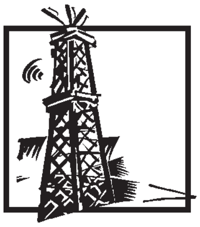

Chapter 6: Energy in the Southeastern US

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 for 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.

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, it 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**, such as **coal**, oil, and **natural gas**. Our reliance on fossil fuels is driven by a number of factors:

***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.**

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.

energy • *the power derived from the use of physical or chemical resources.*

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

heat • *a form of energy transferred 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.*

system • *a set of connected things or parts forming a complex whole.*

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

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the low upfront cost, very high energy densities, and the cost and durability of the infrastructure built to use fossil fuels.

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 different regions of the US.

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 roughly 1055 **joules**, or the amount of energy released by burning a single wooden match. A joule is the energy expended (or work done) to apply a force of one newton over a distance of one meter. Since a typical apple weighs about one newton, lifting an apple one meter requires about a joule of energy. That means that one Btu—the energy contained in a wooden match—is equivalent to the total amount of energy required to lift an apple 1000 meters, or one 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.

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

Another measure of energy, the kilowatt-hour (kWh), represents the amount of energy required to light ten 100-**watt** light bulbs for one hour. *Figure 6.1* compares different ways to make and use one kWh.

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). Especially as the global population grows and standards of living increase in some parts of the world, so too does global energy demand continue to grow.

Review

British Thermal Unit (BTu or BTU) • *the most commonly used unit for heat energy. One Btu is approximately the amount of heat required to raise one pound of water by one degree Fahrenheit.*

joule • *the energy expended (or work done) to apply a force of one newton over a distance of one meter.*

kinetic energy • *the energy of a body in motion.*

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.*

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

Energy

6

Review

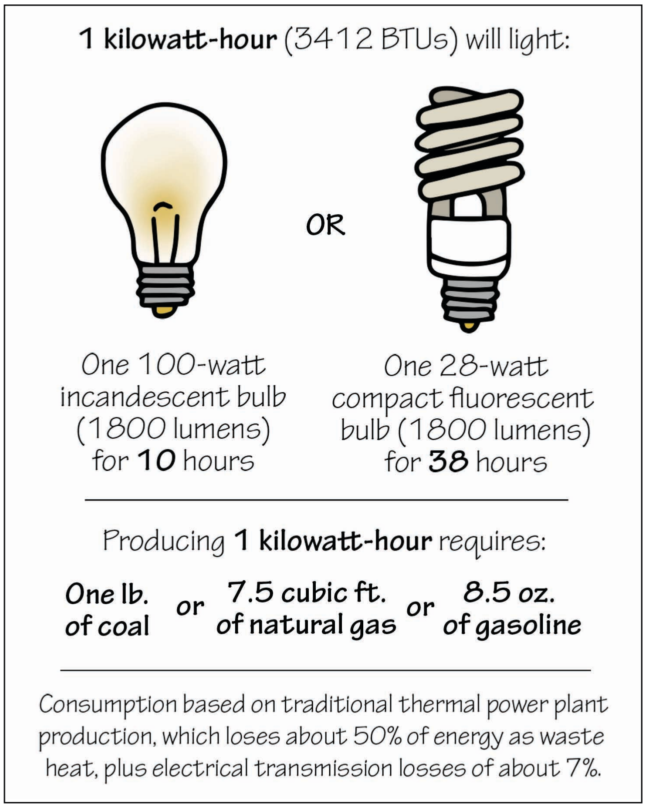

Figure 6.1: Examples of uses and sources of one kilowatt-hour.

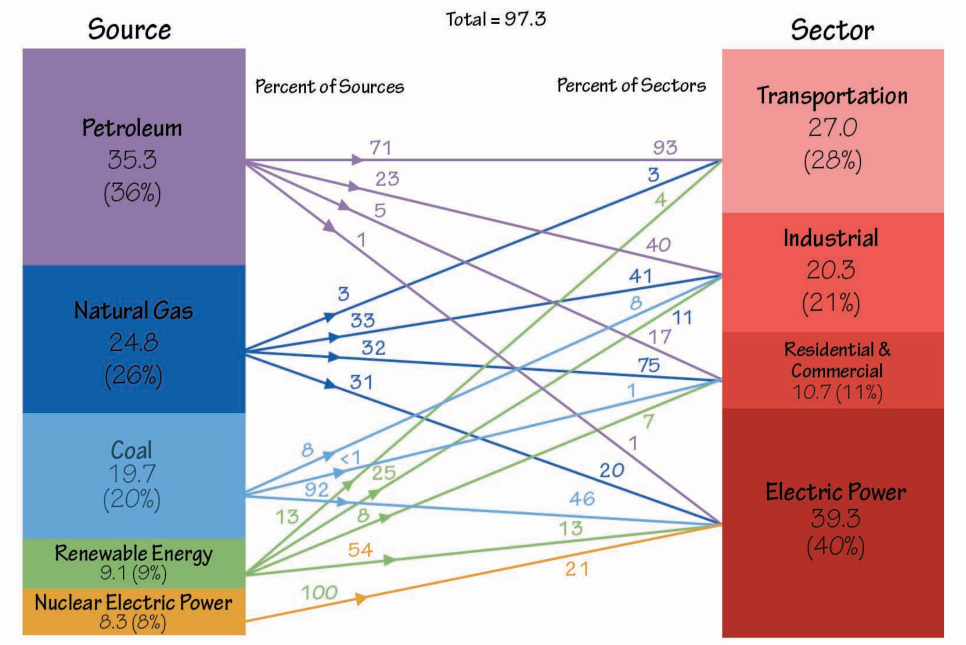

Figure 6.2: US energy production sources and use sectors for 2011. Petroleum provides more energy than any other source, and most of it is used for transportation. More energy is used to generate electricity than for any other use, and electricity is generated by all five energy sources. Nuclear is unique among sources in that all of the energy it generates goes to a single sector: electric power.

6

Energy

Review

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

Figure 6.2 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 as follows:

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 curricula. 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 Southeastern Regions

The Southeast produces fossil fuels (coal, oil, and natural gas) in modest to large quantities, and production of fossil fuels has been a major part of the area's economic and historical development for over a century (*Figures 6.3 and 6.4*). Most fossil fuel discoveries in the Southeast come from two distinct geologic provinces: the Inland Basin (including the **Appalachian**, **Illinois**, and Black Warrior basins) and the Gulf Coastal Plain.

Regions

Appalachian Basin • *an inland basin, formed by the Taconic and Acadian mountain-building events.*

Illinois Basin • *an inland basin centered in the state of Illinois, which formed when Baltica approached North America in the Ordovician.*

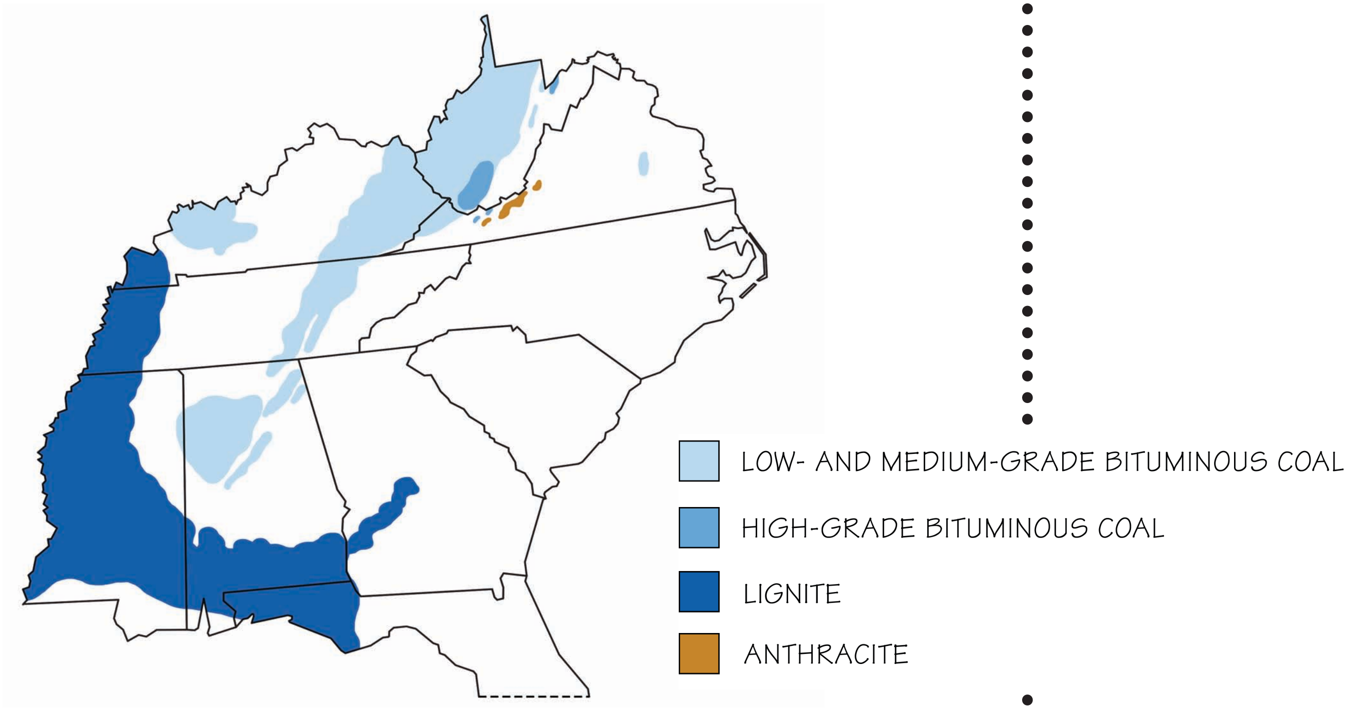

Figure 6.3: Coal-producing regions of the Southeastern US. The Inland Basin is a particularly significant coal-producing area. (See TFG website for full-color version.)

The Southeast also produces a substantial proportion of its electricity using nuclear energy, and the Southeastern states collectively produce about 35% of the nuclear energy consumed in the US (*Figure 6.5*). Nuclear energy growth in the Southeast has been enabled not because uranium (the raw material used for fission in nuclear power plants) is locally abundant, but rather that the Southeast has substantial water resources necessary for steam production and cooling in the power plants.

Regions

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

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).*

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

active plate margin • *the boundary between two plates of the Earth's crust that are colliding, pulling apart, or moving past each other.*

hot spot • *a volcanic region thought to be fed by underlying mantle that is anomalously hot compared with the mantle elsewhere.*

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

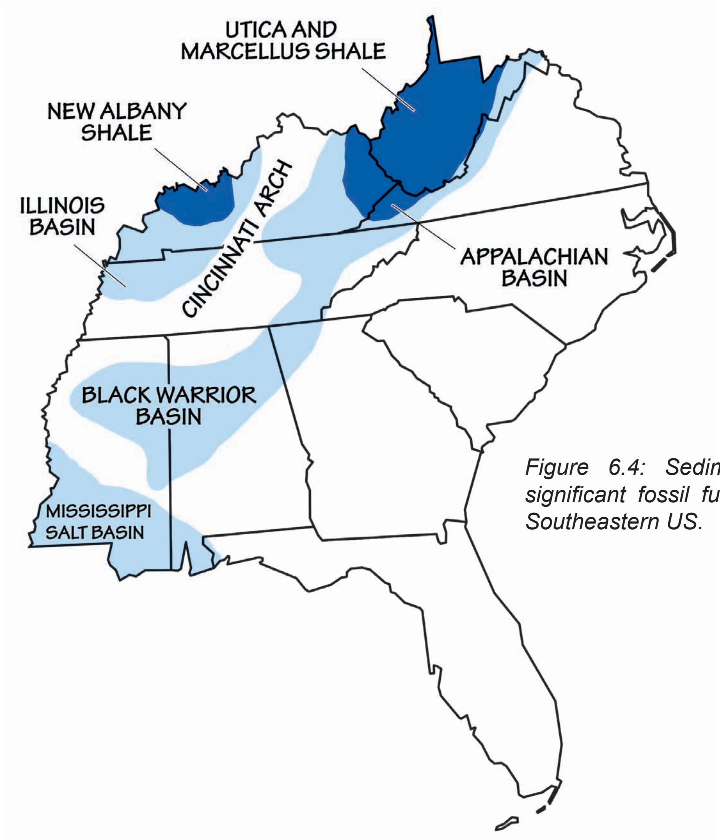

Figure 6.4: Sedimentary basins contain significant fossil fuel accumulations in the Southeastern US.

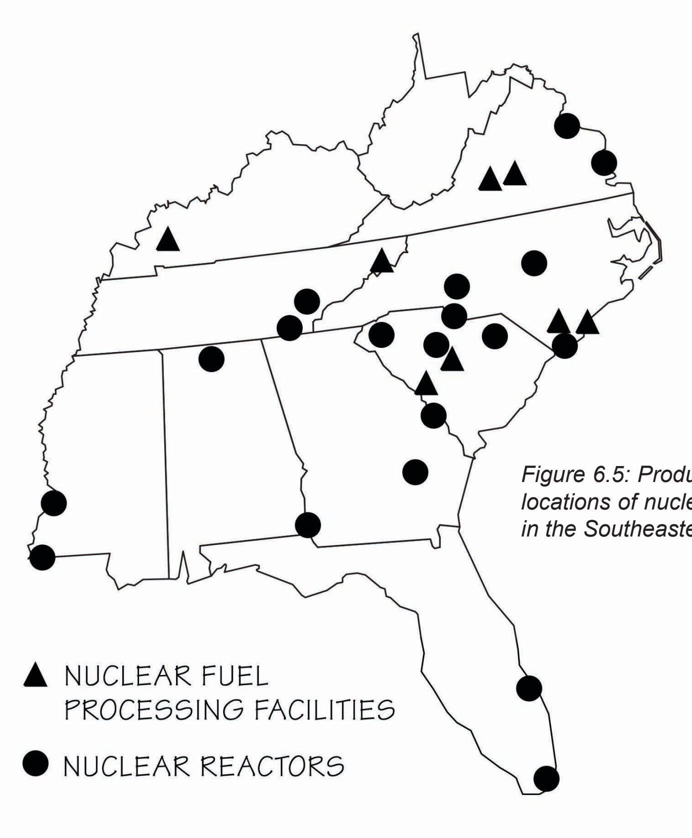

Figure 6.5: Production of nuclear power and locations of nuclear fuel processing facilities in the Southeastern states.

Energy

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The Southeast has a relatively high capacity for generating solar energy and **biofuels**, given its **climate** and agricultural potential. Though these sources are increasing rapidly, they remain a relatively small part of energy production in the Southeastern US. The area has low wind energy potential by comparison to the rest of the US (with the exception of West Virginia) due to generally low wind speed associated with climate and **topography**, and relatively low potential for deep geothermal energy due to its distance from **active plate boundaries** and **hot spots**.

Energy in the Blue Ridge and Piedmont

Region 1

The Blue Ridge and Piedmont is not known for its energy production by comparison with the other regions of the Southeast. Fossil fuel resources here are minimal, hydroelectric power generation occurs mostly along the region's eastern periphery, and solar and wind production remain minor compared to total energy demand. Nuclear power is a major local source of energy production.

Fossil Fuels

Oil and gas are not produced in the Blue Ridge and Piedmont region. The area is underlain primarily by **igneous** and **metamorphic rocks**, which do not form under the conditions necessary to produce petroleum. **Bituminous coals** occur in small, isolated **Triassic**-**Jurassic rift basins** in the North Carolina and Virginia Piedmont (*Figure 6.6*). These **rifts** formed as the supercontinent **Pangaea** broke apart during the **Mesozoic**, creating numerous cracks in the **crust** along the margins of North America, Africa, and

See Chapter 1: Geologic History to learn more about the rifting of Pangaea in the Mesozoic.

