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: Language Arts (Communication, Debate), Mathematics, Science (Ecology, Environmental, Physical), Social Studies (Geography, Government)

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 continue on next page

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 from the Student Book)
• Copies of the following pages from the Student Book:
  – The Project Proposal Form, page 7
  – Project Components for Research and Preparation, page 8
  – Project Components for the Proposal
    – Presentation/Debate Phase, page 9
    – Proposal/Presentation Recording Sheet, page 11
  – Evaluation Criteria, page 12
• Other materials needed by students to prepare and give their presentations

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 a “The 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 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* in the *Student Book* 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.

**Standards Addressed:**

- **Common Core ELA:** SL.6-8.1, SL.6-8.4, W.6.1a, W.6.1b, W.6.7
- **Common Core Math:** MP3, 5.MD.2
- **NGSS:** 4-ESS3-1, MS-ESS3-4
- **SEP:** Engaging in Argument from Evidence, Obtaining, Evaluating, and Communicating Information
- **DCI:** ESS3.A: Natural Resources, ESS3.C: Human Impacts on Earth Systems
- **CCC:** Cause and Effect

**Resources:**

For a list of additional resources related to this activity, visit the KEEP website at *keepprogram.org* and click on *Curriculum & Resources*. 
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 Project Components Activity Sheets):** One of the first things groups should do is decide their research strategies. If you plan to use activities within KEEP’s 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, in the Student Book). 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.”
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) and (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 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*).
The 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.
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
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: ________________________________

**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.
The 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.

<table>
<thead>
<tr>
<th>A well-organized system was developed for recording information</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other considerations:</td>
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</tr>
<tr>
<td>Were all the Project Components for research and preparation addressed?</td>
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<td></td>
</tr>
<tr>
<td>Were references cited near stated facts and data?</td>
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<tr>
<td>Was a bibliography included?</td>
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<tr>
<td>Did the group gather information from materials other than the supplied Energy Fact Sheets?</td>
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</table>

<table>
<thead>
<tr>
<th>The group appeared to be prepared and knowledgeable about its energy resource.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other considerations:</td>
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<tr>
<td>Did the group effectively teach people about their energy resource?</td>
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<tr>
<td>Did the presentation address the project components?</td>
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<tr>
<td>Did the group (or student) cite up-to-date relevant research and authors with good credentials?</td>
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<tr>
<td>Was the group adept at countering or anticipating opposing viewpoints and questions?</td>
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<table>
<thead>
<tr>
<th>The group formulated its own arguments in support of their energy resource.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
<tbody>
<tr>
<td>Other considerations</td>
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<tr>
<td>Did the group recognize advantages and disadvantages of the various energy resources?</td>
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<tr>
<td>Were opinions backed by some kind of rationale and/or empirical support?</td>
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</table>

<table>
<thead>
<tr>
<th>The group presentation was well organized and effective.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other considerations</td>
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</tr>
<tr>
<td>Were appropriate arguments and facts presented in a timely and coherent fashion?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>The Challenger asked appropriate questions of the other groups.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other considerations</td>
<td></td>
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<tr>
<td>Was the group perceptive to the weak points of other presentations?</td>
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<tr>
<td>Were criticisms only of the opposition’s point of view and ideas, not the person saying the ideas?</td>
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</table>

<table>
<thead>
<tr>
<th>The group made the presentation interesting to the class.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other considerations</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Did the group strive to make the presentation relevant to the listeners? (Did they use text concepts, ask rhetorical questions, make controversial statements, give examples, etc)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>The group appeared to work well together.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

Additional criteria can be added that addresses specific expectations of the Researchers and Presenters.
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 gasses (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 wood, 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. 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 ag 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.

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 gasses 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.

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/ft³, 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 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.
**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.

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

* 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.
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.

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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.

**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.

**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.
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.
Facts about Future Energy Resources

Introduction
Fossil fuels and nuclear energy, the resources used to meet most of our energy needs today, are expected to be widely used in the near future. However, fossil and nuclear energy resources are nonrenewable and will someday be exhausted, while their continued use poses environmental risks related to air pollution, global climate change, land use, and waste disposal. These challenges have stimulated the search for alternative means of producing and using energy.

New resources that are being researched or developed include hydrogen, nuclear fusion, ocean thermal energy conversion, and tidal and wave energy. (Solar, wind, and geothermal energy are dealt with in separate fact sheets).

Hydrogen
One fuel that has the potential of being widely used in the future is hydrogen gas (H2). Like natural gas, hydrogen can be burned to heat buildings, cook food, and produce electricity in power plants. Should hydrogen replace natural gas, the existing natural gas pipeline network could be modified to transport hydrogen. Hydrogen gas can also be compressed in a fuel tank and used to power cars and buses, although difficulties in storing enough hydrogen for motor vehicles to run long distances need to be overcome. Another problem is building the infrastructure to refuel these vehicles.

