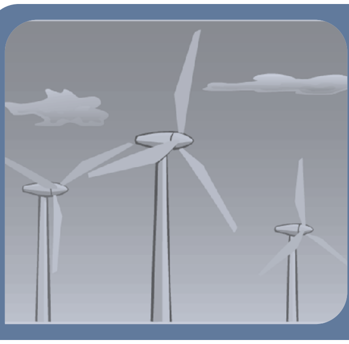

Why Use Renewable Energy

Students analyze the results of interviews with home and business owners to determine why they use renewable energy.

Grade Level: 5–8

Subject Areas: English Language Arts, Family and Consumer Science, Science, Social Studies

Setting: Classroom and community

Time:
Preparation: One hour
Activity: One 50-minute period to one week, depending on whether students conduct interviews

Vocabulary: Renewable Energy

Major Concept Areas:

- Management of energy resource use
- Future outlooks for the development and use of energy resources

Objectives

Students will be able to

- identify factors that influence home and business owners to use renewable energy; and
- discuss the pros and cons of using renewable energy resources to meet current and future energy needs.

Rationale

Interpreting reasons why people choose to use renewable energy enhances students' abilities to make their own energy choice decisions.

Materials

- Copy of the ***Renewable Energy Influences*** chart (optional)
- Copies of the following:
  - ***Contacting and Interviewing Home and Business Energy Users***
  - ***Sample Survey for Renewable Energy Home or Business Owners***
  - ***Analyzing the Results of Interviews***
  - ***What Home and Business Owners Have to Say about Using Renewable Energy***
- Find additional resources related to this activity on keepprogram.org > Curriculum & Resources

Background

A growing number of people in Wisconsin use the sun to heat their homes and businesses at night. How can this be? Are they able to make the sun shine at night? No. Many of these home and business owners have houses and buildings that are designed to store the sun's heat during the day and re-radiate it throughout the evening. Other homes and businesses burn firewood. Wood contains stored energy from the sun (trees convert solar energy to chemical energy through the process of photosynthesis). Some homeowners and business owners use sunlight to generate electricity, or they may use the wind, which is a renewable energy resource created by the sun.

Renewable energy systems use resources that are constantly replaced. Examples of renewable energy resources that are used for home heating and electricity include solar, wind, biomass (wood), biogas, and hydropower (falling water). In Wisconsin, 12.4 percent of the energy consumed for residential use came from renewable resources in

2012. For information on each of the renewable energy resources and how they can be used in homes and businesses, see the ***Fact Sheets***. Many factors influence people to choose renewable energy resources. The ***Renewable Energy Influences Chart*** identifies several of these influences.

Today's technological advancements have developed more efficient means of harnessing and using renewable energy sources, and these sources are gaining increasing popularity. They offer us alternatives to nonrenewable energy sources, such as nuclear (which has safety and disposal issues), oil, coal, and natural gas (which can cause acid rain and may contribute to the overall warming of Earth's atmosphere known as the greenhouse effect). Existing renewable energy installations are making significant contributions to the U.S. energy supply, and research activities are demonstrating the far-reaching impact that a greater reliance on renewable energy sources could have on our country's energy security. In addition, ongoing and planned research offers still more possibilities.

Procedure

Orientation

Ask students to list energy resources used to heat and power their homes. If they say electricity, determine which energy resources are used to generate the electricity. Have students identify which resources are renewable and which are nonrenewable. Add renewable resources, such as solar energy, wind, and hydropower, to the list if they are not mentioned.

Renewable Energy Influences

Influence	Description
Already in place	Uses renewable energy resources because the home or business already had renewable energy use apparatus when purchased.
Desire for independence	May not want to depend on a large corporation for energy.
Distance from utility	Decided to use renewable energy resources because it was impractical and expensive to connect power lines to homes or business located in remote areas.
Economic	Argues that nonrenewable are cheaper because they are subsidized. When the real costs and impacts of fossil and nuclear fuels are considered, renewables become much more competitive. Using renewable energy resources may avoid short-term price shocks and long-term price increases.
Affordability	Because a major component of a household's budget is energy costs, asserts that a house that uses energy efficiently and renewable energy technologies makes it more affordable.
Creating jobs	Advocates that building homes with renewable energy technologies requires that skilled workers be available in Wisconsin (as opposed to in different states or countries).
Promote energy resource autonomy in Wisconsin	Because Wisconsin imports 94 percent of its energy (petroleum, natural gas, coal, and nuclear fuels), advocates supporting the Wisconsin economy by buying technologies that use resources found in Wisconsin such as wood, water, wind, and sunlight.
Environmental and human health	Maintains that fossil fuels pollute the environment and nuclear resources are dangerous.
Interest in technology	Enjoys trying out new things and making changes to the structural and functional workings of the home or business.
Proximity of resource	Uses renewable energy resource because it is available within the local environment; that is, the proximity of a resource (such as wood on property to be used in a woodstove) makes it a good option.
Sustainable development	Points out that nuclear and fossil fuels are nonrenewable, and will eventually run out. Believes with proper management and efficient use, renewable resources are essentially limitless.
Cultural/religious	Desires maintaining the traditional way of doing things.

Review or have students research different ways renewable energy is used in household heating and other activities (see **Background**).

Steps

1. Tell students that a number of homes and businesses in Wisconsin that use renewable energy resources as their primary energy source.

2. Ask students to list reasons why they think people chose to use renewable energy. As needed, share information found within the ***Renewable Energy Influences Chart*** as well as from the ***Values Descriptors***.

3. Inform the class that they will find out for themselves which of these influences lead people to use renewables. Students will analyze interviews to determine which values are prevalent in their responses. NOTE: If it is not feasible for students to conduct their own interviews, they can read the interview results described in ***What Home and Business Owners Have to Say about Using Renewable Energy***.

4. Hand out and discuss ***Contacting and Interviewing Home and Business Energy Users*** and ***Sample Survey for Renewable Energy Home or Business Owners***. Decide if this project will be done in small groups or as a class. NOTE: If this activity will be repeated several years in a row, you may want to encourage students to locate new home and business owners each year, ask the home or business owners if they mind being contacted yearly, or save the interview results from the first year to be used by students in the next class.
   - If this activity is a class project, the whole class locates one business or home. In this case only a few students will be directly involved in finding someone to interview. Unless the whole class plans to take a field trip to the home or business, sending the home or business a survey in the mail may work better than having only one student conduct the interview. The class can work together to develop the survey and analyze the results.
   - If this activity is a group project, each group should locate a different home or business to interview. Group members can be responsible for specific tasks. Duties include locating homes or businesses that use renewables, developing or adapting the survey form, contacting the home or business owner, and setting up and conducting the interview. The group should work together to analyze the results; however, one student can be chosen to present the results to the class.

5. Give students a deadline for contacting the home or business owners and conducting the interviews.

6. After the interviews are completed, hand out and discuss ***Analyzing the Results of Interviews***. Have students use this activity sheet to analyze the results of the interviews.

Closure

Revisit the ***Renewable Energy Influences Chart*** presented earlier in the activity. Have students present the results of their analysis, identifying which influences on the chart were most prevalent or how the chart needed to be adjusted to better represent what they learned.

Ask students if they would use renewable energy resources in their future home or business. Students' defense of their reasoning can be used to evaluate their understanding of the reasons why people choose to use renewable energy resources (see **Assessment**).

Assessment

Formative

- How efficiently did students conduct and complete the interview?
- To what extent did students carefully analyze the results of the interview?

Summative

Have students predict the percentage of home and business owners who will use renewable energy resources for heat and electricity 20 years from now. What about in 50 or 100 years? Students can defend their predictions in a debate.

Extension

Tap into national or statewide tours of model homes. Every summer, during the Midwest Renewable Energy Fair, the Midwest Renewable Energy Association conducts a tour of homes. The American Solar Energy Society organizes the National Tour of Solar Homes.

Related KEEP Activities

The Activity “At Watt Rate?” can be used to orient students to the ways they use electricity in the home. It may help if prior to this activity, students understand how most citizens in Wisconsin get their electricity and heat (see “Fuel That Power Plant,” “Harnessing Nuclear Energy,” “Electric Motors and Generators,” and “So You Want to Heat Your Home?”). Other complementary activities include “Shoebox Solar Cooker” and “The Miracle of Solar Cells.” Have students project the likelihood of more homes using renewable energy resources through the activity “Energy Futures.” Students can organize a tour of homes that use renewable energy or participate in an established tour. (Midwest Renewable Energy Association.)

