Wind Energy Teacher's Guide

American Wind Energy Association

Wind Energy Teacher's Guide

Table of Contents

	Page
Teacher Information	3
Guide to Class Activities	5
Directory of Resources	11
Appendix	13

WIND ENERGY TEACHER'S GUIDE

Teacher Information

Learning about wind energy can be both fun and instructive, whether it is at the elementary school or 6-12th grade levels.

This guide provides teacher information, ideas for sparking children's and students' interest, suggestions for activities to undertake in and outside the classroom, and research tools for both teachers and students.

Grade levels:

The suggestions in this guide are divided into two grade levels groups for your convenience (K-4; and 5-12)[1]. However, we recommend that you read through the full guide and look up the resources before selecting an activity for your class. Class levels and interests vary widely. You may find that an activity suggested in the 5-8 grade category would work very well for a 4th grade class, and that the activities in the 3-5 section are fun and instructive for high schoolers.

Background information:

- What is wind energy?

Wind energy is the use of the wind as an energy source. A wind energy system transforms the kinetic (moving) energy of the wind into *mechanical* or *electrical energy* that can be harnessed for practical use.

Mechanical energy: Wind energy can be harnessed by sails for transportation (sailboats) and other purposes such as grinding grain and pumping water. In the United States, some six million mechanical windmills were in operation in the late 1880s until about 1935, helping homesteaders and farmers to settle the West. Mechanical wind energy is most commonly used today for pumping water in rural or remote locations.

Electrical energy: Harnessing the wind for electricity generation is the most widespread use of wind energy today. Wind turbines, activated by the wind, generate electricity for homes, businesses, and for sale to utilities. In the U.S., use of wind for electricity generation by utilities is limited but growing. In 2002, less than 1% of U.S. electricity supply came from wind power. Some European countries get a larger share of their electricity from the wind (Denmark gets 20% of its total electricity supply from wind power, Germany 5%).

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[1] See National Science Education Standards, Science Contents Standards.
An overview is available at http://solar-center.stanford.edu/standards.
For full standard description and updates see http://www.nap.edu/readingroom/books/nses.

- How does a wind turbine work?

Horizontal-axis wind turbines are most commonly used today. The wind blows through **blades**, which converts the wind's energy into rotational shaft energy. The blades are mounted atop a high tower to a **drive train**, usually with a **gearbox,** that uses the rotational energy from the blades to spin magnets in the **generator** and convert that energy into electrical current. The shaft, drive train and generator are covered by a protective enclosure called a **nacelle**. **Electronic and electrical equipment** including controls, electrical cables, ground support equipment, and interconnection equipment control the turbine, ensure maximum productivity, and transmit the electrical current. Today's utility-scale turbines can be 100 meters (over 300 feet) high or more.

- Electricity: how is it measured?

Electricity production and consumption are most commonly measured in *kilowatt-hours (kWh)*. A kilowatt-hour means one kilowatt (1,000 watts) of electricity produced or consumed for one hour. One 50-watt light bulb left on for 20 hours consumes one kilowatt-hour of electricity (50 watts x 20 hours = 1,000 watt-hours = 1 kilowatt-hour). The average American household consumes about 10,000 kWh annually.

- How much does a wind turbine generate?

The output of a wind turbine depends on the turbine's size or power rating, and the wind's speed through the rotor. Wind turbines being manufactured now have power ratings ranging from 250 watts (for battery charging) to 10-kW (which can generate about 15,000 kWh annually, more than enough to power a typical household) to 1.8 megawatts (MW) or more—enough to power some 500 households.

- Why wind power?

Wind power is a growing source of electricity generation today. Worldwide, wind is the fastest-growing energy source -- installed generating capacity increased by an average 32% annually from 1998 to 2002. Its use is expanding because modern technology has reduced the cost by more than 80% since the first commercial wind turbines were installed in California in the 1980s (many of those wind turbines still work today, and can be seen in Palm Springs and Tehachapi in Southern California, and in the Altamont Pass outside San Francisco). In areas with an excellent wind resource, it can sometimes be more affordable to get new power by building a wind farm than by building a coal, natural gas, or other type of power plant. In addition, wind energy is a clean, safe, and renewable (inexhaustible) power source.

- More information?