Fuel cells have high efficiencies (up to 60 percent), or two to three times more efficient than an internal combustion engine running on gasoline. Hydrogen can be used in fuel cells. The electrons in hydrogen atoms generate electricity in the fuel cell. The combination of hydrogen and oxygen creates water and heat from the reaction. The heat may be used to produce electricity, but can be used simply to heat things. At the anode, hydrogen is split into protons and electrons. The electrons move down a separate channel generating electricity. The U.S. space program has used them since the 1960s; the space shuttle uses fuel cells to generate electricity. Electrical power plants could be built using large banks of fuel cells, while small groups of cells could provide electricity for individual home and commercial buildings. Experimental cars and buses powered by fuel cells have already been built and tested and in recent years have been coming onto the market.

Hydrogen is used to store energy produced in other ways. Plentiful hydrogen is available from water (H2O), which can be split into gaseous hydrogen and oxygen using an electrical process called electrolysis. This process, however, is very energy intensive. Hydrogen can also be produced from natural gas and biomass resources (see Facts about Biomass). Hydrogen is cleaner than other fuels, although it is necessary to take into consideration from where the hydrogen is derived. When burned, because it is reacting with oxygen and nitrogen in the air, it produces only water vapor and, in some cases, small amounts of nitrogen oxides. Hydrogen is often considered a renewable fuel because the water vapor produced by burning hydrogen cycles back into the environment. But, Earth’s supply of water is finite, so we are limited to what we have on Earth and the locations of these water sources may change over time. Hydrogen fuel, when produced by renewable sources of energy like wind or solar power, can be considered a renewable fuel. Although hydrogen’s explosiveness has given it a reputation for being unsafe, studies have shown that hydrogen is no more hazardous than gasoline and natural gas.

Choosing a renewable source of electricity to produce hydrogen is important. Using electricity from coal- or nuclear-fueled power plants can erase hydrogen’s advantage as a clean, renewable fuel. Using solar cells,
hydroelectric dams, or wind turbines maintains this advantage. A number of experts foresee the expanded use of hydrogen going hand in hand with the increased development of renewable energy resources.

Before hydrogen is widely developed, three goals must to be met: cheaper renewable electricity, improved fuel cells, and better ways to store hydrogen for vehicles. When these problems are solved, there is a good chance that hydrogen fuel and fuel cells will be common in the future. Since hydrogen can be produced from water and transported by pipeline, there would be few geographic restrictions to its use, making the future use of hydrogen possible in Wisconsin, the United States, and the rest of the world.

**Nuclear Fusion**

Nuclear fusion occurs when the nuclei of light elements (such as isotopes of hydrogen) are forced together at ultra-high temperatures and pressures to form the nucleus of a slightly heavier element (such as helium). Fusion releases large amounts of energy. The energy of the sun, other stars, and hydrogen bombs come from fusion. A fusion reaction can release over four times as much energy as does uranium fission.

The main challenge of controlled fusion has been to create the same high temperatures (15 million degrees Celsius/27 million degrees Fahrenheit) that exist in the sun’s interior. Two strategies have been tried: confining and heating the hydrogen fuel inside a strong magnetic field and shooting hydrogen fuel pellets with powerful laser beams. During the past several decades, a number of countries have built experimental fusion reactors that use these two methods. Although progress has been made, creating a sustainable fusion reaction that produces more energy than it consumes has yet to be achieved.

Should fusion power plants ever be built, they could provide Wisconsin and the rest of the world with abundant electrical energy. This is because plentiful amounts of deuterium, the hydrogen isotope needed for fusion, are found in ordinary water. However, controlling fusion has proved to be a formidable engineering challenge, and it may be many decades before a successful fusion reactor becomes a reality. Even then, it may take many more years to design and construct commercial fusion plants. Some experts believe that fusion power plants could be built by the middle of the twenty-first century, while others do not foresee them ever becoming a reality.

**Ocean Thermal Energy Conversion (OTEC)**

The large temperature difference between the warm surface waters of tropical oceans and the cold, deep waters lying beneath them provides a
potential energy source. A device that works like a refrigerator in reverse can use this difference in temperature
to drive a turbine that generates electricity. This process, called ocean thermal energy conversion (OTEC), could
provide electricity for tropical islands and coastal nations. OTEC power plants can be placed offshore on floating
platforms; they do not need to be built on land.

Since the sun produces the temperature difference between surface and deep ocean waters, the energy source
for OTEC plants is inexhaustible for the foreseeable future. On the other hand, OTEC plants are more expensive
to build than other types of electrical power plants, and the technology is still young. The best sites for OTEC are
often located far from the nations and population centers that most need electricity. The temperature differences
in bodies of water outside of tropical latitudes are too small to operate an OTEC power plant. For this reason,
OTEC power plants on Wisconsin’s Great Lakes are not feasible.

**Tidal and Wave Energy**

Changes in tide levels can be harnessed as a source of energy by building a barrier similar to a dam across a
bay and allowing the incoming and outgoing tides to spin turbines that produce electricity. A large tidal energy
site has been built in Canada’s Bay of Fundy, near Maine. The tide changes in Alaska’s Cook Inlet are also large
enough to be harnessed for energy.

