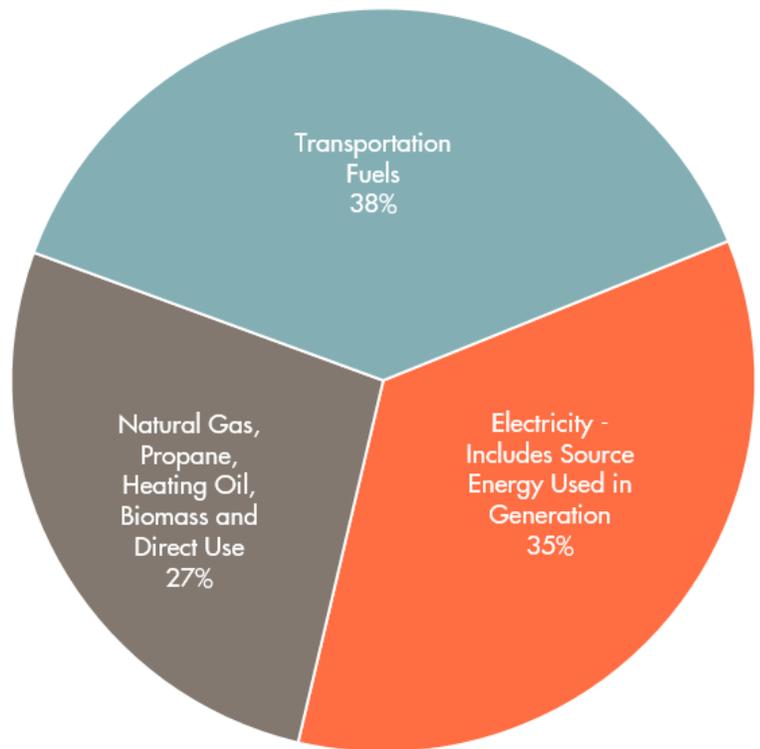


Energy Use in Oregon

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

Energy consumption is often tracked by how it is used among four main end-use sectors: Residential, Commercial, Transportation, and Industrial. In Oregon in 2016, those four sectors combined consumed 977 trillion Btu of energy. Profiles of each sector are included later in the report.

For this introduction to Oregon’s energy use, and in the next section on our energy production, the report sorts energy into three main categories:



35%

of Oregon’s 2016 energy consumption

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

27%

of Oregon’s 2016 energy consumption

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

38%

of Oregon’s 2016 energy consumption

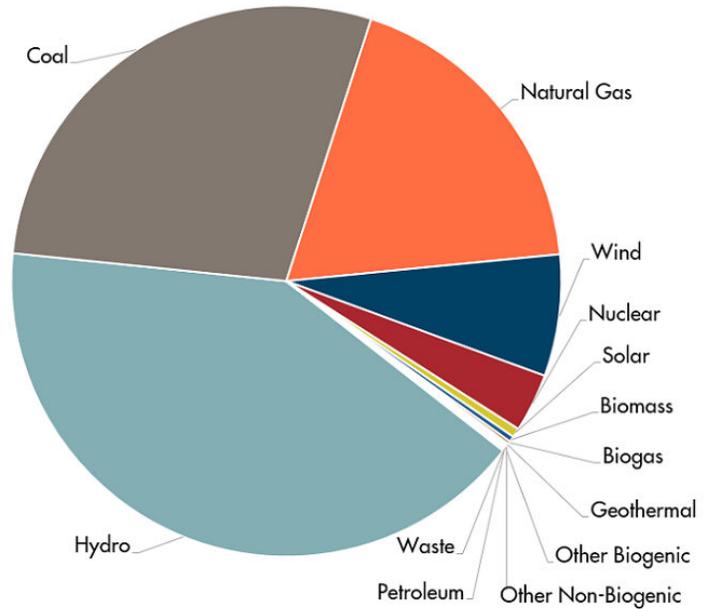
Transportation Fuels: this includes personal, passenger, and commercial vehicles, both on and off the roads, plus airplanes, boats, barges, ships, and trains. Nearly all transportation-related sources of energy are imported from out of state for in-state use.

Electricity

35%

of Oregon's
2016
energy
consumption

41.1%	Hydropower
28.4%	Coal
18.5%	Natural Gas
7.1%	Wind
3.4%	Nuclear
.54%	Solar
.33%	Biomass
.16%	Biogas
.12%	Geothermal

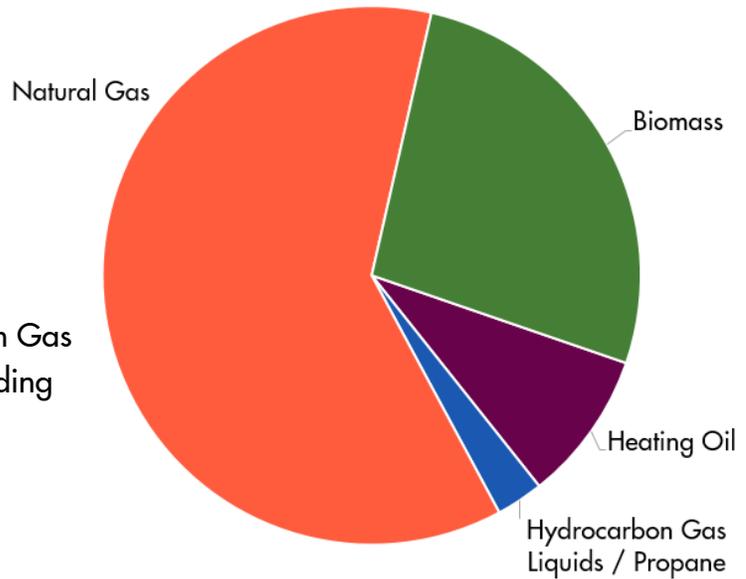


Direct Use Fuels

27%

of Oregon's
2016
energy
consumption

61.4%	Natural Gas
26.7%	Biomass
9%	Heating Oil
2.8%	Hydrocarbon Gas Liquids Including Propane

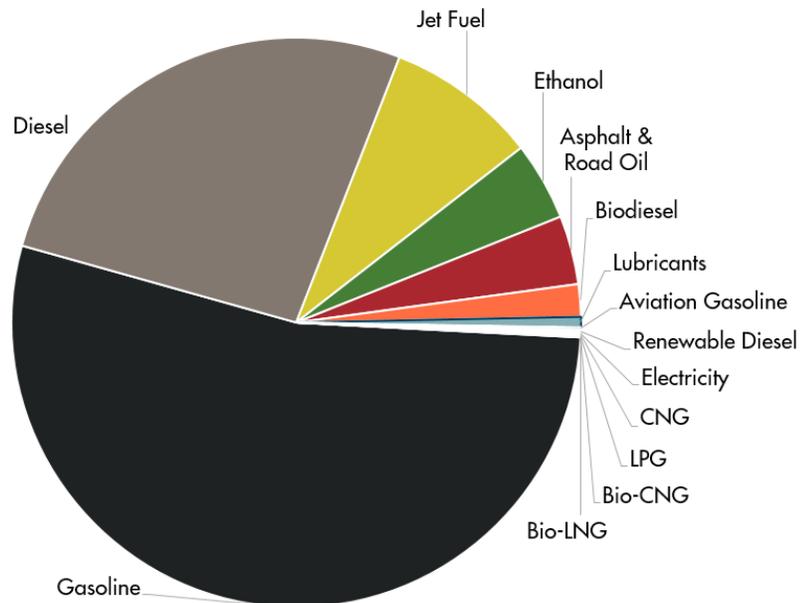


Transportation Fuels

38%

of Oregon's
2016
energy
consumption

53.5%	Gasoline
26.6%	Diesel
8.6%	Jet Fuel
4.4%	Ethanol
3.9%	Asphalt, Road Oil
1.8%	Biodiesel
.60%	Lubricants
.15%	Aviation Gas
.12%	Renewable Diesel



Energy Use in Oregon

Oregon's Energy Consumption Over Time

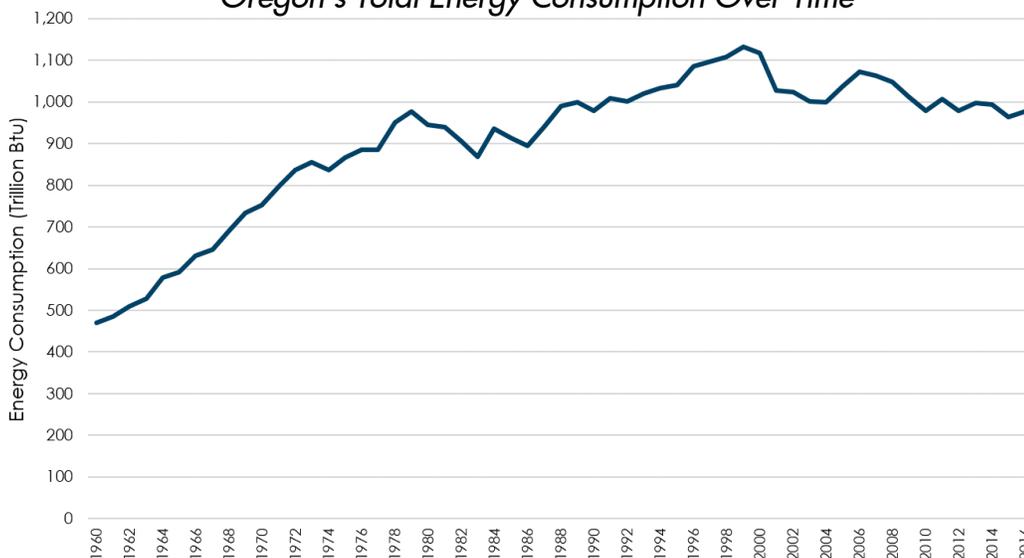
Oregon saw an overall trend of increased energy use for almost four decades—an average of 3.6 percent growth per year from 1960 to 1999.

During that time, we shifted from a reliance on fuel oil and wood to increased usage of natural gas and electricity in our homes and businesses. Oregon reached our highest consumption in 1999; since then, energy use has been decreasing. The amount of energy we used in Oregon declined by 12.5 percent between 2000 and 2016.

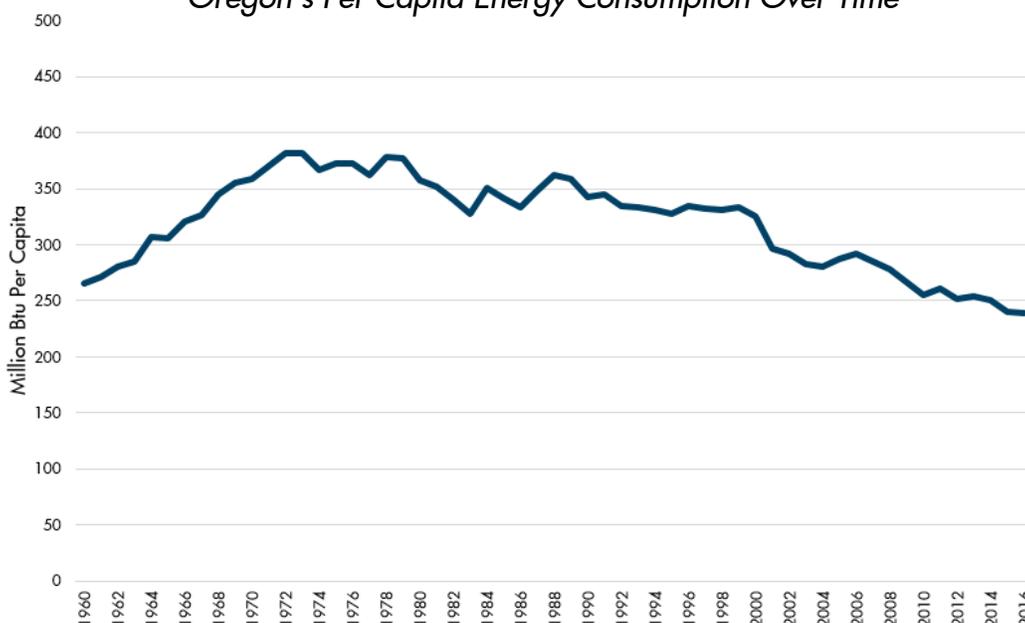
Factors affecting Oregon's energy consumption over time include energy efficiency; economic recessions, recovery, and growth; and changes to Oregon's industrial sector, such as the closure of energy-intensive aluminum plants.

In 2016, Oregon ranked 13th for lowest per capita (per person) energy use

Oregon's Total Energy Consumption Over Time



Oregon's Per Capita Energy Consumption Over Time



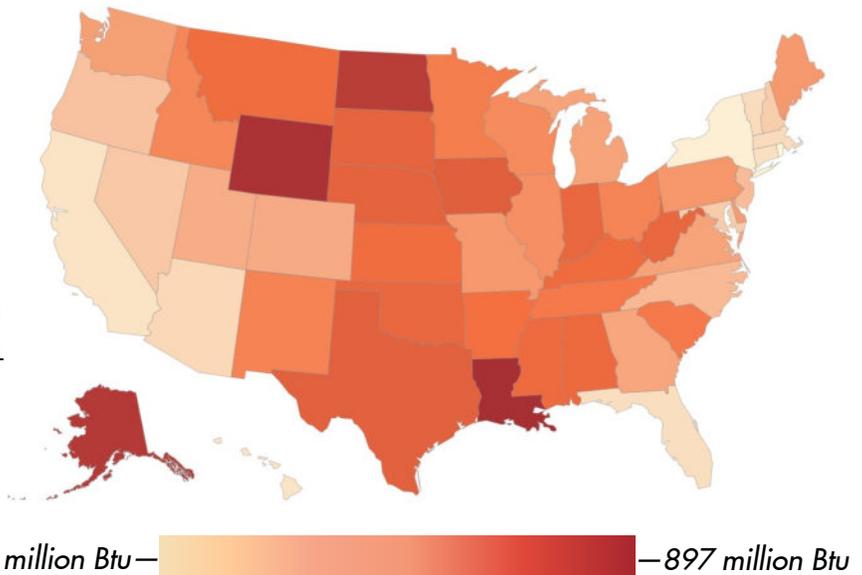
Btu

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

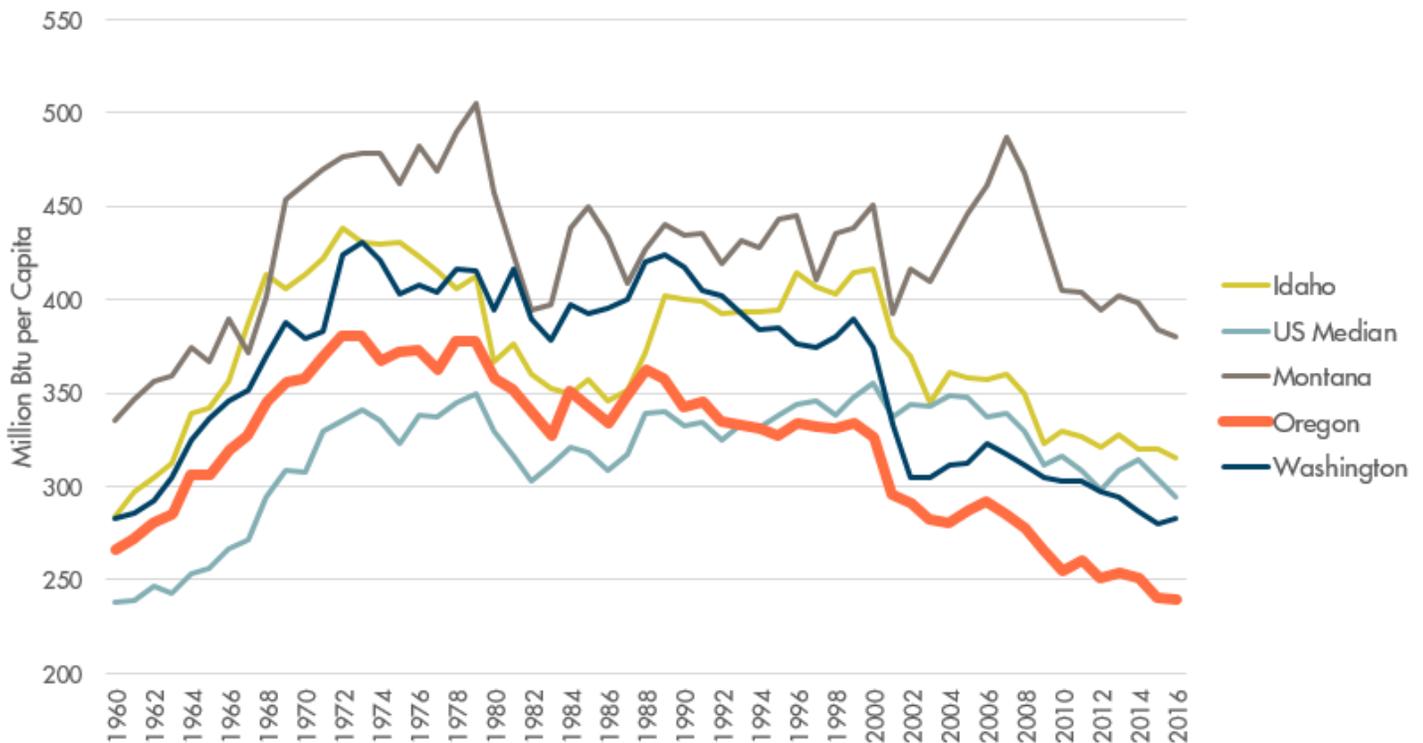
Energy Use in Oregon

Per Capita Energy Consumption

Per capita energy consumption in Oregon is the lowest since 1960. After a peak in 1972, per capita consumption declined by 37 percent, reaching 239 million Btu per capita in 2016 compared to the U.S. median of 301 million Btu per person. That same year, Oregon consumed 19 percent less than the U.S. median. Our per capita use is also the lowest in the Pacific Northwest.



Total Energy Consumption Per Capita:
Northwest States and U.S. Median Over Time



Consumption & Use

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

Energy Use in Oregon

Energy Consumption and Economic and Population Growth

Between 1960 and 1999, economic and population growth in the U.S. generally corresponded with growth in energy consumption. Starting in the early 2000s, in Oregon and the country as a whole, energy consumption is no longer directly correlated with growth factors like population and gross domestic product.

Energy efficiency and changes in industry have led to decreases in Oregon's total and per capita energy use. As discussed later in this chapter and in chapter 6, Oregon's emphasis on energy efficiency has helped reduce both total and per capita energy use despite an increasing population, thereby avoiding the need to build new electricity generation plants.

Between
2000 and 2016:
Oregon Population

↑ 19%

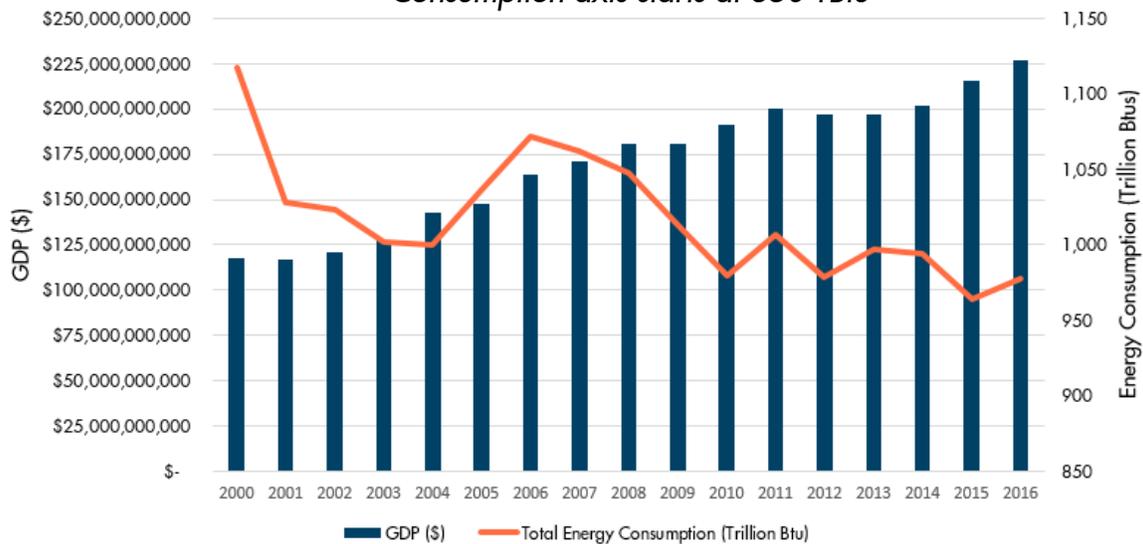
Oregon GDP

↑ 93%

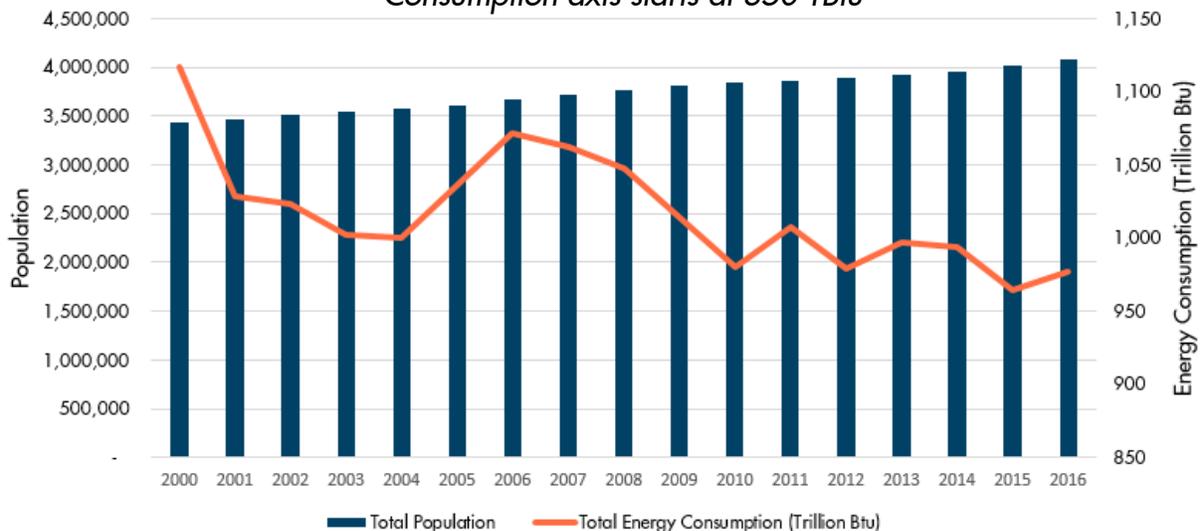
Oregon Energy Use

↓ 12.5%

Oregon's GDP and Energy Consumption: 2000-2016
Consumption axis starts at 850 Tbtu



Oregon's Population and Energy Consumption: 2000-2016
Consumption axis starts at 850 Tbtu



Electricity Use

Resources Used for Oregon's Electricity Mix

In 2017, Oregon used 49,615,797 megawatt hours, or MWh, of electricity from both in-state and out-of-state sources. Hydropower, coal, and natural gas make up the bulk of Oregon's electricity resources, commonly called resource mix, although the share of each resource is evolving. Oregon's only coal plant will cease coal operations in 2020, and renewable energy makes up an increasingly larger share of the mix each year.

The breakout below of electricity resources used in Oregon is based on statewide averages using three years of data. A three-year average helps to round out variability of the output from hydropower electricity due to annual weather patterns in the Pacific Northwest. The five largest sources of electricity fuels are labeled; the other resources are each under 1 percent.

32%

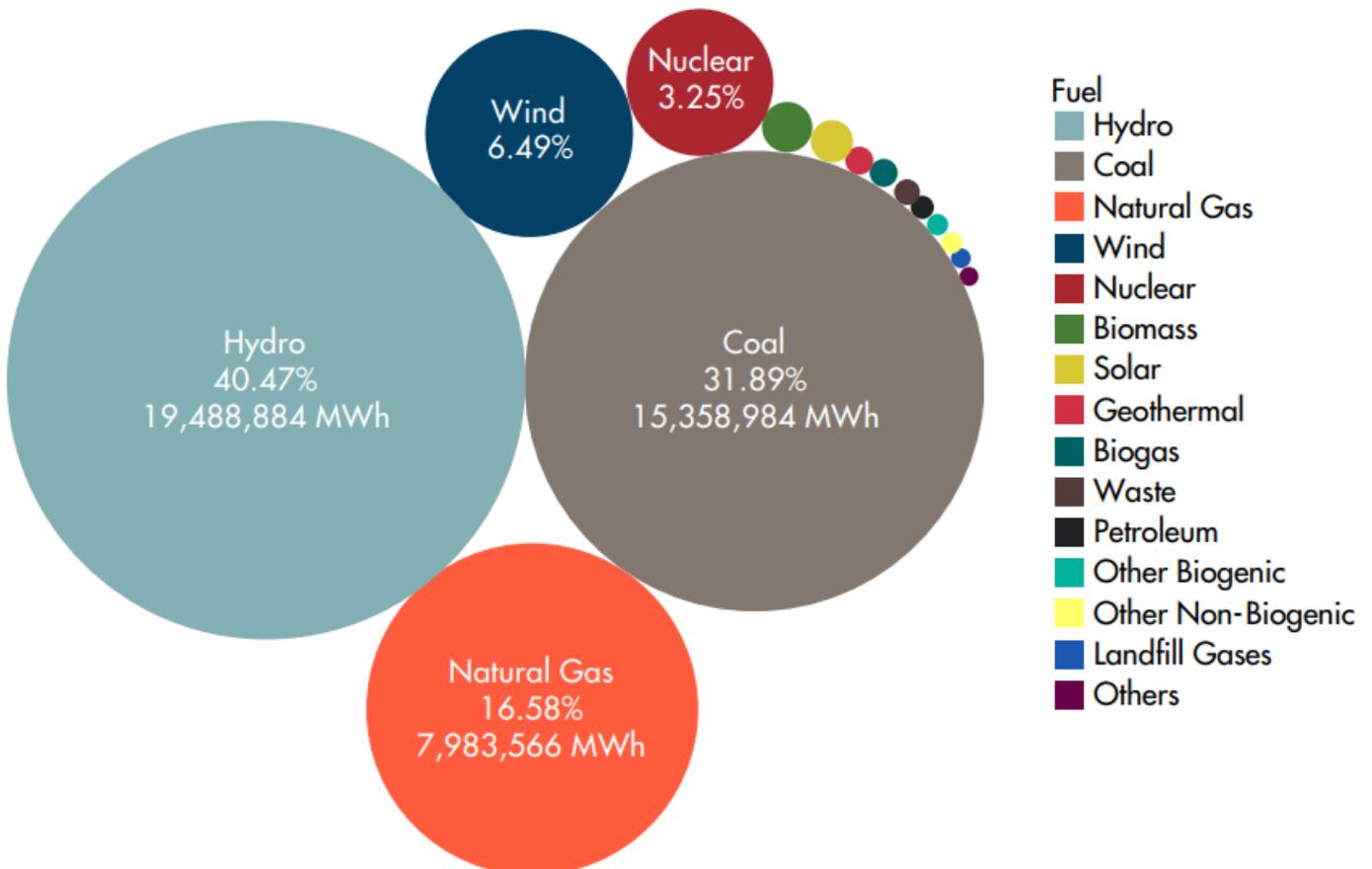
Percentage of Oregon's current electricity mix that comes from coal

2035

Year by which Oregon's two largest utilities will no longer be able to generate or contract for electricity from coal for use by Oregon consumers

Resources Used to Generate Oregon's Electricity

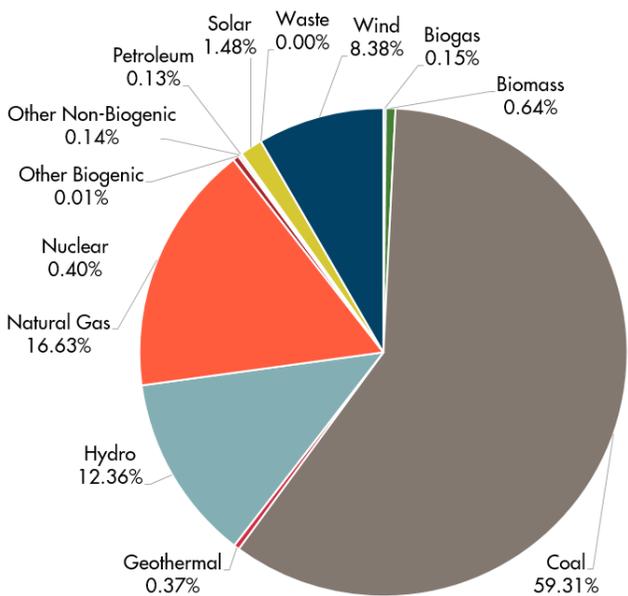
Based on a three-year average (2014-2016), this chart shows the energy resources used to generate the electricity that is sold to Oregon's utility customers.



