Taking the Energy Challenge

Lesson Overview:
As nations and populations grow, energy demands increase. To meet these demands, new sources of renewable energy are emphasized along with traditional dependence on fossil fuels. In this lesson, students compare and contrast two forms of renewable energy (geothermal and solar) with fossil fuel and nuclear energy. Students will become familiar with energy plants, future technologies, physical science of energy and what is powering America today. In the culminating activity, students will determine if renewable energy offers a real alternative in the near term to fossil fuels.

Unit Question: Will renewable sources of energy and power be viable alternatives to fossil fuel consumption in the United States?

Learning Objectives:
Students will be able to:

- Collect, analyze, organize and display energy production and consumption data
- Record and complete fact sheets about various energy sources
- Create a visual representation of geothermal, solar, nuclear and petroleum energy plants
- Present each energy option to the class for review and discussion
- Compare and contrast renewable and non-renewable energy sources
- Evaluate energy options and make a claim based on data regarding viability of renewable energy sources compared to fossil fuel energy

Academic Standards:

National Science Education Standards (SCES)

Physical Science

Transfer of Energy

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

Earth and Space Science

Geochemical Cycles

- Movement of matter between reservoirs is driven by the Earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter.
- The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element on Earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of the geochemical cycle.

Science and Technology

Propose designs and choose between alternative solutions.

- Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in the process.

Benchmarks for Science Literacy

Although the various forms of energy appear very different, each can be measured in a way that makes it possible to keep track of how much of one form is converted into another. Whenever the amount of energy in one place diminishes, the amount in other places or forms increases by the same amount.

Time Frame:
This lesson requires four 45 minute consecutive classes if all activities are to be completed.

Background for the Teacher:
This lesson develops critical thinking skills by asking students to compare and contrast alternative sources of energy based on data and information they will locate. Four sources of energy are considered: geothermal, solar, nuclear and fossil fuel. Students construct an energy profile for the country and their particular state, including both renewable and nonrenewable sources of power. This provides an understanding of the current level of diversification in energy production and thus serves as an energy-use "baseline." The potential to harness geothermal and solar energy illustrates the means of supplying renewable energy, taking advantage of locations in the US where potential exists. Information sources are provided for national sources; state sources of energy data are to be located by teachers. After becoming "specialists" in energy comparisons, students will determine whether renewable sources of energy provide a real alternative to fossil fuels in the near term.

Materials for the teacher:

- A whiteboard, or some type of interactive whiteboard
- LCD projector for web pages
- Textbooks for energy and geophysical processes
- Library reservation privileges to bring class(es) in for reading, web preparation
- Poster presentation material and markers

Materials needed for each group of students:

- Student access to computers
- Graphing resources and/or software programs for graphing
- Textbooks/other readings on energy, power production, and physical science. Media center access to readings on renewable energy
- Art supplies (construction paper, glue, markers, scissors, colored paper, and others as needed) for drawing, illustrating and building energy production facilities

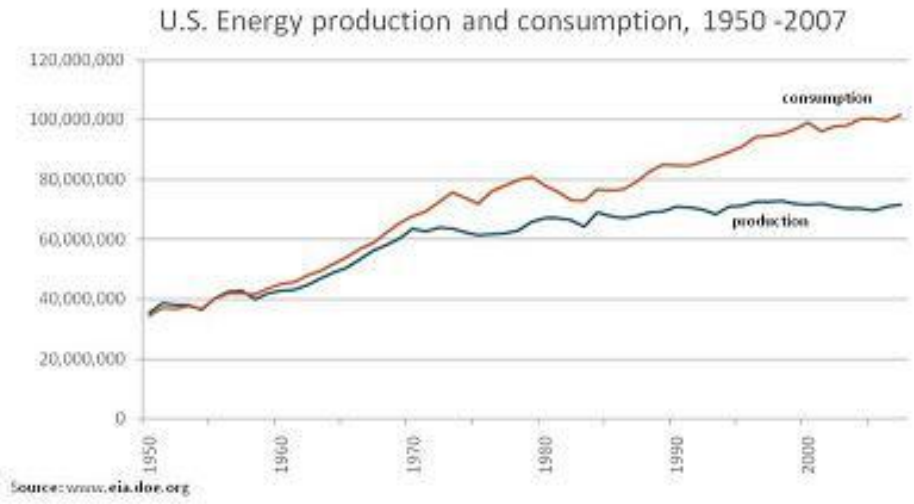
Classroom Activities:
Note to teacher: use as few or as many of these activators as fits your curricular goals.

