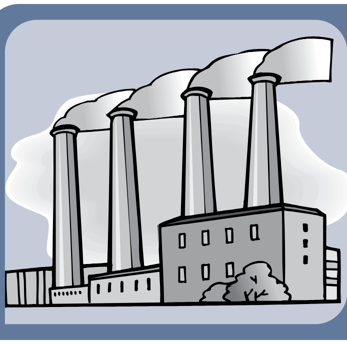


Fuel That Power Plant

Students construct and experiment with simple electrical circuits using batteries, wires, and bulbs.

Grade Level: 5–8

Subject Areas: English Language Arts, Mathematics, Science, Social Studies

Setting: Classroom

Time:
Preparation: 20 minutes
Activity: Three 50-minute periods

Vocabulary: Megawatt, Unit train

Major Concept Areas:

- Development of energy resources
- Consumption of energy resources

Getting Ready: Wisconsin state highway maps are available from bookstores, map stores, and service stations. Copies may also be ordered from the Wisconsin Department of Tourism or the Wisconsin Department of Transportation. Maps may be laminated and written on with non-permanent markers. On index cards, write the name of each power plant listed on the Wisconsin Power Plant Information Sheet. An answer key map showing the locations of the power plants and the fuel supply routes is provided.

Objectives

Students will be able to:

- identify where electric power plants are located in Wisconsin;
- identify the conditions that influence where power plants are located;
- describe how fuel is delivered to a power plant;
- recognize that Wisconsin's electric power plants depend primarily on fossil and nuclear fuels that are imported into the state; and
- recognize that modern power plants are dependent on the transportation industry.

Rationale

Mapping the locations of Wisconsin's major electric power plants, showing their fuel supply routes, and investigating why many power plants are located next to large bodies of water helps students become aware of the resources needed and the geographic and environmental factors required for the large-scale production of electricity.

Materials

- Copies of Wisconsin state highway maps (see **Getting Ready**)
- Pencils
- Copies of the following pages:
  - ***Wisconsin Power Plant Information Sheet***
  - ***Facts about Coal***
  - ***Facts about Natural Gas***
  - ***Power Plant Fuel Supply Routes***
- Index cards
- Highlighting markers of different colors
- Find additional resources related to this activity on keepprogram.org > Curriculum & Resources

Background

(Also see ***Facts about Coal***, ***Facts about Nuclear Energy***, ***Facts about Oil***, and ***Facts about Natural Gas***.) Power plants that run on fossil and nuclear fuels produce 90 percent of the electricity used in Wisconsin. How these fuels are delivered to the plants depends not only on the type of transportation used, but on the transportation routes and the locations of the power plants as well. Plotting the locations of Wisconsin's major power plants and tracing their fuel supply routes leads to a clearer understanding of these relationships.

Patterns emerge when power plant locations are plotted on a map of Wisconsin. One pattern shows that most power plants are situated by lakes or rivers, especially large ones like Lake Michigan and the Mississippi and Wisconsin Rivers. The main reason power plants are built next to bodies of water is because water is used to remove excess heat produced by the power plant as it generates electricity (see ***How Water Is Used to Cool an Electric Power Plant***). Building coal-fired power plants by navigable rivers like the Mississippi or by large lakes like Lake Michigan has the added advantage of providing a delivery route for barges or boats that carry large quantities of coal to these plants.

Fuel can be delivered to power plants in other ways as well, which means that the river or lake near the power plant does not have to be navigable. Unit trains—special trains that only transport coal—as well as other types of freight trains deliver a significant amount of coal to many of the state's coal-fired power plants. Power plants that burn oil or natural gas are supplied by pipelines. Nuclear fuel made from enriched uranium is delivered to Wisconsin's nuclear power plant by truck. The location

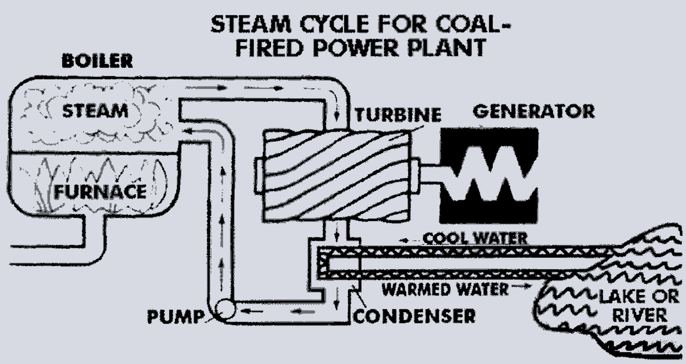
How Water Is Used to Cool an Electric Power Plant

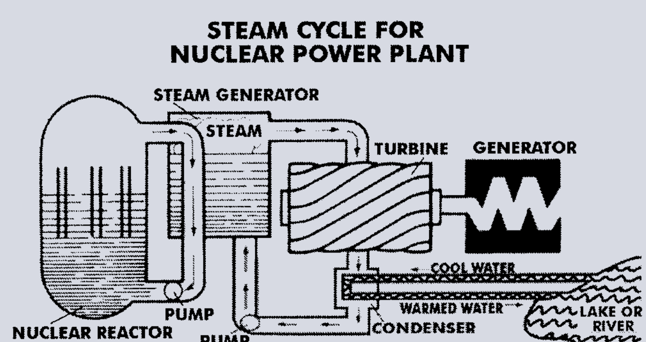
The main reason large coal and nuclear power plants are built next to rivers and lakes is so that cool water can be used to remove excess heat produced by the power plants as they generate electricity. It is often easier and more economical to use river or lake water to cool a large power plant than it is to use the surrounding air or other means.

Coal and nuclear power plants generate electricity using a steam cycle (see the diagrams of the coal and nuclear power plant steam cycle below). Energy from burning coal or nuclear fission is used by a boiler to turn water into steam. Under high pressure, the steam spins the turbine. The spinning turbine rotates the generator, causing it to produce electricity. After passing through the turbine, the steam is cooled back into liquid water using a condenser and then pumped back to the boiler. Cool water from a lake or river is piped directly into the power plant's condenser tubes, where it absorbs the heat from the steam. The warmed water is then piped back into the river or lake. The water used in the steam cycle does not mix with the water piped into and out of the condenser.

Using a river to cool a power plant has an added advantage—the power plant can use cool water from upstream and release the heated water downstream. Sometimes the heated water is released into an artificial pond and allowed to cool there before being put back into a river or lake.

Oil- and natural gas-fired power plants burn these fuels to create combustion gases that spin the turbine. These gases do not need to be condensed as part of a closed cycle the way steam does. Instead, they are released as exhaust into the surrounding air. Oil- and natural gas-fired power plants are usually smaller than coal and nuclear plants. They are usually used during peak summer conditions when the demand for electricity is high.





of existing railways, pipelines, and major highways are important factors to consider when deciding where to build a new power plant.

Reliable fuel supply routes to Wisconsin's power plants are important, because the state does not have its own fossil or uranium resources (see relevant ***Fact Sheets***). A look at the maps titled U.S. Coal Deposits and U.S. Natural Gas Proved Reserves supports this point (see ***Power Plant Fuel Supply Routes*** for further details).

Another pattern that emerges when plotting power plant locations is that most are found in the southern and eastern parts of Wisconsin. This is because most of the state's population is located in these areas. Fewer people live in the northern and western parts of Wisconsin; hence fewer power plants are needed there. In addition, some northern and western Wisconsin communities get their electricity from power plants located in neighboring Minnesota. Power plants in Minnesota, like those in Wisconsin, are also located near rivers and lakes, transportation routes, and populated areas.

Procedure

Orientation

Post a copy of a Wisconsin state highway map on the wall. Divide the class into groups of two or three. Give each group a Wisconsin state highway map and a set of markers. Have each group locate and mark on the map the city or town in which they live or go to school.

If students need to review basic mapping skills, have each group locate major cities and towns, highways, and other features on the map. Examples of these major features might include Milwaukee, Madison, Green Bay, the Wisconsin River, the Mississippi River, Lake Michigan, major highways, and railroad lines (if shown). Make this activity a contest or a scavenger hunt by listing a number of cities, towns, rivers, and other features on the board and seeing which group finds them first. Students should become familiar with the map legend, the map index, and using the number-letter descriptions (such as 6-E, 7-C, etc.).

Steps

1. Have students discuss whether they live near a fossil fuel or nuclear power plant or have seen one while traveling around Wisconsin. What have they observed through sight, sound, and smell? The students could write down their impressions in one or two paragraphs and then share them with the class.

2. Ask students where they think they would find electric power plants in Wisconsin. They should use the map to indicate locations by marking them lightly in pencil. Have them discuss why they think power plants are found in these locations.

3. Hand out a ***Wisconsin Power Plant Information Sheet*** to each group and review the information. Review the definition of a megawatt to help students understand how this unit is related to a power plant's size. Mention that the ***Wisconsin Power Plant Information Sheet*** only lists major coal and nuclear power plants found in the state, along with some natural gas-fired and oil-fired power plants. There are also plants that burn multiple fuels including biomass and wood. It does not list hydroelectric dams, wind generators, or other smaller power plants that run on fossil fuels or wood.

4. Tell each group to mark with a dot the location of the power plants listed on the ***Wisconsin Power Plant Information Sheet***. Label the type of fuel the power plant uses by writing "C" (coal), "N" (nuclear), "O" (oil), "NG" (natural gas), or "W" (wood) inside or near the dot. Students can vary the size of the dots to correspond to the different sizes of the power plants.

5. After the power plant locations have been mapped, have each group comment on the pattern they see. Some of the students' observations should include the following ideas:
   - Many power plants are located near major rivers and Lake Michigan
   - There are fewer power plants in northern and western Wisconsin than in southern and eastern Wisconsin

   Have the class discuss possible reasons for these patterns. Some reasons may include access to water or fuel supply routes and location near cities or populated areas. Ask students why many power plants are located near large bodies of water.

6. Distribute one or two index cards with the names of power plants to each group. Tell students they will be responsible for gathering and recording information about these power plants during the activity and will present what they learned to the class later on. Have each group match the power plant listed on the card to its map location.

7. Briefly review with students how large electric power plants use water for cooling purposes (see ***How Water Is Used to Cool an Electric Power Plant***).

8. Ask the students where they think the power plants listed on the index cards get their fuel. Hand out copies of U.S. Coal Deposits and U.S. Natural Gas Proved Reserves from ***Facts about Coal*** and ***Facts about Natural Gas***. Students should see that fuel for Wisconsin's power plants comes from outside the state because Wisconsin does not have any fossil fuels or uranium for nuclear fuel of its own.

9. Ask each group to develop their own fuel supply routes through Wisconsin for the power plants listed on the index cards they received. They should explain where fuel for their power plants comes from and sketch possible routes to the plants by marking them lightly in pencil on the Wisconsin state maps. They should also describe how the fuel is transported (by barge, boat, train, truck, or pipeline).

10. Hand out the ***Power Plant Fuel Supply Routes*** to each group. Have each group create a legend that assigns colors and combinations of solid and dashed lines to represent coal supply routes using unit trains, other kinds of freight trains, barges, and boats. They should trace oil, natural gas, and nuclear supply routes as well.

11. Have each group read the ***Power Plant Fuel Supply Routes*** descriptions for the power plants on their index cards and mark their fuel supply routes on the map. They should draw lines in accordance with the legend they created, beginning their routes from locations just outside of Wisconsin and placing arrows at the end of the routes when they reach the power plants.

Closure
Each group should summarize the information they learned about the power plants listed on the index cards. Have students come up to the Wisconsin state map posted in the front of the classroom and make a short presentation about their power plants. The presentation should include marking where the power plants are located (the index cards can be taped near the marks if space allows), drawing the fuel supply routes, and commenting on why the power plants are located where they are (near a major body of water, population density, etc.).