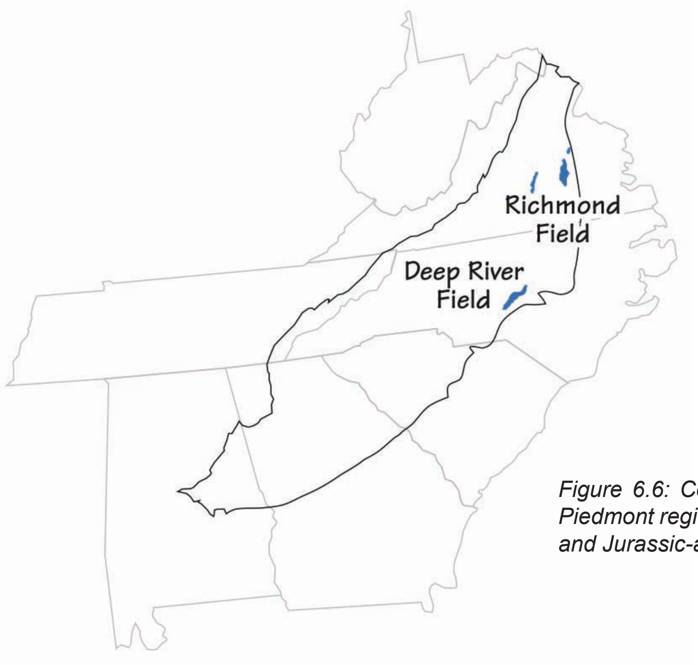


Figure 6.6: Coal in the Blue Ridge and Piedmont region is found only in Triassic- and Jurassic-aged rift basins.

Region 1

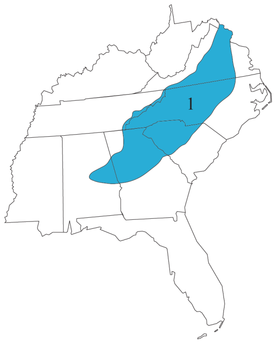
metamorphic rocks • *rocks formed by the recrystallization and realignment of minerals in pre-existing sedimentary, igneous, and metamorphic rocks when exposed to high enough temperature and/or pressure.*

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

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

Triassic • *a geologic time period that spans from 252 to 201 million years ago.*

Jurassic • *the geologic time period lasting from 201 to 145 million years ago.*



England. The rift basins filled with sediment, sometimes becoming swampy lowlands. **Peats** accumulated in these swamps and were altered to coal after they were buried.

None of the coal deposited in the Triassic-Jurassic rift basins is currently mined, although there has been some historic production. The Richmond Basin of Virginia was the nation's first major coal field, discovered in 1699 and mined primarily in the early 1800s. The only other notable coal deposits in the Southeast's Mesozoic rift basins are those of the Triassic Deep River rift basin in North Carolina. Bituminous coal beds there, occupying a zone about 56 kilometers (35 miles) long and 8 to 16 kilometers (5 to 10 miles) wide, were mined for about a century between the 1850s and 1950s. Production during 1949 was around 14,000 tons, but the coal seam is deeply buried and badly broken by numerous dissecting **faults**, and mining ceased in 1953. It is estimated that 110 million tons of coal remain in the area.

peat • *an accumulation of partially decayed plant matter.*

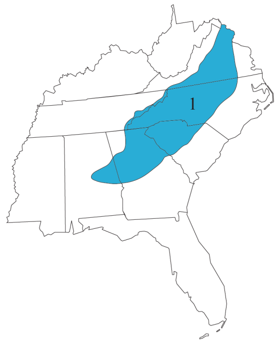
tree • *any woody perennial plant with a central trunk.*

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.*

Fossil Fuels

Fossil fuels—oil, natural gas, and coal—are made of the preserved organic remains of ancient organisms. Coal and lignite result from the burial, compaction, and heating of preserved plant matter, whereas petroleum and natural gas originate deep underground through a slow process involving the low-grade heating of sedimentary source rocks that contain an abundance of organic matter. In either case, organic matter is only preserved when the rate of accumulation is higher than the rate of decay. This happens most often when the oxygen supply is sufficiently low that oxygen-loving bacteria cannot thrive, greatly slowing the breakdown of organic matter. In this way, 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.

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.



Alternative Energy

Nuclear power is a major source of energy production in the Blue Ridge and Piedmont, especially in North and South Carolina (*see Figure 6.5*). Throughout the Piedmont, abundant rivers and lakes provide the means to facilitate the production of nuclear energy. Currently, Virginia and the Carolinas are planning expansions of their existing plants, or bringing new plants on board. North Carolina has also been at the forefront of expanding its solar power production, taking advantage of several federal government incentives to increase the state's solar energy production by over 1100% since 2007 (*see Figure 6.21*). The North Carolina Solar Center at North Carolina State University works to promote and educate the public about solar, wind, biofuel, and other renewable energy options throughout the state. A few solar plants are also scattered through Georgia's Piedmont.

Precipitation and the relatively high topographic area associated with the Blue Ridge and Piedmont provide the region with great potential for hydroelectric power (*Figure 6.7*), which uses the gravitational force of falling or rushing water to rotate turbines that convert the water's force into energy. There are also several pumped storage facilities within the region, where water is pumped uphill into reservoirs in times of excess production, essentially acting as batteries. Hydroelectric plants are scattered throughout the Blue Ridge and Piedmont; many are located along the topographic drop associated with the Fall Line, where the harder rocks of the Piedmont meet the sediments of the Atlantic Coastal Plain

See Chapter 4: Topography to learn about the Fall Line, which divides the Piedmont from the Coastal Plain.

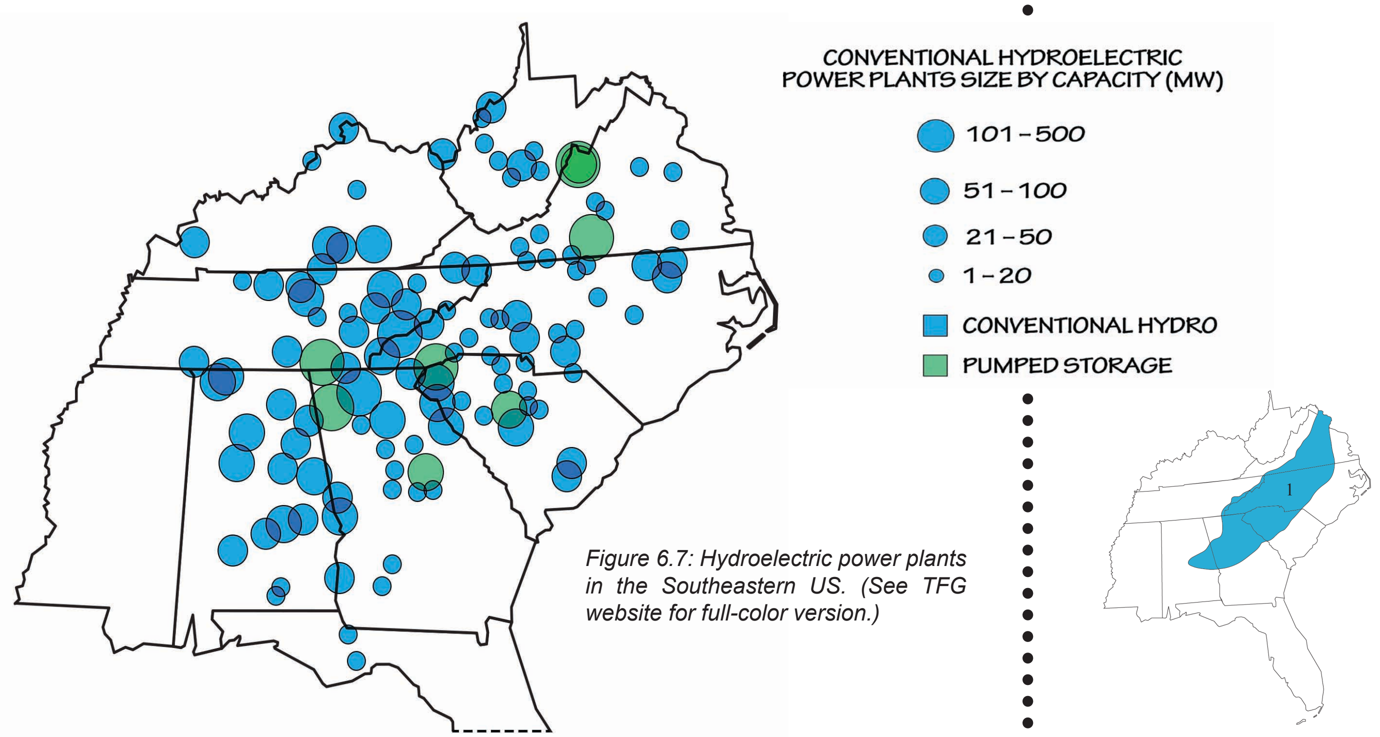


Figure 6.7: Hydroelectric power plants in the Southeastern US. (See TFG website for full-color version.)

relief • the change in elevation over a distance.

Paleozoic • a geologic time interval that extends from 541 to 252 million years ago.

Taconic Orogeny • a late Ordovician mountain-building event involving the collision and accretion of a volcanic island arc along the eastern coast of North America.

Acadian Orogeny • a Devonian mountain-building event involving the collision of the eastern coast of North America and the accreted terrane of Avalon.

(*Figure 6.8*). The steep **relief** and waterfalls of the Appalachian Mountains, especially in western North Carolina and northern Georgia, also provide ample opportunities for hydroelectricity production. North Carolina ranks 9th in the US for hydropower generation, with over 70 hydroelectric dams, though this only accounts for about 3% of the state's electric demand.

Figure 6.8: The J. Strom Thurmond Dam (also known as Clarks Hill Dam) is located on the Savannah River at the border of Georgia and South Carolina. The 334-meter-wide (1096-foot-wide) dam houses a 380 MW hydroelectric plant.

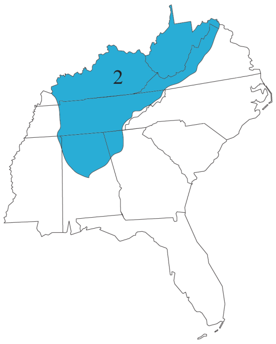
Energy in the Inland Basin

Region 2

The Inland Basin is a renowned source of fossil fuels: its ancient environments and geological history were ideal for the formation and preservation of widespread deposits of coal, oil, and natural gas (*see Figures 6.3 and 6.4*). Appalachian Basin coal, along with oil and natural gas, fueled the industrial growth of the Eastern Seaboard and westward expansion. The coal-bearing region of the Appalachian Basin extends 1300 kilometers (800 miles) from northern Pennsylvania to Alabama, and covers an area of 186,000 square kilometers (72,000 square miles) in parts of nine states. The Inland Basin also has modest hydroelectric power generated by a wet climate and topographic relief. Solar energy and biofuel production are growing industries, but remain small.

Oil and Gas

The Appalachian Basin, a sedimentary basin formed in the **Paleozoic** during the **Taconic** and **Acadian orogenies**, was the site of much early oil



exploration. During the formation of the ancestral Appalachian Mountains, the crust was buckled and **downwarped** repeatedly to form the basin, which is deepest beneath the Appalachian Plateau. The **sedimentary rocks** of the Appalachian Plateau are not tightly folded like the Valley and Ridge (an adjoining **physiographic** region), but have broad, gentle folds, as well as faults, which provide the opportunity to trap oil and gas (*Figure 6.9*). These energy resources have been extracted from rock layers of **Ordovician** through **Pennsylvanian** age. Famous rock units acting as reservoirs include the Oriskany Sandstone, which extends from New York into Virginia, and the Greenbrier Limestone (the "Big Lime") and its equivalents, which extend throughout West Virginia, eastern Kentucky (*Figure 6.10*) and Tennessee, and parts of Alabama, Georgia, and Virginia. Not all reservoirs are extensive—more isolated reservoirs are found in the **Mississippian**-aged Fort Payne Formation in eastern Tennessee. These reservoirs occur in **permeable carbonate** mounds (called **bioherms**) that were formed in shallow seas. The mounds were buried by mud, which formed a **shale caprock** that acts as a **stratigraphic** trap for oil that migrated into the mounds.

Thomas Jefferson visited springs venting natural gas on a stream called Burning Springs, a tributary of the Little Kanawha River in West Virginia, as early as 1781. He wrote an article describing the brilliant flame that could be produced by thrusting a lighted candle into the escaping gas.

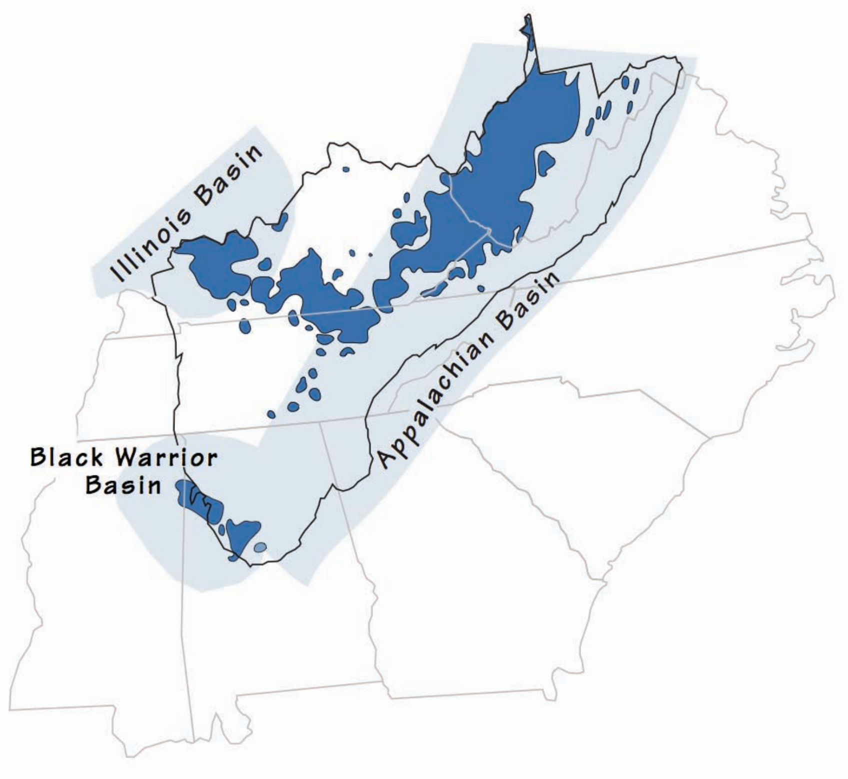


Figure 6.9: Clusters of oil and gas fields in the Inland Basin.

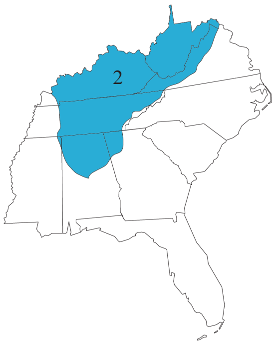
downwarp *• a segment of the Earth's crust that is broadly bent downward.*

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

physiography *• a subfield of geography that studies the Earth's physical processes and patterns.*

Ordovician *• a geologic time period spanning from 485 to 443 million years ago.*

Pennsylvanian *• a subperiod of the Carboniferous, spanning from 323 to 299 million years ago.*



salt • a mineral composed primarily of sodium chloride (NaCl).

Devonian • a geologic time period spanning from 419 to 359 million years ago.

