Chapter 7: Energy in the Western US

Everything we do depends upon **energy**—without it there would be no civilization, no sunlight, no food, and no life. Energy moves people and goods, produces electricity, heats our homes and businesses, and is used in manufacturing and other industrial processes. But what *is* energy? Energy is the **power** derived from the utilization of physical or chemical resources. In this chapter, we are especially interested in the energy used to provide light and **heat**, or to power machines.

For most of human history, the way we captured and used energy changed little. With very few exceptions, materials were moved by human or animal power, and heat was produced largely through the burning of wood. Nearly all the energy to power human society was, in other words, **biomass***. But the transition from brute force and wood burning to the various industrial sources of energy—and the accompanying adoption of energy-intensive lifestyles—has occurred remarkably quickly, in the course of just the last several generations. This has caused changes in virtually every aspect of human life, from economics to war to architecture. Much of the rural US was without access to electricity until the 1930s, and cars have been around only slightly longer. Our energy **system** (how we get energy and what we use it for) has changed and is changing remarkably quickly, though some aspects of the energy system are also remarkably resistant to change.

***Exceptions include the use of sails on boats by a very small percentage of the world's population to move people and goods, and the Chinese use of natural gas to boil brine in the production of salt beginning roughly 2000 years ago.**

The use of **wind** to generate electricity, for example, grew very quickly in the late 2000s and early 2010s. In 2002, wind produced less than 11 million megawatt hours (MWh) of electricity in the US. In 2011, wind produced more than 120 million MWh—more than 1000% growth in ten years! That aspect of change stands in contrast to our long-lasting reliance on **fossil fuels**, **coal**, oil, and **natural gas**. Our reliance on fossil fuels is driven by a number of factors: the low upfront cost, very high energy densities, and the cost and durability of the infrastructure built to use fossil fuels.

power • *the rate at which energy is transferred, usually measured in watts or, less frequently, horsepower.*

heat • *the transfer of energy from one body to another as a result of a difference in temperature or a change in phase.*

biomass • *organic material from one or more organisms.*

wind • *the movement of air from areas of high pressure to areas of low pressure.*

fossil fuels • *fuel for human use that is made from the remains of ancient biomass.*

coal • *a combustible, compact black or dark-brown carbonaceous rock formed by the compaction of layers of partially decomposed vegetation.*

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Energy

Review

degrade (energy) • *the transformation of energy into a form in which it is less available for doing work, such as heat.*

watt • *a unit of power measuring the rate of energy conversion or transfer designated by the International System of Units as one joule per second.*

Energy production and use not only changes across time, but also with geography, as we will see by looking at energy production and use across the different regions of the US.

Electricity is a good example of an *energy carrier*: a source of energy that has been subject to human-induced energy transfers or transformations.

Wind power, on the other hand, is a *primary energy source*: a source of energy found in nature that has not been subject to any human manipulation.

What do different units of energy mean?

Heat is energy, and heat is at the root of all the ways that we move materials or generate light, so measurements of heat can be thought of as the most basic way to measure energy. The **British Thermal Unit** (abbreviated Btu or BTU) is the most commonly used unit for heat energy and is approximately the amount of heat required to raise one pound of water by one degree Fahrenheit. A Btu is also about the amount of energy released by burning a single wooden match. One Btu is also equal to 1055 joules. A **joule** is the energy expended (or work done) to apply a force of one newton over a distance of one meter. A typical apple weighs about a newton, so lifting an apple one meter takes about a joule of energy. That means that one Btu—the energy contained in a wooden match—would be all the energy required to lift an apple 1000 meters, or a kilometer.

This comparison of the energy of heat to the energy of motion (**kinetic energy**) might be a little confusing, but energy is transformed from one type to another all the time in our energy system. This is perhaps most obvious with electricity, where electrical energy is transformed into light, heat, or motion at the flip of a switch. Those processes can also be reversed—light, heat, and motion can all be transformed into electricity. The machines that make those transitions in either direction are always imperfect, so energy always **degrades** into heat when it is transformed from one form to another. A kilowatt-hour (kWh) is the amount of energy required to light ten 100-**watt** light bulbs for one hour. *Figure 7.1* compares different ways to make and use one kWh.

The principle of *Conservation of Energy* tells us that energy is neither created nor destroyed, but can be altered from one form to another.

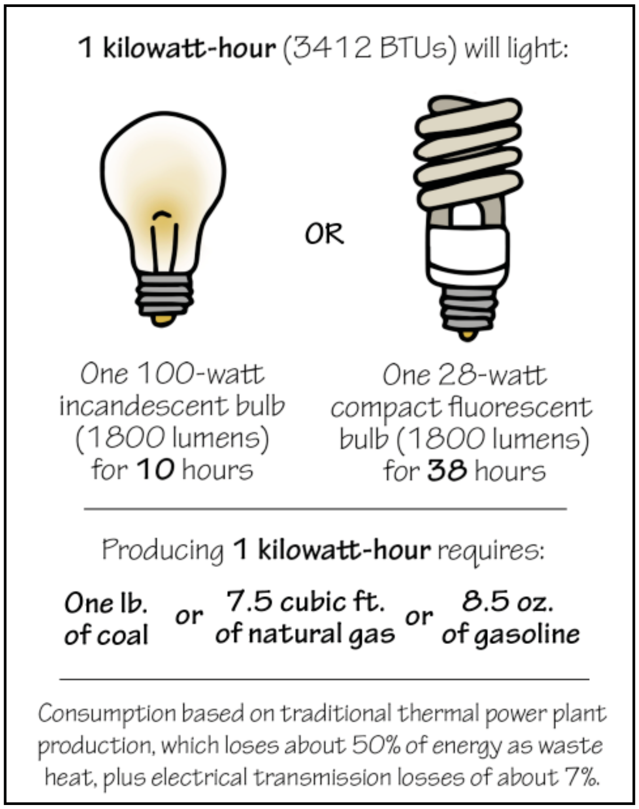

Figure 7.1: Examples of uses and sources of 1 kilowatt-hour.

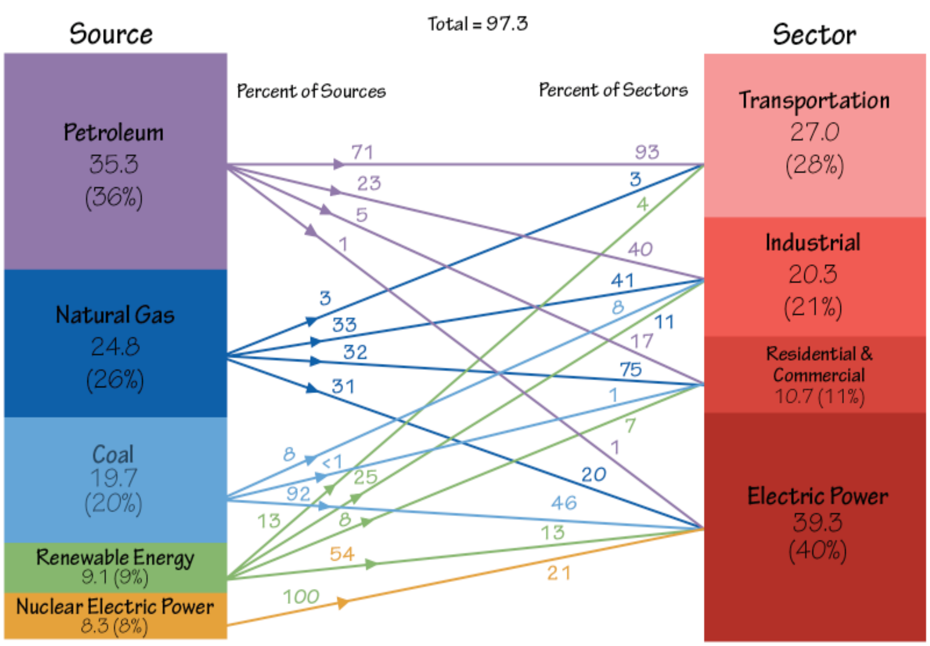

Figure 7.2. US energy production sources and use sectors for 2011. Petroleum provides more energy than any other source, and most of it is used for transportation. More energy is used to generate electricity than for any other use, and electricity is generated by all five energy sources. Nuclear is unique among sources in that all of the energy it generates goes to a single sector: electric generation. (See TFG website for full-color version.)

