

Just about everything involves energy. It’s part of our daily lives – from driving our cars and heating our homes to turning on our computers and firing up the grill after a long day.

This section builds the foundation of the energy story: how energy is produced, used, and transformed. These Energy 101s were developed for people new to energy or specific energy topics, along with those looking for a resource to help tell the story of how energy systems affect their work and interests. Energy policy is complex and, without being armed with technical information and understanding, it is sometimes difficult to be part of the conversations.

101s this year touch on a variety of topics. We look at important emerging topics like the clean hydrogen economy, the state of “agrivoltaics,” and what’s driving electricity rates. We also look at the effects climate change has on our energy systems, and provide the basics on electricity day-ahead markets, the nexus of energy and water, what “waste” energy means and how waste can be reduced, and more.

Energy is intertwined in everything that Oregonians do – from powering vehicles to support our livelihoods and economy, to electricity and fuels that serve as the backbone for industry and businesses. Everyone should have the opportunity to engage in energy choices, whether its options to reduce energy use and costs for homes, businesses, and industry or how we meet the challenge of transitioning our energy systems to cleaner, more renewable resources. We hope these 101s continue to build foundational knowledge so readers can make informed choices about the energy resources, uses, and investments that can change our work, lives, and communities.

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Advancements in a Clean Hydrogen Economy

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



Defining Clean Hydrogen

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

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

Per HB 2530, renewable hydrogen means hydrogen produced using:

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

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

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

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

Hydrogen Use and Potential

Hydrogen has been used in industrial applications in the United States for many decades, including in crude oil refining, fertilizer, steel and chemical production, and food processing. But hydrogen has far broader applicability, and because it can be produced and used with little or no carbon emissions, there is growing excitement around its potential to help address the climate crisis. Clean hydrogen and hydrogen-derived fuelsⁱⁱⁱ can be used as fossil

alternatives in heavy-duty transportation, including shipping, aviation, long-distance freight, and transit buses. It can be a key low-carbon input for steel, cement, and chemical production, as well as other high-heat industrial processes. It can provide clean back-up power for data centers, hospitals, and other critical infrastructure through stationary fuel cells. It can even increase grid reliability and flexibility, supporting the expansion of intermittent renewables by serving as long-duration energy storage and quickly ramping up or down when needed.^{iv}

Interest in clean hydrogen is growing rapidly in the United States and abroad due to this potential to serve as a replacement for fossil fuels and help entities reach goals for deep decarbonization.

Governments and project developers around the world are investing in hydrogen and hydrogen technologies at a feverish pace. As of January 2023, more than 1,000 large-scale (> 1 MW) hydrogen projects had been announced globally, representing \$320 billion in direct investments through 2030.⁵ Further, companies have announced plans for 38 million tons of clean hydrogen production by 2030 – a significant ramp up from the less than one million tons of clean hydrogen produced today.⁶ As the clean hydrogen economy develops in the U.S., it has the potential to create jobs and revenue for U.S. businesses. A 2020 report by McKinsey estimated that, with ambitious federal regulation and policies requiring emissions reduction across industries, by 2030, the U.S. hydrogen economy could generate an estimated \$140 billion per year in revenue and support 700,000 total jobs; by 2050, these numbers jump to \$750 billion per year in revenue and a cumulative 3.4 million jobs.⁷

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



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

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

^{iv} For more background information on hydrogen and its characteristics as an energy carrier and feedstock, see the Oregon Department of Energy’s [Renewable Hydrogen Report](#) and its [2022 Biennial Energy Report](#).

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

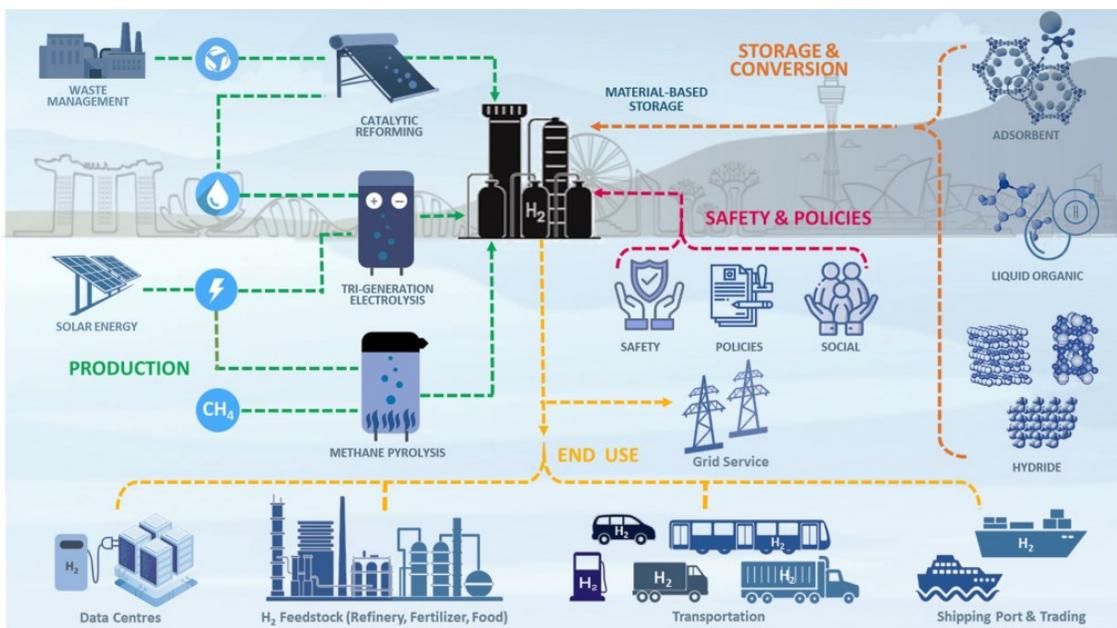
Role of Federal Investments in Building a Clean Hydrogen Economy

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

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

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

Figure 1: The Hydrogen Value Chain¹³

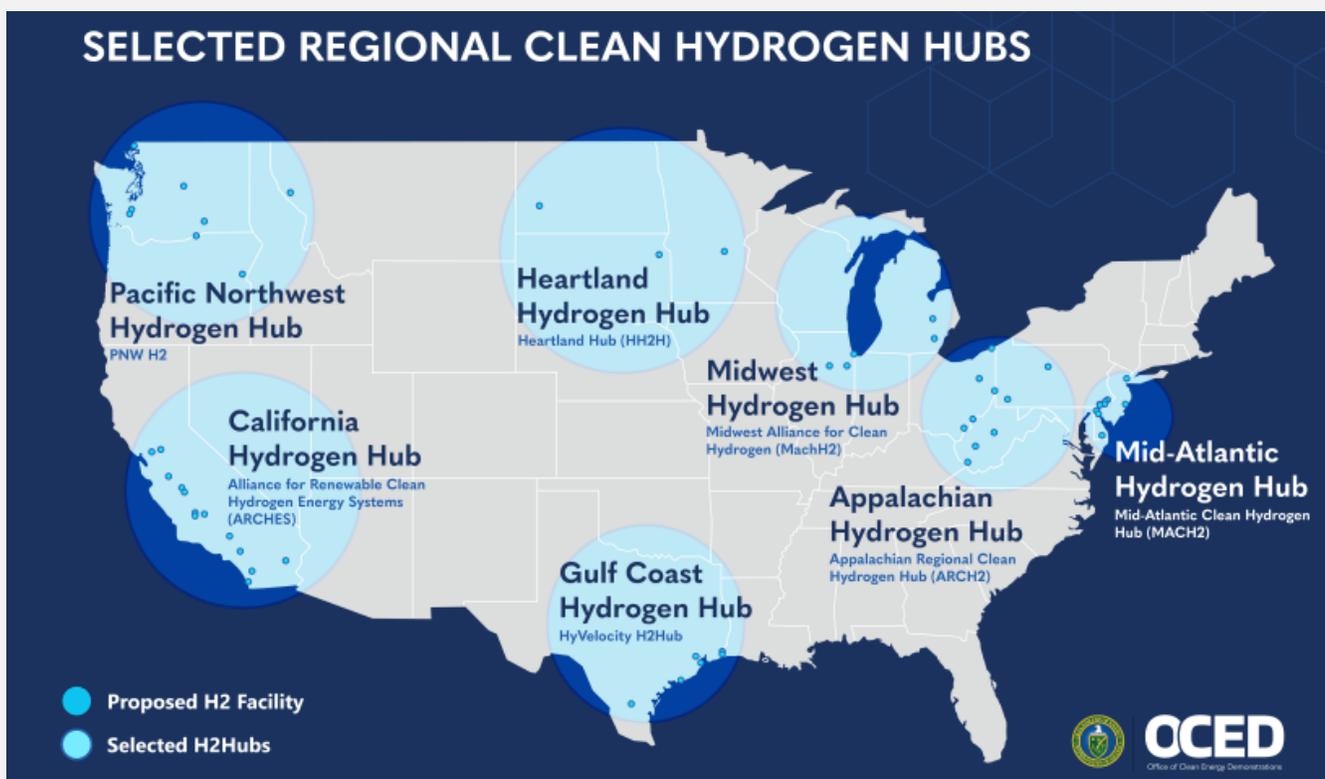


After a competitive application process, in October 2023 the U.S. Department of Energy announced \$7 billion in awards to seven H2Hubs across the nation, including one in the Pacific Northwest.^v This \$7 billion in public funding will be matched by recipients to leverage nearly \$50 billion in investments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

Regional Hydrogen Hubs

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

Figure 2: Map of Regional Clean Hydrogen Hubs¹⁶



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

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

Table 1: U.S. DOE’s Seven Regional Hydrogen Hubs¹⁷

Hydrogen Hub	States	Feedstocks	Connecting Infrastructure	End Uses
Appalachian (ARCH2)	<ul style="list-style-type: none"> • Ohio • Pennsylvania • West Virginia 	<ul style="list-style-type: none"> • Natural gas with carbon capture 	<ul style="list-style-type: none"> • Pipelines • Refueling 	<ul style="list-style-type: none"> • Industry • Transportation (heavy-duty trucking)
California (ARCHES)	<ul style="list-style-type: none"> • California 	<ul style="list-style-type: none"> • Biomass • Renewables 	<ul style="list-style-type: none"> • Freight line 	<ul style="list-style-type: none"> • Power generation • Transportation (heavy-duty trucking, port operations, public transit)
Gulf Coast (HyVelocity H2Hub)	<ul style="list-style-type: none"> • Texas 	<ul style="list-style-type: none"> • Natural gas with carbon capture • Renewables 	<ul style="list-style-type: none"> • Pipelines • Refueling • Salt cavern storage 	<ul style="list-style-type: none"> • Industry (ammonia, refineries, petrochemicals) • Power generation • Transportation (heavy-duty trucking, marine fuel)
Heartland (HH2H)	<ul style="list-style-type: none"> • Minnesota • North Dakota • South Dakota 	<ul style="list-style-type: none"> • Biomass • Nuclear • Renewables 	<ul style="list-style-type: none"> • Open access storage • Pipelines 	<ul style="list-style-type: none"> • Heating • Industry (agricultural fertilizer production) • Power generation
Mid-Atlantic (MACH2)	<ul style="list-style-type: none"> • Delaware • New Jersey • Pennsylvania 	<ul style="list-style-type: none"> • Nuclear • Renewables 	<ul style="list-style-type: none"> • Bus mechanic depots • Pipelines • Refueling 	<ul style="list-style-type: none"> • Heating • Transportation (aviation, heavy-duty trucking, refuse/sweeper trucks) • Power generation
Midwest (MachH2)	<ul style="list-style-type: none"> • Illinois • Indiana • Michigan 	<ul style="list-style-type: none"> • Natural gas with carbon capture • Nuclear • Renewables 	<ul style="list-style-type: none"> • Refueling 	<ul style="list-style-type: none"> • Industry (refining, steel, glass production) • Power generation • Transportation (heavy-duty trucking, sustainable aviation fuel)
Pacific Northwest (PNWH2)	<ul style="list-style-type: none"> • Washington • Oregon • Montana 	<ul style="list-style-type: none"> • Renewables 	<ul style="list-style-type: none"> • Freight line 	<ul style="list-style-type: none"> • Industry (agriculture, refineries, data centers) • Power generation (peaker plants, generators) • Transportation (heavy-duty trucking, port operations)

The 45V Clean Hydrogen Tax Credit

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

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

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

Well-to-Gate Emissions (kg CO ₂ e / kg H ₂)	ITC Percentage	PTC Value (\$/kgH ₂)
0 – 0.45	30 percent	\$3.00
0.45 – 1.5	10 percent	\$1.00
1.5 – 2.5	7.5 percent	\$0.75
2.5 – 4	6 percent	\$0.60

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

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

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

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

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

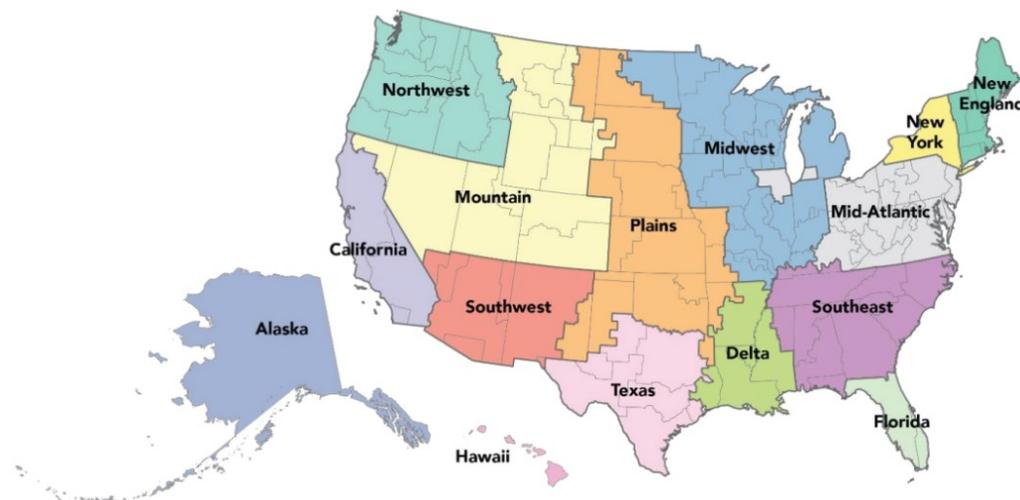
The Debate Over the Three Pillars of the 45V Clean Hydrogen Tax Credit

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

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

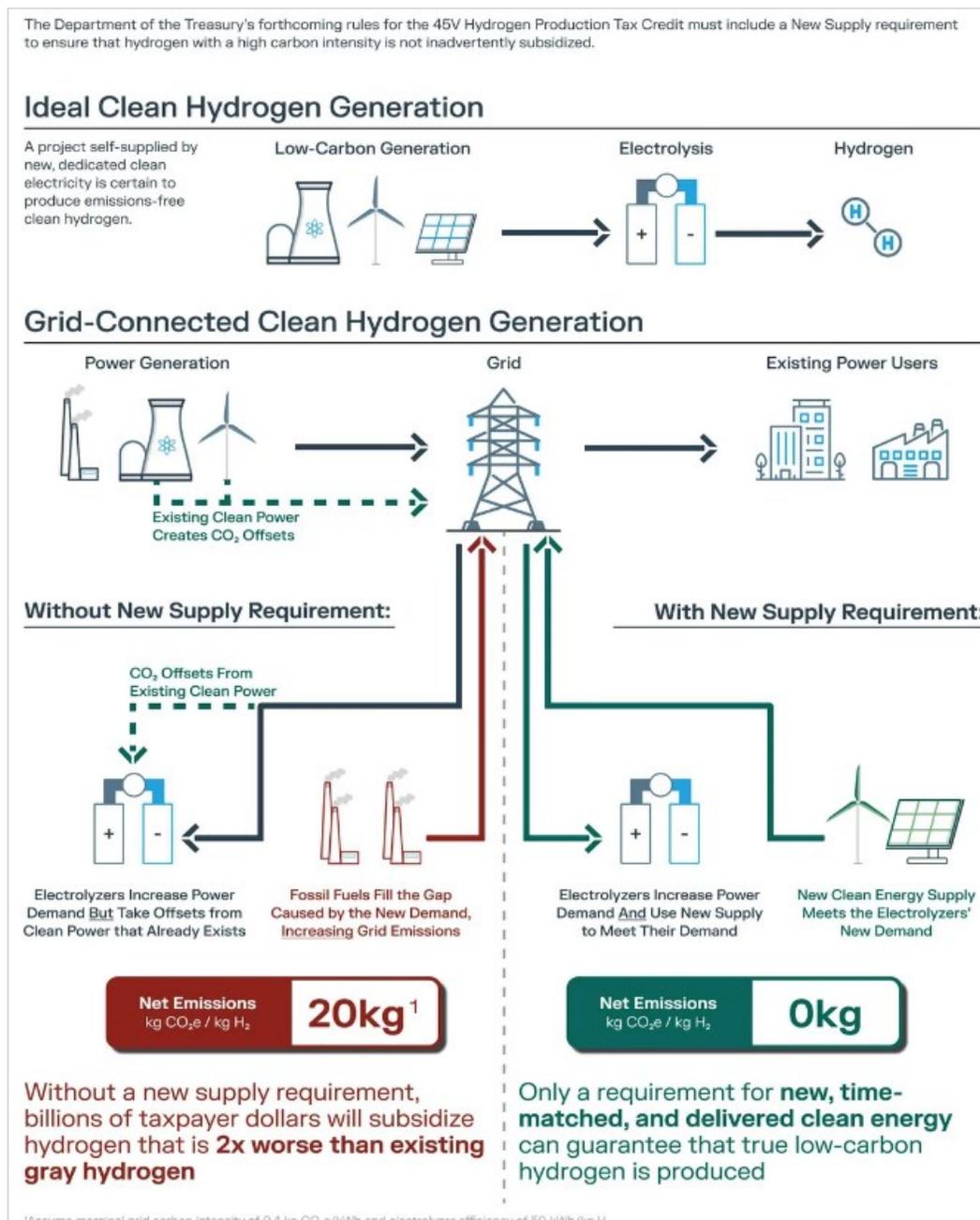
- 1) **Incrementality**, also known as additionality, requires EACs to come from new clean power generation placed in service within 36 months of the associated hydrogen facility.
- 2) **Temporal Matching**, also known as hourly matching, requires electricity represented in the EAC be generated in the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

Figure 3: Geographic Regions for Demonstrating Deliverability in 45V Proposed Regulations²⁵



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

Figure 4: Impact on GHG Emissions without a 45V Supply/Incrementality Requirement²⁹

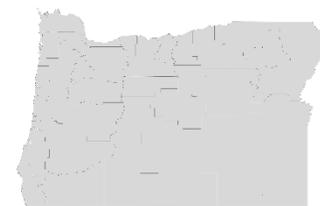


On the other hand, opponents of the “three pillars” argue that such regulations will hamper the electrolytic hydrogen industry in the U.S. These voices insist that looser rules are needed to launch the clean hydrogen sector and that requiring additional, deliverable, and hourly matched clean energy to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

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

Opportunities for Clean Hydrogen in Oregon

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



Oregon’s Supportive Regulatory Landscape

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

- Through the Oregon Department of Environmental Quality’s Advanced Clean Cars II³² and Advanced Clean Trucks³³ rules, the state will see increasing percentages of zero-emission vehicles for sale in the light-, medium-, and heavy-duty sectors.^{vii} Hydrogen fuel cell electric vehicles are an attractive zero-emission alternative to internal combustion vehicles, particularly in the heavy-duty transportation sector where battery electrification may be more difficult.^{viii}
- Oregon DEQ’s Climate Protection Program^{ix} set a declining limit on greenhouse gas emissions for fossil fuels used throughout Oregon, including diesel, gasoline, natural gas, and propane used in transportation, residential, commercial, and industrial settings, requiring a 50 percent reduction by 2035 and a 90 percent reduction by 2050.³⁴ The program also regulated site-specific GHG emissions at manufacturing facilities. Clean hydrogen and hydrogen-derived fuels such as Fischer-Tropsch liquid fuels or ammonia could play a role in CPP compliance, particularly for sectors that are difficult to electrify, such as high-heat industrial processes and heavy-duty trucks or ships.

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

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

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

- Oregon DEQ's Clean Fuels Program, Oregon's low-carbon fuel standard, establishes annual standards for carbon intensity of transportation fuels that decrease over time through 2035.³⁵ The program requires the switch to lower carbon fuels through a market-driven credit and deficit system, whereby low-carbon fuel providers generate credits that can be sold to high-carbon fuel providers, who need them for compliance with the program. The CFP encourages fuel suppliers to source and supply the lowest carbon fuels to customers in Oregon. In the case of hydrogen, the owner of a hydrogen fueling station for vehicles or the owner of a fleet of hydrogen forklifts can generate credits through the CFP, helping to offset the cost of investing in these technologies and complying with other climate policies.
- Oregon's 100% Clean Electricity Standard (HB 2021) and its Renewable Portfolio Standard ensure more renewables will be added to the electric grid in coming years. HB 2021 requires the state's two largest investor-owned utilities and retail electricity service suppliers to reduce the GHG emissions associated with the electricity sold to Oregon consumers by 100 percent below baseline emissions levels by 2040.³⁶ The RPS requires electric utilities to meet an increasing portion of their in-state retail electricity sales with qualifying renewable energy.

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

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

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

Figure 5: Potential Project Locations for the PNWH2 Hub⁴⁰



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

Table 3: PNWH2 Hub Projects in Oregon⁴⁰

Node	Location	Project Lead	Details
3	Port of Morrow	Air Liquide	<ul style="list-style-type: none"> • H₂ liquefaction to bring H₂ to market. • Anchor end uses: heavy duty transportation along I-5, I-90 and I-84; port decarbonization through drayage and cargo handling equipment.
5	Durkee	Express Ranch Hydrogen	<ul style="list-style-type: none"> • Includes dedicated pipelines, above ground storage, and a H₂ refueling station. • Anchor end uses: mining and other heavy-duty trucks. • Byproduct O₂ to be used for cement production.
6	Boardman	MHI Hydrogen Infrastructure	<ul style="list-style-type: none"> • Redevelopment of a decommissioned coal power plant to produce power with clean hydrogen. • Demonstration of clean hydrogen used for long-duration energy storage. • H₂ pipeline built along existing pipeline right-of-way. • Anchor end uses: Dispatchable 100 percent H₂ turbines; providing H₂ to node 3.

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

Challenges to Achieving a Clean Hydrogen Economy

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

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

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

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

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

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

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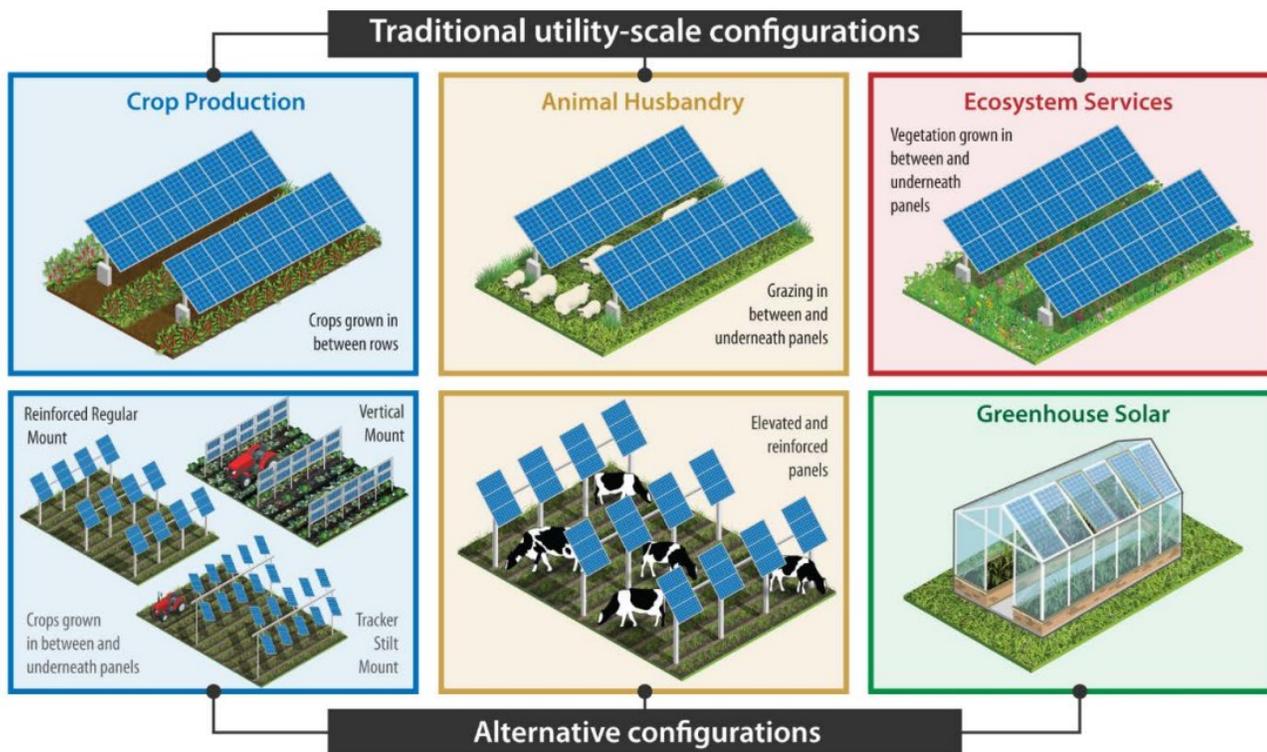
Agrivoltaics in Oregon

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



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

Figure 1: Agrivoltaics Configurations and Mounting Systems for Dual Use³



While the concept originated in the 1980s, interest and activity around agrivoltaics have accelerated recently in several countries, including Japan, China, South Korea, France, Italy, Germany, and the U.S.,¹ largely driven by concerns about conversion of farmland to meet future renewable energy demands. In its “Solar Futures Study,” the U.S. Department of Energy predicted that achieving

decarbonization of the electric sector by 2050 will require 10.4 million acres of land for solar energy generation, representing approximately 0.5 percent of U.S. land area.^{2 4} For context, Yellowstone National Park encompasses 2.2 million acres, about one-fifth of the area U.S. DOE predicts would be needed to meet future needs for solar generation.⁵

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

Preserving Farmland While Increasing Solar Generation

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



“Smart Solar” development meets the following criteria:

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

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

Farmland is attractive for solar development for many reasons. Researchers comparing land with different types of vegetation found that croplands have the highest solar photovoltaic power potential, with grasslands coming in a close second. As explained by the study, “Solar panels are most productive with plentiful insolation, light winds, moderate temperatures and low humidity. These are the same conditions that are best for agricultural crops.”⁹ When comparing farmland to other

categories of land that have been altered from its natural state and could host solar arrays, such as brownfields or former quarries,³ high-quality farmland is often more attractive to solar developers “because it is flat, sunny, cleared and near energy infrastructure.”^{9 10}

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

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

Current State of Research and Implementation

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

Figure 2: Map of Agrivoltaics in the United States¹³



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

Researchers in the U.S. and elsewhere are actively exploring methods to combine solar generation with raising crops, methods that are site-specific to take into account differences in soils, climates, water availability, market demands, and other factors.^{13 2} The “Innovative Solar Practices Integrated with Rural Economies and Ecosystems” or InSPIRE program is the most comprehensive and coordinated agrivoltaics research program in the U.S. InSPIRE, which is led by the National Renewable Energy Laboratory and funded by the U.S. Department of Energy, has awarded grants for agrivoltaics research at 28 sites in 11 states plus Puerto Rico and Washington, D.C. since 2015.²⁰ In summarizing findings from its first two rounds of funding, the InSPIRE program enumerated five central elements that contribute to successful agrivoltaics projects, what it calls the “5 Cs of Agrivoltaics”:³

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

Two additional federal programs have announced awards for agrivoltaics research to move agrivoltaics closer to commercialization at utility scale, building upon early lessons under InSPIRE and other basic agrivoltaics research. The “Foundational Agrivoltaic Research for Megawatt Scale,” or FARMS program under the U.S. Department of Energy, aims to reduce barriers to the adoption of agrivoltaics at utility scale, including studying how agrivoltaics could be integrated into existing solar installations and partnering with university extension projects to educate farmers about agrivoltaics.²¹

²² Meanwhile, the U.S. Department of Agriculture has recently announced the “Sustainably Co-

locating Agricultural Photovoltaic Electricity Systems” or SCAPES project headed up by the University of Illinois and focusing on commodity row-crop farming with research sites in Illinois, Arizona, and Colorado.²³ Additionally, the U.S. Department of Energy has announced its \$8.2 million “Large Animal and Solar System Operations” or LASSO prize challenge to encourage pilot and demonstration projects combining cattle grazing and solar energy development.²⁴

In the Pacific Northwest, crops that researchers have found to be successful as part of agrivoltaics systems include vegetables^{25 26} and vegetable seed,²⁷ herbs and leafy greens,^{28 29} and pasture grasses.^{12 29} Dry farming researchers at Oregon State University have found success growing potatoes interspersed with solar panels while also seeing potential for reducing blossom end rot in tomatoes grown in dry farming systems that incorporate agrivoltaics, but express doubt that some sun-loving crops such as melons or squash would fare as well with agrivoltaics in the Pacific Northwest.^{30 3} Other U.S. growing regions have had notable successes with various local crops, for example: tomatoes and peppers in the hot and arid southwest and California’s Central Valley,^{26 31} tea and leafy greens in Hawaii,²⁸ blueberries in Maine,³² and cranberries in Massachusetts.³³ As mentioned above, researchers are also exploring conditions under which commodity row crops like corn^{34 2} and potatoes²⁹ can thrive as part of agrivoltaics installations.

