Chapter 7: Energy in the Midwestern 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 work machines.

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

Exceptions include the use of sails on boats by a very small percentage of the world's population to move people and goods, and the Chinese use of natural gas to boil brine in the production of salt beginning roughly 2,000 years ago.

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

Review

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

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

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

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

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

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

CHAPTER AUTHOR

Carlyn S. Buckler

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Energy

Review

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

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

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

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

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

What do different units of energy mean?

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

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

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

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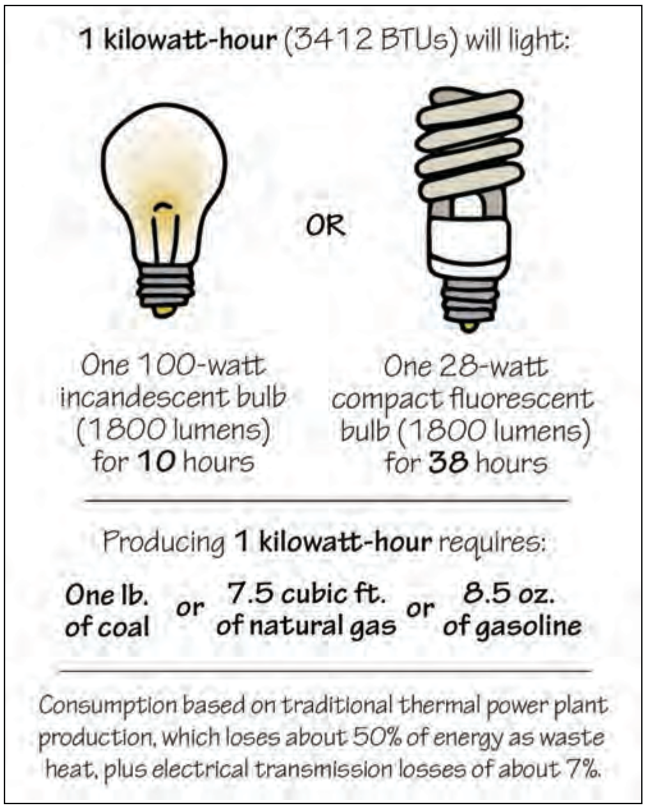

Figure 7.1: Examples of uses and sources of 1 kilowatt-hour.

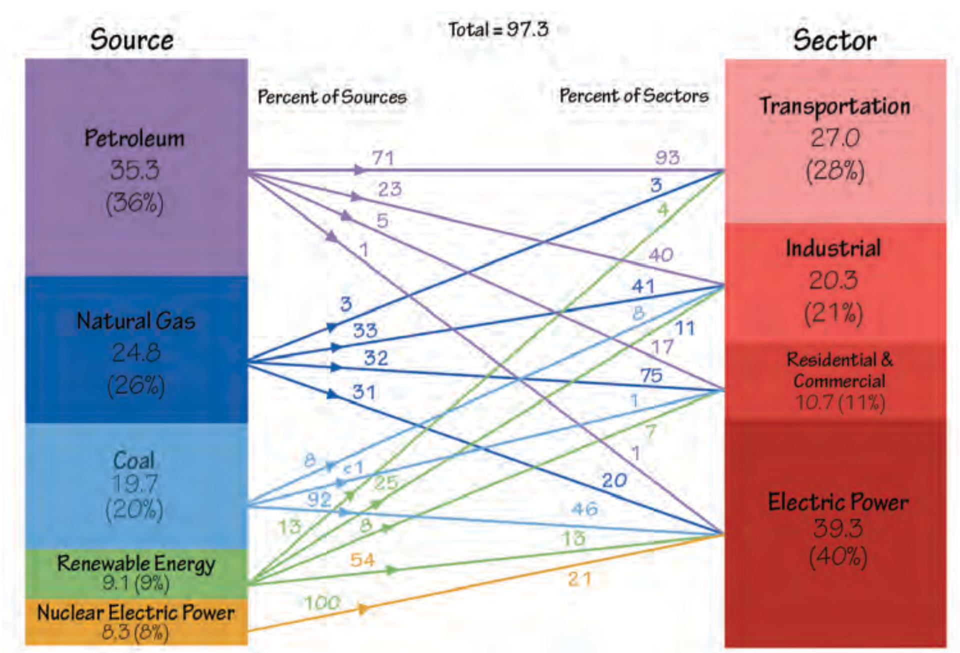

Figure 7.2. US energy production sources and use sectors for 2011. Petroleum provides more energy than any other source, and most of it is used for transportation. More energy is used to generate electricity than for any other use, and electricity is generated by all five energy sources. Nuclear is unique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

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

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

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

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

How do we look at energy in the Earth system?

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

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

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

Becoming "Energy Literate"

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

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

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

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

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

Energy in the Midwestern Regions

The primary energy resources in the Midwest come from fossil fuels. Illinois, Indiana, and Ohio combined represent 13% of the total coal production in the US, and it is the primary source of energy. Illinois was once a major producer of oil, and natural gas production has been increasing in Ohio.

Fossil Fuels

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

Regions

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

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

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

sulfur • a bright yellow chemical element (S) that is essential to life.