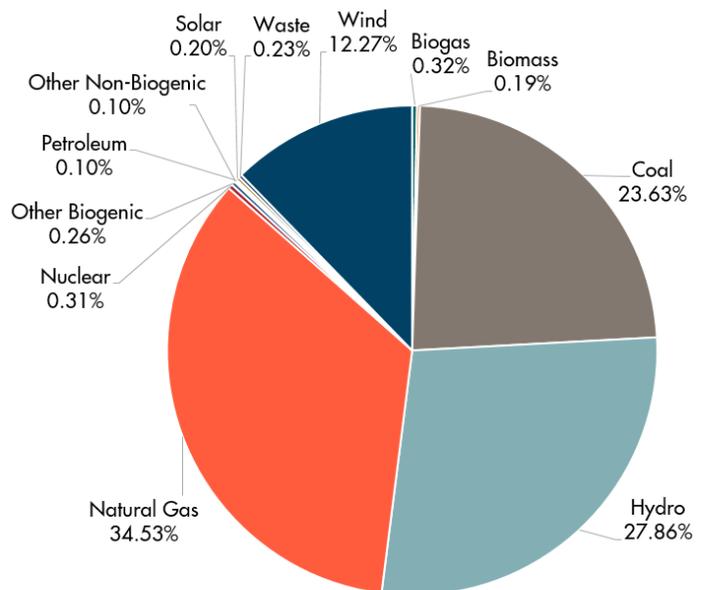
Electricity Use

Investor-Owned Utility Resource Mix

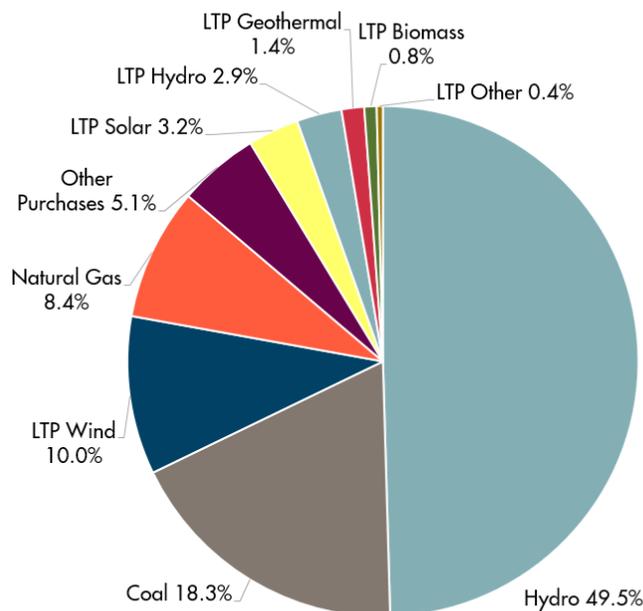
The resources utilities use to generate electricity consumed in Oregon vary depending on the utility provider. The electricity resource mixes for Oregon’s three investor-owned utilities are shown below. One year of data is shown for each utility; mixes will fluctuate year to year depending on the availability of certain resources. Oregon Department of Energy’s online Electricity Resource Mix tool uses a three-year average of data to account for variability in hydroelectricity. The information below includes real-time supplemental market purchases of electricity that utilities make to meet demand.



**Pacific Power
2016**



**Portland General Electric
2016**

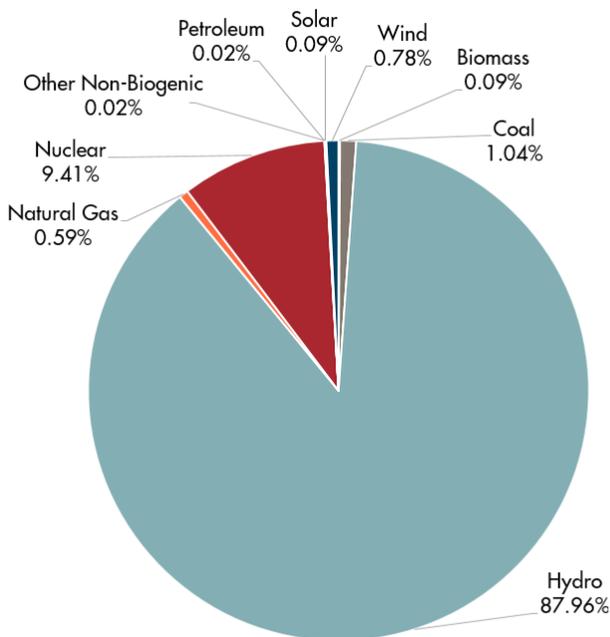


**Idaho Power
2017**

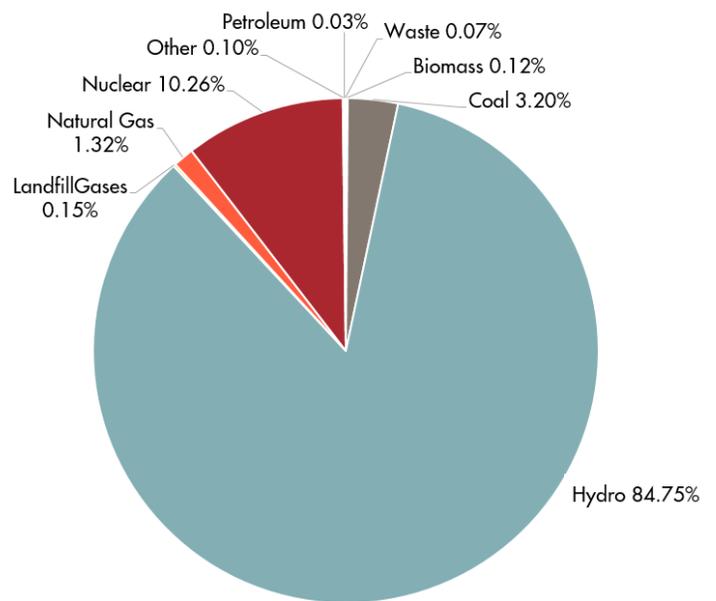
Electricity Use

Consumer-Owned Utility Resource Mix

The electricity resource mixes for the Eugene Water & Electric Board and a composite of other consumer-owned utilities operating in Oregon are below. One year of data is shown for each utility; mixes will fluctuate year to year depending on the availability of certain resources. Oregon Department of Energy’s online Electricity Resource Mix tool uses a three-year average of data to account for variability in hydroelectricity. The information below includes real-time supplemental market purchases of electricity that utilities make to meet demand; these purchases are called “unspecified” because the exact mix delivered to consumer-owned utilities is not certain. For example, the charts below include a percentage of coal from BPA’s unspecified market purchases on behalf of COUs.



*Eugene Water & Electric Board
2016*



*Average of Oregon Consumer-Owned Utilities, Not Including Eugene Water & Electric Board
2016*

Bonneville Power Administration

Consumer-owned utilities in Oregon purchase most of their electricity from the Bonneville Power Administration, a not-for-profit federal agency that markets wholesale electrical power from 31 federal hydroelectric facilities in the Northwest, a nonfederal nuclear power plant, and several other small, nonfederal power plants. The dams generating the hydroelectric power are operated by the U.S. Army Corps of Engineers and the Bureau of Reclamation. BPA provides about 28 percent of the electric power used in the Northwest.



The Dalles Dam in the Columbia River Gorge produces up to 2,000 MW of power.

Electricity Use

Rise In Renewables

Renewable electricity in Oregon has grown due to customer demand, dramatic decreases in costs, and policies like the Renewable Portfolio Standard.

In 2008, Oregon's electricity resource mix included 28 MWh of solar generation out of a total of more than 49 million megawatt hours for the year. In 2013 – five years later – solar was up to 30,000 MWh, with small increases over the next two years until 2016, when the resource mix jumped to 266,000 MWh of solar for the year.

Oregon's percentage of wind — topping 7 percent of our energy resource mix in 2016 — continues to grow as new wind facilities open up across the western U.S.

With this increase in renewable energy, other resources in our electricity mix have changed as well. The amount of coal included in Oregon's resource mix has been dropping since 2005. Natural gas—a resource that can help to integrate variable renewable resources like wind and solar into the grid—has increased. The percentage of natural gas-powered electricity in Oregon's resource mix increased from 12.1 percent in 2012 to 18.4 percent in 2016.

Renewable Hydropower

Hydropower makes up a large and important part of Oregon's electricity resource mix—providing more than 40 percent of the state's electricity. In some Oregon utility territories, hydropower provides more than 90 percent of consumers' electricity.

Most of this hydropower—from dams built decades ago—is not eligible for credit toward the state's Renewable Portfolio Standard, which was created to encourage the development of *new* renewable electricity resources. However, the RPS can include two types of electricity from these older but still critical hydro facilities: generation attributable to efficiency upgrades made at existing hydropower facilities after 1995 is eligible, as is generation from an existing facility if it became certified as a low-impact hydroelectric facility after 1995.

Megawatt (MW): A unit of measurement for power. One million watts of electricity capacity—the equivalent of 1,340 horsepower, or enough power to simultaneously illuminate 25,000 standard 40 Watt lightbulbs. **Megawatt Hour (MWh):** A unit of measurement for energy output that represents the amount of energy supplied continuously by 1 MW of capacity for one hour. **Average Megawatt (aMW):** Represents 1 MW of energy delivered continuously 24 hours/day for one year. A power plant with 50 MW capacity that operates at full output for 50 percent of the hours in a year delivers 25 aMW of energy.

50%

Percentage of Oregon's electricity that must come from renewable resources by 2040 through the Renewable Portfolio Standard (RPS)

741%

Percent increase in wind energy consumed in Oregon between 2004 and 2016

212,744

Megawatt hours of solar photovoltaic added to Oregon's electricity mix between 2015 and 2016

60%

Increase in natural gas used for electricity between 2012 and 2016

Electricity Use

Energy Efficiency

Energy efficiency plays a critical role in our state. It is the second largest resource in Oregon after hydropower, and Oregon has consistently met increased demand for electricity by implementing energy efficiency strategies. The Northwest Power & Conservation Council reports that since 1978, the Pacific Northwest has produced nearly 6,600 average megawatts of savings through efficiency programs and improvements. That's more electricity than the whole state of Oregon uses in a year.

Over the past decade, Oregon reduced per capita energy use despite our state population growing, and energy efficiency is one reason why. In 2018, Oregon scored in the top ten states for energy efficiency in national rankings—the twelfth year in a row making this list.

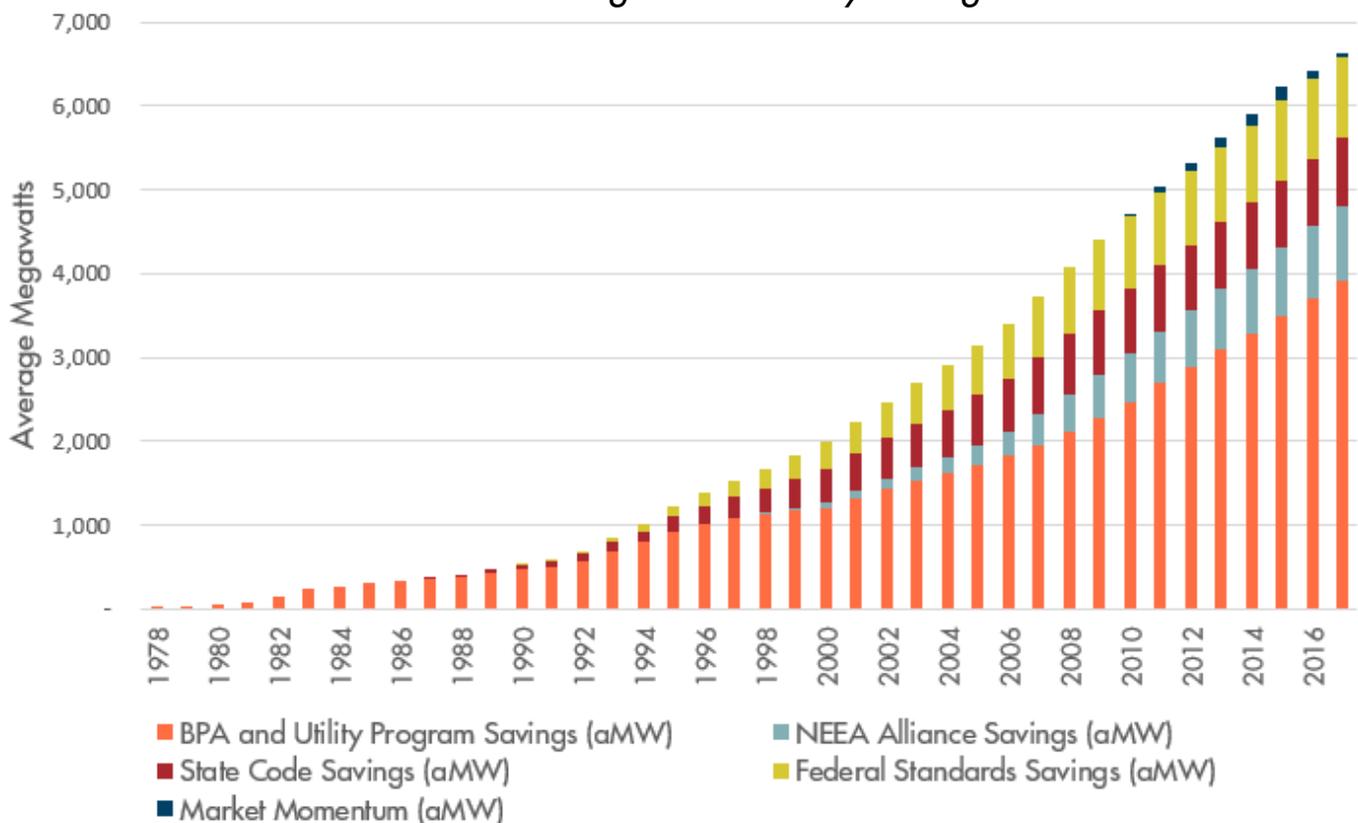
6,600

Average megawatts of regional electricity savings due to energy efficiency from 1978 to 2017

1,900

Average megawatts of electricity savings in Oregon from energy efficiency over that same time period

*How We Got Here:
Cumulative Regional Efficiency Savings*



Oregon's gains in energy efficiency have been helped by federal standards, state policies and programs, utility programs such as Energy Trust, and other nongovernmental organizations. For the region's cumulative savings, 60 percent comes from utility and BPA programs. Energy efficiency gains are cumulative and continue paying dividends for the region over time.

More energy efficiency will be realized in the future. The NWPCC’s 7th Power Plan, published in 2016, concludes that cost-effective efficiency can meet a large amount of new load growth in the region – allowing Oregon to grow without needing significant new electricity resources. The plan calls on the region to develop new energy efficiency programs equivalent to acquiring 4,300 average megawatts of power by 2035. Integrated Resource Plans from Oregon’s large electric utilities also identify energy efficiency as a key strategy they will use to meet demand over their planning horizon.

At an estimated \$30 per MWh, energy efficiency continues to be a more cost effective approach to acquiring new energy resources compared to traditional sources of electricity.

Oregon’s efficiency efforts have also reduced direct use fuels used to heat homes and provide energy in commercial and industrial settings. See the sector profiles section, beginning on page 38, for more details.

City of Portland HOME ENERGY SCORE

U.S. DEPARTMENT OF ENERGY
THIS HOME'S SCORE **1** OUT OF 10

THIS HOME'S ESTIMATED ENERGY COSTS
\$2,932 PER YEAR

Better Buildings Home Energy Score

HOME PROFILE
LOCATION: 1234 Anyplace St, Portland, OR 97201
YEAR BUILT: 1923
HEATED FLOOR AREA: 945 sq. ft.
NUMBER OF BEDROOMS: 2

ASSESSMENT
ASSESSMENT DATE: 12/22/2017
SCORE EXPIRATION DATE: 12/22/2025
ASSESSOR: Maria Gomez, Gomez Energy Partners
PHONE: 503-555-1211
EMAIL: mgomez@gomezenergymodeling.com
CCR LICENSE #: 1234567890

Flip over to learn how to improve this score and use less energy!

HOW MUCH ENERGY IS THIS HOME LIKELY TO USE?

Electric: 10,000 kWh/yr	\$930
Natural Gas: 0 therms/yr	\$0
Other: 776 gal/yr	\$2,002
TOTAL ENERGY COSTS PER YEAR	\$2,932

THIS HOME'S CARBON FOOTPRINT:

15 tons/yr WORSE → 9.2 This Home → 0 tons/yr BEST

What should my home's carbon footprint be? Between now and 2030, Portlanders should reduce carbon pollution per household to 3 metric tons per year to reach our climate goals.

- Actual energy use and costs may vary based on occupant behavior and other factors.
- Estimated energy costs were calculated based on current utility prices (\$0.11/kWh for electricity; \$1.00/therm for natural gas; \$2.26/gal for heating oil; \$2.21/gal for propane).
- Carbon footprint is based only on estimated home energy use. Carbon emissions are estimated based on utility and fuel-specific emissions factors provided by the Oil Department of Energy.
- Relating 2-7 years after the assessment date requires a free reprint of the Report form: www.greenbuildingregistry.com/portland to update energy and carbon information.
- This report meets Oregon's Home Energy Performance Score Standard and complies with Portland City Code Chapter 12.106.

Home Energy Scoring

Home Energy Score systems help Oregonians better understand a home's energy use and how even small improvements can save energy. A certified professional evaluates a home's energy features and issues a score, similar to the bright yellow Energy Guide label found on home appliances. The City of Portland now requires homes for sale to have a home energy score when placed on the market. More than 6,600 homes in Portland have already received a score that evaluates energy use and energy efficiency opportunities.

23.5 million

Tons of carbon emissions reduced per year in the region due to energy efficiency

\$4 billion

Amount saved by Pacific Northwest residents due to lower electricity bills in 2015

\$182 million

Amount utilities, governments, and nonprofit programs invested in Oregon energy efficiency in 2017

\$12.7 million

Amount Oregon spent in 2017 on energy efficiency programs targeting low-income households

Electricity Use

Where It Comes From

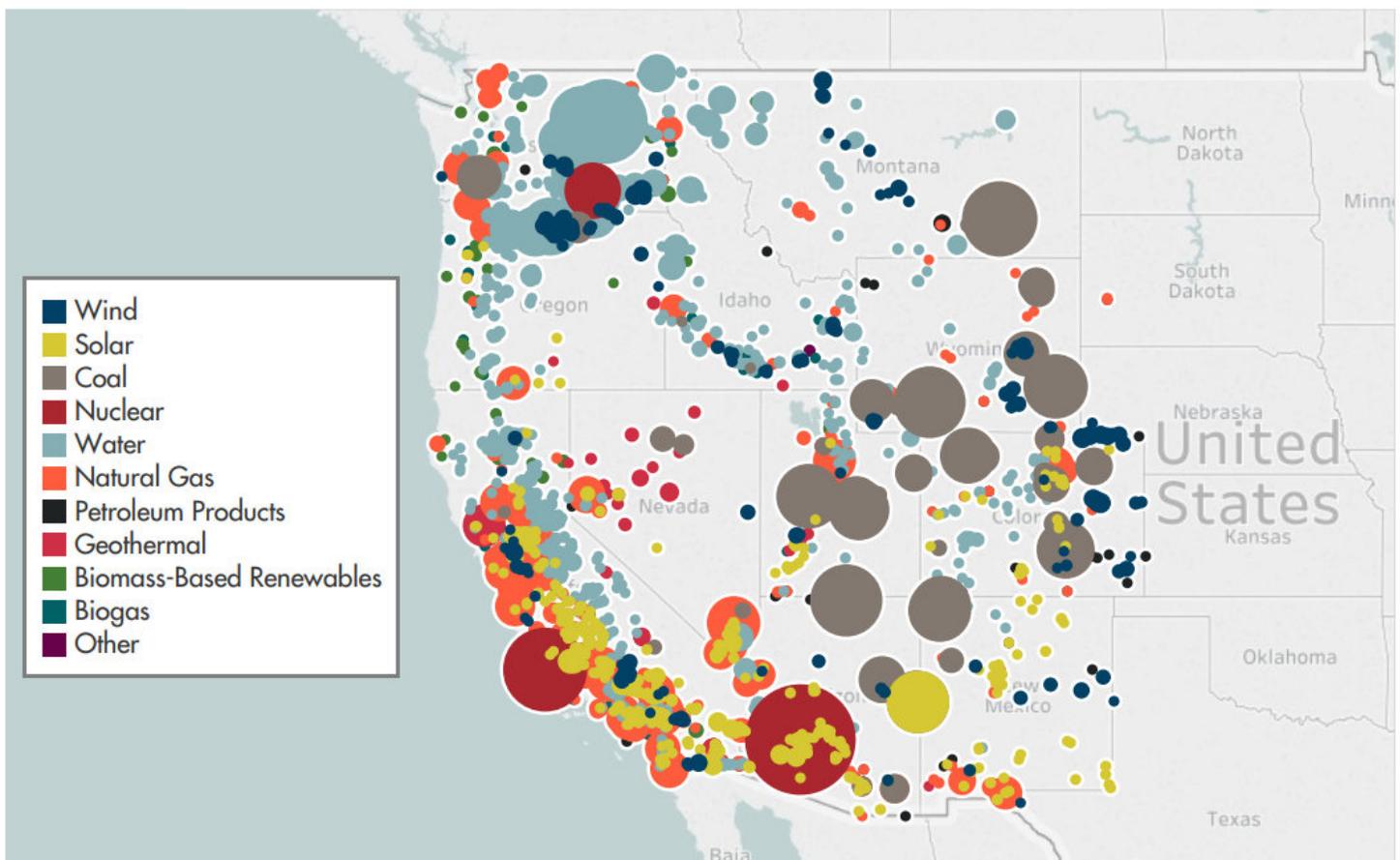
Electricity used by Oregonians can come from facilities across the western United States. We rely on hydroelectric power produced on the Columbia River, access small amounts of nuclear power from the Columbia Generating Station in Washington, and use electricity generated at coal-powered facilities.

The map below shows the various electricity generation sources in the Western Electric Coordinating Council. The map uses data from the Energy Information Administration and includes facilities with a nameplate capacity of 1 megawatt or greater. Not all of the resources or facilities shown contribute to Oregon's overall fuel mix but are available when a utility purchases power on the open market. In the same way, electricity generated in Oregon may be sold through the market to support electricity needs in other states.

"WECC"
The Western Electricity Coordinating Council is a nonprofit corporation that focuses on system-wide electricity reliability across a geographic region known as the Western Interconnection. This diverse region includes Oregon as well as most of the intermountain west and parts of Canada.

Electric Generation Sources in the Western Electric Coordinating Council Region

Average 2014-2016 Net Generation in MWh by Plant



3.25%
Share of Oregon's electricity that comes from Washington's Columbia Generating Station Nuclear Facility

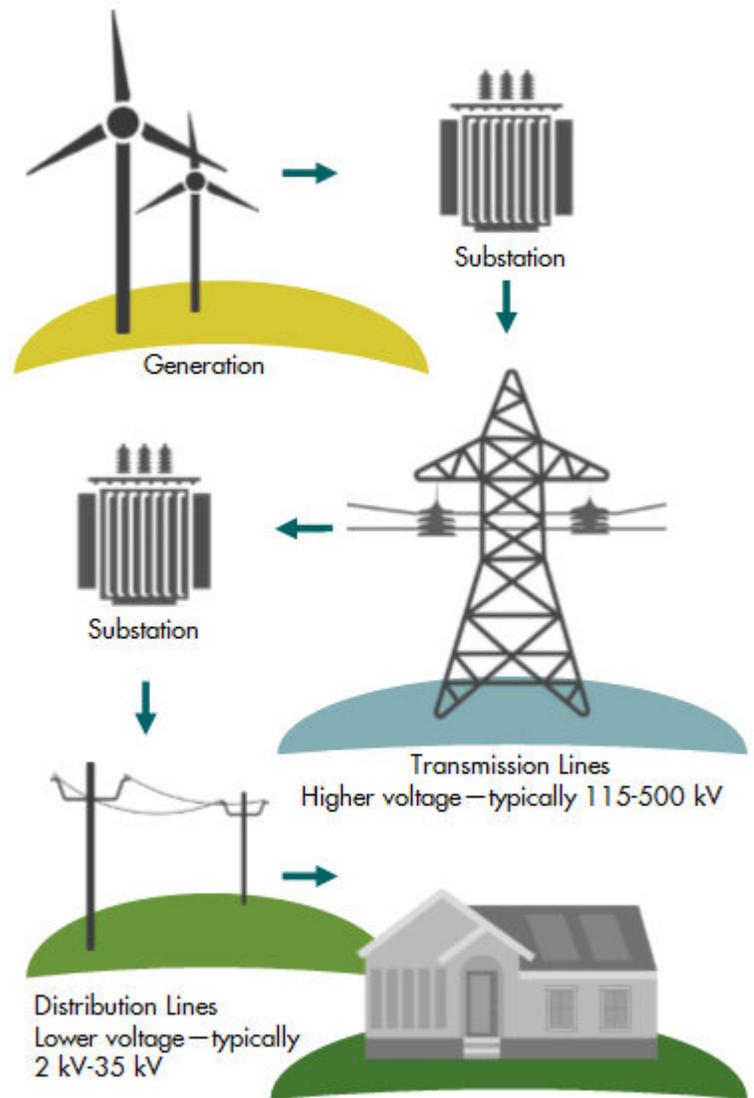
Electricity Use

How It Gets To Us

Electricity travels from generating facilities to customers over an interconnected network of transmission and distribution wires and substations, which connect the higher-voltage transmission system with the lower-voltage distribution network.