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Energy

Review

chemical reaction • *a process that involves changes in the structure and energy content of atoms, molecules, or ions but not their nuclei.*

petroleum • *a naturally occurring, flammable liquid found in geologic formations beneath the Earth's surface.*

renewable energy • *energy obtained from sources that are virtually inexhaustible (defined in terms of comparison to the lifetime of the Sun) and replenish naturally over small time scales relative to human life spans.*

nuclear • *a reaction, as in fission, fusion, or radioactive decay, that alters the energy, composition, or structure of an atomic nucleus.*

How do we look at energy in the Earth system?

The concepts used to understand energy in the Earth system are fundamental to all disciplines of science; energy is an interdisciplinary topic. One cannot study physics or understand biomes, photosynthesis, fire, evolution, seismology, **chemical reactions**, or genetics without considering energy. In the US, every successive generation has enjoyed the luxury of more advanced technology (e.g., the ability to travel more frequently, more quickly, and over greater distances), and we require more and more energy to maintain these new lifestyles and to power new technologies.

Figure 7.2 shows the sources and uses of energy in the US, by sector. The Energy Information Administration (EIA) categorizes energy as coming from one of five sources (**petroleum**, natural gas, coal, **renewable energy,** and **nuclear** electric power) and being used in one of four energy sectors (transportation, industrial, residential & commercial, and electric power). All of the energy that powers our society comes from one of these five sources and is used in one of these four sectors.

The more we come to understand the Earth system, the more we realize that there is a finite amount of consumable energy, and that harvesting certain resources for use in energy consumption may have wide ranging and permanent effects on the planet's life. Understanding energy within the Earth system is the first step to making informed decisions about energy transitions.

Becoming "Energy Literate"

Energy is neither lost nor gained within the universe, but rather is constantly flowing through the Earth system. In order to fully understand energy in our daily lives—and make informed decisions—we need to understand energy in the context of that system. Becoming energy literate gives us the tools to apply this understanding to solving problems and answering questions. The Seven Principles of Energy, as detailed in "*Energy Literacy: Energy Principles and Fundamental Concepts for Energy Education*" are:

Energy Literacy: Energy Principles and Fundamental Concepts for Energy Education **is a publication of the US Department of Energy. It can be accessed for free online; see Resources for more information.**

1	**Energy is a physical quantity that follows precise natural laws.**
2	**Physical processes on Earth are the result of energy flow through the Earth system.**
3	**Biological processes depend on energy flow through the Earth system.**

4	**Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.**
5	**Energy decisions are influenced by economic, political, environmental, and social factors.**
6	**The amount of energy used by human society depends on many factors.**
7	**The quality of life of individuals and societies is affected by energy choices.**

Each principle is defined by a set of fundamental concepts that can help clarify ties to curriculum. Keeping these energy principles in mind when we teach others about energy can help us contextualize and make relevant our own energy consumption and its effect on the Earth system.

Energy in the Western Regions

The primary energy resources in the contiguous Western states come from renewable sources, such as solar, wind, and hydroelectric power. California is the exception to this rule, with 54% of its energy production stemming from fossil fuels, and 15% from nuclear power.

Alaska's energy production relies solely on fossil fuels, and Hawai'i's solely on renewables.

Fossil Fuels

Fossil fuels—oil, natural gas, and coal—are made of the preserved organic remains of ancient organisms. Petroleum typically forms from the remains of aquatic life, primarily one-celled photosynthetic organisms, which can accumulate in sediments. Coal forms primarily from the accumulation of land plants. In either case, organic matter is only preserved when the rate of accumulation is higher than the rate the rate of decay. This happens most often when the oxygen supply is sufficiently low enough that oxygen-loving bacteria cannot thrive, greatly slowing breakdown of organic matter. In this way, the organic matter can be incorporated into the buried sediment. The organics are compacted and heated with the rest of the rock, eventually transforming into fossil fuels.

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Region 1

topography • the landscape of an area, including the presence or absence of hills and the slopes between high and low areas.

Fossil Fuels (continued)

The history of surface environments, evolution of life, and geologic processes beneath the surface have all influenced where fossil fuel deposits formed and accumulated. The largest oil and gas reserves were at one time nutrient-rich seas with abundant surface phytoplankton and organic-rich bottom sediments; the largest coal beds were swampy environments where fallen forest trees and leaves were buried in stagnant muds.

Energy in the Basin and Range
Region 1

The Basin and Range region is named for its erratic and abrupt changes in elevation and **topography**. Not surprisingly, deserts, mountain ranges, lakes, and valleys can be found within this region. A famous geologist from the 1880s, Clarence Dutton, once said the parallel valleys and mountains looked like an "army of caterpillars crawling northward." With some of the lowest and highest points in the contiguous US, the region is prime for wind, hydroelectric, and solar energy production. Although natural gas provides much of the region's power, most of this resource is imported from elsewhere.

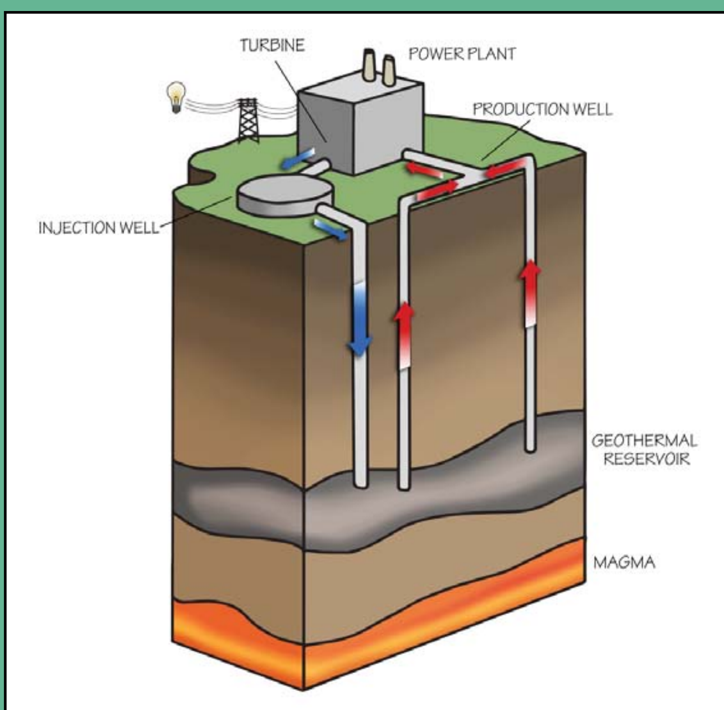
Unfortunately, because this area is home to some of the most unusual and inhospitable ecosystems in the world (the Mojave Desert and Death Valley, among others) and its large cities are located hundreds of miles apart, the human population has been spread out over long distances of deserts and mountain ranges, making the delivery of petroleum and natural gas products difficult. Further complicating these difficulties is the fact that the presence of pipelines in the region remains highly controversial. However, this region is rich in tectonic activity, and several research projects are underway by the USGS to study the possibility of significantly increasing the harvest of geothermal energy. The Sedimentary Geothermal Research Project, headed by a team from the USGS and the Utah Geological Survey, has tested several sites and found temperatures of 93°C (200°F) a mere 3.2 kilometers (2 miles) below the surface. Therefore, the area has the potential to become a major energy provider for the eastern and central parts of this region in the next decade.

Region 1

How does geothermal energy work?