Engage

1. Introduction
   Ask the students how they got to school today. You can take a sample of students, hopefully gathering several different examples. No matter how they traveled, even if they walked, a source of energy was required. Now ask, "What do we mean by energy, anyway?" Answer: No matter the power source, energy is defined as the ability to do work.

2. A. Using energy
   We use energy to take a ride in the car, charge our computers, cell phones and take hot showers. Our homes, schools and workplaces use energy every day, but we rarely wonder where energy comes from. As our dependence on energy increases, will our supplies remain adequate? Alternatively, will demand outstrip supply?

2. B. Show students the figure below, using either a projection board or photocopy as a handout.



Source: http://www.eia.doe.gov/

2. C. Data interpretation
   Ask the students to consider the figure together. What is the figure telling us? Have students jot down 2-3 key messages by studying the production and consumption curves over time. Using think-pair-share, have students work individually for 2-3 minutes, then pair with a neighbor and discuss. Finally, the teacher records student observations by sharing them aloud with the class.

   One question you may raise is: How can we use more energy than we produce? Answer: the difference is made up from US oil imports.

3. Energy use
   Now that we have looked at consumption and production, let us try to think of what the major uses for energy would be and how we might classify them. Divide the class into groups of four and have them decide on four major categories, capturing the ways we use the most energy. After 5 minutes, collect responses, and see how they compare to the standardized list below:
   - Residential, or home use, of electricity, natural gas, heating oil
   - Commercial, energy required to run our commercial areas such as shopping centers and schools
   - Industrial uses, such as factories
   - Transportation, including cars, airplanes, trains, ships, public transport

4. Energy production
   Now that we have identified some uses for energy, what do you think the primary sources of energy are for our community? Use the same procedure as above, this time looking at *sources* of energy. Have students estimate what percentage of power comes from each applicable energy resource. Possible answers could include:
   - Petroleum
   - Gas
   - Coal
   - Hydroelectric
   - Nuclear power
   - Renewable sources of energy (solar, geothermal, wind)

Explore

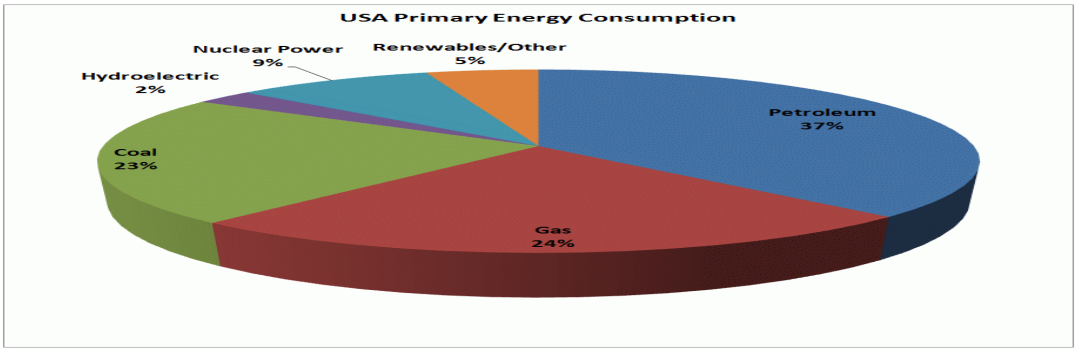
1. A. Mastering vocabulary
   Write the words listed below on the board. Have students form groups of two or four, and ask them to brainstorm definitions and compile background knowledge of energy sources in the United States. After 10-12 minutes of discussion, let them capture their ideas on the Vocabulary Worksheet (Appendix 1) at the end of the lesson.
   Note to teacher: Appendix 1 can be used with or without the text definitions.

