Comprehensive Theme Activity: Energy Debate

Through a debate-oriented discussion, students report on basic facts about how energy resources are developed, and highlight the advantages and disadvantages of each. This project also serves as a Comprehensive Theme Activity for the theme Developing Energy Resources.

This project can be assigned at the beginning, middle, or end of a unit related to the development of energy resources. It can also be the energy unit, where students use the research and debate process to teach themselves and classmates how energy resources are developed. Basic information students need to learn about resource development can be obtained from the ***Energy Resources Fact Sheets***. Students will probably need to research information to prepare for the debate, so additional time may be needed. Students can also gain knowledge and skills about energy resource development by participating in other KEEP activities.

Grade Level: 5–8

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

Objectives

Students will be able to:

- describe what is involved in developing energy resources to generate electricity;
- critically analyze the advantages and disadvantages of various energy resources; and
- use persuasive arguments to present and defend an energy resource.

Rationale

A debate-oriented discussion encourages students to become independent thinkers. Students are challenged to conduct practical research and to answer questions, analyze information, and draw their own conclusions. Through this activity, students will gain knowledge needed to make prudent energy choices.

Materials

- Writing utensils and paper
- Reference materials related to energy resource development (including ***Energy Resources Fact Sheets***)
- Copies of the following pages:
  - ***The Energy Debate: Which Resource Is Best?***
  - ***Project Proposal Form***

Setting: Classroom, library, and community

Time: The time frame depends on when and how the project is implemented. The following is a possible timeline for the project.

Week One
Introduce assignment and have students develop their project proposal (**Orientation** and **Steps 1–4**)

Weeks Two and Three
Students conduct research (in and outside of class) and participate in class activities related to effects of energy resource development. Meet with students to discuss progress reports (**Step 4**). NOTE: This extra time is necessary only if students are expected to obtain information beyond that which is found in the ***Energy Resources Fact Sheets.***

Week Four
Students prepare presentation and participate in debate (**Steps 5–6** and **Closure**).

- *Project Components for Research and Preparation*
- *Project Components for the Proposal Presentation/Debate Phase*
- *Proposal/Presentation Recording Sheet*
- *Evaluation Criteria*

- Other materials needed by students to prepare and give their presentations
- Find additional resources related to this activity on keepprogram.org > Curriculum & Resources

Background

The aim of the theme Developing Energy Resources is for students to learn what is involved in acquiring the energy they use. Energy comes from many sources and is found in many forms. This wide range of form and scale lends itself to a diversity of applications. Energy is used for heating, for fuel, to sustain life, to move objects, to generate electricity, etc.

Classroom debates provide students with a motivating and constructive format that encourages them to research what is involved in developing these energy resources. Through the debate process, students defend, explain, and analyze what they think about a topic such as developing energy resources. Although students will be having fun, they also will be enhancing important communication, critical thinking, and decision-making skills.

This activity is based on the premise that students are responsible for their own and their classmates' learning. Students may use an ***Energy Learning Log*** to keep track of their research. This log can be maintained much like a portfolio where students can file important information related to their energy resource.

Procedure

Orientation

Present students with one of the following scenarios, depending on which is more relevant to your area.

- Utility forecasters have determined that the demand for electricity by their customers will increase over the next ten years. Although the utility's conservation programs will offset some of the increased demand, they will not completely eliminate the need for more electricity. To meet the increase in demand not covered by conservation, the utility has determined that a power plant or other means of generating electricity must be built.
- The local utility owns a 60-year-old, inefficient, coal-fired power plant. The utility decides that this outdated plant is not worth fixing and plans to shut it down. To maintain the supply of electricity customers need, the utility needs to build a new power plant or find other means of generating electricity.

Hand out copies of ***The Energy Debate: Which Resource is Best?*** for discussion. Throughout this project, stress that this exercise is not a contest or competition. The primary objective is for all students to learn facts about each resource's advantages and disadvantages. Accurate portrayal of the content as well as effective use of persuasive arguments should be emphasized.

Steps

1. ***Introduce students to project objectives, evaluation criteria, and time considerations:*** share and discuss the ***Project Components for Research and Preparation*** and the ***Project Components for the Proposal Presentation/Debate Phase*** the two phases of this project. Students can add their own criteria to the list.

   Remind students that the proposal and presentation are their own, but you will help them clarify their content or the main points in their argument as needed.

2. ***Divide the class into groups and assign each group an energy resource.*** ***Energy Resources Fact Sheets*** have been provided on the following resources: solar, wind, oil, coal, natural gas, hydroelectric power, nuclear energy, and biomass fuels. Because of time limitations, it may be best to have the class focus on four to six of these resources. However, alternate resources can be added to the list if desired.

   An alternative to assigning each group one resource is to have them select their own. Randomly assigning resources may avoid disputes among groups, but students may be concerned if they have to represent a resource they do not care for. Tell students there will be opportunities to express their resource preference. Stress the benefits to knowing what the "other side" thinks. Explain that understanding the strengths and weaknesses of alternative viewpoints provides ammunition that can be used to enhance the argument they support.

Group size will depend on the number of resources chosen, class size, and the extent of the research. Four students in a group is usually the most manageable and productive. This exercise can also be an individual project, but group work allows students to share responsibilities and learn to work cooperatively.

3. ***Identify the different responsibilities of the group project, and have the groups meet to assign roles:*** a variety of tasks must be accomplished to make this project successful. These responsibilities are included on ***The Energy Debate: Which Resource is Best?*** handout. Recommendations for the number of students needed for each task are included in the description of the responsibilities. Below are additional considerations for planning the presentation.

   Panel Members: The panel (people who listen to each group's presentations and decide which resource to use) can be composed of teachers, students, or a combination. The students can be from another class, a separate group within the class, or can be composed of one member from each energy resource group. If the panel is formed as a separate group at the project's onset, make sure they have things to do while the other groups are preparing their presentations (see "Preparing the Panel" below). This is especially true if the groups have a week or two to prepare. If the panel consists of a student from each energy resource group, it can be formed the day before the presentations.

   Moderator for the Presentation: The moderator can be one of the panel members or you can take this role. The moderator monitors the discussion and makes sure presentations keep within time limits. Group members and panelists must be instructed not to speak unless acknowledged by the moderator. The moderator also keeps the discussion moving. If argument of trivial points continues for an extended period, the moderator simply asks that the participants proceed to another point (e.g., "I think we've exhausted this issue; let's go on to another"). One problem with you serving as the moderator is that students may be tempted to address you rather than each other during the debate (see "Your Role" below).

4. ***Allow groups to meet to complete the necessary research and prepare their proposals and presentations (following instructions on each of the Project Components pages):*** One of the first things groups should do is decide their research strategies. If you plan to use activities within KEEP's *Energy Education Activity Guide* or other resources, share the agenda with students to make them aware which concepts will be addressed when.

   Encourage students to complete the ***Project Proposal Form*** near the beginning of the information-gathering phase. Plan a brief meeting with each group to help them clarify their presentation ideas. Point out the strengths of the draft proposal first. Then identify shortcomings and possible alternatives. This is also a good time to discuss strategies for gathering additional information about their resource and to correct any misinformation (See ***Energy Resources Fact Sheets***). Have students revise the ***Project Proposal Form*** as needed.

Conduct the Presentation/Debate: The actual presentation (debate-oriented discussion) can be set up in any fashion. One suggested format is found on the ***Project Components for the Proposal Presentation/Debate Phase***. If this option is used, make sure the groups understand the procedures on this sheet.

Time Allotments: Prior to handing out the ***Project Components for the Proposal Presentation/Debate Phase*** sheet to students, figure out how much time will be needed for the presentations and for questions and answers. Suggestions for dividing up the time are provided. Most likely more than one class period will be needed.

Preparing the Panel: A day or two before the presentation, organize a group of Panel Members (see Panel Members under responsibilities of the group project, Step 3). The panel should develop questions they want to ask each of the groups. They can be asked to complete other tasks such as drafting a protocol for presentations, establishing guidelines for decision making, or developing a rating scale. It is important that the panel takes their role seriously, because they will set the atmosphere for the discussion.

Setting the Stage: Treat the actual day for the presentations as significant. Students can be encouraged to dress formally. Set up the room so that each group has a specified location, and make name tags or placards. The panel should be positioned so that they can see each group.

Your Role: Let the students see that you are keeping copious notes during the presentations, but keep a moderately low profile. Avoid having the participants direct their remarks to you. Instruct speakers to steer statements to the panel or other groups. If, after this instruction, participants continue speaking to you, avoid eye contact with them by looking down. They will gradually direct their comments elsewhere.

5. ***Make the Decision:*** After the presentations, allow the panel an allotted amount of time to make a decision. They should also develop a formal statement explaining the rationale for their choice. Depending on class time and structure, groups can be allowed to ask clarifying questions about the panel's decision, rationale, or both.

Closure

Following the decision, provide feedback to the groups and the panel. Most of this feedback should be positive and specific, in order to shape future discussions. Negative comments should be avoided, but can be given as a general comment for the entire class. The feedback period is an appropriate time to correct any misinformation presented. If the students prepared adequately and you met with them prior to their presentation, misinformation will rarely be presented; however, if it does happen, it should be corrected in a matter-of-fact manner.

Throughout this process, help students to understand that there is not a clear "winner" when it comes to choosing a resource. Chances are the panel had difficulty choosing one resource because each resource has advantages and disadvantages. Ask them to share their decision-making processes and challenges with the class.

Assessment

Formative

- Did students work together cooperatively in groups?
- What strategies did they use to gather information about their resource?
- How seriously did they prepare for the presentation/debate?

Summative

- Have the class create a bulletin board or display providing facts about how each resource is developed, and summarizing advantages and disadvantages.
- The ***Evaluation Criteria*** sheet provides agree/disagree scales to evaluate the groups' research, organization, and the presentation/debate.

The Energy Debate: Providing Insight for Future Investigations. During this project, students probably discovered various issues related to resource development and use. Encourage students to make note of these for future investigation. Specifically note issues addressed by activities in the themes "Effects of Energy Resource Development and Managing Energy Resource Use."

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Energy Learning Log

Energy Learning Logs are similar to portfolios and are used for projects within the performance standard activities. Use an Energy Learning Log throughout the entire developmental process of students' learning about energy. An Energy Learning Log can be of any type, such as an accordion folder, a spiral or loose-leaf notebook, etc. Invite students to personalize the outside of their logs with drawn or cut-and-pasted illustrations relating to energy.

Energy Learning Logs Can Be Used…

…as a Vehicle for Pre-assessment

Prior to any instruction on energy, invite students to write about energy for 15 minutes or so. Emphasize that this is not a formal writing task. They should write down anything that comes to mind, keeping their pen or pencil to the paper at all times. If their mind is blank, suggest they write the word energy over and over again until they think of something related to energy, or they can write about why they can't think of anything related to energy. After students are done writing, ask them to summarize what they wrote by writing down three statements that they think they know about energy, and three questions that they have about energy. These questions can be discussed as a class, shared with the teacher on an individual basis, or kept private. At the end of the energy unit, have students revisit these questions and statements and answer or rewrite them as needed.

…to Help Organize and Plan a Project

After students have been introduced to the purpose of a project, encourage them to use the Energy Learning Log as a planning and organizing tool. They can outline their objectives and identify what they need to acquire. The log can be used to collect background information and reference materials such as journal articles and interview results. This is one reason why a large three-ring binder or accordion folder serves as a good log.

The system students use to organize the information they collect provides insights into their thought processes. Have students construct outlines or concept maps that diagram their arrangements. This allows you a good opportunity to evaluate their work in progress. Assist them by identifying new categories or suggesting ways they can narrow their scope.

…as a Reflective Tool and to Monitor Progress

Use the Energy Learning Log to link different energy concepts students have learned. When students are learning new concepts, encourage them to refer to previous information.

Allow time at the end of each energy education activity for students to summarize and interpret what they experienced. They should view these writing opportunities as a means to express their personal insights. They are striving to make the energy activity meaningful and to apply it to their own lives. By relating what they have observed in their own words, students will discover gaps that need to be filled, make connections among existing thoughts, and raise questions that require further exploration.

Students may wish to use parts of the log as a diary. They can record their personal reflections, wishes, and frustrations in a special section of the log, in code, or in a separate journal. In some cases, this section will be designated as writing not to be viewed by the teacher.

...to Report and Evaluate Results

An Energy Learning Log can be used to document the results of a project or activity, or it can be the project. Actual samples of student work can be part of the log. Samples include artwork, videos, poetry, draft writings, calculations, and test results. One strategy involves having students use the log to show what they think is their best work. Reflective questions should accompany this presentation. For example, students can be asked to explain why they think this is their best work, what they did to make the project successful, what they would do differently, and how this applies to their overall development as a current and future energy consumer.

If the log itself is graded, one or more of the following criteria can be used: accuracy of content, creativity, originality, evidence of increased knowledge about energy, thorough expression of attitudes toward energy, completeness, etc. It is best to present these criteria to students before they initiate their log work; then they will know what they should achieve. These criteria can be adapted into a rubric evaluation form.

Resources

Barrow, Lloyd. “A Portfolio of Learning.” *Science and Children* 31, no. 3 (1993):38-39.

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Cook Publishers, Inc., 1991.

Benjamin, Carol Lea. *Writing for Kids*. New York: T. Y. Crowell, 1985.

Cole, Donna J., Charles W. Ryan, and Fran Kick. *Portfolios across the Curriculum and Beyond*. Thousand Oaks, Calif.: Corwin Press, Inc., 1995.

The Watercourse and Western Regional Environmental Education Council. “Water Log” pp. 19–22 in *Project WET Curriculum and Activity Guide*. Bozeman, Mont.: The Watercourse and the Western Regional Environmental Education Council (WREEC), 1995.

The Energy Debate: Which Resource Is Best?

Introduction

You have just learned of a hypothetical but possible scenario about choosing an energy source for a new power plant or other means of generating electricity. You will be working in groups, where each group represents a firm that develops a particular energy resource for electricity generation. Your task is to convince the utility that your energy resource is the best choice for generating electricity. If your proposal is accepted, the utility will build a power plant or other means of generating electricity that uses your energy resource. Fulfilling the proposal will meet the needs of the utility's customers, and your group will live comfortably for the rest of your lives on the profits you will earn.

Purpose of Project

The purpose of this project is for your group to design, present, and defend a proposal that states why a certain energy resource is ideal for generating electricity. Ultimately, the purpose of this project is for you to learn the basic facts and advantages and disadvantages of each energy resource.

Group Responsibilities

To complete this project, there are various tasks that need to be accomplished. The two main tasks are:

1. Gathering and organizing information about an energy resource (see ***Project Components for Research and Preparation***)
2. Designing and conducting a presentation (see ***Project Components for the Proposal Presentation/ Debate Phase***)

The group can work together on each responsibility or certain group members can be made accountable for specific tasks. The following is a description of suggested titles and responsibilities for group members.