Geothermal power stations use steam to power turbines that generate electricity. The steam is created either by tapping a source of heated groundwater or by injecting water deep into the Earth where it is heated to boiling. Pressurized steam is then piped back up to the power plant, where its force turns a turbine and generates power. Water that cycles through the power plant is injected back into the underground reservoir to preserve the resource.

There are three geothermal sources that can be used to create electricity. Geopressurized or dry steam power plants utilize an existing heated groundwater source, generally around 177°C (350°F) in temperature. Petrothermal or flash steam power plants are the most common type of geothermal plant in operation today, and they actively inject water to create steam. Binary cycle power plants are able



to use a lower temperature geothermal reservoir by using the warm water to heat a liquid with a lower boiling point, such as butane.The butane becomes steam, which is used to power the turbine.

Region 2

inland sea • *a shallow sea covering the central area of a continent during periods of high sea level.*

volcanism • *the eruption of molten rock onto the surface of the crust.*

lava • *molten rock located on the Earth's surface.*

fuel • *a material substance that possesses internal energy that can be transferred to the surroundings for specific uses.*

tree • *any woody perennial plant with a central trunk.*

Energy in the Columbia Plateau
Region 2

Nestled between the Cascade and Rocky Mountain ranges, the Columbia Plateau was an **inland sea** for tens of millions of years, until about 15 million years ago when **volcanic** activity deposited layer upon layer of **lava**. Because of its topography, this region is tops in the nation for hydroelectric power generation. The Columbia Plateau is more than 80% powered by renewable energy, with wind energy production second only to hydroelectric.

The Grand Coulee Dam is the largest hydroelectric plant in the US (*Figure 7.3*). The Grand Coulee was built from 1933 to 1942 and was originally designed to irrigate the Northwest. However, the advent of WWII significantly raised the need for energy in the region when the Northwest became a manufacturing hub for the war. A third power station was added to the complex in 1974, making it the largest, most productive hydroelectric plant in the nation.

Hydroelectricity uses the gravitational force of falling or rushing water to rotate turbines that convert the water's force into energy.

Figure 7.3: The Grand Coulee Dam.

Regions 3–5

Energy in the Northern Rocky Mountains
Region 3

The tall mountains of the Rockies provide ample resources for harvesting hydroelectric power, and much of the energy produced here is from hydroelectric plants. The forests also provide some biomass and **fuel** for wood-burning power plants, and wind makes up a portion of the power generated in this area.

Energy in the Cascade-Sierra Mountains
Region 4

Just like the Rockies, these two tall mountain ranges provide perfect opportunities for hydroelectric power. There are hundreds of hydroelectric power plants throughout the region, which provide the area with a majority of this renewable energy. Although there are also thousands of acres of forests, some of the region is protected by the National Forest Service, including Sequoia National Forest, home to some of the largest and oldest **trees** in the world. One of the most famous environmental conservationists, John Muir, helped promote the preservation of the area, which resulted in the founding of Yosemite National Park. Much of this region is managed wood forest, and although hydroelectric energy is by far the major source of energy, several wood-burning power generation plants can also be found here. Wind, biomass, and several solar power plants round out the energy production profile for the region.

Energy in the Pacific Border
Region 5

Including both the Coastal Range and the San Joaquin Valley, the Pacific Border's topographic variation allows for a variety of energy production methods. The Coastal Range provides ample hydroelectric and wind energy capability, and the flat desert lands of the San Joaquin Valley makes the generation of solar power profitable. The vast acreage of forests also provides material for biomass and wood burning power plants.

Coastal California has long been a resource for the extraction, export, import, and refining of oil and gas, with the ports of Long Beach, Los Angeles, and San Francisco being the main hubs. Ranking third in the nation for crude oil production, refineries and terminal storage facilities dot the area. And with the "car culture" and lack of public transportation in most of California, the demand for and flow of oil has continued unabated over the last century.

7 Energy

Region 5

sandstone • *sedimentary rock formed by cementing together grains of sand.*

Monterey Formation • *a distinctive light-colored sedimentary rock unit that formed in the Miocene seas.*

Miocene • *a geological time unit extending from 23 to 5 million years ago.*

Pliocene • *a geologic time interval extending from roughly 5 to 2.5 million years ago.*

sedimentary rock • *formed through the accumulation and consolidation of grains of broken rock, crystals, skeletal fragments, and organic matter.*

California's vast oil production is the result of several large sedimentary basins, complex geology creating significant traps, and more recently, the development of large offshore oil fields (*Figure 7.4*). California's first productive well was drilled in the Central Valley in 1865. This area, east of San Francisco, became the scene of heavy drilling activity through the rest of the 1800s, providing enough oil for the nearby market of San Francisco. The Los Angeles Basin, first drilled in 1892, ultimately turned out to contain the most productive fields in the state. By the early 1920s, California was the source of one-quarter of the world's entire output of oil, due in large part to the high productivity of the Long Beach Field.

Figure 7.4: Oil and gas production in the Western US.

The source for most of California's oil is **sandstone** from coastal marine deposits, particularly the **Monterey Formation** (formed during the **Miocene** epoch, but which also includes other units into the **Pliocene**). This oil has generally been tapped through conventional drilling in places where the oil migrated to and became trapped in other formations. The Monterey Formation is porous, and is estimated to retain a large but uncertain amount of oil that could be reached through unconventional drilling, such as horizontal drilling and hydraulic fracturing. Although there is economic interest in such drilling, there is also concern about associated environmental impacts.

Nuclear power also plays a part in the region's energy production, but when the San Onofre Nuclear Power Plant in Southern California was decommissioned in 2012, the state's nuclear energy production was cut in half, from about 4000 MW to about 2000 MW. Because of the loss of this power source, California has had to rely more heavily on natural gas-powered energy plants, and the California Air Resources Board estimates that through the loss of the "clean" nuclear energy and an increase in the use of natural gas, air pollution in the area has increased by about 25%. The Diablo Nuclear Facility in San Luis Obispo, California and the Columbia Generating Station in Richland, Washington are the only two operating nuclear energy plants on the West Coast.

Despite the Pacific Border's reliance on fossil fuels, California, Oregon, and Washington are nevertheless leading the way by providing incentives and programs to significantly decrease energy consumption and increase

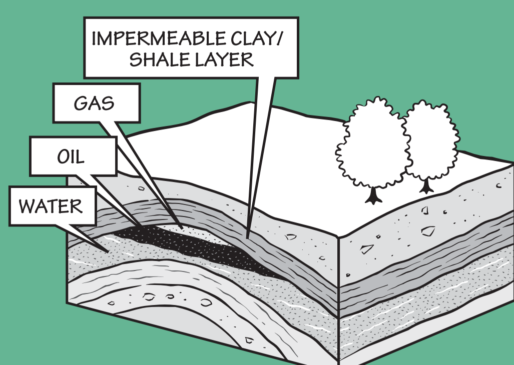
Region 5

Oil and Gas

Oil and gas form from organic matter in the pores of *sedimentary rocks*. Shale in particular is often organic-rich, because organic matter settles and accumulates in the same places that fine *clay* and *silt* particles settle out of the water. Further, such quiet waters are often relatively stagnant and low in oxygen, thus organic matter decay is slow. Because oil and gas are under pressure, they will move to areas of lower pressure, gradually upward, through tiny connections between pore spaces and natural fractures in the rocks.

Often, natural gas and oil are trapped below the surface under *impermeable* layers that do not have sufficient spaces for liquids and gases to travel through. Folds or "arches" in impermeable layers, or *faults* in rock layers, are common ways of trapping oil and gas below the surface. Most oil and gas has been extracted using the "conventional" technique of seeking such reservoirs and drilling into them, allowing the gas or oil to come to the surface through a vertical well.

