes are some of the most energy efficient codes in the country.[5] Governor Brown's Executive Order 20-04 included a directive to update building codes to reduce building energy consumption by 60 percent by 2030, compared to a 2006 baseline.[6] Existing code reduces residential energy use by about 35 percent[7] and the commercial code by about

[i] The Northwest Power and Conservation Council previously reported about 7,200 aMW in energy efficiency; the Council updated its estimate to 7,530 in September 2022.

45 percent[8] from this baseline, and future code increases will be introduced incrementally. Oregon also established voluntary residential and commercial reach codes which are optional energy construction standards that exceed existing energy codes. Reach codes are designed to allow the energy efficiency and construction industries to prepare for future code requirements. By introducing new technologies and practices through a reach code, industry learns and modifies its approach, paving the way for future adoption into the next code iteration.

As shown in Figure 1, about 70 percent of residential sector energy end-uses (heating & cooling, lighting, and water heating) are directly affected by building codes. In the commercial sector, the primary end-uses that are directly affected by energy codes (space heating, cooling, ventilation, water heating, and lighting) account for approximately 55 percent of total energy usage. Other end-uses not directly covered, such as refrigeration, cooking, and computing, can be influenced by the building code through efficiency and control requirements for the equipment that serves these uses.

Figure 1: Energy End-Uses in the Residential and Commercial Building Sectors[9] [10]



Appliance Efficiency Standards

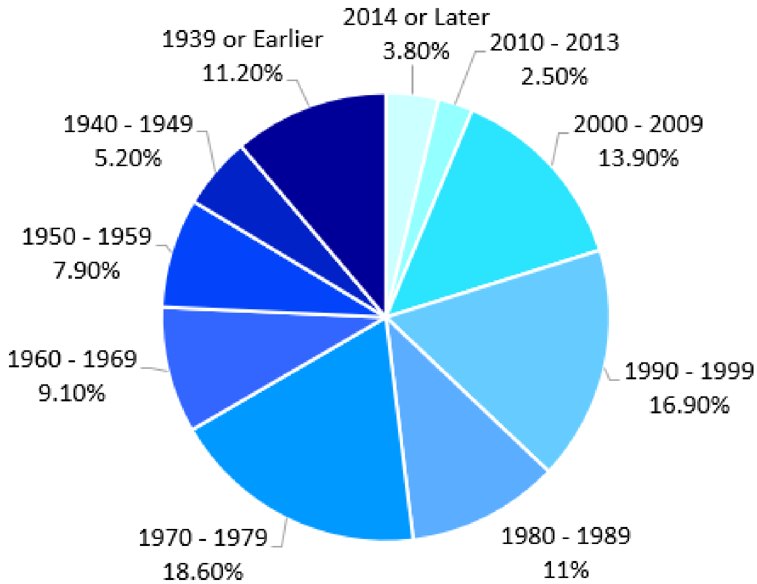
New consumer products such as water heaters, commercial dishwashers, and televisions are required to meet Oregon's product efficiency standards when they are installed in new or existing buildings.

These standards ensure improvements in energy savings for consumers. Governor Brown's Executive Order 20-04 directed Oregon to update and improve its appliance efficiency standards.[6] An ODOE public rulemaking and legislative passage of HB 2062 in 2021 created nine new and two updated product efficiency standards,[11] [12] which match the highest standards in the country. Savings and reductions will continue into the future as long as the standards remain in place. By 2025, implementation of the standards will result in an estimated 111 gigawatt-hours of electricity savings, 414 billion Btus of natural gas savings, and will reduce approximately 49,500 metric tons of CO2.[13] ODOE will continue to evaluate opportunities for new efficiency standards. Regular updates help maintain consistency and alignment with comparable standards, eliminate marketplace confusion, and achieve cost-effective energy conservation for Oregon consumers.

Existing Building Energy Use

There is potential for significant energy savings in existing residential and commercial buildings. About 25 percent of all energy use in Oregon supports existing residential buildings.[14] In 2018, there were 1.8 million existing residential housing units in Oregon, compared to about 17,600 new residential building permits issued per year (representing about 1 percent of that total number of existing residential units).[9] Most existing residential buildings are also relatively old; 63 percent were built before 1990, when building energy codes were substantially lower than today.[15] Comparatively speaking, the opportunity for energy saving and greenhouse gas reduction in existing buildings far exceeds the opportunity in new buildings.

Figure 2: Oregon Homes by Vintage



Commercial buildings account for 19 percent of Oregon's energy consumption.[14] There are 3.4 billion square feet of commercial buildings in the Pacific Northwest,[16] and approximately 60 percent of that square footage was built before 1990.

Current Oregon Programs Supporting Energy Efficiency in Existing Buildings

In 1999, the State of Oregon created the Oregon Public Purpose Charge as part of Senate Bill 1149, which requires the state's two largest investor-owned electric utilities to provide funding to support cost-effective energy efficiency improvements.[17] Most funds are administered by Energy Trust of Oregon through incentive programs that help utility customers offset the cost of energy efficiency upgrades. These programs, and the individual measures they support, must pass Oregon Public Utility Commission required cost-effectiveness tests to ensure energy efficiency investments are in the best interests of ratepayers. Consumer-owned utilities also offer energy efficiency incentive programs, supported by the Bonneville Power Administration.

The Northwest Power and Conservation Council collects information each year about the progress the region makes toward its energy efficiency targets, and with every new plan, forecasts future cost-effective energy savings. NWPCC reported that the region missed the 7th Power Plan targets significantly, and is projecting a substantial decrease in overall available cost-effective energy efficiency.[18] While voluntary energy efficiency incentive programs are effective, the current pace of savings acquisition is slowing and will take a very long time to capture all the potential available savings in existing buildings.

Examples of programs promoting energy efficiency in the existing buildings include:

Audits and Weatherization

Energy audits can help identify the best options for energy efficiency improvements in a building. Energy audits vary in complexity from in-person, in-depth data collection performed by a trained expert – including building energy leakage measurements – to a more self-directed audit that allows owners or occupants to enter home characteristics using an online entry system. This information can be used to prioritize upgrades to the building, such as addressing the building envelope through air-sealing, increasing insulation, and replacing windows. These types of envelope upgrades are supported by incentives made available through utility programs and Energy Trust of Oregon to encourage building improvements.

Space Heating and Water Heating Upgrade Incentives

Space and water heating make up 64 percent of an average residential building's energy use.[15] Utility programs provide incentives for space and water heating upgrades. Many programs also offer incentives, rebates, and/or low-interest loans for new heat pump installations that are particularly effective at reducing building energy consumption. Heat pumps use energy to transfer heat, rather than using energy to create heat, and are up to three times more efficient than electric resistance space heat. Heat pumps also come in many configurations, sizes and options that help keep installation costs down. For more information about heat pumps, see the *Energy Efficient Building Technologies* Resource and Technology Review.

New Program Options for Existing Buildings

New energy efficiency programs are needed to increase the adoption rate of energy efficiency technology in existing buildings. There are four main programmatic strategies that help drive energy efficiency in existing buildings.

- **Education and Awareness**
- **Incentives**
- **Mandatory Requirements**
- **Decarbonization of Fuels**

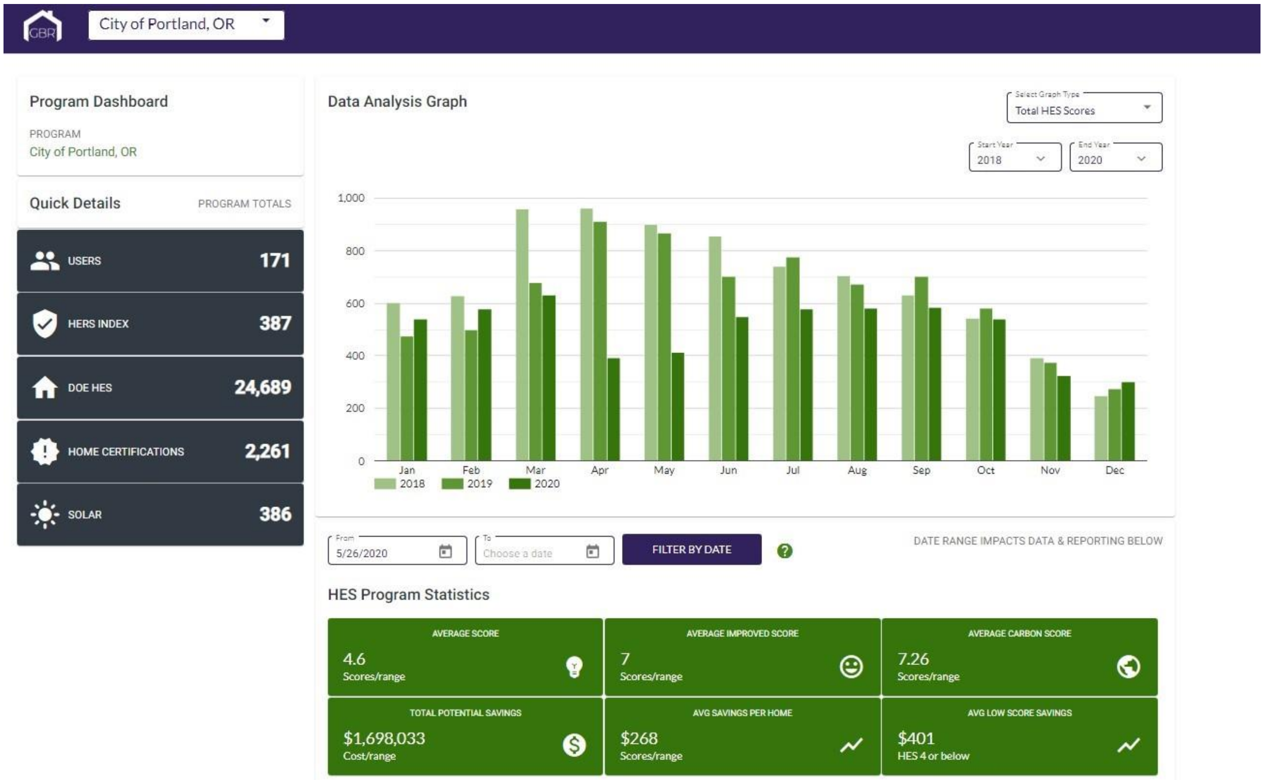
Education and Awareness

Programs that provide information about building energy consumption and options to reduce that consumption help building owners and occupants make informed decisions about improving their building's energy performance. These programs are informational, and do not set requirements for adoption or provide monetary incentives, are more effective when used in conjunction with other strategies.

Home Energy Scoring

Home Energy Scoring increases the awareness of the home's energy consumption and identifies specific energy efficiency improvements that could improve a home's overall score. The Home Energy Score captures 40 characteristics within each home, calculates the estimated annual energy use, and describes the overall efficiency of the home using a 1-10 scale.[19] A scorecard is produced, and also includes a graphic that describes the carbon footprint of the home, and like the energy score, assigns a 1-10 rating. Each scorecard calculates what cost-effective measures can be used to improve performance and reduce greenhouse gas emissions. The scorecard also shows the total potential savings in dollars if the recommended efficiency upgrades were added to the home. Oregon has three cities that have adopted mandatory Home Energy Scoring – Portland, Milwaukie, and Hillsboro, which represent 18 percent of Oregon's population[20] – and numerous other cities considering adoption. Overall, the three cities have done over 35,000 scorecards,[13] with the City of Portland's Home Energy Score program producing more than 32,000 home energy scores. The average score in Portland is 4.6 and the average score with improvements is 7.[21] Figure 3 below from the City of Portland's HES program dashboard, shows the number of home energy scores done by month from 2018 through 2020.

Figure 3: City of Portland Home Energy Score Program Dashboard

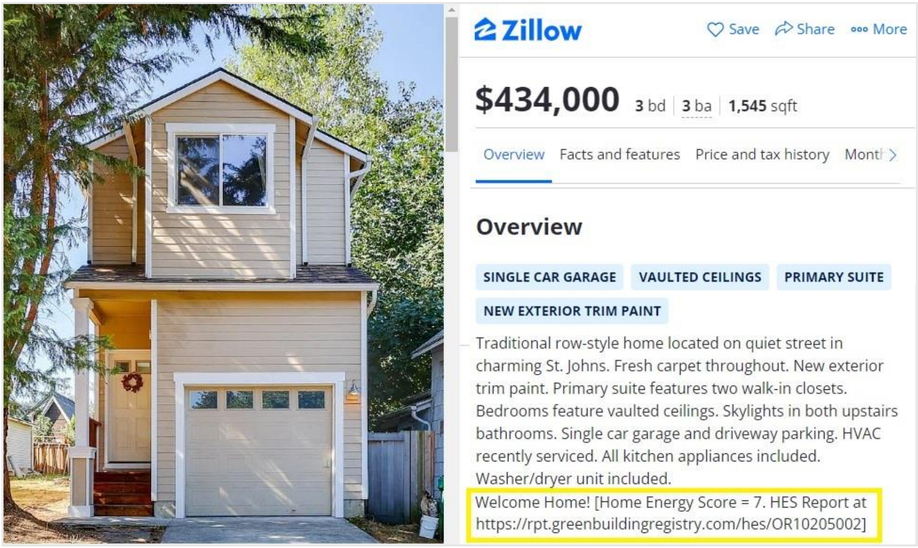


One major gap in the HES programs is data on rental units, which are estimated to be 38 percent of all homes in Oregon.[22] Most HES programs require scores only when a home is listed for sale, and there are currently no programs in place that require a score when a rental unit turns over. In 2023, ODOE is planning on developing a HES program design to create energy scores for single family and multi-family home rentals.

Commercial Building Benchmarking

Benchmarking programs increase visibility and awareness of energy performance and motivate investment in efficiency improvements through market competition, transparency, and comparison. They allow commercial building owners to track, compare, and measure energy performance relative to similar buildings, and provide local and state governments with information and data to inform the development of energy efficiency policies and programs. There are many types of commercial buildings, such as retail, office, medical, and educational occupancies. Tracking building energy efficiency is often performed using the U.S. Environmental Protection Agency's ENERGY STAR® software, and there are many examples of commercial building benchmarking in place nationwide.[23] Locally, the City of Portland has required commercial buildings larger than 20,000 square feet to report energy consumption since 2016.[24]

Educational Campaigns



Educational marketing can inform broad or targeted audiences about energy efficiency options and benefits. Utility and government websites, real estate advertising, professional and social networking platforms, and the mainstream media all have examples of energy information available to the general public. For example, the Home Energy Score is widely incorporated into popular real estate-oriented mobile apps like Zillow and Redfin because the data is required as part of the listing in some cities. These apps use HES data to target consumers interested in energy efficient homes and allow users to search for homes within a specific energy score range.