Oregon Agrivoltaics: “Farmer First, Solar Second”

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

Additionally, changing energy demands and Oregon’s goals to transition to clean electricity offer opportunities to farmers and ranchers. Integrating solar arrays with agricultural production is one advancement that researchers at Oregon State University are exploring. However, Oregon’s most

productive farmlands are rich with nutrients from centuries of glacial and volcanic activity, so the suggestion of converting any of this productive farmland to other, non-agricultural uses sparks big questions for local farmers and ranchers. This is where agrivoltaics comes into focus, and where researchers and farmers are finding mutual benefits by adding solar to agricultural production.

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



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

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

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

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

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

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



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

State-level Investments in Agrivoltaics

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

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

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

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

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

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

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

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



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

Agrivoltaics in Oregon

Potential Benefits

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

- Irrigation water savings.** Partial shading by solar panels cools soil and plants, reducing moisture losses from both water evaporation from the soil and transpiration¹ occurring when plants take up water from the soil and release water vapor from their leaves.³⁵ Partial shading lowers the rate at which plants use water for transpiration and lessens the need for irrigation.⁹ ³⁶ For more information on the connections between water use and energy, see the Energy 101 section of this report.
- Beneficial shade for crops and livestock.** Partial shade from solar panels can relieve heat stress for crops, including forage and livestock.² ³⁷ Research studies have found increased yields and/or nutritional quality for several crops when grown as part of an agrivoltaics installation. For example, an Oregon State University study found higher yields for pasture grasses in the shade of solar panels while researchers from the University of Arizona found that crops including basil, tomatoes, and celery had higher yields when grown in an agrivoltaics system.³⁸ ³⁹ ³⁵
- Creation of microclimates.** In addition to reducing temperatures during the day, solar panels may raise temperatures in the evening for crops growing under them, creating microclimates that provide frost protection and potentially extend the growing season.¹¹ ⁴⁰ Solar panels can also protect crops from heavy rains and hail.⁴⁰ Conversely, growing crops or pasture grasses under solar panels — rather than bare ground or gravel as has been industry practice until recently — cools the panels, which can boost energy production.⁴¹
- Energy generation, economic benefits, and resilience for rural farms and communities.** Farmers and ranchers may install agrivoltaics as part of a microgrid system, powering their on-site electrical equipment and even battery storage systems. Generating and possibly storing energy on-site would make farmers more resilient to power outages. Farmers may also sell the energy they generate to a local utility or rent their land to a solar developer. Installing agrivoltaics may also create jobs in rural communities and provide useful renewable energy generation, including for electric vehicle charging.⁴² ⁷ ⁴³ Researchers also cite the potential for agrivoltaics to assist farmers with precision agriculture and automation, providing mounting structures and power for sensors and field robots.⁴³ ⁴⁴
- Income to support farm operations.** Farmers and ranchers may be able to boost their incomes by selling electricity generated on the farm or by receiving payments from solar developers, adding a second income stream from their land.² Many farm operators rely upon off-farm employment to supplement their farm income, while receipts from farming fluctuate with weather and market prices, making a steady income from renting their land for solar development highly desirable.¹⁴ Given that the average age of Oregon farmers is 60 years, and that according to the Oregon Agricultural Trust, 81 percent of Oregon farmers do not have a

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

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

Potential Challenges

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

Land Use Law

Oregon land use law treats the siting of agrivoltaics projects that would generate electricity for public sale in the same manner as the siting of solar photovoltaic generating facilities that do not incorporate agrivoltaics practices. Existing administrative laws governing the siting of solar photovoltaic generating facilities on agricultural land do not disallow or discourage agrivoltaics, but

also do not provide an incentive for incorporating agrivoltaics.⁵⁰ Sheep grazing is becoming an industry standard method for vegetation management in utility-scale solar developments; in one recent instance, a solar developer in Oregon has amended their Wildfire and Weed Mitigation Plans to incorporate sheep grazing.^{51 52}

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

County Jurisdiction

The Oregon Land Conservation and Development Commission has adopted administrative rules specifying the conditions under which landowners may develop “photovoltaic solar power generation facilities,” including agrivoltaics projects, on EFU-zoned land. For smaller projects that fall under county jurisdiction, counties may permit the development of solar arrays covering up to 12 acres on high-value farmland and up to 20 acres on arable land including as part of an agrivoltaics installation on EFU land as a conditional use without an exception to Goal 3.⁴⁸ The Land Conservation and Development Commission adopted rules in May 2019 that allowed dual-use solar and agricultural projects up to 20 acres on high-value farmland; this rule change included a sunset provision repealing the increased threshold on January 1, 2022.⁵⁴

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

Energy Facility Siting Council Jurisdiction

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

Conclusion

Recent research and early commercial projects have demonstrated that agrivoltaics has potential as a path to increase solar energy generation while preserving agricultural production at the individual plot or field level. Future research into crop varieties and installation configurations along with development in solar technologies promises to improve upon initial successes. However, policymakers and utility leaders will need to address broader questions about how electricity generation from

agrivoltaics fits into future decarbonization plans for the state’s energy system, and to coordinate public policies and energy system-level planning and investment to harvest the potential value of agrivoltaics to the energy system.

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Climate Change Effects on the Energy System

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

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

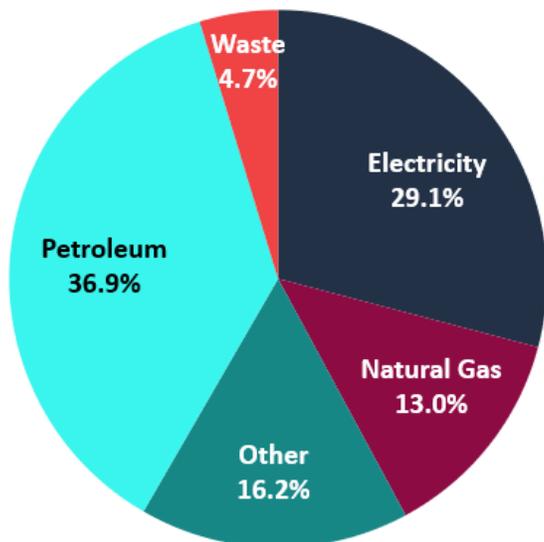
Table 1: 2019-2024 Oregon Emergency Declarations

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

*January-June 2024.

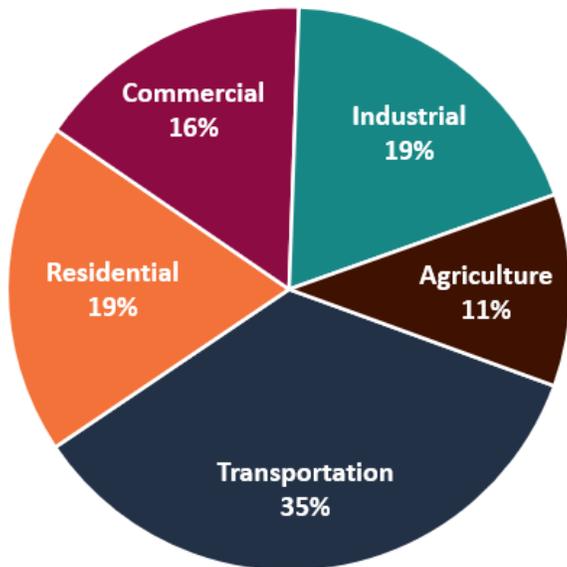
Most of Oregon’s greenhouse gas emissions come from the energy used every day, including electricity, direct use fuels, and transportation fuels. Five main economic sectors – transportation, commercial, residential, industrial, and agricultural – contributed about 61 million metric tons of carbon dioxide equivalent in Oregon in 2021.³ For context, Oregon’s greenhouse gas emissions should be 3 million MTCO₂e or lower by the year 2050 to meet the Oregon Climate Action Commission’s recommended goals.⁴

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



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

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



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

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

Climate Change Effects on Energy

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

Energy Demand

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

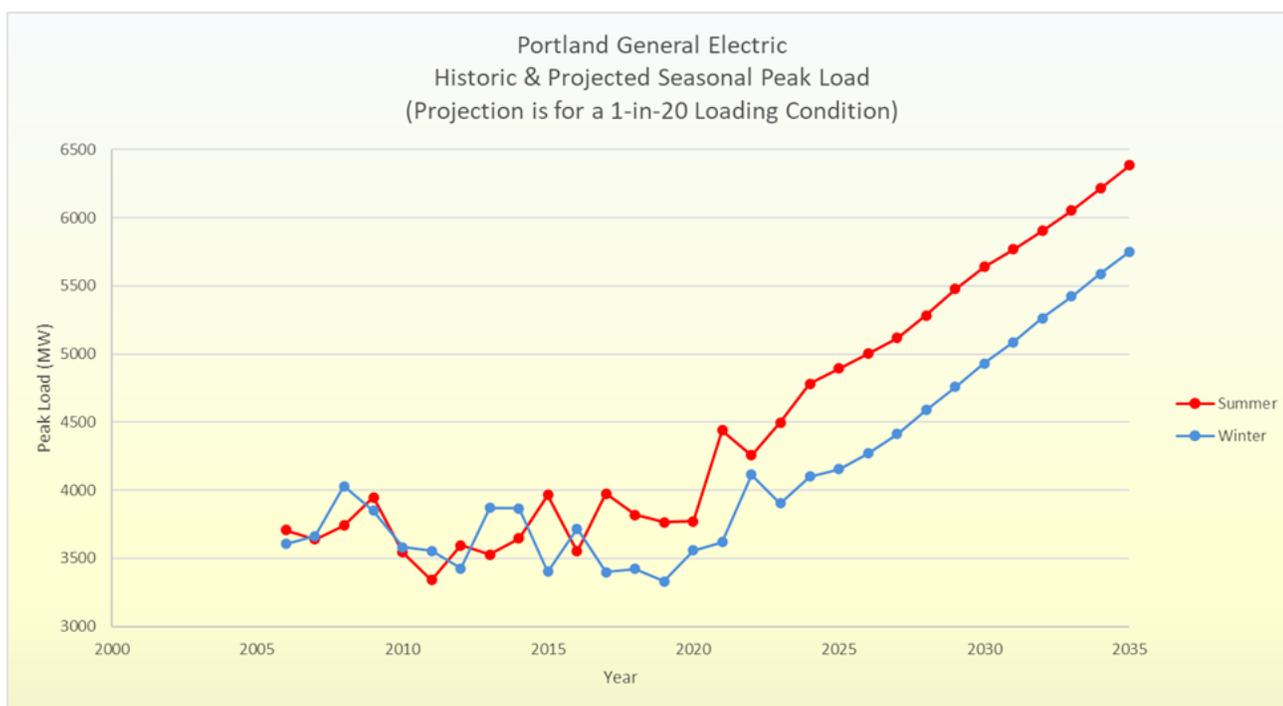
These warmer temperatures and more frequent heat waves have created new summer peaks in electricity demand to meet additional cooling needs in homes and workplaces. This puts stress on Oregon’s current electricity systems and creates challenges for utilities to meet demands. Summer heat events are also likely to coincide with increasingly frequent wildfires and planned transmission line outages to reduce the risk of wildfire ignition. According to the National Center for Environmental Health, “studies have shown that for every 1°F (0.6°C) increase in summer air temperature, the

electricity demand in medium and large cities can increase by an estimated 1.5 to 2.0 percent. During extreme heat events, which are exacerbated in urban heat islands, the demand for cooling can overload systems and result in power outages.”⁷

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

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

Figure 3: Portland General Electric Historic and Projected Seasonal Peak Load⁹



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

Energy Supply

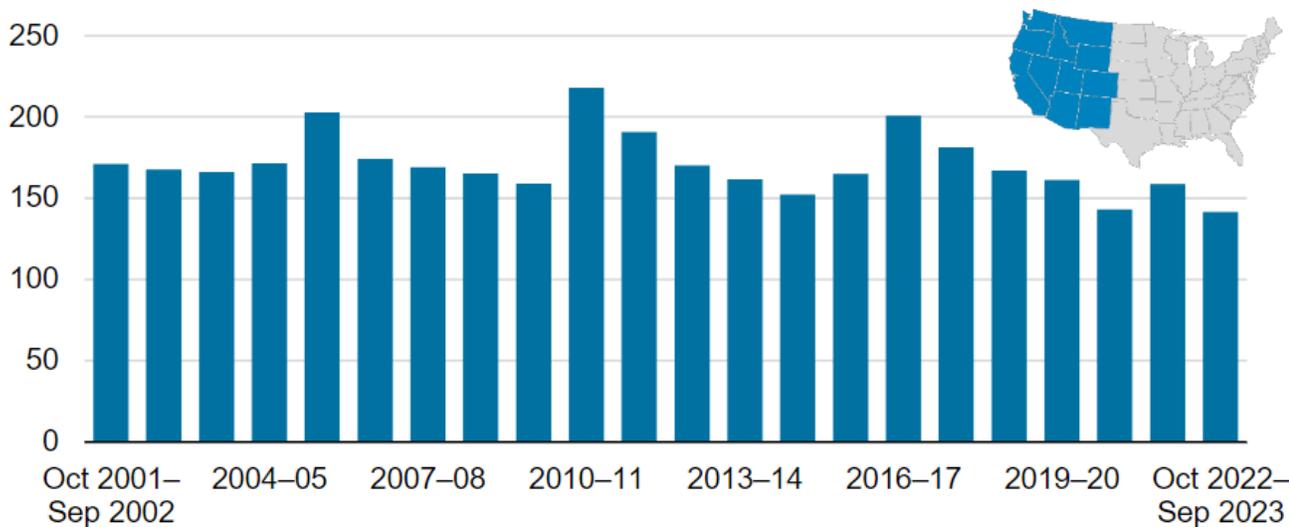
With higher temperatures caused by climate change, many areas of Oregon that historically received snow during the winter are more likely to receive rain. This change in precipitation type will shift decades-long patterns of when hydropower – which accounts for nearly 40 percent of the electricity

Oregonians use¹² – is available across the Pacific Northwest. A significant shift could lead to increases in electricity costs and new infrastructure needs. Lower water availability and higher water temperatures can make energy generation, transmission, and distribution systems less efficient.

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

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

Figure 4: Western U.S. Hydropower Generation by Water Year (Oct 2001 – Sept 2023), in Million Megawatt Hours¹⁵



Data source: U.S. Energy Information Administration, [Electricity Data Browser](#)

Note: The water year runs from October 1 to September 30.



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

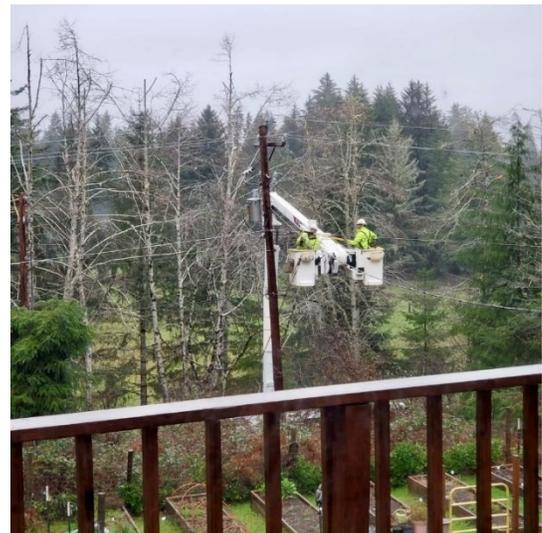
Thermoelectric power facilities, such as natural gas generation facilities, require water or air for cooling and can be sensitive to increases in ambient temperatures.¹⁶ Even small changes in temperatures could result in efficiency losses. For example, one study noted that natural gas-fired power plants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

Electricity Reliability

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

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

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



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

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

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

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

Transportation Fuels

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

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



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



September 2020 wildfire damage in Detroit, OR.

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

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

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

Financial Costs

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

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

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



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

The January 2024 winter storm took a heavy toll on the energy system and infrastructure in the state. Interstate 84 had to close for some time due to hazardous conditions, and landslides, rock falls, floods, and downed trees blocked roads and took out power lines in multiple counties. For example, in Lane County, local utilities experienced significant damage to their electric distribution systems. Lane Electric lost more than 200 power poles and associated lines due to ice damage and falling trees.²⁰ In Cottage Grove, critical city services had to rely on backup power for nearly a week, and Blachly-Lane Electric Cooperative suffered damage to about 30 miles of power lines.

In Lincoln County, about 50 miles of Central Lincoln PUD’s lines were damaged, including seven miles that had to be completely replaced. The Confederated Tribes of the Siletz Indians needed to acquire a portable generator to operate water pumps and services to local homes. Hundreds of gallons of diesel fuel were needed to operate generators at various tribal facilities, including a warming shelter.²⁰

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

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

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

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

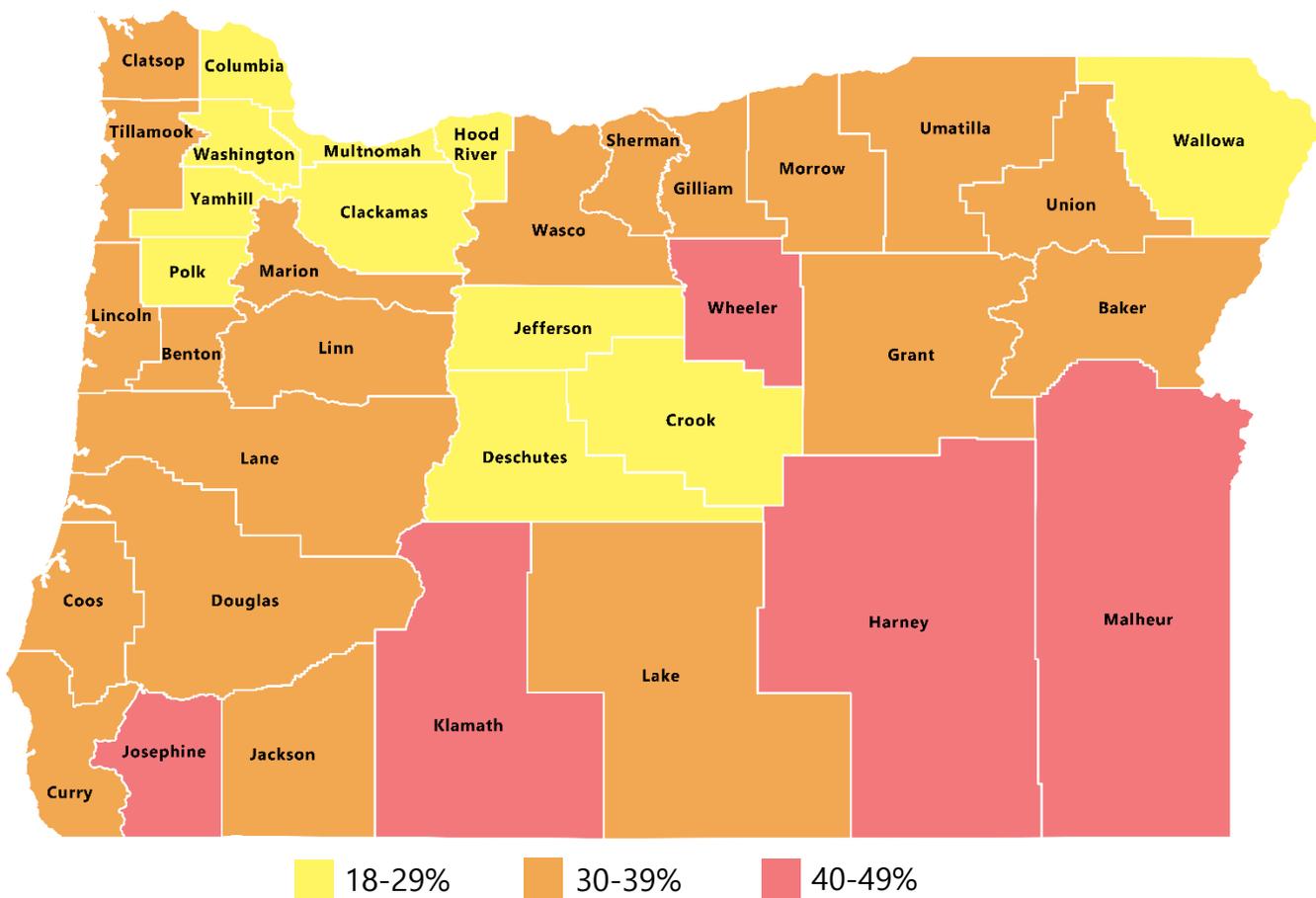
“Insurance analysts say the growing risk of severe wildfires due to climate change, and a shifting legal landscape that increasingly holds utilities accountable for the damages caused by these conflagrations, has indeed changed the calculus that goes into a utility’s liability insurance policy. But they’re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

Equity

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

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

Figure 5: Percentage of Oregon Households Considered Energy Burdened and Earning 200 Percent or Below Federal Poverty Level by County³⁶

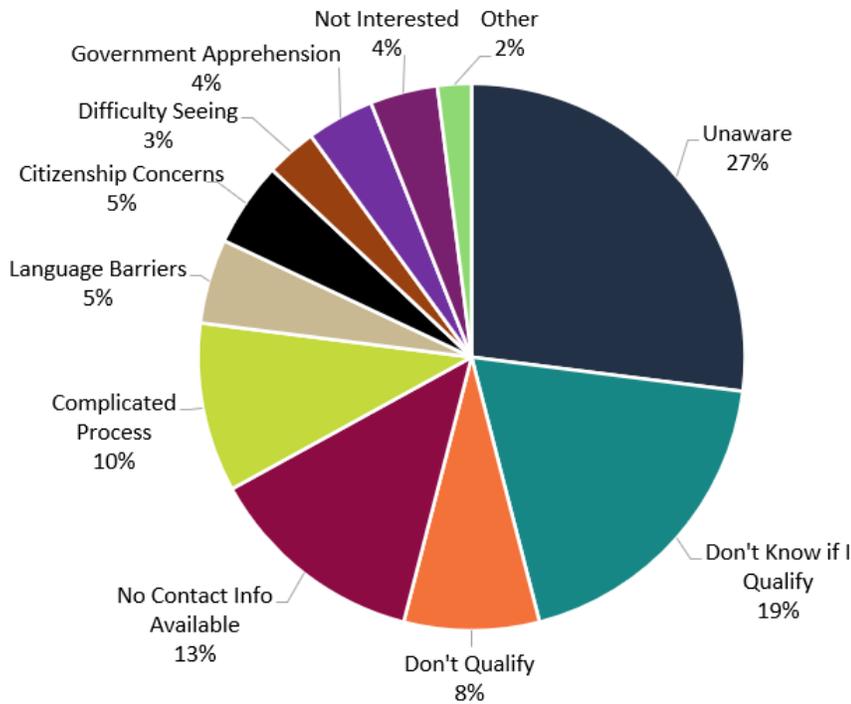


The Oregon Department of Energy's *2023 Cooling Needs Study* identified social and economic barriers that residents face in accessing existing resources for energy and cooling. Many residents shared that they do not use existing cooling equipment due to the associated energy costs. Air conditioning is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

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

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

Figure 6: Reasons Cooling Needs Survey Respondents Have Not Used Assistance Programs²⁶



Energy Actions to Mitigate and Adapt to Climate Change

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

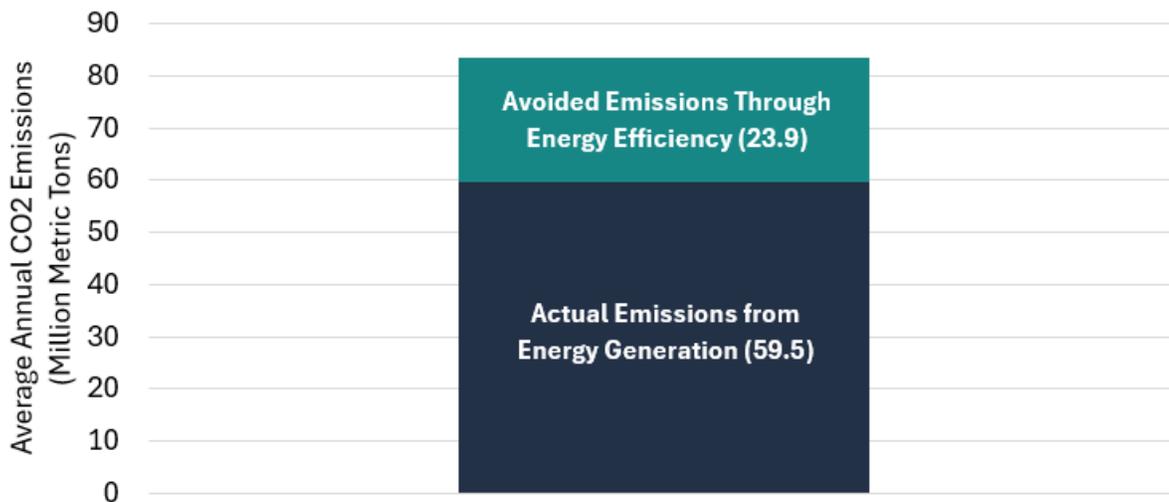
Energy Efficiency and Conservation

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

Energy efficiency is the second-largest electricity resource in Oregon and the Pacific Northwest behind hydropower.³⁷ Between 1978 and 2021, efficiency has saved over a cumulative 7,500

megawatts^v of power in the region – about half the region’s growth in demand for electricity.³⁷ Maximizing energy efficiency and smart-grid technologies in homes, schools, offices, farms, and industries can lower electricity demand and costs, increase energy resilience, and reduce greenhouse gas emissions.