When students have marked all the supply routes, have the class comment on what they see. Their observations might include the following:

- There are many different ways in which fuel is transported to the power plants
- There may be more than one fuel supply route to a given power plant
- Coal can be delivered by barges, boats, trains, or trucks to coal-fired power plants

To supplement the presentation, students can be given time to write or call the public relations representatives of electric utilities that own and operate the power plants for more details. Help the class develop a list of questions they have about the plant. Students should find out who to contact, and then develop and conduct a phone interview or mail questionnaire.

Assessment
Formative

- Did students use the information from the ***Wisconsin Power Plant Information Sheet*** to find and properly mark the power plant locations?
- Did students use the information from the ***Power Plant Fuel Supply Routes*** to find and properly mark the fuel supply routes to the power plants?
- What conclusions did students draw about the location of power plants in Wisconsin?
- How thoroughly did students present information about their power plants to the rest of the class?

Summative
The conditions that influence the location of power plants in Wisconsin generally apply to all power plants. Assess students' understanding of these influences by asking them to:

- recommend a possible location and fuel supply route for a power plant that may be built in Wisconsin in the future; and
- predict where power plants and fuel supply routes might be found in other neighboring states such as Minnesota, Illinois, Iowa, or Michigan.

Extensions
Contact the utility that serves your area to see if a tour of a power plant can be arranged or if a utility representative can give a presentation on power plants to the class. Visit keepprogram.org for addresses of some utilities.

Have students research other ways that energy resources are transported to homes, businesses, farms, service stations, etc., using pipelines (oil, natural gas), transmission lines (electricity), trucks (oil, propane, wood), and oceangoing ships such as supertankers, etc.

(oil, coal, liquefied forms of natural gas).

Unit trains are used to supply subbituminous coal to the Columbia power plant located near Portage, Wisconsin. Each unit train consists of 115 hopper cars, with each hopper car holding 100 tons (90 metric tons) of coal.

- If the Columbia power plant burns 3.6 million tons (3.24 million metric tons) of coal per year, how many unit trains are needed to deliver coal to Columbia each year? (Answer: 313 unit trains)

Suppose the Columbia power plant burns 1.4 million pounds (630,000 kg) of coal per hour when the demand for electricity is greatest. Suppose this demand for electricity occurred over the course of an entire day.

- How many tons of coal would Columbia burn in a day? (Answer: 16,800 tons [15,120 metric tons] of coal)
- How many unit trains would be needed to deliver coal to Columbia in a day? (Answer: 1.46 unit trains)
- How many hopper car loads of coal does this represent?
- (Answer: 168 hopper car loads of coal)

Related KEEP Activities

Conduct the surveys from "At Watt Rate?" to orient students to the ways they use electricity in the home. Students can investigate how a nuclear power plant works in "Harnessing Nuclear Energy." They can learn more about services their power plant provides through "Reading Utility Bills" and "Reading Utility Meters." Have students look into the different occupations that are involved in transporting fuel to and operating a power plant in "Careers in Energy." The activity "Advertising Energy" can be used by students to analyze public relations strategies employed by an electric or natural gas utility.

Further investigations of different types of resources can accompany this activity. Have students experiment with procedures described in "Electric Motors and Generators" to simulate electricity generation. Also, students can explore alternative forms of producing energy through "The Miracle of Solar Cells" and use "Why Use Renewable Energy?" to interview people who do not get their electricity from a power plant.

Credits

Activity adapted from University of Northern Iowa, Center for Energy and Environmental Education, Energy Education Curriculum Project. "Getting to Know Iowa's Power Plants." pp. SS-1 to SS-3 in *Iowa's Electrical Energy Sources Today*. Cedar Falls, Iowa: University of Northern Iowa, Center for Energy and Environmental Education, 1995. Used by permission. All rights reserved.

"Steam Cycle for Coal-Fired Power Plant" and "Steam Cycle for Nuclear Power Plant" illustrations adapted from Wisconsin Public Service Corporation. *Generating Electricity...at Wisconsin Public Service*. p. 2. Green Bay, Wisc.: Wisconsin Public Service Corporation, 1995.

Answer key map showing power plant locations and fuel supply routes adapted from "Location of Major Power Plants in Wisconsin" in Wisconsin Division of Energy, Department of Administration. *Wisconsin Energy Statistics*. Link to most recent version found on the KEEP website.

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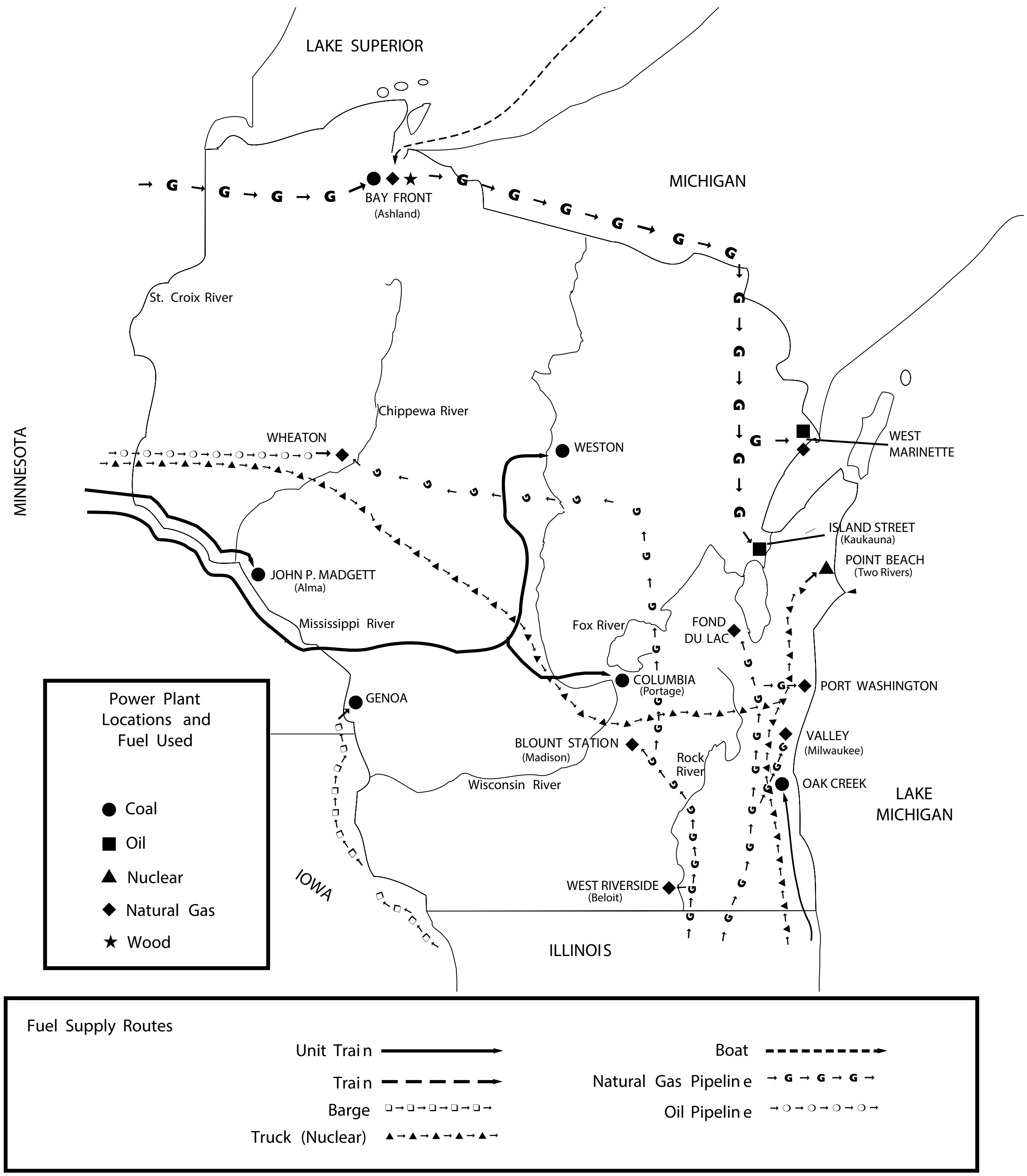
Wisconsin K-12 Energy Education Program (KEEP)
College of Natural Resources
University of Wisconsin-Stevens Point

Answer Key
Power Plant Locations & Fuel Supply Routes



Wisconsin Power Plant Information Sheet

Introduction

Information on selected power plants in Wisconsin is grouped by the utilities that operate them and given below. These power plants include Wisconsin's major coal and nuclear power plants plus selected natural gas-fired and oil-fired plants. The list does not include hydroelectric dams, wind generation, or other smaller plants that burn coal, oil, or natural gas.

Megawatts and the Size of Power Plants

Electrical power is measured in units called watts. However, watts are too small to describe the electrical output of a power plant. The megawatt, a multiple of the watt, is used instead. A megawatt is equal to one million watts, or the electrical output of ten thousand 100-watt light bulbs. Most of the large power plants in Wisconsin produce electrical power in the hundreds of megawatt range, with the largest power plants producing more than 1,000 megawatts under full operating conditions.

Power Plant Name	Location	Size in Megawatts	Fuel Type
Alliant Energy, Madison Gas and Electric Company & Wisconsin Public Service Corporation			
Columbia 1,2	Wisconsin River and intersection of US 151 and State Highway 16, south of Portage	1,023	Coal
Alliant Energy			
Fond du Lac 2, 3	Just south of intersection of US 151 and US 41, south of Fond du Lac	191	Natural Gas
West Riverside Energy Center	Located north of Beloit, at 1401 W B R Townline Road just west of the Rock River	675	Natural Gas
Dairyland Power Cooperative			
John P. Madgett Station	Mississippi River, just south of Alma	400	Coal
Genoa	Mississippi River, just south of Genoa	379	Coal
Madison Gas and Electric Company			
Blount Station	Downtown Madison, just east of the State Capitol	100	Natural Gas

Wisconsin Power Plant Information Sheet

Power Plant Name	Location	Size in Megawatts	Fuel Type
Xcel Energy (Northern States Power Company)			
Bay Front	Chequamegon Bay at Ashland	56	Coal, Natural Gas, Wood
Wheaton	Chippewa River, just north of Eau Claire	330 summer 430 winter	Natural Gas, Oil
NextEra Energy Resources			
Point Beach	Lake Michigan, just north of Point Beach State Forest, which is north of Two Rivers	1193	Nuclear
We Energies (Wisconsin Electric Power Company)			
Port Washington	Lake Michigan at Port Washington, north of Milwaukee	1,150	Natural Gas
Oak Creek	Lake Michigan at Oak Creek, south of Milwaukee	1,135	Coal
Valley	Lake Michigan in downtown Milwaukee	272	Natural Gas
Wisconsin Public Service Corporation			
West Marinette 31, 32, 33	Southwest and outside of the city of Marinette	187	Natural Gas, Oil
Weston	Wisconsin River, just south of Wausau and West of Interstate 39 (US 51)	945	Coal
Wisconsin Public Power, Inc. (WPPI)			
Fond du Lac 1, 4	Just south of intersection of US 151 and US 41, south of Fond du Lac	154	Natural Gas, Oil
Island Street Peaking Plant	770 Island Street, downtown Kaukauna	52	Natural Gas

Power Plant Fuel Supply Routes

Introduction

You have just marked the locations of a number of power plants found in Wisconsin. The next step is to mark the routes showing how fuel is delivered to the power plants. Descriptions of the fuel supply routes for each of the power plants are given below. Be aware that more than one route may be used to deliver fuel to a power plant.

A unit train is a special kind of freight train that only transports coal and uses up to 115 hopper cars. Freight trains are made up of a mix of hopper cars for transporting coal and boxcars, flatcars, and other cars for transporting other kinds of freight. Your Wisconsin state map may show railroad routes. If so, the route descriptions below should help you locate them.