Fossil Fuels (continued)

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

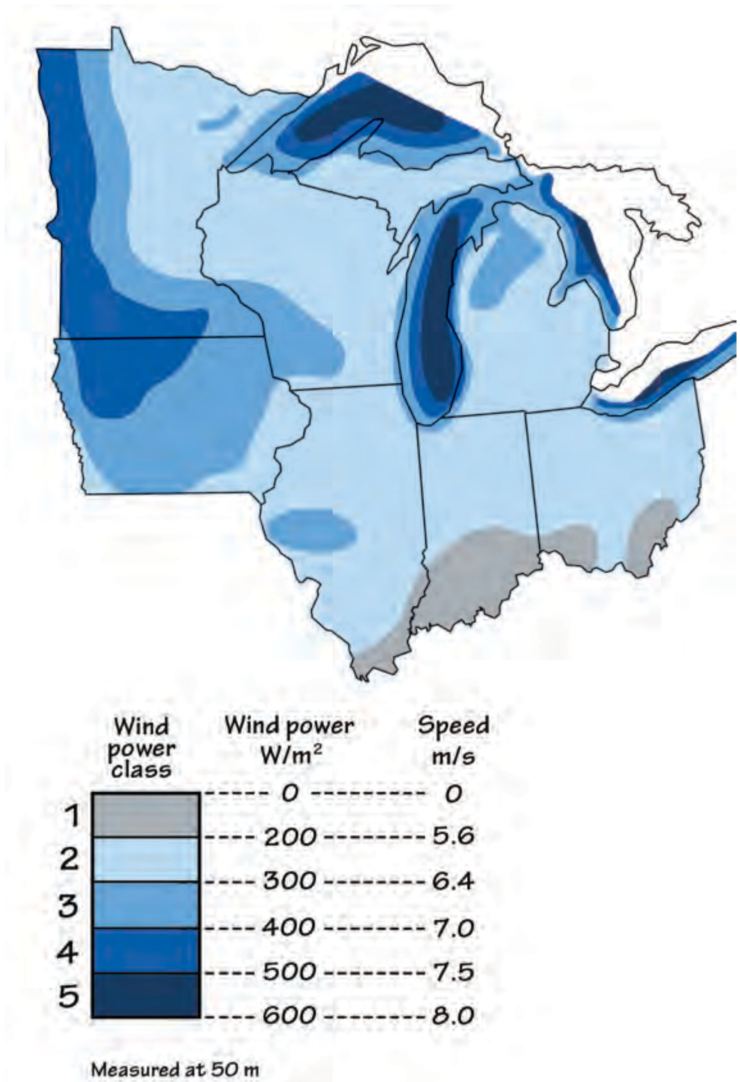

Figure 7.3: Average annual wind power distribution in the Midwest.

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While fossil fuels represent both the majority of energy produced and consumed within the Midwest, growth of renewables has been substantial in the last several years. Between 2011 and 2012, electricity produced from wind increased 30% in the area. While Iowa leads the Midwest in production, both Michigan and Ohio much more than doubled their production in this timeframe. In 2012, wind produced 25% of Iowa's electricity and 15% of Minnesota's (*Figure 7.3*).

Biofuels (from biomass) also represent a significant energy resource throughout the Midwest, with production and consumption rapidly rising. Between 2001 and 2011, ethanol grew from less than 1% (by volume) of US gasoline to 10%. Most gasoline in the US is now blended with 10% ethanol (E10). Ethanol is not as energy dense as gasoline, so it provides about 6% of the energy in E10 gasoline. The Midwestern states are major producers of both ethanol and biodiesel, and production of both has much more than doubled in the last ten years. Liquid biofuels now provide about 1% of US energy while wind provides about 1.5%. As biofuels are produced from many different crops and through a range of different processes, their environmental impact is difficult to measure.

Energy in the Superior Upland
Region 1

Coal is the number one source of energy for this region, but it is all mined outside the Superior Upland. The abundant water resources of this "Land of 10,000 Lakes," however, allow for abundant hydropower. The harvest of oil and natural gas for energy is not significant in the Superior Upland, yet imports of petroleum provide a significant source of power to the region.

Energy in the Central Lowland
Region 2

The use and production of coal is big in this region, providing the majority of power, followed by hydropower and petroleum. The most important sources of coal come from **Pennsylvanian** period deposits in the **Illinois Basin** in Southern Illinois and part of southern Indiana (*Figure 7.4*). Coal from these deposits is relatively **sulfur**-rich **bituminous coal**.

The use of coal has declined in recent decades, associated with environmental concerns about **acid rain**. However, through the widespread use of technology that removes sulfur dioxide at coal-fired plants, mining from these deposits has recently begun to increase again. There are also small Pennsylvanian-age coal deposits in central Michigan.