Ocean waves can also be used as an energy source. Ocean waves oscillate, moving in a circular motion.
Terminator devices capture an oscillating water column and cause it to move up and down. Scientists and
inventors have designed and tested experimental devices that harness the kinetic energy in a wave to generate
electricity through turbines. Some of the more promising designs are undergoing demonstration testing at
commercial scales.

Tidal and wave energy are renewable resources that produce little or no pollution. Despite these advantages, the
potential for developing tidal or wave energy is limited to a few coastal areas. Tidal and wave energy systems
may also affect aquatic life. The equipment must also be able to withstand storms and saltwater corrosion.

Because of these limitations, many experts do not foresee tidal and wave energy making a major contribution
toward meeting the energy needs of the United States or the world. The Great Lakes do not experience large
tides, so tidal energy is not an option for meeting Wisconsin’s energy needs. Harnessing wave energy from the
Great Lakes may be technically feasible, but it is not likely to be pursued because of limited energy output and
high costs.

**Outlook**

Hydrogen has the best chance of being widely used in the future. Sources of hydrogen are plentiful, it
has many uses, and most of the needed technology has already been developed. However, hydrogen
is not a primary energy source like solar or wind power; it is used to store energy produced by other
means and an input of external energy is needed to power hydrogen fuel cells. Nuclear fusion continues
to pose formidable engineering problems and waste disposal and storage obstacles. Limited sites,
high costs, and the need for technological development will also likely restrict the growth of OTEC, tidal,
and wave energy systems. However, technical breakthroughs combined with the proper economic and
environmental incentives may result in the successful development of these energy resources, despite their
limitations. In addition, development of energy resources unknown to today’s society may also occur.
Facts about Geothermal Energy

Introduction
Like the sun, Earth’s inner core provides energy in the form of heat to the surface above. This form of heat energy is called geothermal energy. Geothermal energy can be used for heat or power, depending on the location, with minimal impact to the environment. Geothermal resources range from shallow ground sources (low temperature) to hot water, steam, and rock miles below Earth’s surface (high temperature).

Geothermal heat originates from Earth’s fiery consolidation of dust and gas created over 4 billion years ago, called primordial heat. In addition to the primordial heat, the planet’s internal heat source is mainly provided by the radioactive decay of long-lived unstable isotopes such as $^{238}$U, $^{235}$U, $^{232}$Th, and $^{40}$K and by latent heat. At Earth’s core—4,000 miles deep—temperatures may reach over 9,000 degrees F. Energy from Earth’s core continuously flows outward, heating a surrounding layer of rock called the mantle. As heat energy flows outward from the core, the mantle convects (hotter mantle rises to the surface, as it cools, it falls back down lower where it is heated again by the core). When temperatures and pressures become high enough, some of the upper mantle and crust rocks melt, becoming magma. Sometimes the hot magma reaches all the way to the surface, where it is called lava; however, most often the magma remains below Earth’s crust. Mantle convection heats nearby rock and water, sometimes to temperatures above 700 degrees F. Heat also comes from the radioactive decay of isotopes found in the crust and mantle from earth’s formation billions of years ago.

There are some places in the world known for their highly active geothermal sites, such as Yellowstone National Park. Throughout the globe, Earth’s crust receives heat generated from its core and convected by the mantle. In Wisconsin, the temperature of the ground six-eight feet below Earth’s surface is relatively stable, about 45-58 degrees F, throughout the year. So, in the summer, the ground temperature is generally lower (cooler) than the air temperature, and in the winter the ground temperature is generally higher (warmer) than the air temperature. Burrowing animals take advantage of the stable ambient ground temperatures, as it is cooler underground in the summer and warmer underground in the winter.

Geothermal Heating and Cooling
There are locations in Wisconsin and other parts of the world where people take advantage of the relatively stable ambient temperatures just below (six to eight feet) Earth’s surface to keep indoor temperatures comfortable by using geothermal heat pumps to both heat and cool buildings. This is called low-temperature geothermal energy. Geothermal heat pumps circulate water or other liquids through pipes buried in a continuous loop (either horizontally or vertically) next to a building. Depending on the weather, the system is used for heating or cooling. For example, in cold weather, geothermal energy can be used to heat a home as the circulating liquids in the underground pipes transfer (via conduction) the heat from the ground (between 45-58 degrees F) to the building. In this case, a supplementary heat source like a natural gas furnace or electric...
heater is often needed to increase the temperature in the building from ground temperature to a slightly warmer temperature. During hot weather, the continually circulating fluid in the pipes transfers heat from the building to the ground, thus cooling the building. The U.S. Department of Energy recommends indoor temperatures of 68 degrees F in winter and 78 degrees F in summer. Using geothermal energy conserves the amount of energy used by supplementary heating and cooling systems by getting the air temperature much closer to the recommended indoor temperatures than the actual outside air temperature.

