2024 BIENNIAL ENERGY REPORT

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Executive Summary

In 2017, the Oregon Department of Energy 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 report – based on analysis of data and information collected and compiled by the Oregon Department of Energy – provides a comprehensive review of energy resources, policies, trends, and forecasts, and what they mean for Oregon.

What You Can Expect to See in the 2024 Biennial Energy Report

The 2024 report is divided into several sections, focusing on where Oregon is today in the clean energy transition and what energy options exist to forge ahead on the path to a cleaner, low-carbon future. Data and examples included in the report illustrate how the energy sector is evolving, with more renewable energy available than ever before, new clean and renewable technologies on the horizon, and more resources to help Oregonians make informed decisions about their energy choices.

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 interactive tool enables readers to move through the years and learn more about what has shaped the state's energy history. 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 new and innovative technologies that could play a role in Oregon's energy future, and in this edition of the report include enhanced geothermal electricity generation and fusion power. The topics covered are prevalent in Oregon or of interest to ODOE's various stakeholders.

The **Energy 101** section aims to help readers understand the basics: how energy is produced, used, and transformed. 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 home energy scoring and utility rate increase drivers to energy resilience and the nexus between energy and water.

The final section includes more detailed **Project Updates** that provide information about ODOE's Energy Security Plan and Oregon Energy Strategy.

The focus of the 2024 report is to cover relevant aspects of Oregon's clean energy transition. Even as we work to move to cleaner energy resources, climate change is increasingly taking a toll on our energy systems. At the same time, energy demand is growing faster than it has in several decades, led by the proliferation of data centers and industrial growth. It will require innovative technologies, economies, and investments to meet these challenges, many of which are highlighted in this or previous reports.

The report also provides information on how meeting these challenges also comes with opportunities. Home Energy Scoring gives buyers more certainty about future energy costs and creates more local jobs. Installing more solar and wind generation helps Oregon meet climate goals and uses less water. Reducing waste energy through energy efficiency and conservation also reduces energy costs, makes resilience measures more efficient, and reduces greenhouse gas emissions.

While the challenges are great, this report empowers Oregonians with data and information to make informed energy choices to address these challenges and take advantage of opportunities to create a safe, equitable, clean, and sustainable energy future.

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 ODOE'S DIRECTOR

We are in the midst of a significant energy transition. Energy technology and the way that energy consumers interact with it is rapidly developing. Oregon has bold clean energy targets, including 100 percent clean electricity by 2040, achieving greenhouse gas emissions levels that are 45 percent below 1990 levels by 2030, a 100 percent zero emission vehicle sales target by 2035, and others. At the same time we are working to achieve these ambitious goals, Oregon is already experiencing the effects of climate change, from extreme weather to natural disasters like wildfires made worse by climate change. Transitioning our energy systems while adapting to climate change is a daunting task, and the state has choices to make about how we will do it. What are the best pathways that we can take to reach these big goals while ensuring that all Oregonians can be part of an equitable and affordable clean energy future? What steps do we need to take now to position us for future success?

Two years ago, when the Oregon Department of Energy last published this Biennial Energy Report, we left readers with an idea:

> *"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."*

The Oregon Legislature agreed, and in 2023 directed ODOE to develop an Oregon Energy Strategy. We are well underway on the project, engaging with other state agencies, energy experts, community partners, Tribes, and the public as we dive into data and policy analysis. Over the next year, we'll review different energy scenarios, modeling results, and potential actions Oregon can take to achieve an equitable clean energy future. We look forward to presenting the new energy strategy in November 2025.

Our agency also recently looked at energy security in the state and published a new Oregon Energy Security Plan in September. The plan outlines the state's current energy infrastructure, quantifies threats and hazards that cause energy insecurity, and identifies potential measures the state and our partners can implement to manage risk and strengthen Oregon's energy security.

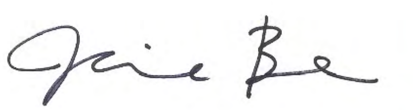
With these significant projects in mind, ODOE considered topics for this year's Biennial Energy Report that could support discussions and planning for an equitable and secure clean energy transition. We chose emerging technologies and resources that could contribute to clean energy goals, such as enhanced geothermal electricity generation and fusion power. Building on the foundation of past reports' Energy 101s, we identified new topics like advancements in clean hydrogen, agrivoltaics, day-ahead markets, and other areas that Oregon's energy experts and leaders are thinking about as we forge ahead. We tried to answer questions like what is driving recent electricity rate increases and what options do we have that could reduce the need to build new transmission lines, which can be expensive, time-consuming, and have effects on ratepayers, the environment, and local communities.

As with past reports, we start with Energy by the Numbers – a section that lays out data, trends, and indicators that illustrate Oregon's current energy landscape. One trend that the report reflects this year is a rise in electricity use – as Oregon's population grows, new industrial loads like data centers are introduced, and extreme weather leads to increased installation and use of air conditioning and heating. We also take a look back, with new moments of interest on our interactive Energy History Timeline, including a modernized Oregon Climate Action Commission, a significant federal investment in Pacific Northwest clean hydrogen, and other new milestones.

In service of our mission, ODOE provides a venue for problem-solving Oregon's energy challenges – like developing a new Oregon Energy Strategy – and we act as a central repository for energy data, information, and analysis. 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.

We hope you will use this information to engage in discussions and consider options for addressing the energy challenges we face today. Join us for discussions in 2025 as we continue working toward a new Oregon Energy Strategy. Reach out to us anytime to have a conversation, explore solutions, or request a workshop or presentation on an energy topic for your organization or community.

In 2025, the Oregon Department of Energy will celebrate its 50th year of public service — and we're already looking ahead to the next 50. Let's work together to chart a course 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

TABLE OF CONTENTS

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 use 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 greenhouse gas emissions – and how each sector uses energy to provide goods and services.

Key Energy Indicators

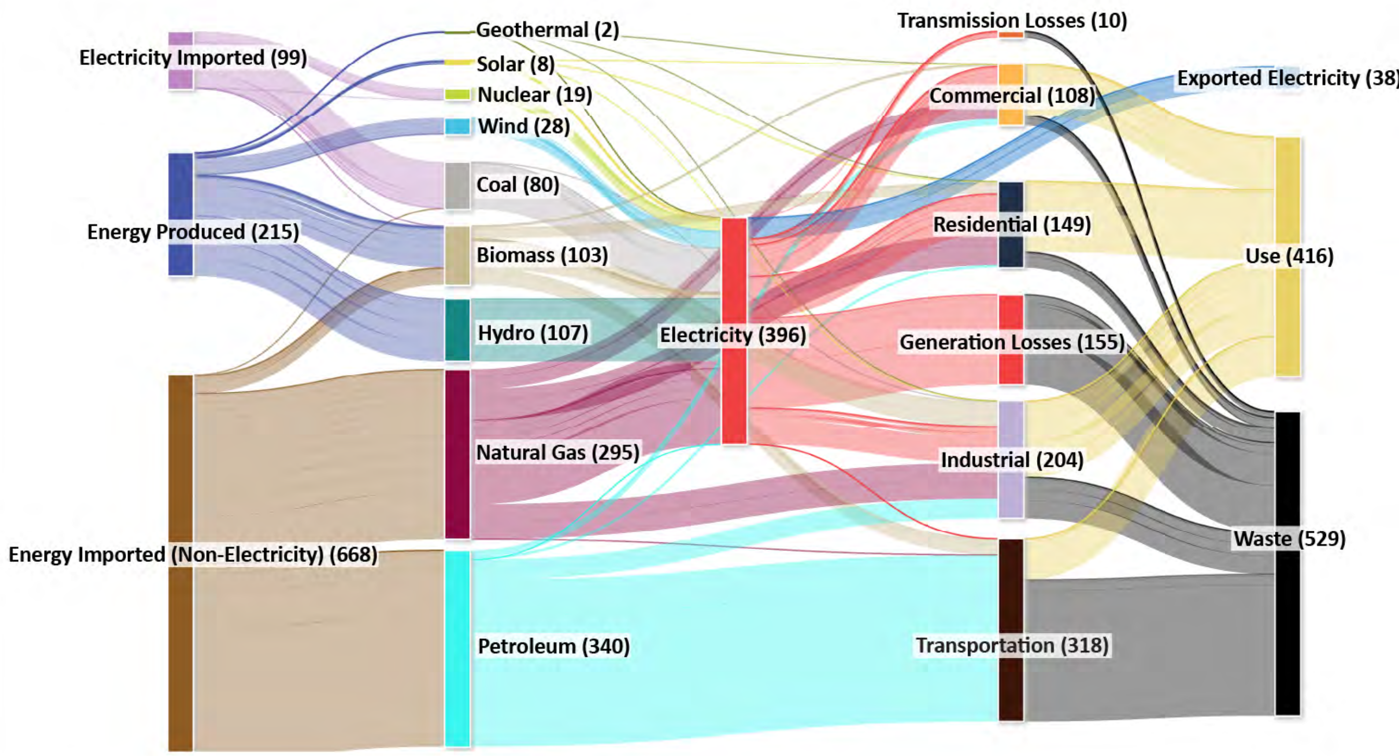
The Oregon Department of Energy's Strategic Plan includes an initiative to develop Key Energy Indicators that will help the state monitor and assess Oregon's energy landscape, progress on energy-related goals, and general status of Oregon's energy systems. KEIs can indicate progress toward energy-related statutory and administrative targets and goals as well as non-energy goals, such as job creation and economic development. ODOE has been collaborating with partners to identify a set of KEIs to track, and will finalize and share an initial list soon. In the meantime, look for this special symbol in this section to see some of the data points we expect to include as key indicators for energy in Oregon.

KEI

TABLE OF CONTENTS

Understanding Oregon's Energy Story

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.



Numbers represent trillions of Btu of energy.

Today, Oregon's energy resources are more diverse. In the chart above, start at the left 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 produced in Oregon and what is imported 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 or **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.

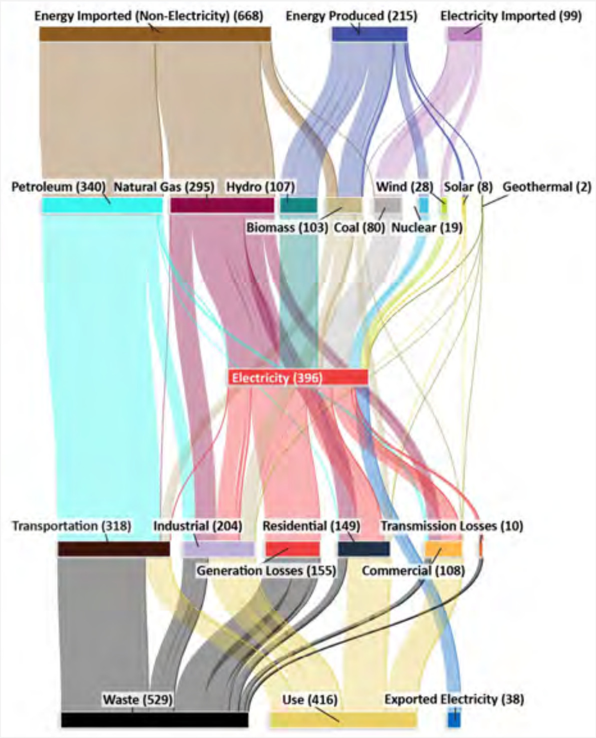
The flow to **Waste Energy** includes all the energy that is not harnessed, from the point of extraction to the point of use. This amounts to 54 percent of our energy use (529 trillion Btu). This includes energy lost as heat during combustion or transformation into electricity, transmission losses, and many other factors.[i] Learn more about waste energy in the Energy 101 section of this report.

Between 2020 and 2022, the residential and commercial sectors experienced shifts in energy consumption. **Residential** sector energy consumption increased from 144 to 149 trillion Btu (an increase of about 3.5 percent), while **commercial** sector energy consumption increased from 101 to 108 trillion Btu (nearly 7 percent increase) as more people and businesses have recovered from the COVID-19 pandemic. Meanwhile, **industrial** sector energy consumption increased from 187 to 203 trillion Btu, an increase of about 8.5 percent. **Transportation** energy consumption experienced the largest change, decreasing to 281 trillion Btu in 2020 and then increasing to 307 trillion Btu in 2022 (over a 9 percent increase), likely due to factors such as shifts away from telecommuting and increasing travel opportunities as the state recovered from the pandemic.[1]

Changes in the Energy Flow Chart Methodology and Design

This report relies on data from the U.S. Energy Information Administration. In September 2023, the EIA changed its methodology for the way primary energy is calculated for renewable resources. This change from a fuel equivalency method to a direct conversion using the heat content of electricity resulted in a reduced amount of energy attributed to the waste energy category, and reduced electrical system losses associated with energy use in the Energy Flow Chart.[3]

Read more about this change in the About the Data section of this report.



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

Energy Sources Used in Oregon

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

Natural gas. Fossil fuel extracted from beneath the earth's surface. Oregon has a single natural gas field located in Mist, and imports most of the natural gas the state consumes for electricity and as a direct fuel. Oregon has 16 natural gas electricity generation facilities with a combined capacity of 4,384 MW.[4] Natural gas is also used directly for residential, commercial, industrial, and transportation uses.

Hydropower. Electricity generation from the flow of water through dams. Oregon has 105 hydropower facilities of varying sizes, 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.[4]

Biomass. Includes 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 12 biomass and 45 biogas operating facilities converting waste products to electricity.[4] Oregon produces some renewable natural gas, a biogas that has been purified to be a substitute for fossil natural gas, often to meet specifications required for injection into a natural gas distribution pipeline. Oregon also produces plant-derived ethanol fuel and biodiesel from used cooking oil to be used as transportation fuels.

Coal. Combustible rock burned to support industrial processes and create electricity. Oregon's last coal-fired power plant, the 575-MW Boardman facility, closed in October 2020 and was demolished in September 2022.[5] The state imports coal-generated electricity from neighboring states.

Wind. Generation of electricity by the force of wind turning turbines. As of 2022, Oregon has 50 operating facilities in the state with a total capacity of 3,981 MW.[4]

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.

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 2022, annual solar generation in Oregon increased from 95,100 megawatt-hours to about 2.2 million MWh (a 23-fold increase).[4]

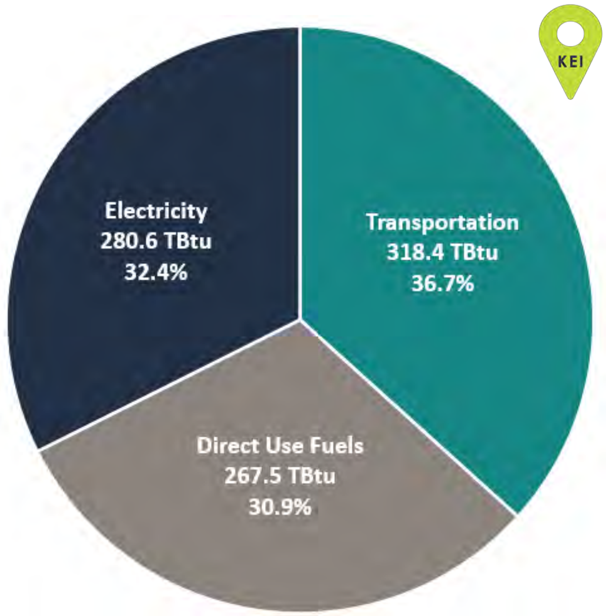
Geothermal. Energy extracted from hot water or steam from natural underground sources can be used for water/space heating or the generation of electricity. Oregon has three geothermal electricity generation facilities with a capacity of 38.5 MW.[4]

Note: *Since the 2022 edition of this report, some energy facilities were retired and no longer serve Oregon load. Please see the About the Data section for more information.*

Energy Use in Oregon

Consumption by Source

Oregon relies on energy from a variety of resources. The state imports energy such as gasoline, natural gas, propane, and other fuels, and uses electricity from both in- and out-of-state sources — including hydropower, natural gas, coal, nuclear, wind, and other renewable resources.[1] In 2022, Oregon used a total of 866.5 trillion Btu of energy. The pie chart to the right shows energy use by source for the primary energy required to meet demand in Oregon.



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

32.4% of Oregon's 2022 energy consumption[1]

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, including Oregon. This percentage also accounts for the energy in fuels that come from out of state but generate electricity in state, such as natural gas, as well as the energy losses associated with electricity generation.[ii]

30.9% of Oregon's 2022 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.

36.7% of Oregon's 2022 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.

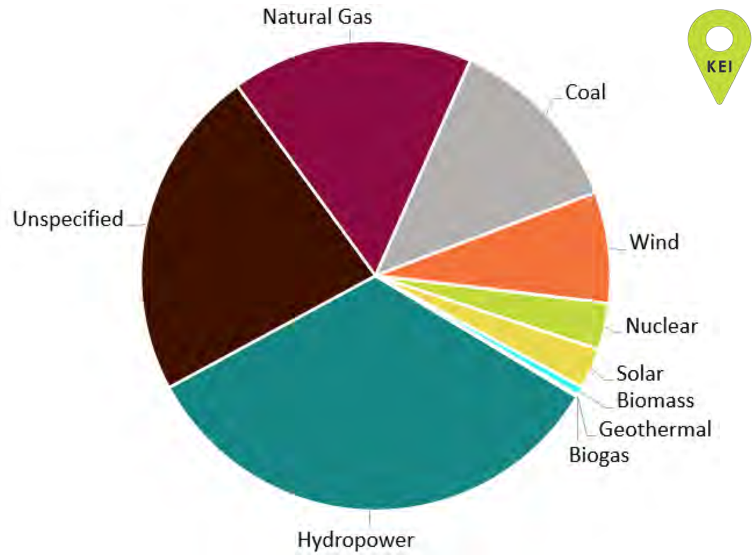
[ii]The decrease in electricity use here from 45 percent in 2020 reflects the change in EIA methodology for estimating the source energy for renewable resources. See the About the Data section of this report for more information on this change.

Electricity

32.4%

of Oregon's 2022 energy consumption[4]

33.4%	Hydropower
22.8%	Unspecified[iii]
16.6%	Natural Gas
12.6%	Coal
7.6%	Wind
3.2%	Nuclear
2.8%	Solar
0.6%	Biomass
0.1%	Geothermal
0.02%	Biogas

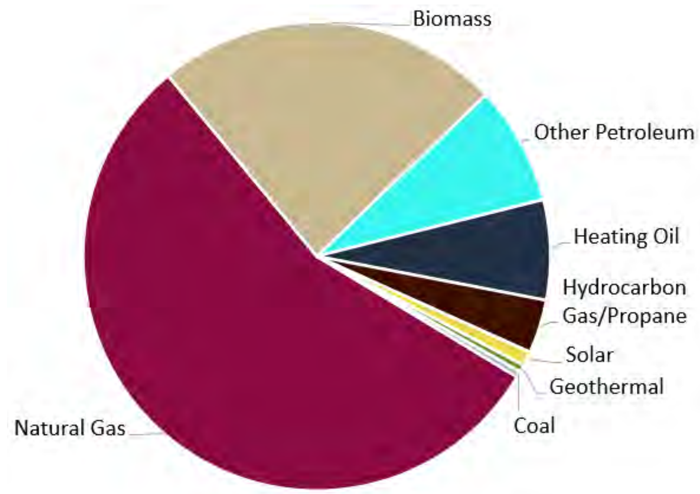


Direct Use Fuels

30.9%

of Oregon's 2022 energy consumption[2]

55.4%	Natural Gas
23.9%	Biomass
8.2%	Other Petroleum
6.9%	Heating Oil
3.7%	Hydrocarbon Gas Liquids Including Propane
1.0%	Solar
0.5%	Geothermal
0.4%	Coal

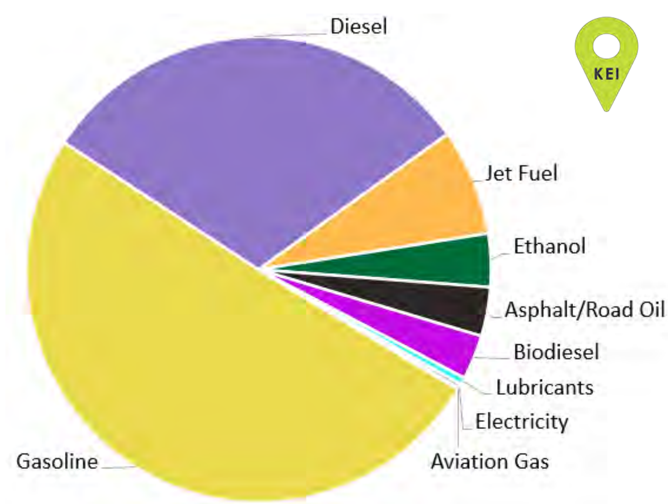


Transportation Fuels

36.7%

of Oregon's 2022 energy consumption[3]

50.6%	Gasoline
30.9%	Diesel
7.4%	Jet Fuel
3.7%	Ethanol
3.4%	Asphalt/Road Oil
3.1%	Biodiesel
0.5%	Lubricants
0.3%	Electricity
0.1%	Aviation Gas

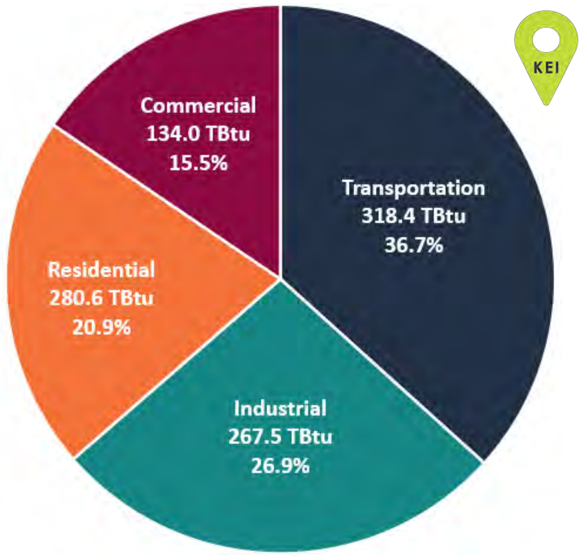


Note: *Fuel percentages are rounded to the nearest tenth and not all are listed.*

[iii] Unspecified includes real-time supplemental market purchases of electricity that utilities make to meet demand. More information about the methodology change that led to inclusion of the unspecified category in the Electricity Resource Mix data represented here can be found in the Electricity Use section of this Report.

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 2022, those four sectors combined consumed 866.5 trillion Btu of energy,[2,3] including each sector's respective share of electrical system losses,[iv] as discussed earlier in *Understanding Oregon's Energy Story.*

20.9% **of Oregon's 2022 energy consumption[2]**

Residential: this category includes single-family, multifamily, and manufactured homes for Oregonians. Energy is used for lighting, heating and cooling living spaces, cooking, and operating 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.

15.5% **of Oregon's 2022 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.

26.9% **of Oregon's 2022 energy consumption[2]**

Industrial: this category includes facilities used to produce, process, and manufacture products – including agriculture, fishing, forestry, manufacturing equipment (including chip manufacturing), mining, data centers, and energy production. Energy powers industrial equipment and machinery to manufacture products. This sector has seen contractions in aluminum, forestry, and manufacturing, and expansions in technology manufacturing and data centers. The change in use happened along with improvements in efficiency of industrial facilities and equipment.

36.7% **of Oregon's 2022 energy consumption[3]**

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.

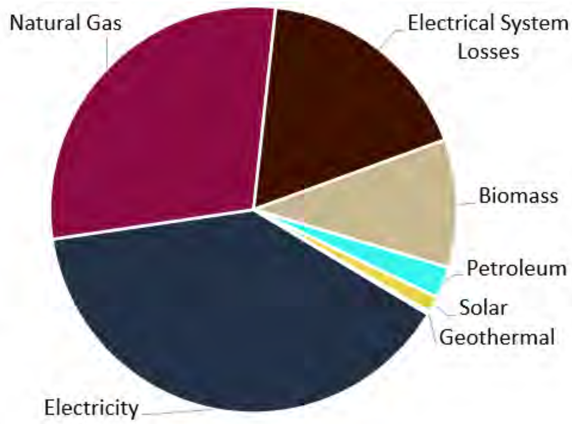
[iv] Electricity generation and transmission result in energy losses that are estimated and included in EIA consumption data. In 2023, the EIA changed the methodology for calculating primary energy from renewable resources (further explained in About the Data). Electrical system energy losses account for energy lost during generation, transmission, and distribution of electricity.

Residential

20.9%

of Oregon's 2022 energy consumption

39.1%	Electricity
29.1%	Natural Gas
17.7%	Electrical System Losses
10.2%	Biomass
2.5%	Petroleum
1.3%	Solar
0.2%	Geothermal

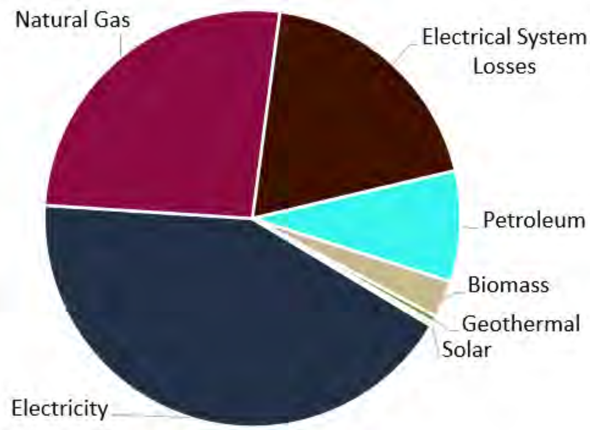


Commercial

15.5%

of Oregon's 2022 energy consumption

42.4%	Electricity
26.1%	Natural Gas
19.2%	Electrical System Losses
8.6%	Petroleum
2.5%	Biomass
0.4%	Geothermal
0.3%	Solar

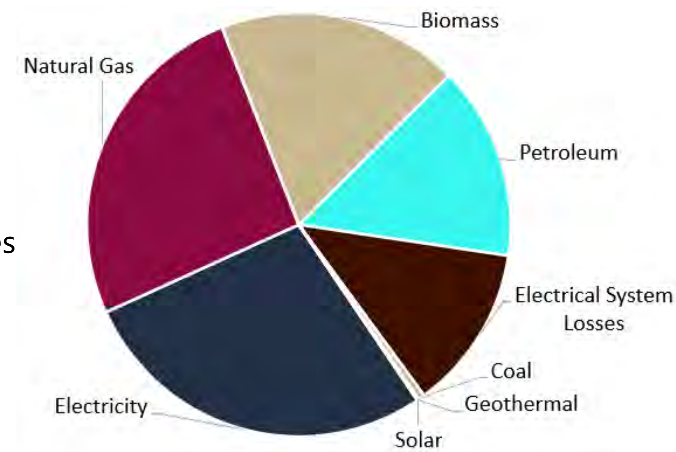


Industrial

26.9%

of Oregon's 2022 energy consumption

27.7%	Electricity
25.9%	Natural Gas
18.5%	Biomass
12.6%	Electrical System Losses
14.8%	Petroleum
0.5%	Coal
0.1%	Geothermal
0.03%	Solar

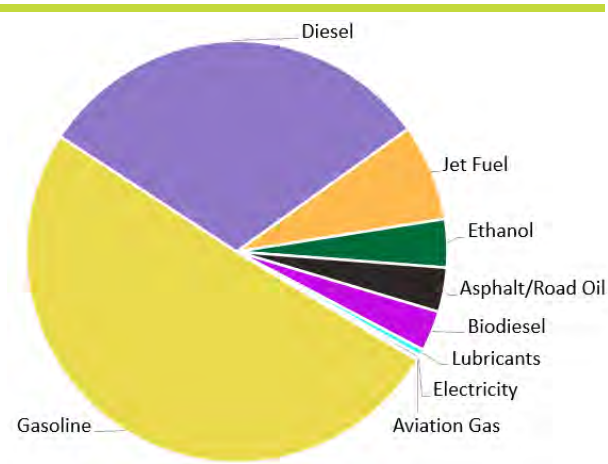


Transportation

28.6%

of Oregon's 2022 energy consumption

50.6%	Gasoline
30.9%	Diesel
7.4%	Jet Fuel
3.7%	Ethanol
3.4%	Asphalt/Road Oil
3.1%	Biodiesel
<1%	All Other Sources



Energy Use in Oregon

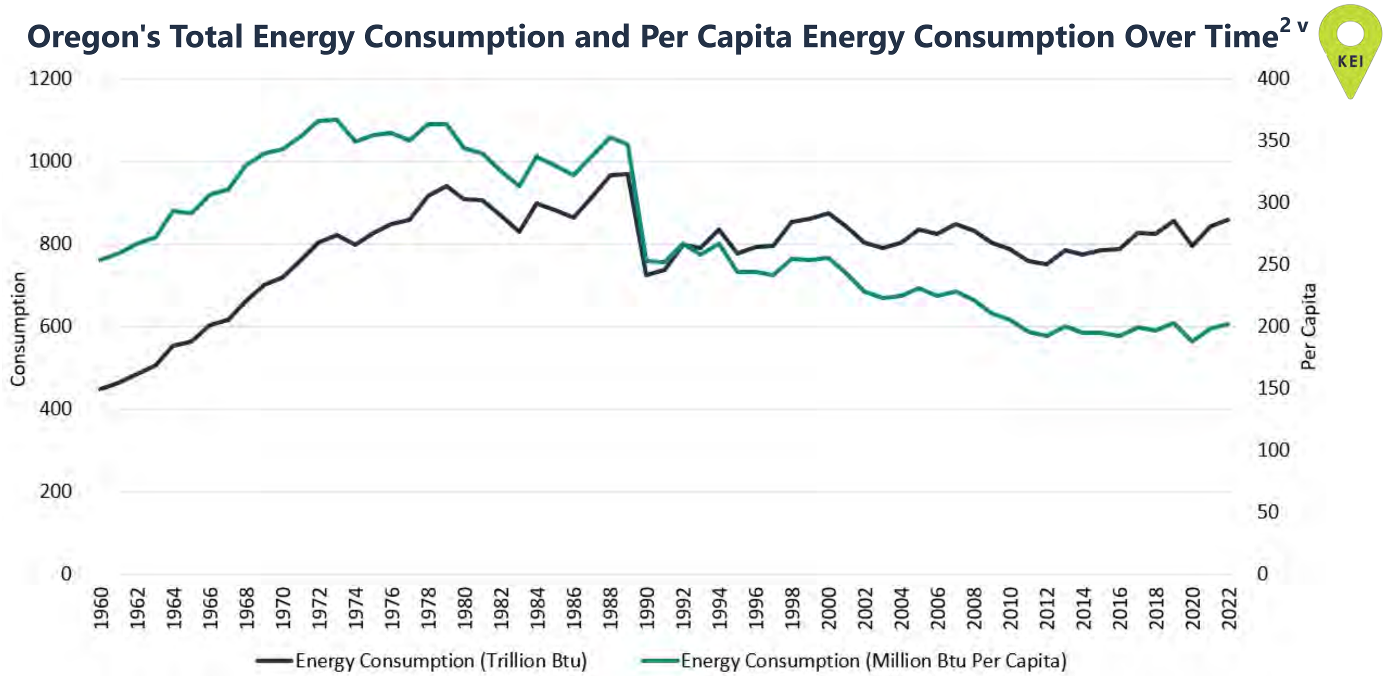
10th

Oregon's rank for lowest per capita energy use among states in 2022.[2]

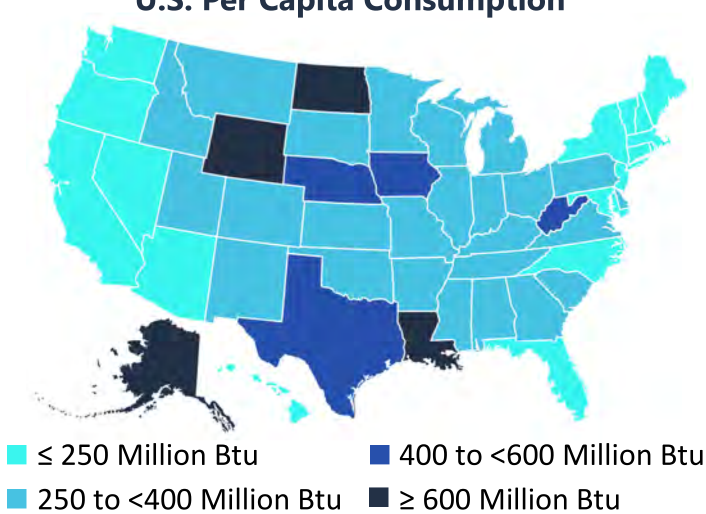
Oregon's Energy Consumption Over Time

Oregon saw an overall trend of increased energy use from 1960 through the early 1970s then a sharp decline in 1989.[2] During this time the state shifted from reliance on fuel oil and wood to natural gas and electricity (mostly efficient hydroelectric generation). Oregon reached its highest energy consumption for stationary and transportation uses in 1972. Since then, total energy use has been relatively stable with a short period of slight decline and a recent period of small increases and drops. Energy consumption per capita does not directly correlate with overall energy use. In the last 30 years, Oregon's population has steadily increased while overall energy consumption has slightly declined, driven by energy efficiency savings. 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 v]



U.S. Per Capita Consumption[2]



Energy Efficiency

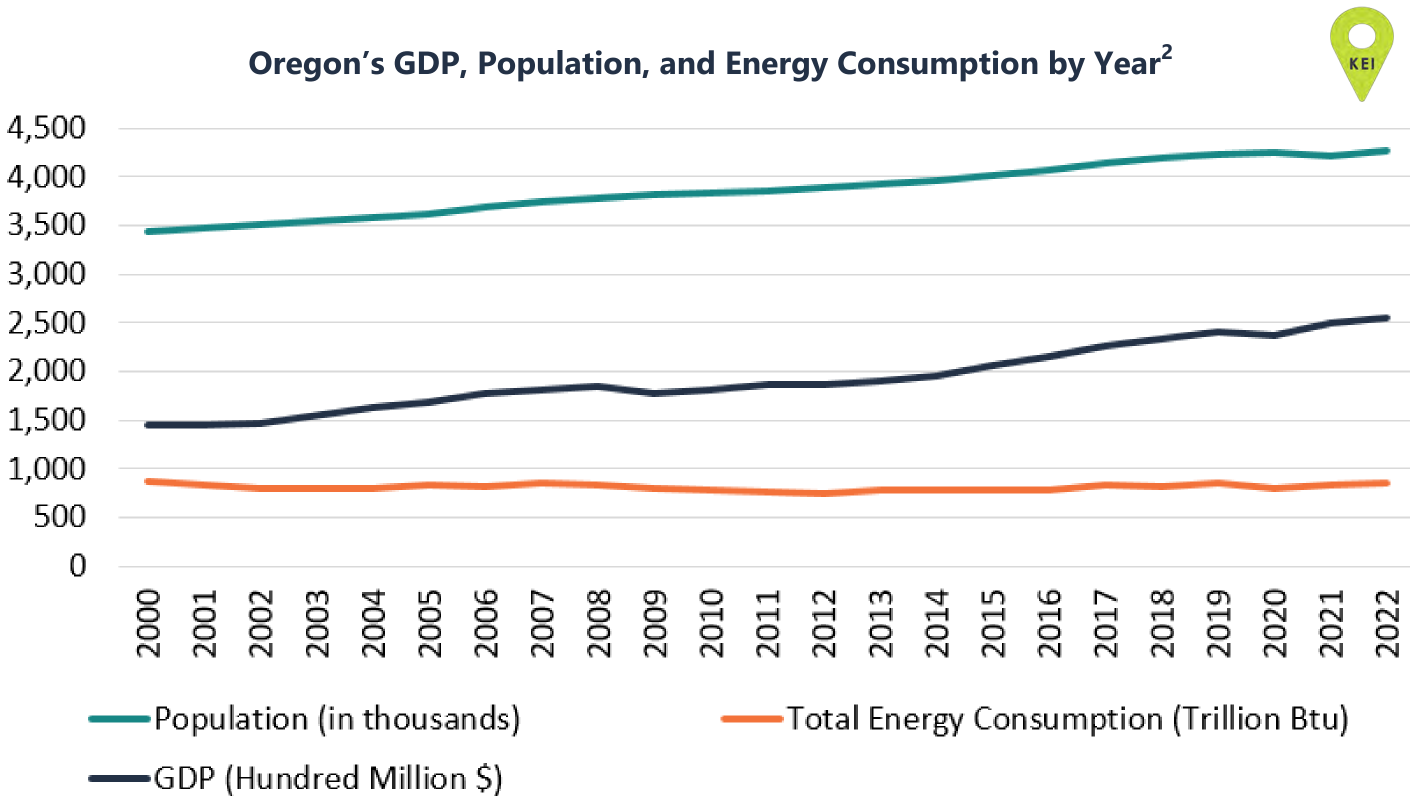
While energy efficiency is not "consumed," it can be considered the second largest resource available in Oregon after hydropower. Increasing energy efficiency effectively reduces overall energy consumption, eliminates waste, and reduces the need to build more energy generation facilities or import fuels — providing the same services for less use and expense. Historically, Oregon has consistently met increased demand for electricity by implementing energy efficiency strategies.

[v] Data are affected by EIA's methodology change for primary energy, so this visual differs from previous versions of this report.

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 and a growing economy, thereby avoiding the need to build new electricity generation plants to match the growth – though the region has seen some generating facilities closed and new ones come on board during this time. The graph below shows that since about 2000, economic growth (measured by gross domestic product or GDP) does not directly 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 shows 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 2022, Oregon used 58.7 million megawatt hours 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 (average from 2010-2012) by 2030, 90 percent below by 2035, and 100 percent by 2040.[1] The seven largest sources of electricity are labeled below; the other resources not listed in the bubble chart are each under 2 percent.[2]

12.6%

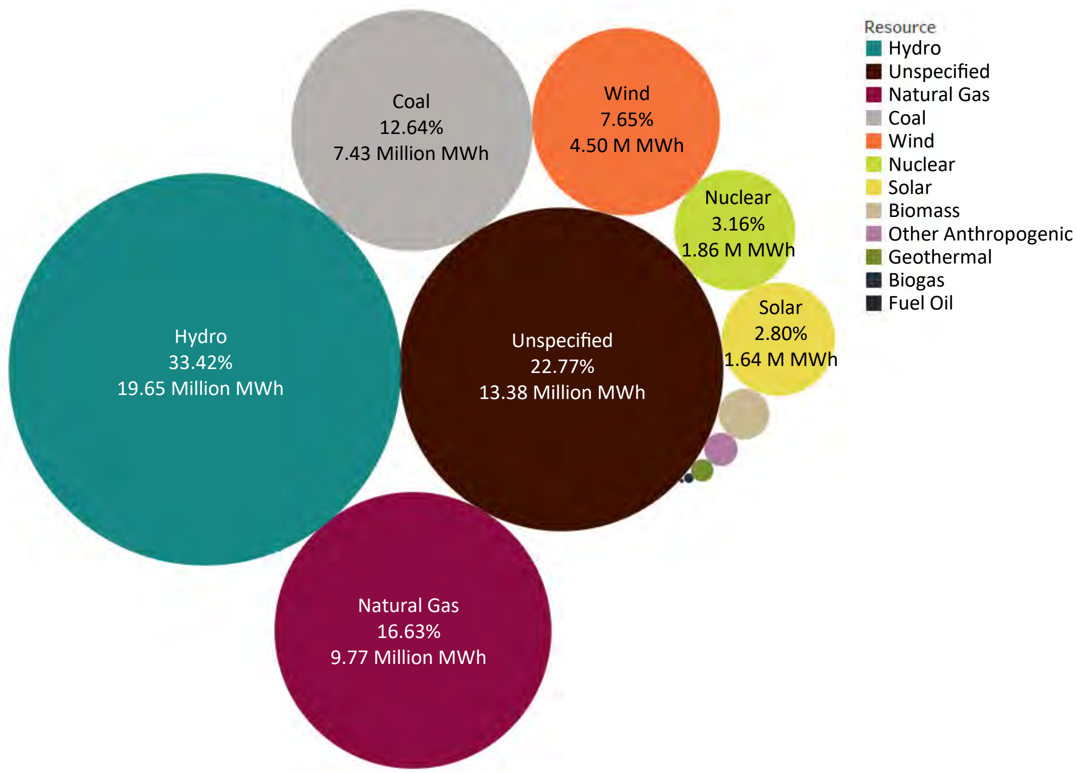
Percentage of Oregon's 2022 electricity mix that came from coal.[2]

2040

Year by which Oregon's two largest utilities and all Electricity Service Suppliers will need to reduce emissions for electricity sold in the state by 100 percent below baseline emissions levels.[1]

Resources Used to Generate Oregon's Electricity[2]

Based on 2022 data, this chart shows the energy resources used to generate the electricity that is sold to Oregon's utility customers.

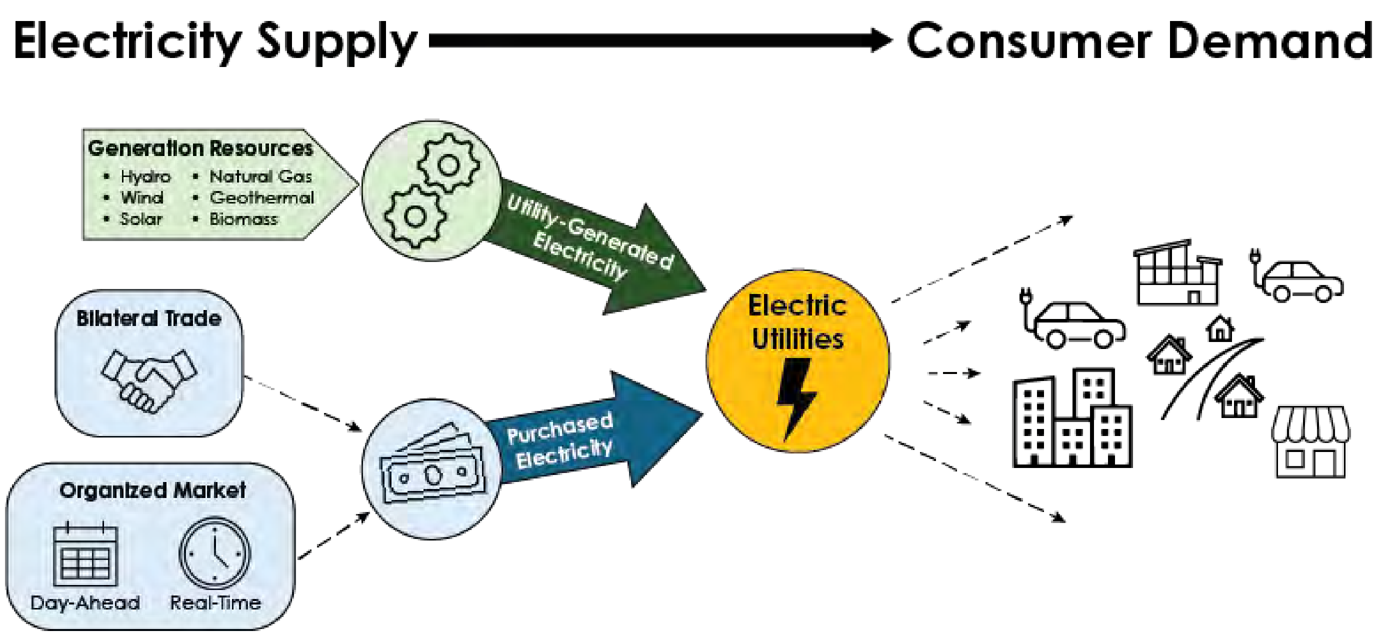


Electric utilities are privately owned electric companies (investor-owned utilities) or consumer-owned utilities that provide electricity to retail electricity consumers. Oregon utilities generate their own electricity, purchase power from wholesale providers, or enter into short- or long-term contracts to buy electricity from third-party owned power plants or regional markets.

Change in Methodology

In 2024, in response to feedback from utilities and after consultation with other state agencies and community partners, ODOE changed the way it calculates the Electricity Resource Mix, which is the data source for this section on Electricity Use. Instead of doing a detailed, complex analysis of the specific resources that make up the "unspecified" market purchases by utilities (a calculation only used by ODOE to develop the ERM), ODOE now uses the same data reported in the Oregon Department of Environmental Quality's Greenhouse Gas Emissions Reporting program. The change was necessary due to the inability to access the increasingly complex data sets necessary to accurately calculate a resource mix for market purchases.

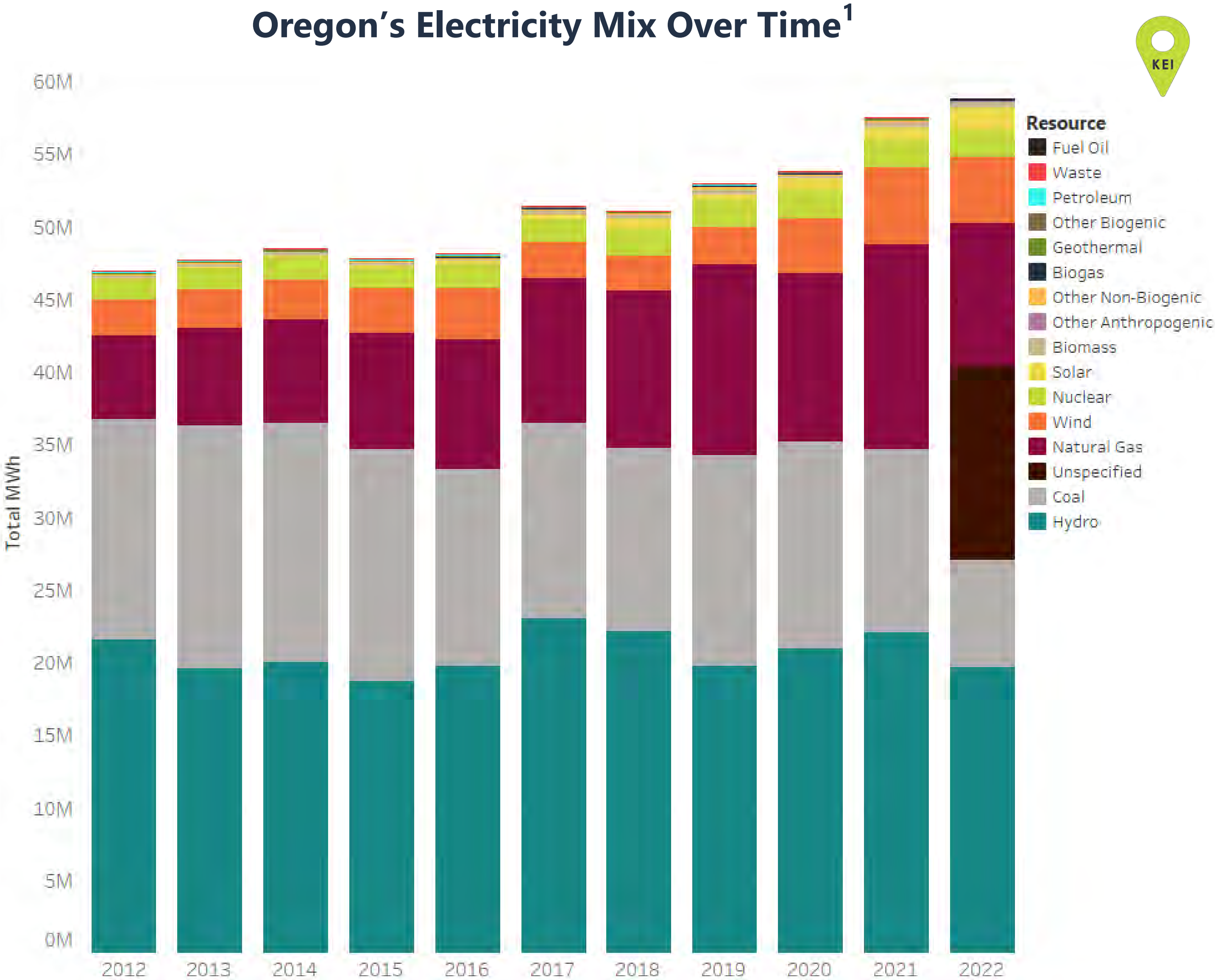
While DEQ's program provides emissions factors for the resources Oregon's utilities use to meet load, they do not assess or report the resources and emissions from utility purchases or sales in the real-time[vi] and day-ahead markets. Instead, DEQ assesses greenhouse gas emissions from all these market purchases using a single emission rate.[vii] They use the default emissions rate that California calculates and uses to estimate emissions from "unspecified" market purchases of electricity. It is based on the average emissions from a natural gas combined cycle power plant.[5] [6] ODOE's previous analysis showed that the unspecified market purchases included diverse resources available across the western U.S., such as hydro, coal, and natural gas. Since resources contributing to market purchases are now combined into the less specific "unspecified" category, the total amounts of individual resources may appear lower than in previous years. However, as utilities in states with clean electricity standards work to achieve their targets, and market purchases are used more and more, there may be a future need for more transparency in the resources and emissions that make up these electricity market purchases.



[vi] Real-time markets support electricity sales across multiple utility service territories to balance fluctuations in supply and demand within the current hour.[3]

[vii] The DEQ Greenhouse Gas Emissions Inventory program refers to market purchases as "unspecified emissions," and assigned an emissions rate of 0.428 metric tons of carbon dioxide equivalent per megawatt-hour.[4]

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 2022 and shows two notable trends. First, total annual electricity consumption has increased from 47 to 59 million megawatt hours between 2012 to 2022, driven by factors like economic and population growth and increased customer demand. Second, the percentage that each resource contributes to total electricity for consumption changes year to year. Although the methodology for calculating the resource mix changed between 2021 and 2022 to include a bulk category for unspecified market purchases, some trends are still evident in the data. Hydro is still a predominant resource for the region. Coal continues to decline as plants are shuttered, and natural gas, wind, and solar are increasingly a larger proportion of the mix.

Note that changes to the methodology that occurred in 2024 and affect data starting in 2022 make this comparative analysis more complicated. The addition of the "unspecified" category does not attribute use to a particular resource, though this portion is likely made up of the most abundant resources in the region, including hydro, natural gas and coal.

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.[2]

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, dispatching them to meet customer demand at least cost. This often results in prioritization of hydropower, wind, and solar. 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 sources, such as natural gas power plants, to meet additional demand. It is worth noting that the availability of renewable resources — such as wind, solar, and hydropower — also 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.

Utilities also meet customer demand through real-time supplemental purchases from regional markets. These real-time purchases typically come from resources that the utility does not own or for which it does not have any prior contractual arrangement. This electricity is considered "unspecified," signifying that the purchasing utility does not have a right to designate the electricity as coming from a particular resource.

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 fortunate to have an abundance of renewable energy resources and is one of the leading producers of renewable energy in the country.[7] 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 nearly all 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.[8]

Oregon also imports electricity from all over the western U.S.; this imported electricity comes from various resources.[8]

Oregon 2022 Exports

45.1% of wind generation[9]

37.2% of hydroelectric generation[9]

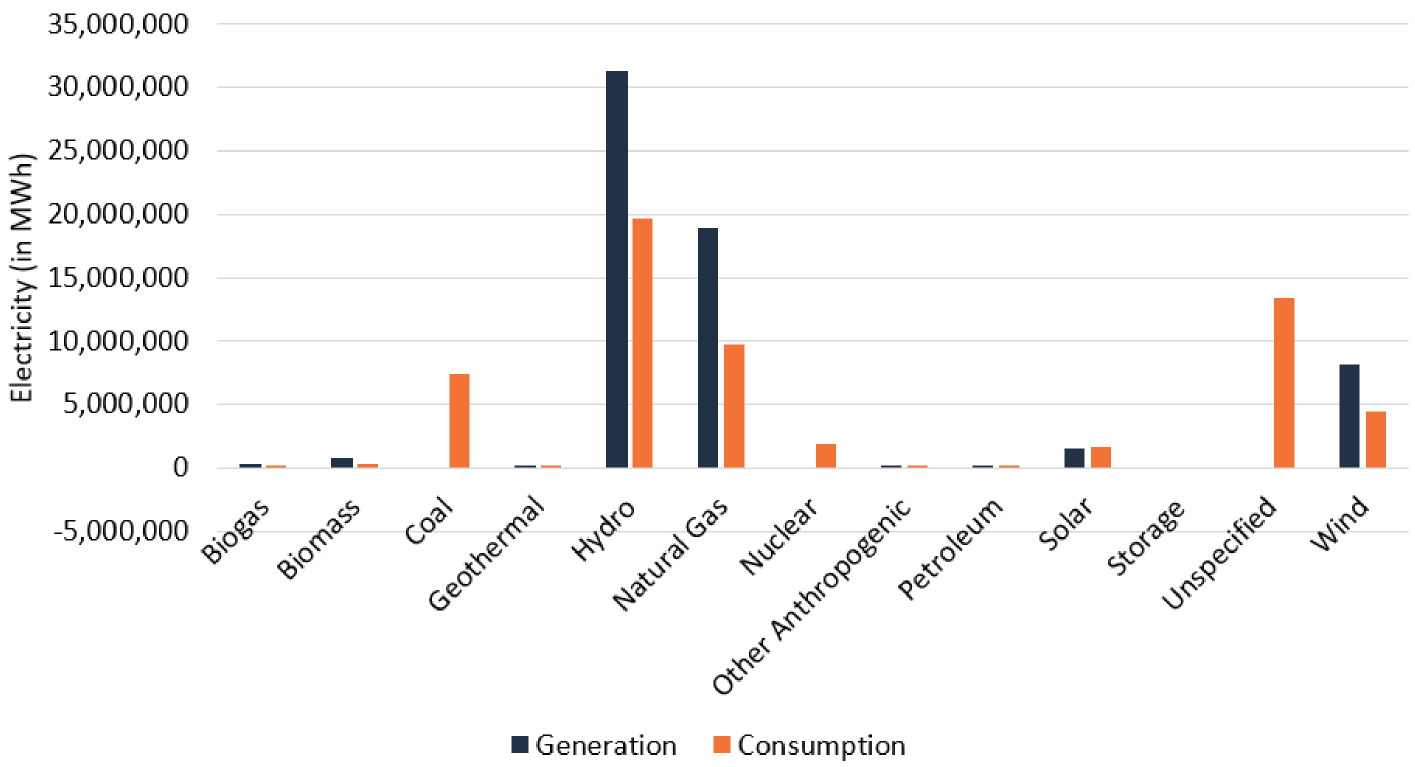
Oregon 2022 Imports

100% of coal based electricity[9]

100% of nuclear electricity[9]

8.4% of solar electricity[9]

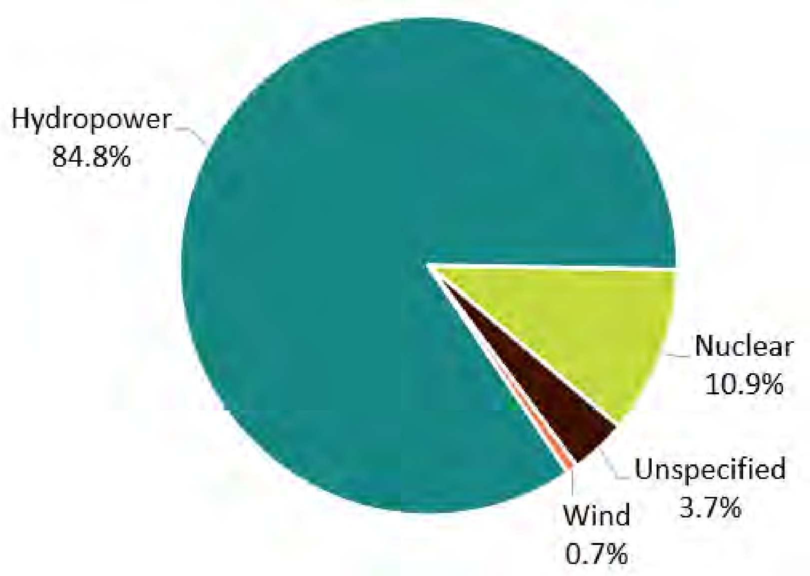
Oregon's Electricity Generation and Consumption (2022)[10 11]



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

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 29 percent of the electricity used in Oregon.[2]



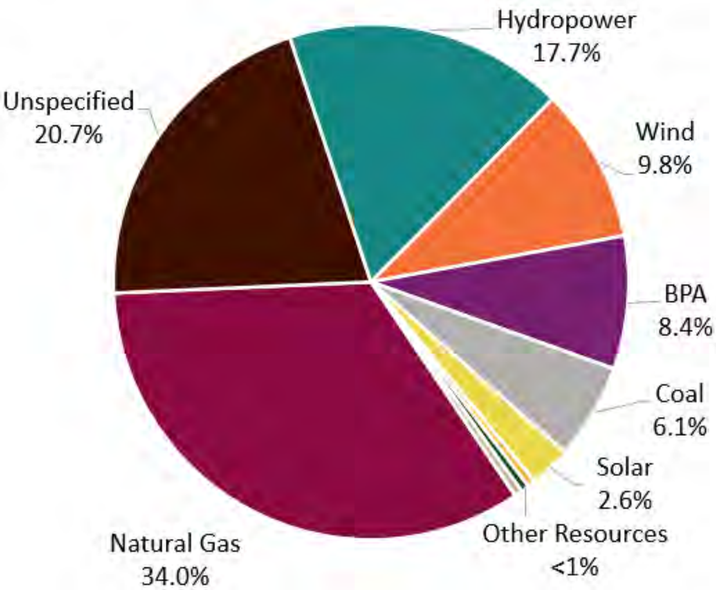
Bonneville Power Administration 2022[2]

Market Purchases

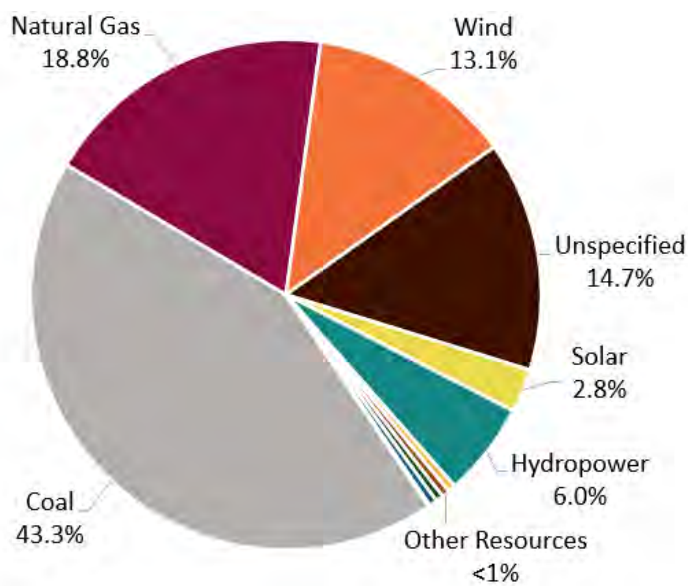
Oregon generation facilities sell electricity to Oregon utilities and the regional power market. Oregon electric utilities own facilities that generate power, but they also purchase power from the regional market to meet customer demand. Some market purchases can be tied to specific resources, but in most cases the specific generation resource is not known. In Oregon, these unspecified purchases accounted for 12.8 million megawatt hours in 2022.[2]

Investor-Owned Utility Resource Mix

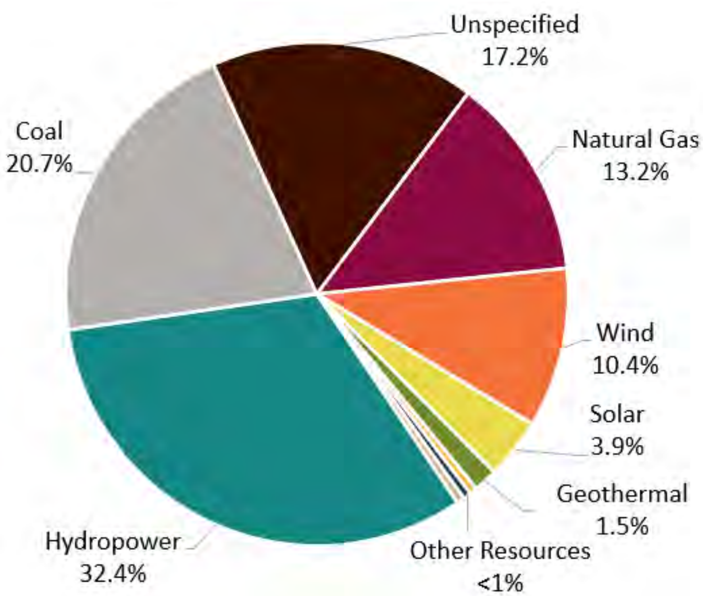
The resources utilities use to generate electricity consumed in Oregon vary depending on the utility provider. The electricity resource mixes for Oregon's three investor-owned utilities are shown below. Only 2022 data are shown for each utility; mixes will fluctuate over the years depending on the availability of certain resources like hydro or, increasingly, solar. The dark brown wedge labeled as "unspecified" represent the real-time market purchases to meet demand.[2]



Portland General Electric 2022



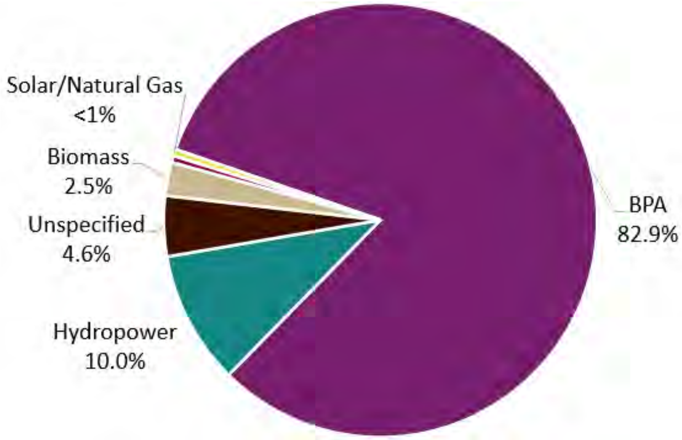
Pacific Power 2022



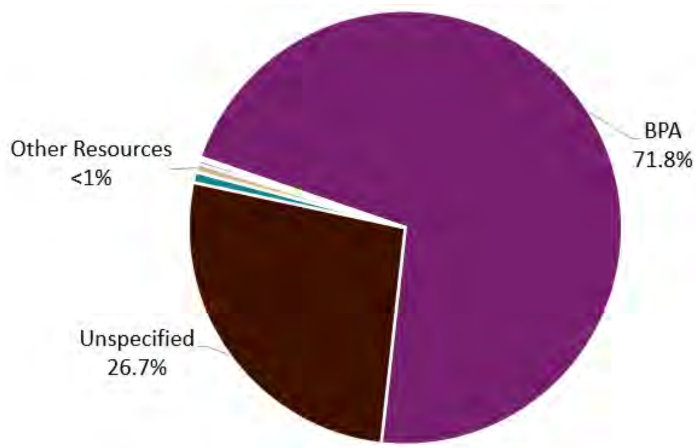
Idaho Power 2022

Consumer-Owned Utility Resource Mix

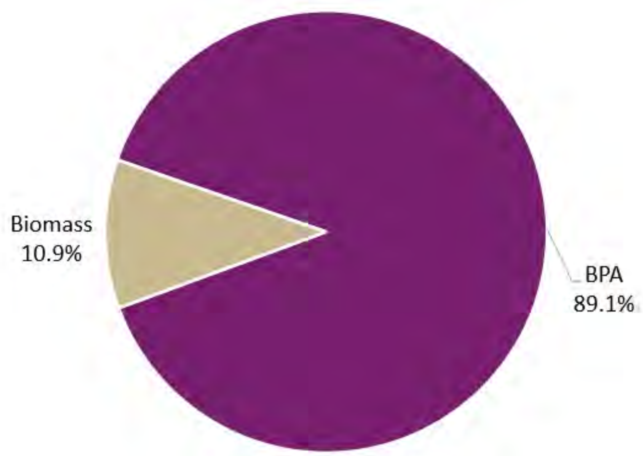
The electricity resource mixes for the Eugene Water & Electric Board (the largest consumer-owned utility by number of customers) and a composite of other COUs operating in Oregon are below. Clatskanie People's Utility District is also included as an example. Only 2022 data are shown for the utilities; COU mixes fluctuate less over the years as many depend on the Bonneville Power Administration to provide their electricity and BPA's mix is consistent year to year.[2]



Eugene Water & Electric Board
2022



Composite of Consumer-Owned Utilities (not including EWEB)
2022



Clatskanie PUD
2022

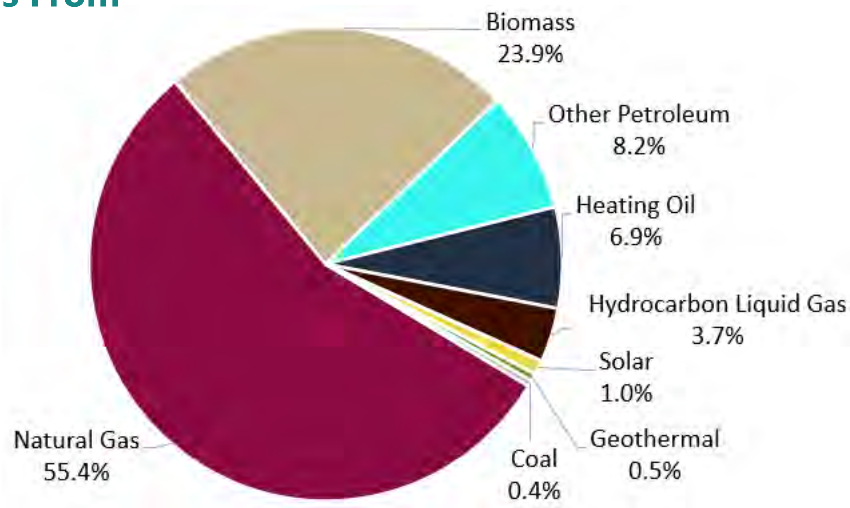
While the majority of power supplied by Oregon's consumer-owned utilities comes from the Bonneville Power Administration, **COUs have also invested in their own energy-generation sources**. For example, Clatskanie PUD supplements the electricity it buys from BPA with purchase agreements for biomass and biogenic facilities.[viii] 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.

[viii] Biogenic facilities produce energy from waste materials breaking down in a landfill.[10]

Direct Use Fuels

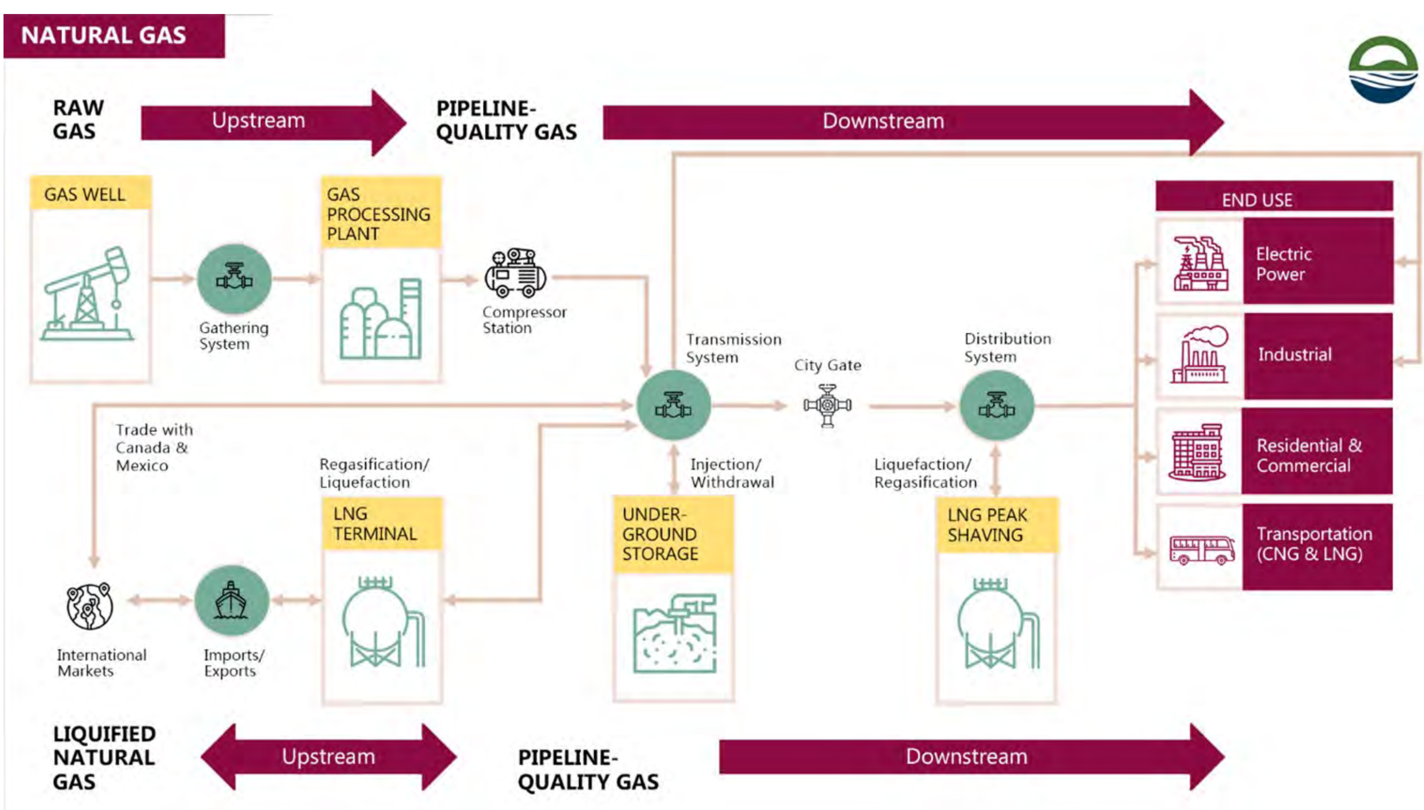
What We Use and Where it Comes From

In 2022, Oregon used 267.5 trillion Btu of direct use fuels to heat buildings, cook food, and support commercial and industrial processes.[1] Direct use fuels make up about 30.9 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. Natural gas can be cooled to a liquid state which is called Liquefied Natural Gas or LNG. LNG is about 600 times smaller in volume than in a gaseous state, making it more efficient to transport or store. Oregon does not have an LNG import or export facility, but may be affected by export capacity expansion in North America as natural gas becomes more of a global commodity and Oregon utilities compete for fuel supply.[3]

Natural Gas Supply Chain



In 2022, Oregon used 148.1 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 near Mist, Oregon and its resources go to NW Natural, one of three investor-owned gas companies serving the state.[4] The Mist field is primarily used for natural gas storage and produced only 0.027 trillion Btu of natural gas in 2022, representing 0.01 percent of Oregon's annual use.[1]

Natural Gas Consumption by Sector[1]

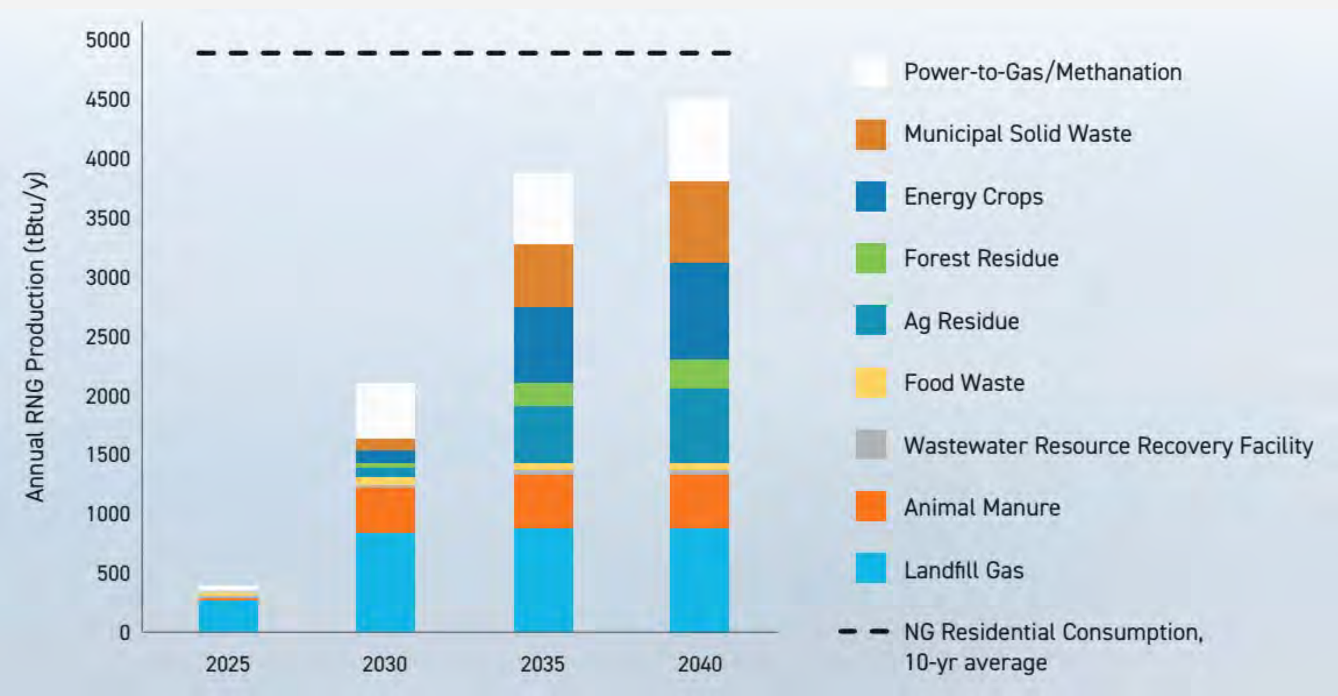
Commercial Sector | 35.0 trillion Btu

Residential Sector | 52.6 trillion Btu

Industrial Sector | 60.5 trillion Btu

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.[5] Oregon natural gas utilities are investing in RNG projects in and outside the state to reduce the greenhouse gas emissions attributed to natural gas combustion.[6]

Potential National Annual Renewable Natural Gas Production[6]



NW Natural VISION 2050 Destination Zero Complete Carbon Neutrality Scenario Analysis Report.

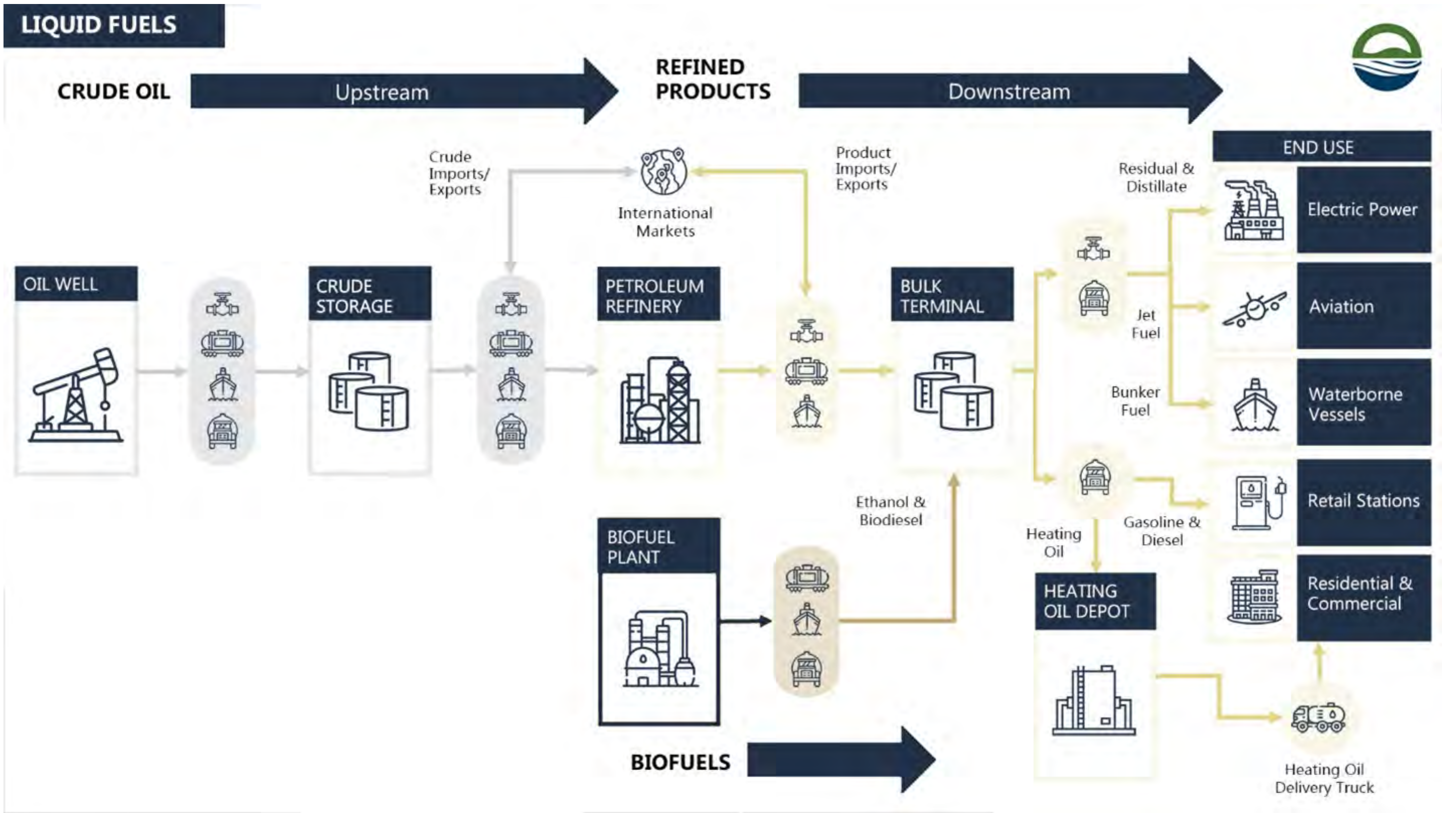
Biomass. Biomass is an organic material that comes from plants and animals that is burned to create energy. Biomass is considered a renewable source of energy, and comes from resources like wood, agricultural crops and waste, food or yard waste, and animal and human waste. Organic materials are collected and combusted to make energy that can be used on site or distributed to a facility instead of filling space in a landfill. Biomass also commonly refers to end-products such as wood chips, wood pellets, and charcoal that are used for thermal energy. 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] Oregon has 12 wood and wood waste biomass-generating facilities.[8] In 2022, Oregon consumed 64 trillion Btu of biomass as a direct use fuel.[1]

Biomass Consumption by Sector[1]

Commercial Sector | 3.8 trillion Btu
Residential Sector | 18.4 trillion Btu
Industrial Sector | 41.7 trillion Btu

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.

Liquid Fuels Supply Chain



In 2022, Oregon used 18.5 trillion Btu of heating oil for direct uses, and 3 percent of Oregon homes use fuel oil for heating.[1 9] 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 a renewable fuel made from vegetable oils, like soy and canola, that are grown domestically. Biofuels are mixed with regular heating oil to create blends of 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. Policies such as the Oregon Renewable Fuel Standard and Oregon Department of Environmental Quality's Clean Fuels Program are driving increased demand for biodiesel and other biofuels as they displace petroleum fuels used for transportation and heat.[10 11] For more information about biofuels powering transportation in Oregon, see the 2022 Transportation Resource and Technology Review.

Heating Oil Consumption by Sector[1]

Commercial Sector | 2.4 trillion Btu

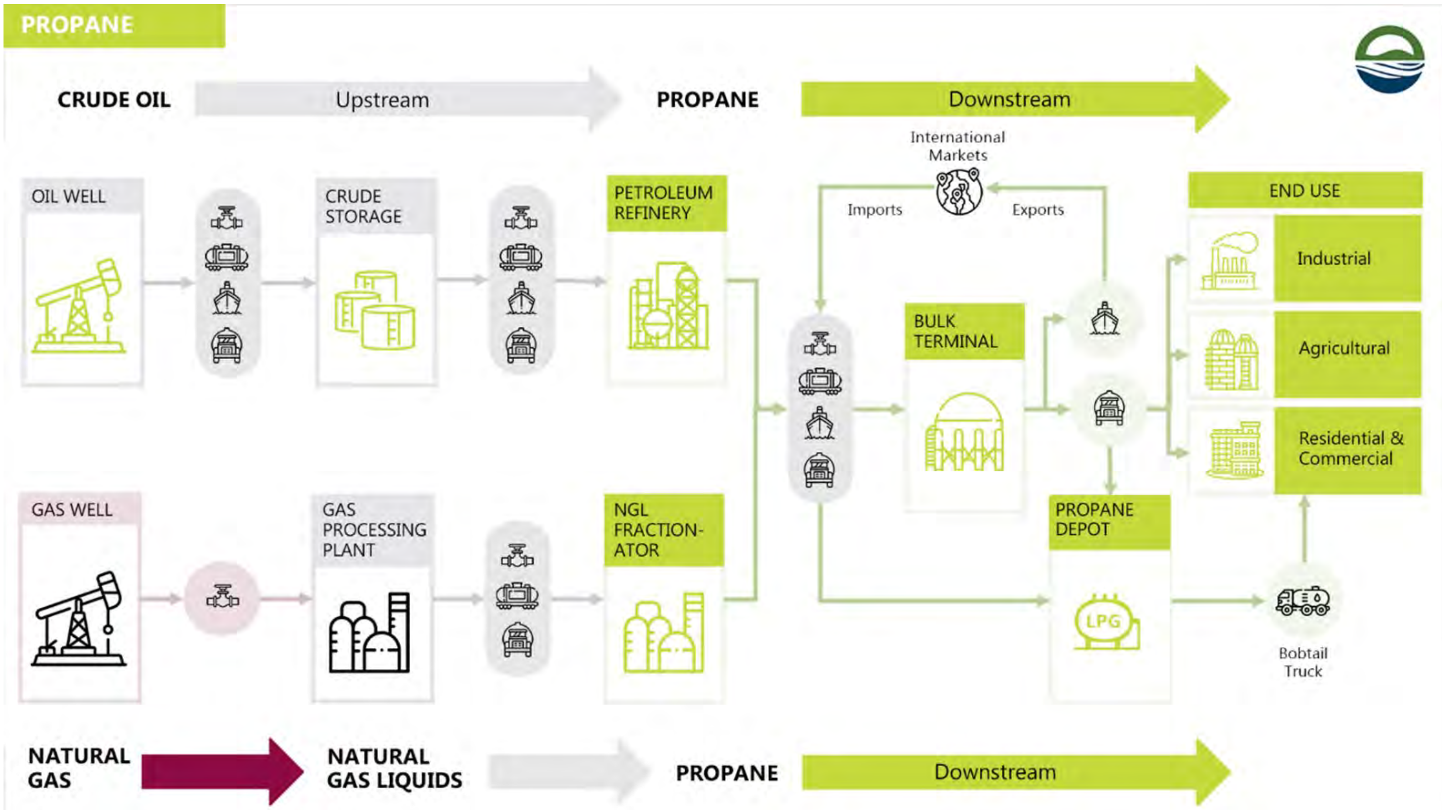
Residential Sector | 1.9 trillion Btu

Industrial Sector | 14.3 trillion Btu

Hydrocarbon Gas Liquids and Propane. HGLs are gases at atmospheric pressure and can be liquefied by cooling and pressurizing. 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.[12] As U.S. natural gas production has increased, the supply of propane has followed, making it an affordable and attractive option for many Oregonians.[13]

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.[14]

Propane Supply Chain



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 in its early stages, with the first commercial production in the United States beginning in 2018. It is most often created as a byproduct of renewable diesel or sustainable aviation fuel production. Other methods for producing renewable propane are being studied and tested.[15] Renewable propane is 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.[15]

Oregon consumed 9.8 trillion Btu of propane in 2022 as a direct use fuel.[7] About 1 percent of Oregon residents use propane boilers or furnaces to heat their homes; even more use it for cooking.[9] While propane use on-road as a transportation fuel is a small segment of the total fuel usage in Oregon, some school districts use propane as a fuel for bus fleets.