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



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

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

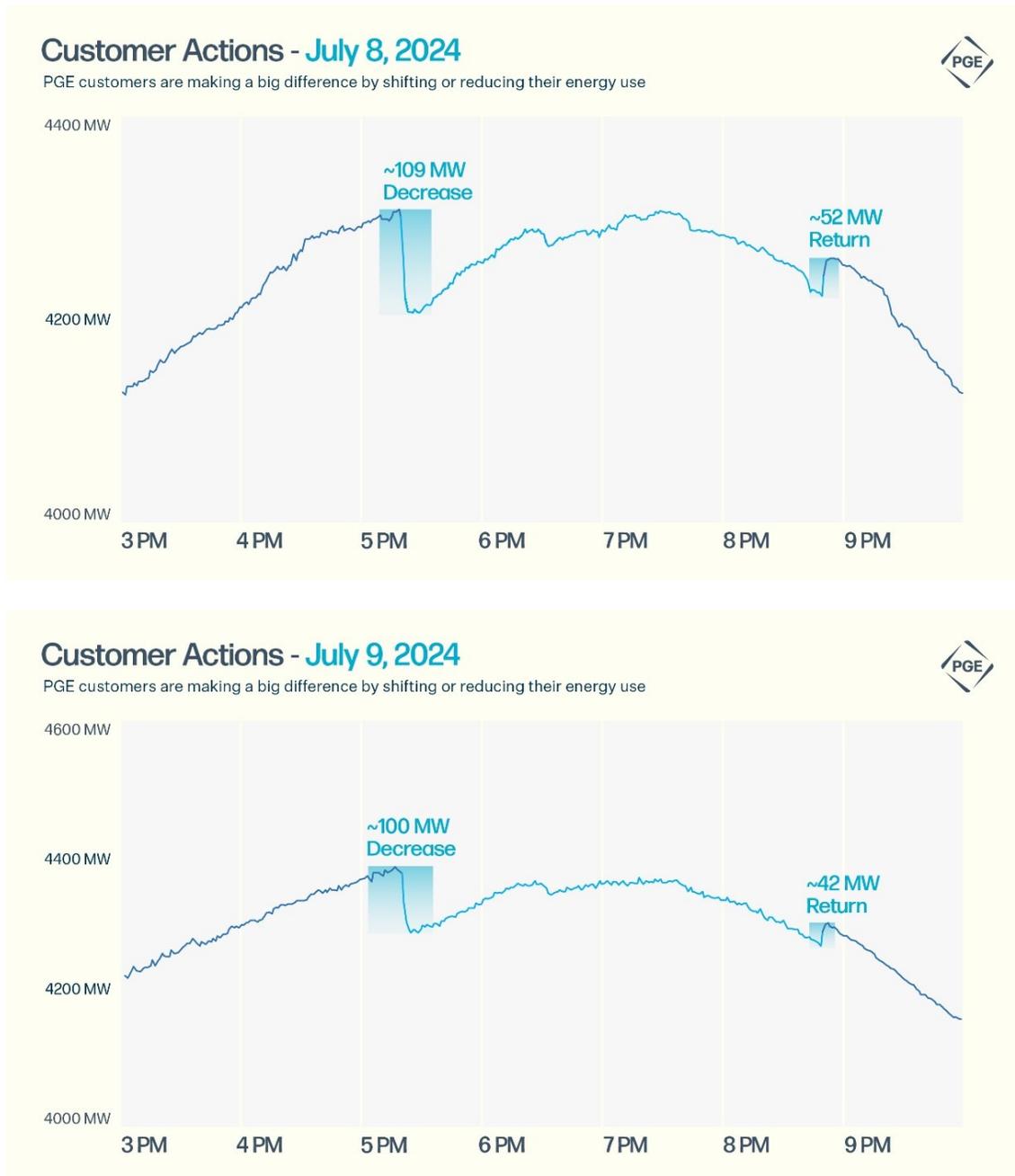
During peak periods of electricity demand, utility customers can adjust their energy use to conserve energy and reduce overall demand – including during extreme weather events. Utilities may ask customers to shift their energy use when peaks are expected to avoid overloading the system. This can include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

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

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

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

Figure 8: Portland General Electric Customer Peak Power Demand Shifting, July 8-9, 2024³⁹

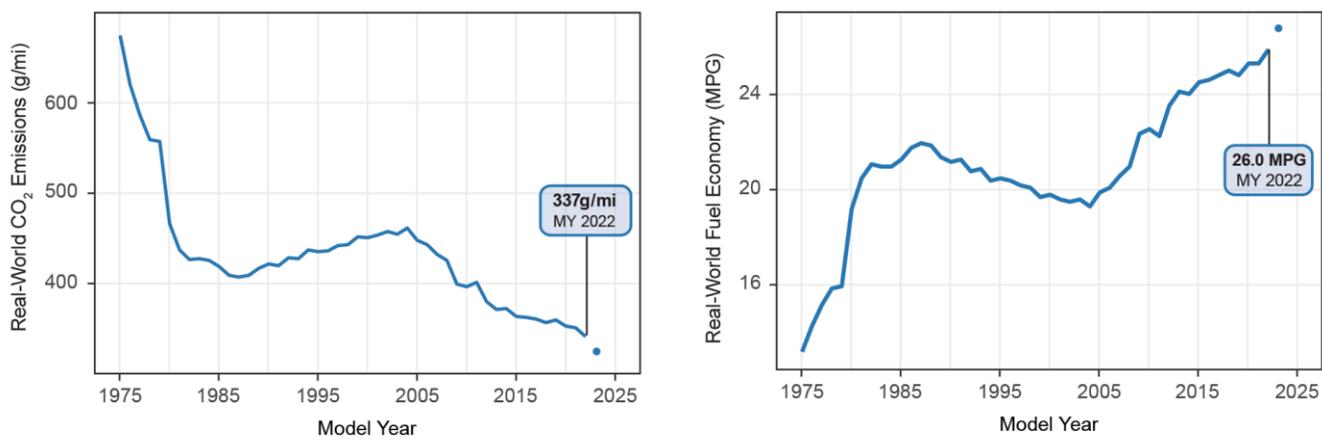


The transportation sector, which is the largest contributor to Oregon’s greenhouse gas emissions,³ can also benefit from efficiency improvements. According to the U.S. Environmental Protection Agency’s *2023 Automotive Trends Report*, vehicles in the 2022 model year had the biggest annual improvement in fuel economy – and in CO₂ emissions – in the last nine years.⁴⁰ The report notes the

expectation that model year 2023 will improve even further. As vehicles become more efficient, CO2 emissions will continue to drop.

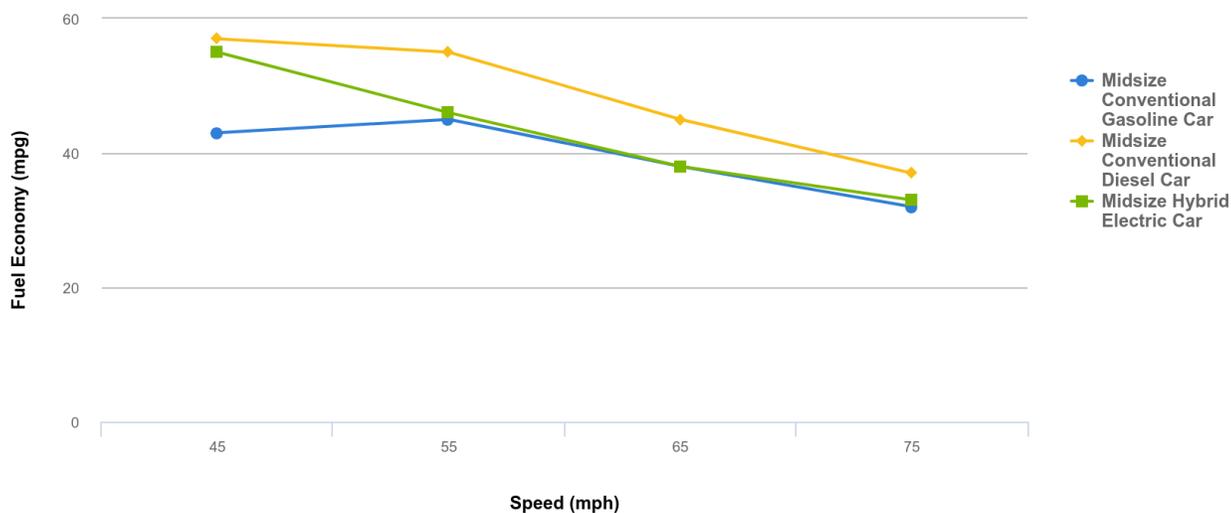
One of the main drivers of increasing vehicle fuel efficiency is electric vehicles. EVs conserve energy over gas-powered models. EVs convert over 77 percent of their electricity as fuel to power their wheels, while internal combustion engines convert just 12 to 30 percent of their fuel to power their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

Figure 9: Estimated CO2 Emissions and Fuel Economy by Vehicle Model Year⁴⁰



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

Figure 10: Fuel Economy at Various Driving Speeds⁴²



Last updated: May 2021
Printed on: May 23

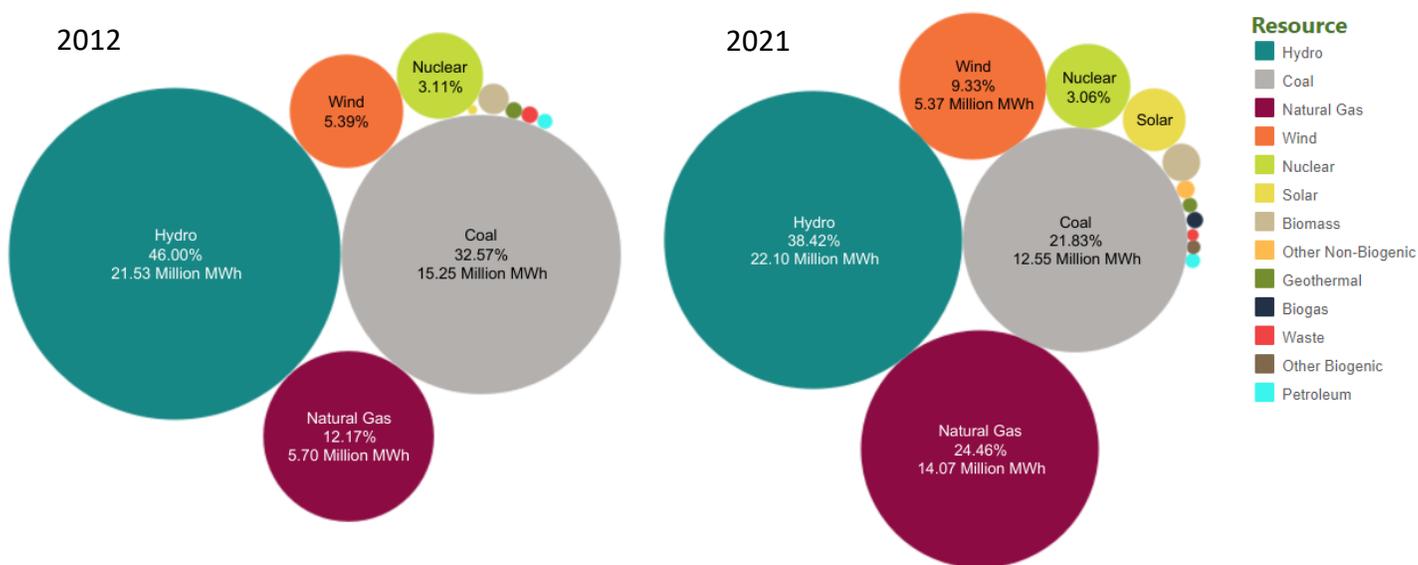
Alternative transportation options, such as public transit or micromobility devices (e.g., electric bicycles and scooters) are also efficient options for travel as they effectively remove individual passenger cars off the road. For example, TriMet, which serves the Portland Metro region, had nearly 5.7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

Diversifying Energy Resources

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

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

Figure 11: Oregon’s Electricity Resource Mix in 2012 and 2021¹²



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

^{vi} Learn more about microgrids in the [2020 Biennial Energy Report’s Technology Review section](#) and the [2022 Biennial Energy Report’s Energy 101 on Backup Power](#).

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

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

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

While Oregon’s electric grid moves toward 100 percent clean, transportation fuels continue to be the largest source of emissions among sectors and sources, as noted earlier in this 101. The emissions are primarily from the combustion of petroleum products, like gasoline and diesel. Of the emissions generated, over half are from gasoline, mostly for use in passenger vehicles, and over a third are from fuels powering medium- and heavy-duty vehicles.⁴⁵ In 2021, the Oregon Environmental Quality Commission approved a new Climate Protection Program for Oregon, targeting a 90 percent reduction in greenhouse gas emissions from fossil fuels, including gasoline, diesel, and natural gas by 2050.⁴⁶ The program used a declining limit or cap to reduce emissions over time, prioritizing the reduction of emissions and other types of air pollution in the underserved communities most affected by climate change and pollution. In late 2023, the Oregon Court of Appeals held the administrative rules for the program were invalid because the program rulemaking didn’t comply with certain notice requirements under the federal Clean Air Act.⁴⁷ In 2024, the Oregon Department of Environmental Quality restarted its administrative rulemaking process to reestablish a climate mitigation program beginning in 2025.⁴⁸

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



The Oregon Department of Energy’s *2020 Biennial Energy Report* discussed [alternative fuel options for medium- and heavy-duty vehicles](#). Several factors come into play when determining the best medium- and heavy-duty alternative fuel vehicles for a fleet, including: fueling timing and infrastructure needs, the climate and terrain where the vehicles will operate, existing air quality requirements and supporting clean fuels policies, costs, and the current availability of vehicles.²² Oregon’s efforts to increase the availability and use of cleaner fuels are supported by the Oregon Department of Transportation Statewide Transportation Strategy⁵¹ and DEQ’s Advanced Clean Trucks rule⁵² and Oregon Clean Fuels Program.⁵³ Oregon is also a signatory to the Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding,⁵⁴ which directed the existing Multi-State ZEV Task Force, in which the State of Oregon participates, to develop a multi-state action plan to identify barriers and propose solutions to support widespread electrification of medium- and heavy-duty vehicles.

Strengthening Electricity Reliability and Resilience

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

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

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

Addressing Equity

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

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

^{ix} Learn more about Oregon Department of Energy incentive programs, including grid resilience:

<https://www.oregon.gov/energy/Incentives/Pages/default.aspx> <https://www.oregon.gov/energy/energy-oregon/Pages/IJJA.aspx>

Figure 12: Oregon Disadvantaged Communities and Tribes in the Climate and Economic Justice Screening Tool⁵⁷



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

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

Future Planning

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

Energy Security Plan

The Oregon Department of Energy was directed by the federal government and the Oregon Legislature through Senate Bill 1567⁵⁹ to prepare an Energy Security Plan for Oregon. The plan, which was published on September 30, 2024, identifies risks to electricity, liquid fuel, and natural gas and propane systems, including risks resulting from climate change.

Read the [full report on ODOE’s website](#) and read a summary in this report’s section on State Energy Projects.

^x Learn more about these federal programs on the Oregon Department of Energy’s website: <https://www.oregon.gov/energy/energy-oregon/Pages/IIJA.aspx>

Oregon Energy Strategy

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

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

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Electricity Rate Increase Drivers

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



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

Are Electricity Rates Increasing Statewide?

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



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

In a review of Oregon's 10 largest utilities by number of customers served,⁵ only one utility — Oregon Trail Electric Cooperative — had not increased its rates at least once between January 2020 and October 2024.⁶ Customers of Oregon's two largest electric utilities — Portland General Electric and PacifiCorp (operating in Oregon as Pacific Power) — have seen their rates go up multiple times since 2020.⁷⁻¹¹ While different customer classesⁱⁱ have different rates and often different consumption patterns, a typical residential customerⁱⁱⁱ of PGE or PacifiCorp saw their average bill increase 50-60 percent, from roughly \$100/month in January 2020 to roughly \$150-160/month in January 2024.^{12 13 14 15} Both PGE and PacifiCorp are seeking to raise rates further in 2025.^{16 17}

Customers of Oregon's largest consumer-owned utilities are also facing electric rate increases. The state's largest consumer-owned utility — Eugene Water & Electric Board — has raised rates multiple times since 2020.¹⁸ EWEB estimates a residential customer's average monthly electric bill increased from \$167 in 2020 to \$190 in 2024, or roughly 13.8 percent.¹⁸ The aggregate increase for other large consumer-owned utilities has ranged from approximately 5 to 11 percent from 2020 to 2024.¹⁹⁻²⁴ Not every utility reports a bill increase in percentage terms. For example, Oregon's tenth largest utility — Tillamook People's Utility District — has not reported a significant percentage

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

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

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

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

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

Electricity Consumption

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

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

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



^{iv} Tillamook PUD's current volumetric rate is \$0.08/kWh.²⁵

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

Oregon's Energy Supplier Assessment



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

Are Other States Seeing Electricity Price Increases?

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

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

At the same time Oregonians have faced rising electricity prices, the electricity sector's greenhouse gas emissions in Oregon have fallen. According to data gathered by the Oregon Department of Environmental Quality, emissions fell from 18.8 million metric tonnes of carbon dioxide equivalent in 2019 to 17.6 million MTCO₂E in 2022, even as overall electricity consumption increased.³⁰ DEQ reports the emission intensity of Oregon's electricity fell from 0.36 MTCO₂E/MWh in 2019 to 0.30 MTCO₂E/MWh in 2022.³⁰

Numerous state and federal clean energy policies have contributed to these emissions reductions. Some policies, such as federal tax credits, have focused on reducing the costs, thereby fostering the increased deployment of low- and non-emitting technologies. As renewable technologies have become increasingly cost competitive, the competition has put pressure on older and less efficient generation sources, particularly coal plants.³¹ Federal and state environmental regulations have also contributed to cost pressures on emitting generation sources. For example, PGE agreed to close the Boardman Coal Plant, the last coal power plant located in Oregon, as part of a federal Clean Air Act lawsuit settlement; the plant closed in 2020.³²

Oregon's Public Purpose Charge

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

Achieving Oregon's climate goals will require further emissions reductions.³⁴ In 2021, the Oregon State Legislature enacted House Bill 2021.³⁵ HB 2021 requires PGE, PacifiCorp, and certain providers called electricity service suppliers^{vi} to, among other things, "eliminate greenhouse gas emissions associated with serving Oregon retail electricity consumers by 2040."³⁵

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

Overseeing Rate Increases

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

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

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

For customers of PGE, PacifiCorp, and electricity service suppliers, the answer is a bit more complicated. HB 2021 is not a direct driver of recent rate increases, but it will likely have future cost impacts. Any new investments that are made to comply with HB 2021 — and that the OPUC reviews and approves — will affect electricity prices at some point. However, those new investments and potential price impacts specific to HB 2021 are generally not being reflected in rates yet. For example, in reviewing PacifiCorp’s 2023 Integrated Resource Plan and Clean Energy Plan, OPUC staff noted that the utility’s progress toward HB 2021’s emissions reduction targets so far only reflected the planning and investments that predated HB 2021.³⁹

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

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

Oregon’s Renewable Portfolio Standard

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



Why Are Electricity Rates Increasing?

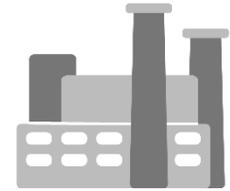
This section explores three common cost drivers: 1) rising power costs; 2) ongoing infrastructure needs, compounded with inflationary pressures; and 3) costs to mitigate the increasing prevalence and risks of wildfires and extreme weather.^{vii} These cost drivers are not mutually exclusive and often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

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

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

Rising Power Costs

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



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

While BPA's rates for Oregon consumer-owned utilities generally declined from 2022-2023, BPA is proposing higher rates in 2024 and beyond.^{46 47} When BPA raises the wholesale cost of power for Oregon's consumer-owned utilities, that affects each utility's need to adjust retail rates that customers pay. For instance, Central Electric Cooperative reported that when BPA adjusted its rates for 2024-2025, it raised CEC's power costs by 11.5 percent.⁴⁸ This was one factor CEC cited in explaining its 5.9 percent rate increase to customers.⁴⁸ Similarly, EWEB noted that increased power costs from BPA account for 5.25 percent of the anticipated 15 percent rate increase for 2025.⁴⁹ Even with the cost increases, however, power that BPA sells from federal generating resources costs less than power from other wholesale sources.

Long-term contracts with BPA provide a smaller share of the portfolio of resources that investor-owned utilities rely upon. Instead, investor-owned utilities rely more on long-term contracts with other providers, short-term market purchases, or fuel purchases for their own generating resources, where applicable. With greater reliance on these more variable options, investor-owned utilities are particularly sensitive to fluctuations in market conditions. Through an annual process overseen by the OPUC, each investor-owned utility forecasts its power costs for the upcoming year and updates its rates to pass the forecasted costs along to customers. At the end of that year, the investor-owned utility compares its forecast to its actual costs and, if the difference exceeds a certain amount, updates its rates to refund or charge customers for the difference. From 2020 to 2024, PGE and PacifiCorp's forecasted power costs increased by roughly double the amount or more.⁵⁰⁻⁶⁹ Some of these increases are due to load growth: both PGE and PacifiCorp's loads have increased since 2020.³⁰ However, load growth alone does not explain the entirety of the increases in power costs that Oregon's large investor-owned utilities have encountered. To some extent, for both PGE and PacifiCorp, these power cost increases reflect a rising cost for them to generate and deliver electricity.

There are a number of factors contributing to rising power costs. As noted above, power costs include the costs of long-term contracts and short-term market transactions. The amount of generation a utility owns or procures through long-term contracts affects how much the utility

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



As noted above, power costs also include fuel costs for a utility's own generation. Some fuels are not always available, forcing the utility to pursue other options. For example, BPA sells power primarily from hydroelectric facilities. In dry years with reduced rainfall, the hydroelectric facilities generate less electricity. To compensate, BPA may need to buy power from the market to meet customer needs; BPA also may not be able to sell excess electricity on the market for revenue to defray costs. Fewer sales from BPA or other generators into the market can also mean higher prices for other utilities when buying from the market. Further, fuel supply constraints increase the cost of what fuel is available. For example, natural gas is a commodity that is bought and sold internationally. As such, its price is affected by international affairs. In recent years, the Russian invasion of Ukraine in February 2022 had a significant effect on the natural gas market. As Russia significantly reduced its natural gas exports to European countries, the United States' exports of natural gas to Europe have risen considerably.⁷¹ The higher international demand has contributed to a more limited and more expensive fuel supply for domestic needs, such as electricity production. Recent reports indicate that natural gas commodity prices are decreasing and becoming less volatile since 2022.⁷²

Natural Gas Rates

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



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

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

Grid Investments

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

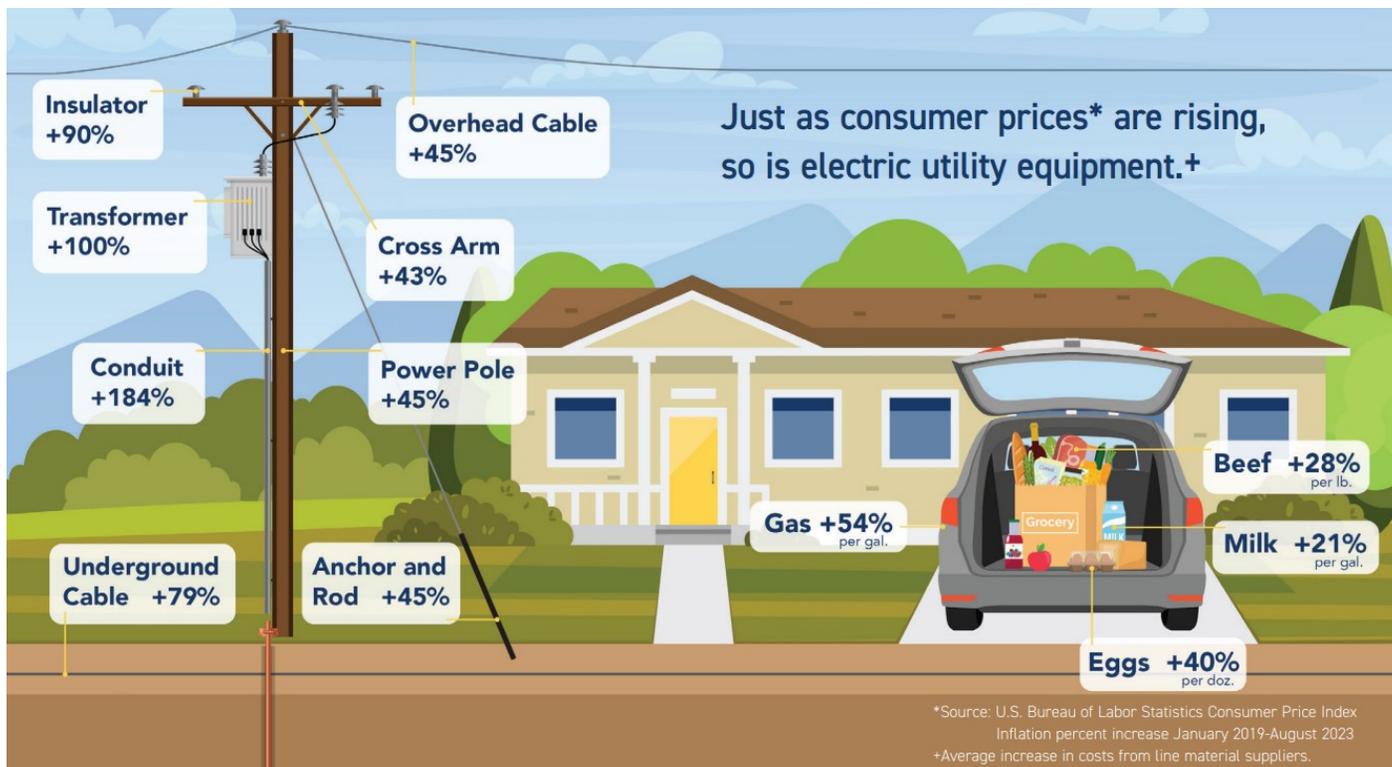
Further, the cost of otherwise routine infrastructure investments has been exacerbated recently by supply chain delays and inflation. In the fall of 2023, Central Electric Cooperative summarized these price impacts as follows:

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



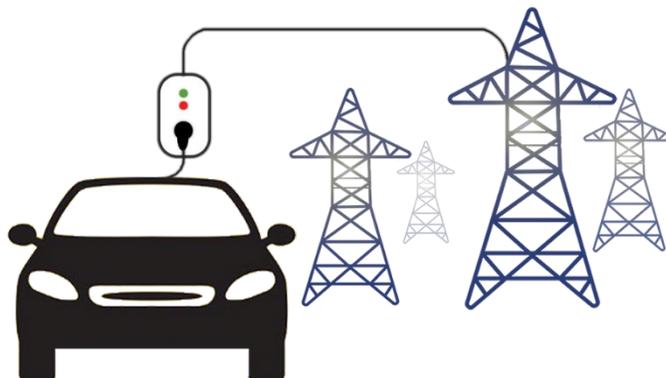
Crews from Central Electric Cooperative perform maintenance and repairs on high-voltage lines.

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



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

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



Federal Investments

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



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

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

Wildfires and Extreme Weather

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

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

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

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

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

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

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

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

^{viii} PacifiCorp provides updated information on wildfire litigation on its website at <https://www.pacificorp.com/about/information-wildfire-litigation.html>.

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

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

Other Energy Assistance Programs

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



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

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

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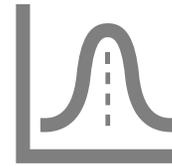
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Peak Electricity Demand

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



Peak Electricity Demand and Utility Planning

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

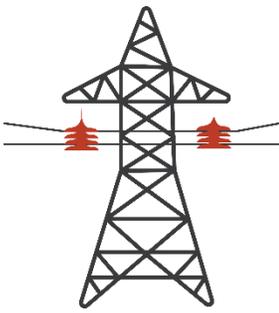
The resources grid operators use to meet peak loads include options on both the supply and demand side. In general, utility planning efforts seek to identify the least cost and least risk resources to meet future load. This includes procuring all the infrastructure necessary to deliver power to the consumer,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

Energy efficiency measures reduce demand across all hours, including peak hours. Efficiency has historically been one of the most cost-effective resources for the Pacific Northwest, with 7,678 average megawatts of energy savings from 1978 through 2022.³ Energy efficiency savings can occur on the supply side when utilities use more efficient types of generation, such as upgrading to more efficient turbines. Savings are also available on the customer side, by using more efficient appliances and lights, weatherizing and insulating buildings, and using advanced heating and cooling technologies like smart thermostats and water heaters.

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



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



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

Transmission lines move electricity by creating a pathway for power to flow from sources of supply to loads.⁵ Transmission lines also connect all utilities to each other, allowing for a networked power grid that not only allows power to flow across the entire footprint of a single utility service area, but also across the footprints of multiple utilities. Like generation, transmission lines also have an

upper capacity threshold, limiting the amount of energy that can be transferred at any given time. The capacity of the line is dependent on ambient temperatures, with lines losing capacity as outdoor temperature increases. This means that during heatwaves, transmission lines will generally have less capacity than during cold weather events.