Credits

Portion of background adapted from U.S. Department of Energy, NCI Information Systems Inc., and Advanced Science Inc. “*Renewable Energy: An Overview*” in U.S. Department of Energy Information Bulletin FS 175, 3rd Edition. March 1990. (DOE/CE-0359P). Used with permission. All rights reserved.

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

Values Descriptors

The purpose of an issue analysis is to identify values and analyze how they contribute to the issue. There are many reasons people think and feel the way they do. One factor is their personal values. Values are the worth or importance someone attributes to something or someone else.

The descriptors listed below may be helpful as you analyze issues. These statements attempt to name and define values that might be held by individuals. The definitions, as well as the list itself, should not be considered complete. They are simply tools to help you in the complex task of identifying values.

Value	Description: The appreciation of, or focus upon...
Aesthetic	form, composition, and color through human senses.
Economic	the use and exchange of money, materials, and/or services.
Ecological	natural biological systems and principles.
Educational	the accumulation, use, and communication of knowledge.
Egocentric	self-centered needs and fulfillment.
Ethical/Moral	present and future human responsibilities, rights and wrongs, and ethical standards.
Ethnocentric	the fulfillment of ethic/cultural goals.
Health & Safety	the maintenance of positive human physical conditions.
Legal	national, state, or local laws; law enforcement; law suits.
Political	the activities, functions, and policies of governments and their agents.
Recreational	human leisure activities.
Religious	the use of belief systems based on faith or dogma.
Scientific	the process of empirical research; knowledge gained by systematic study.
Social	shared human empathy, feelings, and status.
Technological	the use of technology for human/societal goals.

Contacting and Interviewing Home and Business Renewable Energy Users

1. **Locate people in your community.** Your teacher may give you the name of a business or home owner who uses renewable energy resources, or you may already know of one. Otherwise, try contacting any of the following to get a list of people to call:
   - Chamber of Commerce
   - Realtors
   - Your local utility
   - Parents, other adults, and friends
   - One of the following organizations:

Arrow Electric
280 E. Ferman Avenue
Oshkosh, WI 54901
(920) 426-4252

Artha Renewable Energy
9784 County Road K
Amherst, WI 54406
(715) 824-3463
info@arthaonline.com
arthaonline.com

Midwest Renewable Energy Association
7558 Deer Road
Custer, WI 54423
(715) 592-6595
midwestrenew.org

Gimme Shelter Construction
PO Box 176
343 County Road KK
Amherst, WI 54406
(715) 824-7200
gimme@gimmeshelteronline.com
Gimmeshelteronline.com

Bear Paw Design and Construction
N50694 County Road D
Strum, WI 54770
(715) 797-3624
memorgan@triwest.net
bearpawdc.com

Renew Wisconsin
214 North Hamilton Street, Suite 300
Madison, WI 53703
(608) 255-4044
info@renewwisconsin.org
Renewwisconsin.org

Lake Michigan Wind & Sun
1015 County U
Sturgeon Bay, WI 54235
(715) 743-0456
info@windandsun.com
Solar-flairs.net

Public Service Commission of Wisconsin
North Tower, 6th Floor
Hills Farms State Office Building
4822 Madison Yards Way
Madison, WI 53705
(608) 266-5481
psc.wi.gov

SOLutions
P.O. Box 309
Cornucopia, WI 54827
(715) 742-3406

2. **Develop the survey.** See ***Sample Survey for Renewable Energy or Business Owners*** for some ideas.

3. **Contact the home or business owner.** You can contact this person by making a phone call or by sending a letter. A phone call is more likely to provide an immediate response. Prior to contact, develop a script of what you will say. Following is a sample script.

   Hello, my name is __________________. I'm calling from ________________school. We are doing a project on renewable energy in our community. I was informed that your (home/business) uses

Contacting and Interviewing Home and Business Renewable Energy Users

renewable energy. Is this correct? (If yes, continue. If no, thank them for their time and hang up). I was wondering if you would be interested in being interviewed to help us learn why you use renewable energy. May I interview you?

If they say yes, either inform them of the type of interview you plan to conduct or ask if they prefer a phone interview, a face-to-face interview, or a survey through the mail. If they say no, thank them for their time and hang up.

Phone interview. If your plan is to conduct a phone interview, ask the person if this is a convenient time to continue with the survey questions. If this is not a convenient time, arrange a different time to call.

Face-to-face interview. If you plan to visit a home or business, arrange a convenient time and, if necessary get directions.

Mail survey. If you conduct a mail survey, you will need to develop a cover letter to send with the survey (see ***Template for a Cover Letter*** for ideas.) You may want to call business or home owners first to secure cooperation. Rephrase the last sentence of the phone script as follows:

"Would you complete a short survey that we will mail to you about your (home/business)?"

If they say yes, confirm their address and thank them for their time. If they decline, thank them for their time and hang up.

Conduct the interview/survey. Speak clearly and politely. Take careful notes. You may want to ask permission to tape record the interview. Be considerate of their time. If this is a mailed survey, provide the respondent with a stamped, return addressed envelope. Send a thank you letter within a week after the interview is completed or the survey is returned.

Template for Cover Letter

Name of home or business owner
Address

Dear Mr. or Ms. ___________:

We are surveying home and business owners who use renewable energy resources. The purpose of the survey is to learn why people choose to use renewables. We would appreciate it if you would complete and return the enclosed survey within the next two weeks (an envelope has been provided). If you have any questions or would like further information, do not hesitate to call. Thank you for your assistance; we look forward to your response.

Sincerely,

Your name(s)
Address
Phone number

Sample Survey for Renewable Energy Home or Business Owners

Home or business owner's name: ______________________________

Address: ______________________________

Date of interview: ______________________________

a) Which renewable energy resource(s) do you use in your home or business? Circle those that apply.

Solar: **Water heater**
Photovoltaic
Passive solar design

Hydro: **Privately owned hydroelectric generator**
Other: ________________

Wind: **Wind turbine**
Windmill
Other: ________________

Biomass: **Wood (space heating)**
Other: ________________

b) Why did you decide to use renewable energy resources in your home or business?

c) What, if any, adjustments to your lifestyle have you made to live/work comfortably in your home or business? Which do you like? Which do you find inconvenient?

d) How would you respond if someone said to you:"I've often though about using renewable energy resources, but ______________________________."
(Fill in the blank with one or more reasons you've heard or can think of why people don't use renewables. Then provide a response for each reason.)

e) Is there anything else you would like to add?

*Remember to thank the person for taking the time to answer these questions. If this survey is to be mailed, be sure to include a cover letter (see ***Template for Cover Letter***) and to remove this and the previous sentence from their copy.

Analyzing the Results of Interviews

1. Was this person identified as a home owner, a business owner, or both? Is the identification correct? If not, in which group should the individual be placed?

2. Describe the community in which this person lives (large city, small town, rural, suburban, etc.).

3. Which renewable energy resource(s) does this person use?

4. What influenced the person to use renewable energy resources? Refer to the ***Renewable Energy Influences Chart***. Try to match responses to influences listed in the chart. If necessary, add new categories to the list.

5. Compare these influences to results of other interviews conducted by class members or found in the ***What Home and Business Owners Have to Say about Using Renewable Energy*** handout. Summarize three main reasons that influence people to use renewable energy in their homes or businesses.

6. What do you think about these influences? How do they apply to you or your family?

What Home and Business Owners Say About Using Renewable Energy

Respondent Number 1

a) Which renewable energy resource(s) do you use in your home or business? Check those that apply.

Solar: Water heater ✔
Photovoltaic✔
Passive solar design✔
Other: __________

Wind: Wind turbine✔
Windmill
Other: __________

Hydro: Privately-owned Hydroelectric generator
Other: ___________

Biomass: Wood (space heating)✔
Other: ___________

Other: ________________

b) Why did you decide to use renewable energy resources in your home or business?