Organizer

The Organizer should be one student, with an assistant if the group size permits. The Organizer is the group leader. She or he works with the Researchers to decide what additional information needs to be gathered and meets with the Presenters to develop the proposal and presentation. The Organizer is also responsible for maintaining communications between the Researchers and the Presenters. It is recommended that a filing system, such as an "Energy Learning Log," be developed to record and organize the researched information. Your teacher will inform you if this approach is to be used.

Researchers

One or two students will be responsible for locating and recording information needed. Their aim is to provide the Presenters with important information they can use to support the proposal. The bulk of their research will focus on their assigned or chosen resource; however, they should also obtain information about the other resources. See ***Project Components for Research and Preparation*** for more details about job responsibilities.

Presenters

One to three students will be Presenters. At least one student should work closely with the Organizer and Researchers to design the presentation, making sure it is thorough, accurate, and well-organized. One student can be assigned to prepare speaker-support materials such as charts, graphs, and photographs. See ***Project Components for the Proposal Presentation/Debate Phase*** for more details about job responsibilities.

The Energy Debate: Which Resource Is Best?

The Presenters have specific responsibilities during the actual presentation:

One student, the Prover, announces the group's proposal and provides supporting information. This student must present relevant research to back up the statements made in the proposal. She or he must have good knowledge of the resource. The Prover may have prepared notes but should be advised that the presentation is a conversation, not a reading experience.

A second student, the Challenger, is responsible for leading the arguments against the other groups. His or her research may be limited to reading the ***Energy Resources Fact Sheets*** on other resources, but he or she will be required to listen well, think on his or her feet, discern logical flaws and opinions that are disguised as facts, and question the empiricism of quoted materials.

Panel Members

The Panel Members represent planners from the utility who listen carefully to the groups' presentations and decide which energy resource should be used to generate electricity. See the ***Proposal/Presentation Recording Sheet*** for keeping track of the advantages and disadvantages of each resource. The panel should meet to discuss this sheet and decide if it should be adapted to evaluate other aspects of the presentations (see ***Project Components for the Proposal Presentation/Debate Phase***).

Project Proposal Form

Instructions

Complete the ***Project Proposal Form*** and meet with the teacher to discuss research and presentation plans and strategies.

Proposal Statement

Overview of Presentation

Description of Diagrams, Charts, and Graphs Supporting the Energy Resource

Prepared Questions about Other Resources

Anticipated Questions Posed by Other Groups, and Answers to Those Questions

Optional: The true opinion of your group or group members about the use of the resource in a power plant.

Project Components for Research and Preparation

Instructions

To help you create a comprehensive and organized presentation, you'll need to know your facts. You will also need a system to quickly locate facts during the presentation. A carefully developed filing system, such as an "Energy Learning Log," will serve as a vital resource for your presentation. Your teacher will inform you if "Energy Learning Logs" will be used.

Gathering Facts

Carefully read the ***Energy Resources Fact Sheet*** for your resource. Use the ***Energy Resources Fact Sheet*** and your prior knowledge to address the project components listed below. Decide what additional information needs to be gathered (this includes information needed to answer questions not addressed in the ***Energy Resources Fact Sheet*** and other references that can confirm answered questions). Some of the information you need to know about your resource may be presented during class activities. Researchers need to pay close attention to these activities and record relevant information. Sources for information about your energy resource include: class activities, interviews, your local utility, journal articles, letters, newspaper articles, reference books, and surveys.

Organize Researched Information

A filing system, such as an "Energy Learning Log," can be divided into sections based on the project components listed below. The system can include notes, diagrams, data tables, etc. NOTE: Always cite your information source and compile a bibliography, including relevant class activities. Your teacher will tell you how detailed the bibliography should be, but you will most likely need to cite the author, title, and date of publication. If the source is an interview or letter, state the person's name and title.

Project Components

Basic background information about the resource

- Type of energy resource
- Where it can be found
- Where (geographically) the energy resource is currently used to generate electricity
- Reserves: how long supplies will last
- End uses other than generating electricity

Overview of what electricity is and how the resource is developed for electricity generation

- How the resource is obtained
- How the resource is processed
- Transportation considerations
- What type of power plant or other means of generating electricity is needed

Reasons why the resource is preferable to other resources

- Advantages of the energy resource
- Costs of producing electricity
- Disadvantages of other resources

Reasons why the resource is not preferable to other resources

- Disadvantages of the energy resource
- Environmental impact
- Advantages of other resources

Project Components for the Proposal Presentation/Debate Phase

Instructions

Following are the components of the proposal and presentation/debate phase. Your teacher will give you time allotments and tell you if there are any variations to this format. Keep careful notes on other presentations. During the discussion, be considerate of each other. Attacks should not be made on personal attributes of the participants but on the merits of the prepared presentations and the ideas put forth on the issue. Speak only when called upon by the moderator. Pay attention to the time and HAVE FUN!!

Project Components

The proposal and presentation/debate consists of five stages:

1. Announcement of the Proposal (Prover)
2. The Presentation (Prover)
3. Clarifying Questions (asked by Panel Members, answered by Prover)
4. Free-Form Discussion/Debate (Challenger and Prover)
5. Position Restatement and Conclusion (Prover)

Announcement of the Proposal

In the first stage, the Provers announce the proposal for their group. Each student should complete her or his announcement within one minute.

The Presentation

In the second stage, the Provers use their presentation to clarify the position of their group. The presentation should concisely and creatively cover the researched project components. The main emphasis of the presentation should be why the group's resource is the best for the utility. The time allotted for your presentation will depend on the number of groups and the total time available for this activity (approximately a third of the total time allotted for the entire presentation/debate).

Time allotted for each presentation: ______________________________

Clarifying Questions

At the end of the presentation stage, the panel can ask clarifying questions. These questions are answered by the Prover with assistance from other group members. Depending on time, the groups may ask clarifying questions of each other. It is important to understand what is meant by a clarifying question. The purpose of these questions is to ensure a clear understanding. Clarifying questions are often phrased as

"What do you mean by...
or
"Are you saying that..."

Questions that challenge or argue a point should be reserved for the Discussion/Debate stage. However, this phase allows each group to begin pinning down the other group as to the specifics of their position. Time allotted for these questions is usually quite short, perhaps five minutes.

Time allotted for questions: ______________________________

Project Components for the Proposal Presentation/Debate Phase

Discussion/Debate

During this stage, the groups question each other, looking for strengths and weaknesses in each others' arguments and citing disadvantages of other groups' resources. Most of the questions asked will be put forth by the Challengers. The Prover is responsible for answering most of the questions. The rest of the group should be available to coach and back up these speakers. The panel interjects questions as needed. Their questions are designed to help them make a decision rather than find fault. They may want to ask one or two questions that all groups should answer. Allow about half of the total time for the presentation/debate session for this stage.

Time allotted for discussion/debate: ______________________________

Position Restatement and Conclusion

During this last stage, the Provers restate their proposal. Proposals may be revised to reflect outcomes of the discussion. Again, each group is allowed about one minute.

Proposal/Presentation Recording Sheet

Group Name

Energy Resource Represented

Summary of Proposal

Facts about Resource

Advantages of Resource

Disadvantages of Resource

Other Comments

Each panelist will need one copy of this form for each group presenting.
If the groups are using this form, they will also need one copy for each group presenting.

Evaluation Criteria

Following are a few criteria that can be used to evaluate the research, preparation, and presentation/debate.

A well-organized system was developed for recording information	Strongly Agree	Agree	Disagree	Strongly Disagree

Other considerations:
- Were all the Project Components for research and preparation addressed?
- Were references cited near stated facts and data?
- Was a bibliography included?
- Did the group gather information from materials other than the supplied Energy Fact Sheets?

The group appeared to be prepared and knowledgeable about its energy resource.	Strongly Agree	Agree	Disagree	Strongly Disagree

Other considerations:
- Did the group effectively teach people about their energy resource?
- Did the presentation address the project components?
- Did the group (or student) cite up-to-date relevant research and authors with good credentials?
- Was the group adept at countering or anticipating opposing viewpoints and questions?

The group formulated its own arguments in support of their energy resource.	Strongly Agree	Agree	Disagree	Strongly Disagree

Other considerations
- Did the group recognize advantages and disadvantages of the various energy resources?
- Were opinions backed by some kind of rationale and/or empirical support?

The group presentation was well organized and effective.	Strongly Agree	Agree	Disagree	Strongly Disagree

Other considerations
- Were appropriate arguments and facts presented in a timely and coherent fashion?

The Challenger asked appropriate questions of the other groups.	Strongly Agree	Agree	Disagree	Strongly Disagree

Other considerations
- Was the group perceptive to the weak points of other presentations?
- Were criticisms only of the opposition's point of view and ideas, not the person saying the ideas?

The group made the presentation interesting to the class.	Strongly Agree	Agree	Disagree	Strongly Disagree

Other considerations:
- Did the group strive to make the presentation relevant tot he listeners? (Did they use text concepts, ask rhetorical questions, make controversial statements, give examples, etc)

The group appeared to work well together.	Strongly Agree	Agree	Disagree	Strongly Disagree

Additional criteria can be added that addresses specific expectations of the Researchers and Presenters.

Facts about Solar Energy: Solar Electricity

Introduction

Harnessing energy from the sun holds great promise for meeting future energy needs because solar energy is a renewable and clean energy resource. Fossil fuels will eventually run out and the future of nuclear power is uncertain. For these reasons, other energy sources need to be harnessed. Solar energy is one of these sources.

Solar energy is produced by the sun, which is essentially a gigantic nuclear fusion reactor running on hydrogen fuel. The sun converts five million tons of matter into energy every second. Solar energy reaches the Earth's surface as ultraviolet (UV) light, visible light, and infrared light. Many other electromagnetic waves are stopped in the upper parts of the atmosphere. Scientists expect that the sun will continue to provide light and heat energy for the next five billion years.

Solar Energy Potential

The amount of solar energy that strikes Earth's surface per year is about 29,000 times greater than all of the energy used in the United States. Put another way, in one hour more energy from the sun falls on the earth than is used by everyone in the world in an entire year. The solar energy falling on Wisconsin each year is roughly equal to 844 quadrillion Btu of energy, which is almost 550 times the amount of energy used in Wisconsin.

Although the amount of solar energy reaching Earth's surface is immense, it is spread out over a large area. There are also limits to how efficiently it can be collected and converted into electricity and stored. These factors, in addition to geographic location, time of day, season, local landscape, and local weather, affect the amount of solar energy that can actually be used.

Producing Solar Electricity

Solar electricity is measured like most electricity, in kilowatt-hours, a unit of energy. Solar cells convert sunlight directly into electricity, and many solar-powered devices have been in use for decades, including wrist watches and calculators. Traditional cells are made of silicon, a material that comprises 28 percent of the Earth's crust. One solar cell measuring four inches across can produce one watt of electricity on a clear, sunny day. However, its efficiency can be affected by many factors including the wavelength of light, the temperature, and reflection. To produce more electricity, cells are wired together into panels (about 40 cells), and panels are wired together to form arrays.

Solar cells are reliable and quiet, and they can be installed quickly and easily. They are also mobile and easily maintained. They provide an ideal electrical power source for satellites, outdoor lighting, navigational beacons, and water pumps in remote areas. In the United States, more than 784,000 homes and businesses have 'gone solar.'

Facts about Solar Energy: Solar Electricity

Concentrated Solar Power (CSP)

Solar energy can be used to heat a fluid to produce steam that spins a turbine connected to an electrical generator. These systems are called solar thermal electric systems. Concentrated solar power systems use mirrors to reflect and concentrate sunlight onto a small area. The concentrated sunlight heats a fluid and creates steam, which then powers a turbine generating electricity.

One type of solar thermal electric system, the solar power tower, uses mirrors to track and focus sunlight onto the top of a heat collection tower (see Fig. 1.1). An experimental 10-megawatt solar power tower called Solar Two was tested in the desert near Barstow, California. It was used to demonstrate the advantages of using molten salt for heat transfer and thermal storage. The experiment showed that this type of solar energy production was efficient in collecting and dispatching energy. The world's largest operating power tower system is the Ivanpah Solar Electric Generating System in the Mojave Desert of California. Ivanpah currently runs 69 percent below operating capacity, lacking thermal storage. It cannot compete with PV panels which have undergone a huge price reduction and can be installed on homes.

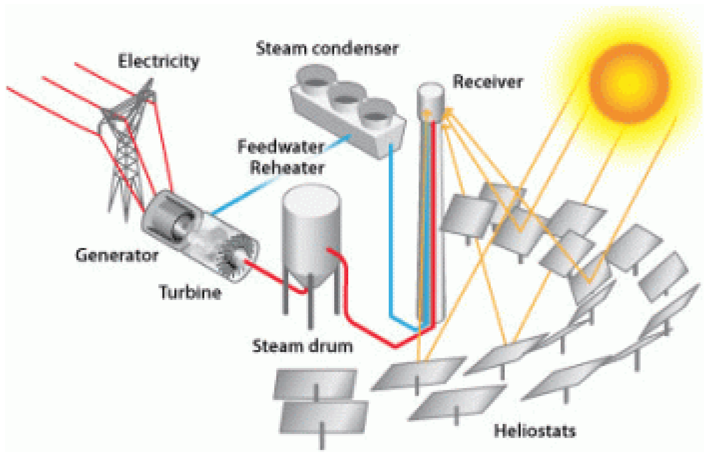

Fig. 1.1 Power Tower Power Plant

Source: energy.gov/eere/energybasics/articles/power-tower-system-concentrating-solar-power-basics

A second type of solar thermal electric system is called a parabolic trough. It is a linear concentrator system and uses curved, mirrored collectors shaped like troughs. The concentrated sunlight heats a working fluid running through the pipes that is then used as a heat source to generate electricity (see Fig 1.2). The largest system of this type is located in northern San Bernadino County in California with a capacity of 354 MW combined from three locations.

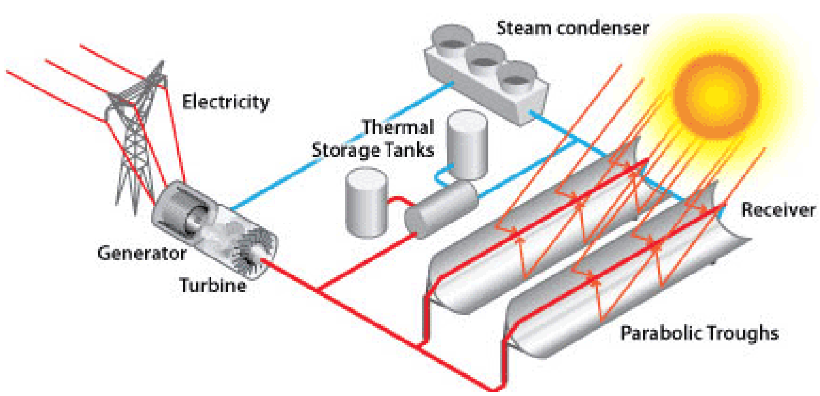

Fig. 1.2 Linear Concentrator Power Plant using Parabolic Tough Collectors

Source: energy.gov/eere/energybasics/articles/linear-concentrator-system-basics-concentrating-solar-power

Facts about Solar Energy: Solar Electricity

A third type of solar thermal electric system is an enclosed trough which use mirrors encapsulated in glass like a greenhouse to focus sunlight on a tube containing water, yielding high-pressure steam (see Fig. 1.3). This system was designed to produce heat for enhanced oil recovery.