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

Peak Electricity Demand and Ratepayer Costs

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

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

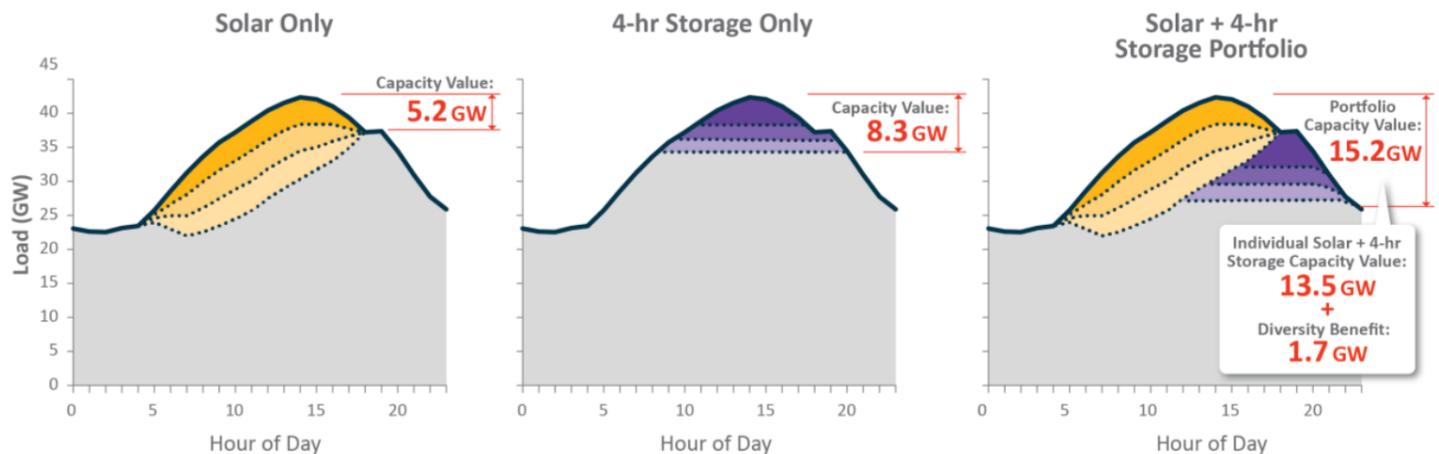
Batteries can provide additional power during peak load hours, offsetting the need for additional generation to meet that load.⁷ The rapid expansion of the electric vehicle market has led to significant reductions in battery costs, and electric utilities are increasingly adding them to their operations.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

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

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

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

Figure 1: Portfolio Benefits for Solar + Storage in Capacity Accreditation⁸



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

Peak Electricity Demand and Electricity Reliability

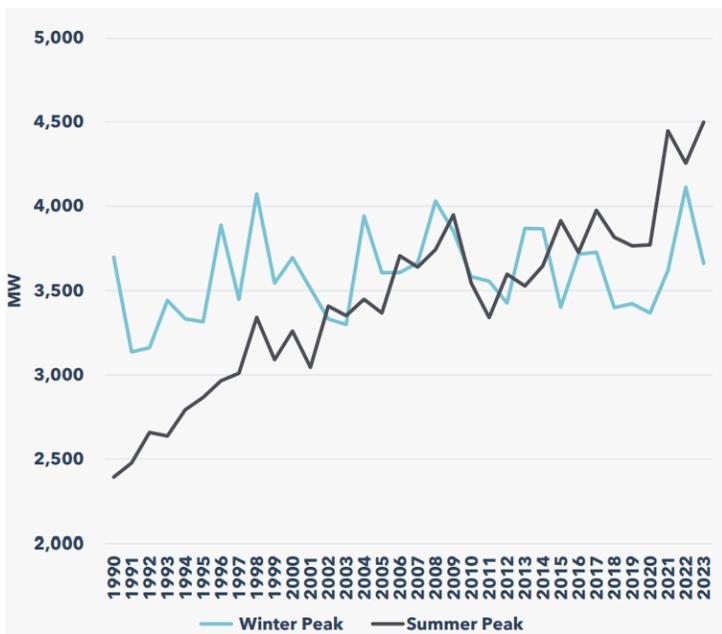
The risk of electricity supply shortfalls is higher during extreme weather events.⁹ Extreme temperatures and conditions often reduce the performance of electricity generation, battery storage, transmission, and distribution equipment.¹⁰ This limits the ability of grid operators to manage and balance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

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

The Pacific Northwest’s summer electricity peak has increased significantly in the past four years. Winter still produces the greatest seasonal load in the region, including the region’s highest peak since the 1990s.ⁱ A cold snap on January 13, 2024 drove electricity demand up to 35,594 MW.¹⁴ Until 2021, summer peak demand was always below 30,000 MW. Since then, summer peak has exceeded 32,000 MW, with a record peak of 33,300 MW on July 9, 2024.¹³

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

Figure 2: Historical Peak Demand in Winter and Summer for Portland General Electric¹⁶

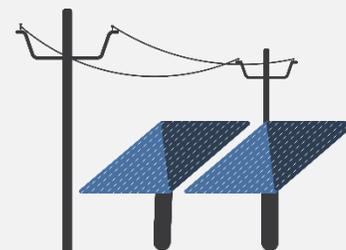


ⁱ Prior to the 1990s, high-load aluminum smelters and certain other industrial customers in the region produced a very different energy profile. These industrial users were largely shuttered by the 1990s.¹³

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

Capacity, Generation, and Energy Demand

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

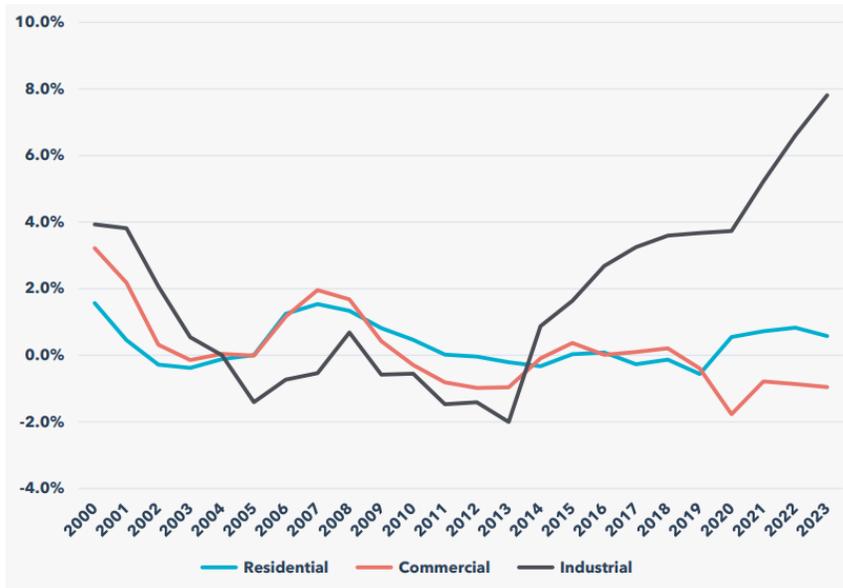


Generation refers to the cumulative energy output over a period of time, and is measured in megawatt hours, or MWh. As an example, a solar array with a 100 MW capacity operating at 50 percent capacity for 12 hours of the day would generate 600 MWh over the course of that day.

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

Peak load is expected to increase as the overall annual electricity demand increases. The Northwest Power and Conservation Council analyzed future growth in annual energy demand and found that it is expected to rise from 104,000 average megawatts today to between 130,000 and 155,000 aMW by 2045.¹⁹ Currently, load growth is primarily driven by large tech sector industrial loads, such as data centers and semiconductor manufacturing.¹⁶ Figure 3 shows percent changes in annual load growth for the residential, commercial, and industrial sectors in PGE territory. While Residential has remained basically flat, industrial growth, shown by the black line, has risen by nearly 8 percent in the last five years.

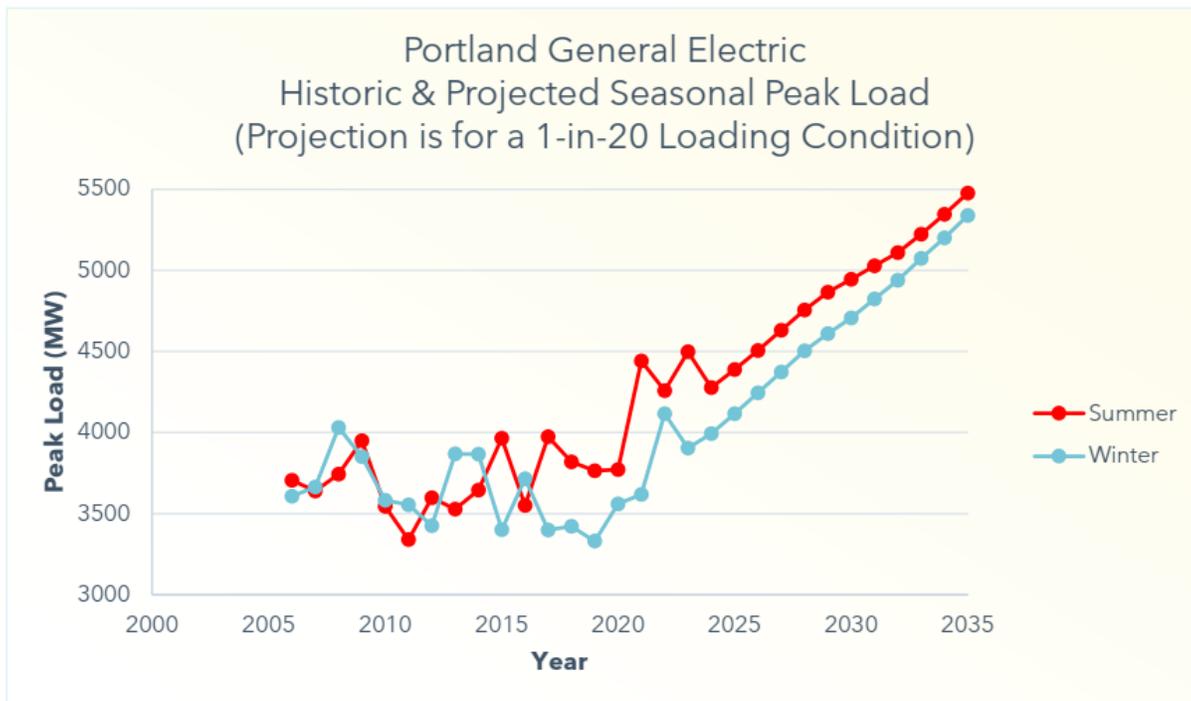
Figure 3: Average Five-Year Load Growth Rate by Sector for Portland General Electric⁷



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

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

Figure 4: Portland General Electric Historic and Projected Seasonal Peak Load²²



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

Learn more about peak demand and related energy reliability topics:

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

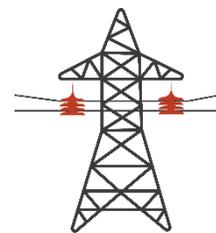
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Electricity Day-Ahead Markets

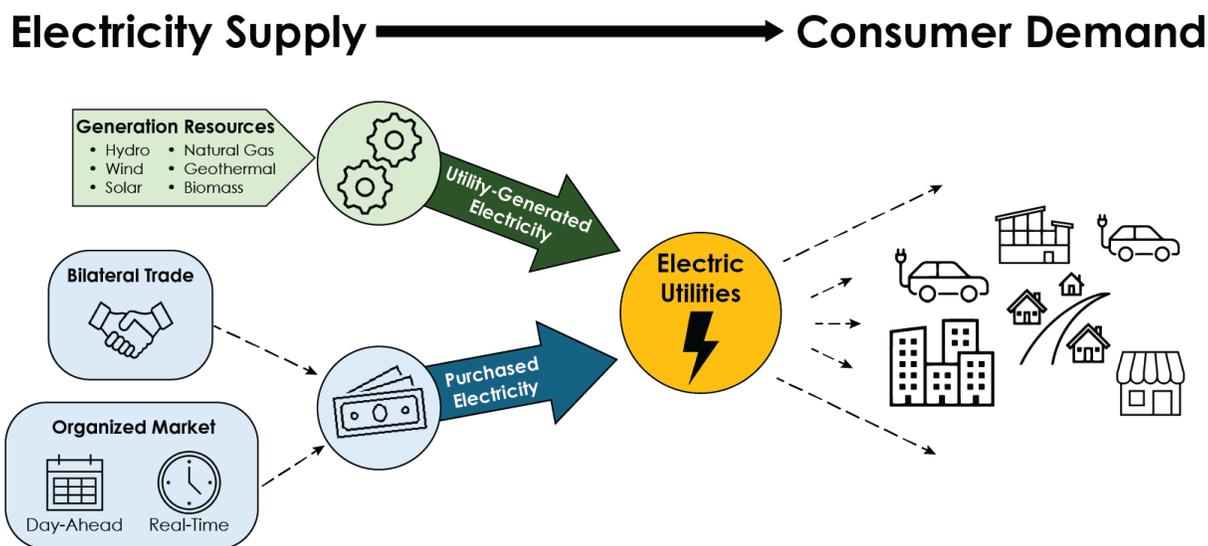
Every day, electric utilities work to reliably provide electricity to consumers. Because there is currently limited capacity to store electricity on the system, utilities must typically meet consumer demand in real time—perfectly balancing the supply of electricity with demand every minute of every day.¹



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

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

Figure 1: Balancing Electricity Supply and Demand



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

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

Figure 2: Day-Ahead Forecasted Demand for March 1, 2024⁴

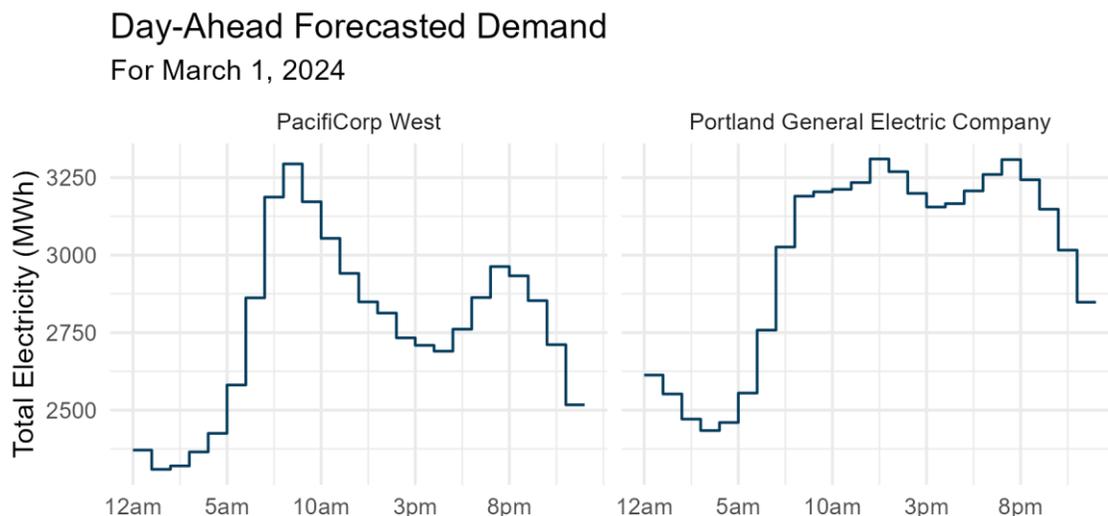


Figure 2 shows an example of Portland General Electric’s and PacifiCorp West’s forecasted demand in the day ahead planning window for service on March 1, 2024. For these load forecasts, each utility predicted how much electricity would be demanded for each hour of the day on March 1 using information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

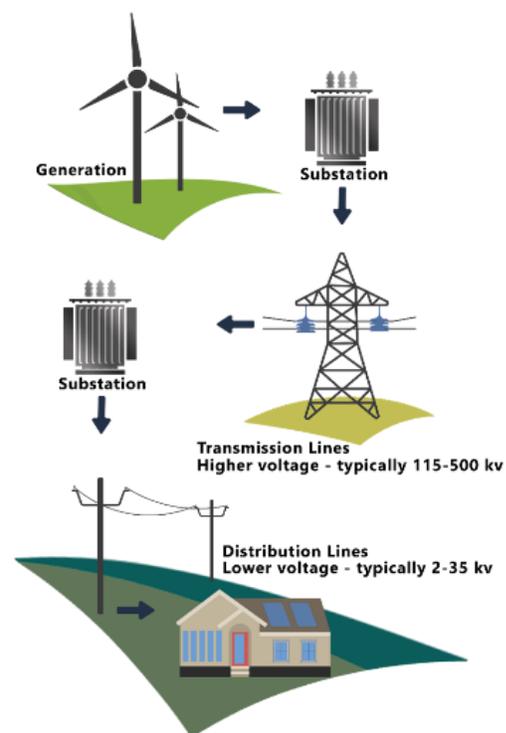
This article describes how day-ahead markets work, provides an overview of where day-ahead markets can be found in the United States, and closes with a discussion of the benefits and challenges of participating in and developing a day-ahead market.

Complexities in Meeting Electricity Demand

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

Transmission

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



Reliability Requirements

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

In many areas, RTO/ISOs operate additional markets in parallel with the wholesale electricity markets to address reliability. **Ancillary service markets** refer to the various organized markets that provide secondary services to ensure reliability of the overall electricity system. These markets cover a wide range of secondary services, but not all RTO/ISOs have markets for all ancillary services, with many of these markets still evolving. One example of a common ancillary service market is the market for operating reserves.⁷ Even with all the planning and forecasting by RTO/ISOs and utilities, it is still

possible that at the time of service, demand may be higher than anticipated or a generating resource may trip offline. When this happens, it is necessary to have electricity generating resources or demand response resources that can quickly respond (usually within 10 minutes) to rebalance supply and demand.¹ In some RTO/ISOs these resources, known as operating reserves, are bought and sold through markets, using a similar auction system as the day-ahead market described here.⁷ While an exhaustive list of the types of services that are provided through ancillary service markets is beyond the scope of this article, to learn more about ancillary services and the market systems that support these services, see "[Ancillary Services in the United States: Technical Requirements, Market Designs, and Price Trends](#)" by the Electric Power Research Institute.

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

Demand Response

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



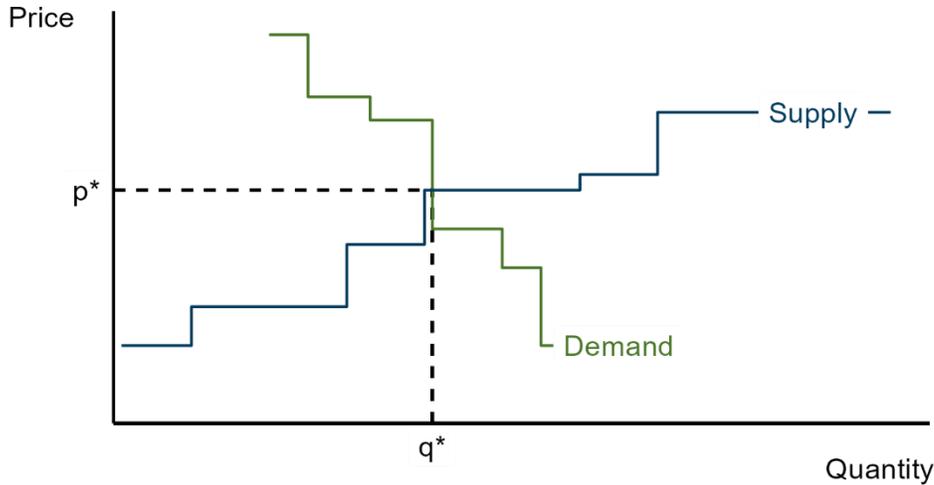
How Do Electricity Day-Ahead Markets Work?

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

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

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

Figure 3: Example Day-Ahead Market Supply and Demand Curves⁹

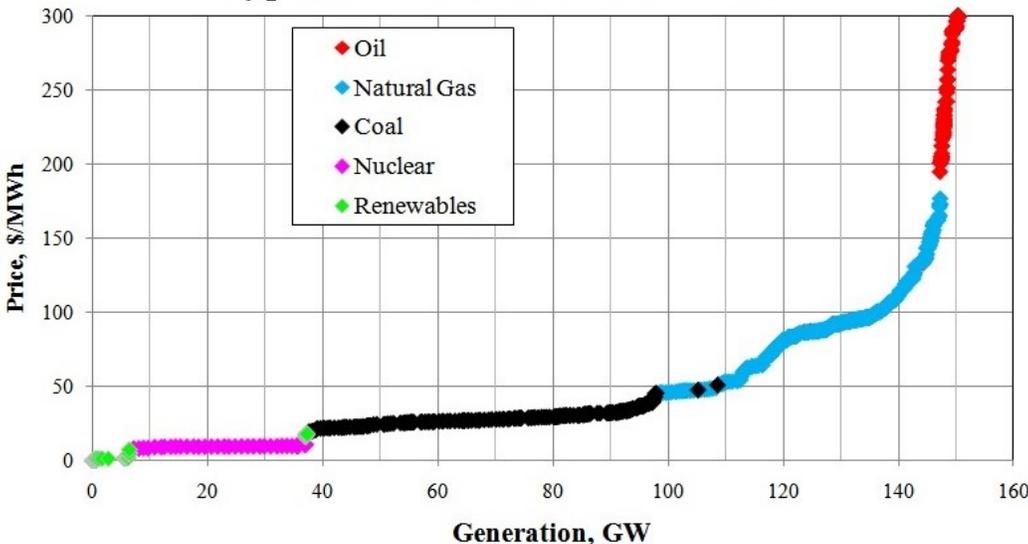


The market operator sets the market price at the point where the supply and demand curves meet, denoted by p^* in Figure 3. Like with other markets, this point represents the market equilibrium. At the equilibrium market price, the quantity of electricity that buyers are willing to purchase exactly equals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

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

Figure 4: Example Electricity Supply Curve by Generation Type¹¹

Typical PJM Generation Stack

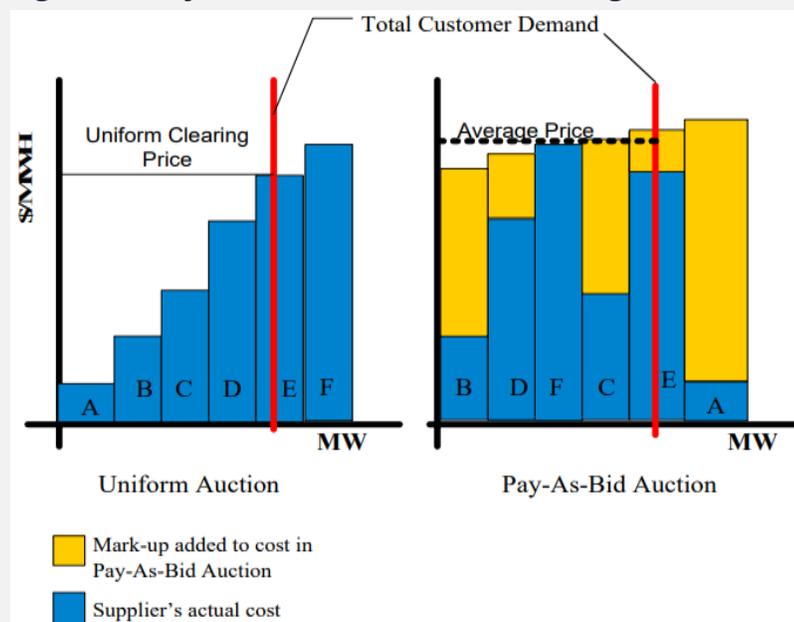


It is important to note that because buyers and sellers submit bids for specific time periods, each time period will have individual supply and demand curves and a separate market price. For example, the price of electricity tomorrow may be \$22/MWh at 8 a.m. and \$45/MWh at 8 p.m. Additionally, while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

Why is There a Uniform Clearing Price?

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

Figure 5: Pay-As-Bid vs. Uniform Clearing Price Auction¹²



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

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

Figure 6: Map of Day-Ahead Markets in the United States²



While each of the day-ahead markets in the U.S. currently only operates within an RTO/ISO region, there are ongoing discussions about how a day-ahead market might function outside of an RTO/ISO region. There are already two real-time electricity markets that operate with participants from outside of the operating RTO/ISO region. The Western Energy Imbalance Market is one example of how an organized market can work outside of an RTO/ISO region. The Western Energy Imbalance Market is a real-time electricity market that is run by the California Independent System Operator but is open to participation from utilities across the western region who are not CAISO members.¹⁴ For example, Portland General Electric, PacifiCorp, Idaho Power, and Bonneville Power Administration all participate in the Western Energy Imbalance Market.¹⁵ CAISO has proposed expanding its existing day-ahead market for participation by non-member utilities, calling it the Extended Day-Ahead Market. CAISO has received approval for its Extended Day-Ahead Market¹⁶ from the Federal Energy Regulatory

Commission and expects to onboard its first participants by 2026.¹⁷ Portland General Electric and PacifiCorp have signed implementation agreements to join the Extended Day-Ahead Market, with Idaho Power indicating it is leaning toward EDAM as its preferred day-ahead market option.¹⁸ The Southwest Power Pool also operates a real-time electricity market, the Western Energy Imbalance Service Market, which is open to utilities outside of the SPP RTO, though no Oregon utilities currently participate in this market.¹⁹ SPP has also proposed a new day-ahead market to serve non-members in the western region called Markets+ (pronounced “markets plus”). SPP has submitted the Markets+ tariff to FERC for approval.ⁱⁱⁱ Bonneville Power Administration staff have recommended that the agency join Markets+, though a final decision has yet to be made.²⁰

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

Benefits

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

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

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

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

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

Challenges

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

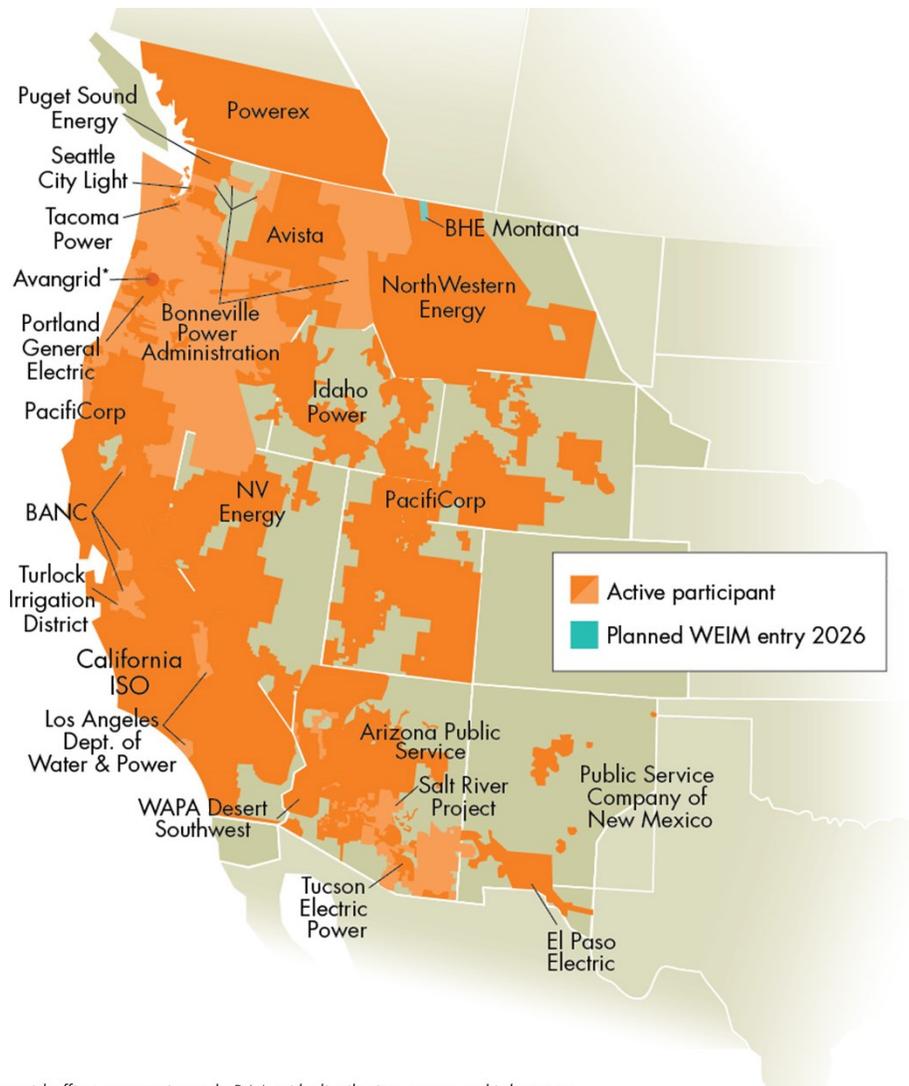
While this challenge should not be understated, work toward the formation of these types of organized markets in the western United States have shown substantial progress in recent years. Most notably, as discussed above, there exist already fully functioning real-time electricity markets with participating utilities that are not members of an RTO/ISO, the Western Energy Imbalance Market and the Western Energy Imbalance Service Market. The Western Energy Imbalance Market is operated by the California ISO and serves all the areas shown in orange in Figure 7 even though these utilities are not part of CAISO. The utilities that participate in the Western Energy Imbalance Market represent 80 percent of the demand in the West.²² The Western Energy Imbalance Service Market is run by the Southwest Power Pool but serves the areas shown in yellow in Figure 8 that are outside of the RTO area.¹⁹ The formation of the Western Energy Imbalance Market and the Western Energy Imbalance Service Market can provide helpful guidance on how this type of non-member day-ahead market could be governed.²³ Additionally, the two prospective day-ahead markets for the western region, the Extended Day-Ahead Market²⁴ and Markets+²⁵ each have developed proposals for their new governance structures with incorporated input from potential participants. CAISO has a governance structure for the EDAM that relies more heavily on expert staff support²⁶ and which involves joint decision-making between the Western Energy Markets Governing Body, “whose members are nominated by a committee of Western energy stakeholders” and the ISO Board of Governors, “whose members are appointed by the California Governor and must be confirmed by the California Senate.” However, the ISO Board and Western Energy Markets Governing Body recently voted to make a change to this governance structure in response to a recommendation from the West-Wide Governance Pathways Initiative. This change will give the Western Energy Markets Governing Body primary decision-making authority over the Western Energy Imbalance Market and EDAM.²⁷ SPP has proposed a governance structure for Markets+ that relies more heavily on working groups and task forces to make recommendations to the independently appointed Market+ Independent Panel, which

has final decision-making authority with independent oversight from the SPP board of directors.^{25,28} There are still discussions around the governance structures of both proposed markets, however, and aspects of the governance may change. A group of individual public utility commissioners from western states have developed a West-Wide Governance Pathways Initiative to support the development of additional market support in the west and help further overcome this potential challenge.²⁹



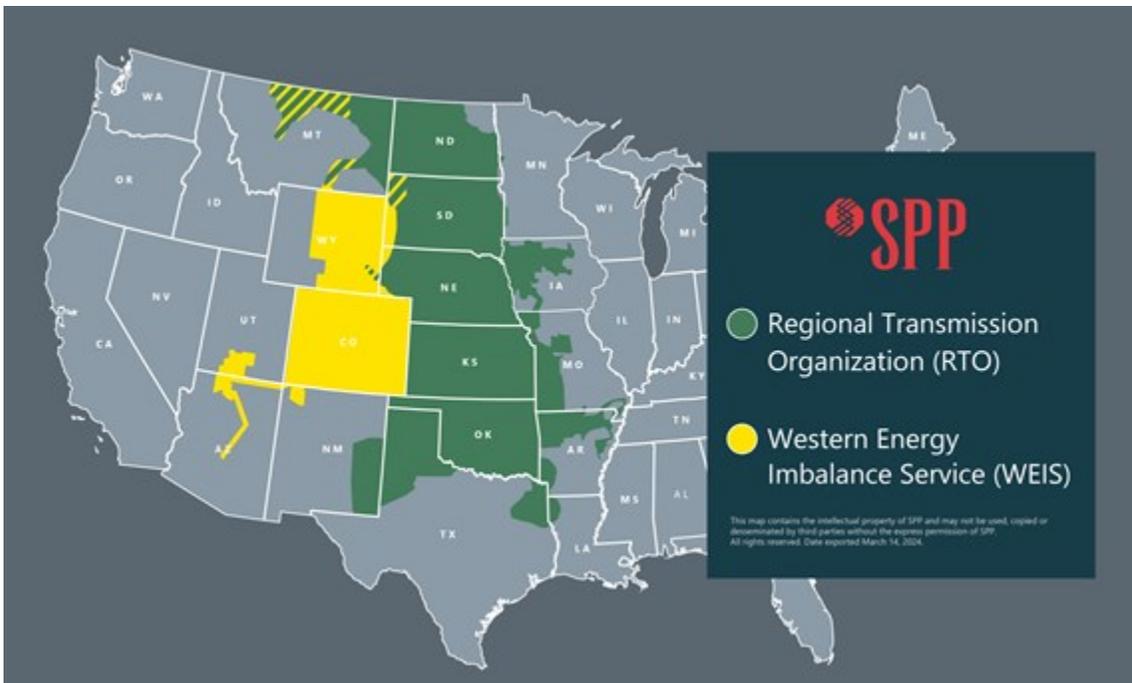
For more information about the Western Energy Imbalance Market see the Oregon Department of Energy's 2020 Biennial Energy Report.

