Energy Resource and Technology Reviews

Rapid advancements in resources and 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 updated information on electricity generation, clean vehicle technologies, and fuels. This includes technologies that people are familiar with, like hydro, solar, and natural gas electricity generation, but also ones that are less well known, like conduit hydro and biogas. Gasoline and diesel fuels remain the primary transportation fuels in Oregon, but renewable diesel and electricity are growing, fundamentally changing the mix of fuels that underpins the state's economy. The growth in electric vehicles is also changing Oregon's energy landscape, with EV charging becoming increasingly prevalent across the state.

Innovation is a cornerstone of fundamental change, and new and improved technologies are certain to play an important role in Oregon's energy future. Another 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. In the 2026 report, we included overviews of up-and-coming grid technologies that could play a role in Oregon's energy future, focusing on those highlighted in the Oregon Energy Strategy. This new section was developed in response to Executive Order 25-29, which directed ODOE to report on up-and-coming technologies that can help the state achieve its energy and climate goals.

Previous Biennial Energy Reports have also included resource and technology reviews that cover more energy innovations. 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 previous reports.

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Electricity Generation Technologies

Hydroelectricity Generation

Total capacity in Oregon	**9,026.85 MW**
Number of utility-scale facilities	**91**[i]
Resource share of electricity consumption	**33.91%**
Total generation	**26.93 million MWh**
In-state consumption	**21.17 million MWh**
Exports	**5.77 million MWh**

Technology Overview



Hydropower converts the energy of moving water into electricity using turbines connected to generators.[1] This includes generators at large dams in the region, but also smaller dams along tributary rivers. Hydropower is also generated by water flowing through pipes, which is described in the Conduit Hydropower Energy Resource and Technology Review. As the largest source of electricity generation in Oregon and the broader Pacific Northwest, hydropower is renewable and can be a dispatchable energy resource that allows operators to increase or decrease electricity generation to meet changing electricity demand by directing more or less water though the turbines. This attribute helps balance the ebb and flow of electricity from variable resources like solar and wind, and respond to fluctuations in electricity demand. Most hydropower facilities operate either as water storage reservoirs behind a dam that can be released as needed, or as run-of-river systems that use the natural flow of rivers. Dams can also be designed with pumps that can move water to a higher elevation when water is plentiful to serve as storage for times when more electricity generation may be needed. Hydropower operations must be balanced with the other uses that rivers serve, including fish habitat, irrigation, recreation, and navigation.

Hydropower has been foundational to the Pacific Northwest economy since the early 1900s, providing power to rural areas, navigable waterways for goods, support for agricultural activities in arid parts of the region, and a source of low-cost electricity. Like other electricity generation resources, dams have also had an impact on the region's cultural and ecological health. Many were built on Tribal lands and affected Tribal resources without permission or compensation for damages.[2–4] For example, construction of The Dalles dam flooded Celilo Falls, important Tribal fishing grounds that served as an economic center of Columbia River Tribal economies.[5] The dams have also disrupted the ecology of the region's rivers, leading to diminishing numbers of salmon and other fish species that are

[i] This does not include conduit hydropower facilities.

traditional First Foods for Tribes and contribute to the regional economy. Significant investments through Bonneville Power Administration, state, and Tribal governments have and are being made to mitigate these effects.

Trends in Oregon

Figure 1: Share of Hydro Electricity Consumed in Oregon

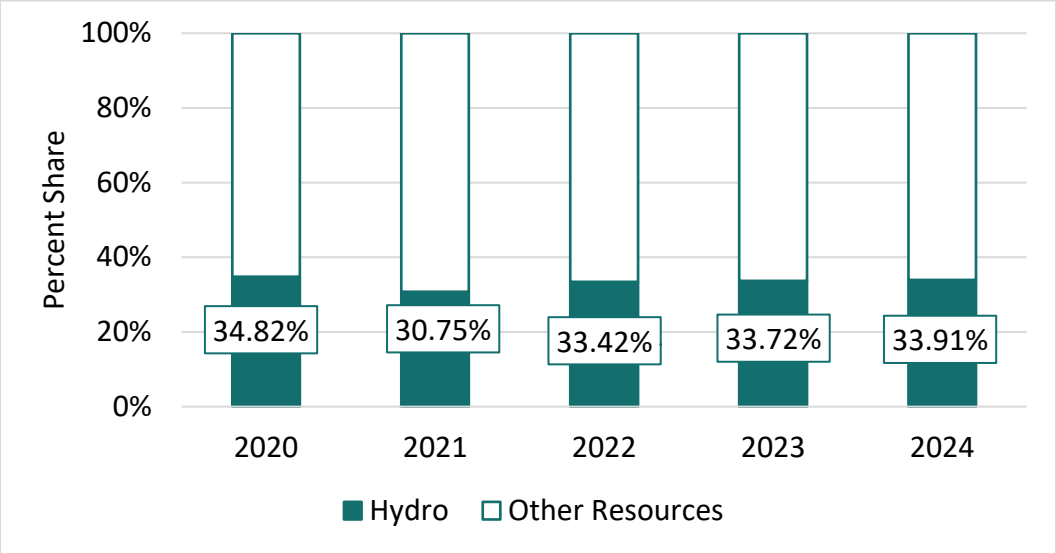
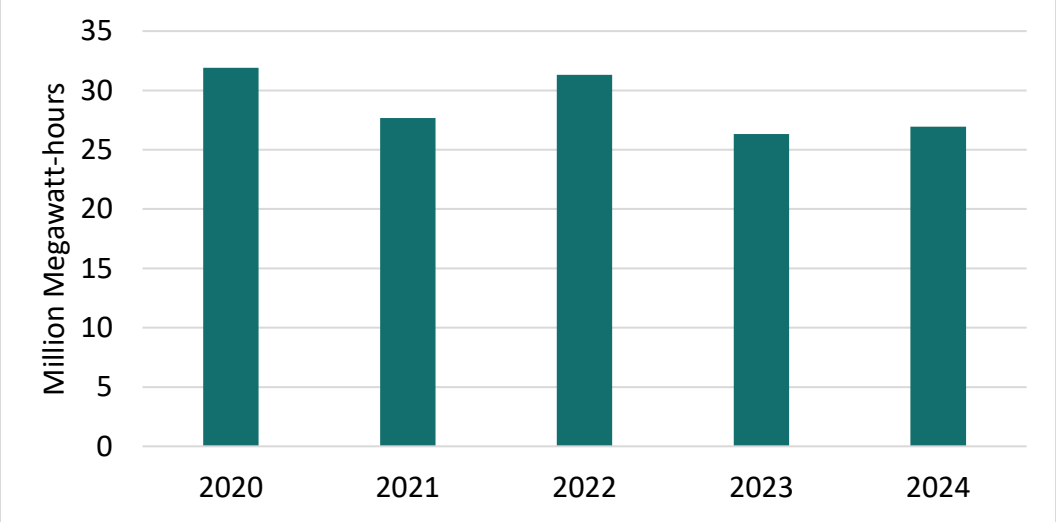


Figure 2: Amount of Hydro Electricity Generated in Oregon



Hydropower provides about a third of the electricity Oregonians use, though consumption fluctuates between seasons and from year-to-year. It comprises over 50 percent of the electricity generated in the state. Most of Oregon's hydropower is generated by federal and utility-owned facilities, and annual generation varies primarily with precipitation and mountain snowpack. Hydropower is an important resource for achieving Oregon's clean electricity goals, because it is non-emitting and can help support increasing amounts of variable renewable resources. The development of new large dams is unlikely given the high up-front cost, environmental risk and mitigation measure expenses, and land use needs. However, improving and modernizing existing facilities continues to occur. Ongoing dynamics between NW Tribes, the States of Oregon and Washington, and the federal

government regarding the Columbia River dams and fish passage are also leading to changes in the operation of dams.[6]

Climate change is affecting hydro electricity generation outputs. The warming climate reduces average annual snowpack amounts, which the system relies on as storage that is slowly released during the drier months of summer. Climate change is also affecting rainfall patterns, which in addition to affecting snowpack, is changing water levels across the year. At the same time, climate change is also creating more heatwaves in the summer months, creating higher electricity demand from cooling at a time when hydro resources are often at seasonal lows. These changes are expected to continue, affecting the future level of hydropower availability in Oregon and the region.

Additional Resources

- U.S. Energy Information Administration: Hydropower explained
- Bonneville Power Administration: Hydropower 101
- 2026 Biennial Energy Report: Energy by the Numbers – Electricity
- U.S. Department of Energy: Hydropower Basics
- U.S. Energy Information Administration: Hydropower and the environment

Natural Gas Electricity Generation

Total capacity in Oregon	**4,483 MW**
Number of utility-scale facilities	**13**[ii]
Resource share of electricity consumption	**20.4%**
Total generation	**24.9 million MWh**
In-state consumption	**12.7 million MWh**
Exports	**12.2 million MWh**

Technology Overview



Natural gas facilities combust fuel to propel turbines and engines that in turn generate electricity.[7] Natural gas facilities can increase or decrease production to reliably meet power demand, but the production efficiency and flexibility are determined by how they are designed to operate and their age. There are many types of natural gas generation technologies, but essentially they fall into two categories: combined cycle or peaker plants. Combined cycle units are designed to provide efficient, low-cost, and consistent

[ii] Includes combined heat and power facilities, campus generation, and other facilities using natural gas to produce electricity onsite and to be distributed by a utility.

baseload power over long periods. Peaker plants[iii] are capable of rapidly ramping up output to meet peak demand but are generally less efficient and therefore cost more to operate. While all natural gas plants play a role in meeting demand and complementing production from variable renewable generation resources, peaker plants are operated less frequently because of their higher operational costs. Over time, technological innovations have led to efficiency improvements in natural gas generation technologies, which means older plants tend to be less efficient, and thus more expensive to operate.

Natural gas is the second largest generating resource in Oregon behind hydropower. In 2024, generation from in-state and out-of-state facilities supplied 12.7 million megawatt-hours of electricity to Oregonians, a little more than 20 percent of Oregon's total electricity consumption. Facilities located in Oregon produced over 24 million MWh in 2024, helping meet state and regional demand. Oregon exports more electricity from natural gas than it imports. Because they are available to operate most of the time, natural gas generators can be a go-to resource whenever more power is needed. However, natural gas production and combustion both emit greenhouse gases. Emissions from natural gas generation are growing and now account for about 35 percent of emissions from electricity generation serving Oregon. If this trend continues, natural gas may surpass coal, which is currently the largest emitter of greenhouse gases resulting from Oregon electricity consumption, but is declining.

Natural gas is comprised of methane, a greenhouse gas that is more potent than carbon dioxide. Methane emissions that occur during the extraction, transport, and combustion of natural gas directly affect land, water, and air quality and contribute to climate change. Natural gas extraction and distribution pipelines require clearing land and drilling into the earth, producing air pollutants from equipment and flaring. Extraction also produces large volumes of contaminated wastewater that must be treated and disposed of appropriately to minimize polluting nearby lands and waters.[8] Natural gas combustion in Oregon and the region also releases nitrogen and sulfur oxides, particulates, and other pollutants, though power plants are required to have controls to reduce emissions.[iv] They generally require less land than wind or solar developments, depending on the type and size of the facility. Plant operations typically require water for cooling purposes. Most of the water is discharged back into the environment, but this can raise temperatures in local waters, which may negatively affect local ecosystems.[9] [10]

[iii] Peaker plants include simple-cycle turbines, steam turbines, and internal combustion engine forms of power generation, all of which are often referred to as "peaker" plants.

[iv] Electricity generating facilities must report greenhouse gas emissions to the Oregon Department of Environmental Quality. DEQ's Cleaner Air Oregon regulates emissions of toxic air contaminants from facilities based on risk to nearby communities. Cleaner Air Oregon requires facilities to report toxic air contaminant emissions, assess potential health risks to people nearby and install emissions controls to reduce toxic air contaminant risk if it exceeds legal limits.

Trends in Oregon

Figure 3: Share of Natural Gas Electricity Consumed in Oregon

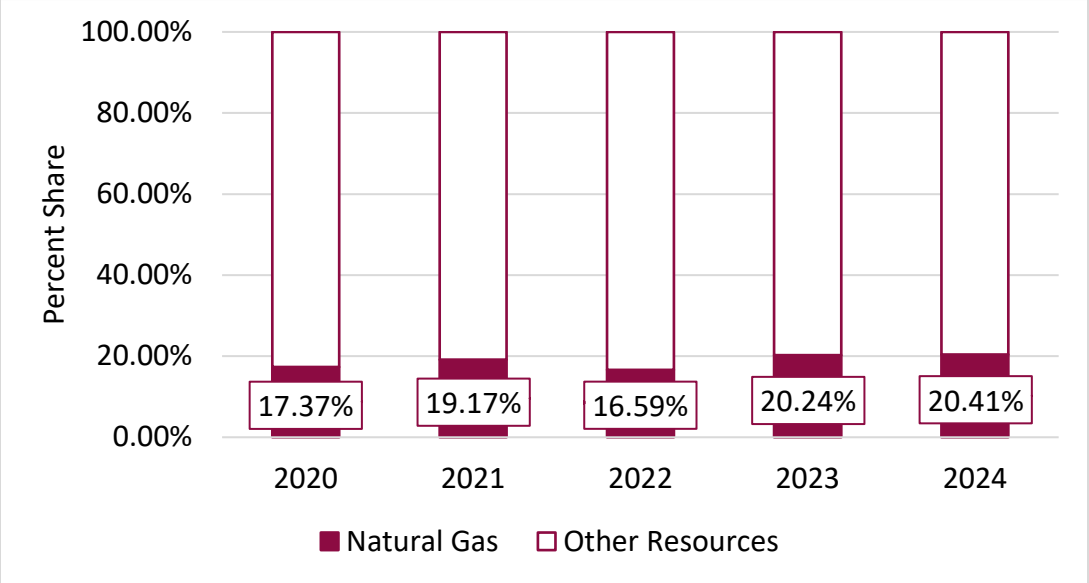
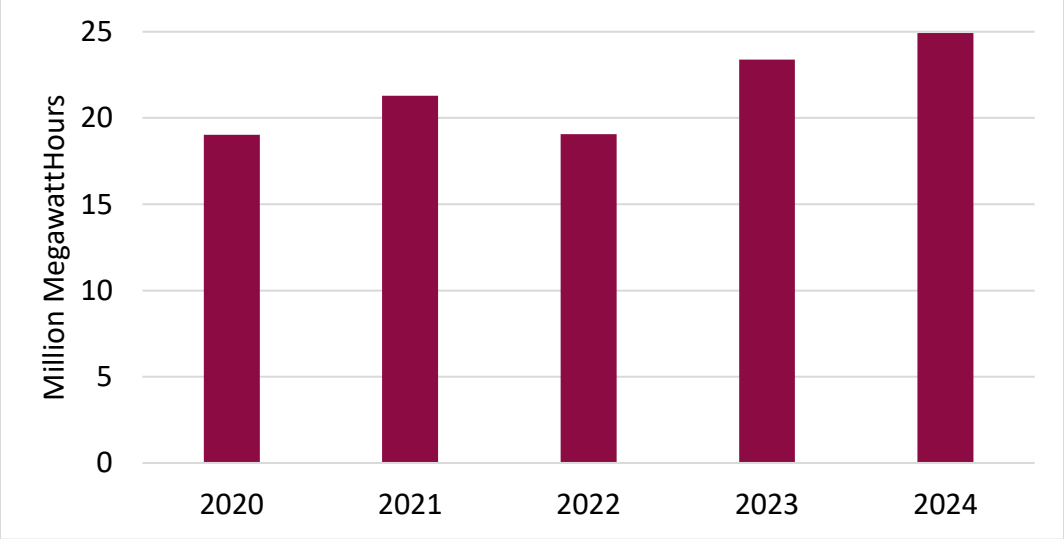


Figure 4: Amount of Natural Gas Electricity Generated in Oregon



Natural gas consumption has been steadily growing in Oregon, but whether that growth continues in the near-term is uncertain. Growth is driven by declining coal generation in Oregon's electricity mix, rapidly rising electricity demand, and the need to balance variable renewable energy resources. At some point, however, natural gas consumption will likely begin to decline. Utilities are testing and adopting many different technologies that can provide reliable electricity while also reducing greenhouse gas emissions. These will help the state's two largest utilities meet Oregon's clean electricity targets, which necessitates reductions in natural gas generation. At the same time, changes to Oregon's electricity system to achieve state targets need to be balanced with the need to maintain grid reliability, resilience, and affordability.

The future of natural gas electricity use in Oregon depends on many factors, including load growth, technological advancements in grid technologies and operations, energy costs, and state and federal policies. The proliferation of data centers in Oregon and across the Pacific Northwest is creating a

need for additional round-the-clock electricity supply, but how much demand and by when is highly uncertain. More or less natural gas may be needed depending on how quickly demand grows, where the load is located on the grid, how much of the expected load growth materializes, and whether new clean energy technologies can compete with natural gas to reliably serve load. All of these factors will affect the amount of natural gas in Oregon's electricity resource mix.

It is unlikely that new large-scale natural gas electricity generation resources will be built in Oregon in the near-term. Several states in the West, including Oregon, have established clean energy policies and targets that discourage natural gas development and use. Oregon statute prohibits the state's Energy Facility Siting Council from approving new natural gas permits, which applies to any natural gas facility to be located in Oregon that has a capacity of 25 megawatts or larger. However, natural gas plants can and are being developed across the broader Pacific Northwest, and these may contribute power to regional wholesale markets.

Additional Resources

- U.S. Energy Information Administration: Natural gas explained
- 2020 Biennial Energy Report Natural Gas Energy 101
- 2026 Biennial Energy Report: Energy by the Numbers – Electricity
- American Gas Association: Back to Basics Natural Gas 101
- U.S. Energy Information Administration: Natural gas and the environment

Coal Electricity Generation

Total capacity in Oregon	**0 MW**
Number of utility-scale facilities	**0**
Resource share of electricity consumption	**8.29%**
Total generation	**0 MWh**
In-state consumption	**5.17 million MWh**
Exports	**0 MWh**

Technology Overview

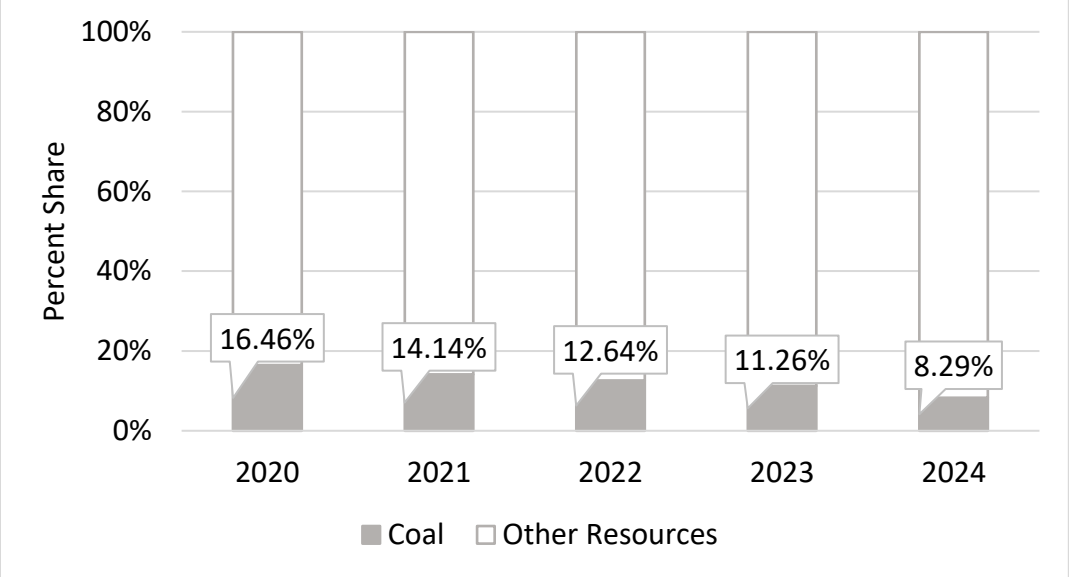
Coal-fired power plants generate electricity by combusting coal to produce high-pressure steam that drives electricity-generating turbines.[11] They can provide consistent power throughout the year but are not engineered to meet hourly changes in demand. Coal accounts for approximately 8.29 percent of Oregon's electricity consumption. All coal-generated electricity consumed in Oregon is imported. Coal generators likely contribute to Oregon's electricity mix from purchases made through wholesale electricity markets, which is not included in the above percentage. Oregon has no active coal mining, processing operations, or generating facilities.

Coal is a non-renewable fossil fuel that is abundantly available in the United States. It is also a carbon-intensive resource, producing higher greenhouse gas emissions per megawatt-hour than any other form of electricity generation. More efficient coal generators, known as supercritical coal, produce fewer emissions but still more than a typical natural gas plant. Significant greenhouse gas emission

reductions can be attained with carbon capture and storage technologies, but these reduce the plant's overall efficiency and significantly add to its capital and operating costs.

Trends in Oregon

Figure 5: Share of Coal Electricity Consumed in Oregon



Coal's contribution to Oregon's electricity supply has continued to decline over the last five years, reflecting a longer-term national trend driven by cost, technological innovations, and federal and state policy. Beginning in the 1990s, natural gas increasingly displaced coal as the lower cost generation resource, and technological innovations have reduced the cost to develop solar and wind, increasing competitive market pressures. At the same time, federal and state air and water quality mitigation requirements have increased operational expenses for coal plants, making them less economically viable. In 2016, the Oregon legislature passed SB 1547, which restricts Oregon's investor-owned utilities from recovering costs for coal generation beginning in 2030.[v]

Particularly in areas of the country without significant hydropower resources, coal generation was foundational to the early decades of the grid, providing a low-cost, reliable resource to meet electricity demand. Coal mines and power plants served as key drivers for economic development in the communities they operated in, providing jobs, tax revenue, and supporting local economies. However, coal also has well-documented environmental and public health drawbacks. Mining and combustion activities contribute to degraded air and water quality, with associated respiratory and ecological impacts in surrounding communities. Coal combustion is a major source of greenhouse gases and other pollutants, making it a significant driver of climate change. As these environmental and health costs have become clearer, and as cleaner, lower-cost alternatives have matured, the role of coal in Oregon's energy mix has diminished and will continue to do so under current policy and market conditions.

[v] SB 1547 included an exception allowing five additional years for a coal plant which has no more than four generating units and in which the IOU owns a minority share.

Additional Resources

- U.S. Energy Information Administration: Coal Explained
- U.S. Department of Energy: Coal Fact Sheet
- 2026 Biennial Energy Report: Energy by the Numbers – Electricity
- U.S. Energy Information Administration: Coal and the environment

Wind Electricity Generation

Total capacity in Oregon	**3,863 MW**
Number of utility-scale facilities	**48**
Resource share of electricity consumption	**7.85%**
Total generation	**9.5 million MWh**
In-state consumption	**4.9 Million MWh**
Exports	**4.6 Million MWh**

Technology Overview



Wind energy facilities produce electricity by capturing the kinetic energy (movement) of wind, which is a renewable resource.[12] Wind power is considered a variable energy resource because power production depends on wind conditions. Most of Oregon's existing wind energy facilities were built along the Columbia River Plateau. Facilities in this area produce more electricity at night than during the day, and more electricity during the spring and early summer than fall or winter.[13] Some Oregon utilities import wind power from Montana, which has different wind conditions and produces more electricity during the winter than the summer. There is some interest in developing wind facilities offshore where the wind tends to be stronger and more constant.

Wind energy facilities are economical to build and low cost to operate since the resource (wind) is free. Their operations also do not affect local air quality and do not emit greenhouse gases. However, wind energy facilities can negatively affect wildlife, particularly birds and bats that may collide with the turbine blades. Wind facilities also have a large footprint, but most of the land can still be used for other purposes, such as farming around and between each wind turbine tower. There is significant interest in expanding recycling opportunities for used facility components, which otherwise would substantially contribute to landfill volumes.

Trends in Oregon

Figure 6: Share of Wind Electricity Consumed in Oregon

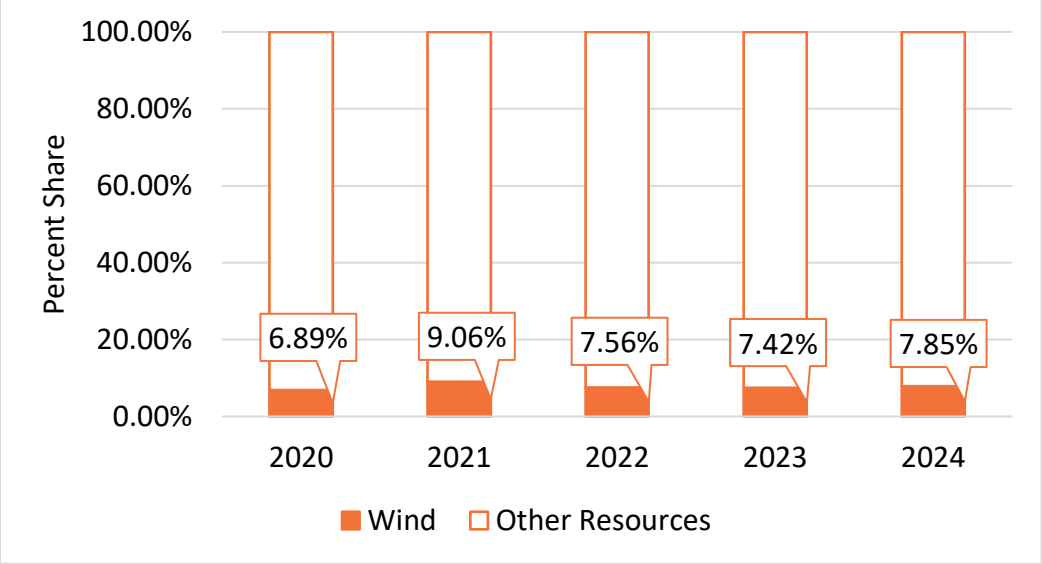
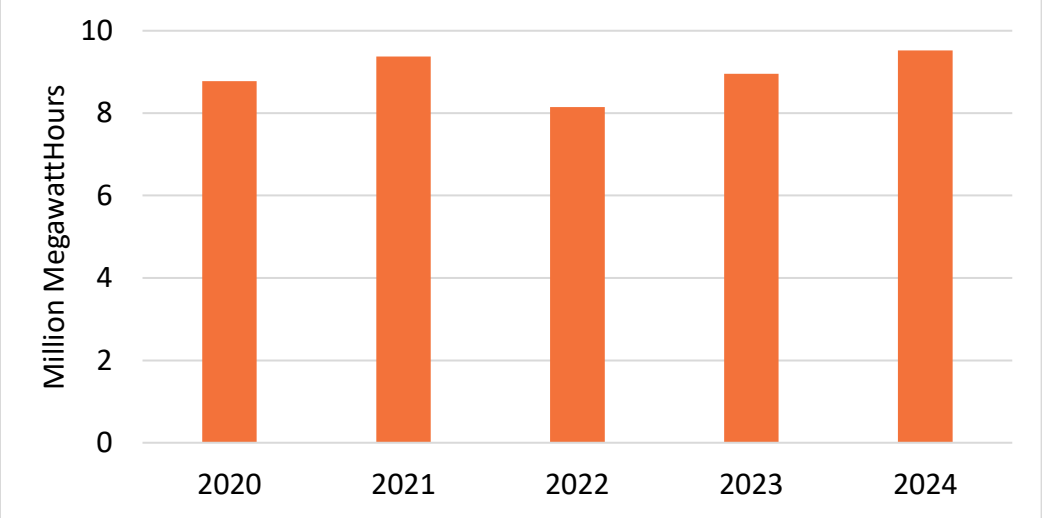


Figure 7: Amount of Wind Electricity Generated in Oregon



Wind energy is commercially available and cost competitive to deploy. The technology continues to advance, making more areas potentially viable for wind energy development, including offshore, and offering increased output at older sites if they are repowered with more modern and efficient equipment. Growing electricity demand from data centers, electrification, and other sources provides a likely market for new wind energy facilities. However, federal policies and incentives for wind and solar have fluctuated significantly in recent years, which may deter or delay new development.

Additional Resources

- U.S. Energy Information Administration: Wind explained
- U.S. Energy Information Administration: Renewable energy explained
- 2026 Biennial Energy Report: Energy by the Numbers – Electricity

- U.S. Energy Information Administration: Wind energy and the environment
- U.S. Department of Energy: Wind Turbine Recycling
- Tethys: Enabling Coexistence Options for Wind Energy and Wildlife

Solar Electricity Generation

Total capacity in Oregon	**1,369.02 MW**
Number of utility-scale facilities	**164**
Total (DC) capacity of residential/commercial units	**182.99 MW**
Resource share of electricity consumption	**3.9%**[vi]
Total generation	**2.16 million MWh**
Utility-scale generation	**2.00 million MWh**
In-state consumption	**2.44 million MWh**[vii]
Exports	**0 MWh**

Technology Overview



Ground mounted solar at the Gresham wastewater treatment plant.

Solar energy is radiant light and heat from the sun that can be collected and used to generate electricity.[14] Solar photovoltaic panels are the most common technology for generating electricity from solar energy. Cells in the panel capture solar photons, which are used to produce electrons that flow along wires embedded in the panel. Panels may be placed on residential or commercial rooftops for energy use or ground mounted for large utility-scale electricity generation. Solar panels produce energy during daylight hours, and the amount of energy they produce varies depending on location, time of day, season, and weather conditions. This means solar is a renewable but also a variable generation resource because it produces electricity only when there is sunlight. Increasingly, solar facilities are using batteries to store solar energy generation before use in the evening or other times when it is most needed.

Solar electricity production does not generate air pollutants, including greenhouse gas emissions, particulate matter, or pollutants that lead to smog. Like most technologies, there are air pollutants generated in the production of the panels and other materials needed for solar facilities. Most utility-scale solar facilities are built on large land parcels close to a utility substation or distribution lines. Siting these facilities may compete with agricultural and industrial interests, which has led to concerns

[vi] Solar's Resource Share of Oregon's Electricity Mix only includes consumption of utility-scale solar power generation, not residential and commercial solar such as rooftop generation.

[vii] Consumption data for Solar power use in Oregon refers only to utility-scale solar.

about land use needs, especially for land designated for agricultural use. Utility-scale solar facilities typically require 5 to 7 acres per MW of capacity. Rooftop solar can help offset some of the electricity needs for the buildings they reside upon and some agricultural uses can be co-located with solar panels.

Trends in Oregon

Figure 8: Share of Solar Electricity Consumed in Oregon

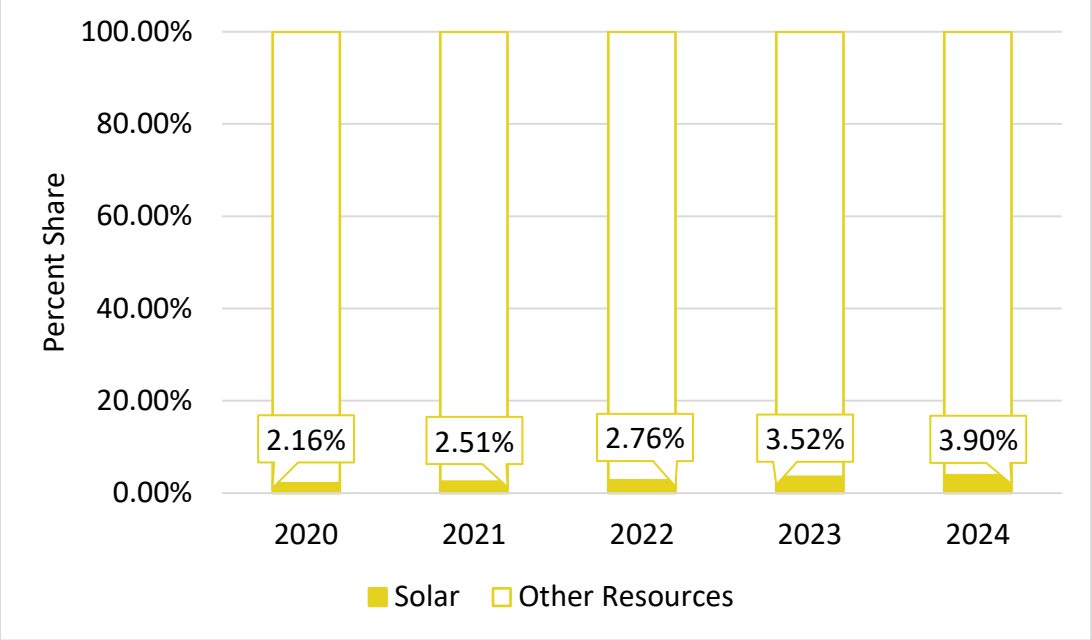
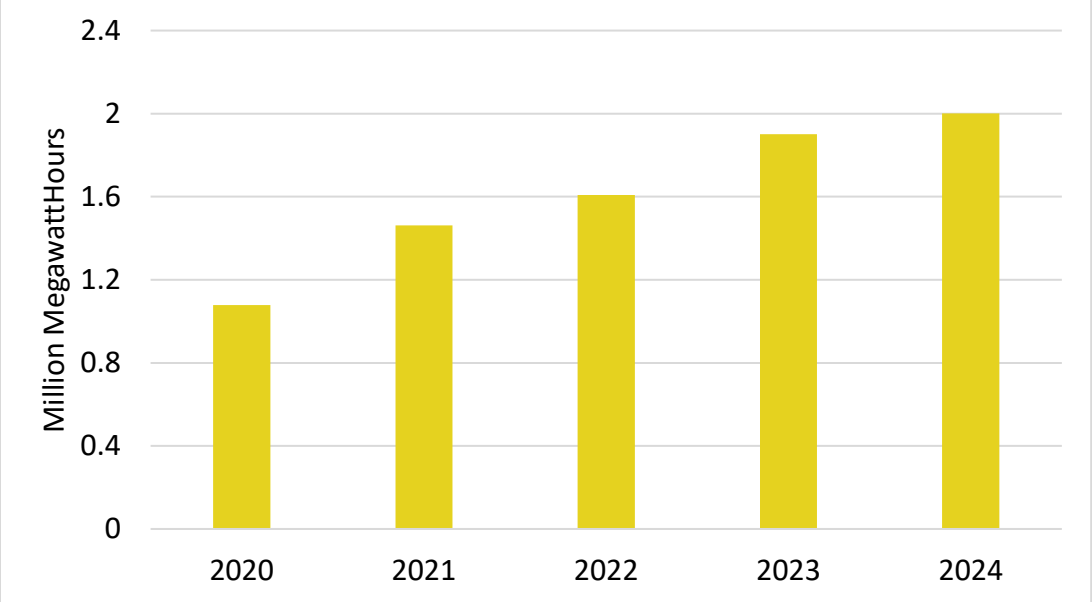


Figure 9: Amount of Solar Electricity Generated in Oregon



Solar generation is the fastest growing electricity resource in Oregon, more than doubling since 2019 with 3.375 megawatts of new capacity installed in 2025. This increase is largely due to the low cost of building and operating solar facilities compared to other types of generation, bolstered by federal tax credits.[15] Utility-scale and other large commercial solar projects are expected to increase in 2026 as

developers race to complete construction by the end of 2027 to qualify for expiring federal tax credits. However, even without tax credits, utility-scale solar is likely to continue to grow in Oregon because it is often the electricity generation resource option with the lowest construction and operating costs, and it contributes to compliance with Oregon's clean electricity targets.

Future adoption trends for rooftop solar are less certain. Installing rooftop solar requires a large up-front investment, which may take more than a decade to pay for itself in reduced electricity bills. The federal residential energy tax credit that helped address some of these costs was eliminated by H.R. 1 in 2025. The Oregon Solar + Storage Rebate Program that supported nearly 7,000 solar and battery installations since 2020, including more than 1,300 on low- and moderate-income households, ran out of funds in 2026. Energy Trust of Oregon and some consumer-owned electric utilities continue to offer financial incentives for solar installations. Rising costs for electricity and growing interest in energy resilience may bolster the residential rooftop solar market in the near future. Higher electricity costs reduce the payback period for rooftop solar investments, making them more appealing for consumers. Climate change may also bolster the market for rooftop solar and battery installations, as wildfires and extreme weather events are driving interest in backup power systems.

Additional Resources

- U.S. Energy Information Administration: Solar explained
- U.S. Energy Information Administration: Renewable energy explained
- 2026 Biennial Energy Report: Energy by the Numbers – Electricity
- U.S. Energy Information Administration: Solar and the environment
- Oregon Department of Energy: Oregon Solar Dashboard

Nuclear Electricity Generation

Total capacity in Oregon	**0 MW**
Number of utility-scale facilities	**0**[viii]
Resource share of electricity consumption	**3.79%**
Total generation	**0 MWh**
In-state consumption	**2.37 million MWh**
Exports	**0 MWh**

Technology Overview

Nuclear fission energy comes from splitting atoms in reactors containing radioactive fuel to heat water into steam, which turns a turbine to generate electricity.[16] In 2024, nuclear power facilities provided about 19 percent of the electricity consumed in the U.S., second only to natural gas.[17] [18] Nuclear provided close to 4 percent of the electricity Oregonians consumed in 2024, behind hydro,

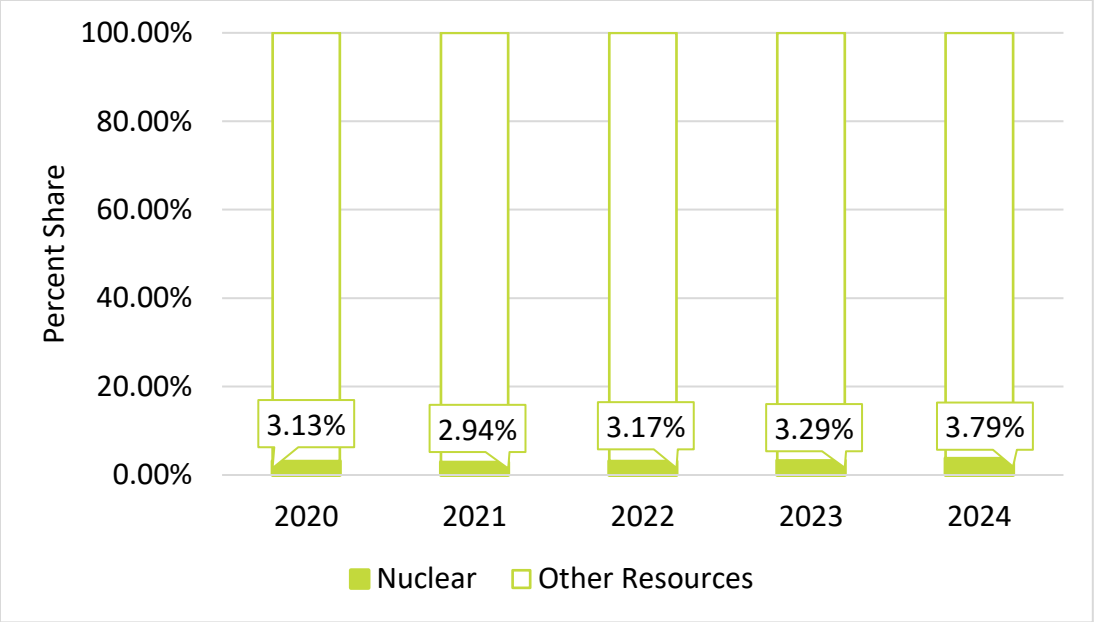
[viii] There are two research reactors in Oregon, located at Reed College and Oregon State University, but these do not produce electricity and are only used for research and training.

natural gas, coal, wind, and solar. Nuclear facilities typically operate more than 90 percent of the time, providing a consistent output of electricity. Existing reactors are not designed to ramp up or down. They are also typically large generators, with most existing reactors rated between 1,000 and 1,600 megawatts of capacity. For reference, the rated capacity of Bonneville Dam is 1,162 MW.[19] There are no nuclear power facilities operating in Oregon since the closure of the Trojan plant in the early 1990s. The Bonneville Power Administration markets power from the Columbia Generating Station nuclear plant in Washington to its customers, including many Oregon utilities.