Fuel Supply Route for the Columbia Power Plant (Portage)

Coal is delivered to the Columbia power plant by unit train from coal mines in Wyoming, Montana, and other parts of the western United States. The unit train route begins on the Minnesota side of the Mississippi River at its meeting point with the St. Croix River. The train route continues along the Minnesota side of the Mississippi until it reaches La Crosse. The route crosses the Mississippi at La Crosse and follows Interstate 90 to Tomah, continuing on Interstate 90-94 to Wisconsin Dells. From Wisconsin Dells, the train route continues just north of the Wisconsin River to Portage and then to the Columbia plant.

Fuel Supply Route for the Fond du Lac 1, 2, 3, 4 Power Plants

Natural gas is delivered to the Fond du Lac power plant by pipeline from natural gas fields in Louisiana, Texas and Oklahoma. The pipeline route begins at the Wisconsin-Illinois border between the town of Zenda and State Highway 120 in southern Walworth County. The pipeline continues to Burlington and passes west of Milwaukee through Muskego, New Berlin, and Brookfield to West Bend. From West Bend, the pipeline continues north to the town of Beechwood in southwestern Sheboygan County. From Beechwood, the pipeline continues northwest to a point just south of the intersection of US 151 and US 41 where the Fond du Lac plant is located.

Fuel Supply Route for the West Riverside Energy Center (Beloit)

Natural gas is delivered to the Riverside power plant by pipeline from natural gas fields in Louisiana, Texas and Oklahoma. The pipeline route begins at the Wisconsin-Illinois border just east of Beloit. It follows Interstate 90 north and angles northeast toward Shopiere. At East L T Townline Road it turns west to the plant located on West B R Townline Road on the west side of the Rock River.

Fuel Supply Route for the John P Madgett Power Plant (Alma)

Coal is delivered to the John P. Madgett power plant by unit train from coal mines in Wyoming, Montana, and other parts of the western United States. The unit train route begins on the Wisconsin side of the Mississippi River at its meeting point with the St. Croix River. The train route continues along the Wisconsin side of the Mississippi until it passes just south of the town of Alma, where the Alma plant is located.

Fuel Supply Routes for the Genoa Power Plant

Coal is delivered to these power plants by barges traveling up the Mississippi River carrying coal from mines in Montana and Wyoming. The coal is brought by unit train to Keokuk and East Dubuque, Iowa, which are located on the Mississippi River. The coal is loaded onto barges and transported up the Mississippi, stopping at the Genoa Plant.

Power Plant Fuel Supply Routes

Fuel Supply Route for the Blount Station Power Plant (Madison)
Natural gas is delivered to the Blount Station power plant by pipeline from natural gas fields in Louisiana, Texas and Oklahoma. The pipeline route begins at the Wisconsin-Illinois border just east of Beloit. The pipeline follows Interstate 90 north and turns east and north again to go around Janesville along Highway 14. In Anderson, it angles northwest through Indianford and Kegonsa until reaches the Blount Station in downtown Madison.

Fuel Supply Route for the Bay Front Power Plant (Ashland)
Coal is delivered to the Bay Front power plant by boat from Ashtabula, Ohio, a port city on Lake Erie. The coal is transported to Ashtabula from coal mines in West Virginia, Kentucky, and other parts of the eastern United States.

Natural gas is delivered to the Bay Front plant by pipeline from natural gas fields in Alberta, Canada. The pipeline route begins at the Wisconsin-Minnesota border south of Superior in Douglas County. The pipeline continues south of Superior to the town of Iron River in Bayfield County and on to Ashland.

Wood from the surrounding area is delivered to the Bay Front plant by truck.

Fuel Supply Route for the Wheaton Power Plant
Natural gas is delivered to the Blount Station power plant by pipeline from natural gas fields in Louisiana, Texas and Oklahoma. The pipeline route begins at the Wisconsin-Illinois border just east of Beloit. The pipeline follows Interstate 90 north and turns east and north again to go around Janesville along Highway 14. In Anderson, it angles northwest through Indianford and Kegonsa. It then travels north through Rio, Montello, Neshkoro, and crosses Highway 10 just east of Weyauwega. The pipeline then parallels the north side of Highway 10, turning west to Bankerville. The pipeline then angles northwest toward Eau Claire to the Wheaton plant near Highway 29.

Fuel Supply Route for the Point Beach Power Plant (Two Rivers)
Trucks deliver nuclear fuel to the Point Beach power plant from a nuclear fuel assembly plant in Columbia, South Carolina. The truck route begins at the Wisconsin-Illinois border at Interstate 94 in Kenosha County. The route continues along I-94 through Milwaukee to Interstate 43, where it continues north to Manitowoc and beyond. The truck route leaves I-43 between the Two Rivers (State Highway 310) and the Bellevue (State Highway 29) exits and continues east toward Lake Michigan until it arrives at the Point Beach plant.

Fuel Supply Route for the Port Washington Power Plant
Natural gas is delivered to the Port Washington power plant by pipeline from natural gas fields in Louisiana, Texas and Oklahoma. The pipeline route begins at the Wisconsin-Illinois border near Highway 120 in southern Walworth County. The pipeline continues north toward Burlington and passes west of Milwaukee through Muskego, New Berlin, and Brookfield. North of Jackson the pipeline turns east just south of County Road NN until it reaches Port Washington where the plant is located.

Fuel Supply Route for the Oak Creek Power Plant
Coal is delivered to the Oak Creek power plant by unit train. The unit train route begins at the Wisconsin-Illinois border at State Highway 32 in Kenosha County. The route follows State Highway 32 along the Lake Michigan shoreline until it reaches the Oak Creek plant between Racine and Milwaukee.

Power Plant Fuel Supply Routes

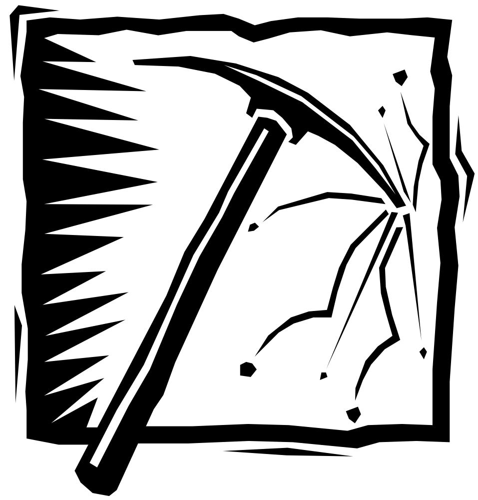
Fuel Supply Route for the Valley Power Plant (Milwaukee)
Natural gas is delivered to the Valley power plant by pipeline from natural gas fields in Louisiana, Texas and Oklahoma. The pipeline route begins at the Wisconsin-Illinois border near Highway 120 in southern Walworth County. The pipeline continues north toward Burlington and passes west of Milwaukee through Muskego, New Berlin, and Franklin. Just south of Greendale the pipeline turns east and follows College Avenue. When it reaches the airport it turns north and runs north along Interstate 794 until it reaches the plant in downtown Milwaukee.

Fuel Supply Route for the West Marinette Power Plants
Natural gas is delivered to the West Marinette power plant by pipeline from natural gas fields in Alberta, Canada. The pipeline route for natural gas from Alberta begins at Duluth, Minnesota and continues to the Wisconsin-Michigan border near Ironwood, Michigan, passing just south of Ashland, Wisconsin. The pipeline then continues through upper Michigan parallel to the Wisconsin-Michigan border, reentering Wisconsin between Florence, Wisconsin, and Iron Mountain, Michigan. The pipeline then continues south parallel to, and west of, U.S. Route 141 to a point near Route 64, then continues on toward Marinette until it arrives at the Marinette power plant. Natural gas for the West Marinette power plant may also originate from Louisiana and Texas.

Fuel Supply Route for the Island Street Peaking Plant (Kaukauna)
Natural gas is delivered to the Island Street Peaking Plant by pipeline from natural gas fields in Alberta, Canada. The pipeline route for natural gas from Alberta begins at Duluth, Minnesota and continues to the Wisconsin-Michigan border near Ironwood, Michigan, passing just south of Ashland, Wisconsin. The pipeline then continues through upper Michigan parallel to the Wisconsin-Michigan border, reentering Wisconsin between Florence, Wisconsin, and Iron Mountain, Michigan. The pipeline then continues south parallel to, and west of, U.S. Route 141 passing west of Green Bay. The pipeline then continues south to Kaukauna until it arrives at the WPPI CT power plant. Natural gas for the WPPI CT power plant may also originate from Louisiana and Texas.

Fuel Supply Route for the Weston Power Plant (Kronenwetter)
Coal is delivered to the Weston power plant by unit train from coal mines in Wyoming, Montana, and other parts of the western United States. The unit train route begins on the Minnesota side of the Mississippi River at its meeting point with the St. Croix River. The train route continues along the Minnesota side of the Mississippi until it reaches La Crosse. The route crosses the Mississippi at La Crosse and follows Interstate 90 to Tomah, continuing on Interstate 90-94 to New Lisbon. From New Lisbon, the route continues along State Highway 80 to the town of Babcock in Wood County. From Babcock, the route continues through Port Edwards, Wisconsin Rapids, Junction City, and Mosinee to just south of Wausau and west of Interstate 39 (US 51) to the Weston plant.

Facts about Coal



Introduction

The United States has more coal than any other fossil fuel resource. Coal is the second most consumed fossil fuel in the world, behind petroleum, (which includes liquids from biomass, crude oil, coal, and natural gas).

Coal is formed from plant matter that decayed in swamps and bogs millions of years ago. Geological processes compressed and altered these plant remains into a solid material made of carbon and other substances, such as hydrogen, oxygen, nitrogen, and sulfur, in other words, it's packed with energy.

There are four main types of coal, which are classified by how much carbon they contain. Anthracite is the hardest and contains the most carbon per pound. Anthracite is followed by bituminous and subbituminous coal. Lignite, a soft coal, has the lowest amount of carbon per pound. The energy content of coal is approximately related to its carbon content. The energy content of coal is measured in Btu (British thermal units) or quads (1,015 Btu).

The table below summarizes the different types of coal in terms of energy, carbon and sulfur content, and percent of known U.S. Reserves.

Coal Types				
Type of Coal	**Average Energy Content (Btu per lb.)**	**Carbon Content (%)**	**Sulfur Content* (%)**	**Percentage of Known U.S. Reserves (%)**
Anthracite	12,500	86–98	0.4–1.9	1.5
Bituminous	12,000	50–86	0.8–5.0	51.0
Subbituminous	9,000	40–0	0.6–1.8	38.0
Lignite	7,000	40	1.6	9.5

* For selected samples of coal types. Numbers may not cover the complete range of sulfur contained in a given type of coal.

Reserves

As of 2014, the U.S. had 480 billion short tons of known coal reserves. Of this, about 256 billion short tons (53 percent) are mineable. Most known coal reserves are in Wyoming, followed by West Virginia, Kentucky, Pennsylvania, and Illinois. Wisconsin has no known coal deposits. (See ***U.S. Coal Deposits***). Based on U.S. coal production in 2013 at 984.8 million short tons, the U.S. estimated recoverable coal reserves would last about 261 years. The actual number of years that those reserves will last depends on changes in production and reserves estimates.

Some refer to the U.S. as the "Saudi Arabia of coal" because it has more than one-fourth of the world's mineable reserves. Current known world coal reserves are estimated to be 861 billion tons. The biggest mineable reserves can be found in China, the U.S., India, Indonesia, and Russia.

Facts about Coal

Mining

Coal is extracted from underground and from surface mines (sometimes called strip mines). Since coal is deposited in broad layers or seams, between 40 and 60 percent of the coal from underground mines must be left behind as pillars to prevent cave-ins and collapse of the surface. Most underground mines are located in the eastern United States.