Collectively, this interconnected network of transmission and distribution wires and substations is referred to as “the electric grid,” or simply “the grid.” Unlike the networks designed to deliver other types of energy—like liquid fuels or natural gas—the electric grid has been designed to simultaneously deliver enough electricity from generators to meet the highest consumer demands on the system.

By comparison, production of liquid fuels or natural gas can occur at a more constant rate and still meet hourly or daily fluctuations in demand, due to the ability to easily and cheaply store large quantities of both. Because it is much more difficult and costly to store electricity, the grid needs to carry electricity from power plants to customers nearly instantaneously to meet fluctuations in demand from moment to moment.



In the Pacific Northwest, the Bonneville Power Administration owns and operates nearly 75 percent of the high-voltage electric transmission network—including more than 15,000 miles of lines. The majority of the rest of the transmission system is operated by one of the region’s larger privately owned utilities, such as PacifiCorp or Idaho Power. The lower voltage distribution system in Oregon is owned and operated by dozens of different distribution utilities.

Transmission System and Federal Dams

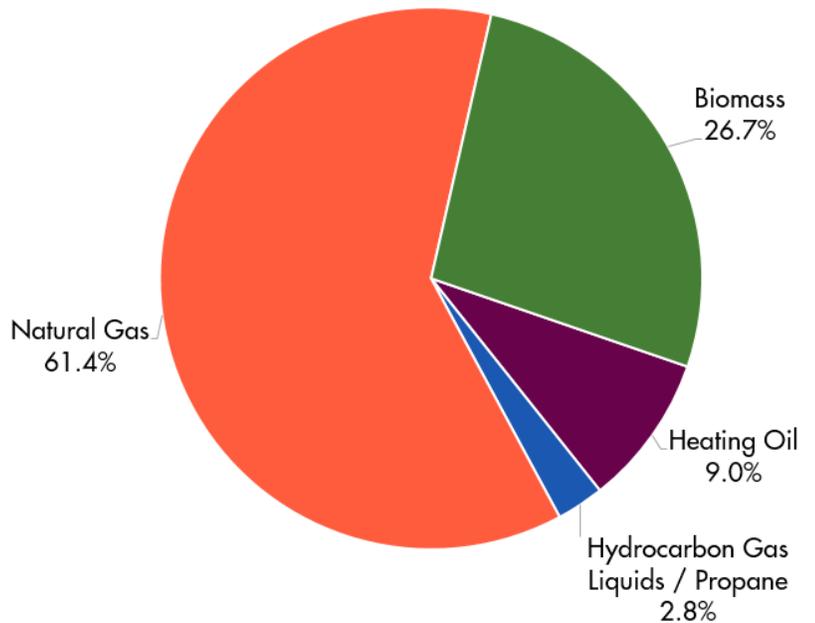
LEGEND	
	BPA Transmission Line
	Federal Dam
	Non-BPA Line
	BPA Service Area



Direct Use Fuels

What We Use and Where It Comes From

In 2016, Oregon used 139 trillion Btu of natural gas, 6 trillion Btu of propane, and 21.1 trillion Btu of heating oil. Biomass is also a significant source; the Energy Information Administration estimates Oregon used 60.4 trillion Btu. Direct uses include cooking, heating, and industrial and commercial process heat. Additionally, the state used thermal energy generated from solar thermal and geothermal sources.



Natural Gas: The previous section focused on natural gas used for electricity, but the resource is equally important for direct uses such as space and water heating, cooking, and many agricultural, commercial, and industrial processes. In 2016, the state used 139 trillion Btu of natural gas for direct uses. Oregon imports most of the natural gas, or methane, we use from Canada and the Rocky Mountain states. The Pacific Northwest’s only natural gas production is at a location outside of the town of Mist, northwest of Portland. The field is owned and operated by NW Natural Gas, one of three investor-owned gas companies in the state. The Mist field produced about 801,491,000 cubic feet of natural gas in 2016, which represents less than one-half percent of Oregon’s annual use. For more information about the Mist facility, see page 23.

Propane: Oregon residents consumed about 66.6 million gallons of propane in 2015; more than 25,000 homes used propane for heat. Nationally, 54 percent of propane is used in residential applications like heating and cooking. Another 19 percent is used in commercial applications, 11 percent as transportation fuel, 7 percent in agriculture, 6 percent in industry, and a little over 3 percent in backyard grills. Propane can be used to power buses, locomotives, forklifts, taxis, farm tractors, and Zamboni machines at ice skating rinks. Propane remains a viable fuel over long periods of storage, making it a common backup fuel for correctional facilities and hospitals and a potential resource in emergency response.

Heating Oil: Many Oregon homes have on-site oil tanks for heating. Fuel oil is also used in commercial, industrial, and institutional sectors. In 2016, Oregon used approximately 21.1 trillion Btu or 150.4 million gallons of fuel oil. Much of Oregon’s supply comes from refineries in Washington.

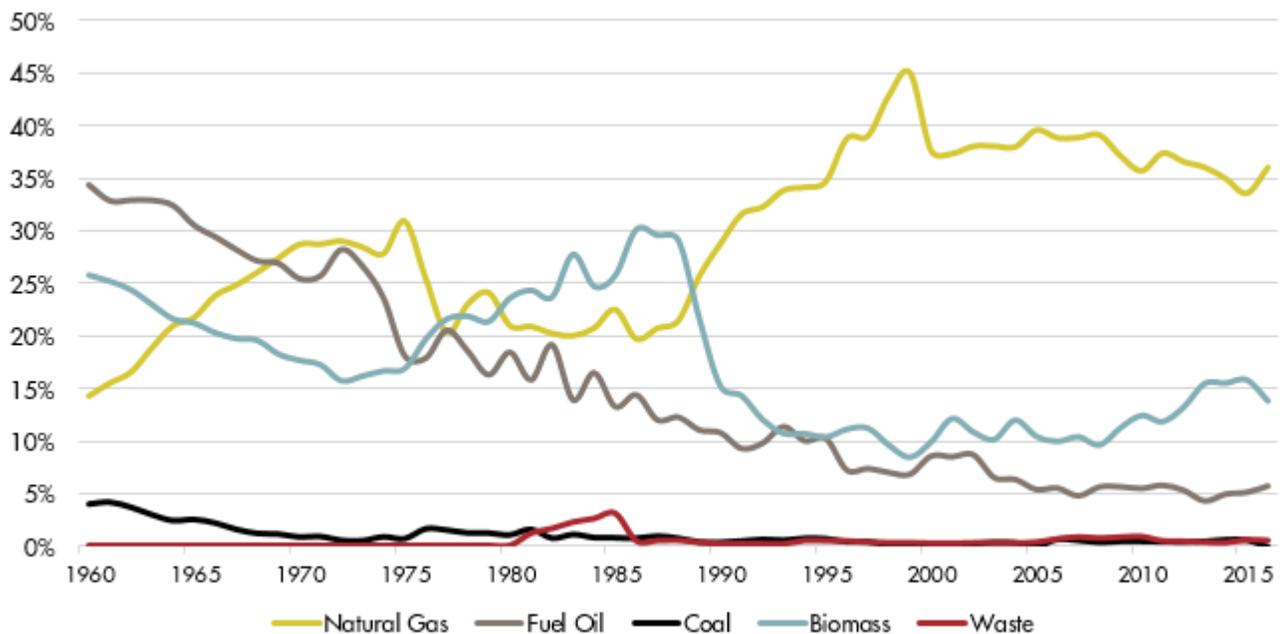
Biomass: Biomass is organic material from plants and animals that can be converted to liquid, gaseous, and solid fuels for direct uses or to generate electricity. Biomass energy sources in Oregon include residuals from commercial forest harvest, agricultural manure, and organic materials breaking down in landfills, wastewater treatment plants, and food waste collection facilities. While some biomass sources are the same as biogas or renewable natural gas (covered under transportation fuels), biomass also commonly refers to end-products such as wood chips, wood pellets, and charcoal that are used for thermal energy.

Geothermal: While geothermal energy is often used for electricity, it can also be used for thermal energy applications such as heating spaces and keeping bridges and sidewalks from icing over. It, too, makes up a small portion of Oregon’s annual direct use energy total.

How Direct Use Fuels Have Changed Over Time

Energy consumption continues to change in Oregon and across the U.S. For direct use fuels in Oregon, that means less wood and fuel oil and more natural gas. The chart below compares percentages of different fuel types used in the residential, commercial, and industrial sectors and their relationship over time. Fuel oil in particular has declined steadily since 1960, while natural gas has increased. More recently, electricity has replaced the use of some direct fuels.

Oregon's Direct Fuels Consumption in the Residential, Commercial, and Industrial Sectors



Solar Thermal

While not included in Oregon's direct use fuels reporting data, solar thermal energy is a resource used directly in Oregon homes. Solar thermal systems use energy from the sun to provide water heating and space heating in buildings. The majority of the systems installed in Oregon provide supplemental energy to residential water heaters and offset up to 70 percent of the households' water heating bills. More than 10,700 solar water heating systems have been installed under the Oregon Residential Energy Tax Credit program. Of these, more than 9,200 were installed before 2008. In the last ten years, residential solar water heating systems have declined from over 300 installations per year to fewer than 100 installations per year. They make up a very small portion of Oregon's annual direct use energy total.

Direct Use Fuels

How They Get to Us

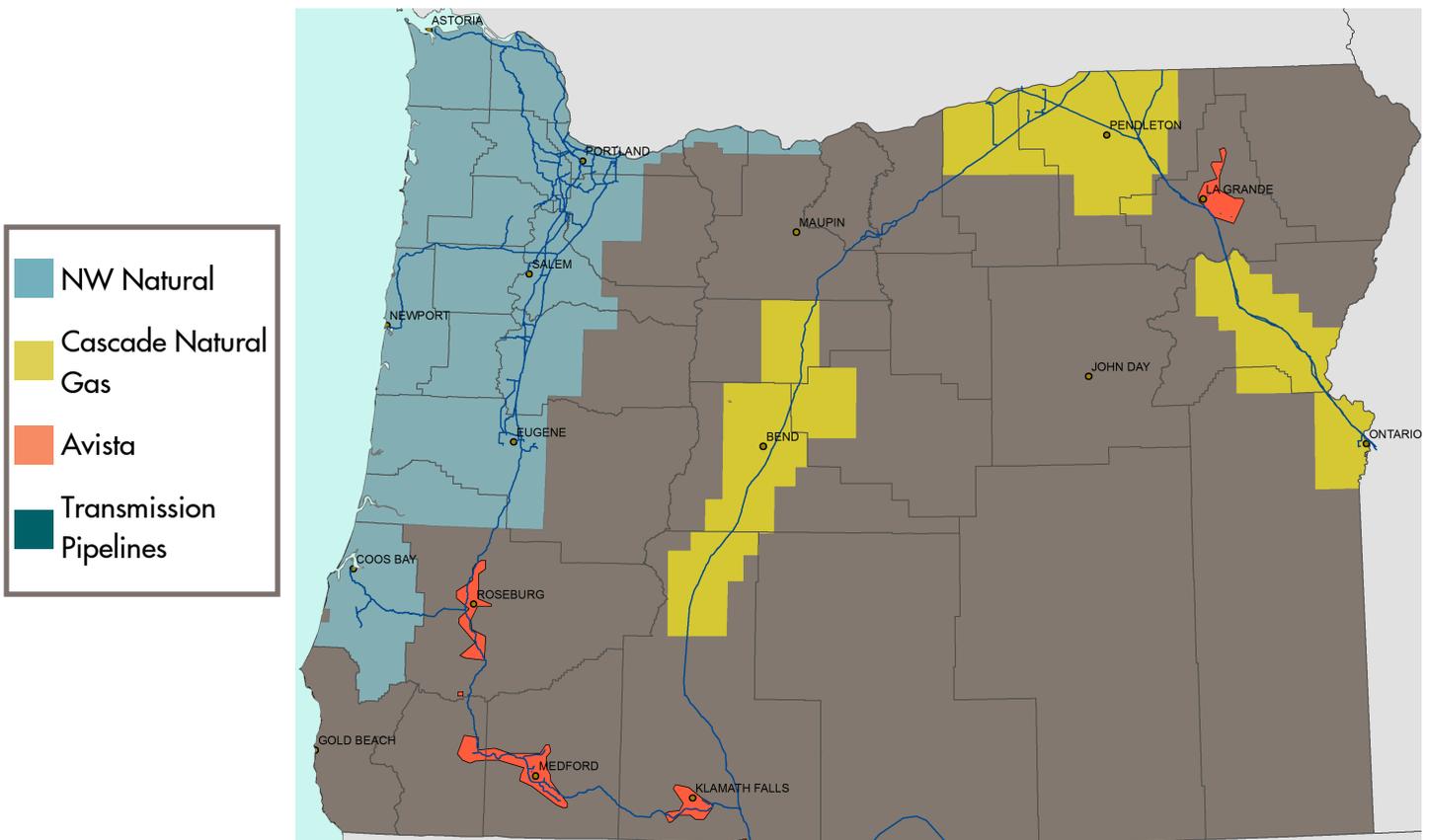
Natural gas is transported across Oregon in pipelines, which are connected to the distribution systems of the three natural gas utilities: NW Natural, Avista, and Cascade Natural Gas. Unlike electricity, natural gas is not available in less-populated areas of the state.

All propane and heating oil used in Oregon arrives by truck or rail car. More than 300 Oregonians manage and operate the propane distribution network.

Numerous facilities across the state convert biomass to energy. Seven companies make liquid biofuels, nine companies make wood pellets, and one company makes charcoal briquettes. Oregon also has seven landfill gas-to-electricity operations and 10 agricultural anaerobic digesters making electricity (six are currently operating). Twelve wastewater treatment plants can generate up to 8.7 MW from biogas; seven woody biomass combined heat and power plants across the state have the ability to generate up to 273.3 MW of electricity and an undetermined amount of thermal energy for commercial and industrial process heat or to heat buildings.

The map below shows natural gas transmission lines and the service territories of Oregon's three natural gas utilities. A large portion of Oregon is not covered by any gas utility territory, and even within existing gas utility territories, many Oregonians lack access to natural gas service.

Oregon Natural Gas Transmission Pipelines and Utility Territories



Transportation Fuel Use

What We Use

Transportation fuels represent the largest energy use in Oregon. Compared to direct use fuels and electricity, transportation fuels account for 38 percent of our state’s total energy use. This includes fuels used for cars, passenger trucks, and SUVs—often called “light-duty vehicles”—heavy duty vehicles used for transport and delivery, plus fuels used in the aviation and marine industries.

When energy use is divided among what are commonly called “end-use” sectors, the transportation sector is the largest—31 percent compared to smaller percentages for residential, commercial, and industrial sectors.

Petroleum-based products accounted for 93.3 percent of fuel consumed in the transportation sector, while biofuels such as ethanol, biodiesel, and renewable diesel accounted for 6.4 percent. Other smaller sources are listed below. As more Oregonians switch to electric vehicles, electricity’s share of transportation will grow. See chapter 4 for more details.

85%

Percentage of energy used in the transportation sector consumed on Oregon roadways

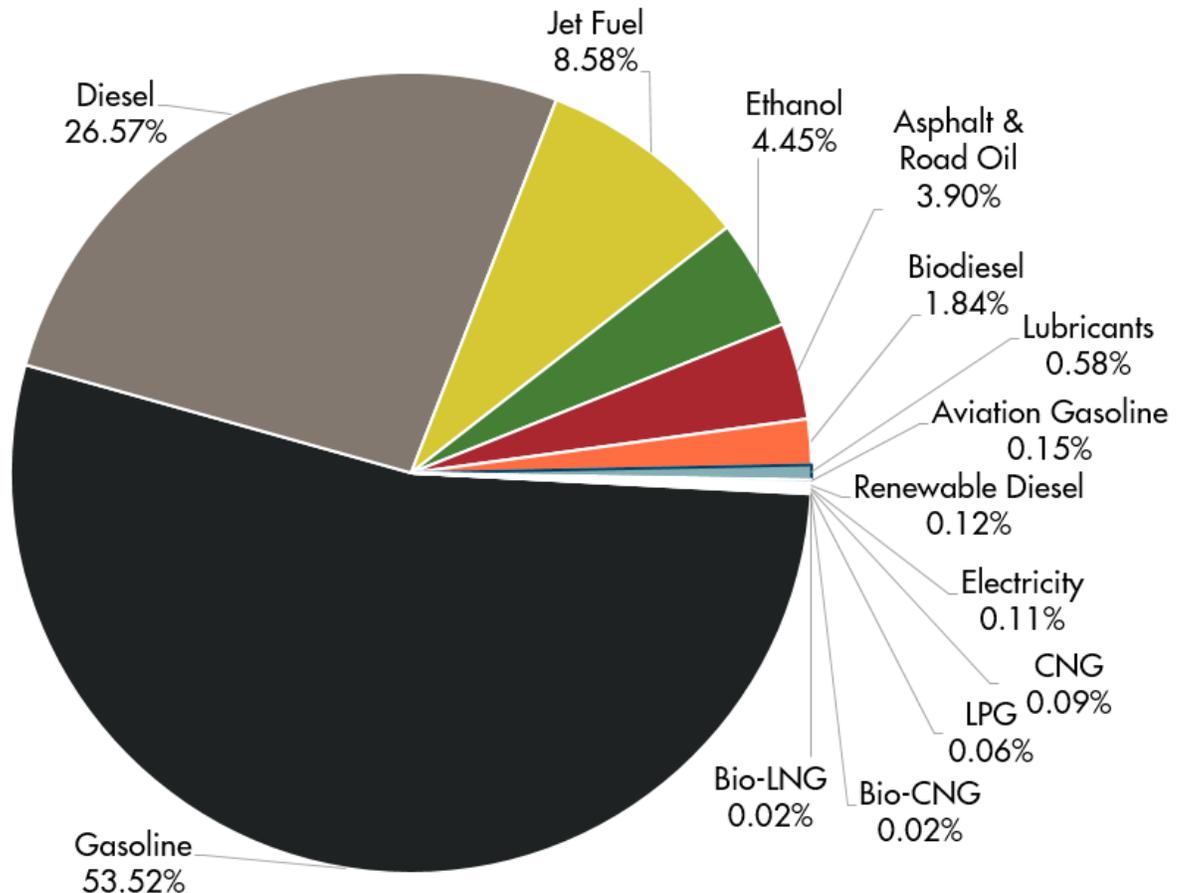
5%

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

10%

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

Transportation Fuels Used in Oregon
2016



Transportation Fuel Use

Where It Comes From

In 2016, less than 2 percent of transportation fuels consumed in Oregon were produced in-state. Oregon does not have crude oil reserves or refineries to process petroleum. Over 90 percent of the petroleum products delivered to and consumed in Oregon come from four refineries in Washington state. Crude oil used at Washington refineries comes from Alaska, western Canada, and North Dakota.

In 2016, more than 75 percent of the ethanol and 84 percent of biodiesel consumed in Oregon was produced out-of-state—primarily in the midwest. About 23 percent of ethanol used in Oregon is produced in Boardman, while biodiesel is produced in Salem; see the next section for production details.

Oregon is exploring how to use more renewable natural gas in the transportation sector. While fossil natural gas is typically associated with oil deposits, biogas and renewable natural gas come from landfills, waste water treatment plants, anaerobic digesters at dairies, food processing plants, or waste processing facilities. Twenty-five Oregon facilities are producing biogas and converting it to electricity for in-state use. This biogas can also be cleaned up for use in the transportation sector or to meet natural gas pipeline standards.



Above, a CNG-powered truck delivers commercial food waste to the North Portland transfer station. The waste will go to JC Biomethane to be digested and converted into electricity and soil amendments. Eventually, the hope is to collect the methane from the anaerobic digester and then turn that methane into renewable natural gas that can fuel trucks currently using CNG.

How It Gets to Us

Transportation fuels are delivered to six Portland-area terminals via the Olympic Pipeline, by barge, and to a lesser extent by rail. These terminals receive, store, blend, and transfer petroleum products. The Portland region has a demand of about 200 to 210 thousand barrels a day. Some of this product flows in a pipeline south to Eugene and to Portland International Airport. The Eugene distribution hub serves southern, central, and eastern Oregon. Eastern Oregon is also served by hubs in the Tri-Cities area, Moses Lake, and Spokane. Additional small amounts of petroleum products come by tanker from California and Pacific Rim Countries. An estimated 1,500 tanker trucks deliver fuel throughout the state to about 2,400 fueling locations.

Ethanol and biodiesel primarily travel to Oregon via rail.

Energy Production in Oregon

The previous section focused on different energy resources Oregon uses. This section discusses what we make. Oregon ranks 33rd in the country for energy production—and seventh in the country for total renewable energy production.

In the following pages, energy production is divided into the three categories below, with specific information on the types of energy produced in Oregon, along with more general information about the environmental effects of each resource no matter where it is produced. Later chapters go into more detail about the benefits, impacts, and tradeoffs associated with various resources.

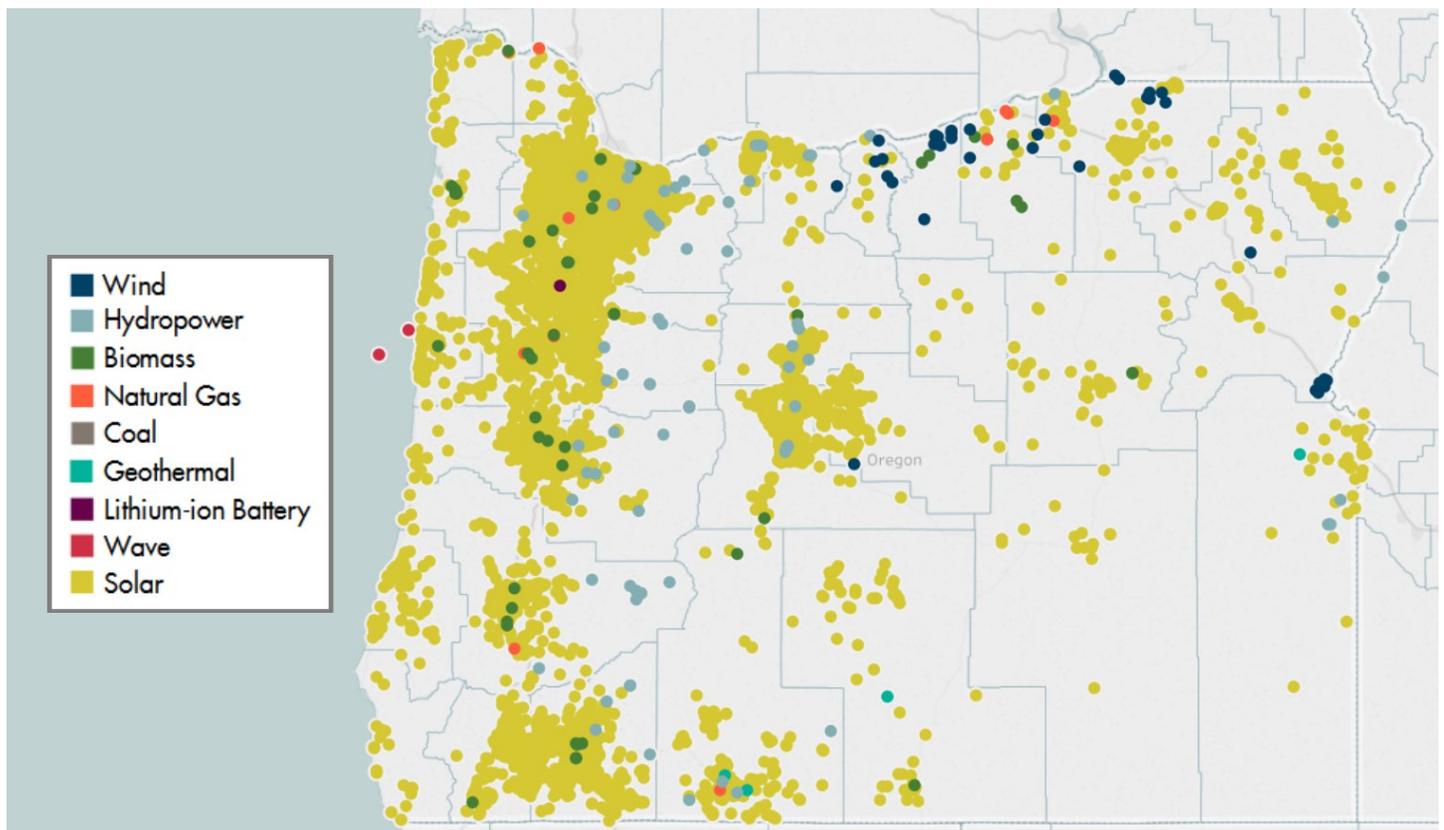
Electricity: Much of the electricity generated in-state uses Oregon-based natural resources—wind or hydropower, for example. Oregon energy facilities also generate electricity using raw materials from out of state; all of the coal and natural gas used at Oregon’s in-state coal and natural gas power plants comes from out of state.

Direct Use Fuels: These include natural gas and biofuels produced in-state; hog fuel, or wood chips, used for industrial heat; commercial wood pellets for commercial and industrial heat; and more.

Transportation Fuels: Oregon produces about 25 percent of the biofuels our transportation system uses; overall, biofuels make up 6.4 percent of Oregon’s use of transportation fuels.

Energy Production in Oregon

The map below shows more than 16,000 sites, including residential rooftops, where energy is being produced across the state.