Nuclear energy does not emit greenhouse gas emissions, but it can affect the environment and communities. Reactors generate radioactive waste that remains hazardous for tens of thousands of years, and most waste is stored on site.[20] For example, spent fuel from Trojan's operations is stored on site in dry casks, pending availability of a federal disposal facility. Site operators must handle and store waste according to federal guidelines to avoid contaminating local water and land resources. Because reactors create hot water for steam, they not only consume water for cooling but also discharge water back into the local environment. This could stress water resources in arid areas. Discharged water can raise temperatures in local waters, which may negatively affect local ecosystems.[9]

Trends in Oregon

Figure 10: Share of Nuclear Electricity Consumed in Oregon



Nuclear generation has provided a share of Oregon's electricity mix for many decades, serving about 2-4 percent of Oregon's electricity load since 2020. The high up-front capital costs of nuclear power plants when compared to solar, wind, energy efficiency, or even procuring additional power through wholesale markets has limited the options for the further development of nuclear energy in the Pacific Northwest. In addition, legal restrictions make nuclear power development in Oregon less likely in the near future. State law prohibits siting new nuclear plants in Oregon unless the federal government opens a permanent geologic repository for used nuclear fuel and voters approve a site certificate issued by the Energy Facility Siting Council for a facility. There is momentum at the federal level to site

one or more used nuclear fuel disposal facilities, but it will take many years before such a facility could be sited and begin operating.[21] The need for more electricity supply is spurring some data center developers to push for reopening previously shuttered nuclear power plants, including in Pennsylvania, Michigan, and Iowa, but there are no viable decommissioned plants in the Pacific Northwest that could be reopened.[21]

Utilities operating in Oregon could still build plants in or purchase nuclear power from other states. While conventional nuclear power is often too expensive to be considered a competitive energy resource to build, interest is growing in the development of advanced nuclear power. This is inclusive of a variety of new technologies that can produce electricity, potentially at lower costs and with more operational flexibility than traditional nuclear power. In its 2025 Integrated Resource Plan update, PacifiCorp included nuclear power from Kemmerer Unit 1, an advanced nuclear plant being constructed in Wyoming, in its preferred portfolio.[22] PacifiCorp is intending to allocate some of that power to Oregon customers through its subsidiary, Pacific Power, beginning in 2032. In addition, advanced nuclear power plants are under development in Washington and Idaho, all of which could potentially provide power for Oregon consumers.

Additional Resources

- U.S. Energy Information Administration: Nuclear explained
- U.S. Department of Energy: Nuclear Energy
- 2026 Biennial Energy Report: Energy by the Numbers – Electricity
- U.S. Energy Information Administration: Nuclear power and the environment

Biomass Electricity Generation

Total capacity in Oregon	**297.8 MW**
Number of utility-scale facilities	**14**
Resource share of electricity consumption	**0.7%**
Total generation	**1.09 million MWh**
In-state consumption	**446,895 MWh**
Exports	**372,200 MWh**

Technology Overview



Biomass, such as agricultural and forestry residuals, animal and food waste, and the organic portion of municipal solid waste, can be burned to generate electricity.[23] The biomass is burned in boilers to create steam that drives turbines, or it can be converted into a synthetic gas to fuel generators. In 2024, about 0.7 percent of the electricity consumed in Oregon came from combusting biomass. Biomass is considered a renewable resource because the feedstocks are replenishable. Oregon has an abundance of wood

waste that can be used to provide electricity, largely from the forest sector, including logging residues, mill waste, and material removed from forests to improve their health and resilience.

Biomass generators provide consistent generation when in operation, like coal and natural gas plants, though they don't produce as much energy per ton of fuel. Biomass combustion produces more air pollutants and greenhouse gas emissions than other renewable resources like hydropower, wind, and solar, and it is subject to state and federal air quality requirements. However, biomass generation facilities with particulate and emissions controls emit fewer pollutants than would otherwise be released if the biomass decayed or burned in the open.

Trends in Oregon

Figure 11: Share of Biomass Electricity Consumed in Oregon

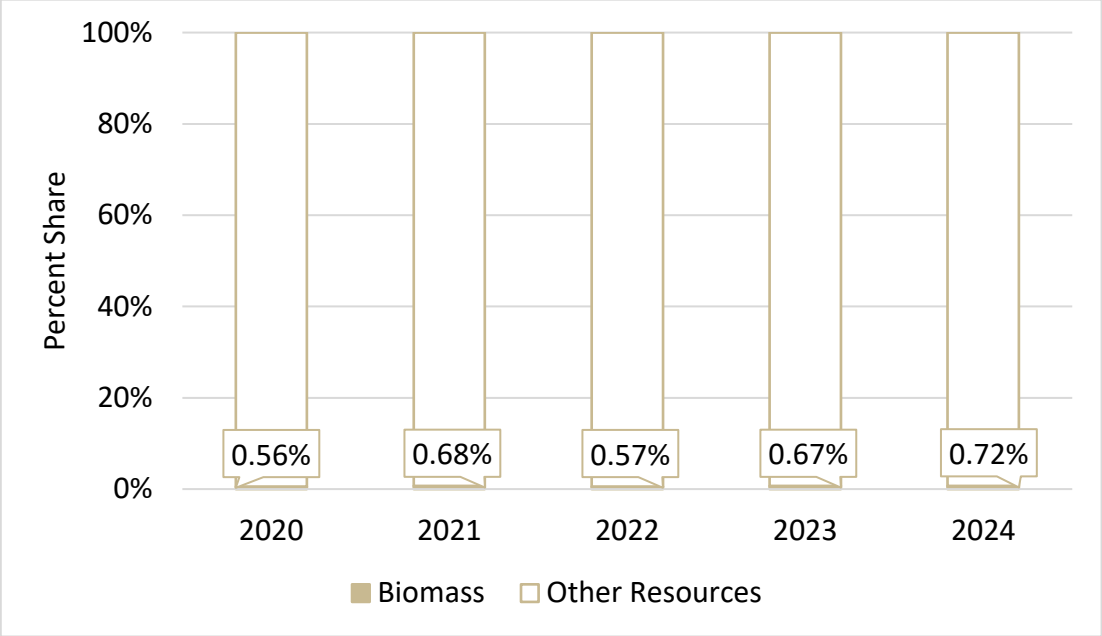
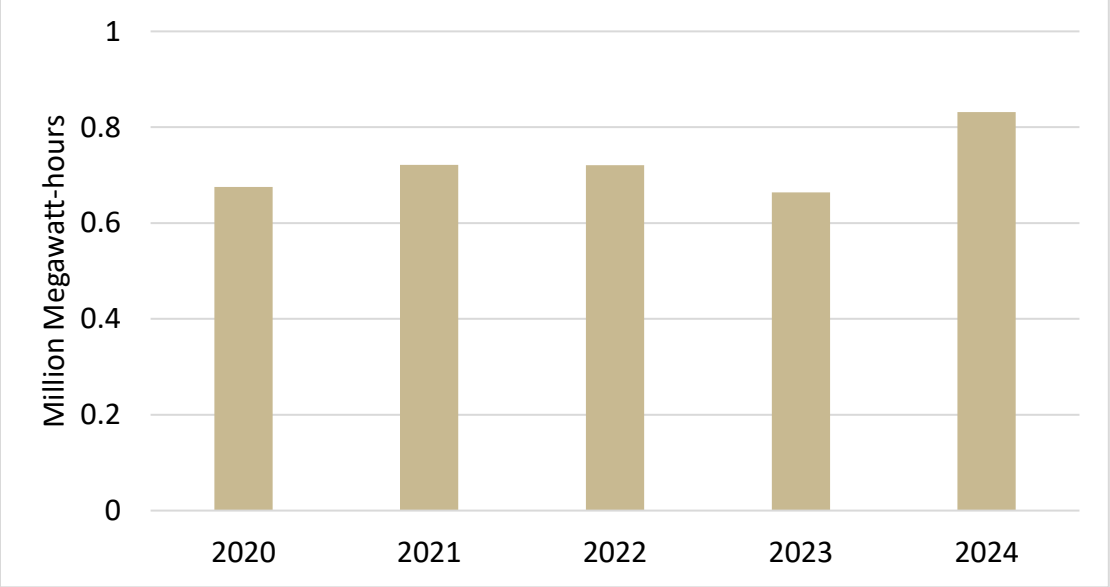


Figure 12: Amount of Biomass Electricity Generated in Oregon



Biomass contributes less than 1 percent of the electricity Oregonians use, though the relative percentage varies from year-to-year. Some biomass facilities in Oregon also supply electricity for use at the facility where it is generated, with any remaining power sent to the grid. The relative availability of the specific biomass feedstock used at the site also affects the amount of electricity that can be generated. Biomass electricity is typically more expensive to produce than many other electricity generation resources. For this reason, it is often used at times when biomass feedstocks are readily available and when other wholesale electricity costs are high.

The future of biomass electricity generation is uncertain. There is interest in the benefits biomass generation can provide, including lowering wildfire risk and providing jobs and support for local economies in rural communities. However, biomass electricity must compete with typically lower-cost wind, solar, and natural gas generation. and additional costs for biomass fuel collection, transportation, and processing often make it a higher cost resource. More expensive resources are typically operated when the cost of electricity is high, such as peak demand times, but biomass generators usually provide only consistent, baseload power, and are not designed to be ramped up or down quickly. Because biomass generation releases air pollutants, investments in air pollution mitigation technologies can also increase the costs for producing electricity. Clean and renewable energy policies that incentivize biomass electricity generation and access to broader regional wholesale electricity markets could help offset some of the costs, but the relative costs of other renewable resources, evolving energy and climate policies, and the speed and degree of electricity load growth will affect the amount of biomass generation in Oregon's future.

Additional Resources

- U.S. Energy Information Administration: Biomass explained
- U.S. Energy Information Administration: Renewable energy explained
- 2026 Biennial Energy Report: Energy by the Numbers – Electricity
- U.S. Department of Energy: Biomass: An Energy Resource
- U.S. Energy Information Administration: Biomass and the environment

Geothermal Electricity Generation

Total capacity in Oregon	**35.03 MW**
Number of utility-scale facilities	**2**
Resource share of electricity consumption	**0.11%**
Total generation	**168,873 MWh**
In-state consumption	**70,561 MWh**
Exports	**99,644 MWh**

Technology Overview

Conventional geothermal power plants use hot water resources from below the earth's surface to generate electricity.[24] Plants are built over wells that tap into these resources and capture the hot water or steam that in turn spins turbines at the site. Newer enhanced geothermal systems require

only hot rocks (>300°C), not water. EGS plants pump water down to the hot rocks where it is heated and then brought back to the surface to generate electricity.

Oregon has two operational geothermal power plants. The first, completed in 2010, is the 1.75 MW Oregon Institute of Technology plant in Klamath Falls that generates heat and electricity used on the Oregon Tech campus. The second, completed in 2012, is the Neal Hot Springs geothermal power plant near Vale, Oregon. This plant has a capacity of 22 MW and provides electricity to Idaho Power.



Neal Hot Springs Geothermal Plant in Vale, OR.

Geothermal electricity generation is a clean and renewable resource that can benefit the grid and help Oregon achieve its clean energy targets. It continuously generates electricity, providing a consistent resource for grid operations. It has a relatively small land use footprint compared with other renewable resources like solar, wind, and hydro, and fewer environmental concerns than fossil fuel resources. It generates near-zero greenhouse gas emissions, and the water it needs can be injected back into the earth to be reheated and reused. The process-water may pick up contaminants including small amounts of radioactive compounds which are naturally occurring in underground water resources.

Trends in Oregon

Figure 13: Share of Geothermal Electricity Consumed in Oregon

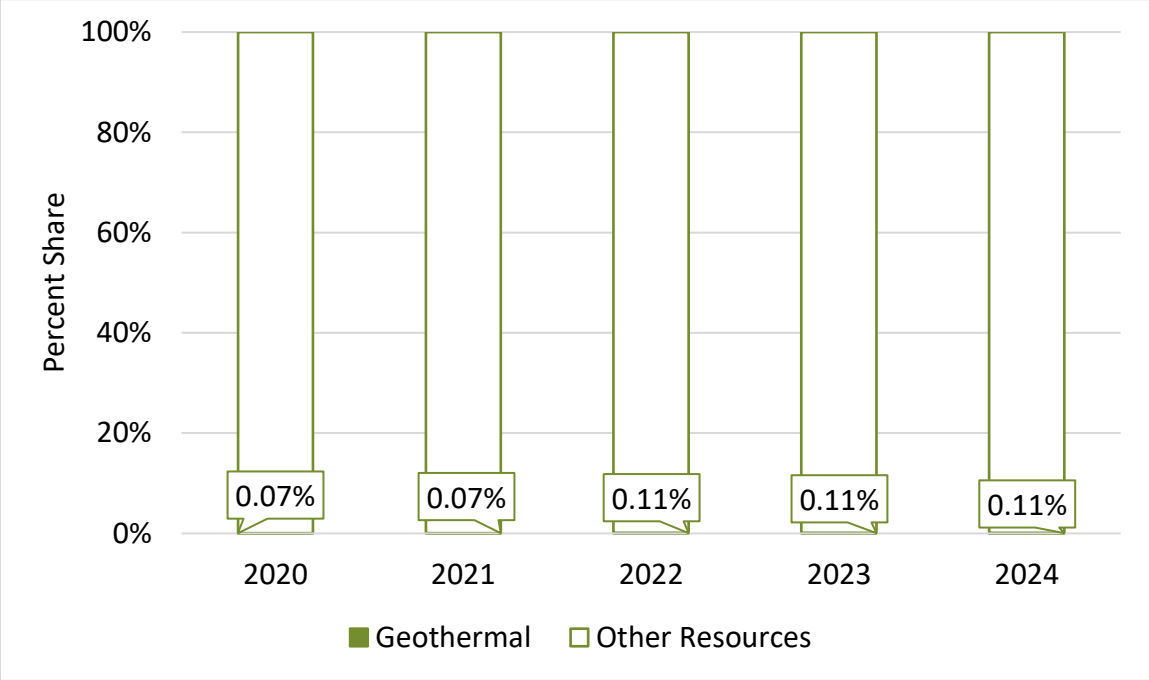
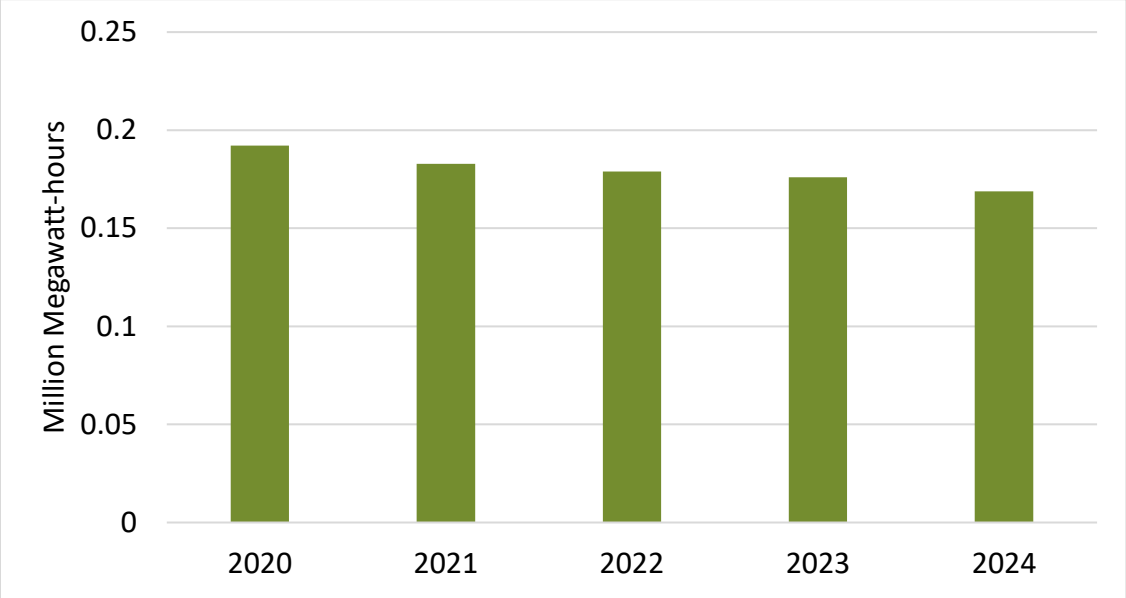


Figure 14: Amount of Geothermal Electricity Generated in Oregon



Advancements in geothermal electricity generation are creating more opportunities for development. For example, new technological innovations reduce drilling timelines by months which reduces costs to test subsurface conditions for geothermal, and significantly changes the project risk considerations. Constructing geothermal plants is expensive and financially risky, even for the large geothermal energy resources present in Oregon. The viability of a traditional geothermal plant depends on water well performance, which can be uncertain, leading to higher upfront costs for development. Emerging enhanced geothermal technologies do not rely on these difficult-to-assess hot water reservoirs; instead, they use heat from abundant hot, dry rock deep beneath the surface. U.S. DOE-funded pilot projects are providing data and insights that could help lower costs for geothermal in the future. Two of these enhanced geothermal projects are currently under construction at the Newberry volcano in Central Oregon, making Oregon a national leader in geothermal energy research.

Additional Resources

- U.S. Energy Information Administration: Geothermal explained
- 2026 Biennial Energy Report: Energy by the Numbers – Electricity
- 2026 Biennial Energy Report: Emergency Technology Review – Enhanced Geothermal
- U.S. Department of Energy: Geothermal Electricity Generation Plants
- U.S. Energy Information Administration: Geothermal and the environment
- Mazama Energy: Newberry Project
- Quaise: Project Obsidian

Biogas

Total capacity in Oregon	**57.4 MW**
Number of utility-scale facilities	**47**
Resource share of electricity consumption	**0.06%**
Total generation	**235,306 MWh**
In-state consumption	**36,670 MWh**
Exports	**199,288 MWh**

Technology Overview

Biogas is a lower-carbon fuel alternative to fossil natural gas and is produced in Oregon by capturing methane and other gases emitted from decomposing food waste, agricultural manure, and municipal waste.[25] When this gas is captured for use, it is referred to as biogas. Oregon's major biogas sources include landfills, municipal wastewater treatment facilities, dairy and livestock operations, and industrial food processors. Once collected and processed to remove moisture and impurities, biogas becomes renewable natural gas, which can be injected into existing natural gas pipelines, used as transportation fuel, or combusted onsite to make electricity.



JC-Biomethane in Junction City, OR transforms food waste into 1.5 MW of renewable electricity.

Biogas generators in Oregon typically provide power for use at the site where the biogas is produced. Biogas collection sites commonly have heat and power systems that use biogas to generate both electricity and useful heat at the same time. The electricity produced onsite can power the facility and any excess can be sold to the local electric utility. Produced heat can be used for space heating or other facility operations, reducing the need for other fuels. Because biogas would otherwise be emitted into the environment, collecting and using biogas reduces on-site methane emissions. It also reduces odors emitted from organic waste. While biogas collection reduces methane emissions, it still emits other greenhouse gases during combustion.

Trends in Oregon

Figure 15: Share of Biogas Electricity Consumed in Oregon

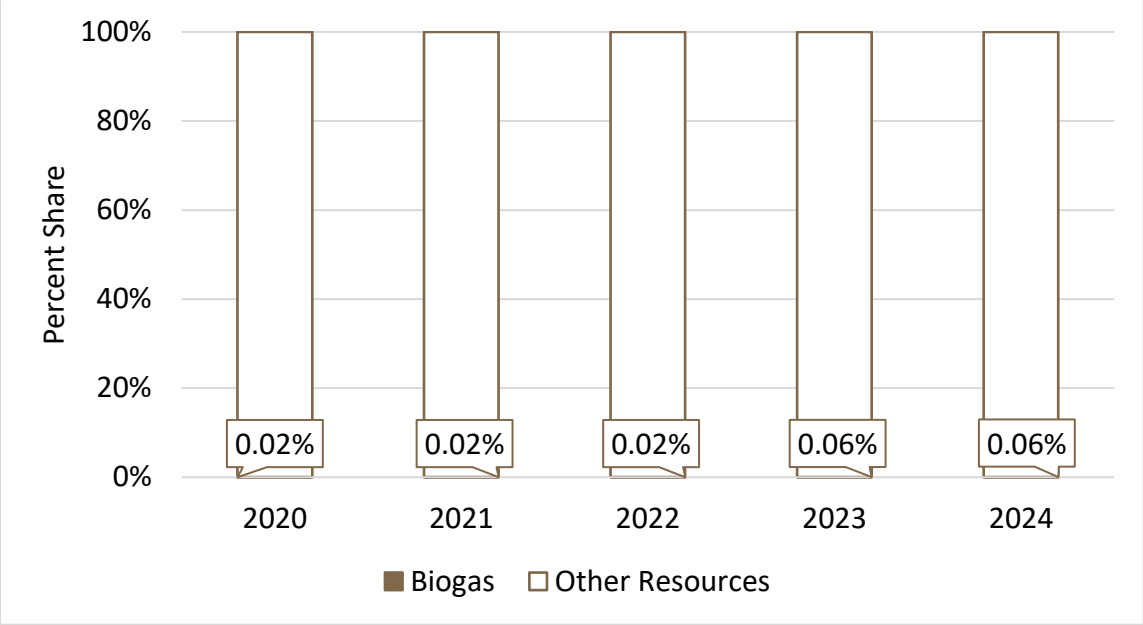
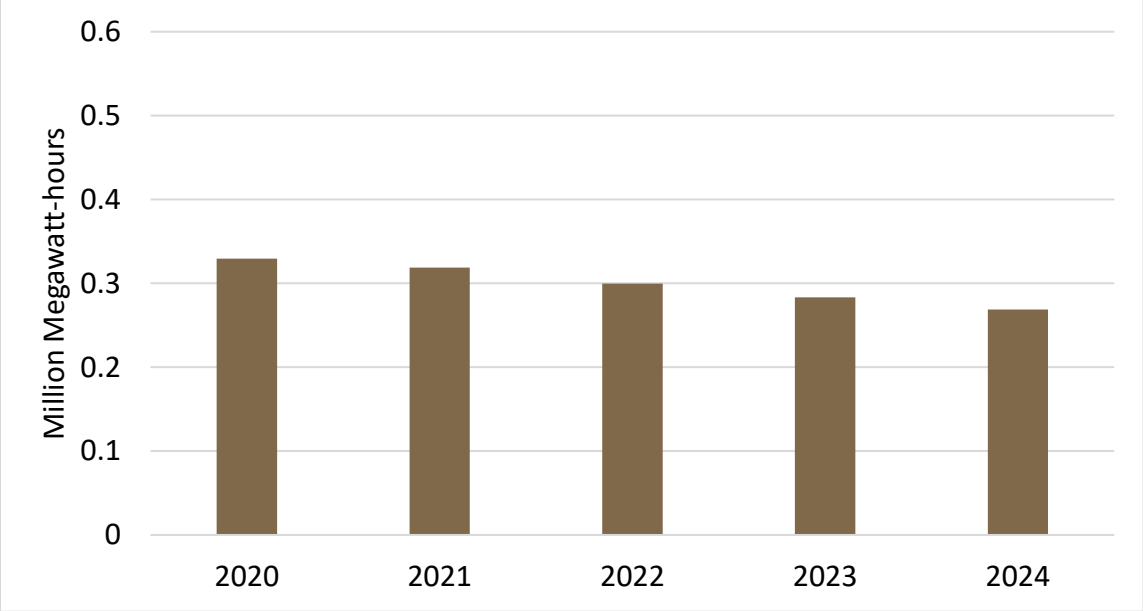


Figure 16: Amount of Biogas Electricity Generated in Oregon



The rising costs of energy coupled with rising electricity demand and state clean energy targets may spur more interest in biogas collection and use. In 2018, the Oregon Department of Energy produced a Biogas and Renewable Natural Gas Inventory that calculated the potential for biogas and renewable natural gas production in Oregon. The report found that state resources could potentially displace up to 17.5 percent of Oregon's total annual natural gas consumption, but several barriers would need to be overcome to achieve this, including high costs, interconnection and gas pipeline access constraints, and evolving regulatory structures for air emissions.

Low-carbon fuels like biogas are needed to meet Oregon's energy and climate goals. Biogas could be used to generate lower carbon electricity, but it could also serve as a low-carbon fuel for Oregon's

hardest-to-electrify transportation and industrial process heating needs.[26] At the same time, increasing electrification of fleets and buildings may create more interest in on-site electricity generation using biogas to offset costs to purchase power from a utility. On-site electricity generation could also provide backup power for facilities, improving overall energy resilience on site and potentially serving as a power source for emergency response activities in communities.

Additional Resources

- U.S. Energy Information Administration: Landfill gas and biogas
- Oregon Department of Energy: Biogas and Renewable Natural Gas Inventory

Conduit Hydropower Electricity Generation

Total capacity in Oregon	**12.84 MW**
Number of utility-scale facilities	**13**
Resource share of electricity consumption	**Data not available**
Total generation	**26,220 MWh**
In-state consumption	**Data not available**
Exports	**Data not available**

Technology Overview

Conduit hydropower refers to electricity generated by installing turbines within pressurized human-made water conveyance systems used for agricultural, municipal, or industrial water delivery. These turbines operate by converting excess water pressure into mechanical energy, moderating flow conditions while producing usable power. Similar to rooftop solar, conduit hydro systems provide power on the customer side of the meter. The electricity generated can be used on site or delivered to the grid, depending on system design and power needs. When generating, conduit hydropower does not emit greenhouse gases and is a renewable energy source that does not require ongoing fuel purchases.

Conduit hydropower installations can be a cost-effective option for municipal projects. They typically have low capital and operating costs because they leverage existing water infrastructure with excess water pressure. For example, the City of Hillsboro's conduit hydropower system generates a little over 200,000 kWh of electricity per year, offsetting the power needs of the Gordon-Faber Recreational Complex. This project lowered the complex's energy costs by $11,000 in 2021, and accrued $83,000 in cumulative cost savings through Fiscal Year 2026.[27] [28] While these benefits accrue over the lifetime of the project, there are technical and financial challenges for in-conduit hydro that can be an initial hurdle. Project development can be complicated by variable water system conditions, limited municipal staffing capacity, and complex permitting and utility interconnection requirements.[29] In addition, some installations, such as agricultural projects that need irrigation system modifications, may have high upfront costs.

Trends in Oregon



The City of Hood River installed conduit hydropower in 2026 with the help of an ODOE Community Renewable Energy Grant. Over its first 30 years, the project will generate roughly 16 million kilowatt hours of electricity.

Nationwide, more than 350 conduit hydropower projects have been permitted or completed.[30] In Oregon, cities such as Hillsboro and Beaverton have already integrated conduit hydropower into their municipal water systems.[31] Hood River and Tualatin both brought new systems online in the summer of 2026, and Bend is moving forward with a project to incorporate conduit hydropower into its planned water system expansion by 2030, signaling expanding municipal interest across the state.[32–35] Agricultural applications are also growing, supported by the collaboration between the Farmer Conservation Alliance and the Energy Trust of Oregon; however, publicly available data do not yet indicate how many of these agricultural systems are currently operating or in development beyond the known project at Siebe Ranch.[36,37] The Three Sisters Irrigation District's final canal-to-pipe modernization continues to demonstrate the broader potential of this approach by restoring year-round flows to Whychus Creek, improving fish habitat, and delivering pressurized water that cuts farm energy use by about 9 million kWh annually.[38] The fully modernized system now includes three in-pipe hydropower facilities producing up to 700,000 kWh per year, demonstrating how irrigation modernization can simultaneously support farms, ecosystems, and renewable energy. Together, these efforts illustrate how conduit hydropower is becoming an increasingly valuable and low-impact energy resource in Oregon's energy infrastructure.

Additional Resources

- National Hydropower Association: Conduit Hydropower
- Hood River harnesses hydropower with ODOE grant
- Oak Ridge National Laboratory: Assessment of Hydropower Potential at National Conduits

References

1. Oregon Department of Energy. (2020). 2020 Biennial Energy Report. Technology Resource Reviews: Hydropower (p. 3). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=3.
2. Baumhardt, A. (2024, June 21). Feds acknowledge dams devastated NW tribes and fish stocks. Washington State Standard. https://washingtonstatestandard.com/2024/06/21/feds-acknowledge-dams-devastated-northwest-tribes-and-fish-stocks/.

3. EnviroLink Network. (2026, May 13). *Seattle Agrees to Pay $1.35 Billion to Tribes in Historic Dam Settlement on Skagit River*. https://www.envirolink.org/2026/05/13/seattle-agrees-to-pay-1-35-billion-to-tribes-in-historic-dam-settlement-on-skagit-river/.
4. Columbia River Inter-Tribal Fish Commission. (2022). Tribal Energy Vision. https://critfc.org/energy-vision/.
5. Columbia River Inter-Tribal Fish Commission. (n.d.). Celilo Falls. Retrieved October 2, 2026 from https://critfc.org/salmon-culture/tribal-salmon-culture/celilo-falls/.
6. Schick, Tony. *Judge orders protective measures for Columbia River salmon after Trump canceled historic deal*. OPB. https://www.opb.org/article/2026/02/25/judge-orders-protective-measures-for-columbia-river-salmon-after-canceled-historic-deal/.
7. Oregon Department of Energy. (2020). *2020* Biennial Energy Technology Resource Reviews: Natural Gas (p. 13). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=13.
8. U.S. Energy Information Administration (n.d.). Natural gas and the environment. Retrieved October 7, 2026 from https://www.eia.gov/energyexplained/natural-gas/natural-gas-and-the-environment.php.
9. National Archives and Records Administration. (2014, August 15). *National Pollutant Discharge Elimination System-Final Regulations To Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities*. https://www.federalregister.gov/documents/2014/08/15/2014-12164/national-pollutant-discharge-elimination-system-final-regulations-to-establish-requirements-for.
10. U.S. Environmental Protection Agency. (2015, January 22). *Cooling Water Intakes* [Other Policies and Guidance]. https://www.epa.gov/cooling-water-intakes.
11. Oregon Department of Energy. (2020). 2020 Biennial Energy Report, Technology Resource Reviews: Coal (p. 22). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=22.
12. Oregon Department of Energy. (2020). 2020 BER Technology Resource Reviews: Wind Power (p. 17). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=17.
13. *Method to Estimate Climate Change Wind Generation*. (n.d.). Retrieved October 2, 2026, from https://www.nwcouncil.org/2021powerplan_method-to-estimate-climate-change-wind-generation/.
14. Oregon Department of Energy. (2020). *2020 BER Technology Resource Reviews: Solar*. https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=27.
15. Lazard. (2026, July). Levelized Cost of Energy+. https://www.lazard.com/media/kcfconhf/lazards-lcoeplus_vf.pdf.
16. Oregon Department of Energy. (2020). 2020 Biennial Energy Report Technology Resource Reviews: Nuclear. (p. 52). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=52.
17. U.S. Energy Information Administration. (2025, April 24). The United States operates the world's largest nuclear power plant fleet. In-brief analysis. https://www.eia.gov/todayinenergy/detail.php?id=65104.
18. Kitegraph. (n.d.). US electricity generation by source. Retrieved October 2, 2026, from https://kitegraph.com.

19. U.S. Energy Information Administration. (2025, April 24). The United States operates the world's largest nuclear power plant fleet. In-brief analysis. https://www.eia.gov/todayinenergy/detail.php?id=65104.

18. Kitegraph. (n.d.). US electricity generation by source. Retrieved October 2, 2026, from https://kitegraph.com.

19. U.S. Energy Information Administration. (n.d.). *Bonneville—Multnomah, OR — Operational Power Plant*. Electricity Data Browser. Retrieved October 2, 2026 from https://www.eia.gov/electricity/data/browser/#/plant/3075.

20. Nuclear Regulatory Commission. (2026, September 14). Storage of Spent Nuclear Fuel. https://www.nrc.gov/facilities-safety/storage-of-spent-nuclear-fuel.

21. Savage, C. (2026, May 10). How Many Decommissioned Nuclear Reactors Have the Potential to Be Restarted in the U.S.? *Energy News Beat*. https://energynewsbeat.com/electrical-generation/how-many-decommissioned-nuclear-reactors-have-the-potential-to-be-restarted-in-the-u-s/.

22. PacifiCorp. (2026, March 31). *2025 Integrated Resource Plan Update* (p. 100). https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2025-irp/2025_IRP_Update.pdf.

23. Oregon Department of Energy. (2020). 2020 Biennial Energy Report, Technology Resource Reviews: Biomass. (p. 31). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=31.

24. Oregon Department of Energy. (2020). 2020 Biennial Energy Report, Technology Resource Reviews: Geothermal (p. 39). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=39.

25. Oregon Department of Energy. (2020). 2020 Biennial Energy Report, Technology Resource Reviews: Biogas (p. 25). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=35.

26. Oregon Department of Energy. (July 2025). *Technical Report for the Oregon Energy Strategy.* https://www.oregon.gov/energy/data-and-reports/Documents/2025-OES-Technical-Report.pdf.

27. Energy Trust of Oregon. (2021, February). *City of Hillsboro Uncovers Hidden Opportunity to Produce Renewable Energy*. https://www.energytrust.org/wp-content/uploads/2021/03/HillsboroInpipeHydro_CS_02_2021.pdf.

28. InPipe Energy. (n.d.). InPipe Energy. Retrieved October 2, 2026, from https://inpipeenergy.com/.

29. Kao, S.-C., Geroge, L., Hansen, C., DeNeale, S., Johnson, K., Sampson, A., Moutenot, M., Altamirano, K., Garcia, K., Downing, J., Day, M. B., & Rugani, K. (2023). *US Hydropower Potential at National Conduits* [Data set]. Oak Ridge National Laboratory. https://doi.org/10.21951/CONDUIT/1993154.

30. Oak Ridge National Laboratory. (2022, October 12). *Existing water infrastructure may hold key to generating more hydropower*. https://www.ornl.gov/news/existing-water-infrastructure-may-hold-key-generating-more-hydropower.

31. *City News*. (n.d.). Sexton Mountain Pump Station Upgrade - CIP 4078C. Retrieved October 2, 2026, from https://beavertonoregon.gov/sexton-mountain-pump-station-upgrade-cip-4078c.

32. Energy Trust of Oregon. (2026, September 23). Hidden hydropower helps Hood River. *Energy Trust Blog*. https://blog.energytrust.org/hidden-hydropower-helps-hood-river/.

33. Frank Bubenik. (2026, July 1). Mayor's Note. *The City of Tualatin Oregon*. https://tualatinoregon.gov/news/2026/07/mayors-note/.

34. Consor for City of Bend. (2026, April). *Outback Facility Plan*. (n.d.). https://bendoregon.gov/wp-content/uploads/2026/05/2026.Outback-Facility-Plan.pdf.

35. Oregon Department of Energy. (2026, October 6). *Hood River harnesses hydropower with ODOE grant*. Energy Info. https://energyinfo.oregon.gov/blog/2026/10/6/hood-river-harnesses-hydropower-with-odoe-grant.

36. What We Do. (2025, August 14). *Farmers Conservation Alliance*. https://fcasolutions.org/work-with-fca/what-we-do/.

37. National Archives and Records Administration. (2022, July 28). *Scott and Kathy Siebe; Notice of Preliminary Determination of a Qualifying Conduit Hydropower Facility and Soliciting Comments and Motions To Intervene*. Federal Register. https://www.federalregister.gov/documents/2022/07/28/2022-16181/scott-and-kathy-siebe-notice-of-preliminary-determination-of-a-qualifying-conduit-hydropower.

38. Three Sister Irrigation District and Deschutes River Conservancy. (2025, June 18). *Three Sisters Irrigation District Completes Final Piping Project—A Major Milestone in the Ongoing Restoration of Whychus Creek.* https://tsidweb.specialdistrict.org/files/1ec822c09/Three+Sisters+Irrigation+Completes+Final+Piping+Project+Benefiting+Whychus+Creek.pdf.

Fuels

Gasoline Fuel

Total annual consumption	**156.8 trillion Btu**
End-use sector(s)	**Transportation**
Percent of total transportation fuels	**50.1%**
Produced in Oregon	**0**
Imported	**156.8 trillion Btu**
Carbon intensity	**98.06 gCO2e/MJ[i]**
Total annual greenhouse gas emissions	**16.6 million MTCO2e**

Fuel Overview



Puget Sound Refinery in Anacortes, WA (photo courtesy of Wikipedia)

Gasoline is a petroleum-based liquid fuel made by refining crude oil, a naturally occurring fossil fuel extracted from underground reservoirs through a process called fractional distillation.[1] In Oregon, gasoline is primarily used as a transportation fuel for light-duty passenger vehicles, though it also powers motorcycles, recreational boats, and some small aircraft and equipment. Gasoline is Oregon's dominant transportation fuel, accounting for more than half of all transportation energy consumption and fueling the majority of the state's approximately 3.7 million registered light-duty vehicles. Oregon does not produce crude oil or refine gasoline; about 90 percent of the gasoline sold in the state is produced at petroleum refineries and blending facilities in Washington and delivered via pipelines, marine terminals, rail, and tanker trucks. Gasoline may sometimes be used as a direct use fuel, such as in a gasoline generator for heating, but these uses are not explored here.

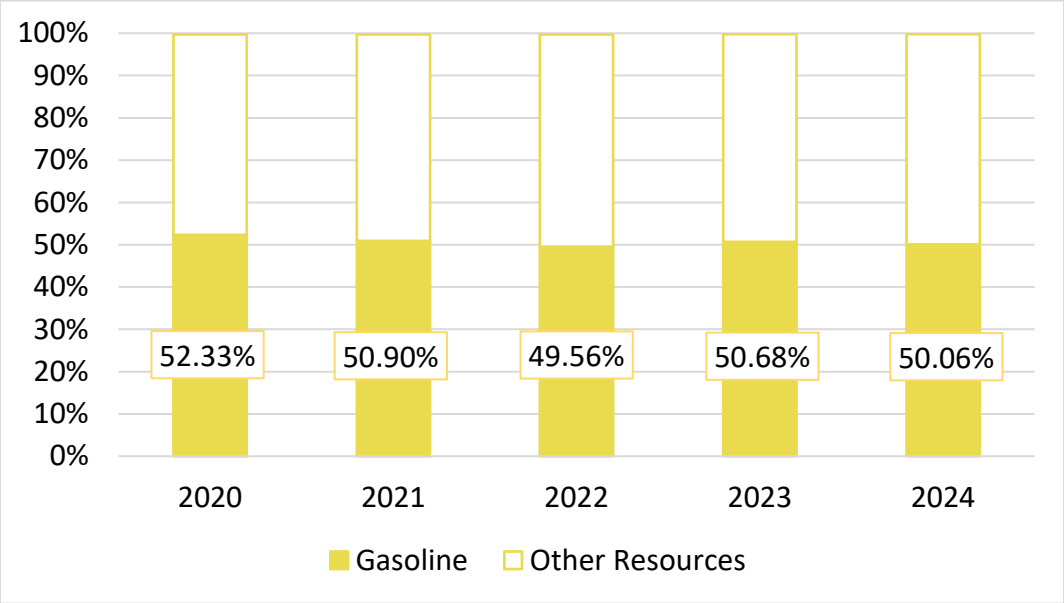
While gasoline is a critical resource for many Oregonians, enabling people to travel for work and pleasure and supporting local economies, it also negatively affects Oregonians' health and wallets. It is the largest source of greenhouse gas emissions in Oregon, contributing to climate change. It also emits carbon monoxide, nitrogen oxides, and particulate matter, which contribute to smog formation and worsen chronic respiratory and cardiovascular diseases. Oil extraction, transportation, and refining also pose environmental risks, including habitat disruption, water contamination, and potential spills. Fuel affordability varies frequently because Oregon imports all of the gasoline it consumes, and prices are highly sensitive to global crude oil market shifts. Supply disruptions and geopolitical events affect the price for crude oil, and refinery outages affect fuel prices, all of which

[i] Oregon's Renewable Fuel Standard requires nearly all gasoline sold for on-road use to contain 10 percent ethanol (E10). As a result, the carbon intensity commonly reported for gasoline under Oregon's Clean Fuel Program reflects the blended fuel rather than pure petroleum gasoline. Without the ethanol blending requirement, gasoline's lifecycle carbon intensity would be modestly higher because ethanol displaces a portion of the more carbon-intensive petroleum fuel.

are reflected at the pump and in household transportation costs. This can be particularly challenging for Oregonians who live in rural areas and live in low-income households, who often travel longer distances and have fewer alternatives to gasoline-powered vehicles.

Trends in Oregon

Figure 1: Gasoline Share of Transportation Fuels Consumed in Oregon



Gasoline consumption in Oregon generally increased until 2020, alongside population growth, economic expansion, and increases in vehicle miles traveled, before declining sharply during the COVID-19 pandemic. Consumption has since stabilized at somewhat lower levels than before the pandemic. Long-term gasoline demand is expected to decline further as vehicle fuel economy improves, electric vehicle adoption increases, and travel shifts to other transportation modes.

Gasoline has been the dominant fuel for passenger vehicles for over a century because it is a high-energy density fossil fuel with an extensive distribution network. However, several state policies are expected to reduce gasoline consumption over time in order to address greenhouse gas emissions. The state Renewable Fuel Standard requires a 10 percent blend of ethanol in most commercially available gasoline, which reduces emissions in the fuel consumed. The Clean Fuels Program requires progressively lower-carbon transportation fuels, as well as investments and policies that support electric vehicles and reductions in vehicle-miles-traveled. At the same time, recent federal policy changes, including the expiration of federal EV tax credits, ongoing legal uncertainty surrounding Oregon's ability to adopt and implement California's emissions standards and programs, and changes to federal vehicle efficiency and emissions requirements, may slow the rate at which gasoline demand declines, making the pace of this transition increasingly uncertain.