Environmental impact of energy choices.
Economic impact of energy choices.
Aesthetic impact of energy choices.

c) What, if any, adjustments to your lifestyle have you made to live/work comfortably in your home or business? Which do you like? Which do you find inconvenient?

We sometimes have to think about the consequences of our use choices which I think is good. I find it morally inconvenient to leave the responsibility for our consumer choices to succeeding generations.

d) How would you respond if someone said to you: "I've often thought about using renewable energy resources, but *I can't afford it.*"

Because of our artificially low energy cost in the U.S., it's likely that renewable energy is more affordable now than it will be in a future of diminished resources and increased population.

What Home and Business Owners Say About Using Renewable Energy

Respondent Number 2

a) Which renewable energy resource(s) do you use in your home or business? Check those that apply.

Solar: Water heater
Photovoltaic✔
Passive solar design✔
Other: __________

Wind: Wind turbine
Windmill
Other: __________

Hydro: Privately-owned Hydroelectric generator
Other: __________

Biomass: Wood (space heating)✔
Other: Wood heated hot tub

Other: ________________

b) Why did you decide to use renewable energy resources in your home or business?

1. *Use of non-renewable energy sources causes air pollution, water pollution, acid rain, acid mine run-off, destroys animal habitats, and depletes the world's resources.*
2. *Nuclear power is not a good alternative. We have no way to dispose of nuclear waste. It is dangerous and causes many human health problems.*
3. *The home that we bought did not have power wires running into it. This was the final incentive to put our beliefs into action by using solar cells to generate our electricity.*

c) What, if any, adjustments to your lifestyle have you made to live/work comfortably in your home or business? Which do you like? Which do you find inconvenient?

1. *We have switched to compact fluorescent bulbs for our lights. Since we supply all of our energy needs, we need to be as conservative as possible. These lights use one fourth the energy of regular bulbs. They put out the same amount of light–we like them.*
2. *We do not have an electric alarm clock by the bed. Instead we use one that runs on batteries. It works fine and never loses power.*
3. *We don't heat the waterbed. Instead we layer blankets underneath the sheets. I miss the warm bed, but would have stopped using the heater anyway because of the Electric Magnetic Field (EMF) problem.*

What Home and Business Owners Say About Using Renewable Energy

Respondent Number 2 Continued...

We heat the house with a wood stove in the basement. There are things that I like and dislike about this.

Pros of using wood	*Cons of using wood*
* *Renewable resource.* * *The heat feels good, not like forced air.* * *Chopping and stacking wood is good exercise.*	* *There is a lot of dust and bark to continually clean up.* * *Can't just turn up the thermostat when you are cold; need to work for heat.* * *I feel bad about cutting trees, so I try to replant some each year to make up for my wood consumption.*

d) How would you respond if someone said to you: "I've often thought about using renewable energy resources, but *they don't work in this climate*."

We get 100% of our energy (electrical) from our own power system. With the proper combination of P.V. cells and battery storage, you can make enough electricity to meet your household needs. If renewables don't work in Wisconsin, then why am I able to do this?

e) Is there anything else you'd like to add?

Our use of oil, coal, and nuclear fuels is one of the major environmental concerns facing the planet. We have the technology to change to more environmentally friendly energy source. All we need now is the commitment of individuals, businesses, and the utilities.

What Home and Business Owners Say About Using Renewable Energy

Respondent Number 3

a) Which renewable energy resource(s) do you use in your home or business? Check those that apply.

Solar: Water heater✔
Photovoltaic✔
Passive solar design✔
Other: solar hydronic heating system

Wind: Wind turbine
Windmill
Other: 1000 watt wind generator

Hydro: Privately-owned Hydroelectric generator
Other: ___________

Biomass: Wood (space heating)✔
Other: Masonry stove

Other: Sun oven

b) Why did you decide to use renewable energy resources in your home or business?

1. *I am very much opposed to the use of nuclear power for electricity generation. When I built my house it was not yet clear if more nuclear power plants might be built and I did not want the addition of the electrical needs for my house to be part of an electrical utilities argument for the need for another nuclear generator.*
2. *I believe a responsibly cared for renewable energy home is easier on the environment.*
3. *It's fun. I enjoy the process of making my home more energy efficient and environment friendly.*

c) What, if any, adjustments to your lifestyle have you made to live/work comfortably in your home or business? Which do you like? Which do you find inconvenient?

When my electrical system was small, just 75 watts of Photovoltaics to charge a single pair of batteries, I was only able to use lights and a radio. I learned quickly to turn off any light I wasn't using. At that stage and a couple years later when my system was large enough to handle refrigeration I became very aware of the weather, specifically sunny versus cloudy days. I tended to concentrate tasks that take electricity (laundry and vacuuming) to sunny days. I still do, but mostly out of habit now. With the addition of more P.V. panels and the wind generator I seldom worry about running low on electrical power now. In the wintertime, sunny days do still make a difference. On sunny days there is no need to add wood to the fire in the stove, the passive and active solar heating systems keep the house nice and warm.

d) How would you respond if someone said to you: "I've often thought about using renewable energy resources, but *it is so expensive*.

Start small. Buy just a few P.V. panels instead of trying to replace all your utility energy with renewable energy - just replace some. Or, start with a solar water heater which will save you money in the long run. When building a new house using a passive solar design just makes sense and does not have to be more expensive than a traditional design.

What Home and Business Owners Say About Using Renewable Energy

Respondent Number 4

a) Which renewable energy resource(s) do you use in your home or business? Check those that apply.

Solar:	Water heater✔	Hydro:	Privately-owned Hydroelectric generator
	Photovoltaic		Other: ___________
	Passive solar design✔		
	Other: __________		
		Biomass:	Wood (space heating)✔
Wind:	Wind turbine✔		Other: ___________
	Windmill		
	Other: __________	Other:	________________

b) Why did you decide to use renewable resources in your home or business?

Village ordinance that requires buildings in Solar Town receive at least 50% of heat from the sun.

c) What, if any, adjustments to your lifestyle have you made to live/work comfortably in your home or business? Which do you like? Which do you find inconvenient?

None.

d) How would you respond if someone said to you: "I've often thought about using renewable energy resources, but *it doesn't work; there's not enough sun in the winter*."

I have used solar energy in my business since 1982. My system requires only one and one-half hours of sun and can be operated manually. I do have backup during periods of 30-50 degrees below zero.

e) Is there anything else you'd like to add?

There is a group from the University of Illinois that comes out yearly to look over my building and system. I would be happy to talk with any group and show them my building plans, etc.

Wonder Bar and Grill
Soldiers Grove, WI 54655

What Home and Business Owners Say About Using Renewable Energy

Respondent Number 5

a) Which renewable energy resource(s) do you use in your home or business? Check those that apply.

Solar: Water heater
Photovoltaic✔
Passive solar design✔
Other: ____________

Wind: Wind turbine
Windmill
Other: ____________

Hydro: Privately-owned hydroelectric generator
Other: _______________

Biomass: Wood (space heating)✔
Other: furnace

Other: _______________________

b) Why did you decide to use renewable energy resources in your home or business?

1. *Our environment.*
2. *Our children.*
3. *Efficiency.*

c) What, if any, adjustments to your lifestyle have you made to live/work comfortably in your home or business? Which do you like? Which do you find inconvenient?

This is a business. We have to adjust the temperature from the solar wall and woodstove so the food does not spoil. And we have to make sure we are not too cold or hot.