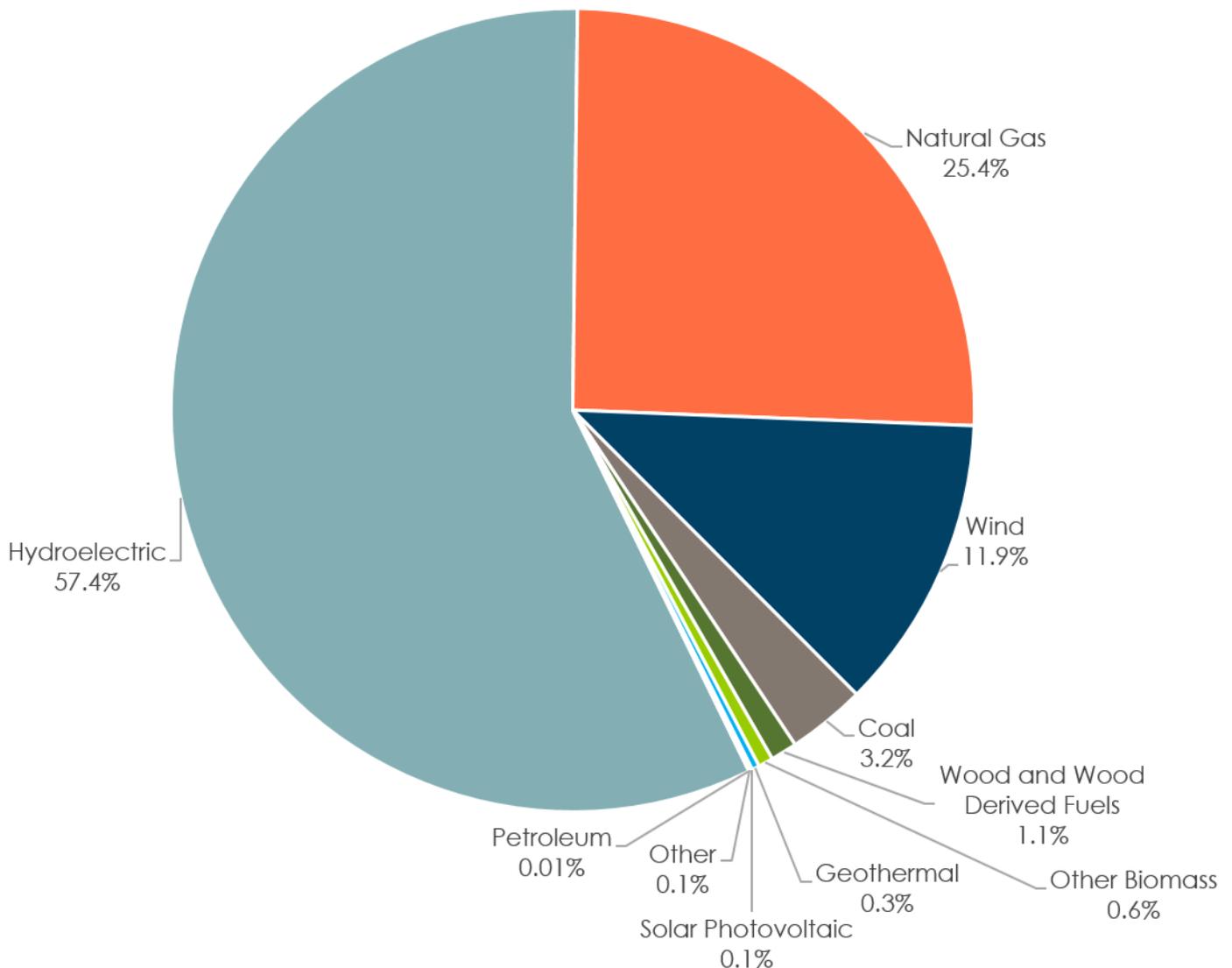
Electricity Generation in Oregon

Oregon generates electricity from a variety of resources; hydropower, natural gas, and wind are the largest. In 2016, 71 percent of Oregon’s utility-scale net electricity generation came from hydroelectric facilities and other renewable energy resources. Oregon also imports coal and natural gas from other states, using the fuels at Oregon-based power plants to generate electricity .

In 2016, Oregon generated 60,182,012 MWh of electricity. A portion of the electricity we generate from hydropower, wind, natural gas, and solar is exported to other states, while electricity from those states is imported for Oregonians’ use. Comparing total megawatt hours of use to generation, we use about 17 percent less electricity than we generate.

Electricity Generated in Oregon — 2016

While the previous page’s map showed all energy generation, this map uses data from EIA and does not include rooftop solar generation.



HYDROPOWER



8,865 MW of capacity

88 hydropower facilities—80 in Oregon, 8 crossing state borders

Smallest: .04 MW

Largest: 2,160 MW

12 facilities over 100 MW

Third highest installed capacity of hydropower in the U.S.

Hydropower was responsible for more than 57 percent of the state's electricity generation in 2016.

Hydropower in Oregon

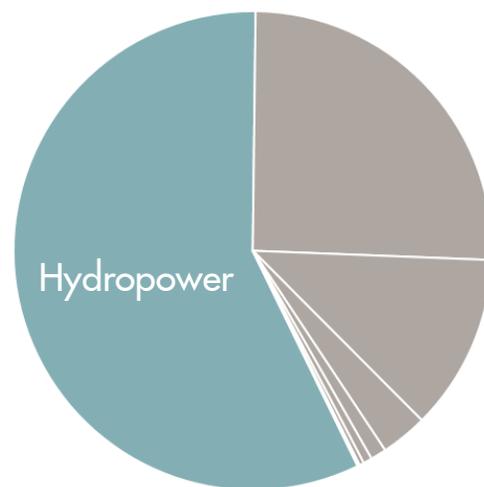
Much of this power comes from the Federal Columbia River Power System (FCRPS), which includes 31 hydroelectric facilities across four states with a total capacity greater than 22,000 MW of power. The dams are operated by the U.S. Army Corps of Engineers and the Bureau of Reclamation, and the Bonneville Power Administration markets the power from the system. Ten of these hydropower facilities are fully located in Oregon, and four of the largest projects—Bonneville, The Dalles, John Day, and McNary—span the Oregon and Washington state borders on the Columbia River.

Oregon's 36 consumer-owned utilities rely on BPA for all or a majority of their power. These utilities span the state. Many of the smaller BPA customer utilities count on BPA for 100 percent of the power they sell to customers, and these utilities have some of the lowest retail power rates in the U.S. After serving their public power customers, BPA also sells a significant amount of power to investor-owned utilities in the region and to entities out-of-state.

BPA is not the only entity in Oregon to sell electricity from large hydroelectric facilities. Portland General Electric and Eugene Water and Electric Board are two examples of Oregon utilities that own and operate utility-scale hydro facilities. PGE wholly owns five hydroelectric plants with 192 MW capacity, and jointly owns two hydroelectric plants with 303 MW capacity.

As of 2016, there were approximately 50 hydroelectric facilities of 1 MW or larger operating in Oregon that were not part of the FCRPS. Oregon also has other smaller hydropower projects, many of which are certified as low impact facilities. For example, the Three Sisters Irrigation District is building three hydropower stations — each sized between 200 and 700 kW — as part of an irrigation modernization project. And as part of a planned retrofit, the City of Portland replaced portions of existing municipal water supply pipes with new pipes that include four in-conduit turbines with a total generating capacity of 200 kW.

These hydropower projects deliver significant benefits to Oregon and the region, including low-cost, carbon-free power, flood control, navigation, and irrigation. Many of these hydropower projects also have significant



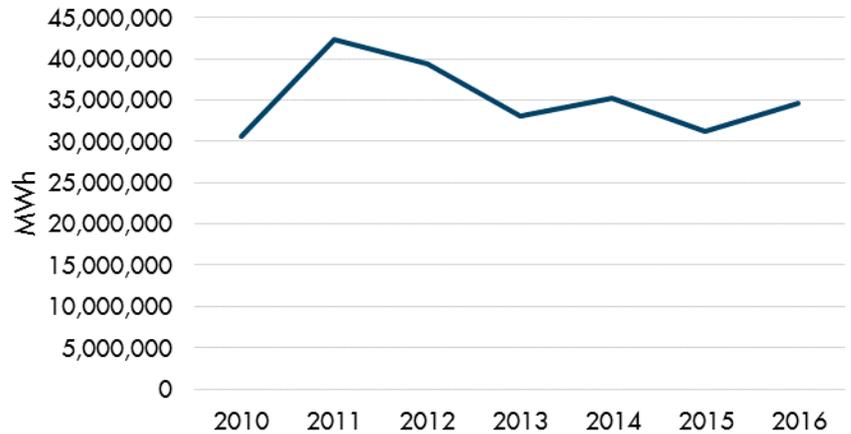
Hydropower is responsible for 57.4 percent of Oregon's in-state electricity generation. Of the electricity Oregon uses, hydropower makes up 40.5 percent of the state's resource mix.

operational flexibility that allows them to ramp output up or down relatively quickly, providing a useful resource to integrate variable renewable resources like wind and solar.

Resource Potential

The first U.S. hydroelectric power generation facility began operation in 1880, and the first of the FCRPS dams began operating in the 1930s. A number of the aging dams in the FCRPS have been retrofitted with more efficient turbines and other improvements such as enhanced fish passage. See chapter 3 for more details. New applications of hydropower technology, including “micro-hydro” projects like in-pipe conduit turbines, have also been deployed.

Oregon Hydroelectric Generation
2010-2016



Annual variations can have a dramatic impact on the hydroelectric system. Years with less rainfall and lower snowpack levels will yield lower amounts of hydroelectric generation.

Environmental Effects

Hydropower in Oregon is considered a zero-emissions resource. Hydropower has a low lifecycle carbon footprint from the embedded GHG emissions from manufacturing and construction. Dams also have significant stream flow and temperature impacts on fish habitat; alter sediment and nutrient regimens; and affect the ability of fish to migrate from the river to the ocean and back. In addition, the initial construction of dams inundates land, and their continued operation changes water levels throughout the year.



Map used courtesy of the U.S. Army Corps of Engineers



NATURAL GAS

More than 4,066 MW of capacity
 20 facilities produce electricity
 45% of state's capacity comes from 3 facilities larger than 500 MW
 3 state universities use on-site natural gas to generate their own power
 Oldest facility came online in 1950, newest in 2016

Natural gas was responsible for 25.4 percent of the state's electricity generation in 2016.

Natural Gas in Oregon

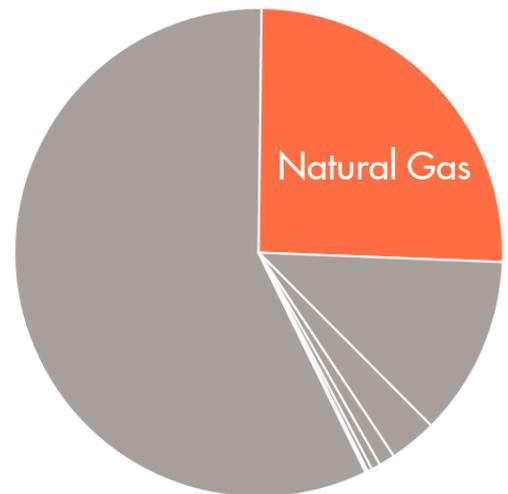
Oregon has 20 operating natural gas-fired power plants, with 10 producing between 220 and 689 MW. The oldest plant is a 1.5 MW plant at the University of Oregon. The oldest plant generating more than 100 MW is Beaver 1 Plant, which began operating in 1974.

Oregon's natural gas plants operate in a variety of ways, with some operating at more constant output, and others operating less frequently to meet peak needs. Some of the plants are owned by Oregon utilities and provide electricity to those utilities' customers, while others generate electricity that is sold to out-of-state customers. Of the electricity generated by Oregon's natural gas plants, about 60 percent is exported to out-of-state users.

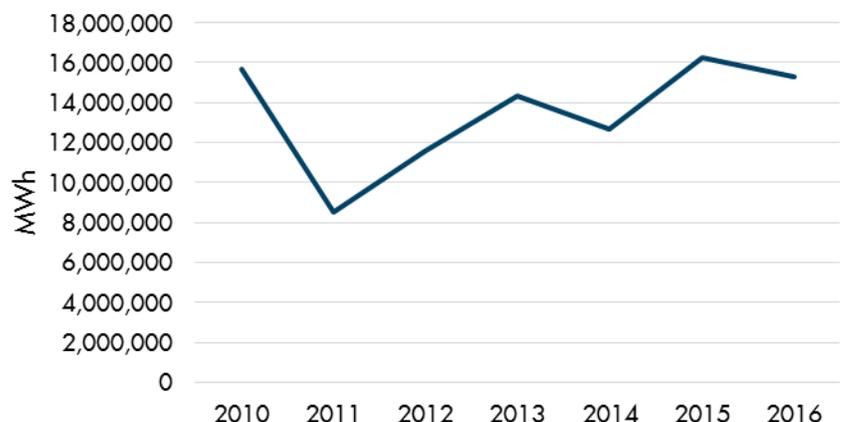
A key benefit of natural gas-fired power plants is their flexibility. Somewhat similar to hydropower plants, many natural gas plants can ramp output up or down quickly, a characteristic that is useful for integrating variable output from renewables. Electricity from natural gas plants has a lower carbon intensity than electricity from coal plants.

Resource Potential

Electricity generated from natural gas in Oregon has increased 1,768 percent in 26 years. This parallels a broader national trend driven primarily by a reduction in cost resulting from increased natural gas production due to fracking across North America.



Oregon Natural Gas Generation 2010-2016



The Pacific Northwest's only natural gas production is at a location outside of the town of Mist, northwest of Portland. The facility is owned by NW Natural, and its production represents less than 0.5 percent of the

state's natural gas use. The main purpose of the facility at Mist is underground gas storage to help align the seasonal mismatch between energy production and energy use for the region's natural gas and electric utilities. NW Natural pumps methane into the underground rock formations for direct use and electric generation during cold weather events, for electric generation during hot weather events, and to help balance additions and withdrawals to its pipeline system throughout the year. The North Mist facility, now under construction, will be used for quick dispatch of natural gas to PGE's Port Westward plant.

Oregon also has a coal bed methane site near Coos Bay. The site has been drilled and the substrate fractured to facilitate coalbed methane gas extraction, but it currently is not producing gas, nor is it connected to any intra or interstate pipelines.

Environmental Effects

Extraction of natural gas has significant land use impacts, but very little natural gas extraction happens in Oregon. A significant impact of natural gas in Oregon is due to pipelines; land on top of buried pipelines can be used for agriculture but not for forestry. Pipeline installation and maintenance can disturb wetlands, riparian zones, and stream channels and cause habitat fragmentation. Pipelines and storage sites have the potential for methane leakage. Gas that leaks from pipelines, storage facilities, and production sites is referred to as fugitive methane. Some natural gas companies in Oregon have taken more advanced measures to reduce fugitive emissions of methane by lining their pipes with plastic and upgrading their control systems to reduce leakage. Combustion of natural gas for electricity generation or for thermal energy emits greenhouse gases, mainly carbon dioxide, with associated climate impacts.

Proposed Energy Facilities

When a new energy facility is proposed in Oregon, it must be approved through the appropriate federal, state, or local regulatory process. The State of Oregon has permitting jurisdiction through the Energy Facility Siting Council (EFSC) for certain energy facilities defined in state law. These include:

- Thermal power plants above 25 MW.
- Wind or geothermal electric power generating plants with an average capacity of 35 MW.
- Solar photovoltaic (PV) energy facilities using more than 100 acres of high-value farmland or high quality soil or 320 acres elsewhere.
- Certain high voltage electric transmission lines.
- Certain natural gas pipelines and storage facilities.
- Nuclear installations.
- Synthetic fuel plants which convert biomass to a gas, liquid or solid product intended to be used as a fuel.
- Storage facilities for liquid natural gas.

EFSC is made up of seven volunteer members who approve or deny an energy facility based on state standards applicable to each proposed facility. Oregon has 14 general standards that most proposed energy facilities must meet to receive approval for a site certificate, plus facility-specific standards. Standards cover issues such as land use, environmental impacts, noise concerns, cultural resources, and more. EFSC makes its decisions through a public process facilitated by the Oregon Department of Energy that includes multiple opportunities for public and other stakeholder engagement and input.



WIND

- 3,383 MW of capacity
- 44 operating facilities, 1 spans Oregon and Washington state line
- 2,147 MW of additional capacity proposed, approved, or under review
- Sites range from 1.6 to 300 MW
- 13 largest facilities make up 69% of total capacity
- 15 facilities, representing 590 MW, came online in 2009

Wind is the third largest electricity resource generated in Oregon—representing nearly 12 percent of Oregon’s electricity generation in 2016.

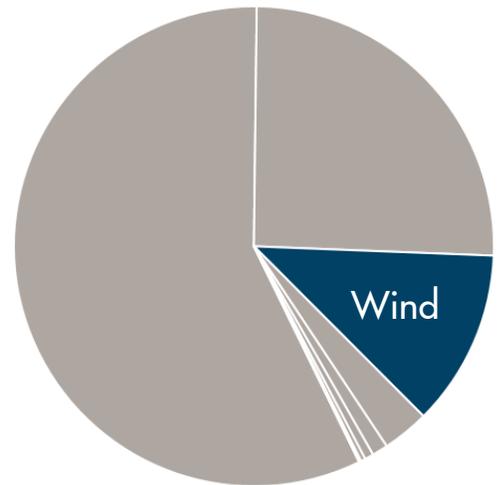
Wind in Oregon

The development of wind energy projects in Oregon has occurred mainly on the Columbia River Plateau in north central Oregon, with additional development in eastern Oregon — both locations offer strong wind resources and proximity to segments of the electric transmission grid with available capacity.

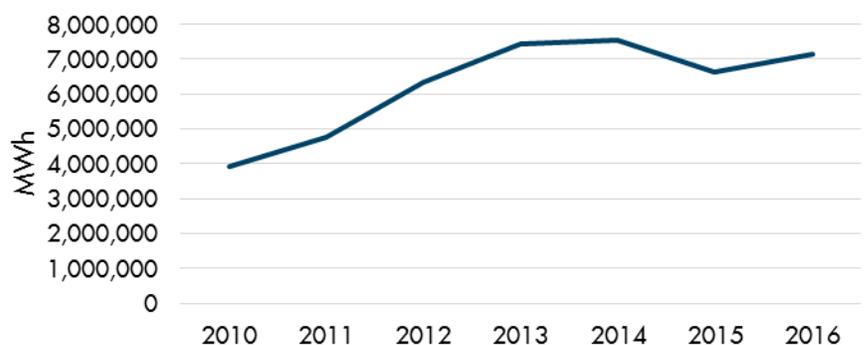
Most wind projects consist of utility-scale wind turbines that each stand hundreds of feet in the air. Most of Oregon’s wind generation capacity comes mainly from large-scale wind projects that supply power directly to the electric grid. Oregon has 34 wind projects of 10 MW or greater and another 10 facilities under 10 MW. Sherman County has 1,057 MW of capacity; Umatilla, Morrow, and Gilliam counties combined have 2,179 MW of capacity.

Large-scale wind projects have made a significant contribution to PGE’s and PacifiCorp’s ability to meet their Renewable Portfolio Standard (RPS) targets to date. With the increase of the Oregon RPS to 50 percent renewable energy by 2040 for these utilities, additional renewable projects, including wind, may be built in the state in the coming years.

Among the key benefits of wind energy projects: the levelized cost of electricity from new projects is increasingly cost-effective compared to alternative resources. Additionally, wind projects have minimal ongoing costs, which should allow them to remain cost-effective during their operating lifetimes.



Oregon Wind Generation
2010-2016

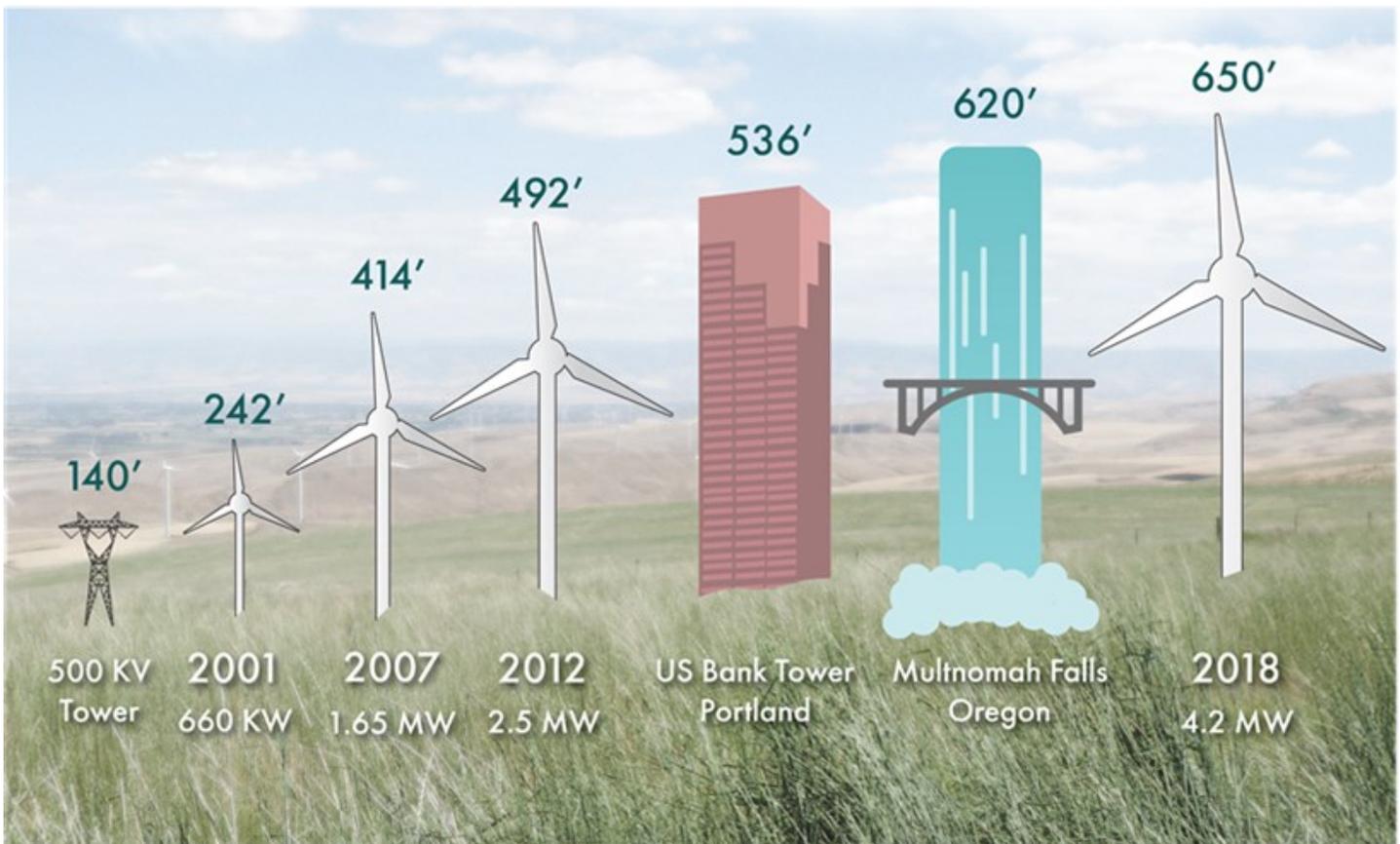


Resource Potential

The most recent large-scale wind facility was completed in 2012. Oregon has significant undeveloped wind energy potential, including near the Cascades, in southeastern Oregon, and in coastal areas (both onshore and offshore). As noted above, transmission access can be a barrier and the development of major new wind resources may require significant transmission investments.

Oregon is 8th in the nation for installed wind capacity

Some facility owners are evaluating whether to repower some older wind projects with new, larger turbines and longer blades to increase generation output. The graphic below compares different sized turbines operating or proposed in Oregon to notable landmarks.



Environmental Effects

Wind energy projects are a zero-carbon emitting resource and have a low lifecycle carbon footprint associated primarily with the embedded GHG emissions from manufacturing and construction.

Wind turbines can cause collisions with birds and bats, although newer designs with slower blade speeds and the elimination of lattice towers have reduced collisions and fatalities. Wind turbines are often sited in dryland agricultural areas versus irrigated high-value farmland, and while some land is removed from production for turbine sites and access roads, ranching and farming can coexist with many wind energy projects.



COAL

601 MW of Capacity

1 operating facility

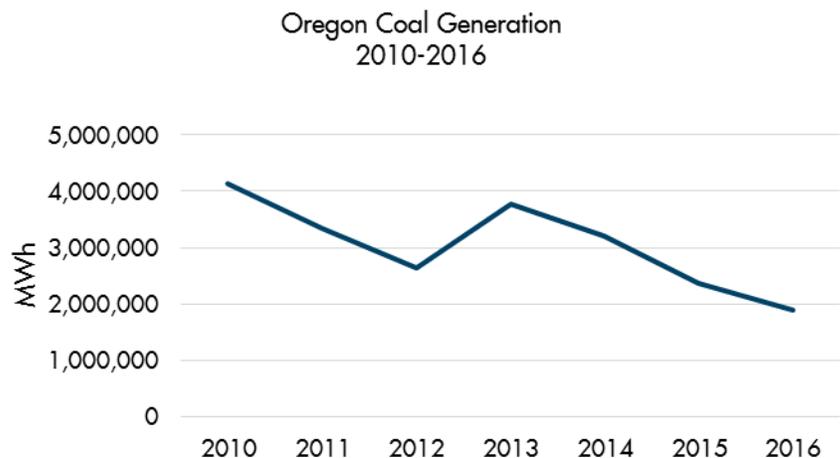
State authorization issued in 1975

Boardman facility due to cease coal operations by December 31, 2020

Of electricity generated in the state of Oregon, about 3 percent comes from coal.

Coal in Oregon

Oregon's only coal plant is jointly owned by Portland General Electric (90 percent) and Idaho Power (10 percent). PGE operates the facility, which is located in Boardman. In 2010, Oregon's Environmental Quality Commission approved PGE's plan to end coal operations at the Boardman plant by December 31, 2020.



Oregon currently meets about one-third of our electricity needs through imports from out-of-state coal-fired power plants. With the passage of the "Clean Electricity and Coal Transition" bill (2016), imported electricity from coal plants will be eliminated from the rates of Pacific Power and PGE customers by 2035. Between now and then, Oregon will continue to see decreases in coal generation as coal-based electricity is gradually phased out of the resource mixes of Oregon's investor-owned utilities.

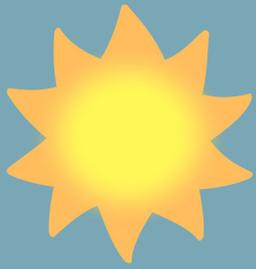
Historically, electricity from coal plants has been low cost relative to alternative sources. As a result, coal plants have tended to operate at a high capacity, near full output, much of the time.

Resource Potential

As noted above, coal use in Oregon will shrink over the next decade. Its use across the country continues to decline as well.

Environmental Effects

Coal mining has large land use impacts in other states. Oregon is affected by air emissions from coal combustion that happens in Oregon and outside the state. Sulfur dioxide emissions from coal plants cause haze and acid rain, while deposition of atmospheric sulfur and nitrogen can cause chemical changes to water and soil. Water deposition of air-borne mercury from coal plants bioaccumulates in certain fish species and animals that prey upon them, and land deposition of mercury has been shown to accumulate in crops. Carbon dioxide and nitrous oxide emissions contribute to climate change.



SOLAR

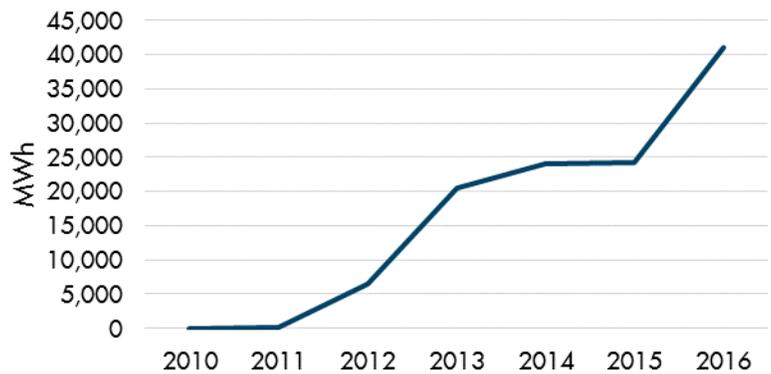
296 MW of capacity for projects 1 MW or larger
 More than 15,000 residential solar projects
 Median number of residential solar projects by county: 114
 First facility greater than 75 MW approved in 2018
 685 MW of capacity proposed, approved, or under review

Solar photovoltaic systems make up a small percentage of electricity generation in the state — less than 1 percent. But our output has grown exponentially, and solar is growing at a faster rate than any other energy resource in the country.