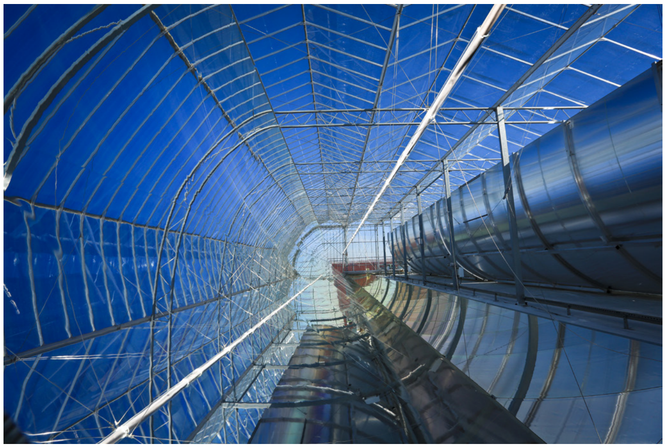

Fig. 1.3 View from inside the enclosed-trough parabolic solar mirrors, used to concentrate sun and generate steam for enhanced oil recovery (EOR).
Source: commons.wikimedia.org/wiki/File%3AInside_an_enclosed_CSP_Trough.jpg

A fourth type of solar thermal electric system is a Dish Stirling system which uses a mirrored dish similar in appearance to a satellite dish (see Fig. 1.4). This system, like the others, uses mirrors to concentrate and reflect solar energy and the heat generated is used to produce electricity by concentrating sunlight onto a receiver-- located at the dish's focal point – containing a working fluid that powers a Stirling Engine.

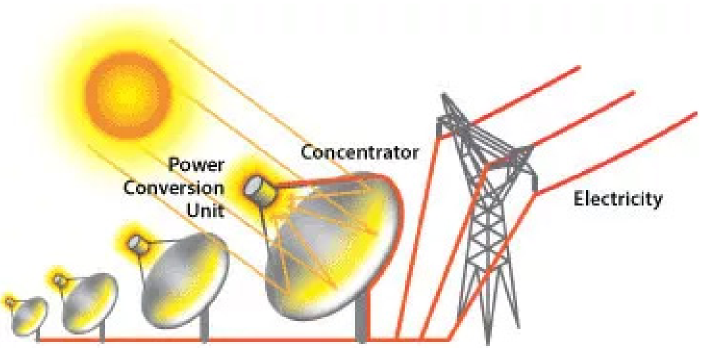

Fig. 1.4 Dish/Engine Power Plant
Source: energy.gov/eere/energybasics/articles/dishengine-system-concentrating-solar-power-basics

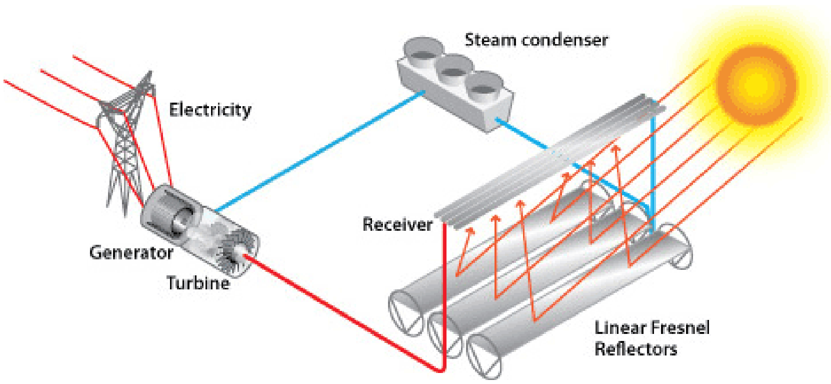

Fig. 1.5 Linear Fresnel Power Plant
Source: energy.gov/eere/sunshot/downloads/linear-fresnel-power-plant-illustration

A fifth type of solar thermal electric system called Fresnel reflectors are long, thin segments of mirrors that focus sunlight onto a fixed absorber located at a common focal point of the reflectors (see Fig. 1.5). Flat mirrors allow more reflective surface than parabolic reflectors and are much cheaper.

Facts about Solar Energy: Solar Electricity

Solar Electricity Production

Of the total electricity production in the United States, solar energy provides less than 2 percent. In Wisconsin only about 0.4 percent of total electricity production is from solar energy. A negligible amount of electricity from solar energy is currently being generated by individual homeowners and businesses.

Effects

Solar electricity has many benefits. Solar electric systems have no fuel costs, low operating and maintenance costs, produce virtually no emissions or waste while functioning, and even raise the value of homes.

Solar electric systems can be built quickly and in many sizes. They are well-suited to rural areas, developing countries, and other communities that do not have access to centrally generated electricity.

Solar electricity also has limitations. It is not available at night and is less available during cloudy days, making it necessary to store the produced electricity. Backup generators can also be used to support these systems. During the manufacturing process of photovoltaic cells, some toxic materials and chemicals are used. Some systems may use hazardous fluids to transfer heat. Adverse impacts can be experienced in areas that are cleared or used for large solar energy generating sites. Large-scale solar electric systems need large amounts of land to collect solar energy. This may cause conflicts if the land is in an environmentally sensitive area or is needed for other purposes. Deaths of birds and insects may occur if they happen to fly directly into a beam of light concentrated by a CSP.

Sometimes large-scale solar electric systems are placed in deserts or marginal lands. CSP developments are common in the southwestern United States (Colorado and Mojave Deserts); however, these locations are not without conflict either. For example, the Mojave desert tortoise is a threatened species that is in decline due to a complex array of threats including habitat loss and degradation.

Another idea is to place solar cells on rooftops, over parking lots, in yards, and along highways, and then connect the systems to an electric utility's power-line system. As the use of solar electric systems increases, laws may be needed to protect peoples' right to access the sun.

Solar Array Near Cantil, California

Source: Hanwha Q CELLS USA.

Facts about Solar Energy: Solar Electricity

Outlook

The sun is expected to remain much as it is today for another five billion years. Because we can anticipate harvesting the sun's energy for the foreseeable future, the outlook for solar energy is optimistic. Continued growth in utility-scale solar power generation is expected. The flexibility and environmental benefits of solar electricity make it an attractive alternative to fossil and nuclear fuels. Although the cost of solar panels has dropped significantly, other solar installations (such as CSP) are relatively expensive when compared to the amount of electricity they generate. Land issues and the need for electricity storage or backup systems are also obstacles, of which many experts are confident can be overcome. Incentives are increasingly offered at the utility, county, state, and federal levels. The U.S. Department of Energy's SunShot Initiative has launched an effort to make solar energy more cost-competitive with other types of energy. Incentives such as these will ultimately assist in the continued growth of solar energy.

In the near future, the use of solar electric systems will likely continue to increase in the Southern and Western parts of the United States where sunshine is plentiful. Solar energy growth in Wisconsin has been slower than that of Southern and Western states but currently has 22 MW of solar energy installed, equivalent to what is needed to power 3,000 homes. A number of homeowners and businesses in Wisconsin have already demonstrated that solar electric systems can meet their needs, and it is reasonable to expect growth of solar electric power in Wisconsin as well.

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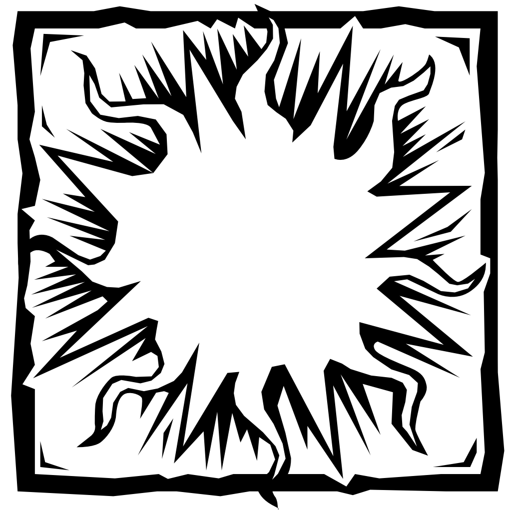
Facts about Solar Energy: Solar Heating



Introduction

Harnessing energy form the sun holds great promise for meeting future energy needs because the sun is a renewable and clean energy resource. Fossil fuels will eventually run out and the future of nuclear power is uncertain. For these reasons, other energy sources need to be developed. Solar energy is one of these sources.

Solar energy is produced by the sun, which is a gigantic nuclear fusion reactor running on hydrogen fuel. The sun converts five million tons of matter into energy every second. Solar energy comes to Earth in the form of visible light and infrared radiation. Scientists expect that the sun will continue to provide light and heat energy for the next five billion years.

Solar Energy Potential

The amount of solar energy that strikes Earth's surface per year is about 29,000 times greater than all the energy used in the United States. Put another way, in one hour more energy from the sun falls on the earth than is used by everyone in the world in an entire year. Solar energy used for heating is measured in Btu (British thermal units). The solar energy falling on Wisconsin each year is roughly equal to 844 quadrillion Btu of energy, which is nearly 550 times the amount of energy used in Wisconsin.

Although the amount of solar energy reaching Earth's surface is immense, it is spread out over a large area. To be used for heat, the energy from the sun must be collected and transferred to some other medium (such as air, water, or rock) to increase its temperature. Solar systems can be used for various applications requiring thermal energy, the most common uses being space heating, hot water heating, and swimming pool heating.

Solar Space Heating

Solar energy can used for space heating in buildings, employing either passive or active systems.
In a passive solar space heating system, the building itself is architecturally designed to capture solar energy and use it to heat the interior. Rooms called sunspaces or solariums, as well as greenhouses, can be built onto the south side of a home or building to collect solar energy. In some cases, structures such as trombe walls may be used to move air through the wall structure itself helping to distribute thermal energy to the interior space. The building is often designed so that the warmed air from these spaces can naturally circulate to other rooms. Large mass brick or stone walls and floors can be used to absorb the sunlight and store energy for heating at night. Because they do not require any type of mechanical system, passive solar buildings usually need little maintenance and can help lower cooling costs. Because they are integrated into the building design, it is usually difficult to retrofit an existing home to include a passive solar system. For new construction however, incorporation of passive solar heating can significantly reduce energy costs for the home owner.

In an active solar space heating system, a solar collector is used to heat a fluid (e.g., water or air) which is pumped or blown through tubes or ducts to deliver heat where it is needed. If air is the heat transfer fluid, then the warm air can be delivered directly the desired interior space. If a liquid is used as the heat transfer fluid, the energy can be transferred by a heat exchanger within the blower unit of a traditional forced air heating system. Alternatively, the heat transfer fluid can also be pumped through a radiator or a radiant floor heating system to warm the interior space. In Wisconsin, active systems frequently use a glycol antifreeze

Facts about Solar Energy: Solar Heating

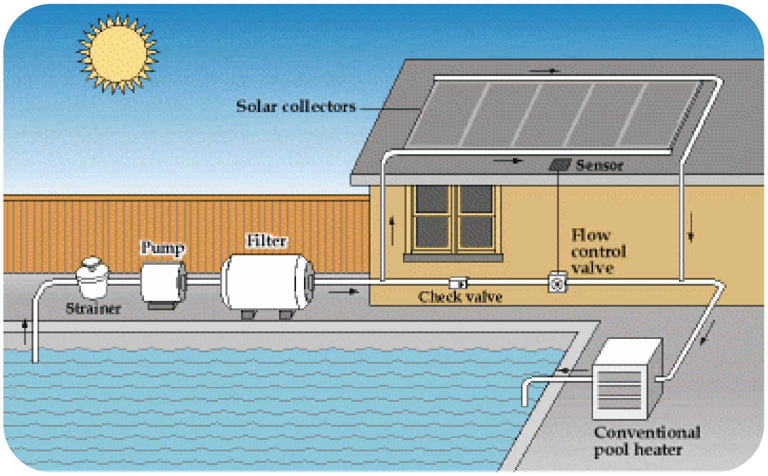
mixture as the heat transfer fluid to prevent freezing during winter months. To provide heat at night or when the sun is not shining, the energy collected by active solar systems can also be stored in a well-insulated bulk container that holds a large volume of hot water, or a large mass of hot solid such as brick or stone.

Solar Water Heating

Solar water heating systems operate in much the same way as active space heating systems. The solar energy is collected, and transferred to a fluid (either water or glycol). Instead of transferring this energy to the interior space of a building as in solar space heating, the energy is instead used to provide hot water. According to the Solar Energy Industries Association (SEIA), the return on investment for solar water heating can be as low as 3-6 years for a well-designed system, the lowest of any solar technology. Solar water heating systems can be used in homes throughout the United States. Solar water heaters are also especially well-suited for applications that require large volumes of hot water, such as laundromats and car washes, and facilities with heavily used shower rooms, such as athletic gymnasiums and college dormitories.

Solar Swimming Pool Heating

Swimming pools are a very good application for solar heating, because they require a substantial amount of energy to heat large volumes of water, but they do not need to achieve very high temperatures. Because the operating temperatures of solar pool systems are relatively low, the solar collector and active pumping heat transfer system can usually be constructed of lower cost materials (in many cases employing inexpensive plastics). Swimming pool heating systems are especially attractive for schools, hotels and resorts that operate large pools and waterparks. Solar pool heaters are also applicable for residential homeowners, and often are more affordable than heating a pool using other energy sources.



Source: Energy.gov. Solar Swimming Pool Heaters.

Other Solar Heating Applications

Other uses of solar heat include applications such as solar cookers, solar crop dryers, and solar wood kilns for drying lumber. All of these applications are based on the construction of an enclosed structure combined with some means to collect solar energy. The structure must be well insulated to reduce heat loss and a thermostatic control system used to monitor and regulate the temperature. In drying applications, an air-handling unit is typically also required to control the humidity of the system. The advantage of all these systems is that the solar energy is available for free, offsetting the purchase of traditional heat sources such as natural gas, propane, or electricity.

Effects

Solar heating offers several benefits. Solar heating systems have minimal, if any, fuel costs. Passive solar heating systems have very low operating and maintenance costs; costs for active systems are somewhat

Facts about Solar Energy: Solar Heating

higher. Solar heating systems produce virtually no air emissions or waste while in use. They can be built quickly and in many sizes. They are also easily adapted to the needs of rural and developing communities and are well-suited for communities with limited access to other energy resources.

One limitation of solar heating is that the sun is not available at night and is less available on cloudy days. Solar heating systems either need to store the heat they collect or use backup heating systems when the sun is not available (e.g., woodstove, electric heating systems, small furnace).

Outlook

Because we can anticipate harvesting the sun's energy for the foreseeable future, the outlook for solar energy is optimistic. The environmental benefits of solar heating and its ability to meet the heating needs of most homes and buildings make it an attractive alternative to using nonrenewable fossil fuels. Reducing costs by mass-producing equipment, designing buildings that include passive solar systems, and improving energy efficiency may also help to encourage the growth of solar heating systems.