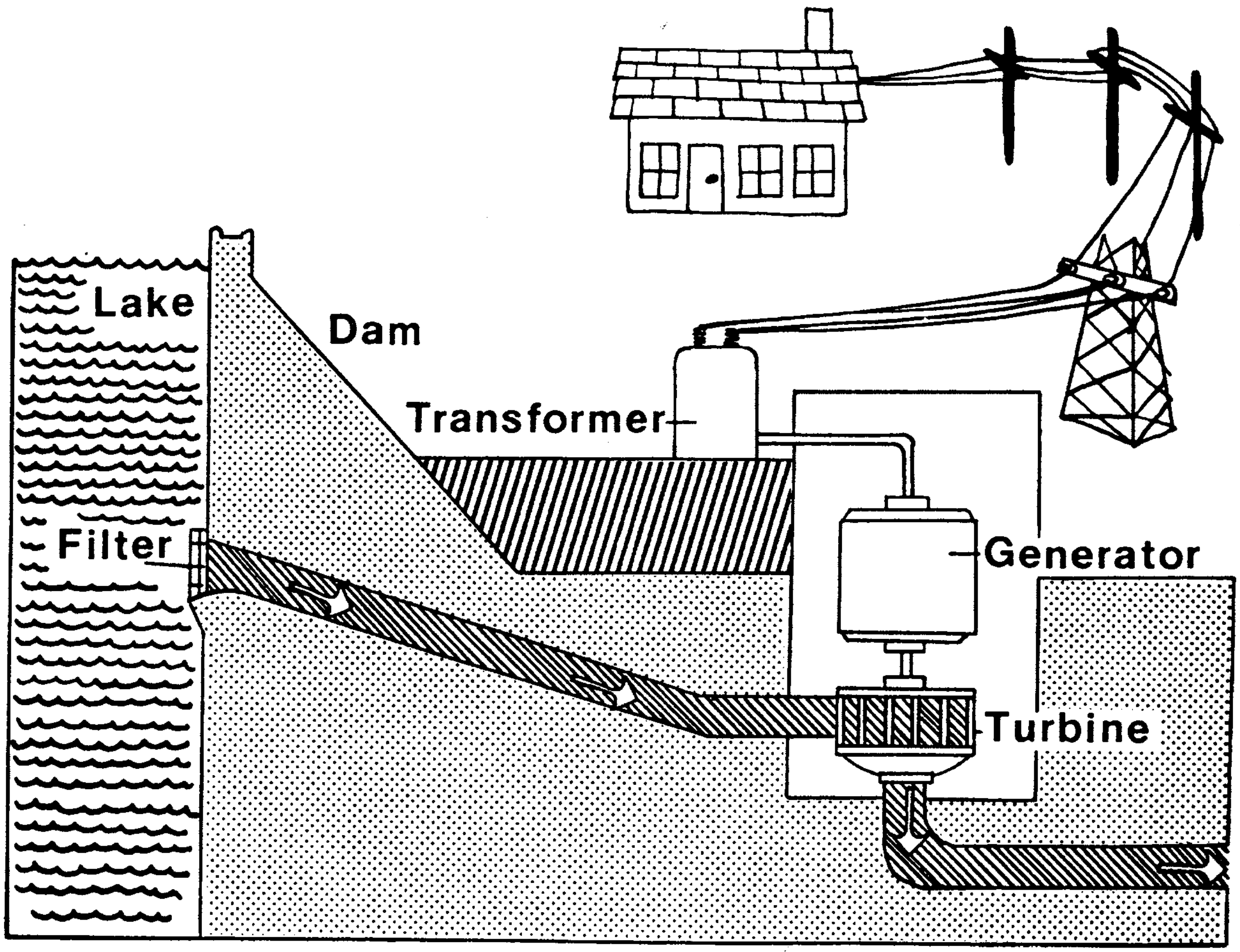
d) How would you respond if someone said the following to you: "I've often thought about using renewable energy resources, but *it's very expensive*."

Over the long run it pays, and the environment is spared to be passed on to our children and their children

e) Is there anything else you'd like to add?

We have run this business on solar and wood for over twenty years. It's been very rewarding.

Electricity from Falling Water



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.

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Facts about Biomass Fuels

Introduction

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

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

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

Types of Biomass Sources (Raw Materials)

Wood

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

Energy Crops

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

Algae

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

Facts about Biomass Fuels

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

Agricultural Wastes

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

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

Human and Animal Wastes

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

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

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

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

Facts about Biomass Fuels

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

Municipal Solid Waste (MSW)

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

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

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

Types of Value Added Biomass Fuels

Solid Biomass Pellets

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

Liquid Alcohol Fuels

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

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

Facts about Biomass Fuels

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

Liquid BioDiesel Fuel

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

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

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

BioMethane / Bio Compressed Natural Gas (Bio CNG)

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

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

Advantages and Disadvantages of Biomass Energy

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

Facts about Biomass Fuels

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

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

Outlook

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

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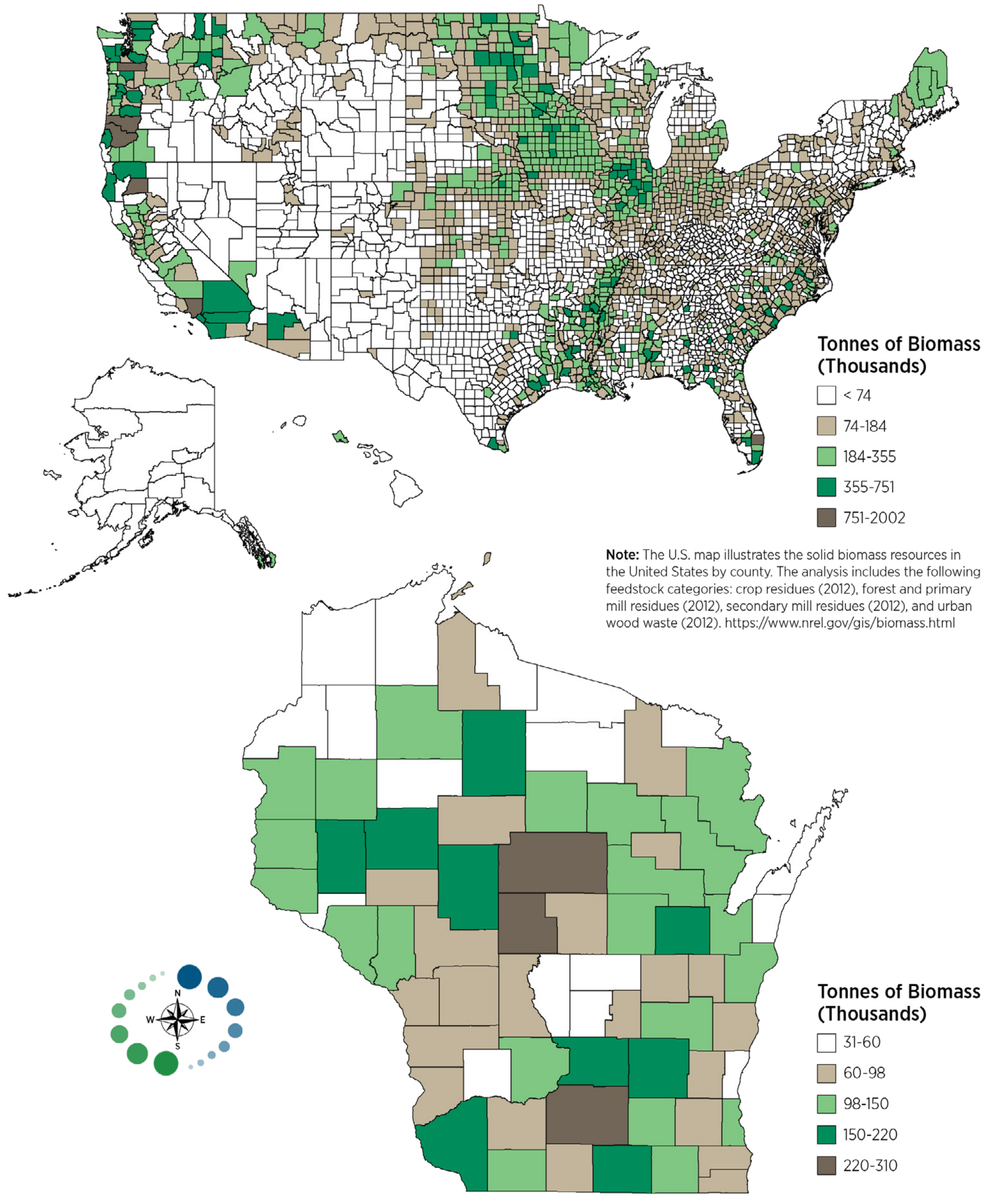

Source: Wisconsin Office of Energy Innovation. Wisconsin Energy Statistics Book.