The largest producer of oil in the region is also the Illinois Basin, which generates about 12,000 barrels a year (*Figure 7.5*). Michigan increased its gas production in the late 1990s with extraction from Late **Devonian** period **sedimentary rocks** of the Antrim Shale, which is part of the **Michigan Basin**. Michigan produces about 1% of the US total, extracting 300 billion cubic feet

Regions 1–2

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

acid rain • *rain or other precipitation that contains high amounts of sulfuric and nitric acid.*

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

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

Michigan Basin • *an inland basin centered on Michigan's Lower Peninsula, which formed when Baltica approached North America in the Ordovician.*

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Region 2

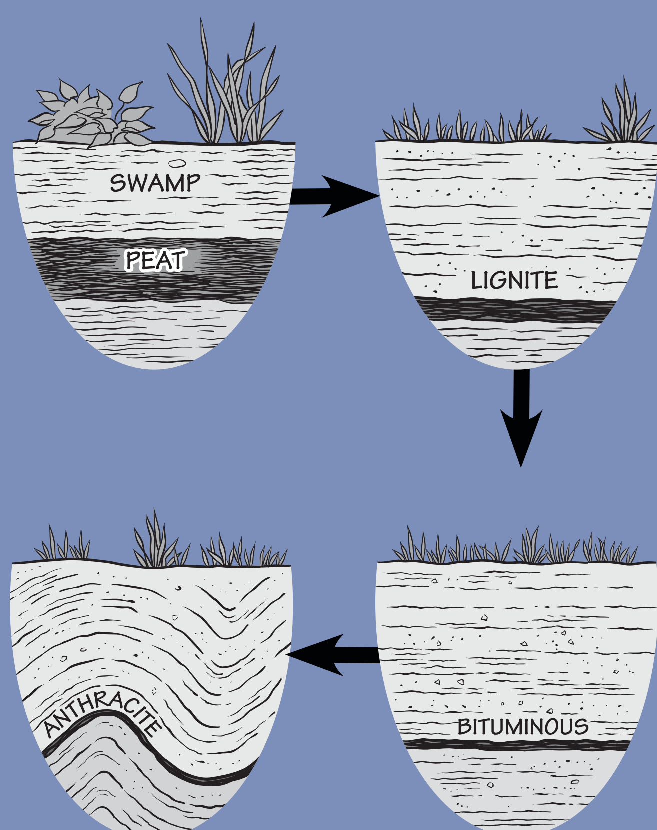
Figure 7.4: Distribution of coal mining in the Midwest.

Figure 7.5: Distribution of oil and natural gas drilling in the Midwest.

Coal

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

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



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

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

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

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

__Appalachian Basin__ • an inland basin, formed by the Taconic and Acadian mountain-building events.

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

__Utica Formation__ • an organic-rich black shale from the Middle Ordovician.

of natural gas per year. Natural gas is also produced in Illinois, Indiana, and western Ohio, but not to a significant degree.

Biofuels (from biomass) also represent a significant energy resource in this region, with production and consumption on the rise. The Central Lowland is also a major oil-refining region. The Chicago area has one of the largest oil refineries in the country, with a capacity of nearly one million barrels a day.

Energy in the Inland Basin
Region 3

The eastern edge of Ohio is a coal-producing region, where mining occurs in the same Pennsylvanian period deposits of the **Appalachian Basin** that have long been famous in Pennsylvania, Kentucky, and West Virginia. Deposits in Ohio are high in sulfur compared to those further east and so have been in less demand since environmental regulations began in the 1990s.

Recently the rate of natural gas production in the region has greatly increased, from both the Appalachian Basin deposits in eastern Ohio and much older **Ordovician** period marine deposits. This production increase has occurred through use of a particular extraction technique, high-volume slickwater hydraulic fracturing, in the **Utica Formation**.

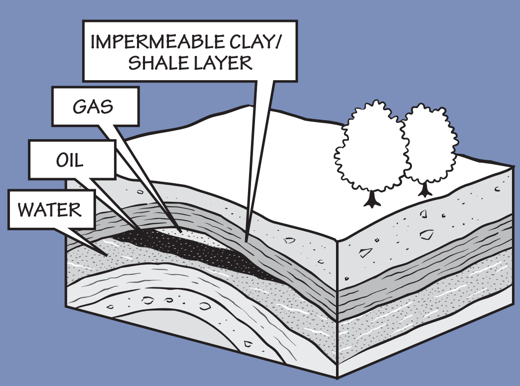
As in the Central Lowlands, because of the significant farming industry in this region, biomass also provides a significant amount of energy in the form of biofuels.