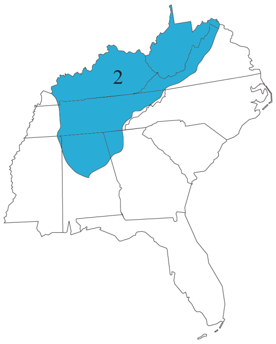
inland sea • a shallow sea covering the central area of a continent during periods of high sea level.

fracture • a physical property of minerals, formed when a mineral crystal breaks.

Figure 6.10: An oil pumpjack in Magoffin County, Kentucky. Between 1980 and 2005, the county produced 3.4 million barrels of oil and 450 million cubic meters (15.8 billion cubic feet) of natural gas.

In the early and mid-1800s, drillers searching for **salt** in the Appalachians sometimes struck oil by accident. In 1819, Martin Beatty of Abingdon, Virginia encountered oil while drilling for salt on the South Fork of the Cumberland River in Kentucky, near the Tennessee state line. Another salt prospect well near Burkesville, Kentucky struck pressurized oil in March 1829. Called the "Great American Oil Well," the gusher flowed into the nearby Cumberland River and the oil was carried over 64 kilometers (40 miles) downstream. The floating oil ignited and burned for three weeks, halting riverboat traffic. Overall, the well is estimated to have produced 50,000 barrels of oil, most of which was sold as lamp oil or medicine. In 1859, the Rathbone brothers struck oil in a well drilled along Burning Springs in West Virginia; based on this discovery, they drilled another well the following year, producing 1200 barrels of oil a day. Petroleum production spread rapidly throughout the Appalachian Basin in the 1860s, reaching its peak by 1900, the culmination of the first major US oil boom.

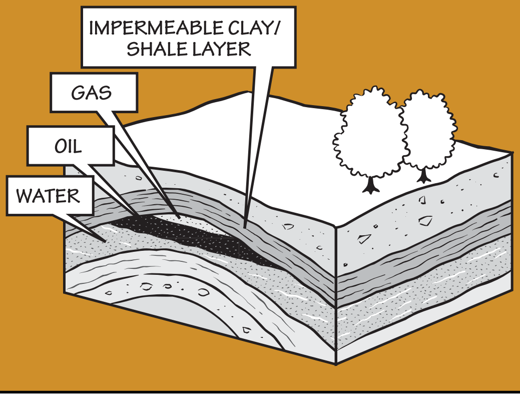
Large amounts of gas have also been produced from thick **Devonian**-aged black shales, deposited in oxygen-poor **inland seas** where organic material was preserved at the sea bed. With time, pressure, and heat, organic material in the shale was changed into petroleum and gas. Devonian-aged shales are the major source rock for most of the Inland Basin's younger petroleum reservoirs, and they are also a major gas reservoir. Because the shales are not permeable, gas production occurs where the rocks are naturally **fractured**, or where it is induced by hydraulic fracturing. This method fractures rocks beneath the surface, releasing gas and oil trapped in source rocks that have very low permeability (also known as "tight" layers). Hydraulic fracturing uses high volumes of water introduced at high pressure through horizontal wells along the source rock layer, to create thousands of tiny fractures (*Figure 6.11*). Most

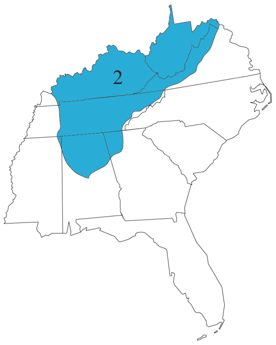


Oil and Gas

Oil and gas form from organic matter in the pores of sediments subjected to heat and pressure. The organic matter is primarily composed of photosynthetic plankton that die and sink to the bottom of large water bodies in vast numbers. Shale in particular is often organic rich, because organic matter settles and accumulates in the same places that mud (clay and silt particles) settles out of the water. In most environments, organic matter is recycled by bacteria before it can be buried, but the quiet waters where mud accumulates are often relatively stagnant and low in oxygen. In these places, the bacterial decay rate is low relative to the rate of organic matter sinking and to the rate that the organic matter becomes buried in muddy sediments. Under such conditions, organic matter may accumulate enough to make up several percent or more of the deposited sediment.

Because oil and gas are under pressure, they will move gradually upward to areas of lower pressure through tiny connections between pore spaces and natural fractures in the rocks. Reservoir rocks typically have a considerable amount of pore space, and to be viable there must be a way of trapping the oil and gas, such as through a geologic structure or a change in rock type that will prevent the resource from escaping. 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.





Gushers, an icon of oil exploration during the late 19th and early 20th centuries, occurred when highly pressurized reservoirs were breached by simple drilling techniques. Oil or gas would travel up the borehole at a tremendous speed, pushing the drill bit out and spewing out into the air. Although iconic, gushers were extremely dangerous and wasteful; as well as spewing thousands of barrels of oil onto the landscape, they were responsible for the destruction of life and equipment. The advent of specialized blowout prevention valves in the 1920s enabled workers to prevent gushers and to regain control of blown wells. Today, this equipment is standard in both on- and offshore oil mining.

horizontal wells are drilled where the source rock is about 100–150 meters (330–490 feet) thick. The fractures are held open by small grains of **sand** carried by gel in the water, increasing its viscosity. A number of chemicals are added to the water to increase the recovery of fossil fuels, including a chemical to reduce friction as the mixture is introduced (thus the term "slickwater"). "Slickwater, high-volume hydraulic fracturing"—often shortened to "hydraulic fracturing" or simply "fracking"—has greatly increased the accessibility of available fossil fuel resources and the production rate of oil and gas. It has also been controversial, in large part because of associated environmental impacts. The middle Devonian Marcellus shale, which underlies part of West Virginia, is the most famous Southeastern unit that has been subjected to fracking. Most of the Marcellus shale, however, underlies Pennsylvania, where natural gas extraction has increased dramatically since 2008.

The Illinois Basin, deepest in south-central Illinois, continues into western Kentucky and extreme north-central Tennessee. Similarly to the Appalachian Basin, oil and gas have been produced from Ordovician through Pennsylvanian-aged strata. The reservoirs are primarily structural and stratigraphic traps in Mississippian and Pennsylvanian **sandstones** that formed in a wide range of **fluvial**, coastal, and shallow marine environments. Some of these shallow-sea sandstones are very **porous**, making them effective reservoir rocks. Many of the Illinois Basin's Mississippian **limestones**, which were deposited in shallow tropical seas, are also reservoirs. Some of these limestone layers are made of spherical grains called **oolites** that form along coastlines as concentric precipitated layers of **calcium carbonate**. These oolitic limestones are extensive and similar in age to the "Big Lime" of the Appalachian Basin.

The Black Warrior basin occupies northwestern Alabama and northeastern Mississippi. The first petroleum discovery in the region was made in 1909, when natural gas was struck in the Pennsylvanian-aged rocks of northwestern Alabama. Most traps in this basin are formed by folds and faults, and contain both oil and natural gas. Less oil is produced in this basin than in parts of the Appalachian Basin or the Illinois Basin to the north.

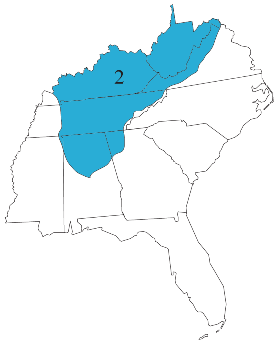
sand • *rock material in the form of loose, rounded, or angular grains, and formed as a result of the weathering and decomposition of rocks.*

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

fluvial • *see outwash plain: large sandy flats created by sediment-laden water deposited when a glacier melts.*

porosity • *the percentage of openings in a body of rock such as pores, joints, channels, and other cavities, in which gases or liquids may be trapped or migrate through.*

limestone • *a sedimentary rock composed of calcium carbonate ($CaCO_3$).*



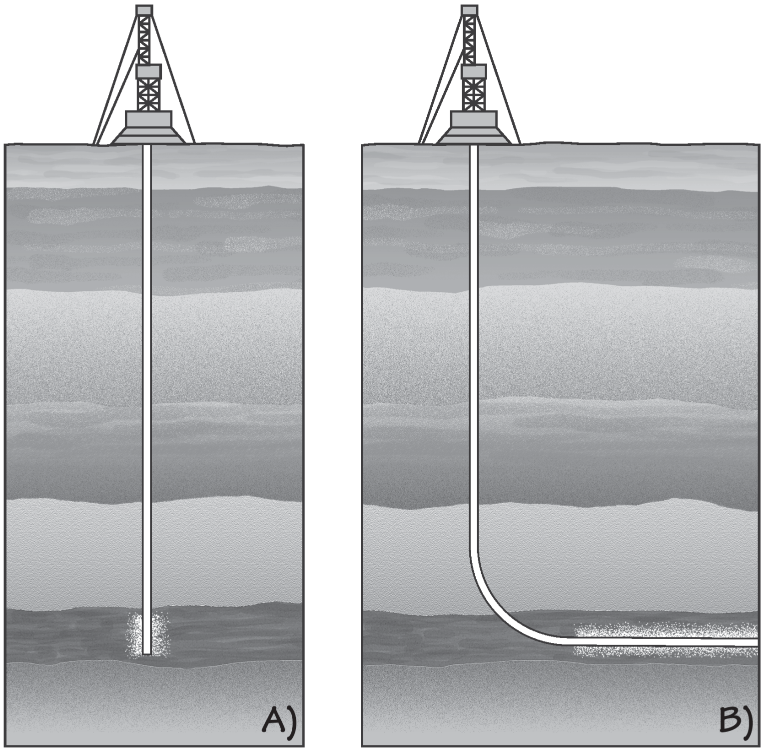


Figure 6.11: Oil wells (not to scale). A) A conventional vertical well. B) An unconventional horizontal well. Hydraulic fracturing may be carried out along horizontal wells running for 1.6 kilometers (1 mile) or more along layers with oil or gas trapped in pore spaces.

Oil and gas are also produced in the "Cumberland Saddle," a sag along the **Cincinnati Arch** separating the Illinois and Appalachian Basins. In the Saddle, **Cambrian** and Ordovician rock units—tens of thousands of meters (yards) deep within the basins—are exposed at the surface. Substantial petroleum has been produced from limestones and **dolomites** of the Cambrian-Ordovician Knox Group in Tennessee and south-central Kentucky. Much of the petroleum from the Knox reservoirs was trapped in ancient sinkholes and caves along an **unconformity**, which marks a surface of **erosion** and **weathering** where the carbonates were exposed during a drop in sea level before being buried by the next marine **transgression**.

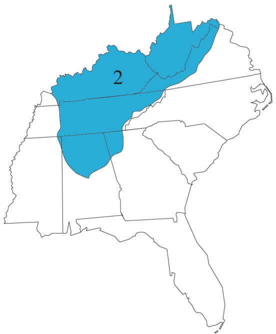
Natural **asphalt** or **bitumen** is present in rocks throughout the Inland Basin. These deposits represent oil reservoirs that have lost most of their lighter hydrocarbons, so they have become viscous, like tar. Oil that trickles out at the Earth's surface is known as a "seep." Natural seeps of crude oil and natural gas were known to Native Americans and used in medicines before European colonization. Early European settlers used surface petroleum for medical purposes, greasing wagon wheels, softening leather, and caulking log cabins. Small local distilleries produced kerosene for lamps by the 1850s. In the Southeast, the most extensive deposits are found in Kentucky and Alabama (*Figure 6.12*); natural asphalt was first "discovered" in Lawrence County, Alabama in 1840. Alabama reserves contain at least 700 million tons of material, including around 100 million tons of petroleum, with limited production from 1927 to the present. Kentucky reserves contain at least 500 million tons.

oolite • *a sedimentary rock consisting of tiny (<2 mm) spherical grains made of concentric layers of calcium carbonate.*

calcium carbonate • *a chemical compound with the formula $CaCO_3$, commonly found in rocks in the mineral forms calcite and aragonite, as well as the shells and skeletons of marine organisms.*

Cincinnati Arch • *an uplifted region that existed between the Illinois Basin, the Michigan Basin, and the Appalachian Basin during the late Ordovician and Devonian.*

Cambrian • *a geologic time period lasting from 541 to 485 million years ago.*



6 Energy

Region 2

derrick • a lifting device in the form of a framework steel tower that is built over a deep drill hole, typically an oil well.

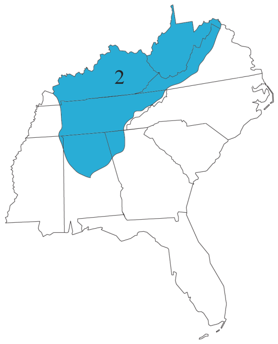
delta • a typically wedge-shaped deposit formed as sediment is eroded from mountains and transported by streams across lower elevations.

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

How does oil drilling work?

Once an oil trap or reservoir rock has been detected on land, oil crews excavate a broad flat pit for equipment and supplies around the area where the well will be drilled. Once the initial hole is prepared, an apparatus called a drilling rig is set up. The rig is a complex piece of machinery designed to drill through rock to a predetermined depth. A typical drilling rig usually contains generators to power the system, motors and hoists to lift the rotary drill, and circulation systems to remove rock from the borehole and lubricate the drill bit with mud. It also contains high-pressure blowout prevention equipment to prevent pressurized oil or gas from rising uncontrollably to the surface after being tapped. The support structure used to hold the drilling apparatus is called a *derrick*. In the early days of oil exploration, drilling rigs were semi-permanent structures and derricks were left onsite after the wells were completed. Today, however, most rigs are mobile and can be moved from well to well. Once the well has been drilled to a depth just above the oil reservoir, a cement casing is poured into the well to structurally reinforce it. Once the casing is set and sealed, oil is then allowed to flow into the well, the rig is removed, and production equipment can be put in place to extract the oil.

Offshore drilling follows much the same process as on-shore drilling, but utilizes a mobile offshore drilling unit (MODU) to dig the well. There are several different types of MODUs, including submersible units that sit on the sea floor, drilling ships, and specialized rigs that operate from atop floating barges.



Coal

Erosion of sediment from the Appalachian Mountains, which were formed by the assembly of Pangaea in the late Paleozoic, created vast coastlines and **deltas** in the Inland Basin. Widespread deposits of coal are associated with these areas. The main period of coal formation is known as the **Carboniferous** because of the abundant carbon (coal) found in rocks of this age. In the United States, the interval of time represented by the Carboniferous is divided into the Mississippian (major limestone and minor coal deposits) and Pennsylvanian (major coal deposits) periods. Globally, Carboniferous-aged rocks contain a substantial amount of the world's coal resources. Coal is a major source of

Figure 6.12: Asphalt seeps from the walls of Tumbling Rock Cave near Scottsboro, Alabama.

power in the Southeastern US, with power plants mostly using coal mined within the area. Kentucky and West Virginia are major centers for coal production and processing in the US. The Lamberts Point coal export facility in Norfolk, Virginia is the largest and fastest coal transload facility (that is, transferring from one form of transportation to another) in the Northern Hemisphere, servicing approximately one-third to one-half of US coal exports since 2000. West Virginia provides coal to most of the Northeastern US, producing well over 100 million tons of coal per year.

Coal is plentiful in the Inland Basin thanks to local environmental conditions during the Mississippian and Pennsylvanian (*Figure 6.13*). Tropical climate, fluctuating sea levels, and basin **subsidence** resulted in the cyclic growth and burial of vast peat swamps, some of which may have been among the largest tropical peat swamps of all time. The sea advanced and retreated hundreds of times, shifting the shoreline back and forth across the region, and leaving hundreds of coal beds preserved when and where conditions were right for burial of peat. Time, deep burial, and metamorphism transformed the peat layers into high grade **anthracite** and bituminous coal beds. Anthracite coals from Mississippian-aged peat swamps are preserved in the Valley Coalfields of Virginia, but none are presently mined. Coals deposited during the Pennsylvanian period occur in repeated successions of sedimentary rock layers known as **cyclothems** (*Figure 6.14*), which resulted from repetitive sea level changes caused by the formation and melting of continental **glaciers** on the supercontinent **Gondwana** from about 330 to 260 million years ago. Coal beds were preserved on the eastern margin of the elongate Appalachian Basin (including the Black Warrior Basin of Alabama), and in the Illinois Basin, which extends southward into western Kentucky. Vast, Pennsylvanian-aged coal

See Chapter 8: Climate to learn more about glacial cycles throughout geologic time.