Most heat pumps use a closed loop system where fluid circulates through loops installed in the ground horizontally or vertically. In other situations, the loops are submerged in a pond or lake. Open-loop systems, while the cheapest to install, have environmental regulations that limit their use. In open-loop systems, ground water is piped from and back into a well; during the process it passes through a building where its heat is transferred to the heat pump. Geothermal heat pumps are more efficient in the cooling cycle. A typical air conditioner takes the hot air from outside and cools it. With a geothermal system, the source of cooling is from underground and does not require as much energy making the geothermal system more efficient and cost effective. Since the systems are more efficient for cooling, if extensive cooling is not required a geothermal system may not be the best option.

In the U.S., thousands of geothermal systems are helping to make homes, schools, and offices more comfortable. Many schools like this technology because it allows each teacher to control his or her own system for improved comfort in the classroom. Temperature control can be applied to heat or cool whole buildings for events in just one area. In Wisconsin, Fond du Lac High School (closed-loop pond system) and Evansville High School (vertical ground closed-loop system) are among some of the structures acclimated by geothermal heat pumps. Geothermal heat pumps use very little electricity. The U.S. Environmental Protection Agency has rated geothermal heat pumps as among the most efficient of heating and cooling technologies, with a 300-600 percent efficiency in the winter. Many homebuilders consider geothermal heat pumps as a means to reduce their home energy costs and impact on the environment, although geothermal manufacturing and shipping activities decreased in 2009. Wisconsin consumed about 600 Btu of energy from geothermal sources in 2013, compared to 39.5 trillion Btu in the United States.

**Electricity Production**

High temperature geothermal resources are underground reservoirs of
hot water or steam that can be tapped for electrical power production. Presence of volcanic activity is a good sign that there is high temperature geothermal power ready to be tapped. Developers drill wells into the geothermal reservoirs to bring the hot water to the surface. Geologists, geochemists, drillers and engineers do a lot of exploring and testing to locate underground areas that contain this geothermal water, so that they will know where to drill geothermal production wells. Once the hot water and/or steam travels up the wells to the surface, they can be used to generate electricity in geothermal power plants.

In geothermal power plants, steam, heat, or hot water from geothermal reservoirs provides the force that spins the turbine generators and produces electricity. The used geothermal water is then returned down an injection well into the reservoir to be reheated, to maintain pressure, and to sustain the reservoir.

There are three kinds of geothermal power plants:

A “dry’” steam reservoir produces steam but very little water. The steam is piped directly into a “dry” steam power plant to provide the force to spin the turbine generator. The largest dry steam field in the world is The Geysers, about 90 miles north of San Francisco. Production of electricity started at The Geysers in 1960, at what has become one of the most successful alternative energy projects in history.

A geothermal reservoir that produces mostly hot water is called a “hot water reservoir” and is used in a “flash” power plant. Water ranging in temperature from 300–700 degrees F is brought up to the surface through the production well where, upon being released from the pressure of the deep reservoir, some of the water flashes into steam in a separator. The steam then powers the turbines.

A reservoir with temperatures between 250–360 degrees F is not hot enough to flash enough steam but can still be used to produce electricity in a “binary” power plant. In a binary system the geothermal water is passed through a heat exchanger, where its heat is transferred into a second (binary, or “working”) liquid, such as isopentane, that boils at a lower temperature than water. When heated, the binary liquid flashes to vapor, which, like steam, expands across and spins the turbine blades. The vapor is then recondensed to a liquid and is reused repeatedly. In this closed loop cycle, there are no emissions.

Since the world’s first production of geothermal electricity in Larderello, Italy in 1904, the use of geothermal electricity has continued to grow. The United States leads the world in the amount of electricity generated with
geothermal energy. In 2015, U.S. geothermal power plants in seven states produced about 16.8 billion kWh, or 0.4 percent of total U.S. electricity generation. In 2013, twenty countries, including the United States, generated a total of about 70 billion kWh of electricity from geothermal energy.

Other Uses
Geothermal water is used around the world, even when it is not hot enough to generate electricity. Any time geothermal water or heat are used directly, less electricity is used. Using geothermal water directly conserves energy and reduces the use of polluting energy resources with clean ones. The main non-electric ways geothermal energy is used are direct uses and geothermal heat pumps.

Direct uses of geothermal waters ranging from 50 degrees F to over 300 degrees F include health spas, greenhouses, aquaculture, and milk pasteurization. These waters can also be used in the space heating of individual buildings and of entire districts. Geothermal district heating systems pump geothermal water through a heat exchanger, where it transfers its heat to clean city water that is piped to buildings in the district. There, a second heat exchanger transfers the heat to the building’s heating system. The geothermal water is injected down a well back into the reservoir to be heated and used again. The first modern district heating system was developed in Boise, Idaho. Modern district heating systems also serve homes in Russia, China, France, Sweden, Hungary, Romania, and Japan. The world’s largest district heating system is in Reykjavik, Iceland. Since it started using geothermal energy as its main source of heat, Reykjavik, once very polluted, has become one of the cleanest cities in the world.

Effects
The environmental impacts of direct uses of geothermal energy and geothermal heat pumps are minimal. The average home built in Wisconsin has sufficient yard space to accommodate the area needed for a geothermal system. However, geothermal energy for heating, cooling, or to produce electricity is not available and/or feasible in all areas. As mentioned previously, Wisconsin is using the Earth’s ambient temperature for heating/cooling, or low temperature geothermal. With open loop systems there is a chance that geothermal systems could pollute groundwater resources. Finally, low temperature geothermal systems are more efficient in the cooling cycle.