Hydrocarbon Gas Liquids and Propane Consumption by Sector[1]

Commercial Sector | 4.0 trillion Btu

Residential Sector | 2.5 trillion Btu

Industrial Sector | 3.3 trillion Btu

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 2022, Oregon consumed almost 22.0 trillion Btu of Other Petroleum fuels.[1]

Other Petroleum Consumption by Sector[1]

Commercial Sector | 5.0 trillion Btu
Residential Sector | 0.1 trillion Btu
Industrial Sector | 16.9 trillion Btu

Solar Thermal. While solar is commonly thought of as a resource to generate electricity, Oregon also uses sunlight to produce energy to heat spaces and water in homes and businesses. Over 2.8 trillion Btu of solar thermal energy was consumed in Oregon in 2022.[1] 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[1]

Commercial Sector | 0.42 trillion Btu
Residential Sector | 2.28 trillion Btu
Industrial Sector | 0.07 trillion Btu

Geothermal. In 2022, 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.[16]

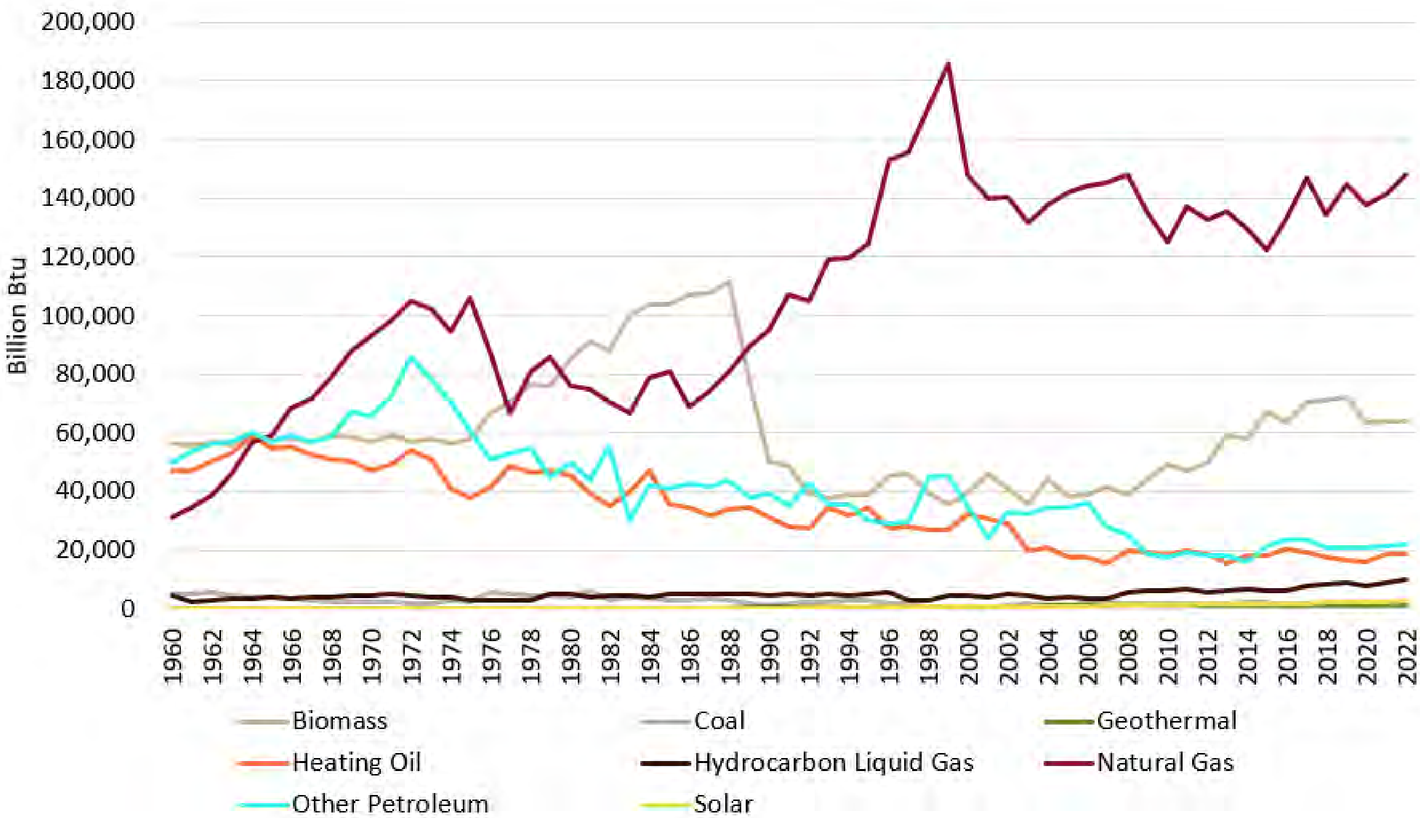
Coal. Coal is imported to Oregon for use as a direct fuel in the industrial sector. Oregon consumed 1.1 trillion Btu in 2022. While coal can also be used to generate electricity, there are no coal-fired power plants operating in Oregon. Most applications of coal as a direct use fuel in Oregon have been replaced by other fuels such as natural gas, which has led to a general decrease in coal use since the 1990s.[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 relatively inexpensive 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 2022. The chart does not include transportation fuels or fuels used to generate electricity used in those sectors.

Oregon Direct Use Fuels Consumption: 1960-2022 (Billion Btu)[1]



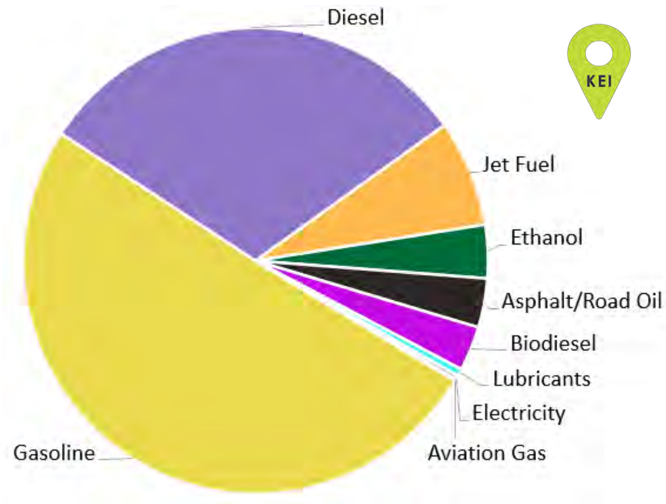
Natural gas has replaced heating oil and coal use in many Oregon buildings and industrial processes as a cleaner-burning and in many cases less expensive alternative. Oregon's natural gas utilities have already begun planning for the blending of lower carbon alternative fuels such as renewable natural gas and hydrogen with fossil natural gas.

Geothermal consumption is one of the smallest of Oregon's direct use fuels in the chart above, but it has the potential to be a greater clean energy resource in the future. EIA began tracking geothermal consumption in 1989 with 0.38 trillion Btu. In 2022, Oregon consumed over 1.2 trillion Btu of energy from geothermal, an increase of 224 percent over that 30-year period.[1] See the Energy Resource and Technology Reviews section of this report to learn more about enhanced geothermal electricity generation.

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.[1]

Transportation Fuels

What We Use



In 2022, Oregon's transportation sector used 36.7 percent — or 318.4 trillion Btu — of the energy consumed in Oregon. Transportation was the largest share of energy use among the sectors in 2022.[1] Petroleum-based products accounted for 91 percent of fuel consumed in this sector. Alternative fuels or biofuels like ethanol, biodiesel, and renewable diesel accounted for 8.6 percent, and electricity and natural gas accounted for 0.3 percent of the fuels consumed.[2]

Oregonians consume many different types of transportation fuels:

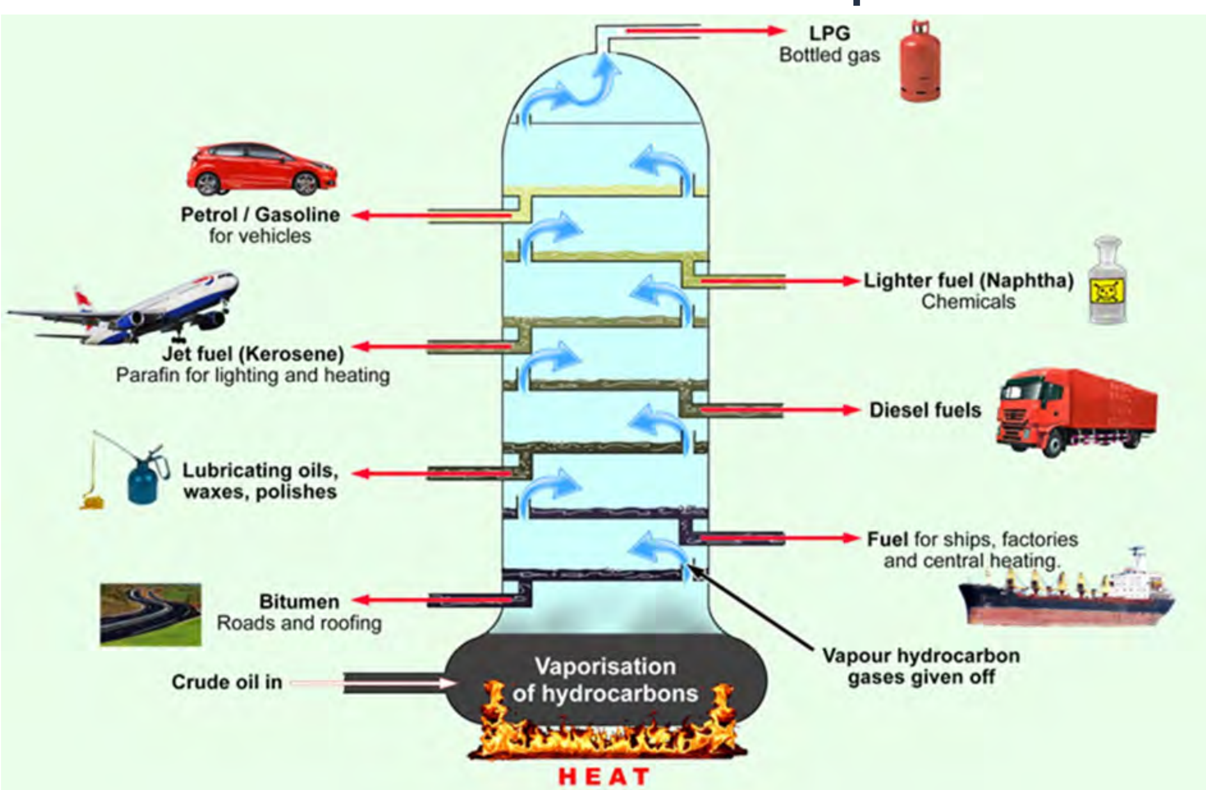
Petroleum-based products make up 91 percent of Oregon's transportation fuel use. They are processed by heating crude oil and separating components by weight, sometimes referred to as fractionations (of the crude oil).

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[3]



Alternative fuels (to petroleum) used in Oregon are produced by various means, usually by collecting and processing 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, school buses, port equipment, and passenger 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.[4,5]

Hydrogen's Potential in Oregon

A potential emerging resource in Oregon and beyond is clean hydrogen, which could be used as a replacement for fossil-based hydrogen currently in use, as a direct transportation fuel (especially for medium– or heavy-duty vehicles), as storage for clean electricity generation, for industrial processes and heat, and other uses. In November 2022, the Oregon Department of Energy published a study on the potential of renewable hydrogen, including opportunities and challenges for using the resource in the state.

In October 2023, the Pacific Northwest Hydrogen Association Hub was selected by the U.S. Department of Energy as one of seven hydrogen hubs throughout the country. The hubs are intended to jumpstart clean hydrogen adoption by encouraging collaboration with suppliers and consumers to develop the new economy. The PNWH2 is a multi-state nonprofit organization made up of Tribal Nations, labor, business and industry, higher education, government, and the environmental community spanning Oregon, Washington, and Montana. By accelerating investment and development of hydrogen production, the association intends to establish a benchmark for successful low-carbon intensity and economically viable hydrogen production to decarbonize hard-to-abate industries.


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

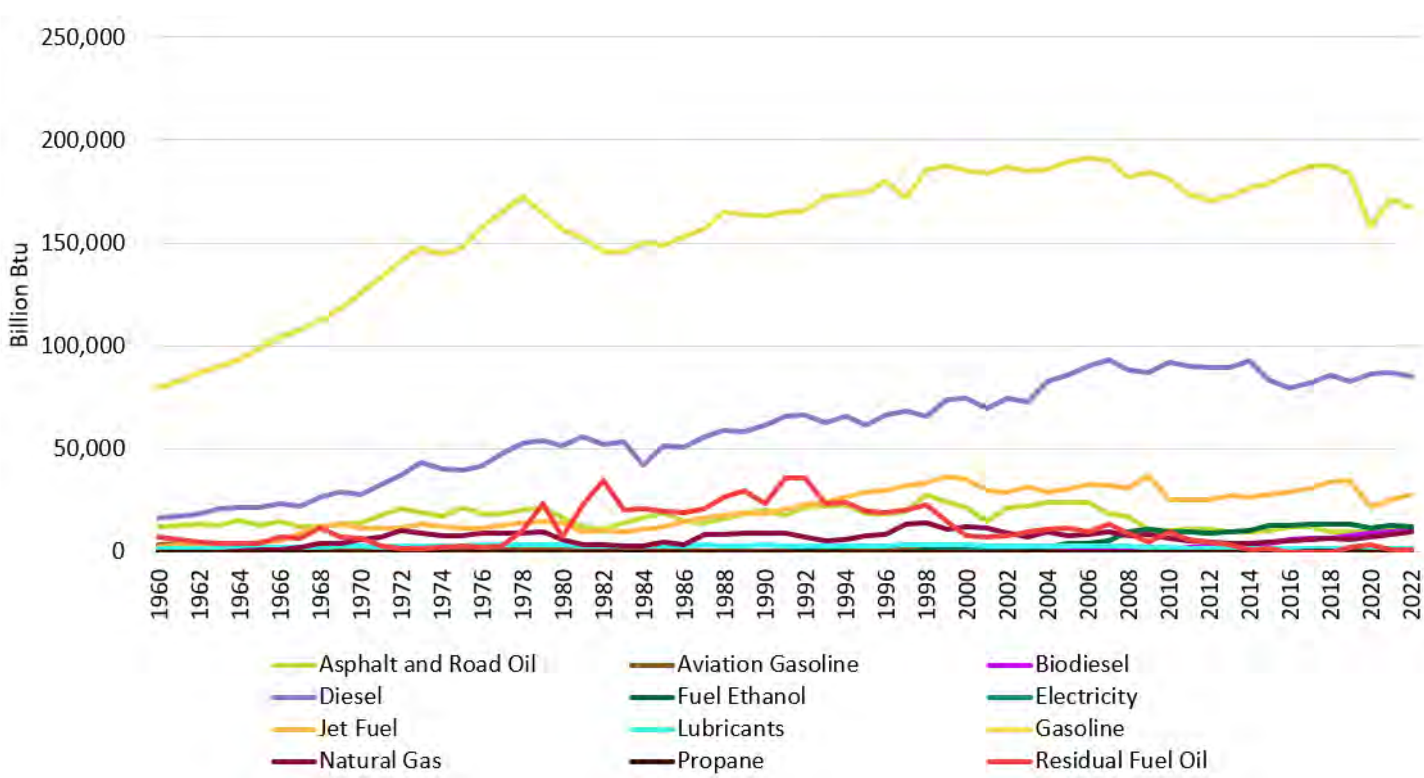
Use Over Time

> **90%**
>
> Percent of petroleum fuels delivered and consumed in Oregon come from four refineries in Washington.[2]

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 indicates this is due to less personal vehicle travel and more delivered goods.[6 7] In 2020, total use was down to 281.3 trillion Btu (affected by COVID) and the previous peak in 2019 was 314.4 trillion Btu.[2] Since 2020, Oregon's transportation sector has returned to its upward trajectory, consuming 318.4 trillion Btu of energy in 2022.

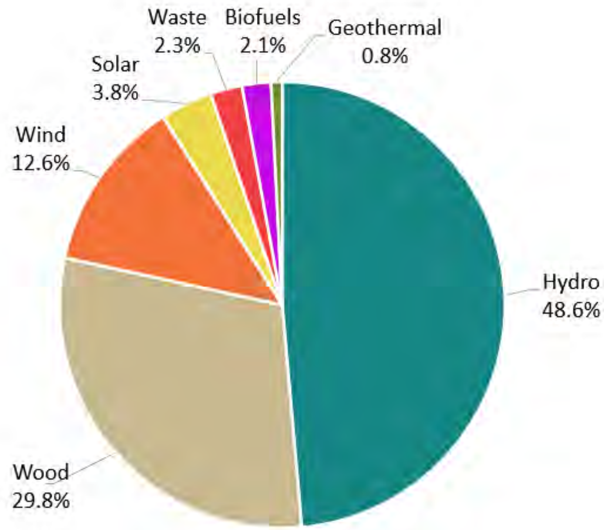
Except for 2019 and 2020, petroleum product consumption has steadily increased over time and still dominates transportation fuel use in Oregon. Nearly all transportation fuels are imported into Oregon. In 2022, just 1.6 percent of transportation fuel used in Oregon was produced in the state, including 4.6 trillion Btu of biodiesel and fuel ethanol.[8] Oregon electric utilities provided 0.54 trillion Btu of electricity to fuel electric vehicles in 2022.[2] 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.[9] Crude oil processed at Washington refineries comes from Alaska, western Canada, and North Dakota.

Oregon Transportation Sector Consumption: 1960-2022 (Billion Btu)[1]



Energy Production

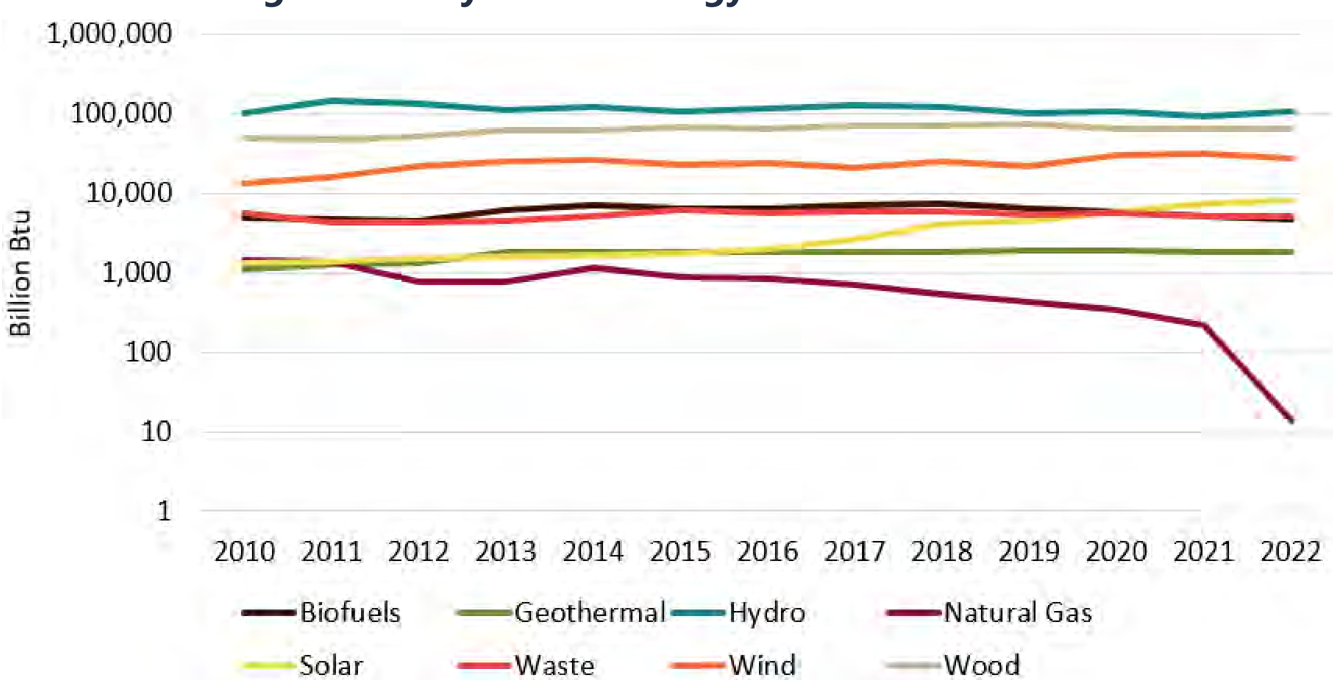
Overview



This section provides energy consumption and energy production data. 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.

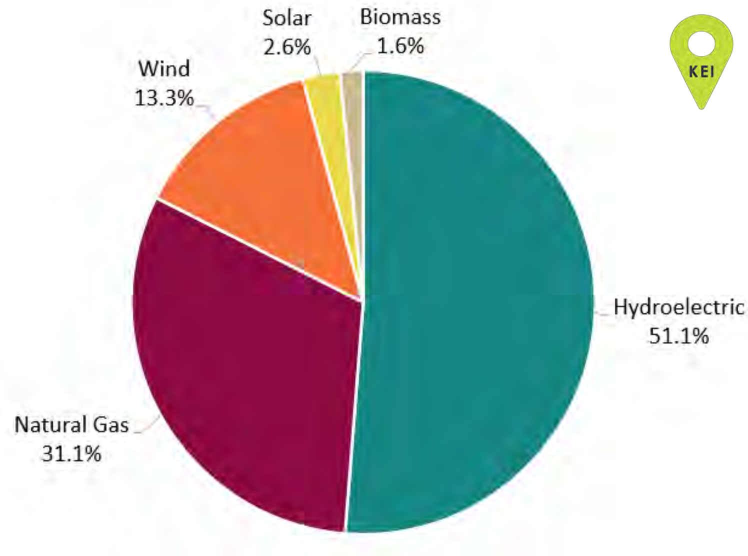
The chart above shows primary energy produced in Oregon in 2022. Almost all the primary solar, wind, geothermal, and hydro energy is converted to *secondary* energy as electricity. Some of the biomass is used to make a variety of renewable fuels and some is combusted to produce heat and electricity.[1]

Oregon Primary Annual Energy Production Over Time[1]



The chart above uses a logarithmic scale to compare energy produced in Oregon. Without the logarithmic scale, the resources with the smallest production in Oregon like natural gas and geothermal would be hard to see, as they are proportionately significantly smaller and would be hidden along the bottom of the chart, and hydroelectric would dwarf all others except for wood and wind. Over the last two decades Hydro has been the largest primary energy source in Oregon. Solar power has been steadily increasing since 2012, with faster growth starting in 2015. Wood has remained the second largest primary energy source. Wind energy has grown at a slower rate, and by 2022 was the third largest category. Between 2014 and 2021, natural gas production slowly declined and in the past year has seen a steep decrease.[1]

Electricity



Oregon generates electricity from a variety of resources — hydropower, natural gas, and wind are the largest. In 2022, Oregon's 105 hydroelectric facilities were responsible for 51 percent of the electricity generated in Oregon.[1] 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.[2] Oregon is the second largest producer of hydroelectric power in the U.S. after Washington.[2]

Oregon's abundance of renewable electricity is used in Oregon and sold on the energy market to utilities in other states. In 2022, 37 percent of Oregon's hydropower and 45 percent of its wind generation were exported.[3] Sixty-nine percent of electricity generated in Oregon in 2022 came from non-greenhouse gas emitting resources.[1]

Natural gas accounted for 31 percent of Oregon's 2022 electricity generation. Nearly all the natural gas used to generate electricity in Oregon is imported. There is only a single natural gas site in Mist, Oregon, but this facility is used primarily for natural gas storage. Oregon has no coal or petroleum resource extraction facilities.

KEI

61.3 Million

Megawatt hours of electricity generated in Oregon in 2022.[1]

KEI

58.8 Million

Megawatt hours of electricity consumed in Oregon in 2022.[3]

KEI

69%

Percentage of Oregon's electricity generation that comes from non-emitting resources.[3]

83%

Percentage of Oregon's electricity generation that is used in state.[3]

Utility-Scale Solar in Oregon

In February 2018, Oregon's Energy Facility Siting Council approved the first solar energy facility within its jurisdiction. However, that facility did not initiate construction and terminated its approval in March 2024. The first EFSC-jurisdictional facility constructed was the Wheatridge Renewable Energy Facility. Fifty megawatts of the approved 150-MW solar energy facility became operational in March 2022.

As of August 2024, there are 20 EFSC-jurisdiction solar facilities under review, under construction, or operating in Oregon, which amounts to 212 MW of operational solar-generating facilities with another 200 MW in construction. The largest proposed facility to date is the 1,200 MW Sunstone Solar Project in Morrow County.

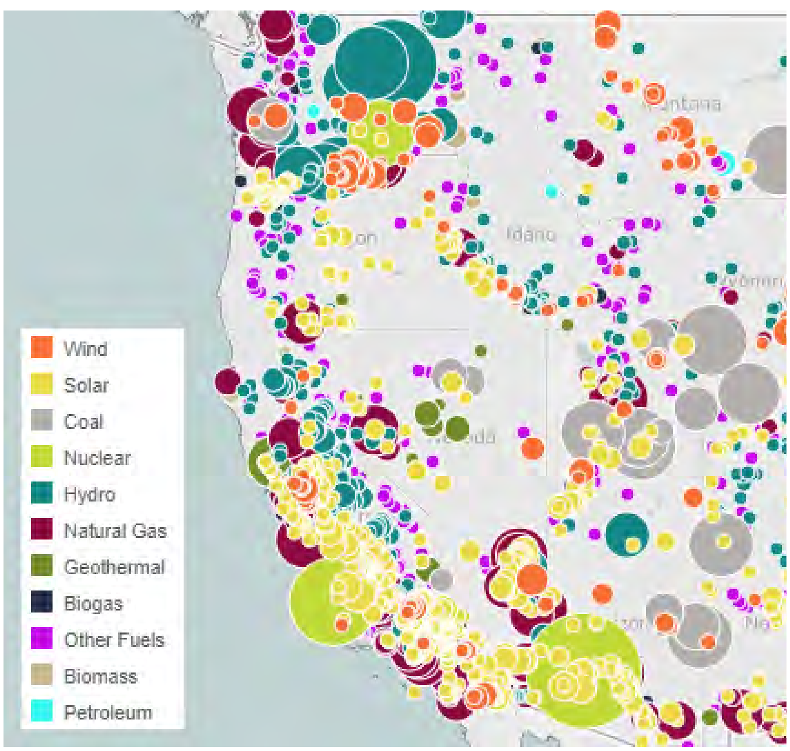
Electric Facilities

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

Electricity used by Oregonians can come from facilities across the western United States. Oregon relies on hydroelectric power produced on rivers in the Columbia River watershed, 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.[4]

The map below shows the various electricity generation sources in the Western Electricity Coordinating Council, 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 and Baja Mexico.[5]

The maps of electricity generating resources use data from the U.S. Energy Information Administration and include facilities with a nameplate capacity of one megawatt or greater.[4]

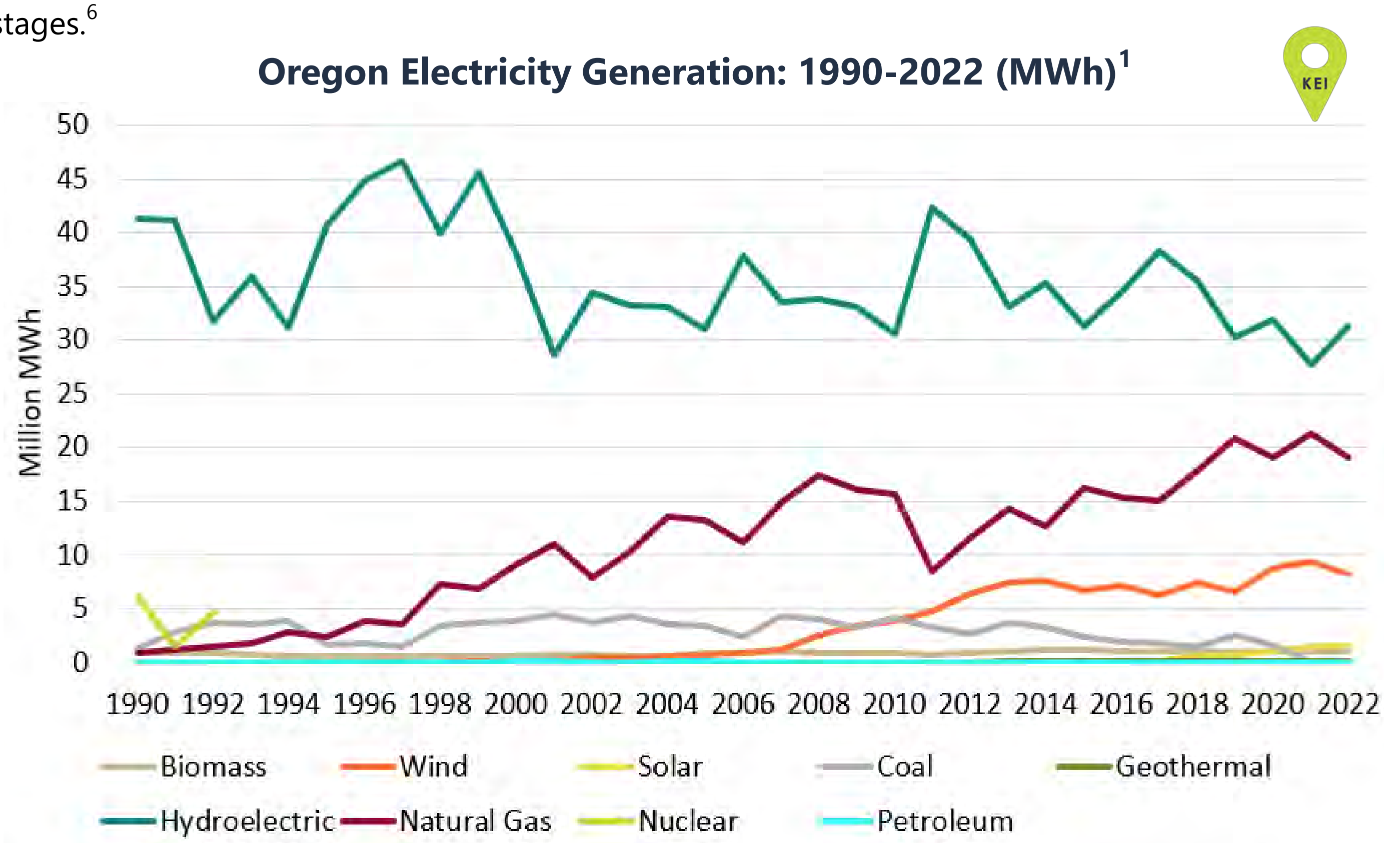


According to the EIA, nameplate capacity is defined as the maximum rated output of a generator, prime mover, or other electric power production equipment under specific conditions designated by the manufacturer. Installed generator nameplate capacity is commonly expressed in megawatts and is usually 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 used when Oregon utilities purchase electricity on the open market. Similarly, 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 as shown in the chart below. Wind and natural gas have both seen a gradual increase in generation over time. In 2022, natural gas was the second largest share of Oregon's electricity generation, at 19.0 million MWh. Coal generation no longer occurs in Oregon, with the last coal-powered plant closing in 2020. Solar has increased each year since 2011, and is expected to continue growing with several proposed large facilities in planning and review stages.[6]

Oregon Electricity Generation: 1990-2022 (MWh)[1]



Utility Scale Storage

Utilities in Oregon are investing in energy storage. There are several options for storing energy, including batteries and hydroelectric facilities. Many hydroelectric facilities store energy as water in reservoirs that can be released to flow through turbines when needed. When electricity demand is low, some of them can use their on-site electricity generation to pump water back upstream to be stored behind the reservoir until needed. Increasingly, utilities are also storing energy in batteries, which can be sited with variable renewable resources like solar and wind. This helps utilities get more out of these resources by storing energy when demand is low, and using them to supplement generation when demand is high.

Portland General Electric's Wheatridge Energy Facility includes battery storage.

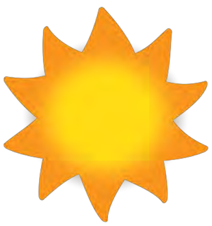
Renewable Electricity

Renewable electricity generated in Oregon has grown due to customer demand, dramatic reductions in costs, and clean energy policies, like the Renewable Portfolio Standard and the 100 percent clean electricity by 2040 target set by HB 2021 (2021). Demand for clean energy in California also spurred prior wind development in Oregon – 45 percent of wind energy in 2022 was exported.[3]

KEI

Solar[7]

2012 Generation	2016 Generation	2020 Generation	2022 Generation
6,400 MWh	40,900 MWh	1,077,900 MWh	1,505,400 MWh



8.4% of Oregon's solar consumption was imported in 2022.[3]

Oregon has 4,809 MW of utility-scale solar facilities and 218 MW of net-metered solar installations on homes and businesses.

KEI

Wind[8]

2012 Generation	2016 Generation	2020 Generation	2022 Generation
6.3 Million MWh	7.2 Million MWh	8.8 Million MWh	8.2 Million MWh[ix]

45% of Oregon's wind generation was exported in 2022.[3]

Oregon has 3,981 MW of wind facilities in operation, with ODOE overseeing even more projects: 300 MW under construction, 360 MW approved but not yet built.[8]

KEI

Hydropower[8]

2012 Generation	2016 Generation	2020 Generation	2022 Generation
39.4 Million MWh	34.6 Million MWh	31.9 Million MWh	31.3 Million MWh

37% of Oregon's hydropower generation was exported in 2022.[3]

In some Oregon utility territories, hydropower provides over 90% of consumers' electricity.[4]

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

[ix] Wind generation varies depending on the weather. Despite a steady increase to the total generating capacity in Oregon's wind facilities, 2022 was a low year for wind electricity production.

Direct Use Fuels

Natural gas is the most consumed direct use fuel in Oregon and almost all of it is imported. Biomass is the most produced direct use fuel but makes up only 21 percent of total consumption in the state as most direct use fuels — consumed by the residential, commercial, and industrial sectors — are imported. In 2022, Oregon used 267.5 trillion Btu of direct use fuels, representing about 30 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 for electrical generation, but Oregon also produces some direct use fuels.

The table below shows the direct use fuels 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 Oregon Department of Energy determines that energy was exported to support neighboring states' energy systems (negative values in the chart). If more of an energy resource was consumed than produced, it is assumed that it was imported into the state for consumption.

100%

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

23% KEI

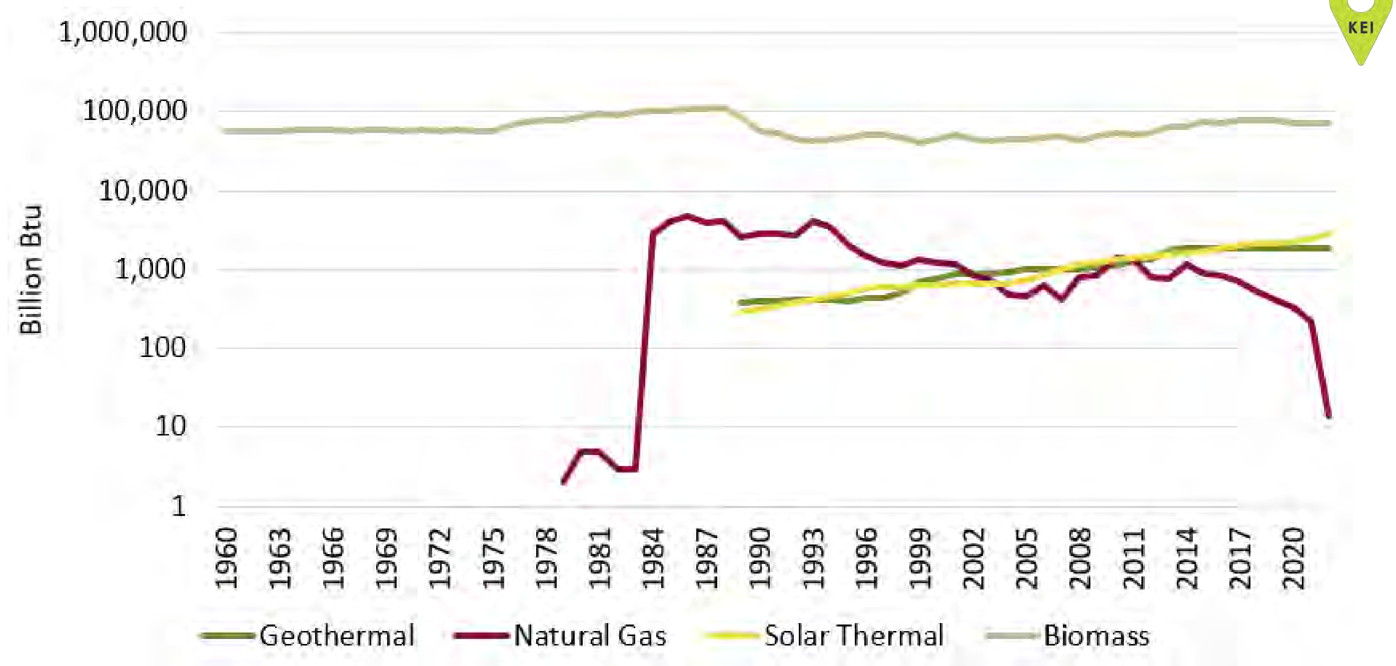
Percentage of Oregon overall direct use fuels consumption that is produced in state.[1]

In 2022, Oregon produced about 56.2 trillion Btu of direct use fuels energy from biomass.[1] Biomass is also used to produce transportation fuels in Oregon such as ethanol or biodiesel, but that is not included here. 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 do not show where each Btu of energy is consumed.

Production & Consumption of Direct Use Fuels in 2022 (trillion Btu)[1]

Resource	Consumption in Oregon	Oregon Production	Imported	% of Consumption Produced in Oregon
Natural Gas	148.1	0.03	147.08	0%
Biomass	64	56.2	-11.8	87.8%
Other Petroleum	22	0	22	0%
Heating Oil	18.5	0	16.1	0%
Hydrocarbon Gas & Liquids/ Propane	9.8	0	9.8	0%
Solar Thermal	2.8	2.8	0	100%
Geothermal	1.2	1.8	-0.61	100%
Coal	1.1	0	1.1	0%
Totals	**267.5**	**60.8**	**194.9**	**23%**

Direct Use Fuel Energy Production in Oregon, 1960-2022[1]



The chart above uses a logarithmic scale to compare direct use energy produced in Oregon so that the natural gas, geothermal, and solar thermal resources can more easily be discerned. Although not an intended effect, this change in scale emphasizes changes in smaller resources like natural gas, solar thermal, and biomass, and deemphasizes changes in resources that constitute a larger proportion of the resources, like biomass.

Natural Gas. The Pacific Northwest's only natural gas production is located outside of Mist, northwest of Portland, and is owned and operated by NW Natural, one of three investor-owned natural gas companies serving Oregon. The Mist field produced about 13 million cubic feet of natural gas or 0.01 trillion Btu of energy in 2022.[1] The facility hit a production peak of 4.7 trillion Btu in 1986 and since then, production has steadily declined.[1]

The Mist facility is primarily 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, to 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. A biogas must be cleaned-up to be a substitute for fossil natural gas, and most often needs to meet stringent 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.[9]

There are six RNG projects located in Oregon, and three are currently operational and able to inject RNG into natural gas pipelines.[10] [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 technological 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 is collected and processed from a regional wastewater treatment plant in Eugene.[13]

Solar Thermal. 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 solar thermal 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. In its place, more Oregonians are installing solar photovoltaic systems combined with energy efficient electric heat pump water heating systems as these combined systems have become more cost-effective.

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 1.8 trillion Btu of geothermal energy in 2022, and 1.2 trillion Btu of it was consumed as a direct use fuel.[1] For decades, the city of Klamath Falls and the Oregon Institute of Technology's Klamath Falls Campus have used geothermal heat sources to heat buildings, residences, pools, and even sidewalks.[14,15] Schools and hospitals in Lakeview use a geothermal well system to heat some buildings.[16] The geothermal energy not used as a direct use fuel, is used to generate electricity.

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. The U.S. Department of Energy ranked Oregon as the state with the third highest geothermal potential, behind only Nevada and California.[2]

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-four years later, Oregon's production was 71 trillion Btu — a 37 percent decrease.[1] In Oregon, the industrial sector is the largest producer and consumer of biomass energy. Eleven woody biomass facilities use biomass to generate electricity used onsite and sold to other businesses in Oregon, primarily in the wood-products industry.[17] Wood is also produced and consumed as firewood 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 five wood pellet plants in Oregon, with an annual production capacity of 207,500 metric tons per year.[18] 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 charcoal briquette manufacturing plants in the U.S. The facility has 90 local employees, is on a 40 acre site, and has been in operation for over 50 years.[24 25]

Transportation Fuels

Only 1.6 percent of the 318.4 trillion Btu of energy Oregonians consumed for transportation in 2022 was produced in state.[21] Oregon does not produce or refine any petroleum-based transportation fuels, but does produce 30 percent of the ethanol that is blended into gasoline and 12 percent of the biodiesel that is blended into petroleum diesel.[1] Though still a small fraction of the total transportation fuels, electricity use for transportation is growing in Oregon. The state consumed 0.8 trillion Btu of electricity in 2022 for transportation, or about 0.3 percent of total transportation fuel consumption.[1]

1.6%

KEI

Percentage of transportation fuel used in Oregon that is produced in state.

5%

Biodiesel blend is used in most heavy-duty vehicles on and off the highway.[22]

10%

Ethanol blend fuel is used in a majority of light-duty vehicles in Oregon.[22]

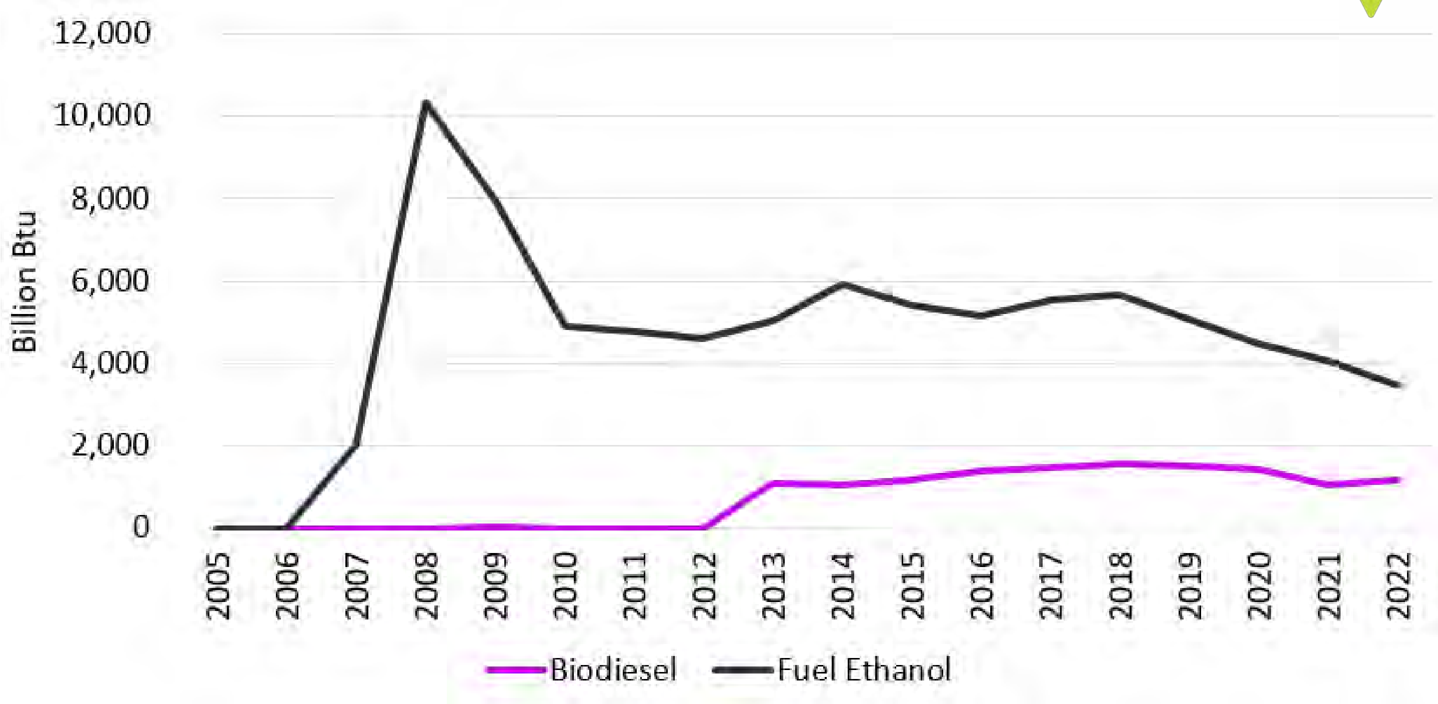
Production & Consumption of Transportation Fuels in 2022 (trillion Btu)[3]

Resource	Consumption in Oregon	Oregon Production	Imported	% of Consumption Produced in Oregon
Gasoline	157.79	0	157.79	0%
Diesel	96.33	0	96.33	0%
Jet Fuel	23.13	0	23.13	0%
Fuel Ethanol	11.56	3.48	8.08	30%
Asphalt & Road Oil	10.65	0	10.65	0%
Biodiesel	9.71	1.18	8.52	12%
Renewable Diesel	5.78	0	5.78	0%
Lubricants	1.54	0	1.54	0%
Electricity* (gge)	0.80	0.54	0.25	68%
Bio-CNG	0.47	0	0.47	0%
Aviation Gasoline	0.32	0	0.32	0%
LPG/Propane	0.22	0	0.22	0%
Renewable Propane	0.06	0	0.06	0%
Compressed Natural Gas	0.03	0	0.03	0%
Hydrogen	<0.01%	0	<0.01%	0%
Totals	**318.38**	**5.21**	**313.16**	**1.6%**

**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 2022.*

Transportation Energy Production in Oregon, 2005-2022[3]

KEI



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 2022, Oregon produced 3.5 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.[23]

Biodiesel. The U.S. Energy Information Administration began tracking Oregon biodiesel production in 2013. In 2022, Oregon produced 1.2 trillion Btu of biodiesel. In January 2024, SeQuential Pacific Biodiesel (the second largest Oregon producer of renewable fuel) was acquired by Neste Corporation and has been merged with Mahoney Environmental. They are expected to continue to collect and provide used cooking oils as a feedstock for renewable fuels, however it is uncertain if production at the biodiesel facility in Salem will continue, as Neste is a partner in a joint venture producing renewable diesel in Martinez, California.[24]

A 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. For more details, see the Renewable Natural Gas paragraph in the Direct Use Fuels section.

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, liquefied 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 in state jurisdiction. EFSC also has ongoing responsibility for approved sites, including monitoring projects going into construction and operation, and reviewing site certificate amendment requests.

62

Total number of site certificates issued by EFSC.

24.5 Gigawatts

Total capacity of electricity-generating facilities approved by EFSC. Nearly 10.3 GW is renewable.

11 Gigawatts

Total 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.

EFSC Jurisdiction Renewable Electricity Projects (Megawatts)[1 2]

Status	Wind	Solar	Geothermal	Hydro	Battery	Total MW
Active						
Operational	2,719	212	-	-	56	2,987
In Construction	300	200	-	-	-	500
Approved	361	1,542	-	-	1,133	3,036
Under Review	201	4,444	-	-	4,606	9,251
Subtotal	**3,581**	**6,398**	**-**	**-**	**5,795**	**15,774**
Inactive						
Approval Expired	1,214	75	35	-	-	1,324
Decommissioned	-	-	-	-	-	-
Denied	-	-	-	80	-	80
Withdrawn	2,445	1,250	180	200	1,600	5,675
Subtotal	**3,659**	**1,325**	**215**	**280**	**1,600**	**7,079**
TOTAL MW	**7,240**	**7,723**	**215**	**280**	**7,395**	**22,853**

EFSC Jurisdiction Non-Renewable Electricity Projects (Megawatts)[1 2]

Status	Coal	Nuclear	Natural Gas	Other	Total MW
Active					
Operational	-	-	3,237	51	3,288
In Construction	-	-	-	-	-
Approved	-	-	-	-	-
Under Review	-	-	-	-	-
Subtotal	**-**	**-**	**3,237**	**51**	**3,288**
Inactive					
Approval Expired	109	5,040	3,636	38	8,823
Decommissioned	550*	1,130	415	-	2,095
Denied	-	-	-	-	-
Withdrawn	431	-	5,147	109	5,687
Subtotal	**1,090**	**6,170**	**9,198**	**147**	**16,605**
TOTAL MW	**1,090**	**6,170**	**12,435**	**198**	**19,893**

*The Boardman Coal Plant has ceased operation and is closed, but not yet fully decommissioned.

EFSC Jurisdiction Non-Electricity Generation Projects (Number) — Part 1[1 2]

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**

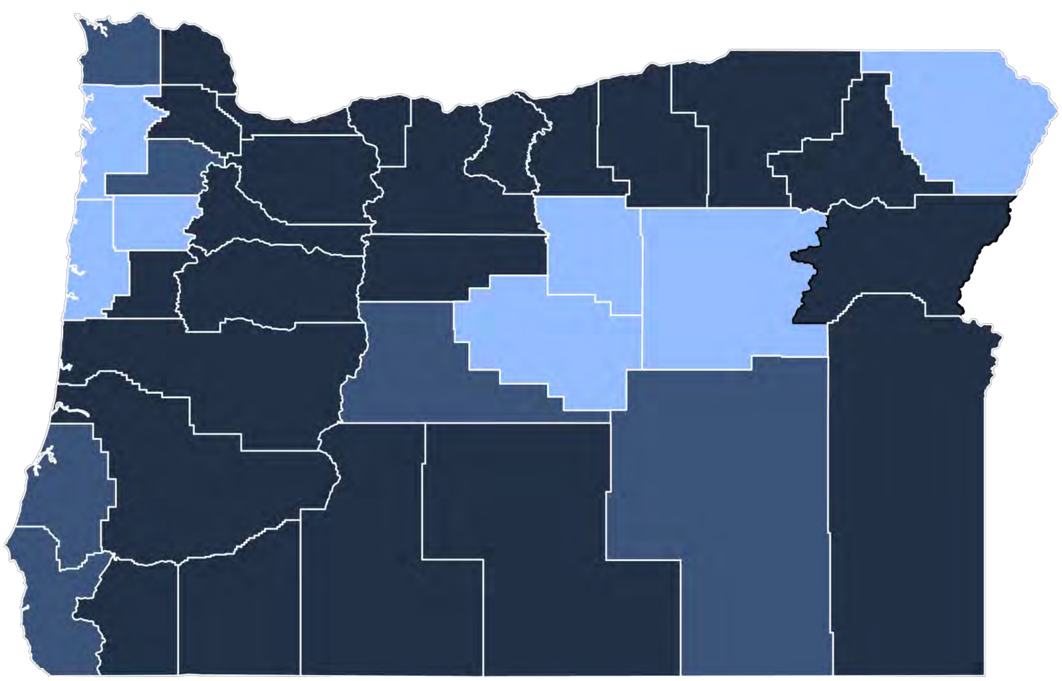
*Portland General Electric's Independent Spent Fuel Storage Installation Facility at decommissioned Trojan Power Plant.
**This is an amendment to the existing in-service Eugene to Medford 500 kV transmission line.

EFSC Jurisdiction Non-Electricity Generation Projects (Number) — Part 2[1,2]

Status	Natural Gas Pipeline	Ethanol Production	Total Projects
Active			
Operational	2	1	3
Approved	-	-	-
Under Review	-	-	-
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 2022, Oregon spent $19.5 billion on energy, an increase from the recent low of $12.1 billion in 2020.[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 2022, Oregonians sent about $11.2 billion in transportation dollars – nearly double the amount in 2020 – to other states and countries where extraction, processing, and refining of transportation fuels occurs.[1]

$19.5 billion

Oregonians spent on energy in 2022, a more than 60% increase from 2020.[1]

12.4 cents

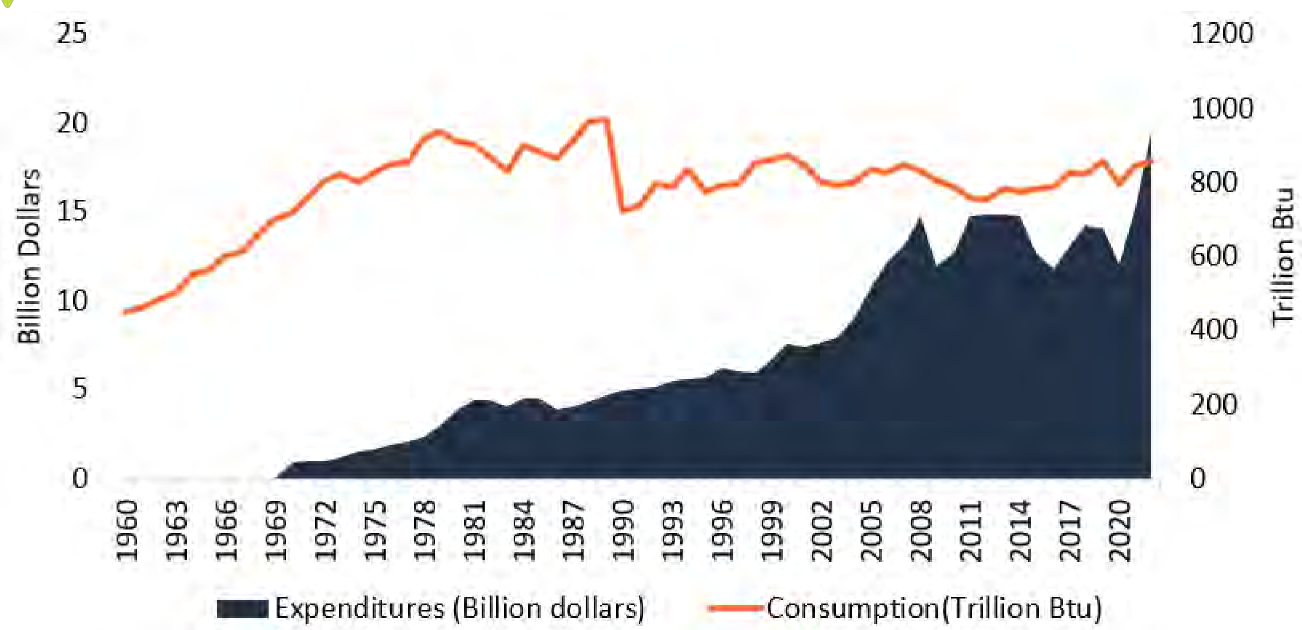
Oregon's average residential retail price per kilowatt hour of electricity for 2022.[2]

6.55%

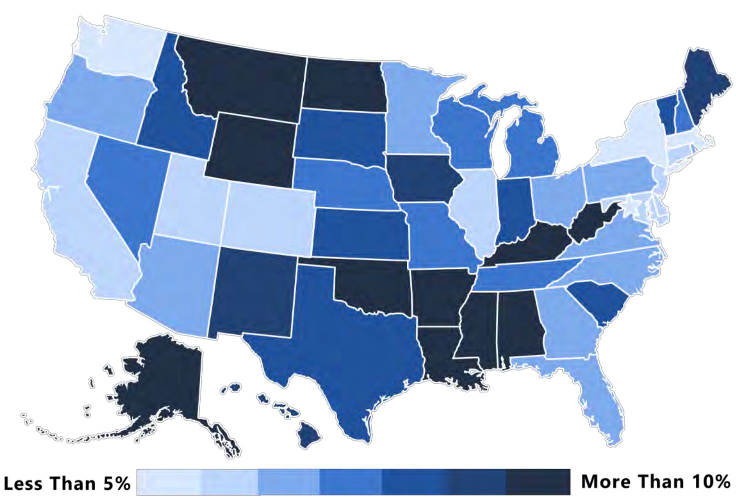
Percentage of Oregon's GDP spent on energy in 2022.[1]

KEI

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



Note: Figure shows expenditures in nominal dollars, which are not adjusted for inflation.



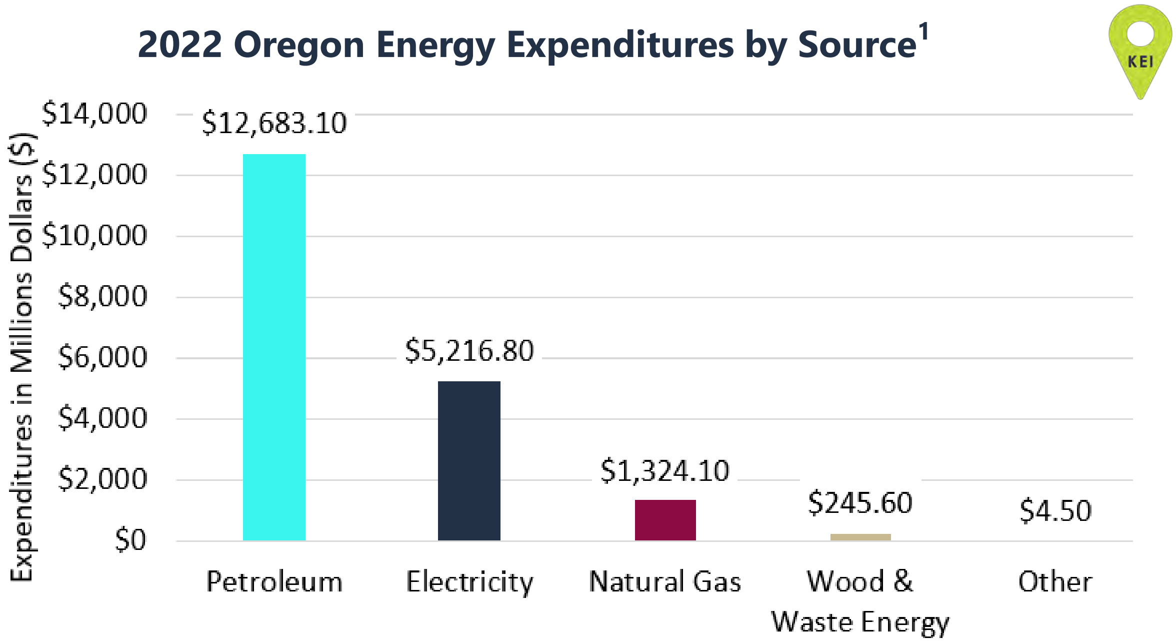
State Total Energy Expenditures as a Percentage of State Gross Domestic Product (2022)[1]

Oregon's energy expenditures as a percentage of the state's gross domestic product was 6.55 percent in 2022, which is just below the national average of 6.68 percent.[1]

Oregon Energy Expenditures by Source

Oregon's industrial, commercial, residential, and transportation sectors spent over $19.5 billion on energy from petroleum, electricity, natural gas, wood, waste, and some coal (other) in 2022.[1]

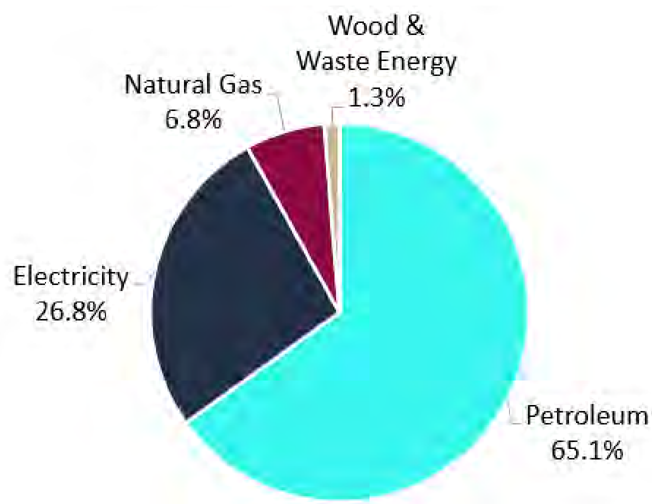
2022 Oregon Energy Expenditures by Source[1]



The petroleum category is dominated by transportation fuels. The transportation sector accounts for $11.2 billion in expenditures, mainly on petroleum products though it also includes some natural gas and electricity expenditures subject to regulation by the Oregon Public Utility Commission. Petroleum product prices are unregulated and experience a high level of price volatility due to global market effects. A sharp increase in price per unit of energy in petroleum products in 2021 and 2022 nearly doubled the amount of money Oregonians spent on transportation fuels compared to 2020.[1]

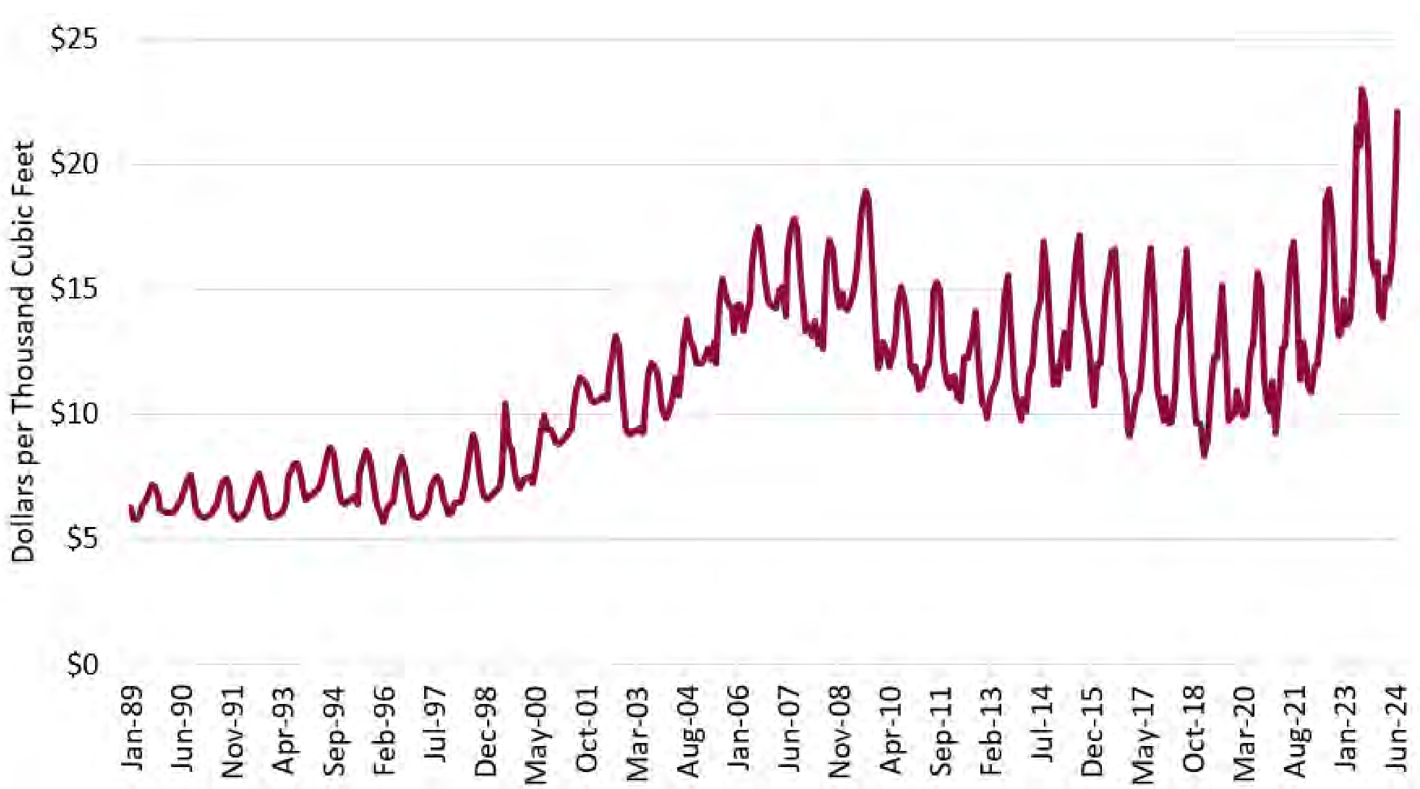
The average price of electricity has increased slowly from 2020 through 2022, but regulation of retail rates by the OPUC and local governing boards of Consumer-Owned Utilities has kept retail electricity prices from being as volatile as transportation fuel costs. Since 2022, many electric utility customers have seen rate increases, with the highest increases for investor-owned utility customers. Additional rate increases are under consideration at the OPUC and at some local COU governing boards.

Share of Energy Expenditures by Source in Oregon (2022)[1]



Natural gas expenditures constitute a smaller portion of total consumer energy expenditures in Oregon, primarily because not all people and businesses use natural gas. Natural gas retail prices are also regulated by the OPUC, and like electricity prices, have increased since 2020. Customers have faced higher retail prices due to a variety of factors, including higher natural gas supply costs in 2021 and 2022.[3] Investments in energy efficiency, low carbon alternative fuels, and other options to decarbonize Oregon's existing natural gas system will likely increase the cost of doing business for utilities and contribute to future retail rate increases.[4] [5]

Oregon Price of Natural Gas Delivered to Residential Consumers Over Time[6]



Get Involved

The Oregon Public Utility Commission offers trainings to help Oregonians better understand its processes and encourage participation. The agency provides recorded online trainings on its website, including support for those new to OPUC processes, information on climate change and utility investment, wildfire and public safety, and information on what to expect for hearings, public meetings, and rulemaking opportunities, among other trainings.

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Energy Burden

Home energy burden is commonly used to refer to the percent of household income spent on home energy bills, including electricity, natural gas, and other home heating fuels. To calculate a household's energy burden, the total electricity and/or heating costs are compared to the total gross income of the people in that household. The U.S. Department of Energy and other consumer-focused agencies regard a household spending 6 percent or more of its income on home energy costs as experiencing high energy burden, while households spending 10 percent or more are considered severely energy burdened.[7] However, percentages are not able to capture all the unique and differing ways that a household may experience energy burden. The energy affordability gap is the difference between a household's actual energy costs and what may be considered an "affordable" energy burden level. Many low-income Oregonians — those making 200 percent of the federal poverty level or less — face high or severe energy burden.

Oregon's energy affordability gap is estimated to be about $277 million per year, or eight times the federal funding Oregon receives for energy assistance.[8]

4x

In Oregon, low-income households spend over four times more on energy costs compared to the average spending of non-low-income households on energy.[8]

477,540

Number of Oregon households that were energy burdened in 2022, an increase of more than 100,000 households in 2020.[8]

28.4%

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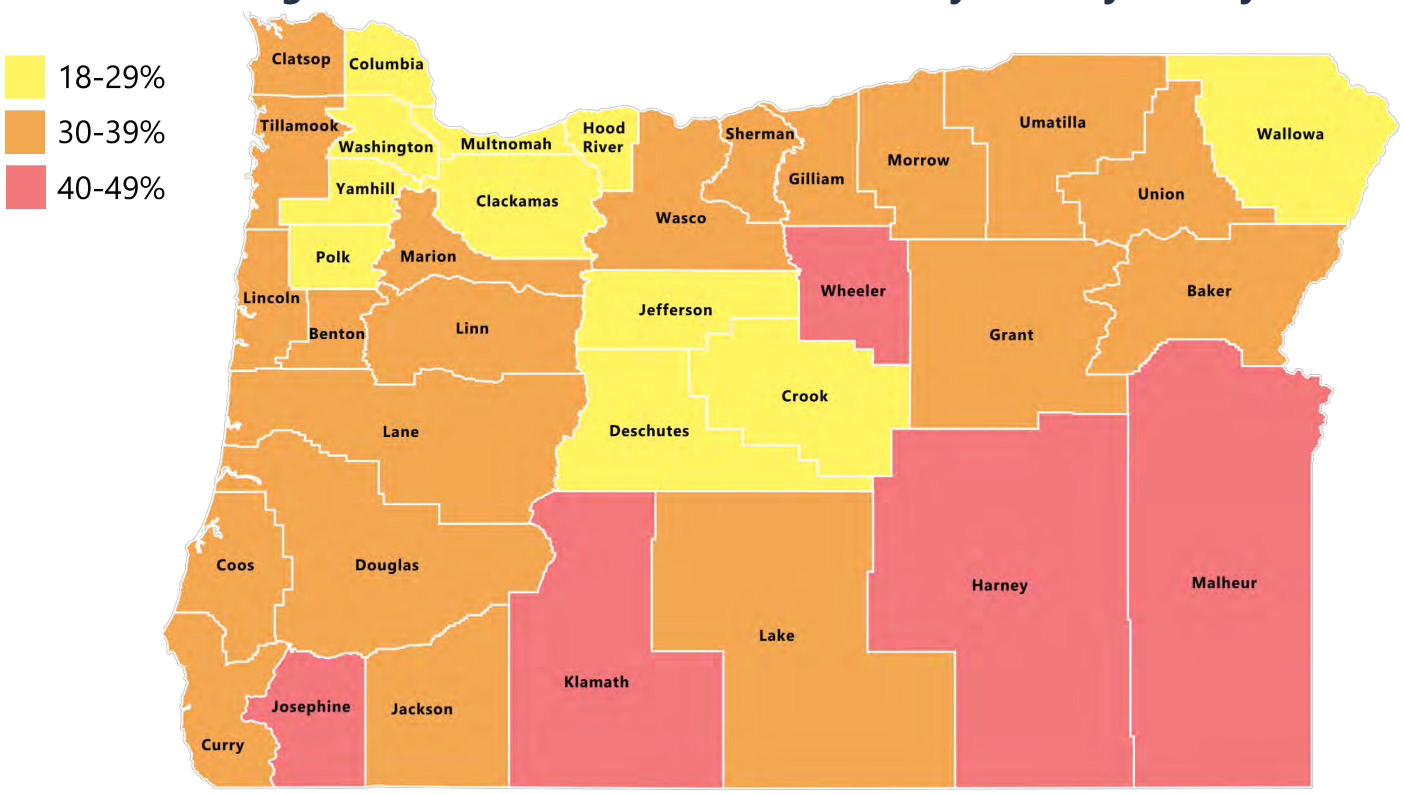
Percentage of all Oregon households that were energy burdened in 2022,[5] a 2% increase from 2020.

Percentage of Oregon Households Experiencing High or Severe Energy Burden and Earning 200 Percent or Below Federal Poverty Level by County[8]



The Oregon energy burden map shows how each county compares in energy burden among very low-income Oregonians. The prevalence of higher energy burden in places outside metropolitan areas shows that many rural Oregonians spend a high percentage of their income on energy. This is in part because there is an increased cost for providing energy services and commodities for consumers in more remote parts of the state, including the costs to deliver fuels to rural areas or to maintain infrastructure such as electricity distribution lines over longer distances.

Transportation burden represents the total annual transportation costs of households in comparison to income of the household.[9] Similar to electricity and heating costs, rural Oregonians have a higher degree of transportation burden than more urban and suburban areas of the state, in part because they have to travel farther distances.

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 2022 and provides more information on transportation energy burden by town: htaindex.cnt.org/map/

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

Energy Costs for Oregonians

Price swings for petroleum products and rate increases for some electric utilities have contributed to a rapidly changing economic situation that is challenging for all Oregonians — but especially for low-income households.

The 2022 BER discussed challenges for Oregonians posed by worldwide events. As the state worked to recover from the COVID-19 Pandemic, heatwaves, and effects from the wars abroad over the last two years, the price of energy and goods has continued to increase. Previously there were downward trends in the percent of Oregon households experiencing energy burden, but those trends have shifted, and more families are now experiencing energy burden than at the peak of the pandemic.[8]

Recent filings at the Oregon PUC indicate that electric utility disconnections in 2024 are on the rise. Utility disconnections are an indicator of energy affordability.[10]

Learn more about what drives electricity rates in the Energy 101 section of this report.

Oregon County Profiles

Oregon county profiles are a compilation of demographic, economic, and geographical datasets representing Oregon's 36 counties. The profiles aim to highlight aspects of each county's economic status and provide a focused perspective on the diverse communities in the state.

The profiles have been updated with data from 2022[X] and include the following categories:

County Characteristics[13]

Many characteristics can influence county-level energy consumption, including county area (total acreage), location, population, number of households, median household income, and the county's diversity index.

Poverty & Energy Burden[14 15]

The county profiles assess the economic impact, home energy burden, and annual energy burden gap of county residents. Home energy burden is the percentage of household income dedicated to home energy bills. If a household spends more than 6 percent of their total income on energy costs, it is considered burdened. The energy affordability gap is the difference between a household's actual energy costs and an "affordable" energy burden equal to 6 percent of the household's income.[13]

Homes[13]

The residential sector contains new, existing, and vintage constructions, with home energy use varying significantly depending on the type and size of the home.[14] Accounting for factors such as the age of residences, type and size of residences, and type of ownership aids in understanding the energy needs of Oregonians.

Energy[16 17]

Energy use represents the direct use of energy resources within each county. These data demonstrate the amount of energy consumed by county residents and include the average annual residential electricity use and cost, average annual residential natural gas use and cost, and the average cost of these as a percent of a typical income for that county.

Home Primary Heating[13]

Home heating evaluates the primary heating resources used by residents within the county. Heating systems vary depending on the energy source and the device that produces the heat. Heating systems can vary depending on current needs and the energy resources available; however, most heating systems are categorized as natural gas, electricity, propane, wood, and fuel oil.

Travel[17]

The transportation and travel section accounts for the transportation burden of county residents. Information in this section includes average vehicle miles traveled per household; the fuel, maintenance, and repair costs associated with that VMT; VMT costs as a percent of typical income; and VMT as a percentage of 200 percent the federal poverty level income.[15]

[X] This is the most recent available data; profiles do not reflect recent changes in energy rates and their effect on customers.

Profiles

Included here are three county profiles that provide diverse examples of the energy, demographic, economic, and geographic factors of Oregon communities. Profiles of all 36 counties are available online.

SCAN OR CLICK

Multnomah County

County Seat: Portland

Area (Total Land Acres)	275,941
Total Population (2022)	787,437
Diversity Index[xi]	54%
Number of Households	343,370
Median Household Income (2022)	$83,668

Poverty and Energy Burden

Energy Burdened Households	93,395
Federal Poverty Level (Family of 3)	$23,030
200% Federal Poverty Level	$46,060
Annual Energy Burden Gap	$493

Homes

Homes Built Before 1990	70%
Owner-Occupied Homes	55%
Renter-Occupied Homes	46%

Energy

Average Annual Residential Electricity (kWh)	9,991
Average Annual Electricity Cost	$1,363
Average Annual Residential Natural Gas Therms	663
Average Annual Natural Gas Cost	$777
Electricity and Natural Gas Average Costs (Percent of Typical Income)	3%

Primary Home Heating

Electricity	48%
Natural Gas	47%
Propane	1%
Wood	1%
Fuel Oil	2%

Travel

Average Annual Vehicle Miles Traveled (VMT) Per Household	13,609
Annual VMT Cost (Fuel, Maintenance, Repairs)	$2,102
VMT Cost as Percent of Regional Typical Income	3%
VMT as Percent of 200% Federal Poverty Level Income	5%

[xi] The diversity index is a measurement that describes how diverse a population is by calculating the probability that two people chosen at random will be from different race and ethnicity groups. This metric considers all of the race and ethnicity data selection options collected in the U.S. Census and is updated every 10 years.

Grant County

County Seat: Canyon City

Area (Total Land Acres)	2,897,783
Total Population (2022)	7,034
Diversity Index	21%
Number of Households	3,368
Median Household Income (2022)	$56,045

Poverty and Energy Burden

Energy Burdened Households	1,084
Federal Poverty Level (Family of 3)	$23,030
200% Federal Poverty Level	$46,060
Annual Energy Burden Gap	$1,180

Homes

Homes Built Before 1990	76%
Owner-Occupied Homes	78%
Renter-Occupied Homes	22%

Energy

Average Annual Residential Electricity (kWh)	12,536
Average Annual Electricity Cost	$1,261
Average Annual Residential Natural Gas Therms	N/A[xii]
Average Annual Natural Gas Cost	N/A[xii]
Electricity and Natural Gas Average Costs (Percent of Typical Income)	2%

Primary Home Heating

Electricity	30%
Natural Gas	1%
Propane	5%
Wood	43%
Fuel Oil	20%

Travel

Average Annual Vehicle Miles Traveled (VMT) Per Household	22,882
Annual VMT Cost (Fuel, Maintenance, Repairs)	$3,532
VMT Cost as Percent of Regional Typical Income	6%
VMT as Percent of 200% Federal Poverty Level Income	8%

[xii] A data discrepancy exists for these data points. The U.S. Census Bureau data indicate 0.7 percent of Grant County residents use natural gas, but Oregon Public Utility Commission data indicate no costs for natural gas in Grant County.

Klamath County

County Seat: Klamath Falls

Area (Total Land Acres)	3,807,981
Total Population (2022)	68,319
Diversity Index	42%
Number of Households	28,186
Median Household Income (2022)	$57,219

Poverty and Energy Burden

Energy Burdened Households	11,855
Federal Poverty Level (Family of 3)	$23,030
200% Federal Poverty Level	$46,060
Annual Energy Burden Gap	$787

Homes

Homes Built Before 1990	69%
Owner-Occupied Homes	67%
Renter-Occupied Homes	33%

Energy

Average Annual Residential Electricity (kWh)	11,434
Average Annual Electricity Cost	$1,227
Average Annual Residential Natural Gas Therms	567
Average Annual Natural Gas Cost	$860
Electricity and Natural Gas Average Costs (Percent of Typical Income)	4%

Primary Home Heating

Electricity	34%
Natural Gas	42%
Propane	3%
Wood	13%
Fuel Oil	4%

Travel

Average Annual Vehicle Miles Traveled (VMT) Per Household	18,663
Annual VMT Cost (Fuel, Maintenance, Repairs)	$2,881
VMT Cost as Percent of Regional Typical Income	5%
VMT as Percent of 200% Federal Poverty Level Income	6%

2023 Oregon Cooling Needs Study

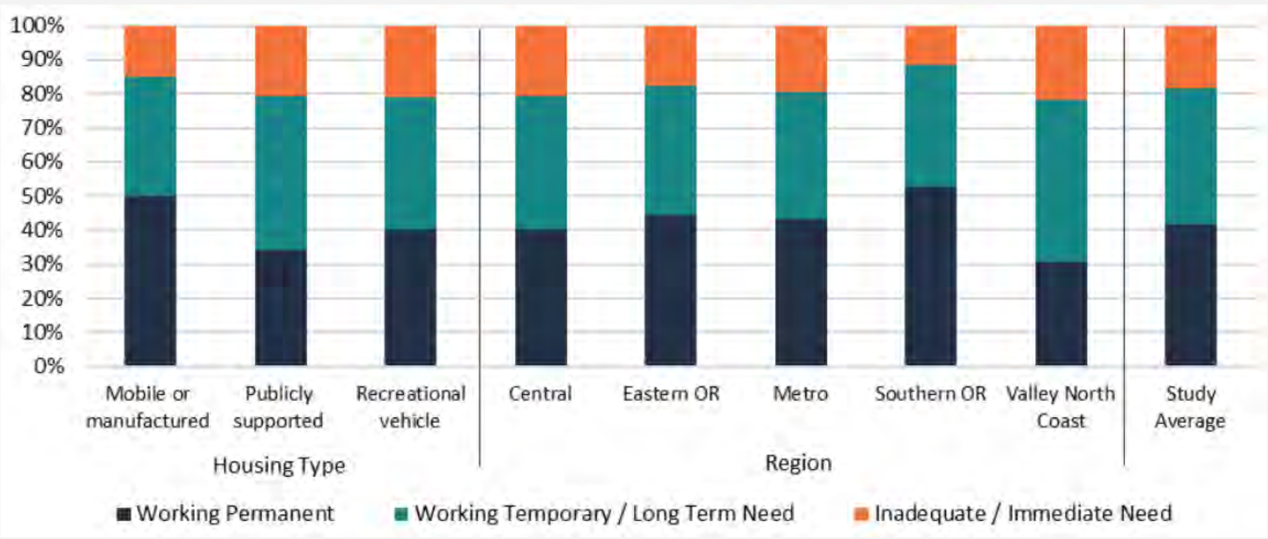
SB 1536 directed the Oregon Department of Energy to conduct a cooling needs study, which the agency published in December 2023.

Following the 2021 heat dome event, during which at least 100 Oregonians died of heat-related illnesses – often in their own homes – the Oregon Legislature directed the Oregon Department of Energy to report on the cooling needs of Oregon households that live in the housing types most vulnerable to heat. The study focused on publicly supported housing, manufactured and mobile homes, RVs being used as housing, and employer-provided agricultural workforce housing.

The study found that:

- Many Oregonians do not have adequate cooling equipment, including 58 percent of residents living in the housing types surveyed.
- The estimated total cost to provide the health and safety baseline level of cooling equipment to avoid the worst effects of extreme heat events is $604,400,000.
- The estimated total cost to provide comprehensive cooling (permanently installed equipment to properly cool the full living space in each housing unit) is $1,082,700,000.
- The average county heat vulnerability index is 57 (out of 100). The counties with the highest heat vulnerability are Morrow (68), Multnomah (68), Malheur (67), Marion (64), Umatilla (62), and Wheeler (61).
- The study also identified social and economic barriers residents face in accessing existing resources and found that only 22 percent of surveyed individuals have used existing cooling, weatherization, or utility bill assistance programs.
- The figure below illustrates the immediate and long-term cooling needs as projected by housing type and region. It does not include ag housing.

Cooling Needs by Housing Type and Region in Oregon



Energy Jobs

91,769

Number of Oregonians employed in the energy industry in 2022.[11]

Oregonians hold many different types of jobs in the energy industry — from energy utility workers to wind turbine technicians to heating, ventilation, and air conditioning (HVAC) 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 and renewable heating and cooling firms, in addition to other specialized areas. 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 plug in hybrid, battery electric and hydrogen fuel cell vehicles for all industries, from large-scale industrial vehicles to small recreational vehicles such as golf carts.

Number of Energy Jobs in Oregon by Type (2020, 2022)[11]

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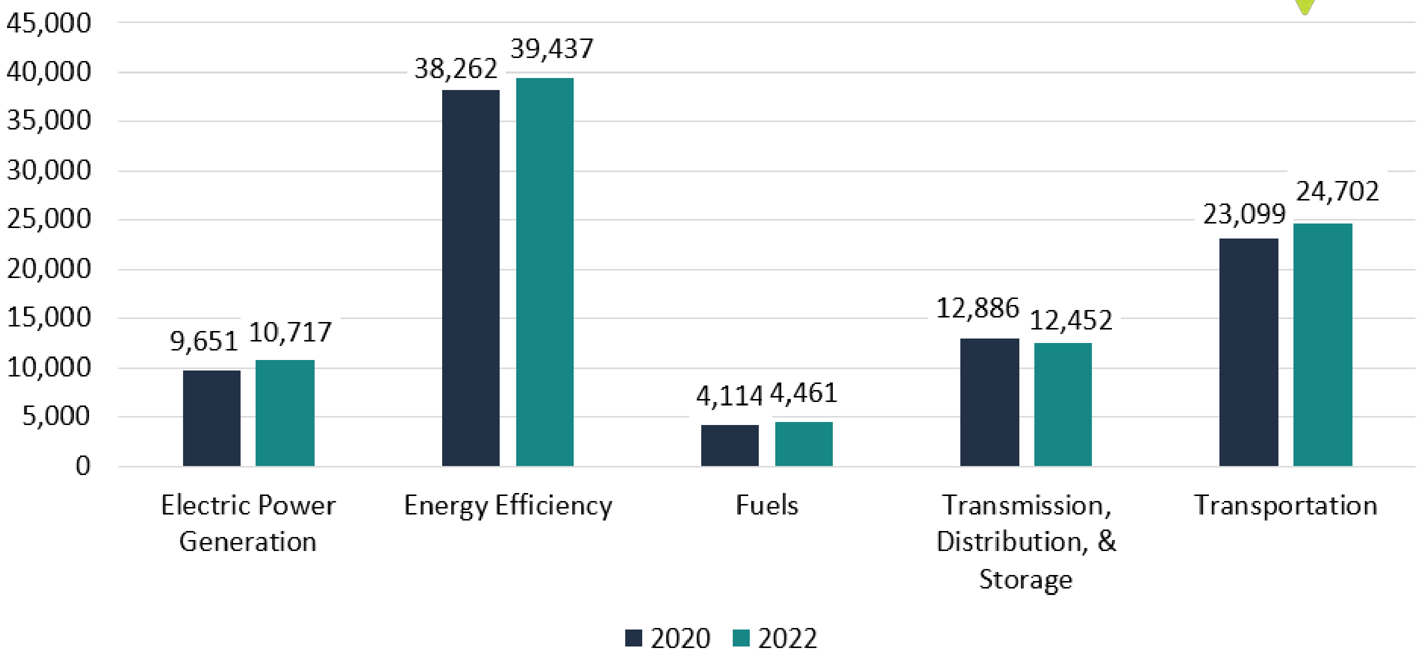


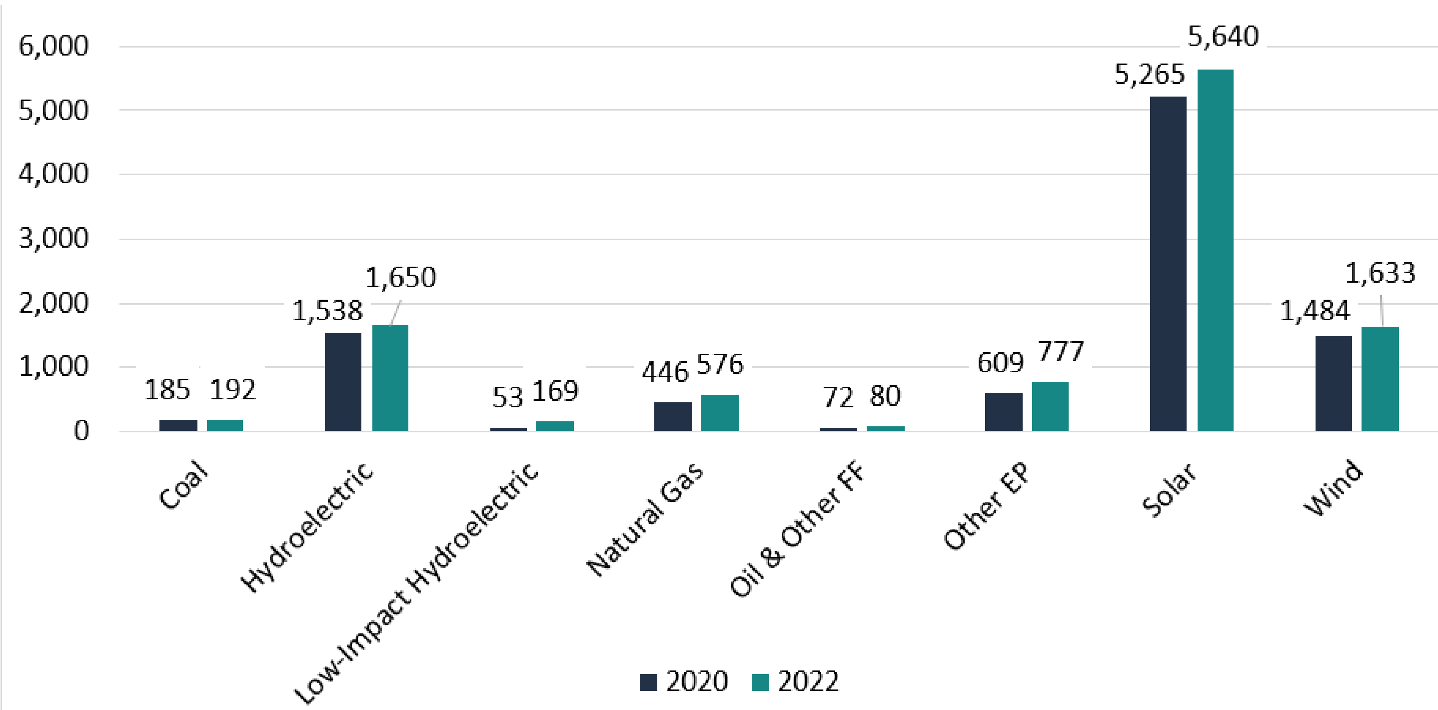
Building Oregon's Energy Workforce

With unprecedented federal funding from the 2021 Infrastructure Investments & Jobs Act and 2022 Inflation Reduction Act comes support for building a clean energy workforce. As programs supporting energy efficiency and renewable energy projects come online in Oregon — such as the Solar for All program and Home Energy Rebates — the state will need the workforce to complete these projects. The Oregon Department of Energy and our partners will be rolling out programs to support workforce development and training, including for disadvantaged communities as defined by Justice40.