Additional Resources

- U.S. Energy Information Administration: Gasoline Explained
- U.S. Energy Information Administration: Oil and Petroleum Products Explained
- ODOE 2026 Biennial Energy Report: Energy by the Numbers – Transportation Fuels
- ODOE 2020 Biennial Energy Report: Where Oregon Gets its Transportation Fuels
- U.S. Environmental Protection Agency: GHG Emissions from a Typical Passenger Vehicle

Natural Gas Fuel

Total consumption[ii]	**140.26 trillion Btu**
Percent of total transportation fuels	**<0.01%**
Percent of total direct use fuels	**55.98%**
Carbon intensity	**79.98 gCO2e/MJ**
End-use sector(s)	**Residential, commercial, industrial, transportation**
Produced in Oregon	**0.17 trillion Btu**
Imported	**140.09 trillion Btu**
Total annual greenhouse gas emissions[iii]	**7.84 million MTCO2e**

Fuel Overview

Natural gas is a fossil energy resource produced from underground reservoirs and shale formations, delivered to Oregonians through interstate pipelines or delivery trucks.[2] It is used for space and water heating, cooking, industrial processes, and transportation. Natural gas is also important to electricity generation in Oregon. Natural gas provides high and controllable heat output, supporting on-demand energy needs across sectors. In areas with distribution pipeline systems, natural gas can be supplied directly to homes and businesses; in other areas, deliveries occur via tanker trucks for onsite storage and use. Approximately 37 percent of Oregon households rely on natural gas for home heating.[3] While less common, compressed and liquefied forms of natural gas are used in Oregon to fuel certain vehicle fleets, including transit buses, refuse trucks, and other heavy-duty vehicles. Almost all the natural gas Oregonians use is imported from Canada. The Pacific Northwest's only natural gas extraction field is located near Mist, Oregon, and it produced 0.09 trillion Btu in 2024, or roughly 0.03 percent of Oregon's annual consumption.[4]

In 2023, natural gas consumption outside the electricity generation sector accounted for roughly 15 percent of Oregon's total greenhouse gas emissions. Methane leaks released from natural gas infrastructure and emissions from fuel combustion contribute to statewide greenhouse gas levels. While natural gas has a lower carbon intensity and produces fewer greenhouse gas and air pollutant emissions than some fossil fuels, it remains a significant source of emissions in Oregon's energy system.

In 2024, Oregon households spent almost $708 million on natural gas, or about $874 per household.[5]

[ii] Includes natural gas consumed in Oregon as a fuel in the residential, commercial, industrial, and transportation sectors. This total does not include natural gas used to generate electricity.

[iii] Emissions data are from US Department of Energy's Energy Information Administration's State Energy Database. Oregon Department of Environmental Quality's Greenhouse Gas Sector-Based Inventory Data for 2024 was not yet available at publishing. This emissions total does not include emissions from electricity generation or the non-carbon dioxide emissions of methane and nitrous oxide from combustion of natural gas.

Trends in Oregon

Figure 2: Natural Gas Share of Direct Use Fuels Consumed in Oregon

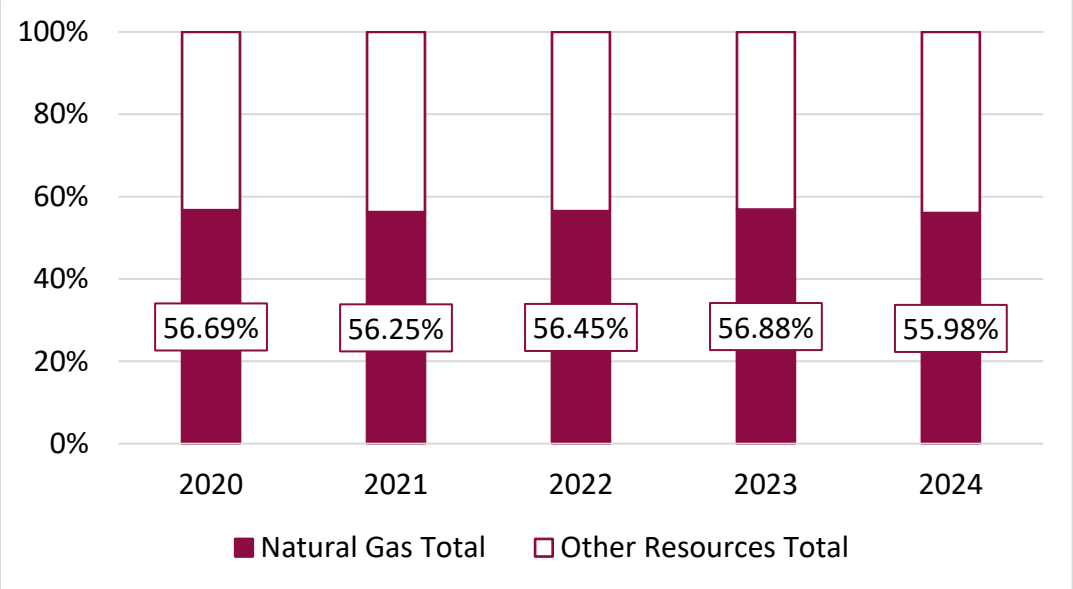
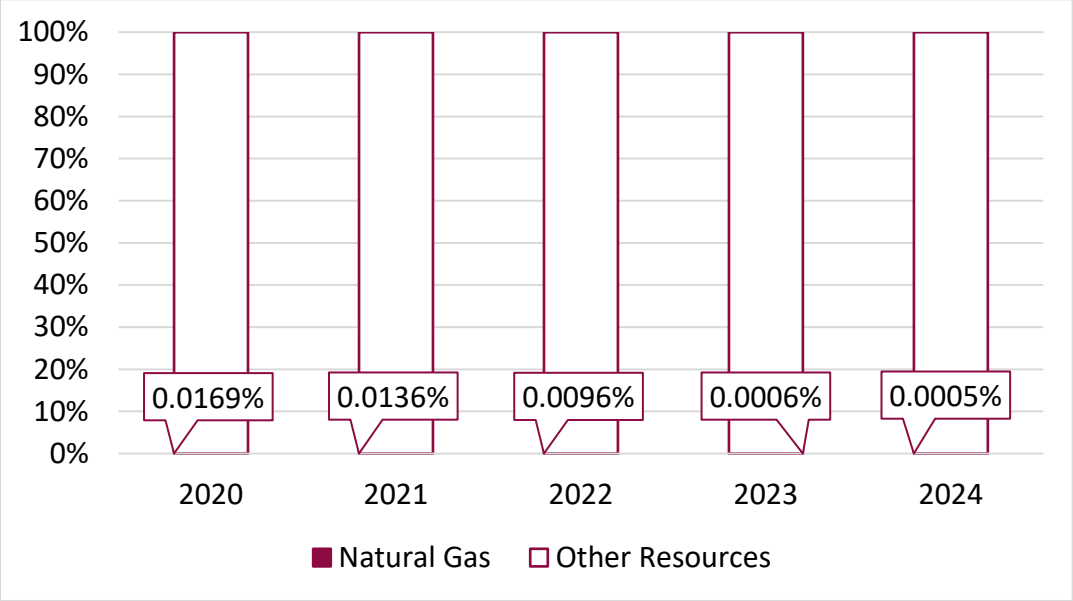


Figure 3: Natural Gas Share of Transportation Fuels Consumed in Oregon



Overall natural gas consumption in Oregon has grown, though trends vary by sector. Natural gas consumption has increased the most in the electricity generation sector. Consumption in buildings and industry has remained relatively stable, as economic and customer growth has been offset by energy efficiency improvements and electrification in some applications. Natural gas continues to provide reliable, high efficiency heating and often remains less costly than electric alternatives, particularly for large commercial and industrial loads. Direct combustion also avoids some energy losses associated with electricity generation, making natural gas a practical option for high-temperature industrial processes. Use of natural gas as a transportation fuel in Oregon has declined as fleets transition to renewable natural gas.

Natural gas is expected to remain an important part of Oregon's energy mix, although its best application and consumption volumes are uncertain. State policies that encourage a transition to lower-carbon fuels, including the Oregon Department of Environmental Quality's Climate Protection Program, are likely to increase adoption of renewable natural gas or biogas alternatives with lower emissions. Many state incentives prioritize electric technologies, such as electric heat pumps. At the same time, some end uses, like high heat applications in the industrial sector, have no cost-effective substitute for natural gas and will continue to rely on this fuel until a low-carbon fuel is more commercially available.

Economic factors and public sentiment are also shaping demand for natural gas in Oregon. Between 2020 and 2025, the price of natural gas delivered to residential customers increased by 53 percent, driven by post-pandemic inflation, higher fuel and operational costs, and capital investments needed to modernize aging infrastructure.[6] Although natural gas has historically been a lower-cost option for space heating compared to electricity, evolving state policies and broader market trends are influencing its relative economics. Growing global demand and the expansion of liquefied natural gas infrastructure are enabling greater international trade, which may contribute to higher market prices that could eventually affect Oregon customers. Public scrutiny of new gas utility infrastructure has also increased in recent years, and some decisionmakers are considering policies that emphasize electrification, which could reduce future natural gas demand.

Additional Resources

- U.S. Energy Information Administration: Natural Gas Explained
- 2020 Biennial Energy Report Natural Gas Energy 101
- ODOE 2026 Biennial Energy Report: Energy by the Numbers – Direct Use and Transportation Fuels
- American Gas Association: Back to Basics Natural Gas 101

Diesel Fuel

Total annual consumption	**74.16 trillion Btu**
End use sector(s)	**Transportation**
Percent of total transportation fuels	**23.68%**
Produced in Oregon	**0**
Imported	**76.66 trillion Btu**
Carbon intensity	**100.74 gCO2e/MJ**
Total annual greenhouse gas emissions	**8.65 million MTCO2e**

Fuel Overview

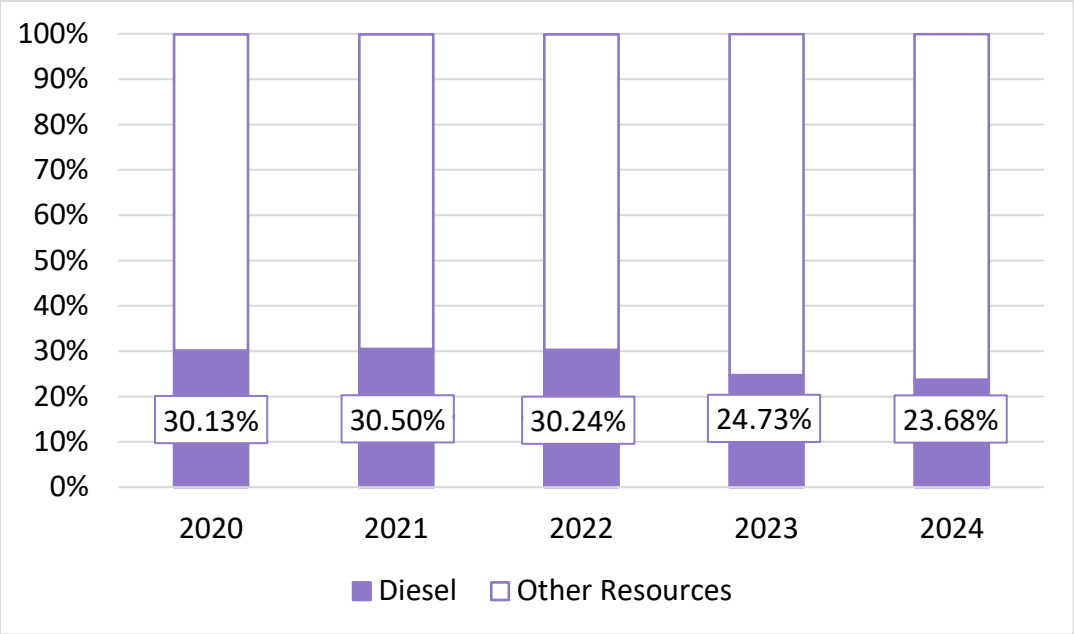
Diesel is a petroleum-based transportation fuel made by refining crude oil into a heavier distillate fuel that contains more energy per gallon than gasoline. Oregonians use diesel primarily to power trucks, buses, trains, ships, farm equipment, construction equipment, and some passenger vehicles. Diesel is widely used across Oregon's freight and commercial transportation sectors. Oregon does not produce or refine petroleum-based diesel, so all petroleum diesel consumed in the state is imported, with

more than 90 percent of diesel sold at Oregon service stations coming from refineries in Washington. Diesel is energy-dense and well-suited for high-power applications, especially in the transportation sector. It can be used for heating or industrial purposes, but the amount used for this purpose in Oregon is very small compared to transportation fuel use and is not discussed here.

Diesel combustion produces particulate matter, which is linked to asthma, respiratory illness, heart disease, and premature mortality. Diesel exhaust disproportionately affects communities located near highways, freight corridors, ports, rail yards, warehouses, and other high-traffic areas, which are often low-income and environmental justice communities. Diesel comprises the second-largest transportation fuel consumed in Oregon, after gasoline, generating 27.83 percent of Oregon's total greenhouse gas emissions, which continue to rise. Oil extraction, transportation, and refining also pose environmental risks, including habitat disruption, water contamination, and potential spills. Diesel is a combustion hazard, and spills can contaminate soil and waterways, although it is generally less flammable than gasoline.

Trends in Oregon

Figure 4: Diesel Share of Transportation Fuels Consumed in Oregon



Diesel consumption in Oregon has declined over the last few years as renewable diesel has grown rapidly and accounted for a larger share of consumption. Consumption remains closely tied to freight movement, construction, agriculture, and goods delivery. Unlike gasoline, diesel demand is less influenced by personal travel patterns and more closely reflects broader economic activity and movement of goods. Consumption remained relatively stable during the COVID-19 pandemic as increased freight activity and e-commerce offset declines in other sectors of the economy. Because Oregon imports nearly all transportation fuels, diesel prices remain highly sensitive to global oil markets and regional refinery supply. Supply disruptions, geopolitical events, refinery outages, and fluctuations in crude oil prices can significantly affect diesel prices and freight movement costs.

Several Oregon policies are expected to reduce diesel consumption over time, including the state's Renewable Fuel Standard, which requires diesel sold or distributed in Oregon to contain at least a 5

percent blend of biodiesel or renewable diesel, and the Clean Fuels Program, which incentivizes lower-carbon transportation fuels. Portland also has its own Renewable Fuel Standard and beginning in July 2026, all diesel fuel sold in the city must contain at least 50 percent biofuel.[7] Diesel is also affected by broader clean transportation policies that support zero-emission trucks, buses, and equipment. However, recent federal policy changes, including ongoing legal uncertainty surrounding Oregon's ability to implement the Advanced Clean Trucks regulation and changes to federal vehicle efficiency and emissions requirements, may slow the pace of diesel displacement and create additional uncertainty around long-term consumption trends.

Additional Resources

- U.S. Energy Information Administration: Diesel Fuel Explained
- U.S. Energy Information Administration: Diesel and the Environment
- ODOE 2026 Biennial Energy Report: Energy by the Numbers – Transportation Fuels
- ODOE 2020 Biennial Energy Report: Where Oregon Gets its Transportation Fuels
- U.S. Environmental Protection Agency: Particulate Matter (PM) Pollution
- Oregon Department of Environmental Quality: Diesel Emissions Program

Renewable Diesel Fuel

Total annual consumption	**21.09 trillion Btu**
End use sector(s)	**Transportation**
Percent of total transportation fuels	**6.73%**
Percent of total direct use fuels	**0%**
Produced in Oregon	**0**
Imported	**21.09 trillion Btu**
Carbon intensity	**16.22-66.00 gCO2e/MJ**
Total annual greenhouse gas emissions	**0.84 million MTCO2e**

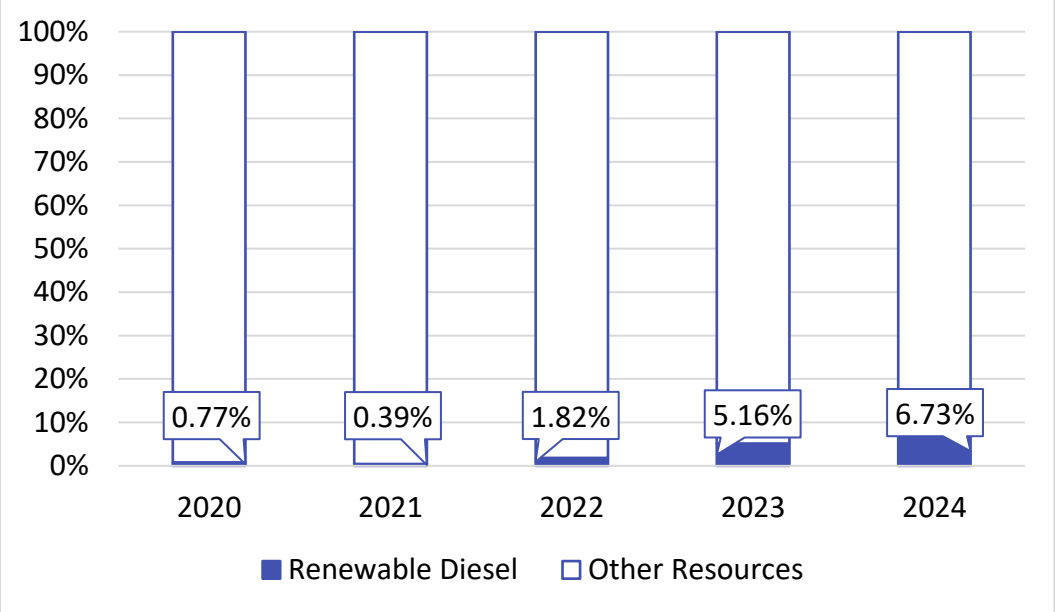
Fuel Overview

Renewable diesel is a drop-in fuel, meaning it can replace or be blended with fossil diesel and biodiesel at any ratio without requiring changes to vehicles or fueling infrastructure.[8] The key difference between renewable diesel and biodiesel is that renewable diesel is chemically similar to fossil diesel and can be used as a full replacement fuel, while biodiesel is chemically different and is typically used as a blend with fossil diesel or renewable diesel. In Oregon, state law requires that diesel sold or distributed contain at least a 5 percent blend of biodiesel or renewable diesel, so most diesel users consume some biodiesel regardless of the fuel they purchase. Renewable diesel is made by refining renewable biomass feedstocks, such as plant- and animal-based fats and oils. Using renewable diesel reduces greenhouse gas emissions 55-65 percent compared to fossil diesel and produces fewer particulate emissions because it burns cleaner.[8] [9] Oregonians use renewable diesel for transportation fuel in on-road vehicles and other uses, such as the Port of Portland's dredging vessel used in the Columbia River. It can also be used to power backup generators. In Oregon, almost 102 million gallons of renewable diesel were consumed in 2025.

All renewable diesel is currently imported into Oregon, primarily from Washington, California, and Louisiana, in addition to international providers. In 2024, Oregon imported approximately 171.6 million gallons of renewable diesel. The only in-state production project under active development is the proposed NXTClean Fuels facility at Port Westward, which is still awaiting final federal approval from the U.S. Army Corps of Engineers. If permitted and constructed, NXTClean would aim to begin refining in 2028.[10] [11] The facility is expected to produce up to 750 million gallons per year of renewable diesel and sustainable aviation fuel with the ability to switch which fuels being produced based on demand. While Oregon's renewable diesel supply will continue to depend on imports for the foreseeable future, an operational in-state facility would significantly increase local production capacity and reduce some reliance on imports. Like the fuel itself, the refining process for renewable diesel produces fewer greenhouse gas and particulate emissions than fossil diesel, resulting in a reduced, but not entirely eliminated, environmental impact.[8]

Trends in Oregon

Figure 5: Renewable Diesel Share of Transportation Fuels Consumed in Oregon



Renewable diesel consumption has been steadily rising in Oregon, with demand exceeding supply, especially in the Willamette Valley where most of the fuel is sold. This is primarily because it offers several advantages over fossil diesel. It has fewer contaminants, which lowers operational costs for vehicle owners by reducing wear and tear on engines. It also performs better in cold weather. With fewer contaminants, renewable diesel also has fewer particulate emissions, mitigating some negative health effects in communities near busy roadways or places where diesel is regularly combusted. Since it was made available in Oregon, renewable diesel has been more expensive than regular diesel, but since May 2025, wholesale prices for renewable diesel (R99) have been trending lower than prices for the two most-used types of fossil diesel fuel (B5 and B20).[12]

State and federal policies encourage renewable diesel uptake. The Federal Renewable Fuels Standard and Oregon's Clean Fuels Program provide systems that enable renewable diesel sellers to monetize credits or certificates for the sale of the fuel. Oregon's Climate Protection Program sets an annual cap on emissions from fuels, and renewable diesel is one option for regulated parties to meet that CPP

requirement. Bills have been proposed but not passed in the Legislature to set adoption goals, including SB 803 (2023), which would have established a phased-in statewide renewable diesel standard, and HB 3308 (2025), which would have set state fleet R99 targets. Renewable diesel is also an eligible fuel to support Portland's Renewable Fuel Standard, which currently has a 50 percent biofuel requirement.

Additional Resources

- U.S. Department of Energy Alternative Fuels Data Center: Renewable Diesel
- U.S. Department of Energy: Biofuels Explained
- ODOE 2026 Biennial Energy Report: Energy by the Numbers – Transportation Fuels
- NXTClean Fuels: Port Westward renewable diesel refinery
- American Chemical Society: *Life Cycle Greenhouse Gas Emissions of Biodiesel and Renewable Diesel Production in the United States*

Ethanol Fuel

Total annual consumption	**11.58 trillion Btu**
End use sector(s)	**Transportation**
Percent of total transportation fuels	**3.7%**
Produced in Oregon	**4.19 trillion Btu**
Imported	**7.4 trillion Btu**
Carbon intensity	**21.91-87.34 gCO2e/MJ**
Total annual greenhouse gas emissions	**0.4 million MTCO2e**

Fuel Overview



Ethanol Production Plant in Clatskanie, OR.

Ethanol is a renewable alcohol-based transportation fuel produced by fermenting and distilling plant-based feedstocks such as corn, sugarcane, wheat, sorghum, and increasingly, agricultural and forestry waste materials.[13] It is most commonly blended with gasoline rather than used as a standalone fuel. Oregonians primarily use ethanol as a gasoline additive, with most gasoline sold for on-road vehicles containing a 10 percent ethanol blend (E10). Ethanol increases the oxygen content of gasoline, promoting more complete combustion and reducing air pollutants and greenhouse gas emissions. Higher blends, including E15 and E85, are available in limited markets and, in the case of E85, can only be used in flex-fuel vehicles.[iv] Most ethanol consumed in Oregon is imported from large production

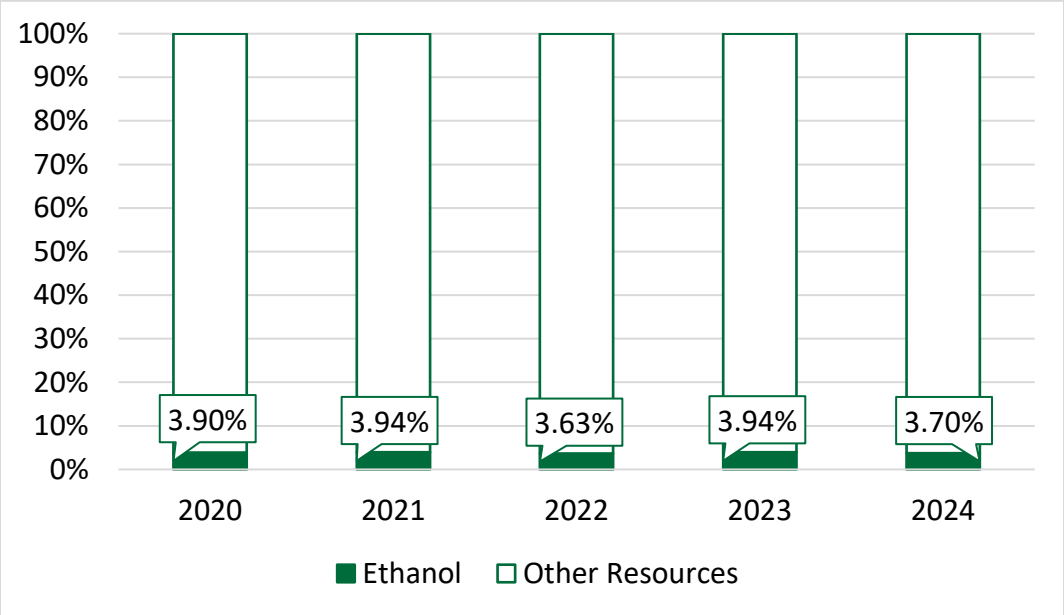
[iv] A flex-fuel vehicle is a type of vehicle designed to run on more than one kind of fuel – typically gasoline or gasoline blended with ethanol, most commonly E85 (a fuel containing up to 85 percent ethanol). Flex-fuel vehicles look and operate like conventional gasoline vehicles but offer drivers the option to use a higher-ethanol, lower-carbon fuel when available.

facilities in the Midwest and transported by rail and truck. There is limited in-state production, including a facility in Boardman.

Blending ethanol reduces greenhouse gases that would otherwise be emitted from fossil gasoline combustion. It also helps reduce criteria air pollutants,[v] including carbon monoxide and volatile organic carbon compounds (VOCs). Using ethanol can reduce negative health outcomes, mitigate climate change, and lower Oregon's exposure to volatile global crude oil markets. Environmental benefits vary substantially depending on feedstock, agricultural practices, transportation distances, and production methods. Corn-based ethanol can contribute to changes in land use, fertilizer runoff, and increased water use. However, lower-carbon pathways that utilize agricultural residues, renewable energy, or carbon capture technologies can significantly improve environmental performance. Ethanol may sometimes be used as a direct use fuel, such as in a gasoline generator for heating, but these uses are not explored here.

Trends in Oregon

Figure 6: Ethanol Share of Transportation Fuels Consumed in Oregon



Ethanol consumption in Oregon has remained relatively stable over the past five years because it is closely tied to gasoline demand. Oregon's Renewable Fuel Standard effectively guarantees statewide E10 adoption, which ensures every gasoline-powered vehicle in the state uses some amount of ethanol. Higher blends like E15 or E85 remain niche fuels and are unlikely to substantially influence statewide fuel consumption in the near term. Use of ethanol is bolstered by Oregon's Clean Fuels Program, which incentivizes lower-carbon fuels. Ethanol will likely remain an important component of Oregon's transportation fuel mix for decades, but consumption is expected to gradually decline over time as increasing electric vehicle adoption reduces demand for gasoline.

[v] Criteria air pollutants are a group of six widespread outdoor pollutants regulated under the U.S. Clean Air Act due to their harmful effects on health, the environment, and property. For each, the EPA has established National Ambient Air Quality Standards to protect public health and welfare. They include ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, nitrogen dioxide, and lead.

Ethanol can modestly reduce gasoline prices by increasing fuel supply and diversifying fuel sources. Ethanol prices may also behave differently than petroleum prices; for example, from June 2025 to June 2026, ethanol prices increased by about 10 percent, roughly one-quarter as much as the approximately 40 percent increase in crude oil prices over the same time period.[14] [15] Ethanol is also the only liquid transportation fuel currently produced at commercial scale in Oregon. Increased demand could support expanded in-state production, while existing production capacity and feedstock supply chains may also provide opportunities to transition toward other low-carbon fuels in the future. However, ethanol contains approximately 30 percent less energy than gasoline, meaning higher ethanol blends can reduce vehicle fuel economy unless engines are specifically designed or optimized to use them.

Additional Resources

- U.S. Department of Energy Alternative Fuels Data Center: Ethanol Fuel Basics
- U.S. Energy Information Administration: Ethanol Explained
- U.S. Department of Energy Alternative Fuels Data Center: Flexible Fuel Vehicles
- ODOE 2026 Biennial Energy Report: Energy by the Numbers – Transportation Fuels

Biodiesel Fuel

Total annual consumption	**9.16 trillion Btu**
End use sector(s)	**Transportation**
Percent of total transportation fuels	**2.9%**
Produced in Oregon	**0**
Imported	**9.16 trillion Btu**
Carbon intensity	**11.68-57.26 gCO2e/MJ**
Total annual greenhouse gas emissions	**0.4 million MTCO2e**

Fuel Overview



A biodiesel fuel pump offering multiple blends. Source: Flickr | United Soybean Board

Biodiesel is a renewable transportation fuel produced by chemically converting vegetable oils, animal fats, used cooking oils, and other organic feedstocks into fatty acid methyl esters[vi] that can be blended with conventional petroleum diesel.[16] In Oregon, biodiesel is used primarily as a blend component in diesel fuel to power trucks, buses, agricultural equipment, construction equipment, and other diesel-powered vehicles and equipment. Unlike electricity or hydrogen, biodiesel can often be used in existing diesel vehicles with little or no modification, making it a near-term option for reducing emissions from medium- and heavy-duty transportation applications. Higher blends may require manufacturer approval and additional fuel management considerations

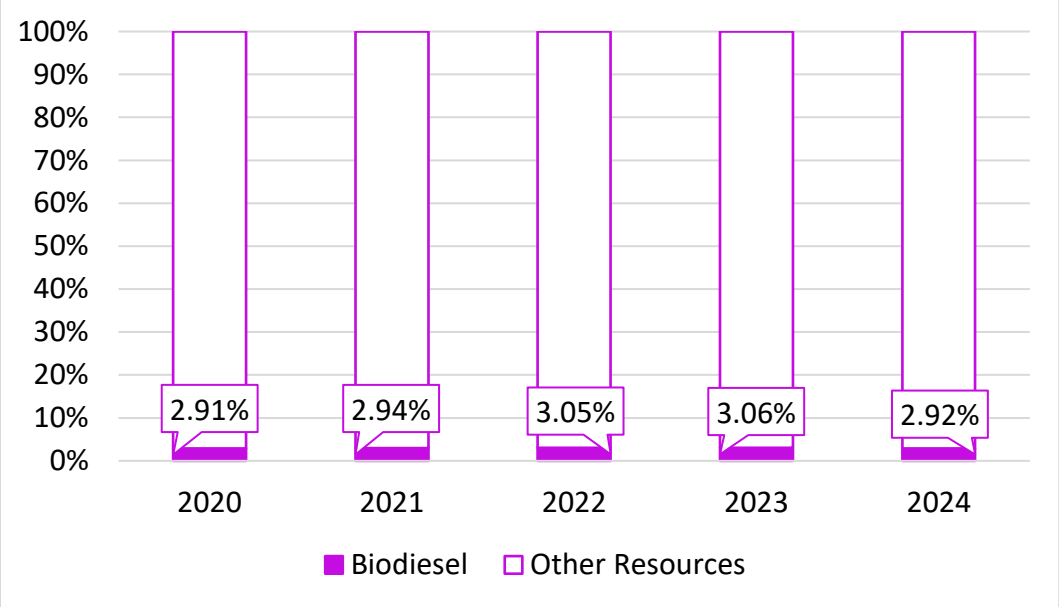
[vi] Fatty acid methyl esters (FAME) are a class of chemical compounds produced by reacting fats or oils, such as vegetable oils, used cooking oil, or animal fats, with methanol. They are the primary chemical components of conventional biodiesel.

because biodiesel's physical properties can affect engine performance and fuel storage, particularly in colder temperatures. Many vehicle manufacturers approve blends up to 20 percent biodiesel (referred to as B20) for certain applications, though higher blends are not universally compatible across all engines and equipment. Biodiesel can also be used for heating or industrial use, but this amount is very small compared to transportation fuel use and is not discussed here.

Oregon has no in-state biodiesel production, so all the biodiesel consumed in the state is imported from producers in other western states and the Midwest, and distributed through Oregon's existing diesel fuel infrastructure. Compared to petroleum diesel, biodiesel can substantially reduce lifecycle greenhouse gas emissions and decrease emissions of particulate matter and other pollutants. However, like other low-carbon fuels, environmental benefits vary depending on the feedstock and production methods. Producing biodiesel from waste oils and fats generally results in lower emissions than crop-based feedstocks. Crop-based feedstocks can contribute to changes in land use, increased water consumption, and fertilizer runoff. Biodiesel is biodegradable and less toxic than petroleum diesel, reducing some spill risks, although improper handling and storage can affect fuel quality.

Trends in Oregon

Figure 7: Biodiesel Share of Transportation Fuels Consumed in Oregon



Biodiesel consumption in Oregon has declined in recent years as renewable diesel has gained a larger share of the diesel fuel market. Biodiesel remains a component of Oregon's transportation fuel supply, driven in part by state fuel policies rather than direct consumer choice because biodiesel is typically sold blended with petroleum diesel rather than as a standalone fuel. Oregon's Renewable Fuel Standard requires most diesel sold or distributed in the state to contain at least a 5 percent blend of biodiesel or renewable diesel,[vii] with exemptions for certain uses including rail, marine, home heating, and emergency power generation. Renewable diesel, unlike biodiesel, can be used at high blend levels or as a direct replacement for petroleum diesel. As renewable diesel availability and

[vii] Biodiesel and renewable diesel are distinct fuels that can be produced from similar feedstocks, including used cooking oil, animal fats, or vegetable oils. They are produced using different processes.

consumption have increased in Oregon, biodiesel has accounted for a smaller portion of the state's diesel fuel supply. Oregon's Clean Fuels Program also incentivizes both biodiesel and renewable diesel based on their lifecycle carbon intensity relative to conventional petroleum diesel.

Most diesel users consume some amount of biodiesel, although the exact amount varies over time based on market conditions and fuel availability. Biodiesel prices in Oregon remain influenced by petroleum diesel prices, feedstock availability, and broader energy market conditions. Supply disruptions, geopolitical events, fluctuations in crude oil prices, and changes in agricultural commodity markets can all affect biodiesel cost and availability.

Additional Resources

- U.S. Department of Energy Alternative Fuels Data Center: Biodiesel
- U.S. Energy Information Agency: Biodiesel Explained
- U.S. Department of Energy: Biofuels Explained
- ODOE 2026 Biennial Energy Report: Energy by the Numbers – Transportation Fuels
- U.S. Department of Energy Alternative Fuels Data Center: Biodiesel Handling and Use Guide

Propane Fuel (Fossil and Renewable)

Fossil Propane

Total annual consumption	**7.95 trillion Btu**
End use sector(s)	**Residential, Commercial, Transportation, Industrial**
Percent of total transportation fuels	**0.07%**
Percent of total direct use fuels	**3.08%**
Produced in Oregon	**0**
Imported	**7.95 trillion Btu**
Carbon intensity	**80.88 gCO2e/MJ**
Total annual greenhouse gas emissions	**0.014 million MTCO2e**

Renewable Propane

Total annual consumption	**Data not available**[viii]
End use sector(s)	**Transportation**
Percent of total transportation fuels	**Data not available**
Percent of total direct use fuels	**Data not available**
Produced in Oregon	**0**
Imported	**0**
Carbon intensity	**17.39-35.34 gCO2e/MJ**
Total annual greenhouse gas emissions	**0.001 million MTCO2e**

[viii] Renewable propane was blended into petroleum propane, distributed, and consumed in state but not tracked in 2024.

Fuel Overview

In 2024, propane, also known as liquefied petroleum gas or LPG, represented approximately 3.1 percent of the direct-use fuels consumed in Oregon. Produced as a byproduct of natural gas processing and crude oil refining, propane is stored and transported in liquid form under moderate pressure, usually in tanks or cylinders. Oregon does not produce propane and relies predominantly on imports from natural gas processing facilities in Alberta and British Columbia.[17] An estimated 33,550 Oregon households, or about 2 percent of homes, use propane for space heating, and it is also commonly used for water heating and cooking.[18] Propane's high energy density, clean-burning characteristics and ease of storage make it a practical fuel option for Oregon's rural communities and areas outside the state's natural gas pipeline network.[19] Beyond residential uses, propane supports commercial and industrial heating loads, agricultural activities such as grain drying and greenhouse heating, backup power generation, and some transportation needs.

Renewable propane is an emerging lower-carbon fuel alternative produced as a coproduct of renewable diesel from waste residues and sustainably sourced materials, including agricultural byproducts, used cooking oils, and animal fats. Because it is chemically identical to conventional propane, renewable propane is fully compatible with existing appliances, vehicles, and storage infrastructure, allowing customers to adopt the fuel without modification. Growing demand for renewable diesel is prompting investment in new production facilities that will also expand renewable propane supply. Currently, only a portion of renewable propane reaches the commercial market because much of it is used on site to power production facilities. Commercial production in the United States began in 2018, but market supply remains limited, with most imports to Oregon coming from Louisiana and California.[20] In Oregon, renewable propane is gaining relevance in applications that are difficult or costly to electrify, such as rural heating, agricultural operations, and some transportation uses, and its adoption is supported by credit generation opportunities under the Oregon Clean Fuels Program, which incentivizes the use of lower-carbon fuels.[21]

Trends in Oregon

Figure 8: Fossil Propane Share of Transportation Fuels Consumed in Oregon

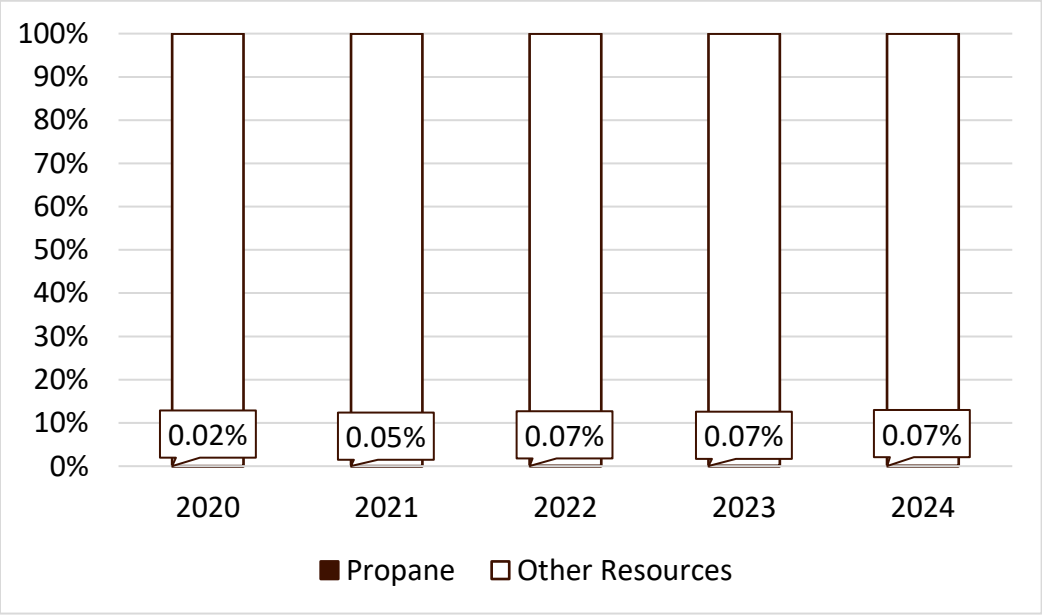


Figure 9: Fossil Propane Share of Direct Use Fuels Consumed in Oregon

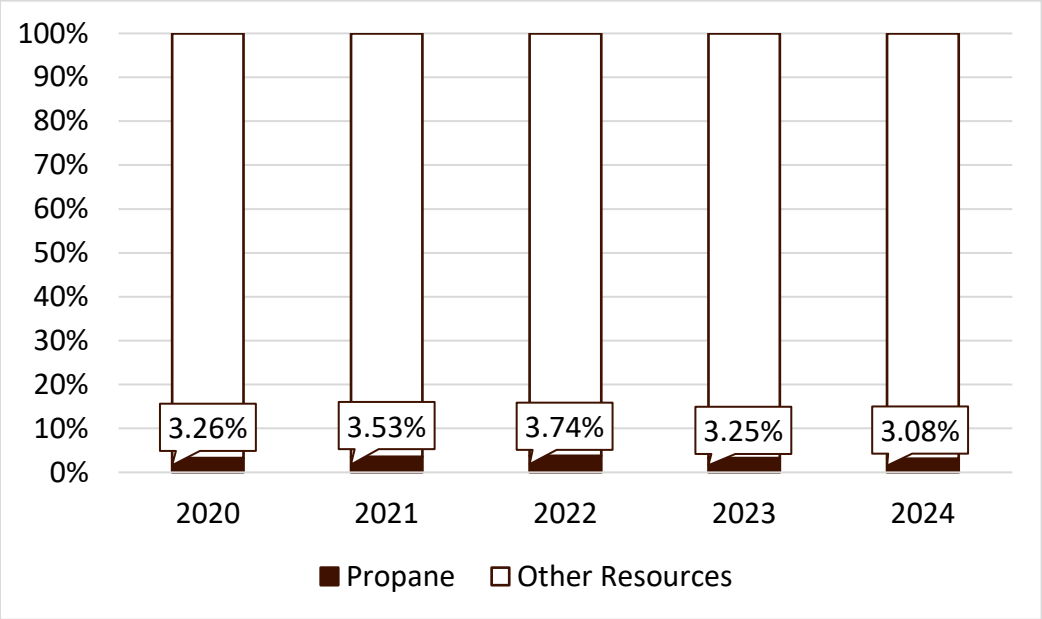
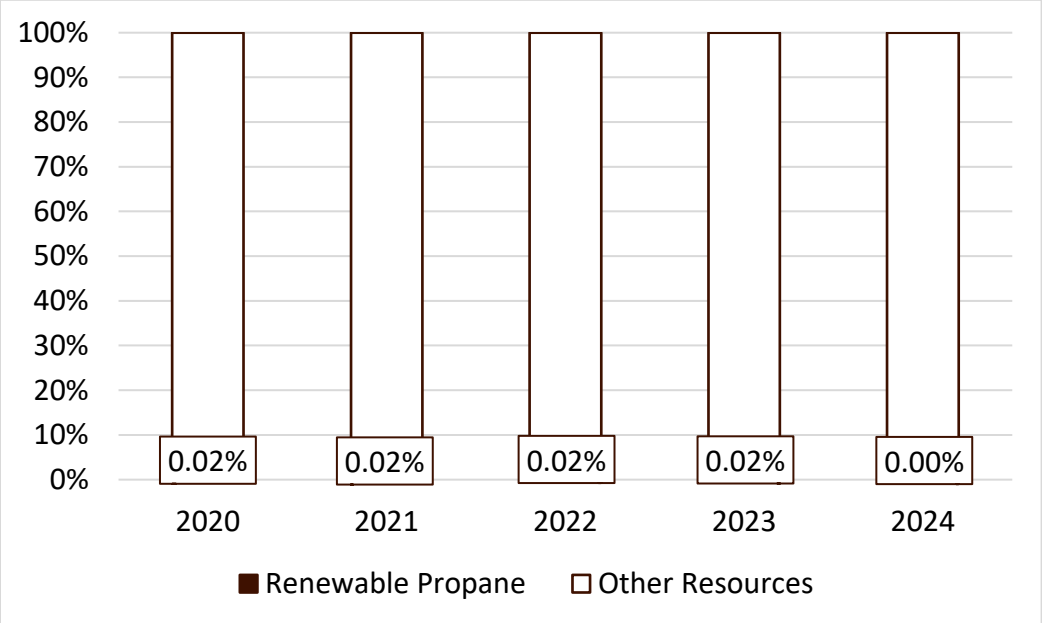


Figure 10: Renewable Propane Share of Transportation Fuels Consumed in Oregon



Propane consumption in Oregon has remained relatively steady due to its affordability, low emissions profile, and energy resilience benefits, such as its ability to be stored for long periods of time. Total consumption fluctuated slightly over recent years, totaling 7.9 trillion Btu in 2020 and 7.7 trillion Btu in 2024, a decrease of about 2.4 percent over this period. Supply has expanded in parallel with growing U.S. natural gas production, which may spur more use especially in the residential sector where propane is delivered and stored on site, providing a reliable energy resource in rural areas and during power outages. State and federal low-carbon fuel programs have also created financial incentives for the purchase and use of both conventional and renewable propane, especially in transportation fuel markets.