A significant number of homeowners and businesses in Wisconsin have demonstrated that both passive and active solar heating systems are an environmentally friendly way to meet their heating needs. One of the main factors that will influence the future growth of solar heating is the cost of other heating fuels and technologies including home heating oil, natural gas, propane, geothermal, and wood heat. As of 2017, hydraulic fracturing (fracking) has made natural gas quite affordable, so consumers with access to natural gas do not have as strong of a financial incentive to pursue solar heat. On the other hand, for those that wish to embrace renewable energy instead of fossil fuels, solar heating is an option to consider. It is usually advised to assess your building design and your local energy resources to determine what type of renewable heating system might provide the greatest economic benefit.

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Facts about Wind Energy

Introduction

Wind energy, used by civilizations for thousands of years to grind grain and pump water using windmills, was reborn during the energy crisis of the 1970s when improvements in materials and technology made wind turbines more common. Today, wind-generated electricity is helping to provide for U.S. electrical needs.

Wind is created when solar energy heats the atmosphere. This heat produces differences in air pressure as cold air is denser than warm air. Air is made of gases and gases will naturally move from an area of high concentration to an area of low concentration to equalize pressure differences (reaching an equilibrium), creating wind as a result. In the process, energy from the sun is converted into kinetic energy (the energy in motion).

The output of a wind energy system is measured in kilowatts (1,000 watts) or megawatts (1,000,000 watts). Energy is power used over time and is calculated by multiplying power and time. Wind-generated electricity is measured in kilowatt-hours, a unit of energy. One kilowatt-hour of electrical energy equals 3,413 Btu (British thermal units).

Wind Potential

Wind resources are plentiful in the United States. With average, reliable wind speeds of 15 miles per hour or more, states in and around the Great Plains area of the United States possess the nation's greatest wind potential.

The best sites for wind potential in Wisconsin are found along Lake Michigan and Superior, where average wind speeds may reach 14 miles per hour (see ***Estimated Wind Power Energy Potential (at 70 meters) and Existing Wind Development Locations, 2015***). It is estimated that Wisconsin has an annual energy potential of 58 billion kilowatt hours, and it currently ranks 18th of the top 20 states for wind energy potential.

Electricity Produced Using Wind

The energy in wind is converted into electricity using wind turbines. A wind turbine is made up of an electrical generator mounted on a tower and connected to a propeller. The wind turns the blades of the propeller, causing the generator to spin and produced electricity. Rotor diameter and general sizes of turbines have increased and changed due to higher efficiency and more advanced technology (see **Average turbine nameplate capacity, rotor diameter, and hub height installed during period**).

Wind turbines can be used to provide electricity to single family homes, especially in rural areas. The electricity produced can be stored in batteries for use when wind speeds are low or when high winds could damage the turbine.

Electric utilities use larger wind turbines. Often the utility will place many wind turbines together in what is called a wind farm. The largest wind farm in the world is Gansu Wind Farm in China. Although it is not fully developed at this time, it had 10.73 GW installed at the end of 2014.

Facts about Wind Energy

Wind Electricity Production

Wind power supplies nearly five percent of our nation's electricity demand across 39 states. Worldwide, there are more than 268,000 wind turbines spinning to produce electricity. In 2014 installed wind capacity in Wisconsin was 648 MW with 417 turbines operating in utilities. Wind electricity production accounted for 2.5 percent of all in-state electricity production, enough to power 150,000 homes.

Other Uses

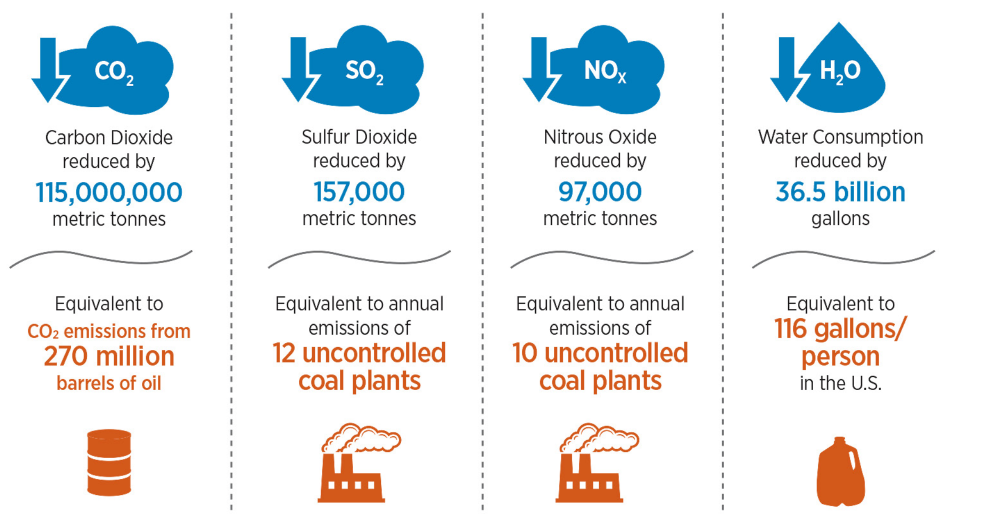
A modern wind turbine gets its design from windmills. Although windmills are not used as commonly anymore, they are still seen in rural parts of the U.S. and developing world to pump water or grind grain. A windmill is a device that has propeller blades connected to an axle with gears. The gears are connected to a vertical shaft that runs down the length of the tower and is connected to other mechanical equipment.

Effects

Wind energy has many benefits (see ***Wind generation in 2013 provided a range of environmental benefits***). Wind turbines have no fuel costs and low operating and maintenance costs. They produce virtually no air emissions or waste while in use. For example, the amount of electricity generated by the wind in one year in California avoided the production of 16 million pounds of air pollutants and 2.7 billion pounds of greenhouse gases. The wind plants also saved the equivalent of 4.8 million barrels of oil. In addition, wind energy creates jobs, is a 'homegrown' energy source, diversifies the national energy portfolio, can provide income for farmers, and can be deployed in all regions of the U.S.

However, wind energy is unreliable because the wind does not blow steadily in most places. Therefore, the electricity produced by home wind turbines needs to be stored in batteries, or a backup generator must be available, which increases the total cost of a wind energy system. On the other hand, a wind farm is

Wind generation in 2013 provided a range of environmental benefits.



Note: Emissions and water savings calculated using the EPA's Avoided Emissions and Generation Tool (AVERT). 'Uncontrolled coal plants' are those emissions control technology.

Source: Wind Vision: A New Era for Wind Power in the United States.

Facts about Wind Energy

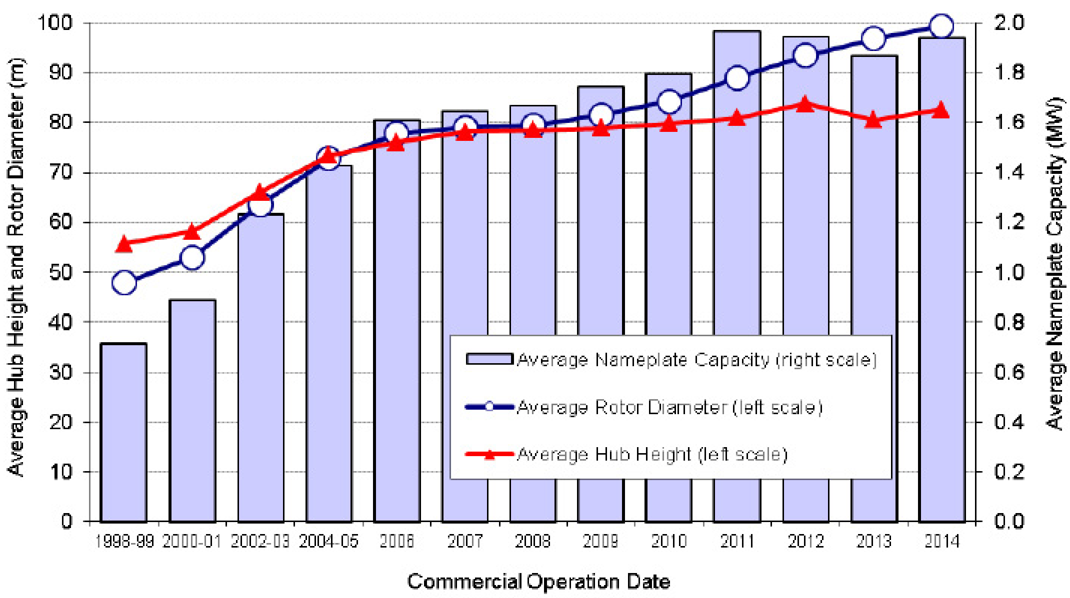
usually connected to a utility's power lines, so other power plants can supply electricity when the wind is not blowing. Some concerns about wind farms are aesthetic problems, propeller noise, and interference with birds' migratory patterns (although cell towers, electric lines, and domestic cats pose comparable threats to bird flight and populations). In addition, it is also important to assess the amount of waste and emissions produced by the manufacturing, transportation, and implementation processes of wind energy. Understanding these impacts and reducing environmental harms during the manufacturing processes will make wind energy even more appealing.

Outlook

After a lull, wind energy additions rebounded in 2014. Continued growth through 2017and beyond is expected and likely to become more mainstream. Texas continues to lead the nation in wind energy production, but other states such as Minnesota have implemented large-scale wind systems. Europe has aggressively developed wind power, and it has taken over hydropower as the third largest source of power generation in the EU. India, Brazil, China, Mexico, and Egypt also have sizable wind power projects underway.

Experts predict that by the year 2020 wind power could supply the U.S. with about 10 percent of the total electricity produced. No offshore wind energy plants are currently operating in the U.S. but progress is being made toward an offshore project in Rhode Island. The cost of wind-generated electricity has fallen and is becoming competitive with other ways of generating electricity. While wind energy is not expected to completely replace fossil- and nuclear-fueled electric power plants, its environmental advantages make it an attractive choice for the future.

Average turbine nameplate capacity, rotor diameter, and hub height installed during period (only turbines larger than 100kW)



Source: AWEA project database

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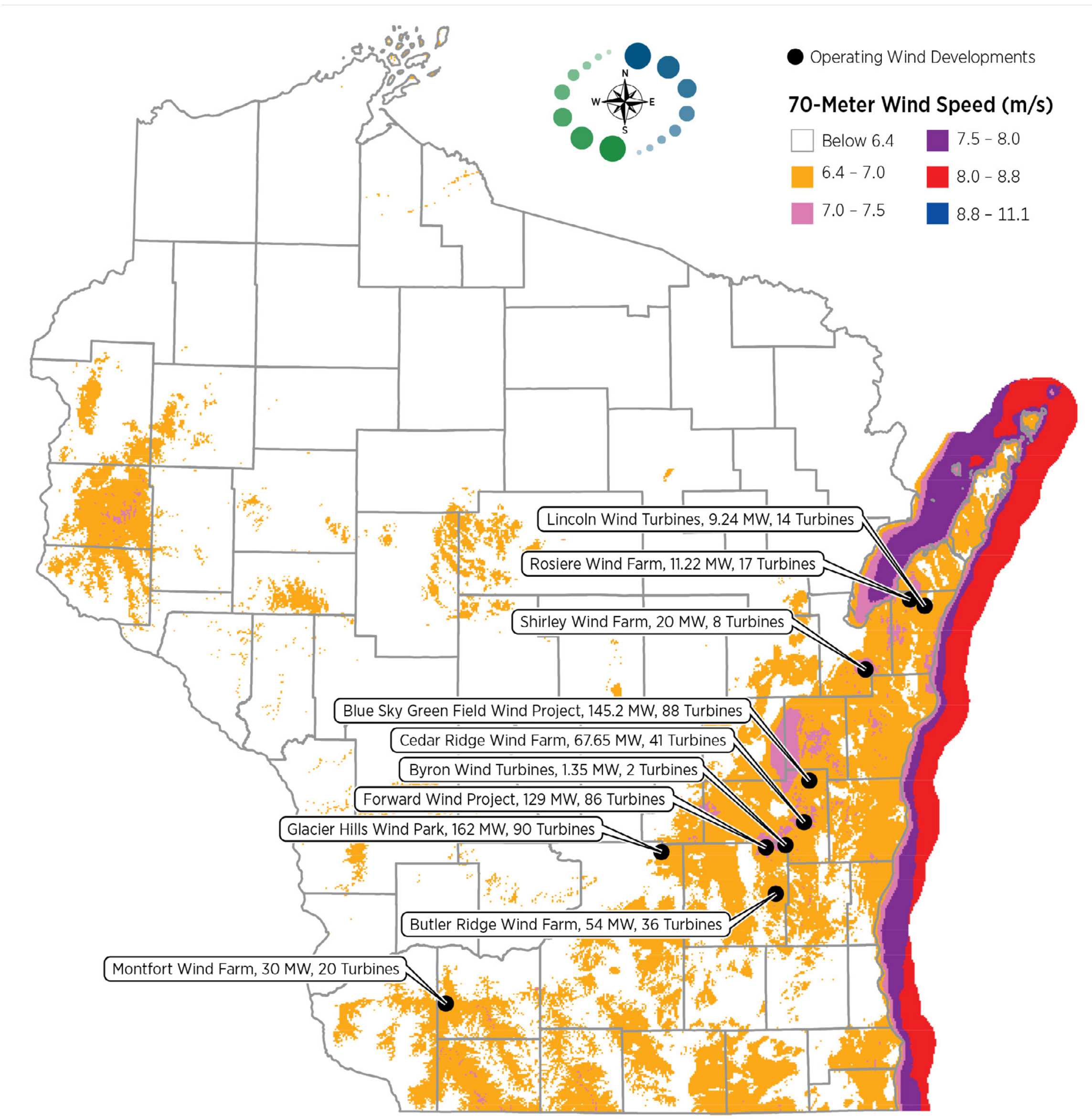
Facts about Wind Energy

Estimated Wind Power Energy Potential (at 70 meters)
and Existing Wind Development Locations
2015



Source: [AWS Truewind (2008); Wisconsin Office of Energy Innovation. Wisconsin Energy Statistics Book: Wisconsin Energy Statistics 2018.]