   Be sure to make other reading material available to allow students to search independently for definitions and concepts.
   - Renewable energy
   - Nonrenewable energy
   - Fossil fuels
   - Solar energy
   - Geothermal energy
   - Nuclear energy
   - BTUs and other measures of energy and their equivalencies
   - Petroleum resources (gas and oil)

1. B. Once finished writing, invite one group/individual to come forward to lead a discussion for each word or phrase. Make sure to add missing points and provide a textbook definition.

2. A. Total energy consumption

   Next, students construct an energy chart showing national and state consumption. Below is an example from the Energy Information Administration (http://www.eia.doe.gov/totalenergy/data/annual/#summary).



Data for energy resources is found on the web and in numerous textbooks. Students should obtain actual amounts of energy consumed and organize the information in table format. Then, have the students use a computer program or hand graph this data to show percentages as well as actual use. While constructing their graph, students can analyze the energy sources and the ratio of renewable to nonrenewable sources (Appendix 2 and 3). For example, this link provides text tables breaking down energy production by source. From such a page, students can then construct their own percentages, ratios and so forth. Source: http://www.eia.doe.gov/aer/pdf/pages/sec1_7.pdf

State energy information available from: http://www.eia.doe.gov/state/

2. B. Students submit labeled pie graph as a graded assessment.

3. A. Participatory, Hands-On Activity: Energy Sources to Meet Our Needs

   How do we meet energy needs when demand exceeds output? To answer this question, explore four energy production systems and their use:

   - Nuclear energy
   - Renewable energy: solar and geothermal. For examples of how a company is approaching these technologies, have students visit the website: http://solutions.3m.com/wps/portal/3M/en_US/Renewable/Energy/
   - Non-renewable sources, such as the petroleum/fossil fuels of oil and natural gas

3. B. Expected Output

   a. Written group report, submitted with one section from each student in a group.
   b. Poster and model prepared of the actual power plant and its technologies as described by each group.

3. C. Resources and expectations for study groups

   Please refer to resources and web links listed in Appendix 4 as a starting point. Students are required to use each of the links listed, but are also expected to find their own source

material from textbooks and library resources. Introduce the exercise and make clear expectations for the report and subsequent presentation. Once student groups are formed, they will need to decide which topic each group member will study. Students can use dedicated time in the library for group writing and research.

3. D. Divide students into groups of four, with each group studying a different source of energy.

   Group 1. Nuclear energy. Topics for study:
   A. Actual locations where nuclear power is generated
   B. Principles of nuclear power generation
   C. Power-generating technologies and machinery used at a nuclear plant
   D. New technology to be added to nuclear facilities: small module reactors (Appendix 6)

   Group 2. Solar energy. Topics for study:
   A. Actual locations where solar energy is generated
   B. Principles of collecting solar energy
   C. Power-generating technologies and solar receptors used at solar facilities
   D. New technology to enhance solar collectors: 3M Concentrated Solar Power Products (Appendix 6)

   Group 3. Geothermal energy. Topics for study:
   A. Actual and potential locations for generating geothermal power and what makes these locations necessary
   B. Principles of collecting geothermal energy and Earth's geothermal processes
   C. Power-generating technologies at geothermal plants
   D. New technology to enhance geothermal energy collection: Binary modular power generators (Appendix 6)

   Group 4. Non-renewable energy. Topics for study:
   A. Actual locations in the US and world from which oil and natural gas are extracted
   B. Principles of collecting oil from deep water drilling rigs
   C. Storage and transport requirements for oil and natural gas for delivery to customers
   D. New technology for off shore energy: advanced drilling technologies (Appendix 6)

3. E. After students finish their individual study and written report, students explain their topic to the rest of the group.

3. F. Using poster board, construction paper, markers and other materials as needed, each group will draw and build a power generation facility for their type of energy production. It should incorporate the new technology. Students will identify an actual location for the plant in their state, the US, or an ocean for the oil rig. Teacher selects various locations so that there is minimal repetition in class. A rubric is helpful to clarify how students are graded and to ensure lesson objectives are met.

3. G. Finally, based on what they have learned, students estimate energy costs and production output from their power facility. This will be compared with similar estimates from the other groups.