Energy-related training is also available to realtors, lenders, and appraisers to help them understand various topics and benefits of energy efficiency. Many realtors are finding value in a "Green Designation" credential,[25] which provides them with knowledge on home energy efficiency options and benefits that they can use to inform home buyers and sellers. Fannie Mae and Freddie Mac provide attractive loan rates through HomeStyle Energy Mortgages[26] that give qualifying buyers lower interest rates by purchasing more energy efficient homes, and they share this information with lenders and realtors.

Incentives

While many energy efficiency measures are cost-effective, the up-front cost of purchasing and installing many technologies can be a barrier to adoption. Incentive programs such as tax credits and rebates can help reduce some of the up-front costs that will allow for more widespread adoption of energy efficiency technologies. Examples of incentive programs include: the Oregon Department of Energy's Residential Energy Tax Credit program (which provided tax credits to more than 600,000 Oregonians from 1977 to 2017[27]); the Energy Trust of Oregon's rebates to residential, commercial, industrial, and agricultural buildings in Portland General Electric and Pacific Power territories; and similar programs offered by Oregon's consumer-owned utilities.[28] In addition to reducing up-front costs, incentive programs have encouraged market acceptance of new energy efficient products like LED lighting, heat pumps, and ductless heat pumps.

Incentive programs have encouraged market acceptance of new energy efficient products.

In 2022, Senate Bill 1536 directed the Oregon Department of Energy to develop two heat pump programs to provide relief to Oregonians during extreme heat events by using high efficiency heating and cooling equipment.[29] A $10 million Community Heat Pump Deployment Program will offer eligible entities funding to provide incentives for the purchase and installation of heat pumps. A $15 million Oregon Rental Home Heat Pump Program will offer incentives for the installation of heat pumps to landlords for rental properties, as well as certain owners of manufactured homes and recreational vehicles.[ii] Utilities and Energy Trust of Oregon also offer direct consumer incentives for installation of heat pumps through their energy efficiency programs.

Oregon may also receive federal dollars from the 2022 Inflation Reduction Act to support heat pump installations in Oregon homes, but details are not yet available as of the date of this report.

Mandatory Requirements

Mandatory requirements programs require audits, performance standards, retrofit, and decarbonization of fuels to save energy and reduce greenhouse gas emission from existing buildings. These are most frequently applied when buildings undergo major remodels, when a building is sold, or when tenants' turnover. Mandatory requirements can be coupled with incentive programs to offset the cost of compliance. There is a good deal of potential for savings. In 2020, the American Council for an Energy Efficient Economy estimated that among buildings at least four years old in the U.S., 14 to 39 percent have had an efficiency-related renovation over the preceding 18 years,[30] but the Northwest, including Oregon, is likely to be higher than the national average. However, most buildings only receive upgrades for one or a few systems instead of all the cost-effective measures.

Auditing

Many jurisdictions require whole building energy audits prior to a sale or remodel. Several cities, including Austin, TX; Piedmont, CA; and San Francisco, CA require an energy audit that identifies all cost-effective energy efficiency improvements as part of the issuance of a residential permit.

[ii] Learn more about ODOE incentive programs: https://www.oregon.gov/energy/Incentives

Building Performance Standards

Building Performance Standards use energy benchmarking data and compare that to regional and national data from similar building types to establish an efficiency performance target for a building. These programs are separate and distinct from building code requirements because they focus only on reducing the building energy consumption of existing buildings. Building Performance Standards can be an important tool to drive improvements throughout an existing building's life by requiring a building to meet outcome-based energy performance targets.[31] Building Performance Standards can also reduce both total and peak building energy demand, which coupled with on-site energy storage can help electric utilities better manage peak load.

These programs typically follow best-practice guidelines for building energy management of existing buildings, outlined in industry standards such as ASHRAE Standard 100 – Energy Efficiency in Existing Buildings, or similar frameworks. Such programs generally include:

- Establishing appropriate energy performance targets for building types and locations.
- Performing energy surveys and audits to identify projects to achieve targets.
- Developing operations and management programs to maintain energy efficiency projects and ensure continued savings.
- Periodic re-analysis or evaluation of actual building performance to confirm achievement savings estimates or adjust building management to get back on track.

Programs start out by prioritizing larger commercial buildings and then gradually phase-in other smaller buildings. Building equipment replacements, retro-commissioning (a building tune-up that helps heating and cooling equipment operate as efficiently and effectively as possible), and operational improvements are often components to help a building meet its targets under a Building Performance Standard.

In recent years, multiple jurisdictions at the city, county, and state levels have adopted some form of building performance standards.[32] Washington State and New York City led the way with BPS programs adopted in 2019. Washington's program tracks energy consumption per square foot of building area, was originally applied to only commercial buildings with 50,000 square feet or more, and was expanded to include all commercial and multi-family buildings with 20,000 square feet or more. New York City's BPS program applies to commercial and multi-family properties greater than 25,000 square feet and uses a performance metric based on annual greenhouse gas emissions. Colorado, Maryland, and the cities of Chula Vista, CA; Boston, MA; and St. Louis, MO also recently adopted building performance standards.[33]

In recent years, multiple jurisdictions at the city, county, and state levels have adopted some form of building performance standards.

Building Performance Standards can be established so they are triggered on a specified timeline, rather than by a specific event such as a property sale or major renovation. These programs require achieving a level of performance by a certain date. They typically do not prescribe specific measures to be installed, but rather allow flexibility for building owners to evaluate and choose which measures they will install to achieve the target.

Decarbonization of Fuels

Energy efficiency programs complement and support overall decarbonization policies and goals. For example, Oregon's 100 percent clean electricity by 2040 law (HB 2021) will significantly reduce the emissions of buildings using electricity in IOU service territories.[12] Similarly, the Oregon Department of Environmental Quality's Climate Protection Program will reduce the greenhouse gas emission from natural gas use in buildings by 50 percent by 2035 and 90 percent by 2045.[34]

Building Performance Standards Supporting Decarbonization

Building Performance Standards can prescribe targets for greenhouse gas emission reductions that are based on corresponding energy use reductions. Reduction targets are normalized for building square feet for different types of buildings so they can be applied to other similar buildings. Building owners are required to assess their building's performance relative to the target standard, determine the gap in performance, conduct a comprehensive building energy audit to identify energy efficiency measures to address the gap in performance, and implement those measures by a certain date. For example, Boston, MA and New York City set building performance standard greenhouse gas emission reduction targets – usually in metric tons of CO2 per square foot – for offices, multi-family buildings, retail buildings, and schools.[32] Each specific building type has its own standard and target. Many building performance standard programs offer exceptions for financial hardship and cost-effectiveness considerations. Buildings owners and jurisdictions can also support decarbonization by electrifying end-uses that currently use fossil fuels and by installing on-site distributed energy systems, like rooftop solar and battery storage.

Implementation Issues/Considerations

As described above, achieving energy efficiency in existing buildings is critical for reducing emissions in the buildings sector, and while there are many benefits, there are also barriers and challenges. This section provides an overview of some potential challenges and questions to consider when designing a new program.

Voluntary vs Mandatory Participation

Voluntary programs encourage investment in energy efficiency through incentives and allow the market to drive adoption. While this potentially allows for more innovation in pathways that encourage efficiency technology adoption, it usually results in a more gradual market change that may not be fast enough to achieve energy or greenhouse gas reduction goals. Mandatory programs drive faster adoption toward achieving goals, but it may be met with opposition because of unmitigated potential costs and the fact that they are regulatory directives. Both approaches have benefits and drawbacks that should be weighed when considering a program design. Many jurisdictions have successfully run voluntary residential and commercial building energy efficiency programs for decades, often funded by utilities. However, the urgency of the need to reduce greenhouse gas emissions may lead more jurisdictions to pursue mandatory programs.

Legal Authority

Regulating existing buildings sometimes requires new legal authority to administer and enforce a new program. This authority can flow from a state or local jurisdiction.[35] [36] In Oregon, there is no state agency with authority to regulate existing building energy performance on a statewide basis. The Oregon Department of Consumer and Business Services' Building Codes Division regulates the energy efficiency measures in new construction and renovations through the building energy code, but this regulation does not extend to operational building performance once the building is occupied. New legislative direction and authority may be required for an Oregon state agency to administer a regulatory energy efficiency program for existing buildings.

Cost and Incentives

The initial cost of energy efficiency projects may be a significant financial barrier to building owners, especially those with low-to-moderate incomes. The American Council for an Energy-Efficient Economy estimates deep energy retrofit project costs for residential homes range from $50,000 to well over $100,000. Commercial deep energy retrofits of average office buildings range from $25 per square foot to over $150 per square foot.[37] [38]

Mandatory energy efficiency programs can be designed to reduce negative financial impacts on building owners.

Mandatory energy efficiency programs can be designed to reduce negative financial impacts on building owners. For example, rules can require only cost-effective energy efficiency measures. Cost caps or building exceptions can be included to limit the investments required by building owners. Other economic hardship exemptions can also be incorporated in program rules to protect home or building owners who may have financial difficulty in meeting the energy performance targets. Programs can set aside or require a certain percentage of the incentive budget for low-to-moderate income owners and for buildings located in environmental justice communities. Penalties collected by jurisdictions for non-compliance to program rules can be used to offset some of the costs in low-income communities.

Local energy efficiency programs to offset the high up-front costs for building owners can remove some financial barriers, but costs to build and implement energy efficiency programs are also significant for state and local governments.

It is important to develop program budgets that account for the many costs associated with developing and operating a program. It is important to include adequate funds for incentives or financing; staffing to support program design, administration, and enforcement; training; education to building owners and trade allies; and outreach to historically underserved communities, including communities of color, rural communities, veterans, and people with disabilities.

The Federal Inflation Reduction Act includes more than $9 billion for states to help overcome these financial barriers for consumers, states, and local governments. The Home Energy Performance-Based, Whole House Rebates (HOMES) program and the High-Efficiency Electric Home Rebate Program (HEERA) are two programs that are targeted specifically at helping consumers with low or moderate incomes achieve energy savings through retrofits and by installing new efficient appliances. Oregon will likely see over $100 million from these programs come to the state over the next few years. In addition to direct assistance, the law also expands and extends tax credits for numerous energy efficiency measures and appliances, including insulation, windows, heat pumps, battery storage, and energy audits. Funding from the Inflation Reduction Act has the potential to help the state make significant progress addressing in reducing energy use in existing buildings.[iii]

Types of Buildings and Customers

During program development, jurisdictions need to determine the types and characteristics of buildings they intend to include. This could be determined through inventory surveys or benchmarking efforts that help identify the building types. Building type consideration could include: commercial, residential, or both; floor area limits; occupancy types; building age; and baseline energy consumption. Program participant consideration could include: income level, owner/renter, and disadvantaged or underserved community members.

Programs should design evaluation metrics that track performance in relation to the identified objective for improved performance, including based on energy costs, greenhouse gas emission reductions, and program timeline, among others.

Specific Measures

Programs should be designed to be flexible and work with the needs of individual building owners. Energy audits can be effective in identifying cost-effective measures in individual homes and buildings. Potential energy efficiency measures cover a wide range of heating, cooling, ventilation, lighting, envelope, and other building improvements. Identifying cost-effective measures while improving the comfort of the building can be a challenge. There is no "one size fits all" set of measures, although there are certain classes of measures that may apply across many building types.

Monitoring and Verification of Savings

Many energy efficiency programs require achievement of performance targets and reporting of building performance data over time to verify compliance. Sometimes more advanced submetering may be required to track the performance of installed equipment, rather than just relying on whole-building level measurements. It is also important to ensure there is adequate resources to do the monitoring and verification of energy or greenhouse gas reductions by participant buildings.

Conclusion

Reducing energy use and greenhouse gas emissions from existing commercial and residential buildings is essential to achieve Oregon's state energy efficiency and climate goals. Most potential building energy savings – and their associated greenhouse gas emissions – are in existing building stock. While advancing building energy codes prepares new buildings for the future, codes have limited effect on existing buildings. Successful voluntary energy efficiency programs have provided significant energy

Reducing energy use and greenhouse gas emissions from existing commercial and residential buildings is essential to achieve Oregon's state energy efficiency and climate goals.

[iii] Track ODOE's work with federal funds online: https://www.oregon.gov/energy/energy-oregon/Pages/IIJA.aspx

savings for many years, but to dramatically reduce energy consumption in buildings would require new state or local existing building programs that may include mandatory program features.

There are many different strategies to achieve significant reductions in building energy consumption. A combination of strategies is likely to be necessary to fully capture the reduction potential in existing buildings, with education and awareness programs, incentive programs, mandatory requirement programs, and enhancement of our existing decarbonization of fuels programs among these potential strategies.

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Policy Brief: Beyond Energy Savings – Co-Benefits of Efficiency

- Energy efficiency is **facing new challenges**, demands, and increased competition from low-cost renewable resources.
- Traditional tests of cost-effectiveness fail to capture the **wide range of co-benefits** of energy efficiency.
- Several organizations, including the Oregon Public Utility Commission and California Public Utilities Commission, are working to **quantify and incorporate** numerous co-benefits into investment decisions.

Energy efficiency is Oregon's second-largest electricity resource after renewable hydropower.

Energy efficiency, actions that enable us to do the same work using less energy, has brought numerous benefits to the Pacific Northwest and now finds itself at a crossroads. Energy efficiency has long been an important energy resource. In fact, it is Oregon's second-largest electricity resource after renewable hydropower. But as other renewable resources like wind and solar have dropped in cost in recent years, and efficiency has been embedded in building codes and appliance standards, opportunities for cost-effective (as historically calculated) energy efficiency have become more scarce.[1–4] At the same time, policymakers are seeking to advance multiple other important policy objectives to which energy efficiency can contribute.

That makes it the right time to re-examine the way we treat energy efficiency and create an economic valuation system that captures its full value – including a complement of non-energy benefits, generally called co-benefits. Not including the co-benefits in the current valuation process sends the message that they have no value. A new system could include making sure the value to the utility system is quantified and counted when applying cost-effectiveness tests, including energy, capacity, reliability, resilience, adoption and use of distributed energy resources (DERs), avoided environmental impacts, and reductions in greenhouse gas emissions. It could also mean making sure its contributions to meeting other important policy objectives such as improving public health, increasing equity, providing jobs, and maintaining a strong energy efficiency market, are also quantified and counted.