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

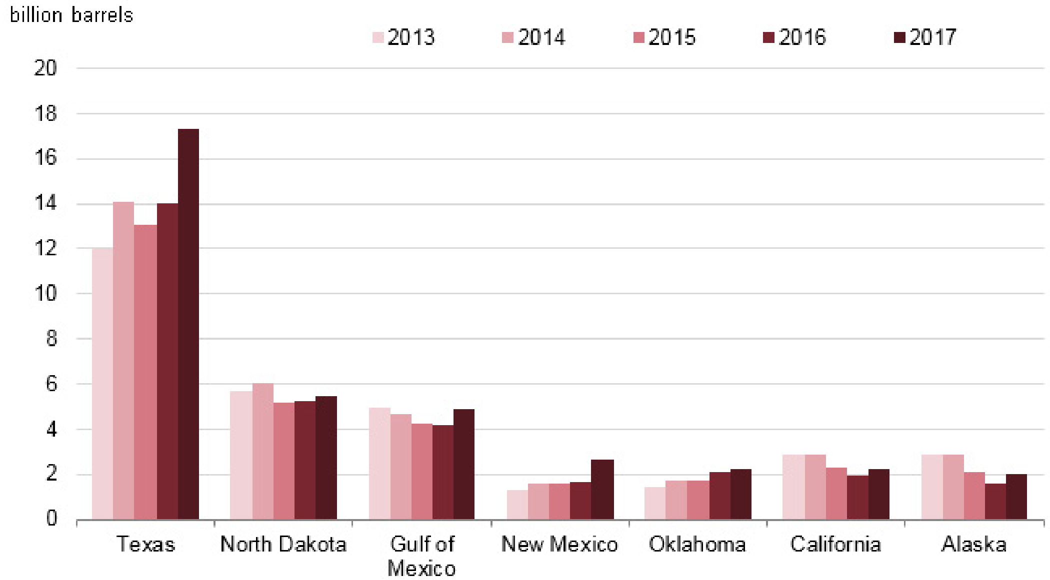
Known crude oil reserves in the United States in 2015 equaled 35.2 billion barrels. Outside the U.S. Venezuela has the largest amount of known oil reserves at 302 billion barrels, followed by Saudi Arabia, Iran, Iraq, and Kuwait.

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.

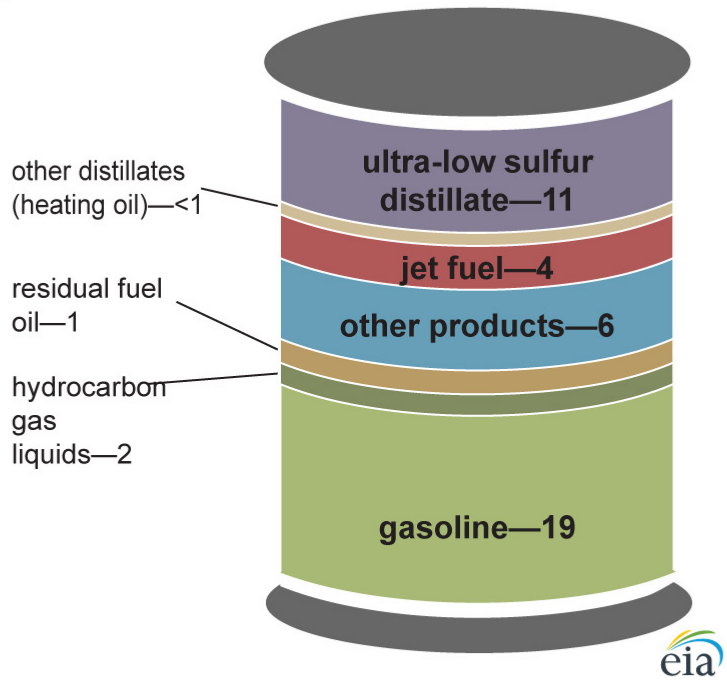
Facts about Oil

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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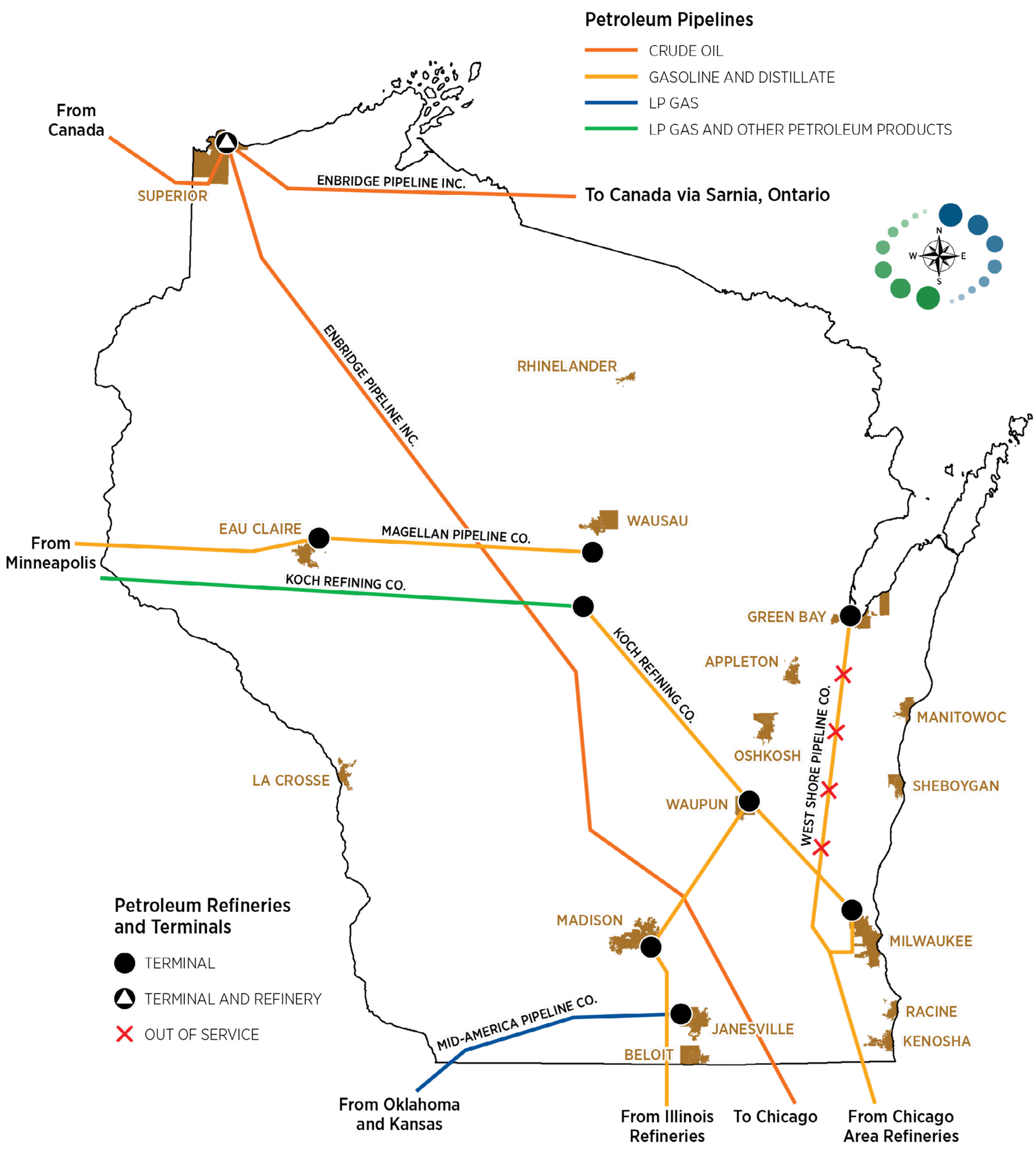
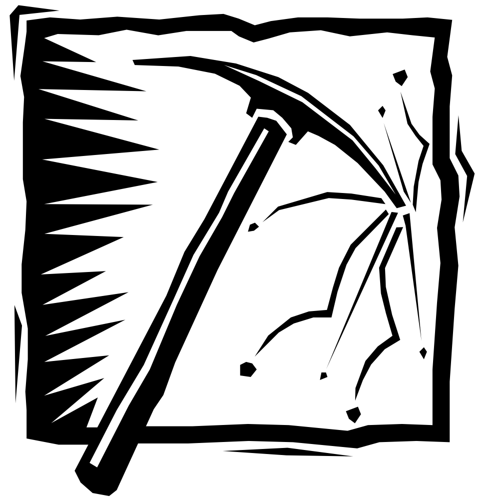
Wisconsin Petroleum Pipelines, 2015



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

Facts about 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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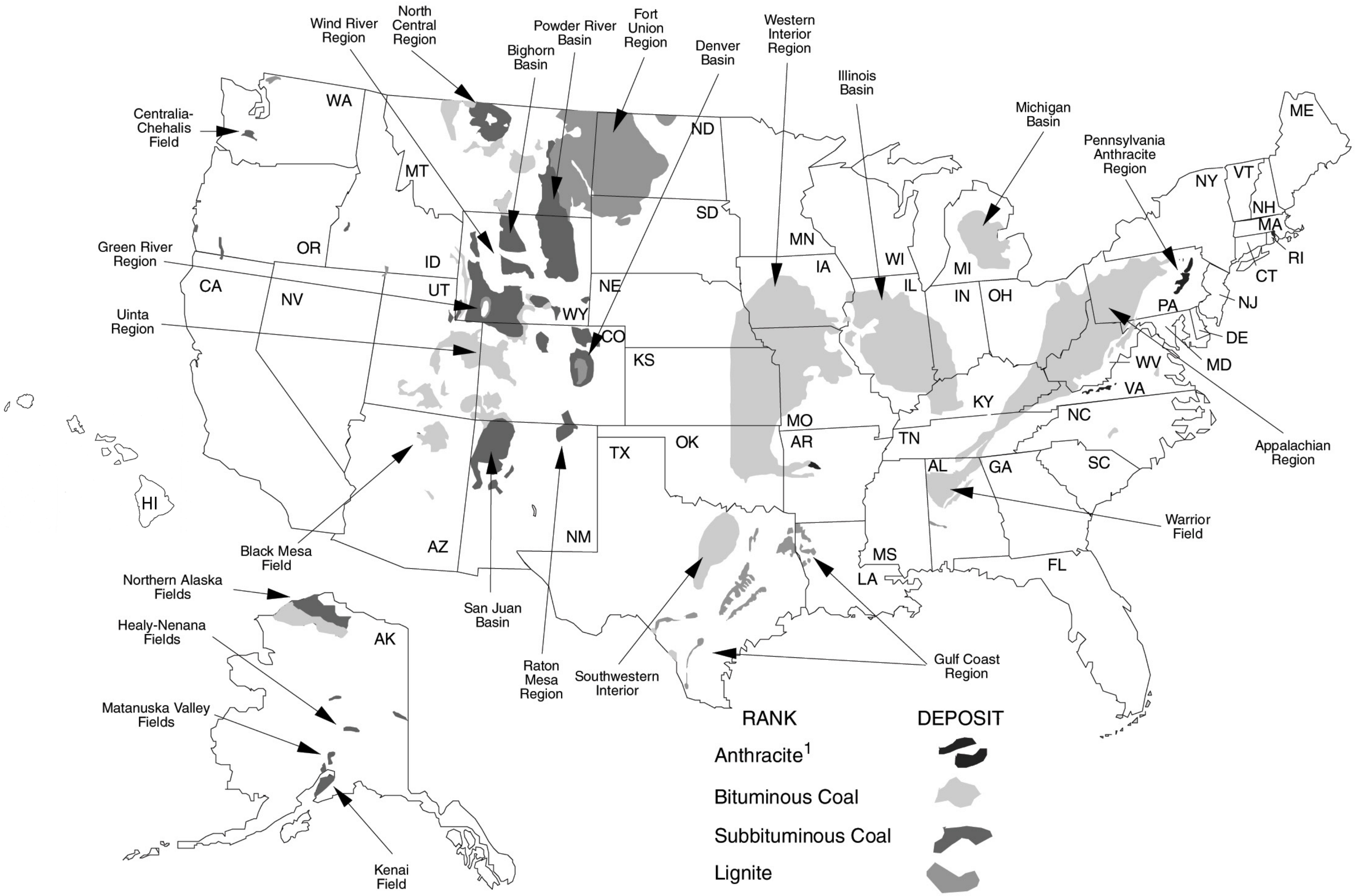
U.S. Coal Deposits

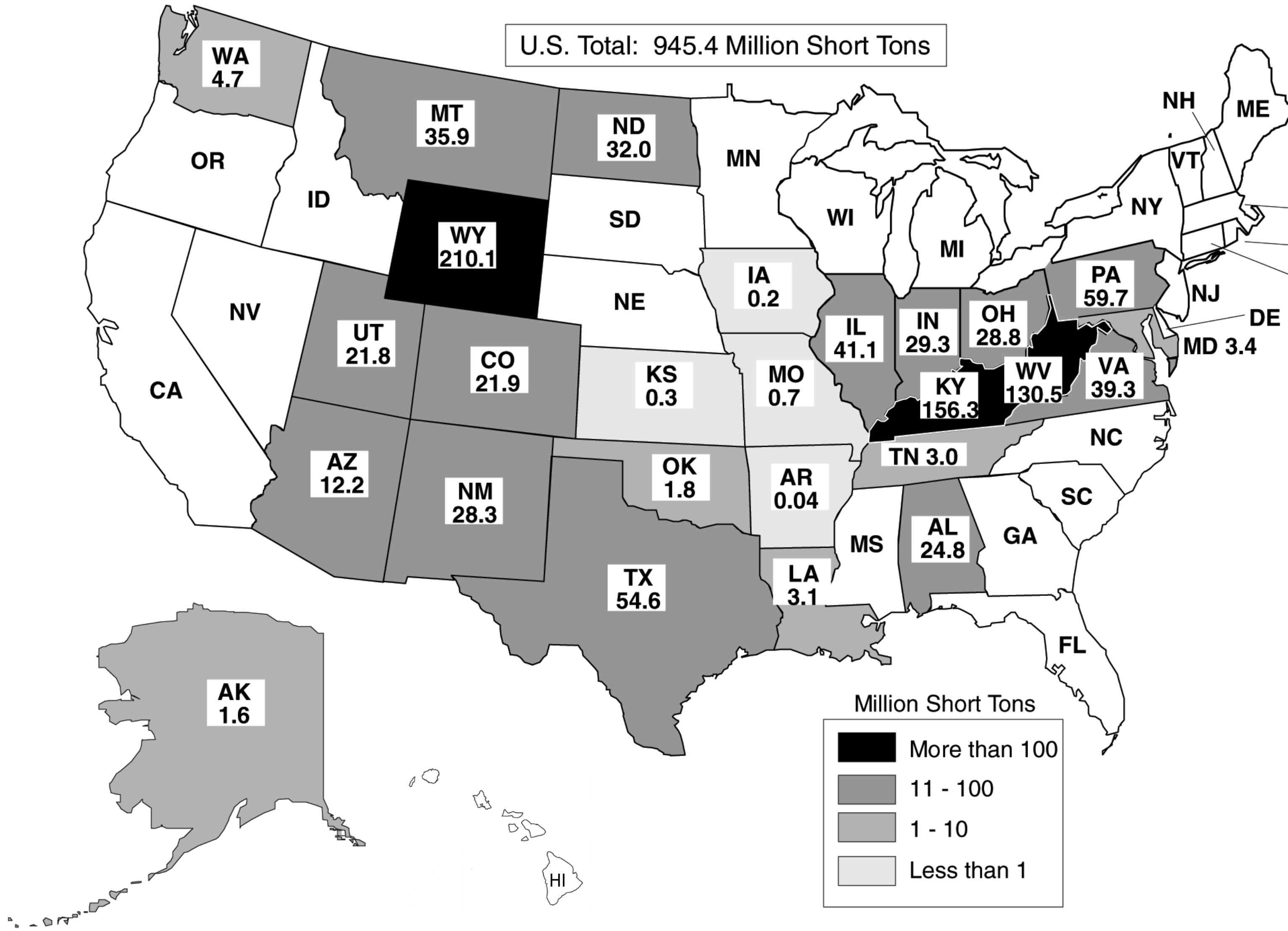


*Principal anthracite deposits are in Pennsylvania. Small deposits occur in Alaska, Arkansas, Colorado, Massachusetts-Rhode Island, New Mexico, Utah, Virginia, Washington, and West Virginia.