Figure 7: Map of Western Energy Imbalance Market Participants¹⁵



*Avangrid office; generation-only BAA with distribution across multiple states. Map boundaries are approximate and for illustrative purposes only.

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Figure 8: Map of Western Energy Imbalance Service Market Participants¹⁹

As renewables grow to account for a larger share of electricity generation, the structure of the market may need to be reconsidered. In the current wholesale electricity market design (outlined above), generation resources with the lowest marginal cost^{iv} are deployed before generation resources with higher marginal costs. Renewables have extremely low or zero marginal cost since they have no fuel costs, which drives down the wholesale price and reduces the likelihood that on any given day or hour, resources with higher marginal costs will make a profit in the market or be used at all. If these resources with higher marginal costs are unable to cover their total costs in the long run with these low short-run prices and less frequent use, they may choose to shut down. In most competitive markets, for firms that cannot cover their costs with market prices, shutting down is economically beneficial as consumer demand can be met by other lower cost producers. However, the need to supply electricity in real-time makes the electricity market different from other competitive markets. These shutdowns may cause problems for reliability if these higher-cost resources are still needed during peak demand hours but are no longer available.⁹ As renewables become a larger share of the market, this market design and the zero marginal cost of renewables could discourage further investment in new generation, including renewable generation, possibly leading to long-term supply and reliability problems.¹⁰ Some U.S. RTO/ISOs have developed capacity markets to mitigate this problem. These capacity markets pay generation resources to be available for future peak demand days whether they are ultimately needed or not. However, capacity markets may not be a long-term solution as they can lead to overbuilding³⁰ or may succumb to the same problems as electricity markets with renewables similarly driving down prices.¹⁰ Instead of using a separate market, like a capacity market, some have proposed redesigning the wholesale electricity markets to address this issue directly.^{30,31} To learn more about this complex and evolving topic, see Paul Joskow's article

^{iv} As a reminder, the marginal cost refers to the cost of producing one additional MWh of electricity.

“Challenges for Wholesale Electricity Markets with Intermittent Renewable Generation at Scale: the US Experience.”³²

The effectiveness of the market can be limited by constraints of transmission. The electricity day-ahead market relies on transmission lines to physically carry the electricity generated by the sellers in one area to the electricity buyer and ultimate end-users in another area. Market participants can miss out on transactions that would have been economically advantageous to both entities if there is simply not enough transmission capacity between the potential buyer and seller to facilitate the trade. Sufficient transmission to connect market participants so that all cost-effective market transactions can be made is necessary for the full benefits of the market to be realized. While it is difficult to know how an electricity day-ahead market outside of an RTO/ISO may encourage or discourage the building of new transmission and/or generation resources in Oregon, it will be important to carefully consider where potential new resources are built to balance any possible market benefits with the needs of local communities.

Different state climate and carbon emission policies must be integrated into the market design.

The design of the day-ahead market in the simple form described here does not account for state level policies around climate and reducing carbon emissions, such as carbon prices or greenhouse gas emission reduction targets. In the case of Oregon, the design of the day-ahead market would need to allow for utilities to account for the greenhouse gas emissions from their purchased electricity so they can use these data in demonstrating compliance with the Oregon House Bill 2021 clean electricity targets.³³ Ideally, any method for counting greenhouse gas emissions would minimize the risk of double counting and also manage the problem of carbon leakage (“the phenomenon through which efforts to reduce emissions in one place simply shift emissions to another location or sector where they remain uncontrolled or uncounted”³⁴ resulting in no net reduction of GHG emissions). Determining a methodology that can overcome these challenges, however, is complex and the proposed markets in the west are still in the process of developing these methods with input from the states.

Benefits of wholesale electricity markets increase with a larger regional footprint. The organized day-ahead market is designed to optimize the use of the lowest cost generation resources over the set of resources available within the market. While markets can provide benefits regardless of their size, these benefits are reduced when the market is optimizing over a smaller pool of resources. Separate markets running simultaneously across different parts of a region will not efficiently use the lowest cost resources available over the entire region because these individual markets are only optimizing the use of resources within their own smaller market. Suppose, for example, that there were two markets in the west: one in the Southwest and one in the Northwest. Some days there may be an overabundance of solar electricity in the southwest market while in the northwest there is a lack of renewable supply such that demand must be met with more costly natural gas combustion turbines. On other days, the northwest may have an overabundance of hydro power while the sun is not shining in the southwest and demand must be met there with more costly natural gas-fired resources. If these two markets were merged, and assuming adequate transmission, each area could benefit from the renewables in the other region for times when their own regional renewables are not producing enough electricity to meet demand. Recent research further emphasizes the need for interregional dependence as electricity needs increase with greater extreme weather events, and

variable renewables account for a larger portion of generation resources.³⁵ In the West, the benefit is further enhanced by there being multiple time zones and weather patterns across the region. While bilateral transactions can still be used to exchange electricity across markets, the markets themselves will be less efficient with higher costs than a single market with the largest possible footprint.

As electricity markets develop in the region, it will be important to continue to monitor and evaluate these benefits and challenges.

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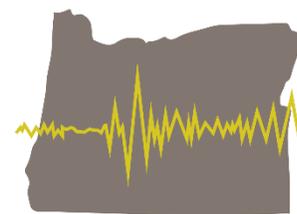
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Energy Resilience

Resilience is a term that is often heard across issues of public concern, but what does it mean in the context of energy? Energy resilience refers to the ability of energy systems, from production through delivery to end-users, to withstand and rapidly restore energy delivery following non-routine disruptions of severe impact or duration.^{1 2} These disruptions can be caused by natural hazards and physical or cyber-attacks on energy systems.



Energy Resilience vs. Energy Security

Energy resilience is a subset of energy security. Energy security encompasses efforts to ensure energy supply, affordability, accessibility, reliability, and resilience.³

Reliability vs. Resilience:

Reliability is the ability of energy systems to withstand and recover from *typical disruptions*.^{2 4} Typical disruptions could include average winter weather or branches falling on a powerline.

Resilience is the ability to withstand and recover from *nonroutine disruptions of severe impact or duration*. Examples of nonroutine disruptions of severe impact or duration include an ice storm lasting several days or a windstorm producing countywide impacts. Actions that strengthen resilience can also increase reliability.

Energy resilience is pursued from the national to the community level with differing emphases. The federal government’s energy resilience efforts put significant focus on increasing collaboration—internationally, across Tribes, states, and territories, and the public and private sectors. Utilities tend to focus on increasing the resilience of larger energy systems and infrastructure. Community-level resilience efforts, in contrast, typically focus on the end-users: ensuring public safety and welfare during nonroutine energy disruptions. This includes ensuring adequately fueled backup power generation and storage to provide energy to critical public service facilities such as hospitals, emergency response centers, and community resilience centers, as well as strengthening household resilience. At the state level, the State of Oregon pursues actions to increase resilience across both larger energy systems and within communities, and facilitates collaboration between all interested parties.



Learn more about backup power in ODOE’s 2022 Biennial Energy Report.

Community Resilience Centers

Community resilience centers are gathering places that provide essential services and resources for community members during disruptive events. Specific to energy resilience, these centers provide residents access to essential energy services such as heating and cooling, air filtration, and charging of essential devices like medical equipment or cell phones.

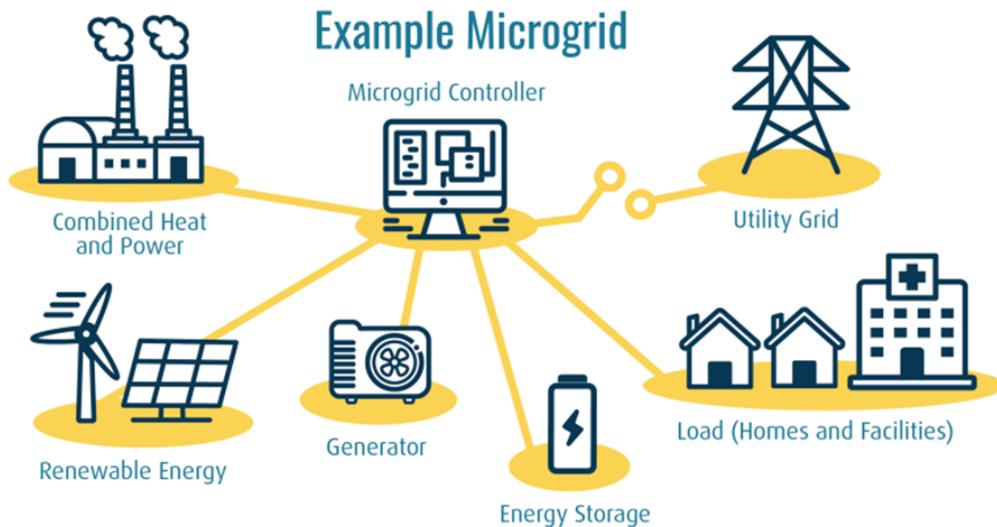


While there are variations in emphases among these different entities, there are two overarching commonalities across their energy resilience efforts:

- Increasing the ability to adapt to changing conditions and prepare for disruptions to reduce impact and speed recovery.
- Elevating equity: ensuring that the needs of those who are most vulnerable to energy disruptions are addressed.

Actions to strengthen energy resilience can occur across larger energy systems or at the community level. Examples of energy resilience actions for larger energy systems, i.e. electricity, liquid fuels, and natural gas, include: upgrading older infrastructure with more durable and resilient equipment; undergrounding power lines to increase their ability to withstand a variety of extreme weather events; using drones to evaluate energy infrastructure to prevent issues via early detection and enable speedier recovery after events; and system segmentation to isolate impacted areas and allow unaffected areas to continue providing energy services (see the Transmission Options 101 in this report). Actions at the community level can look like increasing gasoline, diesel, and aviation fuel storage, installing seismically certified generators, and developing energy generation and storage infrastructure such as microgrids (Figure 1), to support critical public services and/or household resilience. Additionally, actions to increase energy efficiency can support resilience by reducing the energy demand that must be met during energy disruptions.

Figure 1: Example of a Microgrid and Its Components⁵



Why Does Energy Resilience Matter?

Fundamentally, energy resilience matters because access to energy matters. Energy systems are the backbone for essential services such as life safety; heating, cooling, and air filtration; communications and information systems; transportation; production of food and goods; and medical care. These services are important under normal conditions and critical during emergencies.



September 2020 wildfire damage in Detroit, OR.

The need to bolster energy resilience has become more evident in recent years due to an increase in the frequency and severity of threats and disruptions to energy systems. The occurrence and intensity of extreme weather events, such as winter storms or wildfires, has increased in frequency, scale, and duration, with a corresponding effect on energy disruptions (see this report’s Climate Change Effects on Energy Systems 101 for more information).^{6,7} Likewise, there has been a rise in public safety power shutoffs, during which utilities preventatively shut off electricity due to increased incidents of high wildfire risk. The incidence of cybersecurity attacks has also increased in recent years, as has the vulnerability of energy systems due to increased use of

digital technologies.⁸ Finally, a Cascadia Subduction Zone Earthquake poses a threat to Oregon’s energy systems of nearly unparalleled severity.⁹ Though this threat has long existed, in recent decades there have been increased efforts to raise public awareness and create resilient systems to prepare for the catastrophic earthquake.¹⁰

Building energy resilience across larger energy systems and in communities is also critical to help ensure equitable protection from energy disruptions. Some groups are more vulnerable to energy disruptions than others, and those disruptions can also compound other vulnerabilities and inequities that groups experience. For instance, energy disruptions during an extreme heat or cold event or a wildfire with unhealthy air quality can pose a greater risk for individuals with certain medical conditions. Similarly, individuals living in areas with significant urban heat island effects,ⁱ who are more likely to be low-income or People of Color, face elevated risk during extreme heat events;^{12,13} this risk is further amplified during an energy disruption.

During the 2021 heat dome event in Portland, 61 percent of the individuals who lost their lives in Multnomah County were living in an urban heat island area, and the majority did not have working air conditioning.¹³ Individuals with lower incomes may have less financial ability to strengthen household resilience via backup power or efficiency measures — and their homes may also have less efficient weatherization and appliances to begin with.¹⁴ Therefore, efforts to: 1) increase larger energy systems’ ability to withstand nonroutine disruptions and recover quickly, 2) ensure that critical public services function during disruptions to larger systems, 3) provide access to community resilience locations, and 4) increase household resilience, are vital to helping protect vulnerable populations and reduce inequitable impacts from disruptions. Ensuring equity in energy resilience efforts goes hand in hand with the opportunities the broader clean energy transition offers to rectify past inequities and create a more equitable path moving forward.

ⁱ Heat islands occur in urban areas where there is a high density of roads and buildings and limited green space, resulting in increased absorption and remittance of heat. Temperatures in urban heat islands are 1–7°F higher than surrounding areas during the day and 2–5°F higher at night.¹¹

Energy Resilience Efforts

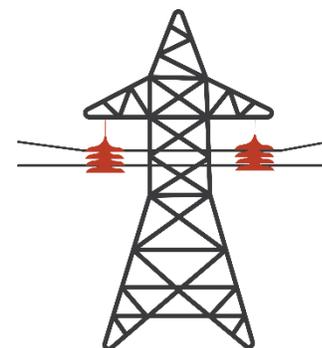
Many organizations, from the federal government to community groups, are working to strengthen energy resilience. While not a comprehensive of all initiatives and efforts, the information below helps illustrate some of the work Tribal Nations, the federal government, the State of Oregon, utilities, and communities are doing to bolster energy resilience. Building partnerships and advancing equity are at the heart of much of this work.

Tribes

Oregon's nine federally recognized Tribes are engaged in planning and project development to bolster energy resilience. For instance, in 2022, the Confederated Tribes of the Umatilla Indian Reservation completed a Strategic Energy Plan.¹⁵ Increasing household resilience through renewable energy generation and energy efficiency is a central component of the plan. The Coquille Indian Tribe is in the process of developing a Resilience Management Plan, which will include an Energy Assessment and strategies that explore potential renewable energy options as a pathway to supporting the Tribe in becoming energy sovereign.¹⁶

In terms of project development, the Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians are developing a solar and battery storage system to provide backup power to Tribal buildings during outages, with support from the Oregon Department of Energy's Community Renewable Energy Grant Program.¹⁷ In 2023, the Confederated Tribes of Warm Springs, in partnership with Portland General Electric, received a \$250 million grant from the U.S.

Department of Energy's Grid Resilience and Innovation Partnerships Program to expand and increase the resilience of the Bethel Round Butte Transmission Line, which is a critical piece of Oregon's electricity infrastructure.¹⁸ The Confederated Tribes of Warm Springs, the Cow Creek Band of Umpqua Tribe of Indians, Coquille Indian Tribe, Burns Paiute Tribe, and Confederated Tribes of the Umatilla Indian Reservation have received U.S. DOE Grid Resilience State and Tribal Formula grants.¹⁹ The Tribes will award funds from these grants to eligible entities for grid resilience improvements.



Federal Government

Federal efforts include programs to support energy resilience planning and project implementation, such as funding for [state energy security plan](#) development and the [Grid Resilience State and Tribal Formula Grant](#), [Grid Resilience and Innovation Partnerships](#), [Home Efficiency Rebate](#), [Home Electrification and Appliance Rebate](#), and [Energy Efficiency and Conservation Block Grant](#) programs. These federal grant programs fall under the [Justice 40 Initiative](#), which specifies that 40 percent of federal grant investments flow to federally recognized Tribes, including Alaska Native Villages, and to disadvantaged communities that are identified using the Climate & Economic Justice Screening tool. The federal government also invests in research, training, and tool development to support energy resilience efforts nationally as well as for Tribes, states, and territories— such as the Department of Energy's recent investment of \$45 million to develop new tools to address cybersecurity threats.²⁰ The federal government fosters opportunities for collaboration across Tribes, states, territories, and the public and private sectors through the Electricity Subsector Coordinating Council and the Oil and

Natural Gas Subsector Coordinating Council, in addition to supporting the work of groups such as the National Association of State Energy Officials and the National Association of Regulatory Utility Commissioners.

State of Oregon

The State of Oregon is engaged in a variety of efforts to increase energy resilience. ODOE has developed the [Oregon Energy Security Plan](#), which includes a risk assessment of the state's liquid fuels, natural gas, and electricity systems, and mitigation measures to address risks and increase resilience. ODOE is also developing the [Oregon Energy Strategy](#), which will present pathways to achieve the state's energy goals, including bolstering resilience. The Oregon Department of Environmental Quality is administering the [Fuel Tanks Seismic Stability Program](#), which evaluates the earthquake vulnerability of large-capacity oil and fuel storage and distribution facilities in Lane, Multnomah, and Columbia counties and requires the facilities to develop plans to minimize risk of damage to employees, surrounding communities, and the environment. The Oregon Public Utility Commission oversees all utilities in Oregon in matters of safety and in recent years has increased focus on energy resilience such as convening utilities and interested parties to learn from disruptive events, with a particular focus on wildfire mitigation. As the economic regulator of the state's investor-owned electric and natural gas utilities, OPUC ensures that the investor-owned utilities have enough resources to implement resilience measures such as vegetation management and hardening of infrastructure.



Learn more about the [Oregon Energy Security Plan](#) on ODOE's website.

The State of Oregon also has a variety of grant programs that support energy resilience. The [Oregon Department of Energy](#) is currently administering several of the aforementioned federal grant programs: Grid Resilience, Solar for All, Home Energy Rebates, and Energy Efficiency and Conservation Block Grants. ODOE also runs several state-created grant programs that support energy resilience projects and planning: the Community Renewable Energy Grant Program, Oregon Solar + Storage Rebate Program, and the County Energy Resilience Program. The Oregon Department of Human Services is administering a [Resilience Hubs and Networks grant program](#) that supports the development of community resilience centers. The Oregon Department of Emergency Management administers [several state and federally funded grant programs](#) that have co-benefits for energy resilience, such as the Emergency Management Performance Grant Program, State Preparedness and Incident Response Equipment Grant Program, Hazard Mitigation Grant Program, Building Resilient Infrastructure and Communities, and State and Local Cybersecurity Grant Programs.

For a more in-depth discussion of Oregon's resilience actions taken in recent years and planned for the future, see sections 10 and 11 of the [Oregon Energy Security Plan](#).

Utilities

Utility actions to strengthen resilience include vegetation management, reconductoring, asset replacement, undergrounding equipment, installing smart grid technologies, and developing or supporting energy resilience projects like microgrids. For instance, in 2020 Portland General Electric partnered with the City of Beaverton to help design a robust backup power system for its Public Safety Center that houses its emergency management and police departments.²¹ The backup power

system includes a generator, solar energy production, and a battery storage system and can support the building throughout prolonged power outages. Utilities also help educate their customers about household resilience and some provide funding opportunities to help support these actions. For example, the Eugene Water & Electric Board offers its residential and commercial customers the Backup Power Program, which offers zero to low-interest loans for backup power systems like generators or battery storage.²² Pacific Power offers a rebate program that supports the purchase of backup power systems for customers in their Medical Certificate Program, who face vulnerabilities to loss of power due to their medical conditions.²³

Cities, Counties, and Other Organizations

Cities, counties, and community organizations are also engaged in planning, project implementation, and education for energy resilience. For example, Hood River and Wallowa counties have developed countywide energy plans with energy resilience components.^{24 25} These counties are also pursuing efforts to build priority resilience projects, such as local microgrids and solar generation and storage, and both counties have utilized ODOE's Community Renewable Energy Grant Program to complete detailed project implementation planning.¹⁷ With the launch of ODOE's County Energy Resilience Program in spring 2024, there will soon be more county energy resilience plans in place across the state. Partnerships among local government entities, local community organizations, and other organizations such as economic development districts and statewide energy-focused nonprofits — for example, Sustainable Northwest and Energy Trust of Oregon, among others — are critical to helping communities achieve their energy resilience goals.

Williams & Russell Project

The [Williams & Russell Project](#), under development in Northeast Portland's Albina neighborhood, centers equity and energy resilience. The development site was formerly the commercial center of the Black community in Albina from the 1940s-1960s, but was condemned in the 1970s and purchased by Legacy Hospital as part of Portland's urban renewal program.²⁶ The project seeks to restore and reclaim the lot as a vibrant part of the neighborhood; the development will provide 85 affordable apartment units, 20 homes for purchase, and a 30,000 square foot Black business hub, with commercial and office space for Black-owned businesses and community organizations. The building will feature energy efficient construction, solar panels, and energy storage — ensuring resilience during energy disruptions — in addition to other sustainable features.²⁷ Partners involved in the project include: the Williams and Russell CDC, Prosper Portland, Portland Community Reinvestment Initiatives, Adre, Legacy Health Services, Portland Housing Bureau, the City of Portland, and Energy Trust of Oregon, among others.^{27 28}



Together these efforts are paving the way to increase the resilience of Oregon’s energy infrastructure and communities. Moving forward, these entities will continue to put plans, programs, and projects in place to bolster energy resilience while continuing to adapt to the changing landscape of energy in Oregon.

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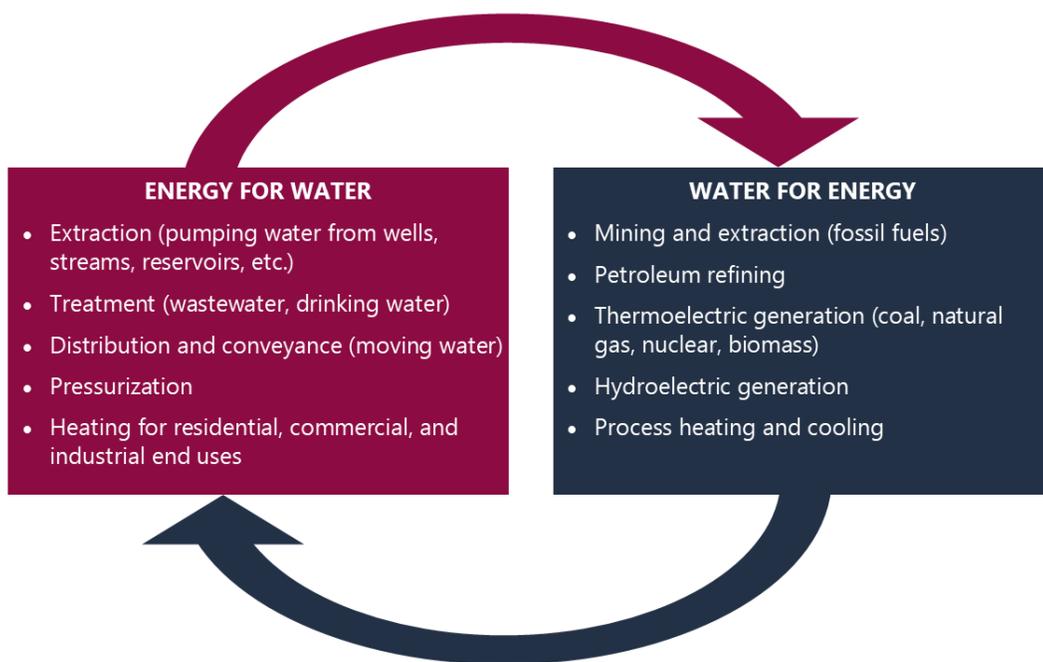
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Water and Energy Nexus

Water and energy systems today are interdependent. Water is used at multiple stages of energy production, and energy is needed to extract, clean, heat or cool, and move water to where it’s used. While they are interdependent, energy and water systems have been developed, managed, and regulated independently.¹ Population shifts, droughts, and climate concerns are driving more interest in the relationship between energy and water. Although this Energy 101 does not provide an exhaustive list, it will explore some major interdependencies and provide a foundation for further exploration.

Figure 1: Water and Energy Interdependencies



Water Used in Energy Production

Water is used in many aspects of energy production, often for cooling, mining and extraction, creating steam for process heat or on-site electricity generation, and for hydroelectric power. How the water is used has broad implications for water quality, availability of water, and effects on the environmental, cultural resources, and local, state, national, and global economies.

In petroleum production, water is needed for cooling and lubricating during drilling. Energy is required to pump water from a local source or to truck water to a site.

Wastewater is also typically *produced* during crude oil extraction and may be treated for disposal or possible reuse, often on site. Often, wastewater generated from crude oil extraction and production must be transported by truck to disposal sites where it is treated and then injected deep underground.³

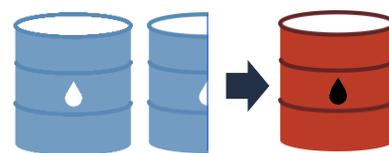


Learn more about Oregon’s oil sources in ODOE’s 2020 Biennial Energy Report.

Coal mining needs water to extract, wash, and process the coal ore. Water is also used in underground mines for cooling and reducing fire and explosion risk.

Conventional natural gas production uses relatively small amounts of water, but typically produces wastewater. Natural gas is extracted from deep reservoirs through wells drilled below groundwater levels. Wastewater is usually reinjected back into the well, typically below groundwater, to be stored.⁴ ⁵ ⁶ More recently, natural gas is often extracted using hydraulic fracturing, or fracking, which unlocks oil or gas reserves by injecting water, sand, and/or chemicals at high pressure into a well to expand existing fissures in bedrock. This process has been shown to pose risks to water resources, both in terms of water quality and quantity.² The amount of water required for natural gas production varies widely depending on the size and nature of the well and whether the water produced is recycled.⁶

Water is also used in petroleum refining for cooling, steam generation, and fire protection. Refineries use up to 1.5 barrelsⁱ of water to process one barrel of crude oil.⁷ Refineries use two types of cooling systems: once-through systems where water is extracted, used for cooling, and then returned to the environment, or recirculating closed loop systems, where water is reused within the system.⁷ Once-through systems require significantly more water.