Finally, energy efficiency has a key role to play in decarbonization, bringing down the scale of the challenge by reducing the amount of clean energy needed. This policy brief provides relevant background on energy efficiency, describes its current position in the energy landscape, and discusses approaches for capturing energy efficiency's full value, including co-benefits.

Energy Trust of Oregon's Cost-Effectiveness Tests[1]

Utility energy efficiency programs commonly use a cost-effectiveness test to determine whether and how much to invest in energy efficiency projects. In Oregon, Energy Trust of Oregon administers electricity and natural gas efficiency programs for Oregon's investor-owned utilities. Statute requires Energy Trust's investments to be cost effective. Energy Trust is overseen by the Oregon Public Utility Commission, which determines what can be counted as a benefit and a cost in cost-effectiveness tests. The OPUC requires Energy Trust to use two benefit/cost ratio tests, the Total Resource Cost (TRC) Test and Utility Cost Test (UCT), to indicate that its investments are a responsible use of ratepayer funds. These two tests compare the benefits of the energy savings to the costs of the investment from two viewpoints – society and the utility.[5]

The TRC is the main test and determines if Energy Trust can offer an incentive for an energy efficient project, and the UCT determines the amount of the incentive. The two tests assess the value of the energy efficiency investment compared to the cost of a utility supplying the same amount of energy with other resources (the avoided cost of energy) to ensure the investment is the most affordable resource and in the best interest of the ratepayers. To calculate the TRC, the benefits (value of the energy savings to the ratepayer over the life of the resource) are divided by the sum of all the costs (the total cost of the resource, including the Energy Trust incentive and administration costs and the remaining amount paid by the customer). For the UCT, the benefits are divided by just the Energy Trust incentive to calculate the benefit/cost ratio. For Energy Trust to invest in a project and provide an incentive, the ratio must be 1.0 or greater for both tests.[5] The Northwest Power and Conservation Council and the Northwest Energy Efficiency Alliance use similar approaches.

In its docket UM 551, the OPUC provided Energy Trust with some flexibility on how it applies the cost-effectiveness requirement. It allowed exceptions for certain situations: pilot programs, new technologies, the presence of significant hard-to-quantify co-benefits, and projects that provide consistency for the market. Energy Trust noted that these exceptions are rare and need to be well supported. Today, projects supported under cost-effectiveness exceptions represent only a small portion of Energy Trust annual savings.[5]

In addition, Energy Trust applies in its cost calculation analysis a 10 percent credit for energy efficiency as required under the Northwest Power Act (1980). In UM 551, the OPUC ascribed the benefits of energy efficiency in addressing risk and uncertainty to the credit.[6]

History and Background

Modern energy efficiency policies and programs are about to celebrate their 50th anniversary. The oil embargo of 1973 created a supply crisis that highlighted the need for more efficiency and ushered in the Corporate Average Fuel Economy (CAFE) standards for automobile fuel efficiency, one of the nation's first energy efficiency-related laws. This law was followed by the Energy Policy and Conservation Act (EPCA) of 1975 and the Energy Conservation and Production Act (ECPA) of 1976.[7] [8]

These acts created the framework of the United States' early energy efficiency policies and programs. The EPCA and ECPA provided the catalyst for energy savings over the coming decades. Also, in the wake of the oil embargo, Oregon, like many other states, was driven to action. In 1975, the Oregon Department of Energy was created. According to the American Council for an Energy-Efficient Economy (ACEEE), from 1980 to 2014, while U.S. gross domestic product (GDP) increased by about 149 percent, energy use only increased by about 26 percent. This 6-to-1 ratio clearly demonstrated that energy use and economic growth were not positively correlated. ACEEE also concluded that, as of 2014, energy efficiency was saving U.S. consumers and businesses about $800 billion per year.[9]

In the late 1970s and early 1980s four nuclear power plants in the Pacific Northwest were being developed by the Washington Public Power Supply System (WPPSS). They were mothballed after a massive planning and financial disaster, known as "whoops" (a play on the developer's acronym). The WPPSS debacle culminated in one of the largest bond defaults in U.S. history (over $2.3 billion, or $5.75 billion in 2022 dollars) in 1983. This situation was one of the reasons why Congress passed the 1980 Pacific Northwest Electric Power Planning and Conservation Act, or the Power Act.[10] This Act directed that energy efficiency be given the top priority for utility resource acquisition, and marked the first time in history that energy efficiency was put on par with generating resources for utility acquisition.[11] [12] Its passing was the dawn of least-cost planning, or *integrated resource planning* as it is known today.

Acting in partnership, the Bonneville Power Administration and Pacific Power developed the Hood River Conservation Project in 1985, which examined the feasibility of electric utility-scale energy efficiency programs that could achieve both high levels of savings per residence and significant market penetration. The project was a success and demonstrated that significant quantities of energy efficiency could be cost-effectively acquired at scale and measured with certainty. The Hood River Project helped launch the energy efficiency revolution in the Pacific Northwest and the utility programs we know today.[13]

Energy Efficiency Today

As of 2020, the Pacific Northwest has acquired more than 7,500 average megawatts[i] of energy savings; over 2,200 aMW of that is in Oregon.[14] That is the equivalent of the annual energy consumption of around 5.5 million homes, or almost three times the annual generation of Grand Coulee Dam (the largest dam in the Pacific Northwest). It also means efficiency has allowed the Pacific Northwest to save an estimated $4 billion each year on residential energy bills and avoid over 25 million metric tons of CO2.[15] [16] Capturing these tremendous benefits from efficiency has come from four main drivers: market forces, technology improvements, targeted programs, and policies.

Energy efficiency has allowed the Pacific Northwest to save an estimated $4 billion each year on residential energy bills.

[i] Average Annual Megawatt (aMW): Represents 1 MW of energy delivered continuously 24 hours/day for one year, or 8,760 MWh.

Main Drivers for Energy Efficiency

Market Forces: Because of the comparatively lower cost of energy efficiency, utilities and customers chose efficiency over other options, thereby accelerating the amount of energy efficiency acquired.

Technology Improvements: As technology improved the performance of equipment and appliances in the marketplace, it resulted in increases in efficiency over time and a substantial reduction in energy use. For example, over time, clothes washers have increased their energy efficiency by 75 percent, air conditioners by 50 percent, refrigerators by 65 percent, and automobile fuel efficiency (MPG) by 25 percent. [9]

Targeted Programs: Programs like U.S. EPA ENERGY STAR labeling, utility efficiency acquisition programs, building codes, and green building programs have resulted in better energy management practices over time that have encouraged and accelerated energy efficiency gains.

Policies: Government policies like efficiency standards and tax credits have helped stimulate more energy efficiency.

The biggest savings often come when the market forces of lower-cost energy efficiency from significant technological improvements are coupled with government policies that require energy efficiency standards. ACEEE reported that states with an Energy Efficiency Resource Standards policy – which requires utilities to achieve a certain percentage of energy savings each year or an annual energy efficiency savings target – typically achieve annual savings at a rate four times more than states without one. Overall, 26 other states in addition to Oregon have a Standards policy.[17]

ACEEE has noted that during the post-1980 era, energy prices do not appear to have been a major historical driver in the country for developing more energy efficiency. They argue that, after accounting for inflation for the period between 1980-2015, energy prices in the country remained relatively flat while energy efficiency grew rapidly.[9]

The Pacific Northwest's cumulative long-term investments in and acquisition of energy efficiency, as noted above, have enabled energy efficiency to become the region's second largest resource after hydropower; it has also had other positive effects on the region, including energy and financial savings and greenhouse gas emission reductions. Oregon has been a national leader when it comes to energy efficiency. The ACEEE produces an annual scorecard that ranks the energy efficiency efforts of the fifty U.S. states. As of 2020, Oregon had landed among the top 10 states for 14 years in a row.[18]

Even though the region and Oregon had historically acquired a great deal of energy efficiency, there was still a significant amount of cost-effective energy efficiency left to be acquired by 2016. In the 7th five-year Northwest Power Plan (2016), the Northwest Power and Conservation Council estimated that an additional 4,413 aMW could be acquired in the Pacific Northwest by 2035.[1] By the 8th Power Plan, the available amount of cost-effective energy efficiency has dropped dramatically.[19]

Unfortunately, the region and Oregon are falling behind when it comes to energy efficiency. Oregon's place in the top 10 of ACEEE's energy efficiency scoring of states is not guaranteed, and recent trends could lead to the state dropping in rank. Overall spending on efficiency and associated savings have declined. The Northwest Power and Conservation Council's 2021 Regional Conservation Progress

Report[15] showed that the region did not meet its 7th Power Plan energy efficiency goal set for 2016-2021. The shortfall occurred in BPA's conservation program and was over 160 average megawatts, enough to supply more than 125,000 typical households annually with electricity.[20]

Energy efficiency maintained its strong position in the energy landscape because it was abundant and had the lowest marginal resource cost (the cost to acquire the next increment of energy). For decades, low-cost energy efficiency measures have been captured by programs, in particular codes and standards; the remaining set of measures are more expensive, and they are having to compete with low-cost, increasingly common renewable resources like utility-scale solar and wind. These cheaper renewable resources lowered the price threshold that determines if an energy efficiency program is determined to be cost-effective, and thus lowered the amount of cost-effective energy efficiency available to be acquired. Accordingly, in the Pacific Northwest, the 8th Power Plan ("The 2021 Northwest Power Plan") dropped the energy efficiency acquisition target by about a third from the 7th plan five years earlier. [ii] [1] [2] [19]

Co-Benefits of Energy Efficiency

At the same time energy efficiency spending and savings are declining, energy policymakers are having to address an increasingly diverse array of energy challenges alongside other important policy objectives. Fortunately, energy efficiency can help policymakers meet these goals – stimulating economic growth and jobs, enhancing reliability and resilience, improving public health, advancing equity, and reducing greenhouse gas emissions. Energy efficiency can support these important policy objectives – more so if there is an economic valuation system in-place that recognizes its co-benefits. That includes counting the utility system co-benefits provided by energy efficiency when applying the cost-effectiveness test. It also includes recognizing that there are other important policy objectives where the traditional cost-effectiveness test may not be the best measure for whether energy efficiency program funding is a prudent investment. The list below[iii] includes some of the additional co-benefits that could be more fully explored, quantified, and included in prudent investment decisions.

Table 1: Co-Benefits of Energy Efficiency

Co-Benefit	Relationship to Energy Efficiency
Jobs	As of 2021, 38,847 Oregonians are working in energy efficiency (1.7 times the combined total of energy generation and transmission/distribution jobs).[21] Across the U.S. there are more than 2.16 million workers in the energy efficiency sector. These family-wage jobs are in construction, manufacturing, and installing energy efficiency measures, as well as contracting and professional services.[22] Maintaining these jobs, and creating more, is an important policy objective for Oregon.

[ii] The 7th Power Plan estimated 3,050 aMW of cost-effective energy efficiency by the end of 2026, and the 8th Power Plan estimates 750-1,000 aMW of cost-effective energy efficiency by the end of 2027.

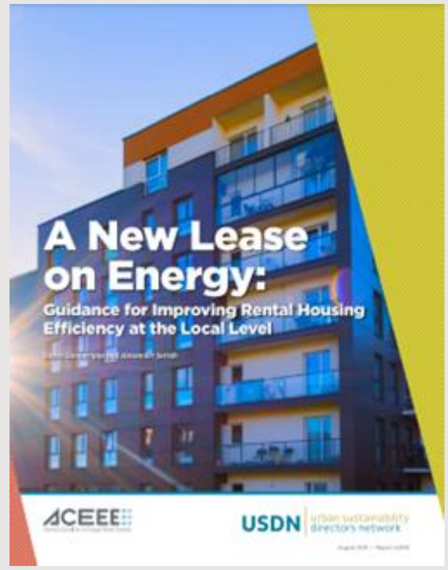
[iii] In true government form, the Oregon Department of Energy uses an acronym to remember this list of benefits offered by energy efficiency: JEDDI CREBBER.

Co-Benefit	Relationship to Energy Efficiency
Enhancing **D**istributed Energy Resources (DERs)	Before installing distributed energy resources,[iv] it is best practice to first make a building as energy efficient as possible – "Energy Efficiency First!" Many energy efficiency measures are cheaper than DERs, and by addressing energy efficiency first, the output of the installed DERs will be able to serve more of the electricity needs of the building at a lower cost, thereby enhancing the effectiveness of the DER in meeting the building's needs.
Decarbonization	For many utilities in Oregon, energy efficiency is a zero-carbon resource that can displace fossil fuel-generation to meet demand – and ultimately help decarbonize buildings and help Oregon meet its GHG emission reduction goals.
Invisible	Because energy efficiency is doing the same work with less energy – using more efficient equipment, improving processes, or adding insulation to make a building envelope more efficient – it works behind the scenes. It is effectively invisible. Energy efficiency, compared to all generation resources, has little to no negative effect on the environment, meaning impacts on air, land, and water are substantially lower.
Capacity	Energy efficiency programs in the Pacific Northwest were originally designed to capture energy savings (kilowatt-hours) as a benefit and did not generally value capacity or demand (kW). As loads grew and the hydro system has become more capacity-constrained, valuing capacity has become more important, including recognizing the benefit of reduced demand from energy efficiency measures. In addition to an accurate and robust value for capacity savings at different times of the day and year (time-of-use), other benefits like marginal line losses, grid flexibility, and renewables integration are also important to accurately quantify and include. Strategically located energy efficiency can also reduce the need for new transmission and distribution additions to grid. For instance, there is value associated with energy efficiency lowering the load on individual buildings and local feeder lines, thereby potentially avoiding necessary infrastructure investments to accommodate future electric vehicle loads.
Resilience	Energy efficiency is an often overlooked, but critical, component of a resilient energy system. Energy efficiency contributes to resiliency in multiple ways. It can lower demand during extreme weather events, reduce the risk of demand-caused grid blackouts or brownouts, and it can enhance the use of DERs during power emergencies. By reducing a building's energy use,

[iv] Distributed Energy Resources (DER) refers to smaller generation units that are located on the consumer's side of the meter. Examples of distributed energy resources that can be installed include: roof top solar photovoltaic units, wind generating units, and battery storage.