The Most Frequently Asked Questions About Wind Energy, a publication of the American Wind Energy Association, is a free guide to more information about wind energy, including wind energy basics, costs, potential, wind energy and the economy, wind energy and the environment, statistics, and much more.

Spark children's interest with wind energy: Grade level K—4

Grades K-1:

Give children a feel for the power of the wind:
Fly a kite with the class or make pinwheels; sail model sailboats on a field trip to garden or pond.

Grades 2, 3, 4:

Include in your science class some discussions and projects about the wind and about wind power. The following are possible class discussion and projects:

- Class discussions:

(a) How do the students think wind is created? What patterns do they notice in the air's movements? Have some of the children in your class ever tried climbed onto a stepladder in their home kitchen when something is baking in the oven, and noticed how much warmer the air is up by the ceiling than when they are standing on the floor?

The discussion should lead to the discovery that wind is caused by the sun's heat: Heated air rises, and colder air moves in to take its place, creating wind. The discussion can then lead to wind patterns, and the factors that influence wind speed, force, and direction.

(b) Who uses the wind, and what for? Do plants, birds, and animals use the wind, and if so, how? How have humans used the wind over time?

This discussion can lead to the discovery of the role played by wind as a medium for movement and transportation – for plant pollen, for birds and other flying animals. The discussion can also lead to the use of wind as a source of mechanical energy since the early days of human antiquity, for transportation (sailing), grinding of grain, water pumping, and other uses.

- Class activities and projects:

(a) <u>How a wind turbine works</u>: Divide the class into groups. Have each group draw a poster illustrating how a wind turbine works (for simple explanations and drawings, see, among others, "Wind Energy, A workbook for wind information and experimentation," and "Wind Energy powers the world," two small color brochures published by the Kern Wind Energy Association). A diagram of the inside of a nacelle – showing blades, drive train and generator -- is also included below.

Make sure the poster shows how the turbine is hooked up to the network of electrical wires that bring electricity to our homes, schools, and offices.

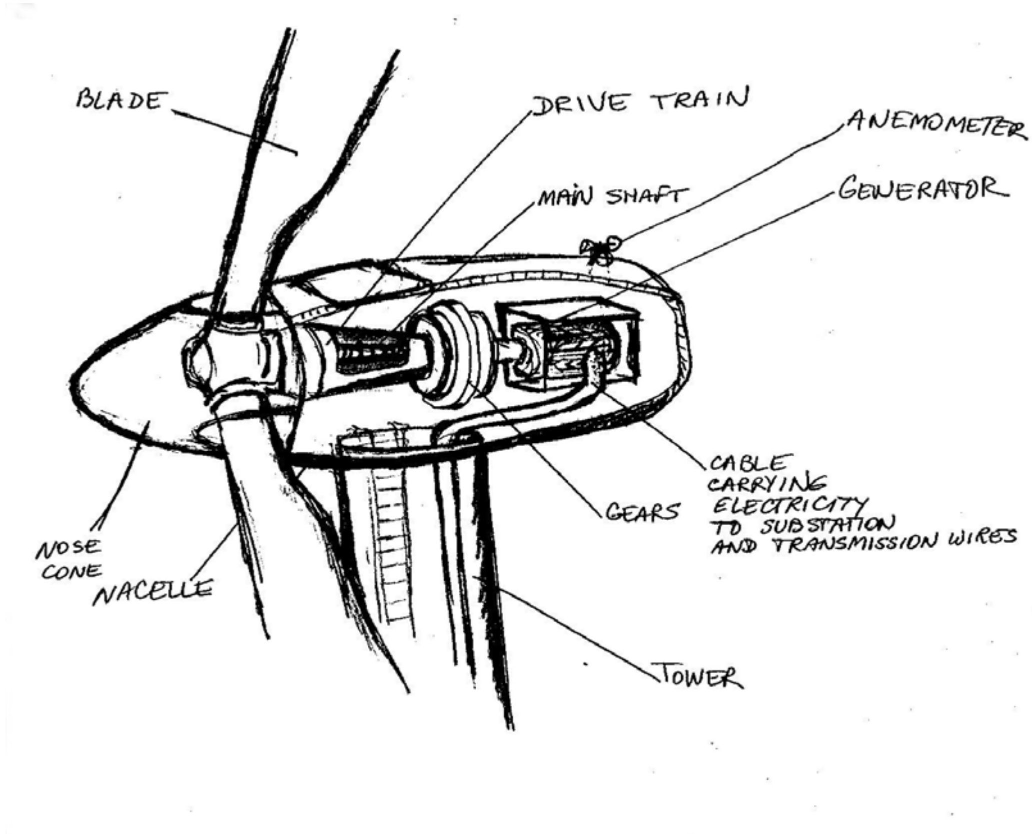

Diagram: Inside the nacelle of a utility-scale wind turbine (*AWEA*)