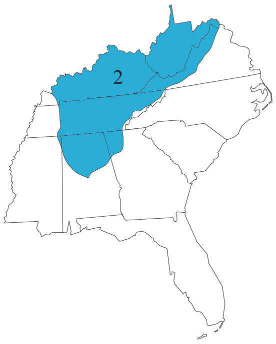
subsidence • *the sinking of an area of the land surface.*

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

cyclothem • *alternating sequences of marine and non-marine sedimentary rocks, usually including coal, characterized by their light and dark colors.*

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

Gondwana • *the super-continent of the Southern Hemisphere, composed of Africa, Australia, India, and South America.*



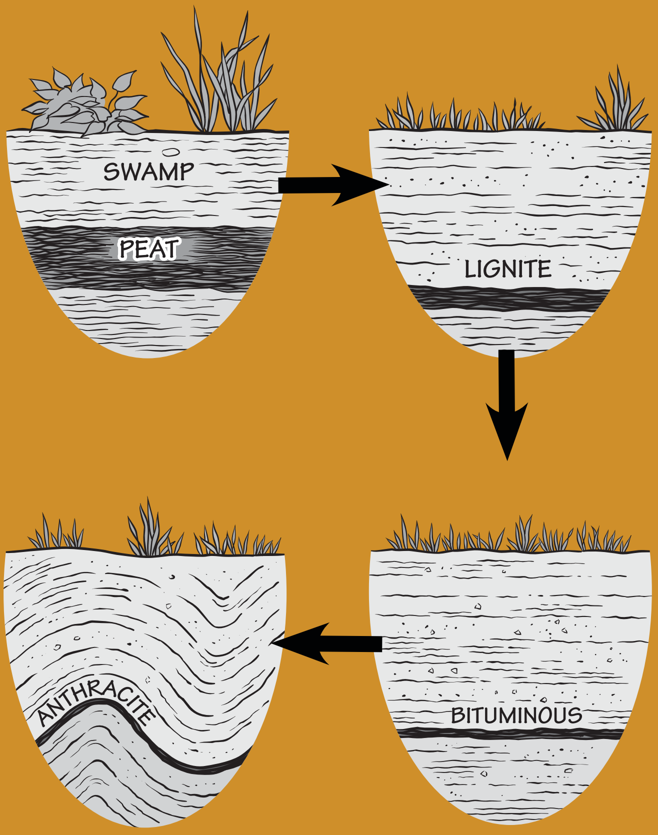
Energy

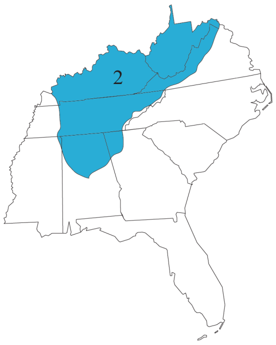
compression • *flattening or squeezing as a result of forces acting on an object from all or most directions.*

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. Globally, a remarkable amount of today's coal formed from the plants of the Carboniferous, which included thick forests of trees with woody vascular tissues.





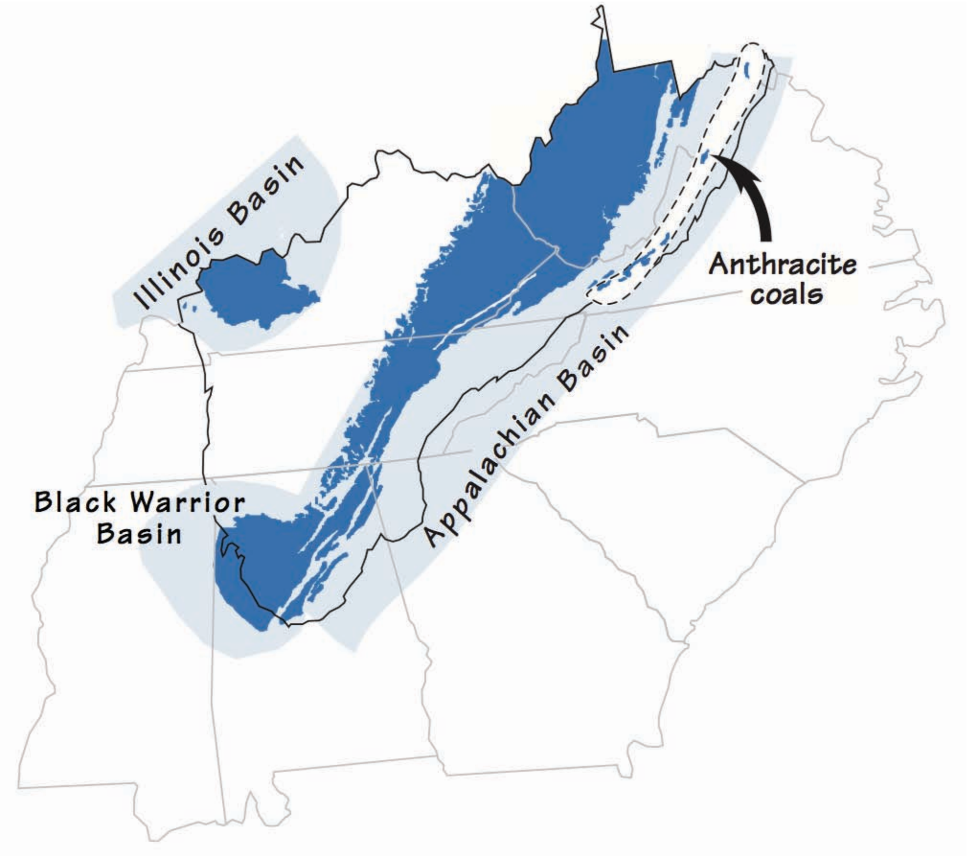


Figure 6.13: Bituminous and anthracite coal deposits of the Inland Basin region. Anthracite coals are found within the dashed circle in Virginia and West Virginia.

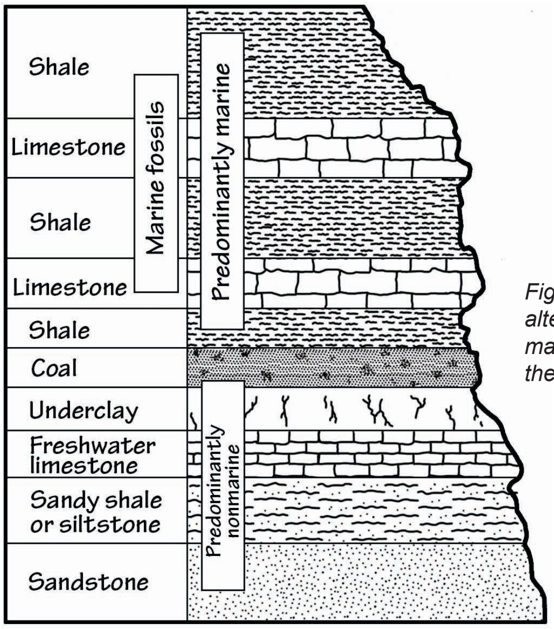
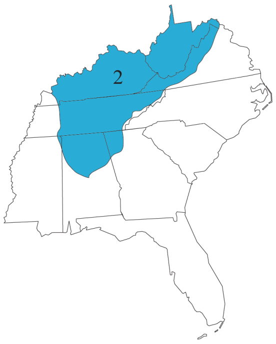


Figure 6.14: An example of a cyclothem: alternating sequences of marine and non-marine sedimentary rocks, characterized by their light and dark colors.



deposits are present from West Virginia and western Virginia, across eastern Kentucky and Tennessee, and into northern Alabama. Lesser amounts of coal occur in **Permian**-aged strata in West Virginia.

Extensive coal is not associated with the coastal deposits and deltas that formed during the earlier Taconic and Acadian orogenies, even though geologic and climatic conditions were similar, because the plants that make up the coastal swamp forests (which produced sufficient biomass for accumulation of large peat deposits) had not yet evolved. Plants had only just begun to spread on to land and evolve roots and vascular tissue during the **Silurian** period. Diversification and evolution of plants during the Devonian was rapid, leading to a proliferation of swamp-loving land plants during the Carboniferous. As forests evolved and increased in size in the late Devonian and Carboniferous, significant quantities of organic matter were produced via photosynthesis on land for the first time. Organisms that would later cause fast rates of decay had yet to evolve, and a relatively high percentage of organic matter in swampy habitats accumulated as peat, which eventually was buried and became coal. The burial of huge quantities of terrestrial organic matter took carbon dioxide out of the **atmosphere**, and CO_2 concentrations decreased to the point that global cooling led to the growth of continental glaciers. Today we are enacting the same process in reverse—in only a few hundred years, releasing carbon dioxide into the atmosphere that took millions of years to be buried.

See Chapter 3: Fossils for more about the plants that lived in the Southeast's Carboniferous swamps.

Coal in the Inland Basin was first reported along a tributary of the Kanawha River, West Virginia in 1742. Initially, only small amounts of coal were used for heating by local blacksmiths or by settlers living near coal outcrops. In 1810, people in Wheeling, West Virginia, began using locally mined coal to heat their cabins. The first steamboat on the Ohio River in 1811 burned coal from West Virginia, and coal began to replace charcoal as a **fuel** for the Kanawha River salt furnaces by 1817. In 1820, the first commercial mine opened in Kentucky. West Virginia produced about 300,000 tons of coal in 1840, of which two-thirds was used in the Kanawha salt furnaces. Factories and homes in Wheeling consumed most of the remainder. Production continued to expand until the outbreak of the Civil War, when coal production became a matter of military strategy. After the war, the Appalachian Basin coal industry began a rapid and sustained growth that paralleled the industrialization of the United States.

See Chapter 5: Mineral Resources to learn about the colonial salt industry along the Kanawha River.

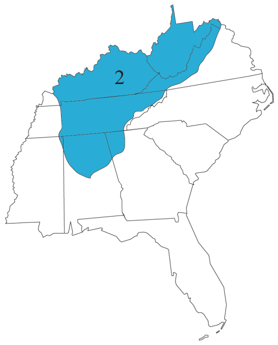
The mining of Pennsylvanian coal is a major industry in Kentucky, Tennessee, Virginia, and West Virginia. More than 60 sites have been or are currently being mined in the southeast part of the Appalachian Basin and southern part of the Illinois Basin in western Kentucky. In 2013, West Virginia and Kentucky

Permian • *the geologic time period lasting from 299 to 252 million years ago.*

Silurian • *a geologic time period spanning from 443 to 419 million years ago.*

atmosphere • *a layer of gases surrounding a planet.*

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



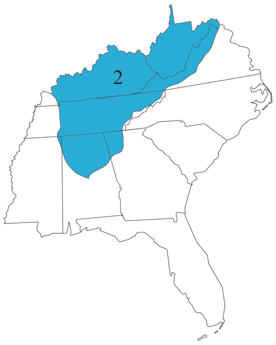
produced the second and third most coal in the country, accounting for 12% and 8% respectively of the national production. Well over half of the coal produced in the US in the last 180 years has come from deposits in the Appalachian Basin. Since the 1960s, coal in the Appalachians has been extracted using mountaintop removal mining, a method that involves blasting away the summit of a mountain to expose underlying coal seams (*Figure 6.15*). West Virginia and Kentucky each use approximately 1100 tons of explosives per day to facilitate this mining method.

Figure 6.15: Mountaintop removal mining for coal on Kayford Mountain, West Virginia. In 2006, mountaintop removal mining provided 30% of West Virginia's coal.

coalification *• the process by which coal is formed from plant materials through compression and heating over long periods of time.*

aquifer *• a water-bearing formation of gravel, permeable rock, or sand that is capable of providing water, in usable quantities, to springs or wells.*

Since about 1980, large reserves of natural gas have been exploited in tandem with coal seams. This gas, called coalbed methane, is a byproduct of the process of **coalification**, and it accounts for over 5% of US methane production. Coal seams have long been vented, in part because of the potential build-up of methane (CH_4, the primary gas in "natural gas") released from fissures around the coal. While long considered primarily a safety hazard to be mitigated in subsurface mines, methods have been developed to trap the methane as an additional energy source. In some subsurface coal seams, water saturates fractures (or cleats) in the seam, making the seam an **aquifer** (which in some places may be clean enough to be part of the local water supply). If there is sufficient water pressure, methane present within the coal fractures may be trapped in the coal. To extract this methane, water can be removed via wells, thereby reducing pressure and allowing methane to escape toward lower pressures along the well bore (*Figure 6.16*). Methane is then separated from the water. After water removal it may take some years for the aquifer to be recharged, that is, refilled with water from rain at the surface that infiltrates below the surface to the aquifer. Production rates for coalbed methane climbed steeply beginning in the early 1990s, and peaked in about 2008, when about



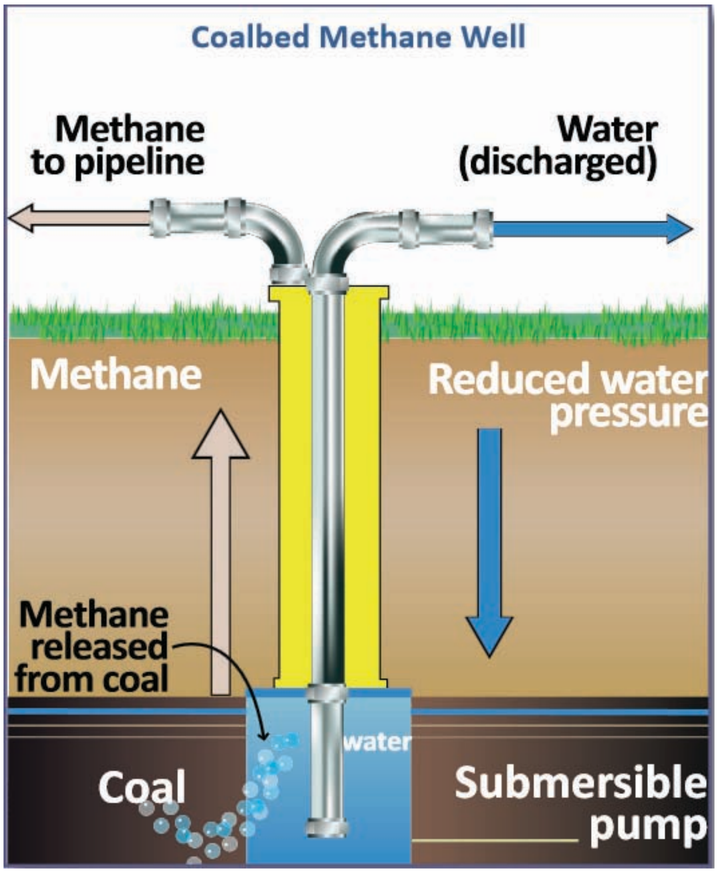
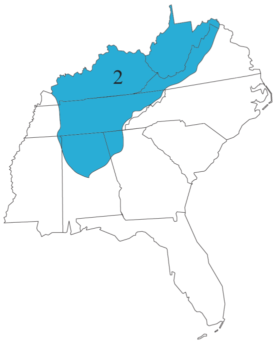


Figure 6.16: Coalbed methane production involves using water or other fluids to reduce pressure on the coal seam by creating a crack through which the methane can escape into a well.

a tenth of the country's yearly natural gas production came from coalbed methane. In recent years, it has declined as shale gas methane production has increased. In Alabama, the gas is sometimes extracted in advance of underground coal mining. The Black Warrior Basin in northern Alabama and the Southwest Virginia Coalfield have hundreds of coalbed methane wells currently in operation, and Virginia is the fifth leading state in coalbed methane production.