Co-Benefit	Relationship to Energy Efficiency
	efficiency can reduce the size and cost of installing and operating backup power systems. For example, a 50 percent reduction in a building's energy use would reduce the size and capital cost of a backup power system by half.[23] A smaller backup power system also reduces the amount of fuel needed, and the frequency of refueling needed, during an emergency; which has the added benefit of reducing exposure to higher fuel costs often seen during emergencies. Lower capital costs can also create an opportunity to use the savings for other resilience investments. Efficient buildings also provide habitable conditions for a longer period of time during blackouts because they can maintain building temperatures better, which is particularly important for community buildings used as disaster recovery centers.[23]
Reducing **E**nergy **B**urden	A household is considered energy burdened if they spend more than six percent of their income on energy. Maintaining and expanding access to energy efficiency programs to low-income communities supports equity because it reduces energy bills and thereby energy burden.[24]
Beneficial **E**lectrification	Electrification is beneficial and in the public interest when a program meets one or more of the following conditions without adversely affecting the other two: 1) saves customers money over the long-term; 2) reduces environmental impacts; and 3) enables better grid management.[25] An example of *beneficial electrification* is an efficiency program that promotes high-efficiency electric heat pumps and water heaters, induction cooktops, and/or EVs with smart charging. Beneficial electrification of buildings is a key step in enabling the growth of grid-interactive efficient buildings (see the 2020 BER policy brief "Grid-interactive Efficient Buildings"). Not all electrification is beneficial. For example, electric resistance heat is less efficient and can be more expensive than its more efficient counterparts. Charging EVs during summer and winter peak hours is another example of electrification that is not necessarily beneficial.[26]
Reliability	Reliability is generally provided through the maintenance of reserves of various forms of generation and redundant transmission/distribution paths. Energy efficiency, by reducing peak demands and energy requirements, either through reducing growth or by controlling loads (e.g., lighting dimming, thermostat management) can offset both the need for such reserves or provide them at a lower cost. In addition, energy efficiency can make the grid more dependable by reducing electric demand during times of stress on the grid, thereby increasing the ability of the system to respond to system emergencies, increasing the reliability of backup power systems to serve critical loads, and mitigating transmission constraints on the grid.

A Focus on Energy Equity for Renters



Rental homes are typically less energy efficient than owner-occupied homes, and renters usually can't make significant energy efficiency improvements – such as installing high-efficiency appliances, new windows, or improved insulation – because they don't own the property. This means renters often use more energy for heating and cooling, leading to higher energy bills and an increased likelihood of being energy burdened (paying more than 6 percent of household income on energy).

The American Council for an Energy-Efficient Economy, a nonprofit coalition of public agencies working together to advance clean energy, is working on an Energy Equity for Renters initiative to encourage local governments to support efforts to improve rental homes. ACEEE selected five local governments in 2022, including the City of Portland, to provide no-cost technical assistance to develop policies and programs to improve energy efficiency in rental homes while preserving affordability.

In 2021, ACEEE also published an online guide for local governments that outlines actions that can reduce energy, including analyzing data to better understand renters' housing and energy affordability needs; engaging with the community to determine needs, particularly among historically underserved groups; developing policies that take other issues into consideration, like overall goals, resources, and community relationships; and developing partnerships to effectively implement potential energy efficiency and housing initiatives.

Learn more: https://www.aceee.org/energy-equity-for-renters

Energy Efficiency at a Crossroads – Choosing a Path Forward

As described above, energy efficiency is evolving. Maintaining the status quo or making modest changes around the edges will facilitate only marginally capturing the numerous co-benefits of energy efficiency. Oregon policymakers have an opportunity to create a new economic valuation system that values all of the co-benefits provided by energy efficiency. If done right, energy efficiency can be empowering; individual and collective efficiency actions could be the "victory gardens" of the war on climate change. California provides a good example of this approach, embracing a fundamental shift and restructuring the way the state treats energy efficiency to incorporate many of its co-benefits.

California Public Utilities Commission

The California Public Utilities Commission fundamentally reformed its approach to energy efficiency in May 2021. The CPUC recognized that there were important policy goals that could be addressed by going beyond a system that selects energy efficiency programs based only on the cost-effectiveness test, and toward one that also captures the co-benefits of energy efficiency. This was especially true at a time where opportunities for highly cost-effective energy efficiency programs were declining. In May 2021, the CPUC decided to create a new cost-effectiveness metric (Total System Benefit), and to include equity and market support as separate categories of allowable energy efficiency programs that do not have to meet the cost-effectiveness test. The CPUC's order (Rulemaking 13-11-005), stated that:

> "[E]nergy efficiency program administrators in recent years have faced increasing pressures to maintain the cost-effectiveness of their portfolios while also delivering a balanced portfolio that meets all of the Commission's numerous policy objectives. As we have noted in decisions over the past few years, highly cost-effective opportunities are becoming more scarce, as many of those low-cost measures with high benefits have become standard practice and have been adopted into building codes or appliance standards, leaving fewer low-cost/high-benefit opportunities as time goes on. This leaves administrators in the position of needing to identify more cost-effective energy savings or risk needing to scale back or eliminate programs that provide support to the portfolio or equity benefits, but without significant near-term energy savings to quantify … Furthermore, we acknowledge that while a TRC ratio appropriately compares the benefits and costs of a program targeted primarily at delivering grid benefits, it may not be the most appropriate tool for judging whether energy efficiency funding was prudently spent on programs which support equity or market support goals. The benefits delivered by these types of programs are not assessed using the [traditional cost-effectiveness test] and therefore other methods are necessary … The traditional definition of resource programs, or programs which deliver energy efficiency savings, neglects the nuance that certain programs that deliver some energy savings have other primary objectives, such as supporting equity goals or long-term market success. These programs serve an important function…"[3]

The CPUC took on this effort explicitly to incorporate the co-benefits of energy efficiency, specifically to better align its 450 energy efficiency programs with reducing greenhouse gas (GHG) emissions, supporting customer equity, promoting long-term market success, and bolstering long-term energy grid stability. To accomplish these changes, CPUC took two significant steps.

First, CPUC focused on energy efficiency goals that maximize GHG reductions and grid benefits rather than goals focused on first-year energy savings. The previous focus on only first-year energy savings did not capture all of the policy goals and benefits of energy efficiency and discouraged longer-duration energy savings and other long-term benefits such as GHG reductions. A new metric was therefore needed to capture and maximize the full dollar benefits of energy efficiency. CPUC created, based on a recommendation from the Natural Resources Defense Council, a new metric called the Total System Benefit (TSB) for resource acquisition programs. The TSB is expressed as the dollar value of the maximized energy and capacity savings, grid benefits, and GHG reduction benefits. This means utility energy efficiency programs will no longer meet targets based on the traditional megawatt-hour targets, but on monetary goals that maximized grid benefits calculated in dollars. The TSB also incorporates costs and benefits not found in traditional cost-effectiveness models. For example, the TSB uses a refreshed Avoided Cost Calculator (ACC) tool, which incorporates monetary metrics that encourage energy savings during peak loads. This incentivizes program administrators to target high-value load reduction periods during late summer afternoons (e.g., June through August from 5 to 9 p.m.), when avoided costs are at their highest. This transition from traditional energy and peak demand savings goals (aMW/MW) to the TSB will take time and will be done over a three-year period and be fully implemented by the beginning of 2024. However, the tracking of portfolio outcomes by energy and peak demand savings will continue in parallel for historical comparisons.[3]

The second significant step the CPUC took was to shift program evaluations away from just a purely economic approach to one that evaluates some programs based on their primary purpose of serving other important state goals. To make this clear, CPUC separated the energy efficiency portfolio of programs into three segments: 1) resource acquisition, 2) equity, and 3) market support.[3]

CPUC Energy Efficiency Program Categories[3]

- **Resource Acquisition**: "Programs with a primary purpose of, and a short-term ability to, deliver cost-effective avoided cost benefits to the electricity system." In general, if a program is designed to specifically achieve measurable energy savings it should be categorized as resource acquisition. Resource acquisition programs will be analyzed and optimized as supply resources in the CPUC's IRP process.
- **Equity**: "Programs with a primary purpose of serving hard-to-reach or underserved customers and disadvantaged communities… The objectives of such programs may include increasing customer safety, comfort, resiliency, and/or reducing customers' energy bills."
- **Market Support**: "Programs with a primary objective of supporting the long-term success of the energy efficiency market by educating customers, training contractors, building partnerships, or moving beneficial technologies toward greater cost-effectiveness."

Under this new approach, only resource acquisition programs must have a cost-effectiveness ratio of 1.0 or greater. In addition, it is no longer required that each individual resource acquisition program be cost-effective on its own (which is policy in Oregon), as long as the combined utility's energy efficiency portfolio of programs met a TRC ratio of at least 1.0 or greater. This allows administrators flexibility to balance their portfolio of resources acquisition programs so the cumulative total TRC meets the 1.0 criteria.

By segmenting out the other two types of programs, CPUC allows market support and equity programs, whose value would not be fully captured in the total resource cost test, to be fully funded. In the CPUC's rulemaking, staff stated: "In the past, combining all of the program segments into one portfolio with a test for cost-effectiveness caused there to be a natural limitation on the amount of budget that could be spent on market support or equity type objectives, since the overall portfolio still had to have benefits that exceeded costs."[3] Not applying the TRC test to equity programs – where the cost-effectiveness ratio of the program is decreased because of the additional costs to serve disadvantaged customers, traditionally-harder-to-reach customers, or under-served customers – means the programs are able to be funded at a more appropriate level. The CPUC set a 30 percent limitation for the combined budgets of the market support and equity programs, and administration costs are capped at 10 percent.

The program categories are also not meant to be mutually exclusive, meaning that market support and equity programs can still deliver quantifiable energy savings that could be used to show progress toward achievement of energy efficiency goals.

For equity programs, the value of co-benefits, such as health, comfort, and safety, are quantified and included. Health benefits come from applying a societal cost test that values the decrease in air pollution and increase in air quality and are quantified using the EPA COBRA[v] and other models. The value of comfort and safety are quantified through surveys. Equity programs are evaluated based on their ability to reach underserved and disadvantaged communities and meeting their relevant program objectives.

Market programs are evaluated based on five objectives:

1) increasing market demand for energy efficiency;
2) building supply chain resources including workforce development;
3) developing partnerships;
4) increasing innovation and accessibility to energy efficiency solutions; and
5) building access to capital for financing efficiency.

In summary, the CPUC found that the TSB metric can better capture the other resource acquisition benefits beyond just direct economic energy savings, including reduced GHG emissions. The Commission also found that direct energy savings goals alone, while important, do not capture all the co-benefits of energy efficiency programs nor do they support other important policy goals such as customer equity, promoting long-term market success, and bolstering long-term energy grid stability.

Oregon Public Utility Commission (OPUC)

UM 551 sets the basic guidelines for assessing cost-effectiveness for energy efficiency programs and measures in Oregon's investor-owned utility territories. It ordered which cost-effectiveness tests to use and how to calculate benefits and costs, thereby establishing the guidelines for acquisition of cost-effective energy efficiency measures. UM 551 also ordered the application of the 10 percent credit for energy efficiency as required under the Northwest Power Act,[6 16] where the OPUC recognizes the benefits of energy efficiency in addressing risk and uncertainty. The value of energy efficiency is based on the avoided cost forecast. In the Order, the PUC stated, "Non-energy benefits will be quantified by a reasonable and practical method. Where non-energy benefits are clear, large, but difficult to quantify, Energy Trust will document this … and propose cost-effectiveness exceptions."[27]

As described above, the OPUC provides some flexibility in how Energy Trust applies for UM 551 exceptions. In UM 551, Section 13 details seven conditions under which exceptions to Oregon's two cost-effectiveness tests may be granted by the Commission.[28] While the exceptions procedure allows for the inclusion of some non-energy or co-benefits, to date few co-benefits have been included in the cost-effectiveness test.

[v] The COBRA model was developed by U.S. EPA to estimate the monetary value health benefits from the reduction of criteria pollutants.

In 2021, the OPUC facilitated a series of workshops to help develop an updated Transportation Electrification (TE) Investment Framework (docket UM 2165) and included discussion of the role non-energy impacts should play in evaluating transportation electrification investments. The fact that traditional cost-effectiveness tests fail to capture numerous quantifiable non-energy impacts or co-benefits was discussed at the workshops. Subject matter experts, including Tim Woolf of Synapse Energy Economics and Lisa Skumatz of Skumatz Economic Research Associates, discussed incorporating non-energy impacts and made the case that many non-energy impacts can and should be quantified. The UM 2165 investigation informed new TE planning rules under Division 87, and adoption of staff's recommendation to work with stakeholders to develop a jurisdiction-specific cost test for use in TE investment evaluations over the next several years. Along with docket UM 1893, which investigates the avoided costs of energy efficiency, this work will explore potential inclusion of additional co-benefits and could affect the cost-effectiveness calculation for energy efficiency in Oregon.[29]

Energy Trust of Oregon

Energy Trust of Oregon, in partnership with the OPUC, has also made some progress in understanding quantifiable co-benefits beyond the traditional application of the TRC test. Energy Trust currently incorporates a limited set of specific co-benefits into its cost/benefit models for its programs and measures and is considering the inclusion of other co-benefits.[5] The OPUC would have to agree to including these additional co-benefits in the cost-effectiveness test calculations. Energy Trust can also request exceptions to cost-effectiveness requirements there are significant hard-to-quantify benefits.

Regional Technical Forum – Policy Advisory Committee

The Northwest Power and Conservation Council's Regional Technical Forum – Policy Advisory Committee works collaboratively with Energy Trust of Oregon, the Oregon PUC, the region's public and investor-owned utilities, experts in energy efficiency, and interested parties on energy efficiency cost-effectiveness issues and is an important partner in investigating and analyzing co-benefits of energy efficiency. The role of the RTF is to determine costs and benefits for energy efficiency measures consistent with the Council's framework for quantifiable resource costs.

The RTF-PAC discussed at its March 30, 2022 meeting whether any analysis on additional co-benefits should be included in its upcoming workplan.[30] Some stakeholders in various forums, including the Oregon Department of Energy, indicated an interest in the RTF considering more co-benefits. Similar to the OPUC and Energy Trust, the Council and the RTF are constrained by a legislatively mandated cost-effectiveness test and framework. At the meeting, instead of discussing whether the framework needed to be updated, the discussion centered around whether specific co-benefits were in or outside the framework to tee up the question of whether the RTF should expand its scope to consider other benefits. The items that were identified as within the scope of the framework included the evaluation of capacity, resilience, flexibility, and greenhouse gases, while the items determined to be outside of the framework included economic development (jobs and productivity), public health, safety, energy security/independence, comfort, aesthetics, satisfaction, business or increased market share, and changes in insurance premiums. For the latter list, the Council commented that while energy efficiency measures may provide these additional benefits, the Council does not consider these to be part of the NW Power Act's definition of energy efficiency as a resource.