(b) Measure the wind: Have students look up Admiral Beaufort's scale, designed in 1805 for measuring wind speed (0:calm/smoke rises vertically; 1: smoke drifts, indicating wind direction; 2: wind felt on face, leaves rustle, flags stir; etc) and still in use today. You can also have the students design and construct a simple wind indicator or gauge, such as wind sock similar to the ones used in airports, or simply a flag. Have them take it outside and install it in an open area at the highest spot possible. Have the students devise a recording scale of their own (for example, is flag or sock limp, fluttering, full?) and keep a log of the performance of their system alongside an assessment of the wind speed according to Admiral Beaufort's descriptions.
The Beaufort scale is provided in appendix B, or can be found on the Web.

(c) Research wind energy potential in the United States and in your area: for information on wind energy potential in the U.S. and a national wind map, see the Department of Energy's Web site at http://rredc.nrel.gov/wind/pubs/atlas/ and http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-06m.html). Regional updates are available from the Department of Energy at http://www.windpoweringamerica.gov
Is there a wind farm in your state, harnessing some of that potential? To find out, check out the map of installed projects at http://www.awea.org/projects/index.html. Plan a field trip to the wind farm if it is close by.

Intermediate and advanced levels: grades 5-8, and 9-12.

This is a short selection of possible discussions and activities. Be sure to check the listing of resources at the end of this guide for additional activities.

- Discussions:

(a) Electricity: How many of the activities in a student's typical day rely on or in some way use electricity? Do the students how that electricity is generated?

This discussion can lead to a simple introduction to the physics of electricity and power generation. Explain how electricity is created. Ask students to think of various ways in which electricity generators can be made to run.

(b) Wind power: How do the students think electricity is generated from the wind? What do they think of this method? Do they think a lot wind power could be generated in their community? in their state? in the United States?

The discussion should lead to the fact that a wind turbine generates electricity without the use of additional resources (such as coal or natural gas, to turn water into steam to activate the generator). It is a simple, clean, process, which uses an energy source that is inexhaustible, or "renewable." Wind resources in the U.S. are vast, and still untapped—see information sources for project (c) above.

If you and your classroom are well equipped with computers, look up "Wind with Miller," at http://www.windpower.org/en/kids/index.htm. "Wind with Miller" is an online introduction to wind energy and wind turbines, designed especially for children. Start with the teacher's guide on that site to test the program and its applicability to your class.

- Projects:

(a) Ask a group to prepare a presentation on the history of windmills and wind turbines.

An excellent resource for such a project is "The Wind at Work, An Activity Guide to Windmills", by Gretchen Woelfle, available through bookstores and through the Educational Resources section of the AWEA online bookstore at http://www.aweastore.com/Merchant2/merchant.mvc. This books uses activities, and many illustrations, to explain the principles of wind energy as well as the work of a windmiller and inventor, and the history of wind power. Experiments include learning the wind's effects on temperature; measuring wind speed; grinding grain by hand to learn about the type of work that windmills did for agriculture; and tracking your own electrical use. Update the information in the book with research on the many new wind farms installed in the U.S. and worldwide since its publication in 1997.

(b) Research the feasibility of installing a wind turbine at your school.