Alternative Energy

The Appalachian Mountains to the east of the Inland Basin, combined with the Cumberland Plateau running through the region, facilitate hydroelectric power. Major hydropower plants dot rivers and lakes from the James River in West Virginia along the Cumberland River running through Kentucky and Tennessee to the Coosa River in Alabama. A substantial fraction of hydroelectric power in the Inland Basin comes from dams built by the Tennessee Valley Authority. Alabama ranks fifth in the nation for renewable electricity generation, and is also one of the largest hydroelectric producers east of the Rocky Mountains. Southern Company, the largest electricity producer in the US, operates 34 hydropower facilities in Alabama and Georgia with a total of 2730 MW produced.



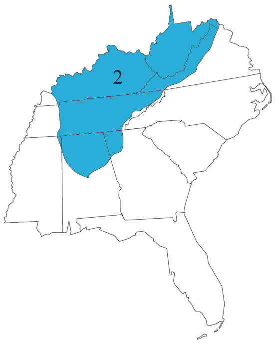
Tennessee Valley Authority

The Tennessee Valley Authority (TVA) was founded in 1933 by the US government to provide a wide range of services to promote economic development, including electricity generation, in the Tennessee Valley, which was hit especially hard by the Great Depression. The area covered the southern part of the Inland Basin—Tennessee and parts of states immediately north, south, and east. Numerous dams were built for hydroelectric plants, in the 1930s for economic development, and in the 1940s for Word War II. Today, TVA remains a large public power utility, with 1/3 of its power from coal, 1/3 from nuclear, 1/10 from hydroelectric, and 1/10 from natural gas. It is beginning to add other sources of renewable energy, such as solar arrays and biofuels.

The Southeast has one of the lowest wind resource potentials in the US, and has not been extensively developed for wind power. The primary exception is the spine of the Appalachians, which is oriented perpendicular to the prevailing winds and thus receives much higher average wind speeds; however, building large wind farms in tightly confined mountainous areas is logistically challenging. West Virginia is the only state in the Southeast with significant existing wind energy production—in 2015, the state ranked about 25th in the US, with five plants producing a total of 615.3 MW of power (*Figure 6.17*). Tennessee has a single 2.1 MW wind farm.

Figure 6.17: Turbines at the Mountaineer Wind Energy Center in Tucker County, West Virginia.

Three nuclear power plants are located in the Inland Basin, two in Tennessee and one in Alabama. All three—the Watts Bar Nuclear Plant (1123 MW, Tennessee), the Sequoyah plant (2277 MW, Tennessee), and the Browns Ferry Nuclear Plant (3310 MW, Alabama)—are located along the Tennessee River.



Energy in the Coastal Plain

Region 3

The Southeastern Coastal Plain is best known for its oil and gas deposits in and offshore of Mississippi and Alabama, though the deposits are not as extensive as adjoining geologically equivalent formations in Louisiana and Texas. While the Gulf Coast in the Southeast has not been nearly as productive as the Gulf Coast of Louisiana and Texas to the west, it shows some similar characteristics as a petroleum producer. Natural gas also drives the Coastal Plain; harvest of natural gas and the infrastructure to move this energy resource throughout the region are extensive, allowing for natural gas to be one of the most consumed energies. The Coastal Plain also supports a variety of alternative energy sources, including solar, biomass, and nuclear power generation.

Conventional Oil and Gas

As Pangaea broke apart during the Jurassic, the Gulf of Mexico opened and began to take shape. In its early stages, the Gulf experienced periods of restricted marine circulation, during which salt was deposited through evaporation in flat layers now known as the Louann Salt Formation (*Figure 6.18*). Since the late Jurassic, the Gulf of Mexico has been accumulating thick deposits of marine sediments, which have been supplemented since that time by sediments eroded from the Mississippi River **watershed** in central North America. The Coastal Plain along southern Mississippi and southwest Alabama was submerged under high sea levels for much of the late **Cretaceous** and Paleogene periods, and it is now the site of thick layers of limestones, shales, and sandstones. Many late Cretaceous and early Paleogene shales became source rocks for oil, significant quantities of which have migrated stratigraphically into the sandstone and porous limestone, ultimately pooling in reservoirs trapped under a variety of impermeable sedimentary deposits such as **gypsum**, anhydrite, limestone, and dolomite. The underlying Jurassic salt structures that occur in abundance along the Gulf of Mexico explain the geographic distribution of many oil and gas reservoirs from eastern Texas to western Alabama. Locally thick occurrences of this salt are found in the Mississippi Interior Salt Basin, which extends from central Louisiana through central Mississippi and southwestern Alabama *(see Figure 6.4)*. Impermeable rocks pushed up by **salt domes** became caprock where oil could be trapped—this is the case in the South Carlton field in southwestern Alabama, the Norphlet Formation in central and southern Mississippi and Alabama, and dozens of fields in central Mississippi, with oil and gas production mostly occurring in Cretaceous sandstones (*Figure 6.19*).

See Chapter 2: Rocks to learn how the Coastal Plain's sedimentary rocks were deposited.

Salt domes in the Coastal Plain are also used to store large quantities of oil and gas. Storage caverns are created by injecting the salt with water to dissolve a cavity within the salt structure—a process called **solution mining** (*Figure 6.20*). Sempra US Gas & Power's Mississippi Hub Storage is one such storage operation, currently holding up to 850 million cubic meters (30 billion cubic

watershed • *an area of land from which all water under or on it drains to the same location.*

Cretaceous • *a geologic time period spanning from 144 to 66 million years ago.*

gypsum • *a soft sulfate mineral that is widely mined for its use as fertilizer and as a constituent of plaster.*

salt dome • *a largely subsurface geologic structure, consisting of a vertical cylinder of salt embedded in horizontal or inclined sedimentary strata.*

solution mining • *the extraction of soluble minerals from subsurface strata by the injection of fluids.*

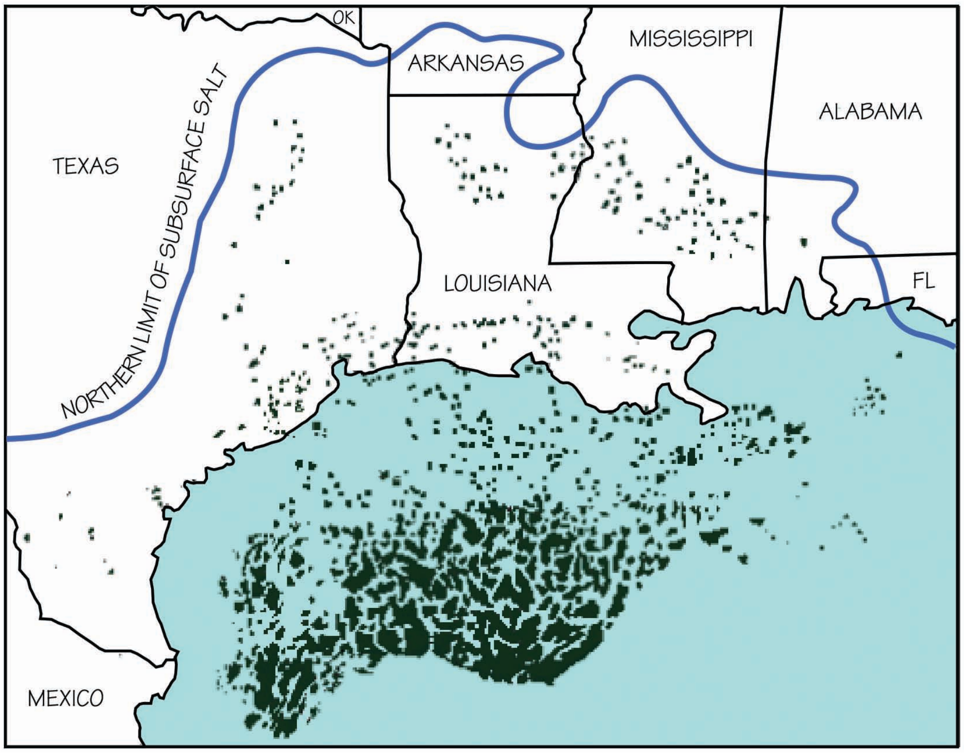


Figure 6.18: The Louann Salt Formation extends under the surface of the Coastal Plain to the blue line. The "blobs" are known salt structures where the salt layer has been deformed.

Figure 6.19: Clusters of known oil and gas fields in the Coastal Plain region.

mineral • *a naturally occurring solid with a specific chemical composition and crystalline structure.*

density • *a physical property of minerals, describing the mineral's mass per volume.*

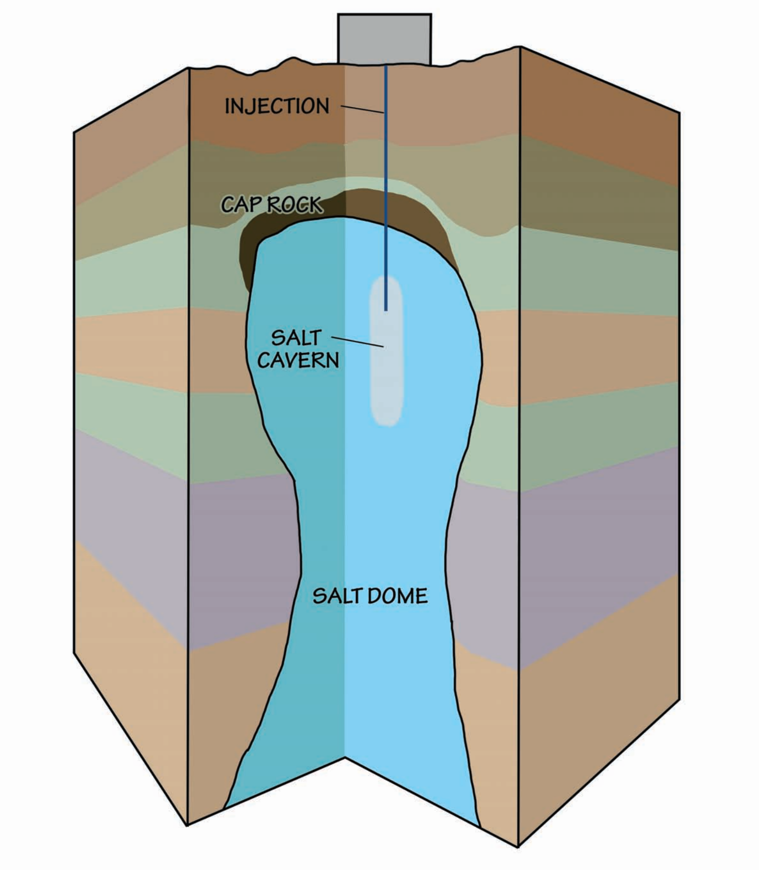


Figure 6.20: Solution mining is used to create a storage cavern inside a salt dome.

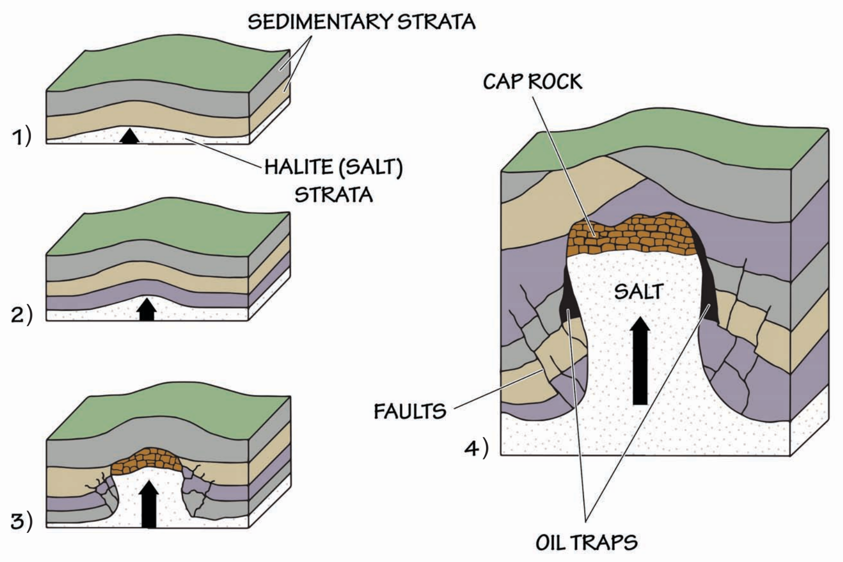
Salt Domes

Rock salt (the *mineral* halite) is solid and impermeable, but when it is under very high pressure it can flow like a thick liquid. When a layer of salt is buried under thousands of feet of overlying sediment, it will start to deform. Because it is less *dense* than the rocks above it, it flows upward toward areas of lower pressure, forming geological structures named for their shapes (e.g., domes, canopies, tables, and lenses). Salt domes are extremely common geologic features along the Gulf Coast, and their origin lies in the Jurassic, when salt was deposited through evaporation in flat layers now known as the Louann Salt Formation. Today, this salt layer is covered by over 6000

Salt Domes (continued)

meters (20,000 feet) of sedimentary rock, through which the salt has moved upward with time, forming hundreds of salt domes.

As salt structures grow, they in turn influence the topography of the surrounding landscape, creating zones of *uplift* surrounding areas of subsidence, fractures, and faults. When salt flows upward, it deforms the surrounding strata, creating gaps in which oil and gas may pool and be trapped. Oil and gas also accumulate under and along the salt structures. Salt domes have led to some of the most prolific oil reservoirs in the Gulf Coast, both on- and offshore. In addition, due to their inherent impermeability, the salt domes themselves are often solution-mined (by pumping water underground to dissolve the salt) to create caverns that have been used to store petroleum, gas, and even chemical waste.



FORMATION OF A SALT DOME

uplift • *upward movement of the crust due to compression, subduction, or mountain building.*

Paleocene • *a geologic time interval spanning from about 66 to 56 million years ago.*

Oligocene • *a geologic time interval spanning from about 34 to 23 million years ago.*

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

Eocene • *a geologic time period extending from 56 to 33 million years ago.*

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

feet) of natural gas in four storage caverns below Simpson County, Mississippi. Other salt dome storage facilities include the Bond Salt Dome Storage Field in Jackson County, Mississippi, and the McIntosh storage cavern in Alabama.

The Florida peninsula has produced small quantities of oil since the mid-1900s from deep (3000–4000 meter [9800–13,100 feet]) Cretaceous-aged rocks. Though the thick sequence of carbonate rocks in Florida is permeable and acts as a reservoir, there are very few source rocks, and therefore, little oil or gas with which to supply the potential reservoirs. Small amounts of oil are still being produced today in a belt of porous Cretaceous limestones from west of Miami to near Fort Myers.

Offshore Oil and Gas

Today, oil and gas production associated with Coastal Plain sediments has moved mostly offshore, into the Gulf of Mexico. Much of this oil and gas formed and was trapped in similar ways to that onshore, with salt structures leading to offshore traps (*see Figure 6.18*). Substantial amounts of sediment were eroded from the midcontinent into the Gulf of Mexico through the ancestral Red, Mississippi, and Sabine river systems. Offshore reservoirs now exist where sandy sediments accumulated, not just on the continental shelf, but also along deeper submarine fans along the continental slope and even abyssal plain. Many of the reservoirs offshore are thick **Paleocene** to **Oligocene** and especially **Miocene** deposits, with Cretaceous and **Eocene**-aged source rocks. The largest Gulf of Mexico oil field to date was found in 1999, 250 kilometers (155 miles) due south of the Mississippi coastline. Drilling in the deepest parts of the Gulf is extremely challenging due in part to **weather**, harsh environments, and water pressure at depth. This became publicly apparent during the Deepwater Horizon oil spill event in 2010, when a seafloor gusher discharged 4.9 million barrels of oil over a period of 87 days before it was capped.