As a result, the RTF's 2022 workplan will analyze potential co-benefits from the energy efficiency/DER interface, the value of energy savings at certain times of the day, and the value of capacity. The RTF's next workplan in 2023 will focus on guidelines for the inclusion of equity metrics in its evaluations. While the extent of the scope of that analysis is yet to be determined, if the RTF wanted to incorporate other co-benefits, equity could include energy burden, health, and jobs. In particular, energy efficiency can benefit public health by reducing heat-related deaths associated with poorly insulated buildings and lack of efficient cooling equipment (such as what happened during the 2021 heat dome event). Good paying jobs installing energy efficient equipment are other benefits that could be included.

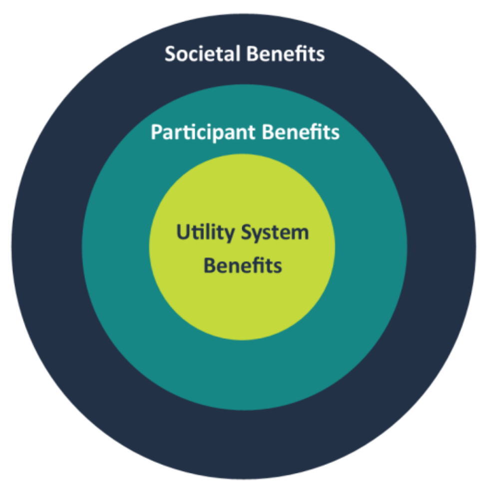
Oregon's Energy Efficiency Future

Energy efficiency is at a crossroads in Oregon and the region. The current and future competition with relatively low-cost wind and solar resources, which resulted in a significant reduction in the 2021 Power Plan's energy efficiency target, seem to put energy efficiency in a precarious position. Oregon has an opportunity to better position energy efficiency for success by exploring how to account for all of the co-benefits when applying the cost-effectiveness test and by recognizing other important policy objectives that can be furthered by energy efficiency.

Oregon has an opportunity to better position energy efficiency for success by exploring how to account for all co-benefits.

While Oregon has not fully analyzed and quantified these co-benefits, we know that they exist and that they have value. Excluding them from the calculation presumes that they have no value. For some of the co-benefits, a detailed analysis can help quantify their value. For others, there may remain some uncertainty; in those cases, it is better to use the best available approximation for the benefit than to assume it does not exist or that its value is zero.

Another way to think of the co-benefits of energy efficiency is as a set of concentric circles moving outward as their sphere of impact expands. Imagine the center circle as a *utility system benefits* circle where the co-benefit directly improves the grid or the utility system. The next circle out would be the *participant benefits* circle, where the benefits accrue directly to the customer who participates in the energy efficiency program. The final outer circle would be the *societal benefits* circle, where the benefits accrue to the population at large. In the traditional way of considering the value of energy efficiency, the center circle (utility system benefits) would be included, with only minimal if any participant or social benefits. The relevant question as we move forward is, can we quantify and include the benefits from the outer circles?



Lawrence Berkeley National Labs and Grounded Research and Consulting reviewed studies that quantified non-energy benefits (NEBs) used in 30 jurisdictions, then analyzed their transferability for use by other jurisdictions.[31] While different from the list of co-benefits in this paper, they reported on 16 similar categories of non-energy benefits.

Table 2: Lawrence Berkeley National Labs Non-Energy Benefits[31]

Non-Energy Benefit	Sphere of Benefit	Percent (Number out of 30) of Jurisdictions Using the NEB
Water resource costs and benefits	Participant	60% (18)
Other fuels costs and benefits	Participant	53% (16)
Avoided environmental compliance costs	Utility	47% (14)
Environmental impacts	Societal	43% (13)
Productivity	Participant	37% (11)
Health and safety	Participant	37% (11)
Asset value	Participant	30% (10)
Energy and/or capacity price suppression effects	Utility	30% (10)
Avoided costs of compliance with RPS requirements	Utility	27% (8)
Avoided credit and collection costs	Utility	23% (7)
Avoided ancillary services	Utility	23% (7)
Comfort	Participant	23% (7)
Economic development and job impacts	Societal	20% (6)
Public health impacts	Societal	13% (4)
Energy security impacts	Societal	10% (3)
Increased reliability	Utility	7% (2)

More detail: https://eta-publications.lbl.gov/sites/default/files/nei_report_20200414_final.pdf

If Oregon policymakers are interested in modifying the state's approach to determining the value of energy efficiency, the state could explore some or all of the following strategies:

- Identifying the co-benefits that can be calculated first, then considering the harder-to-quantify co-benefits, and finally reviewing co-benefits that need qualitative metrics to determine their value.
- Incorporating the full value of reduced GHG emissions, decarbonization, and beneficial electrification from energy efficiency.
- Reflecting the full and accurate value of capacity savings during certain times (e.g., time-of-use periods), marginal line losses, enhancement of DERs, grid flexibility, and other ancillary services provided by energy efficiency.

- Incorporating the value of increased reliability and resilience.
- Calculating and incorporating the value of the new and existing jobs associated with energy efficiency versus the jobs created by investments in alternative resources.
- Including the quantifiable environmental and health benefits accrued from improved air quality.
- Investigating the separation of energy efficiency programs similar to what the CPUC has done. They created three categories of energy efficiency programs: resource acquisition, equity, and market support.
- Considering equity through differential rates, tracking energy burden better, and allowing some programs with statewide equity goals and objectives to be explicitly exempt from the cost-effective test.
- Collecting the necessary data and quantifying the co-benefits of comfort and safety.
- Ensuring that the cost recovery of energy efficiency investments is treated the same way as renewable energy project investments.

Oregon and the Pacific Northwest were the undisputed leaders in capturing the benefits of energy efficiency in the 1980s and 1990s. The state can build on those decades of great work to move energy efficiency in Oregon forward once more.

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Policy Brief: Local Energy Perspectives on Workforce and Supply Chain

- While labor market disruptions due to the pandemic have largely resolved, **long-term workforce issues have re-emerged**: generational turnover, shortages of workers with critical skills, and workers' challenges meeting caretaker needs and finding affordable housing.
- The **clean energy transition presents challenges** for training and recruitment of workers with needed skills but also positions the energy industry as an attractive employer providing challenging and well-paid work at the forefront of meaningful societal change.
- **Pandemic-driven supply chain disruptions** have pushed energy project developers to plan further ahead to procure materials and equipment and have created pressures to increase domestic manufacturing for components like electric vehicle and energy storage batteries.

The COVID-19 pandemic caused significant and unprecedented economic disruptions around the world. The resulting recession was the shortest on record in the U.S., with employment in the economy at large bouncing back to pre-pandemic levels in 2022, both nationally and in Oregon.[1] [2] [3] [4] The pandemic has had other longer-lasting impacts, however, including lingering supply chain interruptions and price increases for certain goods and materials, affecting many types of equipment and components that are important in the energy sector.[5]

In addition to providing an overview of key trends and analyses from national and state research, this policy brief will highlight a variety of views and experiences from some of Oregon's energy sector stakeholders. This summary is meant to be a snapshot covering varied perspectives rather than a comprehensive analysis of workforce and supply chain issues in Oregon. The document is reflective of the comments received, which were focused on these key topics:

- Challenges with workforce recruitment, retention, and training
- Opportunities for energy businesses and workers as the industry transitions to a low-carbon future
- Current efforts in Oregon to train and attract new energy sector workers
- Current challenges procuring the equipment, components, and materials energy businesses need to construct, install, and maintain energy systems

ODOE gathered input from Oregon energy sector stakeholders in the spring and summer of 2022 through a virtual roundtable event, a short email questionnaire, and one-on-one interviews.[6] These perspectives provide useful context as decision-makers consider how to best prepare workers to move the state toward a clean, safe, and resilient energy future.

Outreach Process and Methods

Roundtable convened by ODOE in March 2022. In response to stakeholder interest expressed during a discussion on federal funding opportunities at the January 2022 Energy Advisory Work Group meeting, the Oregon Department of Energy pulled together a follow-up roundtable discussion on workforce development opportunities. Attendees at the March 2022 roundtable included representatives from utilities, labor unions and labor advocates, environmental advocacy organizations, and community-based groups. The main discussions took place in a series of breakout sessions on the following topics: energy auditors, other energy-related occupations, equity and workforce diversity, employee retention and training, and building the workforce pipeline. Detailed notes are available on the ODOE website; stakeholders who participated in the roundtable are listed in Appendix B.[6]

Questionnaire and interviews, Summer/Fall 2022. ODOE sent group and individually targeted emails to more than 200 stakeholders representing a variety of interests in the energy sector. ODOE received comments from and/or interviewed 16 stakeholders representing utilities, renewable energy developers, educational institutions, labor unions and advocates, state agencies, and non-governmental organizations. The questions sent to stakeholders are reproduced in Appendix A, while stakeholders who provided input are listed in Appendix B.

Workforce Challenges and Opportunities

The energy workforce involves individuals with diverse skill sets and knowledge, many of which are shared with other sectors of the economy, while a key cohort of energy workers requires specialized industry knowledge, usually acquired through years of work experience. In 2021 there were 90,543 energy workers in Oregon representing 4.8 percent of total statewide employment, with 10,196 in electric power generation; 4,260 in fuels; 12,225 in transmission, distribution, and storage; 38,847 in energy efficiency; and 25,015 in motor vehicles.[7] The clean energy transition, bolstered by the state's 100 percent clean electricity standard[8] and significant funding through the Infrastructure Investment and Job Act of 2021 and the Inflation Reduction Act of 2022, is expected to greatly increase the need for skilled workers. However, this increased need is coming at a time when the workforce is rapidly changing, and many experienced workers are retiring from the workforce. At the same time, the U.S. lacks the training programs and pathways to quickly build a workforce to fill existing jobs and future roles in the evolving clean energy economy.

Stakeholder Reflections on Workforce Trends and Activities: Highlights

- Historically low unemployment with job openings outnumbering job seekers
- Generational transition as experienced workers move into retirement
- Need to recruit a more diverse population of workers into the sector
- Gaps in workforce needs for some Oregon energy industries
- Anticipated need for more workers to support the clean energy transition
- Need for state and federal investment in U.S. workforce training

COVID-19 Impacts and Current Workforce Market Trends.

Oregon workforce participation has largely recovered from COVID-19 impacts, but long-term trends have re-emerged

In the two years since the start of the COVID pandemic in March 2020, Oregon's economy experienced the "greatest disruption to the workforce since WWII,"[3] according to ECONorthwest, a regional economic consultant firm. While COVID impacts have largely resolved and the workforce participation rate is now higher than pre-pandemic levels in Oregon, unemployment is at near-historic lows and many employers are struggling to fill openings.[9] [10] The Oregon Office of Economic Analysis reported in its September 2022 forecast that there were 1.6 job openings in Oregon for every job seeker, down from 1.9 openings per job seeker in the previous quarterly forecast.[9]

Although both men and women lost jobs during the early months of the pandemic, women, particularly Black and Hispanic women, bore a disproportionate share of lob losses in 2020 and into 2021.[11] Many researchers documented the toll of COVID-related school and childcare closures on working parents, particularly working women.[12] [11] However, by mid-2022, the Oregon Office of Economic Analysis found that "[w]hile some employment disparities by race and ethnicity and by sex did widen initially, they have now closed."[13] Oregon workforce participation has largely recovered from COVID-19 impacts, but long-term trends have re-emerged: workforce participation among men in their "prime" working years remains at-or-near historic lows while U.S. women's workforce participation plateaued in the 1990s after decades of growth and remains level.[14]

Stakeholder Experience: Pandemic-Driven Workforce Challenges

Energy sector stakeholders mentioned increased worker turnover and challenges filling job openings, with utility stakeholders mentioning particular challenges in retaining key and senior employees. Employee burnout has also been a factor in increased turnover. More than one utility mentioned that employee expectations have changed regarding flexibility around work hours and the ability to work remotely, which some employers perceive as presenting new challenges for preserving and building a strong workplace culture.

Economy-Wide Workforce Trends

By mid-2022, overarching trends from pre-2020 had re-emerged as the dominant shapers of the workforce landscape, foremost of which are the continued retirement of the Baby Boom generation and the challenges of meeting family and caretaking needs.[3] According to some researchers, the retirement of the Baby Boom generation is leading to challenges in filling entry-level positions. The pandemic prompted an increase in early retirements which, coupled with fewer younger workers entering the workforce, has provided opportunities for less experienced workers to transition into more senior positions, leaving fewer workers to fill more junior roles, such as face-to-face service positions.[15]

Stakeholder Experience: Economy-Wide Trends

Energy sector stakeholders described challenges in recruiting workers due to the high cost of living in Portland and increasingly in other parts of the state, mostly driven by the cost of housing. Availability and affordability of housing in touristed areas on the coast, and childcare for many workers and apprentices across the state, has been particularly challenging. Rural communities with small populations struggle to retain and support workers and specialized businesses of many kinds, including professionals and businesses with energy-related expertise. Like employers in many sectors, energy employers are considering ways to widen the net as they struggle to recruit employees, including building relationships with educational institutions and community-based groups to reach potential workers and boosting career paths and internal training opportunities to retain existing employees.

The U.S. energy sector weathered COVID with fewer job losses than other sectors, and Oregon's energy sector did better than the national average.

Energy Sector-Specific Workforce Characteristics

The U.S. energy sector weathered COVID with fewer job losses than other sectors, and Oregon's energy sector did better than the national average.[16 7] Compared to the economy at large, the energy industry has historically been well-paying, and subsectors like utilities offer stable employment compared to other industries.[3] Energy sector workers are older, and more likely to be white and male than workers in other Oregon industries.[3 17 18] Nationally, women comprise 25 percent of the energy industry workforce while making up 47 percent of the total U.S. workforce.[19] Women are underrepresented in many roles across the industry, including senior management; women have made greater progress in gaining senior management roles at utilities than in other energy businesses, with women making up 18 percent of senior positions in natural gas utilities, for example, compared to 12.1 percent of senior roles in the rest of the energy sector excluding utilities.[20] A 2019 report on diversity in solar workforce in Oregon and Washington found that women made up 20 percent of the overall solar workforce, but only 4.7 percent of licensed installation crew members and 1.5 percent of unlicensed installation crew members. The same report found that racial and ethnic minorities were underrepresented in the solar industry in Oregon and Washington compared to their participation in the overall workforce in the two states.[17]

Many types of jobs in the sector are not energy-specific, including workers in the construction trades, engineers, and administrative staff such as accountants and finance, human resources, and information technology professionals. For these workers, energy employers compete with other sectors based upon factors like pay and benefits, working conditions such as long-term stability and opportunities for advancement, and location. Other energy sector jobs require deep industry-specific knowledge that is not easily replaced; this category includes workers in key management roles, highly specialized roles such as linemen, and professionals focusing on policy, research, and programming.[3 16]

Stakeholder Experience: Energy Sector-Specific Challenges

Stakeholders shared energy sector-specific challenges, including the need to compete with other sectors for workers. Rural energy developers mention that they frequently compete with data centers for electrical workers, while rural utilities experienced competition with wildfire-related employment for construction workers. An investor-owned utility shared that as a regulated industry, they are not always able to offer as competitive of salaries for some key positions. Several stakeholders explained that they have challenges hiring senior positions requiring industry-specific knowledge that often takes years to acquire, and that Oregon has a small pool of workers with the industry knowledge and experience that would equip them for managerial and programmatic roles. Stakeholders also mentioned specific need for energy auditors: in rural areas; in the commercial, industrial, and residential sectors; with multilingual capabilities and diverse cultural competencies; and with experience working with low-income housing and weatherization programs. Representatives from labor organizations suggest that energy sector-specific labor shortages could be addressed by higher wages and better working conditions to attract employees.