Solar in Oregon

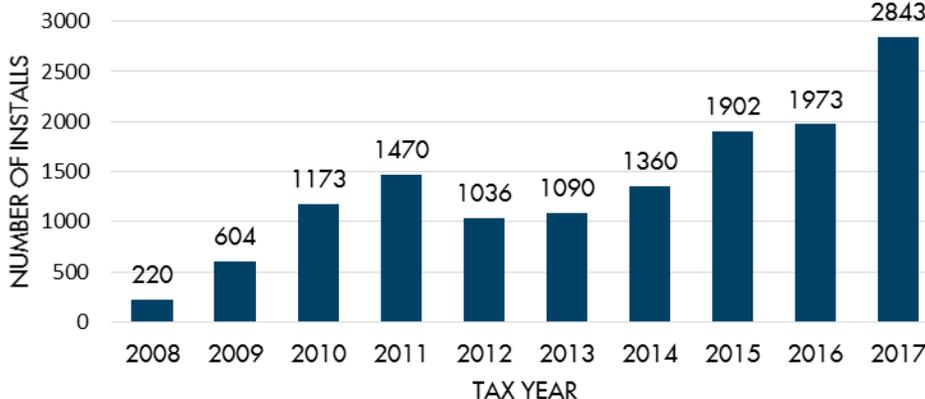
In 2017, solar was the third largest source of renewable energy in the United States after hydropower and wind power. In Oregon, total solar capacity at the end of 2017 also included 70 MW from more than 15,000 residential solar PV systems and more than 40 MW from commercial projects. The 56 MW Gala solar project in Prineville is located on over 300 acres of rangeland and is currently the largest solar project in the state. By comparison, California has installed solar capacity in excess of 20,000 MW.

Oregon Solar Generation
2010-2016



The chart above shows solar generation from facilities over 1 MW through 2016. Oregon's output in 2017 and beyond has grown dramatically over this data, and future reporting will include solar rooftop and smaller commercial generating facilities.

Solar PV System Installations that Qualified for a Residential Energy Tax Credit



Residential solar projects are increasingly common. This chart shows installations per year under the state's residential energy tax credit program.

Solar is available on unshaded sites across the state, including individual customer sites such as residential or commercial rooftops. As a result, many solar PV projects in Oregon, as elsewhere, are located at customer sites and are commonly called “behind-the-meter” solar. Most of these projects are designed to serve on-site demand when the systems are generating and then to export excess to the grid. These type of solar projects are widely distributed across the state.

Larger solar PV projects (typically in excess of 1 MW) that do not directly serve on-site customer demand and that export to the grid are referred to as utility-scale projects. These systems are typically ground-mounted, and in Oregon, most of these projects are located east of the Cascades.

Resource Potential

Solar PV is a mature technology that's likely to expand in the coming years. Solar energy technologies work throughout Oregon and generate electricity in all parts of the state, but given Oregon's variable climate, the output of solar facilities varies depending on location. The solar resource east of the Cascades is typically 30 to 40 percent greater than the Willamette Valley or coast, although even the Oregon Coast has a resource potential on par with Germany, which is a global leader in solar generation.

Most residential solar PV projects are installed in the Willamette Valley. While a large majority of utility-scale projects to date have been located east of the Cascades, more are being proposed on the west side. As solar PV costs continue to fall, Oregon has the potential to see a dramatic increase in solar development across the state. The number of recent applications to install solar PV projects and interconnect to the grid suggests that generation from solar PV projects in Oregon is likely to continue to grow in the coming years.

Environmental Effects

Solar PV projects are zero-carbon emitting resources that have a low lifecycle carbon footprint associated primarily with the embedded GHG emissions from manufacturing and construction.

Solar PV projects can have a large physical footprint that may impact wildlife habitat and remove farm lands from agricultural production. The majority of Oregon's utility-scale solar PV projects are installed on un-irrigated rangeland, and the state's energy facility siting laws are designed to protect wildlife habitat and farmland. The Oregon Department of Land Conservation and Development is undertaking a rulemaking related to solar PV projects proposed for siting on high-value or irrigated farmland. The Oregon Energy Facility Siting Council has also established a rulemaking advisory committee for large-scale solar facilities.

Energy Jobs

Oregon's diverse energy generation, efficiency, and manufacturing industries require a diverse workforce. The *U.S. Energy and Employment Report*, issued earlier this year by the National Association of State Energy Officials, included figures for energy-related employment in Oregon.

Nearly 26,500 Oregonians work in the electric power generation, fuels, or transmission/distribution/storage fields. Of those, more than 6,000 work in the solar industry, while another 1,500 work in hydroelectric generation. Just under 1,300 Oregonians work in the wind industry.

Nearly 42,000 Oregonians work in the energy efficiency sector. Around 25,000 of these jobs are in the construction industry, with another 7,200 in manufacturing.

Transportation fuels represent more than a third of the state's energy use. The report also highlights the more than 25,800 Oregonians who work the motor vehicles sector.



WOOD AND OTHER BIOMASS

- 331 MW of capacity
- 36 operating facilities
- Facility capacity ranges from .2 MW to 51.5 MW
- Facilities are in 16 Oregon counties
- Oldest came online in 1936, newest in 2015

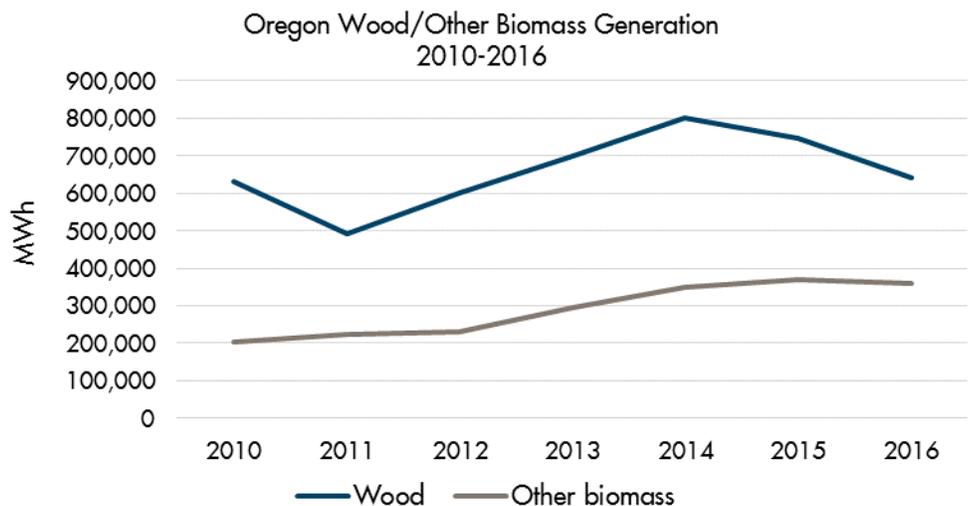
Electricity generated from wood and other biomass fuels amounts to around 1.7 percent of Oregon’s annual generation. Materials used to generate electricity include wood such as lumber mill residue and logging slash, animal manure, food waste, landfills, and waste water.

Wood and Biomass in Oregon

In Oregon, wood is the most common source of biomass-based electricity generation. Direct-fired combustion is the most common method for generating electricity from woody biomass. This process involves burning the woody biomass in a boiler to generate steam, which turns a turbine to generate electricity. Biomass plants are typically sized less than 50 MW. It is often not cost effective to collect and haul the biomass feedstock necessary to sustain a larger plant due to the high costs of collection and transportation. In 2016, 641,447 MWh of electricity was generated in Oregon from wood and wood-derived fuels; 75 percent of that was from industrial combined heat and power facilities – mostly pulp and paper or lumber mills.

Resource Potential

An inventory recently completed by the Oregon Department of Energy looked at six organic material pathways and found that they could be used to generate energy equivalent to 49 trillion Btu, or about 5 percent of Oregon’s total energy needs.



Environmental Effects

Biomass-based energy that replaces fossil fuels can reduce some greenhouse gas emissions, criteria pollutants, and air toxins. Direct combustion of wood can emit significant quantities of GHGs and air pollution contaminants depending on the equipment used. Thermal gasification of organic waste has the potential to reduce air pollution due to changes in how the raw materials are used. Removing some level of logging by-products and thinning some small diameter trees from the forest could reduce the intensity of catastrophic wildfires.



BIOGAS AND RENEWABLE NATURAL GAS

51.1 MW of Capacity

25 Operating Facilities

10-20% of state's total yearly use of natural gas could be replaced by RNG if potential is realized

Some Oregon facilities currently generating biogas simply flare the biogas, while others burn it in a special internal combustion engine that is connected to a generator that produces electricity. Those facilities either consume that electricity on-site or sell it onto the grid through a Power Purchase Agreement with an electric utility. Another option is emerging in Oregon: cleaning up biogas to meet natural gas pipeline quality standards – at which point it is called Renewable Natural Gas (RNG) – and then injecting it into an existing natural gas pipeline. The RNG can be sold as either a direct use stationary fuel or as a transportation fuel.

Biogas and Renewable Natural Gas in Oregon

Oregon recently quantified opportunities to convert persistent, long-term waste streams into useful energy as biogas and RNG. Municipal waste streams — garbage, wastewater, and waste food — and agricultural waste streams like manure, all generate methane, a powerful greenhouse gas. Redirecting these waste streams into controlled processes can capture and use the methane, reducing greenhouse gas emissions and air pollutants when the resulting RNG is substituted for fossil fuels in our transportation and stationary fuels sectors. If Oregon's potential volume of RNG could be captured and used to displace fossil-based natural gas for stationary combustion, we would prevent the release of approximately two million metric tons of greenhouse gases into the atmosphere. Redirecting this fuel source into these sectors can also potentially result in increased economic opportunity, and provide energy security and resilience for Oregon communities.

Resource Potential

The gross potential for RNG production when using anaerobic digestion technology is around 10 billion cubic feet of methane per year, which is about 4.6 percent of Oregon's total yearly consumption of natural gas. The gross potential for RNG production when using thermal gasification technology is nearly 40 billion cubic feet of methane per year, which is about 17.5 percent of Oregon's total yearly use of natural gas. While there are technical and regulatory barriers to overcome, these waste streams represent an opportunity for Oregon to produce between 10 and 20 percent of our current conventional natural gas consumption with locally produced, low carbon renewable natural gas.

Environmental Effects

Greenhouse gas emissions and air pollutants can be reduced when RNG is substituted for fossil fuels in the transportation market or used instead of traditional natural gas in applications like heating, cooking, or commercial and industrial processes. Improved water quality can result from different management practices of the wastes used to generate biogas and RNG. Air pollution reductions can result from using RNG as a substitute for diesel in the transportation market. RNG produces about 30 percent less air pollution and 30 to 40 percent fewer GHG emissions.



GEOTHERMAL

33 MW of capacity

99 MW of planned capacity

3 facilities; the largest is 28.5 MW

Also used as a direct use fuel for heating

Geothermal energy makes up less than 1 percent of Oregon’s electricity generation.

Geothermal in Oregon

The state’s first geothermal power plant began operating in 2010 at the Oregon Institute of Technology in Klamath Falls, with an initial electricity-generating capacity of 280 kW. A second plant at OIT generates 1.2 MW of power. In 2012, a 28 MW geothermal power plant near Vale came online. Additional geothermal opportunities are being explored at Crump Geyser and Glass Butte in Lake County and at Newberry Crater.

Geothermal power plants have the unique ability to provide near constant carbon-free output all year, compared to more variable output renewables such as wind and solar. Geothermal energy is also used in direct heating applications, displacing conventional natural gas and electricity consumption. See page 36 for additional information.

Resource Potential

Geothermal resources are reservoirs of hot water that exist at varying temperatures and depths below the Earth’s surface. Mile-or-more-deep wells can be drilled into underground reservoirs to tap steam and very hot water that can be brought to the surface for use in a variety of applications. In the United States, most geothermal reservoirs are located in the western states, and Oregon has one of the best geothermal resources in the country. The U.S. Geological Survey’s Assessment of Moderate and High Temperature Geothermal Resources of the United States identified 595 MW of high probability capacity in Oregon from conventional geothermal resources.

The same report also identified more than 43,000 MW of potential capacity in Oregon from enhanced geothermal systems (EGS). EGS requires the injection of high-pressure water to modify subsurface conditions to enhance flow and permeability. While the potential to develop EGS in Oregon is significant, the technology is still in the research and development phase, and the U.S. Department of Energy has targeted 2030 for commercialization of the technology.

Environmental Effects

Geothermal power projects are zero-carbon emitting resources that have a low lifecycle carbon footprint associated primarily with the embedded GHG emissions from manufacturing and construction. These projects typically have small footprints and localized land impacts. Geothermal energy generation typically involves extracting and then reinjecting groundwater, but can require the use of additional water.



ENERGY STORAGE

10 MW of capacity

2 facilities with approximately 5 MW of capacity each

Another 150 MW currently approved or under review

Technology types include pumped storage and battery storage

While not an electricity generating resource, energy storage holds great promise for Oregon. This section addresses emerging technologies that are intended to convert electricity—often surplus, carbon free electricity—into another form of storable energy for use at a more optimal time.

Use in Oregon

Portland General Electric's Salem Smart Power Center—a 5 MW (1.25 MWh) battery energy storage system deployed in 2013—was one of the first utility-scale, grid-connected battery energy storage systems in the U.S. Since that time, the adoption of HB 2193 (2015) made Oregon the second state in the nation to require investor-owned electric utilities to deploy energy storage systems. PGE and PacifiCorp recently submitted proposals for new battery energy storage systems to the PUC.

Energy storage systems deliver a wide range of benefits. These systems can capture surplus carbon-free generation during times of the day or year when more electricity is being generated than can be consumed at the time. These systems can help maintain grid stability and allow utilities or individual customers to take advantage of lower prices during certain parts of the day. Finally, some of these systems play a key role in helping to provide resilient back-up power. As costs for lithium-ion battery systems have declined, Oregonians have shown interest in distributed battery systems.

Resource Potential

Costs for different types of energy storage technologies continue to fall. The deployment of specific types of energy storage systems will depend on the particular benefits they provide. For example, while battery storage systems are more scalable and can offer resilience benefits to customers, other types of energy storage systems (such as pumped storage hydro or power-to-gas) might deliver more value in the form of benefits to the bulk power system or in being able to meet longer duration needs for energy storage.

Environmental Effects

Characterizing the environmental effects of energy storage systems is challenging given the wide range of different technologies. The development of lithium-ion battery systems, for example, requires the mining and extraction of lithium and other rare earth metals with associated land impacts. There are also potential concerns about battery disposal after systems' storage capabilities are exhausted. Other types of energy storage systems, like pumped storage hydro or power-to-gas conversion, may require the availability of large amounts of water to operate.



MARINE ENERGY

Emerging technology

2 test sites: 1 operating and 1 under development

Excellent resource potential off of Oregon coast

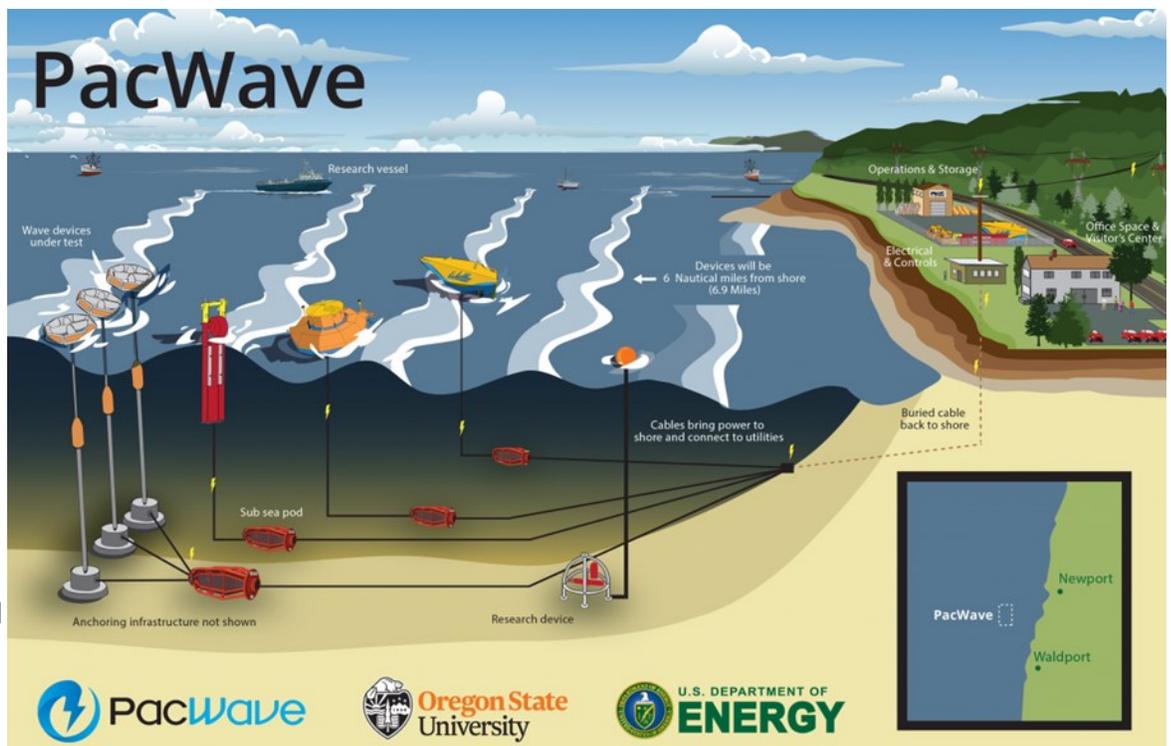
Marine energy encompasses both wave power – i.e., power from surface waves – and tidal power, which is obtained from the kinetic energy of large bodies of moving water. Oregon’s coast has among the best marine energy resources in the world, making it an ideal location for developing marine energy.

Use in Oregon

While there are no marine energy projects yet in commercial operation in Oregon, the state is a global leader in the research and development of these technologies. These efforts have been led by Oregon State University, which received a \$40 million award from U.S. DOE in 2016 to develop a utility-scale, grid-connected marine energy test site. That award followed an earlier \$4 million award from U.S. DOE in 2012, which established two test sites as part of the Pacific Marine Energy Center.

The North Energy Test Site is located two nautical miles from shore, north of Newport, and is not grid connected. The site tests wave energy devices that are connected to the Ocean Sentinel buoy, which collects data on the devices and is powered by the electricity generated from the attached wave energy device. The site measures power generated and characteristics of the wind, waves, and current.

The South Energy Test Site, rebranded in September 2018 as PacWave, is currently under development as the first grid-connected wave energy test site in the United States. PacWave is located five nautical miles off shore between Newport and Waldport. Oregon State University submitted its Draft License Application and Preliminary Draft



Environmental Assessment for the PacWave site to Federal Energy Regulatory Commission in April 2018. Pending approval of U.S. DOE funding from Congress, PacWave is expected to be operational by 2020 and will be able to test utility-scale wave energy devices in the ocean. These wave generators will be connected via subsea cable to the Central Lincoln PUD electric grid. This site will enable four separate wave energy devices to be tested simultaneously.

While marine energy projects are not yet in commercial operation, they have the potential to support Oregon's existing power resources. Marine energy projects can provide more constant power output than wind or solar resources. Wave energy output is strongest during the winter months, which coincides with peak electricity demands in Oregon and complements other carbon-free resources (e.g., hydro peaks in spring, while solar peaks in summer).

Resource Potential

According to the Electric Power Research Institute, total annual technical potential from Oregon's wave energy resource is 143 billion kWh per year, or enough energy to power more than 13 million homes. Currently, the high costs of these technologies compared to other generating sources, combined with limited transmission access in coastal Oregon, are the primary barriers to the cost-effective development of this potential resource.

Environmental Effects

Marine energy projects would be zero-carbon emitting resources and are expected to have a low lifecycle carbon footprint associated primarily with the embedded GHG emissions from manufacturing and construction. Wave energy devices being developed come in various shapes and sizes; they can be fully or partially submerged, anchored or float, or affixed to a dock or jetty. Wave energy devices can be integrated into the natural landscape so they do not cause a negative visual effect from shore. Research to evaluate the potential impacts—both positive and negative—on marine life from the operation of these devices is ongoing.

Federal and Local Energy Facility Permitting

How energy facilities are reviewed and authorized at the state level was briefly discussed on Page 24. For other types of facilities—such as interstate petroleum and natural gas pipelines and liquefied natural gas export terminals—the federal government may have permitting authority. Federal projects are subject to the National Environmental Protection Act. Key agencies may include the **Federal Energy Regulatory Commission**, an independent agency that regulates the interstate transmission of electricity, natural gas, and oil, and licenses hydropower projects; **federal land management agencies** such as the **Bureau of Land Management** and the **U.S. Forest Service**, which own and manage large amounts of land in Oregon; and the **Bonneville Power Administration**.

Facilities that are not under exclusive federal jurisdiction and that do not meet the definition of “energy facility” for state jurisdiction are subject to review and approval by the local jurisdiction where the facility is proposed. For example, wind facilities with average capacity under 35 MW are reviewed by county commissions.

Direct Use Fuels Production in Oregon

Oregon currently produces only small amounts of direct use fuels.

Production in Oregon

Natural Gas: The Pacific Northwest's only natural gas field is located in Mist, northwest of Portland. The field is owned and operated by NW Natural. The Mist field produced about 801,491,000 cubic feet of natural gas in 2016, which represents less than 1 percent of Oregon's annual use. Mist's main purpose is gas storage. NW Natural pumps methane into the underground rock formations for use during cold weather events and to help balance additions and withdrawals to its pipeline system.

Solar Thermal: See page 15 for more details.

Geothermal Energy: Often used in direct heating applications, displacing conventional natural gas and electricity consumption. For decades, the city of Klamath Falls has used geothermal heat sources to heat buildings, residences, pools, and even sidewalks. In Lakeview, a geothermal well system is now being used to heat school properties and hospital buildings. Other examples of direct use of geothermal heat in the state include drying agricultural products, aquaculture (raising fish), heating greenhouses, and heating swimming pools.

Wood Pellets: In Oregon, residual material from forest harvest and mill operations is frequently converted into wood pellets to be used for residential and commercial heating. In 2016, an estimated eight Oregon companies produced about 250,000 tons of pellets per year.

Charcoal Briquettes: Oregon is home to one of the largest charcoal briquettes plants in the western United States. The plant produces around three billion briquettes per year. The source of their raw material is waste wood from local saw mills.

Renewable Natural Gas: Five locations in Oregon are currently taking steps to convert the biogas they produce into RNG and inject it into a natural gas pipeline. Once in the pipeline, the RNG can be used as a stationary fuel or a transportation fuel. It is estimated that the five locations could potentially produce about 1.6 billion cubic feet of RNG per year.

Environmental Effects

Many of these energy sources are generated from waste streams. Natural gas, wood pellets, charcoal briquettes, and RNG are all combusted in order to release their stored energy, and in that process release carbon dioxide and some levels of other greenhouse gases and air pollutants. The carbon dioxide intensity depends on the amount of processing it takes to convert the waste material into a useful energy source. Due to needed change in how some of the waste streams are managed in order to convert them into a useful fuel, there may be reductions in air and water pollution.

Transportation Fuels Production in Oregon

Less than 2 percent of transportation fuel used in Oregon was produced in the state in 2016. The majority of this in-state production was ethanol and biodiesel. The Oregon Department of Energy recently completed an inventory of the state's opportunities to produce renewable natural gas from waste water treatment plants, landfills, and dairies. This market is still developing. Electricity is also a growing source of transportation fuel, and much of that can be produced in the state as well. For more on electricity as a transportation fuel, see chapter 4.

Use in Oregon

Ethanol: Oregon has one commercial ethanol producer. The Columbia Pacific Ethanol production plant in Boardman is the largest transportation fuel producer in the state. The plant produced 37.5 million gallons of ethanol in 2017, which was sold to terminals in Portland and Eugene. The plant also produced 285,000 tons of livestock feed and more than eight million pounds of corn oil used at feed lots and for poultry feed. Carbon dioxide emissions from the plant are used by a neighboring company, Kodiak Carbonic, that turns the emissions into a beverage-grade liquid used to carbonate soft drinks and make dry ice.

Biodiesel: SeSequential Pacific Biodiesel is the second largest producer of transportation fuels in Oregon. SeSequential produces biodiesel from used cooking oil from local restaurants and businesses. The company's plant in Salem produced 7.7 million gallons of biodiesel in 2016 and 8.5 million gallons in 2017. SeSequential says it is on track to increase production by another 40 to 50 percent by the end of 2019. About 85 percent of the fuel is sold in-state as part of a biodiesel blend, while the remainder is exported to Washington, California, Hawaii, and British Columbia.

Renewable Natural Gas: This emerging biofuel has potential to displace some transportation fuels. See previous page for details.

Environmental Effects

Transportation fuels move through Oregon by pipeline, rail, barge, and truck, all of which have associated risks of spilling and leaking onto land and water. The combustion of fossil fuels for transportation emits pollutants such as carbon monoxide and volatile organic compounds, particulate matter, and air toxics such as benzene and formaldehyde, all of which have significant impacts on human health and wildlife. Fossil fuel combustion also causes significant greenhouse gas emissions, mainly carbon dioxide and nitrous oxide, with associated climate impacts. Most transportation fuel sold in Oregon is blended with either ethanol or biodiesel, which is predominantly made from crops grown outside of the state with localized environmental impacts.

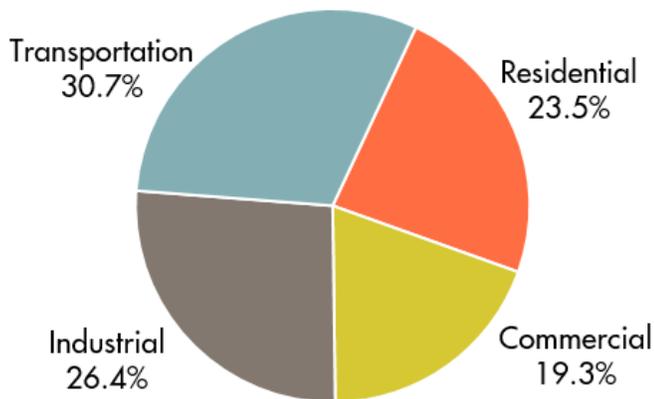


Energy Sector Profiles

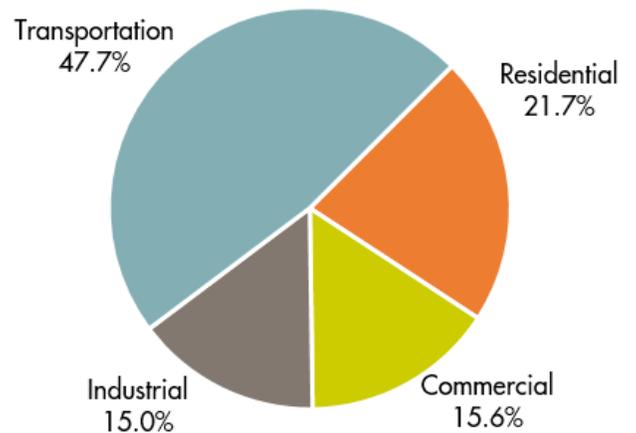
Energy is commonly divided into four end-use sectors: Residential, Commercial, Industrial, and Transportation.

Consumption and cost of energy for each sector varies. For example, while transportation represents about 31 percent of energy consumption, it accounts for almost half the expenditures due to higher per-unit cost of transportation fuels.