Thermoelectric power plants, including coal, natural gas, nuclear, and biomass, generate electricity by producing heat that is used to create steam, which in turn drives a turbine connected to a generator. Not only is water required to create the steam, but it is also used to recondense the steam back into water after leaving the turbine.

Natural gas plants, which are the most common type of thermoelectric generation in Oregon, typically use closed-cycle water cooling systems.⁸ Natural gas plants use wet-recirculating systems that cool down the water that is used to create steam. This closed system only provides cooling to the steam pipes to help recondense that water.⁹ Small amounts of water in these cooling systems are lost to evaporation during the cooling action and when the water is replaced (after multiple cooling cycles). Some newer plants — usually those built after 2000 — use dry cooling systems, which require little to no water. Dry cooling systems have high capital costs and use relatively more energy, resulting in lower overall plant efficiency.¹⁰

Coal and nuclear generators typically use a once-through cooling process, which uses much more water for cooling because that water is used only once before being discharged. The cooling water is first sent to a pond equipped with cleaning and/or filtering devices to be cooled down before final discharge back into the local water source. Local water sources include rivers, lakes, or the ocean. Some water is used to create steam, but most is used for cooling and recondensing the steam once it has passed through the turbine. Both the water for steam and for cooling are circulated through separate pipes at the facility, and are ultimately discharged back into the environment.⁹ Water used for steam must also be periodically purged and replenished.⁹ While there are no coal or nuclear generation facilities in Oregon, some of the electricity sold to Oregon consumers is imported from these types of resources in other western states.¹¹

ⁱ A “barrel” of liquid is equivalent to 42 gallons.

The amount of water withdrawn varies by electric generation type. Calculating the number of gallons of water per megawatt hour of generation, or water-withdrawal intensity, allows comparisons across generation types and timespans.¹² According to the U.S. Energy Information Administration, in 2021, the water-withdrawal intensity for the average coal plant was 19,185 gallons per MWh, while a natural gas plantⁱⁱ averaged 2,803 gallons per MWh, or 85 percent less water use than coal power.⁸

19,185

Gallons of water per megawatt hour of generation.



2,803

Gallons of water per megawatt hour of generation.



Water-withdrawal intensity in U.S. power generation has declined as a result of decreasing coal-fired generation and increasing natural gas, wind, and solar generation.¹² The amount of water used per unit of electric generation in the U.S. has declined from 15,100 gallons per MWh in 2014¹⁴ to 11,595 gallons per MWh in 2021, a 23 percent drop.¹² Wind and solar don't require water for cooling, but do use water for construction, as well as for cleaning wind turbine blades and solar panels. Oregon's electricity resource mix is seeing an increase in renewable energy sources like wind and solar and fewer thermoelectric generators.

In the Pacific Northwest, the most prominent intersection of energy and water is the region's hydropower system. About 40 percent of electricity used in Oregon comes from hydroelectric dams in the Columbia River basin.¹¹ Hydroelectric power generation is not considered a consumptive use of water because water flowing through the turbines to generate electricity is still available for other uses. However, some water impounded behind a dam is lost to evaporation and seepage.¹⁵ Total hydroelectric generation varies directly with precipitation – it is higher in wet and snowy years and

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



lower in dry years. Mountain snowpack, especially in the upper Columbia Basin, acts as a seasonal battery with spring thawing adding to river runoff flows that support increased hydroelectric generation in late spring and early summer.¹⁶ For more on the seasonal variability and shifting availability of hydropower related to climate, see the Climate Change Effects on Energy Systems 101 in this report.

Dams in the Pacific Northwest continue to play a vital role in energy and water needs for Oregon and the region. Hydropower not only provides power to the grid but can also help support increasing amounts of variable renewable resources because it can be throttled up or down to balance electricity supply as wind and solar naturally wax and wane. Many of the dams also support agriculture, flood control, shipping, and recreation.

ⁱⁱ Value is for a combined cycle natural gas plant, which use more water than simple cycle natural gas plants, but are significantly more energy efficient.¹³

Energy and Water Resource Decisions in the Pacific Northwest

The Columbia River and its many tributaries are central to the Native cultures of the Pacific Northwest, who have been living in this area for time immemorial. In the 1930s – 1950s, the United States government developed multiple dams in the region. Fishing and gathering sites like Celilo Falls near The Dalles in Oregon and Kettle Falls in Washington were flooded by dam construction. The building of the dams not only destroyed these and other Tribal fishing resources but have also contributed to declining fish runs in the region. At the same time, Pacific Northwest hydroelectric dams also ushered in the development of high-tech industries, provided low-cost electricity to rural areas, and supplied water to irrigate large swaths of land to support agriculture. Today, energy conversations about the role of dams in the future have implications for people and communities that rely on the river for cultural practices, food, shipping, jobs, flood control, and clean power generation. Decision-makers will need to grapple with the benefits and impacts as Tribal and state governments work to meet future energy and water needs. For more information about the history of energy and its effects on water, see ODOE’s [Energy History Timeline](#).



The cost and negative effects on local environmental and cultural resources make it unlikely that new major hydroelectric dams will be built. The Northwest Power and Conservation Council’s Columbia River Basin Fish and Wildlife Program identified “protected areas” where new hydropower development would have unacceptable risks of loss to fish and wildlife.¹⁷ Federal relicensing of existing power plants may also require adding or improving fish passage and other measures that can add considerable capital costs. Adding hydroelectric generation to non-generating dams typically requires adding fish passage and fish screens to water intakes, also adding to the cost.¹⁸

Although new hydropower dam construction is unlikely, smaller turbines can be installed inside new or existing water pipes to produce electricity. Although much smaller than large dam hydropower, these can help serve very localized energy needs, including energy for irrigation or to support operations at municipal water facilities.

Federal Energy Regulatory Commission licensing says that “a small conduit hydroelectric facility up to 40 MW using a man-made conduit operated primarily for non-hydroelectric purposes may be eligible for a conduit exemption.”¹⁹ Federal regulation defines conduit as “any tunnel, canal, pipeline, aqueduct, flume, ditch, or similar manmade water conveyance that is operated for the distribution of water for agricultural, municipal, or industrial consumption and not primarily for the generation of electricity.”²⁰ Irrigation districts in Oregon and throughout the West use that exemption to license small (typically less than 5 MW) hydroelectric plants in conjunction with piping irrigation distribution canals, which saves water lost to evaporation and seepage. Piping distribution canals may also provide pressurized water delivery for some laterals (laterals come off an irrigation distribution canal or pipeline laterally to deliver water to farms or ranches), which can save farmers and ranchers energy and money. New projects may also require mitigation or adding fish screens at the point of diversion.^{21 22}

Water Considerations in Constructing Energy Projects

When siting an energy production facility or energy-intensive project, access to both adequate energy and water must be considered by the developer. For example, some water is required during construction of wind and solar facilities. Some areas of the state are “ground water limited areas” or “critical ground water areas.” In these instances, water is typically obtained from the closest city that has excess capacity and must be trucked in daily.



For energy projects requiring water for operations, access to water for routine operations also must be considered. For example, hydrogen electrolyzers, which split water atoms into hydrogen and oxygen, require water as a feedstock. It takes about four gallons of water to produce one kilogram of hydrogen.²³ Natural gas electricity generators need water to produce the steam that spins the turbines. Solar farms, which do not require water to generate electricity, occasionally need water to clean the panels of dirt and debris.

Energy to Produce, Convey, and Treat Water

Energy is necessary to deliver water for human consumption, irrigation, and industrial applications. Energy is often needed to power pumps to extract water from sources, convey water, and to deliver it at high pressure. Energy is also used to heat water for use in residential, commercial, and industrial facilities, and required to clean wastewater before it is discharged or for reuse.¹

Electricity is the most common form of energy used for water-related purposes. A 2017 Congressional Research Service report estimated that 4 percent of the nation’s electricity generation supports water-related activities. Regional differences can be significant; as much as 19 percent of California’s electricity consumption is used to clean, produce, and convey water.²⁴

Energy is used to pump water out of wells or to the tops of buildings, as well as to distribute and deliver it to residences and businesses. The higher the water must be pumped; the more energy is needed. Energy is also used in residential and commercial buildings to move water to where it is used, to provide hot water, and to heat and cool buildings. Energy is also needed for water pressurization, such as for various cleaning operations like pressure washing and for irrigation, and for industrial production processes and cleaning tasks.

Heating water consumes a lot of energy. For example, water heaters account for about 20 percent of a home’s total energy use and about 5 percent for commercial buildings.^{25 26}

Energy is used to treat water and remove contaminants for clean drinking water, in wastewater treatment plants, and in businesses.²⁷ Water treatment is typically energy intensive. Drinking water and wastewater systems combined use approximately 2 percent of total annual energy used in the U.S.²⁸ According to the U.S. Department of Energy, \$2 billion is spent annually on water treatment, and electricity can be 25-40 percent of a wastewater treatment plant’s bill, and 15-30 percent of a municipality’s energy bill.²⁹

Data Centers at the Intersection of Energy and Water

Data centers are large facilities with computer servers that support the applications and data that are the backbone of the internet. They host social media, cloud data storage, applications, games, and more recently, artificial intelligence platforms. The demand for data centers has grown along with the internet, and AI is pushing that growth even faster. Data centers require large amounts of electric power for the servers and water to cool the large amounts of heat they produce.



Data centers are often sited where power is cheap and abundant, and to achieve corporate climate goals, owners often look for electricity with lower greenhouse gas emissions.³⁰ Many of Oregon's rural utilities meet these objectives. Data centers are increasingly being built in rural areas, especially in eastern Oregon, where land also tends to be less expensive than in larger metropolitan areas. This places a higher pressure on water in a part of the state that often has limited water resources, and where drought conditions regularly occur.

Data centers' water requirements may compete with other demands and create constraints, or add to existing constraints, on local electricity and water needs. A 2024 study from Virginia Tech found that data centers rank in the top 10 water-consuming industrial or commercial industries in the U.S. The same study found that 20 percent of data centers "draw water from moderately to highly stressed watersheds in the western U.S."³¹ In 2021, Google's data center in The Dalles consumed 29 percent of the town's water supply.³² Environmental advocates are concerned that this high degree of water consumption might reduce water supply for nearby wetlands and rivers.³⁰ Water resources can affect plant life, fish life, wildlife, and local communities.³²

Water, Energy, and Climate

Reducing water consumption reduces greenhouse gas emissions that would otherwise have been emitted by the energy used to provide the water. More water efficient technologies and practices will also help water and energy resource providers adapt to a drier climate.³³

The Sixth Oregon Climate Assessment found that droughts are expected to become more frequent and severe in the state.³⁴ Drought conditions limit local water availability, which means communities will more frequently need to make choices on how to best use the limited resources. This could limit the types of economic growth and development in Oregon, including the development of more water-intensive energy resources.

Just as energy efficiency and conservation efforts reduce overall need for energy, water conservation efforts can do the same for water resources, and because energy and water consumption often go hand-in-hand, conserving one can often help conserve the other. For instance, high efficiency appliances, such as dishwashers, washing machines, and water heaters use less water to perform the same task, which usually makes them more energy efficient. Using graywater – water collected from

bathtubs, sinks, and washing machines – for irrigation, not only conserves water, but also saves on the energy that would otherwise have been needed to collect and treat that water.

Agriculture irrigation is the largest use of water in Oregon, and most irrigation is powered by electricity. Persistent drought has exacerbated overextraction of water in some basins creating the need to access deeper groundwater reserves. In turn, this requires more energy to pump the water from deeper depths as the water table drops. Piping open irrigation delivery canals saves water otherwise lost to seepage and evaporation, which benefits fish and wildlife habitat. It also allows pressurized water delivery for some producers which reduces the energy required for irrigation related pumping. If in-conduit hydroelectric generation is installed along with the pipes, the power produced can offset additional pumping-related energy and contribute to local energy resiliency.³⁵

Water conservation efforts can help reduce greenhouse gas emissions and help farmers adapt to a changing climate. This is especially beneficial in parts of eastern Oregon, where droughts and drier conditions restrict the amount of water available.^{16,36} Regenerative agriculture stores carbon in the soil and can reduce irrigation water use and typically reduces direct and indirect energy from lower fertilizer and pesticide use.^{37,38}

See the Oregon Water Resources Department’s Integrated Water Resources Strategy for more information on opportunities to promote water and energy savings.

Learn more about conduit hydropower in ODOE’s 2020 Biennial Energy Report.



Some Oregon communities are planning for water and energy resilience together, as an adaptation to the changing climate and concerns about energy reliability and water availability. Table 1 provides a list of common energy conservation techniques and efficiency actions that Oregonians, their communities, and businesses can use to reduce water and energy consumption.

Table 1: Water and Energy Conservation and Efficiency Actions

	Conservation Actions	Efficiency
Indoors	<ul style="list-style-type: none"> • Turn faucets off when brushing teeth or shaving • Wash fruits and vegetables in tub of water • Take shorter showers • Check for leaks and monitor water bill 	<ul style="list-style-type: none"> • Use EPA WaterSense fixtures, especially shower, low flow or dual-flush toilets, dishwashers, and washing machines
Outdoors	<ul style="list-style-type: none"> • Reduce or eliminate grass and plant drought-tolerant landscaping (no long-term watering required) • Sweep or use a bucket instead of hosing off sidewalks and driveways 	<ul style="list-style-type: none"> • Install rain-sensors and soil moisture sensors • Use drip irrigation vs spray for lawn and landscaping watering

Conclusion

Today's modern life requires energy and water, and the availability and costs of both are highly intertwined. The Oregon Water Resources Department plans to publish an updated [Integrated Water Resources Strategy](#) in 2025, which discusses some of these interdependencies and includes a more complete discussion of water infrastructure and planning needs — many of which also require energy resources.

ODOE is currently developing an [Oregon Energy Strategy](#), which will assess different pathways the state can take toward a more resilient and sustainable clean energy transition, including how these options affect land and water use. Both reports will facilitate thoughtful consideration of the interdependencies between water and energy choices, and how policy options concerning one will have implications for the other. Understanding the trade-offs of these policy choices is key to making informed energy and water management choices.

ODOE's Community Renewable Energy Grant Program has awarded several communities with water- and energy-related grants, including nine in both 2023 and 2024.³⁹

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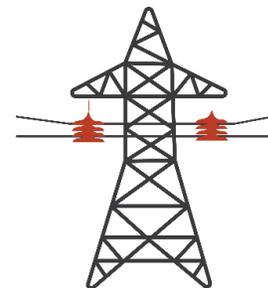
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Alternatives to New Transmission

Studies have shown that expanding transmission infrastructure is critical to achieving Oregon’s clean energy future,¹ but it can be difficult, time-consuming, and expensive to build. Identifying ways to reduce the need for transmission expansion can provide many benefits. Avoiding or delaying transmission development can reduce costs for electricity providers and customers. Alternative investments in local energy resources can support well-paying jobs and improved energy resilience in local communities. Less transmission development can also mean fewer negative effects on environmental, cultural, and community resources. In addition, it can reduce the risk of wildfires ignited by grid equipment and lower ratepayer costs for wildfire monitoring and mitigation efforts.



National, regional, and utility-specific studies consistently indicate that substantially more transmission capacity is needed than what exists today for the grid to reliably meet increasing electricity loads and make progress on clean energy and climate commitments, while also contending with growing extreme weather events driven by climate change.

Expanding transmission capacity has become one of the key issues for the clean energy transition, and it will require electricity planners and providers to bring to bear numerous innovative strategies. The Connected West study released in September 2024 looked at transmission needs for the western U.S. over the next 20 years and found that a significant portion of the needed transmission capacity could be met by enhancing existing transmission lines.² This Energy 101 identifies strategies that can help offset some, but not all, of the need for new transmission lines, including: leveraging diverse loads and resources, repurposing and expanding the capacity of existing transmission corridors, deploying local energy resources, and deploying grid enhancing technologies.³



Transmission towers at the Bonneville Dam.

The traditional way grid planners have met load growth is to build new transmission lines.⁴ Most of the transmission system in the Pacific Northwest was built to move abundant hydropower around the region, including delivering electricity to rural areas. Most of the regional transmission system was built concurrent with the construction of the federal hydropower system from the 1930s through the 1970s.⁵ This initial investment in power lines has served as the backbone of the region’s transmission system, with the federal Bonneville Power Administration owning and operating 75 percent of the region’s high-voltage lines.⁶

Large investments in energy efficiency in the Pacific Northwest have reduced load growth, significantly offsetting the need for new electricity generation and new transmission lines over the last three decades. These immensely successful energy efficiency programs kept electricity consumption in the region relatively flat from the 1990s until 2020, despite growth in Oregon’s population and economy.⁷

Electricity demand forecasts in recent years are changing, with large amounts of load growth expected due to economic growth in high-tech manufacturing, emerging development of data centers, increased use of electric heating and cooling as more extreme weather patterns emerge, and efforts to encourage more electricity-based technologies that can help reduce greenhouse gas emissions.⁸ Power planning studies consistently estimate the buildout of new renewable and transmission capacity needed across the western power grid is in the order of hundreds of gigawatts by 2040.^{i 9} For context, the current size of the entire Pacific Northwest electricity system is roughly 73 GW.¹⁰

Primary Challenges Facing Transmission Expansion

Planning, permitting, and constructing new transmission lines can be expensive, time-consuming, and have effects on ratepayers, the environment, natural resources, cultural resources, and local communities. For these reasons, the transmission build-out needed to meet increasing demand may be difficult to achieve.

There are three primary challenges facing the expansion of the transmission system in the Pacific Northwest:

1. **High capital costs:** Transmission infrastructure is very capital intensive and can cost between \$2 to nearly \$7 million per mile to construct, depending on the voltage. A 100-mile line would cost several hundreds of millions of dollars to construct.¹¹
2. **Long-lead times:** Planning, permitting, and construction of a significant transmission project is complex and it can take 10 years or longer for a project to become operational.^{12 13}
3. **Potential effects:** Constructing transmission projects affects the environment, natural resources, cultural resources, and local communities. Avoiding, minimizing, and mitigating potential impacts is necessary and adds to project risk, complexity, costs, and time.

Options to Alleviate the Need for Transmission Expansion

There are technologies and strategies that can reduce the need to build new transmission lines. Four options are discussed here:

1. Leveraging existing generation resources more effectively.
2. Repurposing and expanding the capacity of existing transmission corridors.
3. Leveraging the use of local energy resources.
4. Using grid enhancing technologies.

This section will cover these options at a high level and describe some of the benefits and challenges for each.

ⁱ 1 gigawatt (GW) = 1,000 (MW). The large Bonneville Dam east of Portland is roughly 1 GW.

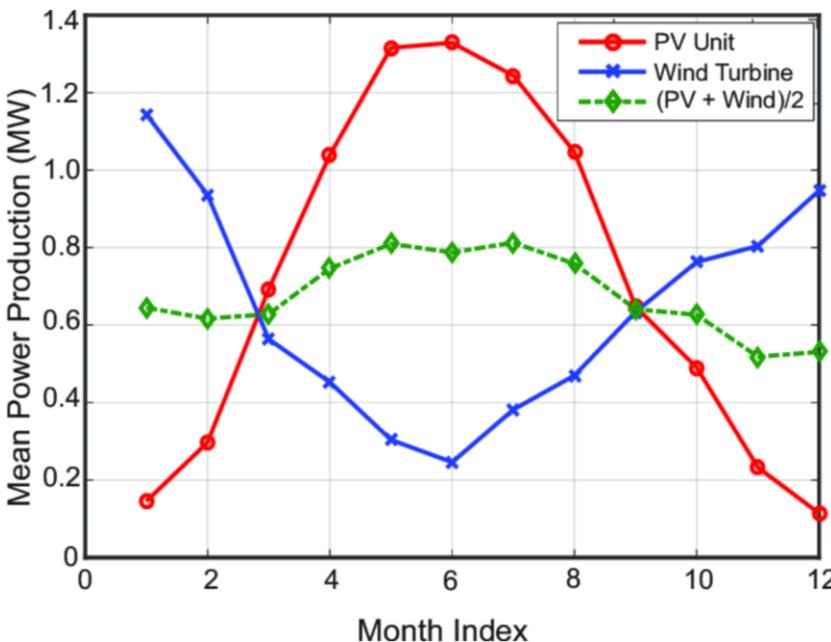
Leveraging Existing Generation Resources More Effectively

Complementary Loads and Resources

When grid operators have access to a wide array of different generating facilities, energy storage options, and loads, they have more options to match supply and demand in ways that get the most out of the entire existing transmission system.¹⁴

Wind and solar can be complementary resources because they can generate electricity at complementary times. An example of this is shown in Figure 1. The red line represents solar, generating the most during the summer months, and the blue line represents land-based wind, generating the most in winter months. The green line represents the average electricity generated by both, which is much more consistent than either one on their own.¹⁵ Complementarity can exist at different timescales, including seasonally, daily, or even hourly.

Figure 1: Comparison of Monthly Electricity Production from Wind and Solar¹⁶



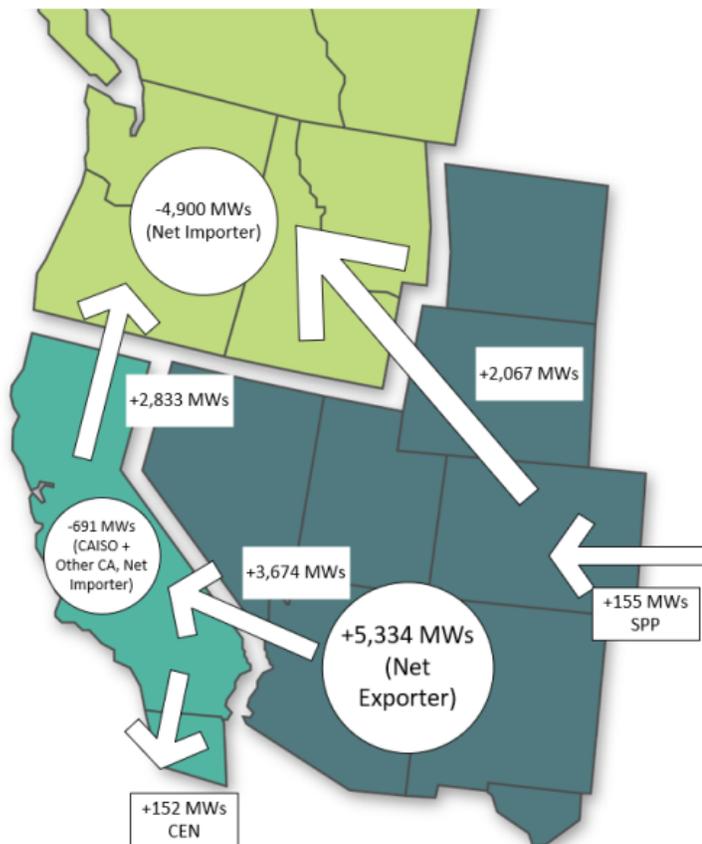
This complementarity between wind and solar reduces the total number of generation resources that need to be connected to the grid to meet load, which in turn reduces the need for more transmission.^{17 18} In other words, if a utility were to build only solar projects or only wind projects, it would need to build more of one of those technologies to meet load than if it were to build a mix of solar and wind. More projects likely means more need for transmission to connect those projects. In practice, utilities build a diverse group of resources – and are increasingly including battery storage – to help balance load and generation.

Increasing grid operators' access to broader geographic areas provides them with more options for sharing and leveraging complementary loads and generating resources. If grid operators have access to very large geographic footprints, the grid can be "bigger than the weather," meaning when local weather systems challenge local grid operators' ability to balance loads and resources in one area, grid operators can keep the lights on by accessing loads and resources in other areas unaffected by

the local weather. In other words, if sufficient generating capacity in other areas already exists, increasing access to these other areas can reduce the overall need for new transmission lines to connect new resources in any one particular area.¹⁹

An example of this is when winter temperatures are cold in the Pacific Northwest and mild in the Desert Southwest, electricity can be imported from the southwest to meet northwest load, rather than expanding transmission capacity to add new generation in the northwest. Figure 2 shows the general flow of power across the West into the Pacific Northwest during the multi-day 2024 cold snap event. Imports from the Southwest and the Intermountain Region, which were not experiencing the same degree of cold weather, helped keep the power on in Oregon.²⁰

Figure 2: Average Net Regional Import into the Northwest January 12-16, 2024²⁰



Regional Transmission Organizations

Regional Transmission Organizations are independent entities that centrally plan and operate the transmission system across large geographic footprints.²¹ The more geographic diversity within an RTO's footprint, the more it can leverage complementary loads and resources to reduce the need for new transmission.



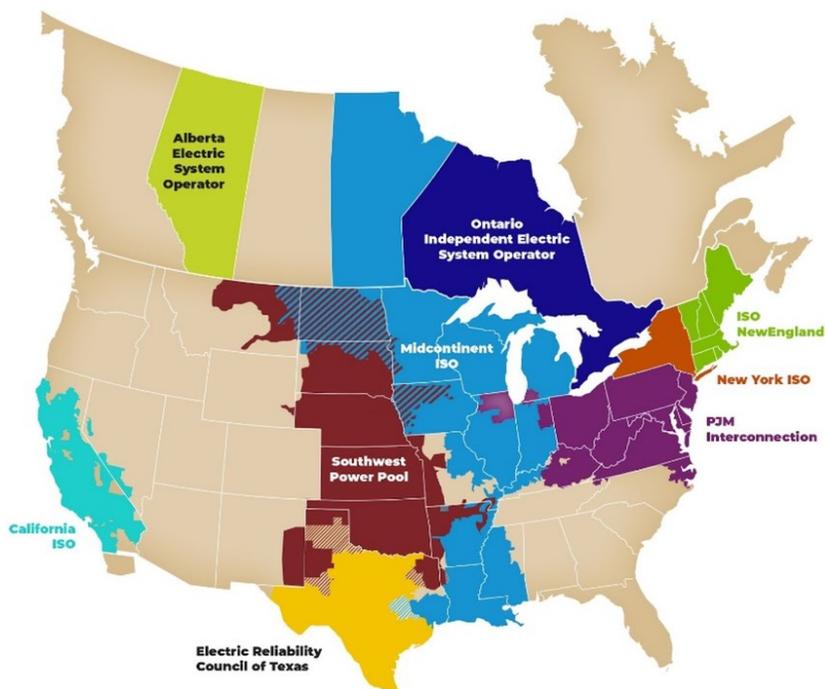
Learn more about regional transmission organizations in ODOE's 2021 study.

Principally, RTOs can reduce the need for new transmission in three ways:

1. Operating centralized real-time and day-ahead markets for the collective regional footprint of the participating utilities and power providers. This increases the efficient utilization of the existing transmission system and all the diverse loads and resources connected to it.
2. Conducting holistic transmission planning for the entire regional footprint to determine the most efficient way to build the transmission infrastructure necessary for all participating utilities and power providers to meet the collective regional demand.^{22 23 24}
3. Standardizing transmission rates so utilities and power providers can transfer power across the region without having to pay multiple different rates, which encourages efficient use of the transmission system.²⁵

Most western utilities outside of California are not members of an RTO, or similar entities known as Independent System Operators (see Figure 3). In the absence of an RTO or ISO, utilities generally contract directly with one another or with an independently owned electricity generation facility to buy and sell electricity and use existing transmission. While these contracts attempt to ensure the resources and transmission are available when needed, they can also create inefficiencies and increase costs.²⁶

Figure 3: Map of Regional Transmission Organizations and Independent System Operators in the U.S. and Canada²⁷



Where transmission expansion is needed, the holistic transmission planning accomplished by an RTO results in more coordinated planning for new transmission needs, so that loads and resources work together more efficiently. Even without an RTO, utilities and power providers can voluntarily collaborate to improve and expand access to diverse and complimentary loads and resources, and individual transmission system planners can also collaborate on holistic, region-wide transmission planning.

Organized Regional Markets

BPA and Oregon utilities, as well as many other power providers and utilities across other western states, participate in the Western Energy Imbalance Market. In this organized regional market, a centralized operator automatically balances supply and demand over 5- and 15-minute intervals by dispatching the lowest cost energy from power plants in the region to meet regional loads most efficiently. BPA and many western utilities, including Oregon's two largest utilities, have also signaled interest in participating in a similar form of market for electricity balancing for the next day, called a day-ahead market.^{28 29 30} More efficient utilization of existing transmission resources was a factor in all three of Oregon's largest electricity providers' (BPA, PGE, and PacifiCorp) analysis about the benefits of joining these markets.^{28 29 30} Learn more in the Electricity Day Ahead Markets 101 in this report.