SCAN OR CLICK

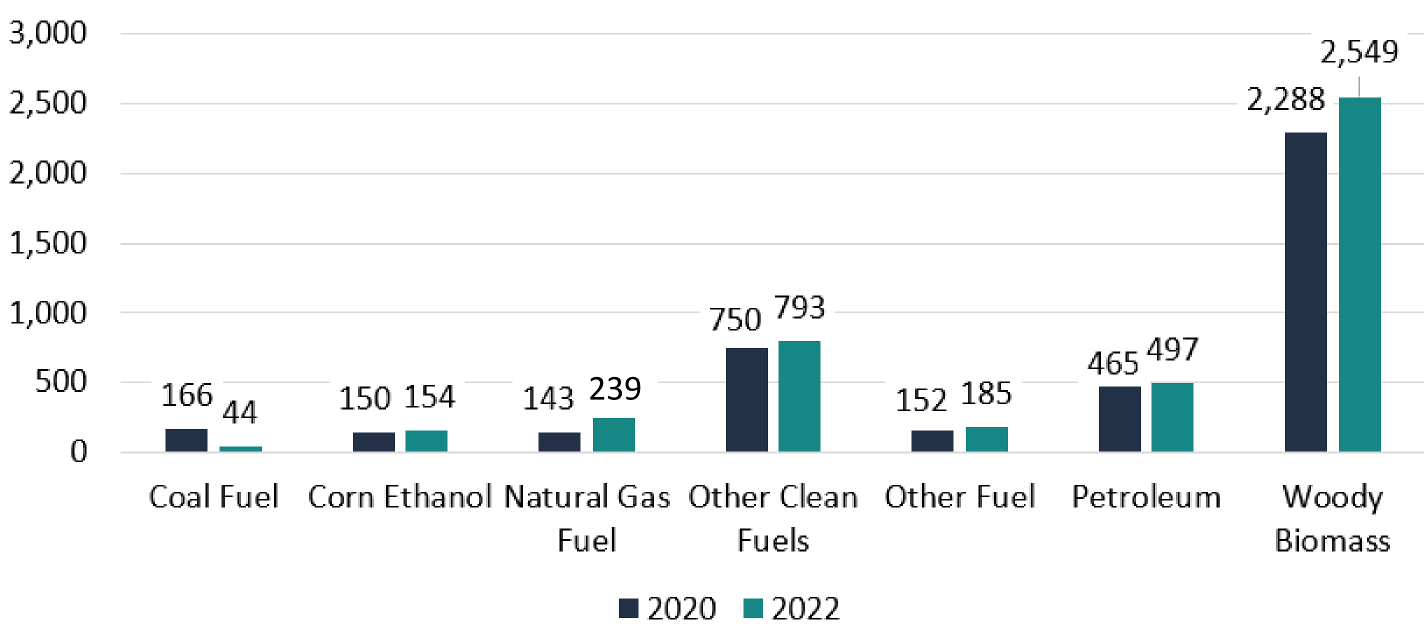
The electric power generation sector in Oregon employed 10,717 workers in 2022, an increase of 1,066 jobs from 2020.[11] In 2022, there were 5,640 solar jobs in Oregon – 375 more than 2020. The solar industry has rapidly expanded since the early 2000s due to many factors, including solar potential, incentive programs, and clean energy policies in the state. In 2022, hydroelectric generation and wind energy provided 1,650 and 1,633 jobs, representing gains of 112 and 149 jobs from 2020.

Electric Power Generation Jobs in Oregon by Technology (2020 and 2022)[11]



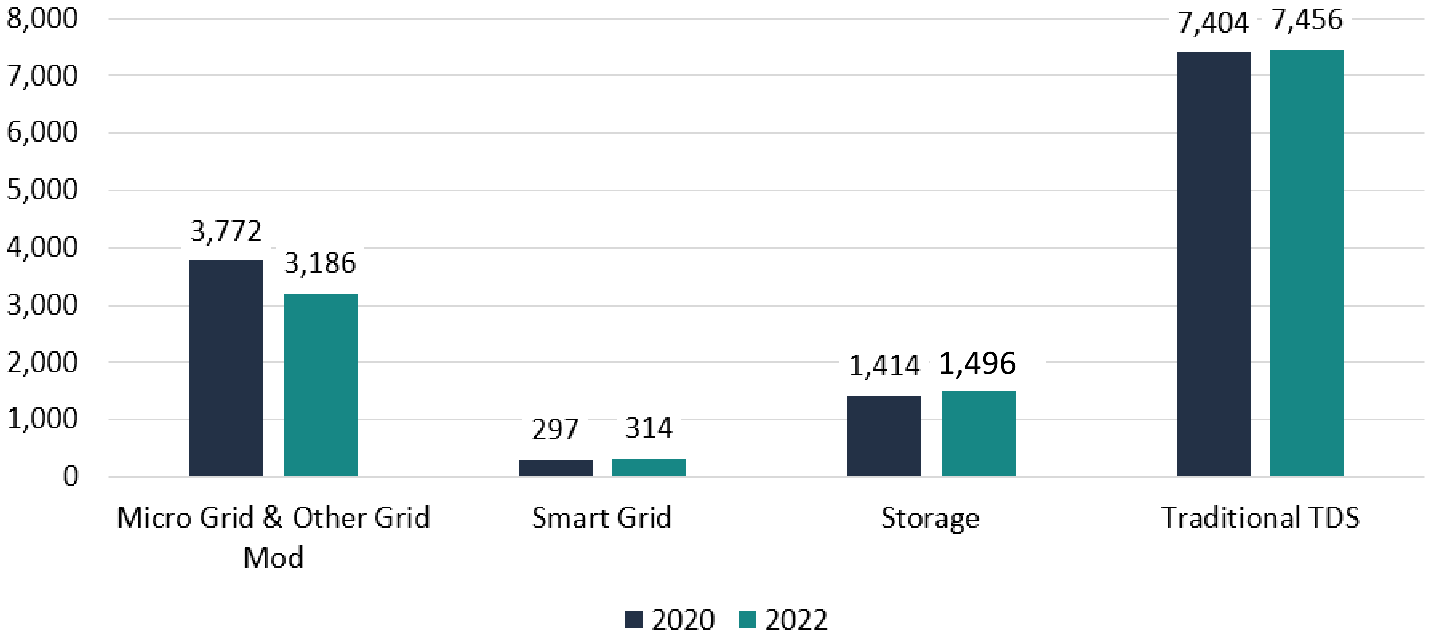
The fuels sector in Oregon employed 4,461 workers in 2022, 347 more than 2020.[11] More than half, or 2,549, of those fuel jobs are related to woody biomass.

Fuels Jobs in Oregon by Resource (2020 and 2022)[11]



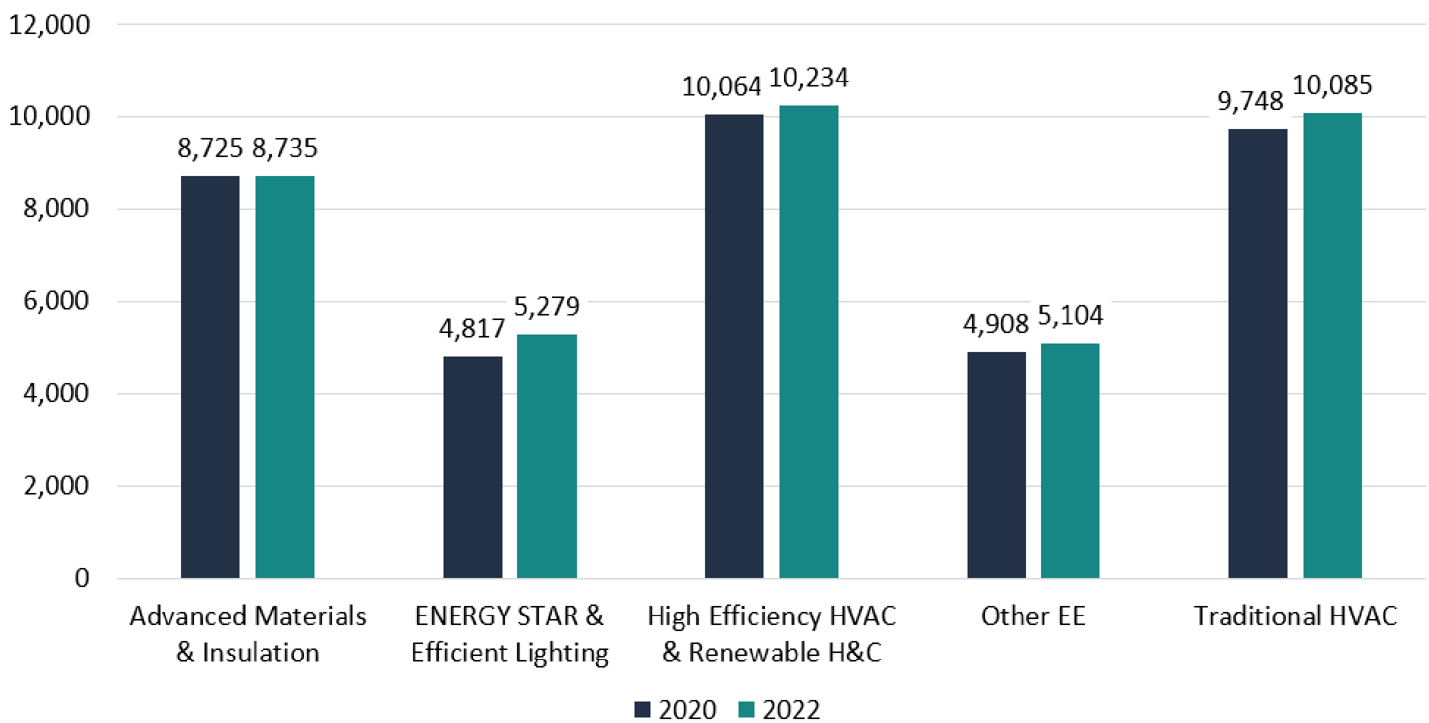
The transmission, distribution, and storage sector in Oregon employed 12,452 workers in 2022, a decrease of 434 jobs from 2020.[11]

Transmission, Distribution, and Storage Jobs in Oregon (2020 and 2022)[11]



The energy efficiency sector in Oregon employed 39,437 workers in 2022, up 1,175 jobs from 2020.[11]

Energy Efficiency Jobs in Oregon by Technology (2020 and 2022)[11]



Energy Efficiency Workforce Statistics

Oregon's energy future will need more people trained in energy efficiency jobs. Traditionally, many of the energy jobs that have been an area of focus have been lineworkers, power plant workers, workers in the renewable energy sector, and solar installers. A healthy workforce of trained HVAC installers/maintenance workers, electricians, plumbers, and building envelope professionals is needed to meet energy efficiency standards for state and federal building codes. They also will support consumer efforts to reduce energy consumption and their climate footprint through energy efficient upgrades in homes and businesses. Energy efficiency standards help Oregon address the 34 percent of greenhouse gas emissions that are produced by the built environment.

Meeting this growing demand means Oregon needs a construction workforce trained in the installation of energy efficient technologies. According to data from the Oregon Employment Department, construction jobs are projected to increase 15.1 percent by 2032, while an expected 85 percent of the current workforce will retire. More support is needed for training programs to fill the approximately 113,936 construction jobs that will be vacant by 2032.[12]

Employment in the categories of *High Efficiency & Renewable Heating & Cooling* and *Traditional HVAC* both grew from 2020 and account for more than half of the energy efficiency sector jobs in Oregon in 2022. *Traditional HVAC* companies are companies where more than 50 percent of installations are not considered high efficiency. *High Efficiency & Renewable Heating & Cooling* indicates businesses where more than 50 percent of installations performed are considered high efficiency, such as heat pumps.

Energy Efficiency

Oregon's Second Largest Resource

11th

Oregon's 2022 rank among U.S. states for energy efficiency by the American Council for an Energy Efficient Economy.[2]

Energy efficiency, the use of less energy to perform the same task or produce the same result, plays a critical role in Oregon.[1] 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 provided about 7,678 average megawatts of savings through efficiency programs and improvements.[1] That's more electricity than the whole state of Oregon uses in a year.

In 2010, Oregon's per capita energy use was 204.9 million Btu. By 2022 it dropped to 202.4 million Btu, despite the state's population growing by a half million people to 4.3 million (up from 3.8 million in 2010). One reason for the drop is energy efficiency. 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, Bonneville Power Administration, and other non-governmental organizations. Of the region's cumulative savings, 59 percent comes from utility and Bonneville Power Administration programs.[1] Energy efficiency gains are cumulative and continue paying dividends for the region over time.

While Oregon has long remained in the American Council for an Energy Efficient Economy's (ACEEE) top ten ranking, the state fell to eleventh place in 2022. This was largely due to other states building momentum in the efficiency space, lower relative costs of renewable energy technologies, and fewer investments in energy efficiency programs.

New Home Energy Rebates Coming to Oregon Homes

In October 2024, The Oregon Department of Energy was awarded over $113 million from the U.S. Department of Energy for two new home energy rebate programs that will provide financial incentives to single-family and multifamily households for eligible high-efficiency home improvements, appliances, and equipment.

The Home Efficiency Rebate Program (also known as HOMES) will provide performance-based rebates for energy efficiency retrofits in single-family and multifamily homes. This can include installing more efficient equipment like a heat pump or on-demand water heater, weatherization measures like insulation or air sealing, smart thermostats, and more. HOMES rebates will be issued for projects that can provide at least 20 percent estimated energy savings, with higher incentives available for projects that could save 35 percent or more. The Home Electrification and Appliance Rebate Program (also known as HEAR) will provide point-of-sale rebates to low- and moderate-income households to install eligible high-efficiency electric appliances and associated upgrades, as well as insulation and air sealing measures.

ODOE is working on the programs' design and start procuring and developing the program guidance, technology systems, coordinating agreements, and other materials necessary to launch two effective and well-run programs. ODOE expects that rebates will be available in late 2025 or early 2026.

Oregon Electricity Savings

7,678

Average megawatts of regional electricity savings from energy efficiency (1978-2022).[1]

2,303

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Average megawatts of Oregon electricity savings from energy efficiency (1978-2022).[3]

The Northwest Power & Conservation Council's 2021 Northwest Power Plan, published in March 2022, concluded that cost-effective energy efficiency could meet a large amount of new load growth in the region – enabling Oregon's economy to grow while reducing the need for new electricity resources. The plan called on the region to develop new energy efficiency programs equivalent to acquiring 2,400 average megawatts of power by the end of 2041.[3] Integrated Resource Plans from Oregon's large electric utilities also include energy efficiency as a key strategy to manage demand over their planning horizons. More recent analysis indicates that the rate of load growth is increasing. The 2024 update to the Pacific Northwest Utilities Conference Committee's Northwest Regional Forecast projects "electricity consumption could increase from about 23,700 aMW in 2024 to about 31,100 aMW in 2033 (an increase of 7,400 aMW). This is an over 30 percent in electricity demand over the next 10 years."[4]

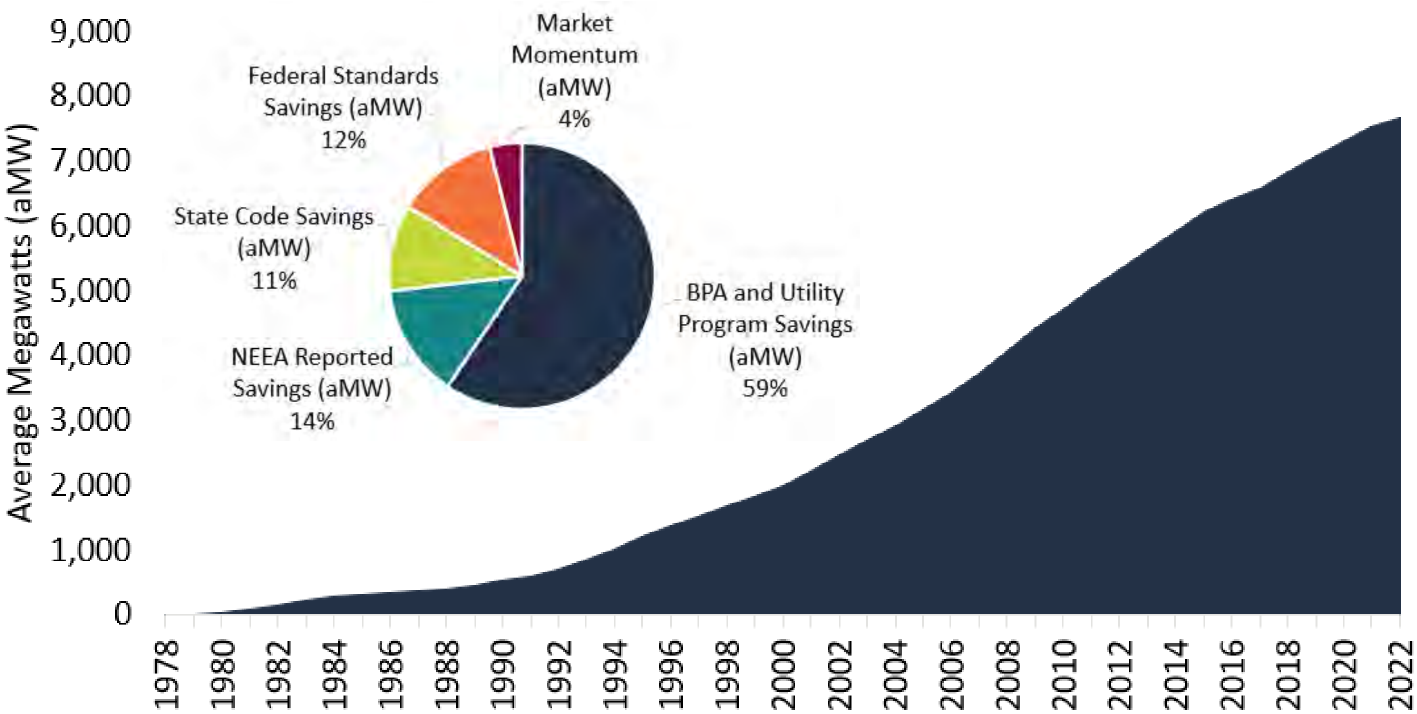
The Regional Conservation Progress Report to the Northwest Power and Conservation Council in October 2023 affirmed the targets set in the 2021 Plan, and noted that the region exceeded the savings achievement target for 2021.[1] Program expenditures have been flat to declining over the last seven years, and the cost of savings has been increasing from $2 per aMW in 2016 to $2.75 per aMW in 2020.[3] The price to achieve energy savings is increasing for utilities as the lower cost, higher savings measures (such as lighting upgrades) hit saturation in the existing building stock, and the remaining measures cost more to achieve the same amount of savings.

Oregon Electricity Savings & Estimated Share of Seventh Power Plan Goal (aMW)[3]

	2016	2017	2018	2019	2020	2021	2022
Energy Trust of Oregon	58.4	62.2	50.0	51.8	39.9	39.9	40.9
BPA	9.3	5.7	8.1	8.9	3.9	4.9	5.8
COU Utility Self-Funded	1.1	0.6	2.6	3.3	0.3	0.3	0.1
NEEA	9.1	8.1	12.9	17.3	14.7	15.5	3.4
Codes and Standards	0.0	0.5	1.9	2.4	3.4	4.1	0.8
Momentum	-1.0	-0.9	12.6	12.9	14.6	10.8	0.0
Market Adjustment	-19.4	-18.7	-12.3	-11.4	-8.0	-7.4	0.0
Total Oregon Savings	57.53	57.50	75.79	85.27	68.62	68.16	50.96
Estimated Oregon Share of Goal	56	56	69	69	86	86	27

The regional savings achievements reported by the NWPCC can be split into state goals and achievements. The split is based on the Oregon percentage of the regional market and is not exact since each state does not set independent efficiency goals — rather, the region and each utility set goals. The previous chart shows how Oregon energy efficiency achievement has varied over the last 7 years. The annual goals are shown in the orange line. After two years of the region not meeting its goals – due to several factors, including increasing cost of energy efficiency measures without increasing investments – the 2022 goal was lowered, and the region was able to exceed it. The table included with the chart indicate the amount of energy savings attributed to specific programs or mechanisms.

NWPCC Cumulative Regional Energy Efficiency Savings (Chart) and Share of Cumulative Savings (Pie) by Mechanism[5]



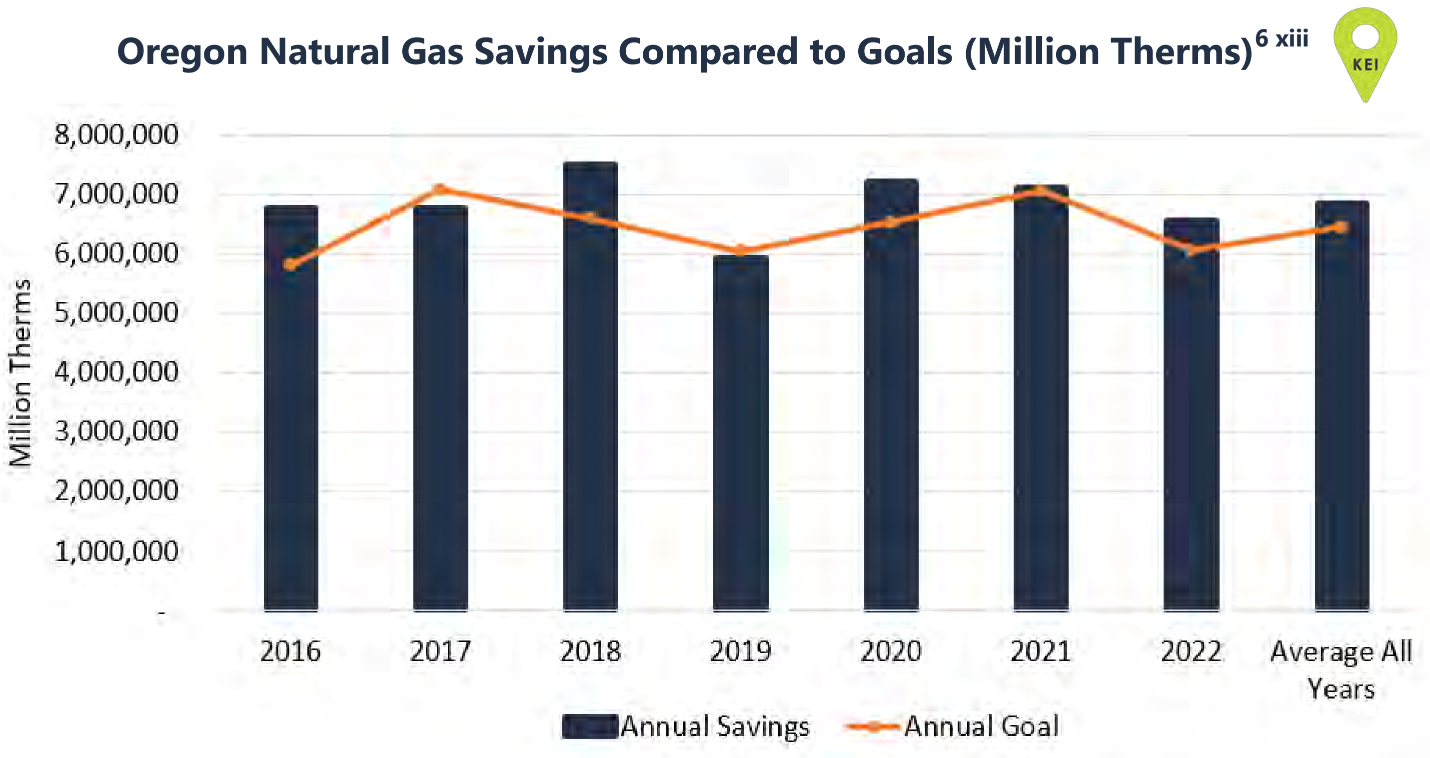
The figure above shows cumulative regional energy efficiency savings since 1978. Savings are shown cumulatively because each measure continues to provide efficiency savings over the life of the equipment. The pie chart indicates how each program or mechanism contributed to the savings over the entire time frame from 1978 through 2022. Federal standards include federal appliance and equipment efficiency standard programs such as Energy Star. States in the region set building codes, efficiency codes, and may set additional standards for appliances and equipment that are not included in the Federal standards. The Northwest Energy Efficiency Alliance supports building code and energy efficiency standard work in the region and implements market transformation programs that seek to remove market barriers to energy efficiency and drive permanent change through the supply chain. Market momentum is an estimate of additional energy savings attributed to the changing market. The largest slice of energy saving contributions is the utility programs shown in dark blue; this is inclusive of all local utility programs and the regional Bonneville Power Administration programs in which some local utilities participate.

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 through 2022.[6] Energy Trust of Oregon implements energy efficiency programs for the state's natural gas utilities. Programs are funded by customer rates, and cost effectiveness tests of natural gas measures ensure that efficiency investments cost less than building new natural gas infrastructure.

For more about cost-effectiveness, see ODOE's 2022 Policy Brief on Co-Benefits of Energy Efficiency.

Oregon Natural Gas Savings Compared to Goals (Million Therms)[6 xiii]



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**

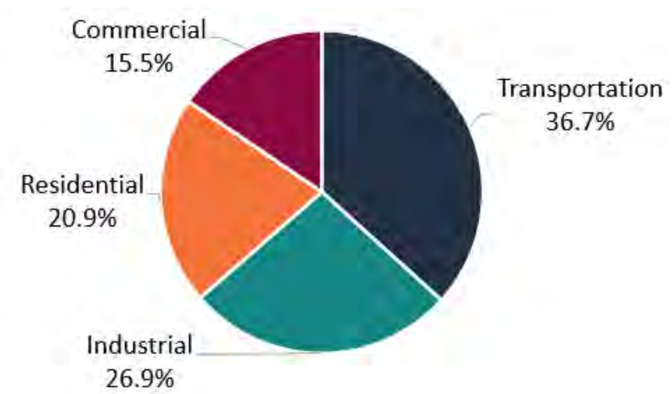
[xiii] A therm is a unit of measurement describing the amount of heat, or energy content, in a unit of natural gas.

Energy End Use Sectors

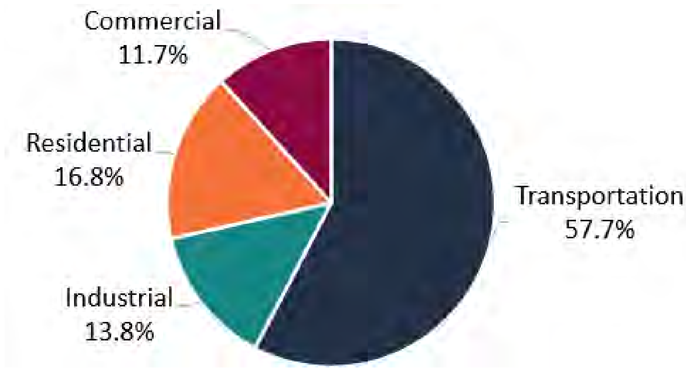
Consumption

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 2022, transportation accounted for 36.7 percent of energy consumption and 57.7 percent of expenditures due to the higher per-unit cost of transportation fuels. The industrial sector used 26.9 percent of the total energy but accounted for only 13.8 percent of expenditures due to lower per-unit costs relative to the other sectors.[1] Industrial users can buy some types of energy in bulk or are large users and in some cases have different (lower) rates.

Oregon Consumption by End-Use Sector (2022)[1 2]

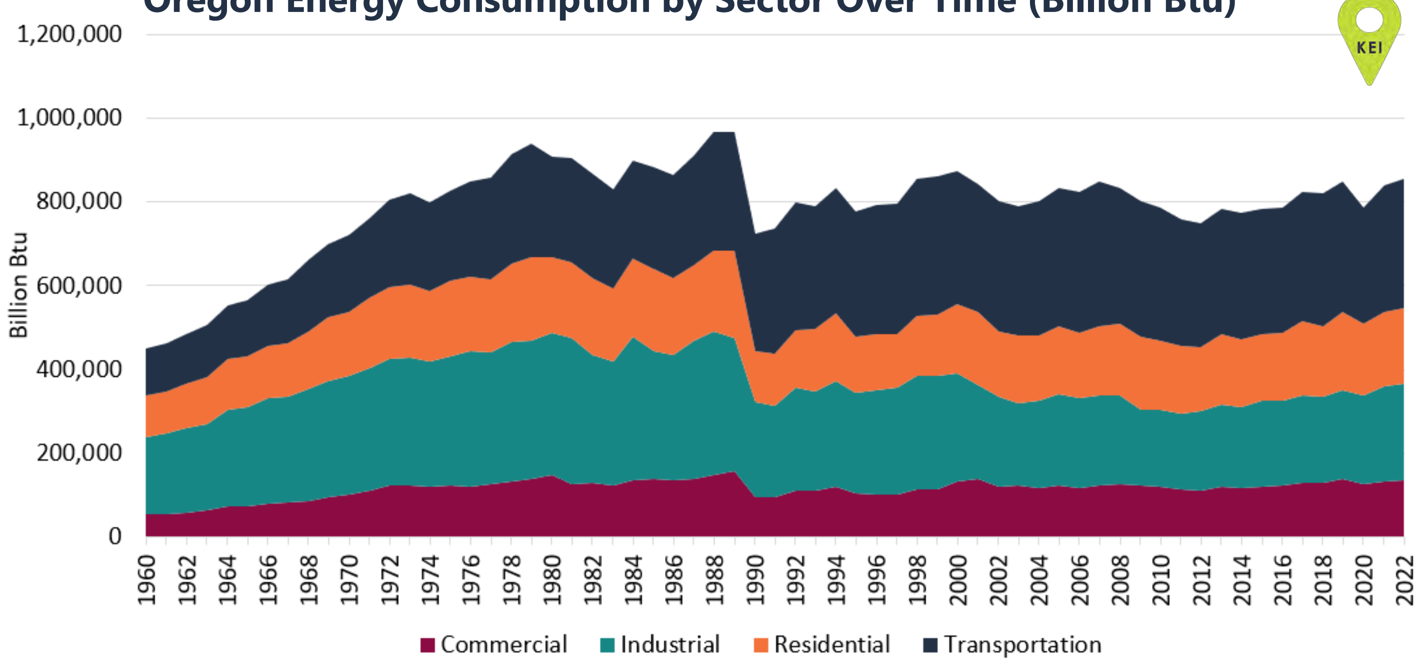


Oregon Expenditures by End-Use Sector (2022)[2 3]



Energy consumption across all sectors has remained relatively steady over the last two decades. Increased population, GDP, and recently increased 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 relatively flat energy use shown in the figure below since the early 2000s.

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



[xiv] The EIA methodology change affects how primary energy is calculated for renewables. See the About the Data section for more.

Expenditures

$4,594

Oregon per capita energy expenditures in 2022. The amount has increased by 61% since 2020.[3]

40th

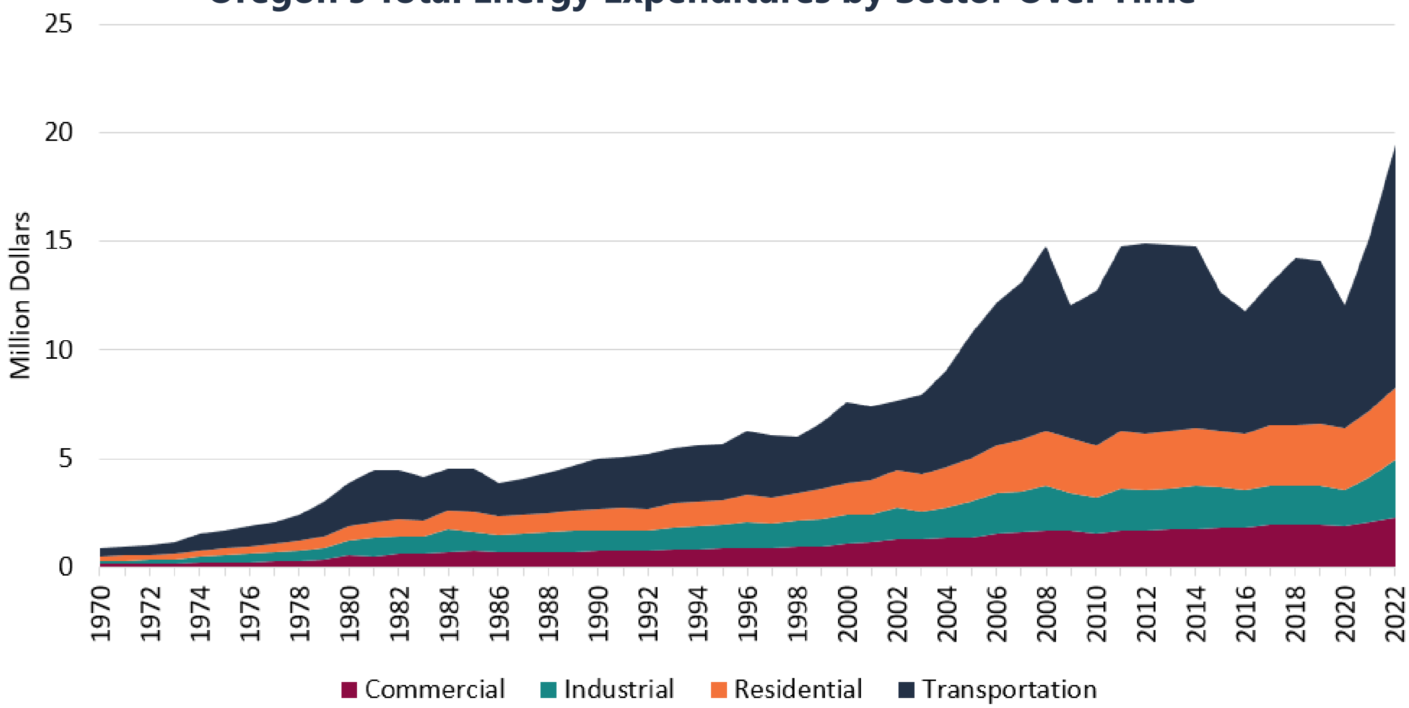
Oregon's national rank for per capita energy expenditures. 39 states spend more per capita.[3]

Oregonians' 2022 energy expenditures can be separated by sector. The transportation sector accounts for more than half of expenditures,[1] and because nearly all Oregon's transportation fuels are imported, most of this money goes to other states and countries.[3] While the residential, commercial, and industrial sectors have experienced gradual increases in spending through 2022, transportation sector expenditures reflect both increasing consumption and price volatility.

The variability in what Oregonians spend on energy is driven primarily by transportation fuel costs. The 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. This coincides with the start of the COVID-19 pandemic, which likely affected energy use and prices as individuals were not driving as much but transportation of goods increased.[1] In 2021 and 2022, expenditures increased from rising costs of energy in all sectors — with the sharpest increase in transportation.

Transportation sector expenditures are increasing due to more driving and higher prices on petroleum fuels since the pandemic low in 2020. Total vehicle miles traveled in Oregon have increased by 13.6 percent between 2020 and 2022.[4] At the same time, crude oil prices[xv] — the primary driver of the price of gasoline and diesel[5] — increased from an average closing price of $41.96 per barrel in 2020 to an average of $82.38 in the first three quarters of 2024.[6] This, coupled with smaller increases in electricity and natural gas costs, are driving overall higher energy costs in Oregon.

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/

[xv] Based on Brent crude oil prices, which are reflective of global crude oil prices

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 annually collects and publishes data on GHG emissions in Oregon and creates a sector-based GHG emissions inventory. To illustrate recent emissions trends, this section includes preliminary 2022 inventory data from DEQ.[7]

GHG emissions can be categorized in multiple ways: by the productive use — for example, industrial heating — that creates emissions, by end-use within a sector, and by the source of the emissions. DEQ provides a mixture of these data categories. As a result, when analyzing the data, various methods of categorization can reveal new insights. In this section, the data are first presented based on end-use sector, then by source, and then by a combination of sector and source.

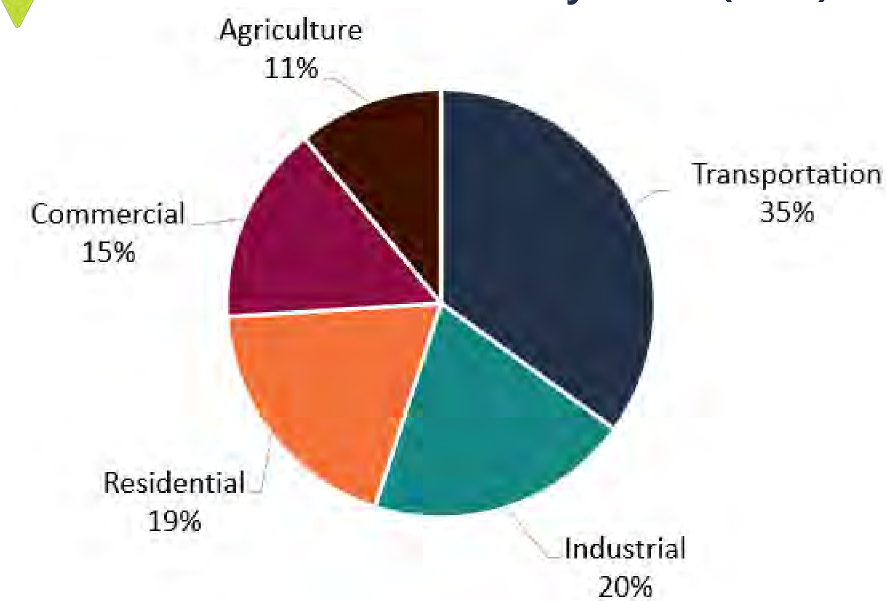
GHG Emissions by Sector

Most of Oregon's greenhouse gas emissions come from the production or use of energy. The state categorizes and reports GHG emissions for five end-use sectors — transportation, residential, commercial, industrial, and agriculture. (Note that in other sections of this report, agriculture is included in the industrial sector.) Oregon's sector-based GHG inventory reports annual emissions from each of these sectors.[7] Except where noted, the results presented here are based on preliminary 2022 inventory data from DEQ.

The chart at right summarizes sector emissions for 2022. Transportation is the largest source of sector emissions, contributing over a third of Oregon's total GHG emissions. The residential and industrial sectors each contribute about 20 percent of state emissions, and the commercial sector contributes 15 percent. Together, energy consumption makes up nearly 90 percent of Oregon's greenhouse gas emissions.

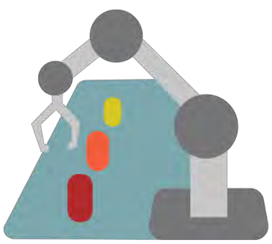
KEI

Greenhouse Gas Emissions by Sector (2022)[7]

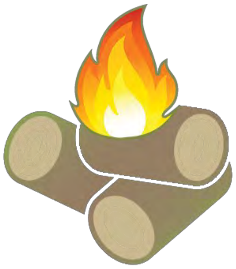


Transportation GHGs. Transportation is the state's largest source of sector-based GHG emissions. Transportation emissions primarily result from the direct combustion of petroleum products in on- and non-road vehicles (such as construction equipment, agricultural vehicles, and off-road recreational vehicles). About 55 percent of Oregon's transportation emissions are from gasoline combustion in passenger cars and other gas-powered vehicles, and about 33 percent are from medium- and heavy-duty diesel vehicles.[3]

Commercial & Residential GHGs. The largest sources of GHG emissions from the residential and commercial sectors include electricity generation, natural gas direct use, municipal landfills, commercial petroleum combustion, and wastewater treatment.



Industrial GHGs. The largest sources of industrial GHG emissions in Oregon are semiconductor manufacturing, natural gas distribution and production, and cement manufacturing.[7] The sector-based inventory includes industrial emissions from electricity generation, natural gas direct use, and petroleum combustion, in addition to GHG emissions from industrial processes unrelated to energy use.



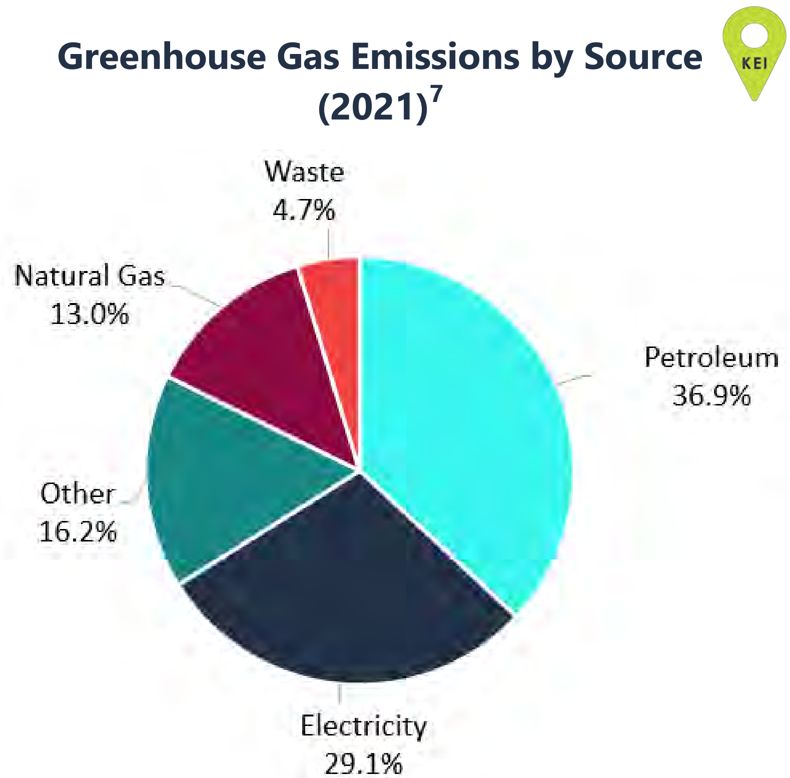
Agricultural GHGs. Oregon's sector-based GHG inventory tracks emissions from certain agricultural processes and waste products, including manure and other organic wastes, fertilizer application and soil management, and agricultural residue burning. The sector-based inventory exclusively tracks anthropogenic (*i.e.,* human-caused) emissions for the agricultural sector, which are primarily methane and nitrous oxide emissions from agricultural processes. Energy consumption, such as electricity and fuels used in this sector, are included in the transportation and industrial sectors.[7]

GHGs by Source

GHG emissions data can also be categorized by the direct source of emissions, which correlates with energy production and consumption processes that directly emit greenhouse gases. This includes petroleum combustion, electricity generation, and natural gas combustion, as well as emissions from waste production and treatment.

Source emissions data for GHG emissions was not available for 2022 at the time of publication, so the data presented here are through 2021. The combustion of petroleum products is the largest source of emissions at nearly 37 percent. Emissions resulting from generating electricity are the second largest source at 29 percent. Natural gas combustion, excluding natural gas used to generate electricity, accounts for 13 percent of source emissions.

Greenhouse Gas Emissions by Source (2021)[7]



Petroleum. Petroleum-derived fuels, including diesel, gasoline, and jet fuel, are primarily consumed by the transportation sector. Emissions from petroleum-fueled equipment used by the residential, commercial, and industrial sectors are also included in petroleum emissions.

Electricity. This accounts for electricity used in all sectors, which includes emissions from the 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, and others.

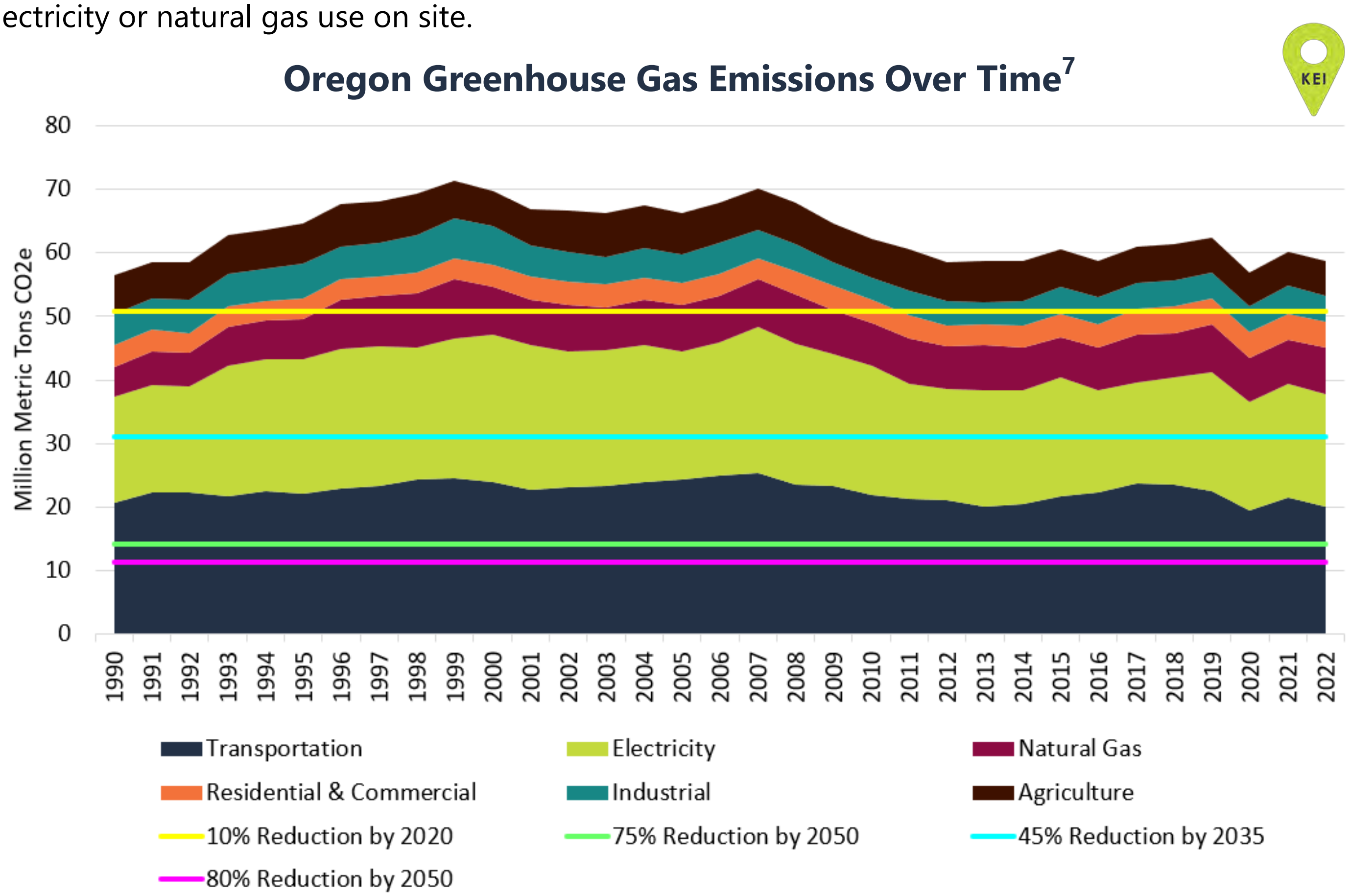
Waste. This includes treatment of waste products from the various sectors, including landfill waste and agricultural waste. Some of these emissions result from the combustion of waste.

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. It includes six emissions categories, including one for each of the sectors outlined earlier (residential and commercial are combined here), as well as ones for electricity and natural gas. Electricity and natural gas reflect source emissions, while the remaining categories are sector specific. As a result, the residential and commercial and the industrial source emissions in this chart do not include emissions associated with electricity or natural gas use on site.

Oregon Greenhouse Gas Emissions Over Time[7]



The Oregon Climate Action Commission[xvi] and others use DEQ's inventory to track progress toward the state's greenhouse gas reduction goals, including goals established in legislation and by executive order. The different goals are indicated by horizontal lines on the chart. Oregon did not achieve its goal of 10 percent below 1990 levels by 2020 (top yellow line).

In 2020, Executive Order 20-04 established updated goals to reduce GHG emissions to at least 45 percent below 1990 levels (light blue line) by 2050 and at least 80 percent below 1990 levels (pink line) by 2050. [8] The recent TIGHGER analysis done by ODOE for the Oregon Climate Action Commission found the state has the policies in place to achieve the 2035 goal if all adopted climate policies and programs are fully implemented.[9]

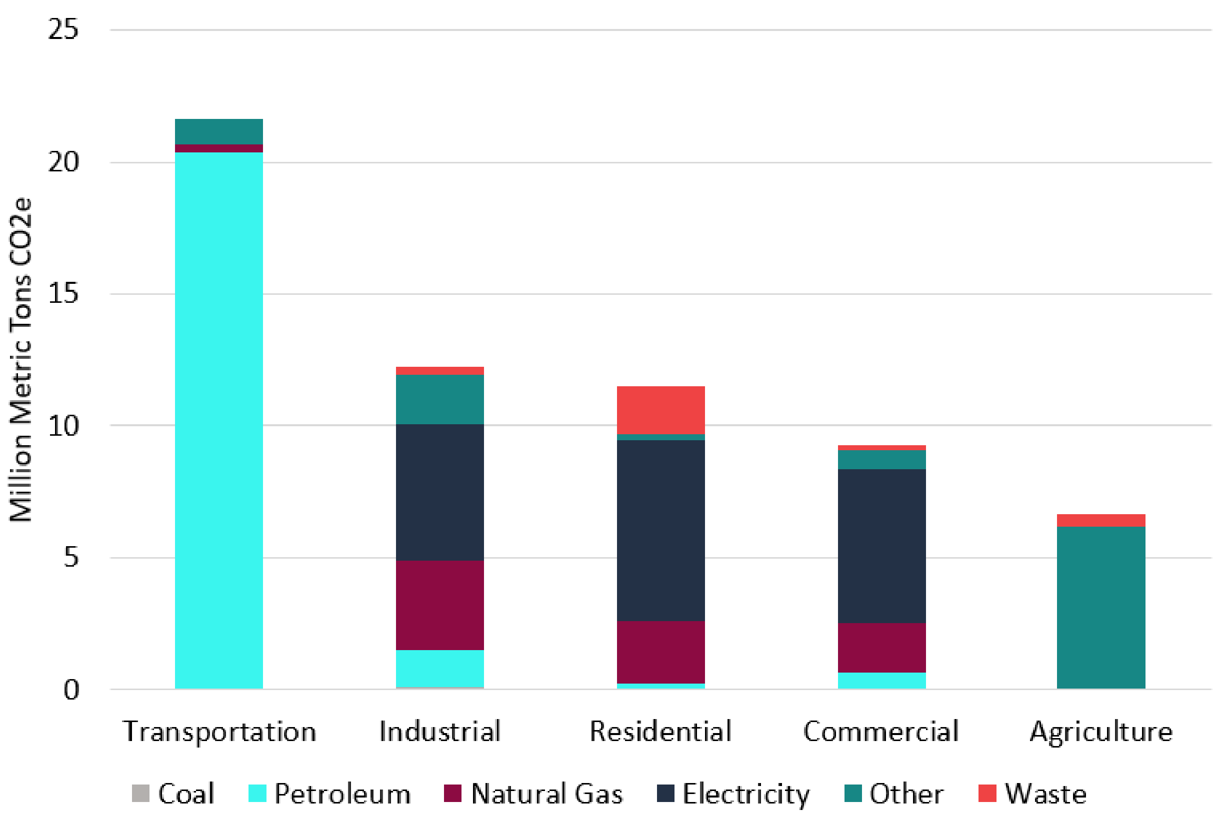
[xvi] Formerly known as the Oregon Global Warming Commission.

The Oregon Climate Roadmap to 2030

The Oregon Climate Action Commission's Transformational Integrated Greenhouse Gas Emissions Reduction (TIGHGER) analysis evaluated the emissions reductions anticipated from existing policies and identified additional actions to further reduce emissions while continuing to grow Oregon's economy. The TIGHGER analysis provided the foundation for the Commission's **Climate Roadmap to 2030**, which presented a list of actions and recommendations to inform state climate action and put Oregon on track to meet its GHG reduction goals. Learn more at **climate.oregon.gov/tighger**.

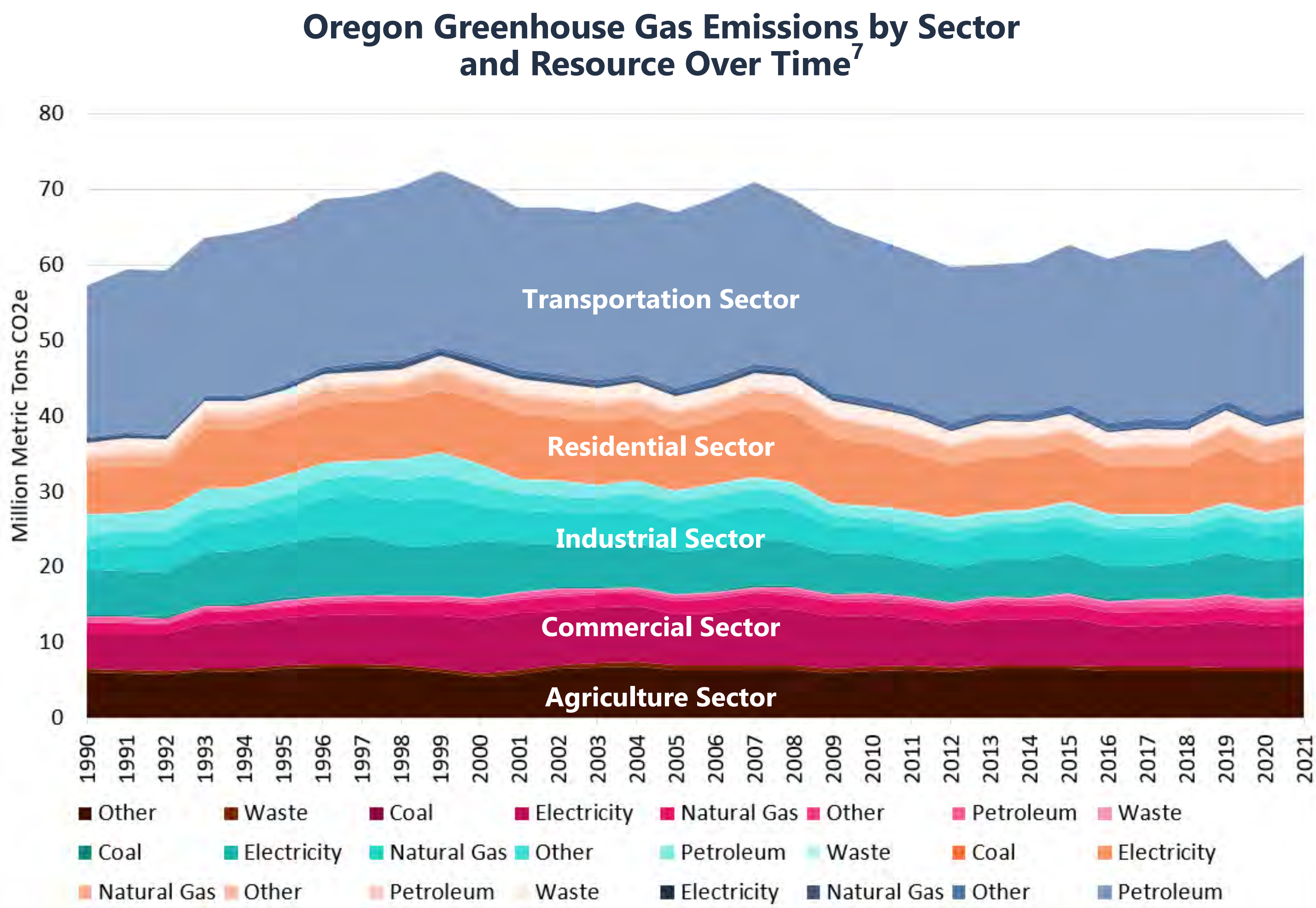
Using DEQ's Greenhouse Gas Inventory data, the chart below shows Oregon's 2021 emissions from the five GHG sectors, broken out into emissions by source within each sector. The light blue, dark blue, and dark red shades in the bar chart reflect energy-related emissions. Transportation emissions are largely driven (pun intended) by petroleum combustion shown in bright blue, while the residential, commercial, and industrial sector emissions largely come from electricity generation, followed by natural gas use. There is a small amount of coal still used in the industrial sector, shown in light gray at the bottom of its bar. The chart shows that energy use is the primary source of GHG emissions in Oregon.

Oregon Greenhouse Gas Emissions by Sector and Source (2021)[7]



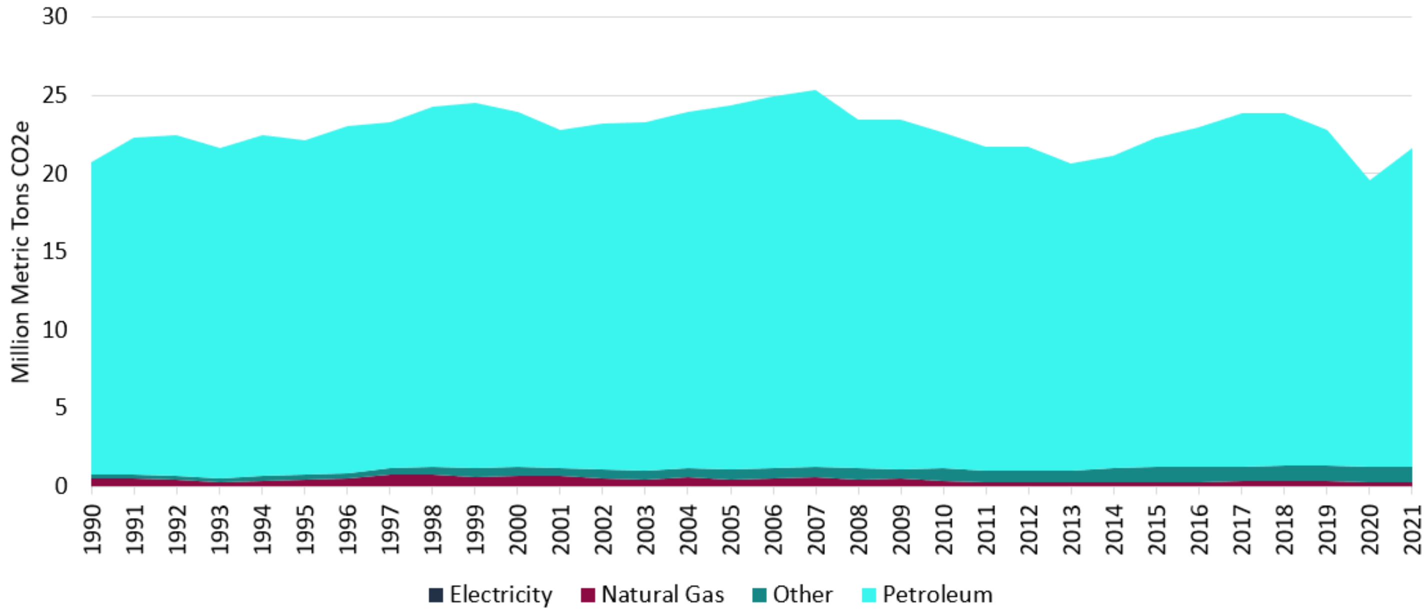
Viewing these data over time shows the variety of emissions sources in Oregon and emissions trends from these sources over time. This level of analysis informs policy makers about what policies will most effectively reduce emissions and meet state goals.

The following chart groups emissions by sector, with emissions by source illustrated using similar color shades within each sector. Following the chart are additional charts showing each sector broken out to provide additional clarity.



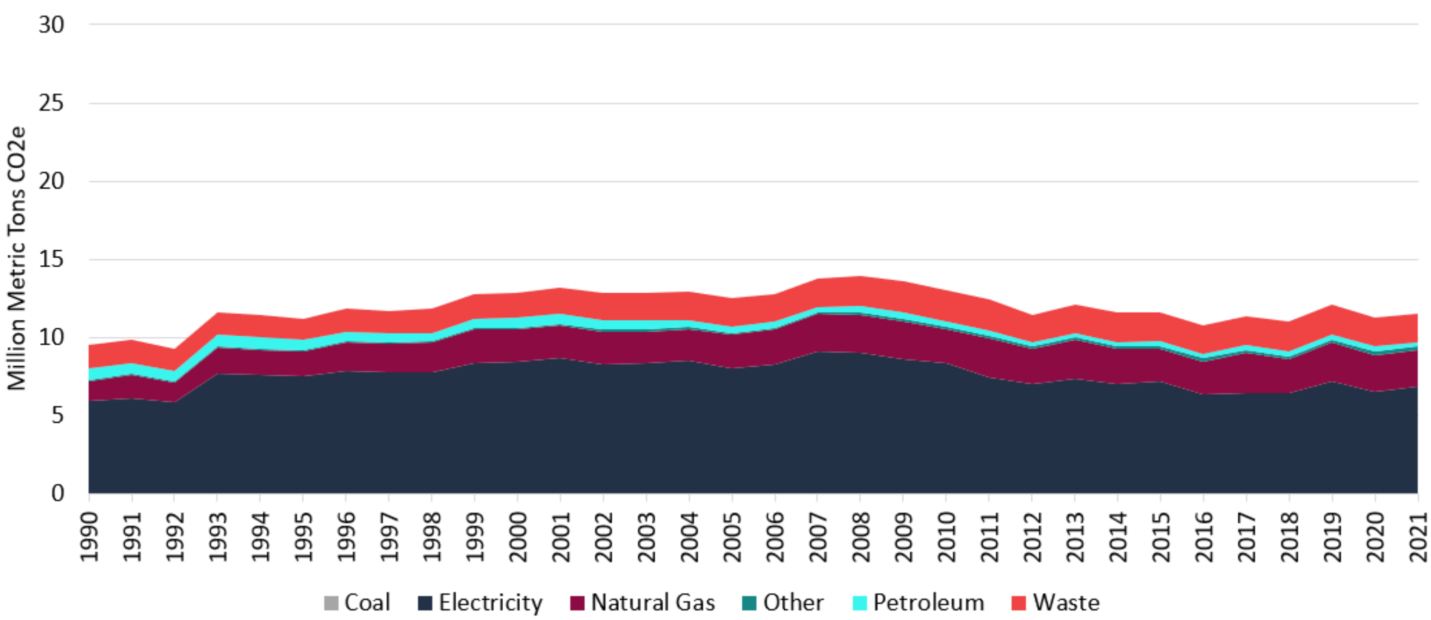
Almost all emissions in the transportation sector come from petroleum use. State greenhouse gas policies, such as the DEQ's Climate Protection Program, Clean Fuels Program, Advanced Clean Cars II rule, and Advanced Clean Trucks rule, drive electrification of vehicles, which, in conjunction with de-carbonization of the electricity sector, will be able to address much of the emissions in this sector.

Oregon Transportation Sector GHG Emissions by Source 1990-2021[7]

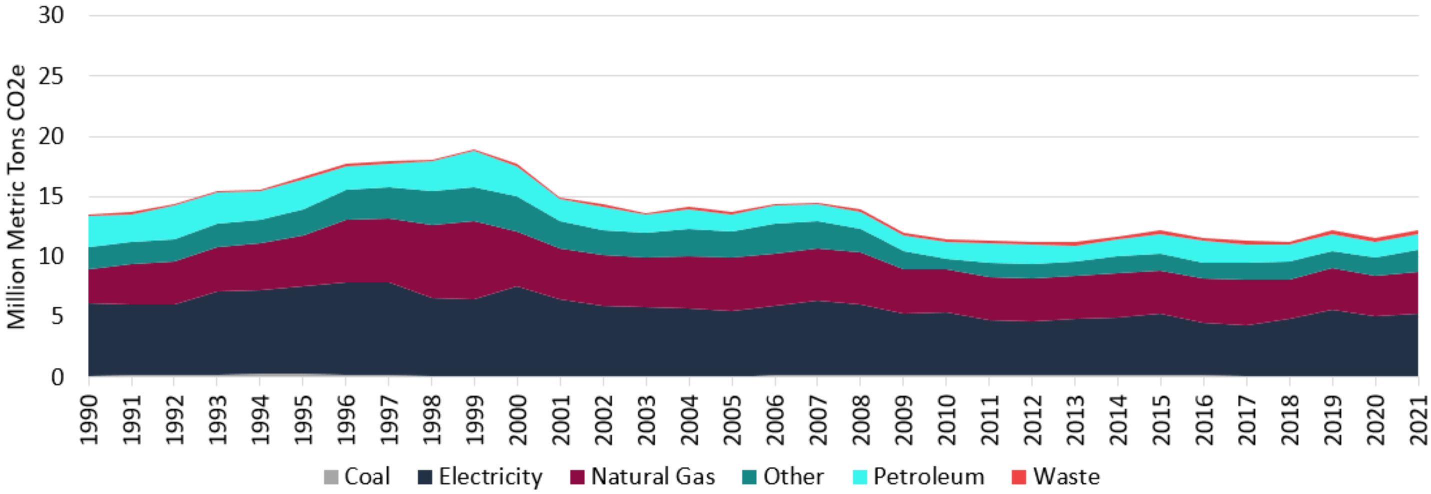


The following individual sector charts show that electricity consumption, shown in dark blue, is the largest source of emissions in the commercial, residential, and industrial sectors. This means policies like HB 2021, which will culminate in a 100 percent reduction in emissions from electricity sold to investor-owned electric utility customers by 2040, will have the greatest effect on emissions across these sectors.

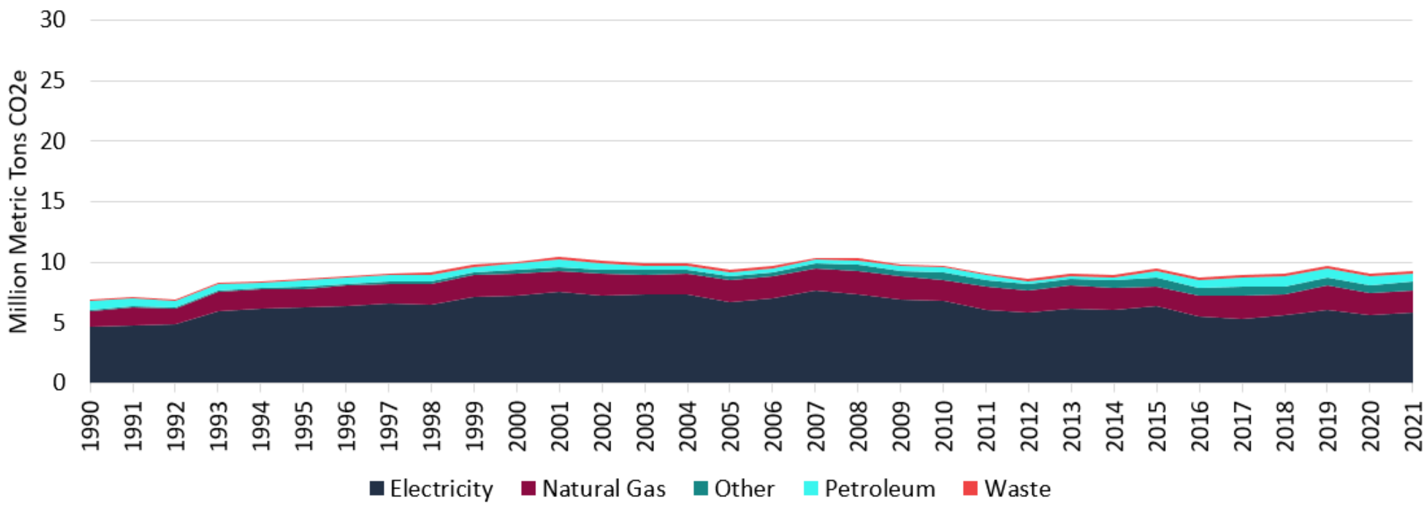
Oregon Residential Sector GHG Emissions by Source 1990-2021[7]



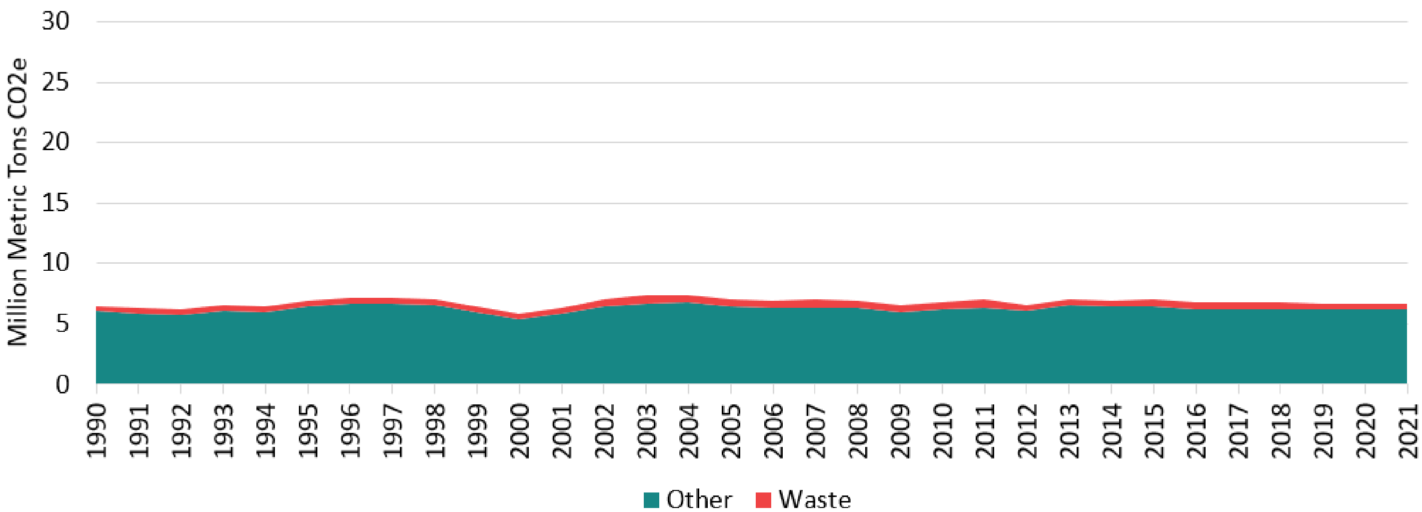
Oregon Industrial Sector GHG Emissions by Source 1990-2021[7]



Oregon Commercial Sector GHG Emissions by Source 1990-2021[7]



Oregon Agriculture Sector GHG Emissions by Source 1990-2021[7]



Sector Profiles

Residential

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 size and vintage (the decade a home is built), and type of housing.

20.9%

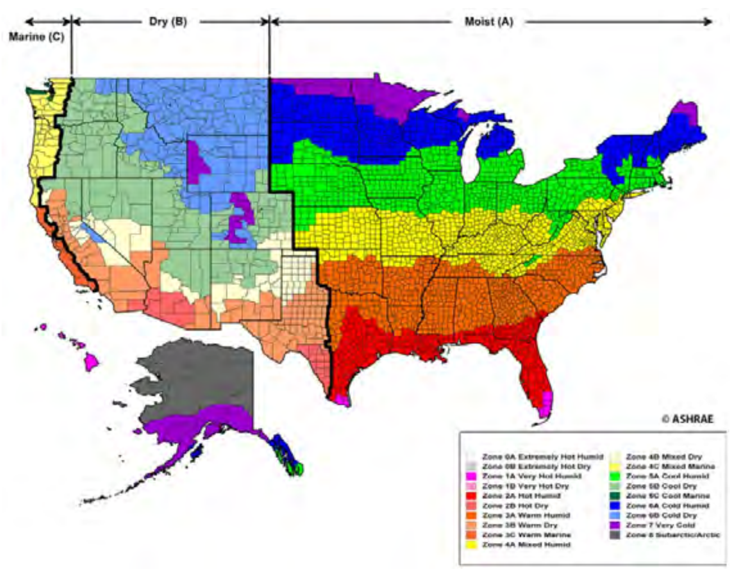
Residential sector's share of Oregon's energy use in 2022.[1]

1.7 Million

Number of occupied housing units in Oregon in 2022.[2]

Weather

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

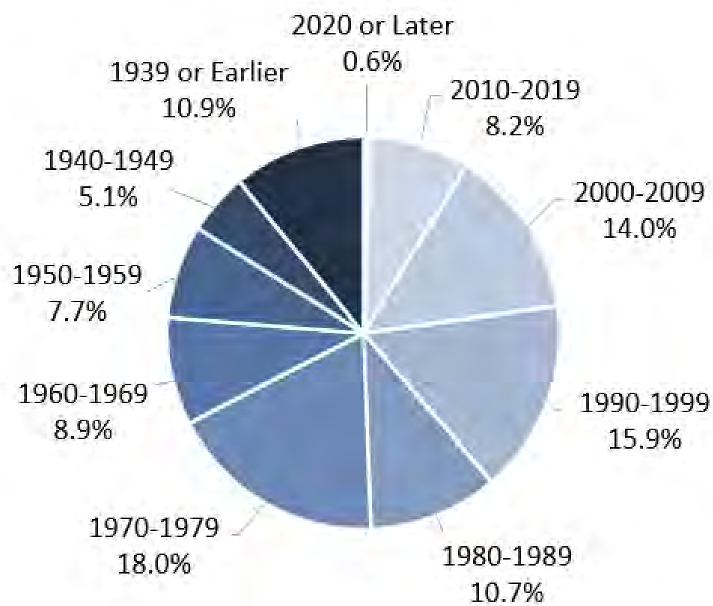


Vintage

The residential sector includes newer and older buildings — 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.

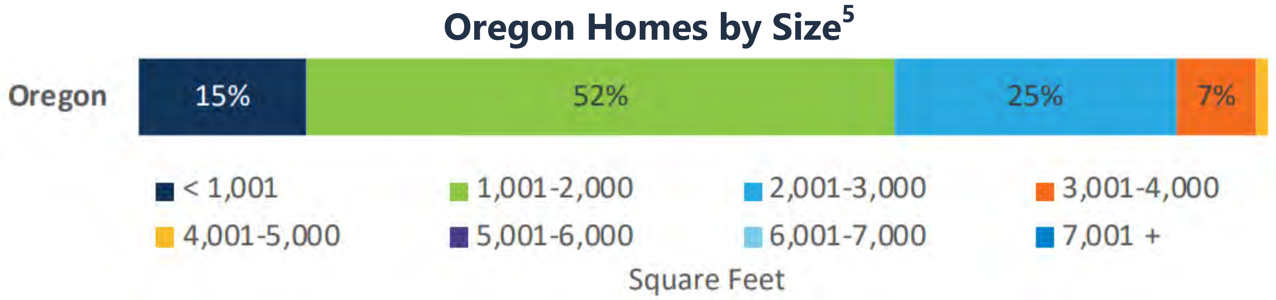
Older homes with less insulation and older equipment use more energy for heating and cooling than newer, more efficient homes. Home vintage can indicate opportunities for updating heating and cooling equipment, water heating, insulation, windows, and house weatherization. About 63 percent of all homes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

Oregon Homes by Vintage[2]



Size of Housing

The size of a home affects energy use. Typically, larger homes use more energy, since there is a greater volume of air to heat or condition. Census data indicate that the size of single-family homes in the United States is again on the rise after declining between 2016 and 2020 during a period where the construction industry focused on building smaller starter homes. Contributing factors to recent increases to home size include increased use and roles of homes – for work and study – in the post COVID-19 environment.[4]

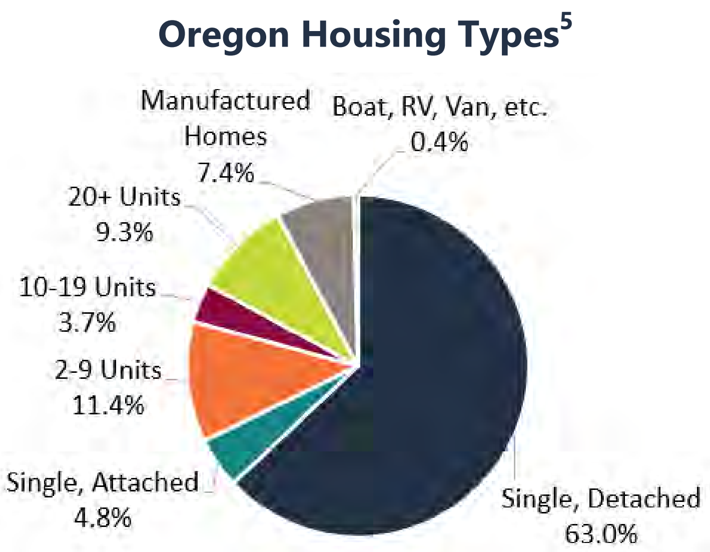


Type of Housing

Most housing in Oregon (63 percent) is detached, single-family. Multifamily complexes with 20 or more units represent 9.3 percent of all housing, followed by mobile/manufactured homes at 7.4 percent. Other multifamily units (like those with fewer than 20 units) comprise the remainder.[2]

Ownership and Vintage

Another way to look at housing stock in Oregon is by ownership and home vintage across the region. Northwest Oregon has the most housing units, as well as the highest percentage of rental units.



Oregon Housing Characteristics by Region[2]

Region	Total Occupied Housing Units	Share of Units That Are Rental Properties	Share of Units That Are Pre-1980 Homes
East Oregon	213,677	32%	54%
NW Oregon	1,222,517	36%	53%
SW Oregon	211,344	30%	52%
All of Oregon	1,642,579	34%	52%

Residential Energy Efficiency

Oregon's energy efficiency programs and policies save residential customers energy and money while increasing household comfort. In its 2021 Power Plan, the Northwest Power and Conservation Council estimated the total technical energy efficiency potential of the residential sector in the Pacific Northwest would meet about 27 percent of the projected load in 2041.

The Northwest Power and Conservation Council's 2021 Annual Regional Conservation Progress Report outlines several opportunities for increased efficiency in residential buildings:

Lighting. Lighting has historically been a significant energy efficiency opportunity, and the region has made great progress. Installations of 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.[8]

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]

Home Energy Scores

Home Energy Score™ was developed by the U.S. Department of Energy and its partner national laboratories to provide homeowners, buyers, and renters comparable and credible information about a home's energy use. Using a 1 to 10 scale (10 is high performance), the score estimates a home's energy consumption and recommends ways to reduce its use, cut costs, and improve comfort. The score also relays greenhouse gas information related to that energy use. At right is part of a Home Energy Score scorecard example.

Learn more about home energy scoring in Oregon in the Energy 101 section of this report.

Score today:	Score with priority improvements:*	Estimated energy savings with priority improvements:	Estimated carbon reduction with priority improvements:
6	9	$285 PER YEAR	19% PER YEAR

TACKLE ENERGY WASTE TODAY!

Enjoy the rewards of a comfortable, energy efficient home that saves you money.

- ☑ Get your home energy assessment. Done!
- ☐ Choose energy improvements from the list of recommendations below.
- ☐ Select a contractor (or two, for comparison) and obtain bids. Check with your local utility for a list of contractors in your area.
- ☐ To find out more information about the state of Oregon Home Energy Score program visit: oregon.gov/energy/home-energy-score
- ☐ Discover local incentives and learn more about Hillsboro's Home Energy Score Program at: Hillsboro-Oregon.gov/EnergyScore

***PRIORITY ENERGY IMPROVEMENTS** | 10 Year payback or less [1]

FEATURE	TODAY'S CONDITION[1]	RECOMMENDED IMPROVEMENTS
Attic insulation	Ceiling insulated to R-0	Insulate to R-38 or R-49 if code requires it
Cathedral Ceiling/Roof	Roof insulated to R-0	Insulate cathedral ceiling/roof to R-30 or maximum possible

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 57 to 66 percent between 2017 and 2022.[9]

Average electricity use in Oregon has increased slightly from 10,827 kWh in 2018 to 11,323 in 2022.[10 11] Average residential electricity use in consumer-owned utility territory is typically higher than in investor-owned territory. In 2022, the average annual COU customer use was 13,404 kWh, while for IOUs it was 10,606 kWh.[11] This may be partially due to higher prevalence of electric resistance heating – which is less efficient than natural gas – in more rural COU territories, and more homes that use natural gas as a heat source in urban IOU areas.

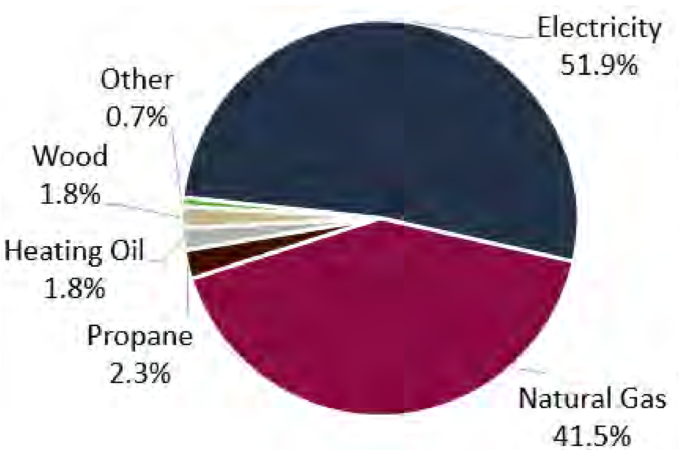
11,323 kWh KEI

Average annual residential electricity use in Oregon in 2022.[11]

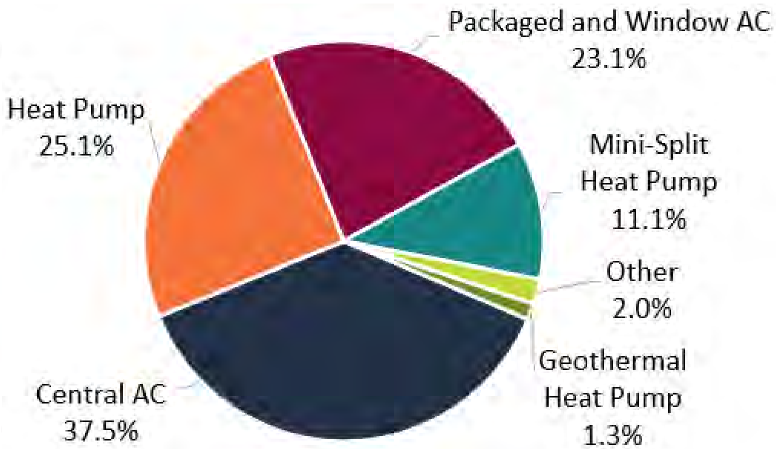
660 therms KEI

Average annual residential natural gas use in Oregon in 2022.[11]

Average Heating Types Across Oregon Homes[12]



Average Cooling Types Across Oregon Homes[8]



Many Oregon homes lack cooling equipment. Historically, weather patterns have kept much of the state's population in a moderate climate. Recent extended high heat weather events have motivated many households to install or purchase new cooling equipment, and state programs have incentivized heat pump installations to provide cooling.