Some impermeable layers contain oil and gas that has never escaped. In the 2000s, the fossil fuel industry began to access these resources through a method, known as high-volume slickwater hydraulic fracturing, that creates thousands of small fractures along impermeable rock layers. The method has greatly increased oil and gas production, but has also been a very controversial topic involving the issues of environmental impact and carbon emissions.



clay • *the common name for a number of very fine-grained, earthy materials that become plastic (flow or change shape) when wet.*

silt • *fine granular sediment most commonly composed of quartz and feldspar crystals.*

permeability • *a capacity for fluids and gas to move through fractures within a rock, or the spaces between its grains.*

fault • *a fracture in the Earth's crust in which the rock on one side of the fracture moves measurably in relation to the rock on the other side.*

glacier • *a body of dense ice on land that does not melt away annually and has sufficient mass to move under its own weight.*

Mississippian • *a subperiod of the Carboniferous, spanning from 359 to 323 million years ago.*

Paleogene • *the geologic time period extending from 66 to 23 million years ago.*

Mesozoic • *a geologic time period that spans from 252 to 66 million years ago.*

renewable energy production and use. Although Washington and Oregon lead the nation in hydroelectric power generation, both states have initiated significant financial incentives for increasing photovoltaic, biomass, and wind energy production. California currently ranks 48th in the nation in terms of per capita consumption of energy, and its incentive programs and resources for geothermal and other renewable sources of energy have ranked first in the nation in these categories. California is also first in large-scale wind energy production in the US. In fact, the Altamont Pass Wind Farm, with 4930 wind turbines that produce 1.1 terawatt-hours (TWh) yearly, is the largest array of wind turbines with the greatest production capacity in the world. In addition, The Geysers geothermal field in California is currently the world's largest complex of geothermal power plants, containing 22 plants that generate an average of 955 MW (*Figure 7.5*).

Figure 7.5: The Sonoma Calpine 3 power plant, one of 22 power plants at The Geysers field in the Mayacamas Mountains of Sonoma County, northern California.

Energy in Alaska
Region 6

Alaska has the lowest population density of any state in the Union, with only a little over one person per square mile. Many people live in rural areas, and with about 20% of the state covered by **glaciers** and water, getting energy to the population is challenging. Running electrical lines throughout the state's 1.72 million square kilometers (663,000 square miles) is not feasible when considering the number of people the lines would serve. Therefore, most people in rural areas use heating oil and/or wood for heat and energy.

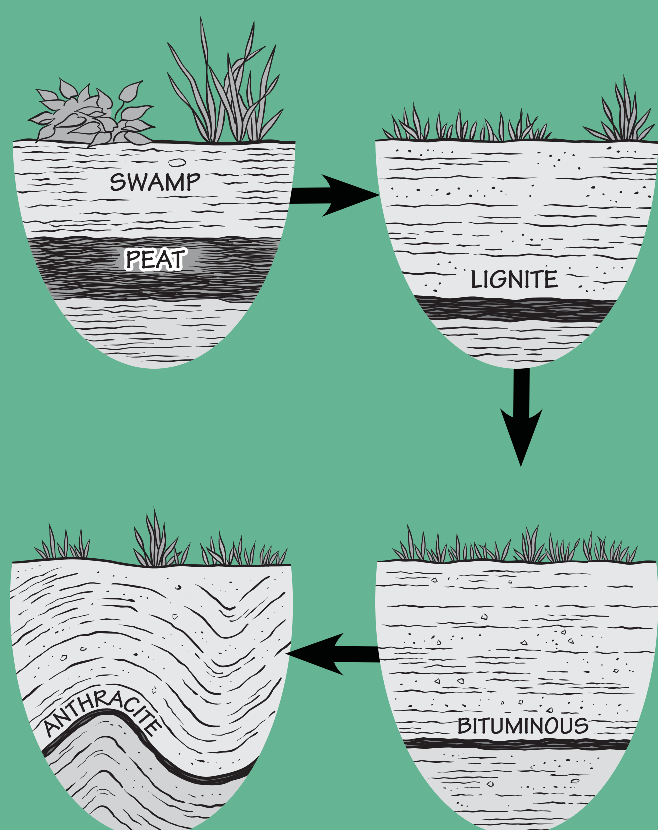
In the late 1960s, oil was discovered in Prudhoe Bay on Alaska's North Slope, and it has proved to be the largest recoverable oil field in the US. The source of this oil is rocks ranging from **Mississippian** to **Paleogene** in age, but particularly organic-rich marine coastal deposits from **Mesozoic** marine coastal

Region 6

Coal

As leaves and wood are buried more and more deeply, pressure on them builds from overlying sediments, squeezing and compressing them into coal. The coal becomes gradually more enriched in carbon as water and other components are squeezed out: *peat* becomes *lignite*, *bituminous* and eventually *anthracite* coal, which contains up to 95% carbon. Anthracite has the fewest pollutants of the four types of coal, because it has the highest amount of pure carbon. By the time a peat bed has been turned into a layer of anthracite, the layer is one-tenth its original thickness.

The *Carboniferous* period takes its name from the carbon in coal. A remarkable amount of today's coal formed from the plants of the Carboniferous, which included thick forests of trees with woody vascular tissues.



peat • an accumulation of partially decayed plant matter.

lignite • a soft, brownish-black coal in which the alteration of plant matter has proceeded farther than in peat but not as far as in bituminous coal.

bituminous coal • a relatively soft coal containing a tarlike substance called bitumen, which is usually formed as a result of high pressure on lignite.

anthracite • a dense, shiny coal that has a high carbon content and little volatile matter.

Carboniferous • a geologic time period that extends from 359 to 299 million years ago.

deposits. Significant amounts of oil and gas were trapped under the Barrow Arch, a regional belt of **metamorphic** and **igneous rock** that formed a cap for the oil reservoir. After significant negotiations with the native populations of Alaska, the Trans-Atlantic Pipeline was finished in 1977, running from the Prudhoe Bay some 800 miles south to Valdez, Alaska, at the Prince William Sound. This produced a boom in oil extraction in the state. Production from the Prudhoe Bay oilfields has dwindled over the years, however, and the largest energy source consumed in Alaska is now natural gas.

Alaska has significant coal reserves in just one active mine, near Healy. The coal was deposited in terrestrial environments during a much warmer and wetter Miocene **climate** than is found there today.

Alaska Energy Authority's (AEA) Alternative Energy and Energy Efficiency (AEEE) program manages and funds projects and initiatives totaling $188 million in state and federal funding. Many of these projects seek to lower the cost of power and heat to Alaskan communities while maintaining system safety and reliability.

metamorphic rocks • *rocks formed by the recrystallization and realignment of minerals in pre-existing sedimentary, igneous, and metamorphic rocks when exposed to high enough temperature and/or pressure.*

igneous rocks • *rocks derived from the cooling of magma underground or molten lava on the Earth's surface.*

climate • *a description of the average temperature, range of temperature, humidity, precipitation, and other atmospheric/hydrospheric conditions a region experiences over a period of many years (usually more than 30).*

rift • *a break or crack in the crust that can be caused by tensional stress as a landmass breaks apart into separate plates.*

Energy in Hawaiʻi
Region 7

Having no fossil fuel resources of its own, Hawaiʻi has been highly reliant on the importation of fossil fuels for its energy needs. However, with its mild tropical climate, Hawaiʻi had the second lowest per capita energy use in the US in 2010. The majority of Hawaiʻi's energy demand in 2010 was for transportation, due in large part to heavy commercial and military aviation fuel use. That year, Hawaiʻi imported 94% of its energy and had the highest electricity prices in the nation.

The Hawaiian government, however, is working on changing that reliance through the use of other energy initiatives. Hawaiʻi has just one geothermal power plant, which is located on Hawaiʻi Island and taps into the heat from Kīlauea volcano. The Puna Geothermal Venture plant generates around 265 gigawatt hours (GWh) of energy a year, which is around 23% of the electricity required on the island. Additional areas around the **rift** zones of volcanoes on Maui are currently under study for similar such power plants. There is potential to generate the entire state's power needs, but it would require considerable infrastructure involving the laying of cables between islands to connect the power grids. Even with these considerable outlays, however, the cost of production is still lower than that of fossil fuels.