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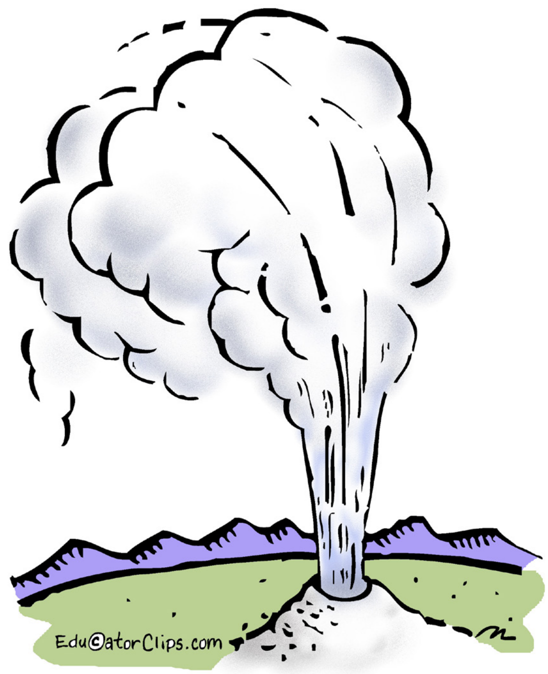
Facts about Geothermal Energy

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 238U, 235U, 232Th, and 40K 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

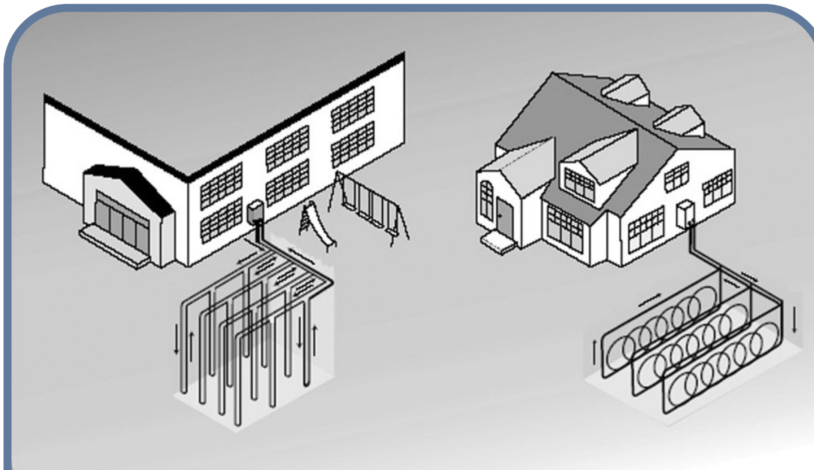
There are locations in Wisconsin and other parts of the world where people take advantage of the relatively stable ambient temperatures just below (six to eight feet) Earth's surface to keep indoor temperatures comfortable by using geothermal heat pumps to both heat and cool buildings. This is called 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

Facts about Geothermal Energy

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.



Source: Focus on Energy. Geothermal heat pumps for Wisconsin homes, businesses and schools. Fact Sheet. Publication REN2004-0602. ©2002 Wisconsin Focus on Energy

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.

Facts about Geothermal Energy

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.

Facts about Geothermal Energy

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 reservoirs can deplete sources of geysers and surface hot springs, damaging ecosystems that depend on the unique characteristics of these for survival. Subterraneous 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.

Facts about Geothermal Energy

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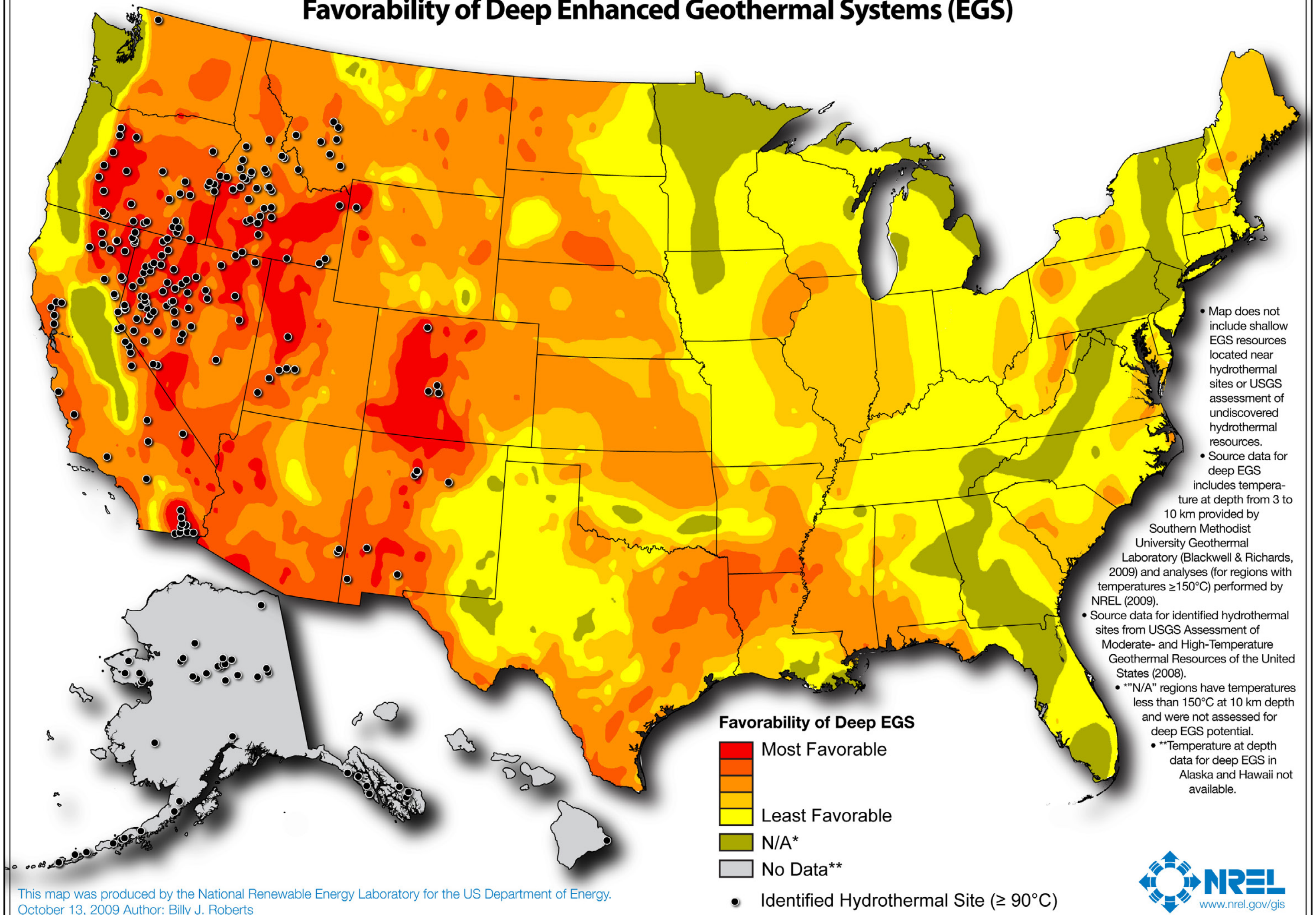
Facts about Geothermal Energy

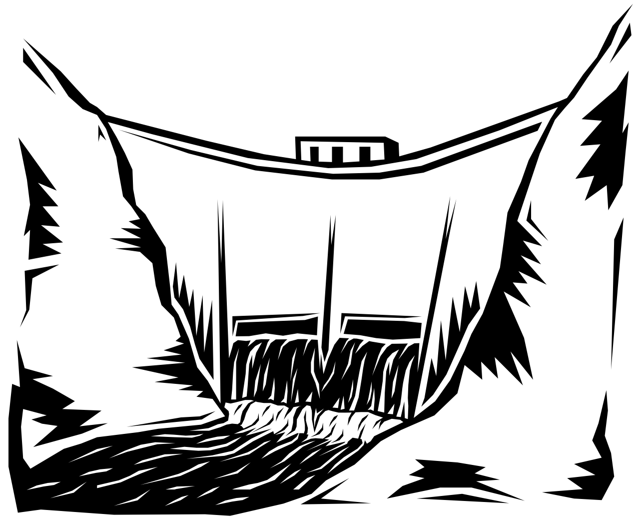
Geothermal Resource of the United States

Locations of Identified Hydrothermal Sites and Favorability of Deep Enhanced Geothermal Systems (EGS)