Oregon County Profiles

As shared earlier in this section, the Oregon Department of Energy has updated its Oregon County Profiles. The profiles are a compilation of demographic, economic, and geographical datasets representing Oregon's 36 counties. The profiles aim to highlight aspects of each county's economic status and provide a focused perspective on the diverse communities in the state. Find them online: **energyinfo.oregon.gov/ber**

Commercial

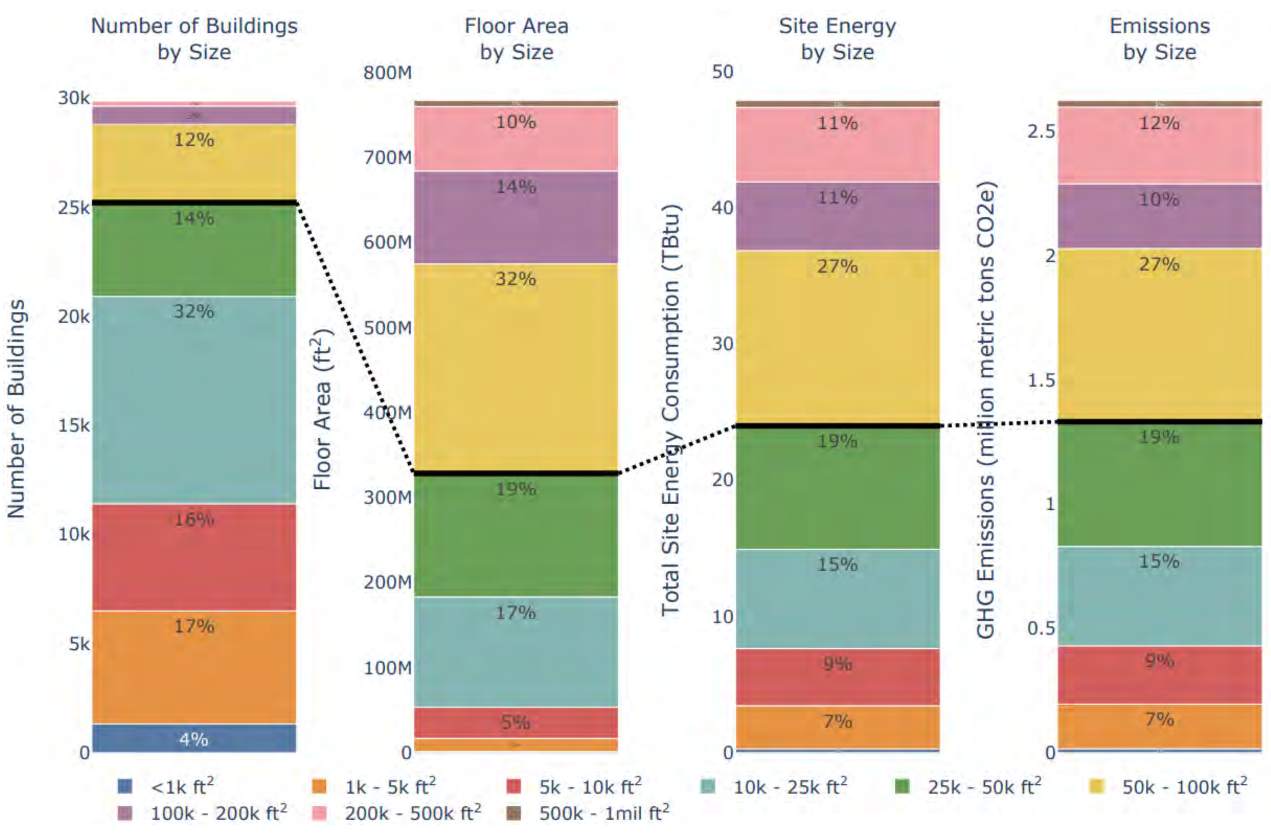
15.5%

Commercial sector's share of Oregon's energy use in 2022.[1]

The commercial sector is diverse and includes buildings with various purposes, 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. This sector is comprised of buildings that span sizes ranging from a few hundred to millions of square feet. In 2022, the commercial sector represented approximately 16 percent of total energy consumption in Oregon. Oregon's total commercial sector energy consumption has fluctuated annually in the past due to combinations of economic, societal, and other factors; however, total sector usage in 2022 was approximately the same as in 2000.[1]

The chart below illustrates the distribution of commercial buildings in the Portland, Salem, and Medford metro areas. According to an analysis by U.S. Department of Energy in 2023, buildings less than 50,000 square feet make up 84 percent of all commercial and multi-family buildings, but only 43 percent of area, 50 percent of building energy consumption, and 51 percent of emissions. Buildings over 50,000 square feet represent just 16 percent of buildings, but 50 percent of energy use and 49 percent of emissions. Thus, policies that target large buildings can address most emissions while affecting fewer buildings.[12] Similar trends exist in other parts of Oregon, and more information and similar analysis may be found in US DOE's Building Segmentation Analysis program reports.[13]

Building Stock Segmentation For Portland, Salem, and Medford Metro Areas[12]



Note: *The black line indicates buildings greater than 50,000 square feet*

Energy Performance

Many factors influence a building's energy consumption and performance, such as design, construction materials, size, equipment efficiency, activities, operation profile, and location. Commercial building energy performance is often measured by comparing a building's annual energy use to its size. This metric combines all energy consumption (like electricity and natural gas) into common units that are normalized to building area — commonly 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.

Financial incentives, improved building code and appliance standards, and energy efficiency programs are helping commercial buildings improve energy performance. In 2023, the Oregon Legislature passed House Bill 3409, establishing an Energy Performance Standard policy for commercial buildings, often referred to as a Building Performance Standard.

This BPS program will set standards for many large commercial buildings to enhance energy management practices, including requiring energy audits and energy efficiency measures to meet EUI targets based on the average energy use for that type of building. Oregon's BPS will be modeled after the ANSI/ASHRAE/IES Standard 100-2024, Energy and Emissions Building Performance Standard for Existing Buildings.[14]

For the purposes of the BPS program, large commercial building compliance will be phased in based on building size. Additionally, commercial buildings are divided into tiers based on building type:

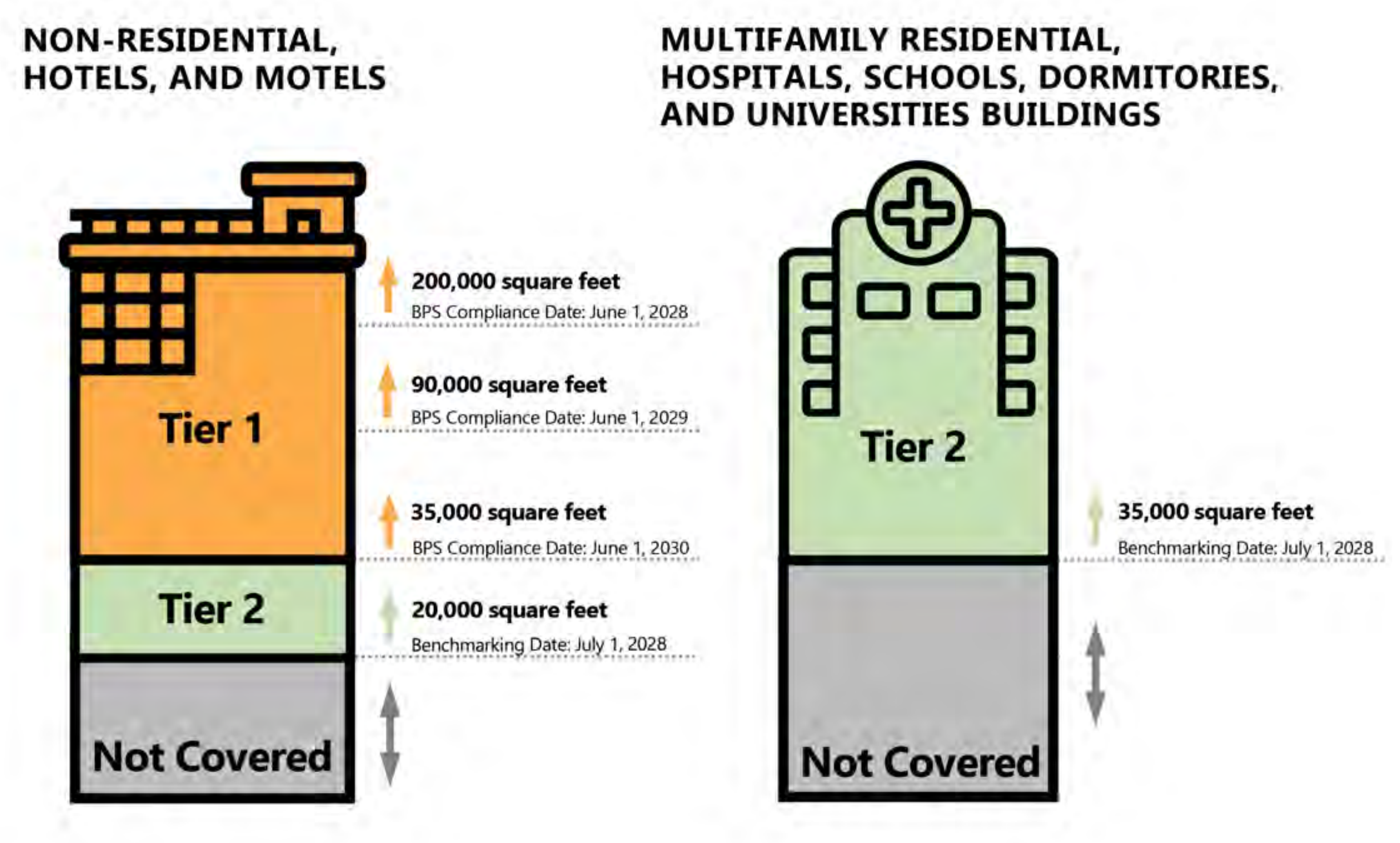
Tier 1 A building in which the sum of gross floor area for hotel, motel, and nonresidential use equals or exceeds 35,000 square feet, excluding any parking garage.

Tier 2 A building with gross floor area, excluding any parking garage, that equals or exceeds 35,000 square feet and that is used as a multifamily residential building, a hospital, a school, a dormitory or university building; or

A building in which the sum of gross floor area for hotel, motel, and nonresidential use exceeds 20,000 square feet but does not exceed 35,000 square feet, excluding any parking garage.

The BPS program first requires benchmarking to assess the building's overall comparison to the standard, followed by a requirement for compliance with program standards. Large commercial building benchmarking and compliance will be phased in based on building size, as shown in the chart below.

Buildings Covered by Oregon's Building Performance Standard Program



ODOE initially estimates that there could be approximately 5,000 Tier 1 buildings and another 5,000 to 10,000 Tier 2 buildings in Oregon. The BPS program will adjust targets over time, leading to progressive improvements in energy efficiency, which will support greenhouse gas reductions from the building sector. These efficiencies will also reduce energy costs for building owners and tenants and help moderate effects on utility ratepayer costs by reducing the need for more energy resources to serve this growth.

Industrial

26.9%

Industrial sector's share of Oregon's energy use in 2022.[1]

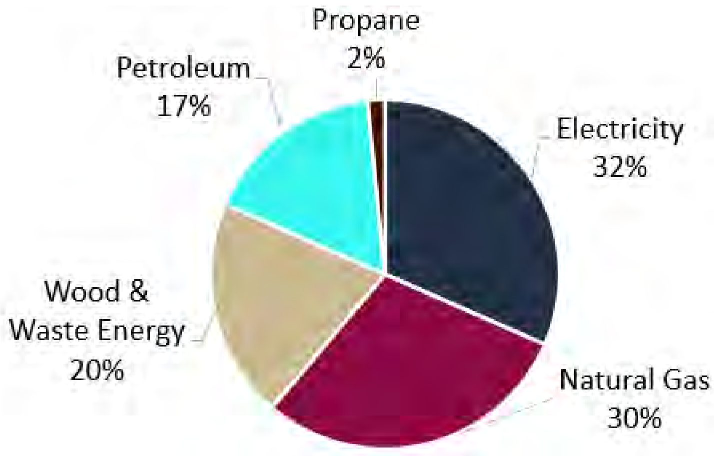
The industrial sector includes all facilities and equipment used for producing, processing, or assembling goods. The U.S. Energy Information Administration defines the industrial sector to include manufacturing, agriculture (including fishing and forestry), construction, and mining (which includes oil and natural gas extraction).[16]

Nationally, manufacturing was 76 percent of industrial energy consumption in 2022, by far the largest share of any of the industrial subsectors. The largest industrial energy consumer of the manufacturing segment is the bulk chemical industry (followed by petroleum refining and paper production). Collectively, these represented a combined 70 percent of industrial energy use in 2018, the latest year for which data are available.[17] Oregon's industrial manufacturing subsector includes paper and food processing, wood products, and computers and electronics.

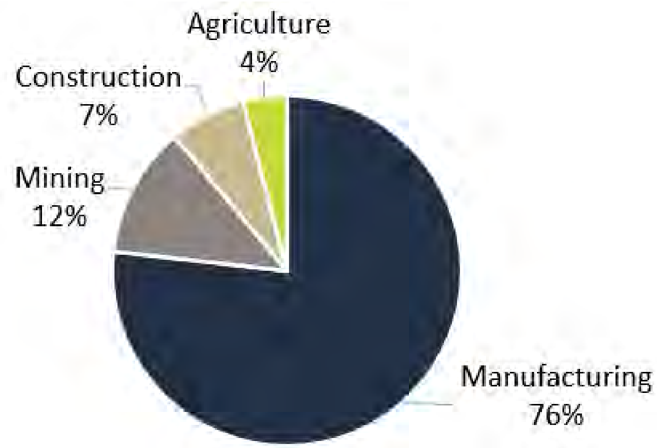
The industrial sector uses electricity to operate machine drives (motors), lights, computers and office equipment, and equipment for facility heating, cooling, and ventilation. Machine drives are the largest use of electricity by U.S. manufacturers.[18] Industry uses fossil fuels and renewable energy 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.[17]

According to the U.S. EIA, most of Oregon's Gross Domestic Product comes from "non-energy-intensive service-providing businesses" — though the energy-intensive subsectors of agriculture, food processing, and forest products manufacturing are important to the state. Computers and electronic products (not including data centers, which are included in the commercial sector) accounted for about 40 percent of Oregon's manufacturing GDP. Relative to other states, Oregon's industrial sector per capita energy use is lower than 60 percent of other states.[19] Computer and electronic manufacturing overall have low energy intensity relative to their high dollar value contribution to GDP.[19] Many forest products and paper operations in Oregon offset natural gas for heat and electricity from the grid by using residual woody biomass and black liquor, respectively, for cogeneration of electricity and steam for process heat.

2022 Oregon Industrial Energy Consumption by Fuel[1]



2022 U.S. Industrial Sector Energy Use Subsector Shares[17]



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 vehicles and to fuel equipment.[21]

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.[22] SUVs and pickup trucks make up 61.4 percent (44.2 and 17.2 percent respectively) of passenger vehicles registered in Oregon.[21]

Of the transportation fuels used in Oregon, gasoline creates the largest amount of greenhouse gas emissions — over 16.6 million metric tons of carbon dioxide equivalent[xvii] in 2022. Diesel is the second largest contributor of emissions at almost 11.2 MMTCO2e.[23] Increased consumption of lower-emitting and renewable fuel sources such as electricity, biodiesel, renewable natural gas, and renewable diesel help reduce emissions from the transportation sector.

36.7%

Transportation sector's share of Oregon's energy use in 2022.[1]

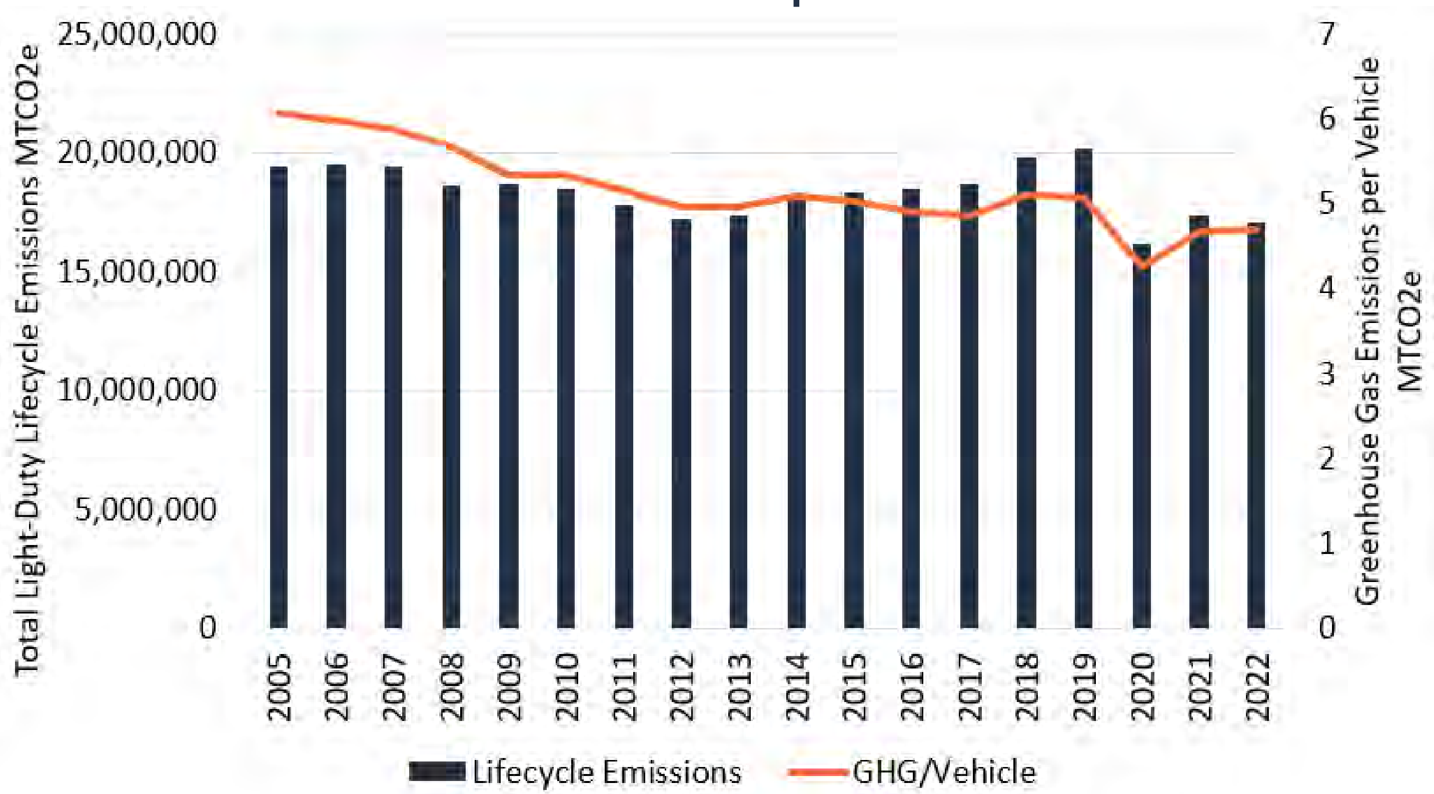
493 Gallons

Annual amount of fuel used by a 2005 typical model vehicle. It also emits about 6.08 metric tons of CO2 equivalent per year.[1]

402 Gallons

Annual mount of fuel used by a 2022 typical model vehicle. It also emits about 4.69 metric tons of CO2 equivalent per year.[1]

Metric Tons of CO2e produced by all Light-Duty Vehicles and Metric Tons of CO2e per Vehicle[23]



[xvii] Carbon dioxide equivalent, or CO2e, is a unit of measurement that enables a standardized comparison of different greenhouse gases. A unit of CO2e is equivalent to the global warming potential of carbon dioxide alone.

Greenhouse gas emissions per light-duty passenger vehicle decreased in the early parts of the century primarily thanks to federal fuel efficiency standards.[24] Emissions per vehicle have held steady since 2012 but dipped in 2020 because although the total number of vehicles remained the same, gas consumption dropped. As gasoline consumption increased, emissions per vehicle rebounded in 2021 and 2022, but not to pre-COVID levels.

Transportation Fast Facts

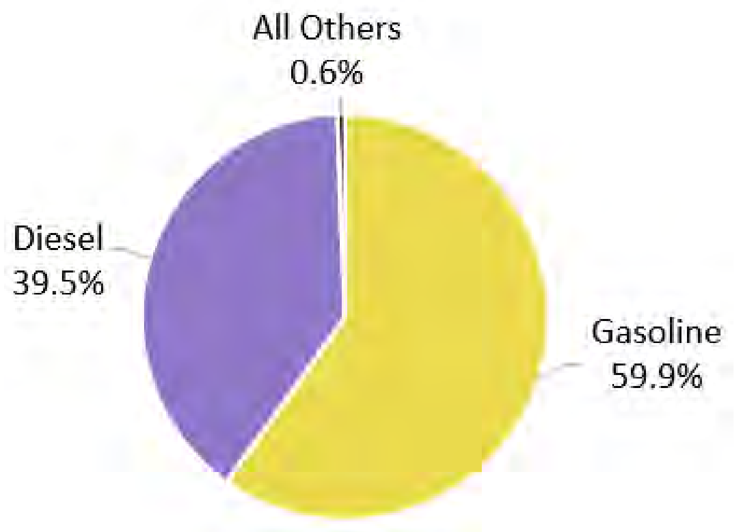
In 2022, nearly 1.36 billion gallons of gasoline powered vehicles on Oregon roads.[23]

That's over 318 gallons per Oregonian.

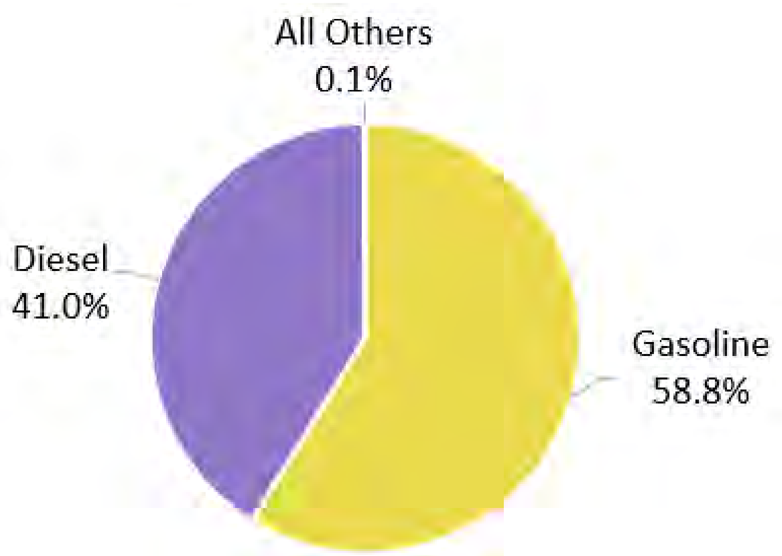
The typical Oregon household has at least two cars.[25]

For electric vehicle drivers, no matter where a car is fueled in Oregon, drivers reduce their greenhouse gas emissions by 50 to 95 percent by fueling with electricity.[26]

Percent of On-Highway Consumption in Oregon (2022)[22]



Percent of On-Highway GHG Emissions Among Fuel Types (2022)[22]



Learn more about electric vehicles in ODOE's 2023 Biennial Zero Emission Vehicle Report.

Electric Vehicles

January 2011: **672 registered EVs**

May 2022: **52,033 registered EVs**

July 2024: **100,360 registered EVs**[27] KEI

More than 45,000 EVs added in two years!

Oregon's Zero Emission Vehicle Targets (Senate Bill 1044 and Advanced Clean Vehicles II Rules)[28 29]

- 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
- 100 percent of new vehicles sold are ZEVs by 2035.

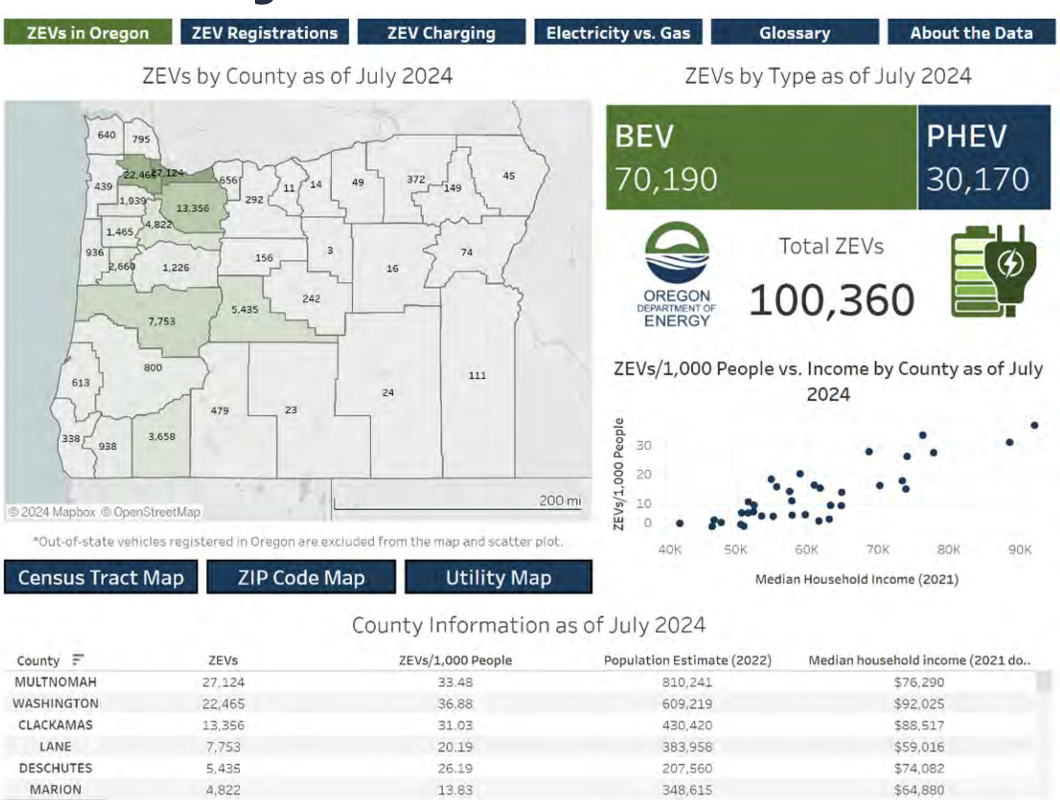
Oregon EVs by the Number

3,675,246 registered passenger vehicles[30]
100,360 registered electric vehicles
2.73% of registered vehicles are EVs
70,190 are battery EVs
30,170 are plug-in hybrid EVs
(data through July 2024)

Oregon's EV Charging

24 charging networks[31]
3,193 public EV chargers
1,259 charging locations
(data through July 2024)

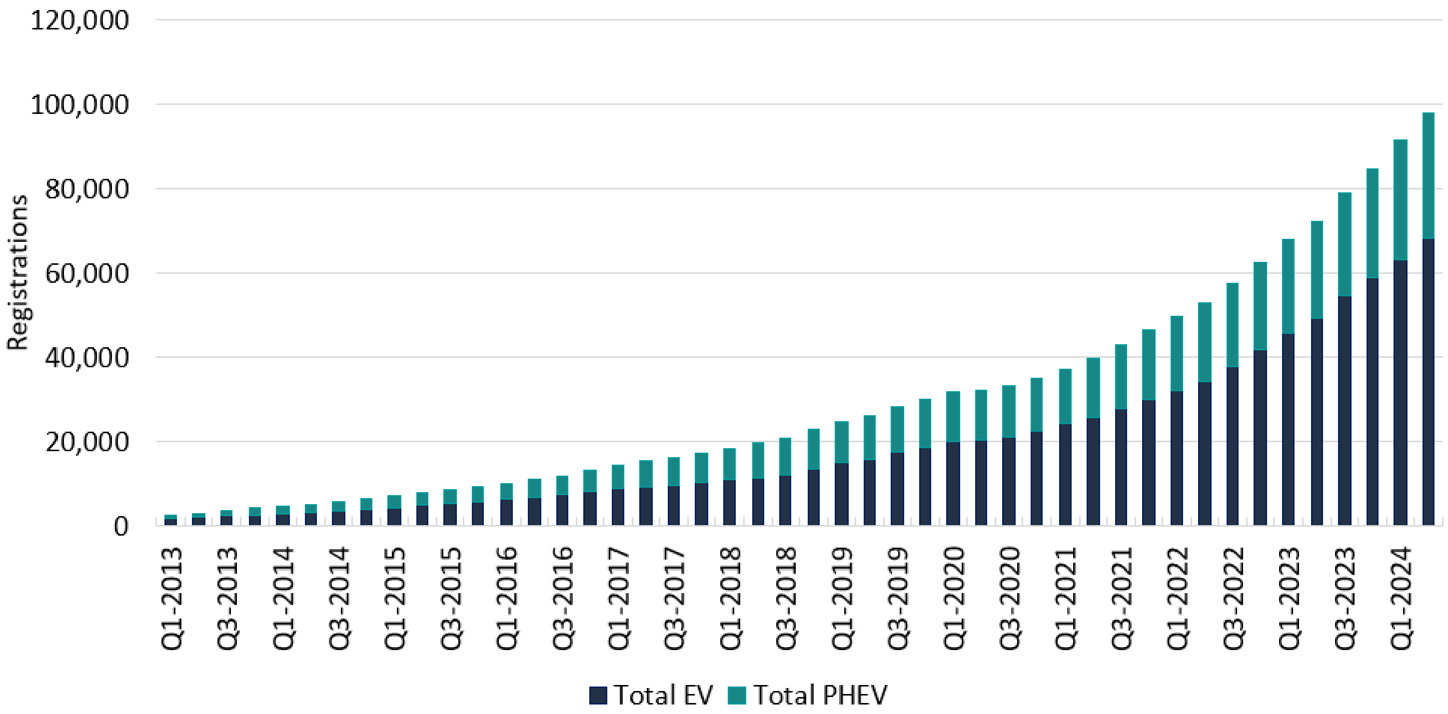
Oregon Electric Vehicle Dashboard



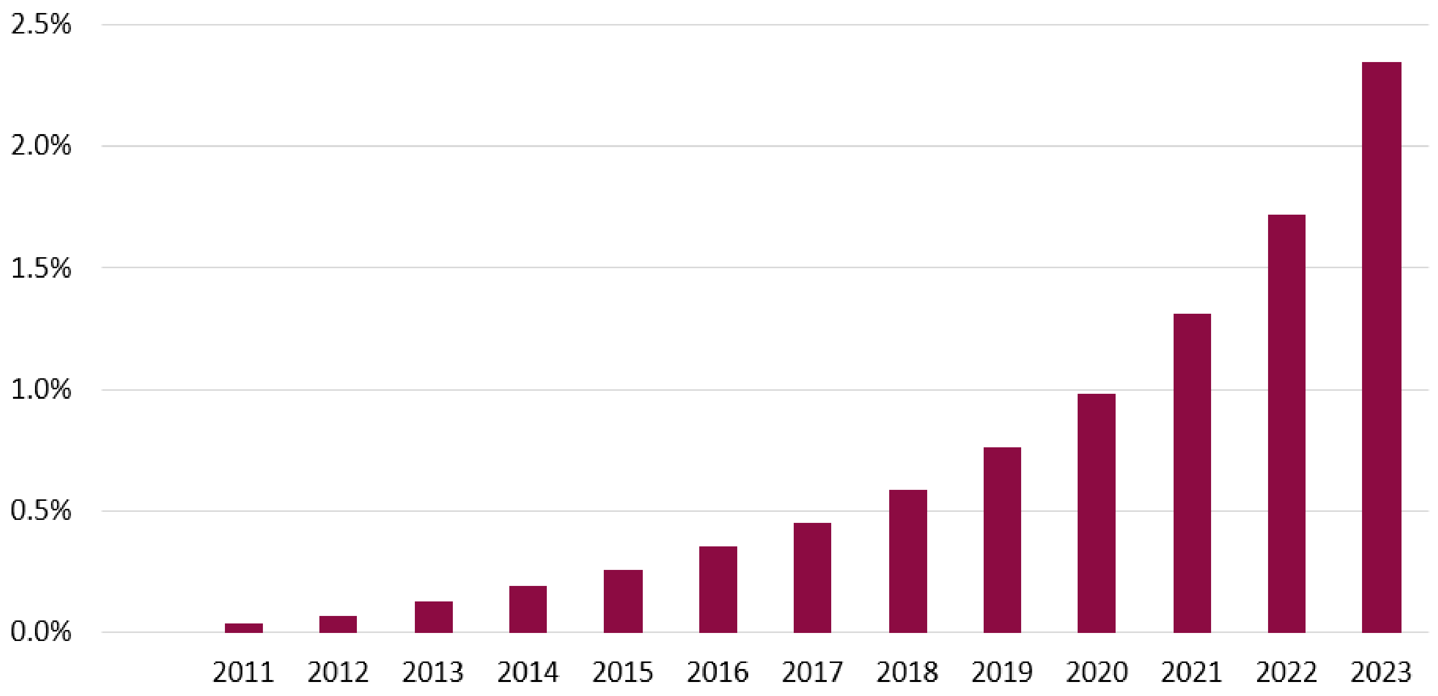
The Oregon Department of Energy developed an interactive Electric Vehicle Dashboard, which shows county-by-county EV adoption information, popular EV models, and other data. The dashboard also includes a calculator to show Oregonians estimated savings by making the switch to an EV.

www.tinyurl.com/OregonEVDashboard

Cumulative Oregon Electric Vehicle (and Plug-in Hybrid EV) Registrations by Quarter Year (2013 Q1 — 2024 Q2)[26]



EVs and PHEVs as a Percent of Total Fleet by Year[26]



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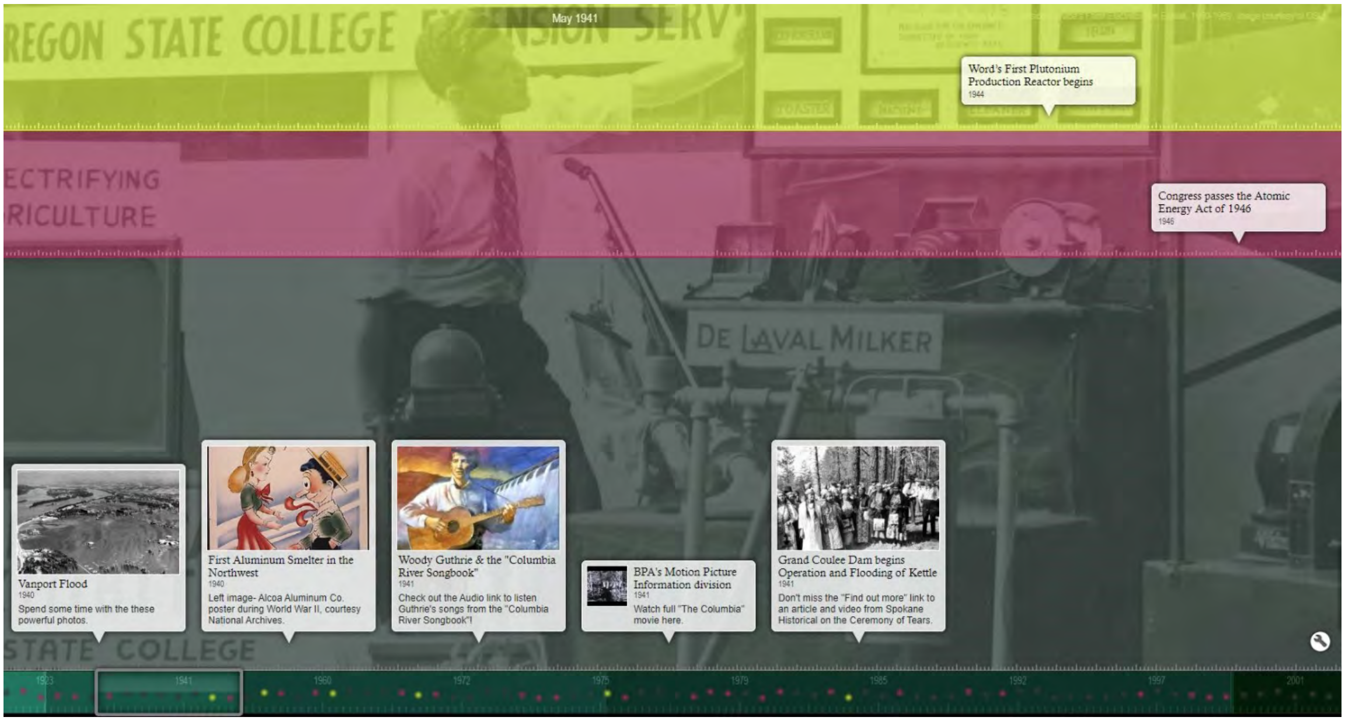
ENERGY HISTORY TIMELINE

The Oregon Department of Energy first introduced an Energy History Timeline in the 2020 edition of this *Biennial Energy Report*. It 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.

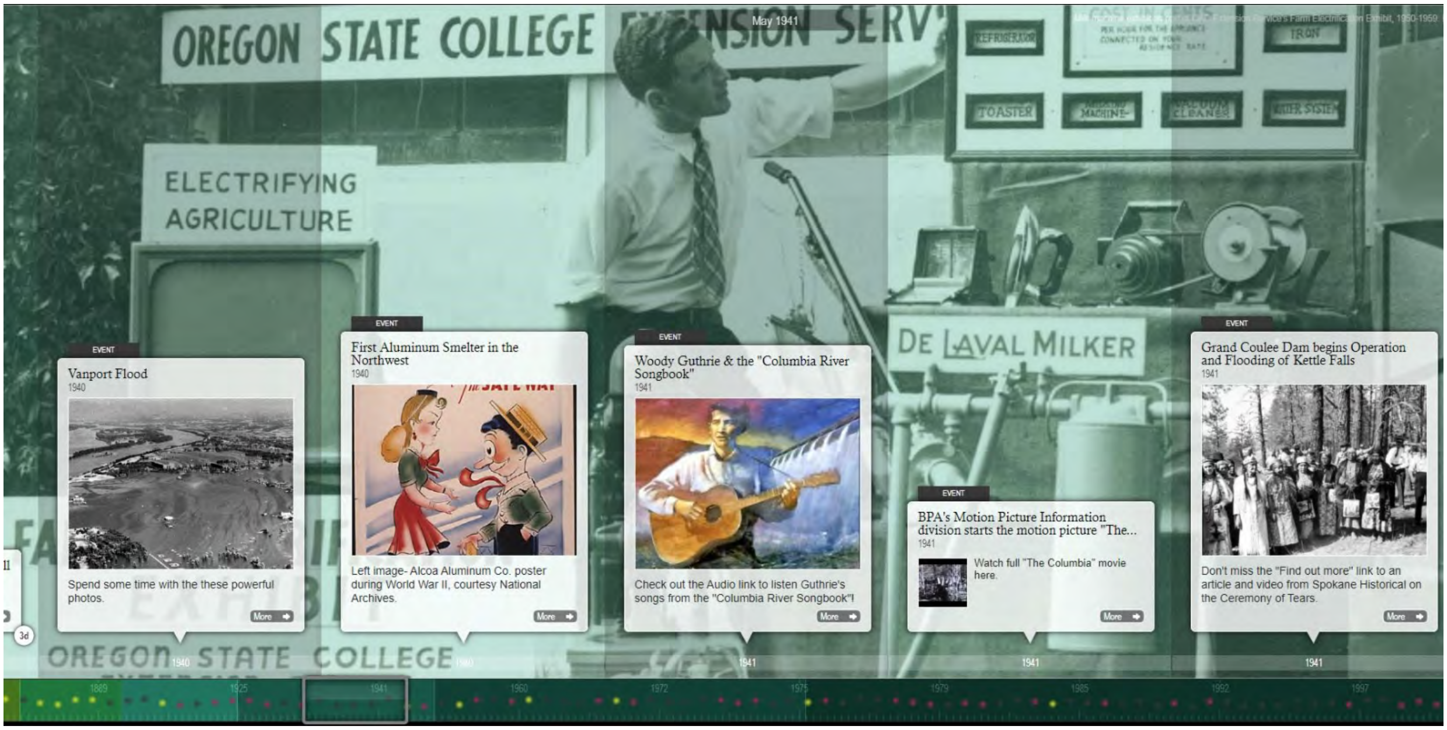
In 2022, the agency evolved the timeline to create an interactive online tool and experience. The ODOE team collected dozens of photographs, stories, videos, and more to create an insightful and informative journey through Oregon's energy history and present. The interactive tool is composed of three 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.

ODOE has added additional milestones from the last two years. Be sure to visit often – we plan to add new media and events regularly. And be on the lookout in 2025 for a new timeline feature (hint: ODOE turns 50 years old in 2025!)



Explore the 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. This year, we focused on two topics that represent emerging and innovative technologies that could generate clean energy in support of Oregon's energy transition.

Enhanced geothermal electricity generation could address some of the high costs and risks associated with conventional geothermal energy development. Fusion power is still in earliest stages of research, but holds the promise of nearly unlimited energy that could easily meet anticipated future energy needs.

Innovation is a cornerstone of fundamental change, and new and improved technologies are certain to play an important role in Oregon's energy future. This purpose of this section is to provide information on energy technologies that people might be hearing about in the news, talking to their family and friends, or in energy-related discussions.

Previous Biennial Energy Reports have also included resource and technology reviews that cover a range of technologies from traditional to innovative, demonstrating the breadth of resources integral to meeting our state's energy needs. You can find information on other resources and technologies — such as hydropower generation, carbon capture and sequestration, electricity storage, zero emission vehicles, and more — in our 2020 and 2022 reports.

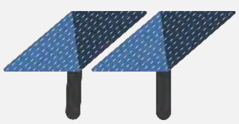
TABLE OF CONTENTS

Enhanced Geothermal Electricity Generation

Geothermal energy comes from heat generated continuously within the earth. The heat can be used as a renewable resource for electricity generation, space and water heating, or industrial processes.

Oregon has two geothermal power plants. The first, completed in 2010, is a 1.75-megawatt facility in Klamath Falls, which provides onsite electricity generation and space heating for the Oregon Institute of Technology. The second, completed in 2012, is the Neal Hot Springs geothermal power plant near Vale. This facility has a capacity of 22 MW and provides electricity to Idaho Power.[1] The City of Klamath Falls has had a downtown geothermal district heating system since 1981, and nearby Oregon Institute of Technology has used geothermal heating since 1964.[2] [3] The town of Lakeview also uses geothermal energy for a downtown heating district, and received a Community Renewable Energy Development Grant from the Oregon Department of Energy in 2023 to evaluate the feasibility of a system expansion.[4] Nearby, the Warner Creek Correctional Facility uses a geothermal well to provide space heating and domestic hot water.[5] These facilities, located in Malheur, Lake, and Klamath counties, demonstrate how Oregon's geothermal resources benefit some of the state's most rural communities.

Community Renewable Energy Grant Program



The Oregon Department of Energy's Community Renewable Energy Grant Program provides grants for planning and developing community renewable energy and energy resilience projects. To date, more than 90 projects have been selected for awards in communities across Oregon. Learn more on ODOE's website.

Geothermal power plants are not widely used because project development carries higher financial risks than many other electricity generation resources. While Oregon has abundant geothermal resources in some parts of the state, it is difficult to find hydrothermal reservoirs with high enough temperatures and sufficient flow to generate electricity. Development usually requires drilling multiple test wells to find an adequate hot water reservoir, which adds to the up-front costs for development. In some cases, test drilling does not lead to the identification of a viable resource. The financial risks associated with drilling unproductive, low-temperature, or dry wells has limited the commercial viability of geothermal power plant development.

SCAN OR CLICK

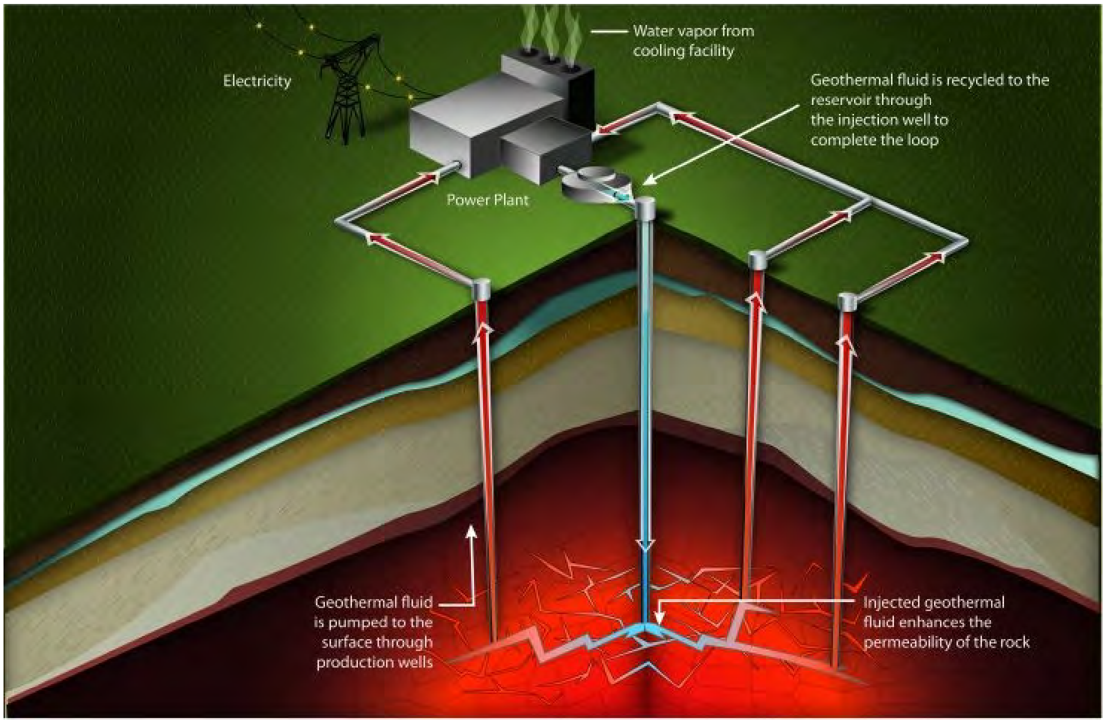
For a deeper dive on geothermal energy, see ODOE's *2020 Biennial Energy Report.*

How Does EGS Work?

Enhanced geothermal systems, also referred to as EGS, eliminate the risk associated with unproductive wells by harnessing energy from hot, *dry* rock deep underground. EGS uses injection wells to circulate fluid from the surface, where it is heated by passing through fractures within the hot rock.

Nearby extraction or production wells collect the heated fluid to generate electricity using a turbine. When the cooled water exits the power plant, it can be reinjected back into the hot rock, resulting in nearly continuous electricity production. Figure 1 shows the primary components of enhanced geothermal energy systems.[6]

Figure 1: Enhanced Geothermal System Diagram[8]



The heated water from enhanced geothermal wells can be used to drive steam turbines that generate electricity.[7] Another option is to use the hot water in a binary-cycle power plant. These plants transfer the heat from the hot water to another liquid – usually pentane, isobutane, or ammonia – that have a lower boiling point than water. The steam from that liquid is then used to drive the turbine.[8]

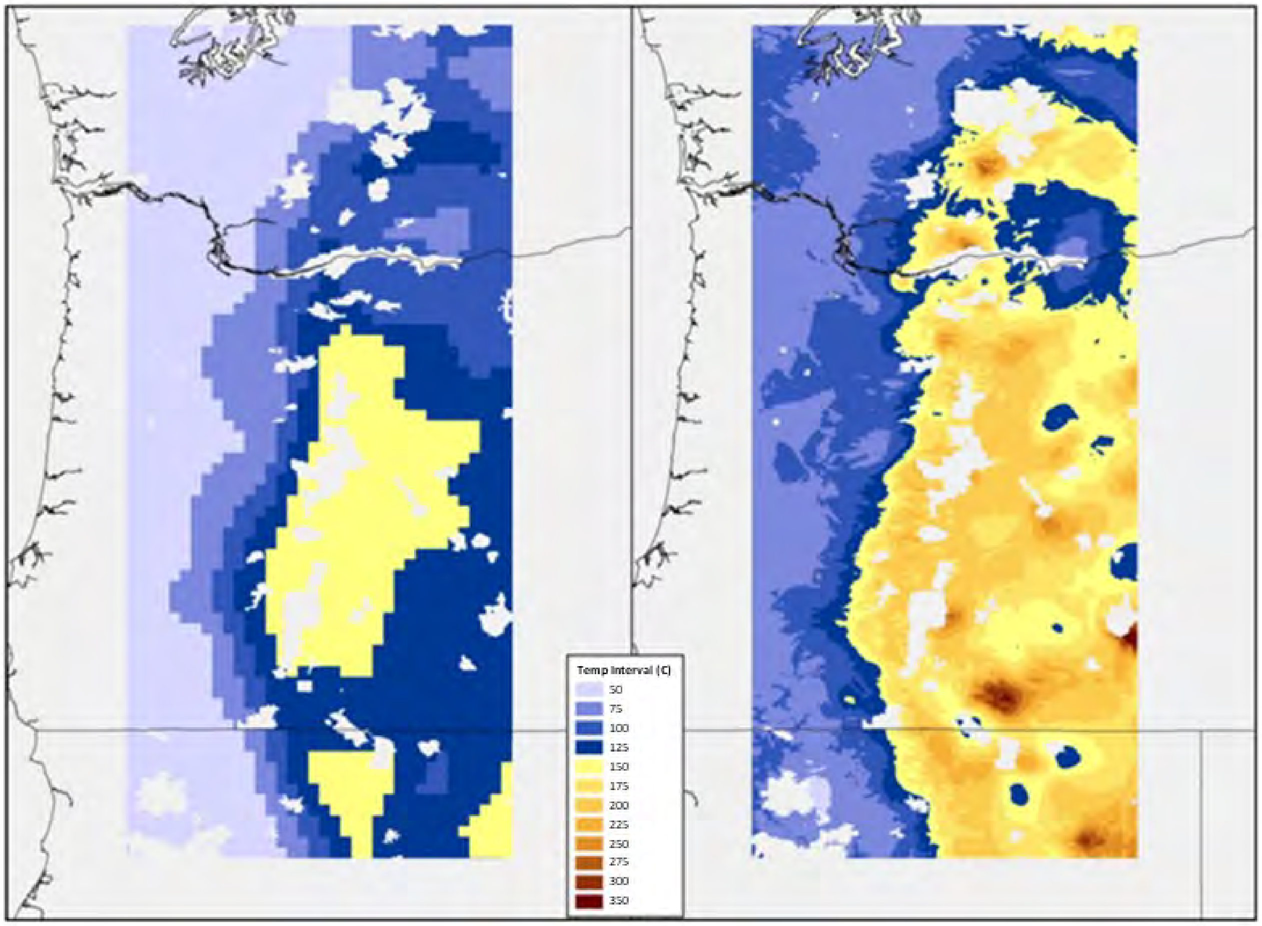
EGS Potential

Decades of research and several projects in many countries have demonstrated the viability of EGS for electricity generation. Early developments date to the 1970s when researchers successfully demonstrated the concept at the Hot Dry Rock project at the Fenton Hill site in New Mexico.[9] The first commercial sites were developed in France and Germany in the early 2000s, followed by projects in the UK, Australia, Japan, and Italy.[9] In the U.S. there are EGS research and production sites in Utah, Nevada, California, and Oregon.[10] In 2009, AltaRock Energy Inc. began development of a test site on the west flank of the Newberry Volcano in Central Oregon for EGS assessment around 10,000 feet underground.[11] Continued research is focusing on reducing the costs of drilling and developing techniques to improve water permeability through the hot rock.

In 2021, the U.S. Department of Energy launched the Enhanced Geothermal Shot initiative to advance innovations in EGS technologies, and reduce the cost of EGS by 90 percent by 2035, from $450 to $45 per megawatt hour.[12] For comparison, a new combined cycle natural gas power plant produces electricity at range of $45 to $108 per MWh.[13]

In 2022, the U.S. DOE, working with the National Renewable Energy Laboratory, completed the Enhanced Geothermal Shot Analysis, which uses the latest cost and performance assumptions to model potential EGS development in 16 states, including Oregon.[14] The analysis used updated EGS resource data that revealed a much greater geothermal resource in Oregon than was originally assumed. The left side of Figure 2 shows assumed geothermal resources taken from a national resource map generated in 2006. The right side of the figure demonstrates the results of an updated geothermal resource model that was used in a detailed regional study published in 2015.[15] The study utilized more granular regional data to better identify EGS development potential in central Oregon.

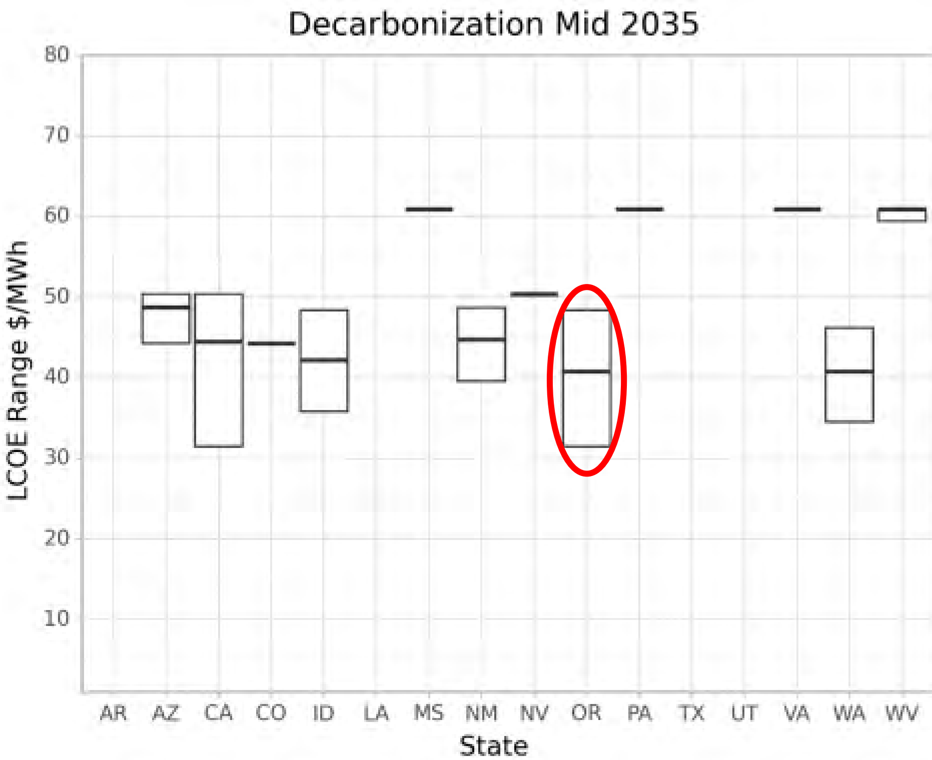
Figure 2: Maps Demonstrating Improved Identification of Potential Geothermal Resources Highlighted in the NREL Enhanced Geothermal Shot Analysis[14]



Oregon has excellent geothermal resources for EGS development. The Enhanced Geothermal Shot analysis shows that Oregon is also expected to have some of the lowest EGS development costs in the country. Figure 3 below shows levelized cost of energy[i] projections from the study for EGS development across 16 states in 2035. The vertical bars for states shows the range of potential LCOE from high to low. Oregon's 2035 LCOE range is about $32-$48/MWh.

[i] Levelized Cost of Energy, or LCOE, is a measure of the total lifetime costs of an energy generation facility divided by the total lifetime energy production. LCOE helps compare the capital and operating and maintenance costs for providing a MWh of power from different types of energy resources.

Figure 3: Range of 2035 Costs for Enhance Geothermal System Electricity Generation by State[14]



The Enhanced Geothermal Shot analysis showed that Oregon could be one of the top states for future EGS electricity generation. Table 1 shows that Oregon is projected to rank third in geothermal electricity resource development by 2035 with 3.4 gigawatts of capacity, and fourth by 2050 with 8.4 GW of capacity.

Table 1: Total Projected Enhanced Geothermal Capacity by State in 2035 and 2050[14]

Year	Installed Enhanced Geothermal Capacity (GW)															
	AR	AZ	CA	CO	ID	LA	MS	NM	NV	OR	PA	TX	UT	VA	WA	WV
2035	-	2.1	18.2	0.3	5.1	-	0.0	1.1	0.1	3.4	0.0	-	-	0.0	0.3	3.1
2050	0.0	9.7	27.9	4.1	8.6	10.5	0.0	2.5	2.4	8.4	0.0	3.1	3.4	1.0	0.5	3.1

Future of EGS in Oregon

Before Enhanced Geothermal System resources can become commercially viable, some technological challenges will need to be overcome. The U.S. DOE's Office of Energy Efficiency and Renewable Energy has identified some specific challenges including:[6]

- High costs associated with deep drilling and operating drills in hot rock.
- The capability to create and sustain flow through rock fissures.
- Lack of subsurface data to inform potential developers and lower project development risk.

Once projects are developed, long-term operational performance will need to be monitored, which will be useful information for future project developments.

Federal and private research and development partnerships are helping to address the financial and technical challenges associated with EGS. The Frontier Observatory for Research in Geothermal Energy, or FORGE, located in Milford, Utah, is a federally funded, dedicated field laboratory where scientists and engineers develop and test new EGS technologies and techniques.[16] In February 2024, U.S. DOE announced funding for three additional EGS research sites, including projects in California, Utah, and Oregon.[17] The Oregon project, a first-of-its-kind superhot rock geothermal project, developed by Mazama Energy, Inc., is located on the Newberry Volcano in central Oregon. Together, the Mazama Energy project, FORGE laboratory, and other research sites may usher in a new source of clean, renewable, and reliable energy to help meet Oregon's clean energy goals.

Oregon Mazama Project

Mazama Energy is developing a first-of-its-kind superhot rock geothermal project at the Newberry caldera volcano in Oregon. Mazama's vision is to harvest heat from superhot rock — subsurface structures that are greater than 374°C (+705°F) — to generate utility-scale, carbon-free, baseload energy. The initial phase of the Newberry project begins in the fall of 2024, where Mazama will prove new technologies and gather data in one of the existing wells on site. In summer of 2025, Mazama will drill a new superhot rock well using additional drilling technologies. The new well will be set up for a connection and initial production test in 2026 in conjunction with the U.S. Department of Energy's Enhanced Geothermal Systems Pilot Demonstrations.

Newberry Volcano.

Beyond technological challenges, effects of EGS developments on local communities will also need to be considered. Oregon's geothermal resources are in rural parts of central and eastern Oregon, including some Tribal lands. Coordination with Tribes and environmental advocacy and local communities is critical for responsible and successful project development. Geothermal sites have benefits such as helping achieve Oregon's clean electricity goals and requiring less land compared to other clean energy resources, but they may create other local issues. For instance, establishing permeability in hot rock requires fluids be pumped deep underground, and injecting fluid into rocks has been shown to increase localized seismic activity.[18] Facilities may also require development of roads to access the sites, generate noise pollution, and require building transmission lines. Understanding the effects of development on local communities and the environment are important to informing EGS policy and development choices.

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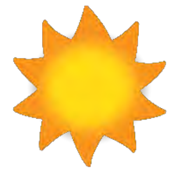
Fusion Power



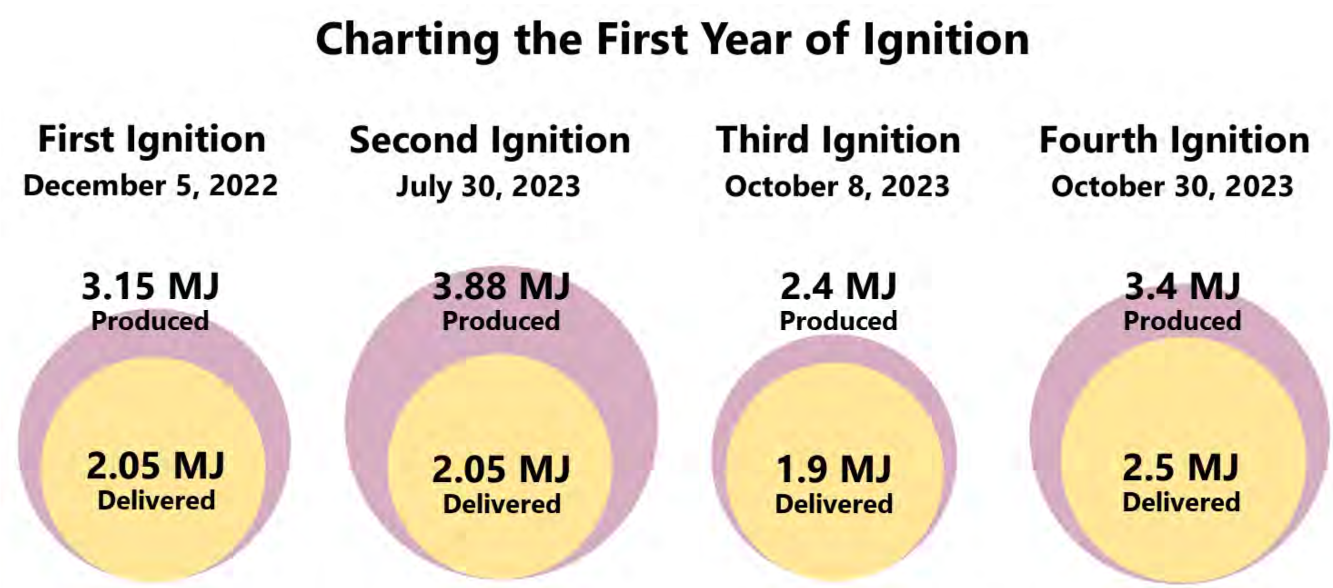
Fusion energy is what powers the sun, and if harnessed could provide nearly limitless clean energy.[1] New scientific advancements hold promise that one day fusion might also power the electricity grid, but significant research and development challenges must first be overcome.

On December 5, 2022, scientists at the U.S. Department of Energy's Lawrence Livermore National Laboratory achieved a major fusion milestone called ignition.[2] Ignition is the point at which a fusion reaction creates more energy than was delivered to start the reaction.[3] That December experiment at LLNL's National Ignition Facility produced 3.15 Megajoules using 2.05 MJ of laser energy – a net gain of 1.1 MJ.[4] While this is only enough energy to run an average refrigerator for an hour or two, it was the first successful real-world demonstration of nuclear fusion producing a net amount of energy. Since that date, the NIF team has recreated ignition multiple times.

Lawrence Livermore National Laboratory's [National Ignition Facility] reaction chamber, where fusion ignition was achieved on December 5, 2022.

A Megajoule is a unit of energy.[5] One MJ = 0.28 kilowatt-hours.[6]

Figure 1: National Ignition Facility Experiments Demonstrate Successful Fusion Ignition[4]



LLNL has achieved fusion ignition at the NIF four times to date. Credit: Brian Chavez

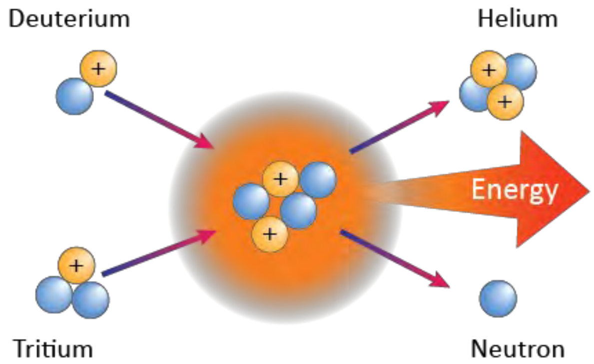
How Does Fusion Work?

Nuclear fusion releases energy through the fusing of two light or very small atoms.[7] This differs from existing nuclear power plants, which use fission — the splitting of heavy or very large atoms — to produce energy. While fusion can involve different types of atoms, the fusion process most studied involves combining two isotopes[i] of hydrogen — deuterium and tritium — to form helium.[8] Also known as D-T fusion, this process releases several times more energy than fission reactions.[9]

SCAN OR CLICK

Learn more about nuclear fission power in ODOE's *2020 Biennial Energy Report*.

Figure 2: Diagram of a Deuterium-Tritium Fusion Reaction[7]



A useful **byproduct of nuclear fusion is helium** — a non-renewable resource that is available in only a few locations around the world.[11 12] Helium is used in many applications, including for scientific research and high-tech manufacturing.

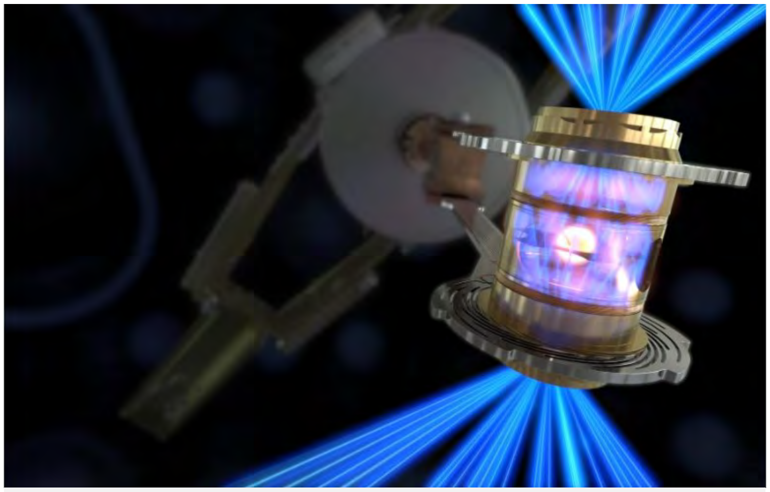
Why does nuclear fusion produce so much energy?

Energy is directly related to mass, as described by Einstein's famous equation $\mathbf{E=mc^2}$, or "energy (E) = mass (m) times the speed of light (c) squared." In the fusion process shown in Figure 2, the fusion of the two hydrogen isotopes produces helium and a neutron — and in the process, a small amount of mass is lost and converted into energy as described in the Einstein equation.[8] While the mass (m) is very small, the speed of light squared (c^2) is very large, which is why so much energy can be generated from such a small amount of matter.[10]

Fusion reactors must be able to heat the deuterium and tritium to about 100 million degrees centigrade — nearly seven times hotter than the sun's core — to form an extreme state of matter called plasma, where atoms are ionized into positively charged ions and negatively charged electrons.[1 13 14] It is in this state that the deuterium and tritium can fuse and release energy. Plasma is highly volatile and difficult to control. Nuclear fusion research focuses on methods to control the plasma state so that the reaction can persist and continue to release energy.

[i] Isotopes are different forms of the same element, which contain the same number of protons but different numbers of neutrons. For example, deuterium has one proton with two neutrons, and tritium has one proton with three neutrons.

There are two main types of fusion reactors currently being studied — inertial confinement fusion systems and magnetic confinement fusion systems.[15] The National Ignition Facility is an ICF machine, where lasers compress the deuterium-tritium fuel until the high pressure induces an extreme plasma state and ignition. MCS facilities use electromagnets to contain and control the plasma to achieve a burning plasma state. In either case, to produce electricity, the energy from the fusion reactions is ultimately used to heat water into steam that can spin electricity generating turbines. To date, only the ICF reactor at the NIF has achieved ignition.



[National Ignition Facility](#) lasers heating the deuterium and tritium fuel to create a super-heated state of matter called plasma.

The December 5 experiment at the National Ignition Facility lasted only a few trillionths of a second, and was initiated by a laser that is 1,000 times more powerful than the U.S. electric grid.[16]

ITER – International Thermonuclear Experimental Reactor

The ITER is an international project to demonstrate technical capability of a Magnetic Confinement System fusion system to produce enough energy to maintain a plasma state without the need for additional energy.[17] One of its goals is to produce 500 MW of power from only 50 MW of input power.

Interest in Nuclear Fusion Power Electricity Generation

Fusion could provide tremendous amounts of energy with very small amounts of fuel, and it would not emit any greenhouse gases or other air pollutants.[1] If the technology can be commercialized, the fuel for the reaction is highly sustainable. While it creates a small amount of radioactive material, it would be continually consumed within the isolated reaction chamber of the reactor, so fusion would not create the amount and type of large-scale nuclear waste being generated by today's fission reactors. Fusion also does not have the potential for a runaway

Fusion reactions require a significant amount of energy to operate, so in the event of a power outage or other disruption, the reaction would simply stop.[1]

reaction, like nuclear fission. As the United States and other countries work to meet decarbonization targets and goals, a large source of consistent and clean power like nuclear fusion could be revolutionary.

However, fusion energy research in this area is still in the initial stages of demonstration, and the challenges to bring it to fruition are immense. Ignition is only the first step toward generating electricity from nuclear fusion power. Creating a sustained fusion reaction will require more technological advancements, and beyond this, building and maintaining a fusion electricity generator will need to be cost-effective.

Scientists have been interested in **fusion as an energy source** since the advent of the atomic age because if it could be developed at commercial scale, it would provide nearly limitless energy. For example, just a few grams of fuel could produce a terajoule of energy — approximately enough energy to support the energy needs of one Oregonian for over sixty years.[1]

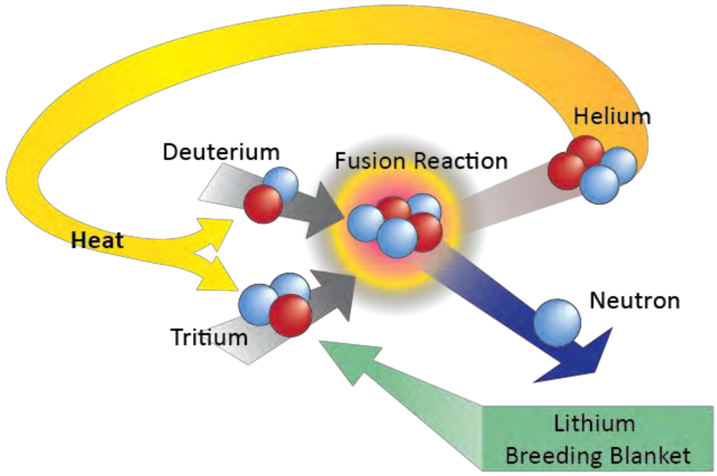
A particular challenge is the limited availability of tritium, one of the two hydrogen isotopes used in D-T fusion. There are only about 25 kilograms of tritium available in the world, making it incredibly rare and expensive.[18] Tritium is also radioactive, meaning any reactor components it comes in contact with will need to be handled and disposed of safely.[19] Because tritium is generally consumed during the fusion reaction, and because the reaction occurs in a chamber with shielding, it is unlikely to create a health hazard.[16] The NIF experiment used only 1 milligram of tritium. The radiation produced does not travel far in the air and cannot penetrate the skin.[19] Although it is generally consumed during the fusion reaction, unused tritium is a potential form of nuclear waste that could be released from a nuclear fusion reactor.

Tritium Exit Signs

Tritium is used in many emergency exit signs, making signs glow without a power source. During a power outage the sign will continue to glow, directing people inside toward the exit.[19] The tritium is enclosed within a tube. The radioactive particles emitted interact with a substance lining the tube, creating the glow. For this reason, these types of exit signs must be disposed of in accordance with Nuclear Regulatory Commission standards. The National Ignition Facility experiments used only about half the amount of tritium in an exit sign.

The primary source of tritium is from the operation of heavy water nuclear fission reactors equipped with a Tritium Removal Facility. Only two such facilities operate globally, and combined could produce about 260 grams of tritium in a year.[20] [21] [22] Fusion reactor operations are estimated to require 100 to 200 grams of tritium annually, so at current production levels, the global tritium supply could at most fuel a single reactor. Some of the global supply is already used for luminous material in exit signs and watches, in nuclear weapons, and as a radioactive tracer for scientific experiments.[23] Without new reactor development and/or additional Tritium Removal Facilities, there will be a dwindling supply of tritium production as existing reactors are decommissioned.

Figure 3: Diagram of a Deuterium-Tritium Fusion Reaction with Lithium Breeding Blanket[7]

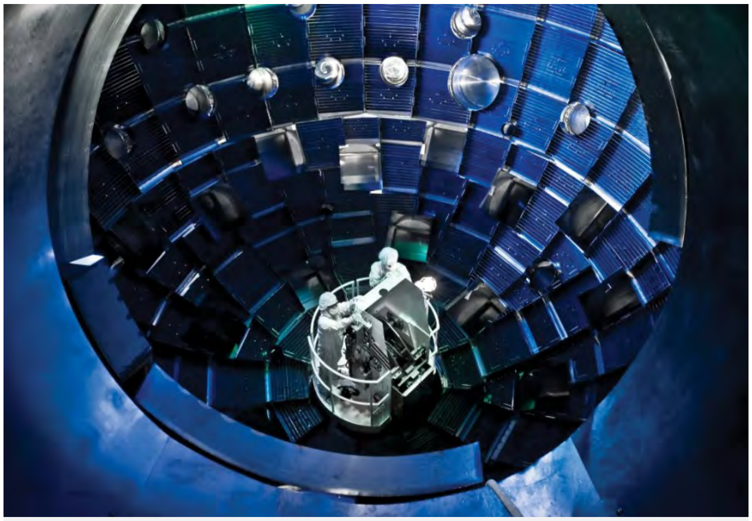


One technology being researched in conjunction with D-T fusion, called a lithium breeding blanket, regenerates tritium after the fusion reaction.[28] The lithium captures the free neutrons created during the reaction to produce tritium and helium. This is a critical technological breakthrough for nuclear fusion to become commercially viable. Unless tritium is being bred faster than it is burned, there will be insufficient supply to fuel reactors of the future.

Unlike tritium, the other hydrogen isotope used to fuel nuclear fusion, deuterium, is significantly more abundant.[29] There are tens of trillions of tons of deuterium available in the earth's oceans. Deuterium is found in all water sources and is separated from normal water using distillation, electrolysis, or through chemical reactions known as isotopic exchange.[30] It is a relatively expensive commodity because the processes for extracting deuterium are energy intensive and complex.[31]

Another type of fusion reaction called D-D fusion occurs when two deuterium atoms are fused together, instead of deuterium and tritium.[32] The advantage of D-D fusion is that it does not require tritium, nor does it have radioactive byproducts.[33] However, most research is in D-T fusion, because it requires less initial energy input and produces more energy. A D-D reaction requires two to three times the amount of energy to ignite than a D-T reaction.[34]

The radioactive waste resulting from current nuclear fusion experiments is much safer than nuclear fission. In 2018, Congress passed the Nuclear Energy Innovation and Modernization Act, which requires the Nuclear Regulatory Commission to develop and implement regulatory frameworks for advanced reactor designs, like nuclear fusion power, by 2027.[24] To implement this, NRC staff conducted an assessment of the types of fusion energy facilities currently being planned.[25] Their 2023 report found that these types of near-term facilities do not have the potential to create large accidental radiation exposures, present no risks of runaway reactions, and that the waste material cannot



Technicians working in the target bay at the National Ignition Facility.

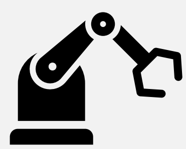
readily be used to develop nuclear weapons.[26] For this reason staff recommended regulating these facilities similarly to today's particle accelerators, which have much less stringent regulatory requirements compared with today's nuclear fission generation plants. On July 10, 2024, Congress passed the Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act, codifying near-term fusion reactor electricity generation facilities like energy particle accelerators.[27] This provision provides additional guidance to the NRC as they work to publish a proposed rule for licensing and regulating fusion energy systems in 2025.[24]

The federal Nuclear Regulatory Commission determined that regulations for byproducts of existing nuclear fusion systems should be addressed differently from nuclear fission reactors, largely because the radiologic waste products are sufficiently different.[46] The new NRC rules for disposal of waste from fusion reaction systems will be based on regulations governing other products containing tritium, including luminous exit signs, smoke detectors, and certain medical or industrial radiography instruments.

Supporting Nuclear Fusion Power Generation Research

The U.S. Department of Energy is seeking to accelerate commercialization of fusion power by facilitating the development of Fusion Innovation Research Engine collaboratives.[35] FIRE collaboratives support the US DOE strategy to achieve commercialized nuclear fusion within a decade by bringing together research scientists and technology innovators to bridge the gap between scientific studies and real-world applications.

Fusion Powered by Artificial Intelligence



AI has the capacity to look at results from solving one problem to predict how to solve related problems. The team at Lawrence Livermore National Laboratory used a combination of sophisticated modeling tools in conjunction with AI to more quickly learn from experimental results and develop new parameters that were more successful.[36] AI can also learn to maintain complex systems faster than human reactions or programming currently allow. An AI platform designed at Princeton University helps manage instabilities within the fusion reactor in real-time to better maintain the conditions needed for ignition to occur.[37]

There are more than 40 private companies working on fusion power or related technologies, providing over $6.2 billion of funding, with the goal of completing a fusion power plant in the 2030s.[38] Breakthroughs in material science technology and artificial intelligence will likely accelerate the potential for fusion-powered electricity.

Fusion in the Pacific Northwest

The Pacific Northwest is a central location for fusion technology research. Several prominent companies in Washington state and British Columbia are conducting reactor research, looking into efficient and affordable ways to produce nuclear fusion-generated power.[39] [40] [41] [42] [43] Helion, a Seattle-based company, is researching a fusion reactor that would directly generate electricity from the fusion reaction, rather than using the reaction's heat energy to generate steam. Helion recently signed a power purchase agreement to provide power from its nuclear fusion plant for Microsoft by 2029.[44] If successful, the 50 MW plant would start up in 2028 and begin providing power a year later.

Is Nuclear Fusion Part of Oregon's Energy Future?

It is uncertain if or when fusion power generation could be built in Oregon. In 1980, voters passed Measure 7, requiring voter approval and the existence of a federally licensed permanent nuclear waste facility in order to approve a nuclear plant site certificate.[45] The ballot initiative passed at a time when nuclear fission resources were the only form of nuclear power plant being considered, and fusion plants have significantly different waste profiles, with very little nuclear waste byproducts. Oregon rules and regulations have not yet been interpreted to include or preclude nuclear fusion development in the state. However, addressing public concerns about safety, environmental impact, effects on environmental justice communities, and any public safety risks associated with fusion energy will play an important role in any possible future development of this resource in Oregon.

SCAN OR CLICK

Learn more about the history of nuclear facilities and radioactive waste in ODOE's *2022 Biennial Energy Report*.

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ENERGY 101

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 look at important emerging topics like the clean hydrogen economy, the state of "agrivoltaics," and what's driving electricity rates. We also look at the effects climate change has on our energy systems, and provide the basics on electricity day-ahead markets, the nexus of energy and water, what "waste" energy means and how waste can be reduced, and more.

Energy is intertwined in everything that Oregonians do – from powering vehicles to support our livelihoods and economy, to electricity and fuels that serve as the backbone for industry and businesses. Everyone should have the opportunity to engage in energy choices, whether its options to reduce energy use and costs for homes, businesses, and industry or how we meet the challenge of transitioning our energy systems to cleaner, more renewable resources. 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

Advancements in a Clean Hydrogen Economy

Hydrogen has the potential to play a critical role in helping the world decarbonize over the coming decades, especially in "hard-to-abate" sectors not easily powered by clean electricity. It is attractive as a fuel and feedstock because it is extremely versatile – it can be used in virtually any application and can be produced from a variety of domestic resources including renewables, nuclear, biomass, natural gas, and coal.[1] But hydrogen's merit as a climate solution depends entirely on how it's produced. Most hydrogen production today is carbon-intensive – more than 99 percent is produced from fossil fuels, mostly from natural gas through a process known as steam methane reformation, or SMR.[i] [2] Clean hydrogen, or hydrogen produced with low or no carbon emissions, makes up less than 1 percent of global production. The clean hydrogen that is produced comes almost entirely from fossil fuels paired with carbon capture technology, though production of hydrogen from electrolysis is growing rapidly.[3]

Defining Clean Hydrogen

Clean hydrogen generally refers to hydrogen produced with little or no carbon emissions. The Inflation Reduction Act defines qualified clean hydrogen as that produced through a process that results in a well-to-gate[ii] lifecycle greenhouse gas emissions rate of no greater than four kilograms of CO2 equivalent per kilogram of H2 (for comparison, hydrogen derived from steam methane reformation produces about 10 kg CO2e/kg H2).[8] The most common methods of producing clean hydrogen are through water electrolysis using renewable electricity or steam methane reformation paired with carbon capture technology, though additional pathways exist.

Renewable hydrogen, on the other hand, generally refers to hydrogen produced from renewable energy sources. Exact definitions vary across states. In Oregon, both renewable and green electrolytic hydrogen were defined through House Bill 2530 in the 2023 legislative session.[9]

Per HB 2530, renewable hydrogen means hydrogen produced using:

- A renewable energy source as defined in ORS 469A.005 (Oregon's Renewable Portfolio Standard);
- Non-emitting electricity that is not derived from a fossil fuel (including hydropower); or
- Electricity with a carbon intensity equal to or less than the average carbon intensity of the Oregon electricity grid in the year construction or expansion of the production facility began.

Green electrolytic hydrogen is defined similarly but specifies that the hydrogen must be produced through electrolysis — and therefore does not include hydrogen manufactured using any conversion technology or steam reforming that produces hydrogen from a fossil fuel feedstock.

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[i] It is common to hear the acronym "SMR" when discussing hydrogen. In the hydrogen context, SMR refers to steam methane reformation, the most prevalent method for producing hydrogen today. This is not to be confused with small modular nuclear reactors, which are also commonly referred to as "SMR."

[ii] Well-to-gate lifecycle GHG emissions refers to total emissions associated with a product or process from its initial production (well) to the point it leaves a production facility (gate) and is used for hydrogen because it does not produce GHGs when combusted.

Hydrogen Use and Potential

Learn more about hydrogen, including in past ODOE reports and studies, on ODOE's website.

Hydrogen has been used in industrial applications in the United States for many decades, including in crude oil refining, fertilizer, steel and chemical production, and food processing. But hydrogen has far broader applicability, and because it can be produced and used with little or no carbon emissions, there is growing excitement around its potential to help address the climate crisis. Clean hydrogen and hydrogen-derived fuels[iii] can be used as fossil alternatives in heavy-duty transportation, including shipping, aviation, long-distance freight, and transit buses. It can be a key low-carbon input for steel, cement, and chemical production, as well as other high-heat industrial processes. It can provide clean back-up power for data centers, hospitals, and other critical infrastructure through stationary fuel cells. It can even increase grid reliability and flexibility, supporting the expansion of intermittent renewables by serving as long-duration energy storage and quickly ramping up or down when needed.[iv]

Interest in clean hydrogen is growing rapidly in the United States and abroad due to this potential to serve as a replacement for fossil fuels and help entities reach goals for deep decarbonization. Governments and project developers around the world are investing in hydrogen and hydrogen technologies at a feverish pace. As of January 2023, more than 1,000 large-scale (> 1 MW) hydrogen projects had been announced globally, representing $320 billion in direct investments through 2030.[5] Further, companies have announced plans for 38 million tons of clean hydrogen production by 2030 – a significant ramp up from the less than one million tons of clean hydrogen produced today.[6] As the clean hydrogen economy develops in the U.S., it has the potential to create jobs and revenue for U.S. businesses. A 2020 report by McKinsey estimated that, with ambitious federal regulation and policies requiring emissions reduction across industries, by 2030, the U.S. hydrogen economy could generate an estimated $140 billion per year in revenue and support 700,000 total jobs; by 2050, these numbers jump to $750 billion per year in revenue and a cumulative 3.4 million jobs.[7]

Many envision a future clean hydrogen economy in the U.S. where clean hydrogen and hydrogen-based fuels are an accessible alternative to fossil fuels; there is infrastructure in place to support its production, distribution, and use; and there is significant economic value and job creation potential. But the clean hydrogen industry has struggled to get off the ground, largely due to the "chicken and egg" problem, where demand for clean hydrogen is limited due to high production costs, and thus production is limited – and therefore unable to benefit from economies of scale – due to low demand. To realize this vision of a clean hydrogen economy and bring the industry from nascency to scale across new sectors, there must be coordinated efforts to simultaneously develop both production

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[iii] Clean hydrogen can be used to produce liquid fuels that serve as drop-in fuels to replace petroleum products or used to power specialized equipment.[4] For example, the Fischer-Tropsch process converts synthetic gas – or syngas, a mixture of hydrogen and carbon monoxide – to liquid hydrocarbons. Similarly, the Haber-Bosch process can be used to produce ammonia using hydrogen and nitrogen.