Coal

During the last 100 million years, the seas have advanced and retreated several times, shifting the position of the Coastal Plain's shoreline back and forth. At different times, peat swamps accumulated along the old coastlines and far up the Mississippi River Valley. The largest deposits of resulting coal are Eocene-aged deposits, which are present from Texas east across northern Louisiana and eastern Arkansas, into Mississippi and Alabama, and also north into the **Mississippi Embayment** (*see Figure 6.3*). These thinly bedded coals are formed from plants that lived in marshy environments, brackish lagoons, and between streams near the Eocene coastline.

See Chapter 1: Geologic History to learn about sea level changes through geologic times.

In contrast to the Carboniferous peats of the Inland Basin, which became anthracite and higher grade bituminous coal, the Coastal Plain's peats were not as deeply buried, and therefore were not exposed to the same pressures and temperatures. Therefore, in the Gulf Coastal Plain only **lignite** and "high volatile" (lower grade) bituminous coals exist. Along the Atlantic Coastal Plain there are some large deposits of peat that have not yet been compacted, including

Holocene deposits in coastal North Carolina. Here, the peat ranges from 0.3–4.6 meters (1–15 feet) thick and averages 1.4 meters (4.5 feet) thick. The largest deposits are found in the Albemarle-Pamlico peninsula and the Great Dismal Swamp.

See Chapter 5: Mineral Resources to learn more about peat and its uses.

Solar Energy

Between August of 2014 and August of 2015, North Carolina's production of electricity from solar power increased 127%—more than in any other state in the country during that time period. The state’s solar electric power production in 2015 accounted for more than twice the total production for all the other states in the Southeast combined (*Figure 6.21*). While production of solar electric power has grown exponentially in North Carolina and in the US as a whole, more than half of the country’s solar electric production is found in California. The total US output of solar power is also still dwarfed by other sources. For example, in August 2015, five times more electric power was produced in Florida from burning natural gas than the entire country produced from solar power that month, and in North Carolina, the explosive growth of solar production brought electric production from non-hydro renewables to just 3.4% of the state’s total.

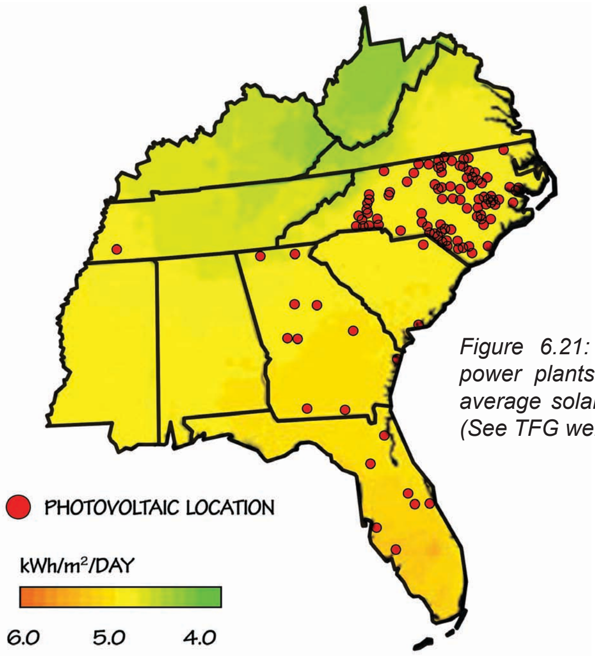


Figure 6.21: Locations of existing photovoltaic power plants overlaid on a map of the annual average solar resource for the Southeastern US. (See TFG website for full-color version.)

Bioethanol and Biomass Plants

The Coastal Plain is rich in biomass resources—organic materials burned to generate energy. Many areas generate hundreds of thousands of tons of biomass materials—including oil (soybeans and canola), sugar (sugarcane, beets, and sorghum), starch (rice, corn, and grains), and cellulose (wood, crop waste, and municipal waste)—every year from forestry, urban waste, and agriculture.

Mississippi Embayment *• a topographically low-lying basin in the south-central United States, stretching from Illinois to Louisiana.*

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.*

Holocene *• the most recent portion of the Quaternary, beginning about 11,700 years ago and continuing to the present.*

Across the Southeastern states, biomass accounts for 6.3% of energy use. States within the Coastal Plain have a slightly higher percentage of their energy coming from biomass. Alabama has the largest share—10.1% in 2013—of the states in the region. Of the 737 public and private-access biodiesel fueling stations nationwide, more than 18% are in North Carolina. A bioethanol and electric power plant that produces energy from wood, vegetable, and municipal wastes was recently built in Vero Beach, Florida. The new fermentation and gasification process uses municipal and other non-food biomass waste, thus avoiding issues associated with using farm crops for biofuel production. The power plant produces commercial-level amounts of biofuel (300 million liters [80 million gallons] of ethanol), as well as electricity to run the plant and to provide from six to eight MW of energy for area homes and businesses. Many people see this type of plant as one possible solution to reducing municipal waste and the use of fossil fuels.

Nuclear Power

Every Southeastern state in the Coastal Plain supports at least one nuclear power plant. Of the 18 plants in the Southeastern US, 9 of these are located in the Coastal Plain region, producing a combined total of 17,029 MW of power. The largest nuclear facility is the Turkey Point Nuclear Generating Station near Miami, Florida, which has a capacity of 3552 MW (*Figure 6.22*). There are also several nuclear reactor fuel processing facilities in the Coastal Plain, notably in North and South Carolina.

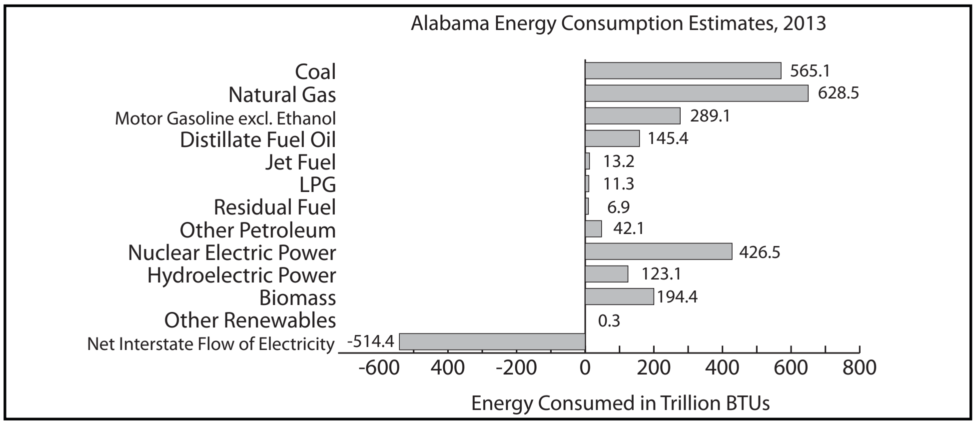
Figure 6.22: Turkey Point is the largest nuclear generating station in Florida and the sixth largest power plant in the US. It currently operates five power-generating units, and an expansion of two additional nuclear reactors is scheduled to begin in 2017.

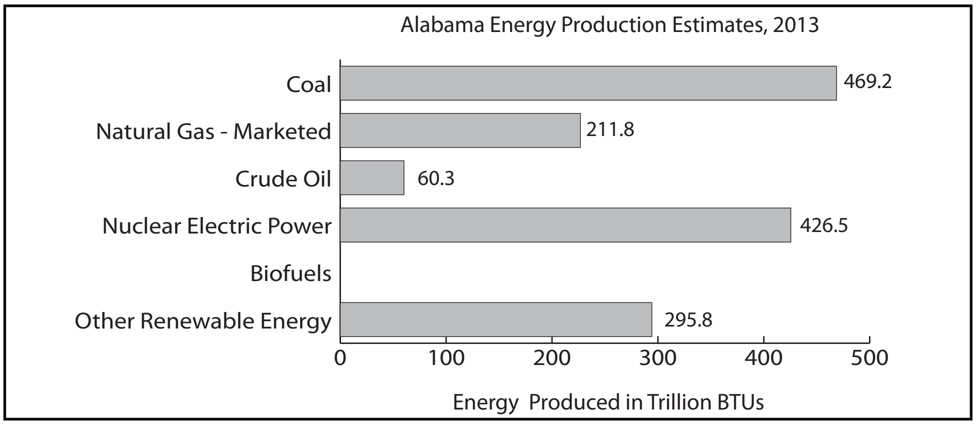
Energy Facts by State

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

Alabama

- The three reactors at the Browns Ferry Nuclear Plant in Limestone County, Alabama have a combined generating capacity of 3310 MW, second in capacity only to Arizona's Palo Verde plant.
- In 2013, Alabama ranked 17th in the nation for the number of producing natural gas wells.
- Mobile, Alabama was the fourth-largest seaport for exporting US coal in 2013. Coking coal used in the steelmaking process accounted for 82% of total exported coal.
- Alabama ranked ninth in 2014 in net electricity generation from renewable energy resources. Conventional hydroelectric power supplied 75% of Alabama's generation from renewable resources.
- Alabama ranked sixth in the US in net electricity generation from wood waste, landfill gas, and other biomass in 2014; nearly all of that electricity was generated by nonutility power producers, primarily in the industrial sector.





Florida

- Geologists believe there may be large oil and natural gas deposits in the Federal Outer Continental Shelf off of Florida's western coast.

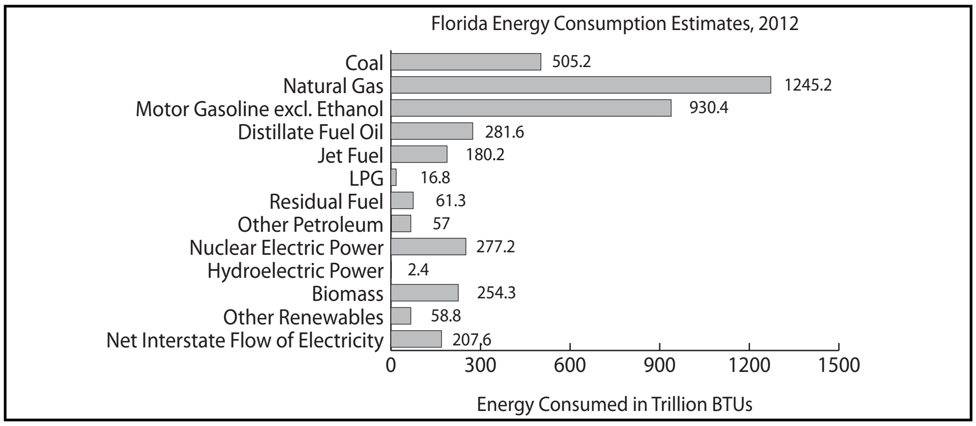
- Electricity accounts for 90% of the site energy consumed by Florida households, and the annual electricity expenditures of $1900 are 40% higher than the US average, according to EIA's Residential Energy Consumption Survey.

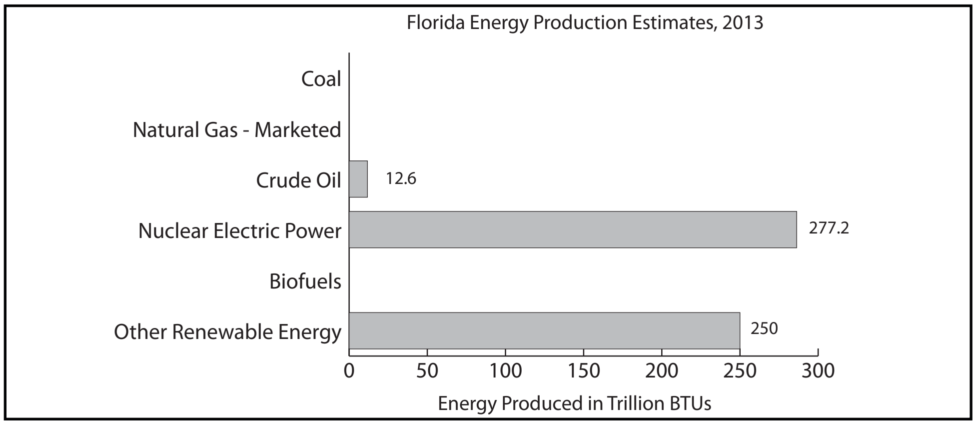
- A Florida facility using a gas fermentation process to produce an estimated 30 million liters (8 million gallons) of cellulosic ethanol from citrus fruit, vegetable, and yard wastes began commercial-scale production in 2013.

- Florida was second only to Texas in 2014 in net electricity generation from natural gas, which accounted for 61% of Florida's net generation; coal accounted for almost 23%, the state's nuclear power plants accounted for 12%, and other resources, including renewable energy, supplied the remaining electricity generation.

- Renewable energy accounted for 2.3% of Florida's total net electricity generation in 2014, and the state ranked 10th in the nation in net generation from utility-scale solar energy.

- In part because of high air conditioning use during the hot summer months and the widespread use of electricity for home heating during the winter months, Florida's retail electricity sales to the residential sector were second in the nation after Texas in 2014.





Georgia

- The Elba Island, Georgia, liquefied natural gas receiving terminal has a peak capacity of 51 million cubic meters (1.8 billion cubic feet) of gas per day, a storage capacity of 330 million cubic meters (11.5 billion cubic feet) of gas, and is pursuing the addition of export facilities.

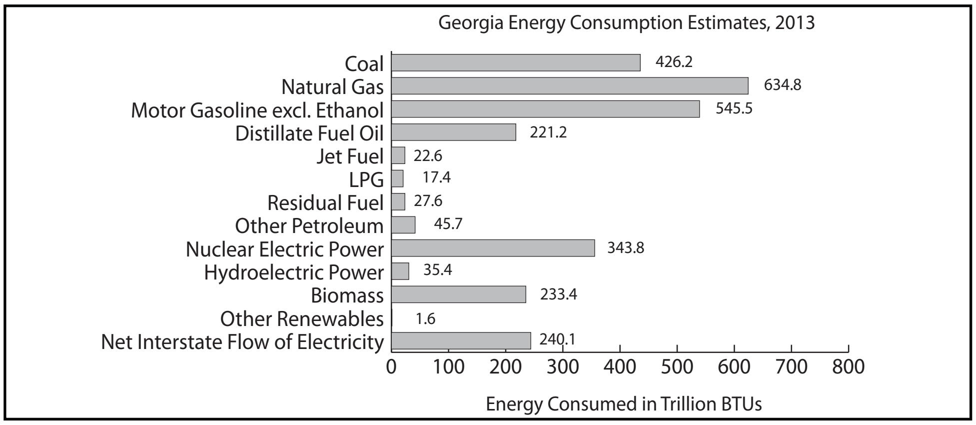
- Georgia is one of the few states where at least 30% of household energy consumption is used for space heating and at least 10% of the energy consumed in homes is used for air conditioning (compared to the national average of 41% for heating and 6% for air conditioning), according to EIA's Residential Energy Consumption Survey.