Some locations use high temperature geothermal energy to produce electricity. Using geothermal energy to generate electricity has more negative environmental effects. Heat and fluid extraction from geothermal energy.
reservoirs can deplete sources of geysers and surface hot springs, damaging ecosystems that depend on the unique characteristics of these for survival. Subterranean extraction of heat and fluid can also cause land subsidence, much like the extraction of groundwater. Certain natural substances, such as arsenic, boron, and mercury, are sometimes present in the water released from geothermal cooling towers. Additionally, carbon dioxide, a greenhouse gas, is released from geothermal cooling towers. However, this release of carbon dioxide is less than one-tenth the amount that would be released from a fossil fuel electrical generation facility of similar capacity.

**Outlook**

Low-temperature geothermal heating and cooling systems are becoming increasingly popular in new construction for the long-term energy savings associated with these systems. Even though the installation price of a geothermal heat pump system can be several times that of an air-source system of the same heating and cooling capacity, the additional costs are returned to you in energy savings in five to 10 years. System life is estimated at 25 years for the inside components and 50+ years for the ground loop. There are approximately 50,000 geothermal heat pumps installed in the United States each year.

The United States has hundreds of locations in at least 15 states that have been identified as having potential to support high temperature geothermal electric power production. Thousands more megawatts of power could be developed from already-identified geothermal resources. As of February 2015, there was 3,522 MW of geothermal resources developed in the U.S. with an additional 1,275 MW planned. With improvements in technology, much more power will become available. The outlook for geothermal energy use depends on several factors including: the demand for energy in general; the inventory of available geothermal resources; and the competitive position of geothermal among other energy sources. The inventory of accessible high temperature geothermal energy is sizable. Using current technology, geothermal energy from already-identified reservoirs can contribute as much as 10 percent of the United States’ energy supply, or about 39,000 MW of geothermal energy. With more exploration, the inventory can become larger.

Enhanced Geothermal Systems, or EGS, could be used to reach geothermal energy that is not easily accessed by other forms of engineering. An EGS is a man-made reservoir created where there is hot rock but insufficient permeability or fluid saturation. A fluid is injected into the subsurface to cause pre-existing fractures to re-open, creating permeability and allowing fluid to circulate throughout the rock, transporting heat to the surface. While this technology could lead to more geothermal electricity production, many risks are associated with it including increased seismic activities, especially dangerous in urban areas where it would be ideal to place. The geothermal resource base becomes more available as methods and technologies for accessing it are improved through research and experience.

Source: National Renewable Energy Lab

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**Geothermal Resource of the United States**

Locations of identified hydrothermal sites and favorability of deep enhanced geothermal systems (EGS)

Source: National Renewable Energy Lab
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).

Hydropower 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 (see page 308 in KEEP’s Energy Education Activity Guide). 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.
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.
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 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 (CH4) 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 2015 were 324.3 trillion cubic feet, most of which is found in Texas, Pennsylvania, Oklahoma, West Virginia, and Wyoming (see Natural gas proved reserves by state/area, 2015). 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.

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).

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.

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.

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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World Energy Council http://www.worldenergy.org/


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Map of “Wisconsin Natural Gas Territories and Major Pipelines” from Wisconsin Division of Energy, Department of Administration. Wisconsin Energy Statistics. Link to most recent version found on the KEEP Web site.

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Figure 16. Natural gas proved reserves by state/area, 2015

U.S. Total: 324.3 trillion cubic feet

Data withheld to avoid disclosure of individual company data.
Wisconsin Natural Gas Company Territories & Major Pipelines

Wisconsin Natural Gas Utility Service Territories and Major Pipelines

Source: Public Service Commission of Wisconsin.
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 (U235) and uranium-238 (U238). Of these two, only U235 can undergo nuclear fission. However, 99.3 percent of naturally occurring uranium is U238 while only 0.7 percent is U235.

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 U235 atom into two smaller nuclei, releasing energy and additional neutrons. The extra neutrons then split other U235 nuclei, releasing still more neutrons that split more U235 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 U235; this fuel is produced from natural ores by an enrichment process. Nuclear fuel can produce immense amounts of energy. One kilogram of U235 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. U235 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 U238 into plutonium (Pu239) while
also 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 U235 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.

**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 U235 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 U235, 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 radio-
activity 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 U235, 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 U235 (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.
Nuclear Power Plant Diagram
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.
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.

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.

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 blowouts) 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.

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.

Petroleum products made from a barrel of crude oil, 2016

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.

Figure 2. Proved reserves of the top five U.S. oil reserves states, 2011-15

billion barrels

2011  2012  2013  2014  2015

Texas  North Dakota  Gulf of Mexico  California  Alaska
Facts about Propane

Introduction
A relative of natural gas, propane occupies a relatively small but significant place in the nation’s energy mix. First produced in 1912, propane has since found many uses in the home, industry, and farm.