[iv] For more background information on hydrogen and its characteristics as an energy carrier and feedstock, see the Oregon Department of Energy's Renewable Hydrogen Report and its 2022 Biennial Energy Report.

capacity and demand. For this, robust policy and financial support will be needed, as well as advancements in technologies across the hydrogen value chain.

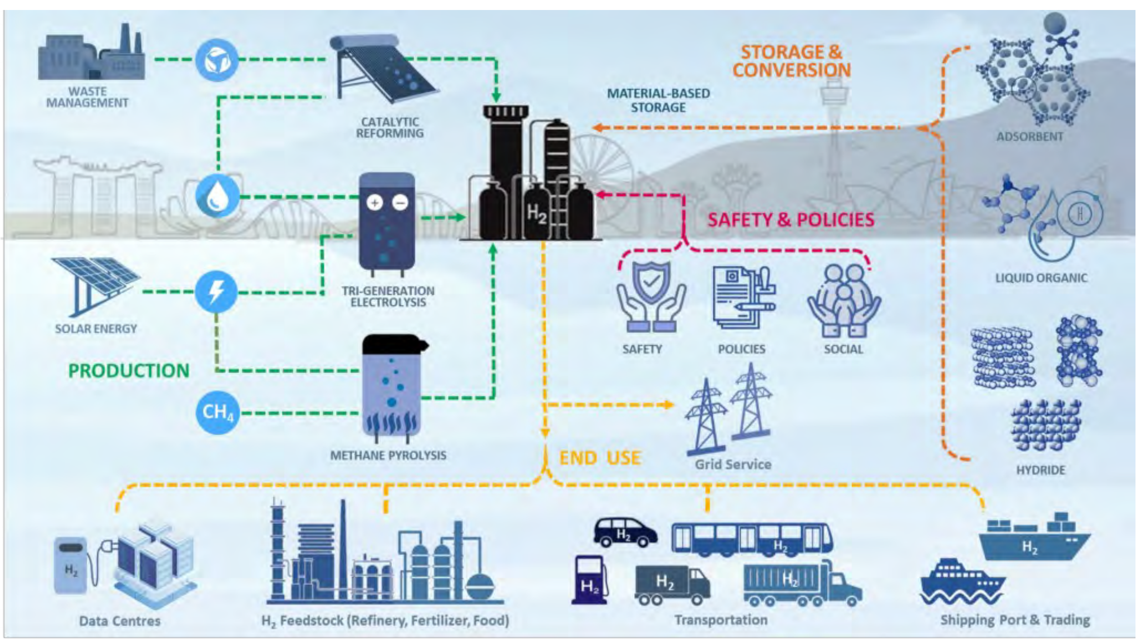
Role of Federal Investments in Building a Clean Hydrogen Economy

Two recent laws have the potential to jumpstart a clean hydrogen economy in the U.S. through historic levels of investment in low-carbon technologies – the Infrastructure Investment and Jobs Act and the Inflation Reduction Act. The Infrastructure Investment and Jobs Act, passed in 2021, allocated $9.5 billion for clean hydrogen research, development, and demonstration programs, including $8 billion for the development of regional hydrogen hubs across the U.S., $1 billion for a clean hydrogen electrolysis demonstration grant program, and $500 million for a clean hydrogen manufacturing and recycling grant program.[10] The Inflation Reduction Act, which followed the IIJA in 2022, established a new, 10-year production tax credit of up to $3 per kilogram for the production of qualified clean hydrogen (known as the 45V tax credit). The IRA also substantially increased the value of the existing tax credit for carbon sequestration (known as the 45Q tax credit).[11] The combined impact of the IIJA and IRA is expected to help catalyze the clean hydrogen economy in the U.S. by creating an enabling environment, fostering innovation, and incentivizing private sector participation.

U.S. DOE's Regional Clean Hydrogen Hubs Program

The $8 billion Regional Clean Hydrogen Hubs program (H2Hubs) is designed to jumpstart the clean hydrogen economy across the country. The program will establish regional networks of hydrogen producers and consumers and the necessary connective infrastructure, such as pipelines and storage. The goal of the program is to accelerate the deployment of clean hydrogen technologies while attracting greater investments from the private sector and promoting substantial U.S. manufacturing.[12] Awarded projects will demonstrate the entirety of the hydrogen value chain – from production and processing to delivery, storage, and end-use. Due to myriad ways hydrogen can be produced and used, U.S. DOE specifically sought demonstration projects with feedstock and end-use diversity.

Figure 1: The Hydrogen Value Chain[13]



After a competitive application process, in October 2023 the U.S. Department of Energy announced $7 billion in awards to seven H2Hubs across the nation, including one in the Pacific Northwest.[v] This $7 billion in public funding will be matched by recipients to leverage nearly $50 billion in investments to build the clean hydrogen economy.[15]

Regional Hydrogen Hubs

Spanning 16 states and seven regions, the hydrogen hubs awarded through U.S. DOE's H2Hubs program will support the development of localized networks of clean hydrogen producers, consumers, and enabling infrastructure. These hubs will form the foundation of a national clean hydrogen network that contributes to decarbonizing various sectors of the U.S. economy.

Figure 2: Map of Regional Clean Hydrogen Hubs[16]

The H2Hubs are expected to collectively produce 3 million metric tons of hydrogen annually – nearly a third of the 2030 U.S. production target – and reduce CO2 emissions by 25 million metric tons each year.[15] The projects within the hubs will demonstrate a variety of feedstocks, including fossil fuels, renewable energy, and nuclear energy. Similarly, the clean hydrogen produced will be used in diverse applications, including the electric power generation, industrial, transportation, and commercial heating sectors. See Table 1 for more details about the awarded H2Hubs.

[v] The remaining $1 billion in program funding will be invested into a DOE-managed demand-side support mechanism for the H2Hubs program to support reliable demand and address market uncertainty for clean hydrogen, which DOE maintains is "critical to ensuring the early commercial viability of a H2Hub."[14]

Table 1: U.S. DOE's Seven Regional Hydrogen Hubs[17]

Hydrogen Hub	States	Feedstocks	Connecting Infrastructure	End Uses
Appalachian (ARCH2)	• Ohio • Pennsylvania • West Virginia	• Natural gas with carbon capture	• Pipelines • Refueling	• Industry • Transportation (heavy-duty trucking)
California (ARCHES)	• California	• Biomass • Renewables	• Freight line	• Power generation • Transportation (heavy-duty trucking, port operations, public transit)
Gulf Coast (HyVelocity H2Hub)	• Texas	• Natural gas with carbon capture • Renewables	• Pipelines • Refueling • Salt cavern storage	• Industry (ammonia, refineries, petrochemicals) • Power generation • Transportation (heavy-duty trucking, marine fuel)
Heartland (HH2H)	• Minnesota • North Dakota • South Dakota	• Biomass • Nuclear • Renewables	• Open access storage • Pipelines	• Heating • Industry (agricultural fertilizer production) • Power generation
Mid-Atlantic (MACH2)	• Delaware • New Jersey • Pennsylvania	• Nuclear • Renewables	• Bus mechanic depots • Pipelines • Refueling	• Heating • Transportation (aviation, heavy-duty trucking, refuse/sweeper trucks) • Power generation
Midwest (MachH2)	• Illinois • Indiana • Michigan	• Natural gas with carbon capture • Nuclear • Renewables	• Refueling	• Industry (refining, steel, glass production) • Power generation • Transportation (heavy-duty trucking, sustainable aviation fuel)
Pacific Northwest (PNWH2)	• Washington • Oregon • Montana	• Renewables	• Freight line	• Industry (agriculture, refineries, data centers) • Power generation (peaker plants, generators) • Transportation (heavy-duty trucking, port operations)

The 45V Clean Hydrogen Tax Credit

A complementary initiative to the H2Hubs program, the Inflation Reduction Act created the 45V clean hydrogen tax credit, a new incentive for clean hydrogen production worth an estimated $100 billion.[17]

Under 45V, clean hydrogen producers can opt for a credit equal to a specified dollar amount per kilogram of hydrogen produced (a production tax credit, or PTC) or a tax credit equal to a percentage of their capital expenses (an investment tax credit, or ITC).[18] In both cases, the level of credit provided is dependent on the carbon intensity of the production pathway, or the well-to-gate lifecycle greenhouse gas emissions associated with how the hydrogen is produced,[vi] as well as whether the hydrogen producer complies with prevailing wage and apprenticeship requirements. The majority of hydrogen producers are likely to elect for the PTC, as it is more valuable than the ITC in most cases.[20] Under the PTC, qualifying facilities that begin production before the end of 2032 will receive a credit of up to $3 for every kilogram of hydrogen produced for the first 10 years of operation. Table 2 lists the value of both tax credits for complying hydrogen producers.

Table 2: Values of the 45V Clean Hydrogen Tax Credit*[8]

Well-to-Gate Emissions (kg CO2e / kg H2)	ITC Percentage	PTC Value ($/kgH2)
0 – 0.45	30 percent	$3.00
0.45 – 1.5	10 percent	$1.00
1.5 – 2.5	7.5 percent	$0.75
2.5 – 4	6 percent	$0.60

**Credits are reduced by a factor of five for noncompliance with prevailing wage and apprenticeship requirements.*

The IRA also significantly increased the tax credit available for carbon capture and sequestration technologies – the 45Q tax credit. The 45Q tax credit provides CCS facilities a dollar-per-ton tax credit for carbon oxide emissions (primarily carbon dioxide) captured and permanently stored underground or used in commercial applications such as enhanced oil recovery. While this credit has existed since 2008, the IRA increased the level of the credit to $85/ton for sequestered CO2 and $60/ton for utilized CO2. Direct air capture facilities receive even more: $180/ton and $130/ton for sequestered and utilized carbon, respectively. Like the 45V clean hydrogen tax credit, these values are reduced by a factor of five if prevailing wage and apprenticeship requirements are not met. Hydrogen producers utilizing CCS can take either the 45V tax credit *or* the 45Q tax credit, but not both. The 45Q tax credit is available regardless of CO2 emissions and as a result, hydrogen producers with higher upstream emissions are likely to find the 45Q more valuable.[21]

For clean hydrogen to scale up, it must be cost competitive with conventional hydrogen. These tax credits, especially when considered in conjunction with DOE's H2Hubs program, could bring clean hydrogen close to price parity with conventional hydrogen. The highest incentive available – $3 per kilogram of clean hydrogen produced – is roughly half today's current costs of $4-$6 per kilogram for hydrogen produced from electrolyzers. Conventional natural-gas derived hydrogen, on the other

[vi] In the context of hydrogen production, well-to-gate emissions include emissions associated with feedstock growth, gathering, extraction, processing, and delivery to a hydrogen production facility, as well as emissions associated with the hydrogen production process, inclusive of electricity used by the production facility and any capture and sequestration of CO2.[19] Taxpayers claiming the 45V credit must determine the lifecycle GHG emissions rate using the most recent Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model applicable to hydrogen production, developed by Argonne National Laboratory.

hand, costs about $1-$1.50/kg, whereas that derived from SMR paired with CCS is approximately $1.60/kg.[22]

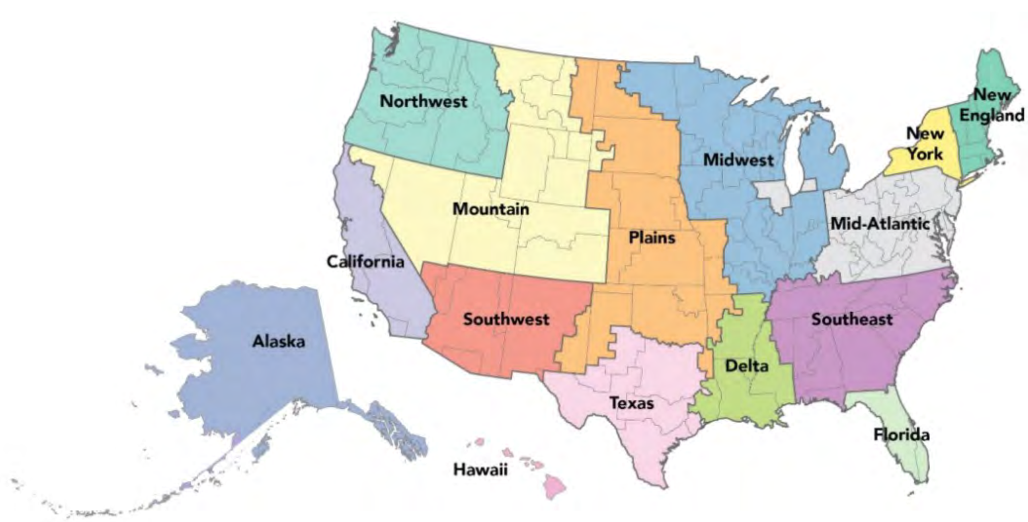
The Debate Over the Three Pillars of the 45V Clean Hydrogen Tax Credit

In December 2023, the U.S. Department of the Treasury and the Internal Revenue Service released highly anticipated proposed regulations for the 45V clean hydrogen tax credit. Leading up to the release, a fierce debate took place over how strict the rules governing clean hydrogen production should be, particularly around carbon accounting for electrolytic hydrogen. The challenge for the federal government is to ensure that increased electrolytic hydrogen production does not increase electricity demand from polluting sources – and thus *increase* GHG emissions – while also allowing sufficient flexibility to enable a cost-competitive domestic industry to develop.

The regulations propose a method for accounting for emissions associated with the electricity used to produce hydrogen through electrolysis in a few scenarios. Hydrogen production facilities that are connected *directly* to a renewable power plant will qualify as hydrogen produced from renewable electricity, provided the clean power generation was built within 36 months of the hydrogen production facility and the site can demonstrate they are not using grid electricity.[23] Hydrogen producers using grid-connected electricity, on the other hand, can treat that electricity as being from a specific electricity generation facility *only if* the producer acquires and retires qualifying energy attribute certificates (EACs) for each unit of electricity claimed from that source.[24] To qualify, EACs must meet the "three pillars" of incrementality, temporal matching, and deliverability:

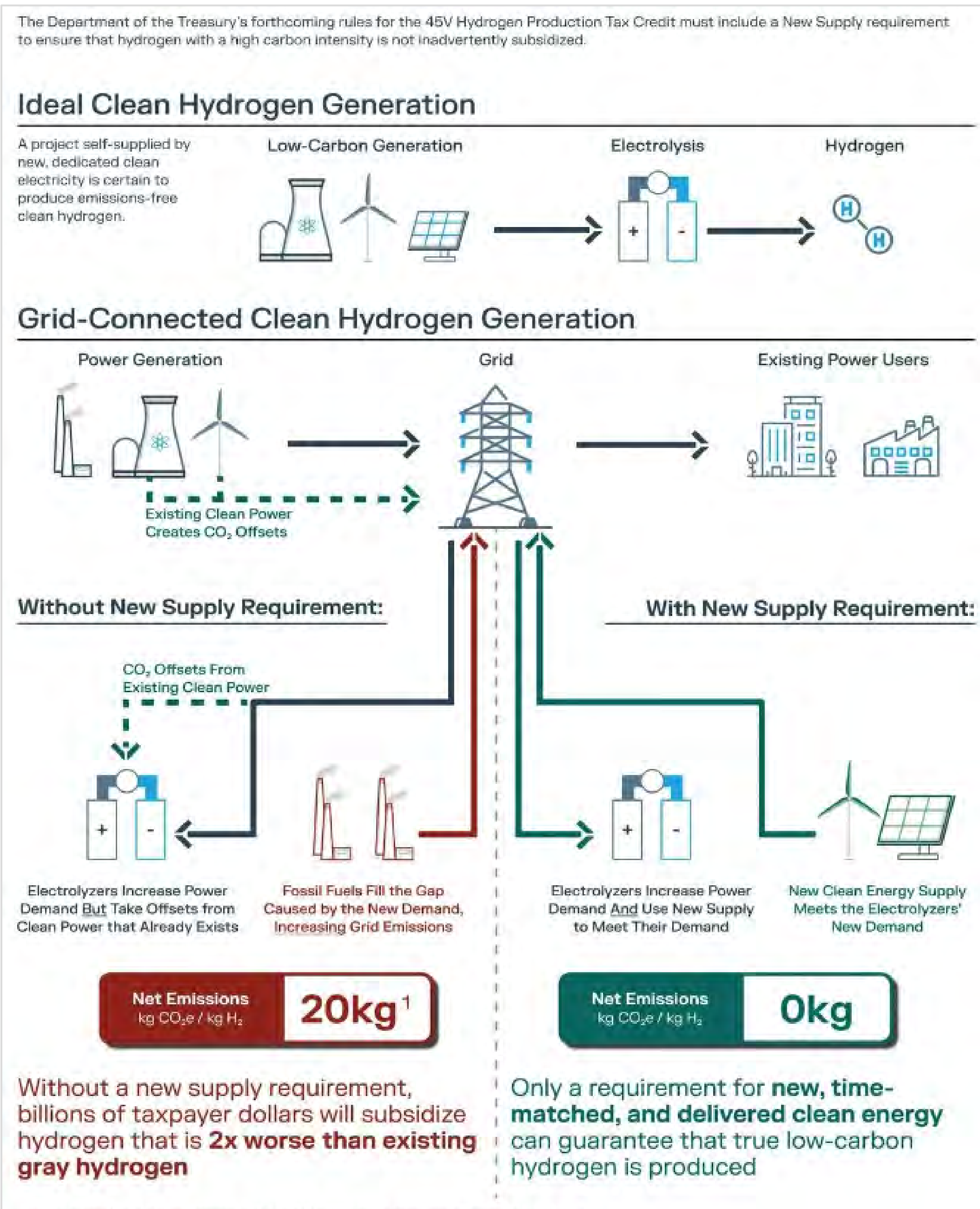
1) **Incrementality,** also known as additionality, requires EACs to come from new clean power generation placed in service within 36 months of the associated hydrogen facility.
2) **Temporal Matching,** also known as hourly matching, requires electricity represented in the EAC be generated in the same hour that the hydrogen production facility uses that electricity to produce hydrogen. The proposed regulations include a transition rule, allowing EACs generated before 2028 to meet yearly, rather than hourly, matching.
3) **Deliverability** requires the electricity represented in the EAC to be sourced from the same region as the hydrogen production facility. Regions are defined as those used in the National Transmission Needs Study from October 2023. These regions are shown below in Figure 3.

Figure 3: Geographic Regions for Demonstrating Deliverability in 45V Proposed Regulations[25]



Proponents of the "three pillars" argue they are needed to ensure the clean hydrogen tax credits lead to projects that truly reduce GHG emissions. Without additionality and hourly matching, for example, studies have shown that hydrogen made from grid electricity will lead to a net increase in carbon emissions.[26,27] Because no portion of the U.S. grid can qualify for any of the 45V credit tiers with its general electricity mix, the lowest-cost option for hydrogen producers wishing to receive the highest-tier tax incentive would be to purchase low-cost, unbundled EACs from anywhere in the U.S., an action that some argue fails to increase the share of clean power on the grid and instead increases demand for fossil-fueled power, as new electricity demand from hydrogen electrolysis outpaces clean energy development.[28] This problem is compounded by the electric load growth many regions are experiencing already, including the Pacific Northwest, as a result of increased electrification and data center demand.

Figure 4: Impact on GHG Emissions without a 45V Supply/Incrementality Requirement[29]



On the other hand, opponents of the "three pillars" argue that such regulations will hamper the electrolytic hydrogen industry in the U.S. These voices insist that looser rules are needed to launch the clean hydrogen sector and that requiring additional, deliverable, and hourly matched clean energy to power electrolysis could not only push costs above those for fossil-derived hydrogen but also limit production to only those parts of the U.S. with the highest amounts of clean energy.[30]

During its open comment period, the IRS received more than 30,000 comments on the proposed regulations under section 45V.[31] Final regulations will be available on the federal register once published.

Opportunities for Clean Hydrogen in Oregon

Clean hydrogen represents a significant opportunity for Oregon to meet its decarbonization goals, demonstrate clean energy leadership, and promote economic growth in the region. With a supportive regulatory framework in place to incentivize a shift to clean fuels as well as historic levels of federal funding coming to the region, clean hydrogen is poised to scale up in Oregon in the coming decades.

Oregon's Supportive Regulatory Landscape

Oregon has built a strong policy foundation to accelerate the state's transition to clean energy. Several existing policies set the stage for a rapid increase in hydrogen production and use in Oregon over the next decade.

- Through the Oregon Department of Environmental Quality's Advanced Clean Cars II[32] and Advanced Clean Trucks[33] rules, the state will see increasing percentages of zero-emission vehicles for sale in the light-, medium-, and heavy-duty sectors.[vii] Hydrogen fuel cell electric vehicles are an attractive zero-emission alternative to internal combustion vehicles, particularly in the heavy-duty transportation sector where battery electrification may be more difficult. [viii]
- Oregon DEQ's Climate Protection Program[ix] set a declining limit on greenhouse gas emissions for fossil fuels used throughout Oregon, including diesel, gasoline, natural gas, and propane used in transportation, residential, commercial, and industrial settings, requiring a 50 percent reduction by 2035 and a 90 percent reduction by 2050.[34] The program also regulated site-specific GHG emissions at manufacturing facilities. Clean hydrogen and hydrogen-derived fuels such as Fischer-Tropsch liquid fuels or ammonia could play a role in CPP compliance, particularly for sectors that are difficult to electrify, such as high-heat industrial processes and heavy-duty trucks or ships.

[vii] The ACC II requires 100 percent of new light-duty vehicles sold in Oregon to be zero-emission vehicles by 2035. Under ACT, between 40-75 percent of new trucks sold in Oregon must be zero-emission by 2035, depending on the vehicle class.

[viii] The adoption of fuel cell electric vehicles in Oregon will require significant investment in hydrogen fueling infrastructure, as there are no such fueling stations in Oregon currently. For more information on hydrogen fuel cell electric vehicles, see the 2020 Biennial Energy Report.

[ix] In December 2023, the CPP was invalidated by the Oregon Court of Appeals due to noncompliance with notice requirements under the rulemaking process. While the Oregon Department of Environmental Quality is in the process of a new rulemaking to reestablish the program before the end of 2024, there is no guarantee that program details will remain the same. For more details, see DEQ's CPP 2024 rulemaking webpage.

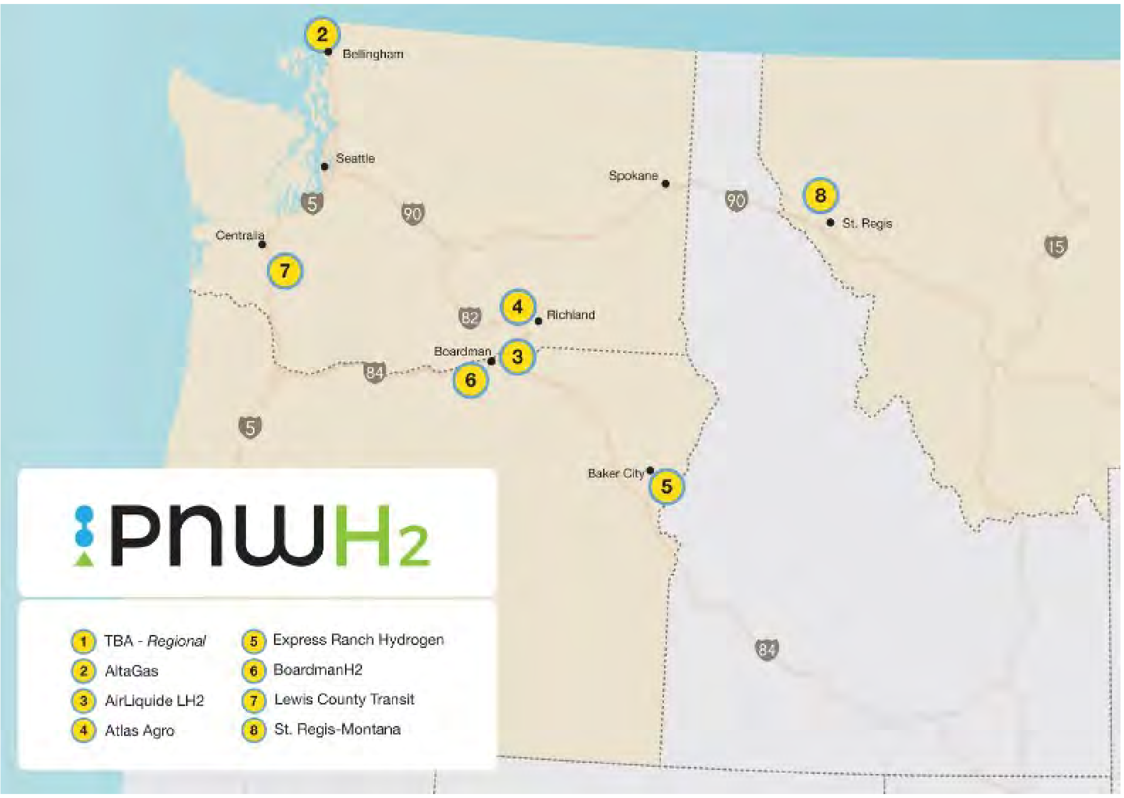
- Oregon DEQ's Clean Fuels Program, Oregon's low-carbon fuel standard, establishes annual standards for carbon intensity of transportation fuels that decrease over time through 2035.[35] The program requires the switch to lower carbon fuels through a market-driven credit and deficit system, whereby low-carbon fuel providers generate credits that can be sold to high-carbon fuel providers, who need them for compliance with the program. The CFP encourages fuel suppliers to source and supply the lowest carbon fuels to customers in Oregon. In the case of hydrogen, the owner of a hydrogen fueling station for vehicles or the owner of a fleet of hydrogen forklifts can generate credits through the CFP, helping to offset the cost of investing in these technologies and complying with other climate policies.
- Oregon's 100% Clean Electricity Standard (HB 2021) and its Renewable Portfolio Standard ensure more renewables will be added to the electric grid in coming years. HB 2021 requires the state's two largest investor-owned utilities and retail electricity service suppliers to reduce the GHG emissions associated with the electricity sold to Oregon consumers by 100 percent below baseline emissions levels by 2040.[36] The RPS requires electric utilities to meet an increasing portion of their in-state retail electricity sales with qualifying renewable energy.

  As more intermittent renewables are added to the grid to meet these targets, energy storage will be increasingly critical to maintaining grid reliability. Lithium-ion batteries supply most of the new storage capacity today but are currently expensive for long-duration or seasonal storage. Pumped hydropower has been used as long-duration energy storage in the U.S. for decades and, once built, offers high round-trip efficiency, a low cost of storage and large quantities of energy. However, new deployments are extremely difficult to build due to cost, large land requirements, complex permitting, local opposition, and highly specific site characteristics.[37] Hydrogen offers another alternative for long duration or seasonal storage. Hydrogen can be produced by an electrolyzer from curtailed or excess renewable electricity, stored as a gaseous or liquid fuel, and then used to produce electricity when needed. This process is currently far less efficient than other storage technologies – with a round-trip efficiency of 18 to 46 percent, compared to 70 to 85 percent for pumped hydro – but it provides an option when other technologies face economic, geographic, or environmental constraints.[38]

The Opportunity to Jumpstart Oregon's Clean Hydrogen Economy through the PNWH2 Hub

The Pacific Northwest Hydrogen Hub will bring up to $1 billion in federal funding to the region and leverage an additional $7 billion in private and other investments to support the development of a clean hydrogen economy across Oregon, Washington, and Montana.[39] The proposed PNWH2 hub includes 17 projects organized into eight nodes that are geographically dispersed across the region.

Figure 5: Potential Project Locations for the PNWH2 Hub[40]



Three of the eight PNWH2 Hub nodes are in Oregon and will include projects across the entire hydrogen value chain, including hydrogen production through electrolysis, transport through a pipeline, liquefaction and storage of H2 at a liquefaction plant, and use as both long-duration energy storage and as a zero-emission fuel for heavy-duty transportation. Table 3 below provides additional details about each of the nodes in Oregon.

Table 3: PNWH2 Hub Projects in Oregon[40]

Node	Location	Project Lead	Details
3	Port of Morrow	Air Liquide	• H2 liquefaction to bring H2 to market. • Anchor end uses: heavy duty transportation along I-5, I-90 and I-84; port decarbonization through drayage and cargo handling equipment.
5	Durkee	Express Ranch Hydrogen	• Includes dedicated pipelines, above ground storage, and a H2 refueling station. • Anchor end uses: mining and other heavy-duty trucks. • Byproduct O2 to be used for cement production.
6	Boardman	MHI Hydrogen Infrastructure	• Redevelopment of a decommissioned coal power plant to produce power with clean hydrogen. • Demonstration of clean hydrogen used for long-duration energy storage. • H2 pipeline built along existing pipeline right-of-way. • Anchor end uses: Dispatchable 100 percent H2 turbines; providing H2 to node 3.

These projects, in conjunction with those in the other nodes, are expected to accelerate deployment and drive down the costs of low-carbon hydrogen in Oregon and across the Pacific Northwest. When all projects are built, the PNWH2 Hub will produce approximately 400 metric tons of clean hydrogen per day and will be one of only two hubs awarded to do so using 100 percent renewable energy. More than 10,000 jobs will also be created for the region, including an estimated 2,000 permanent jobs, and ample opportunities for workforce development through apprenticeships and displaced worker training. Additional community benefits include the redevelopment of brownfield sites, reduced energy costs through energy assistance funding programs for low-income renters and homeowners, local and county tax revenue to support vital government services, and improved localized air quality near H2 production and use sites.[41]

Challenges to Achieving a Clean Hydrogen Economy

The clean hydrogen economy in Oregon is poised for rapid growth due to historic levels of funding available, enabling state and federal policies, and aggressive state climate goals. But challenges to scaling the domestic clean hydrogen industry remain. For the industry to really take off, clean hydrogen needs to be both widely available and cost competitive with other low-carbon technologies.

Clean hydrogen is still much more expensive to produce than conventional fossil-derived hydrogen and remains more expensive than competing low-carbon alternatives such as lithium-ion batteries, due to the high cost of electrolyzers and carbon capture technology. The substantial federal funding available through the clean hydrogen tax credit will offset much of these costs, but advancements in hydrogen technologies are still needed to further drive down costs and improve efficiency.[x]

A thriving domestic clean hydrogen industry is dependent on having the necessary infrastructure in place to connect producers and consumers – such as storage facilities, pipelines, and fueling stations – the building of which comes with substantial costs and long lead times.

The clean hydrogen market still faces a “chicken-and-egg” problem, where lack of demand inhibits production and vice versa. For clean hydrogen production to scale in the Pacific Northwest, there must be established and reliable demand for it.

Overcoming these challenges is feasible, but will require continued public investment and policy support, advancements in technologies across the hydrogen value chain, and the close collaboration of industry and the public sector.

[x] The U.S. DOE has a goal of reducing the cost of clean hydrogen by 80 percent to $1 per 1 kilogram in one decade, known as the Hydrogen Shot program or “1 1 1”. DOE has announced funding opportunities and other activities to help advance progress toward meeting the Hydrogen Shot goals.[42]

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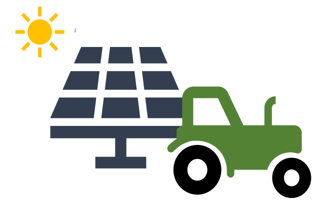
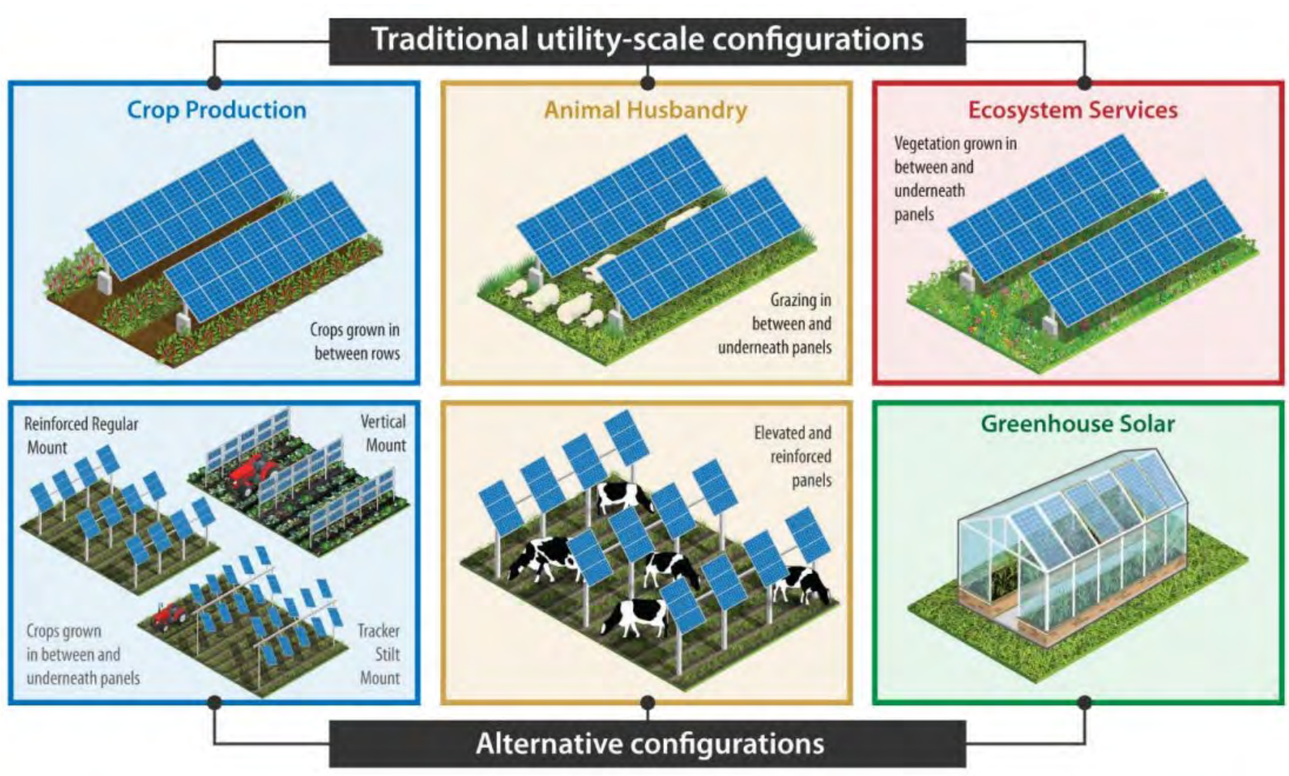
Agrivoltaics in Oregon



Agrivoltaics, sometimes called dual-use solar or agrisolar, refers to the practice of producing both food and electricity using solar panels on the same parcel of land.[1] The term "dual-use solar" is often used to refer to a wider variety of combinations in addition to agrivoltaics, including floating solar, capping irrigation canals with solar arrays, and integrating solar generation with land uses that provide ecosystem services or pollinator habitat.[2] This Energy 101 will focus on agrivoltaics systems that combine solar photovoltaic generation with commercial agricultural production, including raising crops and grazing livestock.

Agrivoltaics systems use the same technologies to generate electricity as conventional solar photovoltaic systems; however, agrivoltaics systems include a variety of adaptations to their structural components to meet the demands of sharing land with agricultural uses. Adaptations include raising panels higher off the ground, installing panels vertically or with racking that allows panels to tilt so that farm equipment may more easily operate between rows, or allowing for more space between rows and/or panels within each row of the array. Growers may also install solar panels as part of a greenhouse operation.[3] Figure 1 depicts several variations of configurations and mounting systems that facilitate dual solar and agricultural installations.[3]

Figure 1: Agrivoltaics Configurations and Mounting Systems for Dual Use[3]



While the concept originated in the 1980s, interest and activity around agrivoltaics have accelerated recently in several countries, including Japan, China, South Korea, France, Italy, Germany, and the U.S.,[1] largely driven by concerns about conversion of farmland to meet future renewable energy demands. In its "Solar Futures Study," the U.S. Department of Energy predicted that achieving decarbonization of the electric sector by 2050 will require 10.4 million acres of land for solar energy generation, representing approximately 0.5 percent of U.S. land area.[2 4] For context, Yellowstone National Park encompasses 2.2 million acres, about one-fifth of the area U.S. DOE predicts would be needed to meet future needs for solar generation.[5]

The American Farmland Trust advocates for policymakers to promote agrivoltaics to reduce the conversion of farmland for solar development as part of its "Smart Solar principles."[6] Researchers in the U.S. and Europe have found that agrivoltaics has the potential to meet a significant portion of electricity demand. For example, Oregon State University researchers calculated in a 2021 study that agrivoltaics systems on an area of land approximately the size of Maryland (just under one percent of the area of U.S. farmland) could supply 20 percent of the total U.S. electricity generation from 2019,[7] while European researchers found that agrivoltaics on 1 percent of farmland in the European Union could produce enough electricity to meet the E.U.'s 2030 solar photovoltaic goals.[8]

Preserving Farmland While Increasing Solar Generation

The American Farmland Trust has articulated "Smart Solar" principles in response to its findings that 83 percent of the solar development expected by 2040 could take place on farmland, with half of the development occurring on the most productive farmland.[77]

"Smart Solar" development meets the following criteria:

1. Prioritize developing solar projects on land not well suited for farming and the built environment.
   American Farmland Trust recommends that states and local governments use tools such as financial incentives, permitting regulations, and mitigation fees to guide the siting of solar projects into higher priority areas.
2. Preserve the ability for land to be used for farming in the future with policies for maintaining soil health during construction and decommissioning.
3. Develop agrivoltaics to increase solar generation while preserving farm production.
4. Ensure that farmers and underserved communities benefit from solar development and are included in stakeholder engagement.[78]

The National Renewable Energy Laboratory recommends strategies for lowering the impact of solar development, prioritizing practices that leave topsoil intact and minimize soil compaction to preserve the ability to grow crops in the future. For example, NREL encourages project designers to work with the natural contours of the land to minimize grading that scrapes away topsoil and to consider structural supports such as driven piles that minimize a project's footprint.[79 80]

Farmland is attractive for solar development for many reasons. Researchers comparing land with different types of vegetation found that croplands have the highest solar photovoltaic power potential, with grasslands coming in a close second. As explained by the study, "Solar panels are most productive with plentiful insolation, light winds, moderate temperatures and low humidity. These are the same conditions that are best for agricultural crops."[9] When comparing farmland to other categories of land that have been altered from its natural state and could host solar arrays, such as brownfields or former quarries,[3] high-quality farmland is often more attractive to solar developers "because it is flat, sunny, cleared and near energy infrastructure."[9 10]

Agrivoltaics can be an attractive option from a farming perspective as well, allowing farmers to manage sunlight as a resource much as they already manage soil and water resources on their grazing and crop lands. For many crops, the amount of summer sunlight they receive is more than they are able to use for growth; scientists at Oregon State University estimate that summer sunlight in Oregon provides 30 to 50 percent more solar energy than a typical crop can use.[11] By providing partial shade, agrivoltaics harnesses the excess solar energy to generate electricity, enabling two simultaneous uses of farmland while reducing the stress on crops and the amount of water they need.[12 7]

This Energy 101 will explore agrivoltaics, including the current state of research and commercial implementation, potential benefits and challenges of implementing agrivoltaics in Oregon, and work in other states and at the national level to provide guidance and incentives for successfully implementing agrivoltaics.

Current State of Research and Implementation

Until recently, almost all agrivoltaics projects in the U.S. were small research plots;[7] agrivoltaics installations on croplands spanning more than 50 acres are still rare.[2] The majority of operational utility-scale agrivoltaics installations in the U.S. are combinations of solar generation with sheep grazing, as identified by the National Renewable Energy Laboratory's InSPIRE program that tracks agrivoltaics installations.[13]

Figure 2: Map of Agrivoltaics in the United States[13]

Incorporating sheep grazing into solar array maintenance plans has become the industry standard for utility-scale installations to manage vegetation and fire risks, with costs roughly equivalent to alternatives such as mowing or underlaying the panels with gravel.[14] The American Solar Grazing Association describes sheep as perfectly suited to grazing under panels due to their size and grazing habits, and offers information and assistance such as contract templates for interested flock owners and solar developers.[15] [16] Flock owners have found the extra income from the services they provide to solar developers to be a helpful supplement to their income from meat, milk, and wool products.[17] Vegetation management under solar panels requires one to five sheep per acre, while the number of sheep kept by U.S. farmers has shrunk from a historic high of 51 million in 1884 to about 5 million currently. The majority of lamb and mutton consumed in the U.S. is imported, while many areas of the U.S. lack livestock processing facilities, meaning that increased demand for solar grazing could lead to significant changes to livestock markets as well.[18] [2] [19]

Researchers in the U.S. and elsewhere are actively exploring methods to combine solar generation with raising crops, methods that are site-specific to take into account differences in soils, climates, water availability, market demands, and other factors.[13] [2] The "Innovative Solar Practices Integrated with Rural Economies and Ecosystems" or InSPIRE program is the most comprehensive and coordinated agrivoltaics research program in the U.S. InSPIRE, which is led by the National Renewable Energy Laboratory and funded by the U.S. Department of Energy, has awarded grants for agrivoltaics research at 28 sites in 11 states plus Puerto Rico and Washington, D.C. since 2015.[20] In summarizing findings from its first two rounds of funding, the InSPIRE program enumerated five central elements that contribute to successful agrivoltaics projects, what it calls the "5 Cs of Agrivoltaics":[3]

1. **Climate, soil and environmental conditions**: The location must have appropriate conditions for both solar generation and growth of the desired crops.
2. **Configurations, solar technologies, and designs**: The design of the infrastructure, site layout, and solar technologies affect the amount of solar irradiation that reaches the solar panels and the ease of agricultural operations. For example, recent projects often use bifacial panels that generate electricity from both direct sunlight and reflected sunlight hitting the downward-facing side, which affects temperatures and the degree of shading under the panels.
3. **Crop selection, cultivation methods, seed selection, and management**: Crops must be able to thrive under solar panels and be profitable in agricultural markets.
4. **Compatibility and flexibility**: Agrivoltaics projects need to meet the different and sometimes competing needs of solar project owners and farmers or landowners.
5. **Collaboration and partnership**: Agrivoltaics projects are often more complex than single-use solar installations. Communication and understanding among partners are crucial, along with community acceptance.[3] [20]

Two additional federal programs have announced awards for agrivoltaics research to move agrivoltaics closer to commercialization at utility scale, building upon early lessons under InSPIRE and other basic agrivoltaics research. The "Foundational Agrivoltaic Research for Megawatt Scale," or FARMS program under the U.S. Department of Energy, aims to reduce barriers to the adoption of agrivoltaics at utility scale, including studying how agrivoltaics could be integrated into existing solar installations and partnering with university extension projects to educate farmers about agrivoltaics.[21] [22] Meanwhile, the U.S. Department of Agriculture has recently announced the "Sustainably Colocating Agricultural Photovoltaic Electricity Systems" or SCAPES project headed up by the University of Illinois and focusing on commodity row-crop farming with research sites in Illinois, Arizona, and Colorado.[23] Additionally, the U.S. Department of Energy has announced its $8.2 million "Large Animal and Solar System Operations" or LASSO prize challenge to encourage pilot and demonstration projects combining cattle grazing and solar energy development.[24]

In the Pacific Northwest, crops that researchers have found to be successful as part of agrivoltaics systems include vegetables[25 26] and vegetable seed,[27] herbs and leafy greens,[28 29] and pasture grasses.[12 29] Dry farming researchers at Oregon State University have found success growing potatoes interspersed with solar panels while also seeing potential for reducing blossom end rot in tomatoes grown in dry farming systems that incorporate agrivoltaics, but express doubt that some sun-loving crops such as melons or squash would fare as well with agrivoltaics in the Pacific Northwest.[30 3] Other U.S. growing regions have had notable successes with various local crops, for example: tomatoes and peppers in the hot and arid southwest and California's Central Valley,[26 31] tea and leafy greens in Hawaii,[28] blueberries in Maine,[32] and cranberries in Massachusetts.[33] As mentioned above, researchers are also exploring conditions under which commodity row crops like corn[34 2] and potatoes[29] can thrive as part of agrivoltaics installations.

Oregon Agrivoltaics: "Farmer First, Solar Second"

Agriculture is an important pillar of Oregon's economy. It is also a way of life and part of family legacies for generations of Oregonians. In recent years, farmers and ranchers have faced many challenges but are turning to new technologies to keep pace with shifts in the economy, climate, and workforce dynamics.

OSU Associate Professor Chad Higgins listens to a local farmer's questions and concerns about agrivoltaics.

Additionally, changing energy demands and Oregon's goals to transition to clean electricity offer opportunities to farmers and ranchers. Integrating solar arrays with agricultural production is one advancement that researchers at Oregon State University are exploring. However, Oregon's most productive farmlands are rich with nutrients from centuries of glacial and volcanic activity, so the suggestion of converting any of this productive farmland to other, non-agricultural uses sparks big questions for local farmers and ranchers. This is where agrivoltaics comes into focus, and where researchers and farmers are finding mutual benefits by adding solar to agricultural production.

One of the leading experts in agrivoltaics research is Chad Higgins, Associate Professor of Biological and Ecological Engineering at Oregon State University. He works closely with farmers and ranchers at the North Willamette Research and Extension Center. There, Higgins and the

OSU research team are learning what crops and practices work best with integrated solar electricity generation.

"An agrivoltaics system to me is a solar installation that is designed to work with the agriculture to benefit the agriculture," explains Higgins. "So you not only have to maintain, but you have to improve the agricultural activity by leveraging the fact that you get better climates for the crops you select."

In fact, there are several plant varieties and crops that need a fraction of naturally occurring sunlight. Certain crops – including tomatoes, strawberries, leafy greens, and herbs – actually thrive when sun exposure is managed, similar to how farmers already think about managing water, drainage, and fertilization.

Higgins' research is showing that. "There are agricultural opportunities where the right mixture of crops and circumstances can leverage the shade from the solar panels to take stress away from crops," he states. "This is not an everywhere solution. This is a situational thing; it has to work for the right crop mixture."

The north star guiding Higgins' research into agrivoltaics is this: "It has to be farmer first, solar second. That's agrivoltaics to me."

SCAN OR CLICK

Learn more by listening to ODOE's *Grounded* podcast episode, "Harvesting Solar: The Science of Agrivoltaics."

State-level Investments in Agrivoltaics

Several state legislatures have invested in either incentives for developing commercial agrivoltaics projects or in state-specific agrivoltaics research and demonstration projects in recent years.[59] In other instances, energy companies and/or state utility commissions are sponsoring state-specific agrivoltaics research or providing tariff-based incentives for agrivoltaics projects. Recent state-level efforts include:

Colorado: The 2023 Colorado General Assembly appropriated $500,000 for grants for new or ongoing demonstration or research agrivoltaics projects as part of a bill that also required the Colorado water conservation board to study the feasibility of floating solar generation facilities over irrigation canals or reservoirs, exempted agrivoltaics and floating solar generation facilities from property taxation, and required the commissioner of agriculture to study greenhouse gas reduction and sequestration opportunities in the agricultural sector.[60 61 62]

Crops growing under solar arrays at the Hawaii Agrivoltaics Research Center.

Hawaii: Three private energy companies are sponsoring work at the Hawaii Agrivoltaics Research Center in support of reaching the state's renewable energy goals. The center prioritizes data collection to validate agrivoltaics' energy and crop yields in a tropical context, with a focus on crops for local consumption, and to inform policymaking.[63] [28]

Maryland: The Maryland legislature adopted legislation in 2022 and 2023 that extended and lifted the cap on the state community solar pilot program while adding provisions that allow larger project sizes and local property tax exemptions when community solar projects co-locate with agrivoltaics projects. [64] [65] [66]

Massachusetts: Under the Solar Massachusetts Renewable Target or SMART program, established in 2017, the state's three investor-owned utilities pay a tariff-based incentive to qualifying solar facilities with the tariff amount declining over time. The program includes adders to the tariff rates for agrivoltaics projects, projects located on brownfields, and low income community solar projects.[67] [68] [69]

New Jersey: Legislation adopted during the 2021 session directed the New Jersey Board of Public Utilities, in consultation with the state Department of Agriculture, to develop a dual-use solar energy pilot program for installations on farmland. The pilot program is to last for three years and allows up to 200 megawatts of installed solar generation. The bill also encourages agrivoltaics projects up to 10 MW each and allows the underlying land used by agrivoltaics projects to be eligible for farmland tax assessment rates under certain conditions.[70] [71] [72]

New York: The New York State Energy Research and Development Authority, a public benefit corporation, has competitively funded six research projects that are producing data on crop and grazing potential and soil health, and considering optimal agrivoltaics siting design considerations. NYSERDA also has commissioned a report to identify opportunities and constraints relevant to New York's agricultural landscape and developed a guide for incorporating grazing into solar facilities in New York.[73] [74] [75]

Washington: The 2023 Washington legislature appropriated almost $40 million in grants for clean energy projects, with preference for "dual-use solar projects that ensure ongoing agricultural operations," and dedicated another $10 million of the state's Climate Commitment Account (established in 2021) for a pilot program to provide grants and technical assistance for commercial dual-use solar demonstration projects.[76] [2]

Agrivoltaics in Oregon

Potential Benefits

Agrivoltaics systems can provide many possible benefits for farmers and ranchers, including:

- **Irrigation water savings**. Partial shading by solar panels cools soil and plants, reducing moisture losses from both water evaporation from the soil and transpiration[1] occurring when plants take up water from the soil and release water vapor from their leaves.[35] Partial shading lowers the rate at which plants use water for transpiration and lessens the need for irrigation.[9] [36] For more information on the connections between water use and energy, see the Energy 101 section of this report.
- **Beneficial shade for crops and livestock**. Partial shade from solar panels can relieve heat stress for crops, including forage and livestock.[2] [37] Research studies have found increased yields and/or nutritional quality for several crops when grown as part of an agrivoltaics installation. For example, an Oregon State University study found higher yields for pasture grasses in the shade of solar panels while researchers from the University of Arizona found that crops including basil, tomatoes, and celery had higher yields when grown in an agrivoltaics system.[38] [39] [35]
- **Creation of microclimates.** In addition to reducing temperatures during the day, solar panels may raise temperatures in the evening for crops growing under them, creating microclimates that provide frost protection and potentially extend the growing season.[11] [40] Solar panels can also protect crops from heavy rains and hail. [40] Conversely, growing crops or pasture grasses under solar panels — rather than bare ground or gravel as has been industry practice until recently — cools the panels, which can boost energy production.[41]
- **Energy generation, economic benefits, and resilience for rural farms and communities**. Farmers and ranchers may install agrivoltaics as part of a microgrid system, powering their on-site electrical equipment and even battery storage systems. Generating and possibly storing energy on-site would make farmers more resilient to power outages. Farmers may also sell the energy they generate to a local utility or rent their land to a solar developer. Installing agrivoltaics may also create jobs in rural communities and provide useful renewable energy generation, including for electric vehicle charging.[42] [7] [43] Researchers also cite the potential for agrivoltaics to assist farmers with precision agriculture and automation, providing mounting structures and power for sensors and field robots.[43] [44]
- **Income to support farm operations**. Farmers and ranchers may be able to boost their incomes by selling electricity generated on the farm or by receiving payments from solar developers, adding a second income stream from their land.[2] Many farm operators rely upon off-farm employment to supplement their farm income, while receipts from farming fluctuate with weather and market prices, making a steady income from renting their land for solar development highly desirable.[14] Given that the average age of Oregon farmers is 60 years, and that according to the Oregon Agricultural Trust, 81 percent of Oregon farmers do not have a

[1] "Transpiration" refers to the evaporation of water from plants, as well as the general process of how water moves through plants. Plants use transpiration to cool themselves. https://biologydictionary.net/transpiration

succession plan, the additional income stream from selling electricity generated by agrivoltaics could preserve farmland by making it more profitable for current farmers and subsequent generations to continue farming.[45]

Potential Challenges

- **High up-front costs, including interconnection**. Some of the main challenges cited by stakeholders are high interconnection costs and long wait times for interconnection for utility-scale agrivoltaics systems. Development costs will be affected by the proximity to electricity transmission and distribution infrastructure, the need for system improvements, and the length of time required for the permitting and interconnection processes.[14] At this early stage of development, it is not yet clear if small farmer-owned and -installed agrivoltaics systems will be economically beneficial, whether selling the associated electricity generation or using it on-farm.
- **Community acceptance**. As with many large conventional solar photovoltaic projects, community members may have concerns about visual and other impacts such as construction traffic and potential changes in agricultural uses or property values from the siting of agrivoltaics projects in their communities.[14] While one recent survey finds that incorporating agrivoltaics leads to higher levels of community acceptance than conventional solar installations,[46] agrivoltaics is still new to most rural jurisdictions and few utility-scale solar projects that incorporate agrivoltaics practices have successfully made it through the permitting process yet.[47]
- **Complexity**. As noted above, agrivoltaics projects are more complex than conventional single-use solar installations and involve stakeholders with different and sometimes competing interests. Successful installations will likely require compromises between maximizing solar generation and maximizing crop yield and/or flexibility in crop choice for a given parcel of land, for example.[3]
- **Impacts on growing area and crop choices**. While researchers are exploring a wide variety of crops and panel configurations for agrivoltaics in crop-growing, success will be site-specific.[2] The seeds researchers and farmers are currently planting were harvested from plant varieties selected for their success in full-sun conditions. Over time growers will have the opportunity to harvest seeds from the plants that are most successful in agrivoltaics conditions, effectively selecting plants that are better adapted to agrivoltaics.[35]
- **Land use and permitting**. Agrivoltaics projects are permissible uses on agricultural land under Oregon's land use laws but are required to obtain a conditional use permit or a Goal 3 exception when constructed for the purpose of generating power for sale.[48] Small-scale agrivoltaics projects intended to generate power for use on site would likely not need to obtain a conditional use permit or Goal 2 exception.[49] [50]

Land Use Law

Oregon land use law treats the siting of agrivoltaics projects that would generate electricity for public sale in the same manner as the siting of solar photovoltaic generating facilities that do not incorporate agrivoltaics practices. Existing administrative laws governing the siting of solar photovoltaic generating facilities on agricultural land do not disallow or discourage agrivoltaics, but also do not provide an incentive for incorporating agrivoltaics.[50] Sheep grazing is becoming an industry standard method for vegetation management in utility-scale solar developments; in one recent instance, a solar developer in Oregon has amended their Wildfire and Weed Mitigation Plans to incorporate sheep grazing.[51] [52]

Goal 3 of Oregon's statewide land use planning goals requires counties to identify farmland, designate it on a comprehensive plan map, and zone it for exclusive farm use (EFU). Oregon Revised Statute defines "farm use" to mean "the current employment of land for the primary purpose of obtaining a profit in money" by raising and selling crops, or livestock or poultry, or products such as eggs or milk.[53] State land use laws restrict development unrelated to agriculture on EFU zoned land to minimize conflicts with farming, while EFU land kept in agricultural production benefits from lower property taxes.[49]

County Jurisdiction

The Oregon Land Conservation and Development Commission has adopted administrative rules specifying the conditions under which landowners may develop "photovoltaic solar power generation facilities," including agrivoltaics projects, on EFU-zoned land. For smaller projects that fall under county jurisdiction, counties may permit the development of solar arrays covering up to 12 acres on high-value farmland and up to 20 acres on arable land including as part of an agrivoltaics installation on EFU land as a conditional use without an exception to Goal 3.[48] The Land Conservation and Development Commission adopted rules in May 2019 that allowed dual-use solar and agricultural projects up to 20 acres on high-value farmland; this rule change included a sunset provision repealing the increased threshold on January 1, 2022.[54]

Solar developers seeking to install arrays encompassing more than 12 acres on high value farmland or more than 20 acres on other designated farmland must seek an exception to Goal 3 through the goal exception process as part of the conditional use review.[48] Goal 2 of Oregon's land use laws provides a process for a local government to grant an exception to a state land use goal when it finds that "unique circumstances warrant a local override of the statewide goal to create a better outcome."[55] [56]

Energy Facility Siting Council Jurisdiction

Solar arrays above certain size thresholds must obtain a site certificate from the Energy Facility Siting Council, including facilities over: 240 acres on high-value farmland, 2,560 acres (four square miles) on land that is predominantly cultivated, or 3,840 acres (six square miles) located on any other land.[57] Oregon Revised Statute 469.504 provides a process for EFSC to consider exceptions to Goal 3 for development of solar facilities on EFU-zoned land.[58]

Conclusion

Recent research and early commercial projects have demonstrated that agrivoltaics has potential as a path to increase solar energy generation while preserving agricultural production at the individual plot or field level. Future research into crop varieties and installation configurations along with development in solar technologies promises to improve upon initial successes. However, policymakers and utility leaders will need to address broader questions about how electricity generation from agrivoltaics fits into future decarbonization plans for the state's energy system, and to coordinate public policies and energy system-level planning and investment to harvest the potential value of agrivoltaics to the energy system.

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Climate Change Effects on the Energy System

From deadly heatwaves to severe storms to increased wildfire risk, Oregon is no stranger to the negative effects of climate change. In the Oregon Climate Change Research Institute's Sixth Oregon Climate Assessment,[1] the institute described how climate change is already contributing to extreme heat, drought, wildfires, coastal erosion, and other erratic weather conditions and hazards in Oregon.

In the past five and a half years, Oregon's Governors have issued 97 emergency declarations requiring response to extreme weather-related events in the state.[2]

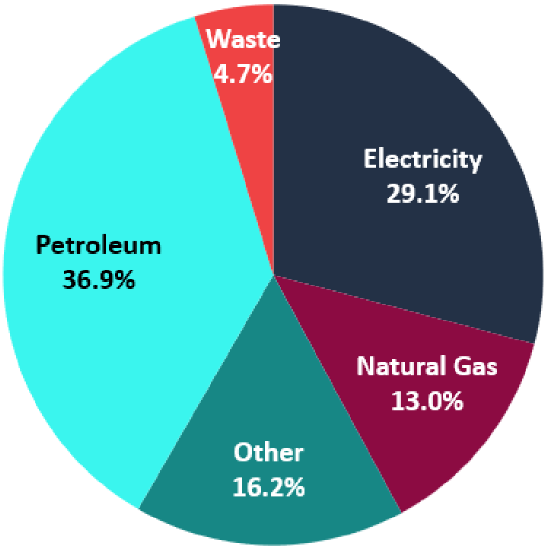
Table 1: 2019-2024 Oregon Emergency Declarations

Year	Floods	Wildfires	Conflagrations[i]	Severe Weather	Landslides	Droughts	Total
2019	1	-	-	1	-	-	**2**
2020	1	3	16	-	-	7	**27**
2021	-	1	9	6	-	10	**26**
2022	-	1	5	1	1	7	**15**
2023	-	1	5	3	-	9	**18**
2024*	-	1	4	3	-	1	**9**
Total	**2**	**7**	**39**	**14**	**1**	**34**	**97**

**January-June 2024.*

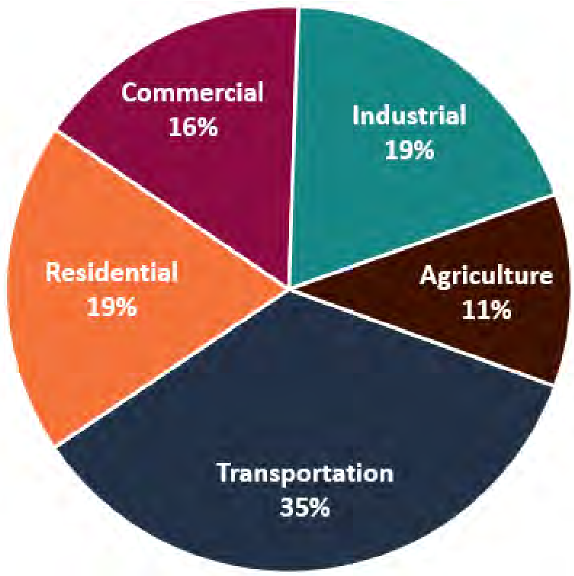
Most of Oregon's greenhouse gas emissions come from the energy used every day, including electricity, direct use fuels, and transportation fuels. Five main economic sectors – transportation, commercial, residential, industrial, and agricultural – contributed about 61 million metric tons of carbon dioxide equivalent in Oregon in 2021.[3] For context, Oregon's greenhouse gas emissions should be 3 million MTCO2e or lower by the year 2050 to meet the Oregon Climate Action Commission's recommended goals.[4]

Figure 1: Greenhouse Gas Emissions Share by Source (2021)[5]



[i] A conflagration is an extensive fire that destroys a significant amount of land or property.

Figure 2: Greenhouse Gas Emissions Share by Sector (2021)[3]



Unless global greenhouse gas emissions decline considerably, the effects of climate change on Oregon's way of life will intensify over the coming decades.

The energy sector plays a unique and important role in climate change – it can be a cause of climate change, can be affected *by* climate change, and can also be part of the solution.

Climate Change Effects on Energy

Energy remains Oregon's largest emitter of greenhouse gases, accounting for over 83 percent of Oregon's 2021 emissions. These gases contribute to climate change, which in turn affects Oregon's energy systems. A changing climate can shift energy demand, alter energy supply, increase energy costs, and have many other effects on the sector.

Energy Demand

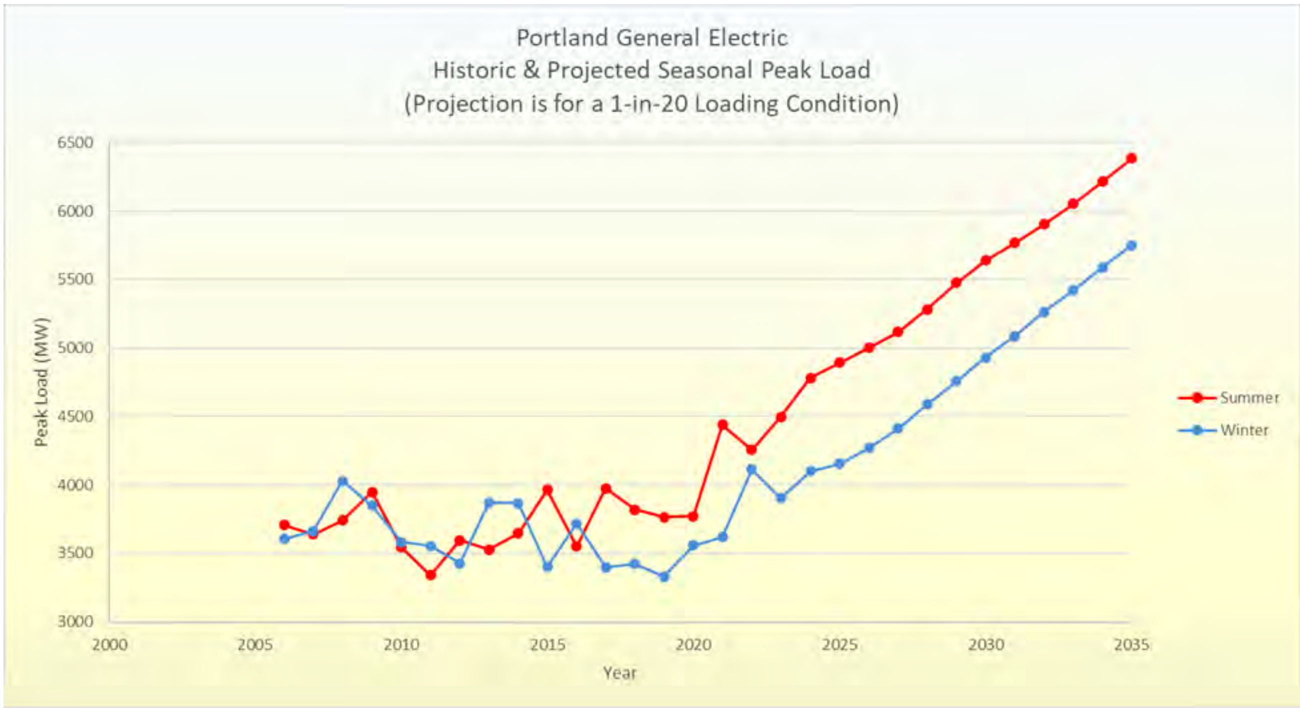
Extreme heat presents a growing threat to Oregon's communities and its natural environment. Over the past 70 years, the number of extremely warm days increased significantly across Oregon, leading to increased energy demand for cooling buildings. In June 2021, a record-shattering heat wave caused at least 96 confirmed deaths in Oregon.[6] That summer was the hottest in Oregon's recorded history, and climate change is projected to increase the duration, intensity, and frequency of extreme heat events in the state. If greenhouse gas concentrations do not decrease, the frequency of heat events as extreme as the 2021 heat dome is expected to increase from once every 1,000 to 100,000 years to once every six years by the end of the century.[1]

These warmer temperatures and more frequent heat waves have created new summer peaks in electricity demand to meet additional cooling needs in homes and workplaces. This puts stress on Oregon's current electricity systems and creates challenges for utilities to meet demands. Summer heat events are also likely to coincide with increasingly frequent wildfires and planned transmission line outages to reduce the risk of wildfire ignition. According to the National Center for Environmental Health, "studies have shown that for every 1°F (0.6°C) increase in summer air temperature, the electricity demand in medium and large cities can increase by an estimated 1.5 to 2.0 percent. During extreme heat events, which are exacerbated in urban heat islands, the demand for cooling can overload systems and result in power outages."[7]

Portland General Electric reports that extreme weather has become more common, "driving unprecedented hourly peaks that can require every available energy resource to meet demand."[8] In the last few years, PGE's service area experienced the deadly heat dome event of 2021 as well as the warmest month on record: August 2022. In addition to extreme heat, major cold snaps have also affected the service area, including the highest single-day peak demand for heating in December 2022.

In an August 2024 email to the Oregon Department of Energy*,* PGE provided the following chart illustrating historic and projected seasonal peak load (taking anticipated weather conditions and other factors into consideration).[9]

Figure 3: Portland General Electric Historic and Projected Seasonal Peak Load[9]



The Northwest Power and Conservation Council's *2021 Power Plan* notes that overall end-use consumption of natural gas tends to peak in the winter months.[10] Residential use in particular is highly seasonal, with about 75 percent occurring between November and March. The Council forecasts slight growth (about 0.5 percent) in natural gas end use in its 20-year planning horizon.[11] With over a third of natural gas use happening in the residential sector,[10] changes in heating and cooling needs during more frequent extreme weather could affect home, business, and industry demand for natural gas.

Energy Supply

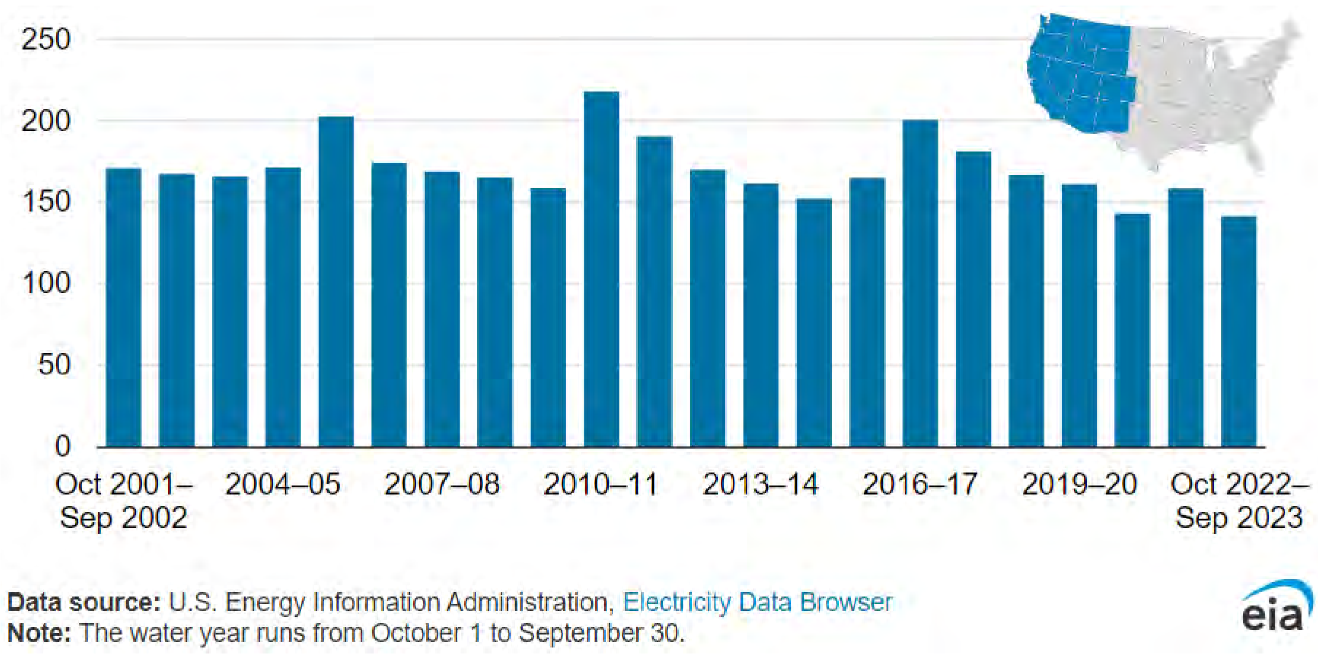
With higher temperatures caused by climate change, many areas of Oregon that historically received snow during the winter are more likely to receive rain. This change in precipitation type will shift decades-long patterns of when hydropower – which accounts for nearly 40 percent of the electricity

Oregonians use[12] – is available across the Pacific Northwest. A significant shift could lead to increases in electricity costs and new infrastructure needs. Lower water availability and higher water temperatures can make energy generation, transmission, and distribution systems less efficient.

Seasonal changes in the amount of precipitation and reduced snowpack are likely to result in higher winter stream flows, earlier peak spring runoff, and lower summer flows. This would increase the amount of hydropower that is available in the winter and early spring (November through March) but decrease the amount available in the late spring and summer (April through September).[13] As summer temperatures and loads grow, Oregon could see an imbalance between the amount of hydropower that is available and the amount that is needed in the summer months, particularly in July and August. The increased variability in the timing and amount of precipitation makes forecasting energy supply more difficult, which could complicate power planning in many areas of the state.[14]

In March 2024, the U.S. Energy Information Administration released data showing that western U.S. hydropower generation dropped to a 22-year low, 11 percent lower than the previous "water year" (October 1 to September 30).[15] The EIA reported that drought conditions contributed to the historically low hydropower. During the fall and winter of 2022-2023, precipitation was near normal but a significant heat wave in May 2023 melted the snowpack more rapidly than usual. This meant that high flows for hydropower occurred during the spring instead of later summer months when there is more demand for power.

Figure 4: Western U.S. Hydropower Generation by Water Year (Oct 2001 – Sept 2023), in Million Megawatt Hours[15]



As climate change affects the availability of hydropower flows, other resources step in to support supply. Natural gas plants often fill in when hydropower generation decreases, so a changing climate and hotter days can lead to more natural gas generation — which leads to increased greenhouse gas emissions. This is a good example of how the energy system can be affected by climate change while also contributing to it.

Thermoelectric power facilities, such as natural gas generation facilities, require water or air for cooling and can be sensitive to increases in ambient temperatures.[16] Even small changes in temperatures could result in efficiency losses. For example, one study noted that natural gas-fired power plants produce 100 percent output when operating at 59°F. Above that temperature, the capacity of a combined-cycle natural gas plant could be reduced by as much as 0.7 percent per 1.8°F increase in ambient temperature, and the capacity of a simple cycle plant could be reduced by as much as 1 percent per 1.8°F increase.[17] The resulting reductions in output decrease the amount of consistent power that natural gas plants contribute to the overall daily supply of electricity — as well as during peak times when the electricity system needs to ramp up quickly, like in the afternoon on very hot days when people get home from work.

Electricity Reliability

Climate change may also affect the reliability of the region's energy system. Increased frequency and intensity of extreme weather can affect energy facilities and transmission lines, threatening the reliability of the energy services Oregonians need.

Crews from other electric utilities responded through mutual aid agreements to Central Lincoln PUD's service area to help repair the system following the January 2024 ice storm.

In addition to climate change causing temperatures to increase, it is also causing precipitation extremes to increase. Extreme winter storms in the West are projected to get wetter and larger, and a 2023 Pacific Northwest National Lab study found that "Such changes in winter storms, driven by climate change, are especially strong in storms fueled by atmospheric rivers."[ii] [19] When temperatures fall below freezing, those strengthened storms can result in extreme winter weather, including heavier and often wetter snow at high elevations.

In January 2024, a severe winter storm and strong winds caused tens of thousands of power outages across the state. Portland General Electric dealt with outages for over a week in its service area, including nearly 400,000 customers without power at some point during the storm – and a peak of 165,000 at once.[20] Along the coast, Central Lincoln People's Utility District customers were also without power for several days. As the utility and its partners worked to get customers back online, melting ice would sometimes cause a new outage to recently restored areas. On Facebook on January 16, 2024, the utility informed customers that a transmission line outage was due to "ice on the lines, which caused them to sag. When the ice [melted and] fell, the lower line bounced up, making contact with the sagging line above."[21]

Longer wildfire seasons, more frequent wildfires, and greater area burned could lead to more Oregonians experiencing fire-related infrastructure outages or proactive public safety power shut-offs

[ii] According to the National Oceanic and Atmospheric Administration, an atmospheric river is a "flowing column of condensed water vapor in the atmosphere responsible for producing significant levels of rain and snow, especially in the Western United States."[18]

to reduce risks. Public safety power shutoffs during severe fire weather — typically a combination of hot temperatures, high winds, and dry landscapes — are a safety measure where a utility will proactively shut off power to electric transmission or distribution lines if there is a high risk the lines might ignite a wildfire. This shutoff leads to individual homes and businesses losing power – potentially during a time of extreme heat or cold. Turning the power back on can also take time as crews will inspect lines to ensure there is no damage before reenergization.

Transportation Fuels

Extreme flooding and landslides can inundate and block roads and rails, as well as damage pipeline pumping stations and storage facilities for transportation fuels. Increased frequency and intensity of extreme weather events, flooding, and power outages can disrupt fuel distribution networks and gas stations.

Learn about where Oregon's transportation fuels come from on ODOE's blog.

The Pacific Northwest has no crude oil resources and is isolated from major petroleum production regions like Texas, North Dakota, and Alberta, Canada.[22] That means Oregon imports all of its petroleum-based fuels. They arrive in Oregon primarily by pipeline, with some arriving by barge or rail, to Portland-area terminals. From there, most fuels are then transported and delivered by trucks or small barges to individual stations across the state. In the event of severe weather, such as flooding, landslides, or ice storms, it may be difficult for trucks to safely travel and deliver fuels to certain communities.

September 2020 wildfire damage in Detroit, OR.

In September 2020, a drought combined with a severe windstorm resulted in five simultaneous "megafires"– fires greater than 100,000 acres in size – in Oregon. In a matter of days, more than 1 million acres burned across the state.[23] In some areas, access to transportation fuels became an issue. Fire suppression and utility crews who were responding to affected areas lacked fueling capabilities for their trucks within the response area. The Oregon Department of Energy coordinated with fuel cardlock facilities[iii] to secure fuel cards for firefighters and utility crews so they wouldn't have to drive more than an hour away to fill their tanks.

During the January 2024 winter storm, some areas of southern Oregon were inaccessible due to the severity of ice on Interstate 5 and other major thoroughfares. This led to fuel delivery delays in some areas, including Medford. The local news reported that some gas stations had to close because they ran out of fuel.[24] As roads began to clear, the Oregon Department of Energy and Oregon Department of Transportation worked with fuel companies to ramp up deliveries to the area.

[iii] Cardlock facilities are unstaffed fuel stations (typically for commercial fleets) where people use a membership fuel card to access self-serve fuel.

Financial Costs

As climate change affects Oregon's energy system physically, it also creates additional financial costs. This can include costs from generating electricity, responding to emergency events, repairing infrastructure, and investments in additional heating and cooling equipment in homes and businesses.

As noted above, because hydropower is the dominant source of electricity in Oregon, increased precipitation variability can affect the entire electricity power market — including utilities that are less reliant on hydropower. For example, in 2000, below-average snowpack and above-average late summer temperatures reduced the availability of hydropower in Oregon and across the northwest. Most of the region's electric utilities incurred higher costs because they had to purchase more power from the larger electricity market. Those higher costs were later incorporated into long-term adjustments that increased electricity rates.[25]

The 2021 "Heat Dome" event in Oregon brought soaring temperatures across the state and resulted in at least 96 confirmed heat-related deaths.[6] In response, the Oregon Legislature directed the Oregon Department of Energy to study the cooling needs of Oregon's most vulnerable housing types, including manufactured dwelling parks and mobile homes, publicly supported multifamily housing, recreational vehicles, and employer-provided agricultural workforce housing. The *2023 Oregon Cooling Needs Study* found that many Oregonians do not have adequate cooling equipment, including 58 percent of residents living in the housing types surveyed for the report.[26] The study showed the estimated cost to provide a baseline level of cooling equipment — to avoid the worst effects of extreme heat events in the types of homes surveyed — is over $600 million. To provide more comprehensive, permanent equipment that can properly cool the full living space of a housing unit, the estimate jumps to more than $1 billion.[26]

Downed trees and power lines in Lincoln County in January 2024.

The January 2024 winter storm took a heavy toll on the energy system and infrastructure in the state. Interstate 84 had to close for some time due to hazardous conditions, and landslides, rock falls, floods, and downed trees blocked roads and took out power lines in multiple counties. For example, in Lane County, local utilities experienced significant damage to their electric distribution systems. Lane Electric lost more than 200 power poles and associated lines due to ice damage and falling trees.[20] In Cottage Grove, critical city services had to rely on backup power for nearly a week, and Blachly-Lane Electric Cooperative suffered damage to about 30 miles of power lines. In Lincoln County, about 50 miles of Central Lincoln PUD's lines were damaged, including seven miles that had to be completely replaced. The Confederated Tribes of the Siletz Indians needed to acquire a portable generator to operate water pumps and services to local homes. Hundreds of gallons of diesel fuel were needed to operate generators at various tribal facilities, including a warming shelter.[20]

Following a declaration of emergency by the Governor, the state government provided assistance to communities, including staffing warming shelters, offering transportation support, distributing fuel and generators, and others. A joint Preliminary Damage Assessment, which supports potential financial federal assistance from the Federal Emergency Management Agency, estimated costs of the disaster in several categories, totaling over $48 million. The cost to utilities was the greatest share, at an estimated $32 million.[20] In April 2024, President Biden officially declared the January 2024 winter storm a major disaster and ordered federal assistance to the state.[27]

One method of potentially strengthening the resilience of the electric grid is burying power lines rather than hanging them on power poles. Buried lines are less susceptible to effects from major weather events, such as wind or ice storms. However, burying lines can be cost prohibitive. The cost of constructing a high-voltage underground transmission line can be four to 10 times the cost of constructing an overhead line due to material costs, labor costs, and environmental factors.[28] Oregon-based Lane Electric utility reports that it would cost about three to five times more per foot to construct underground power lines rather than overhead lines. Burying the existing overhead lines in its service area would cost more than $600 million.[29]

Electric utilities also incur costs due to wildfires, which are increasing in frequency, severity, and size due to climate change.[30] Oregon's three investor-owned electricity providers – Portland General Electric, Pacific Power, and Idaho Power – each submit wildfire mitigation plans for review and approval by the Oregon Public Utility Commission. The plans outline how utilities will approach tree trimming, equipment maintenance, and other activities that can mitigate effects from wildfires. In their 2023 mitigation plan reports, the estimated costs for each utility's mitigation efforts were: $50.6 million for Portland General Electric, $136.7 million for Pacific Power, and $47.2 million (for 2023-2025) for Idaho Power.[31]

Insurance companies that provide services to electric utilities are also considering how rates or insurance availability may be affected by increasing wildfire risk. Energy industry publication *Utility Dive* reports that the utility insurance industry will likely have to adapt to this new reality:[32]

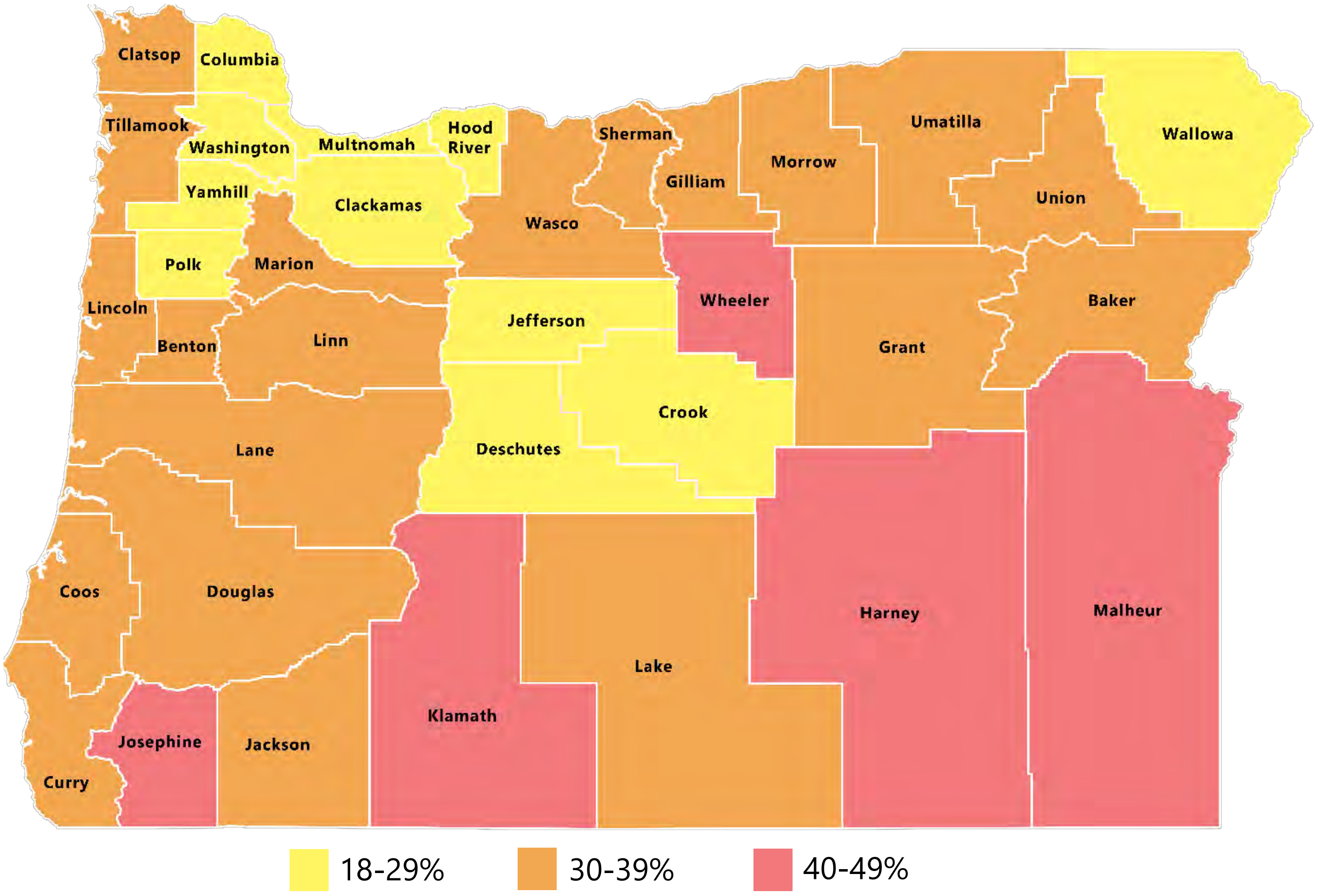
> *"Insurance analysts say the growing risk of severe wildfires due to climate change, and a shifting legal landscape that increasingly holds utilities accountable for the damages caused by these conflagrations, has indeed changed the calculus that goes into a utility's liability insurance policy. But they're split on what that means for the long-term. Some analysts believe that the growing need for wildfire-related liability insurance will spark ingenuity, bringing new insurance products to market. Others, however, believe the government may need to intervene in order to quite literally keep the lights on in some parts of the U.S."*

Equity

Climate change has a disproportionate effect on certain communities—particularly environmental justice communities, communities of color, and low-income, rural, and coastal communities—that have been traditionally underrepresented in public processes and typically have less access to resources for adapting to climate change.