While renewable propane offers value across all consuming sectors, it carries higher market value when sold as a low-carbon transportation fuel and is used primarily by medium- and heavy-duty fleets. In 2025, Oregon consumed slightly more than 27.74 billion Btu, or 238,982 gasoline-gallon equivalents, of renewable propane in the transportation sector, representing about 0.01 percent of annual fuel consumption.[21] The fuel is imported from production facilities in Los Angeles and is currently blended into existing propane supplies for distribution to vehicle fleets.

Oregonians used over 1.9 million gasoline-gallon equivalents of propane in vehicles in 2024, accounting for roughly 0.07 percent of statewide transportation fuel consumption, an increase of 50 percent compared with 2021.[21] Propane-fueled vehicles typically cost less to operate, emit less pollution, perform better in cold weather, and operate more quietly compared to diesel. Many Oregon school districts operate propane school buses.[22] Adoption of propane vehicles remains modest and is supported by small fleets and 39 public fueling stations statewide.[23] State clean energy policies are also strengthening demand for low-carbon fuels, including renewable propane. These programs aim to reduce lifecycle emissions from fuels over time; however, the long-term effects on conventional propane availability remain uncertain.

Additional Resources

- U.S. Department of Energy Alternative Fuels Data Center: Propane Basics
- U.S. Energy Information Administration: Hydrocarbon gas liquids explained
- ODOE 2026 Biennial Energy Report: Energy by the Numbers – Transportation Fuels

Renewable Natural Gas Fuel

Total annual consumption	**2.53 trillion Btu**
End use sector(s)	**Transportation, Residential, Commercial, Industrial**
Percent of total transportation fuels	**0.16%**
Percent of total direct use fuels	**Data not available**
Produced in Oregon	**2.03 trillion Btu**
Imported	**0.5 trillion Btu**
Carbon intensity	**-420.3 to 84.16 gCO2e/MJ**
Total annual greenhouse gas emissions	**0.02 million MTCO2e**

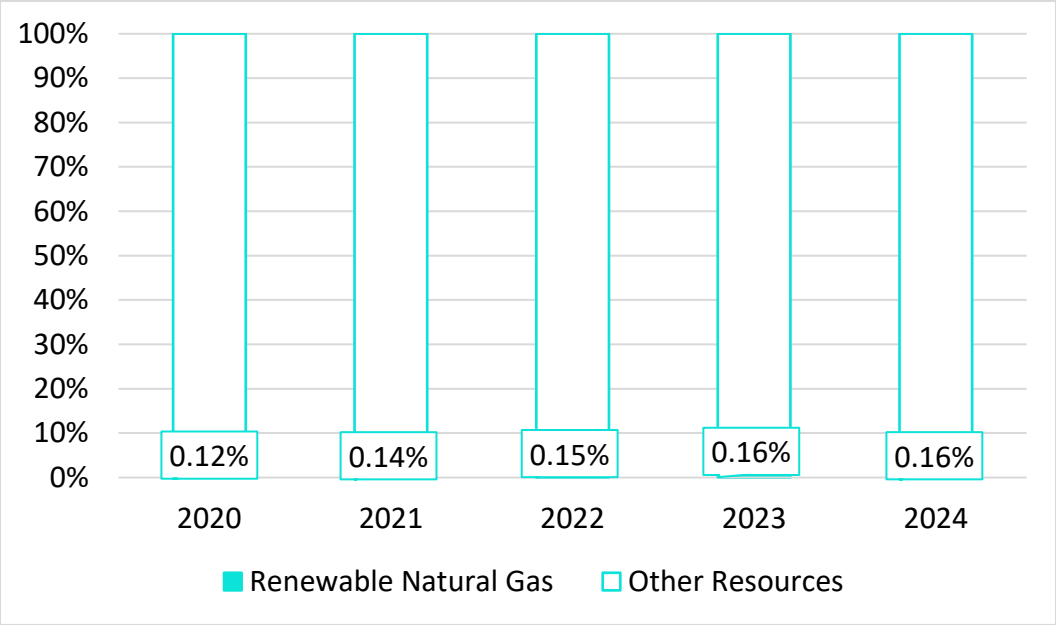
Fuel Overview

Renewable natural gas is pipeline-quality methane produced by upgrading biogas from such feedstocks as manure, food waste, wastewater sludge, and landfill material through anaerobic decomposition, and then refining it to 90-98 percent methane by reducing/removing CO2, water, and other impurities.[24] Oregonians use RNG through existing natural gas infrastructure for heating, industrial processes, electricity generation, and as a transportation fuel in natural-gas vehicles.[25] Because RNG is often mixed with natural gas, Oregonians who use natural gas are likely consuming a small amount of RNG.

Renewable natural gas reduces greenhouse gas emissions by capturing methane that would otherwise be released into the atmosphere at landfills, wastewater treatment plants, and manure-producing agricultural operations. This is a critical benefit because methane is a far more potent climate pollutant than CO2. Reduction benefits depend on how the RNG is made and how effectively operations capture methane and minimize leaks, which has led to a wide range of potential emissions reduction values. Some RNG production pathways reduce emissions more than three times the level that would otherwise occur if methane had not been released. Collecting biogas at these sites also helps manage waste and can improve local air and water quality. Like fossil natural gas, RNG produces emissions when combusted, but those emissions are far less harmful than the methane that would have escaped into the atmosphere without capture.

Trends in Oregon

Figure 11: Renewable Natural Gas Share of Transportation Fuels Consumed in Oregon



Recent trends show Oregon's RNG use is steadily increasing, largely driven by procurement efforts to achieve utility and state decarbonization requirements, primarily in the transportation sector. Although some RNG may be used as a direct use fuel for the residential, commercial, or industrial sectors, data are not available on actual amounts consumed. Natural gas utility customer interest has remained low for voluntary RNG purchase programs.[26] RNG is delivered through the existing natural gas network by Oregon's three major utilities—NW Natural, Cascade Natural Gas, and Avista—which procure RNG to help meet these emissions-reduction goals. Improved technologies for capturing and upgrading biogas into pipeline-quality fuel are expanding procurement options for utilities. NW Natural reported that it supplied 3.35 percent of its total gas mix as RNG to its customers in 2025 and anticipates as much as 4 percent in 2026.[27] In 2019, the Oregon Legislature passed SB 98, which authorized regulated natural gas utilities to procure increasing amounts of RNG. The Oregon Public Utility Commission oversees procurement decisions and cost allocations across utility customers.

The cost difference between fossil and renewable natural gas is a major challenge for greater RNG uptake. RNG is more expensive to produce than conventional natural gas because it must be conditioned to remove contaminants, compressed, and interconnected to a pipeline. For example,

landfill gas projects are estimated to produce RNG at a cost of $10-20 per million British thermal unit (MMBtu), and dairy manure projects may reach costs closer to $40 per MMBtu.[28] In comparison, the price of natural gas the 2026 Henry Hub[ix] price for natural gas averaged $3.44 per MMBtu.[29] Developers and suppliers can monetize federal and state renewable and clean fuels programs to help offset some of these costs. For example, RNG use can generate credits from the Oregon Clean Fuels Program that can be sold on the market, often making environmental credits a key source of revenue.[21] [30] RNG is also an option for utilities to comply with the Oregon Climate Protection Program that sets a decreasing cap on greenhouse gas emissions. In addition to utility procurement, RNG is already being used in Oregon's transportation sector, including fleets like Weyerhaeuser's RNG-powered log trucks and in some Cherriots' buses.[31] [32]

Additional Resources

- U.S. Environmental Protection Agency: An Introduction to Renewable Natural Gas
- U.S. Energy Information Administration: What is biogas?
- ODOE 2026 Biennial Energy Report: Energy by the Numbers – Transportation Fuels
- Oregon Department of Energy: 2018 Biogas and Renewable Natural Gas Inventory
- 2020 Biennial Energy Report: Renewable Natural Gas Policy Brief

Hydrogen Fuel

Total annual consumption	**0.002 trillion Btu**
End use sector(s)	**Transportation, Industrial**
Percent of total transportation fuels	**<0.01%**
Percent of total direct use fuels	**0**
Produced in Oregon	**0**
Imported	**0.002 trillion Btu**
Carbon intensity	**13.11 - 157.62 gCO2e/MJ[x]**
Total annual greenhouse gas emissions	**16.8 million MTCO2e**

Fuel Overview

Hydrogen is an energy carrier, meaning it can be used to store and deliver energy produced by other sources. Because hydrogen rarely occurs naturally in pure form, it must be produced from other resources. Today, most hydrogen is produced from natural gas through steam methane reformation, but it can also be produced through electrolysis, which uses electricity to split water into hydrogen and oxygen. Renewable hydrogen is hydrogen produced using renewable energy sources, such as

[ix] Henry Hub is used as the benchmark for U.S. natural gas prices.

[x] Hydrogen carbon intensity varies significantly depending on the production method and energy source. For example, hydrogen produced through electrolysis using renewable electricity can have a relatively low carbon intensity, while hydrogen produced using grid electricity or fossil fuels can have a substantially higher carbon intensity. The range shown reflect the different hydrogen production pathways recognized under Oregon's Clean Fuels Program.

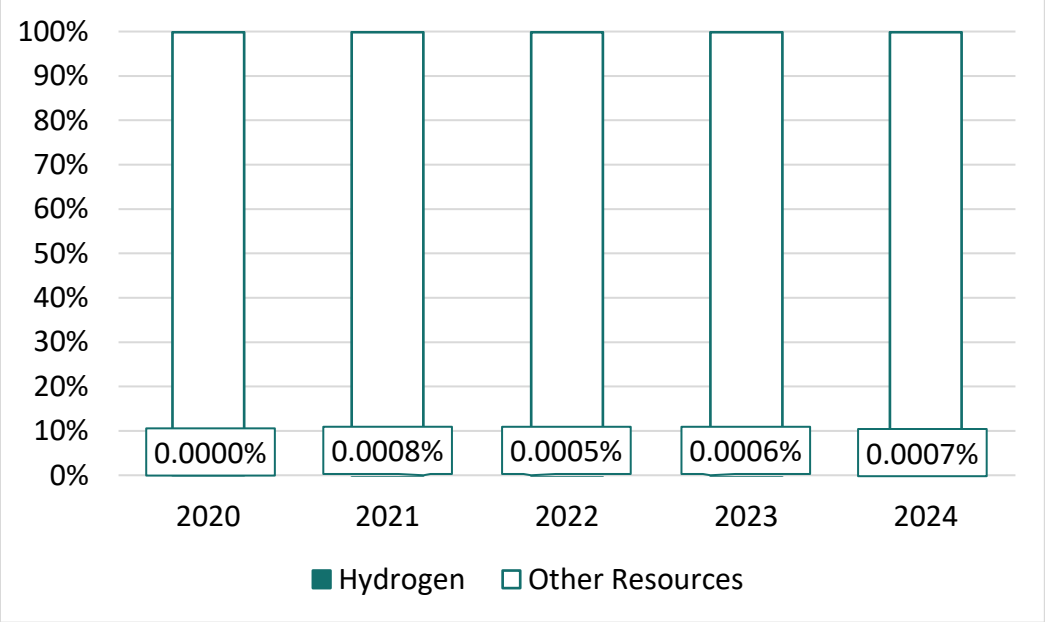
renewable electricity, and can have substantially lower greenhouse gas emissions than conventional hydrogen.

In Oregon, hydrogen use for energy production is currently limited, but it could be used as a transportation fuel in hydrogen fuel cell vehicles, as a substitute for fossil-based hydrogen in industrial processes, and for high-temperature industrial heat, energy storage, backup power, electricity generation, and production of chemicals and fuels. Hydrogen is generally less efficient and more expensive than direct use of electricity for many applications, including light-duty vehicle and building energy use. However, it may offer advantages where direct electrification is difficult or where long range, fast refueling, high equipment utilization, or high-temperature heat are important. ODOE's *2022 Renewable Hydrogen Report* similarly found that hydrogen is likely to be most valuable in Oregon for specific applications where electrification or other alternatives are less practical or cost-efficient, such as heavy-duty transportation like long-haul trucking or transit, industrial heat, backup power, and long-duration energy storage.[33]

Hydrogen can reduce local air pollution when used in fuel cell vehicles because the vehicle tailpipe emits only water vapor rather than greenhouse gases or criteria pollutants. However, the lifecycle emissions associated with hydrogen depend on how it is produced. Hydrogen also presents safety and infrastructure considerations because it is highly flammable, must be compressed or liquified for many uses, can leak more easily than other fuels, and requires specialized storage, handling, and emergency response practices.

Trends in Oregon

Figure 12: Hydrogen Share of Transportation Fuels Consumed in Oregon



Oregon does not have large-scale hydrogen production, distribution, or fueling networks. Since hydrogen is not readily used for energy in Oregon, recent trends are characterized by emerging project development and policy support. In October 2025, InEnTec completed installation of a waste-to-hydrogen facility at the Columbia Ridge Landfill in Arlington.[34] This pilot project is expected to produce about 600 to 1,100 kg of renewable hydrogen per day to be sold in the Pacific Northwest,

some of which may be used to fuel TriMet's pilot hydrogen bus expected to begin operating as early as 2027. This location is anticipated to be the source of hydrogen for the full fleet of hydrogen buses to be deployed on 82nd Avenue in 2029.[35] Beyond this project, there is interest in developing a hydrogen economy in the region. The Pacific Northwest Hydrogen Association was formed to apply for federal funding to support an association of public and private partners interested in developing a new clean hydrogen production and infrastructure in the region. While the association was successful in winning an award, the federal government terminated the funding before construction of projects could begin. The association remains, although project timelines and deployment levels remain subject to uncertain funding, market conditions, and policy decisions.

Hydrogen use is likely to grow first in targeted industrial, fleet, and heavy-duty applications rather than as a broadly available consumer transportation fuel. State and federal policies support hydrogen availability. Clean transportation policies like the Oregon Department of Environmental Quality's Clean Fuels Program and Climate Protection Program encourage hydrogen use as a means to address climate change. House Bill 2530 passed in 2023, directing ODOE to support the development of a renewable hydrogen economy.[36] The Oregon Energy Strategy identified low-carbon fuels like hydrogen as a critical pathway needed to meet state climate goals and energy objectives.[37] The federal Inflation Reduction Act created a clean hydrogen production tax credit of $3/kg, though the passage of H.R.1 in 2025 moved up the sunset date on that credit from 2032 to 2027. Hydrogen costs remain high compared to conventional fuels and other low-carbon technologies, and Oregon's lack of infrastructure remains a major barrier to adoption.

Additional Resources

- U.S. Department of Energy: Hydrogen Fuel Basics
- Oregon Department of Energy: Hydrogen
- Oregon Department of Energy: Renewable Hydrogen Study
- Pacific Northwest Hydrogen Hub
- Renewable Hydrogen Alliance: Hydrogen Education

References

1. Oregon Department of Energy. (2022). *2022 Biennial Energy Report: Energy Resource and Technology Reviews: Gasoline* (p. 18). https://www.oregon.gov/energy/Data-and-Reports/Documents/2022-BER-Energy-Resource-Tech-Reviews.pdf#page=18.
2. Oregon Department of Energy. (2022). *2022 BER Technology Resource Reviews: Natural Gas Fuel* (p. 97). https://www.oregon.gov/energy/Data-and-Reports/Documents/2022-BER-Energy-Resource-Tech-Reviews.pdf#page=23.
3. U.S. Census Bureau. (2024). *B25040: House Heating Fuel—Census Bureau Table*. https://data.census.gov/table/ACSDT1Y2024.B25040?t=Heating+and+Air+Conditioning+(HVAC):Housing&g=040XX00US41&y=2024.
4. Oregon Department of Energy. *Internal analysis.* (n.d.). Data on file. [Data set].

5. Oregon Public Utility Commission. (2024). *2024 Oregon Utility Statistics* (p. 42). https://www.oregon.gov/puc/forms/Forms%20and%20Reports/2024-Oregon-Utility-Statistics-Book.pdf.
6. U.S Energy Information Administration. (n.d.). *Oregon Price of Natural Gas Delivered to Residential Consumers (Dollars per Thousand Cubic Feet)*. Retrieved August 11, 2026, from https://www.eia.gov/dnav/ng/hist/n3010or3a.htm.
7. City of Portland. (2026, May 28). *Renewable Fuel Requirements Start Soon | Portland.gov*. https://www.portland.gov/bps/climate-action/renewable-fuel-standard/news/2026/5/28/renewable-fuel-requirements-start-soon.
8. Oregon Department of Environmental Quality. (n.d.). *Renewable Diesel 101*. Retrieved July 17, 2026, from https://www.oregon.gov/deq/FilterDocs/cfpdieselfaq.pdf.
9. Babamohammadi, S., Birss, A. R., Pouran, H., Pandhal, J., & Borhani, T. N. (2025, March). Emission control and carbon capture from diesel generators and engines: A decade-long perspective. *Carbon Capture Science & Technology*, *14*, 100379. https://doi.org/10.1016/j.ccst.2025.100379.
10. NXTClean Fuels. (2023, August 2). *Port Westward near Clatskanie, OR*. https://nxtclean.com/projects-facilities/port-westward/.
11. Your Oregon News.com. (2023, August 2). *NXTClean Fuels moves closer to development; public comment open*. https://nxtclean.com/projects-facilities/port-westward/.
12. StarOilco. *Fuel Market Report | Star Oilco*. (multiple dates). Accessed October 8, 2026. https://staroilco.net/fuel-market-report-3/.
13. Oregon Department of Energy. (2022). *2022 BER Energy Resource Technology Reviews: Ethanol* (p. 103). https://www.oregon.gov/energy/Data-and-Reports/Documents/2022-BER-Energy-Resource-Tech-Reviews.pdf#page=29.
14. Federal Reserve Bank of St. Louis. (2026, July 13). *Global price of Brent Crude*. https://fred.stlouisfed.org/series/POILBREUSDQ.
15. U.S. Grains & Bioproducts Council. Ethanol Market and Pricing Data –*U.S. Grains & BioProducts Council*. https://grains.org/ethanol_report/ethanol-market-and-pricing-data-june-18-2025/.
16. Oregon Department of Energy. (2022). *2022 BER Energy Resource Tech Reviews: Biodiesel Fuel* (p. 107). https://www.oregon.gov/energy/Data-and-Reports/Documents/2022-BER-Energy-Resource-Tech-Reviews.pdf#page=33.
17. U.S. Department of Energy. (n.d.). *How It Works: Propane Supply Chain: Office of Cybersecurity, Energy Security, and Emergency Response*. Retrieved October 8, 2026 from https://www.energy.gov/sites/default/files/2023-08/Propane%20Supply%20Chain%20Backgrounder_v3-Formatted_041723_508.pdf.
18. National Propane Gas Association. (2025, September 18). *Residential Heating Marketplace: Oregon*. NPGA. https://www.npga.org/news-resources/residential-heating-marketplace-oregon/.
19. Oregon Department of Energy. *2022 BER Energy Resource Tech Reviews: Propane Fuel* (p. 100). https://www.oregon.gov/energy/Data-and-Reports/Documents/2022-BER-Energy-Resource-Tech-Reviews.pdf#page=26.
20. Kriz, E. (2023, April 19). Renewable propane: Diverse players seek production pathways. *LP Gas*. https://www.lpgasmagazine.com/renewable-propane-diverse-players-seek-production-pathways/.

21. Oregon Department of Environmental Quality. (n.d.). *Quarterly Data Summaries: Oregon Clean Fuels Program*. https://www.oregon.gov/deq/ghgp/cfp/pages/quarterly-data-summaries.aspx.
22. Oregon Department of Transportation. (n.d.). *Propane School Buses Active In Oregon—ODE. Data on file at ODOE.* [Data set].
23. U.S. Department of Energy. (n.d.). *Propane Fueling Station Locations by State*. Alternative Fuels Data Center : Office of Critical Minerals and Energy Innovation. Retrieved July 15, 2026, from https://afdc.energy.gov/data/10371
24. U.S. Energy Information Administration. (n.d.). *Biomass Explained*. Retrieved July 23, 2026, from https://www.eia.gov/energyexplained/biomass/landfill-gas-and-biogas.php.
25. U.S. Energy Information Administration. (n.d.). *Oregon Natural Gas Consumption by End Use*. Retrieved October 8, 2026, from https://www.eia.gov/dnav/ng/NG_CONS_SUM_DCU_SOR_A.htm.
26. CarbonCandor. (2026, April 10). *Voluntary RNG Programs Had Almost No Takers*. https://carboncandor.com/research/voluntary-rng-nobody-signed-up.
27. NW Natural. (2026, July 1). *NW Natural Announces Another Year-Over-Year Increase in Renewable Natural Gas*. https://ir.nwnaturalholdings.com/news/news-details/2026/NW-Natural-Announces-Another-Year-Over-Year-Increase-in-Renewable-Natural-Gas/default.aspx.
28. American Gas Foundation. (2025, July). *Renewable Natural Gas Supply Assessment*. https://gasfoundation.org/wp-content/uploads/2025/07/AGF-RNG-Study_FINAL-09022025.pdf.
29. U.S. Energy Information Administration. (2026, October 6). *Short-Term Energy Outlook*. https://www.eia.gov/outlooks/steo/report/natgas.php.
30. NW Natural. (n.d.). *Renewable Natural Gas: NW Natural Supports SB98*. Retrieved July 28, 2026, from https://olis.oregonlegislature.gov/liz/2019R1/Downloads/CommitteeMeetingDocument/157640.
31. Cherriots. (n.d.). *Cherriots is Oregon's Cleanest Public Transit Fleet*. Retrieved October 8, 2026, from https://m.cherriots.org/news/cherriots-is-oregons-cleanest-public-transit-fleet/.
32. *Renewable Natural Gas Trucks Debut in Oregon Timberlands*. (2025, December 15). https://www.weyerhaeuser.com/blog/renewable-natural-gas-trucks-debut-in-oregon-timberlands/.
33. Oregon Department of Energy. (2022, November 15). *2022 ODOE Renewable Hydrogen Report*. https://www.oregon.gov/energy/Data-and-Reports/Documents/2022-ODOE-Renewable-Hydrogen-Report.pdf.
34. InEnTec, Inc. (2025, October 13). *InEnTec and Columbia Ridge Facility Achieve Mechanical Completion of Hydrogen Plant, Initiate Commissioning*. https://www.prweb.com/releases/inentec-and-columbia-ridge-facility-achieve-mechanical-completion-of-hydrogen-plant-initiate-commissioning-302580427.html.
35. TriMet. (2026, May). *Hydrogen and 82nd Ave: Two Contracts*. https://trimet.org/meetings/board/pdfs/2026-05-27/82nd-and-hydrogen-update.pdf.
36. Relating to Development of a State Renewable Hydrogen Economy, H.B. 2530, 82nd Oregon Legislative Assembly. https://olis.oregonlegislature.gov/liz/2023r1/Downloads/MeasureDocument/HB2530.
37. Oregon Department of Energy. (2025). *Oregon Energy Strategy*. (p 15). https://www.oregon.gov/energy/data-and-reports/Documents/Oregon-Energy-Strategy.pdf#page=21.

Clean Vehicle Technologies

Electric Vehicles

Total number of light-duty EVs registered in Oregon:	**141,715**
Number of plug-in hybrid electric vehicles:	**38,409**
Number of battery electric vehicles:	**103,306**
Percentage of EVs in total registered light-duty fleet	**3.78%**
Percentage of light-duty sales that are ZEVs (2026 Q2)	**12%**
State target by 2030[1]	**25% of registered vehicles**
Total number of medium- and heavy-duty EVs registered	**1,051**
Percentage of EVs in total registered MHD	**0.8%**

Technology Overview



Electric vehicles use electric motors powered by onboard batteries rather than internal combustion engines.[1] The two primary types are battery electric vehicles, which operate entirely on electricity, and plug-in hybrid electric vehicles, which combine a battery-powered drivetrain with a conventional gasoline or diesel engine. EVs are refueled by charging their batteries from the electric grid. They generally cost less to fuel and maintain, are more energy efficient, and reduce exposure to fuel price volatility, though they often have higher upfront costs. Electric vehicles are more efficient than internal combustion engine vehicles because electric motors convert a much larger share of energy into moving the vehicle, lose less energy as heat, and can recover energy through regenerative braking that would otherwise be wasted when slowing down.

Full battery electric vehicles produce no tailpipe emissions, and their use can improve local air quality and reduce exposure to pollutants linked to respiratory and cardiovascular illness. They also have fewer lifecycle greenhouse gas emissions than comparable internal combustion vehicles, and these emissions continue to decline as the electric grid becomes cleaner.[2] There are environmental impacts associated with EV battery material extraction, manufacturing, recycling, and end-of-life disposal. These environmental impacts are typically outweighed by long-term emissions reductions. There are also safety concerns associated with the lithium-ion batteries used in the cars. While battery fires are relatively rare, they can be more difficult to extinguish than conventional vehicle fires due to the potential for thermal runaway and re-ignition. Available evidence suggests that overall vehicle fire risk remains lower than that of conventional gasoline vehicles.[3]

[1] DEQ's Advanced Clean Cars II regulations established minimum sales requirements for light-duty zero emission vehicles.

Trends in Oregon

Figure 1: Cumulative Light-Duty Electric Vehicle Registrations in Oregon (2021-2025)

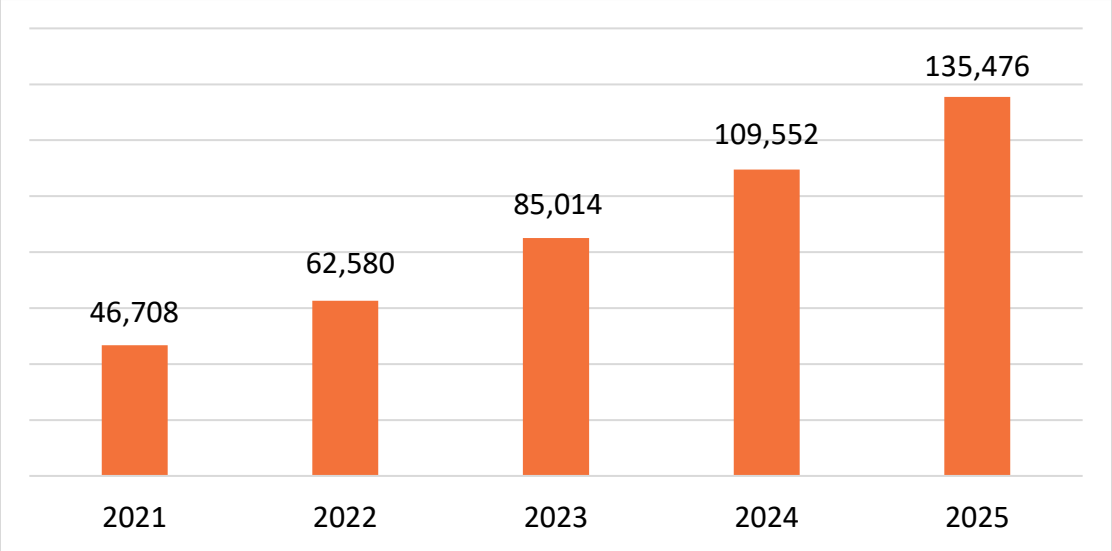
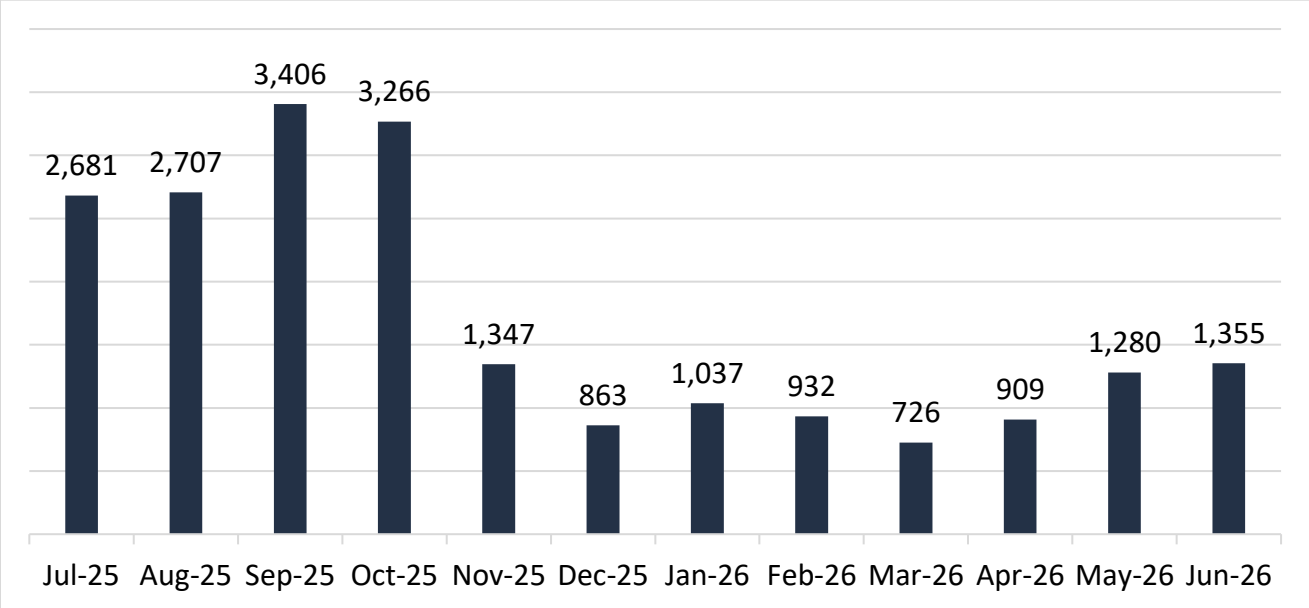


Figure 2: New Light-Duty Electric Vehicle Registrations in Oregon by Month (2025-2026)



Oregon has experienced substantial growth in EV adoption over the past decade, increasing from just over 3,000 registered EVs in 2015 to more than 130,000 by 2026.[4] EV adoption in Oregon has grown as battery costs have declined, vehicle model availability has expanded, consumers have become more familiar with EVs, and state and federal policies have supported the transition. While many of these factors have contributed to EV adoption nationwide, Oregon's adoption has generally outpaced national trends, reflecting additional state-level policies, incentives, and other market conditions that have supported EV uptake. Adoption has been concentrated in the passenger vehicle market, but registrations of medium- and heavy-duty EVs are also growing and have more than tripled since 2023. EVs are now registered in every Oregon county, though adoption remains highest in urban areas and among higher-income households.

Despite overall growth, adoption rates remain below the levels needed to achieve the state's transportation, air quality, and climate objectives. Recent federal policy changes have dampened growth by removing key incentives and regulations[2] that supported EV uptake.[5] Following expiration of the federal EV tax credit in September 2025, EV registrations in Oregon declined significantly through early 2026. While sales have since shown signs of recovery, driven potentially by rising gasoline prices and growth in the used EV market, continued progress will likely depend on expanding the several state policies and utility programs in place that help expand vehicle availability, reduce ownership costs, and build the infrastructure needed to support transportation electrification.

Oregon's EV market appears to be transitioning from early adopters toward broader consumer adoption. EV affordability is improving, which is expanding ownership potential for more households. However, higher upfront costs for new vehicles, limited charging access for renters and rural communities, and concerns about driving range and charging convenience continue to be barriers for some Oregonians. More economical used EVs are approaching price parity with used gasoline vehicles,[6] [7] and EVs continue to offer substantial operating cost savings. On a per-mile basis, an EV charged at home can cost less than half as much to operate as a comparable gasoline vehicle, especially when those fuel prices rise.

Additional Resources

- ODOE: 2025 Biennial Zero Emission Vehicle Report
- ODOE: EV Dashboard
- U.S. DOE Alternative Fuel Data Center: Electric Vehicles
- U.S. EPA: Electric & Plug-in Hybrid Electric Vehicles

Fuel Cell Electric Vehicles

Total number of FCEVs registered in Oregon	**0**
Number of hydrogen fueling stations in Oregon	**0**



An Xcelsior CHARGE FC 60-foot fuel cell electric bus to be used at TriMet's 82nd Avenue Facility. Image courtesy of TriMet.

[2] In June 2025, the Trump Administration and Congress used the Congressional Review Act to purportedly disapprove of EPA waivers authorizing California's Advanced Clean Cars II and Advanced Clean Trucks regulations, creating uncertainty for states like Oregon that have adopted CA's vehicle emissions standards. Oregon joined a multi-state legal challenge to the action. If upheld, the purported disapproval would prevent Oregon from enforcing these regulations and is likely to significantly slow EV adoption in the state.

Technology Overview

Fuel cell electric vehicles, sometimes called hydrogen vehicles, use electric motors for propulsion but store energy as hydrogen rather than in a large battery pack.[8] Hydrogen stored onboard the vehicle is converted into electricity through a fuel cell, which combines hydrogen and oxygen to produce electricity that powers the drivetrain. Like battery electric vehicles, FCEVs are classified as zero-emission vehicles because they produce no tailpipe emissions; the only by-products of the fuel cell reaction are water and heat. FCEVs are refueled at dedicated hydrogen fueling stations, which can provide refueling times comparable to gasoline vehicles but require specialized hydrogen production, delivery, storage, and dispensing infrastructure. Compared with battery electric vehicles, FCEVs are generally lighter and offer faster refueling, making them well suited for applications requiring long range, high utilization, heavy payloads, or centralized fleet fueling. However, vehicle availability remains limited, fueling infrastructure is sparse, and vehicle and fuel costs are higher than competing technologies.

FCEVs have fewer greenhouse gas emissions when fueled with low-carbon hydrogen. Because they are most likely to be deployed in medium- and heavy-duty applications, they could also eliminate diesel emissions contributing to local air pollution, which improves health outcomes for environmental justice communities located close to busy roadways and thoroughfares. However, broader environmental benefits depend largely on how the hydrogen is produced, with most hydrogen production today creating greenhouse gases and local air pollutant emissions. Hydrogen safety is also a common concern because hydrogen is a highly flammable gas that must be stored at very high pressures. Like gasoline and diesel vehicles, fuel cell EVs use an energy source that can ignite under certain conditions, but the risks differ. Unlike liquid fuels that can pool on the ground and continue burning, hydrogen disperses rapidly when released.[9] Modern fuel cell vehicles and fueling stations are engineered with multiple safety systems to manage these risks and are subject to rigorous testing and safety standards.[10]

Trends in Oregon

Fuel cell electric vehicles remain a niche transportation technology in Oregon, with adoption significantly lagging battery electric and conventional vehicles. While a small number of passenger FCEVs are available in the United States, deployment has been concentrated almost entirely in California where the nation's most extensive hydrogen fueling network exists.[11] Oregon currently has little to no FCEV adoption and no public hydrogen fueling stations. Unlike the rapid growth seen in Oregon's light-duty battery EV market, hydrogen vehicle deployment is expected to remain limited in the near term and concentrated in demonstration projects and fleet applications.

Interest in hydrogen transportation has increased in recent years as transit agencies, ports, and freight operators explore hydrogen's potential role in decarbonizing difficult-to-electrify transportation applications. For example, TriMet is actively developing one of the Pacific Northwest's largest transit hydrogen projects. The agency secured federal funding for 14 hydrogen fuel-cell buses and associated fueling infrastructure, is constructing facility upgrades and a hydrogen fueling station, and plans to deploy buses along the 82nd Avenue corridor beginning in 2029.[12] The project remains in the implementation phase, with infrastructure construction, fuel procurement, and workforce training underway. The Oregon Department of Transportation also secured funding through the Charging and

Fueling Infrastructure Grant Program to develop one hydrogen fueling station along the I-5 corridor in Oregon.[13]

Additional Resources

- U.S. Department of Energy: Hydrogen
- National Lab of the Rockies: Hydrogen and Fuel Cells
- U.S. Department of Energy: Alternative Fuels and Feedstocks Office
- Hydrogen Fuel Cell Partnership

Electric Vehicle Charging

Public Level 2 and fast-charging stations in Oregon	**1,651 locations**
Total public Level 2 ports	**2,938**
Total public fast-charging ports	**1,324**

Technology Overview



Electric vehicle chargers supply electricity to battery electric and plug-in hybrid electric vehicles.[14] Charging technologies vary by vehicle type and how the vehicle is used. Charging generally falls into three categories: Level 1 charging using a standard 120-volt outlet, Level 2 charging using 240-volt power, and DC fast charging, which delivers much higher power levels and is commonly used for rapid charging during long-distance travel, public charging for those without access to charging at home, and medium- and heavy-duty zero emissions vehicles. A new charging standard, the Megawatt Charging System, is emerging to support larger vehicle classes, such as freight trucks, delivering up to 10 times more power than today's fastest car chargers.[15] Not all electric vehicles are compatible with every charger due to varying connector standards, though the industry is increasingly converging around J3400 (formerly known as the North American Charging Standard, or NACS), and adapters are becoming widely available.

Most passenger EV charging occurs at home, but public charging plays a critical role in supporting long-distance travel, drivers without access to home charging, and commercial and fleet operations. Charging technology varies in cost, charging speed, and infrastructure requirements. Slower Level 1 and Level 2 chargers are generally less expensive to install and well suited for locations where vehicles remain parked for several hours, such as homes, workplaces, and overnight fleet depots. DC fast chargers and megawatt charging systems recharge vehicles much more quickly but require substantially more electrical capacity and often costly utility upgrades.