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 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.

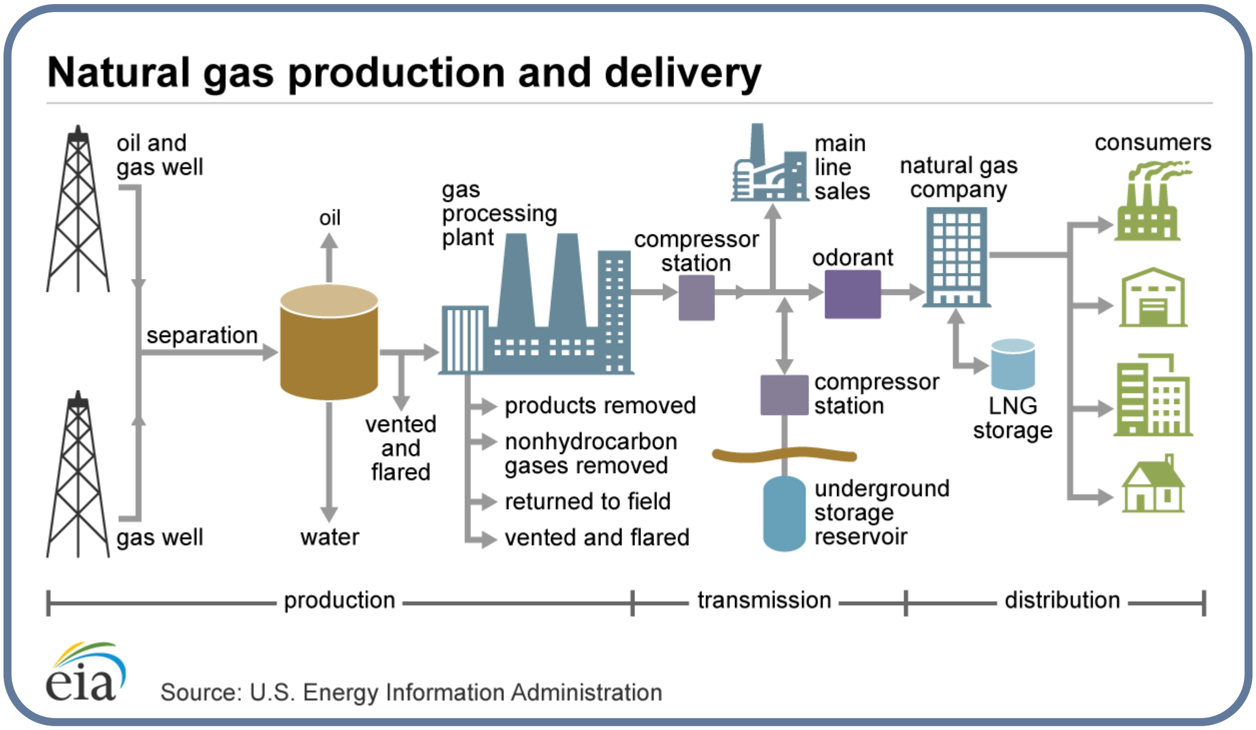
Facts about Natural Gas

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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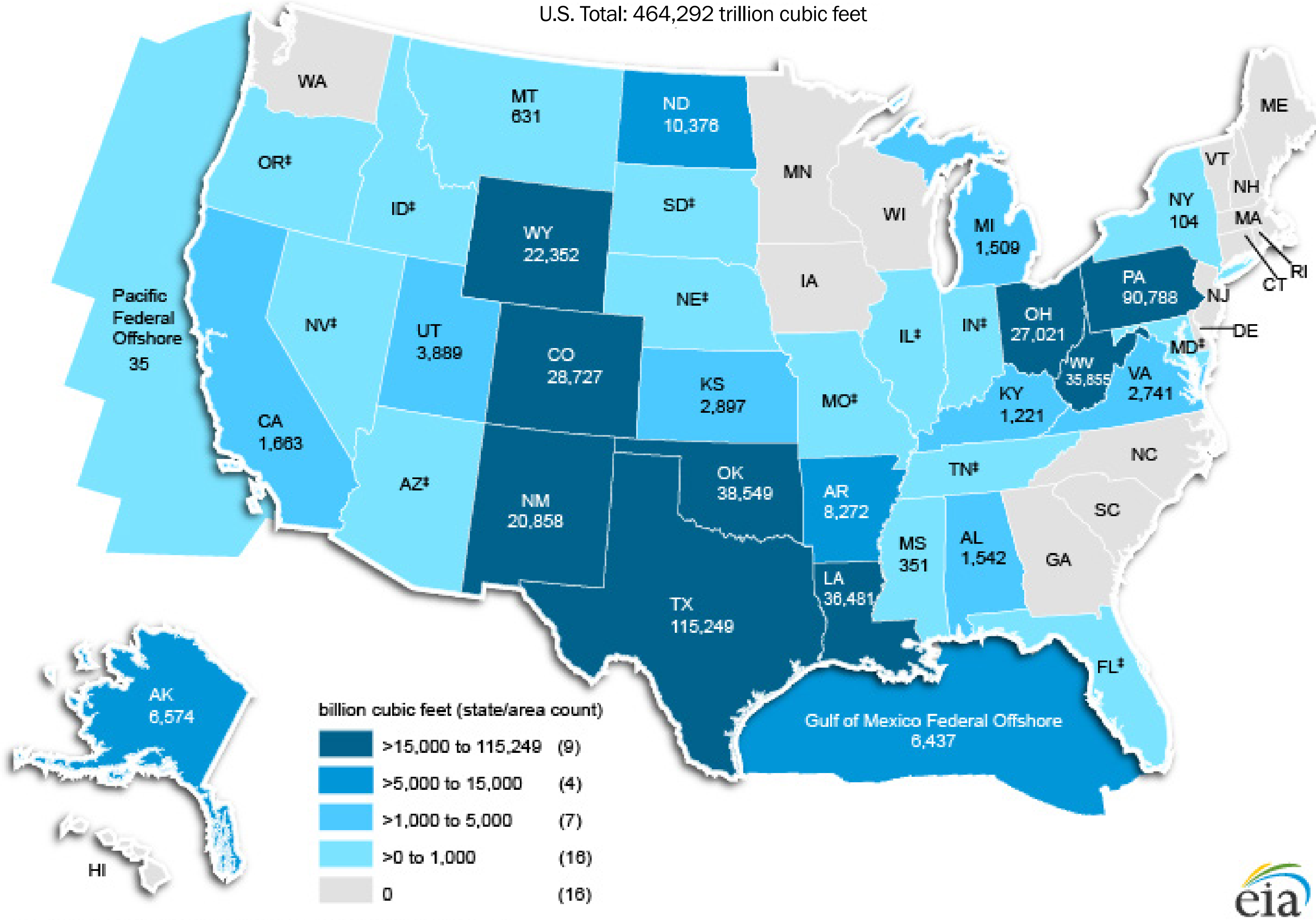
U.S. Natural Gas Proved Reserves, 2017

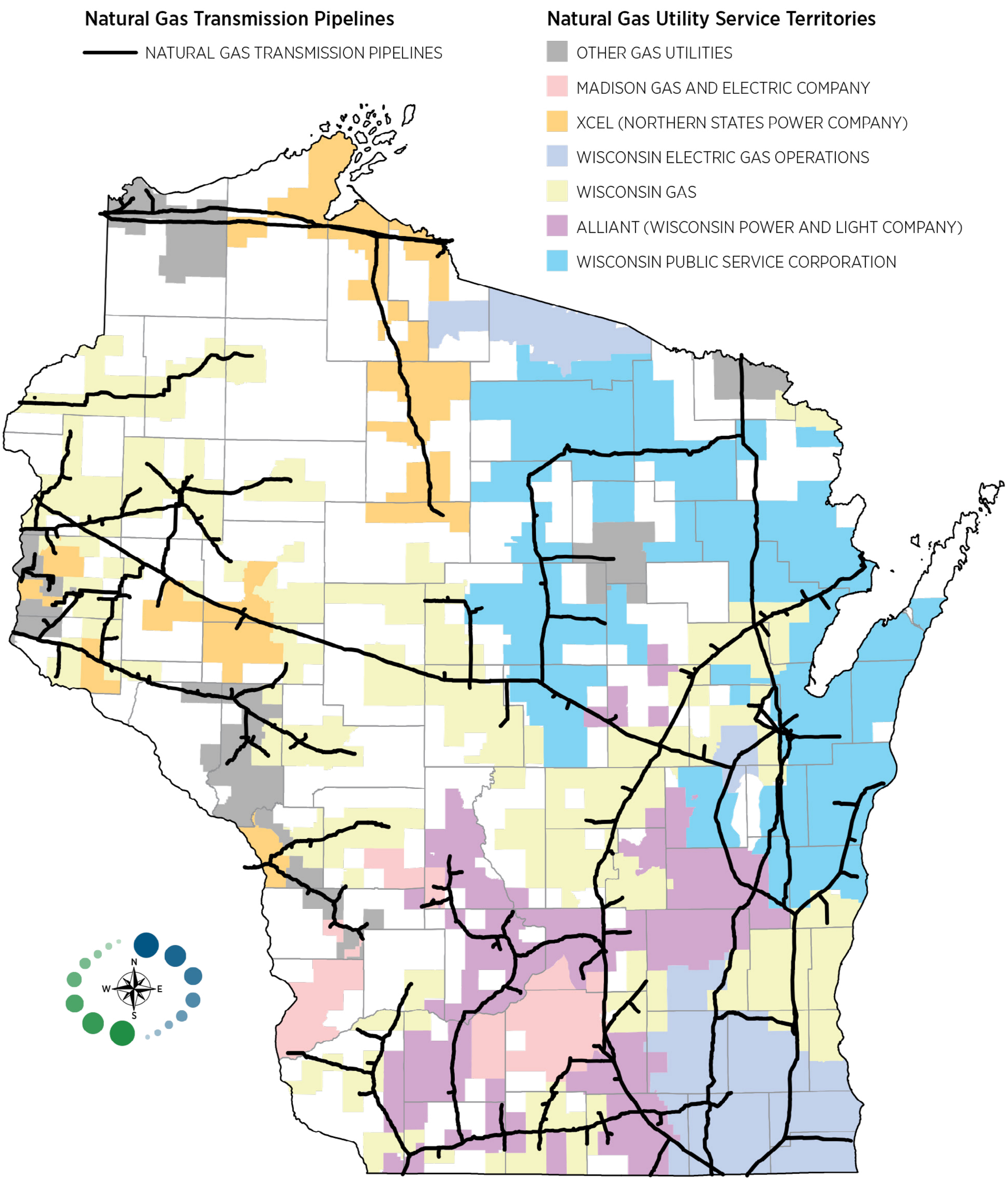
U.S. Total: 464,292 trillion cubic feet



‡ 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*

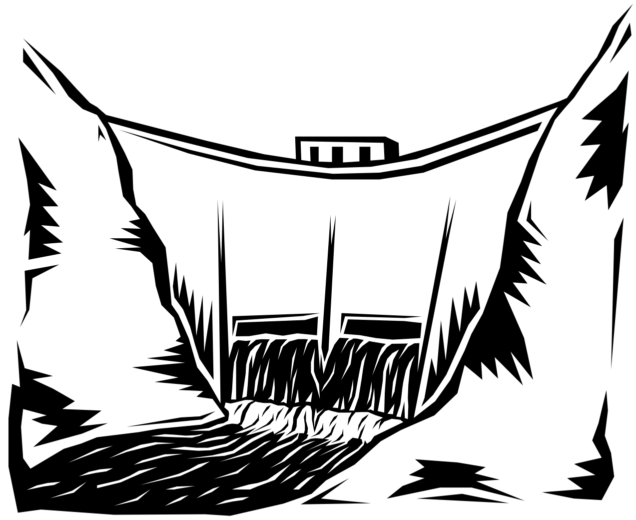
Wisconsin Natural Gas Utility Service Territories and Major Pipelines, 2015



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

Facts about Hydropower

Introduction



Humans have used water as source of power for thousands of years. Civilization's earliest machines were waterwheels for grinding grain. The earliest reference to hydropower is in China between 202 BC and 9 AD. Later, waterwheels were adapted to drive sawmills, pumps, and bellows and to provide mechanical power for textile mills. Hydropower plants that produced electricity were developed in the late nineteenth century. Today, nearly all hydropower plants in the United States produce electricity. The term "hydroelectric power" is often used interchangeably with the term "hydropower."

A hydropower system converts the kinetic energy (energy of motion) in flowing water into other forms, such as electrical or mechanical energy. This conversion occurs when water flows past a waterwheel, propeller, or turbine. The farther the water falls the more kinetic energy it has. The kinetic energy of flowing water can be increased by building a dam across a river or stream.

Hydroelectric power is measured in kilowatt-hours, which is a measure of energy that calculates the power used over time. Kilowatt-hours is abbreviated as kWh. One kilowatt-hour of electrical energy is equal to 3,413 Btu (British thermal units). The power output of a hydroelectric power plant is measured in kilowatts (1,000 watts) or megawatts (1,000,000 watts).

Hydroelectric Power Plants

Hydroelectric power plants are generally located at places on rivers or streams that can be easily dammed to create a reservoir of water. Larger rivers with sufficient height for dams are ideal for providing electricity because the farther the water falls, the more kinetic energy there is to be harnessed. Penstocks channel flowing water into turbines which provide the mechanical energy to produce electricity in the generator. The amount of water released can be adjusted to meet the demand. Spillways divert excess water that builds up behind the dam. Most of the larger hydroelectric dams in the United States are on sizable rivers, such as the Colorado and Columbia in the West and those in the Tennessee Valley Authority region in the South.

One of the world's first hydroelectric power stations was built in Appleton, Wisconsin, in 1882, only three years after Thomas Edison's invention of the light bulb. This station's output was 12.5 kilowatts, which lit two paper mills and a house. The Wisconsin River, which runs the length of Wisconsin and spills into the Mississippi River, has been described as the "hardest working river in the nation." Most of the hydroelectric dams on the Wisconsin River are located on the upper two-thirds of the river. These dams have generating capacities between 700 kW and 29.5 MW (see ***Wisconsin Hydroelectric Sites***).

Electricity Production

In 2015, six percent of all electricity generated in the United States was generated using hydropower. Of the approximately 3,900 dams in Wisconsin, about 150 are used to generate hydroelectric power. These sites produced about 192,000 MWh (192,000,000 kWh) of electricity in 2015.