Oil and Gas

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

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

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



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

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

7 Energy

State Facts

Energy Facts by State

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

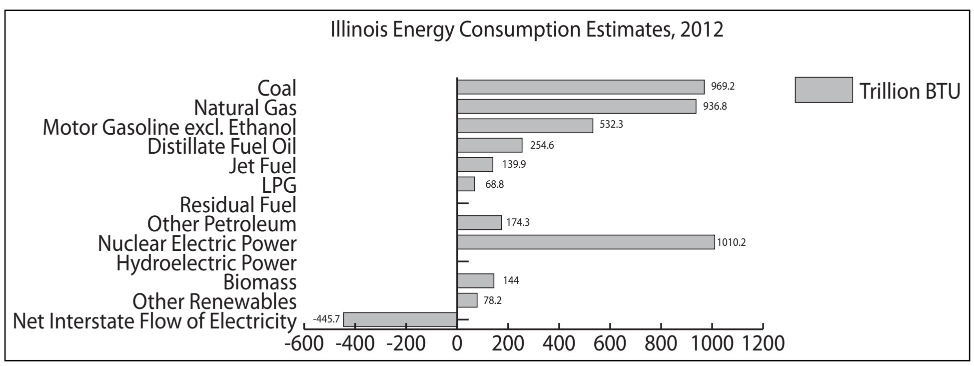
Illinois

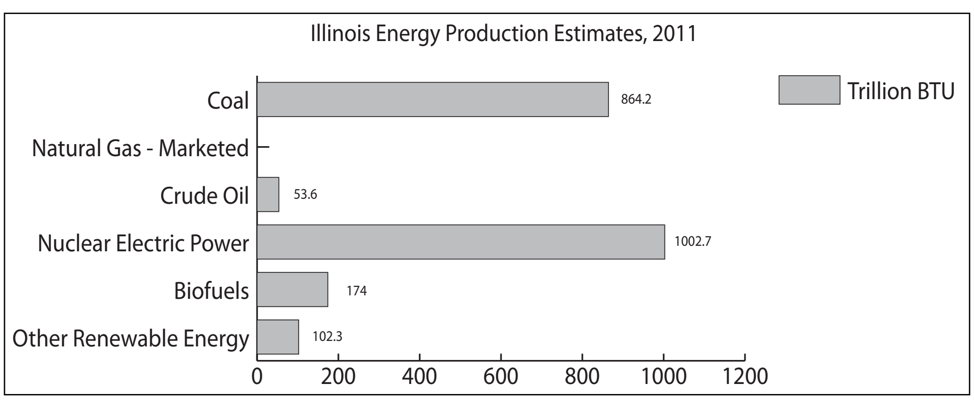
- Illinois is a key transportation hub for crude oil and natural gas moving throughout North America, with over a dozen interstate natural gas pipelines, two natural gas market centers, several petroleum and petroleum product pipelines, and an oil port.

- In 2010, Illinois' producing coal mines had the third largest recoverable coal reserves in the nation. It also ranked first in the nation for both generating capacity and net electricity generation from nuclear power; generation from its nuclear power plants accounted for 12% of the nation's total.

- In 2011, Illinois led the Midwest in crude oil refining capacity and ranked fourth in the nation.

- With a production capacity of 1.5 billion gallons per year, Illinois is a top producer of ethanol; it ranked third in the United States in 2011.





Indiana

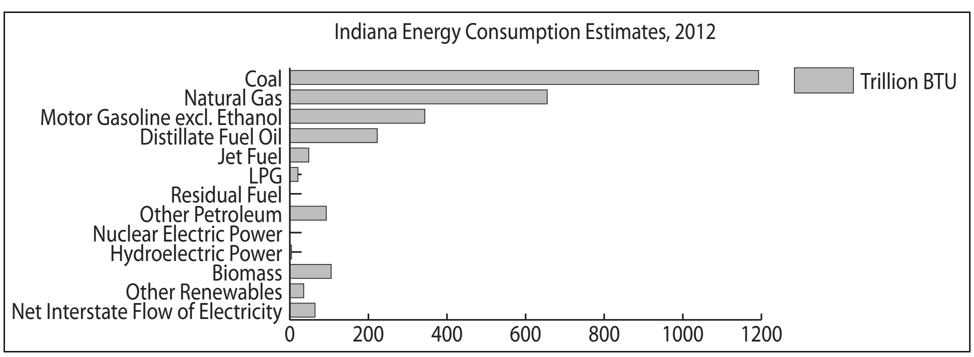
- Indiana's industrial sector, which includes manufacturers of aluminum, chemicals, glass, metal casting, and steel, consumed more energy in 2010 than the residential and commercial sectors combined.

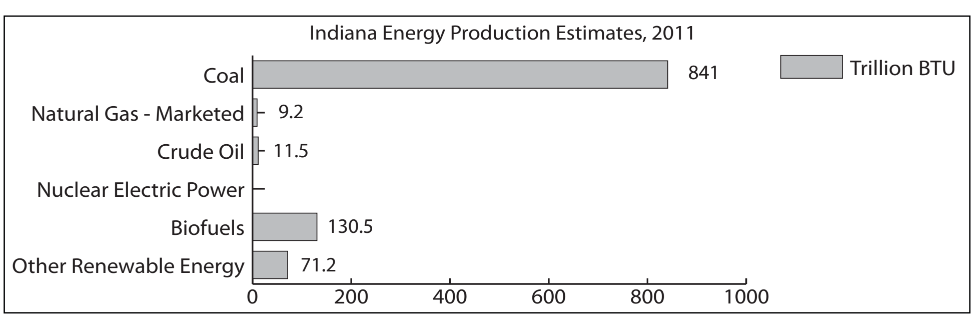
- The largest geothermal heating and cooling system in the United States is being built in Muncie, Indiana.

- Indiana ranked seventh among all states in coal production in 2010, and coal-fired electric power plants provided 83% of Indiana's net electricity generation in 2011.

- In 2011, the Whiting oil refinery had the largest processing capacity of any refinery outside of the Gulf Coast region.

- Indiana is a major producer of ethanol; in 2011, it had 13 ethanol plants capable of producing 906 million gallons per year.