Trends in Oregon

Figure 3: Total Cumulative Electric Vehicle Charging Ports in Oregon

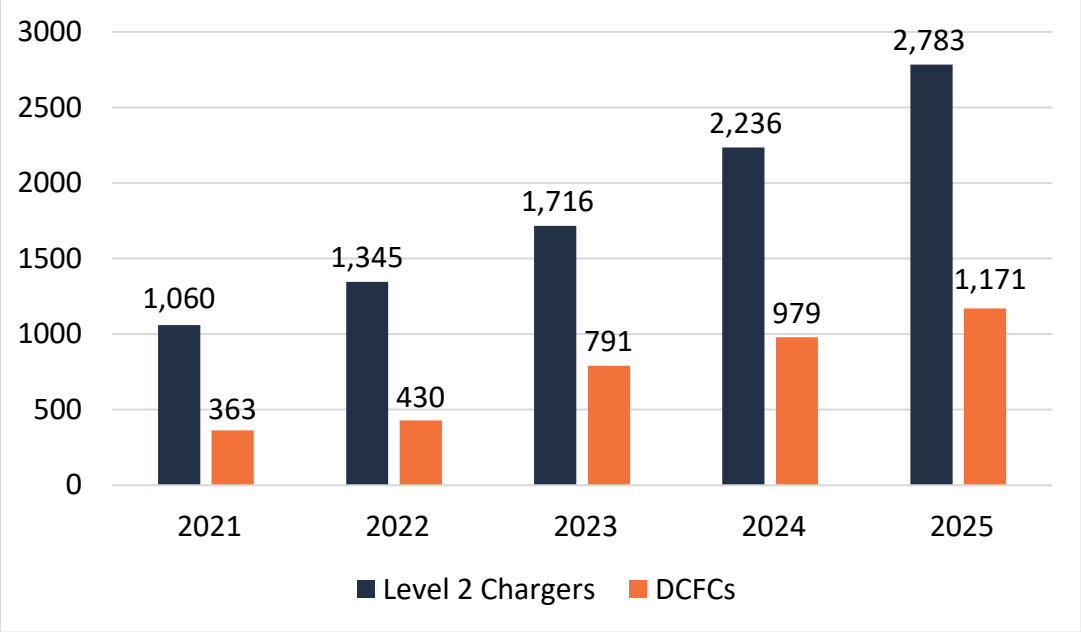
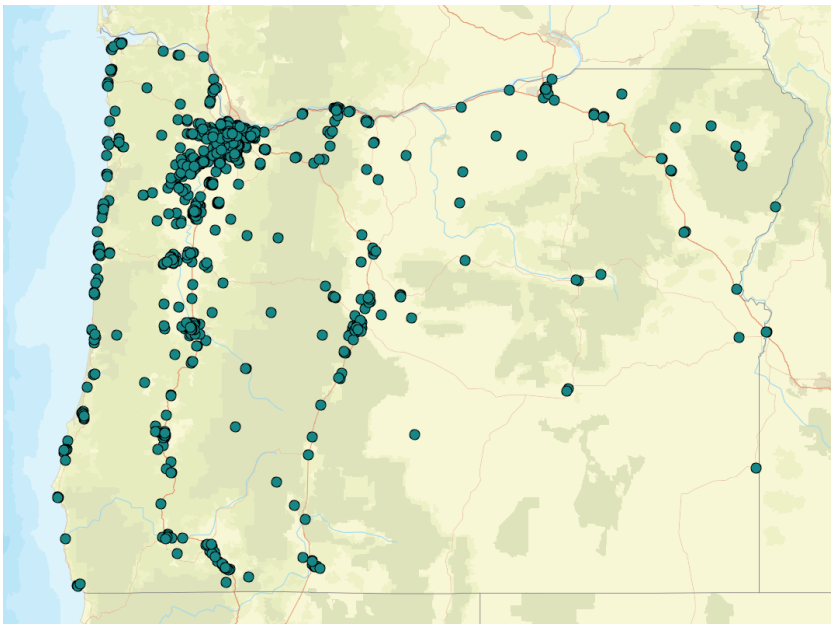


Figure 4: Map of EV Charging Station Locations in Oregon



Oregon's EV charging infrastructure has expanded rapidly over the past decade alongside increasing EV adoption and growing public and private investment. Public chargers are largely concentrated around population centers, major travel corridors, workplaces, and key destinations; however, utilities and public entities continue investing in expanding access to underserved and rural communities. Although Level 2 charging remains the most common charger type in Oregon, deployment of DC fast chargers is accelerating. State and federal investments, including the National Electric Vehicle Infrastructure program, utility transportation electrification programs, Clean Fuels Program credit revenues, and other funding sources have helped accelerate deployment statewide.

Charging infrastructure for medium- and heavy-duty vehicles has significantly lagged light-duty deployment. While many medium-duty electric vehicles can use existing higher-powered public fast chargers, heavy-duty vehicles often require specialized infrastructure, including pull-through station designs, overnight truck parking, and megawatt charging systems. As a result, most medium- and heavy-duty charging infrastructure in Oregon has been privately developed depot charging. There is currently only one publicly accessible charging station in Oregon specifically designed for heavy-duty vehicles: Electric Island in Portland.[16] [17] The site was designed to support up to 5 megawatts of charging capacity, currently includes 15 fast-charging ports, and plans to add megawatt charging capability in 2026. Over the next several years, federal and state funding administered by DEQ and ODOT will add dozens of additional medium- and heavy-duty public charging ports along Interstate 5, Interstate 84, and elsewhere.[13] [18] [19]

Charging station deployment remains well below the levels identified to support Oregon's EV adoption goals. Key barriers include installation costs, electrical service upgrades, utility interconnection timelines, and limited availability for renters, multifamily residents, and those living in rural and underserved areas. Recent federal policy changes have also created uncertainty for EV charging station deployment by reducing incentives for both charging infrastructure and EV adoption. Charger reliability also remains a persistent challenge, with EV drivers frequently encountering broken or nonfunctional chargers that can lead to unexpected delays and undermining confidence in EVs. Recent improvements to reliability standards, maintenance requirements, and interoperability across charging networks are expected to improve the user experience over the next several years.

Additional Resources

- Oregon Department of Energy: 2025 Biennial Zero Emission Vehicle Report
- U.S. Department of Energy: Electric Vehicle Charging Stations
- GreenCars.com: How EV Charging Works: A Beginner's Guide

References

1. Oregon Department of Energy. *2020 Biennial Energy Report Technology Review: Electric Vehicles*. (pp 82–84). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=84.
2. Rachael Nealer, David Reichmuth, & Don Anair. (2015). *Cleaner Cars from Cradle to Grave | Union of Concerned Scientists*. https://www.ucs.org/sites/default/files/attach/2015/11/Cleaner-Cars-from-Cradle-to-Grave-full-report.pdf.
3. National Fire Protection Association. (n.d.). Electric Vehicle Safety Information. *Retrieved October 7, 2026 from* https://www.nfpa.org/education-and-research/energy-transition/electric-vehicles.
4. Oregon Department of Energy. (n.d.). EV Dashboard. *Retrieved October 7, 2026 from* https://www.oregon.gov/energy/Data-and-Reports/Pages/Oregon-Electric-Vehicle-Dashboard.aspx.

5. Electrification Coalition. (2025, July 17). EV and Charging Tax Credits After the One Big Beautiful Bill Act. https://electrificationcoalition.org/resource/ev-and-charging-tax-credits-after-the-one-big-beautiful-bill-act/.

6. Dan McCarthy. (2026, May 1). Used EVs are on the upswing in America. *Canary Media.* https://www.canarymedia.com/articles/electric-vehicles/used-evs-upswing-america.

7. Cox Automotive. (2026, March 25). Q1 2026 Industry Insights and Sales Forecast Call. (pp 26–30). https://www.coxautoinc.com/insights/replay-available-cox-automotive-q1-2026-industry-insights-and-sales-forecast-call/.

8. Oregon Department of Energy. (2020). *2020 Biennial Energy Report Technology Review: Fuel Cell Electric Vehicle (Hydrogen Cars)*. https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=89.

9. Hydrogen Tools. (n.d.). Hydrogen Compared To Other Fuels. *Retrieved October 7, 2026 from* https://h2tools.org/bestpractices/best-practices-overview/hydrogen-basics/hydrogen-compared-to-other-fuels.

10. U.S. Department of Energy. (2011). Safety, Codes, and Standards : Fuel Cell Technologies Program. https://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/doe_h2_safety.pdf.

11. U.S. Department of Energy. (n.d.). Hydrogen Fueling Station Locations. *Alternative Fuels Data Center. Retrieved October 7, 2026 from* https://afdc.energy.gov/fuels/hydrogen-locations.

12. TriMet. (n.d.). 82nd Avenue Transit Project. Retrieved October 7, 2026 from https://trimet.org/82nd/.

13. Oregon Department of Transportation. (2026, September). Medium- and Heavy-Duty Zero Emission Vehicle Infrastructure Programs in Oregon. *Climate Office* https://www.oregon.gov/odot/climate/pages/mhdzev.aspx.

14. Oregon Department of Energy. (2020). *2020 Biennial Energy Report Technology Review: Electric Vehicle Chargers*. (pp 76–80). https://www.oregon.gov/energy/Data-and-Reports/Documents/2020-BER-Technology-Resource-Reviews.pdf#page=78.

15. CharIN. (2025, May 8). *Megawatt Charging System - Recommendations and Requirements for MCS Related Standards Bodies and Solution Suppliers (Version 2.0)*. https://www.charin.global/media/pages/technology/knowledge-base/0c2cc2c8da-1747654352/250508_whitepaper_megawatt_charging_system_2.0.pdf.

16. Black & Veatch. (n.d.). Electric Island: Providing the Pathway to Carbon-Free Trucking. *Retrieved October 7, 2026 from* https://www.bv.com/projects/electric-island-providing-the-pathway-to-carbon-free-trucking.

17. Portland General Electric. (2021, April 21). Daimler Trucks North America, Portland General Electric open first-of-its-kind heavy-duty electric truck charging site. Newsroom : Archive. https://portlandgeneral.com/news/2021-04-21-daimler-portland-general-electric-open-electric-charging-site.

18. Oregon Department of Transportation. (2026, May). Carbon Reduction Program. *Climate Office* https://www.oregon.gov/odot/climate/Pages/CarbonReductionProgram.aspx.

19. Department of Environmental Quality. (n.d.). Oregon Zero-Emission Fueling Infrastructure Grant. *Clean Vehicles* Retrieved October 7, 2026 from https://www.oregon.gov/deq/aq/programs/Pages/OZEF.aspx.

Emerging Technology Reviews



New clean energy technologies are under development that could one day help meet Oregonians' energy needs. The Oregon Energy Strategy found that emerging technologies are likely needed to complement new traditional renewable energy resources to meet state energy objectives and climate goals.[1] In early stages of development, it is uncertain if or when different emerging technologies might become cost-competitive options for Oregon. Monitoring advancements can help policymakers, grid operators, and regulators support the development and deployment of technologies that increase access to affordable, safe, and reliable clean energy. The Oregon Energy Strategy included an action for ODOE to report on developments in emerging technologies, identify the role they can play in meeting the state's electricity needs, and explore opportunities for pilot programs in the near term.

In November 2025, Governor Kotek directed the Oregon Department of Energy and other state agencies through Executive Order 25-29 to identify and evaluate emerging clean energy technologies that could play a role in Oregon's energy future, and to publish findings in the *Biennial Energy Report*.[2] The emerging technologies presented in this edition of the report include those indicated in the energy strategy, which incorporated the views and input of hundreds of experts and members of the public who informed that process. The technologies include enhanced geothermal, floating offshore wind, marine hydrokinetic energy, advanced nuclear, and long-duration energy storage. While these are primarily focused on the electricity sector, future reports may include emerging technologies and resources in transportation, heating, or industrial fuels.

Carbon capture technologies, critical mineral resources, and mining technologies are also important pieces of the clean energy transition. The Oregon Department of Geology and Mineral Industries follows emerging technologies such as the minerals (elements) needed to produce batteries, lithium, cobalt, nickel, among others, and the growing interest in geological hydrogen that could someday be used for electricity production. The department also focuses on geologic carbon sequestration and associated capture technologies that could play an important role in decarbonization.

Evaluating emerging clean energy technologies requires understanding how they work as well as projected costs and barriers to development. The information provided below describes how costs and barriers will be compared across all the emerging technologies in this report, with more detailed information provided in the individual emerging technology reviews. Projected costs are taken from multiple publicly available sources to enable objective side-by-side comparisons. Barriers to development are followed by recommendations to improve processes, including cross-agency frameworks that may better serve project developers and Oregon communities.

Key Takeaways

Emerging clean energy technologies have the potential to help build a resilient clean energy economy in Oregon but still face considerable barriers to commercial development. Technology improvements, cost reductions, economies of scale, and local community involvement will all be necessary for emerging technologies to become commercially viable resources in future energy markets. Oregon is rich in renewable energy resources and has been selected by many developers as their preferred location to test and demonstrate emerging technologies. Marine energy research, long-duration

battery storage, enhanced geothermal and other emerging technologies are all under development in Oregon.

A few of the key findings regarding opportunities for emerging technologies that could play a role in Oregon's energy future include:

1. **Long-duration storage can stretch low-cost renewables.** Solar and wind facilities provide some of the lowest cost energy on the grid but require flexible, dispatchable resources to balance their intermittent generation. To date, Oregon's hydro and natural gas generators have provided balancing services. In the future, long-duration storage technologies have the potential to further complement variable renewables by capturing low-cost energy during periods of surplus production and delivering it during periods of peak demand. Some technologies, such as iron-based batteries, utilize more common and lower cost materials than lithium-ion batteries and have the potential to dramatically reduce storage costs. If long-duration storage can reach the $0.05 per kWh target set by the U.S. Department of Energy, it may reduce the amount of other dispatchable energy resources needed to balance wind and solar. Utility-scale solar and wind are projected to be about $25 per MWh by 2035. Adding $5/MWh would make long-duration storage plus wind and solar cheaper than the projected costs for enhanced geothermal and nuclear.

   Next Steps:

   - Coordinate with BPA, utilities, and other energy suppliers to determine the scale and timing of curtailed renewables in the Northwest. This will enable utilities and developers to consider energy storage solutions for the surplus energy.
   - Conduct a review of codes, product standards, and operational standards that apply to battery energy storage systems. This will enable counties, or other permitting entities, to establish eligibility criteria and safety requirements for emerging battery storage facilities.
   - Implement recommendations in the *Accelerating Clean Energy Deployment Through Oregon's Land Use Planning Framework* developed by the Department of Land Conservation and Development. This study provides best practices for policy makers and local jurisdictions to consider when siting battery energy storage systems.

2. **Emerging baseload resources can provide critical grid services and enhanced geothermal is projected to be the lowest cost emerging resource for Oregon.** Enhanced geothermal and advanced nuclear have the potential to provide similar grid services though nuclear is projected to be higher cost. Both have a resource potential that could supply a significant share of the energy needed in Oregon through 2050, and both are baseload resources that may be operated to support grid stability. The differences between the two will emerge with siting, permitting, and cost. Advanced nuclear facilities can be placed anywhere fuel can be delivered but face development limitations in Oregon and may face public scrutiny due to their dangerous radioactive waste streams. Absent a change in state law, nuclear energy needs to be imported from other states. Enhanced geothermal systems have no fuel requirements but are best sited in central and eastern Oregon where geothermal resources are strongest — but

access to transmission is limited. Development will affect communities in these areas and other parts of central and eastern Oregon where transmission lines may need to be developed. Enhanced geothermal has lower cost projections than nuclear but actual costs will depend on technological advancements and economies of scale.

Next Steps:

- Support coordination between federal, state, and local entities that play a role in permitting geothermal, other emerging energy technologies, and new transmission. Develop permitting roadmaps to improve permitting efficiency and transparency.
- Consider the ability to interconnect Oregon renewable energy resources when evaluating future transmission corridors and upgrades, giving higher priority to investments that support such interconnection.

3. **Oregon has excellent floating offshore wind and marine energy resources, but costs are uncertain, and local communities have many concerns.** Floating offshore wind has comparable projected costs to enhanced geothermal in the Lazard's levelized cost of energy analysis but higher projected costs in the National Lab of the Rockies ATB analysis. Marine hydrokinetic energy lacks cost projections. Oregon has one of the best wind and wave resource areas in the country, which could provide renewable energy during periods of low production from solar and onshore wind. Oregon is also poised to be a global leader in wave energy, which could have positive economic effects for Newport, Coos Bay, and other coastal communities. However, Oregon Tribes, coastal industries, and coastal communities have concerns about how offshore energy facilities could affect the environment and their livelihoods.

   Next Steps:

   - Development of the PacWave test facility and the Oregon Offshore Wind Energy Roadmap included extensive outreach with Tribal leaders, fishing industry representatives, community organizations, and coastal communities. Lessons learned from these efforts should be applied to other emerging technologies and local communities in Oregon.
   - State agencies should coordinate with OSU/PacWave to help attract wave energy researchers and developers.
   - State agencies should support implementation of the Recommended Strategies and Actions for the Seven Objectives identified in the Oregon Offshore Wind Energy Roadmap.

4. **Tribal coordination and community engagement are needed early and often throughout clean energy development processes.** Development of emerging clean energy facilities should be seen as a partnership between potential developers, Tribes, and the local communities that would be affected by the projects. In Oregon, coastal Tribes and communities have been at the forefront of emerging energy developments, including the development of the PacWave test facilities and ongoing discussions about offshore wind. Central and eastern Oregon Tribes and communities are likely to be the most affected by

enhanced geothermal developments. Utility-scale storage facilities could be sited anywhere in Oregon. Regardless of the facility type, development can only be successful with support from Tribal partners, community-based organizations, municipal leaders, and community members.

Next Steps:

- Lessons learned from marine energy discussions in coastal communities should be applied to other emerging technologies and communities in Oregon.
- Development of the Oregon Offshore Wind Energy Roadmap includes a list of 10 key recommendations for policymakers relating to Tribal coordination and community engagement. Lessons learned from this process should be applied to other emerging technologies that affect local communities in Oregon.
- Tribal and community benefits agreements should be developed between communities and developers to ensure an equitable distribution of the costs and benefits associated with new emerging technology facilities.

Cost Comparisons

Cost projections for the emerging technologies presented in the report are derived from several sources and, wherever possible, are specific to conditions in the Pacific Northwest. Emerging technologies, by definition, lack a prolonged commercial track record with documented construction and operating costs, making estimates for projected costs of emerging technologies difficult. This report uses costs and projections from the *Annual Technology Baseline* report developed in 2025 by the National Laboratory of the Rockies, and Lazard's *2026 Levelized Cost of Energy report*.[3] [4] Both sources provide side-by-side cost comparisons for existing and emerging technologies, including comparisons of each technology, known as the levelized cost of energy. LCOE projections are calculated for some of the technologies presented here, though marine hydrokinetic energy and iron oxide batteries are not included due to lack of data.

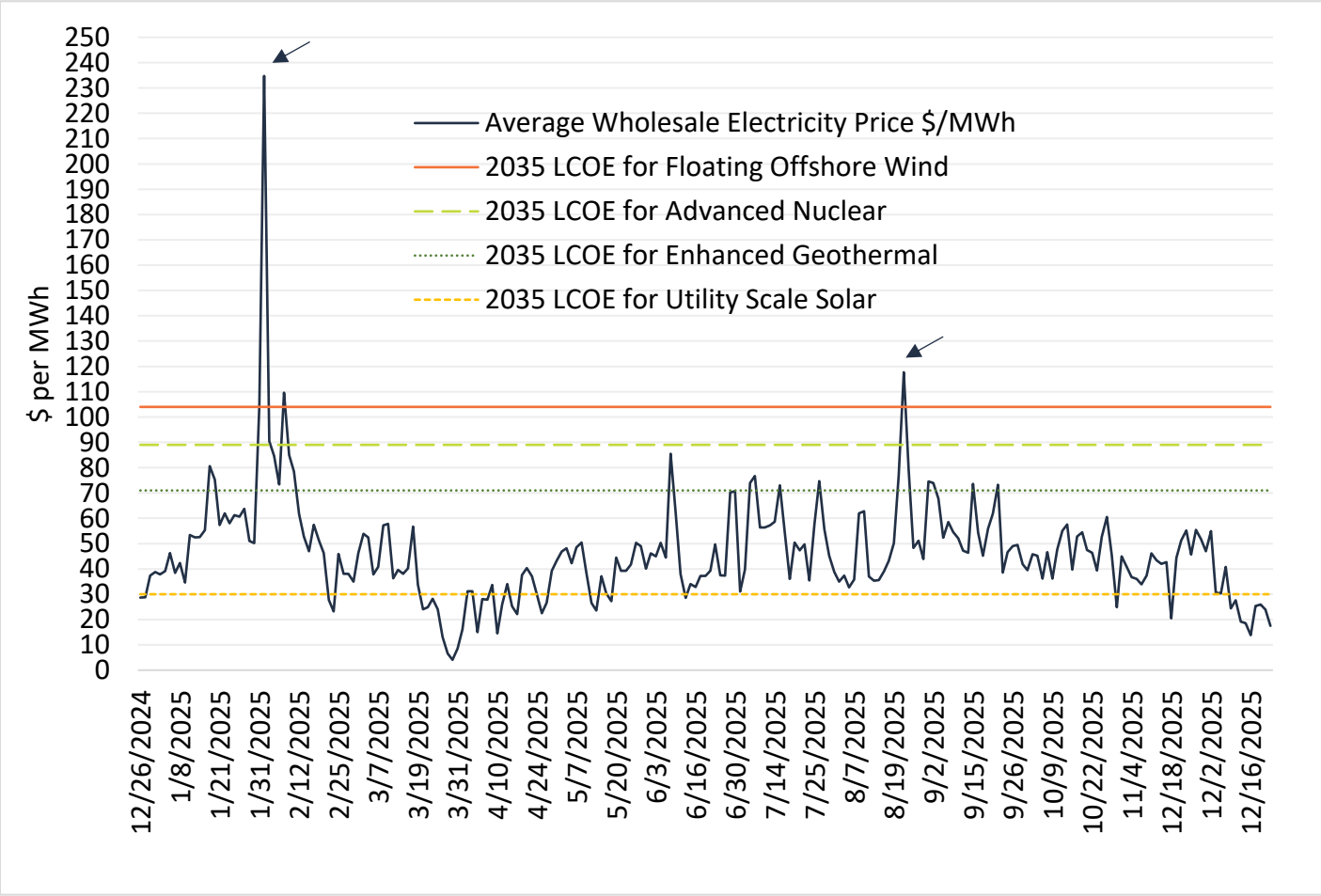
LCOE provides an easy way to compare projected energy costs across different types of electricity generation technologies, but it does have limitations. The LCOE is a calculation of the total lifetime costs to build and operate an energy facility divided by the total lifetime energy generation of the facility. It is presented in units of dollars per megawatt-hour of electricity and represents the rate at which an energy facility must sell energy to recover all capital, operations, and maintenance costs. Energy facilities provide more than just megawatt hours to the electric grid, and LCOE does not describe how energy generators may play a role in future markets. For example, LCOE takes into account the low cost for power from facilities that do not have ongoing operational fuel costs like solar, wind, and hydro, but it does not include the value of a facility to provide flexible power when needed, like hydro, natural gas, and geothermal do. Both low-cost variable and dispatchable resources provide value to rate payers and are necessary for Oregon to meet clean energy goals.

Dispatchable energy refers to electricity sources that can be turned on and off or ramped up and down (dispatched) on command to meet real-time grid needs.

One way to look at LCOE projections is to see how future technologies might interact with Oregon's wholesale electricity markets. The Mid-Columbia price hub, often referred to as simply Mid-C, is a key wholesale electricity trading point in the Pacific Northwest. Trading prices at Mid-C represent wholesale electricity costs across the Pacific Northwest over the course of the year. The relative cost-competitiveness of emerging technologies can be assessed by comparing their projected LCOEs against Mid-C prices from last year.

Figure 1 shows daily average wholesale electricity costs at the Mid-C price hub throughout 2025.[5] Superimposed on the wholesale price graph are projected 2035 LCOEs for emerging technologies from the NLR *Annual Technology Baseline* report. The 2035 values were selected as representative spot prices with the expectation that emerging technology projects could be operational by that time, but it should be taken into consideration that energy costs will change over the next decade. For reference, the LCOE for solar energy, represented by a dashed line at $30 per MWh, is included as an example of low-cost, mature renewable energy technology. The graph shows that projected costs for floating offshore wind and advanced nuclear would rarely offer cost-competitive energy. Enhanced geothermal would also rarely be competitive but has the lowest projected costs of the three.

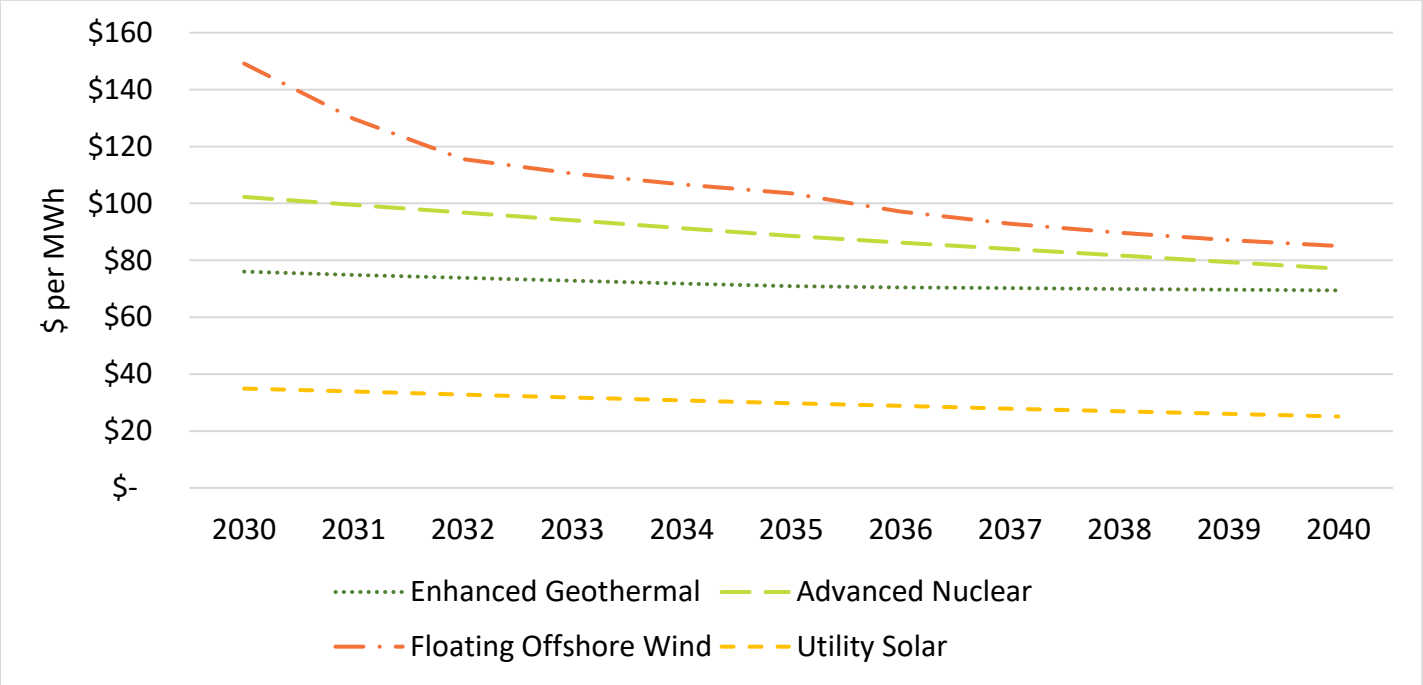
Figure 1: 2025 Wholesale Electricity Prices at the Mid-C Price Hub Compared to Projected 2035 LCOE for Emerging Technologies and Solar[i]



[i] The National Laboratory of the Rockies Annual Technology Baseline values are based on the following within the ATB spreadsheet: Solar - Utility PV R&D Tab, Class 5, Moderate | Floating Offshore Wind Tab, Class 12, Moderate | Nuclear Tab, Nuclear-Small, Moderate | Geothermal Tab, Geothermal – Deep EGS / Flash, Moderate

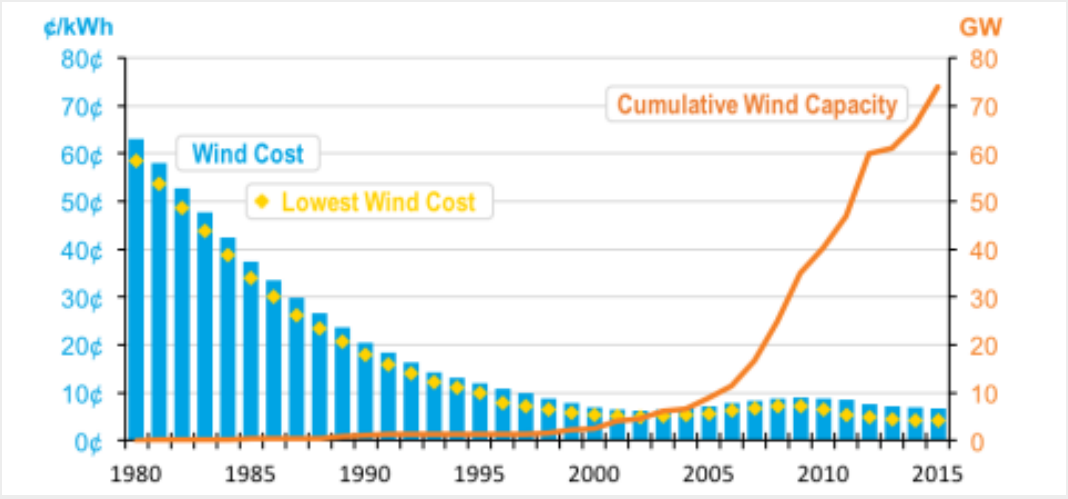
Emerging technology prices are expected to decline over time, improving their overall competitiveness in Oregon markets. Figure 2 shows projected LCOE values declining for facilities developed from 2030 to 2040. Enhanced geothermal, advanced nuclear, and offshore wind are expected to level off well below $100 per MWh in that timeframe.

Figure 2: 10-year Levelized Cost of Energy Projections Derived from National Laboratory of the Rockies Annual Technology Baseline Data



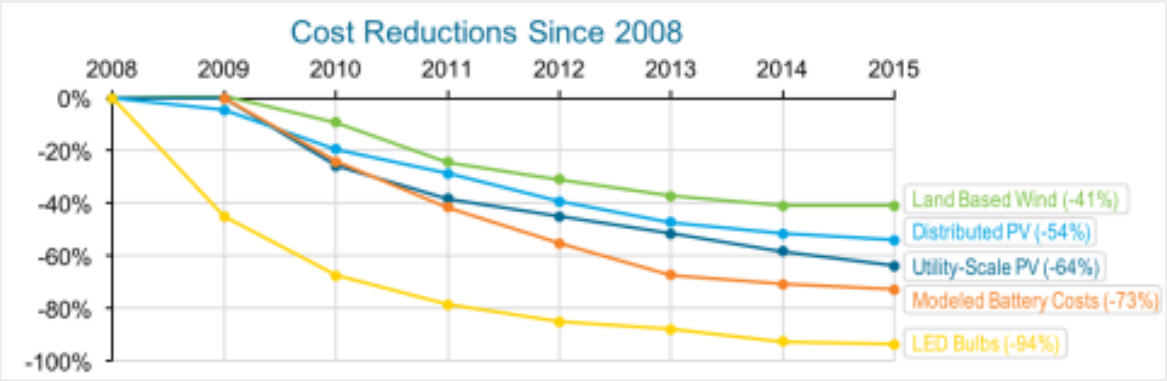
Emerging renewable energy technologies have the potential to transform global energy systems. Solar and wind energy are among the cheapest energy sources available, but 20 years ago they were more costly emerging technologies. As pilot facilities are built, and technologies are proven, costs will come down and volumes will increase. The following charts were developed in 2016 to demonstrate dramatic cost reductions associated with emerging wind and solar technologies.[2]

Figure 3: Decreasing Costs and Increasing Volume of Wind Turbines from 1980 to 2015[ii]



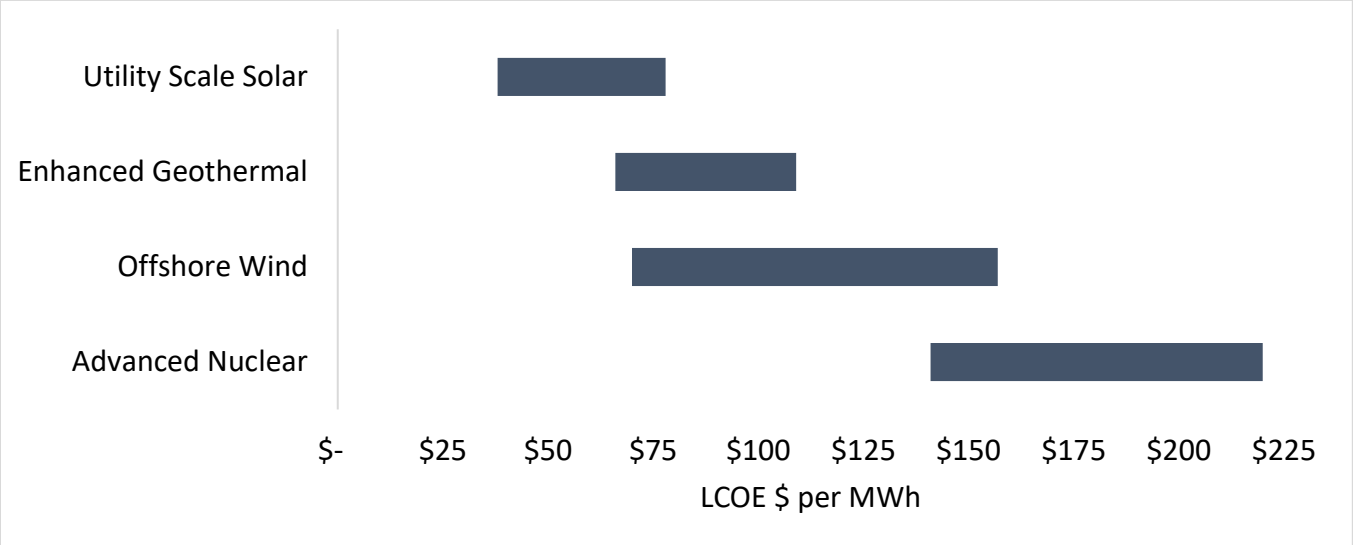
ii. Charts are from a 2016 U.S. DOE blog post (please forgive the low-resolution): https://www.energy.gov/policy/articles/6-charts-will-make-you-optimistic-about-americas-clean-energy-future

Figure 4: Cost Reductions of Four Emerging Technologies from 2008 to 2015



The Lazard LCOE analysis shows similarly higher costs for enhanced geothermal, advanced nuclear, and offshore wind. Unlike the National Laboratory of the Rockies LCOEs, the Lazard values are presented as a range. NLR values are more specific because they differentiate between specific installation conditions and timelines, while Lazard provides a range that is inclusive of different conditions. Figure 5 shows the 2026 Lazard LCOE assessments for emerging technologies are all more expensive than solar. Lazard's assessed the LCOE for offshore wind to be lower than advanced nuclear, but the Lazard report does not differentiate fixed bottom and floating offshore wind. Lazard values align with the NLR projections for enhanced geothermal and floating offshore wind, but its projections for advanced nuclear, at $141 to $220 per MWh, are considerably higher than the $82 per MWh NLR projection. This reflects the high degree of uncertainty in assessing costs for technologies that are still evolving toward commercial viability.

Figure 5: Lazard Levelized Cost of Energy Projections for Emerging Technologies and Solar



Common Risks and Challenges

Each emerging technology review provides an overview of risks and challenges specific to that technology and specific to Oregon. In some cases, emerging technologies like enhanced geothermal, will require much smaller land areas compared to solar or wind, but face longer development timelines as the technologies mature. Site selection, permitting, long lead times, transmission access,

workforce, and utility interconnection agreements are a few of these common challenges, many of which are subjects of other state agency studies, which are linked below.

Cross Agency Frameworks

Emerging technologies may face long development timelines and regulatory uncertainty. Responsible development can be supported by cross-agency frameworks that ensure efficient and transparent processes are in place for the developers and communities involved in projects. The state plays an important role ensuring all voices are heard and considered as siting and permitting decisions are made. Similarly, Tribal, federal, utility, and local regulations may affect how facilities are developed, including adjacent infrastructure such as roads, transmission, and access to water and sewer. While these processes can slow siting and permitting and create challenges to the fast development timelines needed to meet state goals, they are essential to ensure Oregonians have a say in energy decisions and ensure potential negative outcomes are considered and addressed. Cooperation between agencies can help to simplify the development process while maintaining strict standards for responsible development.

EO 25-29 directed ODOE and other state agencies to propose cross-agency frameworks to support development of advanced technologies that increase access to affordable, safe, and reliable clean energy. Following the release of the order, ODOE has been consulting with Tribes in Oregon, and meeting with the Oregon Public Utility Commission, Departments of Environmental Quality, Land Conservation and Development, State Lands, Geology and Mineral Industries, and others. The meetings have identified many cross-agency frameworks that already exist or are in progress, including:

- Oregon Department of Energy's Oregon Renewable Energy Siting Assessment Tool provides geospatial maps and information to prospective developers on different siting considerations, including environmental, ecological, cultural, and logistical opportunities and constraints.
- Oregon Department of Energy's Report on Reducing Barriers to Clean Energy Deployment recommends actions such as convening recurring forum discussions on cross-jurisdictional topics, including opportunities to align siting, interconnection, and procurement processes to support further conversation and actions on these topics.
- Oregon Department of Land Conservation and Development's Accelerating Clean Energy Deployment Through Oregon's Land Use Planning Framework reviews existing land use rules and practices and recommends actions and rule changes to accelerate deployment of clean energy resources and grid infrastructure needed to deliver reliability and clean energy to Oregon consumers.
- Oregon Department of Land Conservation and Development's Offshore Wind Energy Roadmap provides four principles guiding the roadmap pathways including meaningful engagement, credible information, regional coordination, and a holistic accountable approach.
- Oregon Department of State Lands' 2024 Asset Management Plan identifies a new classification of Renewable Energy Lands including characteristics, management requirements, performance expectations and opportunity considerations.

Continued coordination between agencies aims to provide consistency across agency actions and communications, providing developers and communities with information that is accessible, easy to use, and reliable.

The agencies also discussed other opportunities for interagency coordination, especially as some of these emerging technologies mature. Of note was the complexity involved in navigating the siting and permitting process for different types of energy facilities. For example, siting a geothermal plant in Oregon involves, at a minimum, navigating processes and timelines across eight different federal, state, and local agencies. For this reason, the agencies determined that collaborating on the development of technology-specific roadmaps would be beneficial in helping developers plan and navigate these processes.

The roadmaps should include information about siting, permitting, financial incentives, community engagement, and operational and monitoring reporting requirements for each type of facility. The following proposed actions would leverage existing cross-agency activities and facilitate the development of the roadmaps:

1. State agencies involved in regulating, permitting, and/or incentivizing specific types of emerging technology energy facilities should collaborate on roadmaps for developing facilities on federal, state, and private lands, including providing information on timelines, key deliverables, financial incentives and requirements for each process. Agencies should request additional items to include from developers and communities.
2. State agencies should coordinate with federal permitting agencies to fill in the federal permitting information for the roadmaps. This work may include collaboration with one or more national labs who may be able to offer federally funded technical assistance.
3. The state should recognize Tribal sovereignty and coordinate with Tribes to understand their needs and interests. State agencies should use their expertise and authorities to collaborate with Tribes on shared interests in developing emerging energy technologies.
3. State agencies should coordinate with Bonneville Power Administration and electric utilities to identify where interconnection agreements and power purchase agreements fit into the development process.
4. Once all the development resources are identified, ODOE, or a consortium of state agencies, should build and maintain web resources to help guide developers through the development process. The web resources should include contacts for staff at each agency identified in the roadmaps. Electric utilities should be invited to provide information relating to interconnection and power purchase agreements on resource pages.
5. Once a roadmap is complete, state agencies should continue to coordinate with each other, Tribes, federal agencies, utilities, project developers, industry associations, and community partners to identify opportunities to streamline processes while maintaining protections for cultural resources, the environment, and wildlife.

Permitting an Enhanced Geothermal Project



Two enhanced geothermal projects underway at Newberry volcano in central Oregon are currently involved in permitting their proposed facilities. The facilities are located on national forest land, meaning they must get a permit from the U.S. Forest Service to break ground. Once the site is permitted by USFS, the Bureau of Land Management must provide a permit for wells to be drilled below the surface, even if the facility is not on BLM lands. The well must also be permitted by the state Department of Geology and Mineral Industries. The electricity generating plant will need to be permitted by the county or state Energy Facility Siting Council, depending on the facility size. Other Tribal, local, state, and federal agencies may be involved in each step of construction, each with their own timelines and requirements that increase the project development complexity. The following represents a partial list of agencies that may be engaged in permitting a geothermal facility at Newberry volcano:

- U.S. Department of Agriculture (U.S. Forest Service): land use permits on national forest lands.
- U.S. Department of the Interior (Bureau of Land Management): subsurface use permits on national forest lands.
- Oregon Department of Geology and Mineral Industries: drilling / resource extraction permits.
- Oregon Water Resources Department: water use permits.
- Oregon Department of Energy: siting energy facilities exceeding 55.5 megawatts in nameplate capacity.
- Oregon Department of Environmental Quality: site pollution controls.
- Oregon Public Utility Commission: cost recovery oversight for investments made by Oregon's investor-owned utilities.
- Deschutes County: multiple actions, including siting energy facilities below 55.5 megawatts in nameplate capacity.

Conclusion

Emerging clean energy technologies have the potential to support Oregon's clean energy goals. As technologies develop, it is important to consider how each technology might affect Tribes and local communities, compete in future energy markets, and support reliable and resilient operations of the grid. The following pages provide an overview of different emerging electricity generation technologies. Each technology comes with its own unique benefits and challenges, and each could potentially play an important role in Oregon's electricity resource mix. Each technology has the potential to contribute more consistent and dispatchable power to the grid, a role currently filled by hydropower, coal, and natural gas, and one which will be crucial to meeting Oregon's objectives of clean, affordable, and reliable energy. At the same time, it is important for Oregon decisionmakers to understand how each technology might fill other specific needs, support economic development, or result in negative outcomes such as affecting other industries or using land or water resources.