Several stakeholders expressed a desire to build a more diverse, equitable, and inclusive workforce within the energy sector and identified a need for broader efforts to ensure that energy sector occupations and workplaces are seen as attractive and welcoming to populations that have not historically been employed by the sector in large numbers, including people of color and women. As noted by researchers, people of color and women experience unique challenges in construction-related roles in the energy sector, including harassment in the workplace and unequal access to job opportunities.[19] [21] Utility stakeholders expressed the opinion that the industry has made improvements in being seen as a more welcoming environment for historically underrepresented populations and pointed to efforts to involve women and people of color in pre-apprenticeship programs to introduce them to the industry.

Several stakeholders expressed a desire to build a more diverse, equitable, and inclusive workforce within the energy sector.

Representatives from labor organizations stress that the solution begins with ensuring greater diversity among applicants to apprenticeship programs, and that "there is no quick fix to this issue." According to IBEW Local 48, "25 percent of our apprenticeship program is comprised of woman and minorities. We have two full-time staff dedicated to recruitment of underserved communities." IBEW and the BlueGreen Alliance both point to a recent study by the University of Oregon Labor Education and Research Center which found that union apprenticeship programs, like those run by IBEW, have done better at recruiting, retaining, and graduating women, people of color, and veterans compared to their non-union counterparts. The study's author notes that in 2020, women made up 11 percent of newly-enrolled apprentices for the construction trades in Oregon, while workers of color were 31 percent of all newly-enrolled apprentices - an increase of more than 50 percent over the previous decade for both categories.[22] (See section below on "State and federal responses to workforce challenges" for more information on apprenticeship programs.)

According to BlueGreen Alliance, the renewable energy sector needs to be "all in" on building the skilled workforce and providing union wages and benefits to attract and retain diverse workers; BGA argues in favor of policies similar to the labor standards found in House Bill 2021 (see call-out box on House Bill 2021 labor standards).[8] BGA would like to see public agencies, utilities, and developers/owners promoting apprenticeship in contracting and incentives, as well as "high road" training partnerships with employers providing good wages and benefits, pointing to Metro's Construction Career Pathways Project and efforts by the California Workforce Development Board as models.[23] [24] [25]

HB 2021 Labor Standards

House Bill 2021,[8] enacted by the Oregon Legislative Assembly in 2021, requires Oregon's large investor-owned utilities and electricity service suppliers to reduce greenhouse gas emissions associated with electricity sold in Oregon, requiring emission-free electricity by 2040. The bill requires renewable project developers and contractors to document and meet specific labor standards when constructing renewable energy generating or storage facilities with capacity of 10 megawatts or greater. Under House Bill 2021, developers and contractors must:

1) Participate in an apprenticeship program registered with the State Apprenticeship and Training Council, with 15 percent of the total work hours on a project performed by workers in "apprenticeable" occupations.

2) Establish and execute a "plan for outreach, recruitment and retention of women, minority individuals, veterans, and people with disabilities to perform work under the contract," with the goal of at least 15 percent of total work hours performed by individuals in one or more of those groups.

3) Have anti-harassment and anti-discrimination policies in place.

4) Pay workers a prevailing wage and offer health care and retirement benefits.

The Clean Energy Transition and Workforce Impacts

Making the transition from fossil fuels to clean, renewable energy sources is central to meeting U.S. and Oregon decarbonization goals. Current efforts to expand clean energy generation facilities and infrastructure are increasing demand for workers in the construction trades and with a variety of other skills. The clean energy transition is expected to spur rapid technological innovation, presenting both challenges and opportunities for good, well-paying jobs.[18] [26] Compared to states with prominent fossil fuel and extractive industries, Oregon has fewer challenges relating to displacement and retraining of energy workers.[18] [26] However, uncertainty about the technological and commercial viability of future energy technologies like renewable hydrogen, ocean energy, and biofuels brings uncertainty about the workers and skills that these nascent industries will need.[6]

As some researchers argue, an energy sector working toward cleaner generation sources may offer greater appeal to younger workers due to its leading role in decarbonization.[18] A no- or low-carbon energy sector will increasingly demand sophisticated digital skills, especially data analysis, as energy workers grapple with issues like managing customers' energy demand and integrating renewable energy resources and energy storage.[18] Researchers see potential for job growth to build out and operate renewable energy and energy storage systems, transmission and distribution infrastructure, and electric vehicle charging infrastructure, as well as in roles such as building controls management and energy auditors.[26 28 29 30] Various authors make the case that attention to building a diverse future energy workforce is important both to make sure that the clean energy sector has enough workers with suitable skills as it competes with other sectors for skilled future workers, and to ensure that people of color and women are not left out of the opportunities presented by this historic economic transformation.[31 24 23 21 17]

Stakeholder Experience: Clean Energy Transition

Stakeholders identify several workforce challenges that are currently constraining clean energy development in Oregon. The primary workforce challenges as cited by stakeholders include a shortage of qualified electrical workers, a shortage of contractors and skilled workers in rural areas, difficulties recruiting and retaining workers, and low rates of clean energy-related employment by underserved communities, like people of color and women workers. If left unaddressed, these challenges will impede the clean energy transition in the state.

Shortage of qualified electrical workers. Electric utilities, renewable energy developers, and solar contractors all identified a shortage of qualified electrical workers as a key workforce-related challenge in the state. Stakeholders reported shortages of journeyman electricians (including those who install solar arrays and EV chargers), limited renewable energy technicians (LRTs)[i], and electrical apprentices across Oregon. The solar industry reports being particularly affected by workforce shortages. Residential and commercial solar PV contractors would like to hire around 100 additional LRTs, and companies building utility-scale projects in Oregon are reportedly unable to fill 25 to 100 electrician positions on a given day. Stakeholders indicated that the electrical worker shortage is limiting opportunities for growth and job creation within the clean energy sector. "We want to supply more local jobs but need qualified people to hire," one solar contractor explained. Labor representatives involved with electrical worker training programs have a different perspective, perceiving that wait-times for completing electrical work have shortened since the early months of the pandemic and that many of the difficulties in hiring electricians are due to prospective employers offering below-market wages.

Rural workforce shortages. While all areas of the state are affected by a shortage of qualified workers, the issue is particularly pronounced in rural areas. Several stakeholders reported difficulties finding local contractors in rural communities and securing workers for large renewable energy projects in remote areas of the state, although labor representatives noted that this issue does not affect the energy sector alone: "Smaller rural communities simply do not have the population density to support large scale electrical contractors/workers on an ongoing basis." Sustainable NW reported a

While all areas of the state are affected by a shortage of qualified workers, the issue is particularly pronounced in rural areas.

[i] The LRT, or "limited renewable energy technician," license classification allows work to be completed on small renewable energy systems in Oregon by individuals who do not have a full electricians license. Senate Bill 338 (2021) raised the threshold of the project size that LRTs may work on from 25kW to 50kW.

"dire need for energy auditors and efficiency contractors in rural Oregon," adding that the limited availability of local contractors is particularly challenging for rural projects requiring multiple bids, as used in tribal or public sector projects. Oregon Department of Energy staff observed the shortage of energy auditors available to perform energy audits in rural areas of the state when recruiting firms to perform audits under a USDA Rural Energy Development Assistance (REDA) grant. Depending on location, auditors must travel long distances to perform work under the program.

Recruitment and retention challenges. Clean energy industry stakeholders are also having difficulty recruiting and retaining workers. High housing costs and low housing availability make it challenging to attract new employees in some areas. For example, a solar contractor in the Portland metro area reports struggling to attract experienced solar installers for the past two years. At the same time, inflation is putting upward pressure on labor costs, and some clean energy developers report struggles to retain workers as wage and benefit costs increase. Renewable energy developers also report challenges retaining qualified electrical workers for remote projects, with utility-scale solar developers often hiring electrical workers from other states. In the perception of one stakeholder, solar employment in Oregon appears to follow a boom-and-bust cycle which may discourage potential workers from pursuing a career in the solar industry and could contribute to ongoing recruitment challenges moving forward. Alternately, IBEW emphasizes that they are seeking to attract energy sector workers to the electrical trade in general, which gives workers additional options to work in other sectors during "bust" periods of the business cycle.

State and Federal Responses to Workforce Challenges

Over the past decade, policymakers, employers, and educators increasingly recognize that the U.S. has fallen behind other nations in workforce training for both future and displaced workers. Several researchers have proposed both higher levels of investment in training, and institutional reforms and innovations that would improve communication and coordination between training institutions and employers and provide better information for job seekers.[3] A 2020 bill passed by the U.S. House of Representatives to reauthorize the Workforce Innovation and Opportunity Act, one of the core federal workforce programs, would have made fundamental changes to, and substantially increased investment in, youth-focused programs.[32]

Recent federal legislation such as the Infrastructure Investment and Jobs Act and the Inflation Reduction Act includes provisions to increase the available workforce for clean energy and other infrastructure projects.[33] [34] [35] (For more information, see the Energy 101 on the Infrastructure Investment and Jobs Act.) The National Governors Association is providing resources and support for states to engage with these federal efforts; Oregon is one of four states selected to participate in a NGA-led pilot program on training for EV-related workforce.[36] At the state level, the Future Ready

Oregon package includes a variety of investments to improve workforce training and provide opportunities to historically underserved workforce entrants and improve workforce training.[37]

Stakeholder Experience: Responses to Workforce Challenges

Stakeholders provided perspectives on the types of efforts needed to improve the workforce pipeline for energy careers. Several stakeholders focused on the need to build awareness in students and parents starting in middle school and high school, emphasizing that construction trades are good career options for many young people and that a solid background in math and science will provide future opportunities. Stakeholders including employers and educators emphasized the needs of many potential workers for an individually customized and coordinated set of support services, often termed "wraparound services," to ensure they can participate in and successfully complete training programs.

Oregon-based energy companies are undertaking a variety of efforts to boost workforce training and retention.

Oregon-based energy companies are undertaking a variety of efforts to boost workforce training and retention. Portland General Electric has convened a broad coalition of energy stakeholders to focus specifically on energy sector workforce issues, in addition to several efforts within the company. PGE constructed its Sherwood Training Center and Integrated Operations Center to provide training for trade personnel as well as opportunities for some key functions within the company's energy management system. PGE also launched its first pre-apprenticeship cohort this year that will use the Sherwood Training Center, and sponsors paid green internship opportunities for underserved youth ages 20-24 with local non-profit conservation and stewardship partners. NW Natural is preparing to launch an intern program in its customer field service team, after success with its construction intern program in boosting diversity in its construction field workforce.

Energy-related training in educational institutions. Training for energy workers occurs in community colleges, apprenticeships, universities, and on the job, with much of it occurring in programs and institutions that do not have an energy-specific focus. On the programmatic side, for example, university curricula do not include energy efficiency; utilities or Energy Trust of Oregon tend to hire recent graduates with quantitative analysis and business skills who learn about energy efficiency principles on the job or they hire experienced workers from related businesses. A few Oregon community colleges run energy-specific programs, such as the building energy management program at Lane Community College[38] and the renewable energy program at Clackamas Community College.[39] [40] Community colleges are increasingly adding instruction on electric vehicles to their automotive repair and maintenance programs. Stakeholders suggest that an inventory of all existing energy-related training programs and certifications in Oregon community colleges could help the state to build upon existing successes and "scale what's working to address workforce development barriers."

Energy Management – Building Controls Program, Lane Community College

The Energy Management – Building Controls program at Lane Community College was started in 1980, closed in 1988, and reopened in 1992. Federal policy and funding have been a strong driver for programs like this on a national scale: as part of American Recovery and Reinvestment Act funding in 2009, the program's coordinator, Roger Ebbage, received a National Science Foundation grant to help establish around 30 other similar programs across the country. Only six of those programs are still running after federal funding dried up.[41]

The Energy Management with Controls program is a career-technical program offering a two-year degree; the program focuses on commercial building energy efficiency, with long-standing options for students to add coursework in sustainability and solar energy system design.[38] The building control systems content is new to the program. Students following the building controls curriculum are in high demand by the industry. For example, LCC has a memorandum of understanding with Siemens Corporation allowing the company an opportunity to meet students in the program after the winter quarter before their graduation.

Students in the program come mostly from the Lane County area, although since going fully remote prior to the COVID pandemic and expanding the program's advertising reach, the program has recently attracted many students based in the Multnomah County area. Students can attend other community colleges for general education requirements, as needed. Very few students start the program right out of high school. Some graduates who have gone on to further academic pursuits, while others have used their credential as the basis for a successful career in the field. The cost to complete the two-year program is about $15,000.

The program registered its Building Energy and Controls Apprenticeship (BECA) program with Oregon Bureau of Labor and Industries in October 2021; 12 apprentices started the program in 2021, and 32 started the program in 2022. Over 120 people have filled in an interest form for the apprenticeship program. The apprenticeship program consists of two components: a minimum of 13 core energy courses plus courses in math and physics, and 2,000 hours of paid on-the-job training. The reason for creating the apprenticeship program is that building energy efficiency and controls professionals operate "behind the curtain," with few people knowing about their existence. With an apprenticeship option, guidance counselors can refer students to this path as they would for students in other career paths — and the building energy efficiency and controls path will also be more visible to parents of potential students. A helpful resource that the program shares with students and parents is an online "Green Buildings Career Map" showing various educational and training paths and related career options.[42]

Apprenticeships. On the construction side, many energy workers come to the industry from union-based apprenticeships or are trained by energy-related companies through multi-employer apprenticeship programs (see vignette on union-based electrician apprenticeships). Apprenticeships were an important topic for many energy stakeholders, given the key role that apprenticeship programs play in training many energy sector workers. Apprenticeships in Oregon come in two main models: the union-based model where both coursework and on-the-job training are provided by the union, and a non-union model in which apprentices often take coursework at an educational institution or community college followed by on-the-job training with an employer certified as a registered training agent by the Oregon Bureau of Labor and Industries.