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State Facts

Iowa

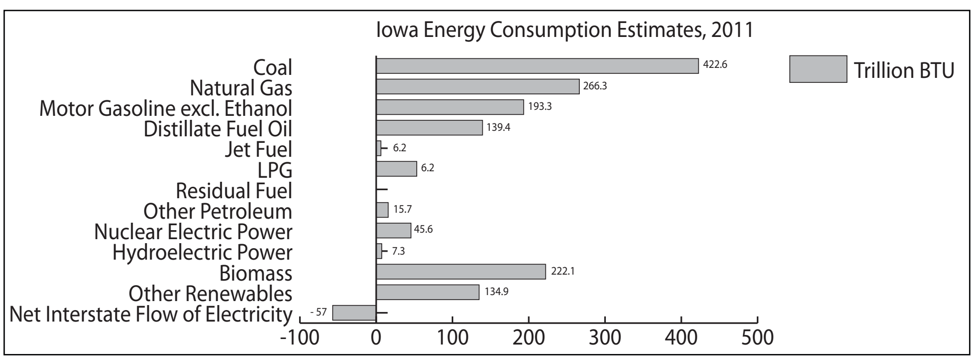
- The use of liquefied petroleum gases (LPG) in the residential and industrial sectors contributes to Iowa's relatively high consumption of LPG.

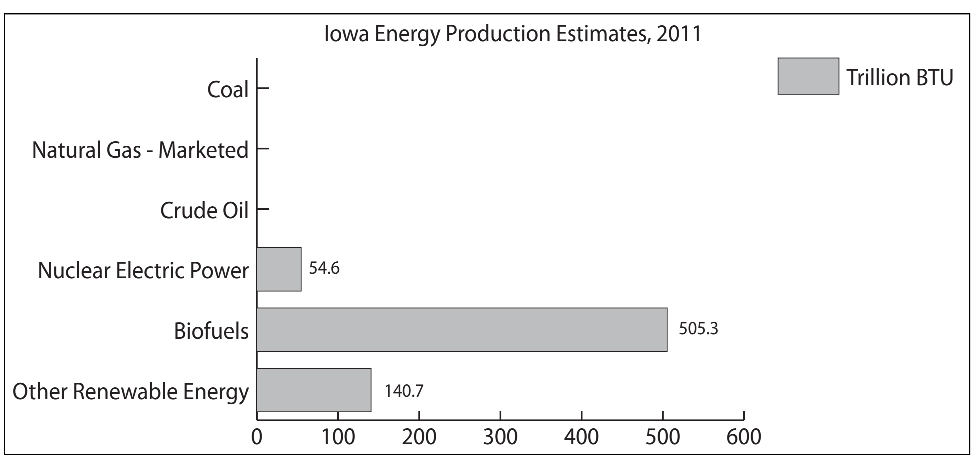
- Iowa was the largest producer of ethanol in the United States in 2011, accounting for 27% of the nation's fuel ethanol production.

- Seventy-seven percent of Iowa's 2011 net electricity generation came from electric utilities; most of the rest came from independent power producers.

- In 2011, Iowa was ranked third in the share of net electricity generation from non-hydroelectric renewable energy resources.

- Wind provided 19% of Iowa's total electricity generation in 2011; it was second only to coal as an energy source for electricity generation in the state.





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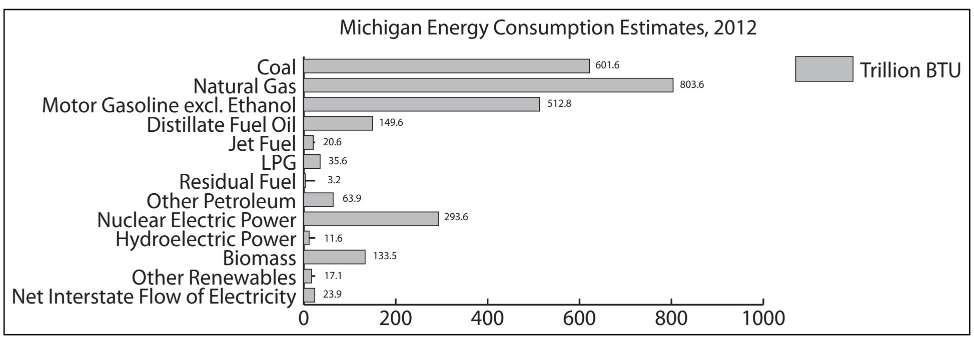
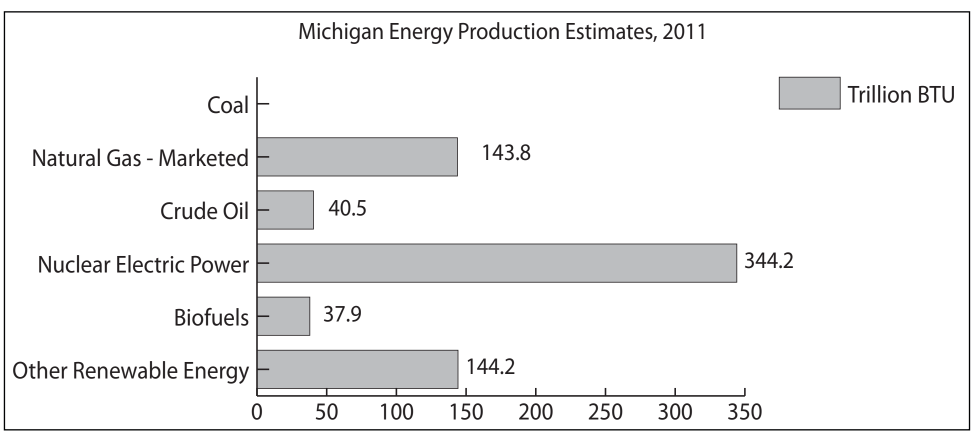
State Facts

Michigan

- In 2010, Michigan had more underground natural gas storage capacity—1.1 trillion cubic feet—than any other state in the nation.
- The Antrim Gas Field, located in Michigan's Lower Peninsula, was ranked 15th in the nation in estimated wet natural gas reserves as of 2009 and produced an estimated 126 billion cubic feet of gas that year.
- In 2011, Michigan's three nuclear power plants, with four reactor units, provided 30% of the state's net electricity generation.
- Michigan used coal for 54% of its net electricity generation in 2011; much of its coal is imported from Wyoming.
- Biomass from Michigan's almost 19 million acres of forest land provided fuel for 54% of Michigan's renewable net electricity generation in 2011.