Coal seams within 300 feet of the surface can be surface mined. Most of the coal produced in the U.S. comes from surface mines, which are often found in the central and western U.S. To mine the coal, the ground above the seams, called overburden, is first removed. After mining, the land is reclaimed; the overburden is put back and the surface is graded to match the original shape of the land (although it will be somewhat lower in elevation) and replanted with the same type of vegetation.

Production

The United States produced 984.8 million short tons of coal in 2013. About 47.8 percent of which is bituminous coal, which is mined mostly in West Virginia, Kentucky, and Illinois. About 44.1 percent is sub-bituminous, mined principally in Wyoming, and 7.8 percent is lignite which is mined chiefly in Texas, North Dakota, and Louisiana. Anthracite is mined only in northeastern Pennsylvania and makes up about 0.2 percent of the US coal production.

In 2013, Wyoming produced most (40 percent) of the nation's coal, providing 388 million tons. West Virginia was the second highest producer at 11 percent while Kentucky produced eight percent. These three states account for 59 percent of total U.S. coal production.

In 2013, world coal production was around 7,823 million tons. China is the highest producer, and together, China and the US produce more than half of the world's coal. Other large coal producers include India, Indonesia, Australia, Russia, South Africa, Germany, Poland, and Kazakhstan.

Processing and Transportation

Coal requires little processing to be used as fuel. Processing includes washing impurities from the coal and then grinding it into fine particles at electric power plants to improve burning.

Sixty-seven percent of US coal is transported either partially or completely by rail in the United States. The balance is moved by river barge, truck, and--for power plants located at the coal mine--by conveyor. Coal slurry, a mix of finely ground coal and water, can also be transported by pipelines, although this is rare.

In Wisconsin, coal shipments are handled at several of the state's ports along the Mississippi River and the Great Lakes. Most of the coal consumed in Wisconsin arrives by rail from Wyoming, and almost all of it is used by the electric power sector to generate electricity. The remaining coal is used by the industrial sector, with only about 0.1 percent being consumed by the commercial sector.

Electricity Production

Coal currently provides 40 percent of the world's electricity needs. Most of the coal produced in the United States is burned in power plants to generate electricity. Wisconsin's electric power plants consume 94 percent of all coal delivered to the state, dominating electricity generation in Wisconsin. In 2013, coal provided 62 percent of the state's net electricity generation.

Facts about Coal

Other Uses

Coal is used as a source of energy by industries that manufacture cement, chemicals, paper, and metals. Coal can also be used to produce methane using a process called gasification. There are several gasification plants in the United States.

One percent of the coal consumed in the United States is used for heating homes and commercial businesses. In Wisconsin, virtually no homes (out of more than two million) are still heated with coal. Coal is used to produce coke, a material used to make steel. Roughly 70 percent of global steel production is dependent on coal. Manufacturers also use coal as an ingredient to create photographic film, electrodes, varnishes, perfumes, and inks.

Consumption

During 2013, Americans consumed 924 million short tons of coal. Total coal consumption in Wisconsin was more than 25 million short tons; 94 percent of this was burned in power plants to generate electricity. World consumption of coal was 4,762 million tons. The global coal demand is projected to reach 9 billion tons by 2019.

Effects

The mining and transportation of coal provide jobs. However, conflicts between miners and mine owners and managers have led to numerous strikes throughout the past century and caused supply disruptions within the United States. Underground mining is hazardous because of cave-ins, methane gas explosions, and dust inhalation. Surface mining is safer, although accidents and noise may cause problems. Mine safety has greatly improved during this century.

Coal use has serious environmental drawbacks. Mining can scar the land unless it is carefully reclaimed. Groundwater may become polluted. Surface collapse above old underground mines, called subsidence, is also a potential problem.

Mercury, a toxic, heavy metal, is released into the air when coal is burned. The airborne mercury attaches to water and dust particles and enters lakes and streams in rain, snow, and runoff. Fish absorb mercury through their gills or by ingesting contaminated smaller organisms. Humans may get mercury poisoning by eating contaminated fish. Serious neurological damage, especially to children, has been linked to mercury poisoning.

Compared to other fossil fuels, coal produces the greatest amount of carbon dioxide and solid particles per pound when burned. Carbon dioxide contributes to climate change. Coal burning also produces sulfur dioxide (which leads to acid rain) and nitrogen oxides. Large amounts of ash remain after burning coal and must be disposed of. Some of these air pollutants can be reduced using scrubbers and other pollution control devices. To reduce sulfur dioxide emissions, many electric utilities, including those in Wisconsin, have switched to burning low-sulfur subbituminous coal mined in Wyoming and other western states.

Carbon Capture and Storage (CCS)

Carbon Capture and Storage (CCS) is a technology that can capture up to 90 percent of the carbon dioxide (CO2) emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing the carbon dioxide from entering the atmosphere. There have been some positive efforts to build more efficient plants, retrofit old plants, and decommission the oldest, least efficient plants. Carbon capture and storage (CCS) is the most promising technology to reach near-zero CO2 emissions from large CO2 sources.

Facts about Coal

Outlook

At current rates of use, the nation's known mineable coal reserves should last hundreds of years. In the future, coal may be converted into gaseous and liquid fuels, thus supplementing finite supplies of natural gas and oil. However, coal-derived fuels will likely be more expensive. Environmental drawbacks such as acid rain and climate change, along with mining restrictions on protected lands, may limit future coal use.

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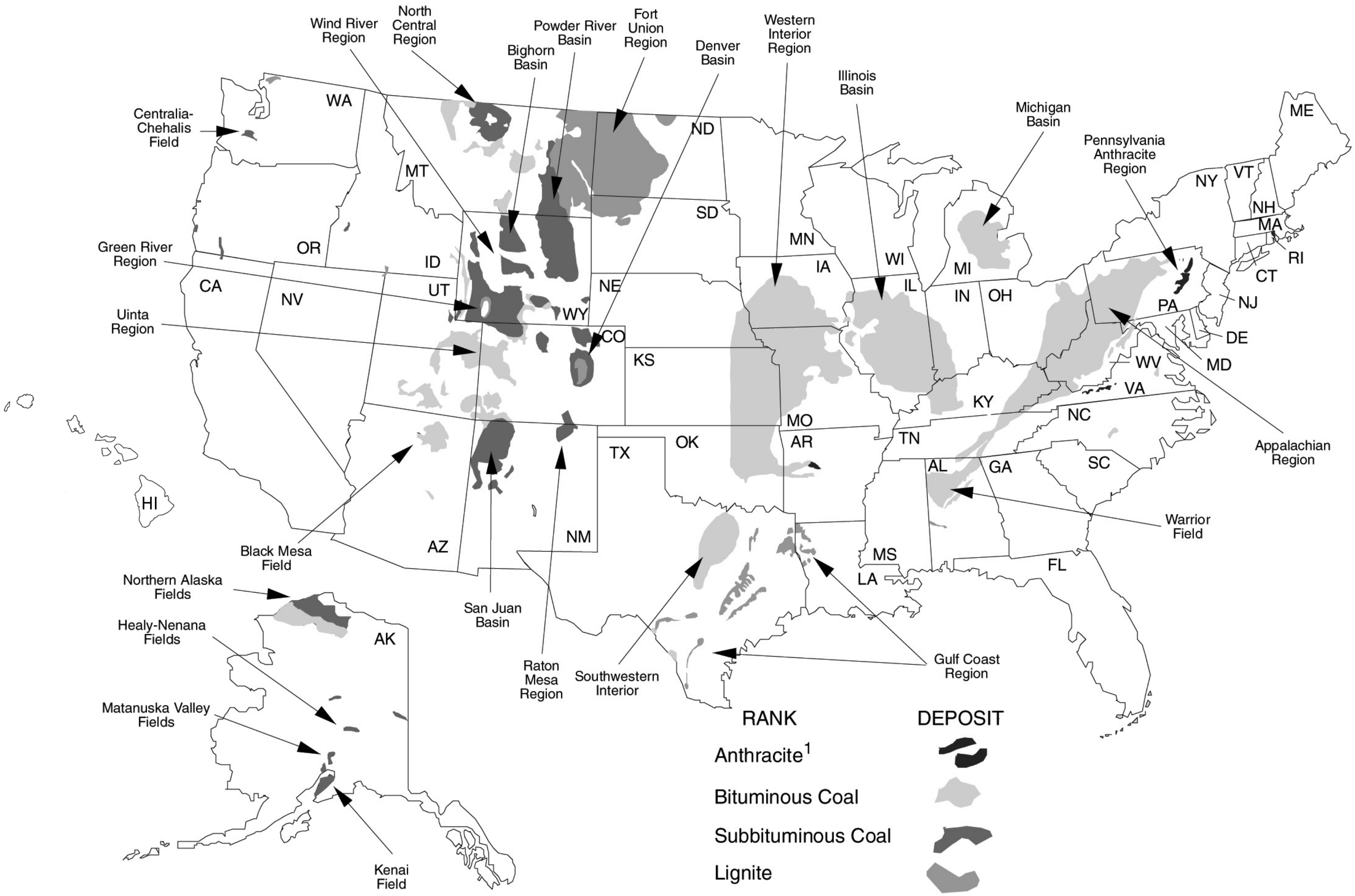
U.S. Coal Deposits

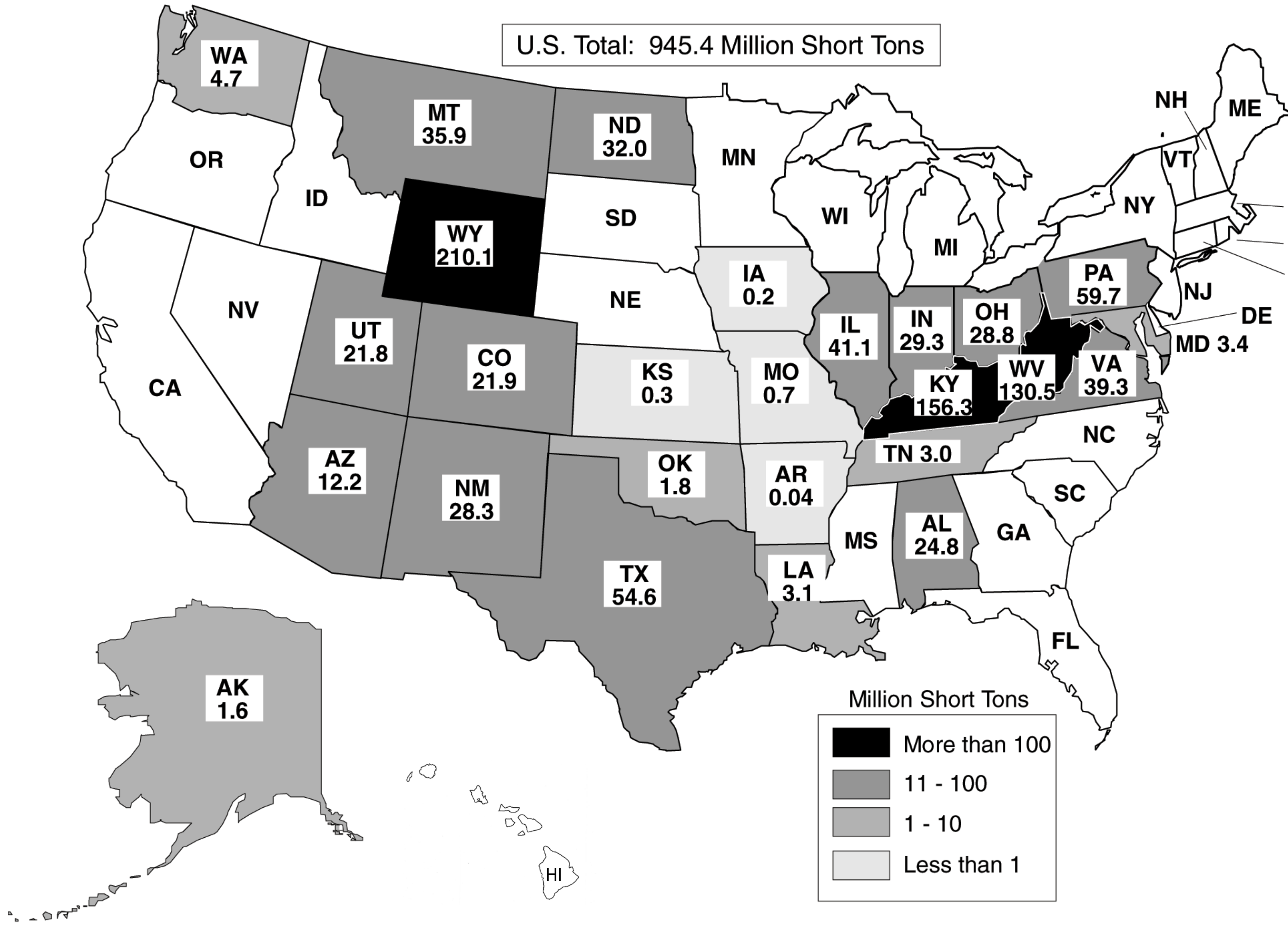


*Principal anthracite deposits are in Pennsylvania. Small deposits occur in Alaska, Arkansas, Colorado, Massachusetts-Rhode Island, New Mexico, Utah, Virginia, Washington, and West Virginia.