Hawaiʻi has the potential to generate all its electricity needs using wind-generated power. A study in 2010 by the National Renewable Energy Laboratory (NREL) showed that onshore wind generation could produce 12 billion kWh a year—considerably more than the 10 billion KWh that was used in Hawaiʻi in 2011. Offshore wind generation potential is even higher. There are currently six operating “wind farms” in Hawai‘i, which include arrays on Oahu, Maui (*Figure 7.6*) and Hawai‘i. The largest is Kawailoa Wind Farm on the northern shore of Oahu, which has 30 windmills that generate a total of 69 MW per year.

biofuel • *carbon-based fuel produced from renewable sources of biomass like plants and garbage.*

Figure 7.6: Kaheawa Wind Farm, Maui.

Hawai‘i has the world’s largest commercial electricity generator that is fueled exclusively by **biofuels**. Since existing power plants use expensive, imported liquid fossil fuels, converting to biodiesel was cost-efficient by comparison. The biodiesel is produced using waste agricultural materials and waste oils from restaurants.

Solar photovoltaic (PV) capacity increased 150% in Hawai‘i in 2011, moving the state up to 11th in terms of PV capacity. Still, solar power provides only a few percentage points of overall electricity production in Hawai‘i, but new projects are being planned on almost all the major islands.

The first hydroelectricity was generated near Hilo on Hawai‘i Island in the 1880s, but today there are only a few small hydropower plants used in the state (mainly to power sugar mills and other small industry), with the largest on Hawai‘i Island on the Wailuku River in Hilo.

7

Energy

State Facts

Energy Facts by State

Because of many local laws and guidelines, energy production and use is highly dictated by each state government. Below is a state-by-state assessment of energy production and use in the Western US (from http://www.eia.gov/state/).

Alaska

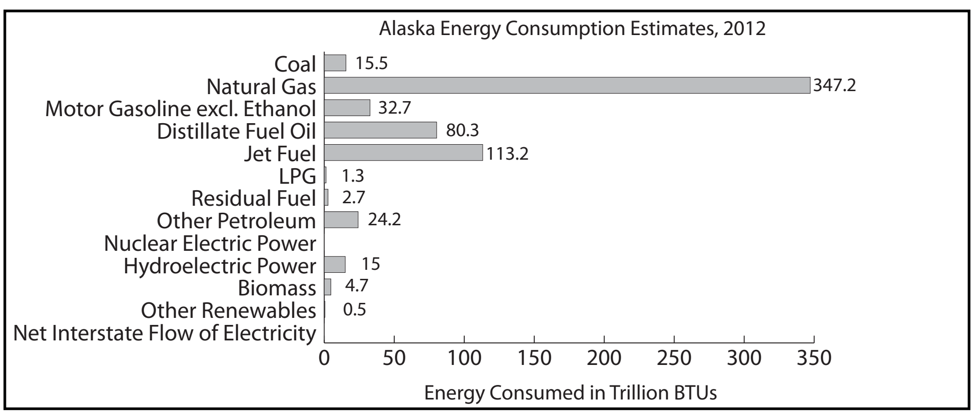
- Alaska's electricity infrastructure differs from that of the lower 48 states in that most consumers are not linked to large interconnected grids through transmission and distribution lines; rural communities in Alaska rely primarily on diesel electric generators for power.

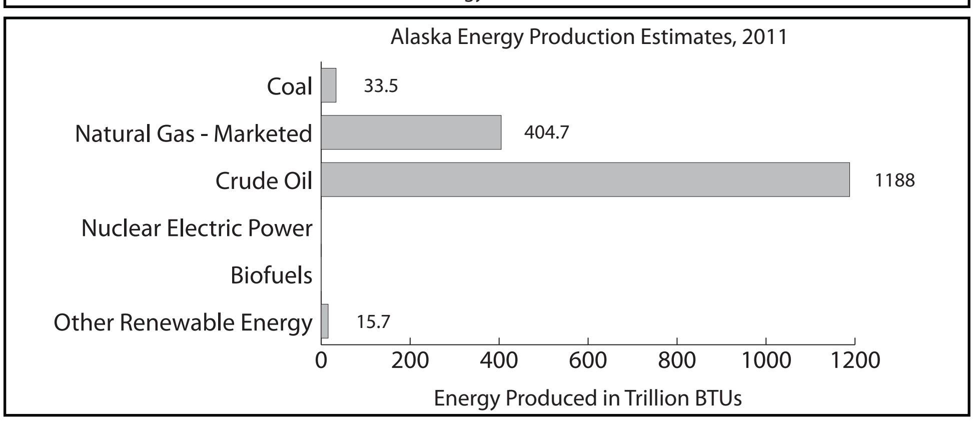
- Alaska is one of eight states generating electricity from geothermal energy sources.

- The Kenai liquefied natural gas (LNG) export facility is the only existing LNG export terminal in the United States.

- When Federal offshore areas are excluded, Alaska's crude oil production of 0.6 million barrels per day ranked second in the nation, after Texas, in 2011.

- In 2011, Alaska ranked fourth in the United States for the total amount of electricity generated from petroleum liquids.





State Facts

California

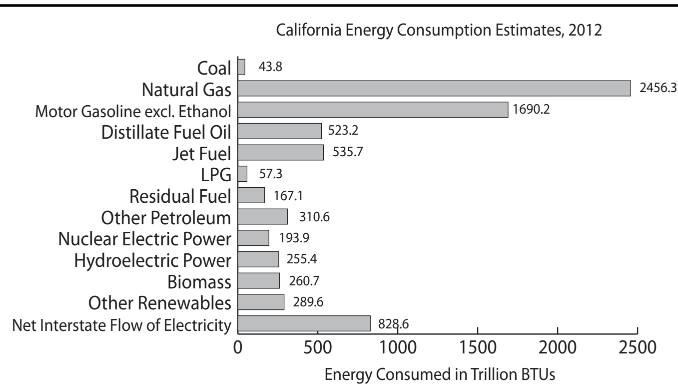
- Average site electricity consumption in California homes is among the lowest in the nation (6.9 MWh per year), according to EIA's Residential Energy Consumption Survey.

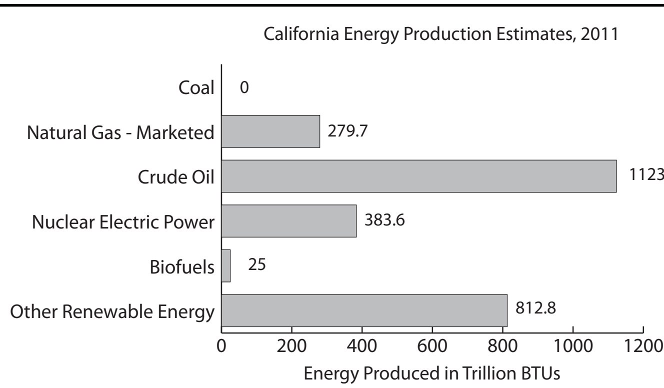
- In 2010, California's per capita energy consumption ranked lowest in the nation; the state's low ranking was due in part to its mild climate and energy efficiency programs.

- Excluding federal offshore areas, California ranked third in the nation in crude oil production in 2011, despite an overall decline in production rates since the mid-1980s.

- California also ranked third in the nation in 2011 in refining capacity, with a combined capacity of almost two million barrels per day from its 20 operable refineries.

- In 2011, California ranked first in the nation as a producer of electricity from geothermal energy, third in conventional hydroelectric generation, and first for net electricity generation from other renewable energy resources.