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State Facts

Minnesota

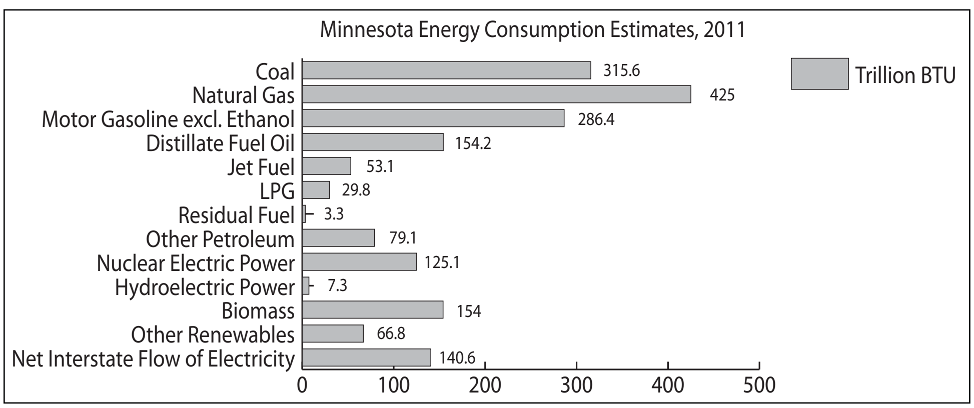
- Two nuclear power plants near Minneapolis-St. Paul, the Monticello reactor and the Prairie Island I and II reactors, account for 22% of Minnesota's net electricity generation.

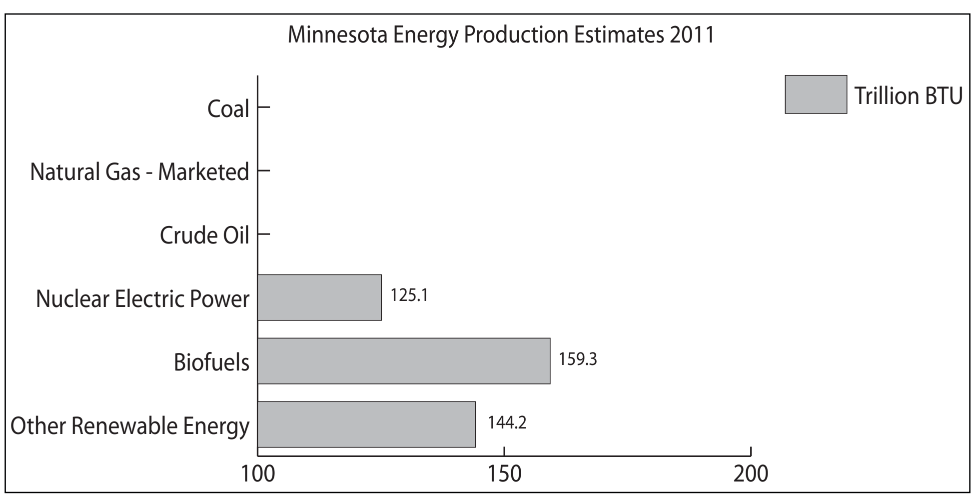
- Despite its extremely cold climate, Minnesota ranked 20th among all states for per capita energy use in 2010.

- Minnesota ranked fourth in the nation for ethanol production in 2011, and has approximately two dozen ethanol production plants.

- Fifty-three percent of the electricity generated in Minnesota came from coal-fired electric power plants in 2011; most of its coal supply was brought in by rail from Montana and Wyoming.

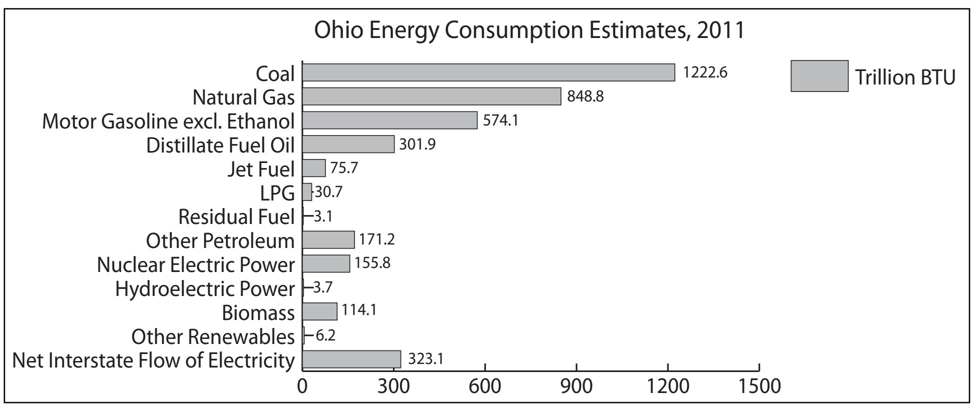
- Minnesota ranked fourth in the nation in net electricity generation from wind energy in 2011; its net generation was 6.8 million MWh in 2011, an increase of 42% from 2010.