2016 Oregon Energy Consumption by End Use Sectors

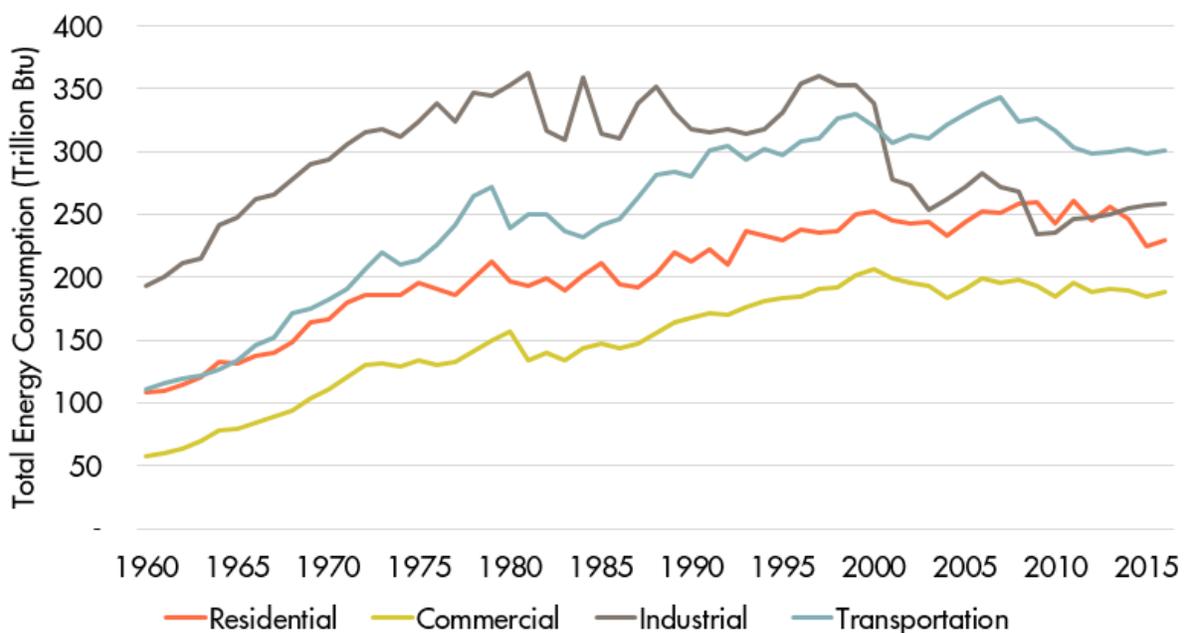


2016 Oregon Energy Expenditures by End Use Sectors



Sector energy consumption for residential, commercial, and transportation has remained fairly steady in recent years. The industrial sector saw consumption decrease in Oregon around 1999. Learn more on the following pages.

Energy Consumption by Sector Over Time

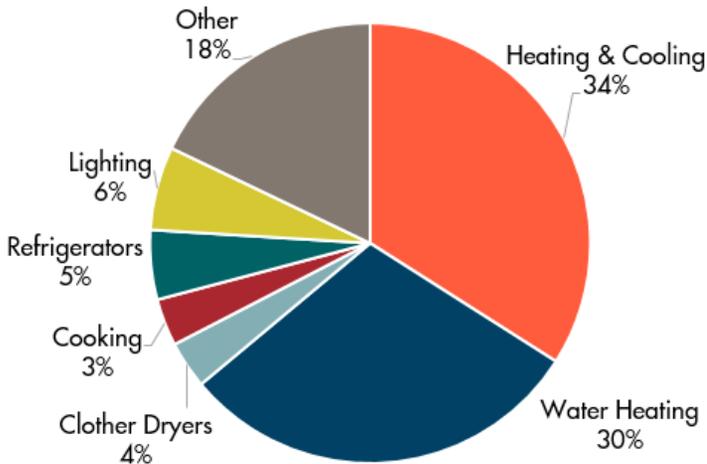


Oregon's Residential Sector

23.5%

Residential sector's share of total energy use in Oregon

Residential Sector: Homes, apartments, and other structures used for housing people. In the Pacific Northwest, energy — from all sources, including electricity, natural gas, or other fuels — is used for heating, cooling, and other residential needs:



1,768,494 homes in Oregon

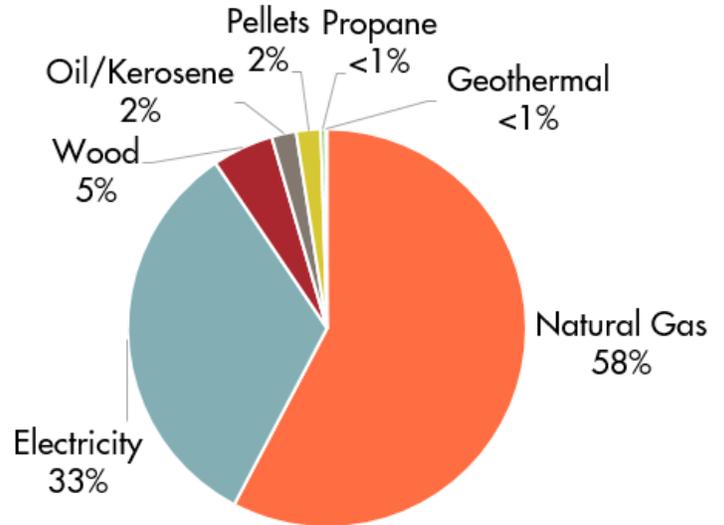
77% single-family | 23% multi-family

17,600 average annual new residential building permits

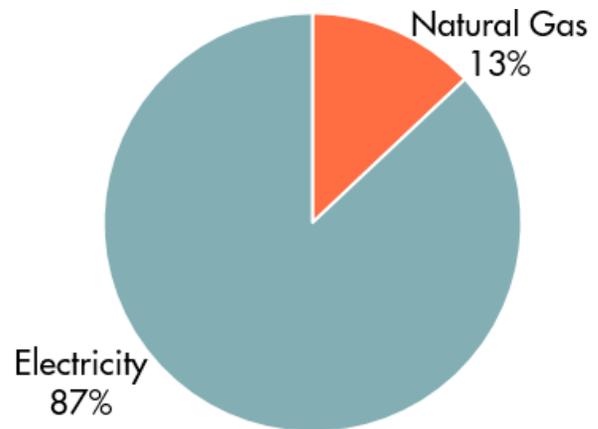
56% single-family | 44% multi-family

Nearly 50 percent of Oregon homes use electricity for heating. Natural gas is also a popular heating fuel, especially in newer single-family homes.

Single-family



Multi-family



8th

Oregon's national ranking for lowest per capita residential energy use

8.8%

Percent decrease in residential energy use since 2000

Heating and cooling uses the most energy in Oregon homes. Common appliances are central furnaces or boilers, individual devices like baseboard heaters or AC units, or mini-split heat pumps.

Water Heating

A majority of single-family home water heaters are gas or electric storage heaters. Large multi-family buildings are more likely to have central water heating. While increasing, only a small number of heaters are tankless or heat-pump style.

Lighting

Since 2012, the use of efficient LED home lighting use has increased 17 percent, while incandescent and fluorescent lighting decreased (44 percent and 7 percent).

Appliances and Electronics

Energy-intensive appliances include refrigerators, clothes dryers, and devices like TVs and related electronics. Many of these still consume energy when not in use.

Trends in Home Energy Use



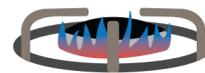
Increased Solar PV

Adoption of LED lighting



"Smart" devices, like thermostats and lights

Many homes have appliances past their useful life



Using gas for primary heating, water heating, and cooking

6,600

Number of Portland homes scored through Oregon's Home Energy Score program, which evaluates home performance and energy savings

Oregon's Residential Energy Code

Year-over-year improvements to Oregon Energy Code:

2008	2011	2017
15%	10%	6%

2017 energy code changes expected to save more than **\$750,000/year** in consumer energy costs.

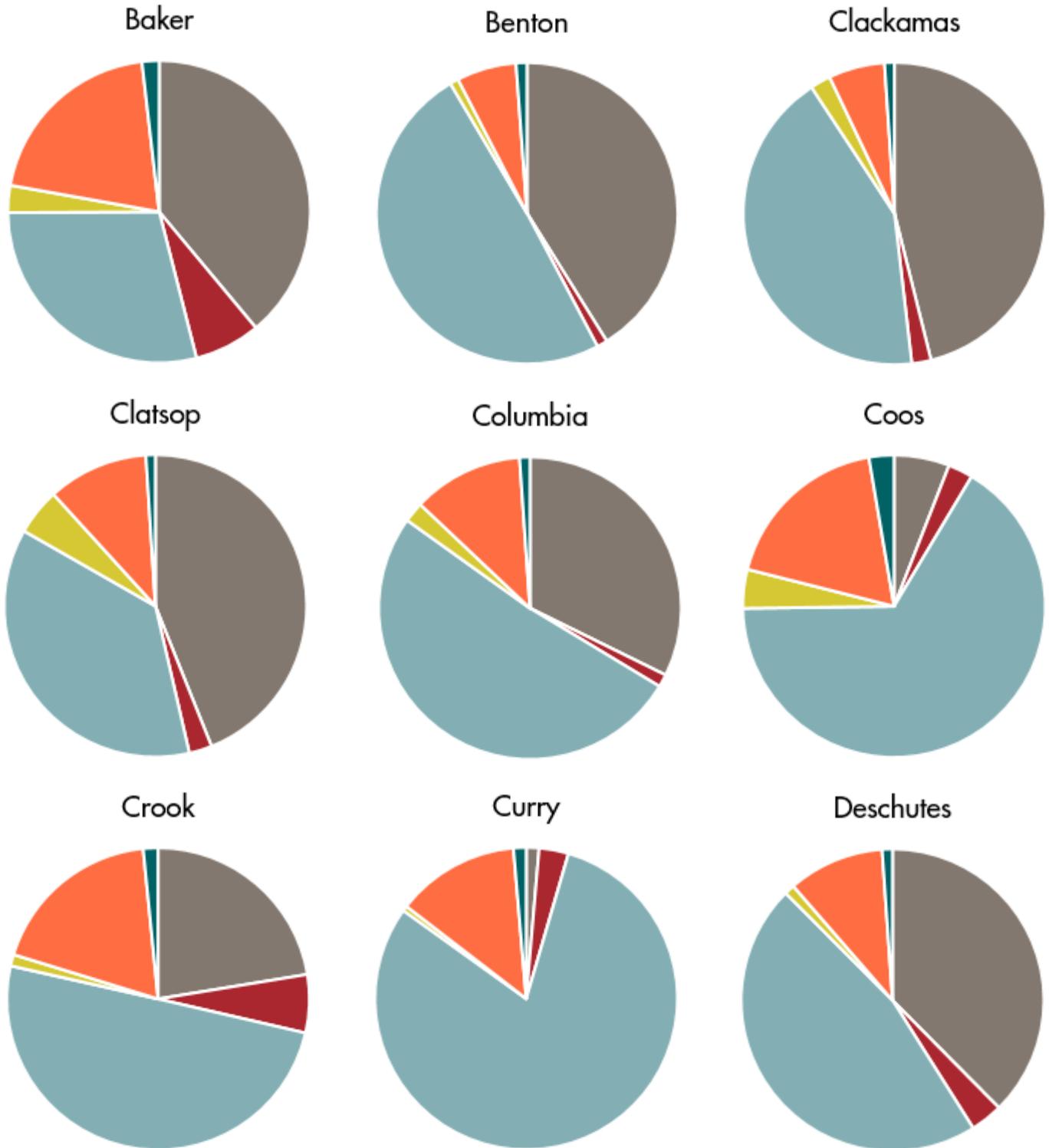
Energy performance is measured by comparing a home's annual energy use to its size, and depends on a home's construction, equipment, location, and how its occupants are using energy.

Financial incentives for homeowners and landlords, improved residential code and appliance standards, and home energy scoring all help Oregon's housing stock — and its residents — improve energy performance.

Portland now requires Home Energy Scores to be included in real estate listings to increase transparency for homebuyers and renters. Learn more in chapter 6.

Residential Sector

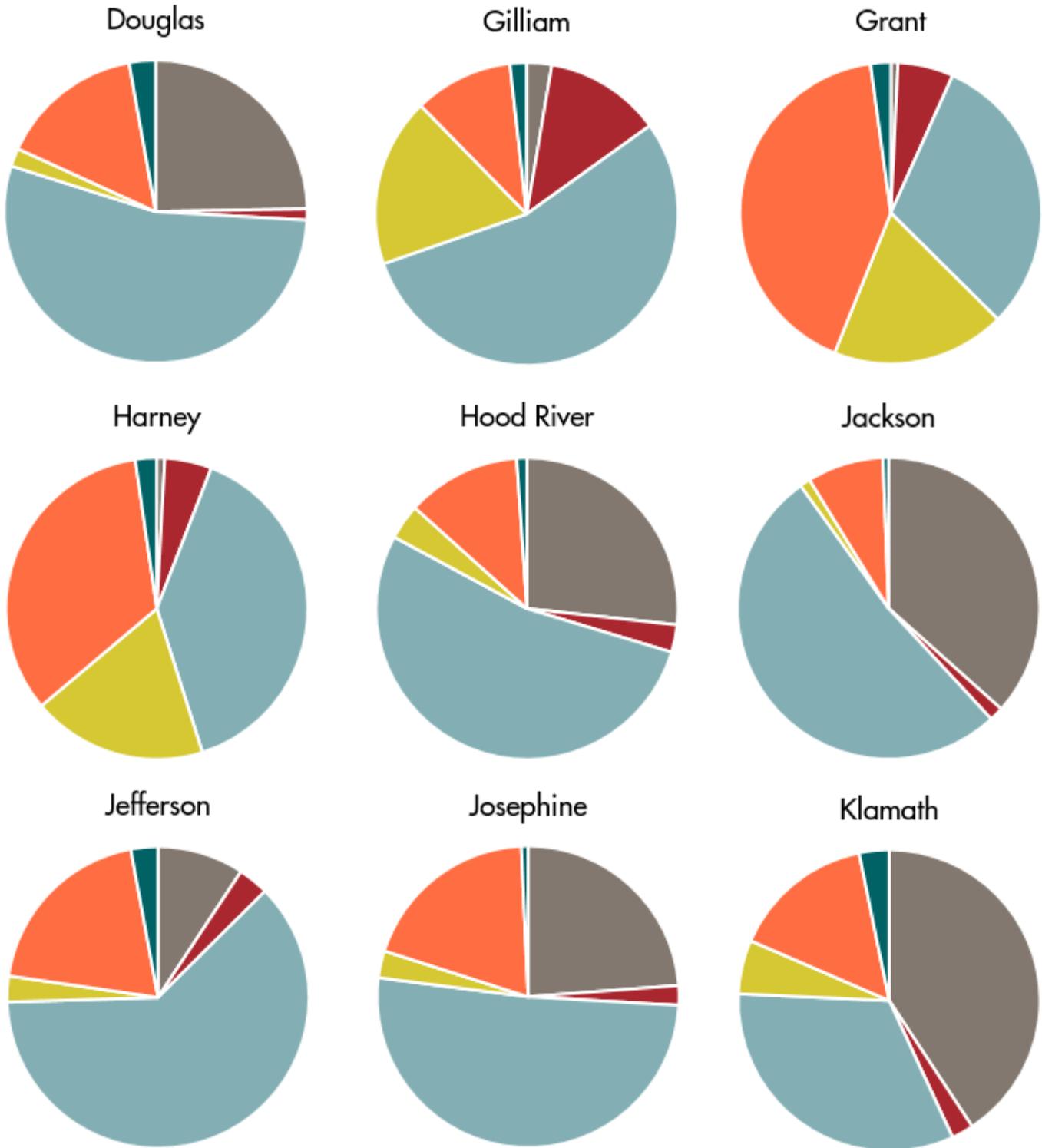
How Oregonians Heat Their Homes



- Natural Gas
- Electricity
- Wood
- Propane
- Fuel Oil/Kerosene
- Other and No Fuel

Residential Sector

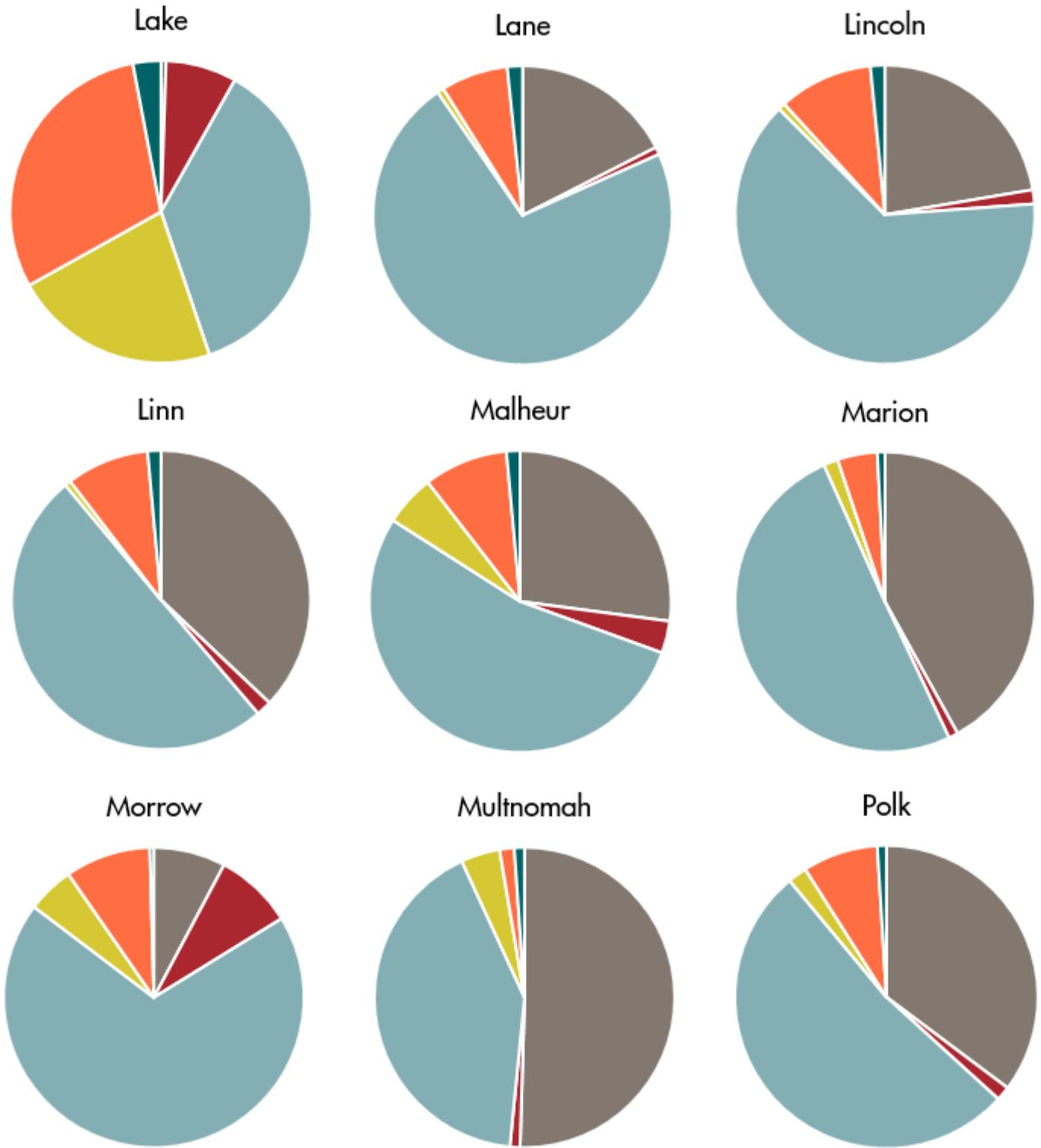
How Oregonians Heat Their Homes



- Natural Gas
- Electricity
- Wood
- Propane
- Fuel Oil/Kerosene
- Other and No Fuel

Residential Sector

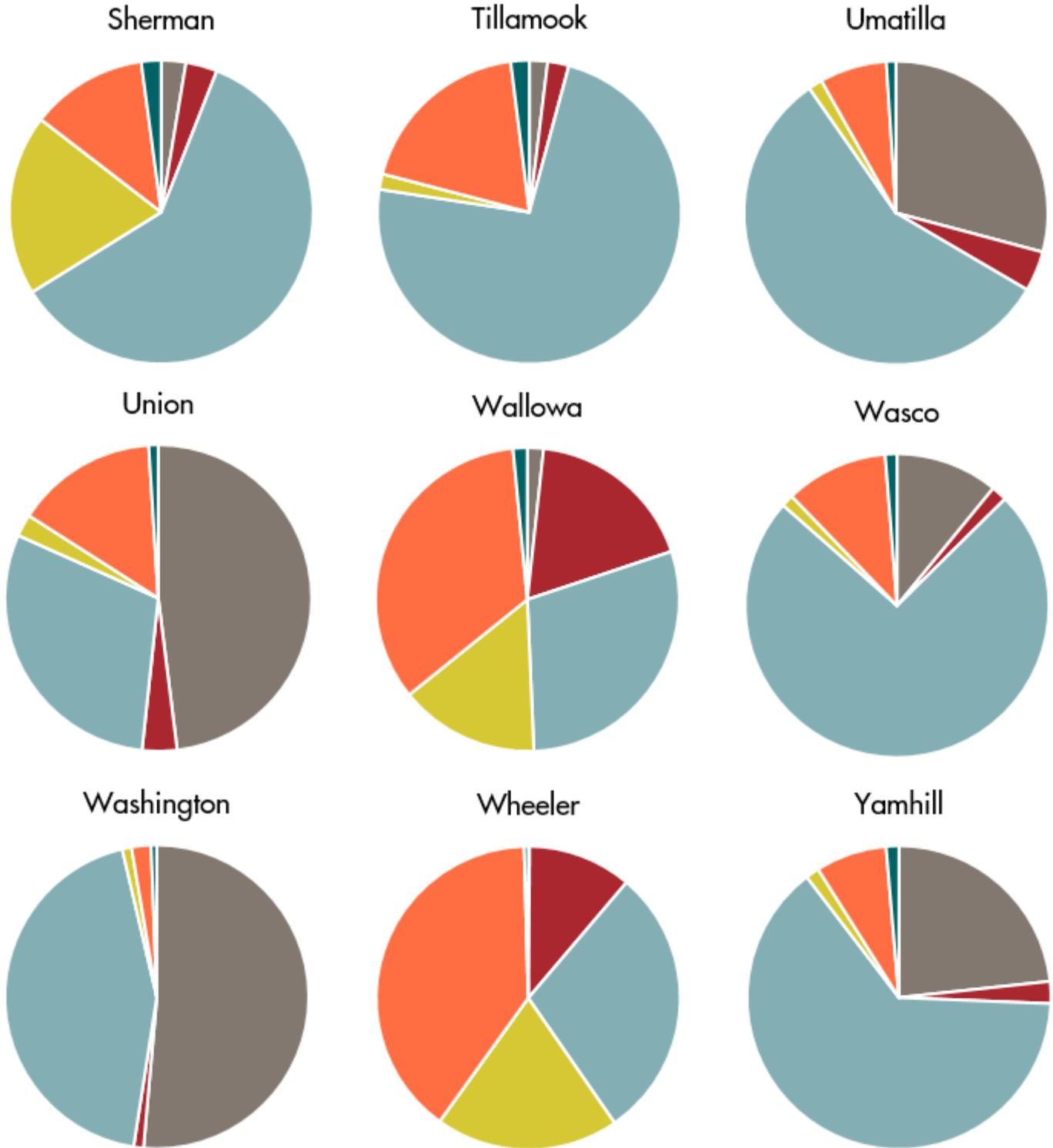
How Oregonians Heat Their Homes



- Natural Gas
- Electricity
- Wood
- Propane
- Fuel Oil/Kerosene
- Other and No Fuel

Residential Sector

How Oregonians Heat Their Homes



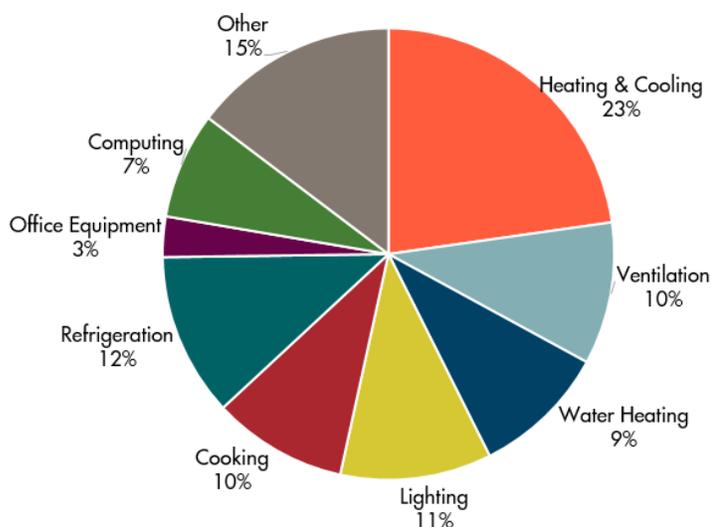
- Natural Gas
- Electricity
- Wood
- Propane
- Fuel Oil/Kerosene
- Other and No Fuel

Oregon's Commercial Sector

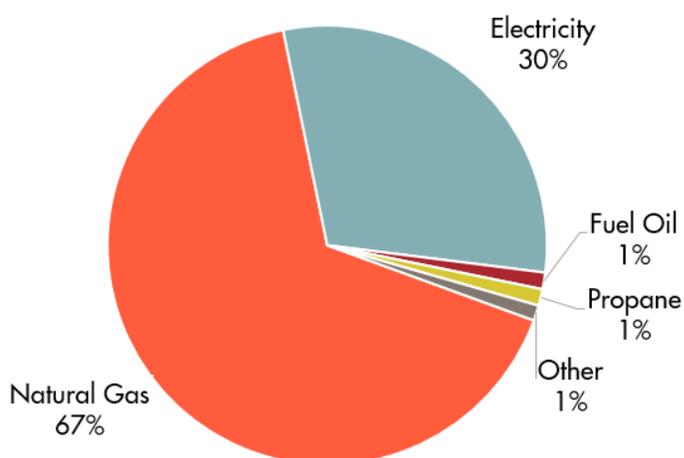
19.3%

Commercial sector's share of total energy use in Oregon

Commercial sector: offices and businesses, government, schools, and other public buildings, hospitals and care facilities, hotels, malls, warehouses, restaurants, and places of worship and public assembly. In the Pacific Northwest, energy — from all sources, including electricity, natural gas, or other fuels — is used for HVAC, lighting, computing, and other commercial needs.



97 percent of Oregon commercial buildings use electricity or natural gas for heating:



Heating, cooling, and ventilation, which is responsible for the largest share of electricity and natural gas use in a commercial building, is provided through central systems, individual units, or a combination of both.

Lighting is the third largest share of energy use. Efficiency and type of lighting are evolving as incandescent and fluorescent lighting is replaced with energy-efficient LEDs.

Oregon's commercial sector has reduced energy use by **8.4 percent since 2000**. The amount of energy used per square foot in the region also decreased:

2000 18.7 kWh/sf		2015 15.6 kWh/sf
---------------------	--	---------------------

Energy used per dollar (in 2012 dollars) of economic output in the region has also decreased since 2000:

2000 1.2 million BTUs per \$1		2015 810,000 BTUs per \$1
-------------------------------------	--	---------------------------------

References: 1, 2, 79, 80, 81

Refrigeration and cooking use a lot of energy, with refrigeration accounting for about 18 percent of overall electricity use and cooking about 25 percent of natural gas use in commercial buildings.