NOTE: Alaska and Hawaii not to scale of conterminous United States. Small fields and isolated occurrences are not shown.

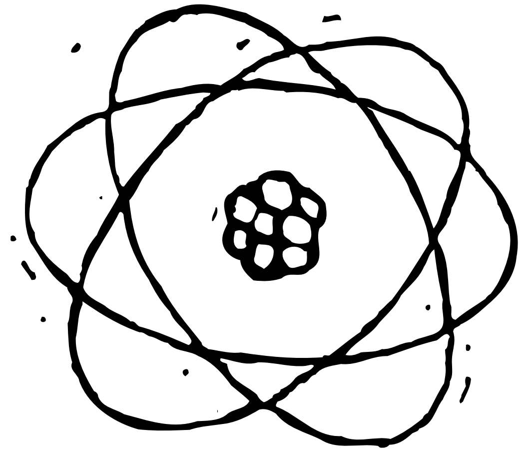
Source: U.S. Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels. "U.S. Coal Deposits." p. 7 in *Coal Data: A Reference*. Washington, D.C., February 1995. DOE/EIA-0064 (93).

U.S. Coal Production by State



Source: Energy Information Administration, *Annual Coal Report 2013*, U.S. Department of Energy, Washington, DC, April 2015.

Facts about Nuclear Energy



Introduction

A recent revival on the energy scene, nuclear energy is associated with the promise of vast quantities of energy. It is also associated with health issues and environmental problems due to radiation and nuclear waste disposal. Despite the controversy surrounding it, nuclear energy supplies a significant amount of electricity for Wisconsin, the United States, and the world.

Uranium

Mineral ores contain uranium in the form of uranium oxide. Two types of uranium atoms, called isotopes, are found in these ores: uranium-235 (U^{235}) and uranium-238 (U^{238}). Of these two, only U^{235} can undergo nuclear fission. However, 99.3 percent of naturally occurring uranium is U^{238} while only 0.7 percent is U^{235}.

Generally, foreign ores have a higher uranium content than those found in the United States. Ores found in the United States contain from 0.05 to 0.3 percent pure uranium. The uranium content of foreign ores ranges from 0.035 percent in southern Africa to 2.5 percent in northern Saskatchewan, Canada.

Nuclear Fission

Nuclear energy can be obtained by a process called nuclear fission (or simply "fission"). Fission occurs when a neutron splits the nucleus of a U^{235} atom into two smaller nuclei, releasing energy and additional neutrons. The extra neutrons then split other U^{235} nuclei, releasing still more neutrons that split more U^{235} nuclei, and so on. This process is called a nuclear chain reaction.

A nuclear chain reaction cannot take place using naturally-occurring uranium. Nuclear power plants use fuels with a mixture of 3 percent U^{235}; this fuel is produced from natural ores by an enrichment process. Nuclear fuel can produce immense amounts of energy. One kilogram of U^{235} can produce two to three million times the energy of one kilogram of coal.

Nuclear Power Plants

In a nuclear power plant, energy from nuclear fission is produced in the reactor. A nuclear reactor is made up of the fuel assemblies, control rods, a moderator, a cooling tower, and the pressure vessel.

The fuel assemblies, control rods, and cooling system make up the reactor's core. U^{235} in the fuel assemblies undergoes fission, releasing neutrons and large amounts of heat. Control rods are moved up and down between the fuel assemblies to absorb some of the neutrons, thereby regulating the rate of fission. A moderator, such as graphite, slows down the neutrons so that the fission reaction is more efficient. A coolant circulates through the reactor's core to remove the heat so that it can be used to make steam in another part of the plant. The steam spins a turbine connected to a generator that produces electricity.

The core is surrounded by the pressure vessel, which is located inside the containment building, a structure made of thick concrete reinforced with steel bars.

A special type of nuclear reactor called a fast breeder reactor converts U^{238} into plutonium (Pu^{239}) while also

Facts about Nuclear Energy

producing electricity. Because plutonium is fissionable, breeder reactors could greatly increase the amount of usable nuclear fuel. Breeder reactor projects were once considered in Germany, the United Kingdom, Japan, and the United States but research has since been discontinued due to the extreme risk in extracting plutonium and the cost of developing the reactors.

Electricity Production

There were 61 nuclear power plants with 99 reactors located in 30 states in 2016. Combined they produced 805.3 kWh of electricity in the United States in 2016, close to 20 percent of the nation's electricity. Nuclear power plant construction ceased in the late 1990's, but has rebounded and several new power plants are ordered and at the same time many existing plants have been extended to continue operations.

The United States has more nuclear capacity than any other country in the world. France has the second, Russia the third, and South Korea the fourth. In 2016, 63 reactors are under construction in 15 countries throughout the world, mostly in the Asian region. Nuclear power capacity worldwide has been increasing steadily.

Wisconsin utilities currently have two nuclear power units, both at Point Beach in Two Rivers, Wisconsin. These units produce about one-sixth of all electric power in Wisconsin. There are now 444 operable civil nuclear power reactors around the world.

Uranium Reserves

Uranium reserves are described in terms of how much it costs per pound to mine the ore. Ores with a high concentration of uranium cost less to mine than those with low concentrations. The U.S. Department of Energy estimates that there were about 66 million pounds of $30 per pound uranium reserves and 362 million pounds at up to $100 per pound uranium reserves in the United States in 2015. (Plutonium from decommissioned weapons can also be used as a nuclear fuel).

U.S. uranium deposits in 2014 were over 207,400 tons of uranium, which is 4 percent of the world reserves. Wisconsin, however, has no known reserves. Other countries with major reserves include Australia, Kazakhstan, Canada, Russia, and South Africa.

Mining and Processing Uranium

Most uranium ore is mined using surface mining, also called "open mining." At a mill near the mine the ore is crushed and ground and the uranium oxide is chemically extracted. This yields uranium concentrate, also referred to as yellowcake. The ore, rocks, and soil left over after mining and milling are called tailings. The tailings contain radioactive materials and must be buried.

Other types of mining include underground mining, in situ leach (ISL) mining (where fortified groundwater is pumped into the aquifer, dissolving the uranium from the host sand), and heap leaching.

Trucks or trains then ship the uranium concentrate to a chemical plant where it is converted into a gas. This gas is then enriched, which increases the amount of U^{235} in the uranium mixture from 0.7 percent to 3.5-5 percent.

After enrichment, the gaseous uranium compound is converted into ceramic fuel pellets. The pellets, which are the size of a fingertip, are sealed inside metal tubes called fuel rods. Each 12- to 14-foot fuel rod contains about 200 pellets. Fuel rods are bound together in assemblies, each containing about 240 rods. Trucks or trains transport finished fuel assemblies to a nuclear power plant.

Facts about Nuclear Energy

Other Uses

Nuclear energy is widely used in the military to power submarines and aircraft carriers. Nuclear power plants aboard naval vessels offer great reliability and allow ships and submarines to sail for long periods of time without refueling. Nuclear weapons use U^{235} or plutonium to produce nuclear explosions. Nuclear energy also has important uses in medical diagnosis and treatment.

Effects

Nuclear energy has some important benefits. Because large amounts of energy can be obtained from a small amount of U^{235}, some of the environmental effects of mining uranium for energy are not as great as they are for coal. Also, nuclear power plants do not produce air pollutants or release carbon dioxide (a cause of global climate change) into the atmosphere. Some experts believe that nuclear energy is better able to meet the world's growing demand for energy than fossil fuels or renewable energy resources.

The main disadvantage of nuclear energy is that uranium and the waste materials produced from nuclear fission are radioactive. Radioactive materials emit alpha and beta particles and gamma rays, which can harm living cells. Radioactive materials are present in the mining, production, and transportation of nuclear fuel; in the operation of nuclear power plants; and in nuclear waste. Transportation is one of the most serious concerns related to nuclear energy use. After the fuel is mined, it needs to be transported to the plant and after the fuel is spent, it is transferred to the storage site. Transporting the fuel many miles to a permanent storage site adds even more risk and complications. On a global scale, there is fear associated with countries exporting and importing fuel by sea and by air. All these operations must be designed and managed to protect the environment from the release of radioactive materials. This often requires expensive and complex technology.

Although nuclear power plants are designed with many safety protocols to prevent releases of radiation, accidents at the Three Mile Island power plant in the United States in 1979 and the Chernobyl plant in the Ukraine in 1986, as well as the Fukushima plant in Japan in 2011, increased public concern about their safety. Safer nuclear reactors have been designed and tested, and are being put into use today.

Radioactive waste is classified as one of the following: Exempt waste; very low-level waste, low-level waste, intermediate-level waste, or high level waste. Low-level waste, for example, contains a small amount of radioactivity within a relatively large amount of material. These wastes include tools, equipment, and protective clothing exposed to radioactive materials. They must be stored in steel drums and buried for several decades until their radioactivity decreases to a safe level. The U.S. government has burial sites for low-level wastes in Barnwell, South Carolina; Richland, Washington; Clive, Utah; and Andrews, Texas.

Nuclear fuel from power plants is an example of a high-level waste. These wastes are extremely hazardous and must be safely stored for thousands of years until their radioactivity decreases to a safe level.

New research in reusing radioactive wastes is being conducted. It may be feasible at some point in time to remove the uranium, plutonium, and minor actinides for recycling in a fast breeder reactor. Currently, however, this recycling of radioactive wastes is not available on a commercial scale.

In the U.S., no permanent storage site for high-level waste exists. Currently, all nuclear power plants in the U.S. store their spent nuclear fuel in steel-lined concrete pools. These are temporary facilities near the plant; some of which are nearly full. Storing wastes deep underground is the option most likely to be used in the near future. The wastes would be sealed in metal canisters and buried about half a mile underground in a

Facts about Nuclear Energy

location where earthquakes do not occur and contact with groundwater is avoided. (However, it is difficult to predict whether an underground site will be geologically stable for thousands of years). Yucca Mountain in southern Nevada has been the leading candidate for a permanent disposal site since the 1980s. Studies of the area have been conducted to ensure the repository would be safe and environmentally sound for a one-million-year period of waste isolation. No final decision has been made about use of the site as of 2017.

Outlook

Nuclear energy has some important benefits. Because large amounts of energy can be obtained from a small amount of U^{235}, some of the Reserves of uranium will last for the projected lifetimes of the world's current nuclear power plants. Because only a small fraction of uranium is U^{235} (0.7 percent), uranium reserves are only thought to be enough to last about 90 years. However, new technologies could potentially extend this outlook past 200 years supply.