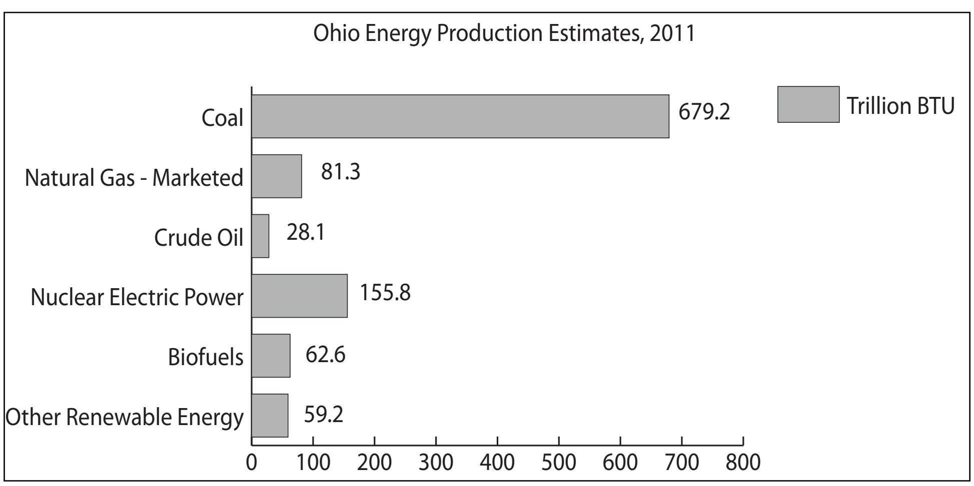




Ohio

- Current interest in Ohio oil and gas exploration is focusing on two of its **shale** formations—the Marcellus Shale and the Utica Shale.
- In August 2003, a transmission failure in Ohio led to the largest blackout in North American history, affecting over 50 million people.
- Ohio had the eighth largest crude oil refining capacity in the nation in 2011.
- Coal fueled 78% of Ohio's net electricity generation in 2011, nuclear energy contributed 11%, and natural gas added another 8.9%.
- Ohio ranked fifth in the nation in 2010 in energy consumption by the industrial sector; in 2011, Ohio ranked third in manufacturing employment, with 5.4% of US manufacturing jobs.





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State Facts

Wisconsin

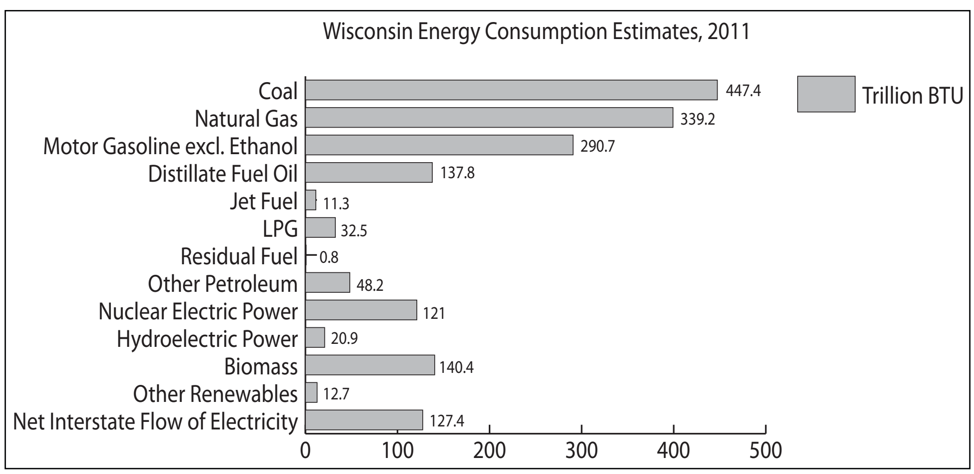
- Wisconsin's industrial sector, which includes energy-intensive industries such as food processing, chemical manufacturing, plastics, and forest products, was the highest energy-consuming sector in the state at 577 trillion Btu in 2010.

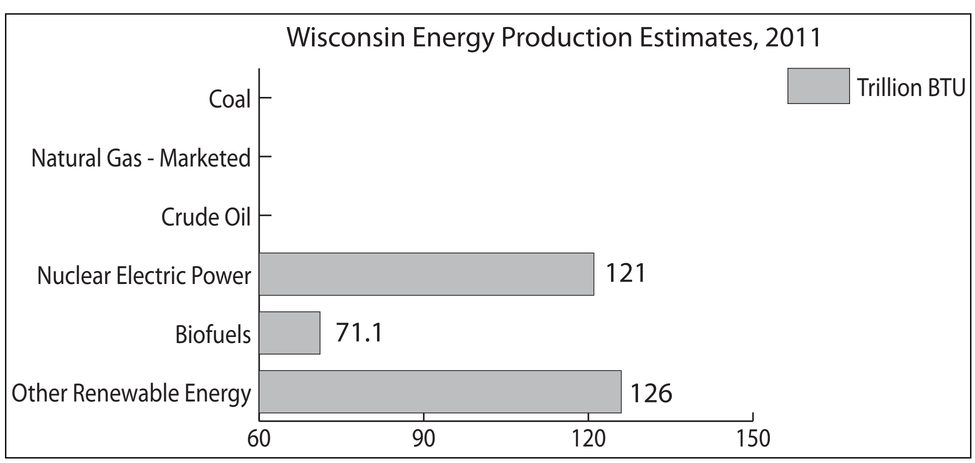
- In 2010, Wisconsin produced 438 million gallons of ethanol and ranked ninth among all states in ethanol production.