Water heating is the second largest user of natural gas. Water heating tanks or boilers are present in 86 percent of buildings in the region, and are predominately natural gas fueled.

Trends in Commercial Energy Use



Increased Solar PV

Adoption of LED lighting



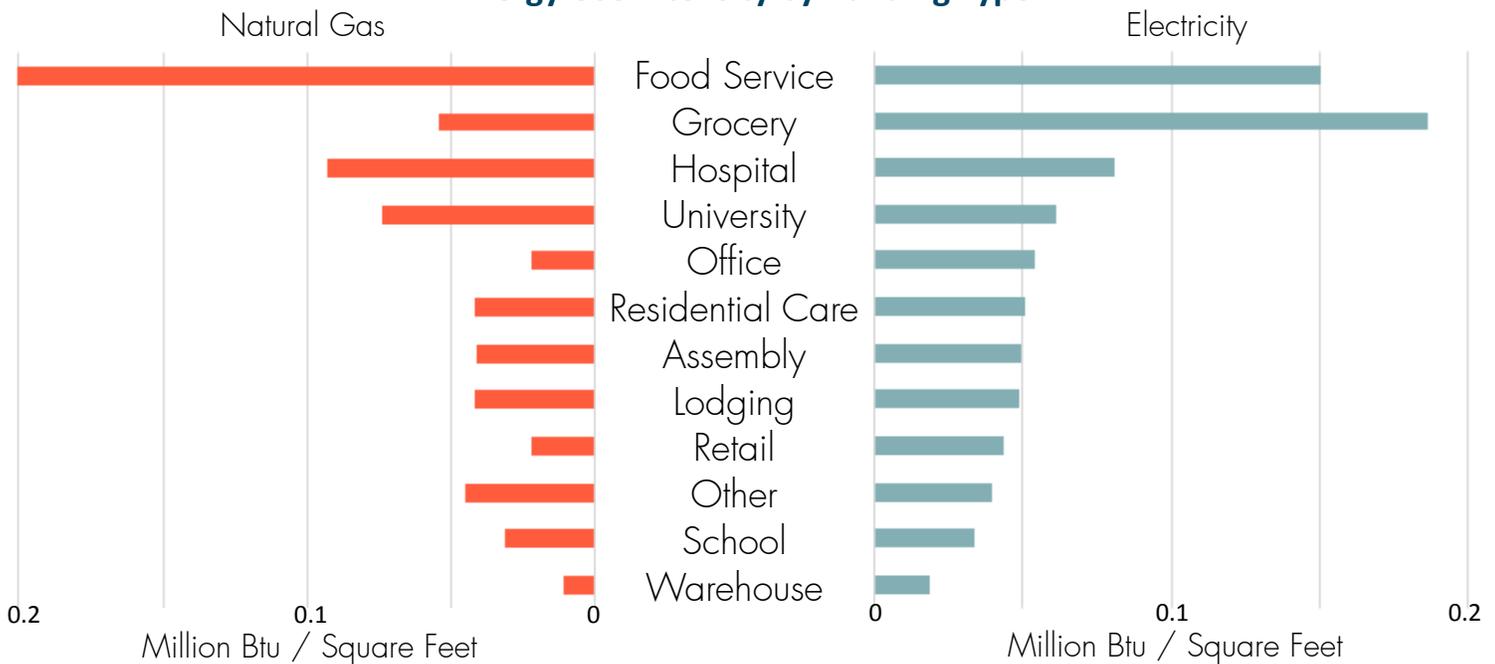
Commercial buildings are using energy management and benchmarking

Almost 75% of the region's schools report having energy management staff

Energy Performance is measured by comparing a building's annual energy use to its size, and depends on a building's construction, equipment efficiency, operation, and location. In commercial buildings, floor space, the type of building, and its activities drive energy use.

Financial incentives, improved building code and appliance standards, and energy efficiency programs are helping commercial buildings improve energy performance. The Portland Commercial Energy Performance Reporting policy requires buildings to benchmark and report annual energy use. Learn more in chapter 6.

Energy Use Intensity by Building Type



Oregon's Industrial Sector

26.4%

Industrial sector's share of total energy use in Oregon

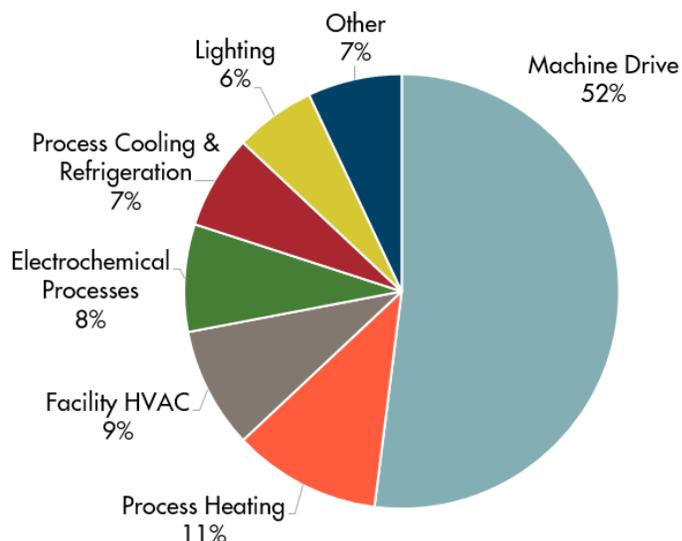
Industrial Sector: Facilities and equipment used for producing and processing goods and services, including manufacturing, forestry, mining, and construction. Oregon's extensive agricultural industry is also included in this sector profile. The industrial sector's primary use of energy is for process heating and powering machinery. Energy in the form of feedstock fuels are also used as raw material for production.

Oregon's industrial sector:

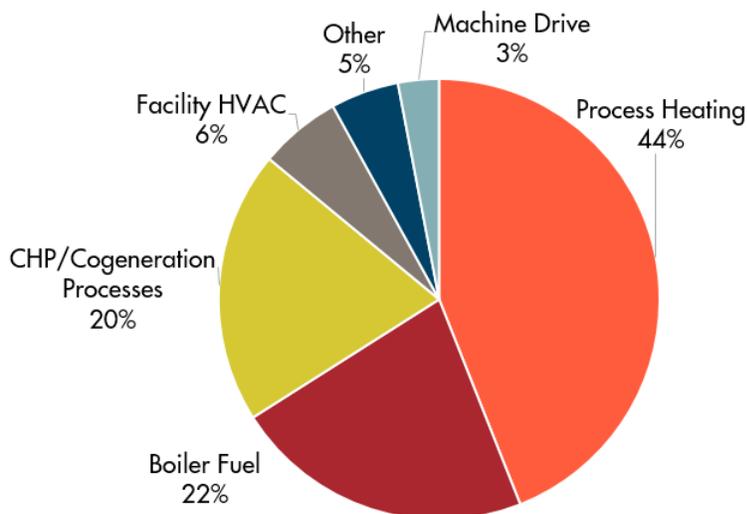
- Manufacturing
- Semiconductor fabrication
- Agriculture
- Food processing
- Forestry
- Wood and paper products
- Construction

The industrial sector uses electricity and other fuels in a number of ways:

Electricity



Other Fuels



15%

Industrial sector's share of total energy costs in Oregon

23.7%

Reduction in total energy use in Oregon since 2000

A significant reason for the decline in energy use in the industrial sector is due to the closure of Oregon aluminum smelters and a shift to less energy-intensive industries.

Energy-Intensive Industries

Energy-intensive industries in the U.S. include food processing, pulp and paper, chemicals, refining, iron and steel, metals, and minerals (primarily aluminum and cement). Bulk chemicals, refining and mining, and manufacturing are large users as they require high amounts of energy to turn raw materials into new products.

Boiler Fuel

- Steam generation
- Water heating for industrial processes
- Electricity generation

Fossil Fuels and Renewable Energy

- Heat in industrial processes
- Space heating

Electricity

- Industrial motors
- Machinery
- Lights
- Computers
- Office equipment
- Irrigation pumps

Petroleum

- Agricultural equipment

Trends in Industrial Energy Use



Manufacturing is incorporating electronic and robotic devices, which may increase labor productivity

Natural gas use in manufacturing is increasing



96 percent of regional industrial facilities use energy management techniques

Energy used per dollar (2012 dollars) of economic output in the region has decreased since 2000:

2000
17 million BTUs
per \$1000

2015
10 million BTUs
per \$1000

Energy performance is measured in terms of productivity (energy cost per unit of product or per dollar of output).

Energy is a substantial cost for industrial facilities. Financial incentives and adoption of strategic energy management approaches such as ENERGY STAR and ISO 50001 will continue to improve energy performance in the industry.

Oregon's Transportation Sector

30.7%

Transportation sector's share of total energy use in Oregon

47.7%

Transportation sector's share of total energy costs in Oregon

93%

Percentage of Oregon's transportation fuel that comes from petroleum-based products

85%

Percentage of transportation sector energy consumed on our roadways

3.5 million

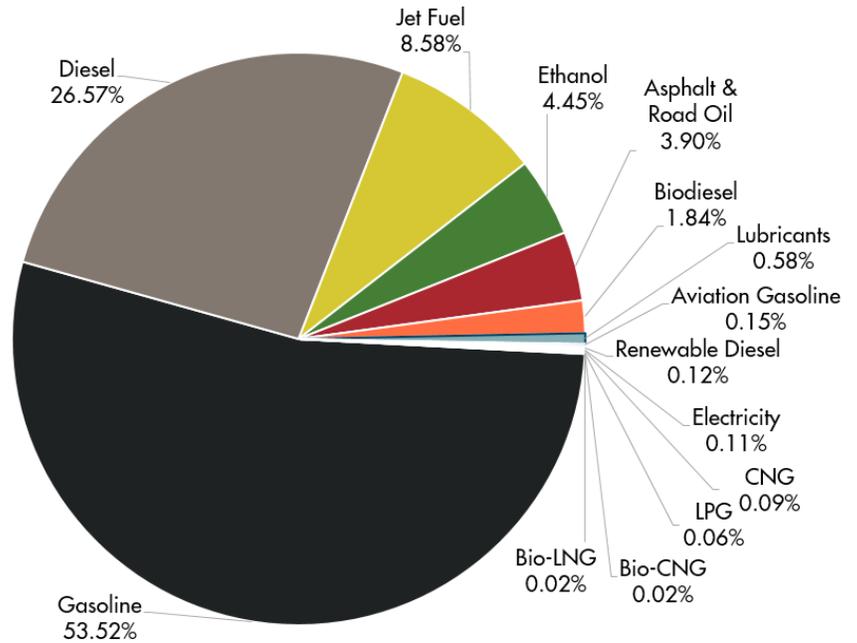
Total number of registered passenger vehicles in Oregon (2017)

17,893

Number of electric vehicles registered in Oregon (June 2018)

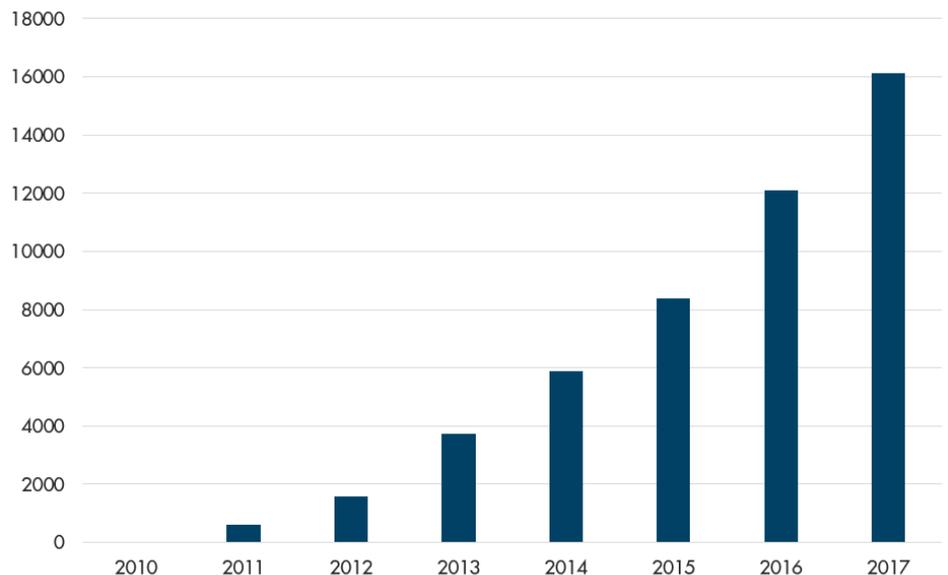
Transportation Sector: The movement of goods, services, and people—including passenger and commercial vehicles, trains, aircraft, boats, barges, and ships. Energy, mostly in the form of petroleum products, is used directly for transportation vehicles and to fuel equipment.

Transportation Fuels Used in Oregon in 2016



Cumulative Total Electric Vehicle Registrations in Oregon

25% Year-Over-Year Increase Since 2010



Between 2005 and 2017, Oregon reduced:
Passenger vehicle emissions by

↓ 12.5%

Fuel consumption in passenger vehicles by

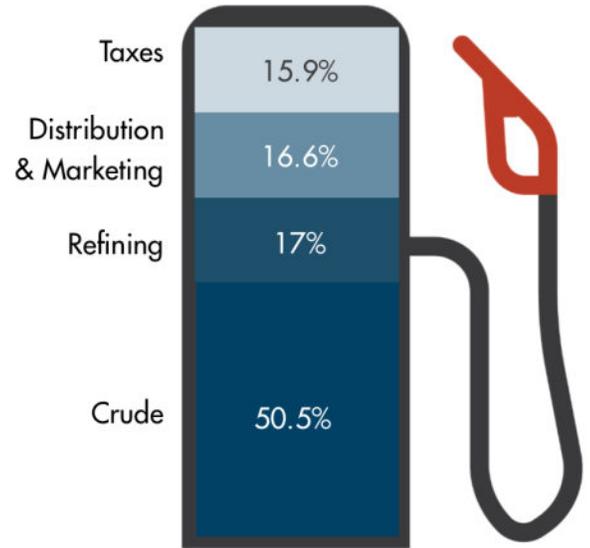
↓ 10%

Transportation fuel costs tend to be higher in Oregon because of the region's distance from fuel supplies and a limited number of refineries.

Oregon's transportation sector:

- The percentage of SUVs and pickup trucks registered in Oregon is greater than national average
- Passenger vehicles—including cars, trucks, and SUVs—in Oregon are older than the national average
- Largest portion of the transportation sector's energy use comes from passenger vehicles
- Passenger vehicle stats includes miles driven on highways, gravel roads, and all roads in between

Oregon Regular Gasoline
 Retail Price: \$3.30 / Gallon (October 2018)



Total and Per Passenger Vehicle GHG Emissions

While overall on-road fuel consumption and emissions are on the rise in Oregon, per vehicle consumption and emissions are dropping.



68%

Share of Oregon's total transportation fuel costs attributed to gasoline

98%

Percentage of transportation fuels used in Oregon that are imported into the state

Typical Oregon vehicle in 2005:
490 gallons fuel/year
6 MTCO2e

Typical Oregon vehicle in 2017:
439 gallons fuel/year
5.3 MTCO2e

Greenhouse Gas Emissions

2050

This section provides a brief overview of Oregon’s sector-related greenhouse gas emissions. Most of Oregon’s GHG emissions come from the energy we use every day. For a deeper dive into Oregon’s energy-related greenhouse gas emissions, current policies, and mitigation efforts, see chapter 2.

Target year for Oregon to reduce GHG emissions by 75 percent below 1990 levels

9%
of Oregon’s 2016 GHG emissions

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

7%
of Oregon’s 2016 GHG emissions

Industrial: When electricity and natural gas use are accounted for separately, industrial accounts for 7 percent of the state’s emissions and is comprised primarily of emissions from petroleum combustion, industrial waste and wastewater, and manufacturing. With electricity and natural gas use included, this sector accounts for about 20 percent of Oregon’s total GHG emissions.

7%
of Oregon’s 2016 GHG emissions

Residential & Commercial: When electricity and natural gas use are included, these sectors comprise 32 percent of Oregon’s GHG emissions. When electricity and natural gas use are accounted for separately, residential and commercial GHG emissions drop to 7 percent and stem primarily from fuel oil for heating and emissions from waste and wastewater originating from these sectors.

12%
of Oregon’s 2016 GHG emissions

Natural Gas Use: Percentage accounts for direct use of natural gas in all sectors, plus fugitive emissions from distribution.

26%
of Oregon’s 2016 GHG emissions

Electricity Use: This accounts for electricity used in other sectors. This number is down from 30 percent in 2015 and includes emissions associated with electricity used in the state, regardless of where it is generated. Emissions from electricity generated in Oregon but used out of state are not included.

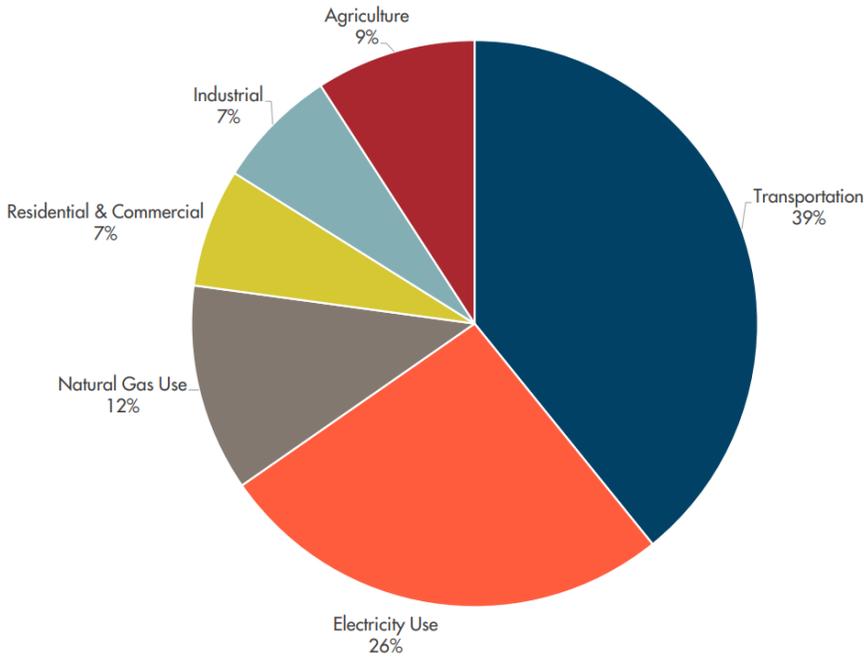
39%
of Oregon’s 2016 GHG emissions

Transportation: This sector is the state’s largest single source of GHG emissions: 36 percent of the statewide total in 2015 and 39 percent in 2016. Estimates from 2015 indicate that 47 percent of transportation emissions are generated from passenger cars and trucks, while approximately 23 percent are from heavy-duty vehicles.

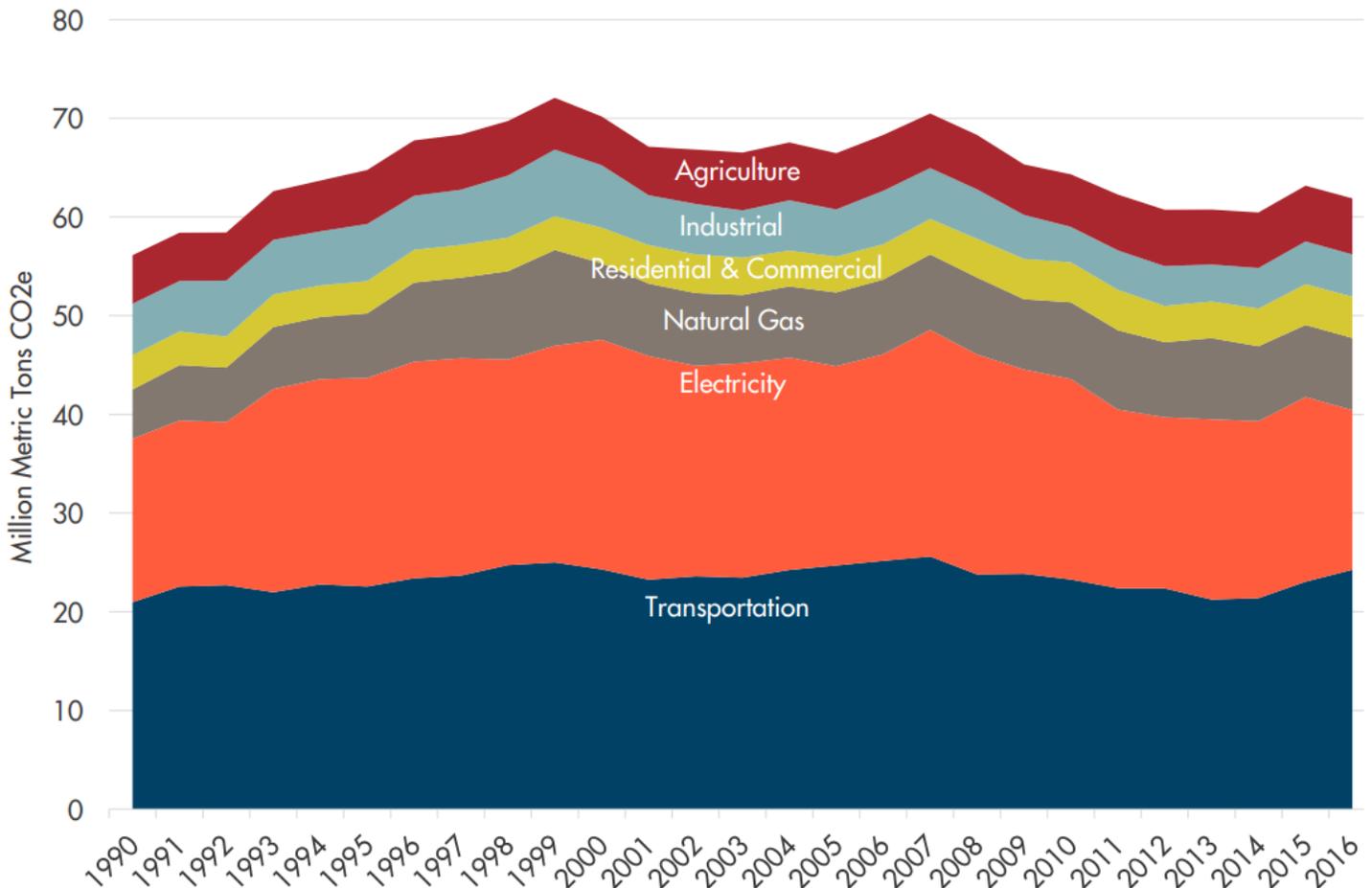
Transportation Emissions

Transportation emissions have grown as a share of Oregon's statewide GHG emissions total compared to emissions from electricity use. Specifically, transportation went from 35 percent of the statewide total in 2014 to 39 percent in 2016, while electricity use emissions decreased from 30 percent to 26 percent of the state's total emissions. All other sectors stayed relatively constant over the same period. While total transportation emissions have fluctuated over the years, GHG emissions per vehicle have gone down thanks to improved fuel efficiency.

Oregon 2016 GHG Emissions



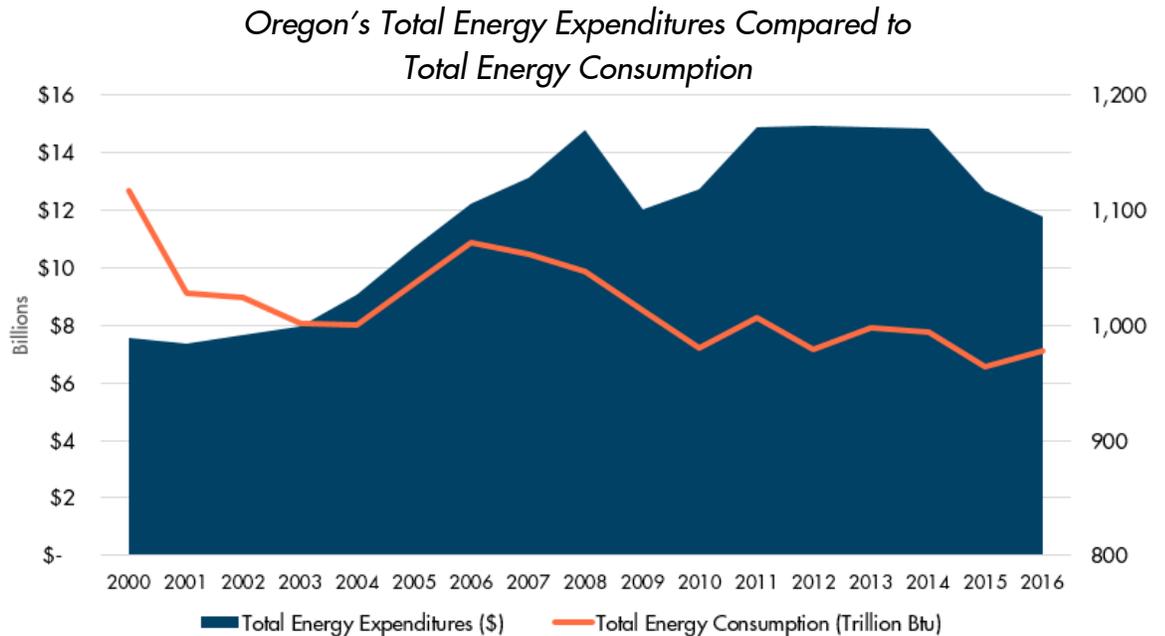
Oregon Greenhouse Gas Emissions by Sector Over Time



Energy Costs and Expenditures

What We Spend on Energy

Oregon spent \$11.7 billion on energy in 2016 – the lowest amount since 2005. This includes electricity and fuel for homes and businesses, industrial energy uses, and petroleum used in the transportation sector.

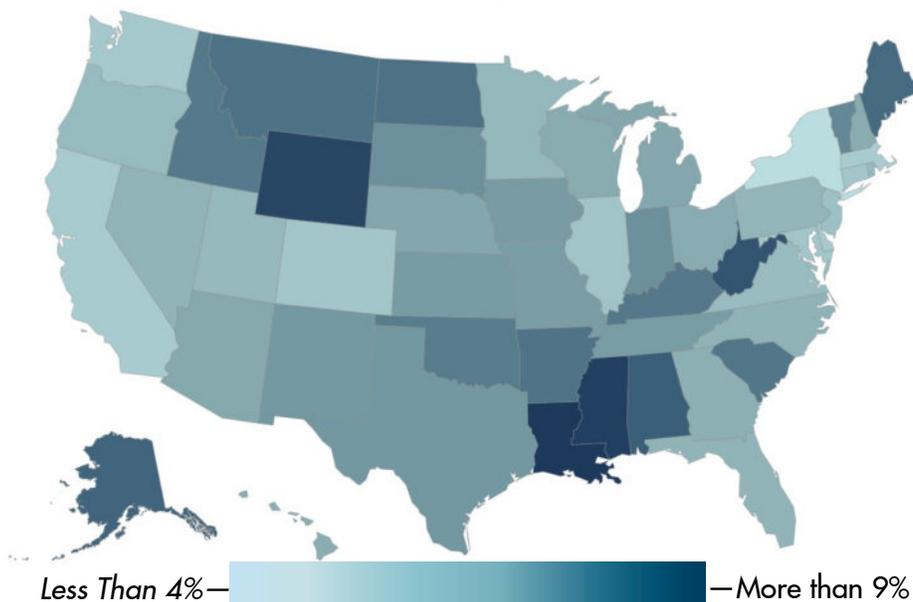


Transportation

accounts for nearly 50 percent of our state's energy expenditures and also sees the largest swings in price. The variability in what we spend on energy is driven primarily by transportation fuel costs.