7

Energy

State Facts

Hawai‘i

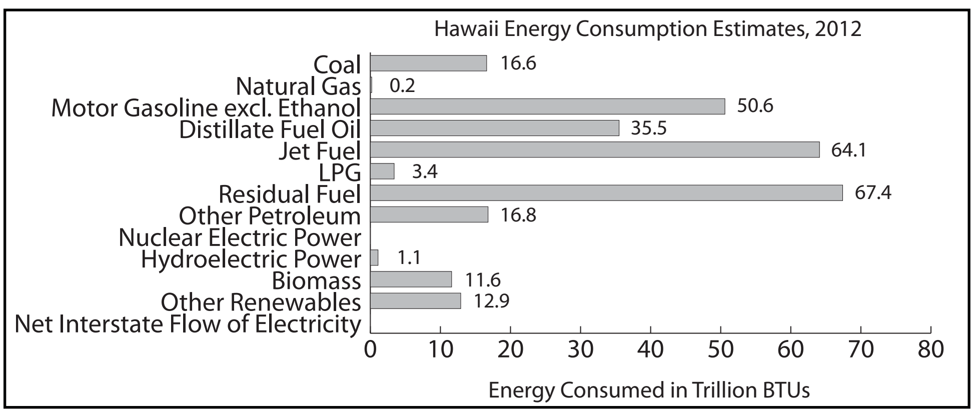
- Hawai‘i has the world’s largest commercial electricity generator fueled exclusively with biofuels; the state’s energy plan aims for an agricultural biofuels industry that, by 2025, can provide 350 million gallons of biofuels.

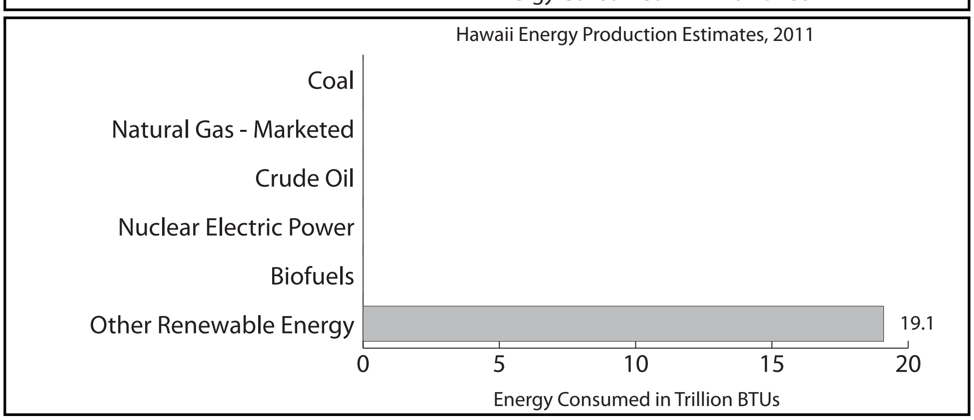
- Thanks to its mild tropical climate, Hawai‘i had the second lowest per capita energy use in the nation in 2010. The transportation sector led Hawaiian energy demand in 2010, due in large part to heavy commercial and military aviation fuel use.

- In 2010, Hawai‘i imported 94% of its energy and had the highest electricity prices in the nation.

- Hawai‘i is one of eight states with installed geothermal capacity; in 2011, 25% of its renewable net electricity generation came from geothermal energy.

- Solar photovoltaic (PV) capacity increased 150% in Hawai‘i in 2011, making it 11th in the nation in PV capacity.



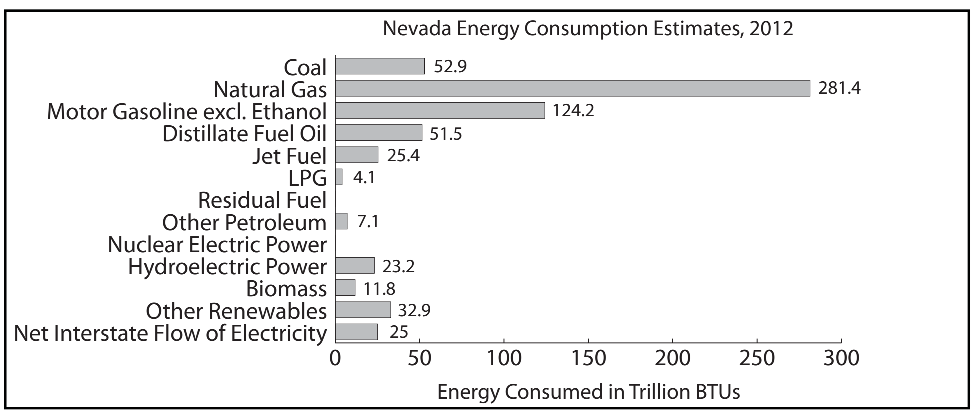


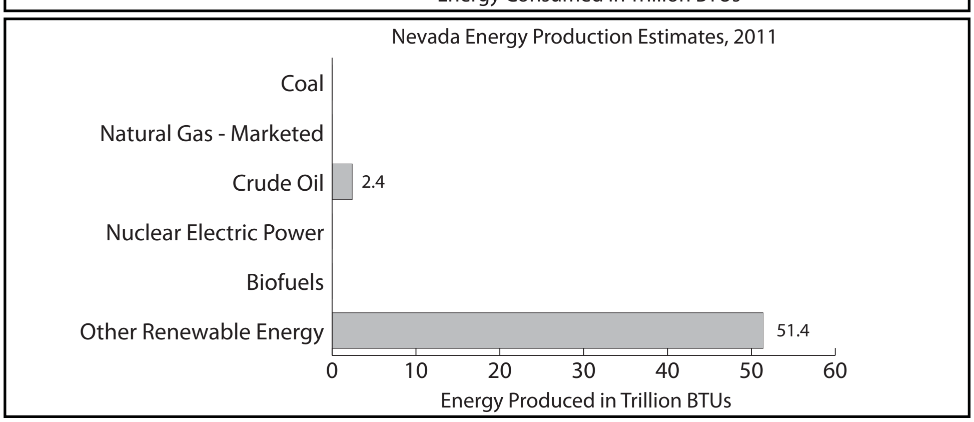
Energy 7

State Facts

Nevada

- More than 90% of the energy Nevada consumes comes from outside the state.
- The state's Energy Portfolio Standard requires that 25% of electricity come from renewable energy resources by 2025; in 2011, 16% of net electricity generation came from geothermal, solar, and hydroelectric power sources.
- Nevada generated two-thirds (67%) of its electricity from natural gas in 2011.
- Nevada ranked second in the nation in net electricity generation from both geothermal and solar energy in 2011; approximately 9.1% of Nevada's net electricity generation came from those two sources.
- The 640-kilometer (400-mile) UNEV pipeline, opened in 2012, lets petroleum products from Salt Lake City area refineries flow to Las Vegas; previously, Las Vegas obtained petroleum products only from three California pipelines.