Facts about Hydropower

Introduction



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

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

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

Hydroelectric Power Plants

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

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

Electricity Production

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

Facts about Hydropower

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

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

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

Effects

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

Outlook

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

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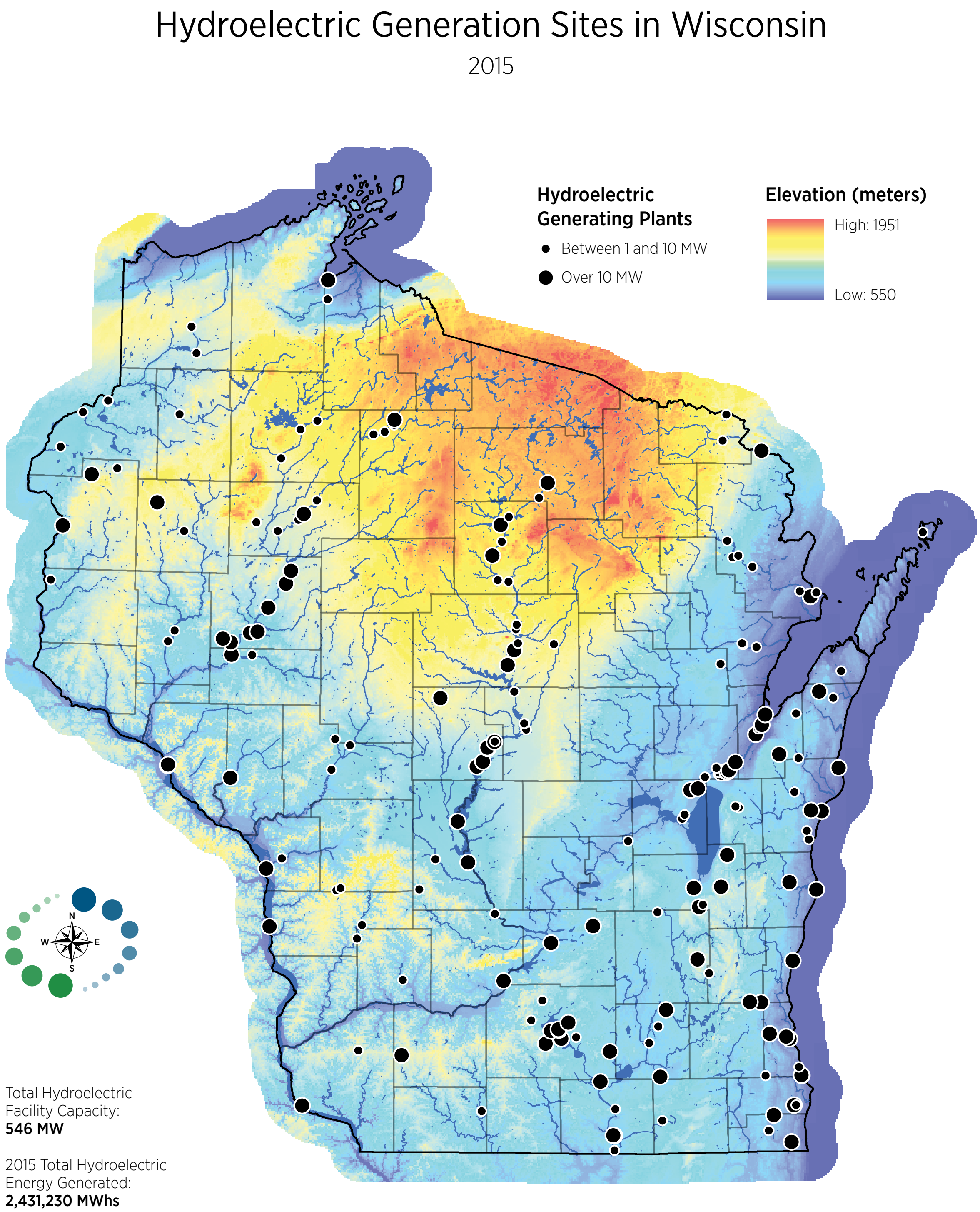
Wisconsin Hydroelectric Sites



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

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

Wisconsin Hydropower

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

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

Facts about Solar Energy: Solar Electricity

Introduction

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

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

Solar Energy Potential

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

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

Producing Solar Electricity

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

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

Facts about Solar Energy: Solar Electricity

Concentrated Solar Power (CSP)

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

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

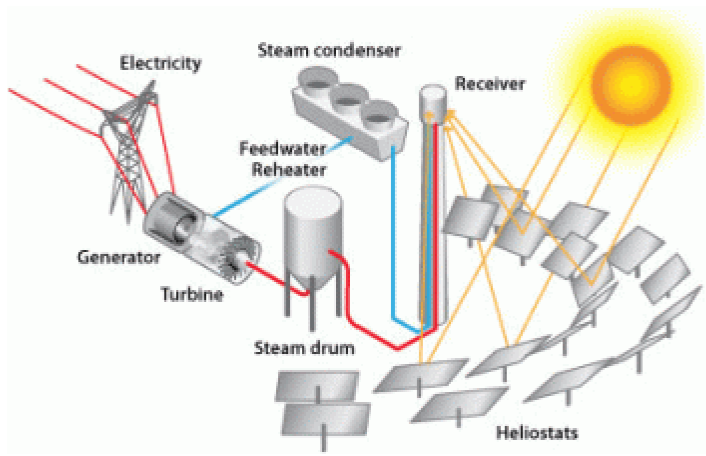


Fig. 1.1 Power Tower Power Plant
Source: energy.gov/eere/energybasics/articles/power-tower-system-concentrating-solar-power-basics

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

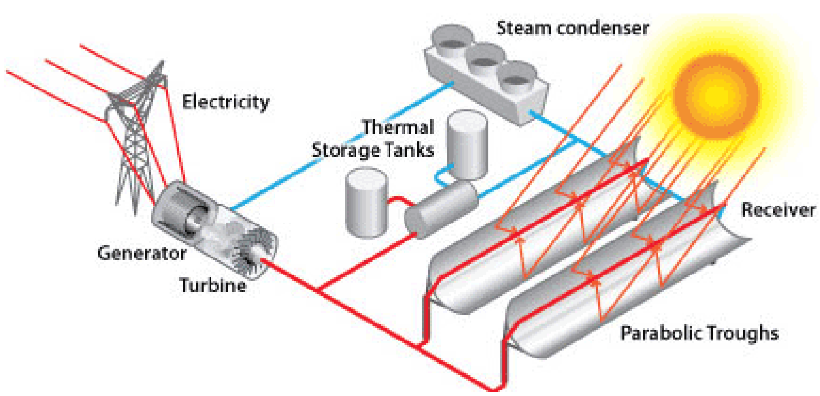


Fig. 1.2 Linear Concentrator Power Plant using Parabolic Tough Collectors
Source: energy.gov/eere/energybasics/articles/linear-concentrator-system-basics-concentrating-solar-power

Facts about Solar Energy: Solar Electricity

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

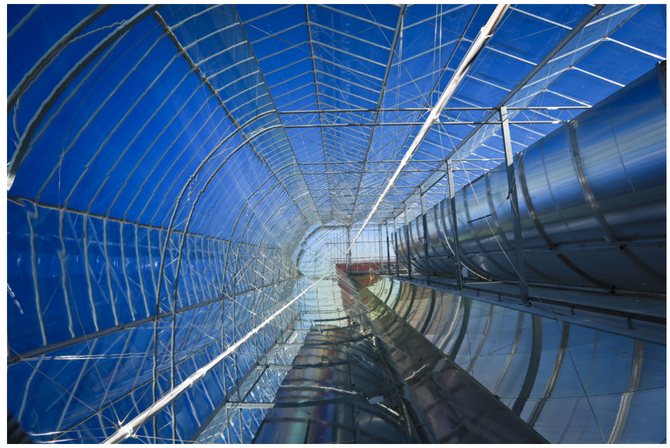


Fig. 1.3 View from inside the enclosed-trough parabolic solar mirrors, used to concentrate sun and generate steam for enhanced oil recovery (EOR).
Source: commons.wikimedia.org/wiki/File%3AInside_an_enclosed_CSP_Trough.jpg