Ultimately, decisionmakers can use this information to inform policies that will guide Oregon to a clean, reliable, and affordable energy future.

Individual Emerging Technology Reviews Follow:

- Advanced Nuclear
- Enhanced Geothermal
- Floating Offshore Wind
- Long-Duration Energy Storage
- Marine Hydrokinetic

Other Related Topics published by ODOE:

- Accelerating Clean Energy Deployment Through Oregon's Land Use Planning Framework
- Floating Offshore Wind Study: Benefits & Challenges for Oregon (2022)
- Report on Reducing Barriers to Clean Energy Deployment

References

1. Oregon Department of Energy. (2025). *Oregon Energy Strategy* (p. 112). https://www.oregon.gov/energy/data-and-reports/Documents/Oregon-Energy-Strategy.pdf.
2. Office of the Governor, State of Oregon. (2025, November 18). *Executive Order 25-29*: *Executive Order on Reducing Greenhouse Gas Emissions and Advancing Oregon's Clean Energy Future.* https://www.oregon.gov/gov/eo/eo-25-29.pdf.
3. National Laboratory of the Rockies. (2025). *Annual Technology Baseline. Electricity Annual Technology Baseline Data Download.* [Dataset]. Retrieved September 24, 2026 from https://atb.nlr.gov/electricity/2025/data.
4. Lazard. (2026, July). *Lazard's LCOE Levelized Cost of Energy*. https://www.lazard.com/media/kcfconhf/lazards-lcoeplus_vf.pdf.
5. U.S. Energy Information Administration. (2026, September 17). *Wholesale Electricity and Natural Gas Markets data*. https://www.eia.gov/electricity/wholesale/.

Emerging Technologies: Advanced Nuclear

Technology Summary



Advanced nuclear technologies include a diverse set of reactor concepts that have the potential to generate electricity, industrial process heat, and hydrogen for future U.S. energy markets. The design of these facilities departs from traditional large-scale facilities in size, coolant choice, fuel type, operating temperature, and safety features. All nuclear power plants currently operating in the U.S. use light water reactors, or LWRs.[1] Some of these facilities, like the retired Trojan nuclear power plant in Oregon, experienced safety concerns and high costs that contributed to facilities closing down.[2] Emerging nuclear technologies aim to overcome issues associated with traditional LWRs by introducing new safety mechanisms and reducing construction costs. One of the primary safety concerns for traditional nuclear power plants is associated with runaway thermal cycles and release of radioactive materials, such as the Fukushima Daiichi accident in Japan.[3]

Advanced nuclear technologies use passive safety design strategies that aim to maintain safe operating conditions without the need for pumps, fans, or external power supplies. Innovative fuels for advanced nuclear facilities are also expected to improve safety compared to traditional nuclear power plants by utilizing smaller fuel particles with special coatings that can withstand extreme temperatures without damage.[4] For example, TRISO particles are small pellets of uranium encapsulated in layers of graphite and ceramic to remain stable at high temperatures.[5] However, the same layers that make TRISO particles stable in a reactor also make them harder to recycle with current technologies, which may add cost and complexity to future waste management.[6]

Interest in nuclear power — particularly advanced nuclear — is growing. Nuclear energy can help achieve greenhouse gas emissions reduction goals and enhance grid reliability. Existing nuclear plants provide a steady source of electricity, but they cannot ramp up or down quickly to meet supply and demand needs and occasionally must be taken offline for refueling. Some modular and advanced nuclear design concepts have the potential to provide more ramping flexibility, which could be used to meet changing electricity supply and demand needs. Another advantage of advanced nuclear power is that facility siting is less constrained by geography than renewable resources that use rivers, wind, or solar energy to operate. These attributes have led to growing interest in advanced nuclear potentially replacing retired coal power plants.[7]

Along with the potential advantages of advanced nuclear, there are drawbacks to consider. Nuclear power generation requires radioactive fuel to operate. Advanced nuclear designs may improve operational safety but still generate dangerous and long-lived radioactive waste products during energy production and fuel manufacturing. Facility components in contact with radioactive materials also become waste when facilities are decommissioned. In some cases, advanced nuclear technologies may generate more waste than traditional nuclear power plants per unit of electricity generated.[8] This waste must be collected and stored appropriately. Waste is currently stored on site at nuclear facilities because there is no designated federal repository for radioactive waste. Cost is also a concern for nuclear energy facilities during construction and operation, and for long-term waste management. A

more detailed discussion of financial considerations is described in the Anticipated Costs section below.

There are many types and variations of modular and advanced reactors, but this topic focuses primarily on three that are actively being considered for commercial operations.

Small Modular Reactors

SMRs represent a diverse set of emerging nuclear power plant technologies that can generate up to 300 MW per unit.[9] They are designed for factory fabrication and modular construction with the intent of improving safety and bringing down construction costs. In addition to passive cooling strategies and advanced fuels, SMR safety is also improved by incorporating smaller core sizes and less fuel inventory on-site — less radioactive material in the core means catastrophic events are likely smaller in scope. Costs and development timelines may be lowered through modular components and factory fabrication. This lower cost and lower risk model has yet to be realized, and significant uncertainty remains. Some SMRs, such as the NuScale Power Module, use light water technology similar to conventional nuclear power plants while others, like those in development by GE-Hitachi and x-energy's XE-100, use alternate or "advanced" cooling methods.[10] [11] The smaller footprint and scalability of SMRs could be a solution for grid-constrained regions with new large loads, such as data centers and industrial facilities.[9] If successful, this could make SMRs more competitive with new natural gas and renewable resources. Drawbacks to SMRs include uncertainty in costs and construction timelines, as well as radioactive waste streams that may generate more waste per kWh than conventional nuclear power plants.[8]

Non-Light Water Reactors

Non-light water reactors represent several proposed nuclear technologies with novel cooling strategies. These reactors may be SMRs or larger facilities that use molten salt, high-temperature gases, or liquid metals as a coolant rather than water. Some molten salt reactor designs include systems that store energy as heat in the salt and enable the facility to ramp power up and down as needed to meet grid supply and demand needs.[12] Molten salt reactors have the disadvantage of using highly corrosive materials that require on-site chemical processing, and present the potential for environmental damage if not handled properly.[8] High-temperature gas reactors use helium as a coolant, enabling them to operate at hotter temperatures than conventional water-cooled facilities. In addition to electricity production, the high heat could be used to generate hydrogen or to provide process heat for industrial applications.[13] Liquid metal reactors use molten sodium or lead as a coolant. They incorporate passive over-heating protection strategies and have the advantage of operating at lower pressures than conventional water-cooled reactors, which also improves safety.[14]

Fusion Energy Systems

Unlike other nuclear energy systems, fusion energy generation comes from energy released during the fusing of atomic particles, rather than splitting atoms. Although not yet viable, fusion technologies are increasingly considered part of the advanced nuclear landscape. Fusion is of great interest because it holds the promise of being able to generate incredibly large amounts of power. It also does not generate any long-lived radioactive waste – although the fuel input and the facility itself would likely be radioactive and require decommissioning. While it has not been demonstrated to be a

viable energy generation technology yet, some emerging companies, such as Commonwealth Fusion Systems and Helion Energy, have raised large amounts private capital to develop fusion technologies.[15] [16]

Resource Potential

Modular and advanced nuclear technologies have the potential to provide significant new energy resources to the grid. In 2023, more than 20 countries, including the United States, committed to tripling nuclear energy capacity by 2050 at the COP28 UN Climate Change Conference in Dubai.[17] As a result, the U.S. Department of Energy set new deployment targets, including the addition of 35 GW of new nuclear capacity by 2035 and a sustained pace of 15 GW per year by 2040.[18] To achieve these ambitious global and domestic capacity targets, the cost of building and operating nuclear facilities must come down, and fuel enrichment and manufacturing capacity must be dramatically increased. In addition to the challenges described above, nuclear energy in the U.S. faces fuel supply chain vulnerabilities, including limited uranium supplies, geopolitical risks, and rising costs.[19]

Recent Developments

There have been several notable milestones for advanced nuclear facilities in the United States. In 2023, the U.S. Nuclear Regulatory Commission approved the NuScale SMR design — the first SMR design to be certified in the U.S. In March 2026, the NRC also announced the approval of a construction permit for TerraPower's Natrium advanced reactor project in Kemmerer, Wyoming.[20] This was the first advanced nuclear reactor in the U.S. to be approved for construction and was followed by an announcement that the project would also receive up to $2 billion in federal subsidies.[21] Similarly, in December 2025, the U.S. Department of Energy announced $800 million in federal funding for SMR facilities in Tennessee and Michigan.[22] In May 2026, U.S. DOE announced $94 million in federal subsidies for site preparation and fuels production, including $8.8 million for expanded nuclear fuels production in Richland, WA.[23]

Siting of nuclear energy facilities is not allowed in Oregon until there is a national repository for radioactive waste. In addition, prior to final approval by the Energy Facility Siting Council, a facility would have to be approved by a majority of voting Oregonians. There are nuclear projects proposed in neighboring states that may serve Oregon customers. TerraPower's Natrium project, on the site of a retiring coal facility in Kemmerer, WY, is being developed in partnership with PacifiCorp and will likely serve Oregon customers of Pacific Power.[24] The proposed advanced nuclear development closest to Oregon is a small modular reactor at the Columbia Generating Station near Richland, WA. The proposed facility is referred to as the Cascade Advanced Energy Facility and — instead of being connected directly to the grid — may be co-located with an Amazon data center.[25]

Despite this progress, advanced nuclear technologies have yet to demonstrate cost-effective commercial operation, though several facilities have demonstrated technical feasibility. The *Akademik Lomonosov* nuclear power plant in northern Russia is a floating SMR that has been in operation since 2020.[26] A second land-based SMR facility is also underway in Russia with commissioning currently scheduled for 2028.[27] In China, a modular reactor using advanced fuel pellets began operation in 2021.[28] Flamanville 3 in Normandy, France achieved full power operation in 2025.[29] Except for the

French facility, information about these facilities, including construction and operating costs, is not available.

Figure 1: The *Akademik Lomonosov* nuclear power plant in northern Russia. Photo credit: Rosatom[30]



Many advanced nuclear technologies are still in the conceptual stage, with just five test reactors having successfully demonstrated sustained nuclear reactions, also known as criticality.[31] In the U.S., only the NuScale SMR reactor design has been approved by the U.S. Nuclear Regulatory Commission.[32] [33] The NuScale power module uses conventional light water reactor technology that has been scaled down into a small modular reactor. Although the NRC has approved the Kemmerer Natrium reactor and the Clinch River, Tennessee SMR for construction, those reactors are still pending design approval.[34] [53] Fusion technologies are still in the proof-of-concept stage, with different designs being tested in research settings but not ready for piloting.[35]

Anticipated Costs

Projected costs for advanced nuclear energy vary by source and availability of data. Some technologies, such as fusion reactors, are still in the research stage and lack cost projections. The Annual Technology Baseline data published by the National Laboratory of the Rockies in 2025 projected the levelized cost of energy for advanced nuclear technologies, including large facilities rated at 100 MW of capacity and small modular reactors rated at 300 MW of capacity. The projected NLR costs range between $65 and $159 per megawatt-hour in 2035 depending upon the specific technology type.[36] The 2026 Lazard's levelized cost of energy estimates for new nuclear facilities is $175 to $255 per megawatt-hour.[37] For reference, the projected levelized cost of energy for utility scale solar installations in 2035 is $20 to $55 per megawatt hour from NLR and $40 to $98 from Lazard's report.

As with any emerging technology, it is difficult to foresee construction costs. For example, in 2015 NuScale energy partnered with Utah Associated Municipal Power Systems to develop a small modular

reactor facility in Utah. The initial cost estimate was $3 billion with a levelized cost of energy around $58 per MWh. By 2023, the revised cost of construction was $9.3 billion for a facility that was 30 percent smaller than the original proposed project, and the project was canceled.[38] Similarly, the 1,630 MW Flamanville 3 advanced nuclear facility in France began operation in 2025, but at an adjusted cost of almost $28 billion compared to an initial cost estimate of $3.9 billion.[29] Cost overruns have been common throughout the history of nuclear energy development and are not unique to emerging advanced nuclear technologies. Historically nuclear power projects have experienced cost overruns of about 66 percent or about $1 billion per project.[39]

Figure 2: The Flamanville 3 Advanced Reactor in Normandy, France. Photo credit: World Energy[40]



There are other taxpayer costs associated with nuclear energy that are not captured in facility construction and operating costs. The nuclear industry requires security on its international and national supply chains, generation sites, and waste management. One report found these security costs represent a federally funded subsidy of about $4 billion per year.[41] Long-term storage of spent nuclear fuel also represents ongoing subsidized costs for the nuclear industry. The Nuclear Waste Policy Act of 1982 required that the federal government provide for storage of spent nuclear fuels by 1998.[42] To date, there is still no permanent federal waste repository and the U.S. Department of Energy has defaulted on agreements with utilities all across the country to begin accepting spent fuel for disposal. For example, U.S. DOE is reimbursing Portland General Electric for costs associated with storing about 5,000 tons of radioactive waste at the site of the decommissioned Trojan nuclear power plant. The total cost to tax payers for all U.S. utility storage reimbursement through 2024 is $44.5 billion.[43] Advanced nuclear reactors will continue to depend on federal subsidies for security and long-term storage costs for the foreseeable future.

Development of the Oregon Energy Strategy included energy modeling to evaluate different scenarios for future loads and new generation to meet those loads. Advanced nuclear energy technologies were considered in the model but were not selected as a generation resource because of their high projected costs. The strategy also recommended policy actions, including development of this emerging technologies report to evaluate how nuclear energy, and other emerging technologies, may play a role in meeting Oregon's energy needs.[44]

Challenges to Commercial Development

There are several technological and policy challenges that would have to be overcome before advanced nuclear facilities reach widespread commercial development. While some advanced nuclear technologies have demonstrated technical feasibility, they have not yet demonstrated that they can overcome significant challenges to nuclear energy development in the U.S. including:[45]

- High upfront and operational costs that have proven challenging to estimate
- Long regulatory approvals processes for licensing, construction, and operating permits
- Lack of regulatory framework for some advanced nuclear technologies
- Scarce or geopolitically sensitive fuel resources
- Lack of repository and mechanisms for used fuel transportation, storage, and disposal
- Public opposition

Additional policy challenges exist at state levels. As of 2026, there are 10 states, including Oregon, that have restrictions on the construction of new nuclear energy facilities.[33] Oregon, California, Connecticut, and Maine require a means for radioactive waste disposal to be in place before a new facility can be constructed. Other states have outright banned construction of nuclear energy facilities or require approval by voters or the state legislature; in Oregon, voter approval is required.[33]

The timeline for development is also a major barrier. Even if restrictions were to be lifted and a nuclear facility were proposed in Oregon, it would initiate a prolonged permitting and public comment process. This includes federal and state approvals, which could take several years. If approved, construction of the facility would also likely take many years. Electricity demand has been rising and is expected to continue to rise rapidly in the next decade. Energy modeling completed for the Oregon Energy Strategy projected demand for electricity doubling in Oregon by 2050.[47] Utilities and regulators will need to consider the timelines for energy development in their planning processes as well as costs. If technological advancements or regulatory decisions shorten any of these timelines, modular or advanced nuclear options may become more practicable.

Effects on Local Communities

According to a 2025 Gallup poll, Americans' favorable opinions on nuclear energy are near an all-time high.[48] Even as interest in nuclear power is growing, many Oregonians are concerned about the potential effects of nuclear power plants on local communities. During the 2025 Oregon Legislative Session, five bills were introduced concerning nuclear energy. These included two bills to study the feasibility of nuclear power in Oregon, two that could have helped enable the development of small modular reactors in Oregon, and one that would have repealed state laws requiring the existence of a

federal repository for spent nuclear fuel and voter approval.[49] Written testimony for these bills was mixed, but there were more submittals in opposition than in support. None of the bills passed. In Kemmerer, WY, the site of a proposed new nuclear facility, residents are split between those who favor economic development opportunities and those who are concerned about the potential risks and effects on their community.[50]

Proposed bills in Oregon and Washington prompted the Confederated Tribes of the Umatilla Indian Reservation to create a draft nuclear policy to help their staff respond to and engage with external partners on conversations regarding nuclear power policies. CTUIR has indicated that the policy "maintains a strong stance of opposition to nuclear activities that threaten Tribal values, rights, and resources," and they conducted a survey to gather input from tribal members.[51]

Potential effects on communities vary across the different technologies. Apart from fusion technologies, all other technologies create radioactive waste, both in the creation of the fuel and after it is used. Risks increase with larger amounts of fuel. If not handled appropriately, the fuel and waste could contaminate local lands and waters, and potentially become airborne. Exposure to radioactive materials can have a negative effect on human health, and this varies depending on the type of radiation and duration of exposure. The risk of exposure is borne by the communities nearest to fuel mining and production facilities, power plants, and waste repositories. People living near these facilities, including downriver and downwind, bear the health and environmental risks the most. Communities may also benefit from jobs and economic development that comes with large energy projects. For example, in 2015, development of the Watts Bar Unit 2 nuclear reactor in TN employed nearly 3200 workers during construction and added about 250 permanent workers for the operation of the plant.[52]

Additional Resources

- U.S. Department of Energy Advanced Nuclear webpage
- U.S. Department of Energy Advanced Small Modular Reactors webpage
- Fusion Power Energy Resource & Technology Review (2024)
- U.S. Department of Energy Fusion Science and Technology Roadmap

References

1. Congressional Research Service. (2023, February 17). *Advanced Nuclear Reactors: Technology Overview and Current Issues* (R45706; p. 1). https://www.congress.gov/crs_external_products/R/PDF/R45706/R45706.7.pdf.

2. EBSCO. (1993, January 4). *Trojan Nuclear Plant Is Retired | Power and Energy | Research Starters | EBSCO Research*. https://www.ebsco.com/research-starters/power-and-energy/trojan-nuclear-plant-retired.

3. World Nuclear Association. (2026, September 23). *Fukushima Daiichi Accident.* Safety-of-Plants/Safety and Security/Information Library. https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-daiichi-accident.

4. U.S. Department of Energy. (n.d.). *Enhanced Safety of Advanced Reactors*. Office of Nuclear Energy. Retrieved October 27, 2026 from https://www.energy.gov/ne/enhanced-safety-advanced-reactors.

5. U.S. Department of Energy. (2019, July 9). *TRISO Particles: The Most Robust Nuclear Fuel on Earth*. Office of Nuclear Energy. https://www.energy.gov/ne/articles/triso-particles-most-robust-nuclear-fuel-earth.

6. Stuart T Arm, Gabrial B Hall, Gregg J Lumetta, & Beric E Wells. (2022, June). *Plan for Developing TRISO Fuel Processing Technologies.* (p. Summary iii). Pacific Northwest National Laboratory. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-32969.pdf.

7. EPRI. (2023, October). *From Coal to Nuclear: A Practical Guide for Developing Nuclear Energy Facilities in Coal*. 2023 Technical Report. https://gain.inl.gov/content/uploads/4/2024/11/From-Coal-to-Nuclear_-A-Practical-Guide-for-Developing-Nuclear-Energy-Facilities-in-Coal.pdf.

8. Kim, T., Boing, L., Halsey, W., & Dixon, B. (2022, November 18). *Nuclear Waste Attributes of SMRs Scheduled for Near-Term Deployment* (ANL/NSE-22/98-Rev.1, 1900154, 179973; p. Summary pages iv-v). EPRI for the U.S. Department of Energy Systems and Analysis Integration. https://doi.org/10.2172/1900154.

9. Congressional Research Service. (2023, February 17). *Advanced Nuclear Reactors: Technology Overview and Current Issues* (R45706; p. 11). https://www.congress.gov/crs_external_products/R/PDF/R45706/R45706.7.pdf.

10. GE Vernova Hitachi. (n.d.). GE Vernova Hitachi's *BWRX-300 Small Modular Reactor (SMR). Carbon-free power*. Retrieved June 2, 2026, from https://www.gevernova.com/nuclear/carbon-free-power/bwrx-300-small-modular-reactor.

11. NuScale. (n.d.). *NuScale Power* Module. Retrieved June 2, 2026, from https://www.nuscalepower.com/products/nuscale-power-module.

12. Larson, A. (2025, June 25). Understanding TerraPower's Natrium Reactor Design and Demonstration Project Progress. *POWER Magazine*. https://www.powermag.com/understanding-terrapowers-natrium-reactor-design-and-demonstration-project-progress/.

13. Congressional Research Service. (2023, February 17). *Advanced Nuclear Reactors: Technology Overview and Current Issues* (R45706; p. 13). https://www.congress.gov/crs_external_products/R/PDF/R45706/R45706.7.pdf.

14. Congressional Research Service. (2023, February 17). *Advanced Nuclear Reactors: Technology Overview and Current Issues* (R45706; p. 17). https://www.congress.gov/crs_external_products/R/PDF/R45706/R45706.7.pdf.

15. Commonwealth Fusion Systems. (2025, August 28). *Commonwealth Fusion Systems Raises $863 Million Series B2 Round to Accelerate the Commercialization of Fusion Energy.* https://www.cfs.energy/news-and-media/commonwealth-fusion-systems-raises-863-million-series-b2-round-to-accelerate-the-commercialization-of-fusion-energy/.

16. Helion. (2025, January 18). *Announcing Helion's $425 million Series F.* https://www.helionenergy.com/blog/announcing-helions-425m-series-f.

17. U.S. Department of Energy. (2023, December 1). *At COP28, Countries Launch Declaration to Triple Nuclear Energy Capacity by 2050, Recognizing the Key Role of Nuclear Energy in Reaching Net Zero*. https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key.

18. U.S. Department of Energy. (2024, November 12). *U.S. Sets Targets to Triple Nuclear Energy Capacity by 2050*. Office of Nuclear Energy. https://www.energy.gov/ne/articles/us-sets-targets-triple-nuclear-energy-capacity-2050.

19. Golden, M. (2026, January 9). *For U.S. nuclear energy future, fuel supply must not be overlooked.* Stanford University Precourt Institute for Energy. Doerr School of Sustainability. https://energy.stanford.edu/news/us-nuclear-energy-future-fuel-supply-must-not-be-overlooked.

20. United States Nuclear Regulatory Commission. (2026, March 4). *NRC Issues First Commercial Reactor Construction Approval in 10 Years For TerraPower in Wyoming*. NRC News, Office of Public Affairs. No: 26-028. https://www.nrc.gov/sites/default/files/cdn/doc-collection-news/2026/26-028.pdf.

21. Engineering News-Record. (2026, April 4). *TerraPower Begins Construction on First US Commercial-Scale Advanced Nuclear Reactor.* Nuclear Power. https://www.enr.com/articles/62891-terrapower-begins-construction-on-first-us-commercial-scale-advanced-nuclear-reactor.

22. U.S. Department of Energy. (2025, December 2). *Energy Department Selects TVA and Holtec to Advance Deployment of U.S. Small Modular Reactors*. Nuclear. https://www.energy.gov/articles/energy-department-selects-tva-and-holtec-advance-deployment-us-small-modular-reactors.

23. U.S. Department of Energy. (2026, May 14). *Energy Department Awards $94 Million to American Companies to Help Expedite the Deployments of Small Modular Reactors in the United States*. https://www.energy.gov/articles/energy-department-awards-94-million-american-companies-help-expedite-deployments-small.

24. Pacific Power. (2025, October 21). *PacifiCorp's Application for Approval of Water Use and Conveyance Agreement and Request for Waiver of Competitive Bidding Rules*. https://www.pacificpower.net/content/dam/pcorp/documents/en/pacificpower/rates-regulation/oregon/filings/docket-um-2408/Application.pdf.

25. Amazon News. (2025, October 16). *How Amazon is helping to build one of the first modular nuclear reactor facilities in the United States*. Sustainability. https://www.aboutamazon.com/news/sustainability/amazon-smr-nuclear-energy.

26. World Nuclear News. (2025, January 16). *Russia's floating nuclear power plant passes one billion kWh*. https://world-nuclear-news.org/articles/russias-floating-nuclear-power-plant-passes-one-billion-kwh.

27. neimagazine. (2025, March 13). *Russia Progresses With First Land-Based SMR*. World-Energy. Retrieved October 20, 2026, from https://www.world-energy.org/article/50471.html.

28. World Nuclear News. (2023, December 6). *China's demonstration HTR-PM enters commercial operation*. https://world-nuclear-news.org/articles/chinese-htr-pm-demo-begins-commercial-operation.

29. NuclearNewswire. (2025, December 17). *Flamanville-3 reaches full power*. Power & Operations. https://www.ans.org/news/2025-12-17/article-7625/flamanville3-reaches-full-power/.

30. Rosatom. (2023, February). *Small Modular Reactor—New Nuclear Trend*. https://rosatomnewsletter.com/2023/03/02/small-modular-reactor-new-nuclear-trend/.

31. U.S. Department of Energy. (2026, August 6). *Office of Nuclear Energy Celebrates Fifth Advanced Reactor Criticality*. Nuclear. https://www.energy.gov/ne/articles/office-nuclear-energy-celebrates-fifth-advanced-reactor-criticality.

32. NuScale. (2025, May 29). *NuScale Power's Small Modular Reactor (SMR) Achieves Standard Design Approval from U.S. Nuclear Regulatory Commission for 77 MWe*. https://www.nuscalepower.com/press-releases/2025/nuscale-powers-small-modular-reactor-smr-achieves-standard-design-approval-from-us-nuclear-regulatory-commission-for-77-mwe.

33. United States Nuclear Regulatory Commission. (2025, May 29). *Standard Design Approval for the NuScale Power Company, LLC US460 Power Plant Design*. https://www.nrc.gov/docs/ML2512/ML25129A004.pdf.

34. U.S. Department of Energy. (2026, March 9). *NRC Issues Construction Permit for TerraPower's Natrium Advanced Reactor*. Office of Nuclear Energy. https://www.energy.gov/ne/articles/nrc-issues-construction-permit-terrapowers-natrium-advanced-reactor.

35. U.S. Department of Energy. (2026, June). *Fusion Science and Technology Roadmap* (p. 12). https://www.energy.gov/fusion/articles/fusion-st-roadmap.

36. Oregon Department of Energy analysis of 2024 National Renewable Energy Laboratory Annual Technology Baseline Data. (2024). [Dataset]. Data on file. https://atb.nlr.gov/electricity/2024/data.

37. Lazard. (2026, July). *Lazard LCOE Levelized Cost of Energy Analysis*. https://www.lazard.com/media/kcfconhf/lazards-lcoeplus_vf.pdf.

38. Utility Dive. (2024, January 31). *The collapse of NuScale's project should spell the end for small modular nuclear reactors.* https://www.utilitydive.com/news/nuscale-uamps-project-small-modular-reactor-ramanasmr-/705717/.

39. Sovacool, B. K., Gilbert, A., & Nugent, D. (2014, September 1). Risk, innovation, electricity infrastructure and construction cost overruns: Testing six hypotheses. *Energy*, *74*. https://doi.org/10.1016/j.energy.2014.7.070.

40. World-Energy. (2024, December 24). *France's Most Powerful Nuclear Reactor Finally Comes on Stream.* Nuclear Power. https://www.world-energy.org/article/47946.html.

41. Barnard, M. (2021, March 29). Nuclear Security Represents $4 Billion Annual Subsidy In US, Trillion All Costs For Fleet For Full Lifecycle. *CleanTechnica*. https://cleantechnica.com/2021/03/29/nuclear-security-represents-4-billion-annual-subsidy-in-us-trillion-for-fleet-for-full-lifecycle/.

42. 97th United States Congress. (2022, December 27). *Nuclear Waste Policy Act of 1982*. https://www.energy.gov/sites/default/files/2023-06/NWPA.pdf.

43. NuclearNewswire. (2024, November 27). *U.S. spent fuel liability jumps to $44.5 billion*. Waste Management. https://www.ans.org/news/article-6587/us-spent-fuel-liability-jumps-to-445-billion/.

44. Oregon Department of Energy. (2025). *Oregon Energy Strategy* (p. 112). https://www.oregon.gov/energy/data-and-reports/Documents/Oregon-Energy-Strategy.pdf.

45. U.S. Department of Energy. (2026, June 4). *Advantages and Challenges of Nuclear Energy*. Office of Nuclear Energy. https://www.energy.gov/ne/articles/advantages-and-challenges-nuclear-energy.

46. National Conference of State Legislators. (2026, April 16). *States Restrictions on New Nuclear Power Facility Construction*. https://www.ncsl.org/environment-and-natural-resources/states-restrictions-on-new-nuclear-power-facility-construction.

47. Oregon Department of Energy. (2025). *Oregon Energy Strategy. Executive Summary* (p. 3). https://www.oregon.gov/energy/data-and-reports/Documents/Oregon-Energy-Strategy-Summary.pdf.

48. Gallup. (2025, April 9). *Nuclear Energy Support Near Record High in U.S.* News. https://news.gallup.com/poll/659180/nuclear-energy-support-near-record-high.aspx.

49. *Oregon Measure 7, Voter Approval for Nuclear Waste Facilities Initiative (1980)*. (n.d.). Ballotpedia. Retrieved June 5, 2026, from https://ballotpedia.org/Oregon_Measure_7,_Voter_Approval_for_Nuclear_Waste_Facilities_Initiative_(1980).

50. SustainablePowerNews. (2026, April 17). *Wyoming Residents Resist TerraPower's Natrium Reactor As Federal Officials Skip Environmental Reviews.* https://sustainablepowernews.com/wyoming-residents-resist-terrapowers-natrium-reactor-as-federal-officials-skip-environmental-reviews/.

51. The Confederated Tribes of the Umatilla Indian Reservation. (2026, June). *Survey on CTUIR & Nuclear Energy*. https://ctuir.org/media/imgougzc/ctuir-survey-flyer-052926.pdf.

52. *Bechtel*. (n.d.). Watts Bar Completion. Projects. Retrieved October 23, 2026, from https://www.bechtel.com/projects/watts-bar-completion/.

53. United States Nuclear Regulatory Commission. (2026, September 29). *NRC Approved Construction of Nation's First Small Modular Reactor*. https://www.nrc.gov/docs/ML2629/ML26293A091.pdf.

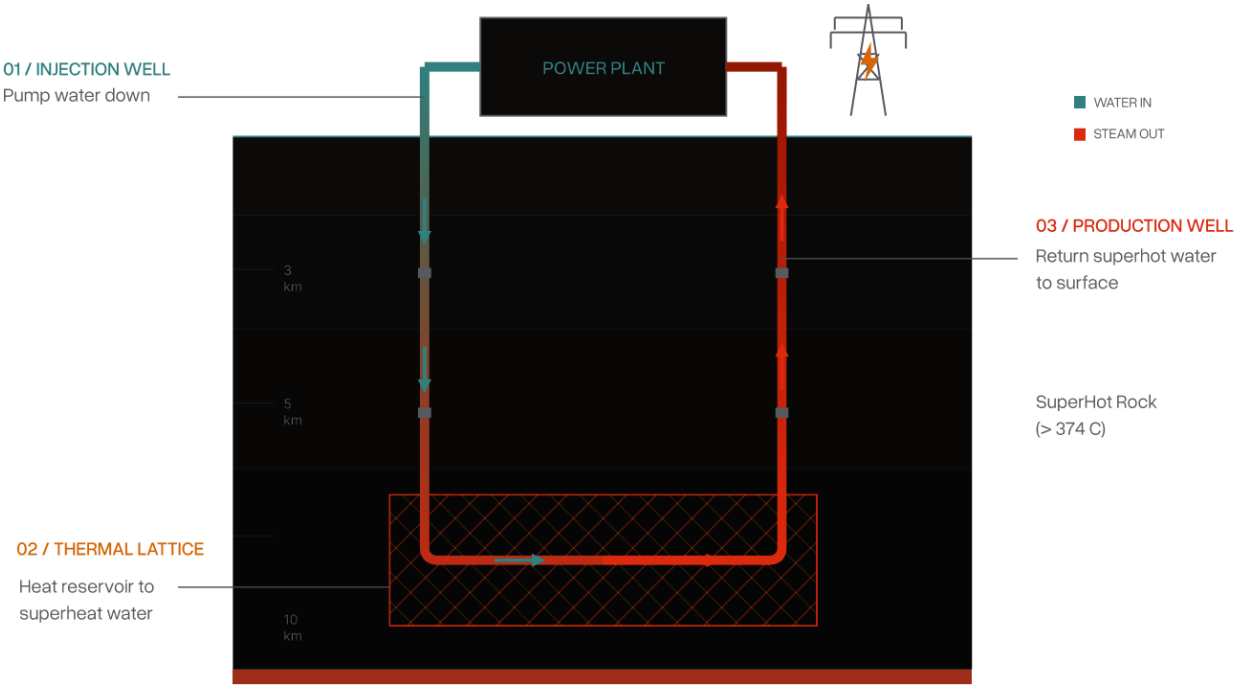
Emerging Technologies: Enhanced Geothermal

Technology Summary

Geothermal energy comes from heat generated continuously within the earth. The heat is a renewable, carbon free resource available 24/7 and can be used to generate electricity, provide space and water heating, or heat for industrial processes. Traditional geothermal energy facilities, including several in Oregon, use hot water wells to generate electricity. While Oregon has abundant geothermal resources, it is difficult to find hot water reservoirs, and the potential of drilling a dry well creates financial risk. Enhanced geothermal systems, also referred to as EGS, reduce this risk by harnessing energy from hot, dry rock deep underground, eliminating the need to find hot water reservoirs and tapping into a much hotter resource.

There are several types of emerging enhanced geothermal technologies. Flash systems pump water into the ground and use the steam generated in the hot rock to spin a turbine. Binary systems work similarly, but transfer heat from the water to a different fluid that spins a turbine. There are also different configurations used to gather the heat from the ground. Closed-loop systems use sealed pipes that pass through the hot rock to collect energy. Open loop systems use injection wells to pass water through fractures in the hot rock, which is then gathered as steam through adjacent collection wells. All EGS configurations recover the water used so 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.[1]

Figure 1: Open Loop Enhanced Geothermal System Diagram; image courtesy of Mazama Energy



Enhanced geothermal facilities would provide power regardless of the weather or time of year, diversifying the portfolio of clean renewable energy resources in Oregon and supporting more reliable and resilient grid operations. Oregon has excellent geothermal resources and is poised to be a leading state in geothermal development with the potential to provide some of the lowest cost

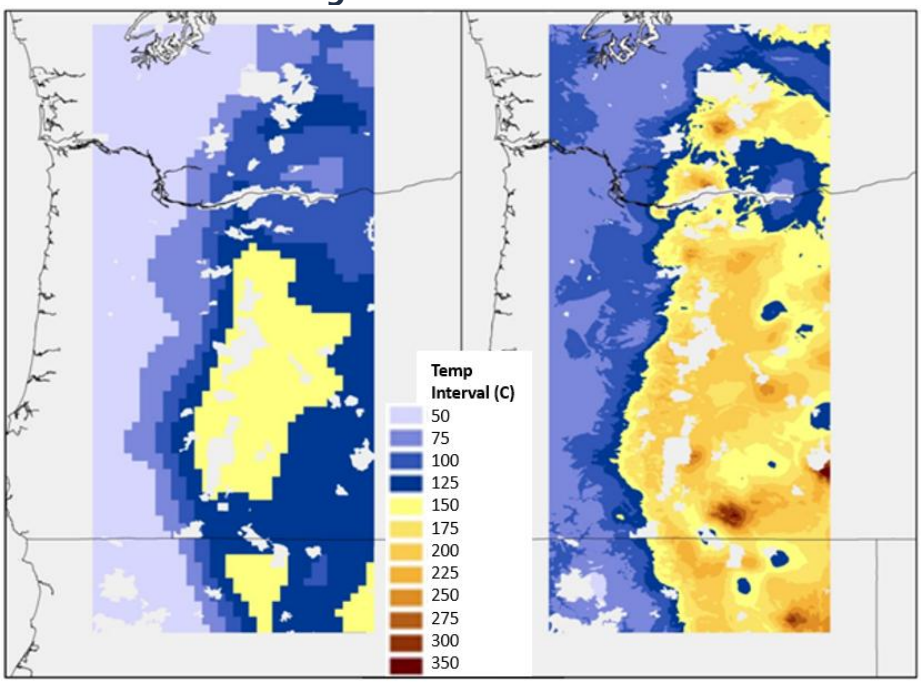
geothermal energy in the country. It has been more than a decade since Oregon's largest conventional geothermal power plant was developed near Vale, with no plans for additional facilities. Enhanced geothermal technologies are reinvigorating the industry in Oregon with active exploration and development projects on Mount Hood, Newberry Volcano, and other potential sites in eastern Oregon.

Resource Potential

Enhanced geothermal technologies are expanding the potential for geothermal project development. The U.S. Geological Survey estimates that enhanced geothermal in the Great Basin, including much of southeast Oregon, could help capture enough geothermal energy to produce as much as 135,000 MW of peak generation.[2] For reference, as of 2024 there are about 3,970 MW of conventional geothermal power plants operating in the United States.[3] In 2023, the National Laboratory of the Rockies[i] estimated that 90,000 GW of EGS capacity could be economically built across the country by 2050.[4] Sixty-one percent of all geothermal capacity contracted for in western states since 2021 has been EGS (approximately 1,007 MW of 1,661 MW total).[3]

Recently updated EGS resource data revealed a much greater geothermal resource potential in Oregon than was originally assumed. In 2023, the U.S. DOE, working with the National Renewable Energy Laboratory (NREL), completed the Enhanced Geothermal Shot Analysis, which modeled potential EGS development in 16 states, including Oregon, using updated cost and performance assumptions.[5] The left side of Figure 2 shows assumed geothermal resources taken from a national resource map generated in 2006, primarily for traditional geothermal resource availability. The right side of the figure shows significantly more geothermal energy resources identified in the NREL Enhanced Geothermal Shot Analysis.

Figure 2: Oregon Geothermal Resource Potential for Traditional Compared to Enhanced Geothermal Technologies



[i] Formerly known as the National Renewable Energy Laboratory (NREL).

Recent Developments

Enhanced geothermal technologies are rapidly moving from research and development sites to full commercial operations. Decades of research and projects in multiple countries have demonstrated the technical 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.[6] Today, several enhanced geothermal systems are already in commercial use and technology improvements are reducing the time and costs associated with future commercial developments. The first commercial EGS sites were developed in France and Germany in the early 2000s, followed by projects in the UK, Australia, Japan, and Italy.[6] In New Mexico, XGS Energy is developing a 150 MW enhanced geothermal facility to support Meta's data center portfolio.[7] The New Mexico project corresponds with a state geothermal study co-authored by many public, university, and private contributors.[8] Other emerging field-scale development and exploration drilling projects are supported by public-private partnerships at 21 federally funded sites in Idaho, New Mexico, Nevada, Oregon, California, Alaska, and Washington.[9]

The Newberry volcano in central Oregon is being used for two geothermal pilot projects. The Newberry Crater has one of the best geothermal resources in the country, with temperatures exceeding 700°F at relatively accessible depths. The first to break ground was the Mazama Energy project, which started with an existing well that was drilled more than 10 years ago by Altarock Energy. Mazama has since drilled additional wells and developed cracks within the subterranean rock where water can move between wells to gather heat. In 2025, the Mazama team set a world record with a well that reached 612°F and have successfully demonstrated steam generation at the site. The next step will be the installation of a steam turbine to generate electricity.[10] Mazama Energy believes the Newberry site could one day generate up to 5 GW of carbon free electricity.[11]

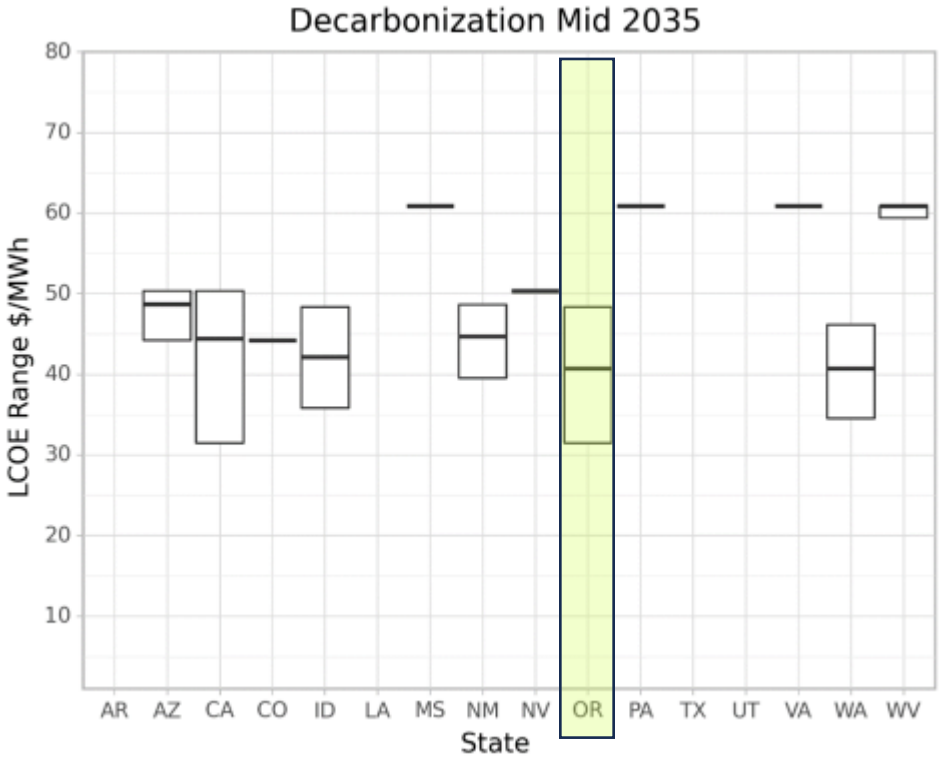
A second EGS facility, known as Project Obsidian, is being developed by Quaise Energy on the south side of Newberry volcano. This project uses innovative "millimeter wave" drilling technology, which is capable of faster and cheaper geothermal well development than other technologies in superhot rock.[12] Drilling began in 2026 for a well to support a proposed 50-megawatt power plant with the potential to expand to over 1,000 megawatts in the future.[13] The superhot rock at these facilities produces very high energy density heat, and Newberry also serves as a test site for developing new high temperature drilling techniques. In principle, the entirety of eastern Oregon is prospective for EGS. However, as the barriers section discusses, a lack of subsurface data and cost of drilling are slowing potential rollout.