- Coal has dominated electricity generation in Wisconsin; in 2011, it provided 63% of the state's net electricity generation.

- Point Beach nuclear power plant's Unit 1 reactor, one of the oldest operating reactors in the United States, started commercial operations in 1970; in 2005, its operating license was extended 20 years (for a total of 60 years).

- In 2011, 8.4% of Wisconsin's net electricity generation came from renewable energy resources, split among conventional hydroelectric power, biomass, and wind.





Energy 7

Climate Change

Energy and Climate Change
the future of energy in the US

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

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

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

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

Some of these changes are grounded in the development of new technologies for energy production and energy **efficiency**; others may be related to changes in behavior. These changes in technology and behavior may go hand in hand; two percent of electricity production now goes to data centers, for example, a

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).*

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

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

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

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.*

use that did not exist in 1985. Additionally, the Internet is rapidly changing other ways we use energy, allowing us to telecommute and changing the way we shop.

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

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

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

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

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

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

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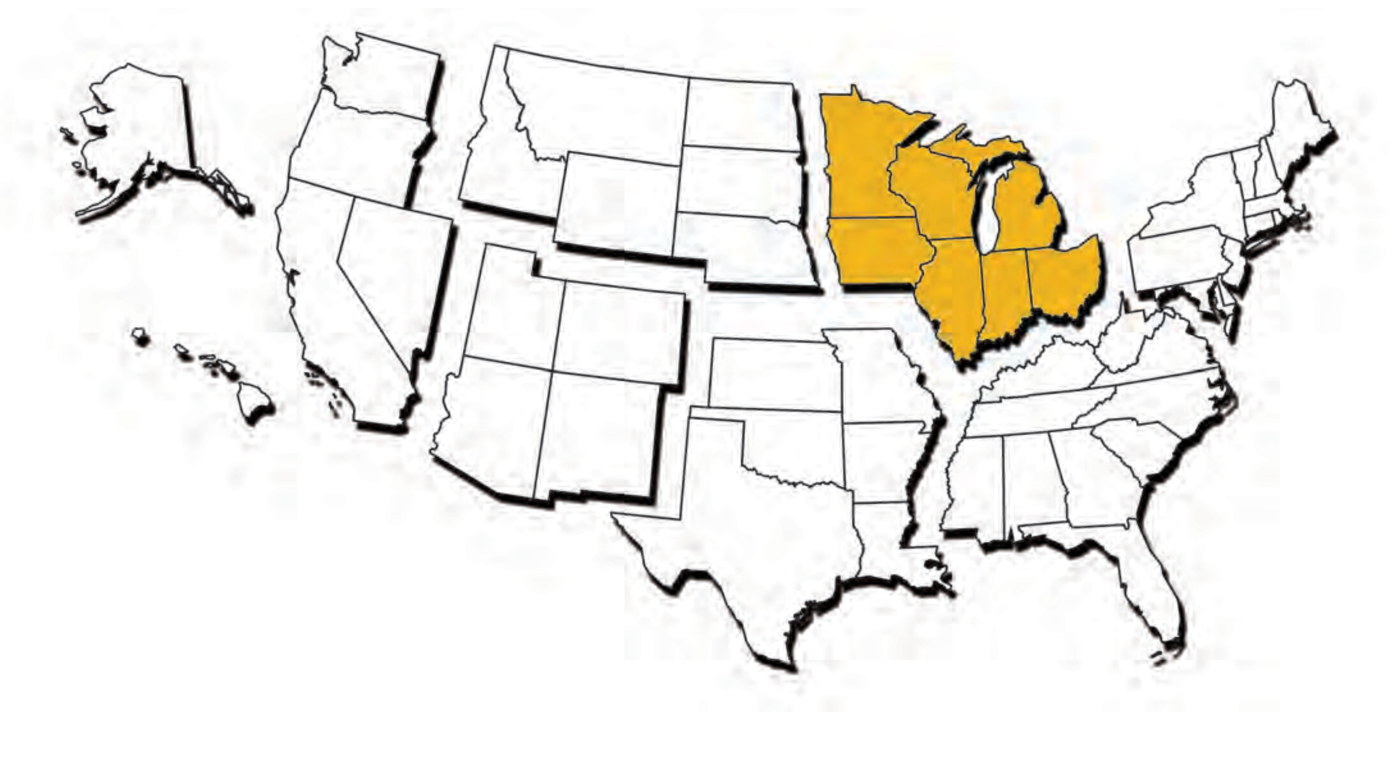
The **Teacher-Friendly** Guide™

to the Earth Science of the Midwestern US



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On the back cover: Blended geologic and digital elevation map of the Midwest. 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.