Learn more about wholesale energy markets in the 2020 Biennial Energy Report.

Regional Transmission Planning

In Oregon and the Pacific Northwest, the regional transmission plan is pulled together by combining the local transmission plans created by individual transmission providers. While it is not the type of holistic, top-down regional planning that would be conducted by an RTO, this bottoms-up approach does support some additional communication and coordination between planners, including agreeing on similar data sets and assumptions used for individual planning activities.

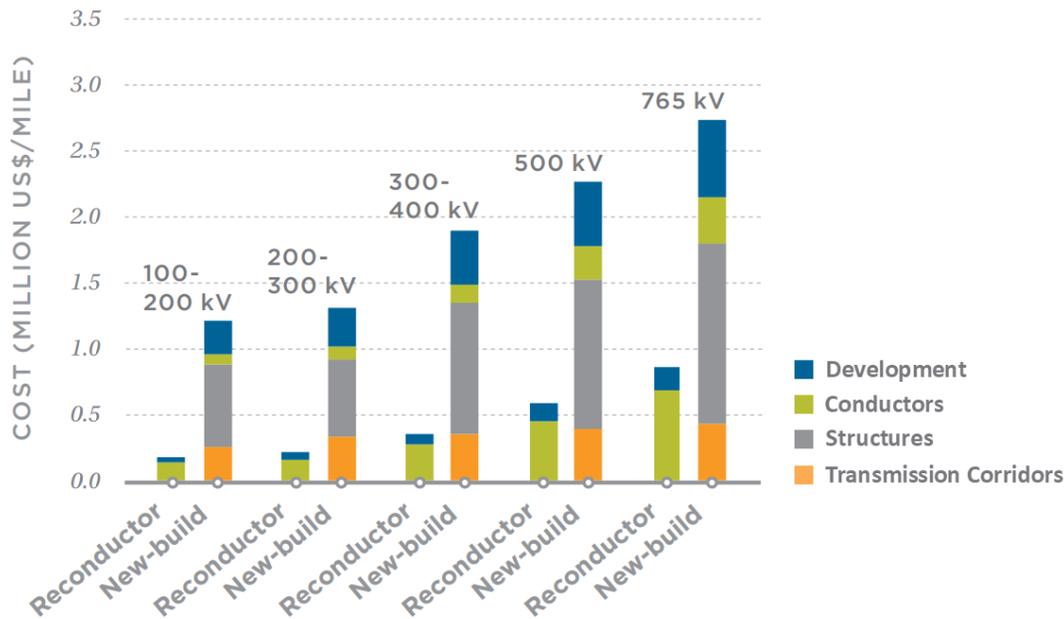
In an effort toward more efficient regional planning across the entire western U.S., the Western Transmission Expansion Coalition is holistically studying transmission needs across the Western Interconnection (a large region comprised of the 11 states west of the Southwest Power Pool in Figure 3 above) over the next 20 years.^{31 32} Comprised of utilities, Tribes, State regulators and representatives, policy makers, and other interested parties, the WestTEC study intends to identify actionable transmission solutions for the entire Western region, taking into consideration economic efficiencies, state policy goals, and grid reliability.³¹ Participation in the study is voluntary, but participants hope the study can inform and complement other existing planning processes to encourage more efficient use and expansion of the regional transmission system.³³

Repurposing and Expanding Existing Transmission Lines

Another option for mitigating the need for new transmission is to repurpose and expand existing transmission corridors.³⁴ For example, an existing transmission corridor originally built to serve a retired generating resource, such as a coal plant, could be repurposed to serve the addition of a new resource, such as a solar or wind facility, located in the same area.³⁴ Transmission operators can expand the transmission capacity of an existing corridor by increasing the operating voltage of an existing line, or by adding a second circuit, or wire, to the corridor.

Advanced reconductoring is a newer option to increase the capacity of an existing transmission line by replacing traditional wires with newer, higher capacity wires, which can double the capacity of an existing line while keeping the existing transmission towers.³⁵ Reconductoring projects typically cost less than half that of new transmission lines regardless of the voltage, as shown in Figure 4.³⁵

Figure 4: Cost Comparison of Reconductoring Versus Building New Transmission³⁶



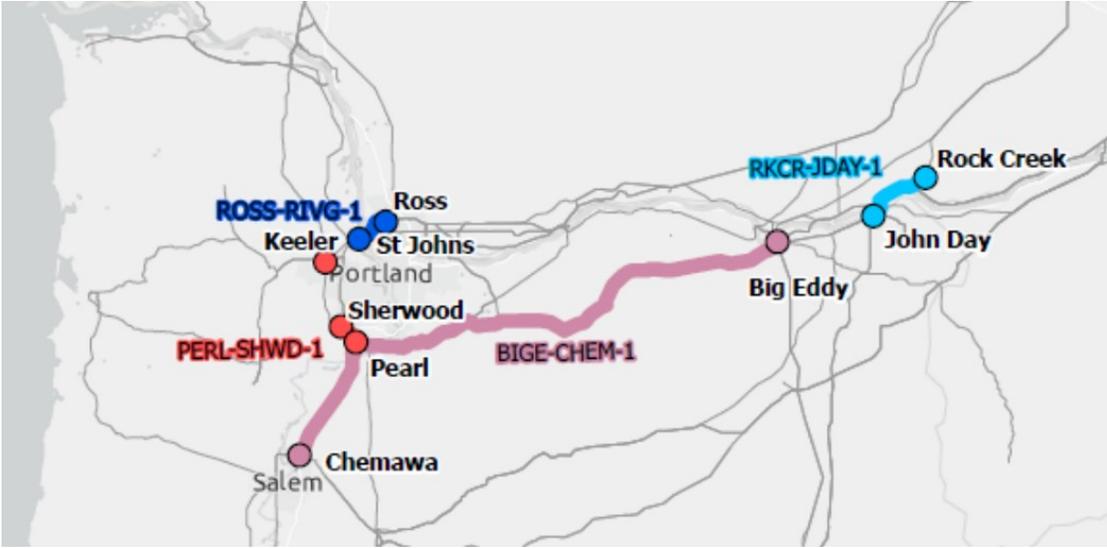
Reconductoring can also mitigate some risks associated with transmission lines. Almost all existing power lines are based on a patent from 1908, which is generally a bare line made up of a steel core surrounded by aluminum wires.³⁷ Modern conductors are much stronger, more conductive, and can be covered with an external insulating layer.³⁸ Conductor design is important because when transmission lines are covered in ice or heated by high flows and hot weather, they can sag and sway if blown by the wind. This can increase the risk of contact with other objects that could damage the line or ignite a wildfire.³⁹ Increasing capacity through reconductoring on an existing transmission corridor can also lessen the load on other parts of the transmission system that may be more susceptible to overloading and line sagging – further reducing outage risks.

Reconductoring projects provide multiple benefits that also align with Oregon’s energy and land use policies. They simultaneously expand transmission capacity, reduce wildfire risks, and minimize the land used for transmission expansion.

Bonneville Power Administration and Portland General Electric are both planning transmission rebuild projects (new wires and new structures) within existing transmission corridors. Both will help alleviate critical transmission bottlenecks by expanding transmission capacity from east to west across the Cascades.

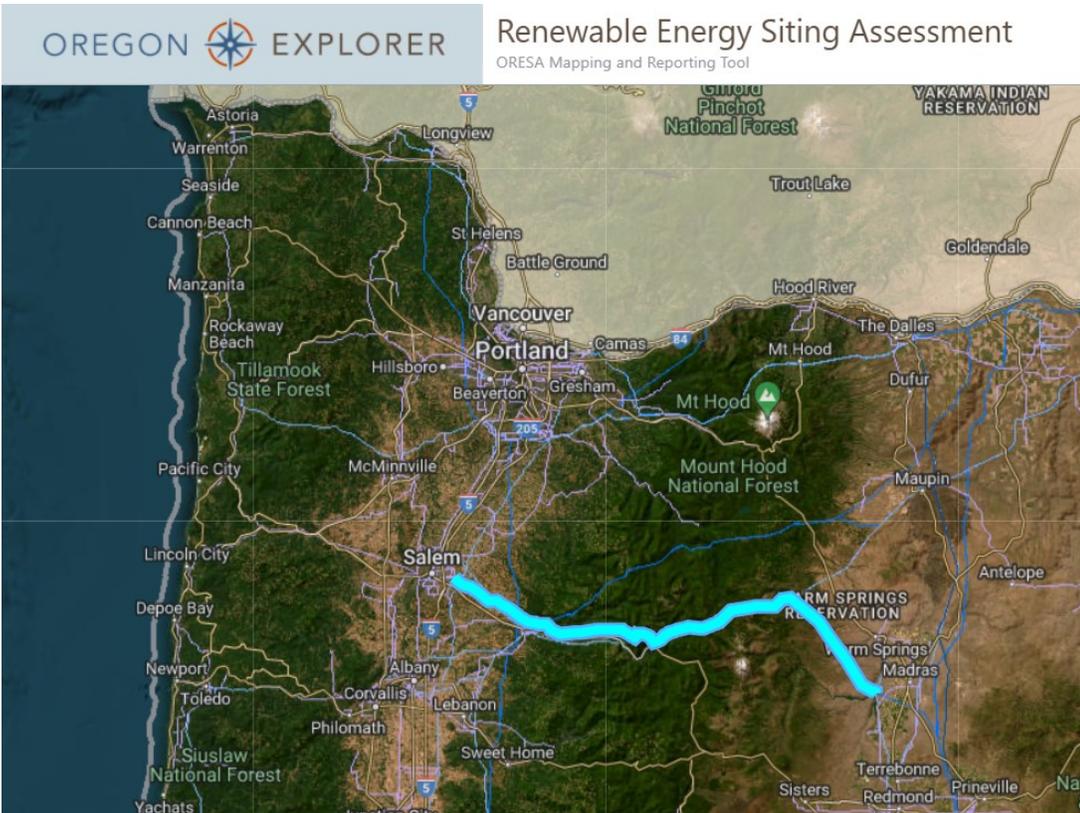
BPA proposes to rebuild and expand 91 miles of its transmission line between Wilsonville (Pearl substation) to the Dalles, OR (Big Eddy substation). The capacity of the line, shown in Figure 5, will be increased from 230 kV to 500 kV⁴⁰

Figure 5: Bonneville Power Administration Proposed Rebuild Project⁴¹



The Infrastructure Investment and Jobs Act is helping utilities, states, and Tribes fund transmission upgrades like these. The Confederated Tribes of Warm Springs was awarded a \$250 million grant from U.S. DOE’s Grid Resilience and Innovation Partnerships Program that is made available through the IJA, with PGE as a subrecipient.⁴² The grants will help fund a rebuild of PGE’s 98-mile transmission line between Salem and Madras shown in Figure 6, increasing its capacity from 230 kV to 500 kV.⁴²

Figure 6: Portland General Electric Transmission Rebuild Project.⁴³



PacifiCorp is also planning transmission reconductoring and rebuilding projects across states within its service territory, including Oregon, and has partnered with the Utah Office of Energy Development as lead state sponsor to receive federal funding support. US DOE’s Grid Resilience and Innovation Partnerships Program awarded ~\$250 million in federal cost share to help fund this multi-state advanced reconductoring demonstration project.⁴⁴

Deploying Local Energy Resources

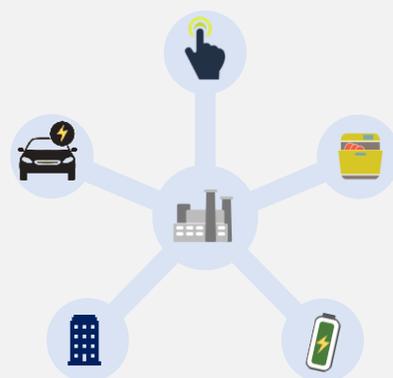
Energy resources developed and used locally can reduce the need to deliver electricity from far away generators to load centers.⁴⁵ These technologies or programs are used to meet customer demand for electricity with local resources. They are particularly useful if they reduce electricity demanded from the transmission system during times of peak consumption. Local resources include:

- Energy efficiency technologies and measures that reduce demand.
- Distributed Energy Resources, or DERs, like customer and utility battery storage systems, rooftop solar, smart appliances, and smart electric vehicle chargers.
- Demand response programs where customers voluntarily reduce or shift their consumption to reduce the need to deliver electricity at peak demand times.
- Time-of-use programs that offer customers lower electricity rates during off-peak hours.
- Programs that enable utilities to reduce or temporarily stop customer electricity use through devices like smart thermostats, water heaters, and electric vehicle chargers.
- “Virtual power plants” where utilities can aggregate DERs to reduce demand.⁴⁶

In April 2023, Portland General Electric announced it would procure 475 MW of new battery storage projects across three sites in North Portland, Troutdale, and Hillsboro – Oregon’s largest area of electricity demand.⁴⁷ The project is the largest commitment to standalone energy storage by a utility in the U.S. outside of California.⁴⁷

What is a Virtual Power Plant?

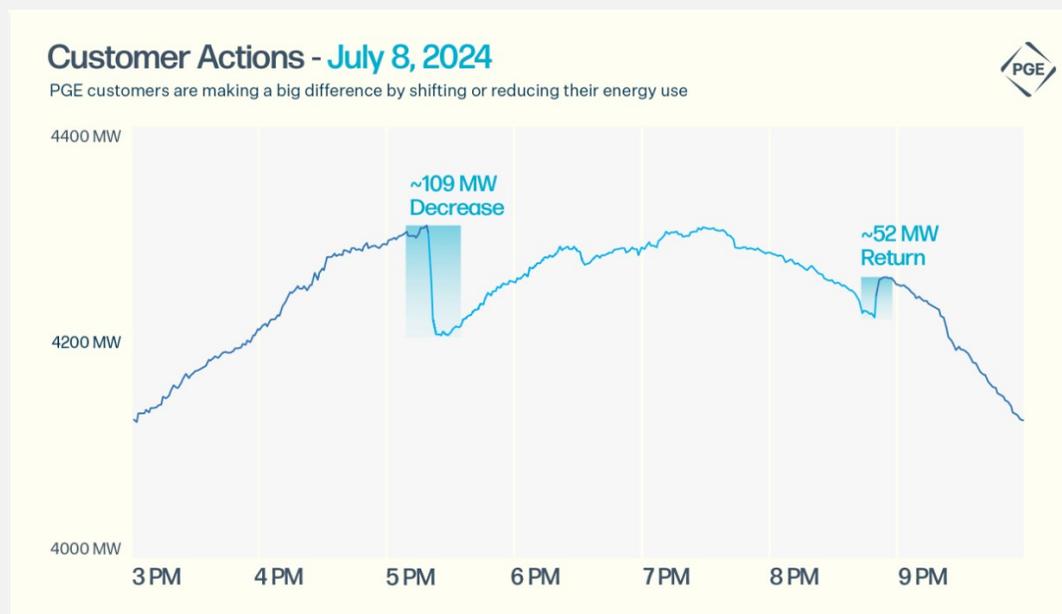
Utilities can use local energy resources, owned by customers or the utility, to alleviate generation and transmission constraints during periods of peak demand. Customer resources may include smart appliances, grid interactive buildings, rooftop solar and battery storage systems, electric vehicles and other resources. The process of coordinating and aggregating these distributed energy resources to provide grid services is referred to as a Virtual Power Plant. Electric utilities and ratepayers benefit by offsetting the need to build new central power plants and expand the transmission system. The participating customers benefit by receiving utility financial incentives.



The customers that participate in a VPP may be prompted by their utility to shed load from the electric grid, or to provide distributed generation capacity. In either case, the result is reduced demand on conventional central power plants and the transmission system.

Management of conservation measures, such as smart thermostat settings that reduce energy use to heat or cool based on usage data or delayed use of large appliances, is often the starting point for VPPs and is collectively referred to as demand response. Demand response programs are already in use in Oregon and provide critical resources during periods of peak electricity demand. Pacific Power manages the Optimal Time Rewards program where customers get financial incentives in exchange for operating smart thermostats and water heaters to minimize peak electrical loads.⁴⁸ On July 8, 2024, customers of Portland General Electric participated in a flexible load program resulting in the largest electricity demand shift in PGE's history.⁴⁹ As shown in Figure 7, 109 MW of load reduction was realized during a peak demand event brought on by a prolonged heat wave. To put this amount of electricity in perspective, 109 MW is about the same capacity as the Klamath Generation Peakers natural gas-fired power plant in Klamath Falls.⁵⁰

Figure 7: Example of the Effects of Portland General Electric Flexible Load Programs on July 8, 2024⁴⁹



While demand response programs reduce the instantaneous load on the grid, distributed generation resources, such as rooftop solar paired with batteries, can also be coordinated to provide other grid services. For example, PacifiCorp's affiliate, Rocky Mountain Power, offers financial incentives to residential and commercial customers in Utah and Idaho for access to battery storage systems through the utility's Wattsmart program.⁵¹ Batteries in this program are charged by rooftop solar each day and discharged during periods of peak electricity demand. In the event of a power outage, the battery systems can also provide emergency backup electricity to customers. More than 4,000 customers have enrolled in the Wattsmart program. Closer to home, PGE is piloting a Smart Battery program to test microgrid operations in Oregon that will provide additional load management capacity.⁵²

Virtual power plants can also play a significant role in future grid operations in Oregon. PGE’s program is over 225 MW today, and is targeting 2,000 MW from VPPs by 2030, to achieve its goal to offset 25 percent of electrical demand during peak events similar to July 8, 2024.^{53 67} Two thousand megawatts is more than the combined capacity of all of the natural gas power plants currently owned and operated by PGE which, in December 2023, totaled 1,811 megawatts.⁵⁴ Meeting future energy demands with VPPs can reduce the need for new transmission while supporting decarbonization, empowering customers, increasing affordability, and improving the reliability of the grid.⁵⁵

Table 1: Examples of Local Energy Resources that Can be Leveraged to Reduce Demand During Critical Hours

Customer Side of the Meter	Utility Side of the Meter
<ul style="list-style-type: none"> • Energy efficiency measures (insulation, double and triple pain windows, etc.) • Heat pumps • Smart water heaters • Solar panels • Electric vehicles • Batteries 	<ul style="list-style-type: none"> • Utility programs (time-of-use rates, demand response programs, net-metering, etc.) • Community-adjacent, utility-scale solar and battery projects interconnected to the distribution system

Using Grid Enhancing Technologies

A suite of sensor and modeling technologies called grid enhancing technologies, or GETs, can help get more out of the existing transmission system.⁵⁶ These modern tools are capable of managing transmission congestion, improving operational efficiencies, and providing real-time data for operators to make more informed decisions.⁴⁶ They do not require permitting or siting, but they do provide performance improvements for existing or reconducted transmission lines.⁵⁶

Transmission lines have thermal ratings that effectively limit the amount of electricity a line can carry. To calculate the capacity of a transmission line, utilities have traditionally used static line ratings, which are calculations of the thermal rating based on historical “worst case” conditions, such as times of the year with the hottest temperatures and lowest wind speeds. Static line ratings are very conservative and fixed, even if weather conditions are mild. If transmission system operators could monitor ambient conditions using sensors and/or software to calculate and update the thermal limits of a transmission line based on real-time and forecasted weather conditions, they could more effectively assess transmission line capacity capabilities.^{57 58} This is known as “dynamic line rating.” DLR not only enhances the utility’s situational awareness of the environment surrounding a line, but it can also provide critical information about conditions that may be conducive to wildfires.⁵⁹

Like dynamic line ratings, dynamic transformer ratings provide real-time information about the thermal ratings of transformers that convert electricity voltages. This technology also takes into account other factors such as the age of the transformer and the type of cooling system it uses.⁶⁰

Another type of GET is a power flow controller. It reroutes electricity away from overloaded lines and onto underutilized corridors, typically by opening or closing existing high-voltage circuit breakers. This helps optimize the power flow across all lines, which allows for more efficient delivery of electricity.⁵⁸

The deployment of GETs is still in the early days and far from widespread. Bringing these new systems into standard use requires investments in new technologies and grid management processes — and, importantly, gaining the confidence of grid managers that they will perform as designed.⁶¹

It is uncertain exactly to what degree GETs could reduce or offset new transmission line expansions in Oregon.⁶² A 2024 study found that during certain times of the year, GETs can enhance the transfer capability up to 50 percent across the existing transmission grid.⁶³ For example, dynamic line rating technology may be able to help provide additional capacity during severe winter cold snaps, when colder temperatures often allow for additional capacity on transmission lines.⁶⁴ However, this also means the opposite could occur during summer droughts and heat waves, where dynamic line rating could actually reduce transmission capacity.

Federal initiatives are advancing utility knowledge and experience with GETs and aim to foster greater adoption of these technologies that would accelerate renewables development. The Federal Energy Regulatory Commission recently adopted Order 1920, which requires transmission providers to consider GETs in their regional planning efforts.⁶⁵ Oregon is one of 21 states committed to a Federal-State Modern Grid Deployment Initiative to prioritize efforts that support the adoption of modern transmission solutions, such as grid enhancing technologies.⁶⁶ PacifiCorp applied for a U.S. DOE Grid Resilience and Innovation Partnerships Program grant. GRIP is a \$10.5 billion grant program to enhance grid flexibility and improve the resilience of the electricity system against growing threats of extreme weather from climate change. PacifiCorp's proposal includes deploying GETs across several states, including Oregon, to increase the operational capacity of existing transmission lines.

Meeting the Challenge of Reducing Transmission Expansion

There are many ways to reduce the total magnitude of transmission expansion that needs to occur to meet increased demand for electricity. Many can also bolster the reliability and resilience of the power grid in the face of extreme weather events, and all can help meet the clean energy and climate policy goals of many western states, including Oregon.



There are economic, environmental, and societal benefits to reducing transmission expansion. It can help avoid or delay significant investments of time and costs into new lines and infrastructure. Not having to develop new transmission corridors avoids environmental, cultural, and societal effects on communities. Fewer line miles to maintain also reduces costs for monitoring and mitigating wildfire risks, and most importantly, reduces costs from wildfires. Many of the options presented here also provide local benefits in the form of well-paying jobs and increased community energy resilience from the deployment of more local energy resources.

Successfully navigating the challenges associated with transmission expansion is essential to maintaining a reliable and affordable electric system as the economy and electricity demand grow and Oregon works to achieve its greenhouse gas goals. This is especially true as extreme weather events caused by climate change are increasing in frequency, intensity, and duration.

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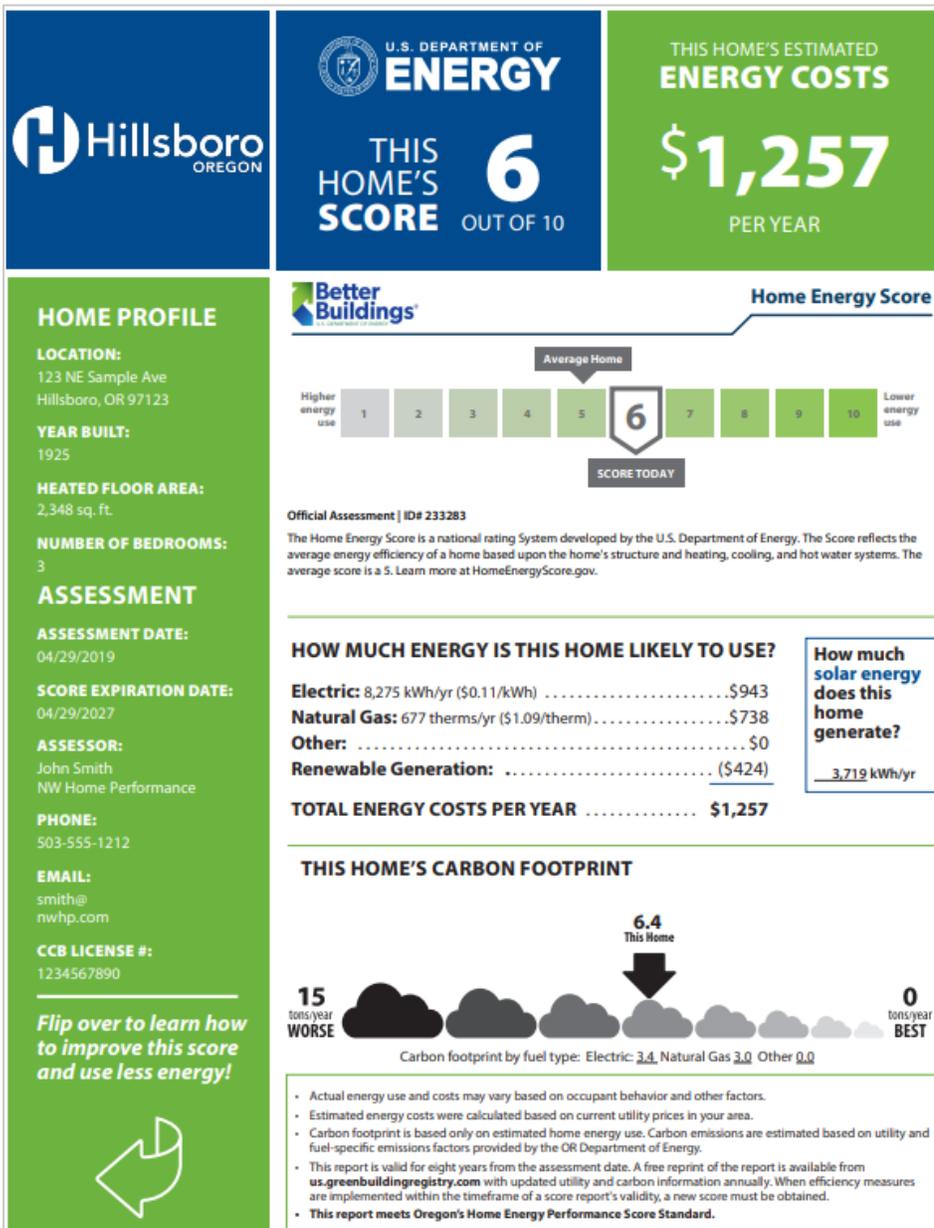
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Oregon Home Energy Scoring

Home Energy Score™ was developed by the U.S. Department of Energy and its partner national laboratories to provide homeowners, buyers, and renters comparable and credible information about a home’s energy use.¹ Using a 1 to 10 scale (10 is high performance), the score estimates a home’s energy consumption and recommends ways to reduce its use, cut costs, and improve comfort. The score also relays greenhouse gas information related to that energy use. Below is an example of a [Home Energy Score scorecard](#). The front page (shown first) relays information about the home’s location, energy score, and estimated energy cost. The front page also provides the home’s carbon footprint and lists other program details at the bottom. The back page (shown below) relays what upgrades to the home may improve energy performance and reduce costs and carbon emissions. This information helps consumers understand the estimated return on investment for specific energy efficiency actions.

Figure 1: Example Home Energy Scorecard in Hillsboro, Oregon



Score today: 6	Score with priority improvements: [*] 9	Estimated energy savings with priority improvements: \$285 PER YEAR	Estimated carbon reduction with priority improvements: 19% PER YEAR
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TACKLE ENERGY WASTE TODAY!
Enjoy the rewards of a comfortable, energy efficient home that saves you money.

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

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

FEATURE	TODAY'S CONDITION ³	RECOMMENDED IMPROVEMENTS
Attic insulation Cathedral Ceiling/Roof	Ceiling insulated to R-0 Roof insulated to R-0	Insulate to R-38 or R-49 if code requires it Insulate cathedral ceiling/roof to R-30 or maximum possible

ADDITIONAL ENERGY IMPROVEMENTS ²

FEATURE	TODAY'S CONDITION ³	RECOMMENDED IMPROVEMENTS
Duct sealing	Un-sealed	Reduce leakage to a maximum of 10% of total airflow
Envelope/Air Sealing	Not professionally air sealed	Professionally air seal
Air Conditioner	16 SEER	
Basement wall insulation	Insulated to R-0	
Duct Insulation	Un-insulated	
Floor insulation	Insulated to R-0	
Foundation wall insulation	N/A	
Heating equipment	Natural gas furnace 96% AFUE	
Skylights	N/A	
Solar PV	Capacity of 3.36 kW in DC	
Wall insulation	Insulated to R-7	
Water Heater	Natural Gas	
Windows	Double-pane, low-E glass	

1. To achieve the "Score with priority improvements" all recommended improvements in Priority Energy Improvements section must be completed. These priority improvements have a simple payback of ten years or less.
2. Additional energy efficiency improvements may take longer than ten years to make a return on investment but can have a significant impact on the comfort, efficiency and environmental impact of your home.
3. Today's Condition represents the majority condition for that feature in the home. Additional energy efficient features may be present in the home and not accounted for in this report. Trees and other features may provide additional energy efficiency benefits to the building.