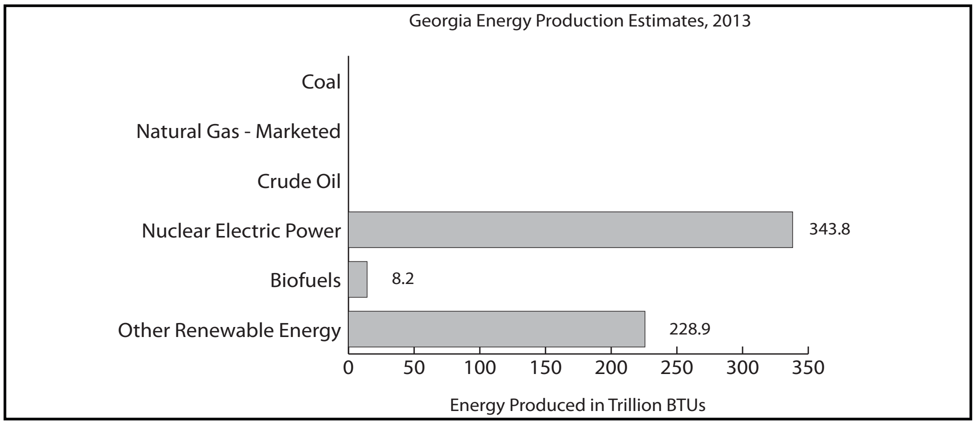
- In February 2012, the Nuclear Regulatory Commission approved the construction of two new nuclear reactors at the Vogtle nuclear power plant in Burke County, Georgia. The anticipated startup dates for the two reactors are in 2019 and 2020.

- Georgia's four existing nuclear reactor units accounted for 26% of the state's net electricity generation in 2014, coal accounted for 36%, natural gas accounted for 32%, and renewable energy, including hydroelectric power, contributed 6%.

- Georgia is heavily forested and has been a leading state in the production of lumber and pulpwood, which contribute feedstock for biomass electricity generation. In 2014, Georgia ranked third in the nation in net electricity generation from biomass.

- In 2014, Georgia ranked 10th in the nation in net electricity generation and 8th in retail sales of electricity.





State Facts

Kentucky

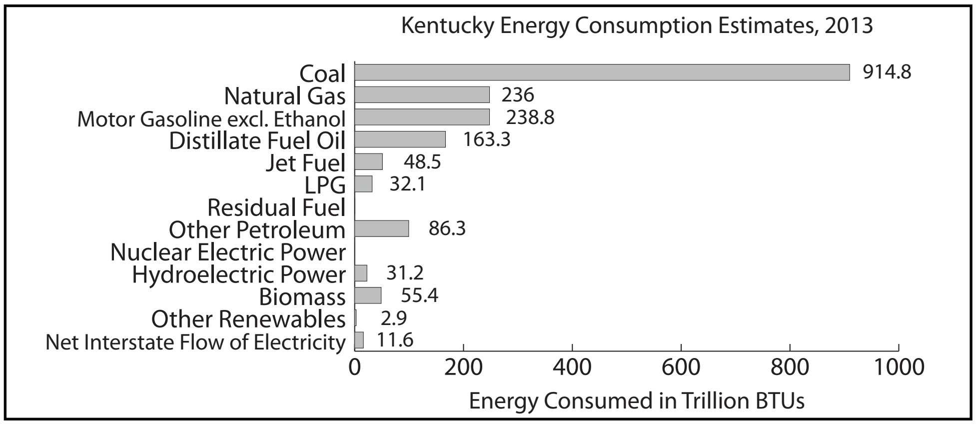
- Most of Kentucky's natural gas comes from the Big Sandy field located in the eastern part of the state. Big Sandy is the largest natural gas field in the Appalachian Basin.

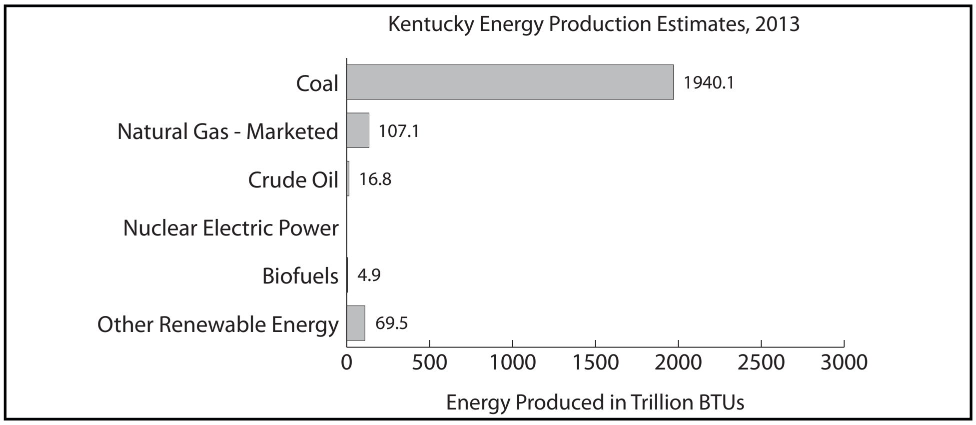
- Three of Kentucky's electric power plants—Paradise, Trimble County, and Ghent—are included on the 2012 list of the 100 largest US power plants by net summer capacity.

- Kentucky was the third largest coal-producing state in 2013. Kentucky's output of 80 million tons of coal accounted for 8.2% of total US coal production.

- Coal fueled 92% of Kentucky's net electricity generation in 2014.

- In 2014, Kentucky had two oil refineries with a combined operating capacity of about 247,500 barrels per calendar day.





Mississippi

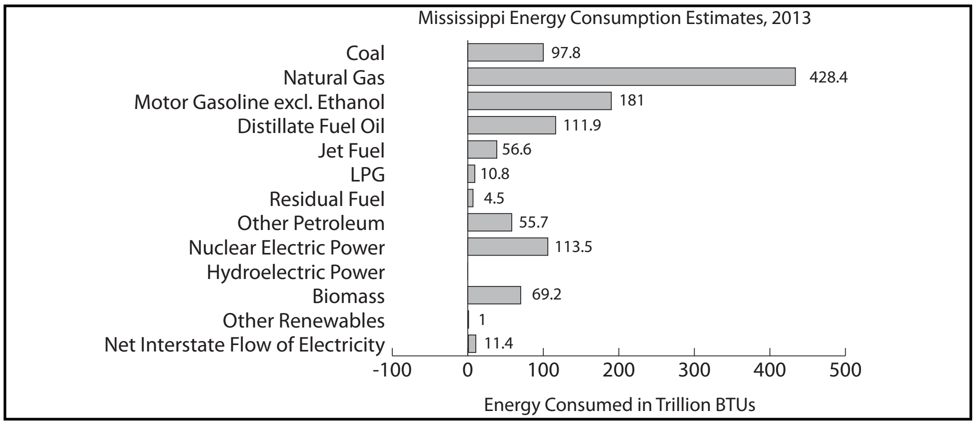
- Mississippi's one ethanol plant can produce 204 million liters (54 million gallons) of biofuel annually, equal to nearly 0.4% of total US ethanol production capacity.

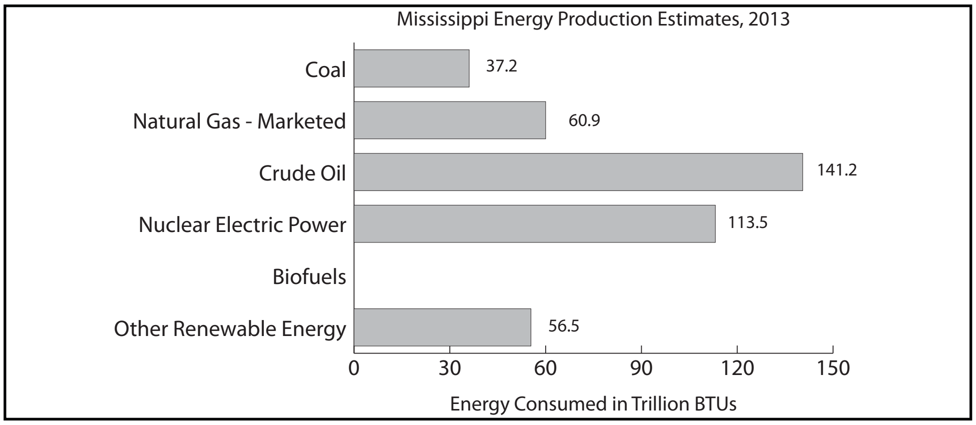
- The Gulf Liquefied Natural Gas terminal at Pascagoula, Mississippi was designed to send imported natural gas by pipeline to users throughout the South. Plans to add liquefaction and export capabilities are being pursued.

- As of January 2014, the Pascagoula oil refinery and a Texas refinery were tied for the 10th-largest refinery by capacity in the United States. The Pascagoula refinery is able to process 330,000 barrels of crude oil per calendar day.

- The 1251 MW Grand Gulf nuclear power plant, near Port Gibson along the Mississippi River, generated nearly 19% of Mississippi's electricity in 2014.

- Mississippi generated 2.7% of its electricity from renewable energy resources during 2014, with wood and wood waste accounting for almost all of the state's renewable electricity generation.





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Energy

State Facts

North Carolina

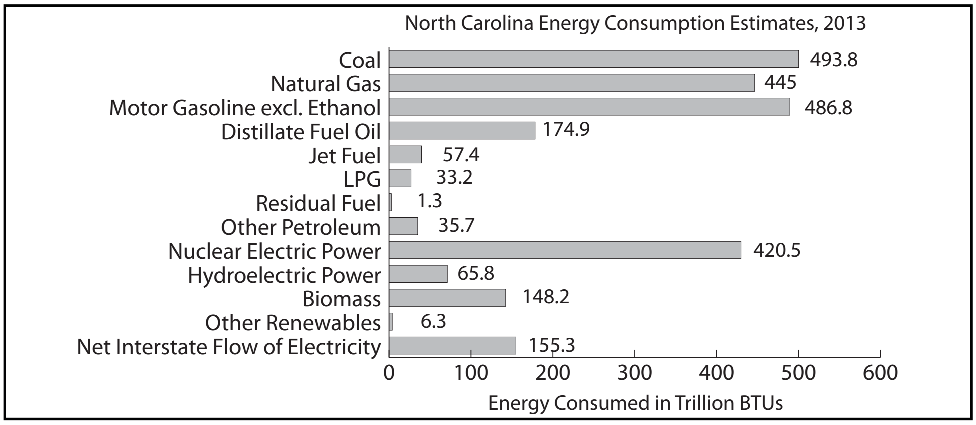
- The Dixie Pipeline transports propane from Texas, Louisiana, and Mississippi to customers throughout the Southeast and terminates in Apex, North Carolina.

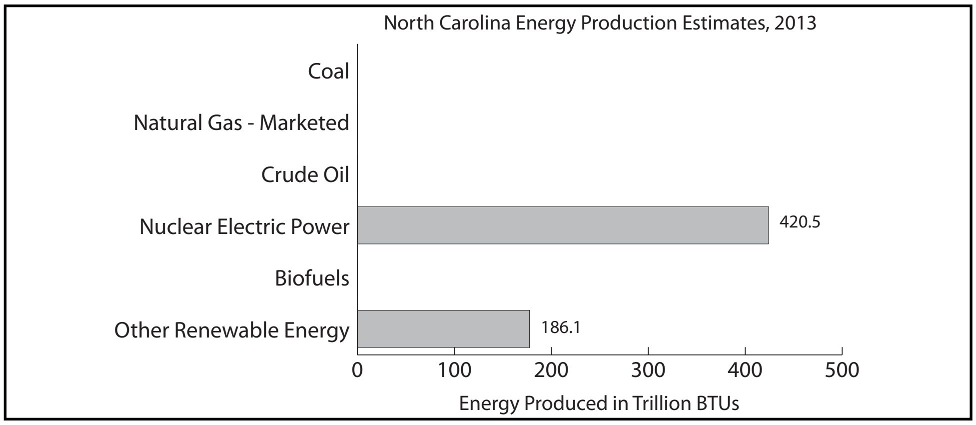
- Of the 737 public and private-access biodiesel fueling stations nationwide, more than 18% are in North Carolina.

- North Carolina ranked sixth in the nation in net electricity generation from nuclear power in 2014, producing 5.1% of the nation's total.

- More than a third of North Carolina's net electricity generation—38.7% in 2014—comes from coal shipped by rail and truck, primarily from West Virginia, Kentucky, and Pennsylvania.

- In 2014, 6.6% of North Carolina's utility-scale net electricity generation came from renewable energy resources, all of which came from conventional hydroelectric power, biomass, and solar energy.





State Facts

South Carolina

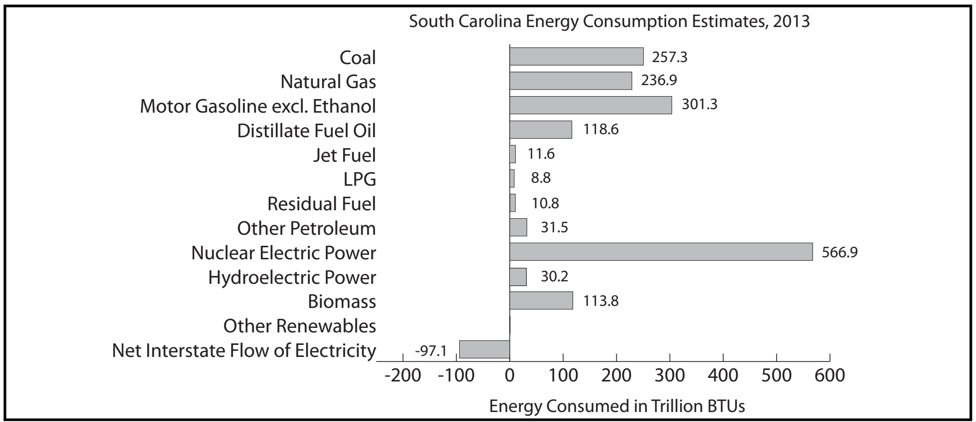
- South Carolina's electric power sector received 34% of its domestic coal deliveries from Kentucky and 29% from Pennsylvania in 2013.

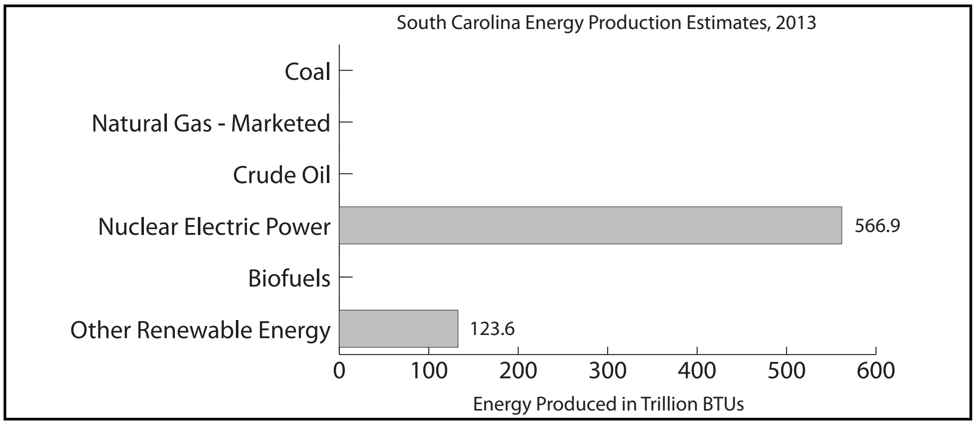
- In 2013, renewable energy resources accounted for 5% of South Carolina's net electricity generation; almost 59% of that generation came from conventional hydroelectric power.

- In 2014, South Carolina was eighth in the nation in per capita retail electricity sales, in part because of high air conditioning demand during the hot summer months and the widespread use of electricity for home heating in winter.

- South Carolina's four existing nuclear power plants supplied 54% of the state’s net electricity generation in 2014. Two new reactors are under construction at the V.C. Summer Nuclear Station site in Fairfield County.

- South Carolina enacted a renewable portfolio standard in 2014 authorizing the creation of distributed energy resource programs to encourage the development of in-state renewable energy generation capacity.