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

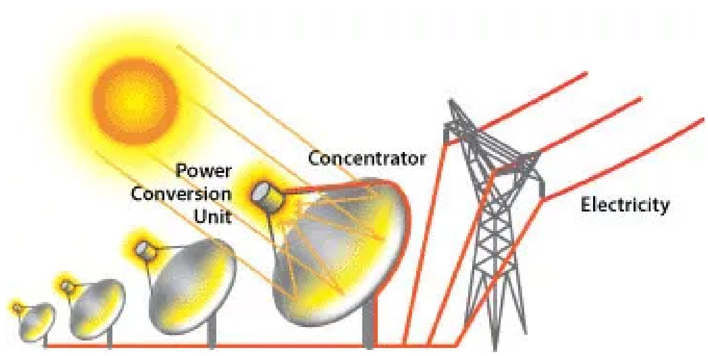


Fig. 1.4 Dish/Engine Power Plant
Source: energy.gov/eere/energybasics/articles/dishengine-system-concentrating-solar-power-basics

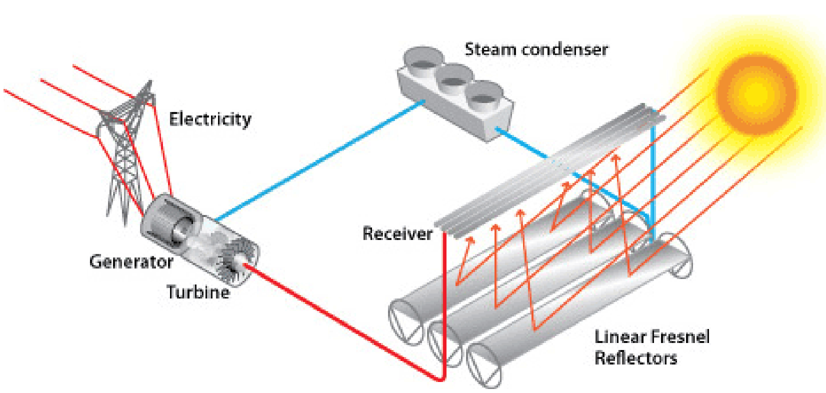


Fig. 1.5 Linear Fresnel Power Plant
Source: energy.gov/eere/sunshot/downloads/linear-fresnel-power-plant-illustration

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

Facts about Solar Energy: Solar Electricity

Solar Electricity Production

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

Effects

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

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

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

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

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

Solar Array Near Cantil, California

Source: Hanwha Q CELLS USA.

Facts about Solar Energy: Solar Electricity

Outlook

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

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

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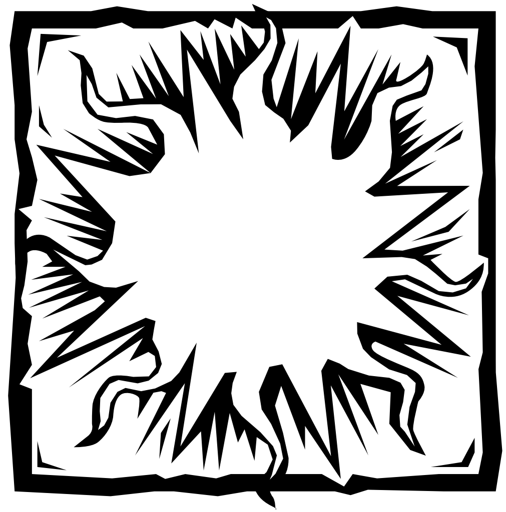
Facts about Solar Energy: Solar Heating



Introduction

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

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

Solar Energy Potential

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

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

Solar Space Heating

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

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

Facts about Solar Energy: Solar Heating

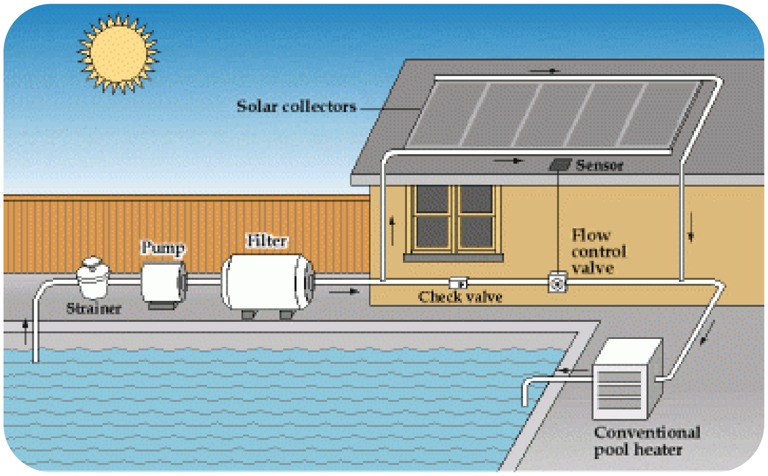
mixture as the heat transfer fluid to prevent freezing during winter months. To provide heat at night or when the sun is not shining, the energy collected by active solar systems can also be stored in a well-insulated bulk container that holds a large volume of hot water, or a large mass of hot solid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

Solar Water Heating

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

Solar Swimming Pool Heating

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



Source: Energy.gov. Solar Swimming Pool Heaters.

Other Solar Heating Applications

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

Effects

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

Facts about Solar Energy: Solar Heating

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

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

Outlook

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

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

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Facts about Wind Energy

Introduction

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

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

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

Wind Potential

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

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

Electricity Produced Using Wind

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

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

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

Facts about Wind Energy

Wind Electricity Production

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

Other Uses

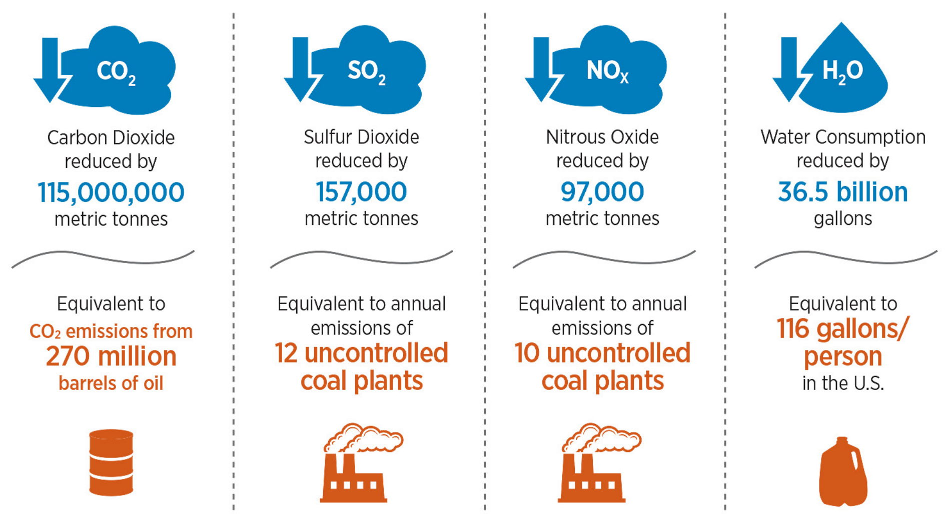
A modern wind turbine gets its design from windmills. Although windmills are not used as commonly anymore, they are still seen in rural parts of the U.S. and developing world to pump water or grind grain. A windmill is a device that has propeller blades connected to an axle with gears. The gears are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

Effects

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

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

Wind generation in 2013 provided a range of environmental benefits.