How are Home Energy Scores Determined?

Home Energy Scores are developed by state certified assessors, who have been trained and licensed in Oregon. Assessors examine a home's characteristics, such as windows, insulation, and heating/cooling equipment, as well as the age, size, and orientation of the property. Information is collected in a program-specific form. Using that information and an online calculator provided by the U.S. Department of Energy, assessors produce a scorecard like the example above.

Benefits of Home Energy Scoring

Home energy scoring provides consistent and trusted information to homebuyers on the energy costs and carbon footprint of a prospective home. In cities that require mandatory scoring, scores are paid

for by the seller and made available at no cost to potential buyers. The information can be accessed through multiple home listing services and other online resources like Zillow and Redfin. The standardized scoring and scorecard allow buyers to easily compare the energy costs and carbon footprintsⁱ of multiple prospective homes.

A Home Energy Score provides information on which energy efficiency measures or upgrades could pay for themselves over a given amount of time. Utilities and organizations like Energy Trust of Oregon and the Oregon Department of Energy provide trusted information about available incentives and the advantages of efficiency upgrades, including economic benefits like energy cost savings, as well as non-economic benefits like better home comfort and indoor air quality.

Energy efficiency upgrades reduce energy costs which often pay for the cost of the upgrade over time, but the up-front cost for the upgrades can still be a barrier for some. Homeowners may be eligible for programs that reduce the cost of completing an energy saving upgrade or replacing an appliance with a more efficient one. Many state, local, and utility programs offer rebates and incentives, and some lenders will include the costs for Home Energy Score recommended energy efficiency upgrades in a new mortgage. Existing homeowners may have the option to include these costs when refinancing or getting a loan specifically for the upgrades.

Green Mortgage Lending

Also called Energy Efficient Mortgages, Green Mortgage Lending is a type of financial loan program that allow borrowers to include the costs of energy efficiency upgrades into a new home loan. These are available through conventional loans backed by Fannie Mae or Freddie Mac, Federal Housing Administration insured mortgages, Department of Veterans' Affairs loans for veterans and their families, and the U.S. Department of Agriculture's loan program for homes in rural areas.³



Lower energy payments have been associated with fewer mortgage defaults. Less money spent on energy bills can translate into more available money to meet a mortgage payment. A study by the Institute for Market Transformation found that energy efficient homes have on average, 32 percent lower default rates.

ⁱA building's carbon footprint is the total amount of greenhouse gases that are emitted into the atmosphere, largely from the use of energy in the building.²

Home Energy Scoring in Oregon

Since implementation of Oregon's Home Energy Score program in 2016, cities can use a framework developed by ODOE to design and implement their own local home energy scoring ordinances. Portland, Milwaukie, Hillsboro, and Bend have instituted mandatory ordinances that require a publicly available Home Energy Score on all residential property listings.^{4 5 6 7} These four cities cover more than 20 percent of Oregon's population. Eugene and Salem have expressed interest in developing similar policies as part of their energy and climate action plans.^{8 9} To date, statewide Home Energy Score programs have resulted in more than 40,000 scores generated. The data can be used to assess the overall efficiency of housing and identify where additional support may be needed to encourage upgrades. As scores are updated — from the resale of a home or at a resident's request — this information can provide insight into trends in residential energy efficiency.

The standardized approach for the Home Energy Score program makes energy assessments a reliable resource for homeowners and residents interested in understanding the costs and benefits of different energy efficiency upgrades. Prior to starting the program, access to energy efficiency information differed depending on the home's location and the specific energy assessor used. Assessors could use different tools, provide varying energy consumption and savings metrics, or assess different parts of a home's energy footprint. Oregon's home energy scoring program provides credible and consistent information about energy efficiency upgrades.

Oregon Home Energy Score assessment costs range from \$119-\$180 compared to the national average of \$425.^{10 11} The standardized training provided through the Home Energy Score program includes efficient practices that bring down costs by reducing the assessors' time gathering information on site. Using the U.S. DOE calculator also reduces time spent calculating and verifying results. In Portland, Milwaukie, Hillsboro and Bend, where sellers must provide a Home Energy Score, there are programs to help low-income residents pay for energy assessor fees.

Improving Accessibility to Home Energy Scoring

The Home Energy Score program can be leveraged to improve access to scoring for homes in cities without mandatory policies, rural areas of the state, and for rentals and mobile homes.

The Home Energy Score training and certification program can be used by any business, utility, or other energy efficiency focused organization throughout the state. Oregon currently has about 75 certified home energy scoring assessors, mainly serving populations in cities with mandatory scoring policies. Some assessors are part of businesses that offer complementary services, such as heating, cooling, and window and insulation installations. Other assessors work independently and offer home inspections or real estate services. A few businesses focus only on providing home energy score assessments.

Oregon Home Energy Score program assessors must complete training programs and state licensing to become certified. This includes building science training, scoring tool simulation training, mentoring, and quality control procedures.

Find an Assessor

ODOE works with Earth Advantage to provide a current list of Home Energy Score assessors [online](#). Consumers can enter the address of their home, and the webpage will provide a list of available assessors for their location.¹²



Many environmental justice communities, especially rural communities, have few to no trained home energy assessment professionals. In some cases, there are no available assessors, and when they are available, services are often more expensive because of increased travel costs. The home energy scoring program includes training to conduct remote assessments. With assistance from the homeowner or tenant, assessors collect data using photos and online discussions, which are then input into the calculator. This option increases access in rural regions and keep costs commensurate with urban and suburban areas.

Currently, renters living in multi-family or manufactured homes do not have access to Home Energy Scores. Nearly 39 percent of Oregon households are renters.¹³ Households with incomes below 60 percent of the area median income in Oregon are more likely to be renters and experience energy cost burdens sometimes above 6 percent. In several census tracts of Portland and Medford, and in most rural areas, energy burden can exceed 10 percent.¹⁴ On average, Oregon renters have higher average housing costs and incomes of less than half that of homeowners. Seventy percent of renter households make less than \$75,000 a year, and half of Oregon renters spend at least 30 percent of their income on housing costs.^{13 15}

Energy Burden

Home energy burden is the percent of household income spent on home energy bills. Energy bills include electricity, natural gas, and other home heating fuels, and are compared to the total income of the people in that household. If a household is spending more than 6 percent of its income on home energy costs, it is considered burdened.¹⁶



When energy burden is a concern, the ability of renters to compare energy costs across different homes could have a dramatic effect on their cost of living.¹⁷ Oregon consumers can make more informed housing choices when they have access to energy cost information across all types of housing. In the absence of a score, renters have limited visibility into building energy performance and costs when selecting their home. The U.S. DOE is currently adding functionality to its calculator to assess the energy footprint for multi-family and manufactured homes. ODOE is preparing to engage with landlords to show them how the program works, the energy savings information it can provide, and how they can share Home Energy Scores with their tenants.

The U.S. DOE anticipates providing an updated scoring calculator with options to score multi-family and manufactured homes by 2025. Cities with mandatory scoring policies have indicated they may add mandatory home energy scoring for rental properties soon.

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Waste Energy

Some amount of energy is lost during the production, delivery, and use of energy. This loss is referred to as waste energy and includes both avoidable and unavoidable losses. Energy is lost or consumed during energy transformations (storing, moving, converting, or using energy). Commonly, energy is lost in the form of heat that dissipates into the surrounding environment. While some energy losses are inevitable, there are many opportunities to improve the efficiency of energy production, processing, transport, and storage, as well as measures to more efficiently use energy. This Energy 101 will describe types of energy losses and the options energy producers and users have that can reduce waste energy.



Waste energy is the difference between the amount of energy input needed to complete a process and the amount of energy used for work. For example, light bulbs produce light (useful work), but also produce some amount of energy as heat that is not used. Heat could be a very useful output from energy processes, if it can be captured to do useful work. However, in many cases processes that produce heat as a byproduct do not occur in locations where it could be captured and used. Some industrial plants recapture waste heat and use it to support their processes – for more information, see the [Combined Heat and Power Technology Review](#) in the *2020 Biennial Energy Report*.

What is Waste Energy and What Causes It?

While the word “waste” implies some level of neglect or inattention in allowing energy to escape, energy loss is a normal outcome of storing, moving, converting, or using energy. Waste energy can be described as the unused portion of energy, or energy required to get to the final work product in a system or process. In Oregon’s energy system flow diagram below, waste energy makes up about 54 percent of all energy produced or imported in the state — some of this is unavoidable energy loss.

Figure 1: Oregon’s Energy Flow, Waste Highlighted

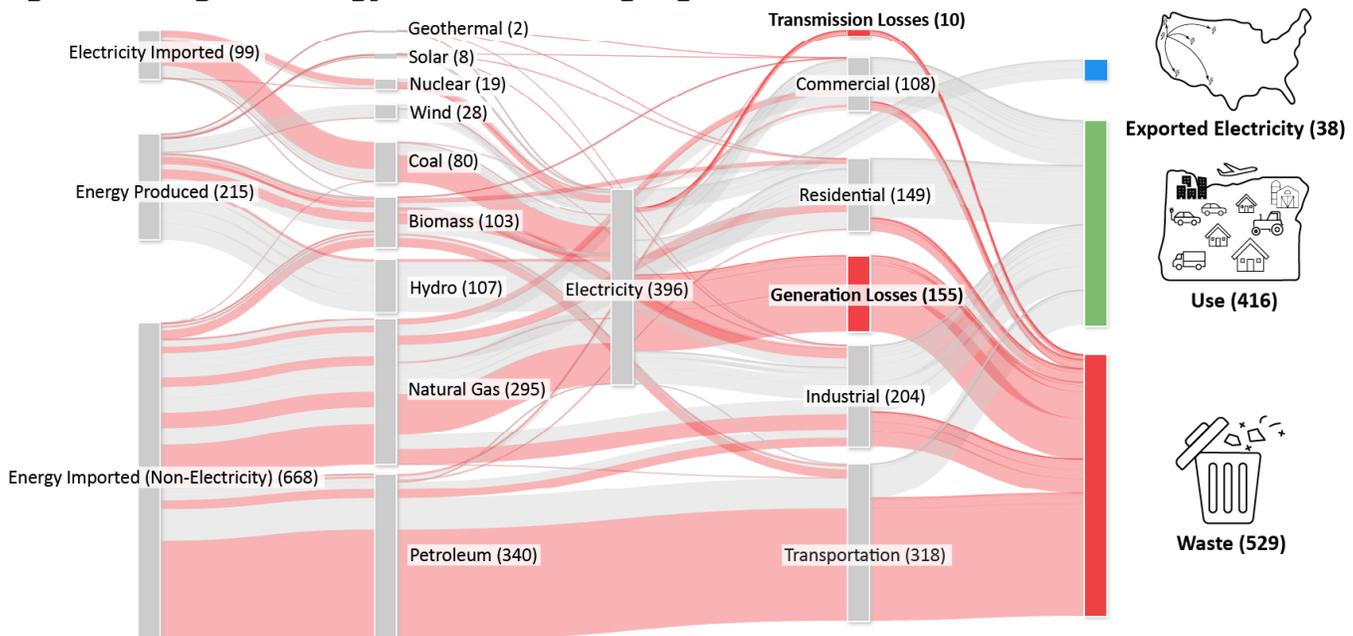


Figure 1 (in Trillion Btu) shows the waste energy for 2022 (further details on this chart can be found in the Energy by the Numbers section of this report). The U.S. Energy Information Administration recently updated the methodology used to calculate primary energy use, which reduced the amount of waste energy estimated in this chart compared to the *2022 Biennial Energy Report*. More information on this change can be found in the About the Data section of this report.

Heat as Waste Energy

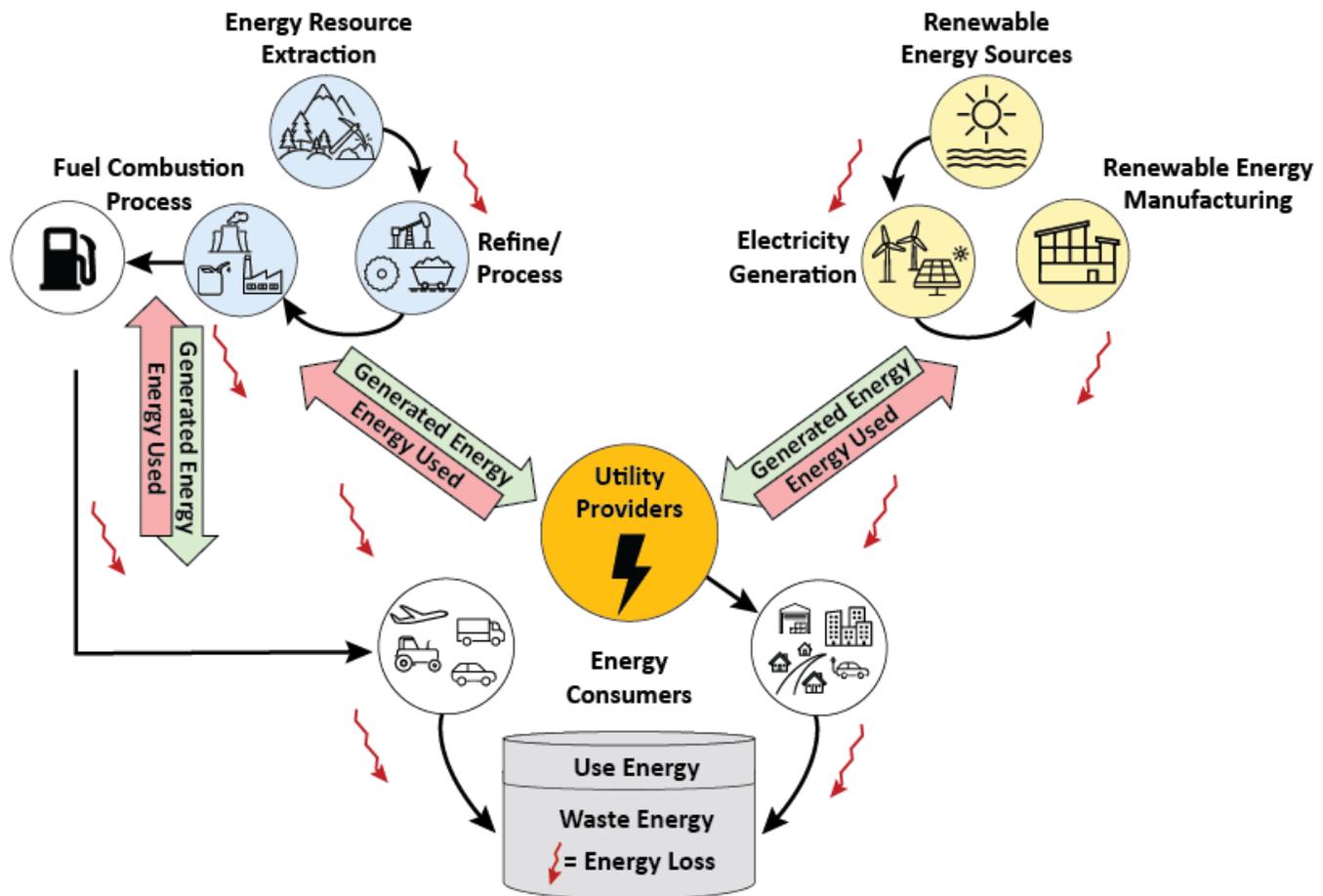
In natural or spontaneous processes, energy always becomes less organized, and heat – energy that comes from the movement of atoms and molecules in a substance – is the least organized form of energy. Heat is a byproduct of many energy-related processes, and always flows in the direction of decreasing temperature.¹ At right, two campers enjoy the fire generating heat, which dissipates into the cold night air.



Where Energy Losses Occur

Energy losses occur at every step necessary to provide energy when and where it is needed. For example, petroleum resources like natural gas, coal, gasoline, diesel, and propane require the use of energy to mine or extract and transport via pipeline, truck, or rail — and often lose some inherent energy during refining and processing. When natural resources are used to generate electricity, additional energy losses occur while generating the electricity and along the transmission and distribution wires carrying it to the point of use. Renewable resources like solar and wind do not require energy to produce or transport fuel to the generation site but – like all energy sources – do require manufacturing and transportation of the generating equipment. Other types of renewable energy resources like biomass from waste wood products and biogas from landfills have other steps in their pathways where energy losses can occur, such as transportation and heat losses from combustion. Figure 2 below shows a simplified overview of the types of processes involved in the production and consumption of energy, and resulting waste energy that occurs in each.

Figure 2: Points of Energy Loss to Provide Energy to Consumers

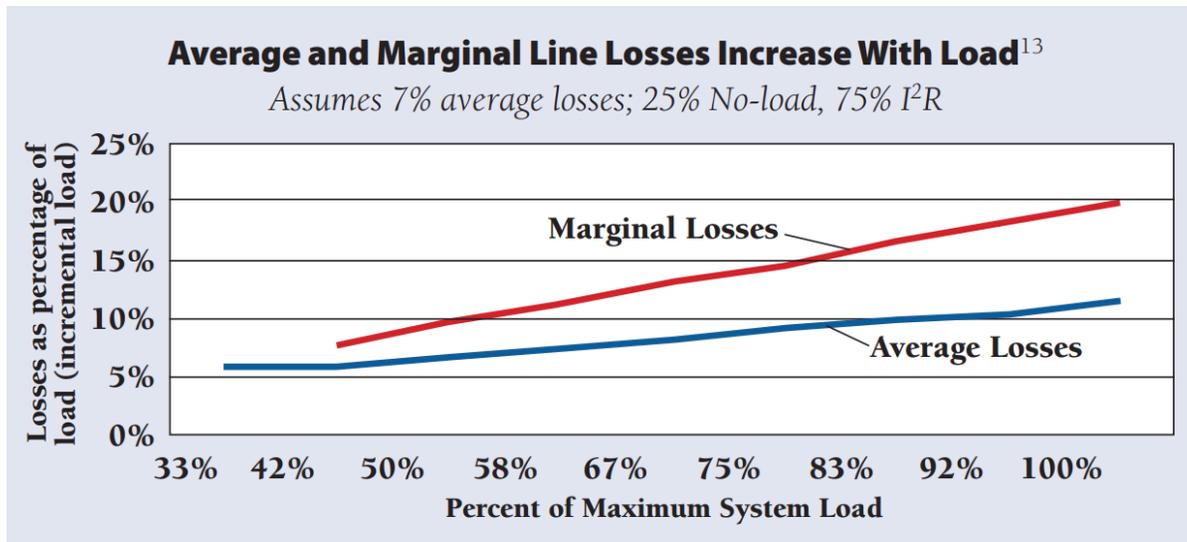


Delivering electricity over transmission and distribution lines also incurs energy losses, known as line losses. In 2022, about 5 percent of the electricity generated for Oregon consumers was lost as it was transmitted from the generation sites to the ultimate end use, which is about the same as the national average.² Energy is not only lost along the lines, but also at every point along the line where transformers are used. Longer lines have more energy waste, which is why rural distribution line energy losses are typically greater than urban lines.³ A study conducted for an electric utility in Ontario calculated typical line losses across distribution lines at 3.6 percent in urban areas and 7.3 percent in rural areas.ⁱ

Losses also increase as load on the electrical line increases. At the highest load hours, line losses can increase up to 10 – 15 percent. Transmission systems are designed for optimal efficiency at a particular load; when demand on the system increases, the loading outside the optimal range increases losses.

ⁱ Rural and urban areas were defined by the utility.

Figure 3: Typical Line Losses Associated with Increasing Load^{3 ii}



The energy that is directly used to extract or mine petroleum products, and transport, refine, or deliver energy products, is not considered waste energy, as this energy produces useful work. Waste energy also does not include solar energy that is not captured by solar panels or wind not captured by turbines. This is energy that exists regardless of whether it is harvested or not. Similarly, water that flows through dams that do not generate electricity or crude oil left in the ground are also not considered waste energy but can be thought of as unharvested energy, sometimes referred to as potential energy.

Waste Energy and Energy Efficiency

Energy efficiency includes technologies and practices that reduce waste energy. The Pacific Northwest has long been a leader in energy efficiency for electricity and direct use fuels in buildings, with a history and current practice of prioritizing energy efficiency and conservation programs across these sectors.⁴ Utilities, policymakers, and other stakeholders consider energy efficiency a resource, like hydropower, natural gas, solar, and wind. Energy efficiency opportunities exist wherever energy waste occurs, including energy production, transmission, transportation, and/or management, as well as residential, commercial, industrial, and transportation end uses. Another advantage of energy efficiency practices and technologies is that in addition to addressing avoidable energy waste, they also reduce the total unavoidable losses that would otherwise have occurred.

The practice of finding uses for as much of the energy in a process as possible is a form of energy efficiency.

ⁱⁱ Marginal losses are those that are avoided if load is reduced. Similar to traffic patterns, small increases or decreases in transmission load can have outsized impact on electricity flow and losses.

At an energy production scale, energy efficiency includes co-locating processes, reduced and/or improved transport and transmission, replacing outdated or inefficient parts and equipment with higher efficiency versions, and strategic control strategies that optimize energy production.

Hydropower Efficiency and Oregon’s Renewable Portfolio Standard

Oregon’s [Renewable Portfolio Standard](#) program allows utilities to use efficiency improvements to hydroelectric facilities to participate in the program. Because hydro dams were in operation before the program was enacted, they are not eligible renewable resources. However, where efficiency measures help operators generate more energy from the same dam, this additional electricity is eligible for the RPS. Increased interest in efficiency and the RPS allowance has resulted in almost 369 MW of increased hydroelectric generation capacity from facilities in Oregon — an overall increase of 4.8 percent over the life of the program. For example, Portland General Electric implemented hydroelectric efficiency retrofits at Round Butte Dam on the Deschutes River:

- Round Butte Unit 3 had an initial nameplate capacity of 82.35 MW and efficiency upgrades increased this capacity by 57.86 percent.
- Round Butte Unit 2 had a nameplate capacity of 82.35 MW and efficiency upgrades increased this capacity by 57.86 percent.
- Round Butte Unit 1 had a nameplate capacity of 82.35 MW and efficiency upgrades increased this capacity by 36.61 percent.

Since generation facilities do not operate at the highest capacity year-round this translates to about a 10 percent increase in annual generation for these facilities. The 2021 Infrastructure Investment and Jobs Act provided \$630 million to support the modernization and expansion of the nation’s hydroelectric resources, including increased funding to the [Hydroelectric Efficiency Improvement Incentives](#) program, which provides incentives for facilities that implement projects that increase their facility efficiency by at least 3 percent.⁵



Round Butte Dam

Photo: Low Impact Hydropower Institute

At the consumer level, reducing energy waste generally means replacing inefficient devices, improving the weatherization of a building, or optimizing the operation of a building. Broadly, this includes better insulation, more energy efficient windows and doors, and more energy efficient devices and control strategies. Heat pumps can save approximately 50 percent of the energy used for home heating when replacing electric resistance heat such as cadet heaters or baseboards.⁶ Replacing aging compressors with advanced adaptive compressors can provide up to 30 percent energy savings in

refrigerators.⁷ In addition to these strategies, Oregon businesses and industry can reduce waste by using more energy efficient equipment, improving the overall efficiency of their operations, or training employees in energy efficient practices (such as training maintenance staff on controls operations and strategies, building staff in use of occupancy sensors to control lighting and plug loads, or training in conservation principles).



Because some types of energy technologies and systems lose more energy than others, using different technologies can sometimes reduce energy losses. For example, electric motors waste far less energy than comparable combustion engines. A common example of this is in passenger vehicles, where conventional gasoline engines convert between 12 and 30 percent of the energy in gasoline to move the vehicle, whereas electric vehicles convert over 77 percent of the electrical energy pulled from the grid.⁸ Replacing incandescent light bulbs with LEDs reduces energy consumption by 75 percent and the LEDs last up to 25 times longer.⁹

We can compare Oregon's overall system energy efficiency — the ratio of useful energy to waste energy — by looking at the [Energy Flow diagrams](#) produced by the Lawrence Livermore National Laboratory for Oregon and Washington to get a better idea of how Oregon compares. Oregon's system efficiency for 2021 was 44 percent while Washington's was 42 percent.¹⁰ Although Washington's population and the size of the energy system is significantly higher than Oregon's, they share many similarities, such as reliance on regional hydropower infrastructure, access to renewable energy resources, similar leading economic sectors, and a similar policy environment that has historically prioritized energy efficiency programs.

Opportunities remain to advance energy efficiency and reduce waste, particularly in waste energy capture and reuse. An example of this is Intel's Fab 34 site in Ireland that was designed with heat recovery in mind, specifically a heat exchanger and hot water system set up to capture excess heat and direct it to other steps in the manufacturing process or to heat buildings.¹¹ Though individual efficiency actions may be small, the sum of energy efficiency design strategies across energy sectors, and from production through use, have a large effect on reducing energy waste. More extensive application of existing energy efficiency technologies and programs could boost Oregon's efficiency and new technological developments, such as extended capacity heat pumps, and solutions for space conditioning in large commercial buildings could drive overall system energy efficiency even higher.

Electricity efficiency will become increasingly important as more end uses, such as personal vehicles and building heating, use electricity as an energy source. This includes options to address transmission and distribution line losses, improve the efficiency of electricity generation, and the efficiency of all energy end use products. Distributed resources that are located closer to end-users, such as rooftop solar, electric vehicle batteries, consumer-owned battery systems, water heaters, boilers, and local microgrids, could all provide energy to the grid. Effective management of these distributed resources could reduce transmission and distribution line losses, as well as congestion on existing transmission lines.

Benefits of Reducing Waste Energy

Reduction in waste energy often means lower costs for all consumers. It can also reduce other societal costs, including those related to climate change and environmental effects on communities. It can help with local health effects, energy reliability, and aid in achieving Oregon's climate and energy goals.¹² Efficiency gains also help utilities avoid or delay the need for new generation that require consumer rate increases. Reducing energy waste also reduces mining and petroleum extraction activities, which have environmental and societal effects around the globe.

In addition to cost reductions, reducing energy waste also has many co-benefits. Efficiency investments support more reliable and resilient energy systems and provide these benefits with little to no negative effect on Oregon's land, air, and water. Energy efficiency activities also provide jobs and economic development opportunities within Oregon and reduce greenhouse gases and other air pollutants.¹³

Energy Efficiency

Learn more about energy efficiency and its benefits in previous ODOE Biennial Energy Reports:

- [Beyond Energy Savings – Co-Benefits of Energy Efficiency](#)
- [Clean and Efficient Building Technologies](#)
- [Energy Efficient Policy Opportunities in Existing Buildings](#)
- [Clean and Efficient Vehicle Technology Review](#)



Waste Energy and Environmental Justice

Reducing energy waste through energy efficiency can help address environmental justice issues across many communities and situations. However, access to energy efficiency measures and technology can be challenging for the disadvantaged and burdened groups that most need the benefits. Replacing inefficient equipment can be out of reach for these communities and households because either energy program information is not accessible, or because energy-efficient options often have a higher up-front cost. This, in combination with other factors including historic underinvestment and discrimination for members of these communities, has led to higher energy costs and higher energy burden among the lowest income households and disadvantaged communities.¹⁴

The production and use of energy often includes local effects on land, air, and water quality. For example, hydroelectric dams can affect water quality as well as fish and other wildlife habitat; natural gas power plants affect air quality; and utility scale solar installations affect landscapes. Neighborhoods near busy roadways and industrial areas have more incidences of respiratory diseases due to higher emissions of particulates and other air pollutants from vehicles and industrial processes. Energy production facilities, which can have effects on local airsheds, watersheds, and viewshedsⁱⁱⁱ are often located near rural and Tribal communities. In Oregon, efforts to ensure energy facility siting is

ⁱⁱⁱ Viewsheds are the view of an area from a specific vantage point, such as a local community or town. Energy production facilities in rural areas can interrupt the views of the natural landscape in rural areas.

done effectively and responsibly while honoring community values is on-going. The Oregon Department of Energy has created an engagement guidebook and an Oregon Renewable Energy Siting [Assessment](#) mapping tool.¹⁵ Together, these tools provide guidance and data to support stakeholders' and energy developers' needs in navigating decisions around energy facility siting. Gains in efficiency also reduce the need for the associated effects of energy production and use by reducing the need for new plants, and in some cases reducing the impacts by diverting waste streams.

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