Explain

1. From the exercise above, each group will present their energy source and power plant to the class. Discussion follows each presentation to clarify any questions/misconceptions. A worksheet is provided to summarize and capture information from the various groups (Appendix 5).

2. Divide the class in half and have students debate the merits of renewable versus fossil and nuclear power sources in meeting the nation's energy requirements.

3. Teacher grades group presentations and posters.

Extend

1. Using the process described above, have some students study wind power and hydroelectric power. Then, compare these to the other energy sources.

2. Students study safety and hazards of energy produced from each source mentioned. Students obtain library and web resources on safety and construct a pro and con organizer for each source of power.

3. Using the energy pie chart from the "Explore" section above, students compare their state energy use and production to California, Oklahoma, Arizona, and Maine. What are the commonalities among energy profiles for each state when compared to the student's home state? What are the differences among the states?

4. Home connections. Have students do a power audit for their homes and transportation. Work out an energy budget that includes heating oil, electricity, natural gas for heating, gas for transportation, propane, firewood and others as relevant. Next, see if students can determine where these various sources of energy are produced within their state. What is their family's energy profile and budget for winter and summer months? They can produce a pie chart to graph this data.

Evaluate

1. Students compare and contrast one source of renewable energy (solar or geothermal) with one source of fossil fuel.
2. Students will provide three reasons why renewable energy is important for power generation in the US.
3. Students will provide three advantages that renewable energy has over fossil fuels.
4. The culminating activity will consist of an essay that begins with the graphs generated at the beginning of the lesson and then explains which sources of energy (nuclear, geothermal, solar) have a realistic, short term impact on reducing America's use of fossil fuels.

Appendices follow.

Appendix 1. Vocabulary Builder

Name: _____ Date: _____ Period: ___

Taking the Energy Challenge: Vocabulary Organizer

Word or Phrase	What You Think it Means	Notes from Class Discussion	Text Definition
Renewable Energy			Natural resources that replenish themselves within time limits that permit sustained use.
Nonrenewable Energy			Nonrenewable resources do not naturally replenish themselves within time limits that permit sustained yield (i.e., minerals and hydrocarbons, such as phosphate rock, limestone, petroleum). Nonrenewable resources have a fixed supply. Some resources, such as soil and water, can be termed either nonrenewable or renewable depending on circumstances.
Fossil Fuels			Materials of biological origin occurring within the Earth's crust that can be used as a source of energy. Fossil fuels include coal, petroleum, natural gas, oil shales, tar sands, and heavy oils. All contain carbon and were formed by geologic processes acting on organic matter from photosynthesis.

Solar Energy			Radiation from the Sun capable of producing heat, causing chemical reactions, or generating electricity.
Geothermal Energy			Power obtained by using heat from the Earth's interior. Most geothermal resources are in regions of active volcanism. Hot springs, geysers, pools of boiling mud, and fumaroles (vents of volcanic gases and heated groundwater) are the most easily exploited sources of such energy.
Nuclear Energy			Energy that is released in significant amounts in processes that affect atomic nuclei.
BTUs and Other Measures of Energy and their Equivalencies			Thermal energy is expressed in British thermal units (Btu), calories, and joules. One Btu is the amount of heat needed to raise 1 lb. of water 1 degree Fahrenheit.
Petroleum Resources: Oil Natural Gas			Oily flammable liquids may vary from almost colorless to black. This occurs in many places in the upper strata of the earth and is a complex mixture of hydrocarbons with small amounts of other substances. It is prepared for use as gasoline, naphtha, or other products by refining. Colorless, highly flammable gaseous hydrocarbon consisting primarily of methane and ethane. It is a type of petroleum that commonly occurs in association with crude oil.