Anticipated Costs

Projected costs for geothermal energy vary by source. The 2025 Annual Technology Baseline report projected the levelized cost of energy for enhanced geothermal to range between $51 and $146 per megawatt-hour in 2035, depending on subsurface conditions and type of plan developed.[14] 2035 values were selected as a reasonable estimate for when new enhanced geothermal energy projects may come online in Oregon. The favorable subsurface conditions in Oregon are consistent with cost estimates around $71 per MWh in 2035. This aligns closely with Lazard's levelized cost of energy projections of $66 to $109 per MWh.[15]

Some studies have predicted much lower costs for enhanced geothermal. In 2023, the Enhanced Geothermal Shot report found that if technical and policy barriers could be overcome, costs as low as $45 per MWh by 2035 could be achieved. This was presented as an aspirational target, but the analysis singled out Oregon as having the potential to be one of the lowest cost EGS markets in the country, with LCOE costs between $30 and $50 per MWh.[16] Even if the aspirational target is not met, when compared to advanced nuclear, offshore wind, and wave energy, enhanced geothermal is still projected in the ATB and Lazard's analyses to be the lowest cost, zero-emission emerging energy resource in Oregon by 2035. Some of the reductions in costs are expected to come from existing oil and gas drilling operations shifting to enhanced geothermal development.[17]

Figure 3: Range of 2035 Costs for Enhanced Geothermal System Electricity Generation by State[16]



Challenges to Commercial Development

There are several technological and policy challenges that need to be overcome before enhanced geothermal systems reach widespread commercial development. The U.S. Energy Information Administration has identified specific technological challenges, including:[18]

- Lack of subsurface data to inform site selection and lower project development risk.
- High costs of deep drilling and operating drills in hot rock.
- The capability to create and sustain flow through rock fissures that are located deep underground.
- Mitigating risks associated with induced seismicity.[ii]

[ii] Data collected at the Newberry site in Oregon demonstrates little seismic risk.

Additional barriers include long and complex permitting processes and limited access to transmission. Permitting may include multiple federal, state, and local agencies with unique requirements and timelines. Enhanced geothermal promises to be less location dependent than conventional geothermal, but in Oregon, some of the best resources may lack easy access to transmission. Building new transmission may be more costly and time-consuming than building the geothermal facilities.

Like all the emerging technologies evaluated in this report, the timing to overcome these barriers is uncertain and will depend upon successful demonstration projects. The two facilities under development at Newberry volcano will demonstrate new technologies and drilling techniques that will inform options to overcome these barriers.

Effects on Local Communities

Enhanced geothermal energy development can provide local economic benefits, but there are some aspects of development that could negatively affect communities and the environment. Oregon's best geothermal resources are in central and eastern Oregon, including some Tribal lands, and many small, rural communities. Enhanced geothermal energy has the potential to be require less land than solar and wind developments, but geothermal projects may still require new transmission lines and roads to service the facilities. Concerns over seismic activity with oil and gas fracking in other parts of the country have raised fears over potential seismic activity induced from pumping water deep underground.[19] The United States Geological Survey is tracking seismic activity at Newberry volcano and has found some induced seismic activity, though nothing that represents a safety concern.[20] Lawrence Berkely National Lab has also been monitoring 10 geothermal sites across the country, with decades of seismic data, and has not found significant induced seismic hazards.[21] Geothermal facilities will include pumps, fans, motors, vehicles, and other equipment that can generate noise pollution that is disruptive to nearby communities. Other disruptions may include new roads for site access, dust, construction noise, and large equipment on local roads.

Geothermal sites can support broader economic development for local communities by providing jobs and infrastructure that could be leveraged to drive more economic growth opportunities nearby, such as developing new roads or transmission lines. However, these may not be desirable by some or all people in these communities. Understanding local interests, needs, and concerns with EGS developments is essential to informing EGS policy and development choices. Coordination with Tribes, environmental advocates, and local communities is critical for responsible and successful project development.

Resources

1. Mazama Energy. (n.d.). *The Power Beneath Us.* Retrieved May 28, 2026, from https://mazamaenergy.com/.

2. Burns, E. R., Williams, C. F., & DeAngelo, J. (2025 Enhanced geothermal systems electric-resource assessment for the Great Basin, southwestern United States. *Fact Sheet* (2025–3027). U.S. Geological Survey. https://pubs.usgs.gov/fs/2025/3027/fs20253027.pdf.

3. National Laboratory of the Rockies. (2025). *2025 U.S. Geothermal Market Report*. https://www.nlr.gov/geothermal/2025-us-geothermal-market-report#market-future.

4. U.S. Energy Information Administration. (2026, February 19). *Enhanced geothermal systems could expand geothermal power generation*. Today in Energy. https://www.eia.gov/todayinenergy/detail.php?id=67204.

5. Augustine, C., Fisher, S., Ho, J., Warren, I. Witter, E. (2023, January). *Enhanced Geothermal Shot Analysis for the Geothermal Technologies Office.* (p. 7). https://docs.nlr.gov/docs/fy23osti/84822.pdf.

6. Paulillo, A., Striolo, A., Lettieri, P. (2022). Environmental Assessment of Renewable Energy Conversion Technologies. *Chapter 8 Life cycle assessment of geothermal power technologies, 8.2.5 Enhanced geothermal systems.*

https://www.sciencedirect.com/topics/earth-and-planetary-sciences/enhanced-geothermal-system.

7. Skidmore, Z. (2025, June 13). *Meta, XGS ink 150MW geothermal deal in New Mexico*. News—The Energy & Sustainability Channel. https://www.datacenterdynamics.com/en/news/meta-xgs-ink-150mw-geothermal-deal-in-new-mexico/.

8. Grimes, Nelson et al. (2025). *The Future of Geothermal in New Mexico*. Project InnerSpace. https://projectinnerspace.org/resources/Future-of-Geothermal-in-New-Mexico.pdf.

9. U.S. Department of Energy. (n.d.). *Pilots and Demonstrations: Next-Generation Field Tests and Drilling for New Resources*. Geothermal. Retrieved October 27, 2026 from https://www.energy.gov/hgeo/geothermal/pilots-and-demonstrations-next-generation-field-tests-and-drilling-new-resources.

10. Mazama Energy. (n.d.). *The Power Beneath Us.* Mazama. Retrieved May 26, 2026, from https://mazamaenergy.com/newberry/.

11. Mazama Energy. (n.d.). *The Power Beneath Us.* See the Path. Retrieved October 20, 2026, from https://mazamaenergy.com/#see-the-path.

12. Quaise Energy. (n.d.). *Project Obsidian—The future of energy is now*. Retrieved May 26, 2026, from https://quaiseprojectobsidian.com/.

13. Quaise Energy. (2026, April 13). *Introducing Project Obsidian*. https://www.quaise.com/news/introducing-project-obsidian.

14. National Laboratory of the Rockies. (2025). *Annual Technology Baseline. Electricity Annual Technology Baseline Data Download.* [Dataset]. Retrieved September 24, 2026 from https://atb.nlr.gov/electricity/2025/data.

15. Lazard. (2025, June). *Lazard's LCOE Levelized Cost of Energy Analysis—Version 18.0*. (p 8). https://www.lazard.com/media/5tlbhyla/lazards-lcoeplus-june-2025-_vf.pdf.

16. U.S. Department of Energy. (2023, August). *Enhanced Geothermal Shot: Unlocking the Power of Geothermal Energy*. https://www.energy.gov/sites/default/files/2023-08/EERE-ES-Enhancing-Geothermal-082223-508.pdf.

17. Jie Cao, Jen Lye, Margie Maria Gonzalez, & Melissa Magalhaes. (2024, February). *Exploring the Synergy: Leveraging Oil and Gas Drilling Solutions for Enhanced Geothermal Drilling.* (Stanford University, SGP-TR-227). https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2024/Cao.pdf.

18. U.S. Energy Information Administration. (2026, February 19). *Enhanced geothermal systems could expand geothermal power generation*. Today in Energy. https://www.eia.gov/todayinenergy/detail.php?id=67204.

19. Schmittbuhl, J., Lambotte, S., Lengliné, O., Grunberg, M., Jund, H., Vergne, J., Cornet, F., Doubre, C., & Masson, F. (2022). Induced and triggered seismicity below the city of Strasbourg, France from November 2019 to January 2021. *Comptes Rendus. Géoscience*, *353*(S1), 561–584. https://doi.org/10.5802/crgeos.71.

20. U.S. Geological Survey. (December 18, 2024). *Earthquake monitoring at Newberry volcano.* Cascades Volcano Observatory. https://www.usgs.gov/observatories/cvo/news/earthquake-monitoring-newberry-volcano-december-18-2024.

21. Nori Nakata, Ernest Majer, Chet Hopp, Steve Jarpe, Tim Elnitiarta, Hongrui Qiu, & Michelle Robertson. (2026, February). *Lessons Learned from Decades of Seismic Monitoring at Enhanced and Conventional Geothermal Fields* (Stanford University, SGP-TR-230). https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2026/Nakata3.pdf.

Emerging Technologies: Long-Duration Energy Storage

Technology Summary



Long-duration energy storage, or LDES, refers to technologies capable of storing and then delivering energy to the electric grid or end users for long periods of time. While definitions vary, the U.S. Department of Energy defines *long-duration* as offering a minimum of 10 hours of discharge at full power, though some technologies seek to extend this period to hundreds of hours or across seasons.[1] [2] These systems can provide important grid services such as balancing variable renewable energy, managing prolonged constraints on the grid such as peak loads from heat waves, or even supporting seasonal differences in grid loads and generation. They can also be used by commercial and industrial facilities, such as data centers, to support operations and provide backup power. Large volumes of energy can also be stored with multiple units of shorter-duration storage technologies, such as lithium-ion batteries. Emerging LDES technologies seek to reduce the cost of long-term storage compared to these existing shorter-duration storage technologies. As Oregon increases the amount of variable renewable energy on the grid and climate change drives more extreme and prolonged weather events, LDES could be a critical technology for maintaining grid reliability.

Long-duration energy storage technologies vary widely. Pumped hydro storage facilities date back more than 100 years and are in widespread global use. Other technologies, such as iron-based batteries, are just emerging. Energy can be stored mechanically, such as compressed air, or as fuel, such as hydrogen generation from surplus renewable energy. All the technologies have a recharge period when energy flows into the storage facility, and a discharge period when energy is delivered back to the grid. This topic will focus on iron-based batteries, compressed air storage, and hydrogen, which are long-duration energy storage technologies emerging across the U.S. Some technologies, such as lithium-ion batteries, are primarily used for short-term storage applications and will not be included in this analysis. Additional energy storage technologies may be covered in future emerging technology reports.

Iron-Based Batteries

There are several emerging iron-based batteries, including iron-air and iron-flow, that are specifically designed for long-duration, large-scale energy storage. Both types of iron-based batteries can withstand many charge/discharge cycles, are safe to operate, and utilize more abundant and lower cost materials than conventional lithium-ion batteries.[3]

Iron-air batteries operate via a reversible "rusting" reaction. During discharge, iron reacts with oxygen in the air, creating rust and electricity. When charging, the rust is converted back into iron in a process that also releases oxygen. Iron-air batteries are designed for long discharge — up to 100 hours — but have low round-trip efficiency, losing about half the energy in a single charge/discharge cycle.[4] This

low round-trip efficiency limits iron-air batteries to applications where they can be charged with free or very low-cost electricity, such as energy from solar or wind that might otherwise be curtailed.[i]

Iron-flow batteries can provide 100+ hours of cost-effective energy storage and are much more efficient than iron-air batteries. Iron-flow batteries are comprised of two liquid electrolytes made from iron salts dissolved in water. Pumps circulate the electrolytes, speeding up the chemical reactions and improving round-trip efficiency to about 70 to 80 percent.[5]



Iron-flow batteries.
Source: ESS Inc, Wilsonville.

Compressed Air Energy Storage

Compressed air energy storage operates by compressing air with electricity — often from renewables — into underground caverns or rock formations. During discharge, compressed air is released and used to spin turbines that generate electricity.[6] Compressed air can also be used to increase the efficiency and output of conventional natural gas power plants, tripling energy output and reducing natural gas consumption by up to 60 percent.[7] Although compressed air has been in use for storing energy from the grid since 1978, there is renewed interest in advanced types of compressed air storage that do not need to work in conjunction with natural gas plants.[8] Compressed air storage projects have not yet been developed in Oregon or the Pacific Northwest.

Hydrogen Energy Storage

Hydrogen can be generated, stored, and used as a carbon-free fuel in specialized electric power plants. Electricity can be used to generate hydrogen (and oxygen) gas from water using devices known as electrolyzers. Electrolyzers have been used since the early 1900s. Today, more than 95 percent of global hydrogen is made using steam to separate the hydrogen from methane in natural gas in a process known as steam methane reformation. The process emits 10-12 kilograms of carbon dioxide for each kilogram of hydrogen (this is roughly equivalent to the embodied energy and cradle-to-grave carbon emissions associated with one gallon of gasoline).[9] [10] However, when powered by clean electricity, electrolyzers can produce carbon-free hydrogen. When hydrogen is burned in a combustion turbine to generate electricity, no carbon dioxide is emitted; however the process results in other pollutants such as nitrogen oxide, or NOx, emissions.[11] Hydrogen can also be used in a fuel cell, which can generate electricity without the emissions associated with a combustion turbine.

Resource Potential

The resource potential of long-duration energy storage technologies is primarily associated with their operational value to electric utilities, grid operators, and end users. LDES facilities may be co-located with solar or wind to enable the facilities to deliver energy when it is most valued or placed in strategic locations to manage congestion on transmission infrastructure, improve resilience and

[i] In this context, "curtailed" refers to unused output of solar or wind energy facilities that corresponds with periods of oversupply on the grid.

reliability, or to provide backup power. In each case, the resource potential is site-specific and determined based on specific operational needs.

In the Pacific Northwest, a promising use case for LDES would be to provide backup power during prolonged grid outages. Natural hazards such as winter storms, summer heat waves and wildfires result in regular prolonged power outages in Oregon. Short-duration storage technologies, such as lithium-ion batteries, are too expensive to provide the many hours or days of backup power necessary during these events. LDES aims to reduce the cost of energy storage to a level where it may be used for multi-day backup power.

Recent Developments

Iron-Based Batteries

The market for long-duration, iron-based batteries is growing rapidly, with record market growth in the first quarter of 2026.[12] While the market continues to be dominated by lithium-ion batteries, iron-based batteries are demonstrating advantages for long-duration storage applications.[5] By 2034, the market for iron-based batteries is forecasted to grow to $25 billion from $1.75 billion in 2025.[13]

Both iron-oxide flow batteries and iron-air batteries are approaching commercial viability, with multiple utilities investing in iron-based batteries. In February 2026, Form Energy announced a partnership with Google and Xcel Energy to develop a 300 megawatt, 100-hour iron-air battery in Minnesota.[14] Additional iron-air facilities are underway in Colorado, Georgia, California, and New York.[15] ESS Inc Energy Solutions, an iron-oxide flow battery manufacturer in Wilsonville, Oregon, recently wrapped up a 21-month demonstration project with Burbank Water and Power where their batteries were coupled with an existing rooftop solar installation.[16] ESS Inc. is also collaborating with the Salt River Project, an electric utility in Arizona, to develop a 50 MWh facility that will be able to provide 5MW of power for up to 10 hours.

Compressed Air Energy Storage

Interest in compressed air energy storage systems has steadily grown in the last decade as a large-scale solution for supporting clean energy grids. Until 2025, there were only two compressed air storage facilities in operation. The first was built in 1978 in Huntorf, Germany, and the second is a 110 MWh plant in McIntosh, Alabama, built in 1991. Both of the facilities were used to boost the output and efficiency of conventional natural gas power plants.[18] In 2025, the Nengchu1 compressed air storage facility began commercial operation in Hubei, China, where it is used to balance variable renewable energy on China's grid. It is the largest compressed air storage facility in the world, with a 300 MW output and 1,500 MWh storage capacity. It is also the first large-scale non-combustion facility, meaning it does not operate in conjunction with a natural gas plant.[19]

In the U.S., the proposed Willow Rock compressed air storage facility in California received a $1.76 billion U.S. DOE loan for construction. It would add 500 MW of storage capacity, expected to provide 4000 MWh of long-duration energy storage for the southern California grid.[20] The facility is anticipated to begin operating by 2030.[21] A 2023 Pacific Northwest National Laboratory and Bonneville Power Administration study on potential geological formations capable of hosting a compressed air storage facility identified multiple sites in eastern Washington and Oregon.[22]

PacifiCorp included compressed air energy storage as a potential resource in its 2025 Integrated Resource Plan, but the modeling did not select it as a least-cost storage option.[23] Portland General Electric's and Bonneville Power Administration's most recent planning modeling efforts have not included compressed air storage as a resource option.

Hydrogen

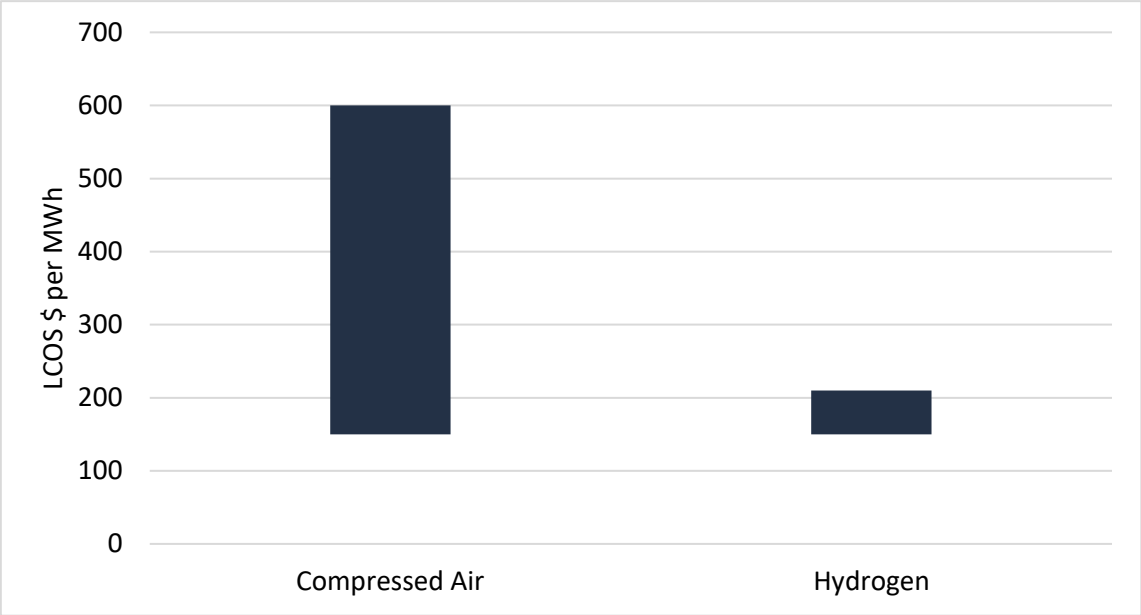
The availability of clean hydrogen is expanding rapidly – installed capacity of hydrogen electrolyzers expanded nine-fold globally from 2021 to 2025.[24] While most hydrogen is used for industrial purposes, there have been advancements in hydrogen storage and electricity production facilities. Across the globe and in the U.S., testing is underway on turbines that use hydrogen to generate electricity. The Advanced Clean Energy Storage project in Delta, Utah aims to combine hydrogen production, storage, and electricity generation in a natural gas power plant that has been modified to burn hydrogen.[25] On a smaller scale, Pacific Gas and Electric Company in California announced completion of a long-duration energy storage microgrid in Calistoga, CA.[26] The 8.5 MW facility combines on-site hydrogen storage, a hydrogen fuel cell, and lithium-ion batteries to provide up to 48 hours of isolated microgrid operations. In England, researchers at the University of Birmingham have developed a new way to split water into hydrogen and oxygen using a low-temperature approach that could make the clean fuel more affordable and easier to produce.[27]

In the Pacific Northwest, hydrogen development suffered a significant setback in 2025 when the Trump administration announced that it was cancelling federal funding commitments for the Pacific Northwest Hydrogen Hub.[28] The hub included projects across Oregon, Washington, and Montana that would have demonstrated the use of hydrogen as a safe and reliable means of energy storage, including for electricity generation during periods of peak demand on the grid.[29] The cancellation of the Pacific Northwest Hydrogen Hub award was a blow to the region but other smaller initiatives remain. In February 2026, the Oregon Institute of Technology was awarded $1.11 million to develop applied research, education, and training in hydrogen production, solar and solar thermal advancements, emerging battery technologies, and long-duration energy storage.[30]

Anticipated Costs

Projected costs of emerging LDES technologies vary. The U.S. Department of Energy tracks several emerging energy storage technologies, including compressed air storage, and hydrogen storage.[31] Iron-oxide batteries are not included in the U.S. DOE assessment. The costs are reported as levelized cost of storage, which is a similar metric to the levelized cost of energy metric reported for emerging generation technologies, but accounts for specific storage cost considerations such as round-trip efficiency, operations and maintenance, and number of lifetime charge and discharge cycles. LCOS does not consider the cost of the electricity used for charging, as this value can vary by location, source, and time of day.

Figure 3. Levelized cost of storage estimates from U.S. DOE Long-Duration Storage Shot Technology Strategy Assessments.[32]



The cost to build compressed air or hydrogen storage facilities is a large barrier to adoption, although each technology has a range of potential costs. Hydrogen storage costs depend on how the hydrogen is stored, with storage in a natural geologic formation being cheaper than above-ground containers.[33] It is also important to note that the LCOS for hydrogen only includes the costs involved in creating and storing hydrogen but does not include costs to develop fuel cells or combustion turbines capable of using hydrogen as a fuel. This would further increase the total costs to use hydrogen as storage for electricity generation. Compressed air costs are also heavily dependent on siting facilities at specific geological formations that can also be cost-effectively linked to the grid.[34]

There is some evidence that the levelized cost of storage for iron-based batteries is close to the low end of the values calculated for the other long-duration storage technologies evaluated by the U.S. DOE. A recent study by Energy Solutions Intelligence estimated an LCOS for iron-oxide flow batteries at $90-160 per MWh, which is near the bottom of the cost range for hydrogen.[35] Another study by the same organization estimated an LCOS for 100-hour iron-air batteries at about $60/MWh by 2035.[36]

The LCOS for these technologies, even at the lower end, is mostly higher than the price of electricity sold through the Pacific Northwest regional pricing hub over the course of 2025.[37] However, there is an additional benefit that long-duration storage could provide that is not captured in the LCOS: addressing costs from renewable energy oversupply situations. In the Pacific Northwest, seasonal variations in hydropower and wind energy create periodic conditions where the supply of electricity exceeds demand.[38] When this oversupply occurs, generators must curtail generation, and this can lead to revenue losses. An example of this is Bonneville Power Administration's Oversupply Management Protocol that requires BPA to reimburse generator owners for lost revenue. Ultimately, this means the surplus energy is not only wasted, but costs ratepayers money. The last time the protocol was used in 2023 resulted in BPA reimbursing almost $3 million to 26 different generators for curtailments during seven days of oversupply.[39] More LDES options could have reduced or eliminated these curtailments,

provided the energy back to the grid when needed, and reduced or eliminated the reimbursement costs.

Challenges to Commercial Development

Long-duration energy storage technologies face several challenges to widespread commercial deployment. A 2024 Center for Climate and Energy Solutions report prepared for their Long Duration Energy Storage Working Group identified three key barriers:[40]

- Overcoming technical challenges
- Reaching economies of scale in deployment (while keeping pace with emerging grid needs)
- Addressing gaps in recognizing the full value of LDES in utility and transmission planning processes and government incentive structures

Another major challenge is access to grid infrastructure for LDES connections. Siting options for compressed air storage and some hydrogen storage are limited to unique locations with specialized geological formations, which may not be near existing transmission lines or substations. LDES is most cost-effective when able to interconnect with grid infrastructure and/or be co-located with energy generation, particularly near large-scale renewable energy facilities that offer low- or no-cost charging during periods of overproduction. In another example, electrolyzers that generate clean hydrogen also require a consistent source of water to operate.

Securing siting and permitting approvals for some LDES projects is a complex process that can take months or years to navigate. Facilities that require more land and subsurface resources, such as compressed air and geologic hydrogen storage, often require permitting processes that can take several years.[41] Different types of energy storage facilities may require approvals and permits from many different authorities, including Tribal, county, state, and/or federal approvals, and this may entail land use, environmental, cultural resource, or other assessments and approvals. Other facilities, such as standalone battery storage facilities, may only need county approval. An advantage of iron-based battery storage is that it does not have many of the risks associated with lithium-ion batteries, such as fire risk, which may lead to shorter permitting timelines.

Effects on Local Communities

Long-duration energy storage projects have the potential to provide many benefits to Oregon communities and households. LDES technologies offer opportunities to make Oregon's grid more reliable and resilient by getting the most out of variable renewable solar and wind resources. Some technologies may also come with fewer environmental, health, and safety concerns than some other grid support technologies. For example, iron-based batteries have low toxicity, low fire risk, and minimal waste profiles compared to lithium-ion or other forms of battery energy storage technologies. Batteries could also offer local community energy resilience benefits by providing a longer-term source of electricity during power outages or other emergency operational needs. In 2023, the U.S. DOE Office of Clean Energy Demonstrations announced awards for 15 LDES projects with the goal to increase community control of local power systems, mitigate risks associated with disruptions to the grid, and help communities develop reliable and affordable energy systems.[42]

Understanding the effects of LDES development in or near local communities and on the environment is important to informing policy and development choices. Large geologic energy storage facilities, such as pumped hydro and compressed air, may be controversial, as they are often located on or near Tribal lands and rural communities. For example, the proposed Swan Lake pumped hydro facility in Klamath County experienced strong pushback from Tribal members. In 2024, the Klamath Tribes General Council voted 77 to 8 against a $40 million Tribal compensation package associated with the proposed facility.[43] Similar opposition has been voiced by the Affiliated Tribes of Northwest Indians regarding a proposed hydro facility near Goldendale, WA.[44] Facilities may also require the development of roads to access the sites, generate noise pollution, and require new transmission lines. While most long-duration storage is not dependent on geology, local communities may have concerns about the chemicals used in the batteries, operational noise, or even the visual aesthetics of the facilities. Early, frequent, and transparent communication, coordination, and consultation with Tribes, environmental advocates, and local communities are critical for responsible and successful project development.

Resources

1. Denholm, P., Cole, W., Frazier, A. W., Podkaminer, K., & Blair, N. (2021). *The Challenge of Defining Long-Duration Energy Storage*. Retrieved https://docs.nlr.gov/docs/fy22osti/80583.pdf.
2. U.S. Department of Energy. (n.d.). *Long-Duration Energy Storage*. Office of Clean Energy Demonstrations—Portfolio. Retrieved October 27, 2026 from https://www.energy.gov/cmei/oced/long-duration-energy-storage.
3. Dixit, M. (2026, April 27). *China develops iron battery 80 times cheaper than lithium that can last 16 years*. Interesting Engineering. https://interestingengineering.com/energy/new-all-iron-battery-sustains-6000-cycles.
4. Talar, K. (2024, February 27). *Iron Air Battery 2026: Iron-Air Battery 100-Hour Long-Duration Storage 2026: Iron-Air Battery's 100-Hour Bet, Reversible Rusting, and Where It Really Fits Next to Lithium and Flow — A Project Developer's View*. How to Store Electricity. https://howtostoreelectricity.com/iron-air-battery-long-duration-storage/.
5. Energy Tech News. (2026, May 1). *Iron-Flow vs. Lithium-Ion Batteries: Cost, Performance, and Deployment Readiness Across Grid-Scale Projects*. https://energytech-news.com/iron-flow-vs-lithium-ion-batteries-cost.
6. Pacific Northwest National Laboratory. (n.d.). *Compressed Air Energy Storage (CAES)*. Energy Storage Cost and Performance Database. Retrieved August 14, 2026, from https://www.pnnl.gov/projects/esgc-cost-performance/compressed-air-energy-storage.
7. Center for Sustainable Systems, University of Michigan. (2025, September). *U.S. Grid Energy Storage Factsheet* (CSS15-17). https://css.umich.edu/sites/default/files/2025-09/CSS15-17_0.pdf.
8. Soloot, H.-E. H. (2020, February 16). *World's First Utility-Scale CAES Plant was Built-in 1978 in Northern Germany—Solar Edition*. https://solaredition.com/worlds-first-utility-scale-caes-plant-was-built-in-1978-in-northern-germany/.

9. International Energy Agency. (n.d.). *GHG emissions of hydrogen and its derivatives – Global Hydrogen Review 2024 – Analysis*. Retrieved September 29, 2026, from https://www.iea.org/reports/global-hydrogen-review-2024/ghg-emissions-of-hydrogen-and-its-derivatives.

10. Consumer Ecology. (2020, November 21). *Carbon Footprint of Gasoline.* https://consumerecology.com/carbon-footprint-of-gasoline/.

11. U.S. Department of Energy. (n.d.). *Does the use of hydrogen produce air pollutants such as nitrogen oxides?* Alternative Fuels and Feedstocks Office. https://www.energy.gov/cmei/fuels/does-use-hydrogen-produce-air-pollutants-such-nitrogen-oxides.

12. Solar Energy Industries Association. (2026, May 21). *U.S. Adds 10 GWh of New Energy Storage Capacity in First Quarter, Marking Largest Q1 on Record*. Energy Storage Market Outlook. https://seia.org/news/largest-q1-on-record-for-energy-storage/.

13. Growth Market Reports. (2026, June). *Iron-Air Battery Market Report 2025-2034*. Energy Efficiency & Conservation: Energy & Power. Retrieved August 13, 2026, from https://growthmarketreports.com/report/iron-air-battery-market.

14. Martucci, B. (21026, March 4). *World's 'largest' grid battery part of Google-Xcel Energy agreement | Utility Dive*. https://www.utilitydive.com/news/worlds-largest-grid-battery-part-of-google-xcel-energy-agreement/813793/.

15. Innovation Library. (2026). *Can Rust Power Grid Scale Energy Storage for 100 Hours?* https://innovationlibrary.com/articles/can-rust-power-grid-scale-energy-storage-for-100-hours.

16. American Public Power Association. (2024, June 1). *Burbank Water and Power Celebrates Commissioning of Long Duration Energy Storage System*. Energy Storage. https://www.publicpower.org/periodical/article/burbank-water-and-power-celebrates-commissioning-long-duration-energy-storage-system.

17. ESS, Inc. (2025, October 9). *SRP and ESS Announce New 50 MWh Long Duration Energy Storage Pilot Project.* Press Release. https://essinc.com/srp-and-ess-announce-new-50-mwh-long-duration-energy-storage-pilot-project/.

18. Baldwin EMC. (n.d.). *Compressed air energy storage technology: Generating electricity out of thin air*. Retrieved September 29, 2026, from https://www.baldwinemc.com/compressed-air-energy-storage-technology-generating-electricity-out-of-thin-air/.

19. Global Times. (2025, June 9). *World's first 300 MW compressed air energy storage plant fully operated in Central China. Business/Economy.* https://www.globaltimes.cn/page/202501/1326611.shtml.

20. U.S. Department of Energy. (2026, June 10). *LPO Announces Conditional Commitment for Long Duration Compressed Air Energy Storage to Enable a Diverse and Reliable Generation Mix*. https://www.energy.gov/edf/articles/lpo-announces-conditional-commitment-long-duration-compressed-air-energy-storage.

21. Advanced Cleantech Deployment Tracker. (2026, October 12). *Willow Rock Energy Storage Center*. https://www.cleantechtracker.com/projects/willow-rock-energy-storage-center.

22. Pacific Northwest National Laboratory. (2013). *Techno-economic Performance Evaluation of Compressed Air Energy Storage in the Pacific Northwest* (22235; p. iii). https://www.researchgate.net/publication/358380391_Techno-economic_Performance_Evaluation_of_Compressed_Air_Energy_Storage_in_the_Pacific_Northwest#read.

23. PacificCorp. (2025, March 31). *2025 Integrated Resource Plan.* (p. 142). https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2025-irp/2025_IRP_Vol_1.pdf.

24. International Energy Agency. (n.d.). *Progress summary dashboard – Global Hydrogen Review 2025 – Analysis*. IEA. Retrieved August 14, 2026, from https://www.iea.org/reports/global-hydrogen-review-2025/progress-summary-dashboard.

25. U.S. Department of Energy. (2026, June 10). *Advanced Clean Energy Storage*. Energy.Gov. https://www.energy.gov/edf/advanced-clean-energy-storage.

26. PG&E Corporation. (2025, September 25). *Energy Vault, PG&E Announce Successful Completion of the Calistoga Resiliency Center, the World's First Ultra-Long Duration Hybrid Battery + Hydrogen Energy Storage Microgrid*. (n.d.). News & Events. https://investor.pgecorp.com/news-events/press-releases/press-release-details/2025/Energy-Vault-PGE-Announce-Successful-Completion-of-the-Calistoga-Resiliency-Center-the-Worlds-First-Ultra-Long-Duration-Hybrid-Battery--Hydrogen-Energy-Storage-Microgrid/default.aspx.

27. ScienceDaily. (2026, June 2). *New hydrogen breakthrough turns waste heat into clean fuel*. Science News. https://www.sciencedaily.com/releases/2026/06/260601025345.htm.

28. Banse, T. (2025, October 2). *Trump administration yanks funding for Northwest green hydrogen project*. Washington State Standard. https://washingtonstatestandard.com/2025/10/02/trump-administration-yanks-funding-for-northwest-green-hydrogen-project/.

29. *Pacific Northwest Hydrogen Association*. (n.d.). Projects. Retrieved June 12, 2026, from https://pnwh2.com/projects/.

30. Oregon Institute of Technology. (2026, February 12). *Oregon Tech Receives $1.123 Million to Advance Energy Innovation and Meet Workforce Needs in Domestic Energy Sector.* Newsroom. https://www.oit.edu/news/oregon-tech-receives-1123-million-advance-energy-innovation-and-meet-workforce-needs-domestic.

31. U.S. Department of Energy. (n.d.). *Storage Innovations 2030*. Office of Electricity. https://www.energy.gov/oe/storage-innovations-2030.

32. *ODOE analysis of data in the Long-Duration Storage Shot Technology Strategy Assessments*. (2026). Data from U.S. Department of Energy. https://www.energy.gov/oe/storage-innovations-2030.

33. U.S. Department of Energy. (2024). *Achieving the Promise of Low-Cost Long Duration Energy Storage* (p. 29). https://www.energy.gov/sites/default/files/2024-08/Achieving%20the%20Promise%20of%20Low-Cost%20Long%20Duration%20Energy%20Storage_FINAL_08052024.pdf.

34. U.S. Department of Energy. (2024). *Achieving the Promise of Low-Cost Long Duration Energy Storage* (p. 31). https://www.energy.gov/sites/default/files/2024-08/Achieving%20the%20Promise%20of%20Low-Cost%20Long%20Duration%20Energy%20Storage_FINAL_08052024.pdf.

35. Energy Solutions Intelligence. (2025, December). *Flow Batteries (Vanadium vs. Iron): LCOS Analysis for 10+ Hour Storage*. https://energy-solutions.co/articles/sub/flow-batteries-vanadium-vs-iron.

36. Energy Solutions Intelligence. (2026, August). *Metal-Air Batteries Strategic Deep Dive 2026-2035: Zinc, Aluminum, Iron, and Lithium.* https://energy-solutions.co/articles/sub/metal-air-batteries-comparison-2027-2035.

37. *Oregon Department of Energy Internal Analysis of Wholesale Electricity Prices at the Mid C Price Hub in 2025.* (2026). Dataset from https://www.eia.gov/electricity/wholesale/#history.

38. Bonneville Power Administration. (n.d.). *Oversupply*. Retrieved June 11, 2026, from https://www.bpa.gov/energy-and-services/transmission/oversupply.

39. Bonneville Power Administration. (2023, October 3). *2023 Oversupply Management*. https://www.bpa.gov/-/media/Aep/transmission/oversupply/annual-oversupply-review/2023-oversupply-managment-protocal-review.pdf.

40. Brattle. (2025, February 10). *Brattle Report Examines Long-Duration Energy Storage (LDES) Benefits and Barriers. Publication. Insight & Events.* https://www.brattle.com/insights-events/publications/brattle-report-examines-long-duration-energy-storage-ldes-benefits-and-barriers/.

41. Permitting Dashboard. (2016, September 22). *Swan Lake North Pumped Storage.* Federal Infrastructure Projects. https://www.permits.performance.gov/permitting-project/fast-41-covered-projects/swan-lake-north-pumped-storage.

42. U.S. Department of Energy Office of Clean Energy Demonstrations. (20223, September 22). *DOE Announces $325 Million for Long-Duration Energy Storage Projects to Increase Grid Resilience and Protect America's Communities*. https://content.govdelivery.com/accounts/USDOEOCED/bulletins/371ce14.

43. Chamless, P. (2024, January 23). $40 million Swan Lake Hydro Energy Project compensation package rejected by Klamath Tribes General Council. *Klamath Tribes News*. *Natural Resources & Environment*. https://www.klamathtribesnews.org/2024/01/23/40-million-swan-lake-hydro-energy-project-compensation-package-from-cip-rejected-by-klamath-tribes-general-council/.

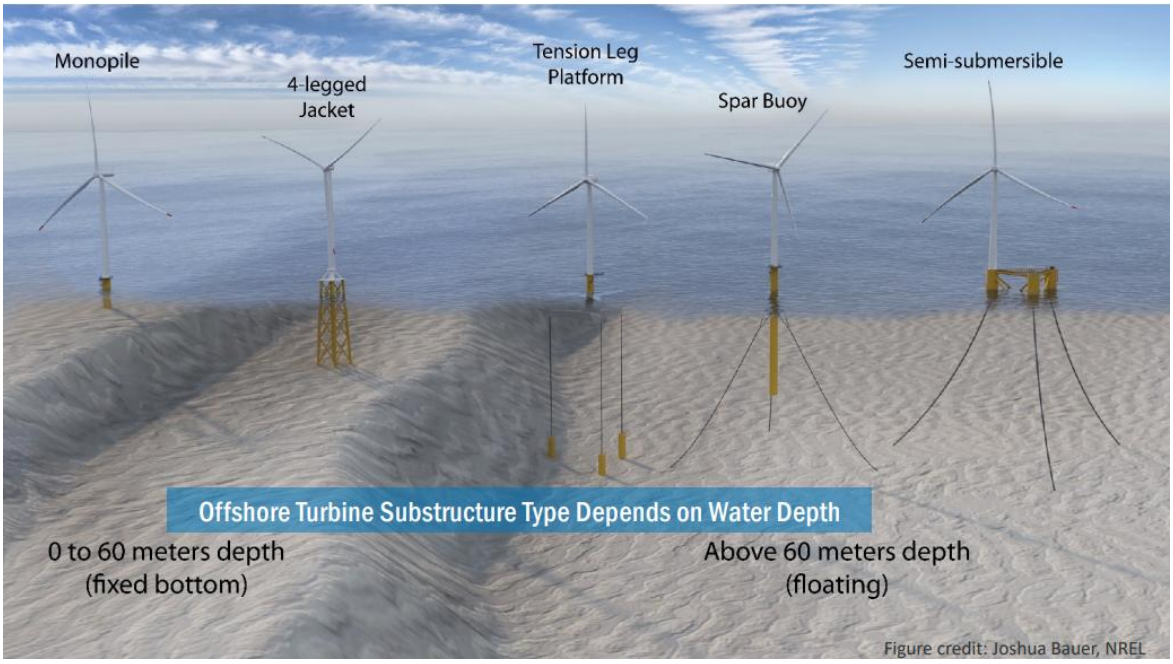
44. Yakama Nation Fisheries. (n.d.). *Goldendale Water Pump Project—Yakama Perspective*. Retrieved September 29, 2026, from https://yakamafish-nsn.gov/GoldendaleWaterPumpProject.