The key factor to research is the wind resource at the school or in the area. The students will gather and make summaries of wind speeds over a period of time at a selected location, using the Beaufort scale (see activity (b), p.6, and Appendix A) to estimate wind speeds. They may then check their findings against wind resource estimates of the U.S. Department of Energy for the region (for a national wind map, see the Department of Energy's Web site at http://rredc.nrel.gov/wind/pubs/atlas/ and http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-06m.html). Regional updates are available from the Department of Energy at http://www.windpoweringamerica.gov)

The students will then determine whether wind energy is a viable option for the school or the local area. For a small turbine (about 10-kW), it is recommended that the location have a wind speed average of 5 meters per second (m/s) (11 miles per hour) or more. For large turbines (750 kW, or more), it is recommended that average wind speeds exceed 6 m/s (13 mph). If the students estimate the average wind speed to be over 6 m/s, then both small and utility-scale turbines are feasible.

Explain that the amount of power generated is proportional to the cube of the wind's speed. If P/a is the power per unit area (P/a), and V is the wind speed, or velocity, then the relation of power to wind speed can be expressed by the following equation:

$$P/a = \alpha V^3$$

Ask the students to figure by how much power would be multiplied if the average wind speed at the site were double (answer: the power generated increases by a factor of eight). What are the implications for the optimal siting of a wind turbine?

If the students have determined that a turbine is feasible, take the research to the second step and have the students determine how much power they would like to have generated by wind. A factor influencing the amount of power generated is the size, or rated capacity, of the turbine. Wind turbines being manufactured now have power ratings ranging from 250 watts (for battery charging) to 10-kW (which generate about 15,000 kWh annually, more than enough to power a typical household) to 1,000 kW (or 1 megawatt (MW)) or more. A 1-MW turbine at an excellent location (average wind speeds of 8 m/s (18 mph) generates 3 million kWh annually, enough to power some 300 average American households. How does the amount of power that one 10-kW turbine, or one 1-MW turbine could generate in one year compare with the annual electricity consumption of the school?

For information on how much power could be generated at different wind speeds by turbines of different sizes, students can look up wind turbine information available on wind turbine manufacturers' Web sites, under product brochures. For example, students can look up information for GE Wind turbines at http://www.gepower.com/dhtml/wind/en_us/products/index.jsp, and within that section, look up the technical data and other information regarding each turbine.

Information for Vestas turbines is available at http://www.vestas.com/produkter/download/download_UK.htm; information for NEG-Micon turbines at www.neg-micon.com. For a listing of turbine manufacturers that are members of the American Wind Energy Association and active in the United States, see http://www.awea.org/directory/wtgmfgr.html.

Several schools have assessed the feasibility of installing a wind turbine and some have proceeded to purchase a wind turbine. The elementary school at Spirit Lake has a 250-kW turbine that provides an average of 350,000 kWh of electricity per year. Excess electricity fed into the local utility system has earned the school $25,000 over five years. The school district has since invested in a second, larger turbine for the high school. See the Spirit Lake School Web site at http://www.spirit-lake.k12.ia.us/dist/wind/index.htm and contact the school for information about their program.

(c) Calculate some of the emissions resulting from electricity generation at the school (this research may be done as part of a unit on the environment and sources/impacts of air pollution) and discuss the feasibility of offsetting these emissions with wind energy.

Step one:

Determine how the electricity used at the school is generated. Students can call the local utility for information about the sources of the power that it provides. If the utility does not provide that information, an average by state can be found on the Web site of the Energy Information Agency of the US Department of Energy at http://www.eia.doe.gov/cneaf/electricity/st_profiles/toc.html The students will then compare their state mix with the national average mix, which can be found on one of the infocards at http://www.eia.doe.gov/neic/brochure/elecinfocard.html.

Step two:

Estimate emissions from generating electricity with the local mix or with the national average utility fuel mix. The students will look up emissions per kWh on the Energy Information Agency (EIA) Web site, or use the emissions spreadsheet provided in appendix B. Look up emissions per kWh, pro-rate for the local energy mix, and calculate annual emissions from the electricity used by the school
OR
Look up the average emissions for the U.S. generating mix and calculate annual emissions from the electricity used by the school if it were to use the U.S. generating mix. Example: for emissions of carbon dioxide (CO2), look up the line entitled "Annual average CO2 emissions for U.S. generating mix" in the spreadsheet in the Appendix, find the amount-- 1.3506 lb/kWh—and multiply by the number of kWh used by the school in one year. [2]