> "Not all apprenticeship programs are built the same. **We need to promote top performing apprenticeship programs** leading their respective craft in recruitment, retention, and graduation rates, and reward employers providing good wages and benefits, and union protections."
>
> – Blue Green Alliance

Stakeholders shared a variety of views on improving apprenticeship program administration and increasing the numbers of potential apprentices. Renewable energy developers expressed some frustration with dual apprenticeship standards coming from both state and federal levels, causing duplication of effort for companies. Renewable energy developers would welcome future study on rural renewable energy apprenticeships with partners like community colleges, Eastern Oregon University, and Tribes: "One specific issue to consider is whether soon-to-be released incarcerated individuals would be appropriate apprenticeship candidates."

Central Lincoln PUD is one example of a consumer-owned utility that runs its own apprenticeship program to train employees from the communities they serve. Central Lincoln observes that running an apprenticeship program "incurs a lot of administrative work," and that small utilities need more support from the state to make running such programs easier. They are hopeful that the "Future Ready Oregon" initiative will bolster apprenticeship programs for utilities. "We have expanded our apprenticeship program under the new 2022 BOLI rules from five apprentices to 10. This is a lot of training that our utility is performing and means shifting our priority away from capital projects, grant programs, or other work while we focus on training. Not all smaller utilities have apprenticeship programs and rely on others to train the workforce."

The Oregon Solar + Storage Industry Association coordinates the licensed renewable energy technician (LRT) apprenticeship program (see footnote above for background on the LRT certification). OSSIA is interested in discussions revisiting the apprentice ratio and existing restrictions on the LRT license. A solar contractor echoes the need for more LRT workers and note that currently there are not enough certified LRTs available to train future LRTs. IBEW is opposed to increasing apprenticeship ratios and expressed concerns that increasing the ratio would negatively affect the quality of training as well as the safety of electrical installations. BlueGreen Alliance also cautions against updating apprenticeship ratios, pointing to U.S. Department of Labor data showing that Oregon currently outperforms states like Colorado with higher apprenticeship ratios.[43] Labor representatives also shared that the journeyman electrician qualification opens up more opportunities for long-term employment in energy and other sectors, compared to the LRT qualification.

Union-Based Electrician Apprenticeships

The only way to become a journeyman electrician is by completing a five-year apprenticeship program consisting of classroom and on-the-job learning, either through a labor union for both aspects of the program or a community college for classroom learning and an employer who acts as the agent for the on-the-job learning aspect of the training. Apprenticeship programs follow a standard national curriculum, including training in all aspects of electrical work and touching on solar and wind energy, pumped energy storage, and electric vehicle charging. According to Robert Westerman of IBEW, "Our IBEW/NECA apprenticeship programs are continually being updated and improved upon to address new technologies, ensuring that electrical trades people have the skills, knowledge, and training to address future workforce needs. At no expense to the taxpayers."

IBEW Local 48 operates a training center in the eastern Portland metropolitan area, covering the northwest corner of the state from the coast to The Dalles. The training center has an annual intake of about 300 new apprentices, with a total of about 1,100 apprentices currently in training. Local 48 is scouting for a location to add a facility in the western metropolitan area to accommodate plans to increase the number of apprentices in training to 1,600 in the next two years. There are seven local IBEW units in Oregon with about 1,900 apprentices currently in training in total around the state.

Demand for participation in an apprentice training program is strong – IBEW Local 48 currently has about 1,000 people on a ranked list who have met qualifications for entry into the electrician apprenticeship program, including passing an interview and one year of algebra coursework, and possessing a high school diploma or GED certificate with at least a 2.0 grade point average. Some of the main challenges they see for apprentices and workers are the shortage of housing, especially on the coast during the summer, and obtaining affordable childcare.

IBEW works with the National Electrical Contractors Association and studies a variety of resources to forecast the need for electricians in coming years to match up the number of apprenticeships and future graduates with the demand for work. On the job training is a significant part of an apprenticeship program, and participants cannot graduate without enough work hours, meaning that some apprenticeships could stretch into six or seven years if there are not enough work hours available.

Supply Chain Challenges

COVID-driven supply chain disruptions have been slower to resolve than disruptions to the labor market. On a global scale, the Federal Reserve Bank of New York's "global supply chain pressure index" for August 2022 showed that while supply chain pressures had eased over the previous four months, they remained at historically high levels.[44] Utilities and renewable energy developers have experienced delays and price increases while trying to purchase specialized equipment such as transformers, switch gear, energy storage batteries, and bucket trucks,[5] [45] while fleet managers and consumers have endured long wait times and cancelled orders for electric vehicles.[46] [47] Meanwhile, solar project developers have contended with uncertainty about tariffs on solar photovoltaic panels from some of the largest supplying countries, causing significant project delays. In June 2022, the Biden Administration announced a two-year exemption from tariffs, but industry watchers cite long-term uncertainty as a concern for developers and investors.[48 49 50]

Recent supply chain challenges have brought a sharper focus to questions about whether supplies of critical components and materials will be sufficient to meet future clean energy and climate goals.[51] Supplies of lithium, various metals, and rare earth minerals are of particular concern,[52 53 47 5] while federal policymakers have also focused on building domestic manufacturing capacity to supply energy generation and storage equipment, including semiconductor chips.[54 55 56] The U.S. Department of Energy, in response to President Biden's Executive Order 14107 on U.S. supply chains,[57] issued a report in February 2022 entitled "America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition" detailing the critical elements of the energy supply chain, including key technologies and materials, and making recommendations for building the domestic industrial capacity to meet clean energy goals.[54 58]

Local Supply Chain Challenges

Supply chain disruptions affected a wide variety of energy stakeholders during the pandemic, and ongoing shortages of certain materials and products continues to affect the state's energy sector. The disruptive impacts from supply shortages and delivery delays are further compounded by recent cost increases for essential supplies and materials.

Stakeholders continue to experience significant disruptions in the availability of electrical equipment and components. Items like electrical transformers, meters, vaults, and utility boxes are delayed or unavailable. Renewable energy developers continue to face delays in the availability of solar PV modules, battery storage systems, and certain kinds of invertors and racking systems. Delays in the availability of battery storage systems present a notable challenge for projects seeking a rebate under the Solar + Storage Rebate Program because solar PV and battery storage systems must be installed at the same time to qualify for a rebate under the program. Stakeholders, including the Oregon Department of Administrative Services Fleet and Parking Services program, are also experiencing delays in the availability of electric vehicles due to supply chain disruptions and shortages of components and materials, including semiconductors and raw materials such as neon, lithium, and palladium.

In addition to supply chain delays and shortages, the prices of many supplies and materials have increased dramatically in recent months, and several stakeholders reported that rising costs are now a larger problem than supply chain disruptions. Cost increases are affecting stakeholders across the energy sector. The prices of electrical supplies, energy efficient equipment and appliances, and EV chargers have all increased during the post-pandemic recovery, and in some cases these cost increases have far outpaced the recent rate of inflation. One public utility district reported that the price of a residential transformer had increased from $2,500 to $15,000 over the course of the year, with a 20-month delivery timeframe. Energy Trust of Oregon mentioned that increasing prices for equipment and materials is affecting the cost-effectiveness of measures to achieve energy savings (see policy brief "Beyond Savings –

In addition to supply chain delays and shortages, the prices of many supplies and materials have increased dramatically in recent months.

Co-benefits of Energy Efficiency" for more information on the variety of benefits from increasing energy efficiency in the built environment).

Stakeholder Experience: Supply Chain Challenges

Multiple stakeholders reported ordering supplies and materials as early as possible to account for long delivery lead times. Product manufacturers are reportedly exploring ways to standardize equipment used for basic functions, such as transformers, which could help alleviate supply bottlenecks for more specialized equipment. There are also emerging efforts for multiple utilities to collectively purchase materials and equipment, which could help smaller utilities access needed supplies. Solar industry stakeholders expressed optimism that the U.S. Commerce Department's actions to suspend tariffs on solar panels imported from certain Asian countries would alleviate the PV supply shortages affecting the solar industry.

Conclusion

Energy stakeholders note many challenges that Oregon will face in recruiting the skilled workforce needed to meet the state's climate and clean energy goals. Some of these challenges stretch across all economic sectors, including generational turnover, the need for affordable housing and childcare, and shortcomings in training opportunities and employment-related information for new and displaced workers. Federal and state policymakers have adopted or proposed a number of system-wide reforms and investments, while a coalition convened by Portland General Electric is working on energy sector-specific efforts to address workforce challenges in Oregon. Meanwhile, recent federal action to stimulate domestic supplies of materials and equipment promises to provide opportunities for clean energy businesses at the state and local levels.

Appendix A: Outreach Email Sent to ODOE Stakeholders

Request: Energy Workforce and Supply Chain Challenges and Opportunities

The Oregon Department of Energy has heard that many in the energy industry are experiencing new or increased workforce and supply chain challenges in the wake of the COVID-19 pandemic — and we would like to hear from you. Are there workforce and/or supply chain issues that are affecting your organization?

ODOE is planning to highlight stakeholder workforce and supply chain challenges and opportunities in our 2022 Biennial Energy Report, due later this year. So far, we have heard from stakeholders about this topic during our January 2022 Energy Advisory Work Group meeting and during a stakeholder roundtable held on March 16 (See meeting summary and other materials on our website).

Please let us know if your organization has data or examples of challenges and/or opportunities that you would like to share, and we will follow up with you. We may not be able to include every example in our report, but your individual stories and concerns are important to help us convey a full and accurate picture of workforce and supply chain issues facing the Oregon energy sector. We know that this can be a sensitive topic with some stakeholders and are willing to share information without attribution if there are concerns.

Our Questions:

- What are your organization's workforce development and/or retention challenges? What energy workforce opportunities do you see? Do you have any specific data or information that you could share that would help illustrate these challenges and/or opportunities?
- What has your organization done to address your workforce-related challenges? Are you aware of workforce development efforts that are working well that we could highlight for readers of the Biennial Energy Report?
- Is your organization experiencing challenges related to supply chain disruptions, either starting before the COVID-19 pandemic or tied to the pandemic? How are these supply chain disruptions affecting your operations? Please indicate if you consider this sensitive information and would like us to share it anonymously or without attribution.
- We are aware of a few Oregon-specific studies on workforce needs, including the Transportation Electrification Workforce Study (Executive Summary), the Metro Construction Career Pathways study (link to download study) and University of Oregon Report "Constructing a Diverse Workforce: Examining Union and Non-Union Construction Apprenticeship Programs and their Outcomes for Women and Workers of Color." Are there other recent Oregon-specific studies or analyses that you are aware of? Do you have workforce or supply chain related questions to recommend for future study to help fill in gaps in this important topic?

Thank you for your time — your stories will help us illustrate Oregon's current challenges and opportunities to share with legislators, community leaders, and other groups and stakeholders.

Appendix B: Stakeholder Contributors

The Oregon Department of Energy thanks the following stakeholders who contributed comments and views for this policy brief.

Roundtable participants

Annette Price, Pacific Power
Brooke Brownlee, Portland General Electric
Chris Carpenter, FocusPoint Communications
Dr. Michelle Maher, Oregon Solar + Storage Industries Association
Franklin Chen, Unite Oregon
Garth Bachman, IBEW 48
Jaimes Valdez, Portland Clean Energy Fund
Jana Gastellum, Oregon Environmental Council
Joshua Basofin, Climate Solutions
Kerry Meade, Northwest Energy Efficiency Council
Marcy Grail, Energy Facility Siting Council
Mary Moerlins, NW Natural
Max Greene, Renewable Northwest
Ranfis Giannettino Villatoro, BlueGreen Alliance
Tucker Billman, Oregon Trail Electric Cooperative

Questionnaire and interview participants

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Chris Carpenter, FocusPoint Communications
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Tyler Dotten, Portland Home Improvement Consultant, Neil Kelly Solar
Roger Ebbage, Energy Management – Building Controls Program Coordinator, Lane Community College
Tyrell Hillebrand, General Manager, Central Lincoln People's Utility District
Matt Hutchinson, Senior Business Developer, Avangrid Renewables
Brian King, Fleet and Parking Services Manager, Oregon Department of Administrative Services
Brian Krieg, FocusPoint Communications
Marshall McGrady, IBEW Local 48 (Portland)
Mary Moerlins, Director of Environmental Policy and Corporate Responsibility, NW Natural
Spencer Moersfelder, Planning Manager, Energy Trust of Oregon
Michelle Slater, Legal and Project Management Services, Obsidian Renewables
Ranfis Giannettino Villatoro, Oregon State Policy Manager, BlueGreen Alliance
Robert Westerman, IBEW Local 932 (Newport)

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REPORT RECOMMENDATIONS

Oregon Statute requires the **Oregon Department of Energy to develop a Biennial Energy Report** to "inform local, state, regional, and federal energy policy development, energy planning and energy investments, and to identify opportunities to further the state's energy policies." Statute also says that the department may include "**recommendations** for the development and maximum use of cost-effective conservation methods and renewable resources…" (ORS 469.059).

ODOE's first Biennial Energy Report, published in 2018, included recommendations in four key areas: data gaps, addressing equity and energy burden, planning for the future, and assessing the need for state engagement and investment. In the 2020 report, ODOE did not include a specific list of recommendations, but instead included ideas embedded in topic-specific policy briefs.

To prepare for and draft this report, ODOE staff engaged in stakeholder and public outreach, original research, discussions with other agencies, and reviews of technical studies. Throughout this effort, staff heard numerous ideas for how the state can and should meet its energy and greenhouse gas reduction goals. From those involved in research and development to industry stakeholders to advocates to consumers, Oregonians have many perspectives on the right approach to modernize and improve our energy systems as the state moves from a reliance on fossil fuels to clean energy. There are multiple pathways to achieve the state's goals, and each comes with opportunities and challenges.

Over the past year, a common theme has emerged during the drafting of this and other legislatively directed reports and has formed the basis of our recommendation:

The state would **benefit from an energy strategy** to align policy development, regulation, financial investment, and technical assistance in support of an intentional transition to a clean energy economy. This strategy could identify specific pathways to meet the state's policy goals that maintain affordability and reliability, strengthen the economy, and prioritize equity while balancing tradeoffs to maximize benefits and minimize harms. Ultimately, this strategy could be used to **make informed decisions and motivate action**.