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Energy

State Facts

Tennessee

- Average site electricity consumption for Tennessee households is 33% higher than the national average and is among the highest in the nation. Spending for electricity is closer to the US average because of relatively low electricity prices, according to EIA's Residential Energy Consumption Survey.

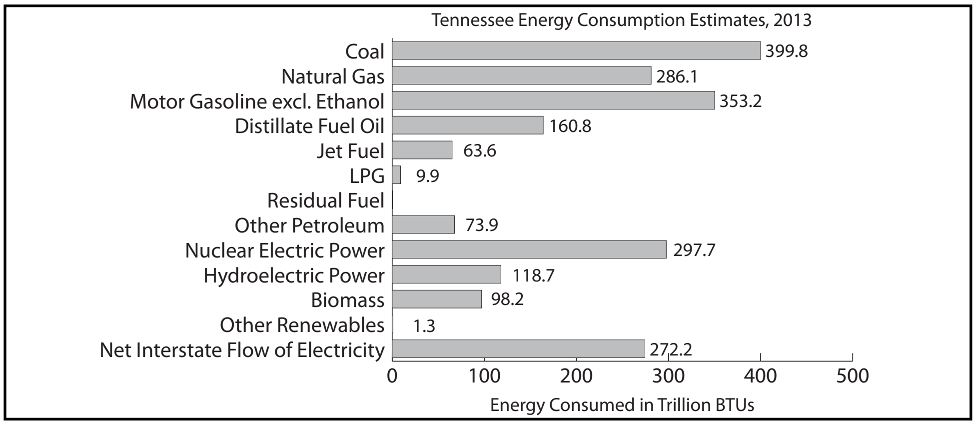
- The newest nuclear reactor in the United States, the single unit at the Watts Bar 1 nuclear power plant, began operating in 1996. Watts Bar 2 is scheduled to be the next US reactor to come online in late 2015.

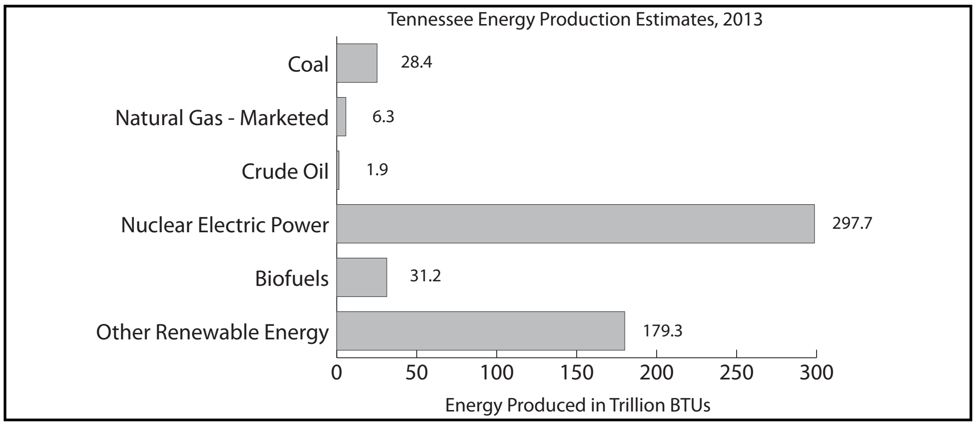
- The Southeast's first major wind farm, located on Tennessee's Buffalo Mountain near Oliver Springs, began operating as a 2 MW facility in 2000. The wind farm's generating capacity has been expanded to 29 MW.

- In 2013, Tennessee ranked among the lowest ten producing states for both crude oil and marketed natural gas production, while coal production ranked fourth from the bottom among the 25 coal-producing states. Exploration for additional oil and natural gas resources is occurring in the Chattanooga shale in the eastern part of the state.

- At 9.6 million MWh in 2014, Tennessee's net electricity generation from hydroelectric power was the third highest of states east of the Mississippi River.

- The largest single solar installation at a US automotive manufacturing facility, and the largest solar installation in Tennessee at 9.5 MW, began operations in Chattanooga, Tennessee in 2013.





Virginia

- For Virginia households, average site electricity consumption (14 MWh per year) and costs ($1584 per year) are higher than the national average but similar to those in neighboring states, where electricity is the most common heating fuel, according to EIA's Residential Energy Consumption Survey.

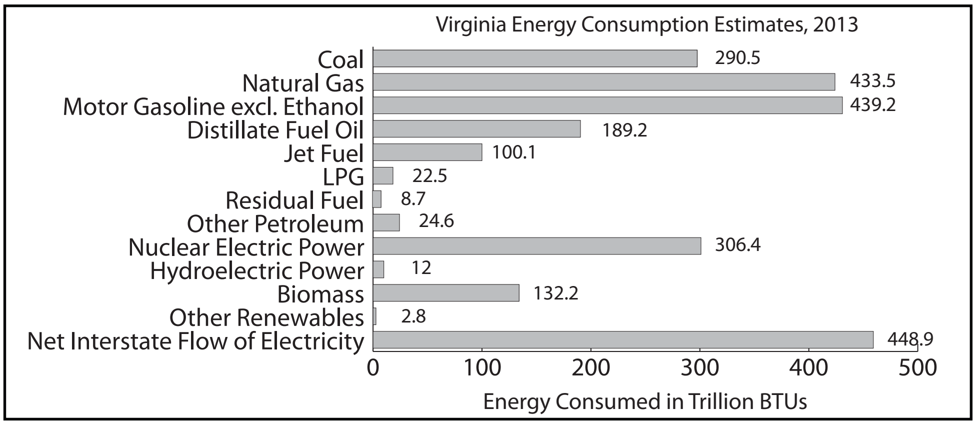
- Based on proved reserves, two of Virginia's natural gas fields were ranked among the top 100 natural gas fields in the US at the end of 2013. Virginia also ranked fourth among the states in coalbed methane proved reserves at the end of 2013.

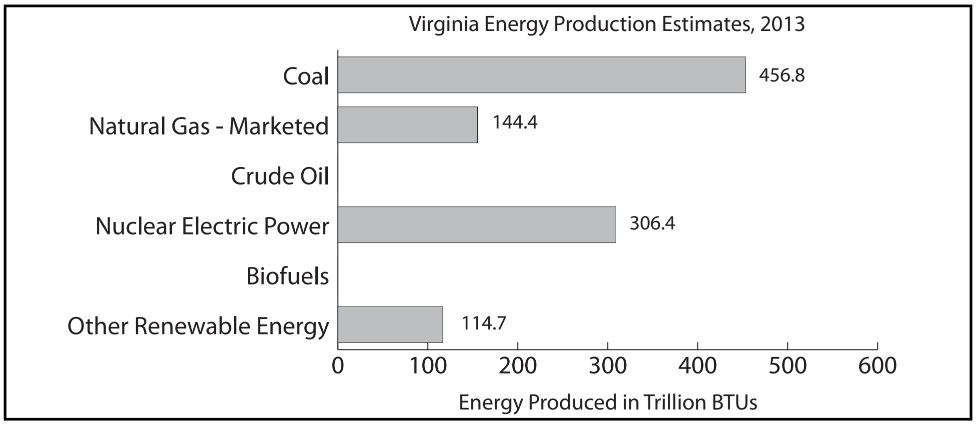
- Virginia accounted for 4.1% of US coal production east of the Mississippi River in 2013. The ports in the Norfolk Customs District—America's largest coal export center—processed more than 42% of US coal exports in 2014.

- Virginia established a voluntary renewable portfolio standard to encourage investor-owned utilities to procure a portion of the electricity sold in Virginia from renewable energy resources. In 2014, 6.5% of the state’s net electricity generation came from renewable energy, three-fourths of which was biomass.

- Virginia’s two nuclear power plants provided 39% of the state's net electricity generation in 2014.

- In 2015, the Virginia Department of Mines, Minerals, and Energy received the first federal offshore wind energy research lease issued by the US Bureau of Ocean Energy Management.





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Energy

State Facts

West Virginia

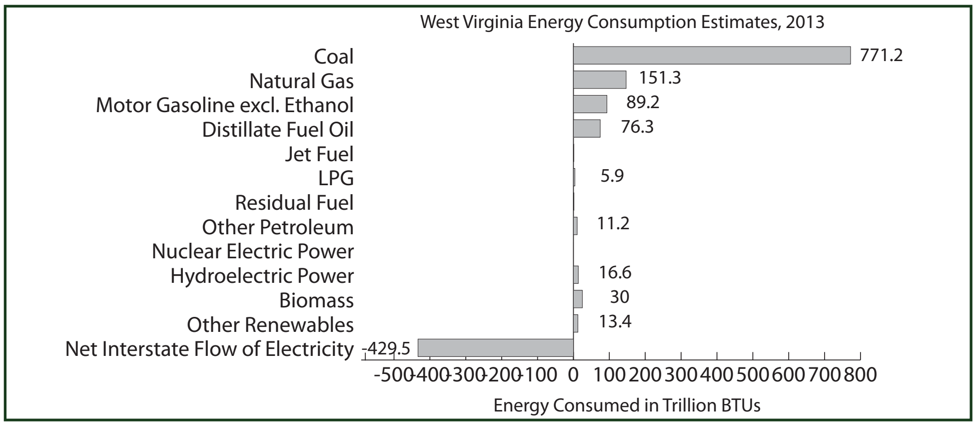
- West Virginia typically generates more electricity than it consumes.

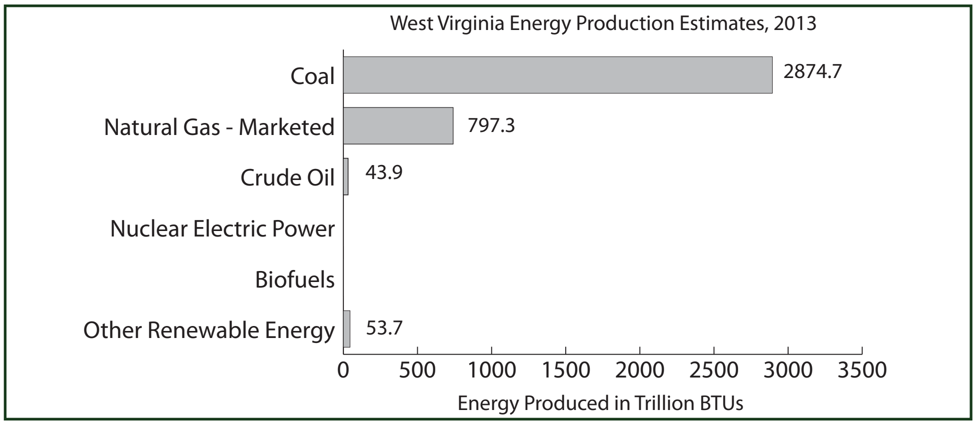
- West Virginia ranked fifth in the nation in total energy production in 2012, producing 4.7% of the nation's total.

- In 2012, West Virginia was the largest coal producer east of the Mississippi River and the second largest in the nation after Wyoming; the state accounted for 12% of the US total coal production that year.

- In 2013, 44% (51 million tons) of the coal that was mined in West Virginia was shipped to other states, and 33% (38 million tons) was exported to foreign countries.

- Coal-fired electric power plants accounted for 95.5% of West Virginia's net electricity generation in 2014, and renewable energy resources—primarily hydroelectric power and wind energy—contributed 3.5%.





Energy

6

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 altering our supply, production, and demand for energy. Increases in temperatures will be accompanied by an increase in energy 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 affecting energy production and supply. For example, 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 types of disruptions affect us both locally and nationally, are diverse in nature, and will require equally diverse solutions.

See Chapter 8: Climate for more information about climate change and its effects on the Southeast.

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 can 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 which 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 for people living in the Southeast are probably not the same as for those in other areas, such as the Southwest or Northeast.

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

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.*

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**, while 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.

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.*

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.

See Chapter 9: Earth Hazards to learn more about extreme weather events.

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 the 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 those of 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.

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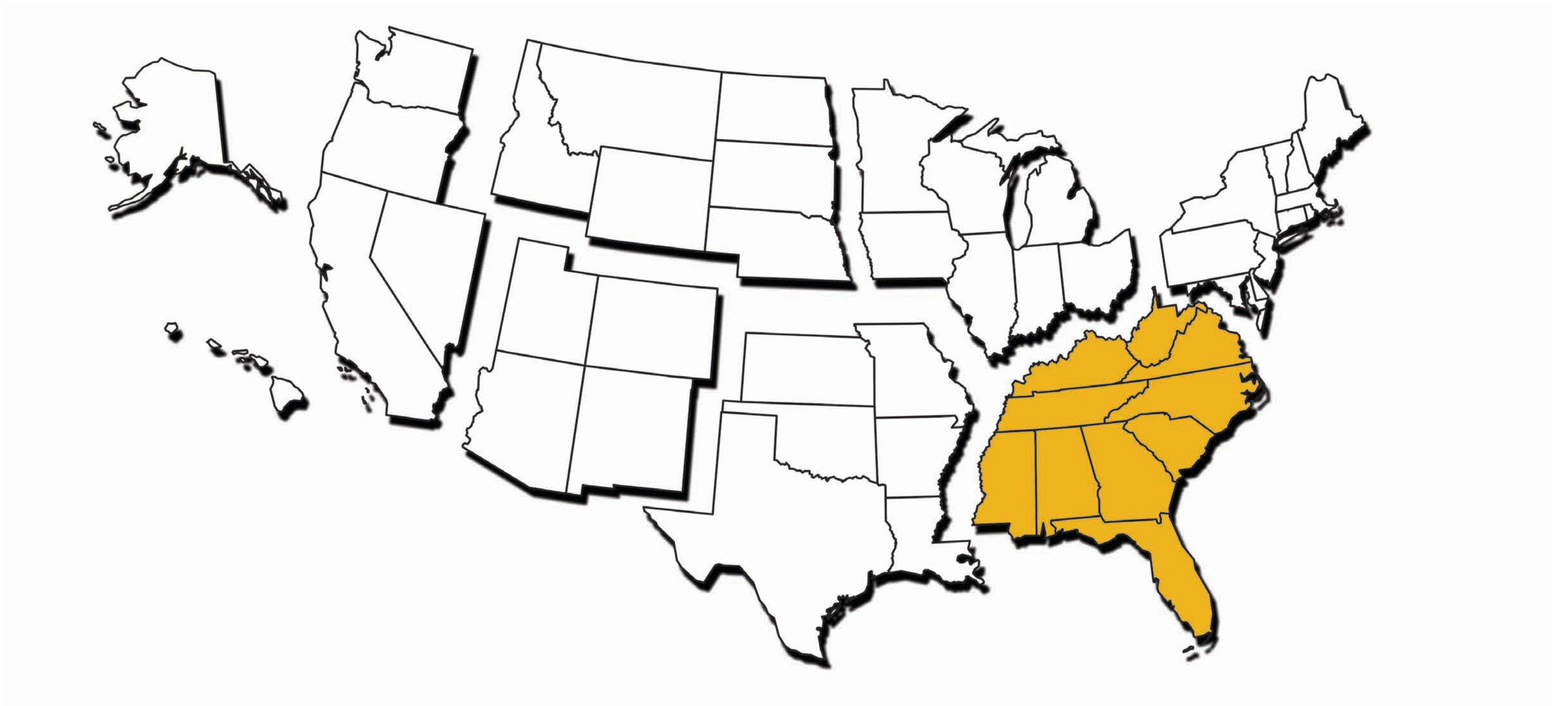

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On the back cover: Blended geologic and digital elevation map of the Southeastern US. Each color represents the age of the bedrock at the surface. Adapted from Barton, K. E., Howell, D. G., Vigil, J. F., *The North America Tapestry of Time and Terrain*, US Geological Survey Geologic Investigations Series I-2781, http://pubs.usgs.gov/imap/i2781.