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[2] Discussion of the health and environmental impacts of these emissions is beyond the scope of this guide. For a systematic overview of the impacts of all types of power generation—including renewables—see "The Environmental Imperative for Renewable Energy," a publication of the Renewable Energy Policy Project (REPP). The report is available on-line at http://www.repp.org/repp_pubs/pdf/envImp.pdf

Step three:

If, based on project (b), students have determined that wind power is feasible in the area and how much power they would like to generate for the school with wind energy, they can now calculate the amount of emissions that wind power will offset.
OR
The students can calculate the average emissions that can be offset by a single, large 1-MW turbine located in a windy area and generating 3 million kWh per year, based on the average emissions for the U.S. generating mix (Answer using the spreadsheet in Appendix B: 4,051,800 lbs of carbon dioxide; 21,300 lbs of sulfur dioxide; and 12,600 lbs of nitrogen oxides).

(d) Build a model wind turbine.

For instructions and kits on building a model wind turbine, see the following Web sites:

http://www.re-energy.ca/t-i_windbuild-1.shtml Features online instructions for a build-your-own turbine: The instructions are for a vertical-axis, electricity-generating turbine, no larger than a plastic water or soda bottle. Includes introduction, list of materials needed, and step-by-step assembly and testing instructions.

http://www.picoturbine.com/ Features downloadable do-it-yourself instructions, as well as kits that include all the materials for a modest charge. Basic instructions are for grades 5-12 approximately, with optional add-on to convert alternating current (AC) to direct current (DC), for grades 8-12. The Picoturbine Web site includes sections on "classroom ideas," on-line animated "rotor simulator," and other features.

You can also organize a wind energy design challenge, encouraging students to design and assemble a wind turbine of their own. Contact the Kid Wind Project, at http://www.kidwind.org/, for information about a curriculum based on a wind energy design challenge that is currently under development.

Directory of Resources:

Books:

The Wind at Work, An Activity Guide to Windmills.
Strongly recommended, even though it needs to be supplemented with up-to-date information about the technology (the book was published in 1997, just before the take-off of wind power in the U.S.). Excellent insights into the ways that humankind has harnessed the power of the wind, with a focus on Europe and America. Includes varied suggested activities, from cooking a recipe of "prairie cookin' corn dodgers", a corn bread and bean dish that was a staple diet of cowboys and windmillers, to how to read your electric bill and understanding wind energy technology.

Web sites:

Spirit Lake Elementary School. http://www.spirit-lake.k12.ia.us/dist/wind/index.htm The Spirit Lake School in Spirit Lake, Iowa, researched the feasibility of installing a wind turbine at the school, and now has two in operation. The Web site provides information about the research and the turbines' performance.

Wind with Miller: http://www.windpower.org/en/kids/index.htm
An entertaining interactive resource for both teachers and students, 5th grade and up. Provides a teacher's guide, on-line course materials and activities, animated interactive sequences, and more. Wind With Miller is a feature of the Danish Wind Energy Association Web, and is available in English, Spanish, and several other languages. The association's site also features an on-line Guided Tour at http://www.windpower.org/en/tour/index.htm, Frequently Asked Questions, and additional useful information.

http://www.eere.energy.gov/windpoweringamerica/wind_faq.html#student A Special page of the Web site of the Department of Energy's "Wind Powering America" program that includes a listing of useful Web sites and an FAQ for students interested in wind power.

http://www.nrel.gov/clean_energy/teach_wind.html
This page provides an inventory of Web-based resources, including links to an introduction to wind energy and to other Web sites.

http://www.earth.uni.edu/EECP/elem/mod3.html
A teacher's module on wind and renewable energy, from the University of Iowa.

Teacher's workshop:
http://www.laurentiancenter.com/htmls/workshops/windenergy.html
Contact the center for information about upcoming workshops.

Build a model wind turbine: http://www.re-energy.ca/t-i_windbuild-1.shtml
Features online instructions for a build-your-own turbine: The instructions are for a vertical-axis, electricity-generating turbine, no larger than a plastic water or soda bottle. Includes introduction, list of materials needed, and step-by-step assembly and testing instructions.

Build a model wind turbine: http://www.picoturbine.com/
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Network with other teachers: http://www.kidwind.org/
The KidWind project brings together teachers interested in including wind energy in the classroom curriculum. See the Web site or contact Mike Arquin at michael@kidwind.org for information about the project.