The expense and complexity of nuclear power plants and concerns about radiation exposure, disposal, and long-term safe containment of nuclear wastes have led many people to oppose nuclear energy. On the other hand, nuclear energy does not add pollutants or carbon dioxide to the atmosphere. It can also meet the world's growing demand for energy. Nuclear energy will continue to be used to produce electricity in the near future, but its long-term fate is somewhat uncertain.

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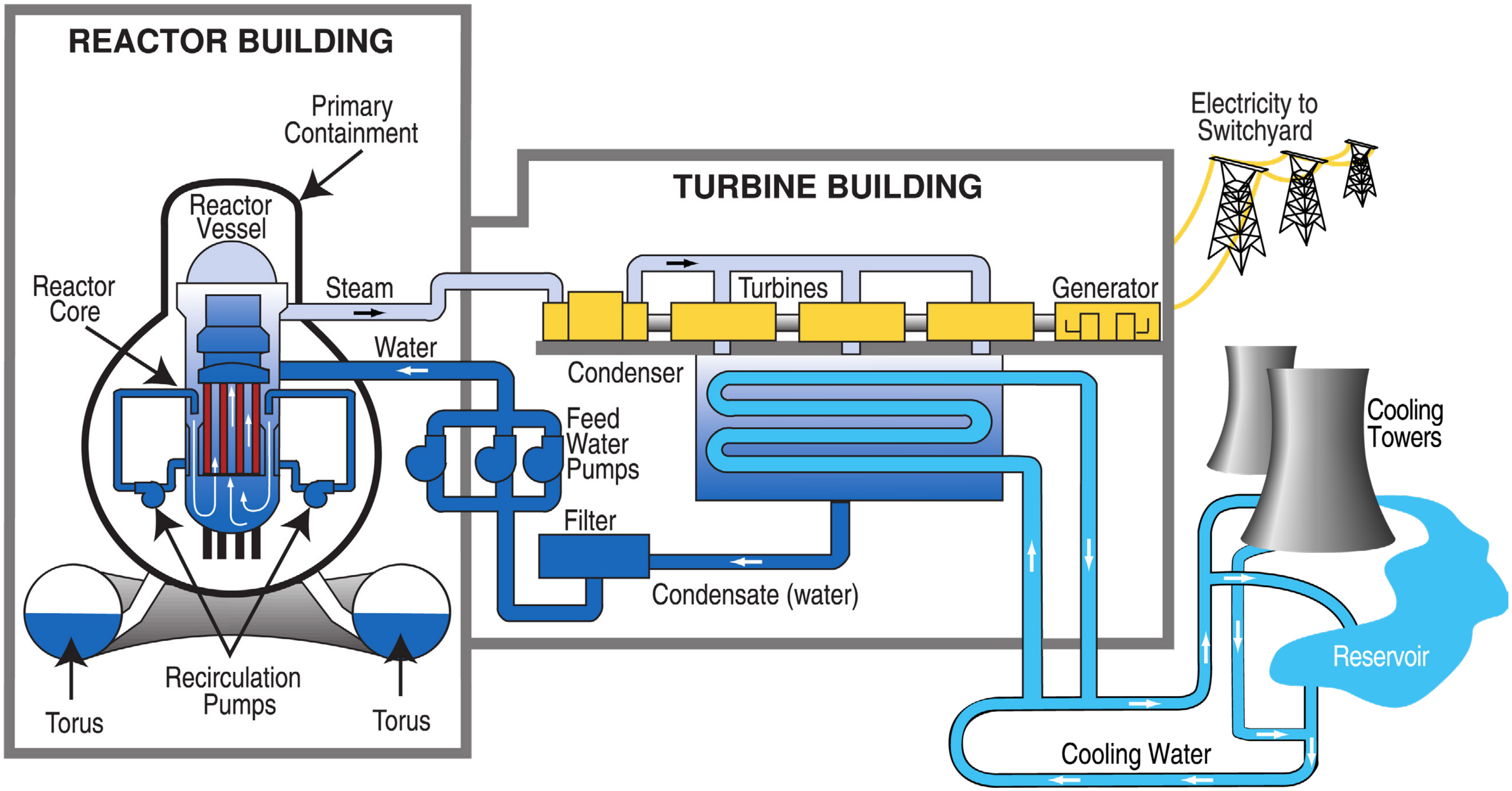
Nuclear Power Plant Diagram



Facts about Oil

Introduction

The most versatile fossil fuel, oil has made possible many of the necessities and conveniences of modern society. Without oil, much of today's transportation system would grind to a halt and many products we rely on would not exist. This dependence, which sometimes leads to international conflict, along with oil's finite supply and environmental problems, has become an increasing concern in a world that thirsts for the miracle liquid many call "black gold."

Crude oil is a yellow-to-black, sticky substance found inside sponge-like sedimentary rocks that remains a liquid when brought to the surface. It is made of hydrocarbons, organic compounds consisting entirely of hydrogen and carbon atoms. Petroleum products are produced from the processing of crude oil and other liquids and include liquefied petroleum gases, aviation gasoline, motor gasoline, kerosene, fuel oil, petrochemical feedstocks, lubricants, waxes, asphalt, road oil. Petroleum is a broad category that includes both crude oil and petroleum products. The terms oil and petroleum are sometimes used interchangeably.

The crude oil we extract today was formed millions of years ago when dead organisms such as plankton, bacteria, and plant matter were deposited on the sea floor. Sediments accumulated above the organic material over millions of years, the organic material decomposed and the heat and pressure broke it into hydrocarbons/oil. Because they were formed in similar ways, crude oil is often found together with natural gas.

One gallon of crude oil contains 138,095 Btu of energy. One barrel of oil contains 42 gallons. One quad equals 172.4 million barrels.

Reserves, Production, and Consumption

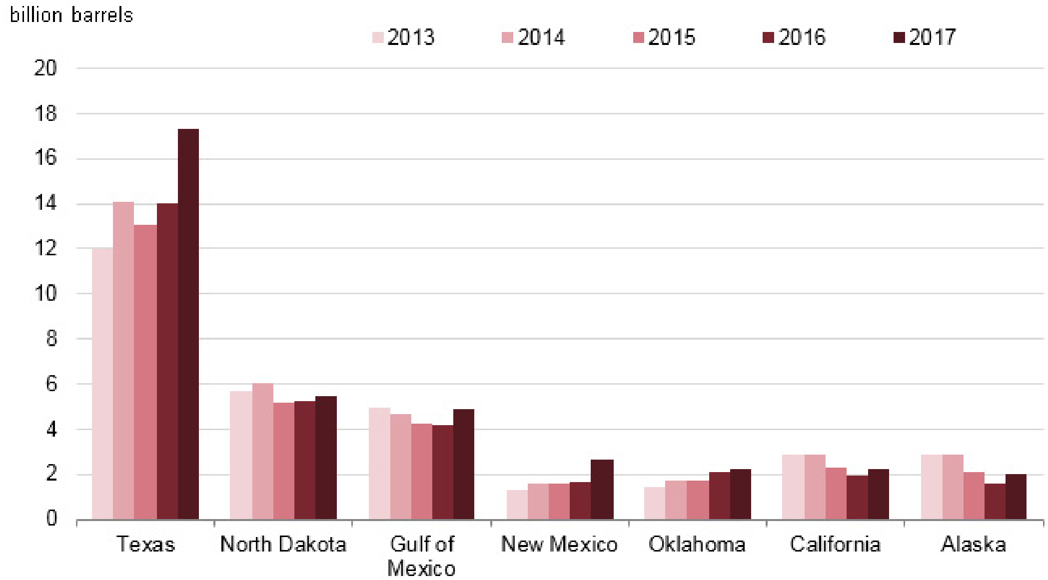
Known crude oil reserves in the United States in 2015 equaled 35.2 billion barrels. Outside the U.S. Venezuela has the largest amount of known oil reserves at 302 billion barrels, followed by Saudi Arabia, Iran, Iraq, and Kuwait.

Total domestic crude oil production averaged about 8,900,000 barrels per day in 2016. The top crude oil producing states/regions in 2016 were Texas, North Dakota, California, Alaska, Oklahoma, and the Gulf of Mexico. (see chart Proved reserves of the top five U.S. oil reserves states, 2011-2015) The world produced 80,557,000 barrels per day in 2016 with about 44 percent of world production from OPEC countries. OPEC is the Organization of the Petroleum Exporting Countries, which was formed to secure fair and stable prices for petroleum producers and regular supply to consumers. The top oil producers in the world are Russia, Saudi Arabia, the United States, Iran, Iraq, China, and Canada.

In 2016, the United States consumed a total of 7.21 billion barrels of petroleum products, an average of about 19.69 million barrels per day. The United States imported approximately 10 million barrels per day in 2016 coming from 70 different countries including Canada, Saudi Arabia, Venezuela, Mexico, and Colombia. Over 3.5 billion gallons of petroleum products were used in Wisconsin in 2012, all of which were imported into the state. Total world consumption of petroleum and other fuel liquids increased 1.5% between 2015 and 2016. A similar trend is projected to continue.

Facts about Oil

Figure 2. Proved reserves of the top seven U.S. oil reserves states, 2013–17



Notes: Oil reserves include crude oil and lease condensate. Gulf of Mexico represents the federally owned offshore portion of the Gulf of Mexico. Although not a state, it is an important U.S. oil and natural gas production area.
Source: U.S. Energy Information Administration, Form EIA-23L, *Annual Report of Domestic Oil and Gas Reserves*, 2013–17

Extracting Crude Oil

Geologists and geophysicists search for oil by conducting underground seismic, gravitational, and magnetic tests. Wells are drilled when tests indicate a strong likelihood of oil. Crude oil under pressure flows to the surface on its own. This type of extraction is referred to as primary oil extraction. Secondary extraction techniques typically make use of water or gas injected to displace oil and drive it to a production wellbore. Tertiary, or enhanced oil recovery (EOR) techniques are more invasive but have the potential to ultimately produce 30 to 60 percent of the reservoir's original oil in place.

Processing and Transporting

Crude oil is transported by pipelines and oceangoing tankers to refineries. About 45 percent of a typical barrel of crude oil is refined into gasoline. An additional 29 percent is refined to diesel fuel. The remaining oil is used to make plastics and other products (see image Products made from a barrel of crude oil, 2016). After refining, gasoline and other types of fuel oil are transported by barges, rail, and pipelines to local storage tanks, and then delivered to homes, businesses, and gas stations by tanker trucks (see map Wisconsin Petroleum Pipelines).

Electricity Production

In some parts of the United States, fuel oil is used in power plants to produce electricity, although it accounts for less than 1 percent of total electricity generation. These power plants are usually smaller than those that use coal, natural gas or nuclear energy. Many oil-fired power plants are only used when the demand for electricity is high, because it costs less to produce electricity using other sources.