7  Energy

State Facts

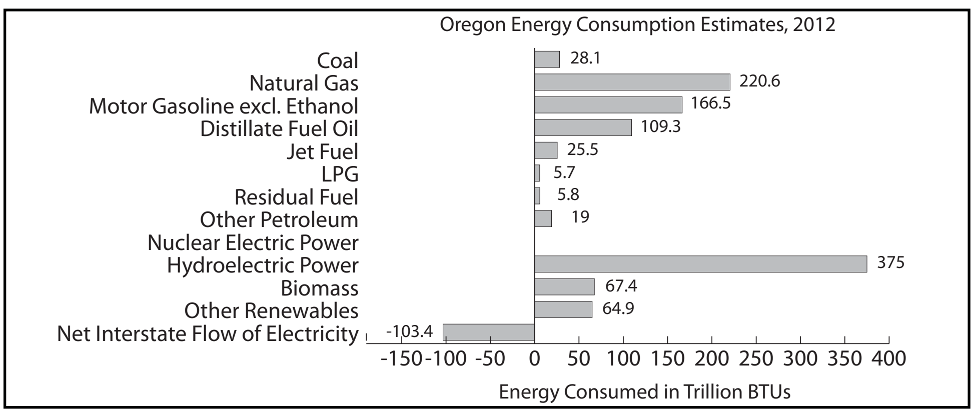
Oregon

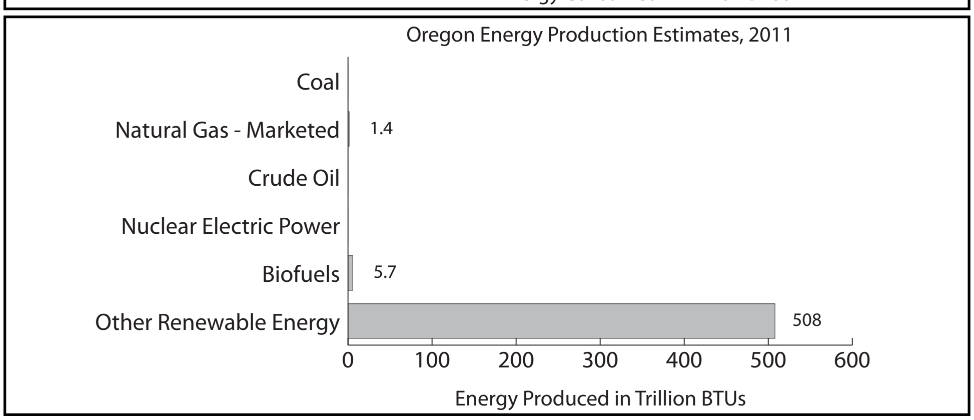
- Major transmission lines connect Oregon's electricity grid to California and Washington, allowing for large interstate electricity transfers.

- The owners of the Jordan Cove Energy Project at Coos Bay, after getting liquefied natural gas (LNG) import approval, decided to seek approval to become the first West Coast LNG export terminal outside of Alaska.

- Oregon is one of the nation's leading generators of hydroelectric power, ranking second in 2011, after Washington, in net electricity generation from conventional hydroelectric power. In 2010 and 2011, Oregon's abundant hydroelectric power contributed to below-average residential electricity prices in the state.

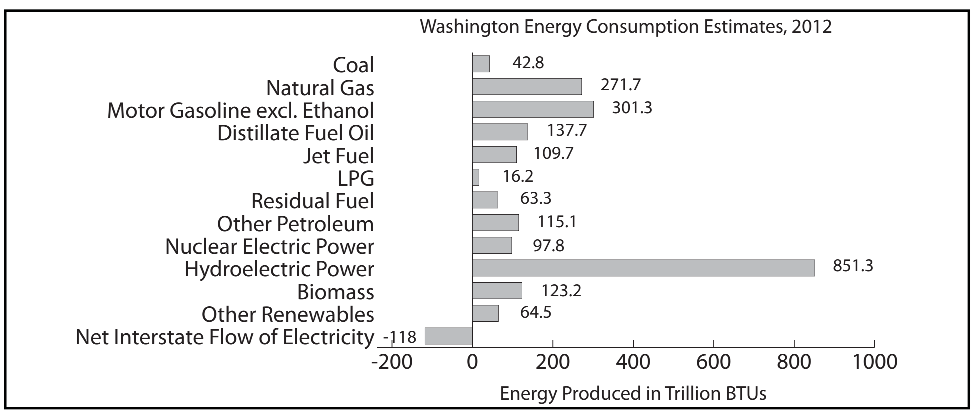
- In 2011, 80% of Oregon's net electricity generation was from conventional hydroelectric power plants and other renewable energy resources.

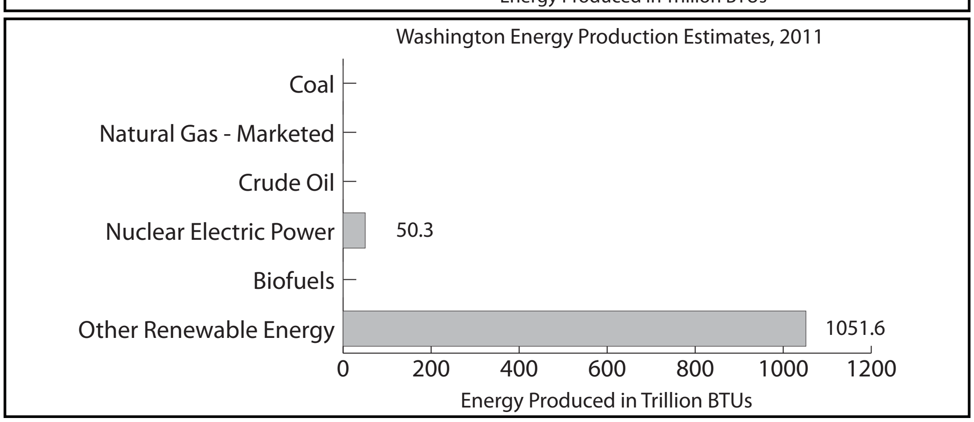




Washington

- The Grand Coulee Dam on Washington's Columbia River is the largest hydroelectric power producer in the United States, with a total generating capacity of 6809 MW.
- The State of Washington's Energy Independence Act requires large electric utilities to obtain 15% of their electricity from new renewable energy resources by 2020 and to undertake cost-effective energy conservation.
- In 2011, Washington was the leading producer of electricity from hydroelectric sources and produced 29% of the nation's net hydroelectricity generation.
- Although not a crude oil-producing state, in 2011, Washington ranked sixth in the nation in crude oil refining capacity.
- Washington ranked sixth in the nation in net generation of electricity from wind energy in 2011.





7 Energy

Climate Change

Energy and Climate Change

The Future of Energy in the US

Americans have come to rely on a diverse and abundant energy system, one that provides a continuous supply of energy with few interruptions. However, **climate change** is projected to play a big part in changing the supply, production, and demand for energy. Increases in temperature will see an increase in energy used for cooling, while projected increases in the occurrence of **hurricanes**, floods, **tornados**, and other extreme **weather** events will continue to have a significant effect on the infrastructure of power grids and energy delivery systems. Drought and water shortages are already beginning to affect energy production and supply. In the Northeast, mild winter temperatures prior to the winter of 2013–2014 had decreased energy demands for heat, but they did not fully offset increased demands for cooling, and the regionally harsher winter of 2013–2014 saw increased demands for heating fuels. These disruptions affect us both locally and nationally, are diverse in nature, and will require equally diverse solutions.

See Chapter 9: Climate for more information about climate change.

Energy is a **commodity**, and supply and demand around the world will also affect the US energy system. As the global population grows and industrialization of the world continues, demand for energy will increase even further as resources are depleted. These factors could significantly affect US energy costs through competition for imported and exported energy products. Mediation of our energy production could have a huge positive impact on climate change. Unfortunately, there is no energy production system or source currently available that is truly **sustainable**. All forms of energy have negative impacts on the environment, as do many of the ways in which we use them.

Until we have a sustainable means of producing and delivering energy, we need to consider which means of energy production and transport make the least impact; we are faced with a sort of "energy triage." The answer to this problem will be multifaceted, depending in large part on what energy resources and delivery methods are available in each part of the US. The sources of energy that provide the least impact for the best price in the West are probably not the same in other areas.

Adaptation—changing our habits of energy use and delivery—can also make it easier for our existing energy infrastructure to adjust to the needs brought on by climate change. Investing in adaptation can pay off in the short term by reducing risks and vulnerabilities, thus minimizing future risks. Increasing sustainable energy practices (including harvesting and production) and improving infrastructure and delivery methods can go a long way toward not only decreasing the effects of climate change, but also our energy security.

climate change • *See global warming: the current increase in the average temperature worldwide, caused by the buildup of greenhouse gases in the atmosphere.*

hurricane • *a rapidly rotating storm system with heavy winds, a low-pressure center, and a spiral arrangement of thunderstorms.*

tornado • *a vertical funnel-shaped storm with a visible horizontal rotation.*

weather • *the measure of short-term conditions of the atmosphere such as temperature, wind speed, and humidity.*

commodity • *a good for which there is demand, but which is treated as equivalent across all markets, no matter who produces it.*

sustainable • *able to be maintained at a steady level without exhausting natural resources or causing severe ecological damage, as in a behavior or practice.*

Some of these changes are grounded in the development of new technologies for energy production and energy **efficiency**; others may be related to changes in behavior. These changes in technology and behavior may go hand in hand; roughly 2% of electricity production now goes to data centers, for example, a use that did not exist in 1985. Additionally, the Internet is rapidly changing other ways we use energy, allowing us to telecommute and changing the way we shop.