Company Web sites:

Some wind energy companies include a special section for teachers and kids on their Web sites. Many of these companies are members of the American Wind Energy Association, and can be located or contacted through the AWEA Member Directory at http://www.awea.org/directory/

Examples include (in alphabetical order):

GE (General Electric) Wind Energy:
http://www.gepower.com/dhtml/wind/en_us/newsroom/just4kids/inmotion.jsp
Includes a curriculum outline and information about wind energy.
The GE Web site also features an on-line photo library of wind farms featuring state-of-the-art wind turbines. The photo library is at http://www.gepower.com/dhtml/wind/en_us/newsroom/gallery.jsp.

Zilkha Renewables: http://www.zilkha.com/forteacherskidsconsumers.asp
Includes a curriculum as well as information about wind power.

Appendix A:

The Beaufort Scale

Admiral Sir Francis Beaufort (1774-1857) of the British navy introduced the scale that bears his name in 1805. The Admiral developed it as a system for estimating wind strengths without the use of instruments. It is still in use today.

Force	Description	Conditions	Wind speed (kph)
0	Calm	Smoke rises vertically	0
1	Light air	Smoke drifts	1-5
2	Light breeze	Leaves rustle; Vane moved by wind	6-11
3	Gentle breeze	Leaves in constant motion; light flag extend	12-19
4	Moderate breeze	Raises dust and loose paper; small branches move	20-29
5	Fresh breeze	Small trees sway; crested wavelets on inland water	30-38
6	Strong breeze	Large branches in motion; whistling in telegraph	39-50
7	Moderate gale	Whole trees in motion	51-61
8	Fresh gale	Breaks twigs off trees; impedes walking	62-74
9	Strong gale	Slight damage to buildings	75-86
10	Whole gale	Large branches broken; some trees uprooted	87-101
11	Storm	Large trees uprooted	102-120
12	Hurricane	Widespread damage	120+

Appendix B:

AMERICAN WIND ENERGY ASSOCIATION
Emissions Offsets
Primary data source: *Annual Energy Review 2000*. (Washington, D.C.: Energy Information Administration, DOE/EIA-0384(2000), August 2001. The *Annual Energy Review* can be accessed on the Web at <http://www.eia.doe.gov/aer>.

Some data has not been updated in *AER 2000*, and in such case, this spreadsheet uses data from AER 1999.