In Oregon, the median household income for people of color is about 30 percent less than for white households,[33] and people of color and low-income households across the nation have a disproportionally high energy burden—the percentage of income spent on energy costs[iv]—compared to other households. In Oregon, Washington, California, Alaska, and Hawaii, the median home energy burden for low-incomes households is nearly three times as high as higher-income households.[34] Environmental justice communities have historically been underserved by public programs and investments, making them more vulnerable than other Oregonians to the effects of climate change. Over time, these inequities have left some communities with less resilient housing and more exposure to extreme heat.[35] The wildfires discussed previously are examples of climate change-related Oregon events that affected environmental justice and other disadvantaged communities.

Figure 5: Percentage of Oregon Households Considered Energy Burdened and Earning 200 Percent or Below Federal Poverty Level by County[36]

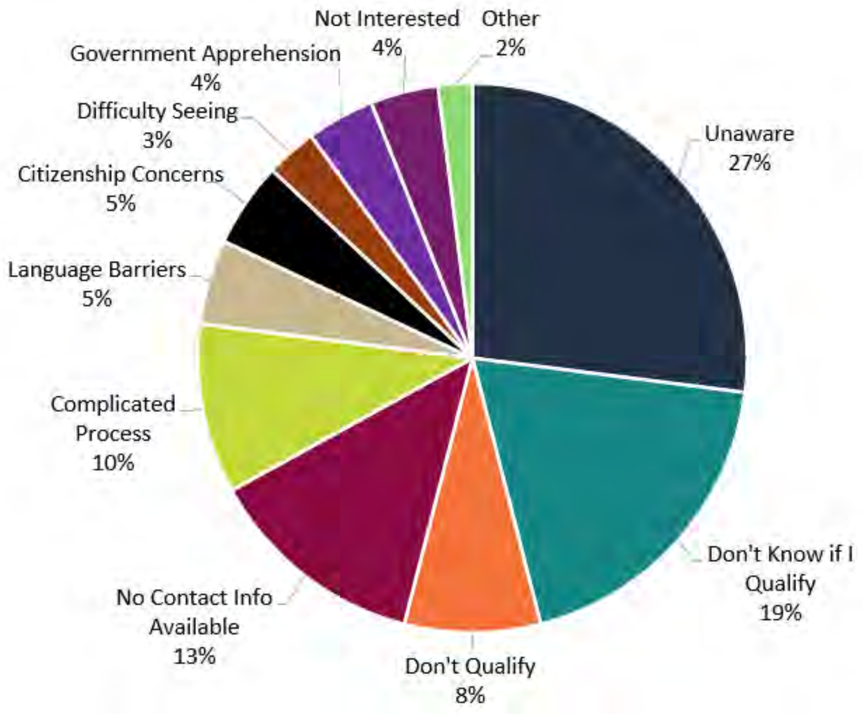


The Oregon Department of Energy's *2023 Cooling Needs Study* identified social and economic barriers that residents face in accessing existing resources for energy and cooling. Many residents shared that they do not use existing cooling equipment due to the associated energy costs. Air conditioning is often seen as an unaffordable luxury rather than a need. Just 22 percent of surveyed

[iv] Energy burden is the percent of household income spent on home energy bills, including electricity, natural gas, and other home heating fuels. If a household spends more than 6 percent of its income on those home energy costs, it is considered energy burdened.

individuals had used existing cooling, weatherization, or utility bill assistance programs available to them.[26] Survey respondents cited several reasons for having not used energy assistance programs, including lack of awareness, confusion about qualifications, apprehension about government programs, and others. During the study process, Oregon Rural Action shared that some Oregonians get overwhelmed by program applications for assistance (especially those with multiple steps), information isn't always accessible for older adults who may face technology barriers for online applications, or program information may not be available in languages other than English.

Figure 6: Reasons Cooling Needs Survey Respondents Have Not Used Assistance Programs[26]



Energy Actions to Mitigate and Adapt to Climate Change

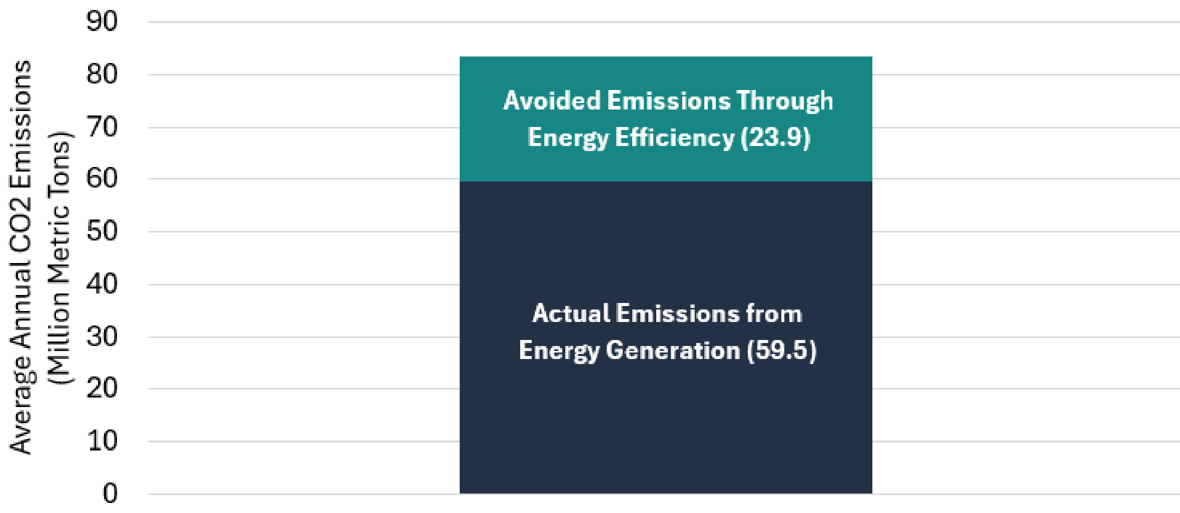
While climate change affects the energy sector, certain actions, policy choices, and consumer behaviors can help mitigate climate change or help Oregonians adapt to the changing climate.

Energy Efficiency and Conservation

Energy efficiency means using less energy to perform the same task or produce the same result, like using an LED light bulb instead of an incandescent model. A room is still lit by the bulb but needs less energy to do so. Similarly, energy conservation means changing behavior to save energy at certain times, such as waiting to run appliances in the late evening or early morning during a heat wave. Both actions can help address increasing demand for energy, including increased demand resulting from the effects of climate change.

Energy efficiency is the second-largest electricity resource in Oregon and the Pacific Northwest behind hydropower.[37] Between 1978 and 2021, efficiency has saved over a cumulative 7,500 megawatts[v] of power in the region – about half the region's growth in demand for electricity.[37] Maximizing energy efficiency and smart-grid technologies in homes, schools, offices, farms, and industries can lower electricity demand and costs, increase energy resilience, and reduce greenhouse gas emissions.

Figure 7: Avoided Electricity Generation Emissions Through Energy Efficiency (2021)[37]



The Oregon Department of Energy's *2022 Biennial Energy Report* discussed energy efficient building technologies that can reduce building energy use.[22] Energy efficient heat pumps, water heaters, smart devices, and other technologies can make the most of energy used in a building. For example, smart thermostats are Wi-Fi enabled and can be controlled remotely as well as programmed to use a phone's location to track occupancy and change temperature settings to save energy. Smart thermostats can also be connected and respond to grid and utility conditions, like peak demand.

In 2023, the Oregon Legislature passed House Bill 3409, establishing an Energy Performance Standard policy for commercial buildings. Often referred to as Building Performance Standards, the policy addresses energy use and emissions from existing commercial buildings in Oregon, which account for nearly 20 percent of energy use in Oregon.[38] The Oregon Department of Energy will administer a program to support existing commercial buildings in implementing energy management practices and efficiency measures to meet energy use targets.

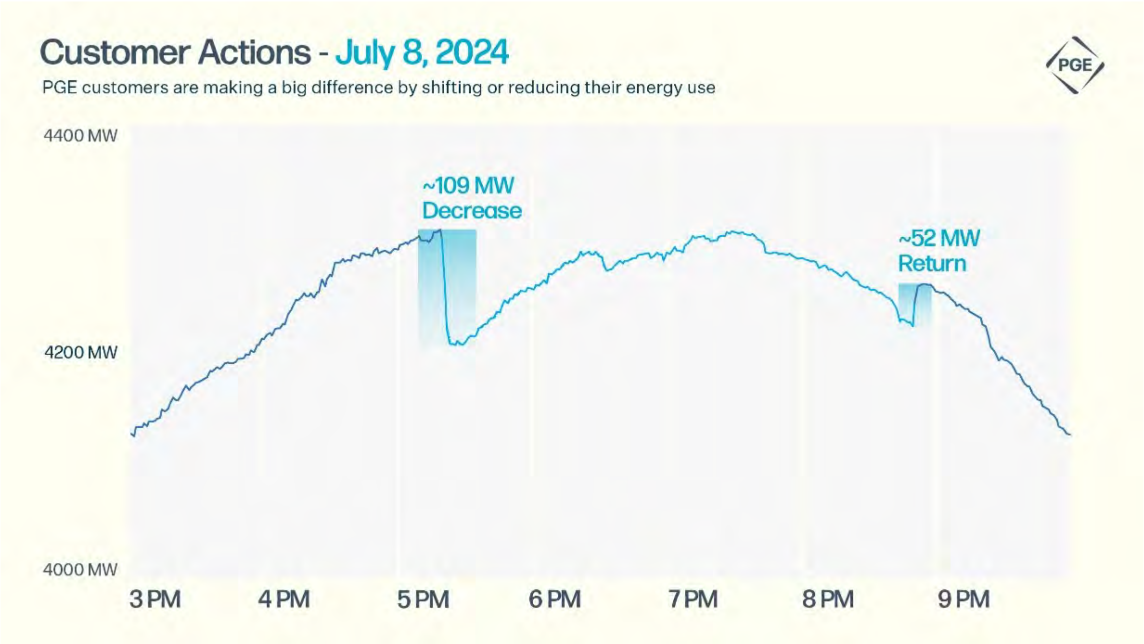
During peak periods of electricity demand, utility customers can adjust their energy use to conserve energy and reduce overall demand – including during extreme weather events. Utilities may ask customers to shift their energy use when peaks are expected to avoid overloading the system. This can include waiting to run appliances until after peak times, such as doing laundry early in the morning instead of after work and charging electric vehicles overnight instead of during the day.

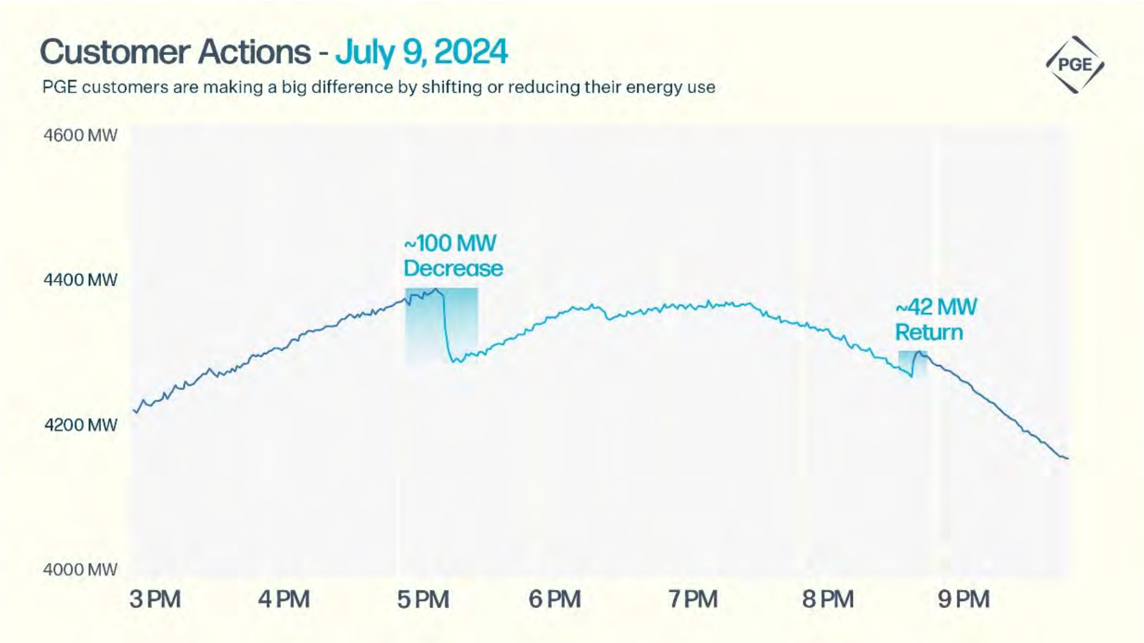
In July 2024, during a significant heat wave, Portland General Electric asked its customers to reduce electricity consumption in the late afternoon to ease stress on the grid and ensure there was enough

[v] An average megawatt (aMW) represents 1 MW of energy delivered continuously for 24 hours per day for one year. Equivalent to 8,760 megawatt hours.

power for the utility's customers. Customers shifted their electricity use in response and reduced demand by 109 megawatts on July 8 and 100 MW on July 9, as shown in Figure 8. PGE reported that this was the largest electricity demand shift in company history, and the amount saved would be enough to power more than 90,000 homes for a four-hour period.[39]

Figure 8: Portland General Electric Customer Peak Power Demand Shifting, July 8-9, 2024[39]

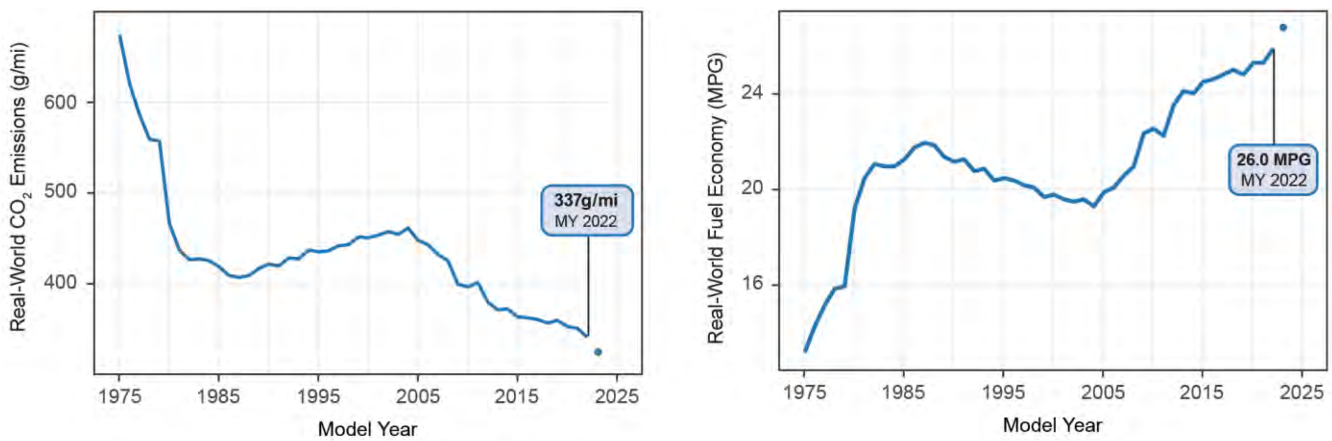




The transportation sector, which is the largest contributor to Oregon's greenhouse gas emissions,[3] can also benefit from efficiency improvements. According to the U.S. Environmental Protection Agency's *2023 Automative Trends Report*, vehicles in the 2022 model year had the biggest annual improvement in fuel economy – and in CO2 emissions – in the last nine years.[40] The report notes the expectation that model year 2023 will improve even further. As vehicles become more efficient, CO2 emissions will continue to drop.

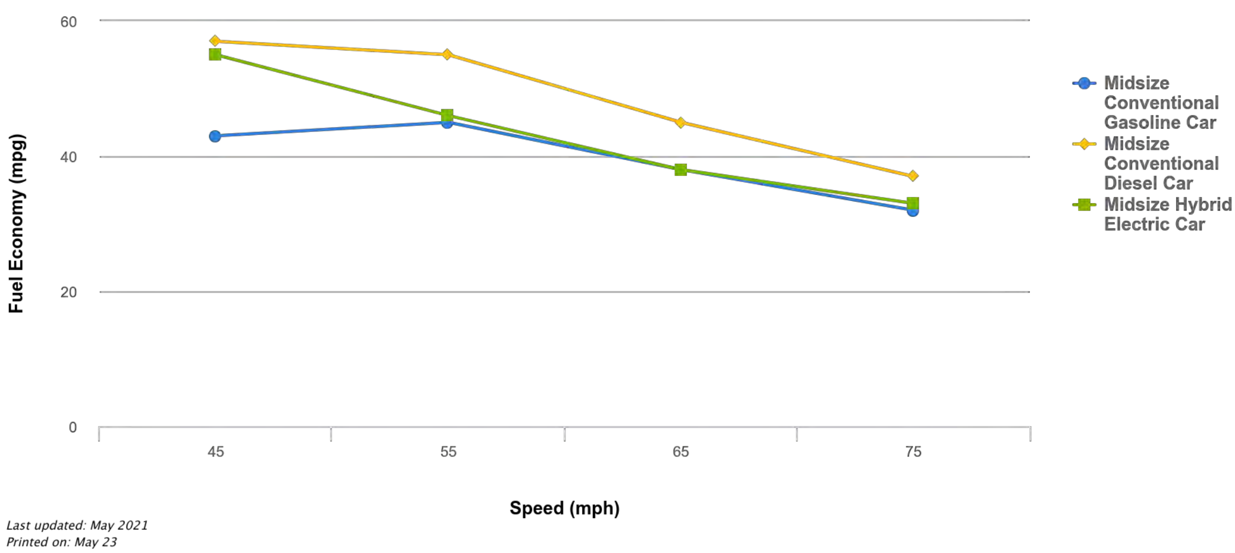
One of the main drivers of increasing vehicle fuel efficiency is electric vehicles. EVs conserve energy over gas-powered models. EVs convert over 77 percent of their electricity as fuel to power their wheels, while internal combustion engines convert just 12 to 30 percent of their fuel to power their wheels.[41] Electricity as a fuel also typically emits far fewer greenhouse gas emissions than petroleum-based fuels. Oregon EV drivers may even be able to charge their vehicles on 100 percent clean electricity, depending on the electric utility providing the power.[12]

Figure 9: Estimated CO2 Emissions and Fuel Economy by Vehicle Model Year[40]



Changes in consumer behavior can also increase energy conservation in the transportation sector. For example, in addition to choosing a fuel-efficient vehicle model, maintaining certain vehicle speeds in conventional gas and diesel vehicles can increase fuel efficiency and lower CO2 emissions. The U.S. Department of Energy's Alternative Fuels Data Center reports that midsize conventional gasoline cars have the best fuel economy driving at 55 miles per hour, while midsize diesel vehicle fuel economy declines gradually between 45 to 55 miles per hour.[42]

Figure 10: Fuel Economy at Various Driving Speeds[42]



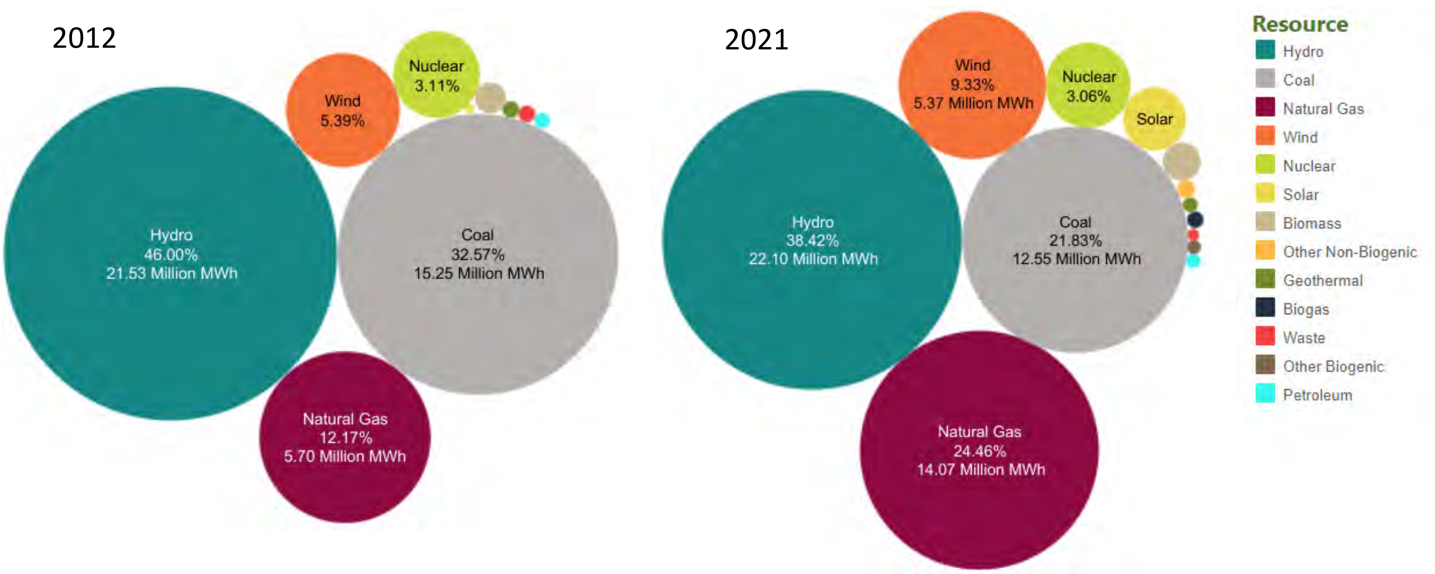
Alternative transportation options, such as public transit or micromobility devices (e.g., electric bicycles and scooters) are also efficient options for travel as they effectively remove individual passenger cars off the road. For example, TriMet, which serves the Portland Metro region, had nearly 5.7 million riders on its system in April 2024, including on its electricity-run MAX trains and on buses (powered by renewable diesel, diesel, and electricity).[43]

Diversifying Energy Resources

Because energy is responsible for most (more than 83 percent) of Oregon's greenhouse gas emissions, the transition to locally generated, low-carbon resources like wind, solar, and alternative fuels is diversifying Oregon's electricity supply and reducing greenhouse gas emissions that contribute to climate change. Diverse and locally generated resources also increase the electricity system's resilience to climate change and other emergencies. For example, a local microgrid[vi] or solar plus storage installation can keep the power on if the larger grid goes down.

When it comes to the resources that generate the electricity Oregonians use, renewable resources like wind and solar have increased over the last decade.

Figure 11: Oregon's Electricity Resource Mix in 2012 and 2021[12]



The differences in the electricity resource mixes between 2012 and 2021[vii] show an increase in wind (5.39 percent to 9.33 percent) and solar (0.04 percent to 1.71 percent). They also show how fossil fuel-based resources continue to be a significant part of the overall mix. House Bill 2021 (passed in 2021) is known as the "100% Clean Energy for All" bill and requires, among other things, that Oregon's large investor-owned utilities and electricity service suppliers reduce greenhouse gas emissions associated with electricity sold in Oregon.[44] Using a baseline,[viii] the utilities must reduce annual emissions by 80

[vi] Learn more about microgrids in the *2020 Biennial Energy Report*'s Technology Review section and the *2022 Biennial Energy Report*'s Energy 101 on Backup Power.

[vii] The Oregon Department of Energy changed its methodology for calculating the Electricity Resource Mix beginning with data year 2022, which appears elsewhere in this report. This section shows 2012 vs. 2021 as it provides a better comparison than the new 2022 data.

[viii] Baseline emissions level: for an electric company, the average annual emissions of greenhouse gas for the years 2010, 2011, and 2012 associated with the electricity sold to retail electricity consumers.

percent by 2030, 90 percent by 2035, and 100 percent by 2040 – effectively requiring emission-free electricity by 2040. Over the next two decades, the resource mix will change significantly, as will the emissions generated by Oregon's electricity sector.

While Oregon's electric grid moves toward 100 percent clean, transportation fuels continue to be the largest source of emissions among sectors and sources, as noted earlier in this 101. The emissions are primarily from the combustion of petroleum products, like gasoline and diesel. Of the emissions generated, over half are from gasoline, mostly for use in passenger vehicles, and over a third are from fuels powering medium- and heavy-duty vehicles.[45] In 2021, the Oregon Environmental Quality Commission approved a new Climate Protection Program for Oregon, targeting a 90 percent reduction in greenhouse gas emissions from fossil fuels, including gasoline, diesel, and natural gas by 2050.[46] The program used a declining limit or cap to reduce emissions over time, prioritizing the reduction of emissions and other types of air pollution in the underserved communities most affected by climate change and pollution. In late 2023, the Oregon Court of Appeals held the administrative rules for the program were invalid because the program rulemaking didn't comply with certain notice requirements under the federal Clean Air Act.[47] In 2024, the Oregon Department of Environmental Quality restarted its administrative rulemaking process to reestablish a climate mitigation program beginning in 2025.[48]

More options are emerging to use low- or zero-emission alternative fuels for transportation, such as renewable fuels and electricity. The Oregon Department of Energy's *2023 Biennial Zero Emission Vehicle Report* includes data and trends related to electric vehicle adoption in the state. Oregon's electric vehicle sales market share was 15.5 percent at the end of 2023, ahead of the national market share of 10.8 percent .[49] As of July 2024, there are 100,360 registered light-duty electric vehicles on Oregon roads.[50]

The Oregon Department of Energy's *2020 Biennial Energy Report* discussed alternative fuel options for medium- and heavy-duty vehicles. Several factors come into play when determining the best medium- and heavy-duty alternative fuel vehicles for a fleet, including: fueling timing and infrastructure needs, the climate and terrain where the vehicles will operate, existing air quality requirements and supporting clean fuels policies, costs, and the current availability of vehicles.[22] Oregon's efforts to increase the availability and use of cleaner fuels are supported by the Oregon Department of Transportation Statewide Transportation Strategy[51] and DEQ's Advanced Clean Trucks rule[52] and Oregon Clean Fuels Program.[53] Oregon is also a signatory to the Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding,[54] which directed the existing Multi-State ZEV Task Force, in which the State of Oregon participates, to develop a multi-state action plan to identify barriers and propose solutions to support widespread electrification of medium- and heavy-duty vehicles.

Strengthening Electricity Reliability and Resilience

Oregon is working to strengthen the energy system's resilience to the effects of climate change and other disasters. Distributed energy generation, renewable energy, microgrids, and energy storage can improve the reliability of energy on the grid and help the system bounce back following a disaster or other interruption in service.

In 2019, the Oregon Department of Energy published an *Oregon Guidebook for Local Energy Resilience*, focused on small- and medium-sized electric utilities. The guidebook serves as an action plan for consumer-owned utilities, including recommended steps to enhance local energy resilience; a list of local, state, and federal resources; and several case studies and resilience topic deep dives to help utilities better prepare for emergencies that could disrupt electricity service.[55] Incremental actions utilities can take to improve resilience include business continuity planning, developing a framework to prioritize investments in distributed energy resources, and understanding the role of local utilities in emergency management planning.

Federal, state, and local programs are available to support certain energy resilience projects, such as the Oregon Department of Energy's Community Renewable Energy Grant Program. The program provides grants to public bodies and Tribes for planning or constructing renewable energy projects and renewable energy projects with a resilience component like battery storage. In addition, the 2021 Infrastructure Investment and Jobs Act included a formula (non-competitive) award for states and Tribes for grid resilience grants. Oregon has about $50 million available over five years for projects that improve Oregon's electric grid infrastructure while providing community benefits.[ix] Projects can include weatherization technologies and equipment, fire-resistant technologies and fire-prevention systems, utility pole management, undergrounding of electrical equipment, and more.

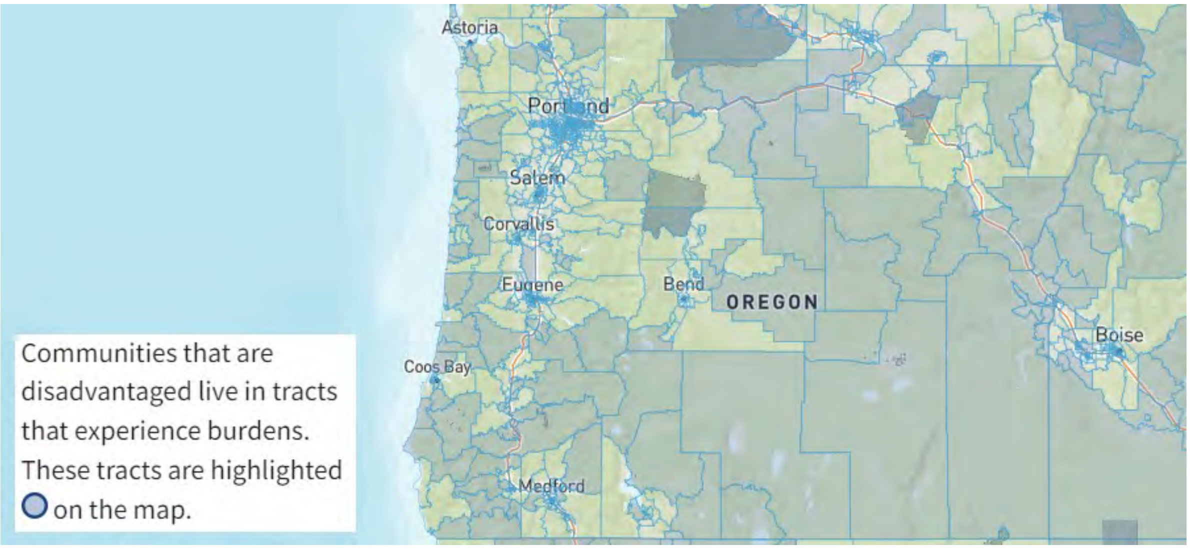
Addressing Equity

As discussed earlier, climate change has a disproportionate effect on communities that have been traditionally and are currently underrepresented in public processes and typically have less access to resources for adapting to climate change.

In the transition to a clean energy future, there is a renewed effort to ensure those communities are not left behind. The historic federal investments of the Infrastructure Investment and Jobs Act and Inflation Reduction Act include President Biden's Justice40 initiative,[56] which requires that at least 40 percent of the benefits of climate and clean energy investments flow to disadvantaged communities and Tribes, as defined in the Climate and Economic Justice Screening Tool.[57] The Oregon Department of Energy will be implementing the Justice40 Initiative in its planning for federal programs to ensure disadvantaged communities and Tribes benefit from these programs that fight climate change and deal with the effects.

[ix] Learn more about Oregon Department of Energy incentive programs, including grid resilience: https://www.oregon.gov/energy/Incentives/Pages/default.aspx https://www.oregon.gov/energy/energy-oregon/Pages/IIJA.aspx

Figure 12: Oregon Disadvantaged Communities and Tribes in the Climate and Economic Justice Screening Tool[57]



The new federal programs will help mitigate the effects of climate change by supporting more renewable energy through programs like Solar for All, while also helping Oregonians adapt to climate change by incentivizing energy efficient improvements, such as Home Energy Rebates for heat pumps and other home improvements.[x] A nearly $19 million Grid Resilience program is providing funding for Oregon electric utility projects that strengthen resilience of the electric grid and provide benefits to local communities.

Recent state energy investments have also been designed with equity considerations, including the Oregon Department of Energy's incentive and rebate programs. Each program is designed to serve disadvantaged communities, including higher rebate amounts for energy projects for low- and moderate-income Oregonians.[58]

Future Planning

In addition to the mitigation and adaptation examples above, Oregon is leading new planning efforts that can guide the state toward meeting its energy and climate goals.

Energy Security Plan

The Oregon Department of Energy was directed by the federal government and the Oregon Legislature through Senate Bill 1567[59] to prepare an Energy Security Plan for Oregon. The plan, which was published on September 30, 2024, identifies risks to electricity, liquid fuel, and natural gas and propane systems, including risks resulting from climate change.

Read the full report on ODOE's website and read a summary in this report's section on State Energy Projects.

[x] Learn more about these federal programs on the Oregon Department of Energy's website: https://www.oregon.gov/energy/energy-oregon/Pages/IIJA.aspx

Oregon Energy Strategy

The Oregon Department of Energy's *2022 Biennial Energy Report* included a recommendation that Oregon develop a state energy strategy to identify pathways to achieving the state's energy policy objectives, including the clean energy transition and efforts to fight climate change. The Oregon Legislature directed ODOE, through House Bill 3630,[60] to develop a state energy strategy by November 1, 2025. The strategy will help identify pathways to achieving the state's policy objectives while increasing the reliability and resilience of the energy system.

See this report's section on State Energy Projects to learn more about the project's progress as of the date of this report.

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Electricity Rate Increase Drivers

For many Oregonians, electricity prices have increased in the past few years. According to the U.S. Energy Information Administration, the average retail price of electricity in Oregon increased from 9.03 cents per kilowatt hour in January 2020 to 11.40 cents/kWh in January 2024, a 26.2 percent increase over four years.[1 2] For residential consumers, the EIA estimates[i] Oregon's average retail price increased from 10.69 cents/kWh in January 2020 to 13.84 cents/kWh in January 2024, a 29.5 percent increase.[1 2] This is lower than prices in many other states – for comparison, the estimated average retail rate for residential customers nationwide in January 2024 was 15.45 cents/kWh.[2]

This Energy 101 explains some major cost drivers for electricity in Oregon. While prices for other goods and services have increased in recent years as well, electricity is used by virtually every household and business in Oregon, making electricity prices a topic of statewide interest.

Are Electricity Rates Increasing Statewide?

The EIA estimates average retail prices for the state as a whole. However, the price an Oregonian pays for electricity depends on where they receive service. Oregon is home to 41 different electric utilities, each of which has its own rates.[4] Not every utility in Oregon has raised rates in recent years, but many have.

Learn more about electric utilities serving Oregonians on ODOE's website.

In a review of Oregon's 10 largest utilities by number of customers served,[5] only one utility — Oregon Trail Electric Cooperative — had not increased its rates at least once between January 2020 and October 2024.[6] Customers of Oregon's two largest electric utilities — Portland General Electric and PacifiCorp (operating in Oregon as Pacific Power) — have seen their rates go up multiple times since 2020.[7-11] While different customer classes[ii] have different rates and often different consumption patterns, a typical residential customer[iii] of PGE or PacifiCorp saw their average bill increase 50-60 percent, from roughly $100/month in January 2020 to roughly $150-160/month in January 2024.[12 13 14 15] Both PGE and PacifiCorp are seeking to raise rates further in 2025.[16 17]

Customers of Oregon's largest consumer-owned utilities are also facing electric rate increases. The state's largest consumer-owned utility — Eugene Water & Electric Board — has raised rates multiple times since 2020.[18] EWEB estimates a residential customer's average monthly electric bill increased from $167 in 2020 to $190 in 2024, or roughly 13.8 percent.[18] The aggregate increase for other large consumer-owned utilities has ranged from approximately 5 to 11 percent from 2020 to 2024.[19-24] Not every utility reports a bill increase in percentage terms. For example, Oregon's tenth largest utility — Tillamook People's Utility District — has not reported a significant percentage

[i] The EIA does not survey utilities about retail prices but estimates retail price based on a sample of utilities' reports of revenue and consumption.[3]

[ii] Customer classes include such groups as residential customers, commercial customers, and industrial customers.

[iii] Utilities sometimes have different billing structures for single-family and multi-family home customers.

increase in the volumetric rate for kwh,[iv] but it has raised the basic charge[v] for residential customers from $23.10/month to $42/month over the last four years.[25] [26] [27] The effect of increasing a basic charge may not be clear in percentage terms, as it depends on a customer's total consumption and monthly bill. However, the effect is the same: monthly bills for customers typically go up.

Across the state, most Oregonians are paying more for electricity in 2024 than they were in 2020. While each utility is different, there are some common cost drivers for all utilities: rising power costs, the ongoing need for grid investments, and costs to mitigate and recover from wildfire and extreme weather. This Energy 101 explains these cost drivers.

Electricity Consumption

A customer's bill depends in part on their consumption, that is, how many kWh of electricity they used. Not every utility reported how much their customers' bills were estimated to change with the rate increases described above. Several instead provided an online calculator for customers to estimate the likely impact for their individual bill.

Consumption can vary significantly across customers, even within a particular class. For example, a number of household characteristics are correlated with usage, including the age and size of the home and the number of occupants. One factor that affects consumption is whether and where a household uses non-electric fuels. For example, some residential customers may have higher electricity consumption due to using electric heating equipment, compared to other customers who may heat their home with natural gas, wood, or propane. Energy efficiency programs provide opportunities for customers to reduce their consumption without sacrificing comfort.

Pursuant to House Bill 3630 (2023), the Oregon Department of Energy will present the inaugural Oregon Energy Strategy to the Oregon State Legislature on November 1, 2025. The strategy will include an analysis of how Oregonians' total "energy wallet" of all energy-related expenditures could change between now and 2050.

[iv] Tillamook PUD's current volumetric rate is $0.08/kWh.[25]

[v] Residential customers typically pay both a basic charge and a volumetric price per kWh. The basic charge is typically a flat rate that customers must pay each billing cycle regardless of how much electricity they use. By collecting more compensation via this flat fee, a utility can potentially avoid changing the volumetric price for each kWh a customer uses. However, customers have less ability to reduce their overall bill through energy conservation or energy efficiency, because using less electricity will not reduce the basic charge they must pay.

Oregon's Energy Supplier Assessment

The Energy Supplier Assessment is charged to fuel providers and utilities producing energy in Oregon and helps to fund the Oregon Department of Energy. All Oregonians pay the assessment when they pay for energy — about $1.87 for each Oregonian in 2023 — and together fund statutorily-required programs that benefit Oregon energy users. The Energy Supplier Assessment is apportioned out to ratepayers based on their reported revenues and is capped at 0.375 percent of revenues. In 2023, the assessment rate was 0.106 percent of Gross Operating Revenues reported by ratepayers, well below the cap.[28 29] In 2023, the agency assessed $7.91 million on $7.45 billion in gross operating revenues of fuel providers and utilities.

Are Other States Seeing Electricity Price Increases?

Oregonians are not alone in seeing rate increases. According to data from the EIA, the 26.2 percent increase in Oregon's average retail price is only slightly more than a 23.7 percent increase nationwide.[1 2] Oregon residential customers' 29.5 percent increase is notably higher than the nationwide increase of 20.8 percent.[1 2] Even so, Oregon residential customers have seen a smaller percentage increase than customers in the District of Columbia (35.9 percent) and eight other states, including Ohio (34.2 percent), Nevada (36.7 percent), and California (47.9 percent).[1 2] As noted earlier, according to January 2024 data from the EIA, Oregon's average retail price for residential customers of 13.84 cents/kWh is still below the national average of 15.45 cents/kWh.[2]

Are Oregon's Clean Energy Policies the Primary Driver of Rate Increases?

At the same time Oregonians have faced rising electricity prices, the electricity sector's greenhouse gas emissions in Oregon have fallen. According to data gathered by the Oregon Department of Environmental Quality, emissions fell from 18.8 million metric tonnes of carbon dioxide equivalent in 2019 to 17.6 million MTCO2E in 2022, even as overall electricity consumption increased.[30] DEQ reports the emission intensity of Oregon's electricity fell from 0.36 MTCO2E/MWh in 2019 to 0.30 MTCO2E/MWh in 2022.[30]

Numerous state and federal clean energy policies have contributed to these emissions reductions. Some policies, such as federal tax credits, have focused on reducing the costs, thereby fostering the increased deployment of low- and non-emitting technologies. As renewable technologies have become increasingly cost competitive, the competition has put pressure on older and less efficient generation sources, particularly coal plants.[31] Federal and state environmental regulations have also contributed to cost pressures on emitting generation sources. For example, PGE agreed to close the Boardman Coal Plant, the last coal power plant located in Oregon, as part of a federal Clean Air Act lawsuit settlement; the plant closed in 2020.[32]

Oregon's Public Purpose Charge

In July of 1999, Senate Bill 1149 instituted a public purpose charge that established an annual expenditure by PGE and PacifiCorp of 3 percent of their revenues to fund energy efficiency, development of small-scale new renewable energy, and low-income weatherization. In 2021, the Oregon State Legislature passed House Bill 3141, making numerous changes to laws governing the collection and use of the PPC. These changes included extending collection of the PPC to 2036, reducing the PPC amount from 3 percent to 1.5 percent, and moving the energy conservation funding out of the PPC to energy efficiency through investor-owned utility rates. Twenty-five percent of the renewable energy funding is dedicated to low- and moderate-income customers. As part of this realignment, PPC funding for low-income weatherization increased.[33]

Achieving Oregon's climate goals will require further emissions reductions.[34] In 2021, the Oregon State Legislature enacted House Bill 2021.[35] HB 2021 requires PGE, PacifiCorp, and certain providers called electricity service suppliers[vi] to, among other things, "eliminate greenhouse gas emissions associated with serving Oregon retail electricity consumers by 2040."[35]

Some have questioned whether HB 2021 is to blame for the recent electricity price increases. For many Oregonians, the answer is simple: no. HB 2021 does not apply to any consumer-owned utilities nor to Idaho Power Company, and HB 2021 is not a primary driver of their cost increases. Further, many of Oregon's consumer-owned utilities have lower emissions intensities, as they get most or all of their electricity from Bonneville Power Administration. While these utilities do face costs associated with complying with environmental policies generally, with lower emissions intensities, Oregon's consumer-owned utilities have historically faced less cost pressure from federal and state clean energy policies. As described above, many consumer-owned utilities to which HB 2021 does not apply have had to raise rates since 2020.

Overseeing Rate Increases

Publicly elected local boards or municipal governments oversee the prices and services for Oregon's 38 consumer-owned utilities.

The state's three investor-owned electric utilities — PacifiCorp, PGE, and Idaho Power — must obtain review and approval of their rates from the Oregon Public Utility Commission. When deciding whether to approve a proposed rate adjustment, the OPUC is obligated to ensure the change is fair and reasonable for utility customers and to allow the utility service provider the opportunity to recover reasonable costs and earn a reasonable return on its investments.[37] The OPUC encourages public comment on proposed rate changes, as part of a robust administrative process.[38]

[vi] Under Oregon's Electric Restructuring Law, all nonresidential consumers can purchase electricity from an Oregon Public Utility Commission-certified electricity service supplier other than their current utility, which is known as direct access. Direct access is an option, but no electric utility customer is required to choose direct access service. Should a customer choose direct access, the local service provider is responsible for the distribution of services, while the ESS would be responsible for the generation and transmission services.[36]

For customers of PGE, PacifiCorp, and electricity service suppliers, the answer is a bit more complicated. HB 2021 is not a direct driver of recent rate increases, but it will likely have future cost impacts. Any new investments that are made to comply with HB 2021 — and that the OPUC reviews and approves — will affect electricity prices at some point. However, those new investments and potential price impacts specific to HB 2021 are generally not being reflected in rates yet. For example, in reviewing PacifiCorp's 2023 Integrated Resource Plan and Clean Energy Plan, OPUC staff noted that the utility's progress toward HB 2021's emissions reduction targets so far only reflected the planning and investments that predated HB 2021.[39]

It is not yet known what the price impacts may be to pursue HB 2021's emission reduction targets. While new utility investments could potentially apply upward pressure on rates, it bears noting that clean energy investments have the potential to mitigate and even avoid certain cost pressures (such as from reduced exposure to volatile fossil fuel markets) so that new investments could mitigate or avoid future rate increases. It is also notable that utilities across the state are expected to need to make investments for reasons other than HB 2021. The Pacific Northwest Utilities Conference Committee's *Northwest Regional Forecast* for 2024 estimates that electricity demand will grow by over 30 percent in the next 10 years.[40] Across the region, many utilities are making or preparing for investments to serve higher electricity demand.

HB 2021 also includes a cost cap provision that empowers the OPUC to exempt a utility from further compliance with HB 2021's requirements if that utility's compliance costs exceed a certain level. The OPUC is conducting a public process to guide the implementation of HB 2021's cost cap.[41]

Oregon's Renewable Portfolio Standard

Oregon's Renewable Portfolio Standard includes a cost cap. Cost caps provide statutory protection against significant cost increases from a policy. The RPS cost cap focuses on "incremental costs" from the RPS and does not cover costs — even costs to invest in RPS-qualifying technologies — if the utility would have made that same investment without the RPS in place. The RPS cost cap has never been triggered.[42][43]

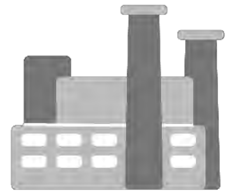
Why Are Electricity Rates Increasing?

This section explores three common cost drivers: 1) rising power costs; 2) ongoing infrastructure needs, compounded with inflationary pressures; and 3) costs to mitigate the increasing prevalence and risks of wildfires and extreme weather.[vii] These cost drivers are not mutually exclusive and often intersect with one another. For example, wildfires can damage existing infrastructure, such as utility poles, and a utility may face high costs to replace the damaged equipment due to market forces

[vii] This BER 101 does not profess to be a comprehensive study of every cost driver or even of every component of the three cost drivers addressed here. Each utility faces its own circumstances. The goal for this section is to provide a general overview of cost drivers that affect all or most utilities in Oregon.

such as inflation. However, each of these cost drivers can also operate independently of the other two.

Rising Power Costs



Rising power costs are a common cost driver for Oregon's utilities. The term *power costs* generally includes, among other things, the costs a utility pays to procure electricity through either contracts or market purchases, as well as the costs to fuel any fuel-powered plants the utility may have (such as coal or natural gas burning plants).

Many of Oregon's consumer-owned utilities receive all or nearly all of their power pursuant to long-term contracts with the Bonneville Power Administration.[44] BPA offers contracts to consumer-owned utilities pursuant to federal law. But BPA's costs change from time to time. BPA usually updates its rates every two years. BPA's rates must be set so that it will be able to recover its total costs, including obligations to repay its debt to the Federal Treasury.[45] The Federal Energy Regulatory Commission reviews BPA's rate adjustments for compliance with federal law.

While BPA's rates for Oregon consumer-owned utilities generally declined from 2022-2023, BPA is proposing higher rates in 2024 and beyond.[46] [47] When BPA raises the wholesale cost of power for Oregon's consumer-owned utilities, that affects each utility's need to adjust retail rates that customers pay. For instance, Central Electric Cooperative reported that when BPA adjusted its rates for 2024-2025, it raised CEC's power costs by 11.5 percent.[48] This was one factor CEC cited in explaining its 5.9 percent rate increase to customers.[48] Similarly, EWEB noted that increased power costs from BPA account for 5.25 percent of the anticipated 15 percent rate increase for 2025.[49] Even with the cost increases, however, power that BPA sells from federal generating resources costs less than power from other wholesale sources.

Long-term contracts with BPA provide a smaller share of the portfolio of resources that investor-owned utilities rely upon. Instead, investor-owned utilities rely more on long-term contracts with other providers, short-term market purchases, or fuel purchases for their own generating resources, where applicable. With greater reliance on these more variable options, investor-owned utilities are particularly sensitive to fluctuations in market conditions. Through an annual process overseen by the OPUC, each investor-owned utility forecasts its power costs for the upcoming year and updates its rates to pass the forecasted costs along to customers. At the end of that year, the investor-owned utility compares its forecast to its actual costs and, if the difference exceeds a certain amount, updates its rates to refund or charge customers for the difference. From 2020 to 2024, PGE and PacifiCorp's forecasted power costs increased by roughly double the amount or more.[50-69] Some of these increases are due to load growth: both PGE and PacifiCorp's loads have increased since 2020.[30] However, load growth alone does not explain the entirety of the increases in power costs that Oregon's large investor-owned utilities have encountered. To some extent, for both PGE and PacifiCorp, these power cost increases reflect a rising cost for them to generate and deliver electricity.

There are a number of factors contributing to rising power costs. As noted above, power costs include the costs of long-term contracts and short-term market transactions. The amount of generation a utility owns or procures through long-term contracts affects how much the utility needs to rely on market purchases. Deciding how much to buy long-term versus short-term requires a utility to predict not only how much electricity it needs to obtain but also how much the price of electricity is likely to change and how much cost risk the utility is willing to expose itself to. But no one can predict market prices perfectly. Doing so is especially challenging when unexpected events occur, such as the COVID-19 pandemic, which led to supply chain issues that slowed resource development over the last few years. Market prices rise when there is increased demand, more so when resources are stretched thin during heat waves or cold snaps. Many utilities across the West need to procure new and additional resources to maintain reliable electricity service, especially with growing customer demand. The Pacific Northwest Utilities Conference Committee's *Northwest Regional Forecast* for 2024 estimates that electricity demand will grow by over 30 percent in the next 10 years.[40] This rising demand, coupled with coal plant closures around the country and delays to new resource development, has contributed to higher costs for market purchases. However, it is hard to know whether — or to what extent — postponing coal plant closures might have mitigated power cost increases, if at all. PacifiCorp's power costs increased in recent years in part due to unexpected limitations in available coal supply,[40] limitations which the EIA reported as affecting the nation's coal market.[70]

As noted above, power costs also include fuel costs for a utility's own generation. Some fuels are not always available, forcing the utility to pursue other options. For example, BPA sells power primarily from hydroelectric facilities. In dry years with reduced rainfall, the hydroelectric facilities generate less electricity. To compensate, BPA may need to buy power from the market to meet customer needs; BPA also may not be able to sell excess electricity on the market for revenue to defray costs. Fewer sales from BPA or other generators into the market can also mean higher prices for other utilities when buying from the market. Further, fuel supply constraints increase the cost of what fuel is available. For example, natural gas is a commodity that is bought and sold internationally. As such, its price is affected by international affairs. In recent years, the Russian invasion of Ukraine in February 2022 had a significant effect on the natural gas market. As Russia significantly reduced its natural gas exports to European countries, the United States' exports of natural gas to Europe have risen considerably.[71] The higher international demand has contributed to a more limited and more expensive fuel supply for domestic needs, such as electricity production. Recent reports indicate that natural gas commodity prices are decreasing and becoming less volatile since 2022.[72]

Natural Gas Rates

Like electricity prices, retail prices for natural gas service have also increased in recent years. Volatile and higher market prices for natural gas in 2021 and 2022 have been one significant contributor.[73 74]

The OPUC approves adjustments annually to the rates of the three regulated natural gas companies: Avista Utilities, Cascade Natural Gas, and NW Natural, to reflect changes in the actual cost of wholesale priced natural gas, known as the Purchased Gas Adjustment. This allows companies to pass through their actual cost of purchasing gas to customers without a markup on the price. In nine of the 11 years from 2009 to 2020, the annual Purchased Gas Adjustment decreased natural gas rates.[75 76] However, higher natural gas market prices contributed to an increase in natural gas rates in 2021 and 2022 for all three utilities.[73 74] Recent filings at the OPUC suggest that wholesale market prices are stabilizing again.

Natural gas is not available to all Oregonians; it is only marketed in the service territories of the state's three investor-owned natural gas utilities. Oregonians living outside these areas rely on other fuels to meet their needs, such as electricity and propane.

Grid Investments

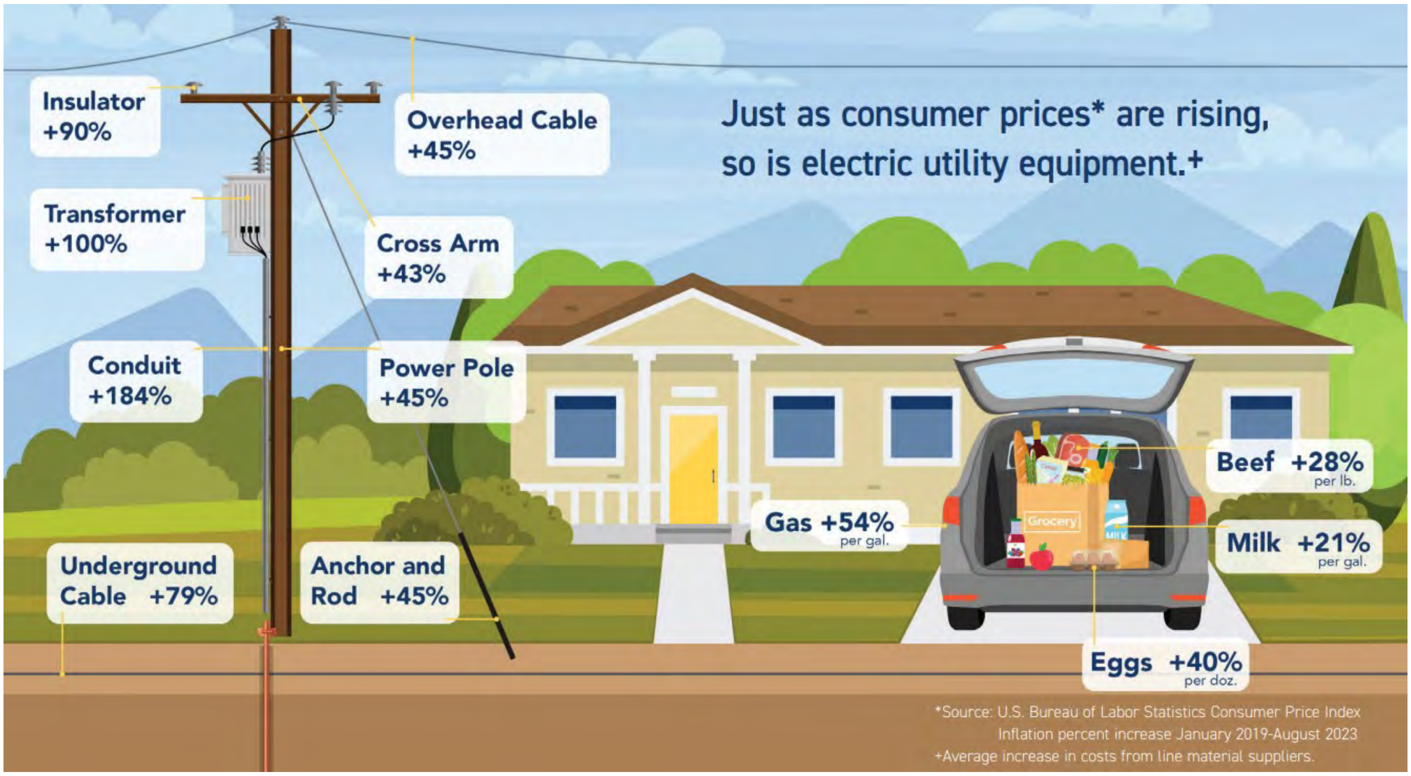
Delivering power requires infrastructure, and maintaining safe and reliable infrastructure requires making regular, routine investments. As more equipment ages, reaches the end of its useful life, and requires replacement, the cost of grid investments has and will likely continue to go up.

Further, the cost of otherwise routine infrastructure investments has been exacerbated recently by supply chain delays and inflation. In the fall of 2023, Central Electric Cooperative summarized these price impacts as follows:

> "Since 2019, CEC has seen the cost of a power pole rise by 35%, overhead power cables by 45%, underground power cables by 79%, and a single-phase (residential) transformer by almost 100%. If ordering the equipment today, the price tag would likely be higher upon receipt of the materials due to the 15-month supply chain delays."[21]

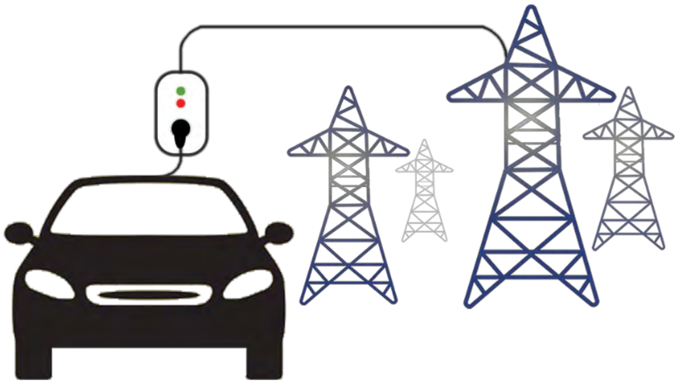
Crews from Central Electric Cooperative perform maintenance and repairs on high-voltage lines.

Figure 1: Inflationary and Supply Chain Cost Pressures (2019-2023)[48]



Extending service to new customers or expanding existing infrastructure to meet growing demand can increase infrastructure costs. This may be an increasing cost pressure in future years. The Northwest Power and Conservation Council reports that “the region is anticipating rapid load growth, driven by forecasted data center growth and transportation electrification.”[77]

Investing to upgrade, or modernize, utility equipment can also contribute to cost increases, at least in the short-term. This is likely to be a growing cost pressure in the future, as the number of opportunities for smart grid infrastructure increases. For many utilities, these investment opportunities include smart meters as well as smart appliances and smart electric vehicle charging infrastructure. Grid modernization can also encompass advanced grid monitoring systems, more sophisticated protective equipment technologies, and advanced communications systems. The expectation is that modernization investments will provide savings or other benefits over the long-term.



Federal Investments

The Federal government, through the 2021 Infrastructure Investment and Jobs Act (also known as the Bipartisan Infrastructure Law), has made billions in funding available for states, Tribes, local governments, and public-private partnership opportunities. This funding, as well as grant opportunities through the 2022 Inflation Reduction Act, will be used to rebuild America's roads, bridges, and rails, expand access to clean drinking water, ensure every American has access to high-speed internet, tackle the climate crisis, advance environmental action, and invest in communities that have too often been left behind. The Justice40 Initiative "directs 40% of the overall benefits of certain Federal investments – including investments in clean energy and energy efficiency; clean transit; affordable and sustainable housing; training and workforce development; the remediation and reduction of legacy pollution; and the development of clean water infrastructure – to flow to disadvantaged communities."[78]

The IIJA and IRA present an unprecedented opportunity for Oregon to secure federal funds to replace aging infrastructure, propel climate action, and invest in urban, rural, and frontier communities across the state, as well as facilitate and advance partnerships across Tribes, stakeholders, state agencies, and local jurisdictions. For more information on IIJA and IRA funding opportunities in Oregon, visit https://www.oregon.gov/energy/energy-oregon/Pages/IIJA.aspx.

Among other programs, the IIJA is funding the Oregon Department of Energy's Grid Resilience Grant Program. This program will provide grants to electric utilities to support resilience projects, which can include weatherization technologies and equipment, fire-resistant technologies and fire-prevention systems, utility pole management, undergrounding of electrical equipment, and more. Grant funding reduces the cost pressure on customer rates that would otherwise be driven by these important grid investments.

Wildfires and Extreme Weather

With increasing numbers of wildfires and extreme weather events in recent years, utility expenditures to both mitigate against and respond to these events have also increased. These expenditures may include increased vegetation management, particularly in high-risk wildfire zones; investments in hardening grid infrastructure through investments like reconductoring or undergrounding electric lines; and replacement costs for damaged equipment. While utilities have always engaged in some level of vegetation management and equipment replacement, costs specific to wildfires and extreme weather are increasing in magnitude alongside both the increased risk of utility-ignited wildfires and the increased number of acres burned when utility-ignitions do occur, due to the compounding effects of extreme weather patterns. In addition to expenses associated with wildfire mitigation, utilities across the West have seen increased costs for and limited availability of commercial insurance, which is also a factor of increased wildfire risk in the region. Learn more in the Energy 101 on Climate Change Effects on the Energy System.

Utility mitigation efforts work to reduce the probability and severity of utility-ignited wildfire, but utility equipment has the potential to cause or contribute to wildfires, even after mitigation efforts have been taken. A number of utilities in Oregon are currently facing litigation about whether utility activities may have caused or contributed to wildfires in the region. For example, PacifiCorp has been accused of wrongdoing regarding the 2020 Labor Day fires.[viii] Whether PacifiCorp's customers should pay through rates for all or some of PacifiCorp's litigation expenses is an unresolved issue in proceedings before the OPUC. Similarly, Bonneville Power Administration has been named in multiple tort claims and one inverse condemnation complaint.[ix] While tort claims against a federal agency are generally paid by the United States Judgment Fund, there has been uncertainty over the potential source of funds that might be used if the complainants prevail against the federal government in the inverse condemnation case.[81]

Pursuant to Senate Bill 762 (2021), electric utilities across Oregon must develop and file wildfire mitigation plans with the OPUC. Plans must include identification of high-risk areas within the utility's service territory and actions to minimize those risks, as well as protocols for implementing public safety power shutoffs. Utilities also need to describe how they determined which risk reduction strategies to pursue.[82]

What is the Status of Implementing Oregon's Energy Affordability Act, and How is it Mitigating Price Increases?

In 2021, the Oregon State Legislature enacted House Bill 2475, the Energy Affordability Act.[83] This Act authorized the OPUC to consider differential energy burdens on low-income customers and other economic, social equity, or environmental justice factors that affect affordability in rate making and program design.[84]

Since the Act took effect, the OPUC has been busy implementing the new authority to address energy affordability in the state. In an effort to balance the need for expedited energy burden relief and the desire to investigate the methodologies and implications of differential rate designs and programs, the OPUC took a staged implementation approach for the bill that allowed for immediate engagement with communities, advocates, and utilities to provide near-term relief.

During the first phase of implementation, the OPUC focused on establishing interim utility bill discounts for income-qualified ratepayers for each utility. The first bill discount program took effect April 2022 for PGE customers; a similar program for PacifiCorp customers took effect in October 2022. The OPUC has reported that more than 80,000 PGE customers and more than 50,000 PacifiCorp customers have benefited, receiving in aggregate over $35 million in assistance.[85]

There is more work to be done. The OPUC gathered stakeholder input on priority issues for the next phase of HB 2475 implementation, which launched in the fall of 2024. In this second phase,

[viii] PacifiCorp provides updated information on wildfire litigation on its website at https://www.pacificorp.com/about/information-wildfire-litigation.html.

[ix] A tort claim seeks reimbursement for injury or damage caused by the wrongful or negligent actions of a person, including but not limited to government entities.[79] An inverse condemnation claim seeks relief from a government "taking" private property — such as by causing property damage — without just compensation.[80]

the OPUC is focused on refining the initial bill discount programs, developing an energy burden data collection framework, targeting energy efficiency and weatherization programs to environmental justice communities, and enhancing current arrearage management programs and disconnection protections.

Other Energy Assistance Programs

While Oregon's Energy Affordability Act focuses on the investor-owned utilities regulated by the state, there are energy assistance programs across the state that aim to provide energy assistance to Oregonians in need. These include numerous energy efficiency and weatherization programs that are critical to ensuring access to safe, affordable, and adequate energy service.

The Low-Income Home Energy Assistance Program is a federally funded program that helps low-income households pay their home heating and cooling bills. The LIHEAP Clearinghouse is an information resource for state, Tribal and local LIHEAP providers, and others interested in low-income energy issues.[86] To see the LIHEAP Clearinghouse page for Oregon, visit https://liheapch.acf.hhs.gov/profiles/Oregon.htm.

There are many tools that are critical to energy affordability, including programs that ensure access and funding for energy efficiency and weatherization measures. The Energy Affordability Act represents an important addition to the existing toolbox.

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Peak Electricity Demand

Peak electricity demand, or peak load, is the highest demand for electricity from all customers across a specific service area during a specified period of time (such as an hour, a month, or a year). It is one of the key metrics utilities and transmission providers track and forecast to assess future electricity demand — and plan for adequate levels of generating resources needed to keep the lights on.[1 2] Tracking and forecasting demand also helps utilities assess operational needs, maintain reliable service, and manage ratepayer costs.

Peak Electricity Demand and Utility Planning

Peak demand has a strong influence on the amount of generation resources, transmission, storage, and distribution infrastructure electric utilities and transmission providers must invest in to maintain a reliable grid. Peak load expectations inform grid planning because the grid must be sized to accommodate the largest need for electricity at any given time.[2] Over a planning horizon, peak load is expected to occur on the hottest and/or coldest days of the year. Even though consumers use less (oftentimes significantly less) electricity during most hours of the year, grid planners must ensure that grid resources can accommodate the anticipated highest peak loads in the coming years.

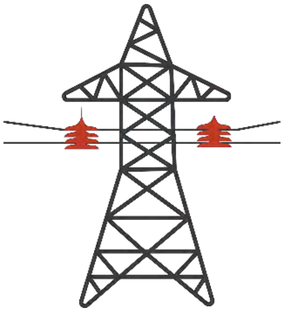
The resources grid operators use to meet peak loads include options on both the supply and demand side. In general, utility planning efforts seek to identify the least cost and least risk resources to meet future load. This includes procuring all the infrastructure necessary to deliver power to the consumer, such as procuring new generation resources, contracting for power from existing resources, participating in energy markets, expanding transmission, or purchasing transmission access.

Energy efficiency measures reduce demand across all hours, including peak hours. Efficiency has historically been one of the most cost-effective resources for the Pacific Northwest, with 7,678 average megawatts of energy savings from 1978 through 2022.[3] Energy efficiency savings can occur on the supply side when utilities use more efficient types of generation, such as upgrading to more efficient turbines. Savings are also available on the customer side, by using more efficient appliances and lights, weatherizing and insulating buildings, and using advanced heating and cooling technologies like smart thermostats and water heaters.

Demand-side management programs encourage consumers to reduce energy consumption during peak hours.[4] For example, many utilities offer lower rates for using electricity in off-peak hours. Demand response programs are a type of load shedding option, where specific loads can be ramped down or even turned off by a utility or a customer, temporarily reducing demand during peak demand hours. Some utilities offer reimbursement for customers who voluntarily reduce energy consumption during major peak load events.

SCAN OR CLICK

Learn more about demand response in ODOE's 2020 Biennial Energy Report.



Transmission expansion is often considered a supply side resource and offers grid operators the ability to connect more loads with more generation and storage resources.

Transmission lines move electricity by creating a pathway for power to flow from sources of supply to loads.[5] Transmission lines also connect all utilities to each other, allowing for a networked power grid that not only allows power to flow across the entire footprint of a single utility service area, but also across the footprints of multiple utilities. Like generation, transmission lines also have an upper capacity threshold, limiting the amount of energy that can be transferred at any given time. The capacity of the line is dependent on ambient temperatures, with lines losing capacity as outdoor temperature increases. This means that during heatwaves, transmission lines will generally have less capacity than during cold weather events.

Grid operators must consider the availability of transmission capacity as well as generating capacity when planning for future grid needs. Transmission lines can become constrained if they are operating at their capacity limit, which is most likely to occur during peak load hours. This means that even if energy generation and storage are available to balance peak load on both sides of the transmission line, the constraint would not allow enough energy to flow to achieve that balance.

Peak Electricity Demand and Ratepayer Costs

Energy costs are directly related to the types of resources utilities use to meet load.[6] Grid operators typically prioritize using lower cost resources to meet load — a least-cost strategy.[1] Existing hydropower and new wind and solar projects tend to be the least cost resources, largely because these types of renewables do not have any associated fuel costs and because new wind and solar also have relatively low capital costs. While hydropower has some flexibility in ramping up or down, solar and wind generation are dependent on whether and to what degree the sun is shining or the wind is blowing. As customers demand more electricity at any given time, more costly resources are dispatched. These tend to be more flexible resources, such as hydro, batteries, and natural gas generation. The last resources dispatched are generally the most expensive supplies of electricity, often highly flexible batteries and natural gas peaker plants that can be ramped up or down quickly as needed.

The primary reason peak demand is such a critical driver for power grid planning is that electricity must be generated just in time for it to be consumed.[5] Unlike transportation and heating fuels that can be stored and used when needed, historically there have been few options for electricity storage.[7] This is beginning to change, as batteries are becoming an increasingly cost-effective way to store electricity for later use.

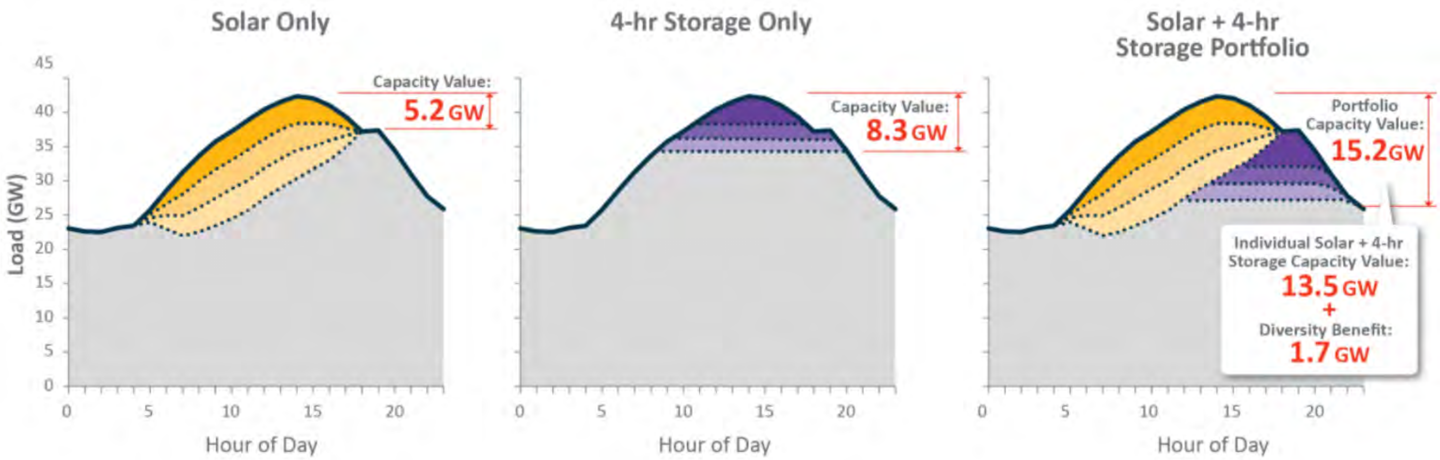
Batteries can provide additional power during peak load hours, offsetting the need for additional generation to meet that load.[7] The rapid expansion of the electric vehicle market has led to significant reductions in battery costs, and electric utilities are increasingly adding them to their operations. Utility-scale batteries generally supply four to 10 hours of energy at their maximum output, and offer an opportunity for utilities to store energy during off-peak hours to meet peak load later in the day.

This is an especially useful resource when storage is located near customers or when located near variable renewables like solar and wind.

Figure 1 shows how solar and battery storage can help cost-effectively meet daily peak load hours. Energy consumption is highest in daylight hours, and generally increases and decreases as the sun rises and sets – hours 6 to 21 (6am to 9pm) show this pattern. Energy consumption also tends to peak in the early afternoon between hours 13 and 15, when most people and businesses are most active, and when the sun is near its apex. Because of this strong correlation between daylight hours and energy consumption patterns, solar resources can play a major role in meeting the daily demand for energy, including at the height of the afternoon peak, as shown by the yellow shades representing solar energy in the first chart in Figure 1. As the sun begins to set, solar generation wanes – which can be seen as less and less yellow as the day moves on – and other sources of electricity must step in to meet that load.

Battery storage can also help meet the daily peak load, as shown by the purple in the middle chart, but it costs more than solar and is limited in the amount of energy it can supply. Batteries can meet a portion of the peak, but other resources including solar are still necessary to meet total load during these hours. The chart on the right shows how batteries in conjunction with solar output can be optimized to meet the peak daytime load. In this example, batteries help the grid operator meet peak load without the need for investments in more expensive generation technologies.

Figure 1: Portfolio Benefits for Solar + Storage in Capacity Accreditation[8]



Batteries offer the opportunity to get more out of existing resources, reducing costs that would be passed on to ratepayers. For example, charging batteries with solar energy that would otherwise not be used during the day, or charging when the wind is blowing at night, reduces the need to use more expensive resources like natural gas to meet peak demand. It is important to note that the energy used to charge the batteries may be less available on the hottest and coldest days of the year, and batteries may also be charged with non-renewable resources like natural gas.

Peak Electricity Demand and Electricity Reliability

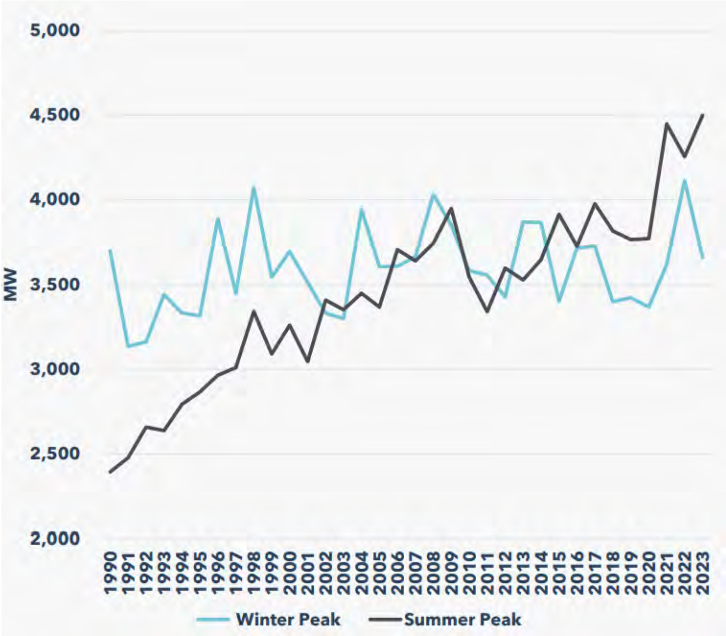
The risk of electricity supply shortfalls is higher during extreme weather events.[9] Extreme temperatures and conditions often reduce the performance of electricity generation, battery storage, transmission, and distribution equipment.[10] This limits the ability of grid operators to manage and balance supply and demand. Uncertainties in the timing and magnitude of extreme events – such as when they may occur, how intense they are, and how long they last – adds additional risk. The coupling of these risks with high electricity demand greatly increases the risk of grid failures.

Climate change makes planning for peak events in the Pacific Northwest more challenging. Increasing instances of high temperature heat events and increased use of cooling equipment in buildings and industry are driving more energy demand in summer months.[11] Once only thought of as a "winter peaking" region, the Pacific Northwest is now considered a "dual peaking" region, which means utilities need to plan for both winter and summer peak events.[12] Learn more in the Energy 101 on climate change effects on the energy system.

The Pacific Northwest's summer electricity peak has increased significantly in the past four years. Winter still produces the greatest seasonal load in the region, including the region's highest peak since the 1990s.[i] A cold snap on January 13, 2024 drove electricity demand up to 35,594 MW.[14] Until 2021, summer peak demand was always below 30,000 MW. Since then, summer peak has exceeded 32,000 MW, with a record peak of 33,300 MW on July 9, 2024.[13]

Although the region remains a winter peaking area, some utilities in the Pacific Northwest now experience their highest loads in the summer. Figure 2 shows the annual highest peak demand for Portland General Electric in both winter and summer. Summer peak load first surpassed winter in 2002, and has consistently been higher than the winter peak since 2014.[15,16]

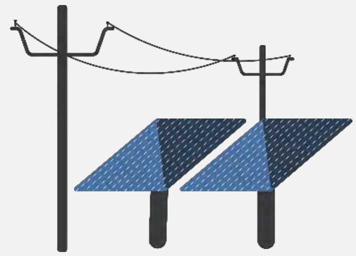
Figure 2: Historical Peak Demand in Winter and Summer for Portland General Electric[16]



[i] Prior to the 1990s, high-load aluminum smelters and certain other industrial customers in the region produced a very different energy profile. These industrial users were largely shuttered by the 1990s.[13]

The likelihood of heat waves and cold snaps is also increasing.[18] More frequent, intense, and longer-lasting extreme weather events mean electric utilities must be able to provide electricity to meet peak demand events that can span multiple days. To keep the lights on during these long, multi-day, high demand events, utilities need sufficient supplies of generating, storage, and transmission capacity needed to meet the more prolonged durations of high demand.

Capacity, Generation, and Energy Demand



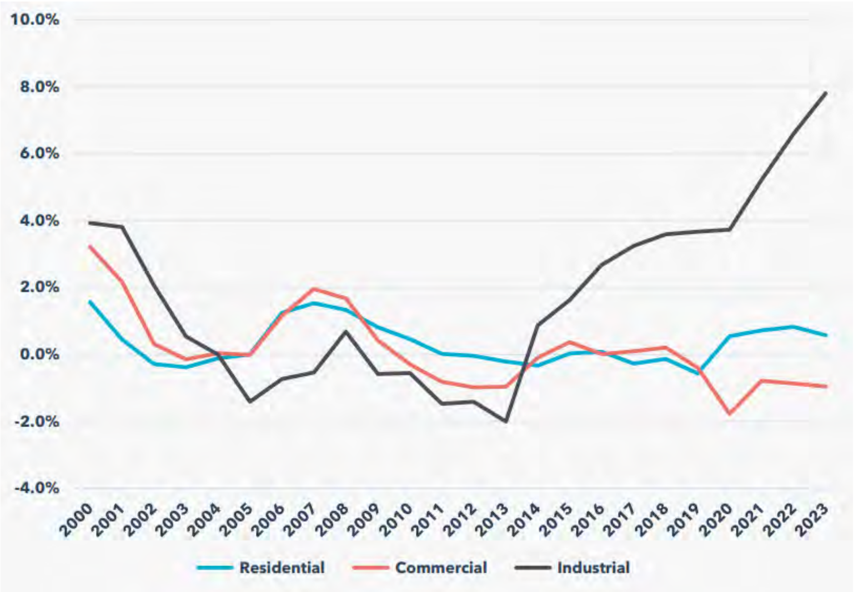
Energy **capacity** is a measurement of the largest amount of energy a resource can generate or a transmission line can carry under optimal conditions. It is measured in megawatts and abbreviated as MW. It is reflective of the upper end of operating output because electricity infrastructure rarely operates at full capacity.

Generation refers to the cumulative energy output over a period of time, and is measured in megawatt hours, or MWh. As an example, a solar array with a 100 MW capacity operating at 50 percent capacity for 12 hours of the day would generate 600 MWh over the course of that day.

Energy Demand refers to the amount of energy consumers need. This can be described simply as the number of MW needed at any given moment, or the number of MWh for a period of time. When forecasting, energy demand is generally provided as average megawatts. An aMW is the maximum amount of power a 1 MW generating plant can produce over the course of a year. This measurement is used in forecasting to describe both projected energy demands and estimated energy savings because at any given operating hour in the system these specific values are uncertain.

Peak load is expected to increase as the overall annual electricity demand increases. The Northwest Power and Conservation Council analyzed future growth in annual energy demand and found that it is expected to rise from 104,000 average megawatts today to between 130,000 and 155,000 aMW by 2045.[19] Currently, load growth is primarily driven by large tech sector industrial loads, such as data centers and semiconductor manufacturing.[16] Figure 3 shows percent changes in annual load growth for the residential, commercial, and industrial sectors in PGE territory. While Residential has remained basically flat, industrial growth, shown by the black line, has risen by nearly 8 percent in the last five years.

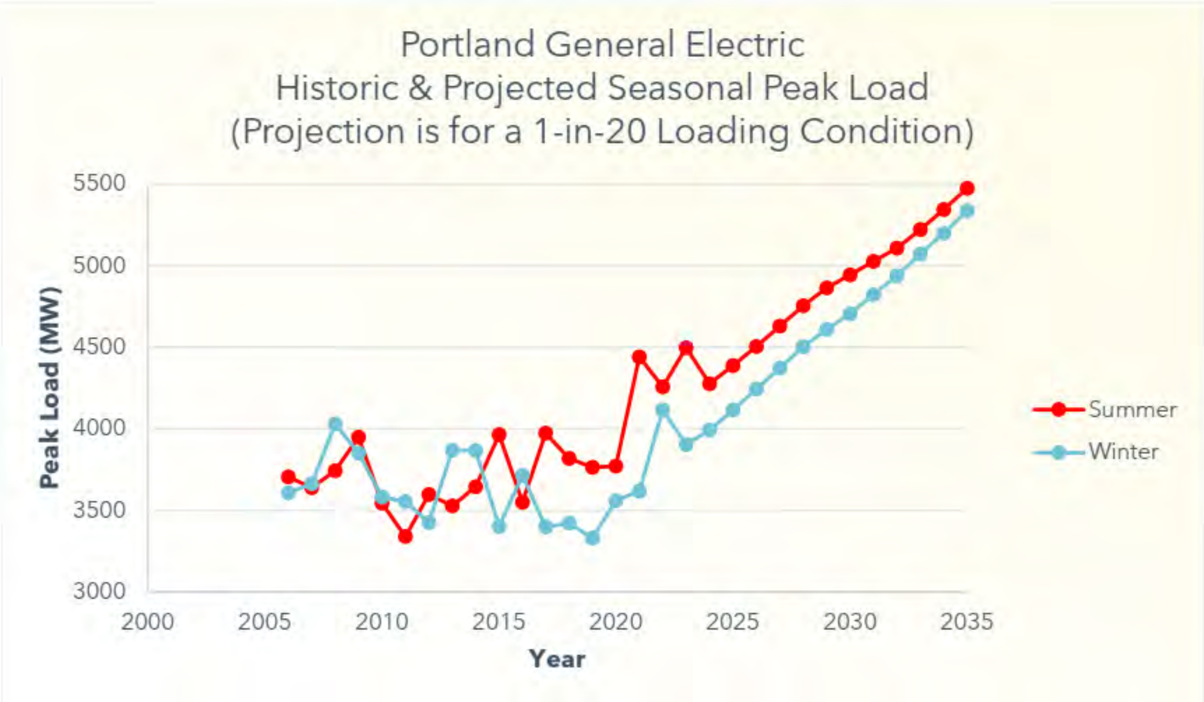
Figure 3: Average Five-Year Load Growth Rate by Sector for Portland General Electric[7]



Included in PGE's historical data on load growth are increases in load resulting from the electrification of end uses previously met by fossil fuels. In the transportation sector, electric vehicles are becoming an increasingly large share of passenger vehicles on Oregon roads, and potentially could contribute to peak load if they are charged in the evenings when people arrive home from work and other activities.[20] However, EVs might also serve as battery storage on the customer side of the grid — and could someday serve as both a load and a resource for utilities to use in managing the grid.[21]

Looking forward Portland General Electric uses historic data trends and industry trends to project peak load with various levels of likelihood. The scenario shown below expands on recent trends in peak load growth and has a one in 20 probability of occurrence.

Figure 4: Portland General Electric Historic and Projected Seasonal Peak Load[22]



Peak load is an important metric for effective grid planning and cost management. Understanding the different types of peak loads and how they influence grid operations is central to maintaining a reliable grid in the face of a changing climate and increasing electricity demand.

Learn more about peak demand and related energy reliability topics:

- 2022 Biennial Energy Report: Electric Sector Resource Planning and Acquisition
- 2020 Biennial Energy Report: Electricity Transmission
- 2020 Biennial Energy Report: Resource Adequacy
- 2018 Biennial Energy Report Chapter 5: Resilience
- Northwest Power and Conservation Council: PNW Power Supply Adequacy Assessment for 2029
- Northwest Power and Conservation Council: Resource Adequacy Overview

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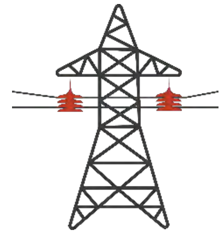
Electricity Day-Ahead Markets

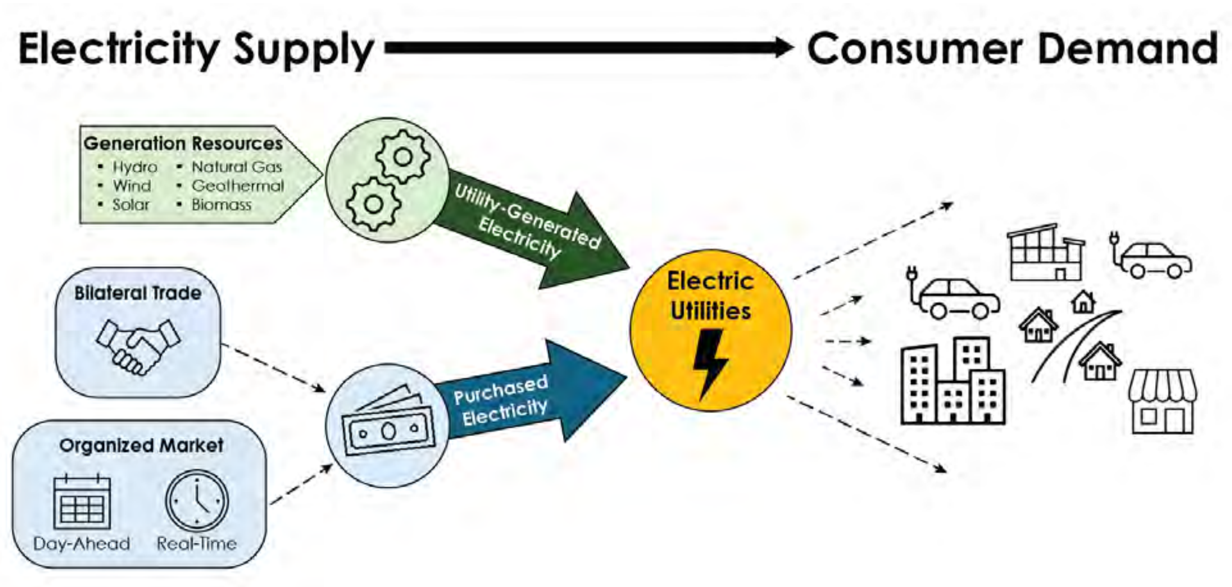


Every day, electric utilities work to reliably provide electricity to consumers. Because there is currently limited capacity to store electricity on the system, utilities must typically meet consumer demand in real time—perfectly balancing the supply of electricity with demand every minute of every day.[1]

Electric utilities can supply electricity by generating their own or by purchasing it from other generators as shown in Figure 1. When utilities purchase electricity, they can either enter into bilateral transactions with other utilities or individual electricity generators, or purchase electricity from an organized market. There are two types of organized wholesale electricity markets: day-ahead and real-time markets. Day-ahead markets allow utilities to purchase and sell electricity the day before service is needed to meet forecasts of demand and generation for the next day. Real-time markets allow utilities to purchase electricity on the day of service to meet unexpected fluctuations in demand or generation from situations such as unforeseen weather events.[2] For more information about the wholesale electricity market and real-time markets, see the Oregon Department of Energy's Policy Brief on Evolving Wholesale Electricity Markets in the *2020 Biennial Energy Report*.