Appendix 2. Primary Energy Production by Source, 1949-2009
(Quadrillion Btu)

	Fossil Fuels						Renewable Energy [1]						
Year	Coal [2]	Natural Gas (Dry)	Crude Oil [3]	NGPL [4]	Total	Nuclear Electric Power	Hydro-electric Power [5]	Geothermal	Solar/PV	Wind	Biomass	Total	Total
2000	22.735	19.662	12.358	2.611	57.366	7.862	2.811	.317	.066	.057	R 3.006	R 6.257	R 71.485
2001	[2] 23.547	20.166	12.282	2.547	58.541	R 8.029	2.242	.311	.065	.070	R 2.624	R 5.312	R 71.883
2002	22.732	19.439	12.163	2.559	56.894	R 8.145	2.689	.328	.064	.105	R 2.705	R 5.892	R 70.931
2003	22.094	R 19.633	12.026	2.346	R 56.099	7.959	2.825	.331	.064	.115	R 2.805	R 6.139	R 70.197
2004	22.852	R 19.074	11.503	2.466	R 55.895	8.222	2.690	.341	.065	.142	R 2.998	R 6.235	R 70.352
2005	23.185	R 18.556	10.963	2.334	R 55.038	R 8.161	2.703	.343	.066	.178	R 3.104	R 6.393	R 69.592
2006	23.790	19.022	10.801	2.356	55.968	R 8.215	2.869	.343	.072	.264	R 3.226	R 6.774	R 70.957
2007	23.493	R 19.825	10.721	2.409	R 56.447	R 8.455	2.446	.349	.081	.341	R 3.489	R 6.706	R 71.608
2008	R 23.851	R 20.834	R 10.509	R 2.419	R 57.613	R 8.427	R 2.511	R .360	R .097	R .546	R 3.867	R 7.381	R 73.421
2009[P]	21.578	21.500	11.241	2.541	56.860	8.349	2.682	.373	.109	.697	3.900	7.761	72.970

[1]Most data are estimates. See Tables 10.1-10.2c for notes on series components and estimation.

[2]Beginning in 1989, includes waste coal supplied. Beginning in 2001, also includes a small amount of refuse recovery. See Table 7.1.

[3]Includes lease condensate.

[4]Natural gas plant liquids.

[5]Conventional hydroelectric power.

R=Revised. P=Preliminary. NA=Not available. (s)=Less than 0.005 quadrillion Btu.

Notes: See "Primary Energy Production" in Glossary. Totals may not equal sum of components due to independent rounding.

Sources: Tables 5.1, 6.1, 7.1, 8.2a, 10.1, A2, A4, A5, and A6.

Appendix 3. Primary Energy Consumption by Source, 1949-2009
(Quadrillion Btu)

Year	Fossil Fuels					Nuclear Electric Power	Renewable Energy [1]						Electricity Net Imports [2]	Total
	Coal	Coal Coke Net Imports [2]	Natural Gas [3]	Petroleum [4]	Total		Hydro-electric Power [5]	Geothermal	Solar/ PV	Wind	Biomass	Total		
2000	22.580	.065	23.824	R 38.263	R 84.732	7.862	2.811	.317	.066	.057	R 3.008	R 6.260	.115	R 98.970
2001	21.914	.029	22.773	R 38.185	R 82.902	R 8.029	2.242	.311	.065	.070	R 2.622	R 5.311	.075	R 96.316
2002	21.904	.061	23.558	R 38.225	R 83.749	R 8.145	2.689	.328	.064	.105	R 2.701	R 5.888	.072	R 97.853
2003	22.321	.051	R 22.831	R 38.808	R 84.010	7.959	2.825	.331	.064	.115	R 2.807	R 6.141	.022	R 98.131
2004	22.466	.138	R 22.909	R 40.292	R 85.805	8.222	2.690	.341	.065	.142	R 3.010	R 6.247	.039	R 100.313
2005	22.797	.044	R 22.561	R 40.391	R 85.793	R 8.161	2.703	.343	.066	.178	R 3.117	R 6.406	.084	R 100.445
2006	22.447	.061	22.224	R 39.955	R 84.687	R 8.215	2.869	.343	.072	.264	R 3.277	R 6.824	.063	R 99.790
2007	22.749	.025	R 23.702	R 39.769	R 86.246	R 8.455	2.446	.349	.081	.341	R 3.503	R 6.719	.107	R 101.527
2008	R 22.385	.041	R 23.791	R 37.279	R 83.496	R 8.427	R 2.511	R .360	R .097	R .546	R 3.852	R 7.366	.112	R 99.402
2009[P]	19.761	-.024	23.362	35.268	78.368	8.349	2.682	.373	.109	.697	3.883	7.744	.117	94.578

[1]Most data are estimates. See Tables 10.1-10.2c for notes on series components and estimation.