Oregon's energy costs are also comparable to what other states spend. Where we differ is on costs per category—our electricity rates tends to be less expensive than other parts of the country, while our transportation fuel costs are somewhat higher.

State Total Energy Expenditures as a Percentage of State Gross Domestic Product — 2016



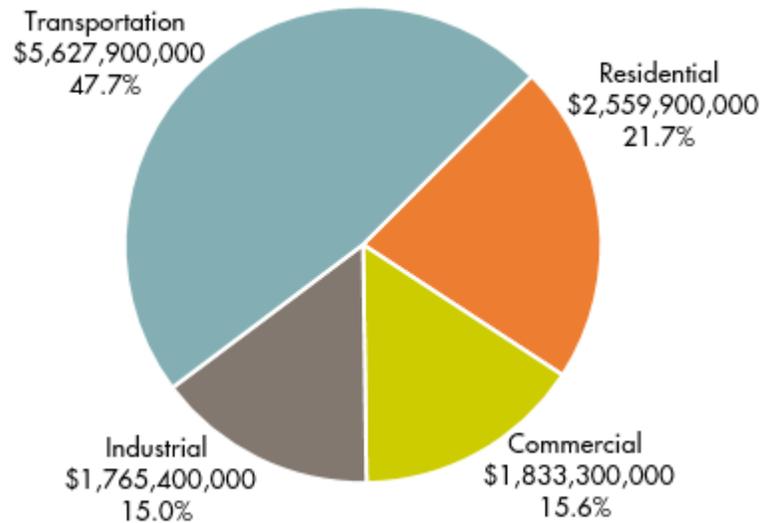
In 2016, Oregon spent 5.2 percent of the state's GDP on energy – right in line with the U.S. median of 6.3 percent. The District of Columbia was lowest at 1.6 percent, and Louisiana highest at 11.1 percent.

Energy Costs and Expenditures

Oregon's 2016 per capita energy expenditure was \$2,885 per person – one of the lowest states in the U.S. The primary reason we rank so low is due to the amount of energy we consume. We use less energy than other states and therefore spend less.

Oregonians' 2016 energy expenditures can be separated by sector. While the transportation sector represents 31 percent of energy consumption, it accounts for almost half of expenditures due to the much higher per unit cost of transportation fuels. Because nearly all our transportation fuel is imported, most of this money goes out of state.

Oregon's Total Energy Expenditures by Sector – 2016



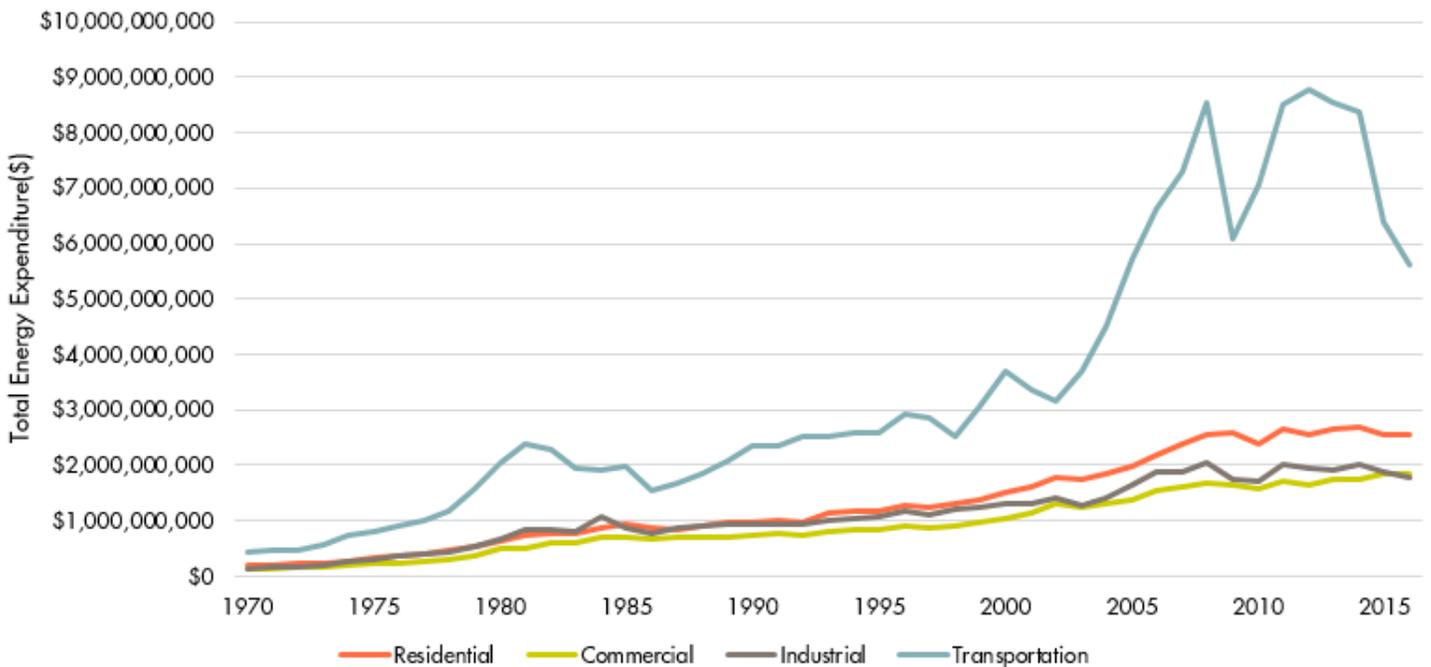
3%

Percentage of median household income Oregonians spent on energy in 2016

5%

Percentage of median household income Oregonians spent on transportation fuel in 2017

Oregon's Total Energy Expenditures by Sector Over Time



While Oregon's residential, commercial, and industrial sectors have experienced gradual increases in what we spend, transportation sector expenditures reflect more price volatility in the transportation fuels market.

Energy Bill Basics

This month's charges (Turn over for details)

Meter #1250627246N, Schedule 07

Energy Charges (395 kWh)	57.73
Adjustments	1.66 CR
	56.07
Total Taxes and Fees	3.13
Current Energy Charges	59.20

Your energy use

Meter #1250627246N

Schedule 07 (residential rate)

Service Period Meter Reading

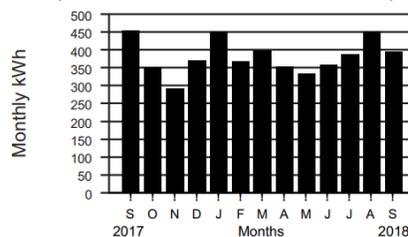
09/12/18 37113

08/13/18 36718

30 days of service 395 kWh

Period Ending	Avg Daily Temperature*	Monthly kWh	Monthly Cost
Sep 2018	N/A	395	59.20
Sep 2017	66	454	60.04

*Temperature source: Portland International Airport



Details of this month's charges

Meter #1250627246N, Schedule 07

Basic Charge	11.00
Energy Use Charge (395.000 kWh x \$0.0651)	25.71
Transmission Charge (395.000 kWh x \$0.00209)	0.83
Distribution Charge (395.000 kWh x \$0.04311)	17.03
Green Source [sm] (395.000 kWh x \$0.008)	3.16
Subtotal - Energy Charges	57.73
102 RPA Exchange Credit (395.000 kWh x \$-0.01016)	4.01 CR
105 Regulatory Adjustments (395.000 kWh x \$-0.00016)	0.06 CR
109 Energy Efficiency Funding Adj (395.000 kWh x \$0.00493)	1.95
110 Energy Efficiency Customer Svc (395.000 kWh x \$0.00005)	0.02
112 Customer Engagement Transformation Adjustment (395.000 kWh x \$0.0003)	0.12
123 Decoupling Adjustment (395.000 kWh x \$0.00009)	0.04
135 Demand Response (395.000 kWh x \$0.00014)	0.06
137 Solar Payment Option Cost Recov (395.000 kWh x \$0.00047)	0.19
143 Spent Fuel Adjustment (395.000 kWh x \$-0.00019)	0.08 CR
145 Boardman Decommissioning Adj (395.000 kWh x \$0.00027)	0.11
Subtotal - Adjusting Schedules	1.66 CR
	56.07
City of Portland Tax (1.5%)	0.81
Multnomah County Tax (0.027%)	0.01
Low Income Assistance	0.69
Public Purpose Charge (3%)	1.62
Subtotal - Taxes and Fees	3.13
Current Energy Charges	59.20

*Your Federal Columbia Benefits are supplied by Bonneville Power Administration (BPA).

Meter

Meters measure how much energy is consumed. Some utilities are making the switch to digital "smart meters," which help track when energy is used, in addition to how much.

Rate Schedule

Rates vary between residential, commercial, and industrial customers.

Basic Charge

A minimum cost of service, regardless of the amount of energy used. This funds the utility provider's costs like maintenance and customer support.

Use Charge

Utilities charge by how much energy is used measured in kilowatt hours.

Public Purpose Charge

For PGE, Pacific Power, and all three natural gas utility customers, a 3 percent Public Purpose Charge is added, which funds conservation projects, renewable resources, weatherization for low-income households, and energy efficiency improvements in schools.

Go Green

Most utilities offer programs for customers who want to use renewable energy. In this sample bill, the customer is enrolled in PGE's Green Source program. Oregon has the country's highest participation rates in voluntary green energy programs.

Energy Bill Basics

Energy Rates

Utilities provide energy to customers using a series of Rate Schedules. The schedules vary based on the type of customer and their needs: residential, commercial, industrial, and others. More than one rate can be used for the energy a building or facility uses. Schedules can be created for specific uses, like traffic signals, street lights, irrigation and drainage pumping, or for time-of-day service or special pilot programs like demand response.



Demand Charges

Utility customers are charged based on the amount of energy they use. Utilities may add demand charges, particularly for commercial and industrial customers based on the customer's highest energy use in a particular interval. Customers with large equipment that uses significant energy may incur high demand charges.

Power Factor

Power factor is the ratio of working power to apparent power. Working power is the actual power used to run equipment, and apparent power is the combination of working power and additional reactive power resulting from an inductive load like a motor. Utilities work with customers to maximize power factor to ensure the full benefit of their electricity use, with the additional advantage of supporting longer equipment life.

Most of this section has focused on electricity bills. Here are a few ways natural gas and other heating bills may differ.

Natural Gas

Natural gas is measured in therms. Natural gas bills have a basic and meter charge. They also commonly have declining or ratcheting rates, as well as firm or interruptible rates, where customers who are willing to have their service interrupted will be charged lower rates.

Fuel Oil and Propane

Fuel oil and propane are typically sold in gallons by individual suppliers, which often offer discounts based on the volume purchased. There is no meter involved, so the charge is based on the volume delivered, not ongoing consumption.

Meeting Energy Demand

Making sure there's electricity available to power Oregonians' lives regardless of seasonal or daily variations in power outputs or customer demand is the core challenge of the electric utility industry. While technologies are improving all the time, electricity has limited storage options and instead must be generated nearly instantaneously to meet consumer demand. As a result, the electric system is sized to be able to satisfy the largest requirements for electricity—called peak demands—at all times, even though consumers use less during most hours of the year. This results in a generation and transmission system that is underutilized much of the time by design, especially when compared to the liquid fuels and natural gas sectors. Natural gas and transportation fuels are comparatively easy and inexpensive to store, so fuel production can occur at a more constant rate when they are needed.

Hourly Energy Demand

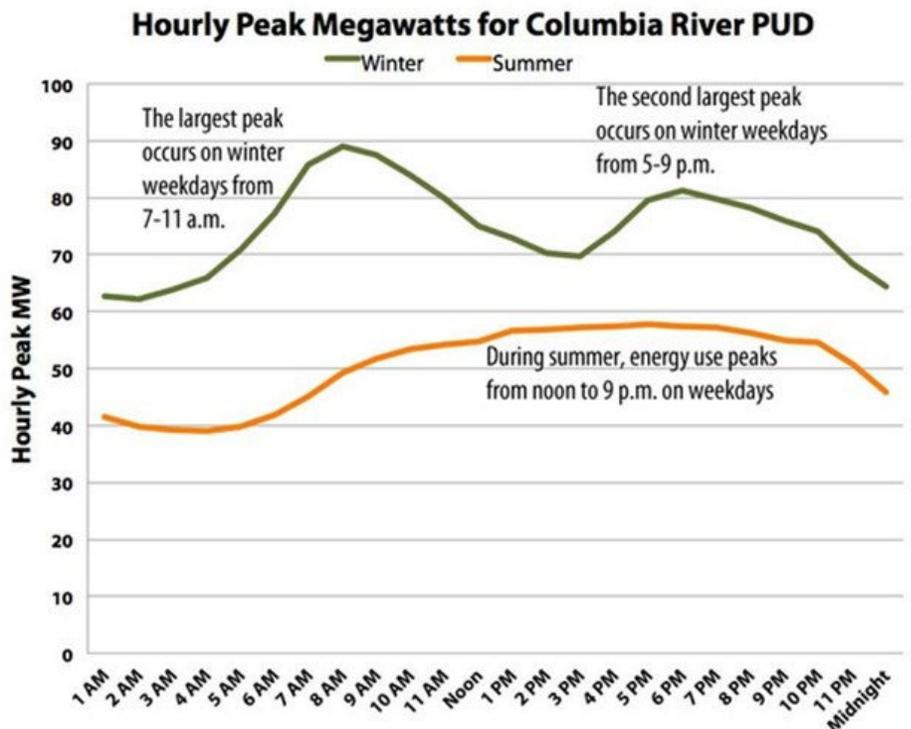
Electric utilities closely watch and manage the timing of consumer demand for electricity, from minute to minute and hour to hour. The image below shows two representative 24-hour electric load demand curves for Columbia River People's Utility District—one from a typical winter day and the other a typical summer day. This example illustrates the change in demand for electricity that can occur on a utility's system over the course of a single day. For example, the peak demand in winter, 90 megawatts at 8 a.m., is nearly 50 percent greater than the minimum demand of 60 megawatts at 2 a.m. These swings in demand across the day can impose stresses on electric

generators and the transmission network needed to deliver that electricity to consumers. While wholesale prices for electricity tend to reflect these conditions—with prices going up during high demand hours and dropping during low demand hours—the regulatory structure for residential consumers means that rates are flatter and less volatile.

Seasonal Energy Demand

Energy demand also changes with the seasons. Colder wintertime temperatures in Oregon result in increased demand for natural gas

and electricity to heat homes and buildings. As Oregon summers get warmer, the state is seeing increasing use of air conditioners in the hottest months. Meanwhile, demand for liquid fuels peaks during the summer months when Oregonians are more likely to take advantage of long days and warmer weather to drive longer distances for vacation.



Change in Supply

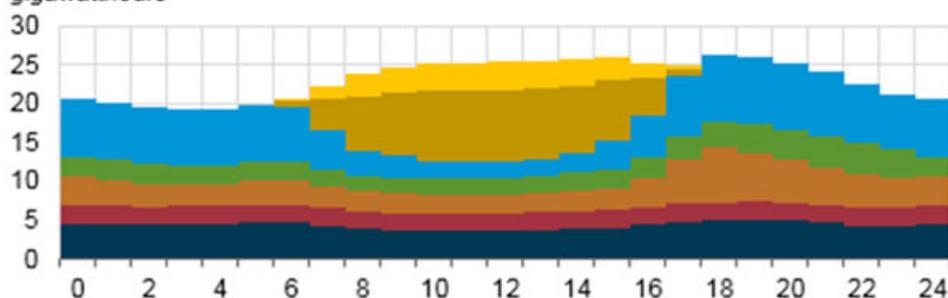
Just as consumers' needs vary by the hour and season, so can the supply of energy. If an Oregonian turns on an overhead light at 11 p.m. in early May, there is a high likelihood that the electricity powering that light bulb originated with a carbon-free hydroelectric power plant. That's the time of year when the Pacific Northwest's hydroelectric system tends to have high output due to spring runoff in our rivers.

If that same Oregonian turns on the same light at 7 a.m. on a chilly November morning, the electricity powering the light will more likely have originated with another type of resource, such as a coal or natural gas power plant.

In the same vein, the availability of different types of energy can vary hour by hour. The amount of wind energy on the grid depends on whether the wind is blowing.

Similarly, solar photovoltaic energy is dependent on the sun being out. In parts of the country with large amounts of solar power, like California, this hour-to-hour variation can be fairly pronounced, as shown in the graph to the right.

California Independent System Operator net generation, March 11, 2017
gigawatthours



Demand Response

One strategy used by utilities to better align demand with the availability of supply is demand response. Demand response is a deliberate change in a customer's normal electricity usage pattern in response to a change in price, contract, or request from a utility or grid operator. This can be most useful to a utility during the hottest or coldest days of the year, when the system's existing resources may be strained to meet high levels of demand from air conditioning or heating. Rather than building or buying a new generating resource, utilities or grid operators can sometimes find it cheaper to pay or offer an incentive for customers to temporarily use less energy.

More than most regions, the Pacific Northwest has historically had sufficient excess capacity because of the robust hydroelectric system at the foundation of our electric system. Primarily for this reason, the region has developed little demand response capacity. This is changing as coal capacity retires and as more energy demand is met by output from renewables. In the Seventh Power Plan, the Northwest Power and Conservation Council identified the development of a significant amount of demand response capacity, combined with additional savings from conservation, as the most cost effective way address system constraints by the early 2020s.

Demand response programs can also be developed to encourage an increase in demand at times that are beneficial for the utility or grid operator. This might occur during times when wholesale power prices are particularly low, or at times when excess carbon-free power is available in the market.

Oregon Utilities Overview

Oregon is served by investor-owned and consumer-owned utilities and by energy service suppliers. The state is also served by the Bonneville Power Administration (BPA), a federal agency that markets electric power from 31 dams in the Pacific Northwest and the Columbia Generating Station nuclear power plant in Washington. BPA also owns and operates 75 percent of the high-voltage transmission system in the Northwest.

How Utilities Are Regulated

Federal Regulation

The Federal Energy Regulatory Commission (FERC) is an independent federal agency with a five-member board appointed by the president. FERC regulates the interstate transmission of electricity, natural gas, and oil. It also has jurisdiction over the siting of interstate natural gas pipelines, natural gas storage facilities, liquid natural gas terminals, and hydroelectric plant relicensing. FERC also monitors and investigates the operations of wholesale energy markets. The many areas outside of FERC's jurisdiction are handled by state regulatory bodies.

Regional Regulation

In the western United States, the Western Electricity Coordinating Council (WECC) provides reliability compliance monitoring and enforcement for electric utilities consistent with rules established by the North American Electricity Reliability Corporation (NERC). WECC also coordinates the regional development of reliability standards and operating and planning activities.

Reliability coordination services—including real-time monitoring and situational awareness—are also conducted at the regional level. WECC used to provide this service, and Peak Reliability Corporation, a nongovernmental organization, has served in this role since 2014, with services scheduled to end by 2019. As of October 2018, balancing authorities across the WECC are evaluating their options for reliability coordination services after 2019. The Bonneville Power Administration, PacifiCorp, and Idaho Power have

References: 64, 65, 87, 88

Types of Utilities

GAS ELECTRICITY

Investor-Owned Utilities

PacifiCorp/Pacific Power
Portland General Electric
Idaho Power

Northwest Natural
Avista

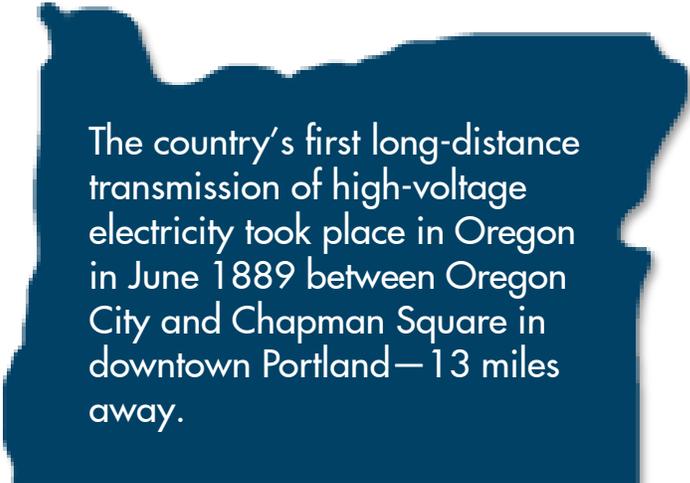
Cascade Natural Gas

- For-profit corporations
- Facilities owned by shareholders
- Governed by private boards
- Regulated by the Oregon Public Utility Commission

Consumer-Owned Utilities

36 electricity cooperatives, municipal corporations, and people's utility districts

- Not-for-profit entities
- Facilities owned by customers
- Governed and regulated by locally elected boards



The country's first long-distance transmission of high-voltage electricity took place in Oregon in June 1889 between Oregon City and Chapman Square in downtown Portland—13 miles away.

committed to receiving reliability coordination services from the California Independent System Operator (CAISO) following CAISO's anticipated certification from federal authorities.

There is no entity analogous to NERC with the responsibility for establishing and enforcing reliability standards for the natural gas system.

State Regulation

The rates charged to retail customers by Oregon's investor-owned electric and gas utilities are regulated by the Public Utility Commission (PUC), a state agency with a three member commission appointed by the Governor. In exchange for a protected monopoly, the IOUs provide energy services to the customers within their designated service territories, and the PUC guarantees their costs plus a reasonable rate of return on their rate-based capital investments. The PUC evaluates the prudence of IOU investments and the continued usefulness of previous investments as part of a rate case that results in the approval of IOU rate schedules and tariffs designed to recover the utility's revenue requirement through rates.

Consumer-owned utilities are regulated by locally elected boards of directors. These boards set rates based on their cost-of-service, and because they are not-for-profit utilities, there is no rate of return on top of the costs. The board approves the rate, resource, and investment decisions of the COU.

How Utilities Buy and Sell Energy

Electric and gas utilities in Oregon buy and sell energy in similar ways. The following core steps are involved in each case:

Long-Term Planning

- Evaluate current energy demand and develop forecasts of expected future demand
- Assess current supply resources (e.g., utility-owned, long-term contracts, liquidity in wholesale markets)
- Develop a plan to meet expected future demand with existing resources, new contracts, market purchases, or the development of new resources, including energy efficiency

Wholesale Transactions

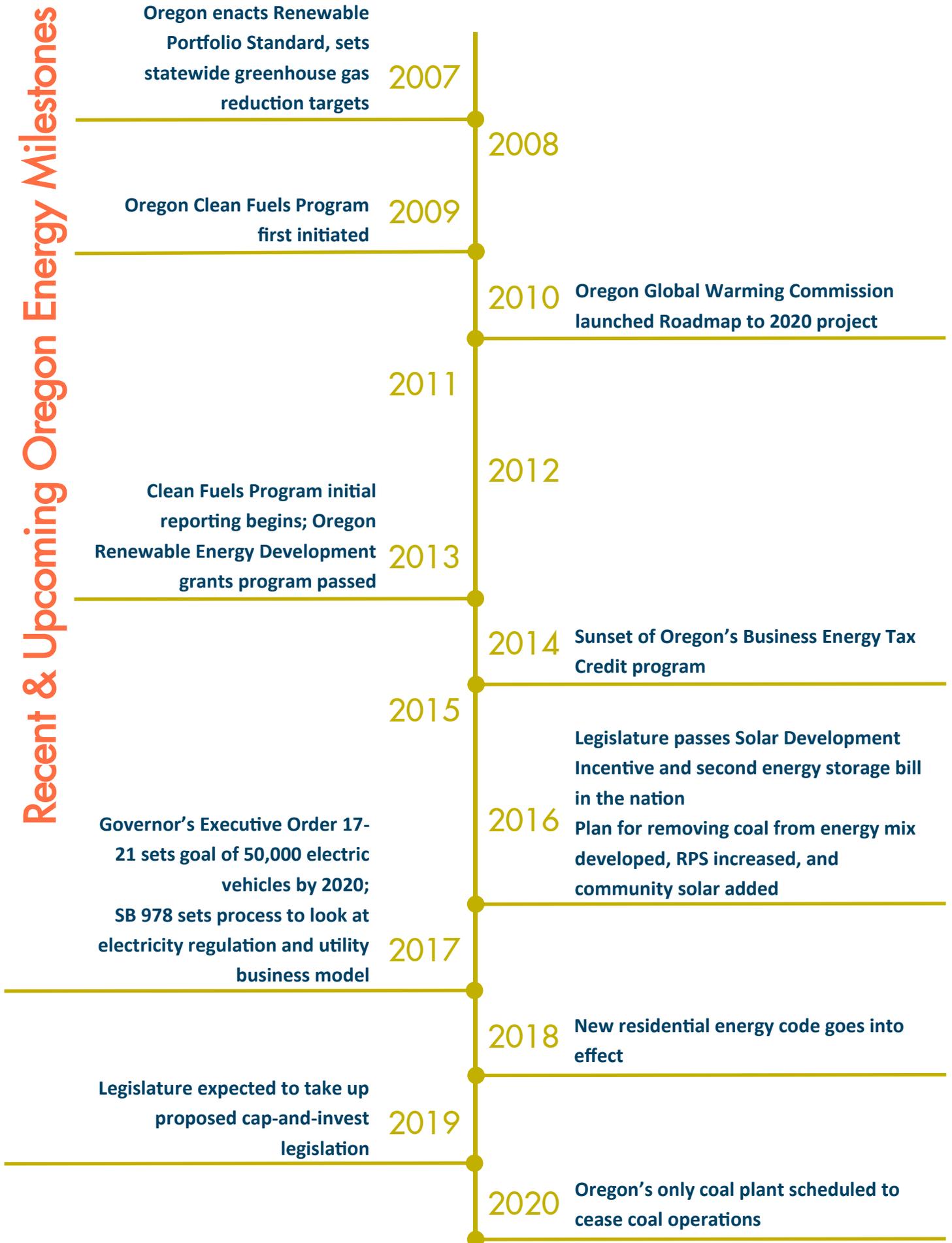
When a utility needs to purchase energy from another party for resale to their retail customers to meet demand, the utility may purchase energy at a wholesale rate in one of the following ways:

- Long-term contracts – e.g., 20 year power purchase agreement with a new third-party owned power plant
- Medium-term contracts – e.g., three- to five-year power purchase agreement with an existing third-party power plant)
- Short-term or real-time transactions – e.g., purchases over time intervals as short as five minutes to meet shortfalls in available supply

Retail Transactions

No matter how the utility acquires the necessary resources to meet demand, the utility will ultimately deliver energy to end-use customers at a retail rate approved either by the PUC (for electric and gas IOUs) or by the boards of COUs.

Recent & Upcoming Oregon Energy Milestones



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