A **Bilateral Transaction**, or bilateral contract, is a written agreement between a buyer/utility and seller of electricity (other utilities or individual electricity generators) where the price ($ per megawatt hour or megawatt) and time limits (hourly to long-term) of the purchase are negotiated ahead of time by the parties.[3]

Figure 1: Balancing Electricity Supply and Demand



Electric utilities provide electricity to consumers by generating electricity themselves or buying it from other sources, which can be done through bilateral trade or through organized electricity markets. There are two types of organized markets: day-ahead markets, where utilities plan purchases a day in advance based on expected consumer demand, and real-time markets, where utilities can buy electricity to address unexpected changes in day of service consumer demand.

Utilities use long-run forecasts of demand and potential generation, looking up to decades in the future, to develop long-term supply strategies such as building new power plants, building new transmission lines, or entering into long-term bilateral contracts. As it gets closer to the day of service, utilities update these demand forecasts (also known as load forecasts) and estimate generation from their own resources — such as hydro, natural gas, solar, or wind — to determine the mix of electricity generation and purchases that they will need to meet real-time demand.[1]

Figure 2: Day-Ahead Forecasted Demand for March 1, 2024[4]

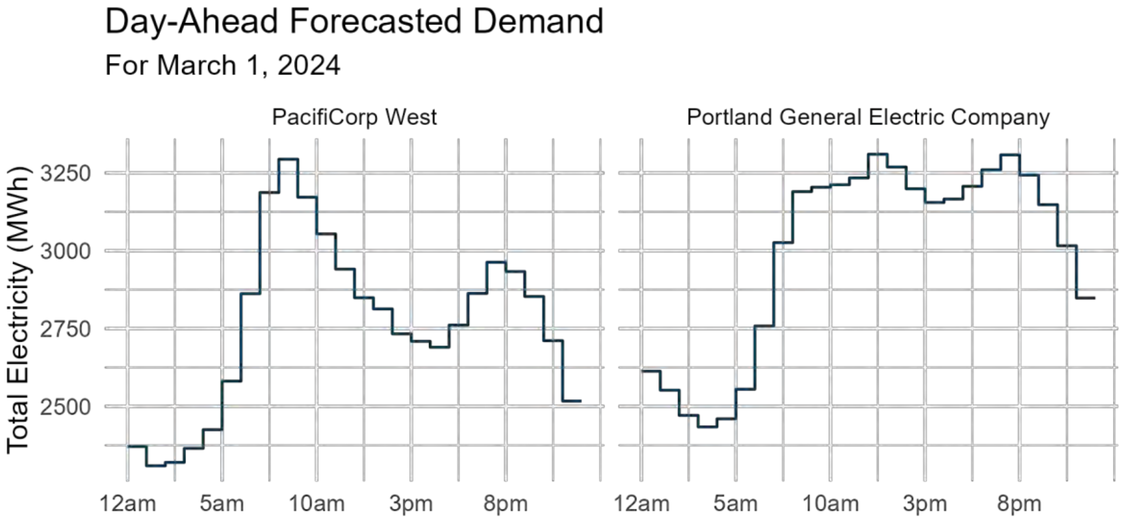


Figure 2 shows an example of Portland General Electric's and PacifiCorp West's forecasted demand in the day ahead planning window for service on March 1, 2024. For these load forecasts, each utility predicted how much electricity would be demanded for each hour of the day on March 1 using information on load influencing factors such as weather forecasts and economic activity estimates. Both utilities estimated that demand on March 1 would peak at about 3,300 MW. If, for example, one utility had 3,500 MW of generation available at this time of peak demand, it could have chosen to sell its excess electricity. On the other hand, if one had only 3,200 MW of generation available at this time, it would have needed to purchase an additional 100 MW of electricity to meet peak demand. Utilities similarly estimate production from variable generation (e.g., solar and wind) in the day-ahead planning window. Utilities often plan balancing energy demand forecast and generation estimates in the day-ahead window with energy purchases/sales to ensure cost-effective energy supply for their customers. Without a formal market, these sales and purchases of electricity are done through bilateral transactions, but day-ahead organized markets can facilitate balancing of generation and demand through the sale and purchase of electricity in a more economically efficient manner.

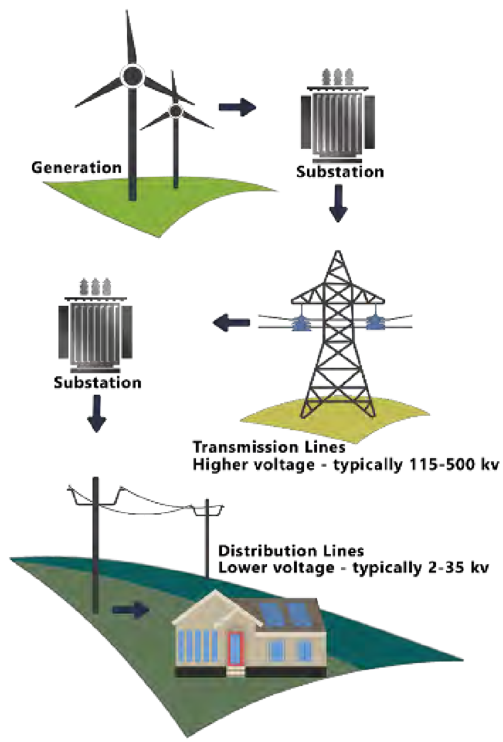
This article describes how day-ahead markets work, provides an overview of where day-ahead markets can be found in the United States, and closes with a discussion of the benefits and challenges of participating in and developing a day-ahead market.

Complexities in Meeting Electricity Demand

The basic framework of electricity supply needing to meet demand provides a helpful overview of the challenge electric utilities face every day. In reality, however, providing safe, reliable, and fairly priced electricity is more complex with utilities also facing physical infrastructure constraints and the need to meet reliability requirements systemwide. In regions with a Regional Transmission Organization or Independent System Operator, electricity markets, transmission, and reliability are all overseen by the RTO or ISO. As Oregon is not part of an RTO or ISO, these three areas are currently coordinated separately by each utility for their service territory. While the focus of this article is on the electricity market, below is a short description of transmission and reliability for additional context with links to where you can find more information.

Transmission

Electricity is the physical flow of electrons and must be routed from its generation source to the consumer through transmission and distribution lines. Large, high-voltage transmission lines are used to efficiently move electricity long distances with fewer losses from where it is generated to areas where it will be used. Distribution lines then make the final connection to the electricity end-user.[5] Day-ahead markets rely on transmission lines to function as any market purchase of electricity must physically be delivered via connected transmission. The capacity of transmission lines must be carefully managed when several purchases are being made that require the use of the same transmission line. For more information about transmission and its role in facilitating the delivery of electricity, see the Oregon Department of Energy's Energy 101: Electricity Transmission in the *2020 Biennial Energy Report*.



Reliability Requirements

Because electricity is essential today for our lives and work, regulations have been put into place to ensure that there is minimal risk of insufficient electricity supply to meet variable electricity demand. Electric utilities are required to meet reliability standards in their service territories. Electric utilities have an obligation to maintain a certain level of resource availability such that they can meet estimated peak demand, plus a given percentage above that peak to account for uncertainty, known as a reserve margin.[6]

In many areas, RTO/ISOs operate additional markets in parallel with the wholesale electricity markets to address reliability. **Ancillary service markets** refer to the various organized markets that provide secondary services to ensure reliability of the overall electricity system. These markets cover a wide range of secondary services, but not all RTO/ISOs have markets for all ancillary services, with many of these markets still evolving. One example of a common ancillary service market is the market for operating reserves.[7] Even with all the planning and forecasting by RTO/ISOs and utilities, it is still possible that at the time of service, demand may be higher than anticipated or a generating resource may trip offline. When this happens, it is necessary to have electricity generating resources or demand response resources that can quickly respond (usually within 10 minutes) to rebalance supply and demand.[1] In some RTO/ISOs these resources, known as operating reserves, are bought and sold through markets, using a similar auction system as the day-ahead market described here.[7] While an exhaustive list of the types of services that are provided through ancillary service markets is beyond the scope of this article, to learn more about ancillary services and the market systems that support these services, see "Ancillary Services in the United States: Technical Requirements, Market Designs, and Price Trends" by the Electric Power Research Institute.

Several RTO/ISO areas in the United States also have markets for capacity,[i] which though typically separated from the other ancillary services, can further support reliability goals. **Capacity markets** are auction markets where utilities can buy and sell future assurance of capacity, or MWs. In this market, sellers of capacity guarantee that on that future date, they will have the agreed upon amount of capacity available for the buyer to purchase at the market rate.[6] Since Oregon is not part of an RTO/ISO, it does not participate in these additional markets. For more information about how Oregon's current transmission, capacity, and reliability planning compares to areas with RTO/ISOs, see the Oregon Department of Energy's Regional Transmission Organization Study: Oregon Perspectives.

Demand Response

Throughout the typical day, demand for electricity rises and falls. To avoid having to build out additional resources to meet times of high demand with additional generation, utilities have implemented programs to incentivize customers to reduce or shift load away from these peak hours. These programs are generally referred to as "demand response" programs and can be an alternative method to meet peak demand.[8] For more information about demand response, see the Oregon Department of Energy's Technology Review: Demand Response in the *2020 Biennial Energy Report*.

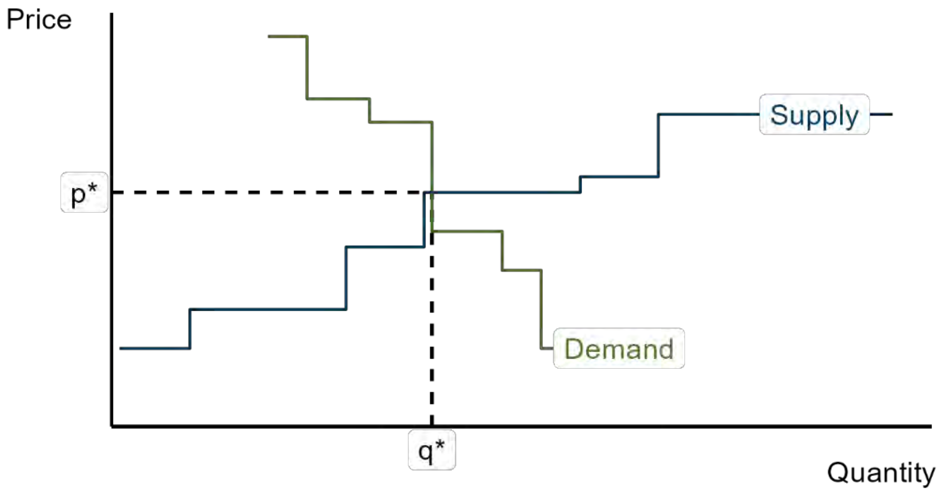
How Do Electricity Day-Ahead Markets Work?

Day-ahead markets function as auction markets for next-day electricity service. Entities that would like to buy or sell electricity for the next day can enter bids with the market operator.[ii] These bids indicate the price at which an entity is willing to buy or sell a quantity of electricity for a given time period, often a specific hour(s) of the next day. The market operator takes the bids it receives, and for each time period of the next day, creates supply and demand curves. The market operator creates the supply curve by ordering each of the *sell* bids from lowest to highest price and creates the demand curve by ordering each of the *buy* bids from highest to lowest price.[9] Figure 3 provides a simple example of what these supply and demand curves look like for a day-ahead market.

[i] Capacity is the maximum amount (MWs) of electricity that a generating resource can produce.

[ii] Market operators are those who work at an RTO/ISO who manage the market bids and establish the market price.

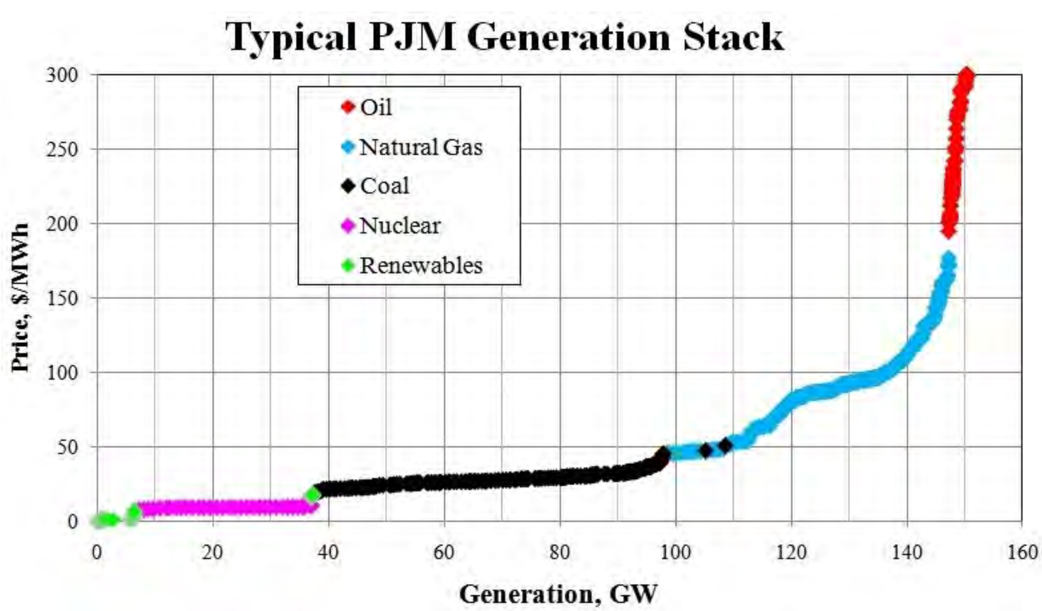
Figure 3: Example Day-Ahead Market Supply and Demand Curves[9]



The market operator sets the market price at the point where the supply and demand curves meet, denoted by p* in Figure 3. Like with other markets, this point represents the market equilibrium. At the equilibrium market price, the quantity of electricity that buyers are willing to purchase exactly equals the quantity of electricity that sellers are willing to sell, represented by q* in Figure 3. In other words, at this price, the market clears. All sellers receive the market price, and all buyers purchase at the market price.[10]

Electricity generators who sell electricity on the day-ahead market will make a profit if the market price is above the cost of generating the MWh of electricity they want to sell. Strategically, this means that they will choose to set their bid price exactly at their marginal cost, or the incremental cost associated with producing one additional MWh of electricity. With the arrangement of the supply curve from lowest to highest bid, this market system ensures that the electricity resources used first are the ones with the lowest marginal costs for that time period.[9] Figure 4 provides an example from the PJM market in the northeast U.S. of how different types of electricity generating resources typically align on the supply curve.[11]

Figure 4: Example Electricity Supply Curve by Generation Type[11]

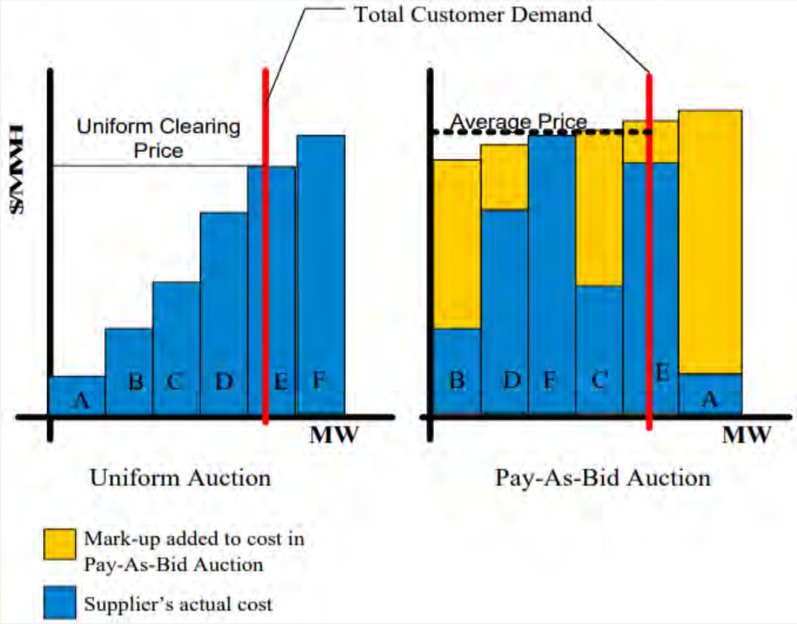


It is important to note that because buyers and sellers submit bids for specific time periods, each time period will have individual supply and demand curves and a separate market price. For example, the price of electricity tomorrow may be $22/MWh at 8 a.m. and $45/MWh at 8 p.m. Additionally, while the uniform price market design described above sets the shared wholesale electricity price for the market, specific purchasers of electricity may ultimately pay a higher price than the market clearing price to account for the transmission needed to get that electricity to them.[1]

Why is There a Uniform Clearing Price?

Like many other markets — such as the wholesale market for oil and gas or the commodity market for corn — there is a uniform clearing price in electricity day-ahead markets. In this type of auction market, it is important to have a singular price to efficiently incentivize bidding behavior among participants. To understand how this design incentivizes efficient bidding behavior, the uniform clearing price auction can be compared to a pay-as-bid auction as in Figure 5. In a pay-as-bid auction, each electricity supplier is paid the amount they bid rather than a single uniform clearing price. In this setting, it is no longer strategic for suppliers to bid in at their marginal cost as they will be guaranteed no profits and will eventually decide to exit the market. Instead, suppliers will attempt to maximize their profits by trying to guess the highest price at which their generation will still be used. This markup is represented by the yellow bars in the figure. In the pay-as-bid scenario, this type of bidding behavior is economically suboptimal, with higher cost resources potentially being used over lower cost ones. For example, in the uniform auction graph the lowest cost resource ("A") is chosen first and the highest cost resource ("F") is not chosen. In the pay-as-bid graph the highest cost resource ("F") is chosen while the lowest cost resource ("A") it is not chosen. For more information about the use of single clearing prices in electricity wholesale markets, see the article "The Benefits of Uniform Clearing-Price Auctions For Pricing Electricity: Why Pay-As-Bid Auctions Do Not Cost Less" from ISO New England.[12]

Figure 5: Pay-As-Bid vs. Uniform Clearing Price Auction[12]



Where Are the Electricity Day-Ahead Markets in the United States?

In the United States today, there are seven electricity day-ahead markets. Figure 6 shows where each of these day-ahead markets operate. Currently, each day-ahead market in the U.S. is concurrent with a Regional Transmission Organization or Independent System Operator. The RTO/ISO in each region runs the day-ahead market. While there are differences and additional complexities in how each of these individual markets function, all day-ahead markets in the U.S. follow the basic form outlined above—with market participants submitting purchase or sell bids and the RTO/ISO managing those bids to determine the market price, applying anti-gaming rules and mechanisms.[2] It is important to note that while the focus here is on the RTO/ISO role in administering the day-ahead markets in their regions, RTO/ISOs serve many additional functions, such as facilitating capacity planning and operating transmission.[13] For more information about RTO/ISOs, see the Oregon Department of Energy's [Regional Transmission Organization Study: Oregon Perspectives](#).

Figure 6: Map of Day-Ahead Markets in the United States[2]

While each of the day-ahead markets in the U.S. currently only operates within an RTO/ISO region, there are ongoing discussions about how a day-ahead market might function outside of an RTO/ISO region. There are already two real-time electricity markets that operate with participants from outside of the operating RTO/ISO region. The Western Energy Imbalance Market is one example of how an organized market can work outside of an RTO/ISO region. The Western Energy Imbalance Market is a real-time electricity market that is run by the California Independent System Operator but is open to participation from utilities across the western region who are not CAISO members.[14] For example, Portland General Electric, PacifiCorp, Idaho Power, and Bonneville Power Administration all participate in the Western Energy Imbalance Market.[15] CAISO has proposed expanding its existing day-ahead market for participation by non-member utilities, calling it the Extended Day-Ahead Market. CAISO has received approval for its Extended Day-Ahead Market[16] from the Federal Energy Regulatory

Commission and expects to onboard its first participants by 2026.[17] Portland General Electric and PacifiCorp have signed implementation agreements to join the Extended Day-Ahead Market, with Idaho Power indicating it is leaning toward EDAM as its preferred day-ahead market option.[18] The Southwest Power Pool also operates a real-time electricity market, the Western Energy Imbalance Service Market, which is open to utilities outside of the SPP RTO, though no Oregon utilities currently participate in this market.[19] SPP has also proposed a new day-ahead market to serve non-members in the western region called Markets+ (pronounced "markets plus"). SPP has submitted the Markets+ tariff to FERC for approval.[iii] Bonneville Power Administration staff have recommended that the agency join Markets+, though a final decision has yet to be made.[20]

"The **Federal Energy Regulatory Commission**, or FERC, is an independent agency that regulates the interstate transmission of natural gas, oil, and electricity. FERC also regulates natural gas and hydropower projects."[21]

Benefits

An organized day-ahead market can reduce the price of electricity by creating a centralized place to efficiently connect buyers with sellers and dispatch the lowest cost resources. A formal electricity day-ahead market improves efficiency through coordination. While any buyers or sellers of electricity could separately identify a bilateral trading partner and negotiate a price for the electricity for a given hour of the next day, this time searching for a trading partner and negotiating a price is costly and inefficient. Moreover, because it is impossible for utilities and generators to contact every possible trading partner for every possible transaction, some buyers or sellers may not find a trading partner even when both entities would have benefited from the transaction. When these trades are not made, more costly resources are used to meet demand while some less costly generation is left unused. An organized day-ahead market eliminates these costly inefficiencies and ensures the use of the lowest cost resources for every time period.

Organized day-ahead markets can reduce greenhouse gas emissions by increasing the likelihood that solar and wind generation are used when available. As outlined above, a formal market ensures that for each time period of the next day, electricity is dispatched from the resources with the lowest marginal costs. Currently, wind and solar are typically the lowest cost resources in the market when available. Wind and solar electricity generation have extremely low or zero marginal costs because the generation of an additional MWh of electricity from these resources is reliant on freely available renewable resources rather than the use of costly stored fuels, like coal or natural gas. Therefore, while the market does not expressly dispatch cleaner electricity generation first, an organized day-ahead market that prioritizes low marginal cost resources can reduce harmful GHG emissions by ensuring that wind and solar resources are the first to be used in the market when available.

As a centralized space for the purchase and sale of electricity, the formal day-ahead market could improve reliability. When weather, unexpected generation outages, or other events disturb the utility's generation plan for electricity supply, utilities must be able to quickly bring online new

[iii] Submitted to FERC 3/29/24, see FERC Docket No. ER24-1658

sources of electricity to reduce the negative consequences for their customers. While regional reliability requirements ensure that utilities always have a certain level of excess generation resources available (the reserve margin), the coordination of buyers and sellers in an organized day-ahead market could make it easier or faster for utilities to quickly identify and bring online a replacement, relatively low-cost generation source. This would also allow them to avoid having to use potentially more costly generation resources.

Challenges

The creation of an electricity day-ahead market with participants that are not part of the operating RTO/ISO is not something that exists yet in the United States. All the organized day-ahead markets in the U.S. today are run by RTO/ISOs, with members of that RTO/ISO as the only participants. These members are subject to the full set of rules and requirements that come with membership in the RTO/ISO. The introduction of a new day-ahead market open to non-member participants requires the development of a new market governance structure to define how those who are not part of the RTO/ISO can fully participate in the new market. With RTO/ISO market operators, current members, and potential new participants all having different perspectives and opinions on how this market could take shape, developing a new governance structure is not a trivial undertaking.

While this challenge should not be understated, work toward the formation of these types of organized markets in the western United States have shown substantial progress in recent years. Most notably, as discussed above, there exist already fully functioning real-time electricity markets with participating utilities that are not members of an RTO/ISO, the Western Energy Imbalance Market and the Western Energy Imbalance Service Market. The Western Energy Imbalance Market is operated by the California ISO and serves all the areas shown in orange in Figure 7 even though these utilities are not part of CAISO. The utilities that participate in the Western Energy Imbalance Market represent 80 percent of the demand in the West.[22] The Western Energy Imbalance Service Market is run by the Southwest Power Pool but serves the areas shown in yellow in Figure 8 that are outside of the RTO area.[19] The formation of the Western Energy Imbalance Market and the Western Energy Imbalance Service Market can provide helpful guidance on how this type of non-member day-ahead market could be governed.[23] Additionally, the two prospective day-ahead markets for the western region, the Extended Day-Ahead Market[24] and Markets+,[25] each have developed proposals for their new governance structures with incorporated input from potential participants. CAISO has a governance structure for the EDAM that relies more heavily on expert staff support[26] and which involves joint decision-making between the Western Energy Markets Governing Body, “whose members are nominated by a committee of Western energy stakeholders” and the ISO Board of Governors, “whose members are appointed by the California Governor and must be confirmed by the California Senate.” However, the ISO Board and Western Energy Markets Governing Body recently voted to make a change to this governance structure in response to a recommendation from the West-Wide Governance Pathways Initiative. This change will give the Western Energy Markets Governing Body primary decision-making authority over the Western Energy Imbalance Market and EDAM.[27] SPP has proposed a governance structure for Markets+ that relies more heavily on working groups and task forces to make recommendations to the independently appointed Market+ Independent Panel, which has final decision-making authority with independent oversight from the SPP board of directors.[25,28] There are still discussions around the governance structures of both proposed markets, however, and aspects of the governance may change. A group of individual public utility commissioners from western states have developed a West-Wide Governance Pathways Initiative to support the development of additional market support in the west and help further overcome this potential challenge.[29]

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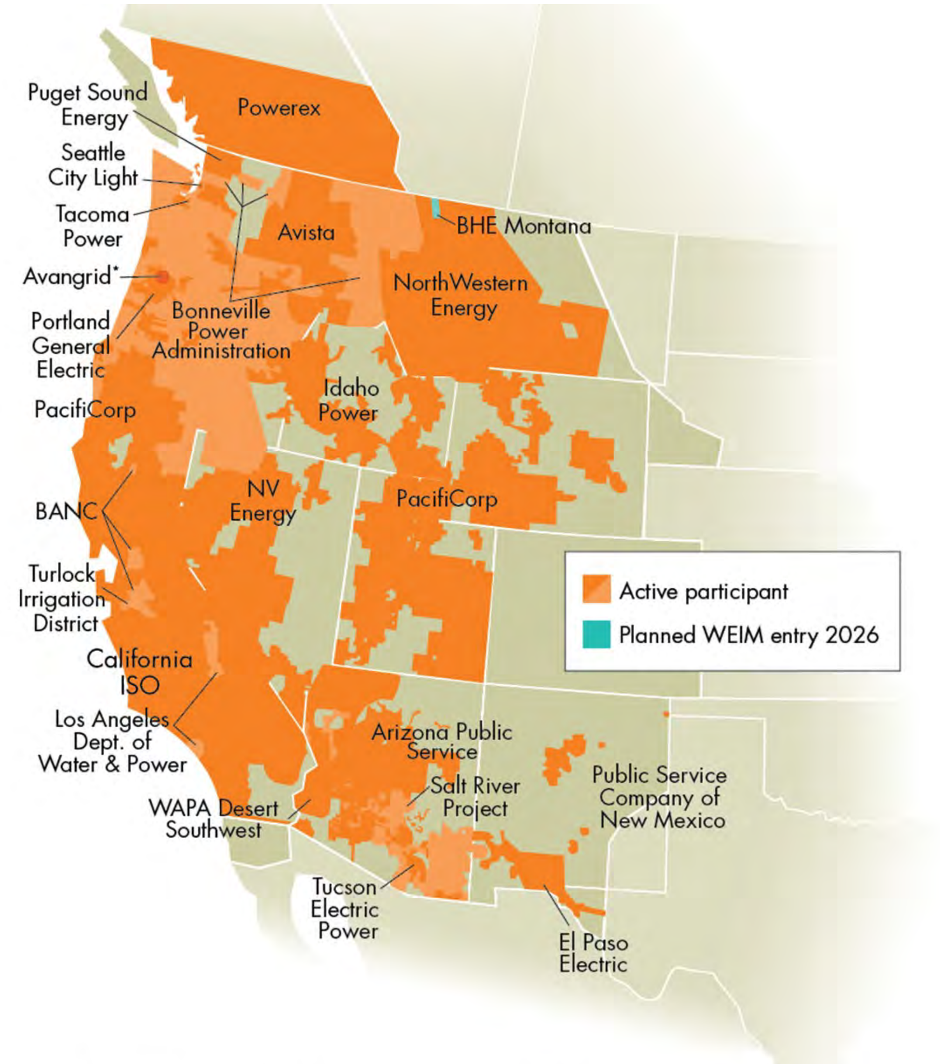
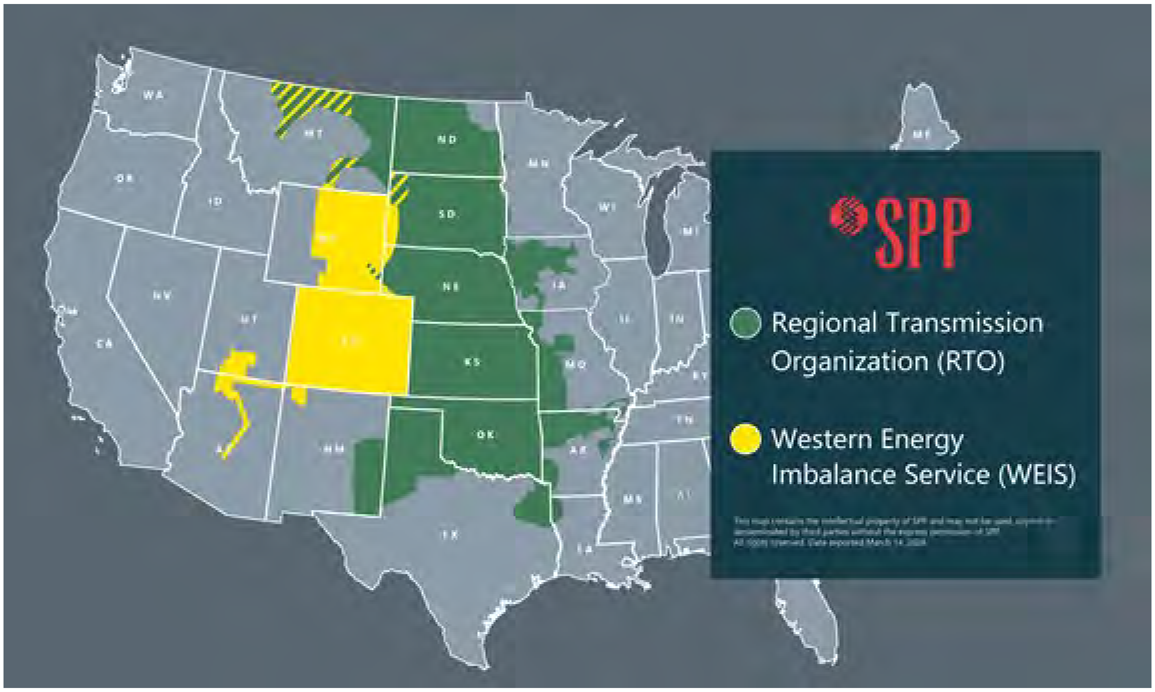
For more information about the Western Energy Imbalance Market see the Oregon Department of Energy's 2020 Biennial Energy Report.

Figure 7: Map of Western Energy Imbalance Market Participants[15]



**Avangrid office; generation-only BAA with distribution across multiple states.*
Map boundaries are approximate and for illustrative purposes only.

Figure 8: Map of Western Energy Imbalance Service Market Participants[19]



As renewables grow to account for a larger share of electricity generation, the structure of the market may need to be reconsidered. In the current wholesale electricity market design (outlined above), generation resources with the lowest marginal cost[iv] are deployed before generation resources with higher marginal costs. Renewables have extremely low or zero marginal cost since they have no fuel costs, which drives down the wholesale price and reduces the likelihood that on any given day or hour, resources with higher marginal costs will make a profit in the market or be used at all. If these resources with higher marginal costs are unable to cover their total costs in the long run with these low short-run prices and less frequent use, they may choose to shut down. In most competitive markets, for firms that cannot cover their costs with market prices, shutting down is economically beneficial as consumer demand can be met by other lower cost producers. However, the need to supply electricity in real-time makes the electricity market different from other competitive markets. These shutdowns may cause problems for reliability if these higher-cost resources are still needed during peak demand hours but are no longer available.[9] As renewables become a larger share of the market, this market design and the zero marginal cost of renewables could discourage further investment in new generation, including renewable generation, possibly leading to long-term supply and reliability problems.[10] Some U.S. RTO/ISOs have developed capacity markets to mitigate this problem. These capacity markets pay generation resources to be available for future peak demand days whether they are ultimately needed or not. However, capacity markets may not be a long-term solution as they can lead to overbuilding[30] or may succumb to the same problems as electricity markets with renewables similarly driving down prices.[10] Instead of using a separate market, like a capacity market, some have proposed redesigning the wholesale electricity markets to address this issue directly.[30,31] To learn more about this complex and evolving topic, see Paul Joskow's article

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[iv] As a reminder, the marginal cost refers to the cost of producing one additional MWh of electricity.

"Challenges for Wholesale Electricity Markets with Intermittent Renewable Generation at Scale: the US Experience."[32]

The effectiveness of the market can be limited by constraints of transmission. The electricity day-ahead market relies on transmission lines to physically carry the electricity generated by the sellers in one area to the electricity buyer and ultimate end-users in another area. Market participants can miss out on transactions that would have been economically advantageous to both entities if there is simply not enough transmission capacity between the potential buyer and seller to facilitate the trade. Sufficient transmission to connect market participants so that all cost-effective market transactions can be made is necessary for the full benefits of the market to be realized. While it is difficult to know how an electricity day-ahead market outside of an RTO/ISO may encourage or discourage the building of new transmission and/or generation resources in Oregon, it will be important to carefully consider where potential new resources are built to balance any possible market benefits with the needs of local communities.

Different state climate and carbon emission policies must be integrated into the market design. The design of the day-ahead market in the simple form described here does not account for state level policies around climate and reducing carbon emissions, such as carbon prices or greenhouse gas emission reduction targets. In the case of Oregon, the design of the day-ahead market would need to allow for utilities to account for the greenhouse gas emissions from their purchased electricity so they can use these data in demonstrating compliance with the Oregon House Bill 2021 clean electricity targets.[33] Ideally, any method for counting greenhouse gas emissions would minimize the risk of double counting and also manage the problem of carbon leakage ("the phenomenon through which efforts to reduce emissions in one place simply shift emissions to another location or sector where they remain uncontrolled or uncounted"[34] resulting in no net reduction of GHG emissions). Determining a methodology that can overcome these challenges, however, is complex and the proposed markets in the west are still in the process of developing these methods with input from the states.

Benefits of wholesale electricity markets increase with a larger regional footprint. The organized day-ahead market is designed to optimize the use of the lowest cost generation resources over the set of resources available within the market. While markets can provide benefits regardless of their size, these benefits are reduced when the market is optimizing over a smaller pool of resources. Separate markets running simultaneously across different parts of a region will not efficiently use the lowest cost resources available over the entire region because these individual markets are only optimizing the use of resources within their own smaller market. Suppose, for example, that there were two markets in the west: one in the Southwest and one in the Northwest. Some days there may be an overabundance of solar electricity in the southwest market while in the northwest there is a lack of renewable supply such that demand must be met with more costly natural gas combustion turbines. On other days, the northwest may have an overabundance of hydro power while the sun is not shining in the southwest and demand must be met there with more costly natural gas-fired resources. If these two markets were merged, and assuming adequate transmission, each area could benefit from the renewables in the other region for times when their own regional renewables are not producing enough electricity to meet demand. Recent research further emphasizes the need for interregional dependence as electricity needs increase with greater extreme weather events, and variable renewables account for a larger portion of generation resources.[35] In the West, the benefit is further enhanced by there being multiple time zones and weather patterns across the region. While bilateral transactions can still be used to exchange electricity across markets, the markets themselves will be less efficient with higher costs than a single market with the largest possible footprint.

As electricity markets develop in the region, it will be important to continue to monitor and evaluate these benefits and challenges.

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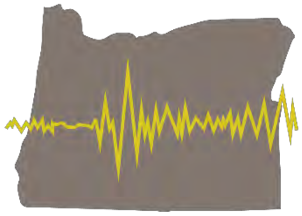
Energy Resilience

Resilience is a term that is often heard across issues of public concern, but what does it mean in the context of energy? Energy resilience refers to the ability of energy systems, from production through delivery to end-users, to withstand and rapidly restore energy delivery following non-routine disruptions of severe impact or duration.[1,2] These disruptions can be caused by natural hazards and physical or cyber-attacks on energy systems.



Energy Resilience vs. Energy Security

Energy resilience is a subset of energy security. Energy security encompasses efforts to ensure energy supply, affordability, accessibility, reliability, and resilience.[3]

Reliability vs. Resilience:

Reliability is the ability of energy systems to withstand and recover from *typical disruptions*.[2,4] Typical disruptions could include average winter weather or branches falling on a powerline.

Resilience is the ability to withstand and recover from *nonroutine disruptions of severe impact or duration*. Examples of nonroutine disruptions of severe impact or duration include an ice storm lasting several days or a windstorm producing countywide impacts. Actions that strengthen resilience can also increase reliability.

Energy resilience is pursued from the national to the community level with differing emphases. The federal government's energy resilience efforts put significant focus on increasing collaboration—internationally, across Tribes, states, and territories, and the public and private sectors. Utilities tend to focus on increasing the resilience of larger energy systems and infrastructure. Community-level resilience efforts, in contrast, typically focus on the end-users: ensuring public safety and welfare during nonroutine energy disruptions. This includes ensuring adequately fueled backup power generation and storage to provide energy to critical public service facilities such as hospitals, emergency response centers, and community resilience centers, as well as strengthening household resilience. At the state level, the State of Oregon pursues actions to increase resilience across both larger energy systems and within communities, and facilitates collaboration between all interested parties.

SCAN OR CLICK

Learn more about backup power in ODOE's 2022 Biennial Energy Report.

Community Resilience Centers

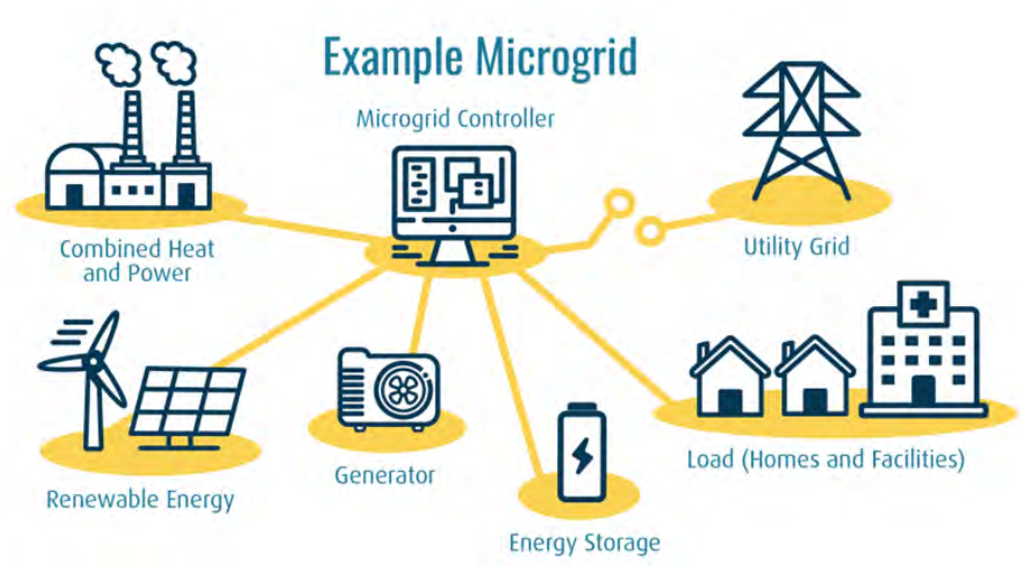
Community resilience centers are gathering places that provide essential services and resources for community members during disruptive events. Specific to energy resilience, these centers provide residents access to essential energy services such as heating and cooling, air filtration, and charging of essential devices like medical equipment or cell phones.

While there are variations in emphases among these different entities, there are two overarching commonalities across their energy resilience efforts:

- Increasing the ability to adapt to changing conditions and prepare for disruptions to reduce impact and speed recovery.
- Elevating equity: ensuring that the needs of those who are most vulnerable to energy disruptions are addressed.

Actions to strengthen energy resilience can occur across larger energy systems or at the community level. Examples of energy resilience actions for larger energy systems, i.e. electricity, liquid fuels, and natural gas, include: upgrading older infrastructure with more durable and resilient equipment; undergrounding power lines to increase their ability to withstand a variety of extreme weather events; using drones to evaluate energy infrastructure to prevent issues via early detection and enable speedier recovery after events; and system segmentation to isolate impacted areas and allow unaffected areas to continue providing energy services (see the Transmission Options 101 in this report). Actions at the community level can look like increasing gasoline, diesel, and aviation fuel storage, installing seismically certified generators, and developing energy generation and storage infrastructure such as microgrids (Figure 1), to support critical public services and/or household resilience. Additionally, actions to increase energy efficiency can support resilience by reducing the energy demand that must be met during energy disruptions.

Figure 1: Example of a Microgrid and Its Components[5]



Why Does Energy Resilience Matter?

Fundamentally, energy resilience matters because access to energy matters. Energy systems are the backbone for essential services such as life safety; heating, cooling, and air filtration; communications and information systems; transportation; production of food and goods; and medical care. These services are important under normal conditions and critical during emergencies.

September 2020 wildfire damage in Detroit, OR.

The need to bolster energy resilience has become more evident in recent years due to an increase in the frequency and severity of threats and disruptions to energy systems. The occurrence and intensity of extreme weather events, such as winter storms or wildfires, has increased in frequency, scale, and duration, with a corresponding effect on energy disruptions (see this report's Climate Change Effects on Energy Systems 101 for more information).[6 7] Likewise, there has been a rise in public safety power shutoffs, during which utilities preventatively shut off electricity due to increased incidents of high wildfire risk. The incidence of cybersecurity attacks has also increased in recent years, as has the vulnerability of energy systems due to increased use of digital technologies.[8] Finally, a Cascadia Subduction Zone Earthquake poses a threat to Oregon's energy systems of nearly unparalleled severity.[9] Though this threat has long existed, in recent decades there have been increased efforts to raise public awareness and create resilient systems to prepare for the catastrophic earthquake.[10]

Building energy resilience across larger energy systems and in communities is also critical to help ensure equitable protection from energy disruptions. Some groups are more vulnerable to energy disruptions than others, and those disruptions can also compound other vulnerabilities and inequities that groups experience. For instance, energy disruptions during an extreme heat or cold event or a wildfire with unhealthy air quality can pose a greater risk for individuals with certain medical conditions. Similarly, individuals living in areas with significant urban heat island effects,[i] who are more likely to be low-income or People of Color, face elevated risk during extreme heat events;[12 13] this risk is further amplified during an energy disruption.

During the 2021 heat dome event in Portland, 61 percent of the individuals who lost their lives in Multnomah County were living in an urban heat island area, and the majority did not have working air conditioning.[13] Individuals with lower incomes may have less financial ability to strengthen household resilience via backup power or efficiency measures — and their homes may also have less efficient weatherization and appliances to begin with.[14] Therefore, efforts to: 1) increase larger energy systems' ability to withstand nonroutine disruptions and recover quickly, 2) ensure that critical public services function during disruptions to larger systems, 3) provide access to community resilience locations, and 4) increase household resilience, are vital to helping protect vulnerable populations and reduce inequitable impacts from disruptions. Ensuring equity in energy resilience efforts goes hand in hand with the opportunities the broader clean energy transition offers to rectify past inequities and create a more equitable path moving forward.

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[i] Heat islands occur in urban areas where there is a high density of roads and buildings and limited green space, resulting in increased absorption and remittance of heat. Temperatures in urban heat islands are 1–7°F higher than surrounding areas during the day and 2-5°F higher at night.[11]

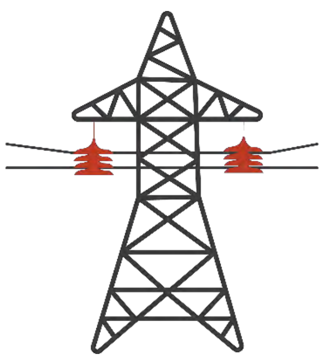
Energy Resilience Efforts

Many organizations, from the federal government to community groups, are working to strengthen energy resilience. While not a comprehensive of all initiatives and efforts, the information below helps illustrate some of the work Tribal Nations, the federal government, the State of Oregon, utilities, and communities are doing to bolster energy resilience. Building partnerships and advancing equity are at the heart of much of this work.

Tribes

Oregon's nine federally recognized Tribes are engaged in planning and project development to bolster energy resilience. For instance, in 2022, the Confederated Tribes of the Umatilla Indian Reservation completed a Strategic Energy Plan.[15] Increasing household resilience through renewable energy generation and energy efficiency is a central component of the plan. The Coquille Indian Tribe is in the process of developing a Resilience Management Plan, which will include an Energy Assessment and strategies that explore potential renewable energy options as a pathway to supporting the Tribe in becoming energy sovereign.[16]

In terms of project development, the Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians are developing a solar and battery storage system to provide backup power to Tribal buildings during outages, with support from the Oregon Department of Energy's Community Renewable Energy Grant Program.[17] In 2023, the Confederated Tribes of Warm Springs, in partnership with Portland General Electric, received a $250 million grant from the U.S. Department of Energy's Grid Resilience and Innovation Partnerships Program to expand and increase the resilience of the Bethel Round Butte Transmission Line, which is a critical piece of Oregon's electricity infrastructure.[18] The Confederated Tribes of Warm Springs, the Cow Creek Band of Umpqua Tribe of Indians, Coquille Indian Tribe, Burns Paiute Tribe, and Confederated Tribes of the Umatilla Indian Reservation have received U.S. DOE Grid Resilience State and Tribal Formula grants.[19] The Tribes will award funds from these grants to eligible entities for grid resilience improvements.



Federal Government

Federal efforts include programs to support energy resilience planning and project implementation, such as funding for state energy security plan development and the Grid Resilience State and Tribal Formula Grant, Grid Resilience and Innovation Partnerships, Home Efficiency Rebate, Home Electrification and Appliance Rebate, and Energy Efficiency and Conservation Block Grant programs. These federal grant programs fall under the Justice 40 Initiative, which specifies that 40 percent of federal grant investments flow to federally recognized Tribes, including Alaska Native Villages, and to disadvantaged communities that are identified using the Climate & Economic Justice Screening tool. The federal government also invests in research, training, and tool development to support energy resilience efforts nationally as well as for Tribes, states, and territories— such as the Department of Energy's recent investment of $45 million to develop new tools to address cybersecurity threats.[20] The federal government fosters opportunities for collaboration across Tribes, states, territories, and the public and private sectors through the Electricity Subsector Coordinating Council and the Oil and

Natural Gas Subsector Coordinating Council, in addition to supporting the work of groups such as the National Association of State Energy Officials and the National Association of Regulatory Utility Commissioners.

State of Oregon

Learn more about the Oregon Energy Security Plan on ODOE's website.

The State of Oregon is engaged in a variety of efforts to increase energy resilience. ODOE has developed the Oregon Energy Security Plan, which includes a risk assessment of the state's liquid fuels, natural gas, and electricity systems, and mitigation measures to address risks and increase resilience. ODOE is also developing the Oregon Energy Strategy, which will present pathways to achieve the state's energy goals, including bolstering resilience. The Oregon Department of Environmental Quality is administering the Fuel Tanks Seismic Stability Program, which evaluates the earthquake vulnerability of large-capacity oil and fuel storage and distribution facilities in Lane, Multnomah, and Columbia counties and requires the facilities to develop plans to minimize risk of damage to employees, surrounding communities, and the environment. The Oregon Public Utility Commission oversees all utilities in Oregon in matters of safety and in recent years has increased focus on energy resilience such as convening utilities and interested parties to learn from disruptive events, with a particular focus on wildfire mitigation. As the economic regulator of the state's investor-owned electric and natural gas utilities, OPUC ensures that the investor-owned utilities have enough resources to implement resilience measures such as vegetation management and hardening of infrastructure.

The State of Oregon also has a variety of grant programs that support energy resilience. The Oregon Department of Energy is currently administering several of the aforementioned federal grant programs: Grid Resilience, Solar for All, Home Energy Rebates, and Energy Efficiency and Conservation Block Grants. ODOE also runs several state-created grant programs that support energy resilience projects and planning: the Community Renewable Energy Grant Program, Oregon Solar + Storage Rebate Program, and the County Energy Resilience Program. The Oregon Department of Human Services is administering a Resilience Hubs and Networks grant program that supports the development of community resilience centers. The Oregon Department of Emergency Management administers several state and federally funded grant programs that have co-benefits for energy resilience, such as the Emergency Management Performance Grant Program, State Preparedness and Incident Response Equipment Grant Program, Hazard Mitigation Grant Program, Building Resilient Infrastructure and Communities, and State and Local Cybersecurity Grant Programs.

For a more in-depth discussion of Oregon's resilience actions taken in recent years and planned for the future, see sections 10 and 11 of the Oregon Energy Security Plan.

Utilities

Utility actions to strengthen resilience include vegetation management, reconductoring, asset replacement, undergrounding equipment, installing smart grid technologies, and developing or supporting energy resilience projects like microgrids. For instance, in 2020 Portland General Electric partnered with the City of Beaverton to help design a robust backup power system for its Public Safety Center that houses its emergency management and police departments.[21] The backup power system includes a generator, solar energy production, and a battery storage system and can support the building throughout prolonged power outages. Utilities also help educate their customers about household resilience and some provide funding opportunities to help support these actions. For example, the Eugene Water & Electric Board offers its residential and commercial customers the Backup Power Program, which offers zero to low-interest loans for backup power systems like generators or battery storage.[22] Pacific Power offers a rebate program that supports the purchase of backup power systems for customers in their Medical Certificate Program, who face vulnerabilities to loss of power due to their medical conditions.[23]

Cities, Counties, and Other Organizations

Cities, counties, and community organizations are also engaged in planning, project implementation, and education for energy resilience. For example, Hood River and Wallowa counties have developed countywide energy plans with energy resilience components.[24 25] These counties are also pursuing efforts to build priority resilience projects, such as local microgrids and solar generation and storage, and both counties have utilized ODOE's Community Renewable Energy Grant Program to complete detailed project implementation planning.[17] With the launch of ODOE's County Energy Resilience Program in spring 2024, there will soon be more county energy resilience plans in place across the state. Partnerships among local government entities, local community organizations, and other organizations such as economic development districts and statewide energy-focused nonprofits — for example, Sustainable Northwest and Energy Trust of Oregon, among others — are critical to helping communities achieve their energy resilience goals.

Williams & Russell Project

The Williams & Russell Project, under development in Northeast Portland's Albina neighborhood, centers equity and energy resilience. The development site was formerly the commercial center of the Black community in Albina from the 1940s-1960s, but was condemned in the 1970s and purchased by Legacy Hospital as part of Portland's urban renewal program.[26] The project seeks to restore and reclaim the lot as a vibrant part of the neighborhood; the development will provide 85 affordable apartment units, 20 homes for purchase, and a 30,000 square foot Black business hub, with commercial and office space for Black-owned businesses and community organizations. The building will feature energy efficient construction, solar panels, and energy storage — ensuring resilience during energy disruptions — in addition to other sustainable features.[27] Partners involved in the project include: the Williams and Russell CDC, Prosper Portland, Portland Community Reinvestment Initiatives, Adre, Legacy Health Services, Portland Housing Bureau, the City of Portland, and Energy Trust of Oregon, among others.[27 28]

Together these efforts are paving the way to increase the resilience of Oregon's energy infrastructure and communities. Moving forward, these entities will continue to put plans, programs, and projects in place to bolster energy resilience while continuing to adapt to the changing landscape of energy in Oregon.

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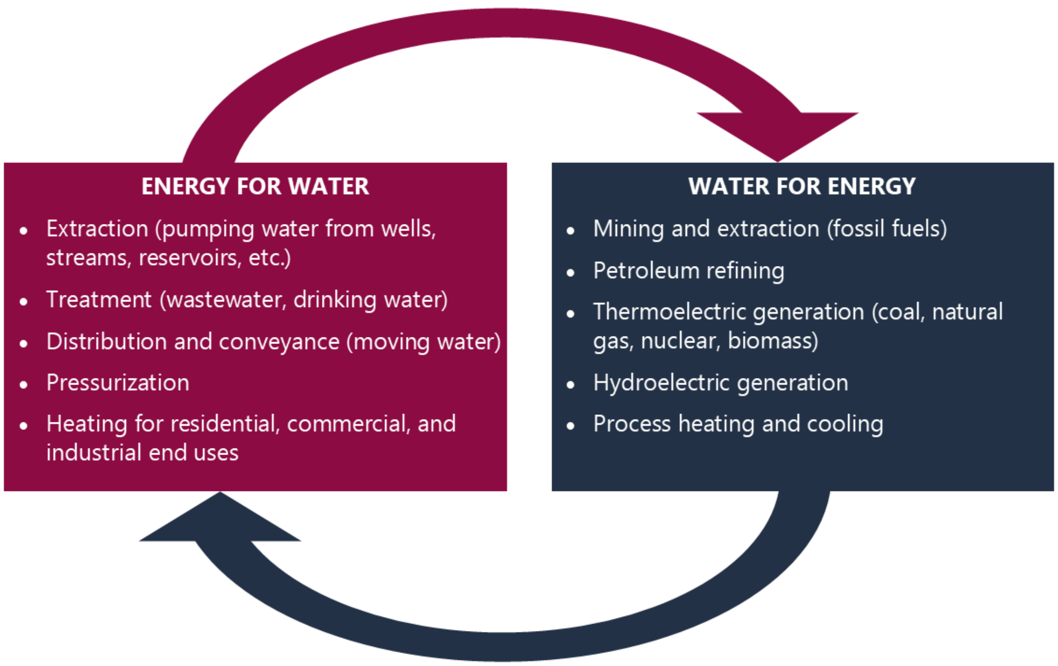
Water and Energy Nexus

Water and energy systems today are interdependent. Water is used at multiple stages of energy production, and energy is needed to extract, clean, heat or cool, and move water to where it's used. While they are interdependent, energy and water systems have been developed, managed, and regulated independently.[1] Population shifts, droughts, and climate concerns are driving more interest in the relationship between energy and water. Although this Energy 101 does not provide an exhaustive list, it will explore some major interdependencies and provide a foundation for further exploration.

Figure 1: Water and Energy Interdependencies



Water Used in Energy Production

Water is used in many aspects of energy production, often for cooling, mining and extraction, creating steam for process heat or on-site electricity generation, and for hydroelectric power. How the water is used has broad implications for water quality, availability of water, and effects on the environmental, cultural resources, and local, state, national, and global economies.

In petroleum production, water is needed for cooling and lubricating during drilling. Energy is required to pump water from a local source or to truck water to a site. Wastewater is also typically *produced* during crude oil extraction and may be treated for disposal or possible reuse, often on site. Often, wastewater generated from crude oil extraction and production must be transported by truck to disposal sites where it is treated and then injected deep underground.[3]

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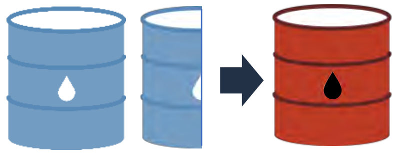
Learn more about Oregon's oil sources in ODOE's 2020 Biennial Energy Report.

Coal mining needs water to extract, wash, and process the coal ore. Water is also used in underground mines for cooling and reducing fire and explosion risk.

Conventional natural gas production uses relatively small amounts of water, but typically produces wastewater. Natural gas is extracted from deep reservoirs through wells drilled below groundwater levels. Wastewater is usually reinjected back into the well, typically below groundwater, to be stored.[4] [5] [6] More recently, natural gas is often extracted using hydraulic fracturing, or fracking, which unlocks oil or gas reserves by injecting water, sand, and/or chemicals at high pressure into a well to expand existing fissures in bedrock. This process has been shown to pose risks to water resources, both in terms of water quality and quantity.[2] The amount of water required for natural gas production varies widely depending on the size and nature of the well and whether the water produced is recycled.[6]

Water is also used in petroleum refining for cooling, steam generation, and fire protection. Refineries use up to 1.5 barrels[i] of water to process one barrel of crude oil.[7] Refineries use two types of cooling systems: once-through systems where water is extracted, used for cooling, and then returned to the environment, or recirculating closed loop systems, where water is reused within the system.[7] Once-through systems require significantly more water.



Thermoelectric power plants, including coal, natural gas, nuclear, and biomass, generate electricity by producing heat that is used to create steam, which in turn drives a turbine connected to a generator. Not only is water required to create the steam, but it is also used to recondense the steam back into water after leaving the turbine.

Natural gas plants, which are the most common type of thermoelectric generation in Oregon, typically use closed-cycle water cooling systems.[8] Natural gas plants use wet-recirculating systems that cool down the water that is used to create steam. This closed system only provides cooling to the steam pipes to help recondense that water.[9] Small amounts of water in these cooling systems are lost to evaporation during the cooling action and when the water is replaced (after multiple cooling cycles). Some newer plants — usually those built after 2000 — use dry cooling systems, which require little to no water. Dry cooling systems have high capital costs and use relatively more energy, resulting in lower overall plant efficiency.[10]

Coal and nuclear generators typically use a once-through cooling process, which uses much more water for cooling because that water is used only once before being discharged. The cooling water is first sent to a pond equipped with cleaning and/or filtering devices to be cooled down before final discharge back into the local water source. Local water sources include rivers, lakes, or the ocean. Some water is used to create steam, but most is used for cooling and recondensing the steam once it has passed through the turbine. Both the water for steam and for cooling are circulated through separate pipes at the facility, and are ultimately discharged back into the environment.[9] Water used for steam must also be periodically purged and replenished.[9] While there are no coal or nuclear generation facilities in Oregon, some of the electricity sold to Oregon consumers is imported from these types of resources in other western states.[11]

[i] A "barrel" of liquid is equivalent to 42 gallons.

The amount of water withdrawn varies by electric generation type. Calculating the number of gallons of water per megawatt hour of generation, or water-withdrawal intensity, allows comparisons across generation types and timespans.[12] According to the U.S. Energy Information Administration, in 2021, the water-withdrawal intensity for the average coal plant was 19,185 gallons per MWh, while a natural gas plant[ii] averaged 2,803 gallons per MWh, or 85 percent less water use than coal power.[8]

19,185
Gallons of water per megawatt hour of generation.

2,803
Gallons of water per megawatt hour of generation.

Water-withdrawal intensity in U.S. power generation has declined as a result of decreasing coal-fired generation and increasing natural gas, wind, and solar generation.[12] The amount of water used per unit of electric generation in the U.S. has declined from 15,100 gallons per MWh in 2014[14] to 11,595 gallons per MWh in 2021, a 23 percent drop.[12] Wind and solar don't require water for cooling, but do use water for construction, as well as for cleaning wind turbine blades and solar panels. Oregon's electricity resource mix is seeing an increase in renewable energy sources like wind and solar and fewer thermoelectric generators.

In the Pacific Northwest, the most prominent intersection of energy and water is the region's hydropower system. About 40 percent of electricity used in Oregon comes from hydroelectric dams in the Columbia River basin.[11] Hydroelectric power generation is not considered a consumptive use of water because water flowing through the turbines to generate electricity is still available for other uses. However, some water impounded behind a dam is lost to evaporation and seepage.[15] Total hydroelectric generation varies directly with precipitation – it is higher in wet and snowy years and lower in dry years. Mountain snowpack, especially in the upper Columbia Basin, acts as a seasonal battery with spring thawing adding to river runoff flows that support increased hydroelectric generation in late spring and early summer.[16] For more on the seasonal variability and shifting availability of hydropower related to climate, see the Climate Change Effects on Energy Systems 101 in this report.

Learn more about hydropower in ODOE's 2020 Biennial Energy Report.

SCAN OR CLICK

Dams in the Pacific Northwest continue to play a vital role in energy and water needs for Oregon and the region. Hydropower not only provides power to the grid but can also help support increasing amounts of variable renewable resources because it can be throttled up or down to balance electricity supply as wind and solar naturally wax and wane. Many of the dams also support agriculture, flood control, shipping, and recreation.

[ii] Value is for a combined cycle natural gas plant, which use more water than simple cycle natural gas plants, but are significantly more energy efficient.[13]

Energy and Water Resource Decisions in the Pacific Northwest

The Columbia River and its many tributaries are central to the Native cultures of the Pacific Northwest, who have been living in this area for time immemorial. In the 1930s – 1950s, the United States government developed multiple dams in the region. Fishing and gathering sites like Celilo Falls near The Dalles in Oregon and Kettle Falls in Washington were flooded by dam construction. The building of the dams not only destroyed these and other Tribal fishing resources but have also contributed to declining fish runs in the region. At the same time, Pacific Northwest hydroelectric dams also ushered in the development of high-tech industries, provided low-cost electricity to rural areas, and supplied water to irrigate large swaths of land to support agriculture. Today, energy conversations about the role of dams in the future have implications for people and communities that rely on the river for cultural practices, food, shipping, jobs, flood control, and clean power generation. Decision-makers will need to grapple with the benefits and impacts as Tribal and state governments work to meet future energy and water needs. For more information about the history of energy and its effects on water, see ODOE's Energy History Timeline.

The cost and negative effects on local environmental and cultural resources make it unlikely that new major hydroelectric dams will be built. The Northwest Power and Conservation Council's Columbia River Basin Fish and Wildlife Program identified "protected areas" where new hydropower development would have unacceptable risks of loss to fish and wildlife.[17] Federal relicensing of existing power plants may also require adding or improving fish passage and other measures that can add considerable capital costs. Adding hydroelectric generation to non-generating dams typically requires adding fish passage and fish screens to water intakes, also adding to the cost.[18]

Although new hydropower dam construction is unlikely, smaller turbines can be installed inside new or existing water pipes to produce electricity. Although much smaller than large dam hydropower, these can help serve very localized energy needs, including energy for irrigation or to support operations at municipal water facilities.

Federal Energy Regulatory Commission licensing says that "a small conduit hydroelectric facility up to 40 MW using a man-made conduit operated primarily for non-hydroelectric purposes may be eligible for a conduit exemption."[19] Federal regulation defines conduit as "any tunnel, canal, pipeline, aqueduct, flume, ditch, or similar manmade water conveyance that is operated for the distribution of water for agricultural, municipal, or industrial consumption and not primarily for the generation of electricity."[20] Irrigation districts in Oregon and throughout the West use that exemption to license small (typically less than 5 MW) hydroelectric plants in conjunction with piping irrigation distribution canals, which saves water lost to evaporation and seepage. Piping distribution canals may also provide pressurized water delivery for some laterals (laterals come off an irrigation distribution canal or pipeline laterally to deliver water to farms or ranches), which can save farmers and ranchers energy and money. New projects may also require mitigation or adding fish screens at the point of diversion.[21] [22]

Water Considerations in Constructing Energy Projects

When siting an energy production facility or energy-intensive project, access to both adequate energy and water must be considered by the developer. For example, some water is required during construction of wind and solar facilities. Some areas of the state are "ground water limited areas" or "critical ground water areas." In these instances, water is typically obtained from the closest city that has excess capacity and must be trucked in daily.

For energy projects requiring water for operations, access to water for routine operations also must be considered. For example, hydrogen electrolyzers, which split water atoms into hydrogen and oxygen, require water as a feedstock. It takes about four gallons of water to produce one kilogram of hydrogen.[23] Natural gas electricity generators need water to produce the steam that spins the turbines. Solar farms, which do not require water to generate electricity, occasionally need water to clean the panels of dirt and debris.

Energy to Produce, Convey, and Treat Water

Energy is necessary to deliver water for human consumption, irrigation, and industrial applications. Energy is often needed to power pumps to extract water from sources, convey water, and to deliver it at high pressure. Energy is also used to heat water for use in residential, commercial, and industrial facilities, and required to clean wastewater before it is discharged or for reuse.[1]

Electricity is the most common form of energy used for water-related purposes. A 2017 Congressional Research Service report estimated that 4 percent of the nation's electricity generation supports water-related activities. Regional differences can be significant; as much as 19 percent of California's electricity consumption is used to clean, produce, and convey water.[24]

Energy is used to pump water out of wells or to the tops of buildings, as well as to distribute and deliver it to residences and businesses. The higher the water must be pumped; the more energy is needed. Energy is also used in residential and commercial buildings to move water to where it is used, to provide hot water, and to heat and cool buildings. Energy is also needed for water pressurization, such as for various cleaning operations like pressure washing and for irrigation, and for industrial production processes and cleaning tasks.

Heating water consumes a lot of energy. For example, water heaters account for about 20 percent of a home's total energy use and about 5 percent for commercial buildings.[25] [26]

Energy is used to treat water and remove contaminants for clean drinking water, in wastewater treatment plants, and in businesses.[27] Water treatment is typically energy intensive. Drinking water and wastewater systems combined use approximately 2 percent of total annual energy used in the U.S.[28] According to the U.S. Department of Energy, $2 billion is spent annually on water treatment, and electricity can be 25-40 percent of a wastewater treatment plant's bill, and 15-30 percent of a municipality's energy bill.[29]

Data Centers at the Intersection of Energy and Water

Data centers are large facilities with computer servers that support the applications and data that are the backbone of the internet. They host social media, cloud data storage, applications, games, and more recently, artificial intelligence platforms. The demand for data centers has grown along with the internet, and AI is pushing that growth even faster. Data centers require large amounts of electric power for the servers and water to cool the large amounts of heat they produce.

Data centers are often sited where power is cheap and abundant, and to achieve corporate climate goals, owners often look for electricity with lower greenhouse gas emissions.[30] Many of Oregon's rural utilities meet these objectives. Data centers are increasingly being built in rural areas, especially in eastern Oregon, where land also tends to be less expensive than in larger metropolitan areas. This places a higher pressure on water in a part of the state that often has limited water resources, and where drought conditions regularly occur.

Data centers' water requirements may compete with other demands and create constraints, or add to existing constraints, on local electricity and water needs. A 2024 study from Virginia Tech found that data centers rank in the top 10 water-consuming industrial or commercial industries in the U.S. The same study found that 20 percent of data centers "draw water from moderately to highly stressed watersheds in the western U.S."[31] In 2021, Google's data center in The Dalles consumed 29 percent of the town's water supply.[32] Environmental advocates are concerned that this high degree of water consumption might reduce water supply for nearby wetlands and rivers.[30] Water resources can affect plant life, fish life, wildlife, and local communities.[32]

Water, Energy, and Climate

Reducing water consumption reduces greenhouse gas emissions that would otherwise have been emitted by the energy used to provide the water. More water efficient technologies and practices will also help water and energy resource providers adapt to a drier climate.[33]

The Sixth Oregon Climate Assessment found that droughts are expected to become more frequent and severe in the state.[34] Drought conditions limit local water availability, which means communities will more frequently need to make choices on how to best use the limited resources. This could limit the types of economic growth and development in Oregon, including the development of more water-intensive energy resources.

Just as energy efficiency and conservation efforts reduce overall need for energy, water conservation efforts can do the same for water resources, and because energy and water consumption often go hand-in-hand, conserving one can often help conserve the other. For instance, high efficiency appliances, such as dishwashers, washing machines, and water heaters use less water to perform the same task, which usually makes them more energy efficient. Using graywater – water collected from bathtubs, sinks, and washing machines – for irrigation, not only conserves water, but also saves on the energy that would otherwise have been needed to collect and treat that water.

See the Oregon Water Resources Department's Integrated Water Resources Strategy for more information on opportunities to promote water and energy savings.

Agriculture irrigation is the largest use of water in Oregon, and most irrigation is powered by electricity. Persistent drought has exacerbated overextraction of water in some basins creating the need to access deeper groundwater reserves. In turn, this requires more energy to pump the water from deeper depths as the water table drops. Piping open irrigation delivery canals saves water otherwise lost to seepage and evaporation, which benefits fish and wildlife habitat. It also allows pressurized water delivery for some producers which reduces the energy required for irrigation related pumping. If in-conduit hydroelectric generation is installed along with the pipes, the power produced can offset additional pumping-related energy and contribute to local energy resiliency.[35]

Water conservation efforts can help reduce greenhouse gas emissions and help farmers adapt to a changing climate. This is especially beneficial in parts of eastern Oregon, where droughts and drier conditions restrict the amount of water available.[16,36] Regenerative agriculture stores carbon in the soil and can reduce irrigation water use and typically reduces direct and indirect energy from lower fertilizer and pesticide use.[37,38]

Learn more about conduit hydropower in ODOE's 2020 Biennial Energy Report.

Some Oregon communities are planning for water and energy resilience together, as an adaptation to the changing climate and concerns about energy reliability and water availability. Table 1 provides a list of common energy conservation techniques and efficiency actions that Oregonians, their communities, and businesses can use to reduce water and energy consumption.

Table 1: Water and Energy Conservation and Efficiency Actions

	Conservation Actions	Efficiency
Indoors	• Turn faucets off when brushing teeth or shaving • Wash fruits and vegetables in tub of water • Take shorter showers • Check for leaks and monitor water bill	• Use EPA WaterSense fixtures, especially shower, low flow or dual-flush toilets, dishwashers, and washing machines
Outdoors	• Reduce or eliminate grass and plant drought-tolerant landscaping (no long-term watering required) • Sweep or use a bucket instead of hosing off sidewalks and driveways	• Install rain-sensors and soil moisture sensors • Use drip irrigation vs spray for lawn and landscaping watering

Conclusion

Today's modern life requires energy and water, and the availability and costs of both are highly intertwined. The Oregon Water Resources Department plans to publish an updated Integrated Water Resources Strategy in 2025, which discusses some of these interdependencies and includes a more complete discussion of water infrastructure and planning needs — many of which also require energy resources.

ODOE is currently developing an Oregon Energy Strategy, which will assess different pathways the state can take toward a more resilient and sustainable clean energy transition, including how these options affect land and water use. Both reports will facilitate thoughtful consideration of the interdependencies between water and energy choices, and how policy options concerning one will have implications for the other. Understanding the trade-offs of these policy choices is key to making informed energy and water management choices.

ODOE's Community Renewable Energy Grant Program has awarded several communities with water- and energy-related grants, including nine in both 2023 and 2024.[39]

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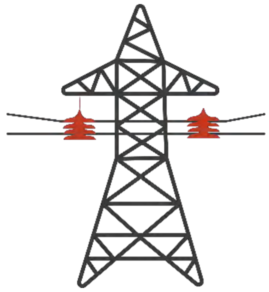
Alternatives to New Transmission



Studies have shown that expanding transmission infrastructure is critical to achieving Oregon's clean energy future,[1] but it can be difficult, time-consuming, and expensive to build. Identifying ways to reduce the need for transmission expansion can provide many benefits. Avoiding or delaying transmission development can reduce costs for electricity providers and customers. Alternative investments in local energy resources can support well-paying jobs and improved energy resilience in local communities. Less transmission development can also mean fewer negative effects on environmental, cultural, and community resources. In addition, it can reduce the risk of wildfires ignited by grid equipment and lower ratepayer costs for wildfire monitoring and mitigation efforts.

National, regional, and utility-specific studies consistently indicate that substantially more transmission capacity is needed than what exists today for the grid to reliably meet increasing electricity loads and make progress on clean energy and climate commitments, while also contending with growing extreme weather events driven by climate change.

Expanding transmission capacity has become one of the key issues for the clean energy transition, and it will require electricity planners and providers to bring to bear numerous innovative strategies. The Connected West study released in September 2024 looked at transmission needs for the western U.S. over the next 20 years and found that a significant portion of the needed transmission capacity could be met by enhancing existing transmission lines.[2] This Energy 101 identifies strategies that can help offset some, but not all, of the need for new transmission lines, including: leveraging diverse loads and resources, repurposing and expanding the capacity of existing transmission corridors, deploying local energy resources, and deploying grid enhancing technologies.[3]

Transmission towers at the Bonneville Dam.

The traditional way grid planners have met load growth is to build new transmission lines.[4] Most of the transmission system in the Pacific Northwest was built to move abundant hydropower around the region, including delivering electricity to rural areas. Most of the regional transmission system was built concurrent with the construction of the federal hydropower system from the 1930s through the 1970s.[5] This initial investment in power lines has served as the backbone of the region's transmission system, with the federal Bonneville Power Administration owning and operating 75 percent of the region's high-voltage lines.[6]

Large investments in energy efficiency in the Pacific Northwest have reduced load growth, significantly offsetting the need for new electricity generation and new transmission lines over the last three decades. These immensely successful energy efficiency programs kept electricity consumption in the region relatively flat from the 1990s until 2020, despite growth in Oregon's population and economy.[7]

Electricity demand forecasts in recent years are changing, with large amounts of load growth expected due to economic growth in high-tech manufacturing, emerging development of data centers, increased use of electric heating and cooling as more extreme weather patterns emerge, and efforts to encourage more electricity-based technologies that can help reduce greenhouse gas emissions.[8] Power planning studies consistently estimate the buildout of new renewable and transmission capacity needed across the western power grid is in the order of hundreds of gigawatts by 2040.[i] [9] For context, the current size of the entire Pacific Northwest electricity system is roughly 73 GW.[10]

Primary Challenges Facing Transmission Expansion

Planning, permitting, and constructing new transmission lines can be expensive, time-consuming, and have effects on ratepayers, the environment, natural resources, cultural resources, and local communities. For these reasons, the transmission build-out needed to meet increasing demand may be difficult to achieve.

There are three primary challenges facing the expansion of the transmission system in the Pacific Northwest:

1. **High capital costs**: Transmission infrastructure is very capital intensive and can cost between $2 to nearly $7 million per mile to construct, depending on the voltage. A 100-mile line would cost several hundreds of millions of dollars to construct.[11]
2. **Long-lead times**: Planning, permitting, and construction of a significant transmission project is complex and it can take 10 years or longer for a project to become operational.[12] [13]
3. **Potential effects**: Constructing transmission projects affects the environment, natural resources, cultural resources, and local communities. Avoiding, minimizing, and mitigating potential impacts is necessary and adds to project risk, complexity, costs, and time.

Options to Alleviate the Need for Transmission Expansion

There are technologies and strategies that can reduce the need to build new transmission lines. Four options are discussed here:

1. Leveraging existing generation resources more effectively.
2. Repurposing and expanding the capacity of existing transmission corridors.
3. Leveraging the use of local energy resources.
4. Using grid enhancing technologies.

This section will cover these options at a high level and describe some of the benefits and challenges for each.

[i] 1 gigawatt (GW) = 1,000 (MW). The large Bonneville Dam east of Portland is roughly 1 GW.

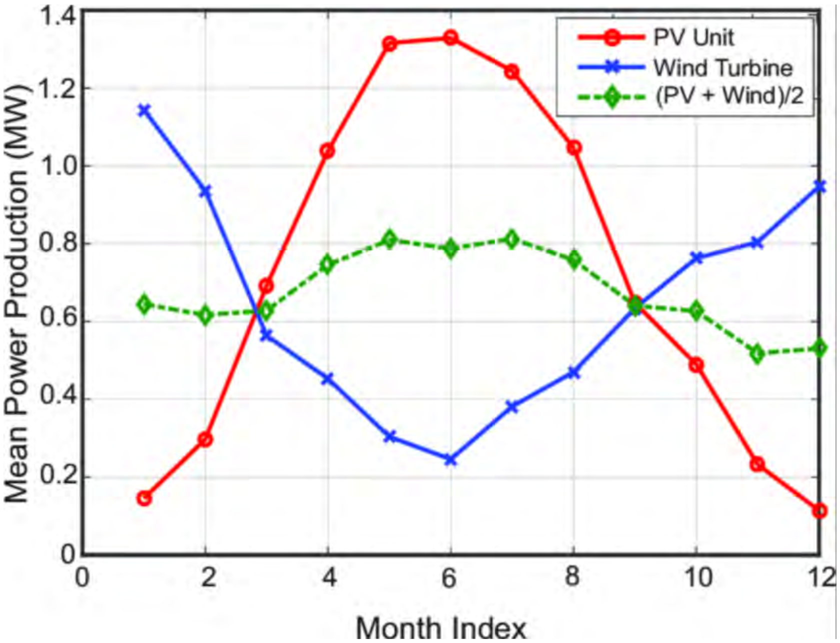
Leveraging Existing Generation Resources More Effectively

Complementary Loads and Resources

When grid operators have access to a wide array of different generating facilities, energy storage options, and loads, they have more options to match supply and demand in ways that get the most out of the entire existing transmission system.[14]

Wind and solar can be complementary resources because they can generate electricity at complementary times. An example of this is shown in Figure 1. The red line represents solar, generating the most during the summer months, and the blue line represents land-based wind, generating the most in winter months. The green line represents the average electricity generated by both, which is much more consistent than either one on their own.[15] Complementarity can exist at different timescales, including seasonally, daily, or even hourly.

Figure 1: Comparison of Monthly Electricity Production from Wind and Solar[16]

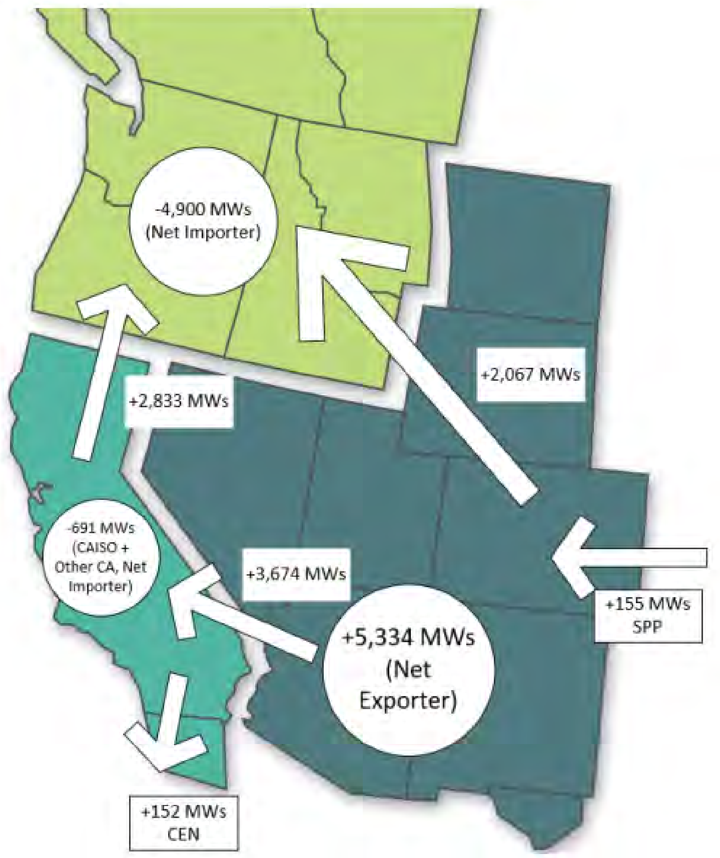


This complementarity between wind and solar reduces the total number of generation resources that need to be connected to the grid to meet load, which in turn reduces the need for more transmission.[17] [18] In other words, if a utility were to build only solar projects or only wind projects, it would need to build more of one of those technologies to meet load than if it were to build a mix of solar and wind. More projects likely means more need for transmission to connect those projects. In practice, utilities build a diverse group of resources – and are increasingly including battery storage – to help balance load and generation.

Increasing grid operators' access to broader geographic areas provides them with more options for sharing and leveraging complementary loads and generating resources. If grid operators have access to very large geographic footprints, the grid can be "bigger than the weather," meaning when local weather systems challenge local grid operators' ability to balance loads and resources in one area, grid operators can keep the lights on by accessing loads and resources in other areas unaffected by the local weather. In other words, if sufficient generating capacity in other areas already exists, increasing access to these other areas can reduce the overall need for new transmission lines to connect new resources in any one particular area.[19]

An example of this is when winter temperatures are cold in the Pacific Northwest and mild in the Desert Southwest, electricity can be imported from the southwest to meet northwest load, rather than expanding transmission capacity to add new generation in the northwest. Figure 2 shows the general flow of power across the West into the Pacific Northwest during the multi-day 2024 cold snap event. Imports from the Southwest and the Intermountain Region, which were not experiencing the same degree of cold weather, helped keep the power on in Oregon. [20]

Figure 2: Average Net Regional Import into the Northwest January 12-16, 2024[20]



Regional Transmission Organizations

Regional Transmission Organizations are independent entities that centrally plan and operate the transmission system across large geographic footprints.[21] The more geographic diversity within an RTO's footprint, the more it can leverage complementary loads and resources to reduce the need for new transmission.

SCAN OR CLICK

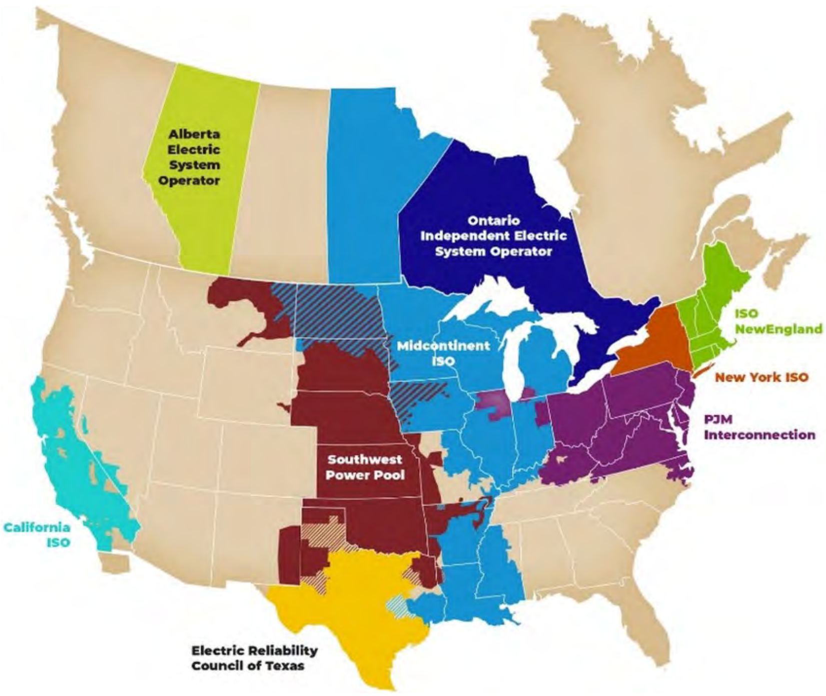
Learn more about regional transmission organizations in ODOE's 2021 study.

Principally, RTOs can reduce the need for new transmission in three ways:

1. Operating centralized real-time and day-ahead markets for the collective regional footprint of the participating utilities and power providers. This increases the efficient utilization of the existing transmission system and all the diverse loads and resources connected to it.
2. Conducting holistic transmission planning for the entire regional footprint to determine the most efficient way to build the transmission infrastructure necessary for all participating utilities and power providers to meet the collective regional demand. [22] [23] [24]
3. Standardizing transmission rates so utilities and power providers can transfer power across the region without having to pay multiple different rates, which encourages efficient use of the transmission system.[25]

Most western utilities outside of California are not members of an RTO, or similar entities known as Independent System Operators (see Figure 3). In the absence of an RTO or ISO, utilities generally contract directly with one another or with an independently owned electricity generation facility to buy and sell electricity and use existing transmission. While these contracts attempt to ensure the resources and transmission are available when needed, they can also create inefficiencies and increase costs.[26]

Figure 3: Map of Regional Transmission Organizations and Independent System Operators in the U.S. and Canada[27]



Where transmission expansion is needed, the holistic transmission planning accomplished by an RTO results in more coordinated planning for new transmission needs, so that loads and resources work together more efficiently. Even without an RTO, utilities and power providers can voluntarily collaborate to improve and expand access to diverse and complimentary loads and resources, and individual transmission system planners can also collaborate on holistic, region-wide transmission planning.