Propane, also known as “bottled gas,” is a colorless hydrocarbon with the chemical formula C3H8. Propane can exist in both gaseous and liquid form. At room temperature and atmospheric pressure (14.7 psi) it is a gas. When tanks or containers are filled with propane they are pressurized to 100-200 psi, and the increase in pressure causes propane to condense and form a liquid. The liquid form is often called liquefied petroleum gas (LPG or LP for short). Although it is odorless, a foul-smelling scent is added to propane so that leaks can be easily detected.

Production, Processing, and Transportation
Petroleum refineries produce propane by heating and distilling crude oil. Natural gas processing plants also make propane. After production, propane is transported in liquid form by pipelines to a central distribution plant, where it is stored in large steel cylinders and tanks. From there it is transported by trains, trucks, barges, or ships to “bulk plants.” One gallon of propane in LPG form contains 84,250 Btu of energy.

Consumption
Nearly 2 percent of the U.S. energy needs are supplied LPG. In 2015, about 1 million barrels of LPG were consumed per day. Propane is a versatile fuel, with a wide variety of uses in industry, in agriculture, in homes, for transportation fuel, and for recreational purposes. Globally, the top five consumers of LPG in 2014 were the United States, China, Saudi Arabia, Japan, and India. In 2012, Wisconsin used 245 million gallons of LPG. Of this amount, over 87 percent was used for residential purposes.

Industrial Use
Nearly half of the propane consumed by industry is used to make plastic. Industries also use propane to run machinery, cut metal, and for process heat. Propane is also used to produce materials such as aerosol propellants, solvents, and synthetic vulcanized rubber.

Agricultural Use
On farms, propane is used to operate various types of farm equipment. Farmers use propane to dry crops, warm chicken coops, sterilize milk equipment, and more. As of 2017, nearly 830,000 farms in the U.S. use propane.

Household Use
Many rural homeowners who do not have access to natural gas pipelines rely on propane for space heating, water heating, and clothes drying. Roughly 8% of the homes in the Midwest are heated with propane fuel, and nationally about 7 million households use propane for space heat. Household use of LPG in 2014 accounted for 44 percent of global propane consumption.

Cooking Use
In the United States, 47 million households use propane to fuel an outdoor gas grill. Restaurants and caterers use propane for cooking and warming food, and also to fuel patio heaters for outdoor seating areas in cold climates. People often use propane for outdoor cooking, and because of its portability, it is especially popular with campers and mobile homeowners.
Transportation Use
Propane is the energy source for more low emission vehicles than any other fuel (including ethanol, electricity, fuel cells, and solar cells). Because propane is a very clean burning fuel with very low emissions, it is especially ideal for equipment such as forklifts and lift trucks that operate in warehouses or construction sites where indoor air quality is important. It is also suitable for operating equipment in underground mines and other enclosed spaces. Propane is used as a fuel for vehicle fleets with access to centralized LPG fueling stations (such as buses or taxis), especially in urban areas that are seeking to reduce tailpipe exhaust emissions.

Electrical Production Use
Some utilities use propane to fuel backup electrical generators when the demand for electricity is very high, or if there is a disruption in the supply of other energy sources. However, most electric power plants do not use much propane fuel, because it costs less to produce electricity from other energy sources such as solar, wind, hydropower, natural gas, coal or uranium.

Effects
Propane has helped many rural residents by providing them with a relatively clean-burning and reliable fuel. Propane distribution and sales of propane-related equipment have helped support rural economies. Like natural gas, propane is one of the cleanest burning fossil fuel products, releasing negligible amounts of emissions. When burned, it leaves no ash and produces practically no sulfur oxides, particulate matter, or mercury emissions. On the other hand, burning propane produces carbon dioxide, a cause of global climate change, and it also emits nitrogen oxides which are key ingredients in the formation of urban smog and ozone.

Outlook
Because it is made from crude oil and natural gas, future supplies and production of propane are based on the continued discovery and production of these fossil fuels. (See Facts about Oil and Facts about Natural Gas). Due to its limited volume of production, propane is unlikely to replace the use of petroleum products such as diesel fuel or gasoline. However, because of its clean burning properties, there will most likely be continued demand for propane fuel for applications where air quality is of major concern, especially in geographic regions where clean burning natural gas is not available.
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.’

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.
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.

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.

**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.

**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.
Types of Concentrated Solar Power

Fig. 1.1 Power tower power plant
Source: https://energy.gov/eere/energybasics/articles/power-tower-system-concentrating-solar-power-basics

Fig. 1.2 Linear concentrator power plant using parabolic trough collectors
Source: https://energy.gov/eere/energybasics/articles/linear-concentrator-system-basics-concentrating-solar-power

Fig. 1.3 A view from inside the enclosed-trough parabolic solar mirrors, used to concentrate sun and generate steam for enhanced oil recovery (EOR).
Source: https://commons.wikimedia.org/wiki/File%3AInside_an_enclosed_CSP_Trough.jpg
Fig. 1.4 Dish/engine power plant
Source: https://energy.gov/eere/energybasics/articles/dishengine-system-concentrating-solar-power-basics

Fig. 1.5 Linear Fresnel power plant
Source: https://energy.gov/eere/sunshot/downloads/linear-fresnel-power-plant-illustration
Introduction
Harnessing energy from 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 be 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 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.