In closing, some key points to keep in mind regarding the future of energy are:

1. Extreme weather events are affecting energy production and delivery facilities, causing supply disruptions of varying lengths and magnitudes and affecting other infrastructure that depends on energy supply. The frequency and intensity of extreme weather events are expected to increase.

2. Higher summer temperatures are likely to increase electricity use, causing higher summer peak loads, while warmer winters are likely to decrease energy demands for heating. Net energy use is projected to increase as rising demands for cooling outpace declining heating energy demands.

3. Both episodic and long-lasting changes in water availability will constrain different forms of energy production.

4. In the longer term, sea level rise will affect coastal facilities and infrastructure on which many energy systems, markets, and consumers depend.

5. As we invest in new energy technologies, future energy systems will differ from the present in uncertain ways. Depending on the way in which our energy system changes, climate change will introduce both new risks and new opportunities.

efficiency • *the use of a relatively small amount of energy for a given task, purpose, or service; achieving a specific output with less energy input.*

Resources

Books: General Resources on Energy

Bird, K.J., 1989, North American fossil fuels, pp. 555–574, in: A. W. Bally, & A. R. Palmer (eds.), *The Geology of North America—An Overview*, The Geology of North America, vol. A, Geological Society of America, Boulder, CO.

Duggan-Haas, D., R. M. Ross, & W. D. Allmon, 2013, *The Science Beneath the Surface: A Very Short Guide to the Marcellus Shale*. Paleontological Research Institution (Special Publication 43), Ithaca, NY, 252 pp.

Hinrichs, R., & M. H. Kleinbach, 2012, *Energy: Its Use and the Environment, 5th edition*, Thomson, Brooks/Cole, Belmont, CA, 640 pp.

Nye, D. E., 1998, *Consuming Power: A Social History of American Energies*, Massachusetts Institute of Technology Press, Cambridge, MA, 331 pp.

Richards, J., 2009, *Wind Energy*, Macmillan Library, South Yarra, Victoria, Canada, 32 pp. (For primary school age.)

Smil, V., 2006, *Energy: A Beginner's Guide*, Oneworld, Oxford, UK, 181 pp.

Smil, V., 2010, *Energy Myths and Realities: Bringing Science To the Energy Policy Debate*, AEI Press, Washington, DC, 213 pp.

Wohletz, K., & G. Heiken, 1992, *Volcanology and Geothermal Energy,* University of California Press, Berkeley, http://ark.cdlib.org/ark:/13030/ft6v19p151/.

Websites: General Resources on Energy

American Association of Petroleum Geology (AAPG), http://aapg.org.

Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education, at Energy.gov, http://www1.eere.energy.gov/education/energy_literacy.html.

History of Energy Use in the United States, by Hobart King at Geology.com, http://geology.com/articles/history-of-energy-use/.

Renewable and Alternative Fuels, US Energy Information Administration, http://www.eia.gov/renewable/state/.

State-by-state CO_2 Emissions Data From Fossil Fuel Combustion, http://www.epa.gov/statelocalclimate/documents/pdf/CO2FFC_2011.pdf.

US Department of Energy (DOE), http://energy.gov.

US Energy Information Administration (EIA), http://www.eia.gov/.

US Energy Information Administration (EIA), by state, http://www.eia.gov/state/.

US Geological Survey Energy Resources Program, http://energy.usgs.gov/.

Energy Resources in the Western US

California Renewable Energy Overview and Programs, California Energy Commission, http://www.energy.ca.gov/renewables/.

Houseknecht, D. W., & K. J. Bird, 2005, Oil and Gas Resources of the Arctic Alaska Petroleum Province, US Geological Survey Professional Paper 1732–A, http://pubs.usgs.gov/pp/pp1732/pp1732a/pp1732a.pdf.

McDonnell, T., 2013, *Washington Is Outdoing California and Texas in Renewable Energy—Renewable Energy Consumption by State*, http://www.slate.com/articles/health_and_science/climate_desk/2013/05/renewable_energy_map_wind_solar_hydroelectric_power_use_by_state.html.

ODOE: Renewable Energy, Oregon Department of Energy, http://www.oregon.gov/energy/renew/Pages/index.aspx.

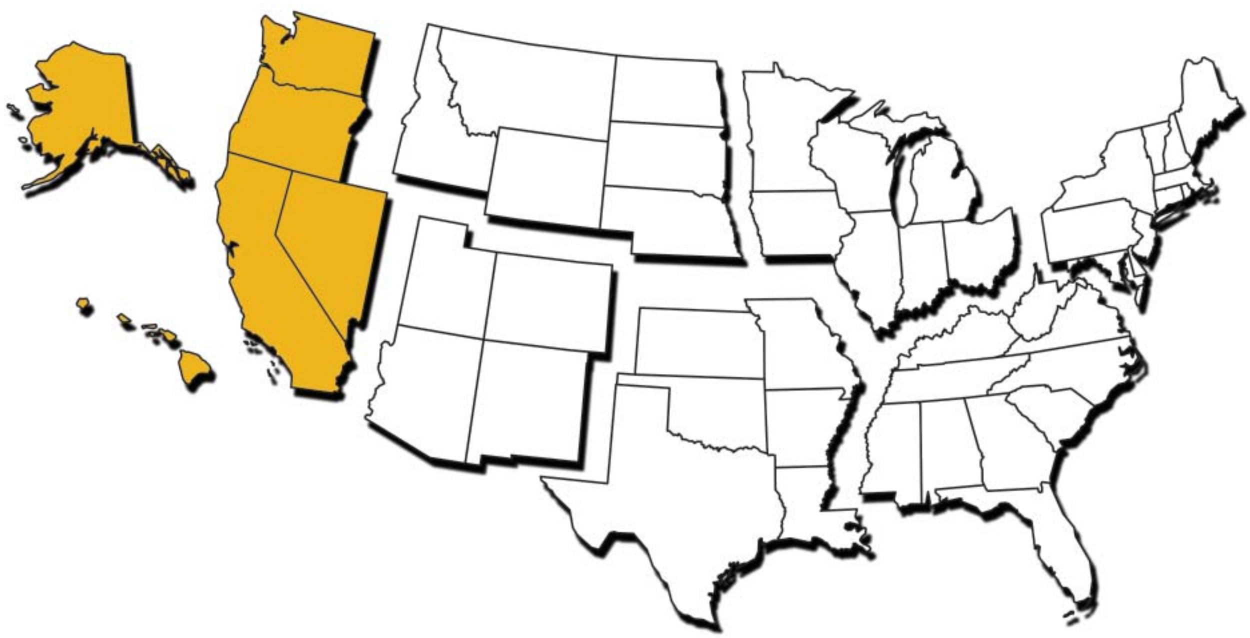
Phelan, S., 2013, *How the Monterey Shale Came to Be*, Bay Nature: Exploring Nature in the San Francisco Bay Area, http://baynature.org/articles/how-the-monterey-shale-came-to-be/.

Rintoul, W., 1990, *Drilling Through Time: 75 Years With California's Division of Oil and Gas*, California Department of Conservation, Division of Oil and Gas, Sacramento, 178 pp.

Smith, T., 2013, Alaska north slope: source rocks hold promise, *GEoExPro,* 10(3), http://www.geoexpro.com/articles/2013/09/alaska-north-slope-source-rocks-hold-promise.

The **Teacher-Friendly** Guide™

to the Earth Science of the Western US



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