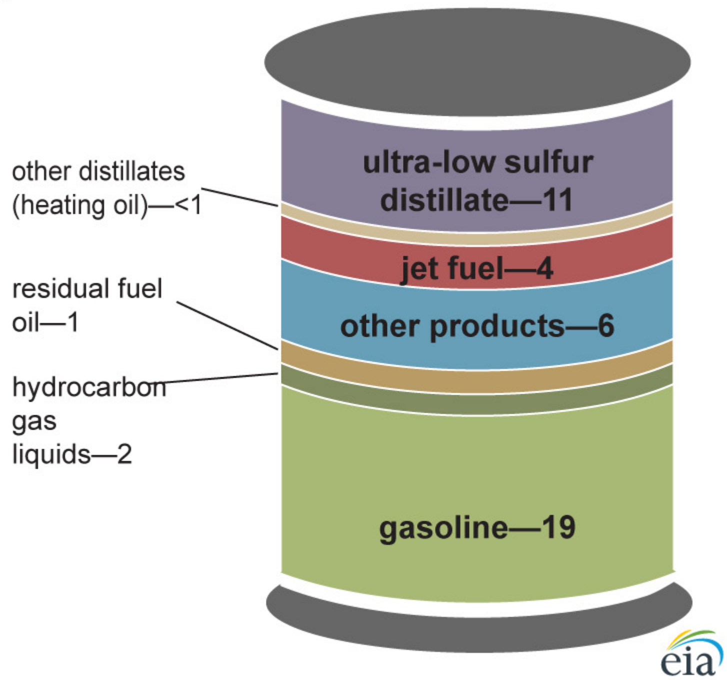
Facts about Oil

Other Uses

Fuels made from oil run power machinery, cars, trucks, and airplanes. Petroleum fuels also provide heat for homes. Over 3,000 different kinds of products can be made from oil. These products include asphalt, lubricants, ink, cosmetics, and waxes. Crude oil is also used to make plastic products such as bags, bottles, inline skate wheels, and parts for computers, stereos, and automobiles.

Petroleum products made from a barrel of crude oil, 2018

gallons



Note: A 42-gallon (U.S.) barrel of crude oil yields about 45 gallons of petroleum products because of refinery processing gain. The sum of the product amounts in the image may not equal 45 because of independent rounding.

Source: U.S. Energy Information Administration, *Petroleum Supply Monthly*, April 2019, preliminary data.

Effects

Because of its many uses, some view oil as the lifeblood of modern civilization. Numerous occupations, ranging from geologists and drill rig workers to gas station managers and attendants have been created by the oil industry. However, oil drilling can damage sensitive wilderness areas. Uncontrolled releases of oil from drilling (called blow-outs) have been a problem in the past, although successful steps have been taken to prevent them. Spills by oil tankers have polluted oceans and inland waterways, harming aquatic life.

Although cleaner burning than coal, petroleum fuels release carbon dioxide, unburned hydrocarbons, sulfur oxides, and carbon monoxide into the atmosphere when burned. Emissions of these substances from automobiles contribute to smog and ground level ozone formation in urban areas, which can lead to respiratory illness. However, automobiles made today are more fuel-efficient and emit fewer pollutants than older models, reducing or slowing increases of harmful emissions.

A significant portion of human-generated greenhouse gases come from oil combustion. Scientists assert that the buildup of human-caused greenhouse gases have contributed to widespread climate change.

Increasing oil imports by the United States have led to concerns over dependence on unreliable oil supplies. For instance, turmoil in the Middle East in 1973, 1979, and 1990 led to worldwide oil supply disruptions and sudden price increases. In response, the United States began to store crude oil in old salt mines and other underground formations. The strategic Petroleum Reserve has a design capacity of 714 million barrels of oil, enough to last the nation up to three months.

Facts about Oil

Outlook

Crude oil is a finite resource and is predicted to run out within the next 25 years; however, there is the potential that global reserves could increase with technological advances in methods of production/extraction. U.S. production, which had been declining from 1970 to 2012, is a more immediate concern. Sources of oil, such as shale oil extraction, that were previously more expensive have now become more economically feasible. Although oil exploration within the United States continues and new oil fields are still being discovered, much of the United States has been thoroughly explored. However, the increase in types of extraction may aid in future production. Imports into the U.S. are likely to be reduced as crude oil production is expected to rise through 2020. Continued improvements in automobile efficiency and increasing the use of other efficient means of transportation should help to extend oil supplies and reduce imports in the future.

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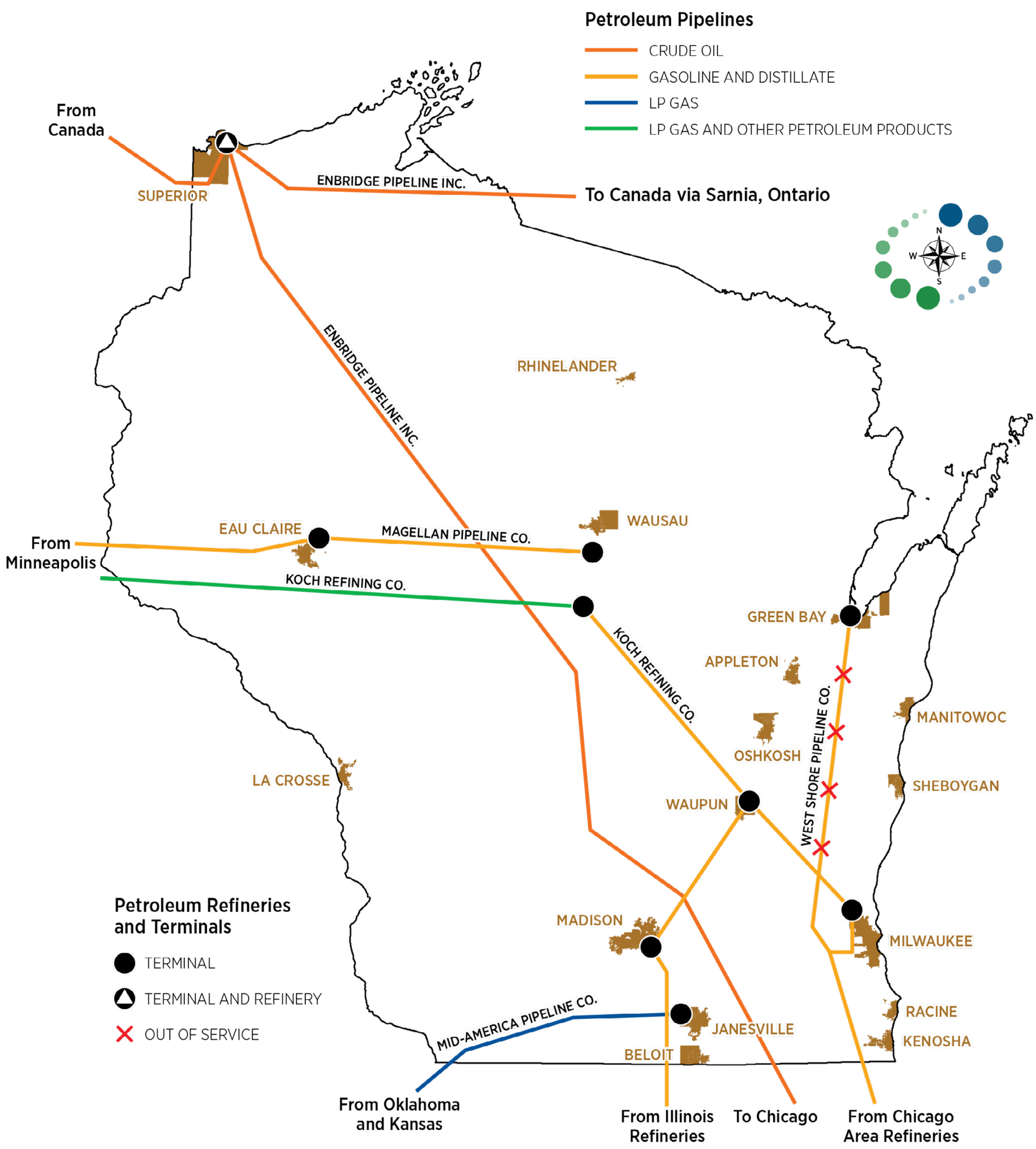
Wisconsin Petroleum Pipelines, 2015



Source: Wisconsin Office of Energy Innovation. [Wisconsin Energy Statistics Book](#).

Facts about Natural Gas

Introduction

Natural gas was once an unwanted by-product that came out of the ground with crude oil. Now it is one of the nation's most important energy resources. It is the fuel used most in homes for space heating, water heating, and cooking.

Natural gas is made of a mixture of molecules called hydrocarbons, chains of carbon and hydrogen atoms. Natural gas is mostly made of methane (CH_4) and other gaseous hydrocarbons (dry gas), although a small portion is in liquid form (wet gas).

Like crude oil, natural gas is formed when dead organisms like plankton, bacteria, and plants are deposited on shallow ocean bottoms. Sediments accumulate on top of the organic material over millions of years, and increasing pressure and temperature slowly change it into natural gas. Because they are formed in similar ways, natural gas and crude oil are often found together.

Reserves

Known U.S. reserves of natural gas in 2017 were 464.3 trillion cubic feet, most of which is found in Texas, Pennsylvania, Oklahoma, West Virginia, and Louisiana (see **U.S. Natural Gas Proved Reserves, 2017**). Wisconsin has no known reserves. Potential U.S. reserves, which include likely but as yet undiscovered gas fields, may be as much as 2,515 trillion cubic feet of technically recoverable resources (2014). The nations that make up the former Soviet Union, including Russia, have the largest reserves in the world. Russia's reserves alone account for about a quarter of the world's total proved reserves. Worldwide proven reserves stood at 708 trillion cubic feet, however, it is estimated that there were 2,561 trillion cubic feet of technically recoverable resources at the end of 2014.

Production

The energy content of natural gas is measured in Btu (British thermal units) or quads (1,015 Btu). The United States produced 28,294,939 million cubic feet of natural gas in 2016. World natural gas production for 2014 was 122,336 billion cubic feet, with the United States producing the most, followed by Russia.

Consumption

In 2016, the United States consumed 27,485,517 million cubic feet of natural gas. Of that, Wisconsin was responsible for 1.75% of that consumption at 481,987 million cubic feet of natural gas consumption (26% residential, 30% industrial, 18% commercial, and 25% electrical power).

Extracting Natural Gas

Exploring and drilling for natural gas is similar to exploring and drilling for crude oil (see ***Facts about Oil***). Synthetic natural gas can also be produced from crude oil or coal using a process called gasification. The largest source of synthetic gas is a plant in Beulah, North Dakota, which produces more than 54 billion standard cubic feet of natural gas annually.

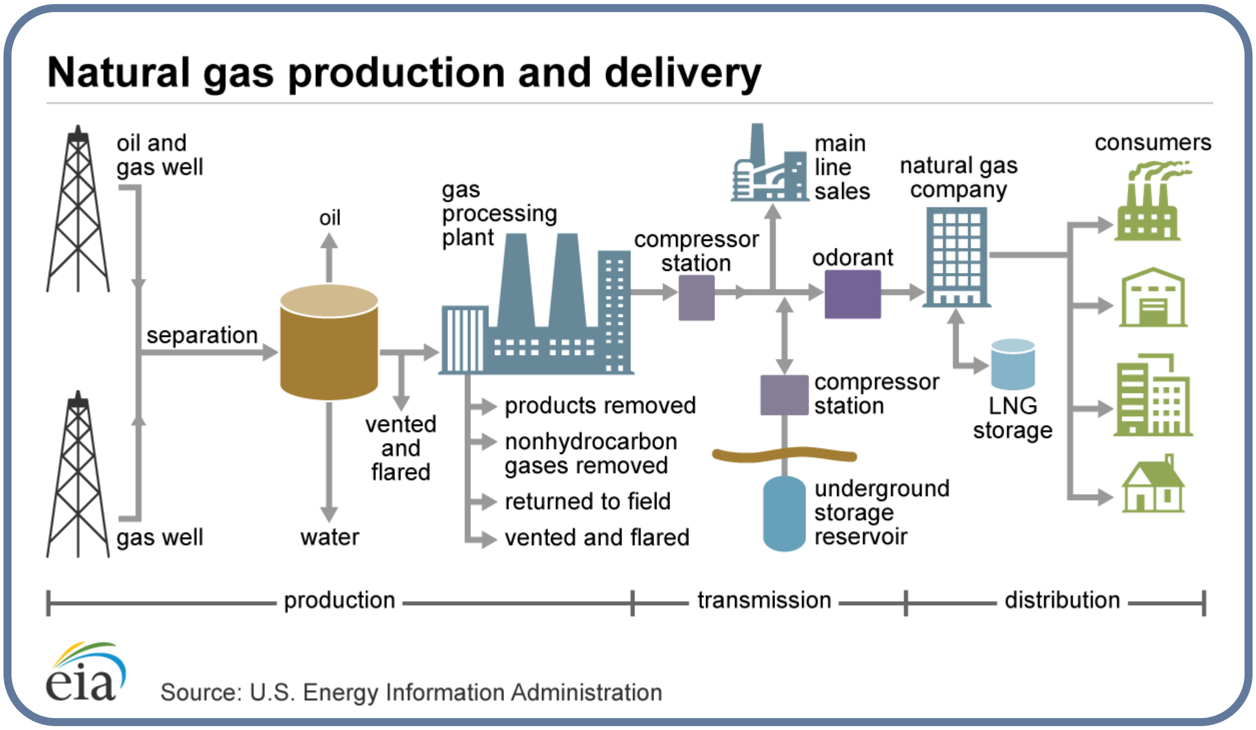
Facts about Natural Gas

Processing and Transportation

Unlike Crude oil, natural gas does not need much processing. Liquids and methane are separated from pipeline quality dry gas near the well or at a processing plant. Because natural gas has no odor, a scent is added to it so that people can smell it if it is leaking.