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 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.
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, 2013). 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).
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.
Figure 20. Average turbine nameplate capacity, rotor diameter, and hub height installed during period (only turbines larger than 100 kW)

Wind generation in 2013 provided a range of environmental benefits.

- **CO₂**
  - Carbon Dioxide reduced by 115,000,000 metric tonnes
  - Equivalent to CO₂ emissions from 270 million barrels of oil

- **SO₂**
  - Sulfur Dioxide reduced by 157,000 metric tonnes

- **NOₓ**
  - Nitrogen Oxide reduced by 97,000 metric tonnes
  - Equivalent to annual emissions of 10 uncontrolled coal plants

- **H₂O**
  - Water Consumption reduced by 36.5 billion gallons
  - Equivalent to 116 gallons/person in the U.S.

Note: Emissions and water savings calculated using the EPA’s Avoided Emissions and Generation Tool (AVERT). “Uncontrolled coal plants” are those with no emissions control technology.

Source: [Wind Vision: A New Era for Wind Power in the United States](http://www.windevelopers.org)
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 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 2017 and 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.
Facts about Wood

Introduction

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. Still, in certain parts of the country, including Wisconsin, wood provides people with a cheap and plentiful source of energy for heating.

Wood gets its energy from the sun and nutrients in the soil and is a type of biomass fuel (see Facts about Biomass Fuels). Sunlight strikes the leaves, photosynthesis uses the light (energy from the sun) to combine air (CO2 mostly) and water to create glucose (“chemical energy”- sugars), which is stored in the wood itself. Wood is a renewable resource, which means that additional resources can be grown to replace any wood that is cut down.

Wood for heating is sold in units called cords. A cord is a stack of wood 8 feet long, 4 feet high, and 4 feet wide (128 cubic feet). A face cord is a stack 8 feet long, 4 feet high, and 12 to 16 inches wide (32 to 40 cubic feet).

A cord of hardwood such as maple, oak, or hickory may contain twice as much energy as a cord of softwood such as pine or balsam fir. This variation in energy is because a cord of hardwood is more dense and heavy than softwood (see Energy Content and Weight per Cord of Certain Types of Wood Found in Wisconsin). For example, about ten cords of white pine are needed to heat a 2,500 square foot home in Wisconsin for the year, while only about six cords of white oak are needed to provide the same amount of heat. These figures assume that a 2,500 square foot Wisconsin home needs 96 million Btu for heating each year and uses a wood stove with an efficiency of 71.7 percent.

Wood Energy Potential

Forests cover one-third of the total land area of the United States (766 million acres). About two-thirds of this forest is productive enough to grow commercially valuable trees. About 17 million acres, or 48 percent, of Wisconsin’s land are forested. Since 2009, Wisconsin has seen a 2.1 percent increase in forested land. With a general increase in forest age throughout the state, overall growing stock volume in Wisconsin’s timberland has increased as well. According to a study conducted at the University of Wisconsin – Madison, Wisconsin’s forests have the potential to displace almost 19 percent of statewide natural gas demand.

Harvesting, Processing, and Transportation

Methods for harvesting wood range from simply cutting down a tree with an ax or saw to removing all the trees from a large area (clear cutting) using chainsaws and other equipment. Other than drying, wood does not require much processing before being used as fuel. Some homeowners may burn wood pellets that are manufactured from finely ground wood fiber, which requires more processing. Wood pellets for burning in power plants are made by harvesting and shredding whole trees. Pellet fuel can also be made from sawdust, shavings, and fines leftover after processing trees for lumber and other wood products. Wood is usually transported by truck or train within the United States.

Wood Fuel Production

In 2015, 10 percent of energy supplied to the United States was from renewable sources, and biomass wood accounted for 21 percent of those renewables. The forest products industry consumes almost two-thirds of all
fuel wood. Nearly 20 percent of U.S. homes get some heat from burning wood, while about 4 percent of households across the country use wood as the main fuel for home heating.

Approximately 200,000 (9 percent) of Wisconsin homes burn about 1.2 million cords of wood every year. The total amount of wood energy used by all economic sectors in Wisconsin in 2012 for heating was more than 46 trillion Btu, about three percent of all the energy used in the state. Worldwide, one-half of all the wood that is cut down is used for fuel, while in many developing countries 90 percent is used for fuel. Sweden and Finland are world leaders in using wood as an energy source. In Sweden the majority of wood used is for fueling district heating plants.

Electricity Produced from Wood
Certain electric power plants in the United States and the rest of the world burn wood to generate electricity. Like coal and fuel oil, wood is burned in a boiler that heats water into steam. The steam then spins a turbine connected to an electric generator. Power plants usually burn wood along with other fuels; they rarely burn wood exclusively.