[2]Net imports equal imports minus exports. A minus sign indicates exports are greater than imports.

[3]Natural gas only; excludes supplemental gaseous fuels. See Note 1, "Supplemental Gaseous Fuels," at end of Section 6.

[4]Petroleum products supplied, including natural gas plant liquids and crude oil burned as fuel. Does not include biofuels that have been blended with petroleum—biofuels are included in "Biomass."

[5]Conventional hydroelectric power.

R=Revised. P=Preliminary. NA=Not available. (s)=Less than 0.0005 and greater than -0.0005 quadrillion Btu.

Notes: ? See "Primary Energy Consumption" in Glossary. ? See Table E1 for estimated energy consumption for 1635-1945. ? See Note 3, "Electricity Imports and Exports," at end of Section 8. ? Totals may not equal sum of components due to independent rounding.

Sources: Tables 5.12, 6.1, 7.1, 7.7, 8.1, 8.2a, 10.1, 10.3, A4, A5, and A6.

Appendix 4. List of resources for web quest/information on the various energy sources studied.

Energy Source	Title	Type	Web Link
Geothermal	Geothermal Energy Information	How Stuff Works Web Links	http://www.howstuffworks.com/environmental/energy/geothermal-energy.htm
	Map of Geothermal Areas in the US	Geothermal Resources US	http://www.nrel.gov/gis/images/geothermal_resource2009-final.jpg
	Geothermal Power Plants	How Stuff Works Article	http://science.howstuffworks.com/environmental/green-tech/energy-production/artificial-geothermal-energy1.htm
	Introduction to Geothermal Energy	United Nations UNICEF Fact Sheet	http://www.our-energy.com/geothermal_energy.html
Fossil Fuels	Fossil Fuel Resources	How the Hydrogen Economy Works	http://auto.howstuffworks.com/fuel-efficiency/fuel-economy/hydrogen-economy.htm
Nuclear Energy	U. S. Department of Energy	Office of Nuclear Energy Homepage	http://www.ne.doe.gov/
	Nuclear Regulatory Commission	Nuclear Reactors and Energy Generation	http://www.nrc.gov/reading-rm/basic-ref/teachers/unit3.pdf
Solar Energy	3M Concentrated Solar Power Products	Technical bulletin for concentrating solar collectors	http://solutions.3m.com/wps/portal/3M/en_US/Renewable/Energy/Products/Product_Catalog/?PC_7_RJH9U5230ON1E02JQNKPVC18P7_nid=43J6P3L1FGbeL4S7689SR8gl
	Facts About Solar Energy	How Stuff Works	http://science.howstuffworks.com/environmental/energy/solar-energy-info.htm

Appendix 5. Worksheet for use during oral presentations

Presentation Group	Key Technologies Employed for Power Generation	Principles of Energy Collection	Locations Where Energy is Generated or Processed
Solar Energy			
Nuclear Energy			
Geothermal Energy			
Non-renewable Energy Sources			

Appendix 6. Energy and Technology – How Can We Provide Energy More Efficiently and Safely?

Energy Source	Power Generation Requirements and Equipment	Technology Added	Research Articles and Web Links
Solar Energy	Solar Panels	3M Concentrated Solar Power Products	http://solutions.3m.com/wps/portal/3M/en_US/Renewable/Energy/Products/Product_Catalog/?PC_7_RJH9U5230ON1E02JQNKPVC18P7_nid=43J6P3L1FGbeL4S7689SR8gl
Oil and Gas (fossil fuel)	Off shore oil well	New drilling technologies	Offshore Oil and Gas Recovery Technology. http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/Appb.pdf
Nuclear Energy	Reactor	Small module reactors	What Makes New Nuclear Reactors Safer http://news.discovery.com/tech/nuclear-reactor-designs-future-110316.html
Geothermal Energy	Power generator	Enhanced **or** engineered geothermal systems **(**EGSs**)**	How Artificial Geothermal Energy Works http://www.howstuffworks.com/environmental/green-tech/energy-production/artificial-geothermal-energy.htm