Emerging Technologies: Floating Offshore Wind

Technology Summary

Floating offshore wind combines existing wind turbine technologies with innovations that enable them to operate in deep ocean waters like those off Oregon's coast. Most existing offshore wind facilities are mounted on rigid foundations fixed to the sea floor, which requires sites where water depths do not exceed 60 meters, or about 200 feet. Floating offshore wind turbines can operate in deeper waters because they are mounted on buoyant platforms rather than fixed to the ocean floor. Platforms are moored to the seabed with cables, stabilizing the structure while accommodating for wave and wind motion. In addition to allowing for operations in deeper waters, floating offshore wind also provides access to stronger, more consistent wind resources farther from shore.

Figure 1: Offshore Wind Mounting Strategies. Image Courtesy of NREL.[1]



Floating offshore wind structures are similar to those on land but have some important differences. Floating offshore wind technologies are often larger than land-based turbines. For example, Portland General Electric's Wheatridge Renewable Energy Facility uses wind turbines with a capacity of 2.5 megawatts each and a hub height – the height of the nacelle that the blades spin around – of around 90 meters. Offshore wind turbines are much larger, with emerging turbines up to 26 MW each and hub heights up to 200 meters.[2] To accommodate for the large size, offshore wind turbines are typically assembled at a port and towed to their site. Turbines must be designed to withstand the effects of the saltwater environment, stronger winds, and ocean waves and currents, which increases maintenance costs and the cost of materials that are used in construction. Floating offshore wind facilities also require underwater transmission cables, offshore substations, and other electrical equipment capable of withstanding marine environments.

Figure 2: GE 12 MW Wind Turbine Nacelle and Blade. Photos courtesy of GE.[3]





Floating offshore wind has been a topic of ongoing conversations in Oregon, especially along the south coast, which has the best offshore wind resource on the west coast of the contiguous U.S. As an energy resource it has the potential to provide abundant clean electricity and complement the increasing amounts of variable solar and wind generation in Oregon's electricity resource mix. Offshore winds blow consistently, making it a resource that could provide power when solar and onshore wind resources are not available. It also has the potential to bring industries and jobs to Oregon, supporting economic development in coastal and rural areas of the state as well as industrial centers along the Columbia River.

Resource Potential

Offshore wind energy developments along the West Coast of the United States have the potential to generate about half of the electricity used in western states.[4] A 2026 study describes the *technical potential* for about 90 GW of floating offshore wind development on the West Coast, generating 355 terawatt-hours (355,000 gigawatt-hours) of annual energy production. However, not all the technically possible offshore wind sites are economically feasible.[4] Most of the west coast is suitable only for floating offshore wind resources, and development of floating offshore wind farms will be limited until technology and siting challenges can be overcome. The *West Coast Offshore Wind Transmission Study* conducted by Pacific Northwest National Laboratory, which took into consideration more economic data on floating offshore wind development, concluded that floating offshore wind could provide about 33 GW of energy to the western U.S. by 2050.[5]

Figure 3: National Laboratory of the Rockies Coastal Wind Resource Assessment[1]

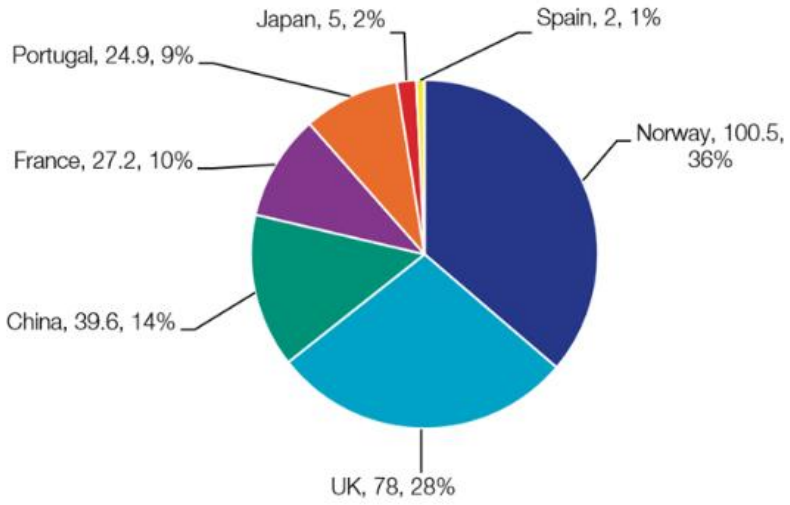


In 2024, the Bureau of Ocean Energy Management identified two lease areas for potential development, comprising about 3 GW of potential capacity off the southern Oregon coast.[6] Opposition from Tribes, the fishing industry, and local communities, as well as the withdrawal of four of the five potential lease bidders, resulted in the planned lease auction being postponed. In 2025, as a result of Federal policy changes, BOEM rescinded both Wind Energy Areas off Oregon.[7] From 2024-2026, Oregon developed an Offshore Wind Energy Roadmap, which described potential alternative futures for Oregon related to offshore wind energy, and recommended policies and actions the state could take to facilitate responsible development while securing the interests of state coastal uses, resources, and community well-being.[8]

Recent Developments

Floating offshore wind technologies have reached several significant milestones in recent years, driven by technological advances and development of new commercial projects. As of late 2025, global operational floating wind capacity reached around 277 MW across 16 projects in seven countries, a 13 percent increase from the previous year.[9] Most floating offshore wind facilities (78 percent) are operating in the United Kingdom, Norway, and China. In May 2026, the largest single wind turbine installed on a floating platform began operating in China — a 16 MW turbine[i] located 70 kilometers offshore.[10]

Figure 4: Operational Floating Offshore Wind Capacity by Country[9]



There are currently no floating offshore wind projects operating or in development in the United States and local, state, and federal actions continue to limit development opportunities. In 2021, the California legislature set planning targets for offshore wind development in state waters for up to 5 GW by 2030 and 25 GW by 2045.[11] In conjunction with this, the federal Bureau of Ocean Energy Management issued leases for floating offshore wind energy exploration in areas off the coasts of California and southern Oregon in 2022. On July 30, 2025, BOEM announced it would rescind all designated offshore wind areas on the U.S. Outer Continental Shelf, which precluded additional leases from being issued for these areas, including unleased areas identified off Oregon. The federal

[i] A 26 MW turbine was also installed in China in 2026 but it is on a fixed platform at a test facility.[2]

government also provided buyouts for existing lease holders in exchange for investing those funds in other types of energy projects, including natural gas and geothermal developments.[12] [13]

Recent Oregon Actions

Offshore wind energy development in Oregon has been the topic of several state-led reports and planning documents in recent years. In 2022, the Oregon Department of Energy published the *Floating Offshore Wind: Benefits & Challenges for Oregon* report as directed by House Bill 3375 (2021). The *Oregon Territorial Sea Plan*, last updated in 2023, outlines ocean management policies for offshore renewable energy development within state waters and in federal waters out to an ocean depth of 500 fathoms (about 3,000 ft). In 2026, the Oregon Department of Land Conservation and Development published the *Oregon Offshore Wind Energy Roadmap* to define standards to be considered in the processes related to offshore wind energy development and approval as directed by House Bill 4080 (2024).

Anticipated Costs

Projected costs for floating offshore wind are higher than other renewable energy development options. Costs depend on water depths where the development will occur, which can range from 80 to over 1,300 meters, and distance to shore, which ranges from 27 to over 200 kilometers. The 2024 *Annual Technology Baseline* projects a 2035 levelized cost of energy for floating offshore wind between $63 and $289 per megawatt-hour, reflecting the wide range of conditions for development.[14] The conditions off the southern Oregon coast align with some of the lowest *Annual Technology Baseline* cost estimates with projections of about $104 per MWh in 2035. Lazard's LCOE projects[ii] $105 to $167 per MWh for offshore wind.[15] These projected costs are higher than some other emerging technologies, such as enhanced geothermal, but lower than advanced nuclear, which Lazard's projects to be above $200 per MWh.

Challenges to Commercial Development

Even with the advantages offshore wind brings to the grid, costs will need to decrease before these facilities can compete in U.S. energy markets. Floating technologies have been demonstrated to work but are still being tested and improved. Existing developments demonstrate the viability of the technologies, but there is still a great deal of uncertainty in how or when offshore technologies and practices could be more standardized. Standardization is key to economies of scale that will bring costs down, including establishing robust supply chains and training workers to produce necessary materials and components.[16] In addition to supply chains, supporting infrastructure, like deep-water ports able to build, maintain, and transport the turbines to and from their sites, will need to be developed.[17] A skilled workforce, capable of installing and maintaining offshore facilities, will also need to be developed. These challenges drive higher costs for development, leading to an LCOE that

[ii] Lazard's does not differentiate between floating and fixed offshore wind installations, except to note a single fixed offshore wind facility in Virginia with a levelized cost of energy of $92 per MWh.

is much higher than most electricity generation resources being procured in the Pacific Northwest today. Technological, logistical, and policy barriers will need to be overcome before floating offshore wind is developed in Oregon.

There is also significant pushback from coastal communities who have voiced concerns about how floating offshore wind could affect their culture and way of life. This includes concerns about the environmental health of the ocean and access to ocean locales, which could affect existing fishing, seafood, tourism, and recreation industries. Prior to the Bureau of Ocean Energy Management recission of offshore wind lease areas off Oregon's coast, there was local and Tribal opposition, including a lawsuit from the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians.[16] CTCLUSI indicated they were concerned that insufficient study had been conducted on how a floating offshore wind facility would affect the marine environment in the Tribe's ancestral territory.[19] The Oregon Offshore Wind Energy Roadmap charts a path for future development that could help address these concerns and secure the interests of coastal communities if implemented.

Effects on Local Communities

Floating offshore wind development has the potential to bring significant economic development to coastal communities. One report found that developing an offshore wind staging area in Coos Bay would inject hundreds of millions of dollars into the local economy to develop a new wharf and facilities, as well as prepare the land and bay for turbine fabrication and transportation.[20] Communities near offshore wind developments would gain jobs needed to directly support offshore wind operations, and other supporting economies like hotels and restaurants. These in turn would indirectly support local shops and provide additional tax revenue for counties. The *Oregon Offshore Wind Roadmap* recommends that the state support a study that assesses the economic costs, benefits, and jobs that could be realized from Offshore Wind Development.[22]

The Oregon Department of Land Conservation and Development's *Oregon Offshore Wind Energy Roadmap* provides an **in-depth assessment of community perspectives** on the benefits, concerns, barriers, and opportunities associated with offshore wind resources.

One concern many Oregonians have is how floating offshore wind facilities will affect their communities. Floating offshore wind facilities will inevitably involve contact with the physical marine landscape, flora, and fauna. Questions arise about how this might affect ancestral Tribal waters and first foods, local fishing and tourism economies, and coastal community culture. The Offshore Wind Roadmap recommended that a cumulative impact assessment, accounting for all proposed wind development sites, could help local communities better understand development effects.[8] Information gathering and dissemination can be further bolstered by working with an Oregon-specific science group and by the state providing information and updates on actions and findings relevant to community effects from offshore wind development.[23]Additional information can help to build trust in local communities and support development of specific community benefits agreements as recommended in the Roadmap.[24]

Tethys: Studies on the Effects of Offshore Wind on Marine Life

Tethys, a marine energy resource organization maintained by the Pacific Northwest National Laboratory and sponsored by the U.S. Department of Energy, collects studies on potential effects of offshore wind facilities.[18] These resources include information about community benefit agreements, the effects of turbines on aquatic life and bird migrations, and many other studies that inform responsible offshore energy development.

Additional Resources

Floating offshore wind has been the topic of several in-depth studies in Oregon. For more information see the following reports:

- Floating Offshore Wind Study: Benefits & Challenges for Oregon (2022)
- Oregon Offshore Wind Energy Roadmap (2026)
- TETHYS Environmental Effects of Wind and Marine Renewable Energy

Resources

1. National Renewable Energy Laboratory. (2023, May 10). *Floating Offshore Wind Technology*. https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Musial-Floating-Wind-Technology.pdf.
2. offshoreWIND.biz. (2025, September 3). *Dongfang Installs 'World's Largest Single-Capacity' Offshore Wind Turbine for Testing*. https://offshorewind.biz/2025/09/03/dongfang-installs-worlds-largest-single-capacity-offshore-wind-turbine-for-testing.
3. National Renewable Energy Laboratory. (2023, May 10). *Floating Offshore Wind Technology*. https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Musial-Floating-Wind-Technology.pdf.
4. Jorgenson, J., Nguyen, C., Bredenkamp, S., Brinkman, G., Mai, T., Zuckerman, G., & Douville, T. (2026, June 25). Key Drivers for Offshore Wind Deployment in the Western United States. *Wind Energy*, *29*(8), e70137. https://doi.org/10.1002/we.70137.
5. Pacific Northwest National Laboratory. (n.d.). *West Coast Offshore Wind Transmission Study. Program*. Retrieved October 16, 2026, from https://www.pnnl.gov/projects/west-coast-offshore-wind-transmission-study.
6. Bureau of Ocean Energy Management. (n.d.). Potential Energy Impact of the Oregon Offshore Wind Energy Lease Sale. Retrieved June 10, 2026, from https://www.boem.gov/sites/default/files/images/oregon_energy_potential_energy_impact.jpg.
7. Bureau of Ocean Energy Management. (2025, July 30). *BOEM Rescinds Designated Wind Energy Areas on the Outer Continental Shelf | Bureau of Ocean Energy Management*. https://www.boem.gov/newsroom/notes-stakeholders/boem-rescinds-designated-wind-energy-areas-outer-continental-shelf.
8. Oregon Department & of Land Conservation and Development. (2026). *Oregon Offshore Wind Energy Roadmap* (p. 121). https://www.oregon.gov/lcd/OCMP/Documents/OR-OSW-Roadmap_FINAL.pdf.

9. RenewableUK. (2025, November 11). *Report shows 13% increase in floating offshore wind capacity worldwide*. https://www.renewableuk.com/news-and-resources/press-releases/report-shows-13-increase-in-floating-offshore-wind-capacity-worldwide/.

10. offshoreWIND.biz. (2026, May 6). China Three Gorges Installs 'World's Largest' Single-Unit Floating Wind Platform Offshore Yangjiang. *Business Development*. https://www.offshorewind.biz/2026/05/06/china-three-gorges-installs-worlds-largest-single-unit-floating-wind-platform-offshore-yangjiang/.

11. California Energy Commission. (n.d.). *On With the Wind: Toward 25 GW of Offshore Wind Energy by 2045*. Retrieved October 28, 2026 from https://www.energy.ca.gov/programs-and-topics/topics/renewable-energy/offshore-renewable-energy/wind-toward-25-gw-offshore.

12. Bureau of Ocean Energy Management. (n.d.). *Golden State Wind LLC (OCS-P 0564). Renewable Energy.* Retrieved July 8, 2026, from https://www.boem.gov/renewable-energy/state-activities/golden-state-wind-llc-ocs-p-0564.

13. Bureau of Ocean Energy Management. (2026, June 12). *Settlement Agreement Between the United States and Invenergy California Offshore LLC*. https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Invenergy%20CA%20Settlement%20Agreement.pdf?VersionId=JweIK.RBJKIZw6QSe_4Ur1W49u.75M_W.

14. National Laboratory of the Rockies. (n.d.). *Electricity Annual Technology Baseline Data Download. Annual Technology Baseline.* Retrieved September 24, 2026, from https://atb.nlr.gov/electricity/2025/data.

15. Lazard. (2026, July). *Lazard 2026 LCOE+ Levelized Cost of Energy*. https://www.lazard.com/media/kcfconhf/lazards-lcoeplus_vf.pdf.

16. Howland, N. (2023, April 27). Costs, supply chain issues plague floating offshore wind. *Energy Source & Distribution*. https://esdnews.com.au/costs-supply-chain-issues-plague-floating-offshore-wind-sector/.

17. International Renewable Energy Agency. (2024). *Floating Offshore Wind Outlook* (p. 42). https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Jul/IRENA_G7_Floating_offshore_wind_outlook_2024.pdf?rev=5677523af0114cde8eb19cb9221b4622.

18. National Renewable Energy Laboratory. (n.d.). Land-Based Wind - Class 4 - Technology 1 OPEX. Retrieved June 10, 2026, from https://public.tableau.com/views/2024Historical_OPEX/Dashboard1?:embed=y&:toolbar=no&Technology=LandbasedWind&:embed=y&:showVizHome=n&:bootstrapWhenNotified=y&:apiID=handler4.

19. Gaines, M. (2024, September 17). *Tribe Files Lawsuit to Stop BOEM's Wind Energy Lease Sale and Reqiure More Extensive Analysis of Wind Energy Impacts.* Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians. https://ctclusi.org/tribe-files-lawsuit-to-stop-boems-wind-energy-lease-sale-and-require-more-extensive-analysis-of-wind-energy-impacts/.

20. Oregon Department of Energy. (2022). 2022 Floating Offshore Wind: Benefits & Challenges for Oregon. (p. 26). https://www.oregon.gov/energy/data-and-reports/Documents/2022-Floating-Offshore-Wind-Report.pdf.

21. Foxwell, D. (2022, March 4). *Oregon port identified as potential floating wind hub*. Riviera. https://www.rivieramm.com/news-content-hub/news-content-hub/oregon-port-identified-as-potential-floating-wind-hub-70048.

22. Oregon Department of Land Conservation and Development. (2026, July). *Oregon Offshore Wind Energy Roadmap* (p. 131). https://www.oregon.gov/lcd/OCMP/Documents/OR-OSW-Roadmap_FINAL.pdf.

23. Oregon Department & of Land Conservation and Development. (2026, July). *Oregon Offshore Wind Energy Roadmap* (p. 122). https://www.oregon.gov/lcd/OCMP/Documents/OR-OSW-Roadmap_FINAL.pdf.

24. Oregon Department of Land Conservation and Development. (July, 2026). *Oregon Offshore Wind Energy Roadmap* (p. 147). https://www.oregon.gov/lcd/OCMP/Documents/OR-OSW-Roadmap_FINAL.pdf.

25. Tethys. (n.d.). *Wind Energy and the Environment.* Retrieved June 10, 2026, from https://tethys.pnnl.gov/wind-energy.

Emerging Technologies: Marine Hydrokinetic Energy

Technology Summary

Marine hydrokinetic energy technologies capture the energy from the motions of ocean waves, tides, and currents, and convert it into electricity. Water is about 800 times more dense than air, meaning marine hydrokinetic technologies can be much smaller than wind turbines while producing an equivalent amount of energy.[1] Several different technologies have demonstrated technical feasibility. A 20 MW tidal energy turbine facility in Nova Scotia, Canada, generated electricity for 37 years by harnessing some of the highest tides in the world.[2]

Types of Marine Hydrokinetic Energy

Tidal: Tidal energy systems capture kinetic energy in tides to generate electricity. Tidal energy facilities are site specific and require subsurface conditions that create tides that can be cycled through hydro turbines.

Ocean Current: Ocean current energy systems would use continuous ocean currents, such as the gulf stream, to spin turbines. No commercial ocean current energy facilities have ever been developed.

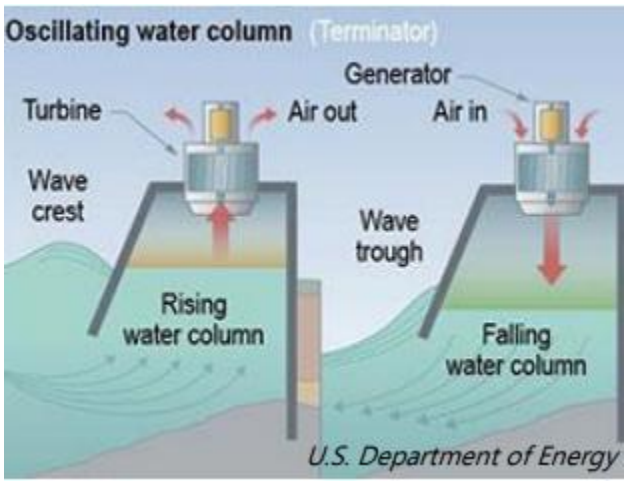
Wave: Wave energy systems capture kinetic energy in ocean waves to generate electricity. Wave energy converters are the most promising emerging technology for marine energy generation off the Oregon coast.

Some marine hydrokinetic technologies are better suited for certain environments than others. For example, most coastal regions don't experience the types of tides found in Nova Scotia, but that facility and other successful marine hydrokinetic projects provide valuable information about operations in harsh marine environments that could inform future technologies.

Marine hydrokinetic technologies can complement a diverse portfolio of renewable energy resources in Oregon to provide a consistent and predictable flow of renewable energy. Diversified resources will be important to Oregon and other west coast states in meeting grid decarbonization targets and maintaining grid reliability.[2] Like other renewable resources, development of marine energy projects has the potential to reduce Oregon's dependency on fossil fuels. Oregon is also a leader in wave energy research, including Oregon State University's O.H. Hinsdale Wave Research Laboratory in Corvallis and the PacWave Wave Energy Test Facility developed by OSU in partnership with U.S. DOE.

Wave energy converters are the most promising emerging technology for marine energy generation off the Oregon coast. There are different formats of wave energy converters, but all of them capture energy from the movement of waves in different ways that can subsequently spin a turbine. One example is the oscillating water column shown in Figure 1, which uses the rise and fall of waves to collect air and then push it through a turbine. Overtopping devices similarly use water captured from waves spilling over the top of the device to spin a turbine. Attenuators and wave surge converters use ocean movements to power a hydraulic motor that spins a turbine.[3]

Figure 1: Oscillating Water Column Wave Energy Devices. Images Courtesy of U.S. DOE and Tethys

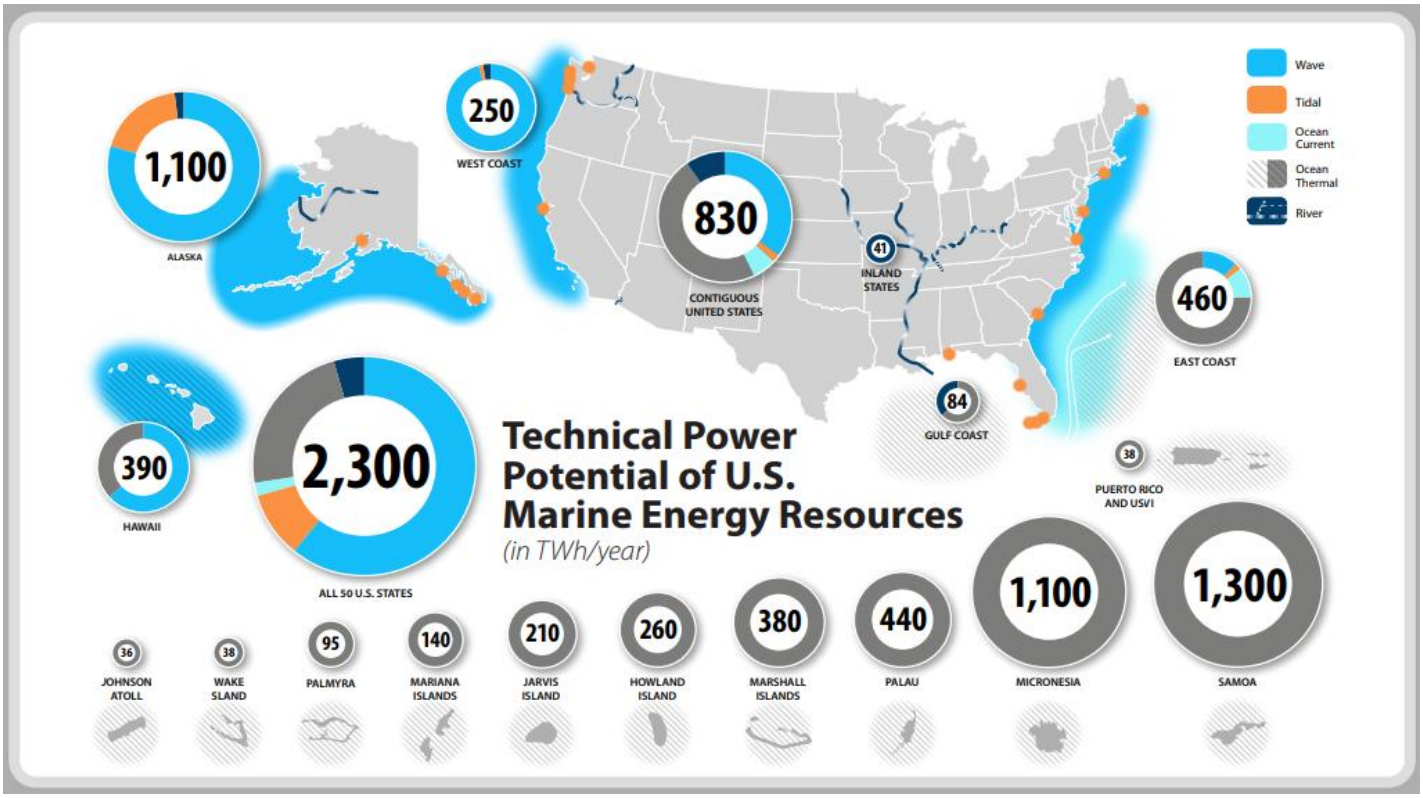




Resource Potential

Marine energy has the potential to contribute a significant share of carbon free electricity to the U.S. grid. A report by Pacific Northwest National Laboratory found that marine energy resources could account for more than 57 percent of all electricity generated in the country using a 2019 baseline.[5] A 2011 study determined that the total wave energy available on the Oregon coast is 143 million megawatt-hours per year – enough energy to power about 28 million homes.[6] A more recent study found 250 million megawatt-hours of annual potential along the whole west coast, and more than 2.3 billion megawatt-hours available nationally.[7]

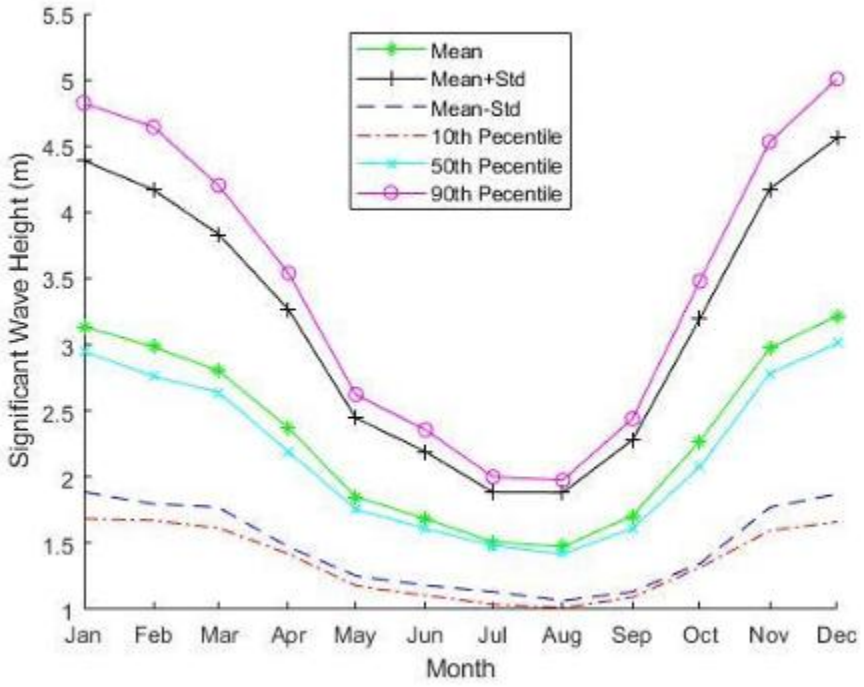
Figure 2: Marine Energy Potential in the U.S.[7]



Note: One terawatt hour (TWh) is equal to one million megawatt-hours (MWh).

In Oregon, wave energy would be ideally suited to complement increasing amounts of solar energy on the grid. Oregon's wave energy resources are strongest during the winter months when solar production is lowest. Data from the PacWave South test site off the coast of Newport demonstrates the winter peaking nature of wave energy in Oregon. Wave energy is also available at night when solar resources are shut down, regardless of season.

Figure 3: Wave Height by Month at the PacWave South Test Site[8]

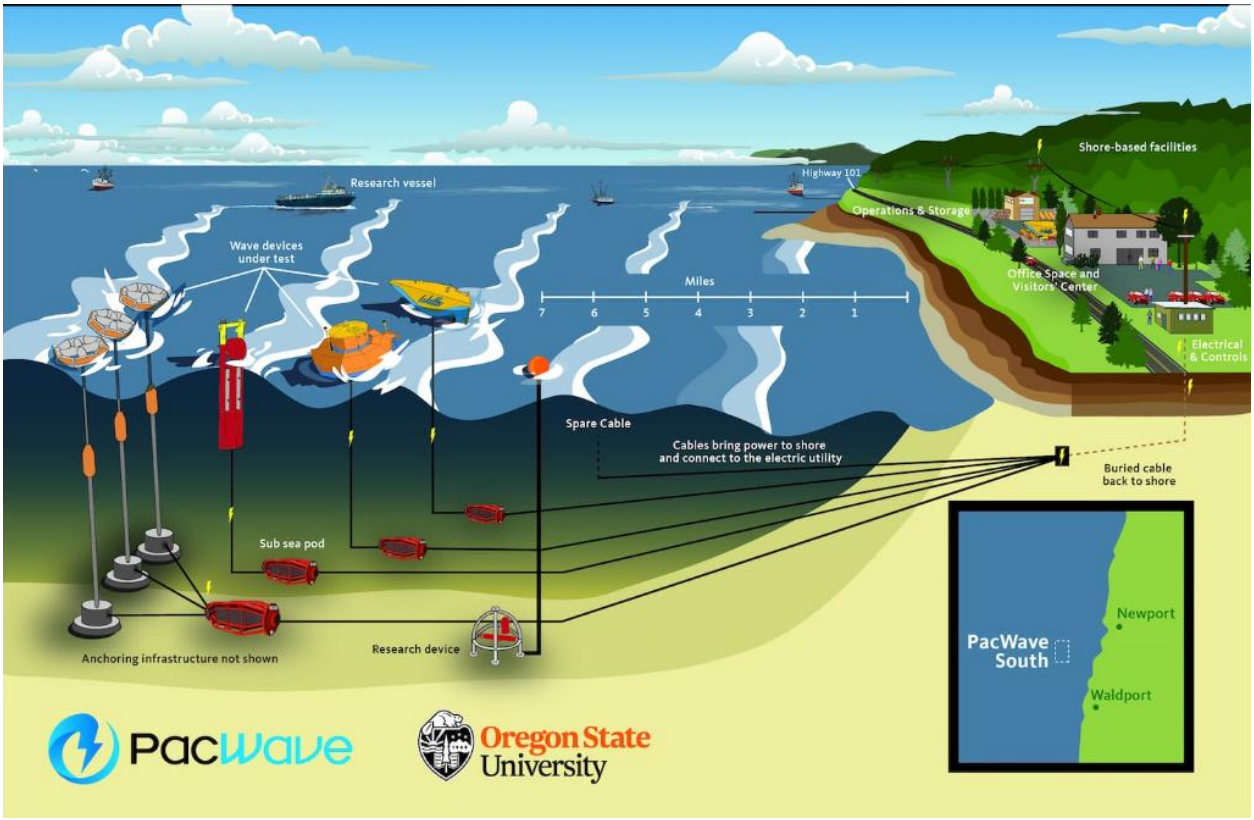


Recent Developments

Most of the recent developments in marine energy are from test sites evaluating wave energy technologies, including sites in Oregon waters. Oregon is a global leader in research and development of marine hydrokinetic energy technologies. Oregon State University, a member of the Pacific Marine Energy Center consortium of regional universities, serves as the research hub. This includes the marine energy initiatives centered around the PacWave test facilities, also supported by the U.S. Department of Energy. PacWave consists of two test areas off the central Oregon coast especially suited to testing emerging wave energy converters. PacWave North, located two miles off Newport, facilitates small-scale prototype testing. PacWave South — situated about seven miles offshore — offers four 5 MW-capable testing berths for up to 20 MW of total capacity.[7]

U.S. DOE's Water Power Technologies Office awarded roughly $25 million to fund research and demonstration projects at PacWave, backing companies like CalWave and Columbia Power Technologies to deploy diverse wave energy converter designs in open ocean conditions.[10]

Figure 3: PacWave South Site Configuration



PacWave is already capable of delivering energy to Oregon loads. Energy generated at the facility travels through an underwater transmission cable and connects to the grid in Newport. PacWave has an interconnection agreement with Central Lincoln People's Utility District and a power purchase agreement with Bonneville Power Administration.[11] Transmission, interconnection, and power purchase agreements are significant barriers to many emerging energy technologies. PacWave's efforts will provide valuable data and information and real-world experience that will be helpful for future marine energy projects as well as for offshore wind projects looking to interconnect with the grid.

Anticipated Costs

Marine energy devices are not included in the two cost indexes used for other technologies in the emerging technologies report. Those include the National Laboratory of the Rockies Annual Technology Baseline and the Lazard's Levelized Cost of Energy report. The scale of economic barriers for marine energy technologies is not yet known. At PacWave, costs and performance of wave energy converters will help to inform future cost estimates.

Challenges to Commercial Development

Marine hydrokinetic energy technologies face many technological, economic, and policy challenges before they become commercially viable. Like all ocean-based technologies, they must be able to operate in turbulent, corrosive ocean environments and be able to function in changing ocean currents and wave directions. Like floating offshore wind, wave energy technologies must be tethered to the sea floor, which will require working in deep water off the Oregon coast. Facilities like PacWave

are designed to test a variety of technologies that will be reviewed and improved over time. As the most promising technologies emerge, they will need to develop standardized designs and establish supply chains to lower costs sufficiently to compete with established renewable energy generation, like onshore wind and solar.

With so many potential technology pathways and options in marine hydrokinetic resources, continued funding for PacWave and other test sites is critical to advancements in wave energy converter technologies. Some sites, such as the 3 MW Sotenäs project in Sweden, have been decommissioned due to limited funding.[11]

Demonstration sites play an important role in understanding cost drivers, identifying failures, testing solutions for optimizations, and supporting more cost-effective technological innovations. Demonstration projects help tease out which technologies can most cost-effectively and reliably supply power to the grid and help lower costs.

Siting wave energy converters requires identifying locations that are best suited for development. Considerations include the frequency and power of the waves, seasonal variations, and hazards such as hurricane frequency and energy security. GIS resources and analysis at the National Laboratory of the Rockies is helping to optimize marine energy site selection.[14] On-shore resources also affect marine energy site selection. Access to workforce, seaports, and transmission may be especially challenging for marine energy resources that require specialized training and equipment. The U.S. DOE, in partnership with organizations like the Pacific Marine Energy Center, are collaborating to identify and address these and other barriers to deployment.[13]

Effects on Local Communities

Wave energy development is already bringing some economic benefits to Oregon coastal communities. Newport's deepwater harbor serves as the launching ground for PacWave research and testing initiatives, bringing some jobs and investment to that area. Expanding these facilities would bring more jobs to build, operate, and maintain the facilities. In turn, these jobs and revenues would feed into the local economy and bolster tax revenues.

Offshore renewable energy development in Oregon state waters is guided by the Oregon Territorial Sea Plan (TSP). Oregon's territorial sea is a strip of ocean under state jurisdiction that reaches from the shoreline to 3 nautical miles out to sea. The PacWave North test site falls within state territorial waters and represents a state permitting process guided by the TSP. PacWave South is further off the Oregon coast, but transmission and communications cables still pass through state waters to reach shore and are therefore governed by the TSP. Tribes and coastal communities in Oregon have expressed concerns about the effects of offshore energy development on existing economies, including fishing and tourism.

Energy Justice Framework for Marine Energy

Part of the planning and construction process for the PacWave facilities included development of an Energy Justice Framework for Marine Energy developed by Pacific Northwest National Labs in partnership with local Tribes, fishing industry, environmental organizations and community members.[17] This framework focuses on three tenets of Environmental Justice including:

1. Distributional Justice: concerning the fair distribution of benefits and costs
2. Procedural Justice: ensuring inclusive decision-making and equitable engagement
3. Recognition Justice: addressing the recognition and incorporation of diverse values, needs, and perspectives.

Marine energy facilities will inevitably involve contact with the marine landscape, flora, and fauna. Communities have expressed concerns about underwater noise created by these facilities, or changes in the sea floor from moorings or foundations that could displace wildlife and natural habitats. These changes could disrupt local industries and traditional fishing zones for local Tribes. There are also concerns about sea mammals colliding with equipment or becoming entangled in lines.[14] Continuing to work with Tribes and local communities is essential to understanding and addressing these concerns, and to finding ways to develop hydrokinetic wave facilities responsibly.

Additional Resources

- Department of Land Conservation and Development: Oregon Territorial Sea Plan
- Pacific Northwest Laboratories: TETHYS Environmental Effects of Wind and Marine Renewable Energy

Resources

1. Sustainability Directory. (2026, January 12). How Does the Power Density of Water Compare to That of Air, and What Are the Implications for Turbine Size in Tidal Stream versus Wind Energy? *Learn.* https://energy.sustainability-directory.com/learn/how-does-the-power-density-of-water-compare-to-that-of-air-and-what-are-the-implications-for-turbine-size-in-tidal-stream-versus-wind-energy/.

2. Garanovic, A. (2021, February 25). North America's oldest tidal power plant set for closing. Offshore Energy. https://www.offshore-energy.biz/north-americas-oldest-tidal-power-plant-set-for-closing/.

3. Pacific Northwest National Laboratory. (2021). Grid Value Proposition of Marine Energy: A Preliminary Analysis (p. 1). https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-31123.pdf.

4. U.S. Department of Energy. (n.d.). *Marine Energy Glossary. Marine Energy Basics, Marine Energy Program.* Hydropower and Hydrokinetic Office. Retrieved October 28, 2026 from https://www.energy.gov/cmei/water/marine-energy-glossary.

5. Pacific Northwest National Laboratory. (2021). Grid Value Proposition of Marine Energy: A Preliminary Analysis (p. ii). https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-31123.pdf.

6. Hagerman, G., Scott, G., Jacobson, P. (2011, November 30). *Mapping and Assessment of the United States Ocean Wave Energy Resource. Knowledge Base*. Tethys Engineering. https://tethys-engineering.pnnl.gov/publications/mapping-assessment-united-states-ocean-wave-energy-resource.

7. Kilcher, L., Fogarty, M., & Lawson, M. (2021, February 1). Marine Energy in the United States: An Overview of Opportunities (NREL/TP--5700-78773, 1766861, MainId:32690; p. NREL/TP--5700-78773, 1766861, MainId:32690). https://doi.org/10.2172/1766861.

8. Robertson, B., Dunkle, G., García-Medina, G., & Yang, Z. (2020). Pac Wave Resource Assessment (p. 10). https://ir.library.oregonstate.edu/concern/parent/hm50tz68v/file_sets/fx719v16s.

9. U.S. Department of Energy. (n.d.). PacWave: Offshore Wave Energy Test Site. Retrieved June 4, 2026 from https://www.energy.gov/cmei/water/pacwave-offshore-wave-energy-test-site.

10. U.S. Department of Energy. (2022, January 25). Water Power Technologies Office Awards $25M for Open-Water R&D at PacWave. *Hydropower & Hydrokinetic Office*. https://www.energy.gov/cmei/water/articles/water-power-technologies-office-awards-25m-open-water-rd-pacwave.

11. CalWave. (2025, November 19). PacWave signs power purchase agreement with Bonneville Power Administration. https://calwave.energy/pacwave-signs-power-purchase-agreement-with-bonneville-power-administration/.

12. Bonneville Power Administration. (2025, August 22). PacWave Power Purchase Agreement. https://www.bpa.gov/-/media/Aep/environmental-initiatives/categorical-exclusions/cx-2025/20250822-pacwave-power-purchase-agreement.pdf.

13. Tethys. (n.d.). *Sotenäs Project. OES-Environmental Metadata.* Retrieved June 8, 2026, from https://tethys.pnnl.gov/project-sites/sotenas-project.

14. Hall, S., Peterson, K., Gjestvang, K, McGilton, B. (2024, August). GIS supported optimal site selection for coastal structure integrated wave energy converters. https://docs.nlr.gov/docs/fy24osti/90299.pdf.

15. U.S. Department of Energy. (n.d.). *Marine Energy Program. Hydropower & Hydrokinetic Office*. Retrieved June 4, 2026 from https://www.energy.gov/cmei/water/marine-energy-program.

16. Department of Land Conservation and Development. (n.d.). Territorial Sea Plan: Oregon Coastal Management Program. Retrieved June 18, 2026, from https://www.oregon.gov/LCD/OCMP/Pages/Territorial-Sea-Plan.aspx.

17. Pacific Northwest National Laboratory. (2024, July 26). Energy Justice Framework for Marine Energy: Considerations from PacWave. https://www.pnnl.gov/publications/energy-justice-framework-marine-energy-considerations-pacwave.