Facts about Hydropower

Hydroelectric power provided 16.6 percent of the world's electricity, or 3,900 terawatt-hours (TWh) in 2014. The world's three largest producers are China, Brazil, and Canada. The relatively small country of Norway generates about 95 percent of its electricity from hydropower.

Although most large-scale hydropower sites in Wisconsin and the U.S. have already been developed, some potential exists for small-scale, local hydropower plants. The amount of hydropower being generated today is nearly five times the worldwide potential amount estimated in 2011 at 946,182 MW. There are also immense undeveloped hydropower resources in northeastern Canada.

A number of industries in Wisconsin and the United States are located near large hydroelectric sites so they can use the cheap, reliable electricity these plants provide. Examples include the paper industry in Wisconsin and the aluminum smelting industry in the Pacific Northwest.

Effects

Hydropower offers several benefits. Hydroelectric power plants have no fuel costs and low operating and maintenance costs. They last two to ten times longer than coal and nuclear plants, emit no carbon dioxide or other air pollutants, and generate no waste. In addition, hydroelectric dams help control downstream flooding, provide water for crop irrigation, and create reservoirs that provide recreation and fishing.
Large reservoirs behind hydroelectric dams also flood vast areas, harm wildlife habitats, move human settlements, and decrease fertilization of farmlands and fish harvests below the dam. A concern currently being researched and mitigated is dam impediment to fish migration. Migrating fish such as salmon can be blocked by dams to traditional spawning sites and their population can be severely harmed. Fish ladders and passages have been implemented on a number of large and small dams across the globe to avoid this issue.

Outlook

Hydropower will continue to be an important energy resource in the United States and the world. However, it is unlikely that enough new hydroelectric plants will take the place of fossil- and nuclear-fueled electric power plants. Most available sites for large-scale hydroelectric power production in the United States have already been developed. On the other hand, the potential for further development of hydropower on smaller rivers and streams still exists. However, water shortages have decreased electricity produced by hydropower by 14 percent over the past two decades globally.

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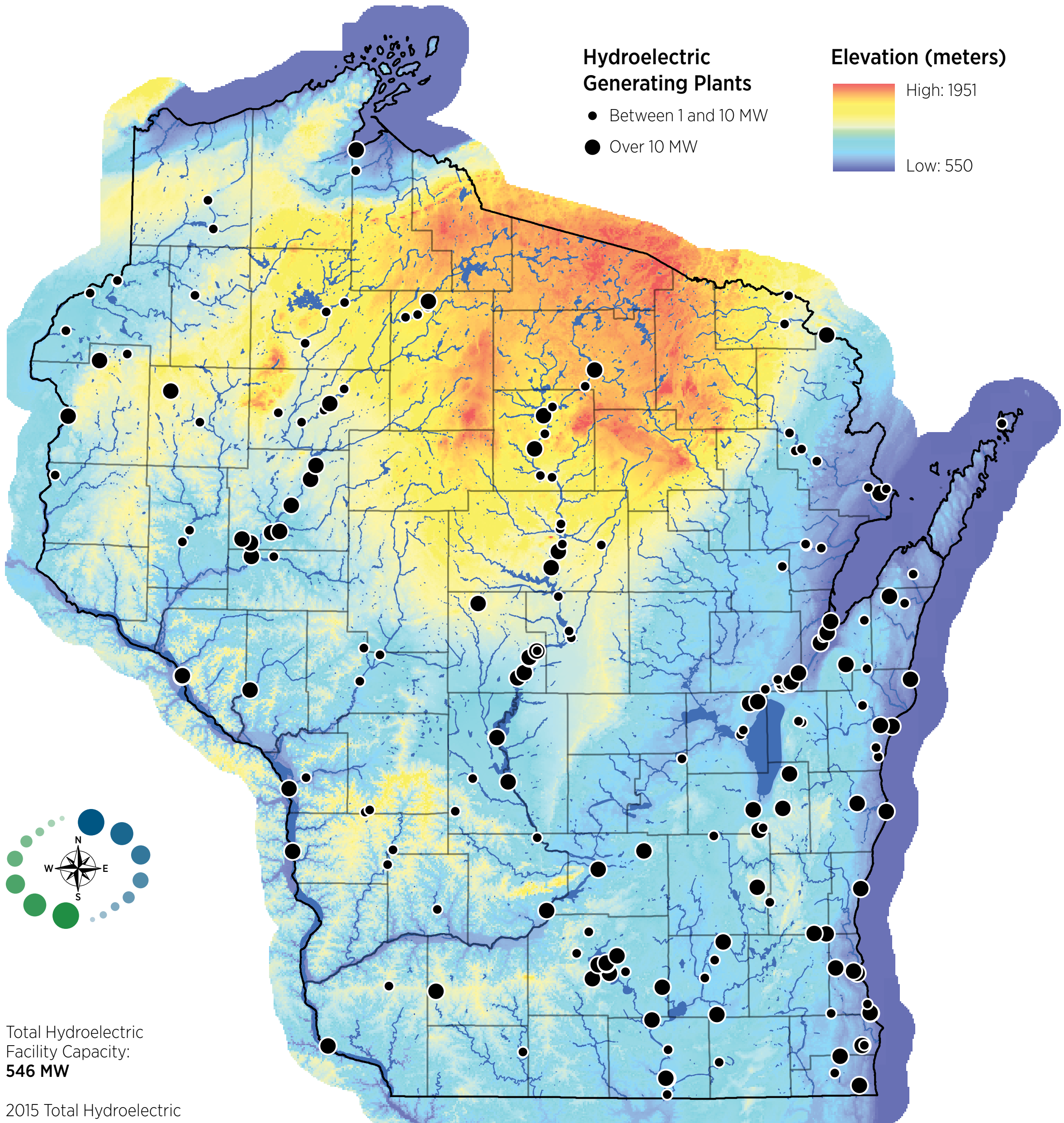
Wisconsin Hydroelectric Sites

Hydroelectric Generation Sites in Wisconsin

2015



Total Hydroelectric Facility Capacity:
546 MW

2015 Total Hydroelectric Energy Generated:
2,431,230 MWhs

(Capacity and energy generated include hydroelectric facilities owned by utilities, merchants, cooperatives, and other nonutilities.)

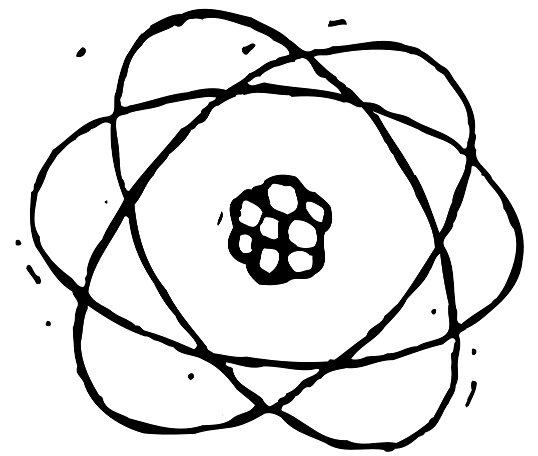
Source: Wisconsin Office of Energy Innovation. Wisconsin Energy Statistics Book.

Wisconsin Hydropower

Spillways at Wissota Hydro. Located on the Lower Chippewa River, this facility was completed in 1918 and produces 36.4 MW. Photo Courtesy of Xcel Energy.

Jim Falls Hydro auxiliary spillway adjacent to the power house. Located on the Lower Chippewa River, this facility was originally constructed in 1923. In 1984, a $92 million redevelopment project made it the largest hydro facility in the Midwest in terms of generating capacity (57.5 MW). Photo courtesy of Xcel Energy.

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

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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.

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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 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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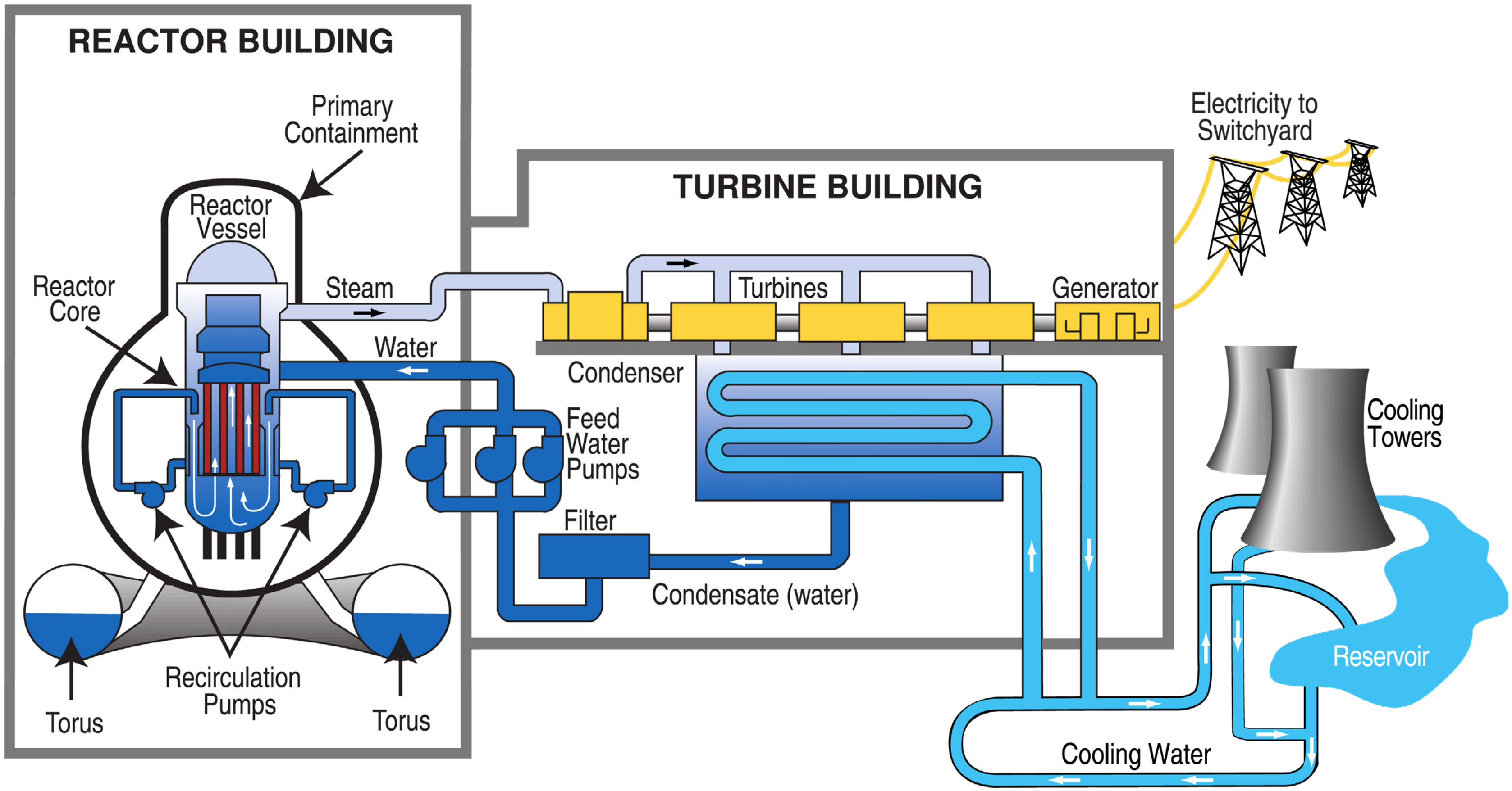
Nuclear Power Plant Diagram



Facts about Biomass Fuels

Introduction

Throughout history humans have used fuels made from plant and animal matter for heating and cooking. Today, technological advances and society's increasing demand for energy have led to an expanded role for these biomass fuels. Biomass is plant or animal matter. The raw materials for biomass include dedicated energy resources such as trees, crops, grasses, and algae. Various waste streams such as agricultural waste, human and animal waste, forest product and paper mill waste, and municipal solid waste can also be collected as biomass sources. Furthermore, biomass sources can be used to produce higher value biomass fuels in the form of solids (e.g., wood pellets), liquids (e.g., ethanol), or gases (e.g., methane).

Biomass gets its energy from the sun. Photosynthesis converts solar energy striking the leaves of plants into chemical energy, which is stored in the plants themselves in the form of sugars, starches, oils, cellulose and lignin. Animals that eat plants store some of this energy in their bodies in the form of fat; some of it is also excreted in manure and other wastes. Biomass fuels are renewable, because the raw materials used to make the fuels can be replaced within a human lifetime simply by growing more crops or collecting more waste.

In the English system of measurement, the energy content of biomass fuels is usually measured in Btu (British thermal units). The energy produced by a lit match is roughly equal to one Btu. The Btu is commonly used in the United States, however scientists, engineers, and most international countries prefer to measure energy using the metric unit of measure, the Joule (J).

Types of Biomass Sources (Raw Materials)

Wood

Wood is by far one of the oldest and most abundant types of biomass feedstocks. Wood was once the main energy resource used during the early history of the United States, but now it plays only a small role in meeting the nation's energy needs (3%). Still, in certain parts of the country, including Wisconsin, wood provides people with an inexpensive and plentiful source of energy for heating. About 20 percent of U.S. homes get some heat from burning wood, while about four percent use it as their primary fuel. In addition to cord word, other types of forest products residues such as tree tops, branches, bark, logging slash, and saw mill waste can be used as sources of biomass energy (See ***Facts About Wood***).

Energy Crops

Many crops that have been traditionally raised for food can also serve as a source of biomass energy. The most dominant examples in use today include corn, sugar cane, soy, and canola. In many cases, a portion of the crop can be used for energy (for example soy oil) while the other portion can be used for food consumption (for example soy meal). Many types of energy crops can be raised on marginal farmlands that are not capable of supporting high yield food crops on an economically competitive basis.

Algae

Aquatic algae are capable of photosynthesis, and many species demonstrate incredible growth rates compared to land based plants. Because they are aquatic, algal growth is not limited by the availability of water.

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Furthermore, because these organisms are suspended in the water column, they do not need to expend energy in the creation of cellulosic structural materials to support them and counteract the force of gravity. As a result, algae are able to store a lot more of their energy in the form of sugars, starches, or oils. In fact, the composition of some algal species can be over 50% stored oil as a percentage of their body mass. Although algae have enormous potential as a biomass source due to their rapid growth rates, there are numerous challenges that must be addressed to make them economical for biomass energy applications. These include issues of cultivation, harvesting, de-watering, drying, and extraction of oil or carbohydrate feedstocks.

Agricultural Wastes

Agricultural wastes are plant parts left over after farmers have harvested their crops. These wastes include stalks, husks, prunings, straw, and corn cobs. Agricultural waste may also include crops that were lost due to diseases or pests, and crops that spoiled in the field before they could be harvested. Agricultural wastes can be collected, dried, and burned to produce energy. Burning agricultural wastes in small power plants can provide a convenient source of energy for rural areas and developing countries. The ash that remains from burning agricultural wastes can be used as fertilizer or added to compost, as it contains minerals such as potassium and phosphorus.