Approximately 85 power plants in the United States burn wood to produce and sell electricity, including the Bay Front Plant in Ashland, Wisconsin.

Other Uses
Wood is unique in that it can be used for the production of solid, liquid, and gaseous fuels for the generation of energy including electricity, heat, and power needed by the industrial, commercial, household and transportation sectors.

Wood is a major fuel source for industries that produce wood products. Most wood-fired power plants currently operating in the United States are owned by industries such as the paper and pulp industry. Many of these industries use wood energy to provide steam, heat, and electricity (this multiple use is called cogeneration).

In parts of the United States where wood is plentiful, many rural homeowners burn wood for space heating. About 200,000 (9 percent) of Wisconsin homes burn wood as a primary or secondary fuel source. Wisconsin residents use about one-half of all wood fuel, while the other half is used for commercial and industrial purposes.

Wood is also used to make building materials, pulp, and paper. Other uses include consumer products (e.g., toys, sporting equipment, pencils, and musical instruments) and chemicals. Wood and its derivatives are used in

References:

Credits:

As many as 10,000 products. Generally, except in facilities that utilize cogeneration, wood harvested to make wood products does not come from the same sources as wood harvested for energy.

Effects
Using wood energy has many benefits. Wood is easy to store and use, it does not require very much processing, and it is a renewable resource when harvested sustainably. Burning waste wood for fuel eliminates having to put it in landfills. Getting wood is easy for many landowners and rural residents in Wisconsin and other parts of the United States.

Air pollution, however, caused by burning wood can be a significant problem. Burning wood produces smoke, carbon monoxide, and polycyclic aromatic hydrocarbons that may cause bronchitis, emphysema, and cancer. Indoor air pollution may occur due to improper burning or leaks in pipes and chimneys. Outdoor air pollution may arise when large numbers of residents burn wood. However, high-efficiency wood stoves can reduce air pollution problems. In the United States, new wood stoves are required to emit 70 percent fewer particulates than those sold before 1990. Burning wood also releases carbon dioxide, a cause of global climate change.

By replanting trees after a timber harvest, the carbon dioxide emitted by burning wood can be absorbed and the pollution can be offset.

Removing most or all of the trees from a large area (sometimes called deforestation or clear cutting) can harm wildlife habitat and cause erosion. Deforestation may also lead to wood shortages and make tree replanting difficult due to topsoil loss. If the deforested area had moderate-high diversity prior to deforestation, repeated harvesting and replanting of one kind of tree will reduce biological diversity.

Large amounts of energy are often needed to harvest large amounts of wood and transport it long distances. This fact may limit the advantages of using wood as an energy resource, especially by larger-sized power plants.

Outlook
Wood will continue to play a role in providing energy for heating. Wood will continue to play a role in providing energy for heating, cooking, and generating electricity in the United States and the world. However, wood will not replace fossil fuels as an energy source due to efficiency, limited availability, restrictions on harvesting wood in protected areas, and competing uses for making various products. Although the use of wood as an energy resource is expected to increase, it will likely be limited.
### Energy Content and Weight per Cord of Certain Types of Wood Found in Wisconsin

<table>
<thead>
<tr>
<th>Type of Wood</th>
<th>Energy Content per Cord of Wood (million Btu per cord)</th>
<th>Energy Content per Pound of Wood (Btu per pound)</th>
<th>Weight per Cord or Air-Dried Wood (pounds per cord)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>20.0</td>
<td>5,814</td>
<td>3,400</td>
</tr>
<tr>
<td>Aspen</td>
<td>12.5</td>
<td>5,787</td>
<td>2,160</td>
</tr>
<tr>
<td>Balsam Fir</td>
<td>11.3</td>
<td>5,381</td>
<td>2,100</td>
</tr>
<tr>
<td>Beech</td>
<td>21.8</td>
<td>5,798</td>
<td>3,760</td>
</tr>
<tr>
<td>Birch (yellow)</td>
<td>21.3</td>
<td>5,788</td>
<td>3,680</td>
</tr>
<tr>
<td>Hickory (shagbark)</td>
<td>24.6</td>
<td>5,801</td>
<td>4,240</td>
</tr>
<tr>
<td>Maple (sugar)</td>
<td>21.3</td>
<td>5,788</td>
<td>3,680</td>
</tr>
<tr>
<td>Oak (white)</td>
<td>22.7</td>
<td>5,791</td>
<td>3,920</td>
</tr>
<tr>
<td>Pine (white)</td>
<td>13.3</td>
<td>6,394</td>
<td>2,080</td>
</tr>
</tbody>
</table>
Hydroelectric power is provided by the motion of falling water. When water that has been trapped in a lake behind a dam is released as needed, it can be made to flow through the turbines, which activate generators that make electricity.
Fossil fuels (oil, gas, coal) produce electrical power when they are burned in a furnace to heat boilers that make steam. The steam turns a turbine, drives a generator that makes electricity.
Uranium is used in a nuclear reactor to produce electrical power. The uranium is split and gives off heat, which makes steam from water. The steam turns a turbine, which drives a generator. The generator makes electricity.