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

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

Facts about Wind Energy

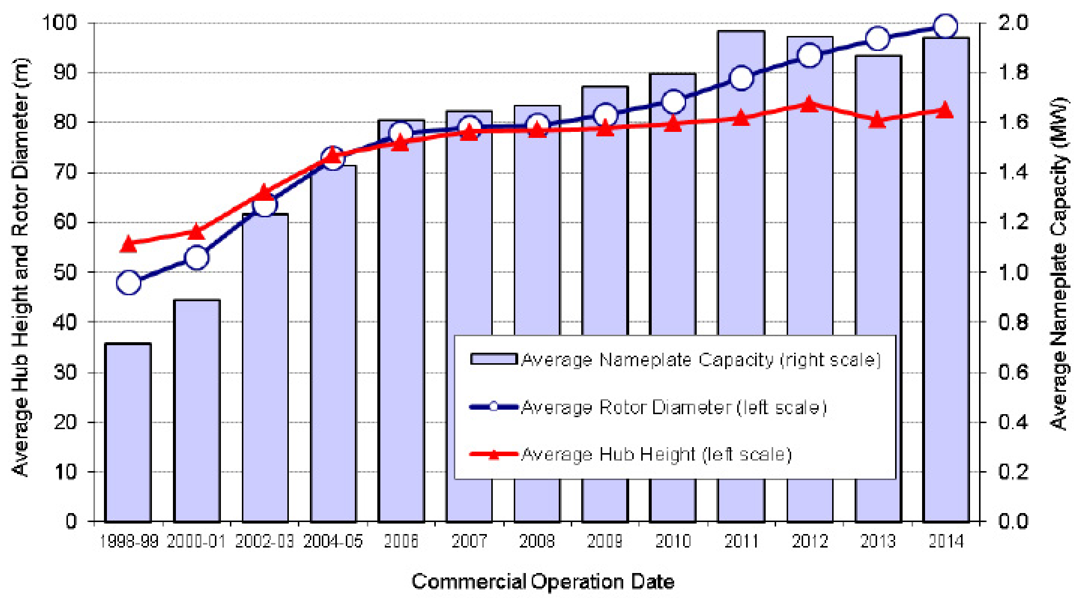
usually connected to a utility's power lines, so other power plants can supply electricity when the wind is not blowing. Some concerns about wind farms are aesthetic problems, propeller noise, and interference with birds' migratory patterns (although cell towers, electric lines, and domestic cats pose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

Outlook

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

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

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



Source: AWEA project database

Facts about Wind Energy

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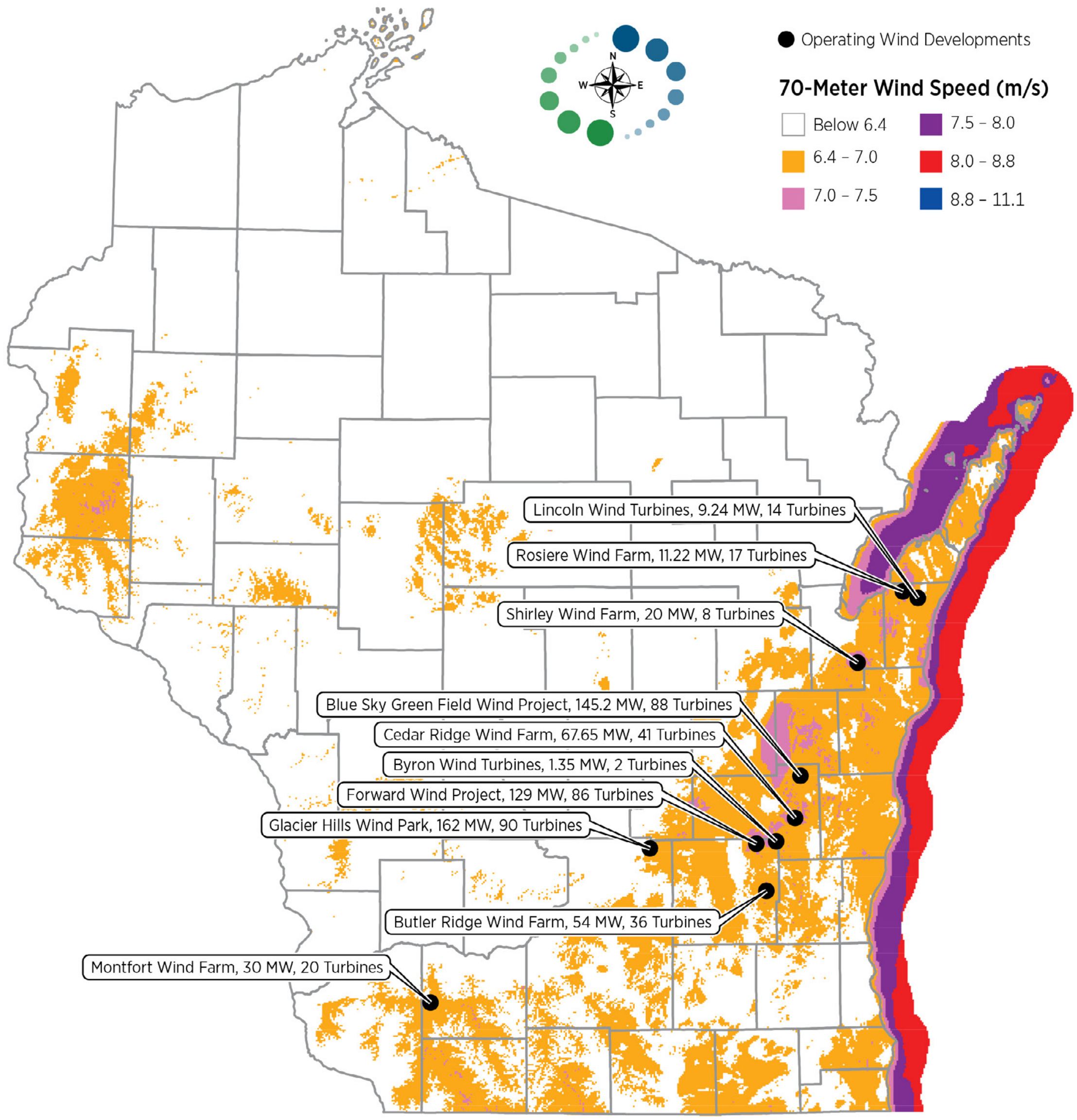
Facts about Wind Energy

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

2015



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

Facts about 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 (CO_2 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***).

Energy Content and Weight per Cord of Certain Types of Wood Found in Wisconsin

Type of Wood	Energy Content per Cord of Wood (million Btu per cord)	Energy Content per Pound of Wood (Btu per pound)	Weight per Cord or Air-Dried Wood (pounds per cord)
Ash	20.0	5,814	3,400
Aspen	12.5	5,787	2,160
Balsam Fir	11.3	5,381	2,100
Beech	21.8	5,798	3,760
Birch (yellow)	21.3	5,788	3,680
Hickory (shagbark)	24.6	5,801	4,240
Maple (sugar)	21.3	5,788	3,680
Oak (white)	22.7	5,791	3,920
Pine (white)	13.3	6,394	2,080

Source: Solar Energy Project "Heating Value of Wood" p. 2–13 in "*Wood: Stored Solar Energy*." Renewable Energy Activities for Biology. Albany, N.Y.: Solar Energy Project, State University of New York at Albany, n.d.
Wisconsin Department of Natural Resources, Bureau of Forestry. *Forest Trees of Wisconsin: How to Know Them*. Madison, WI, 1990. PUBL-FR-053 90REV.

Facts about Wood

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.

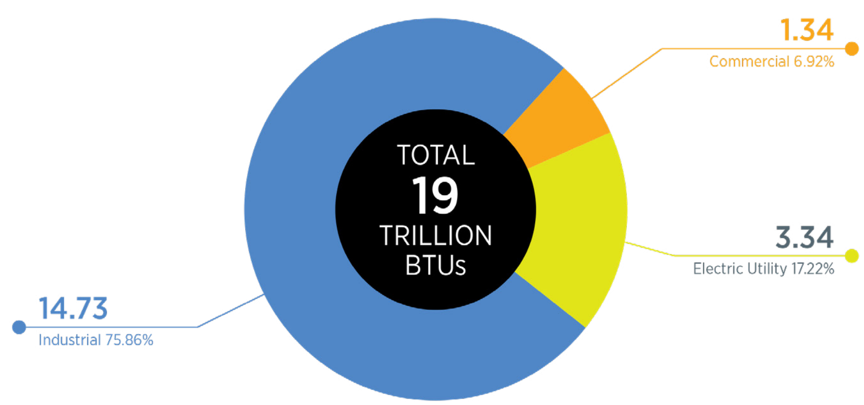
Wood Fuel Production

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 four 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.

Wisconsin Wood Use, by Economic Sector, 2015

(Trillions of Btu and Percent of Total)



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

Facts about Wood

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 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.

Facts about Wood

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.

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