Organized Regional Markets

Learn more about wholesale energy markets in the 2020 Biennial Energy Report.

BPA and Oregon utilities, as well as many other power providers and utilities across other western states, participate in the Western Energy Imbalance Market. In this organized regional market, a centralized operator automatically balances supply and demand over 5- and 15-minute intervals by dispatching the lowest cost energy from power plants in the region to meet regional loads most efficiently. BPA and many western utilities, including Oregon's two largest utilities, have also signaled interest in participating in a similar form of market for electricity balancing for the next day, called a day-ahead market.[28] [29] [30] More efficient utilization of existing transmission resources was a factor in all three of Oregon's largest electricity providers' (BPA, PGE, and PacifiCorp) analysis about the benefits of joining these markets.[28] [29] [30] Learn more in the Electricity Day Ahead Markets 101 in this report.

Regional Transmission Planning

In Oregon and the Pacific Northwest, the regional transmission plan is pulled together by combining the local transmission plans created by individual transmission providers. While it is not the type of holistic, top-down regional planning that would be conducted by an RTO, this bottoms-up approach does support some additional communication and coordination between planners, including agreeing on similar data sets and assumptions used for individual planning activities.

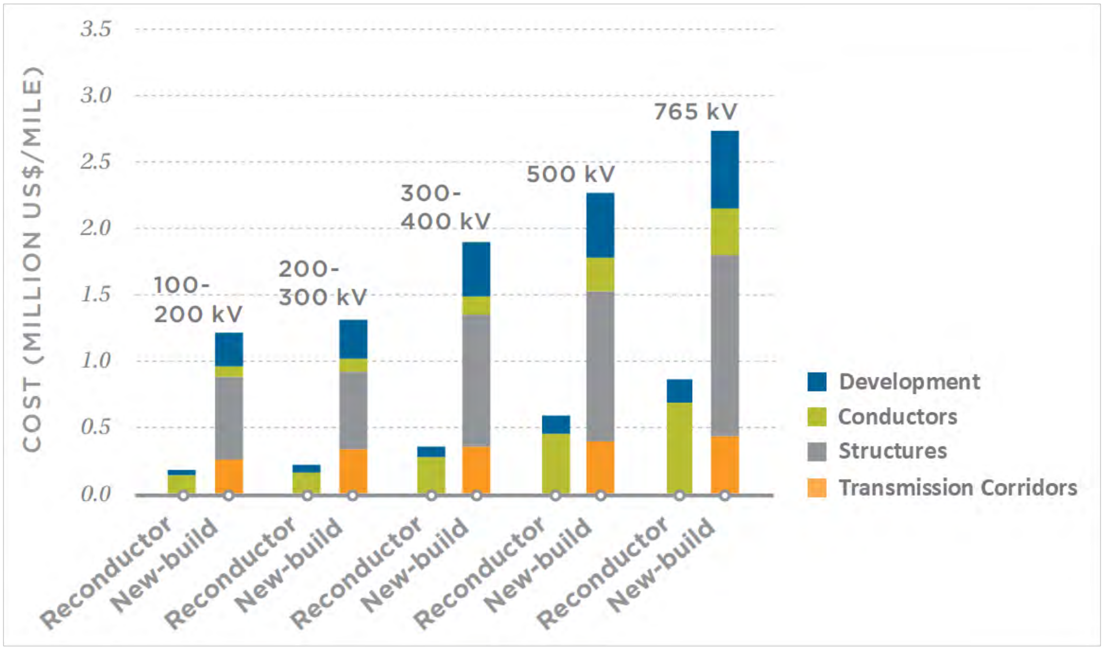
In an effort toward more efficient regional planning across the entire western U.S., the Western Transmission Expansion Coalition is holistically studying transmission needs across the Western Interconnection (a large region comprised of the 11 states west of the Southwest Power Pool in Figure 3 above) over the next 20 years.[31] [32] Comprised of utilities, Tribes, State regulators and representatives, policy makers, and other interested parties, the WestTEC study intends to identify actionable transmission solutions for the entire Western region, taking into consideration economic efficiencies, state policy goals, and grid reliability.[31] Participation in the study is voluntary, but participants hope the study can inform and complement other existing planning processes to encourage more efficient use and expansion of the regional transmission system.[33]

Repurposing and Expanding Existing Transmission Lines

Another option for mitigating the need for new transmission is to repurpose and expand existing transmission corridors.[34] For example, an existing transmission corridor originally built to serve a retired generating resource, such as a coal plant, could be repurposed to serve the addition of a new resource, such as a solar or wind facility, located in the same area.[34] Transmission operators can expand the transmission capacity of an existing corridor by increasing the operating voltage of an existing line, or by adding a second circuit, or wire, to the corridor.

Advanced reconductoring is a newer option to increase the capacity of an existing transmission line by replacing traditional wires with newer, higher capacity wires, which can double the capacity of an existing line while keeping the existing transmission towers.[35] Reconductoring projects typically cost less than half that of new transmission lines regardless of the voltage, as shown in Figure 4.[35]

Figure 4: Cost Comparison of Reconductoring Versus Building New Transmission[36]



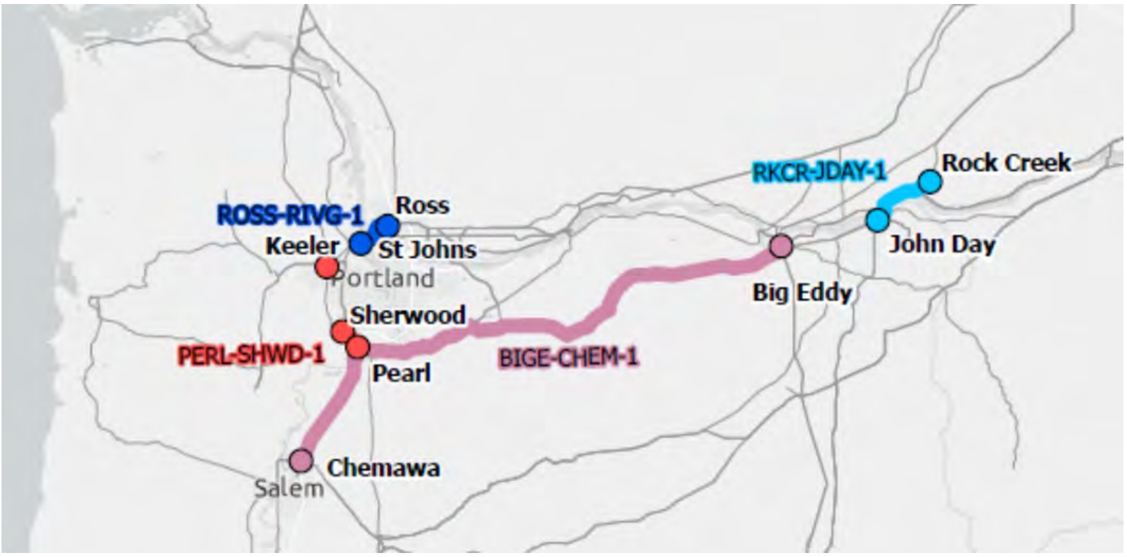
Reconductoring can also mitigate some risks associated with transmission lines. Almost all existing power lines are based on a patent from 1908, which is generally a bare line made up of a steel core surrounded by aluminum wires.[37] Modern conductors are much stronger, more conductive, and can be covered with an external insulating layer.[38] Conductor design is important because when transmission lines are covered in ice or heated by high flows and hot weather, they can sag and sway if blown by the wind. This can increase the risk of contact with other objects that could damage the line or ignite a wildfire.[39] Increasing capacity through reconductoring on an existing transmission corridor can also lessen the load on other parts of the transmission system that may be more susceptible to overloading and line sagging – further reducing outage risks.

Reconductoring projects provide multiple benefits that also align with Oregon's energy and land use policies. They simultaneously expand transmission capacity, reduce wildfire risks, and minimize the land used for transmission expansion.

Bonneville Power Administration and Portland General Electric are both planning transmission rebuild projects (new wires and new structures) within existing transmission corridors. Both will help alleviate critical transmission bottlenecks by expanding transmission capacity from east to west across the Cascades.

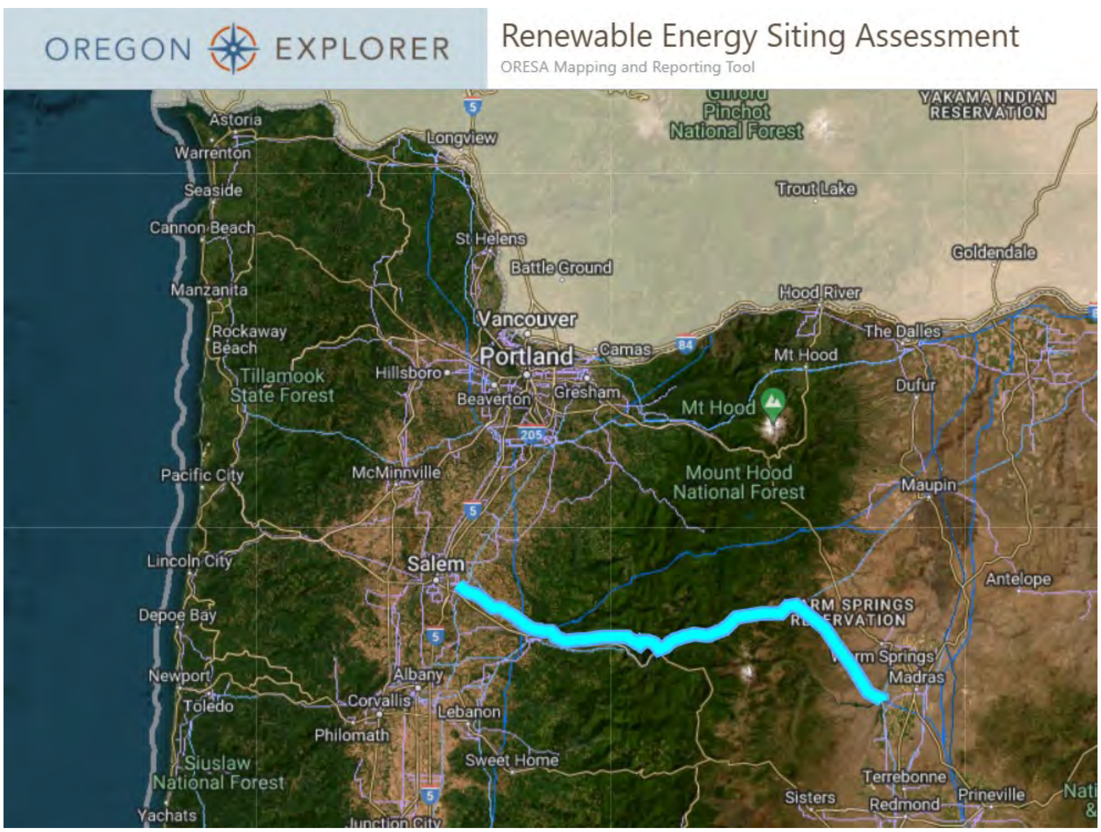
BPA proposes to rebuild and expand 91 miles of its transmission line between Wilsonville (Pearl substation) to the Dalles, OR (Big Eddy substation). The capacity of the line, shown in Figure 5, will be increased from 230 kV to 500 kV [40]

Figure 5: Bonneville Power Administration Proposed Rebuild Project[41]



The Infrastructure Investment and Jobs Act is helping utilities, states, and Tribes fund transmission upgrades like these. The Confederated Tribes of Warm Springs was awarded a $250 million grant from U.S. DOE's Grid Resilience and Innovation Partnerships Program that is made available through the IIJA, with PGE as a subrecipient.[42] The grants will help fund a rebuild of PGE's 98-mile transmission line between Salem and Madras shown in Figure 6, increasing its capacity from 230 kV to 500 kV.[42]

Figure 6: Portland General Electric Transmission Rebuild Project.[43]



PacifiCorp is also planning transmission reconductoring and rebuilding projects across states within its service territory, including Oregon, and has partnered with the Utah Office of Energy Development as lead state sponsor to receive federal funding support. US DOE's Grid Resilience and Innovation Partnerships Program awarded ~$250 million in federal cost share to help fund this multi-state advanced reconductoring demonstration project.[44]

Deploying Local Energy Resources

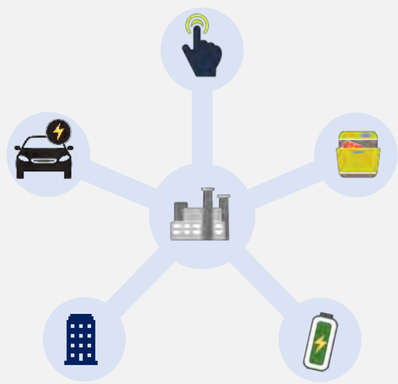
Energy resources developed and used locally can reduce the need to deliver electricity from far away generators to load centers.[45] These technologies or programs are used to meet customer demand for electricity with local resources. They are particularly useful if they reduce electricity demanded from the transmission system during times of peak consumption. Local resources include:

- Energy efficiency technologies and measures that reduce demand.
- Distributed Energy Resources, or DERs, like customer and utility battery storage systems, rooftop solar, smart appliances, and smart electric vehicle chargers.
- Demand response programs where customers voluntarily reduce or shift their consumption to reduce the need to deliver electricity at peak demand times.
- Time-of-use programs that offer customers lower electricity rates during off-peak hours.
- Programs that enable utilities to reduce or temporarily stop customer electricity use through devices like smart thermostats, water heaters, and electric vehicle chargers.
- "Virtual power plants" where utilities can aggregate DERs to reduce demand.[46]

In April 2023, Portland General Electric announced it would procure 475 MW of new battery storage projects across three sites in North Portland, Troutdale, and Hillsboro – Oregon's largest area of electricity demand.[47] The project is the largest commitment to standalone energy storage by a utility in the U.S. outside of California.[47]

What is a Virtual Power Plant?

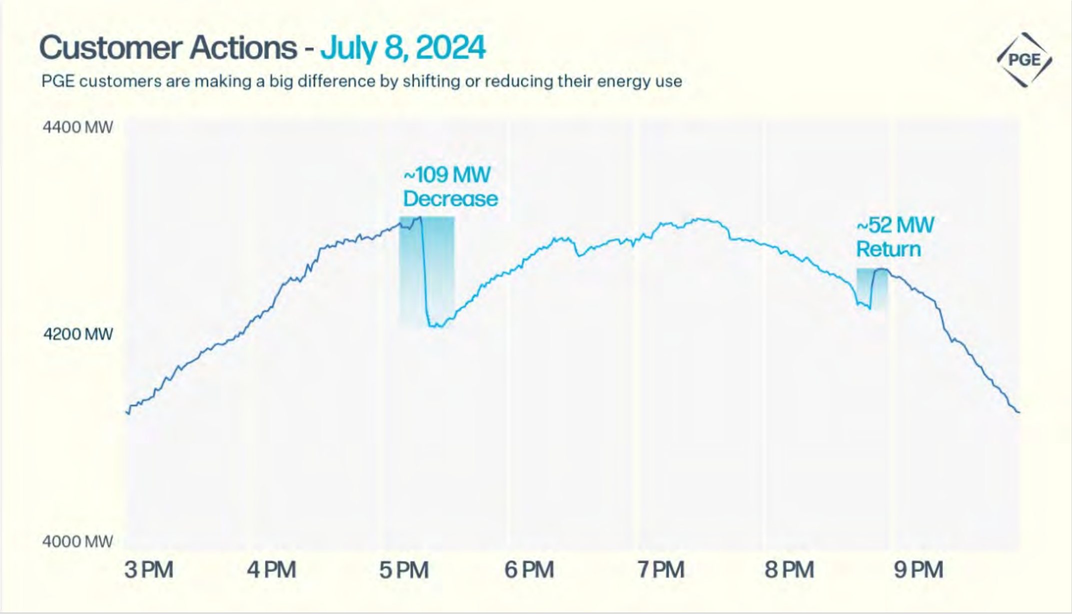
Utilities can use local energy resources, owned by customers or the utility, to alleviate generation and transmission constraints during periods of peak demand. Customer resources may include smart appliances, grid interactive buildings, rooftop solar and battery storage systems, electric vehicles and other resources. The process of coordinating and aggregating these distributed energy resources to provide grid services is referred to as a Virtual Power Plant. Electric utilities and ratepayers benefit by offsetting the need to build new central power plants and expand the transmission system. The participating customers benefit by receiving utility financial incentives.



The customers that participate in a VPP may be prompted by their utility to shed load from the electric grid, or to provide distributed generation capacity. In either case, the result is reduced demand on conventional central power plants and the transmission system.

Management of conservation measures, such as smart thermostat settings that reduce energy use to heat or cool based on usage data or delayed use of large appliances, is often the starting point for VPPs and is collectively referred to as demand response. Demand response programs are already in use in Oregon and provide critical resources during periods of peak electricity demand. Pacific Power manages the Optimal Time Rewards program where customers get financial incentives in exchange for operating smart thermostats and water heaters to minimize peak electrical loads.[48] On July 8, 2024, customers of Portland General Electric participated in a flexible load program resulting in the largest electricity demand shift in PGE's history.[49] As shown in Figure 7, 109 MW of load reduction was realized during a peak demand event brought on by a prolonged heat wave. To put this amount of electricity in perspective, 109 MW is about the same capacity as the Klamath Generation Peakers natural gas-fired power plant in Klamath Falls.[50]

Figure 7: Example of the Effects of Portland General Electric Flexible Load Programs on July 8, 2024[49]



While demand response programs reduce the instantaneous load on the grid, distributed generation resources, such as rooftop solar paired with batteries, can also be coordinated to provide other grid services. For example, PacifiCorp's affiliate, Rocky Mountain Power, offers financial incentives to residential and commercial customers in Utah and Idaho for access to battery storage systems through the utility's Wattsmart program.[51] Batteries in this program are charged by rooftop solar each day and discharged during periods of peak electricity demand. In the event of a power outage, the battery systems can also provide emergency backup electricity to customers. More than 4,000 customers have enrolled in the Wattsmart program. Closer to home, PGE is piloting a Smart Battery program to test microgrid operations in Oregon that will provide additional load management capacity.[52]

Virtual power plants can also play a significant role in future grid operations in Oregon. PGE's program is over 225 MW today, and is targeting 2,000 MW from VPPs by 2030, to achieve its goal to offset 25 percent of electrical demand during peak events similar to July 8, 2024.[53] [67] Two thousand megawatts is more than the combined capacity of all of the natural gas power plants currently owned and operated by PGE which, in December 2023, totaled 1,811 megawatts.[54] Meeting future energy demands with VPPs can reduce the need for new transmission while supporting decarbonization, empowering customers, increasing affordability, and improving the reliability of the grid. [55]

Table 1: Examples of Local Energy Resources that Can be Leveraged to Reduce Demand During Critical Hours

Customer Side of the Meter	Utility Side of the Meter
• Energy efficiency measures (insulation, double and triple pain windows, etc.) • Heat pumps • Smart water heaters • Solar panels • Electric vehicles • Batteries	• Utility programs (time-of-use rates, demand response programs, net-metering, etc.) • Community-adjacent, utility-scale solar and battery projects interconnected to the distribution system

Using Grid Enhancing Technologies

A suite of sensor and modeling technologies called grid enhancing technologies, or GETs, can help get more out of the existing transmission system.[56] These modern tools are capable of managing transmission congestion, improving operational efficiencies, and providing real-time data for operators to make more informed decisions.[46] They do not require permitting or siting, but they do provide performance improvements for existing or reconductored transmission lines.[56]

Transmission lines have thermal ratings that effectively limit the amount of electricity a line can carry. To calculate the capacity of a transmission line, utilities have traditionally used static line ratings, which are calculations of the thermal rating based on historical "worst case" conditions, such as times of the year with the hottest temperatures and lowest wind speeds. Static line ratings are very conservative and fixed, even if weather conditions are mild. If transmission system operators could monitor ambient conditions using sensors and/or software to calculate and update the thermal limits of a transmission line based on real-time and forecasted weather conditions, they could more effectively assess transmission line capacity capabilities.[57] [58] This is known as "dynamic line rating." DLR not only enhances the utility's situational awareness of the environment surrounding a line, but it can also provide critical information about conditions that may be conducive to wildfires.[59]

Like dynamic line ratings, dynamic transformer ratings provide real-time information about the thermal ratings of transformers that convert electricity voltages. This technology also takes into account other factors such as the age of the transformer and the type of cooling system it uses.[60]

Another type of GET is a power flow controller. It reroutes electricity away from overloaded lines and onto underutilized corridors, typically by opening or closing existing high-voltage circuit breakers. This helps optimize the power flow across all lines, which allows for more efficient delivery of electricity.[58]

The deployment of GETs is still in the early days and far from widespread. Bringing these new systems into standard use requires investments in new technologies and grid management processes — and, importantly, gaining the confidence of grid managers that they will perform as designed.[61]

It is uncertain exactly to what degree GETs could reduce or offset new transmission line expansions in Oregon.[62] A 2024 study found that during certain times of the year, GETs can enhance the transfer capability up to 50 percent across the existing transmission grid.[63] For example, dynamic line rating technology may be able to help provide additional capacity during severe winter cold snaps, when colder temperatures often allow for additional capacity on transmission lines.[64] However, this also means the opposite could occur during summer droughts and heat waves, where dynamic line rating could actually reduce transmission capacity.

Federal initiatives are advancing utility knowledge and experience with GETs and aim to foster greater adoption of these technologies that would accelerate renewables development. The Federal Energy Regulatory Commission recently adopted Order 1920, which requires transmission providers to consider GETs in their regional planning efforts.[65] Oregon is one of 21 states committed to a Federal-State Modern Grid Deployment Initiative to prioritize efforts that support the adoption of modern transmission solutions, such as grid enhancing technologies.[66] PacifiCorp applied for a U.S. DOE Grid Resilience and Innovation Partnerships Program grant. GRIP is a $10.5 billion grant program to enhance grid flexibility and improve the resilience of the electricity system against growing threats of extreme weather from climate change. PacifiCorp's proposal includes deploying GETs across several states, including Oregon, to increase the operational capacity of existing transmission lines.

Meeting the Challenge of Reducing Transmission Expansion

There are many ways to reduce the total magnitude of transmission expansion that needs to occur to meet increased demand for electricity. Many can also bolster the reliability and resilience of the power grid in the face of extreme weather events, and all can help meet the clean energy and climate policy goals of many western states, including Oregon.

There are economic, environmental, and societal benefits to reducing transmission expansion. It can help avoid or delay significant investments of time and costs into new lines and infrastructure. Not having to develop new transmission corridors avoids environmental, cultural, and societal effects on communities. Fewer line miles to maintain also reduces costs for monitoring and mitigating wildfire risks, and most importantly, reduces costs from wildfires. Many of the options presented here also provide local benefits in the form of well-paying jobs and increased community energy resilience from the deployment of more local energy resources.

Successfully navigating the challenges associated with transmission expansion is essential to maintaining a reliable and affordable electric system as the economy and electricity demand grow and Oregon works to achieve its greenhouse gas goals. This is especially true as extreme weather events caused by climate change are increasing in frequency, intensity, and duration.

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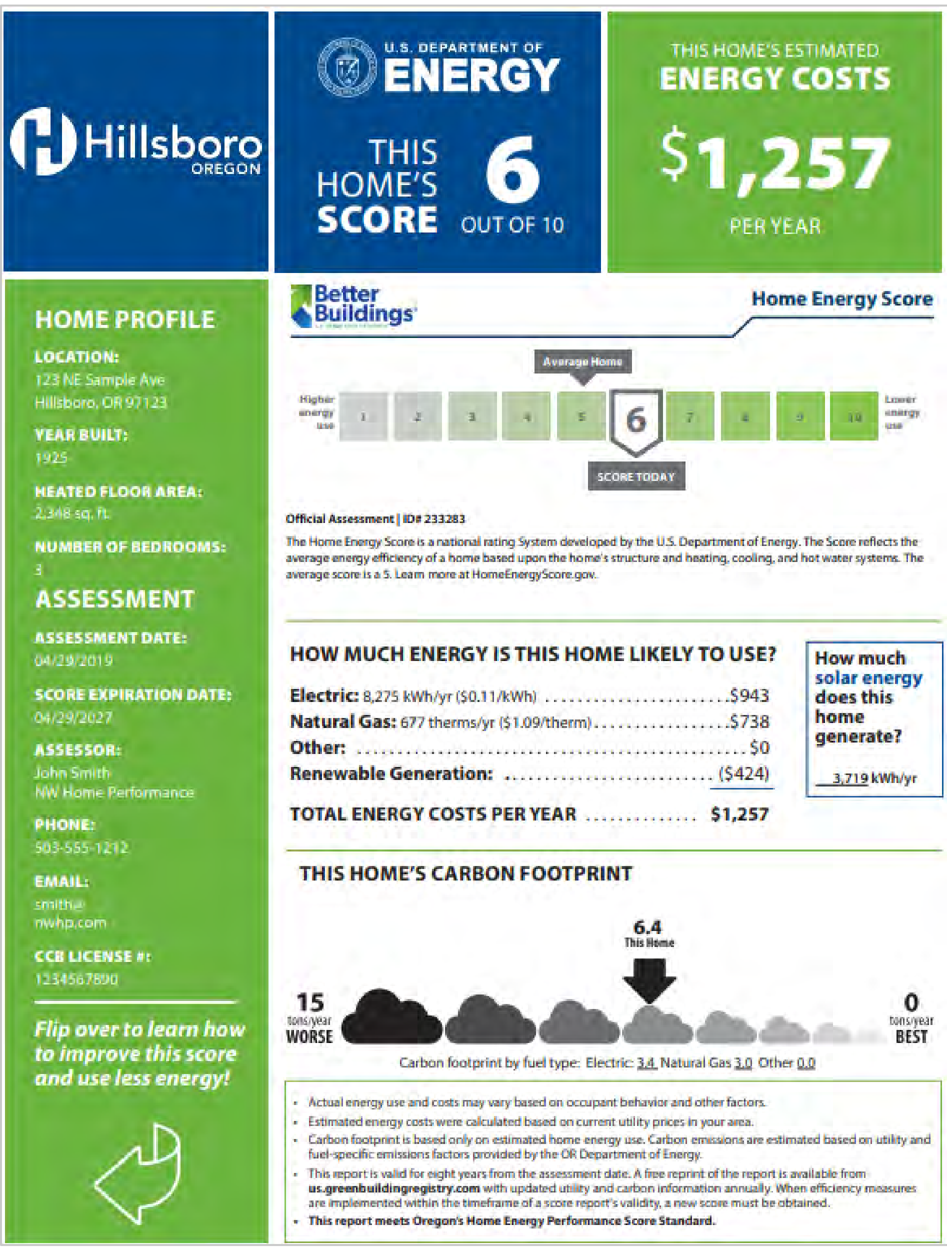
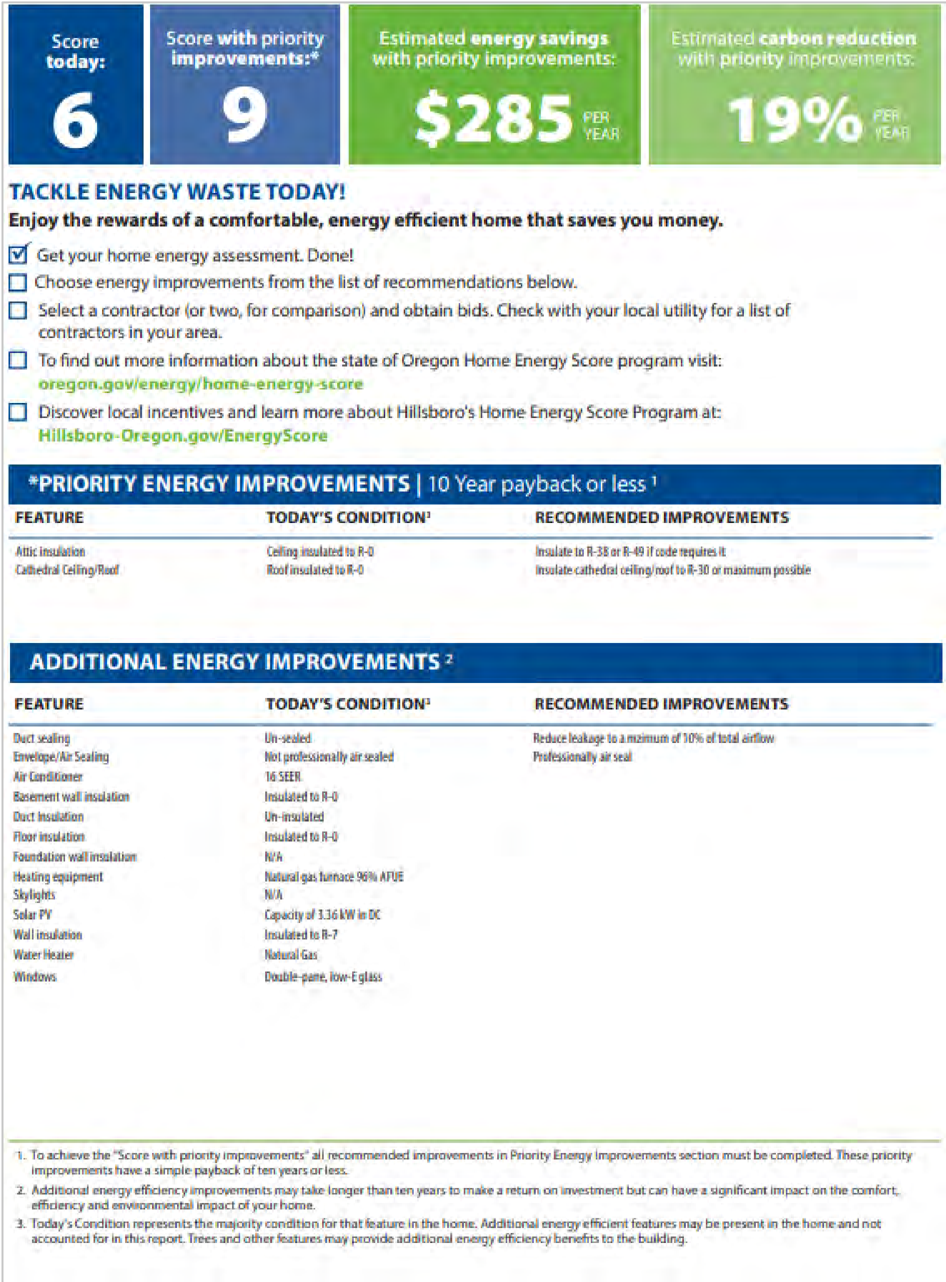
Oregon Home Energy Scoring

Home Energy Score™ was developed by the U.S. Department of Energy and its partner national laboratories to provide homeowners, buyers, and renters comparable and credible information about a home's energy use.[1] Using a 1 to 10 scale (10 is high performance), the score estimates a home's energy consumption and recommends ways to reduce its use, cut costs, and improve comfort. The score also relays greenhouse gas information related to that energy use. Below is an example of a Home Energy Score scorecard. The front page (shown first) relays information about the home's location, energy score, and estimated energy cost. The front page also provides the home's carbon footprint and lists other program details at the bottom. The back page (shown below) relays what upgrades to the home may improve energy performance and reduce costs and carbon emissions. This information helps consumers understand the estimated return on investment for specific energy efficiency actions.

Figure 1: Example Home Energy Scorecard in Hillsboro, Oregon





Score today:	Score with priority improvements:*	Estimated energy savings with priority improvements:	Estimated carbon reduction with priority improvements:
6	9	$285 PER YEAR	19% PER YEAR

TACKLE ENERGY WASTE TODAY!

Enjoy the rewards of a comfortable, energy efficient home that saves you money.

- [x] Get your home energy assessment. Done!
- [ ] Choose energy improvements from the list of recommendations below.
- [ ] Select a contractor (or two, for comparison) and obtain bids. Check with your local utility for a list of contractors in your area.
- [ ] To find out more information about the state of Oregon Home Energy Score program visit: oregon.gov/energy/home-energy-score
- [ ] Discover local incentives and learn more about Hillsboro's Home Energy Score Program at: Hillsboro-Oregon.gov/EnergyScore

***PRIORITY ENERGY IMPROVEMENTS | 10 Year payback or less [1]**

FEATURE	TODAY'S CONDITION[3]	RECOMMENDED IMPROVEMENTS
Attic insulation	Ceiling insulated to R-0	Insulate to R-38 or R-49 if code requires it
Cathedral Ceiling/Roof	Roof insulated to R-0	Insulate cathedral ceiling/roof to R-30 or maximum possible

ADDITIONAL ENERGY IMPROVEMENTS [2]

FEATURE	TODAY'S CONDITION[3]	RECOMMENDED IMPROVEMENTS
Duct sealing	Un-sealed	Reduce leakage to a maximum of 10% of total airflow
Envelope/Air Sealing	Not professionally air sealed	Professionally air seal
Air Conditioner	16 SEER	
Basement wall insulation	Insulated to R-0	
Duct Insulation	Un-insulated	
Floor insulation	Insulated to R-0	
Foundation wall insulation	N/A	
Heating equipment	Natural gas furnace 96% AFUE	
Skylights	N/A	
Solar PV	Capacity of 3.36 kW in DC	
Wall insulation	Insulated to R-7	
Water Heater	Natural Gas	
Windows	Double-pane, low-E glass	

1. To achieve the "Score with priority improvements" all recommended improvements in Priority Energy Improvements section must be completed. These priority improvements have a simple payback of ten years or less.
2. Additional energy efficiency improvements may take longer than ten years to make a return on investment but can have a significant impact on the comfort, efficiency and environmental impact of your home.
3. Today's Condition represents the majority condition for that feature in the home. Additional energy efficient features may be present in the home and not accounted for in this report. Trees and other features may provide additional energy efficiency benefits to the building.

How are Home Energy Scores Determined?

Home Energy Scores are developed by state certified assessors, who have been trained and licensed in Oregon. Assessors examine a home's characteristics, such as windows, insulation, and heating/cooling equipment, as well as the age, size, and orientation of the property. Information is collected in a program-specific form. Using that information and an online calculator provided by the U.S. Department of Energy, assessors produce a scorecard like the example above.

Benefits of Home Energy Scoring

Home energy scoring provides consistent and trusted information to homebuyers on the energy costs and carbon footprint of a prospective home. In cities that require mandatory scoring, scores are paid for by the seller and made available at no cost to potential buyers. The information can be accessed through multiple home listing services and other online resources like Zillow and Redfin. The standardized scoring and scorecard allow buyers to easily compare the energy costs and carbon footprints[i] of multiple prospective homes.

A Home Energy Score provides information on which energy efficiency measures or upgrades could pay for themselves over a given amount of time. Utilities and organizations like Energy Trust of Oregon and the Oregon Department of Energy provide trusted information about available incentives and the advantages of efficiency upgrades, including economic benefits like energy cost savings, as well as non-economic benefits like better home comfort and indoor air quality.

Energy efficiency upgrades reduce energy costs which often pay for the cost of the upgrade over time, but the up-front cost for the upgrades can still be a barrier for some. Homeowners may be eligible for programs that reduce the cost of completing an energy saving upgrade or replacing an appliance with a more efficient one. Many state, local, and utility programs offer rebates and incentives, and some lenders will include the costs for Home Energy Score recommended energy efficiency upgrades in a new mortgage. Existing homeowners may have the option to include these costs when refinancing or getting a loan specifically for the upgrades.

Green Mortgage Lending

Also called Energy Efficient Mortgages, Green Mortgage Lending is a type of financial loan program that allow borrowers to include the costs of energy efficiency upgrades into a new home loan. These are available through conventional loans backed by Fannie Mae or Freddie Mac, Federal Housing Administration insured mortgages, Department of Veterans' Affairs loans for veterans and their families, and the U.S. Department of Agriculture's loan program for homes in rural areas.[3]

Lower energy payments have been associated with fewer mortgage defaults. Less money spent on energy bills can translate into more available money to meet a mortgage payment. A study by the Institute for Market Transformation found that energy efficient homes have on average, 32 percent lower default rates.

[i] A building's carbon footprint is the total amount of greenhouse gases that are emitted into the atmosphere, largely from the use of energy in the building.[2]

Home Energy Scoring in Oregon

Since implementation of Oregon's Home Energy Score program in 2016, cities can use a framework developed by ODOE to design and implement their own local home energy scoring ordinances. Portland, Milwaukie, Hillsboro, and Bend have instituted mandatory ordinances that require a publicly available Home Energy Score on all residential property listings.[4] [5] [6] [7] These four cities cover more than 20 percent of Oregon's population. Eugene and Salem have expressed interest in developing similar policies as part of their energy and climate action plans.[8] [9] To date, statewide Home Energy Score programs have resulted in more than 40,000 scores generated. The data can be used to assess the overall efficiency of housing and identify where additional support may be needed to encourage upgrades. As scores are updated — from the resale of a home or at a resident's request — this information can provide insight into trends in residential energy efficiency.

The standardized approach for the Home Energy Score program makes energy assessments a reliable resource for homeowners and residents interested in understanding the costs and benefits of different energy efficiency upgrades. Prior to starting the program, access to energy efficiency information differed depending on the home's location and the specific energy assessor used. Assessors could use different tools, provide varying energy consumption and savings metrics, or assess different parts of a home's energy footprint. Oregon's home energy scoring program provides credible and consistent information about energy efficiency upgrades.

Oregon Home Energy Score program assessors must complete training programs and state licensing to become certified. This includes building science training, scoring tool simulation training, mentoring, and quality control procedures.

Oregon Home Energy Score assessment costs range from $119-$180 compared to the national average of $425.[10] [11] The standardized training provided through the Home Energy Score program includes efficient practices that bring down costs by reducing the assessors' time gathering information on site. Using the U.S. DOE calculator also reduces time spent calculating and verifying results. In Portland, Milwaukie, Hillsboro and Bend, where sellers must provide a Home Energy Score, there are programs to help low-income residents pay for energy assessor fees.

Improving Accessibility to Home Energy Scoring

The Home Energy Score program can be leveraged to improve access to scoring for homes in cities without mandatory policies, rural areas of the state, and for rentals and mobile homes.

The Home Energy Score training and certification program can be used by any business, utility, or other energy efficiency focused organization throughout the state. Oregon currently has about 75 certified home energy scoring assessors, mainly serving populations in cities with mandatory scoring policies. Some assessors are part of businesses that offer complementary services, such as heating, cooling, and window and insulation installations. Other assessors work independently and offer home inspections or real estate services. A few businesses focus only on providing home energy score assessments.

Find an Assessor

ODOE works with Earth Advantage to provide a current list of Home Energy Score assessors online. Consumers can enter the address of their home, and the webpage will provide a list of available assessors for their location.[12]

Many environmental justice communities, especially rural communities, have few to no trained home energy assessment professionals. In some cases, there are no available assessors, and when they are available, services are often more expensive because of increased travel costs. The home energy scoring program includes training to conduct remote assessments. With assistance from the homeowner or tenant, assessors collect data using photos and online discussions, which are then input into the calculator. This option increases access in rural regions and keep costs commensurate with urban and suburban areas.

Currently, renters living in multi-family or manufactured homes do not have access to Home Energy Scores. Nearly 39 percent of Oregon households are renters.[13] Households with incomes below 60 percent of the area median income in Oregon are more likely to be renters and experience energy cost burdens sometimes above 6 percent. In several census tracts of Portland and Medford, and in most rural areas, energy burden can exceed 10 percent.[14] On average, Oregon renters have higher average housing costs and incomes of less than half that of homeowners. Seventy percent of renter households make less than $75,000 a year, and half of Oregon renters spend at least 30 percent of their income on housing costs.[13 15]

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.[16]

When energy burden is a concern, the ability of renters to compare energy costs across different homes could have a dramatic effect on their cost of living.[17] Oregon consumers can make more informed housing choices when they have access to energy cost information across all types of housing. In the absence of a score, renters have limited visibility into building energy performance and costs when selecting their home. The U.S. DOE is currently adding functionality to its calculator to assess the energy footprint for multi-family and manufactured homes. ODOE is preparing to engage with landlords to show them how the program works, the energy savings information it can provide, and how they can share Home Energy Scores with their tenants.

The U.S. DOE anticipates providing an updated scoring calculator with options to score multi-family and manufactured homes by 2025. Cities with mandatory scoring policies have indicated they may add mandatory home energy scoring for rental properties soon.

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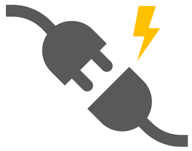
Waste Energy



Some amount of energy is lost during the production, delivery, and use of energy. This loss is referred to as waste energy and includes both avoidable and unavoidable losses. Energy is lost or consumed during energy transformations (storing, moving, converting, or using energy). Commonly, energy is lost in the form of heat that dissipates into the surrounding environment. While some energy losses are inevitable, there are many opportunities to improve the efficiency of energy production, processing, transport, and storage, as well as measures to more efficiently use energy. This Energy 101 will describe types of energy losses and the options energy producers and users have that can reduce waste energy.

Waste energy is the difference between the amount of energy input needed to complete a process and the amount of energy used for work. For example, light bulbs produce light (useful work), but also produce some amount of energy as heat that is not used. Heat could be a very useful output from energy processes, if it can be captured to do useful work. However, in many cases processes that produce heat as a byproduct do not occur in locations where it could be captured and used. Some industrial plants recapture waste heat and use it to support their processes – for more information, see the Combined Heat and Power Technology Review in the *2020 Biennial Energy Report*.

What is Waste Energy and What Causes It?

While the word “waste” implies some level of neglect or inattention in allowing energy to escape, energy loss is a normal outcome of storing, moving, converting, or using energy. Waste energy can be described as the unused portion of energy, or energy required to get to the final work product in a system or process. In Oregon’s energy system flow diagram below, waste energy makes up about 54 percent of all energy produced or imported in the state — some of this is unavoidable energy loss.

Figure 1: Oregon’s Energy Flow, Waste Highlighted

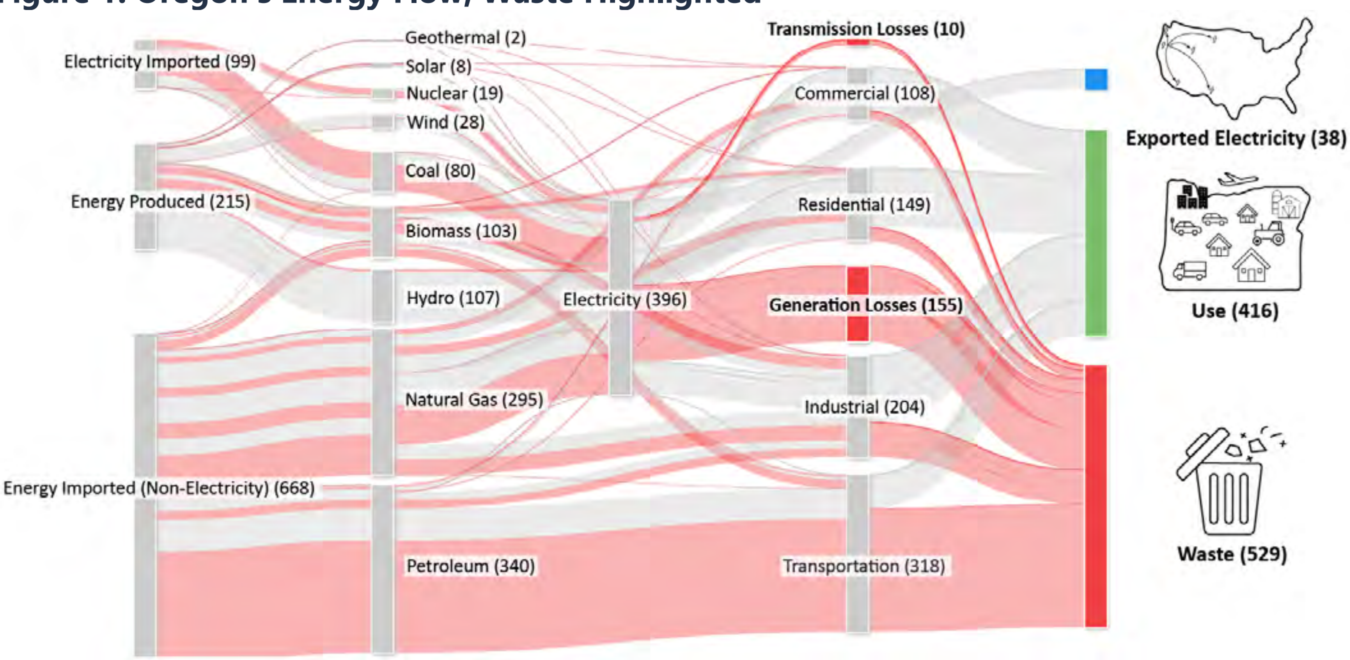


Figure 1 (in Trillion Btu) shows the waste energy for 2022 (further details on this chart can be found in the Energy by the Numbers section of this report). The U.S. Energy Information Administration recently updated the methodology used to calculate primary energy use, which reduced the amount of waste energy estimated in this chart compared to the *2022 Biennial Energy Report*. More information on this change can be found in the About the Data section of this report.

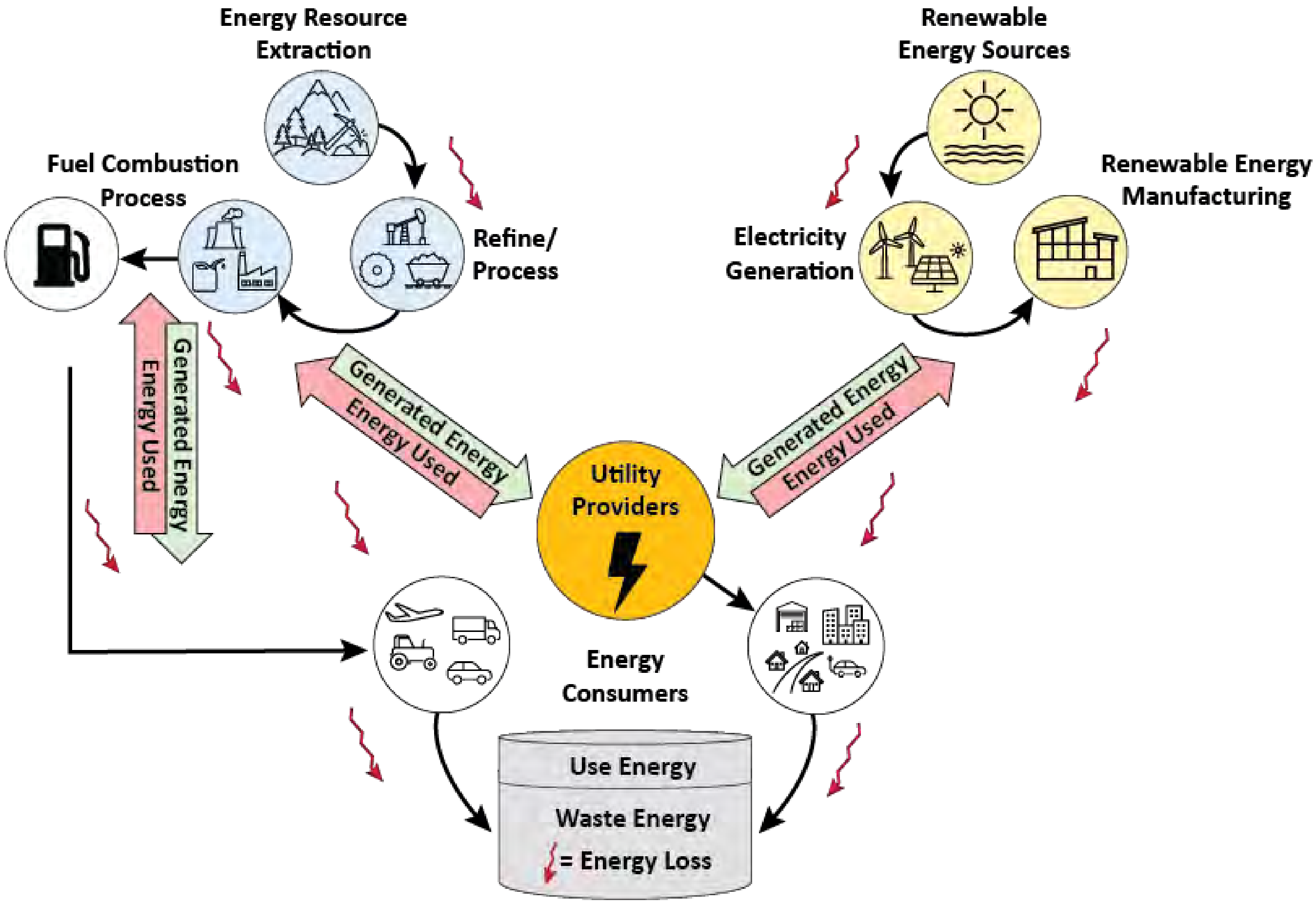
Heat as Waste Energy

In natural or spontaneous processes, energy always becomes less organized, and heat – energy that comes from the movement of atoms and molecules in a substance – is the least organized form of energy. Heat is a byproduct of many energy-related processes, and always flows in the direction of decreasing temperature.[1] At right, two campers enjoy the fire generating heat, which dissipates into the cold night air.

Where Energy Losses Occur

Energy losses occur at every step necessary to provide energy when and where it is needed. For example, petroleum resources like natural gas, coal, gasoline, diesel, and propane require the use of energy to mine or extract and transport via pipeline, truck, or rail — and often lose some inherent energy during refining and processing. When natural resources are used to generate electricity, additional energy losses occur while generating the electricity and along the transmission and distribution wires carrying it to the point of use. Renewable resources like solar and wind do not require energy to produce or transport fuel to the generation site but – like all energy sources – do require manufacturing and transportation of the generating equipment. Other types of renewable energy resources like biomass from waste wood products and biogas from landfills have other steps in their pathways where energy losses can occur, such as transportation and heat losses from combustion. Figure 2 below shows a simplified overview of the types of processes involved in the production and consumption of energy, and resulting waste energy that occurs in each.

Figure 2: Points of Energy Loss to Provide Energy to Consumers

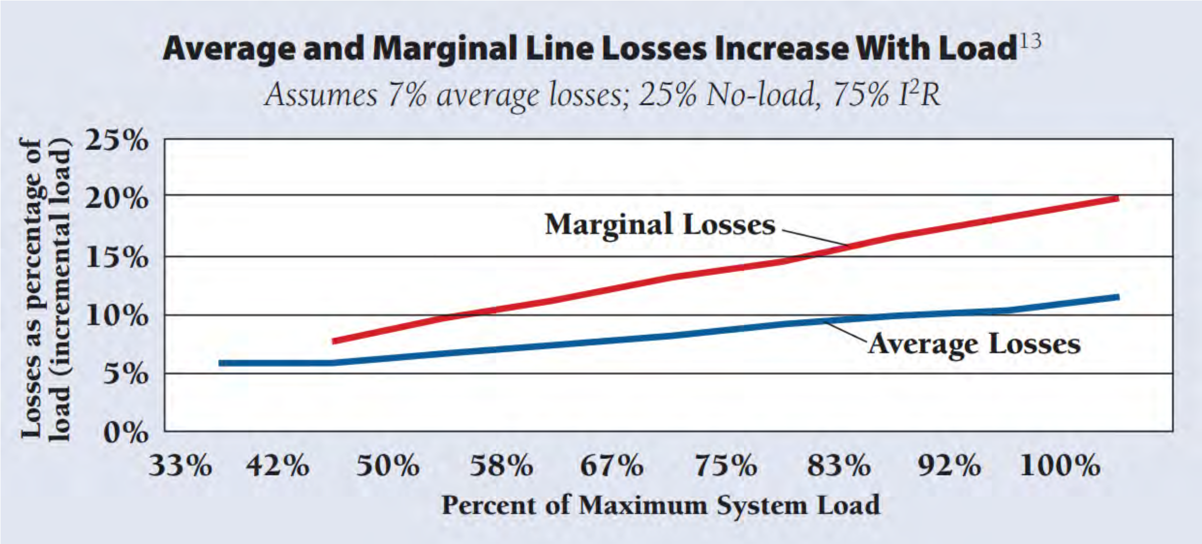


Delivering electricity over transmission and distribution lines also incurs energy losses, known as line losses. In 2022, about 5 percent of the electricity generated for Oregon consumers was lost as it was transmitted from the generation sites to the ultimate end use, which is about the same as the national average.[2] Energy is not only lost along the lines, but also at every point along the line where transformers are used. Longer lines have more energy waste, which is why rural distribution line energy losses are typically greater than urban lines.[3] A study conducted for an electric utility in Ontario calculated typical line losses across distribution lines at 3.6 percent in urban areas and 7.3 percent in rural areas.[i]

Losses also increase as load on the electrical line increases. At the highest load hours, line losses can increase up to 10 – 15 percent. Transmission systems are designed for optimal efficiency at a particular load; when demand on the system increases, the loading outside the optimal range increases losses.

[i] Rural and urban areas were defined by the utility.

Figure 3: Typical Line Losses Associated with Increasing Load[3] [ii]



The energy that is directly used to extract or mine petroleum products, and transport, refine, or deliver energy products, is not considered waste energy, as this energy produces useful work. Waste energy also does not include solar energy that is not captured by solar panels or wind not captured by turbines. This is energy that exists regardless of whether it is harvested or not. Similarly, water that flows through dams that do not generate electricity or crude oil left in the ground are also not considered waste energy but can be thought of as unharvested energy, sometimes referred to as potential energy.

Waste Energy and Energy Efficiency

The practice of finding uses for as much of the energy in a process as possible is a form of energy efficiency.

Energy efficiency includes technologies and practices that reduce waste energy. The Pacific Northwest has long been a leader in energy efficiency for electricity and direct use fuels in buildings, with a history and current practice of prioritizing energy efficiency and conservation programs across these sectors.[4] Utilities, policymakers, and other stakeholders consider energy efficiency a resource, like hydropower, natural gas, solar, and wind. Energy efficiency opportunities exist wherever energy waste occurs, including energy production, transmission, transportation, and/or management, as well as residential, commercial, industrial, and transportation end uses. Another advantage of energy efficiency practices and technologies is that in addition to addressing avoidable energy waste, they also reduce the total unavoidable losses that would otherwise have occurred.

[ii] Marginal losses are those that are avoided if load is reduced. Similar to traffic patterns, small increases or decreases in transmission load can have outsized impact on electricity flow and losses.

At an energy production scale, energy efficiency includes co-locating processes, reduced and/or improved transport and transmission, replacing outdated or inefficient parts and equipment with higher efficiency versions, and strategic control strategies that optimize energy production.

Hydropower Efficiency and Oregon's Renewable Portfolio Standard

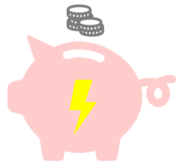
Oregon's Renewable Portfolio Standard program allows utilities to use efficiency improvements to hydroelectric facilities to participate in the program. Because hydro dams were in operation before the program was enacted, they are not eligible renewable resources. However, where efficiency measures help operators generate more energy from the same dam, this additional electricity is eligible for the RPS. Increased interest in efficiency and the RPS allowance has resulted in almost 369 MW of increased hydroelectric generation capacity from facilities in Oregon — an overall increase of 4.8 percent over the life of the program. For example, Portland General Electric implemented hydroelectric efficiency retrofits at Round Butte Dam on the Deschutes River:

- Round Butte Unit 3 had an initial nameplate capacity of 82.35 MW and efficiency upgrades increased this capacity by 57.86 percent.
- Round Butte Unit 2 had a nameplate capacity of 82.35 MW and efficiency upgrades increased this capacity by 57.86 percent.
- Round Butte Unit 1 had a nameplate capacity of 82.35 MW and efficiency upgrades increased this capacity by 36.61 percent.

Since generation facilities do not operate at the highest capacity year-round this translates to about a 10 percent increase in annual generation for these facilities. The 2021 Infrastructure Investment and Jobs Act provided $630 million to support the modernization and expansion of the nation's hydroelectric resources, including increased funding to the Hydroelectric Efficiency Improvement Incentives program, which provides incentives for facilities that implement projects that increase their facility efficiency by at least 3 percent.[5]

Round Butte Dam
Photo: Low Impact Hydropower Institute

At the consumer level, reducing energy waste generally means replacing inefficient devices, improving the weatherization of a building, or optimizing the operation of a building. Broadly, this includes better insulation, more energy efficient windows and doors, and more energy efficient devices and control strategies. Heat pumps can save approximately 50 percent of the energy used for home heating when replacing electric resistance heat such as cadet heaters or baseboards.[6] Replacing aging compressors with advanced adaptive compressors can provide up to 30 percent energy savings in



refrigerators.[7] In addition to these strategies, Oregon businesses and industry can reduce waste by using more energy efficient equipment, improving the overall efficiency of their operations, or training employees in energy efficient practices (such as training maintenance staff on controls operations and strategies, building staff in use of occupancy sensors to control lighting and plug loads, or training in conservation principles).

Because some types of energy technologies and systems lose more energy than others, using different technologies can sometimes reduce energy losses. For example, electric motors waste far less energy than comparable combustion engines. A common example of this is in passenger vehicles, where conventional gasoline engines convert between 12 and 30 percent of the energy in gasoline to move the vehicle, whereas electric vehicles convert over 77 percent of the electrical energy pulled from the grid.[8] Replacing incandescent light bulbs with LEDs reduces energy consumption by 75 percent and the LEDs last up to 25 times longer.[9]

We can compare Oregon's overall system energy efficiency — the ratio of useful energy to waste energy — by looking at the Energy Flow diagrams produced by the Lawrence Livermore National Laboratory for Oregon and Washington to get a better idea of how Oregon compares. Oregon's system efficiency for 2021 was 44 percent while Washington's was 42 percent.[10] Although Washington's population and the size of the energy system is significantly higher than Oregon's, they share many similarities, such as reliance on regional hydropower infrastructure, access to renewable energy resources, similar leading economic sectors, and a similar policy environment that has historically prioritized energy efficiency programs.

Opportunities remain to advance energy efficiency and reduce waste, particularly in waste energy capture and reuse. An example of this is Intel's Fab 34 site in Ireland that was designed with heat recovery in mind, specifically a heat exchanger and hot water system set up to capture excess heat and direct it to other steps in the manufacturing process or to heat buildings.[11] Though individual efficiency actions may be small, the sum of energy efficiency design strategies across energy sectors, and from production through use, have a large effect on reducing energy waste. More extensive application of existing energy efficiency technologies and programs could boost Oregon's efficiency and new technological developments, such as extended capacity heat pumps, and solutions for space conditioning in large commercial buildings could drive overall system energy efficiency even higher.

Electricity efficiency will become increasingly important as more end uses, such as personal vehicles and building heating, use electricity as an energy source. This includes options to address transmission and distribution line losses, improve the efficiency of electricity generation, and the efficiency of all energy end use products. Distributed resources that are located closer to end-users, such as rooftop solar, electric vehicle batteries, consumer-owned battery systems, water heaters, boilers, and local microgrids, could all provide energy to the grid. Effective management of these distributed resources could reduce transmission and distribution line losses, as well as congestion on existing transmission lines.

Benefits of Reducing Waste Energy

Reduction in waste energy often means lower costs for all consumers. It can also reduce other societal costs, including those related to climate change and environmental effects on communities. It can help with local health effects, energy reliability, and aid in achieving Oregon's climate and energy goals.[12] Efficiency gains also help utilities avoid or delay the need for new generation that require consumer rate increases. Reducing energy waste also reduces mining and petroleum extraction activities, which have environmental and societal effects around the globe.

In addition to cost reductions, reducing energy waste also has many co-benefits. Efficiency investments support more reliable and resilient energy systems and provide these benefits with little to no negative effect on Oregon's land, air, and water. Energy efficiency activities also provide jobs and economic development opportunities within Oregon and reduce greenhouse gases and other air pollutants.[13]

Energy Efficiency

Learn more about energy efficiency and its benefits in previous ODOE Biennial Energy Reports:

- Beyond Energy Savings – Co-Benefits of Energy Efficiency
- Clean and Efficient Building Technologies
- Energy Efficient Policy Opportunities in Existing Buildings
- Clean and Efficient Vehicle Technology Review

Waste Energy and Environmental Justice

Reducing energy waste through energy efficiency can help address environmental justice issues across many communities and situations. However, access to energy efficiency measures and technology can be challenging for the disadvantaged and burdened groups that most need the benefits. Replacing inefficient equipment can be out of reach for these communities and households because either energy program information is not accessible, or because energy-efficient options often have a higher up-front cost. This, in combination with other factors including historic underinvestment and discrimination for members of these communities, has led to higher energy costs and higher energy burden among the lowest income households and disadvantaged communities.[14]

The production and use of energy often includes local effects on land, air, and water quality. For example, hydroelectric dams can affect water quality as well as fish and other wildlife habitat; natural gas power plants affect air quality; and utility scale solar installations affect landscapes. Neighborhoods near busy roadways and industrial areas have more incidences of respiratory diseases due to higher emissions of particulates and other air pollutants from vehicles and industrial processes. Energy production facilities, which can have effects on local airsheds, watersheds, and viewsheds[iii] are often located near rural and Tribal communities. In Oregon, efforts to ensure energy facility siting is

[iii] Viewsheds are the view of an area from a specific vantage point, such as a local community or town. Energy production facilities in rural areas can interrupt the views of the natural landscape in rural areas.

done effectively and responsibly while honoring community values is on-going. The Oregon Department of Energy has created an engagement guidebook and an Oregon Renewable Energy Siting Assessment mapping tool.[15] Together, these tools provide guidance and data to support stakeholders' and energy developers' needs in navigating decisions around energy facility siting. Gains in efficiency also reduce the need for the associated effects of energy production and use by reducing the need for new plants, and in some cases reducing the impacts by diverting waste streams.

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STATE ENERGY PROJECT UPDATES

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.

Past editions of the Biennial Energy Report included deep-dive Policy Briefs on energy topics. Readers of our 2022 report will remember a multi-part Policy Brief on "Charting a Course for Oregon's Energy Future." In that piece, we discussed potential pathways and trade-offs for reaching Oregon's energy goals while looking at the different sectors: electricity, natural gas, and transportation. The work completed in that brief led to ODOE's report recommendation that Oregon would benefit from a statewide energy strategy.

Following that recommendation, the Oregon Legislature tasked ODOE with developing a new Oregon Energy Strategy. That work is well underway, and the agency will present a final report on the project in November 2025. This section of this report provides an update on the strategy so far. We hope Oregonians will get involved over the next year as we finalize this important work.

This section also provides a short introduction to a new Oregon Energy Security Plan, published by ODOE in September 2024. The plan identifies risks to electricity, liquid fuel, and natural gas/propane systems, and proposes ways to mitigate those risks.

TABLE OF CONTENTS

Oregon Energy Security Plan

In September 2024, the Oregon Department of Energy published the 2024 *Oregon Energy Security Plan*. The plan was developed in collaboration with the Oregon Public Utility Commission and other government and private sector partners, and with contractor support from CNA and Haley & Aldrich. The *Oregon Energy Security Plan* presents an overview of the state's energy infrastructure, quantifies the threats and hazards that could cause energy insecurity, and proposes mitigation measures that the state and its partners can implement to reduce risk.

The energy sector — including electricity, liquid fuels, and natural gas — is vital to the health, well-being, safety, economy, and way of life for Oregonians. Nearly all commerce and critical activities in the state rely on power and liquid fuels to operate and function. A disruption to Oregon's energy infrastructure can directly affect the security and resilience of other necessary systems, such as water or wastewater, health care, education, emergency response, and many others. The Energy Security Plan primarily analyzes natural hazards and human-made risks, including cyber-security and physical attacks on infrastructure. In a world facing increasing challenges from the consequences of climate change, including extreme weather events and wildfires, as well as risks from earthquakes and human-made threats from foreign and domestic terrorism, a state-wide, collaborative approach to assessing threats, reducing risk, and improving energy security is vital.

In 2024 alone, there have been multiple impacts to Oregon's energy systems. In January, Oregon was hammered by a severe winter storm, which included below-average temperatures, high winds, snow, and ice. Conditions lasted for a week or more in many areas, and the consequences to energy systems were extreme. More than 650,000 Oregon customers were without power, and ice-covered roads limited deliveries of liquid fuel. The cold affected the region's natural gas storage and distribution systems, nearly leading to restrictions on gas use and curtailment of power production. Oregon's major investor-owned utilities, smaller co-operative and locally owned electric utilities, and private energy companies had to respond to the effects of the storm in their service areas.

In July and August, central and eastern Oregon have experienced extreme wildfires and 'micro-burst' storm events. The wildfires have burned well over a million acres. As with the winter storms of January, the fires and storms have severely affected Oregon energy companies, including small electric utilities and large investor-owned utilities.

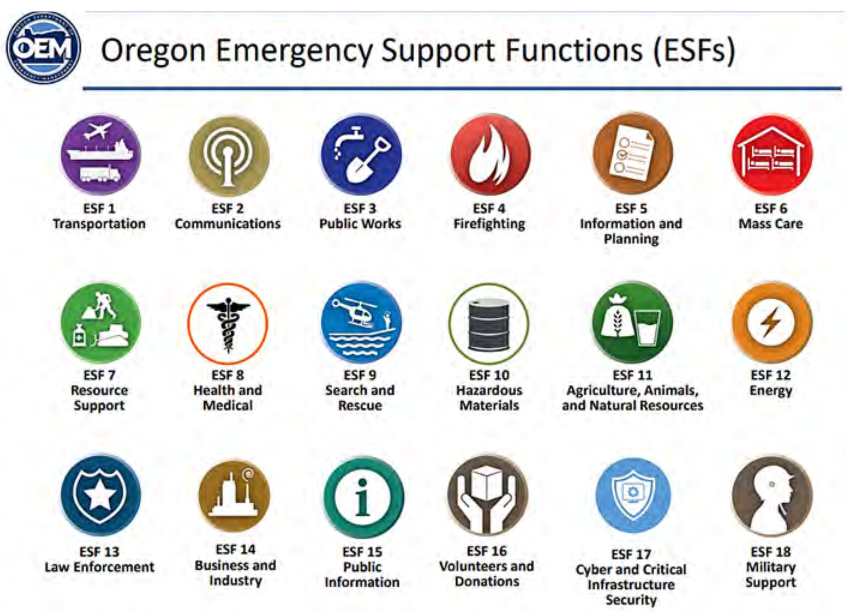
In both cases, natural hazards from extreme weather and wildfire have caused significant damage to Oregon and our energy systems, as well as extreme financial impacts to individuals, families, businesses, communities, and energy providers. Recovery is difficult; small co-operative utilities or locally owned utilities may not have the resources to recover in a timely manner without external support or raising rates on members and customers. A statewide coordinated effort at improving our energy security can help Oregon strengthen preparedness for the next hazard, better withstand the next impact, and reduce our recovery time.

Legislative Requirements

The Oregon Energy Security Plan meets the requirements for a State Energy Security Plan as laid out in the 2021 federal Infrastructure Investment and Jobs Act and in Oregon's Senate Bill 1567 (2022), which in addition to meeting the federal requirements directs ODOE to evaluate strategies to increase geographic diversity of fuel storage throughout the state. The plan, including agency staff time and contractor support, was funded by the federal government through the U.S. Department of Energy's State Energy Program, with money allocated from the IIJA.

Structure and Synopsis

Figure 1: Oregon Emergency Support Functions (ESFs)



The Energy Security Plan is structured in two parts.

The first part provides a foundational overview of energy information and is comprised of Sections I-V. Section I defines energy security and provides an overview of energy security plan requirements, past Oregon energy security planning work, and the planning process for this document. Section II details the entities in Oregon responsible for various aspects of energy security planning, including Tribal Nations, federal agencies, state agencies, and local governments. Section III details Oregon's emergency response structure for energy emergencies. Section IV details the network of coordination among partners for energy security preparedness, response, and longer-term planning. Section V provides a comprehensive overview of energy generation in Oregon.

The second part of the plan, Sections VI-XI, captures more variable information that will be updated regularly. Section VI discusses energy consumption in Oregon. Section VII presents an assessment of threats to Oregon's energy infrastructure, and Section VIII provides a series of mitigation measures for those risks. Section IX provides the results of the fuel storage analysis to increase capacity and geographic diversity of liquid fuel storage across the state. Section X discusses recently completed energy security activities in Oregon and Section XI details upcoming activities and discusses opportunities for further study.

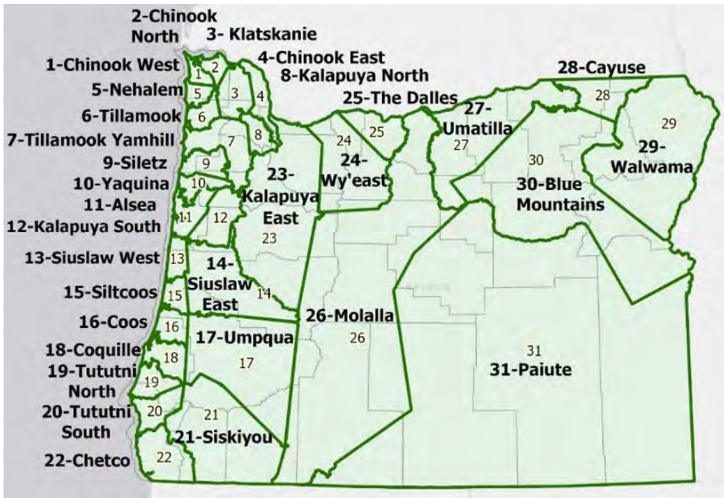
In developing the Oregon Energy Security Plan, ODOE and its team conducted an engagement process with Tribes, the public, utilities and energy companies, and other government agencies. A stakeholder engagement summary report is included as an appendix to the Energy Security Plan.

Key Findings

The risk assessment (Section VII) finds that of the natural, cyber, and physical hazards evaluated, the highest vulnerability to hazards is associated with a Cascadia Subduction Zone earthquake, wildfires, windstorms, and winter storms. Cascadia Subduction Zone earthquake vulnerabilities are highest in the western parts of Oregon, while the level of vulnerability to the other hazards is fairly consistent across the state's other regions. In terms of mitigation measures for these risks (Section VIII), redundancy, hardening, upgrading, and weatherizing are the most recommended physical measures to mitigate vulnerabilities. Other recommended operational measures include additional studies, coordination, and planning.

The fuel storage analysis (Section IX) evaluates fuel storage locations in each of the 31 identified "population islands" in Oregon. Population islands are areas predicted to become isolated from road access as a result of bridge and road failures after a Cascadia Subduction Zone Earthquake. This section also highlights next steps for increasing geographic diversity of fuel storage in the state.

Figure 2: Seismic Population Islands in Oregon



Section XI identifies key future studies and data gaps to address, including: an EV adoption and gasoline demand analysis; exploration of additional uses of rail for emergency fuel delivery; additional infrastructure data; and potential evaluation of climate change, extreme heat, and volcanic activity in the risk assessment.

ODOE will continue to review and update this Energy Security Plan, including collecting and analyzing additional data and considering new threats and risks that emerge to Oregon's energy systems.

Find more information and download the plan from ODOE's website:
https://www.oregon.gov/energy/safety-resiliency/Pages/Energy-Security-Plan.aspx

Energy Strategy Update

The Oregon Department of Energy's 2022 Biennial Energy Report included a Policy Brief about charting a course for Oregon's energy future. The brief led to an overall report 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."*

The Oregon Legislature agreed and directed ODOE, through House Bill 3630 (2023), to develop an Oregon Energy Strategy. The bill requires the strategy to evaluate pathways to meet state energy policy objectives. Focusing on the most affordable solutions, the Oregon Energy Strategy will identify multiple pathways the state could take to maintain a reliable energy system and achieve its anchor greenhouse gas objectives: an 80 percent reduction in greenhouse gas emissions across the economy by 2050; 100 percent clean electricity by 2040 for the state's biggest electric utilities; and a 90 percent reduction in greenhouse gas emissions for natural gas, liquid fuels, and propane by 2050.

ODOE has since embarked on development of the Oregon Energy Strategy. This data-driven process has focused on assessing different options to meet Oregon's energy and climate objectives. ODOE has reached out to Tribes and engaged with the public, data holders, and other state agencies to ensure the strategy is informed by Oregon-specific data and the real-world experiences of Oregonians, communities, businesses, and industry.

The energy strategy will evaluate the costs and benefits of different pathways and develop policy recommendations. Those could be legislative or policy actions, programs, funding, or recommendations on areas requiring further study.

In fall 2023, ODOE issued a project charter and held a public webinar to present the charter and agency plans to issue requests for proposals for consultants. Recognizing that robust data, analysis, and engagement are central to the project, ODOE contracted with both technical and facilitation experts to help develop the strategy.

SCAN OR CLICK

Learn more about the Oregon Energy Strategy and access relevant materials on ODOE's website.

The Clean Energy Transitions Institute is providing technical expertise and analysis to the project. CETI provides independent research and analysis to inform clean energy policy development in the Pacific Northwest. The company partners with Evolved Energy Research, which has developed an energy pathways modeling approach that allows for testing different alternative futures to inform policy discussions. The modeling considers interactions across the economy to test key uncertainties and risks, and to help identify the costs and benefits of different energy choices.

Kearns & West is providing expert facilitation support. K&W specializes in fostering collaboration and strategic communications, helping groups of people and organizations engage in constructive and solutions-driven conversations that take into account and leverage the diverse backgrounds and expertise of all.

In the first few months of the project, ODOE focused on laying the groundwork for the energy strategy. ODOE formed an Interagency Steering Group to ensure the strategy would be aligned with peer agency rules, planning, and objectives.

With the technical, facilitator, and peer agency engagement in place, ODOE launched Phase 1 of the project. This phase focused on developing the energy pathways modeling.

To support this engagement and ensure that a diversity of backgrounds, perspectives, and expertise inform the strategy, ODOE established several consultative structures:

- **Interagency Steering Group**: Serves to ensure ongoing coordination between state agencies. Comprised of the following core Oregon agencies, and engagement with other agencies as needed: Department of Environmental Quality, Department of Land Conservation and Development, Department of Transportation, Public Utility Commission, Business Oregon, Department of State Lands, and Governor's Office.
- **Advisory Group**: Provides insights, advice, and recommendations to the Oregon Department of Energy throughout the process of developing the energy strategy. Comprised of individuals representing a diverse range of a) interests, expertise, and education; b) socioeconomic backgrounds; c) communities; and d) geographic areas of the state.
- **Working Groups**: Serve to inform development of the technical and policy analysis and recommendations for the energy strategy. Comprised of individuals with professional and lived expertise and experience that can help cover the range of topics that HB 3630 directs the strategy to include.
- **Tribal Consultation**: Government-to-Government consultation is an important element of the energy strategy and serves to ensure that tribal priorities, concerns, and interests inform its development. ODOE is conducting outreach to the nine federally recognized Tribes in Oregon throughout the development of the strategy, and engaging with organizations focused on Tribal priorities.
- **Listening Sessions**: Provide an avenue for ODOE to hear from the public on their views regarding important issues relating to the energy strategy during both the technical and policy phases of the project. Listening Sessions are open for anyone to join.
- **Webinars**: Focus on reporting progress at key inflection points in the development of the energy strategy.

During Phase 1, ODOE held four Advisory Group meetings, four Interagency Steering Group Meetings, 14 Working Group meetings, two Listening Sessions, and two webinars. ODOE issued formal letters to each of Oregon's nine federally recognized Tribes at the start of the Oregon Energy Strategy development process in fall 2023 and in spring 2024 prior to launching Phase 1 engagement. In

October 2024, ODOE issued one more letter to invite consultation with Tribes as ODOE lays the groundwork for policy discussions in early 2025.

ODOE's engagement has focused on identifying the most appropriate data sets to inform the model and prioritized gathering Oregon-specific data. The agency worked with the public and different consultative groups to develop modeling assumptions across the buildings, transportation, industry, fuels, and electricity sectors, incorporating considerations relating to environmental justice, equity, and land use.

A Reference Scenario is structured to represent an aggressive but achievable pathway to meeting the state's energy policy objectives, building on existing policies and programs, and on numerous studies that indicate that high levels of energy efficiency and electrification are essential to achieve high levels of greenhouse gas emissions reductions. It will serve as a central point of comparison with Alternative Scenarios that represent other pathways to meet the state's goals.

Building on the Reference Scenario, the Oregon Energy Strategy team undertook further engagement to identify these Alternative Scenarios. ODOE developed six different Alternative Scenarios based on feedback from meetings and written comments. These include scenarios where transmission and large-scale renewable energy development is constrained, where energy efficiency adoption and electrification of transportation and other end-uses occur more slowly, where utilities have less ability to manage loads, and where there is more availability of clean hydrogen.

CETI will be running the Reference and Alternative Scenarios through the end of 2024. In the meantime, ODOE is working with CETI to develop analytical tools to further evaluate the modeling results, including:

- Development of an energy wallet, illustrating energy costs across five representative Oregon households and how they may change over time as Oregon takes different pathways to meet clean energy goals.
- Evaluation of the effects of different pathways on air quality and public health.
- Collection of geospatial data to help further inform policy discussions by providing a deeper understanding of the potential effects of different pathways in different parts of Oregon.
- Analysis of the economic and employment effects of different pathways.

In early 2025, ODOE will launch Phase 2 engagement on the Oregon Energy Strategy with a webinar presenting the modeling results. Building on these, ODOE will facilitate additional conversations to inform development of policy recommendations that support advancement towards Oregon's energy policy objectives.

These conversations will be informed by broad engagement across communities with a diversity of interests to tease out the barriers, opportunities, and challenges in meeting our goals. The results of the modeling and additional analytical tools will help inform these discussions by providing insights into the costs and benefits of different pathways. Ultimately, the goal of the technical and policy analysis is to develop an energy strategy that helps Oregonians make intentional and informed decisions about the state's energy future.

The Oregon Energy Strategy will be presented to the Governor and Legislature by November 1, 2025. The report is expected to include a summary of the energy strategy and pathways to achieving the state's energy policy objectives; policy recommendations; and a description of the engagement process and how Oregonians' perspectives informed the strategy.

ABOUT THE REPORT

The Oregon Department of Energy is pleased to present the **2024 Biennial Energy Report** – the fourth 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 external partners, Tribes, 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. In addition, other agency programs and projects reach out and collect feedback that can inform the Biennial Energy Report, allowing for those questions and ideas to be explored through infographics, Energy 101 articles, and more. 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 responses through a public survey, comment portal, and during staff discussions with Energy Advisory Work Group and other external organizations.

This year, Oregon Department of Energy staff were engaged on two major projects in addition to the Biennial Energy Report: the Energy Security Plan and the Oregon Energy Strategy. There is strong emphasis on updating the Energy by the Numbers section and on Energy 101 content in this edition of the Biennial Energy Report that provides foundational material supporting the Energy Security Plan and the Oregon Energy Strategy, including Alternatives to New Transmission 101, Utility Rate Increase Drivers 101, and Energy Resilience 101.

Later in the process, ODOE also shared a draft Table of Contents with Energy Advisory Work Group members and other external partners to solicit additional feedback. All of this 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 specific equity considerations for this topic?* Incorporating equity in the drafting process prompted additional analysis in the Energy 101s that provided context on equity considerations specific to each topic The development of the Energy Strategy will provide more analysis on more equity issues, including information about how different energy choices might influence consumer costs and air quality outcomes. These analyses support ODOE's strategic focus areas to assess and enhance organizational data capabilities and, in particular, to collect and analyze demographic data to better inform ODOE's work and to identify barriers to achieving equitable energy outcomes.
- Data Management: During each iteration, the Biennial Energy Report has refined internal data collection processes, management roles, and structures. The 2024 report once again included data processing, fact-checking, and validation to ensure report accuracy and quality. 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

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ABOUT THE DATA

The Oregon Department of Energy helps Oregonians make informed decisions about their energy choices and advances 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, supplemented with 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. Department of Energy 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; Energy Trust of Oregon
- State: Oregon Department of Energy; Oregon Department of Transportation; Oregon Housing and Community Services; Oregon Public Utility Commission; Oregon Department of Environmental Quality; Oregon Health Authority; Oregon Department of Administrative Services
- Utilities and energy service providers
- Energy associations and organizations

Notable changes were made to both the methodology and collection of the data used in this iteration of the report.

The biggest change relates to U.S. Energy Information Administration State Energy Data System, which is the data source behind much of the Energy by the Numbers section. The EIA converts all forms of energy use into British thermal units, or Btus. This conversion helps compare and contrast energy consumption across different energy types, including electricity and fossil fuels. For electricity, this generally is calculated by comparing the primary fuel combusted – natural gas or coal – with the amount of electricity generated. For noncombustible generation resources, such as hydroelectric, geothermal, solar, and wind, this value must be a proxy or estimated value because there is no fuel combusted to produce the electricity.

Previously, the EIA used a "fossil fuel equivalency" method, which applies a proxy value for Btus for these resources based on a calculation that averages fuel consumption for all fossil-based generating plants. This proxy value represents the energy consumed as if the electricity were generated by fossil fuels. This value changed year-to-year as combustible generation changed. EIA's new "captured energy approach" applies a constant conversion factor based on the heat content of electricity itself. This is a static value and is more consistent with international energy calculations. The value of the static captured energy approach proxy is lower than the fossil fuel equivalency value.

The change in methodology has created some anomalies in historical renewable energy consumption data presented in the report. This is because it produces significantly lower values for total electric energy consumption, driven by the lower calculated consumption for the noncombustible hydro, solar, wind, and geothermal resources serving Oregon load. In most cases, overall trends in consumption data remain consistent with previous reporting, although anomalies can be seen in some year-to-year comparisons between data presented in the 2020 and 2022 Biennial Energy Reports.

Other changes to the data resulted from changes to data sources for two topics in Energy by the Numbers: the County Profiles and Oregon's Electricity Resource Mix.

In previous reports, we used Oregon Department of Housing and Community Services' County Profiles Dashboard as the data source for home energy burden costs. The data provided in the OHCS dashboard is necessarily focused on housing accessibility and affordability. The purpose of this report is to provide key information on the accessibility and affordability of energy services, so ODOE analyzed the primary data sources that inform the OHCS dashboard to produce energy-specific information with county-level demographic data. Data sources for the County Profiles include the U.S. Census Bureau, the Home Energy Affordability Gap, the Oregon Public Utility Commission, the U.S. Department of Health and Human Services, and the Housing and Transportation Affordability Index.

The data presented in Oregon's Electricity Resource Mix have also changed, largely affecting how the data on electricity market purchases are presented. ODOE now collects data on electricity produced for Oregon consumers from the Oregon Department of Environmental Quality, rather than directly from utilities. Because electricity generation is a primary input for the state Greenhouse Gas Reporting Program, this process ensures consistency of energy data across state agencies, and is a more efficient data collection process from the utilities.

While this change to the production of the ERM is more efficient and consistent, it does not currently provide the necessary data to calculate a specific resource mix for utility market purchases. ODOE has previously produced this information using an external contractor who analyzed data and information about the resources committed across the Pacific Northwest region to produce a mix of likely resources contributing to the market. While this assessment was sufficient to produce a reasonable assessment of the market purchases resource mix, growth in participation in energy imbalance markets and increasing reliance on electric utility market purchases has made this process more challenging and will increasingly produce results that are less certain. As a result, ODOE made the decision to no longer provide this specific data breakout.

Data presented on in-state electricity generation facilities were also modified and improved since the last report. Data were updated to not only include new facilities and remove resources that were retired, but ODOE also conducted an audit of the data and identified several generators serving the same facility that were listed as separate facilities. The data now align with the U.S. EIA in how it identifies generators at the same facility – with unique identifiers assigned based on how the site was permitted and installed. Where ODOE found generators at the same site and with the same unique EIA identifier listed separately, the information was consolidated under a single facility. This appears as a drop in the number of sites when compared to previous reports. However, this is not reflective of actual trends, since only one wind facility and one coal plant in Oregon were retired between 2020 and 2024.

It's important to note that data reported between 2020 and 2022 were influenced by changes in energy consumption resulting from the response to the COVID-19 pandemic. This led to many data points in these years that did not align with previous trends and outcomes. Where analysis provides insights into how the pandemic affected energy trends, ODOE has provided that information. While there is only a single year of post-pandemic response data, ODOE also provides an assessment of whether recent energy data are or are not indicating a return to pre-COVID trends. Future versions of this report will have additional data that provide a more complete understanding of how COVID-19 affected our energy production and consumption.

We are proud of this report and how the data have 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 report about Oregon's energy resources, activities, trends, and forecasts, and the data and analysis presented 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.