After processing, pipelines transport natural gas to various destinations. Like the branches of a tree, smaller pipelines are connected to the major pipelines, and even smaller lines are connected to homes and businesses (see **Wisconsin Natural Gas Utility Service Territories and Major Pipelines, 2015**).

Because pipelines cannot always be built where gas is needed, natural gas may be chilled until it turns into a liquid. The liquid natural gas (LNG) can then be stored in special tanks and shipped to its destination. There, the LNG is changed back into a gas and piped to where it is needed.



Electricity Production

Some power plants also use natural gas to produce electricity. Some of these are peaking plants; they are used when the demand for electricity is high or at its peak. But because of lower natural gas prices and increases in efficiency, natural gas is also being used as a fuel in larger base power plants. Wisconsin has natural gas-fired power plants. In June 2017, for example, natural gas-fired plants generated 1,149 thousand MWh of electricity, as compared to coal-fired plants generating 3,266 thousand MWh.

Other Uses

Besides space heating, natural gas is used to provide heat for manufacturing processes. Like crude oil, natural gas is also used to produce various products, including petrochemicals.

Facts about Natural Gas

Effects

Most of the natural gas used in the United States is produced domestically, so disruptions of supplies from foreign sources are not a major concern. The number of known reserves has been increasing. The natural gas industry has created many different occupations. Jobs in the heating business and appliance industry also depend on plentiful supplies of natural gas.

Natural gas is a relatively clean-burning energy resource compared to other fossil fuels. It produces about half as much carbon dioxide (a contributor to global climate change) per Btu of energy as burning coal does. Emissions of carbon monoxide and sulfur oxides are also lower. However, home heating systems that are not working properly may produce excess carbon monoxide, a poisonous gas that can cause illness or even death. On rare occasions, natural gas leaks can also lead to explosions.

Did You Know?

Because natural gas is colorless, odorless, and tasteless, natural gas companies add mercaptan to natural gas to give it a distinct and unpleasant odor to help detect leaks in natural gas pipelines. Mercaptan is a harmless chemical that smells like rotten eggs.

Outlook

Natural gas use in the United States is expected to continue to increase in the near future. Natural gas exploration within the United States continues, and new discoveries will contribute to production increases. Depending on the amount of natural gas consumed each year, imports, exports, and additions to the reserves, the United States currently has enough natural gas to last about 86 years.

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Wisconsin Office of Energy Innovation: psc.wi.gov/Pages/Programs/OEI.aspx

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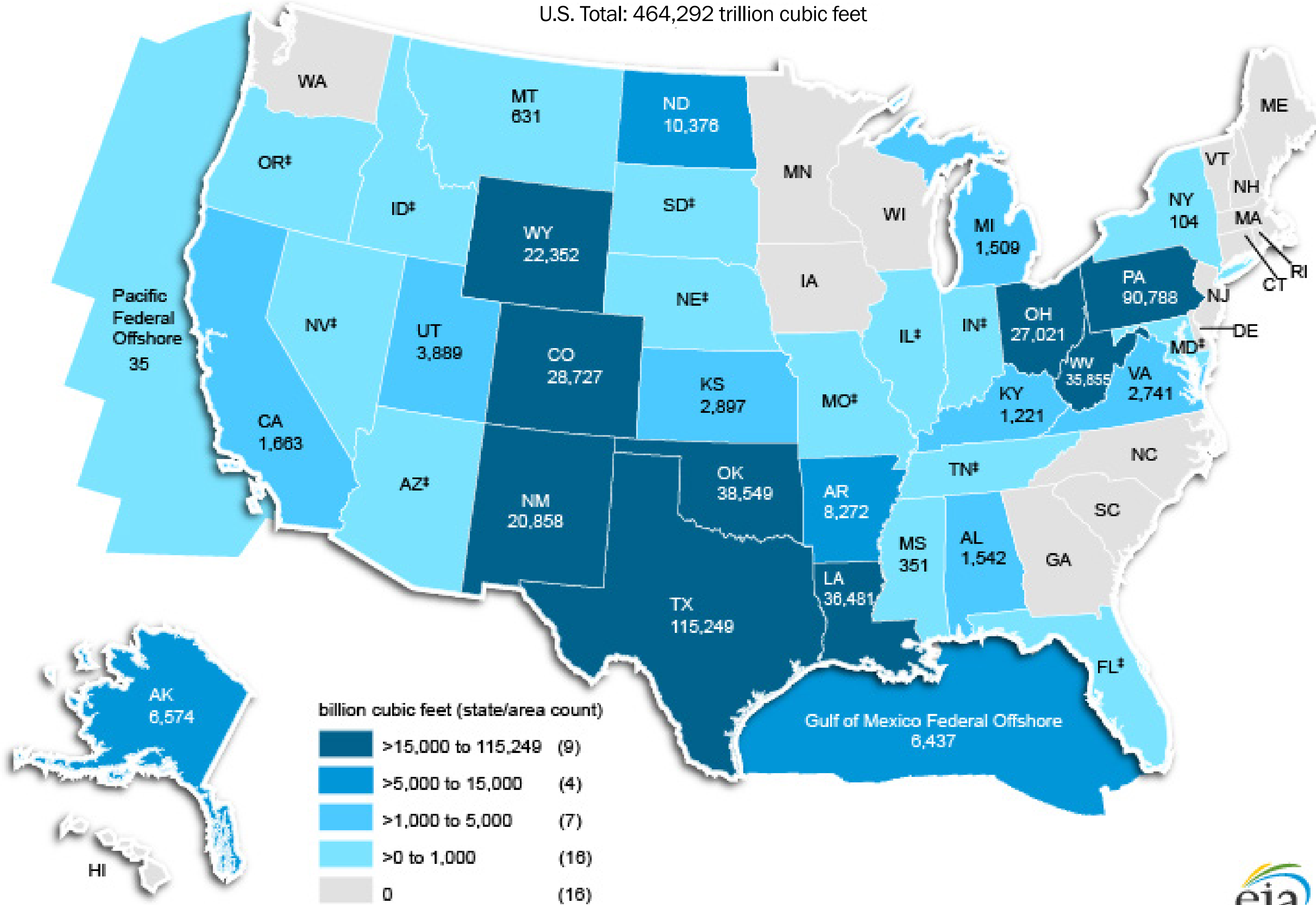
College of Natural Resources
University of Wisconsin-Stevens Point

U.S. Natural Gas Proved Reserves, 2017

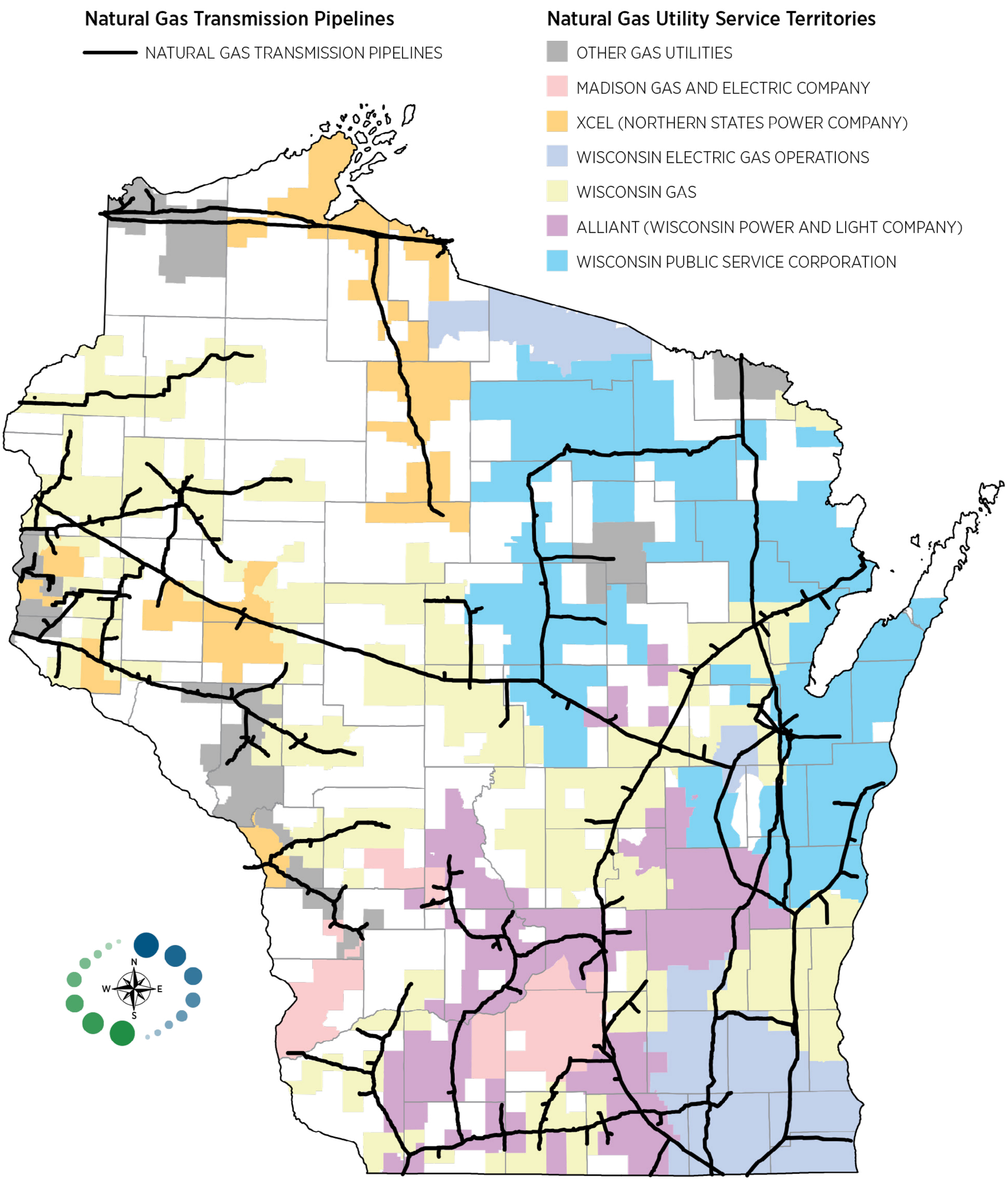
U.S. Total: 464,292 trillion cubic feet



‡ Data withheld to avoid disclosure of individual company data

Source: U.S. Energy Information Administration, Form EIA-23L, *Annual Report of Domestic Oil and Gas Reserves*

Wisconsin Natural Gas Utility Service Territories and Major Pipelines, 2015



Source: Wisconsin Office of Energy Innovation. Wisconsin Energy Statistics Book: Wisconsin Energy Statistics 2018.