Agricultural wastes are used to produce energy in many parts of the world. In Hawaii and Brazil, bagasse, a residue left over after sugarcane is harvested and processed, is burned in power plants to produce electricity. In Denmark, straw is burned to produce heat for farms, and in some parts of rural Wisconsin corn and corn stover (leftover corn cobs, leaves, and stalks) are sometimes burned for space heat. An analysis by the USDA Billion Ton Study found that in 2016 Wisconsin had the potential to produce 2.8 million dry tons of agricultural waste, primarily in the form of corn stover. Under various growth scenarios modeled by the USDA, this resource could grow to over 8 million dry tons of agriculture waste by 2040, which could be used to produce over billion gallons of ethanol per year for transportation fuel (See Liquid Alcohol Fuels below).

Human and Animal Wastes

Animal waste products such as manure have long provided biomass fuel for rural societies. In developing countries throughout Asia and Africa, animal manure is collected and dried into cakes that can be stacked, stored, traded and sold for as a source of solid fuel for heating and cooking. On a larger scale, some plants in the U.S. generate electricity by drying and burning manure from farms and cattle feedlots. One plant in Benson, Minnesota burns turkey manure and produces enough power for 40,000 homes.

Instead of drying and burning manure, it can also be placed into enclosed airtight tanks called anaerobic digesters, where it is broken down by bacteria and various chemical processes to produce biogas (60 percent methane and 40 percent carbon dioxide). In developing countries, small-scale production of biogas can provide fuel for cooking, while in industrialized countries large-scale production of biogas can generate electricity or provide heat for manufacturing processes.

Biogas-fueled electric power plants are becoming increasingly common throughout the world. Over 200 farms in the U.S. have installed biogas recovery systems that use cattle and hog manure to produce electricity. Wisconsin currently leads the U.S. with over 30 operating manure digester biogas electrical generator systems, and many more Wisconsin dairy farms have the potential to produce biogas from manure.

The same anaerobic digestion process can be conducted at waste water treatment facilities to generate biogas energy from human sewage. The biogas can be used to heat water treatment tanks which break down waste and kill pathogens in the waste. The benefits of this technique include odor control, waste reduction, and reducing the energy costs required to operate the treatment plant.

Facts about Biomass Fuels

McCain Foods in several locations around Wisconsin has employed an energy efficiency and renewable energy initiative, including a wastewater treatment facility on site at the Plover location that converts waste into energy. McCain Foods save approximately $875,000 per year in electric bills, partly due to this waste-to-energy system. Likewise, the sewage treatment plant in Madison, Wisconsin offsets about 35 percent of its energy consumption through the use of biogas.

Municipal Solid Waste (MSW)

Waste disposed of by residents and businesses, called municipal solid waste (MSW), can provide a source of fuel. A large percentage of this waste is made up of organic materials such as wood, paper products, food waste, and yard waste. Therefore, some MSW is a form of biomass fuel.

Specially equipped waste-to-energy power plants can use MSW to produce electricity or heat. The waste is separated and non-combustible materials are removed before the remaining waste is taken to the power plant to be burned. At the end of 2015, 71 waste-to-energy facilities existed in the United States. Mostly located in the Northeast and Florida, these plants have a total of 2.3 gigawatts per year capacity and can process more than 26 million tons of waste per year.

Another source of fuel from MSW is landfill gas. This gas is produced by the breakdown of organic material. Landfill gas, which contains a mixture of methane, carbon dioxide and other trace gases can be burned to generate electricity. In Southeastern Wisconsin landfills producing electricity have been in operation for more than 30 years.

Types of Value Added Biomass Fuels

Solid Biomass Pellets

Pellets are made from biomass feedstocks that are dried, pulverized, and compressed. Pellets can be made from several types of biomass including industrial wood waste, food waste, agricultural residues, energy crops, and virgin lumber. Wood pellets are the most common type of pellet fuel and are generally made from compacted sawdust and wastes from the milling of lumber, manufacture of wood products, and construction debris. Pellets can be used as fuels for power generation in a centralized plant, and for commercial or residential space heating. The compression process makes pellets extremely dense and also results in a low moisture content (below 10%). These factors provide a higher combustion efficiency and lower airborne emissions than ordinary cordwood.

Liquid Alcohol Fuels

Biomass feedstocks can be used to produce various types of alcohol fuels such as methanol (wood alcohol), ethanol (grain alcohol), and butanol that can serve as replacements for gasoline. While all of these alcohol fuels can be used in motor vehicles, ethanol is by far the most common alcohol fuel produced in the U.S. Ethanol is created by extracting carbohydrates (sugars and starches) from crops such as corn, sugar beets, or grasses, and fermenting them with yeast. The resulting alcoholic mixture is then distilled to purify the ethanol fuel.

The United States produced over 15 billion gallons of ethanol in 2016. Midwestern states produce most of the U.S. ethanol, because these states grow large amounts of corn and sorghum, the primary feedstocks for ethanol production. Wisconsin produces more than 540 million gallons of ethanol each year, and ranked eighth in the nation for ethanol production capacity in 2017. Analysts estimate potential ethanol production in Wisconsin to be over 900 million gallons annually—enough to meet a large portion of the state's transportation needs. Wisconsin's first ethanol plants were built in 2002, and there are now over 75 operating ethanol plants in Wisconsin, Illinois, Iowa, and Minnesota. These plants operate using a variety of feedstocks including corn, sorghum, sugar beets, cheese whey, corn stover, switchgrass, potato starch waste and paper waste.

Facts about Biomass Fuels

Gasoline mixed with 10 percent ethanol (sometimes called gasohol), is labeled at the pump as E10 and was first introduced for sale to consumers in the Midwest. Over the past decade, E10 has been promoted by the Environmental Protection Agency to help reduce tailpipe emissions from petroleum fuels, and E10 is now sold at most service stations throughout the United States. All vehicles, motors, and equipment produced today can run on E10 fuel. Flex fuel vehicles are designed to operate on fuel mixtures with even higher concentrations of ethanol. Gasoline mixed with 85 percent ethanol is labeled at the pump as E85, and flex fuel vehicles can run on E85, E10, pure gasoline, or any combination thereof.

Liquid BioDiesel Fuel

Biomass feedstocks can also be used to produce various types of fuels that can serve as replacements for petroleum based diesel fuel. The most common group of these are fatty acid methyl esters (FAMEs) are sold in the marketplace as BioDiesel fuel. BioDiesel is created by extracting oils from crops such as soy, canola, or sunflower, or collecting fats such as pork lard or beef tallow from animal rendering processes. The fats and oils are then reacted with methyl alcohol and a strong base catalyst to produce BioDiesel fuel.

The U.S. produced over 1.5 billion gallons of biodiesel in 2016. Wisconsin's largest biodiesel production facility is operated by Renewable Energy Group Inc. It is located in DeForest, Wisconsin, and has the capacity to produce 25 million gallons per year.

Blends of BioDiesel mixed with Petroleum diesel are now commonly sold at the pump throughout the Midwest, with the most common blends being 5, 10, and 20% biodiesel (sold as B5, B10, and B20). Almost all diesel fueled vehicles, motors, and equipment produced today can run on BioDiesel blends up to B20. Some manufacturers also make equipment designed to run on pure biodiesel fuel, or B100. This is most common for off road agriculture equipment used by farmers.

BioMethane / Bio Compressed Natural Gas (Bio CNG)

Raw biogas produced by an anaerobic digester or a landfill can be cleaned and upgraded to improve its utility as a fuel. In addition to methane, raw biogas typically contains carbon dioxide, water vapor, and several other trace gases. The carbon dioxide and water vapor limit the energy content of raw biogas to about 500 Btu/ft3, while the various trace gases such as siloxanes and hydrogen sulfide can adversely affect engine equipment. To produce BioMethane (also known as Bio CNG), the raw biogas is sent through various scrubber units to remove the undesirable components. The scrubbing process increases the energy density of the gas, resulting in a finished product with an energy density of 1000 Btu/ft^3, which is equivalent to pipeline natural gas. Once cleaned, the BioMethane can then be injected into an ordinary natural gas pipeline for delivery to customers, or it can be used to fuel natural gas powered vehicles.

In Wisconsin, the Dane County Landfill operates a BioMethane system for fueling Dane Country public works and trash collection vehicles. The system produces 250 gallons of gasoline equivalent of BioMethane each day from the landfill gas that is captured, cleaned, and compressed for use as vehicle fuel. Because of the success of the BioMethane system, Dane County now buys much less gasoline and diesel fuel to operate these vehicles. The Dane County BioMethane system won the 2011 Project of the Year Award from the U.S. Environmental Protection Agency.

Advantages and Disadvantages of Biomass Energy

Using biomass feedstocks and fuels provides a number of benefits for society and the environment. Biomass is a renewable resource when harvested sustainably. Biomass fuels can be produced from organic materials found throughout the world. Since most biomass is grown in rural areas, biomass fuel production can benefit rural

Facts about Biomass Fuels

economies by providing jobs. Using alcohol and biogas fuels and in motor vehicles helps conserve petroleum resources and reduces America's dependence on imported oil. Sulfur dioxide and mercury emissions from burning solid biomass fuels are much lower than those from burning coal. Sulfur dioxide, nitrogen oxide, and particulate matter emissions from biomass based alcohol and biodiesel fuels are also considerably lower than those of petroleum gasoline and diesel fuels. Emissions from burning biogas and biomass-produced methane are generally comparable to emissions from burning natural gas. Burning biomass fuels does release carbon dioxide, a suspected cause of global warming. However, the plants used to produce biomass consume carbon dioxide. For this reason, the various types of biomass are all generally considered to be net carbon neutral energy sources.

There are however also some drawbacks to using biomass fuels. Harvesting large areas to produce biomass fuels may harm wildlife habitats and may contribute to soil erosion. Repeatedly growing the same kinds of plants may reduce biological diversity. Biomass crops only grow part of the year, and crops may fail. This could disrupt supplies of biomass fuels. Removal of agricultural or forest wastes from the field may deprive the soil of nutrients. Burning municipal solid waste may produce toxic airborne emissions that require exhaust stack after treatment. Using land to produce biomass feedstocks may compete with land use for food production. Large amounts of energy are often needed to harvest crops and transport them. This may limit the use of certain types of biomass, and the locations of biomass facilities especially for large power plants.

Outlook

There are many types of biomass sources and value added biomass fuels, and the type of resource varies geographically. However, almost every part of the world has access to some type of biomass energy; this allows nations with different levels of technical development to meet their energy needs using biomass without having to import fossil fuels. The use of biomass has steadily increased over the past two decades. Although biomass is not likely to completely eliminate the use of fossil fuels in the near future, biomass can be used as a substitute to replace some of our consumption of coal, oil, and natural gas. Environmental impacts, competing land uses, the need for food, and the energy required to produce and harvest biomass material are limiting factors. Cultivating biomass sustainably and burning biomass fuels efficiently will help ensure that they are used wisely in the future.

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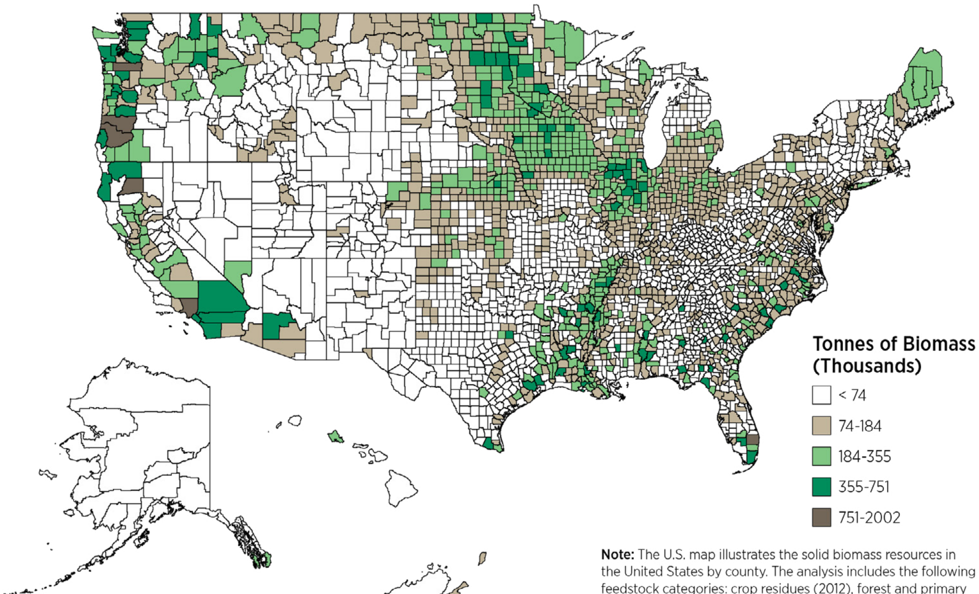
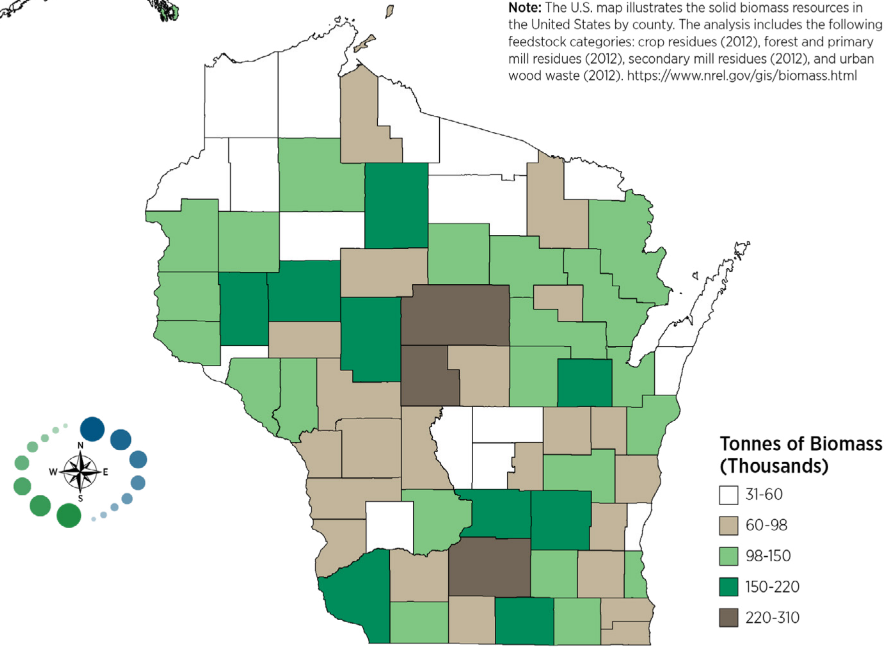


Note: The U.S. map illustrates the solid biomass resources in the United States by county. The analysis includes the following feedstock categories: crop residues (2012), forest and primary mill residues (2012), secondary mill residues (2012), and urban wood waste (2012). https://www.nrel.gov/gis/biomass.html



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

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