Total kWh generated, U.S., 1999 (*Annual Energy Review 2000*, p. 221)	3,706,100,000,000	
Total kWh generated from coal, U.S., 1999 (*Annual Energy Review 2000*, p. 221)	1,884,300,000,000	50.8%
Total kWh generated from oil, U.S., 1999 (*Annual Energy Review 2000*, p. 221)	123,600,000,000	3.3%
Total kWh generated from gas, U.S., 1999 (*Annual Energy Review 2000*, p. 221)	558,200,000,000	15.1%
Total kWh generated from nuclear, U.S., 1999 (*Annual Energy Review 2000*, p. 221)	728,300,000,000	19.7%
Total kWh generated from hydro, U.S., 1999 (*Annual Energy Review 2000*, p. 221)	319,500,000,000	8.6%
Total pounds of CO2 emissions from electric generation, U.S., 1999 (*AER 2000*, p. 327)	5,005,456,000,000	
Annual average CO2 emissions for U.S. generating mix, 1999, lb/kWh	**1.3506**	
Total pounds of SO2 emissions from electric generation, U.S., 1999 (*AER 2000*, p. 327)	26,412,000,000	
Annual average SO2 emissions for U.S. energy mix, 1999, lb/kWh	**0.0071**	
Total pounds of NOx emissions from electric generation, U.S., 1999 (*AER 2000*, p. 327)	15,744,000,000	
Annual average NOx emissions for U.S. energy mix,1999, lb/kWh	**0.0042**	
Number of households, U.S., 1997 (*AER 1999*, p. 49)	99,490,000	
Total household electricity consumption, kWh, 1997 (*AER 1999*, p. 43)	1,037,514,654,162	
Annual average kWh consumption for U.S. household, 1997	**10,428**	
Annual average CO2 emissions from U.S. household's electricity, 1997, lb	14,084	
Annual average SO2 emissions from U.S. household's electricity, 1997, lb	74	
Annual average NOx emissions from U.S. household's electricity, 1997, lb	44	
(Based on 1997 data in *Annual Energy Review 1999*, p. 43) (These numbers only have three significant digits)		
Annual household kWh consumption, Northeast	7,301	
Annual household kWh consumption, Midwest	9,147	
Annual household kWh consumption, South	13,659	
Annual household kWh consumption, West	8,631	
Annual household kWh consumption, U.S.	10,223	
Btus in one kWh (per *Annual Energy Review 2000*, p. 336)	3,412	
Btus needed for one kWh generation from fossil plants, 1997 (p. 332)	10,346	
Heat content in Btus of one short ton coal, electric utility consumption, 2000 (*AER 2000*, p. 335)	20,548,000	
kWh produced by one ton coal (calculation from Btus and heat rate)	1,986	
Electric utility generation from coal, total kWh, 2000 (*AER 2000*, p. 223)	1,692,300,000,000	
Electric utility consumption of coal, short tons, 2000 (*AER 2000*, p. 235)	858,000,000	
kWh produced by one ton coal (calculation)	**1,972**	
kWh produced by coal, utilities, total, 1999 (*AER 2000*, p. 223)	1,767,700,000,000	
(This number is used because latest emissions data, below, are for 1999.)		
Short tons of coal used, utilities, 1999 (*Annual Energy Review 2000*, p. 235)	894,000,000	
Short tons of CO2 emitted from coal plants, utilities, 1999 (*AER 2000*, p. 327)	1,898,133,000	
Pounds of CO2 per kWh from coal, 1999	**2.15**	
Short tons of SO2 emitted from coal plants, utilities, 1999 (*AER 2000*, p. 327)	11,294,000	
Pounds of SO2 per kWh from coal, 1999	**0.0128**	
Short tons of NOx emitted from coal plants, 1999 (*AER 2000*, p. 327)	6,534,000	
Pounds of NOx per kWh from coal, 1999	**0.0074**	

Cont'd from p.14

kWh produced by oil, utilities, total, 1999 (*AER 2000*, p. 223)	86,900,000,000
Barrels of oil used in generation, utilities, 1999 (*AER 2000*, p. 235)	152,000,000
kWh produced by one bbl oil (calculation from bbl used/generation)	**572**
Short tons of CO_2 emitted from oil plants, utilities, 1999 (*AER 2000*, p. 327)	91,912,000
Pounds of CO_2 per kWh from oil, 1999	**2.12**
Short tons of SO_2 emitted from oil plants, utilities, 1999 (*AER 2000*, p. 327)	671,000
Pounds of SO_2 per kWh from oil, 1999	**0.0154**
Short tons of NO_x emitted from oil plants, utilities, 1999 (*AER 2000*, p. 327)	123,000
Pounds of NO_x per kWh from oil, 1999	**0.0028**
kWh produced by gas, utilities, total, 1999 (*AER 2000*, p. 223)	296,400,000,000
Short tons of CO_2 emitted from gas plants, utilities, 1999 (*AER 2000*, p. 327)	198,860,000
Pounds of CO_2 per kWh from gas, 1999	**1.34**
Short tons of SO_2 emitted from gas plants, utilities, 1999 (*AER 2000*, p. 327)	2,000
Pounds of SO_2 per kWh from gas, 1999	**0.000013**
Short tons of NO_x emitted from gas plants, utilities, 1999 (*AER 2000*, p. 327)	376,000
Pounds of NO_x per kWh from gas, 1999	**0.0025**
Total U.S. population, 1997 (*AER 1999*, p. 13)	267,800,000
(This number used because latest household total is for 1997.)	
Average number of persons per household	2.69
Short tons of CO_2 absorbed annually by 1 acre of forest (Global ReLeaf)	5.00
Metric tons of carbon absorbed annually by 1 acre of forest	0.73
(*Our Ecological Footprint*, Wackernagel & Rees, 1996)	
Short tons of CO_2 absorbed annually by 1 acre of forest (Wackernagel & Rees)	2.94

Note: Emissions from non-fossil sources (hydropower and other renewables, nuclear) are negligible or non-existent.

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Cover photo: Turbine at Spirit Lake Elementary School, Spirit Lake, Iowa.