Statewide energy strategies have been recently developed and implemented in many states across the nation, including Washington, Utah, Wyoming, New Hampshire, Minnesota, and others.

The influx of federal funding coming from the Infrastructure Investment and Jobs Act and the Inflation Reduction Act creates an opportunity and adds urgency. The state should invest federal funds and deploy resources strategically in activities and programs that target areas where the market alone may not achieve the optimal outcome for Oregonians. A strategy, informed by the latest information and analysis and developed with input from diverse voices from across the state, could help guide the Oregon Department of Energy, other state agencies, and local jurisdictions as they determine which funds to apply for and how to spend the funding that comes to the state.

A valuable state energy strategy would be a comprehensive, system-wide approach that provides guiding principles and a framework to promote coordination on energy policy, planning, and resource investment. State agencies, regional entities, utilities, and local communities have led the way in developing plans with specific actions that work best for their customers and constituents. A strategy could complement and build on their existing work, identify and address gaps and barriers to success, and improve alignment within the state on energy and other related issues like public health, community development, and land use.

The policy briefs in this report review recent studies that, collectively, identify the types of actions that will be required to achieve the state's climate and energy goals, focusing on four pillars of decarbonization: energy efficiency, electrification of end uses, decarbonizing the electric sector, and developing lower-carbon fuels. The optimal approach for Oregon will likely require some combination of these four pillars, and policymakers will need to make decisions on whether, and to what extent, to encourage specific technologies and resources within this transition. Each pathway comes with tradeoffs; decision-makers need to balance these tradeoffs and make informed decisions that maximize benefits and minimize harms to Oregonians and important state resources.

The exact scope of the energy strategy should be developed by engaging with stakeholders, community members, and other state agencies, ideally as a result of direction from the Legislature and Governor. The strategy should be developed using an inclusive process and should focus not only on how the state's energy systems can decarbonize, but also how to help Oregonians navigate the transition – with previously underrepresented voices at the center of the conversation and decision making. Below are just a few of the key questions that might frame a discussion about an energy strategy.

- **Renewable generation:** Can the state identify a preferred resource development pathway for renewables that optimizes across multiple objectives, such as minimizing land use and agricultural disturbance, protecting cultural resources, supporting fish and wildlife, addressing the need for transmission development, supporting local economic development, offering resilience benefits, ensuring equitable access, and considering total costs of energy?
- **Energy Efficiency:** Efficiency has traditionally been the least-cost, no-regrets resource in the Pacific Northwest and must be the centerpiece of the state's approach to decarbonization. How can a strategy be designed to maximize the energy savings and additional co-benefits of energy efficiency?
- **Creating space for innovation:** Optimal technology solutions may not yet be commercially available. To what extent should Oregon develop policy flexibility to allow for a range of solutions, such as gas power plants with carbon capture, renewable hydrogen, or large-scale development of biofuels? What role should the state play in supporting or pursuing the development of these types of innovative technologies?
- **Equity:** What can the state do to ensure the distribution of benefits and burdens in the transition doesn't exacerbate historical inequities? How can the state ensure that the transition creates opportunities to lift up and invest in communities that have been left behind by previous economic transitions?

- **Cost:** What policy solutions can help mitigate the costs of the clean energy transition across sectors and types of customers, particularly for the state's most energy-burdened and vulnerable residents? Is there a way to meet the state's energy goals in way that reduces costs for Oregonians?
- **Resilience and energy security:** Given that the state is already experiencing the effects of climate change, is there an optimal pathway that achieves the necessary scale of clean energy affordably while also improving community energy resilience and energy security across the state?
- **Regionalization:** Oregon is already part of an interconnected electricity grid and imports most of its transportation and gaseous heating fuels from neighboring states. Is there a regionalization strategy that can balance interests in developing in-state clean energy resources with the efficiencies that might come from increased regionalization?
- **Workforce**: What investments does the state need to make to ensure there is a workforce available to implement the strategy, and how can the state help prepare the energy sector for energy jobs of the future? How can the state promote workforce development practices and programs that value diversity, advance equity, and create inclusive careers and opportunities in the energy sector?

The state's climate and energy goals can be achieved with a combination of different answers to these questions. But how they are answered will affect all Oregonians and have significant implications for the electric, natural gas, and transportation sectors.

With a thoughtful strategy in place, the state can align regulation, policy, financial incentives, and technical assistance to support it. The strategy can help guide Oregon's resources toward the highest priority opportunities, addressing key questions, such as:

- **Incentives:** Where and how should Oregon invest state and federal dollars to help businesses and consumers with the transition? How can the state target assistance to those who need it most?
- **Technical assistance:** What are the questions and challenges that consumers, businesses, and local governments have as Oregonians adopt new clean energy technologies? How should the state support awareness of these opportunities? What technical assistance do communities need as they adopt new clean energy technologies?
- **Data, information, and analysis:** What data gaps remain and what information will help inform policymakers in developing specific programs and investments to advance the strategy? What topics and types of analysis are needed to understand the energy landscape and inform future decision making?

As the Biennial Energy Report demonstrates, the clean energy transition is already happening. Through the development of an energy strategy, the state has an opportunity to proactively plan for an energy transition that works for Oregon and her people.

ABOUT THE REPORT

The Oregon Department of Energy is pleased to present the **2022 Biennial Energy Report** – the third iteration since the inaugural report was published in 2018.

The primary **purpose of the report**, as directed in ORS 469.059, is to inform local, state, regional, and federal energy policy development, planning, and investments, and to identify opportunities to further the energy policies of the state. To do this, ODOE, the state's dedicated energy office, **collects critical energy data and information** and analyzes what they mean for Oregon.

The report evolves based on Oregonians' current interests and inquiries about energy resources, policies, trends, and forecasts across the state. The **biennial nature of the report** provides a **"go-to" document** and reliable agency process that is timely and responsive to stakeholders, communities, and the public. Ultimately, the Biennial Energy Report is meant to **serve as a trusted, data-driven platform** for conversations on emerging issues and policies, informing energy goals and strategies for the future.

Scoping & Development

As directed by statute, ODOE "shall seek public input and provide opportunities for public comment during the development of the report." The agency conducts broad outreach to collect feedback from diverse audiences and perspectives, which is intentionally done early in the scoping process to inform content development. The Biennial Energy Report process is also aligned with ODOE's Strategic Plan focus areas of engagement, equity, and data.

Development of the report also includes **process objectives**:

- Meet statutory requirements while engaging with new people and organizations, including historically and currently underserved populations and communities.
- Focus on content that is relevant and timely to stakeholder interests and responds to questions from Oregonians across the state.
- Ensure collection of stakeholder input and data is integrated with and complementary to other agency engagement and activities.

During the scoping phase, ODOE shared a project summary and key questions to guide input and offered different options for providing feedback online and through various agency communication channels. The agency collected more than 50 responses through a public survey, comment portal, and during staff discussions with experts and interested parties.

- Survey: ODOE's online survey collected responses from the general public, local governments, non-profits, and experts in energy-related fields. Most respondents had read previous reports and offered feedback supporting the continuation of the structure and approach from the 2020 report.
- Online Comment Form: Throughout the scoping process, ODOE provided a website portal to collect input. Feedback came from energy organizations and associations, utilities, non-profits,

government, industry, and the general public. Many respondents use past versions of Energy by the Numbers and requested more granular analysis when possible.

- Direct Discussions: Staff engaged in more than two dozen targeted scoping conversations with utilities, energy organizations, ODOE's Energy Advisory Work Group, legislative and advisory committees, and Government-to-Government tribal staff. Respondents provided specific topic ideas for Energy 101s and Policy Briefs and supported expansion of the Energy History Timeline.

Feedback included **common areas of interest**: technologies and resources like energy storage, renewable natural gas, hydrogen, alternative fuels, hybrid technologies, and heat pumps; consumer costs and energy burden; energy efficiency; EV integration; federal funding; HB 2021; PURPA; renewable energy development considerations; rentals and multifamily housing; supply chain and workforce; understanding the energy landscape; utility system planning and transmission

Later in the process, ODOE also published and shared a draft Table of Contents to solicit additional feedback. All of this stakeholder input was evaluated in scoping the report and selecting final topics. Comments received after the scoping and content development processes were incorporated where possible.

Drafting & Implementation

The project team ensured all input was considered in the development process. The scoping process also helped identify cross-cutting areas of focus for the agency in drafting the report, consistent with ODOE's strategic plan:

- Equity: The agency considered key questions, including: *What are the equity considerations for this topic, including opportunities, challenges, and how are these being addressed?* Incorporating equity in the drafting process prompted additional outreach with community-based organizations and analysis of needs and benefits for underserved communities. These engagements support ODOE's strategic focus area to Build Practices and Processes to Achieve More Inclusive and Equitable Outcomes
- Data Management: During each iteration, the Biennial Energy Report has refined internal data collection processes, management roles, and structures. The 2022 report included improvements in data processing, fact-checking, and validation to ensure report accuracy and quality. Authors were also supported by a new centralized data approach and enhanced data analysis and visualization platforms. The growing collection of data and analysis provided through the report supports ODOE's strategic focus area to Assess and Enhance Organizational Data Capabilities.
- Peer Review and Interagency Collaboration: In preparing this report, ODOE leveraged the knowledge and data of state agencies, energy organizations, and subject-matter experts. **ODOE greatly appreciates the many staff and other experts who reviewed sections of the report with quick turnaround, offered expert feedback, and provided assistance.** Their contributions improved the quality of this report and are an example of collaboration needed to support ODOE's strategic focus area to Expand and Improve Stakeholder Engagement.

Resources

- Project Website: ODOE hosts a public website for the Biennial Energy Report: https://www.oregon.gov/energy/Data-and-Reports/Pages/Biennial-Energy-Report.aspx. The website includes a link to sign up for email updates, online comment form, and materials from past reports and presentations.
- Online Comment Form: ODOE continues to provide a portal to collect feedback on the Biennial Energy Report: https://odoe.powerappsportals.us/en-US/ber-comment. Depending on the type of input and timing, the project team will continue to incorporate comments into report development processes and scoping for future reports.
- Webinars and presentations: ODOE staff are available to make presentations in person and virtually on the Biennial Energy Report; an overview or on specific topics and sections. Past webinars are posted on ODOE's website and new materials are provided throughout the year. Organizations and communities interested in specific presentations can submit a request through the online comment form.

energyinfo.oregon.gov/BER

www.oregon.gov/energy/Data-and-Reports/Pages/Biennial-Energy-Report.aspx

ABOUT THE DATA

The Oregon Department of Energy helps Oregonians make informed decisions about their energy choices and advance solutions that will shape an equitable, clean energy transition. ODOE serves as the state's central repository of energy data, information, and analysis, and fulfills this role through rigorous data collection, production standards, and quality assurance protocols. The agency assesses the quality of data based on its relevance to Oregon, its credibility, and its comprehensiveness.

In alignment with the statutory requirements for the report, **common data and analyses** found in the report include:

- Energy consumption, expenditures, and costs
- Generation and transmission
- Production, imports, and exports
- Energy sectors, markets, and jobs
- Technologies and resources, including facilities
- Energy efficiency and conservation
- The effects of energy use, including greenhouse gas emissions

ODOE's preference is for Oregon-specific data and, where helpful, this is supplemented with more general, national data to fill in gaps or provide context for Oregon's place within a larger energy landscape. For example, Oregon's Electricity Resource Mix and Transportation Sector Fuel Consumption charts were developed from Oregon-specific data sources, rather than using U.S. DOE estimates. ODOE relied on government agencies, academic institutions, and trusted partners with credible and peer-reviewed data and information. Finally, the most thorough and comprehensive datasets from these sources were prioritized, depending on how they could best illuminate specific sectors, markets, resources, and trends.

Common data sources used in development of the report include:

- **Federal/National:** U.S. Energy Information Administration (EIA); U.S. Department of Energy; the National Labs; U.S. Environmental Protection Agency, U.S. Federal Highways Administration; U.S. Census Bureau; American Council for an Energy-Efficient Economy (ACEEE); ASHRAE
- **Regional:** Northwest Energy Efficiency Alliance; Northwest Power and Conservation Council; Bonneville Power Administration
- **State:** Oregon Department of Energy; Oregon Department of Transportation; Oregon Housing and Community Services; Oregon Public Utilities Commission; Oregon Department of Environmental Quality; Oregon Health Authority; Oregon Department of Administrative Services
- **Utilities and energy service providers**
- **Energy associations and organizations**

The COVID-19 pandemic created challenges in data collection because many trusted data sources re-focused their work to respond to the crisis. Thus, in some instances, data production was understandably delayed, incomplete, or not available. This was the primary limitation for the 2022 report as some datasets previously featured in the report were not available (this mostly affected the Energy by the Numbers section). As a result, where data was unavailable or incomplete, the ODOE data team made choices on how best to provide useful information. In some instances, older datasets used in previous reports may still be referenced, or more recent national data used as a proxy. In some cases, ODOE opted to pause covering certain topics because the data did not meet agency needs. This approach enabled ODOE to maintain strong data standards despite some gaps in the datasets.

The effects of the pandemic response across the energy landscape also led to some data points that were not aligned with previous trends and outcomes. This effect is of interest, and can provide valuable information to governments, utilities, and other organizations as they consider how to build more resilient systems and practices. However, it is also problematic, because it may distort trends and conditions, limiting our view of how other events, policies, and activities are influencing the energy sphere. It is tempting to look at aberrational data and attribute it to COVID-19, but it is important to keep in mind that correlation does not imply causation. The data should be interpreted with these limitations in mind, and more weight given to long-term trends. As the world emerges from the pandemic, it will be important to note where data return to anticipated trend lines, and, perhaps more interesting, to understand where they do not.

We are proud of this report and how the data has been presented. ODOE is a steward of accurate, reliable, and credible data, which we achieve through attention to detail, standardized data management practices, and continual efforts to improve and expand our data capabilities. This is crucial to a data-driven approach to better understand Oregon's energy resources, activities, trends, and forecasts, and is foundational to making energy decisions that affect all Oregonians. If you identify any potential data quality issues or know of more representative or complete data sets that can be used in future reports, please reach out to us: https://odoe.powerappsportals.us/en-US/ber-comment/.

The agency, in collaboration with our many data partners, will continue to strive to be a central resource for sound and objective energy information and ensure the report reflects the most accurate and relevant data for Oregon.