AUTHOR

Deborah S. Page, *CA Teaching Credential (Life), M.A. Education.* 19 years educational experience, including elementary classroom instructor; teaching specialist and project developer in gifted education, science, and language arts; instructor at California Academy of Sciences, San Francisco. Her consultation and writing work has included projects for Geothermal Education Office, TERC (an educational software developer), the Watercourse/Project WET (Council for Environmental Education), California Institute for Biodiversity (Cal Alive!), and Project Learning Tree.

EDITOR

Marilyn Nemzer, Executive Director, Geothermal Education Office, Tiburon, CA.

LAYOUT & PRODUCTION

Spitfire Studios, Claremont, CA.

ILLUSTRATIONS

Will Suckow Illustration, Sacramento, CA.

REVIEWERS & SCIENTIFIC CONSULTANTS

LEAD CONTENT REVIEWER

Rick Loomis, Integrated Science Instructor, Cajon High School, San Bernardino, CA.

CONTENT REVIEWERS AND SCIENCE CONSULTANTS

Gordon Bloomquist, Director and Senior Scientist, Washington State University Energy Program.

Anna Carter, Principal, Geothermal Support Services, Santa Rosa, CA.

Kent W. Hughes, Science Consultant, Claremont, CA.

Carolyn Likar-Walline, Teacher, Idaho Falls High School, ID.

John Lund, P.E., Director of Geo-Heat Center, Klamath Falls, OR.

Roy Mink, Director, Idaho Water Resources Research Institute, University of Idaho.

Kevin Rafferty, P.E., Associate Director of the Geo-Heat Center, Klamath Falls, OR.

Julie Scanlin, Water Education Coordinator, Idaho Water Resources Research Institute, University of Idaho.

GEOTHERMAL ENERGY:
A Renewable Option

Teacher's Guide for Grades 6-12

A selection of activities for use in classrooms of social studies, earth science, physics, and environmental science.

About this Teacher's Guide

This teacher's guide and the accompanying video, *"Geothermal Energy: A Renewable Option,"* were developed to help educators introduce their students to the general history and uses of energy resources and the impact of energy use on the environment. They focus on geothermal and other renewable energy sources with respect to science and to public energy policy:

This teacher's guide includes background information, inquiry-based, interdisciplinary student investigations, glossary, a video transcript, and selected resources for further information. The activities are intended for use in the high school classroom; however, a number of them may be easily adapted for middle school use.

The activities address the charge of the California Science Content Standards to investigate societal, science-based issues including the choice of energy sources. They incorporate the recommendations of the National Science Education Standards for inter-disciplinary inquiry-based learning. Additionally, they follow the California Public Schools' Science Framework recommendations, which require that students pursue meaningful projects and inquiries that allow them to make crucial connections between science, technology, and society.

This guide is not intended to be a comprehensive geothermal energy science curriculum, but rather a set of touch-off points. It extends some of the key ideas found in the accompanying video regarding geothermal energy and energy use in general. The author assumes that the guide and video will be used in the context of a broader science or social studies curriculum.

More copies of this guide, the accompanying video,
and additional educational materials about geothermal energy are available from:

GEO
GEOTHERMAL EDUCATION OFFICE

664 Hilary Drive, Tiburon, CA 94920 USA
1-800-866-4436
Fax: 1-415-435-7737
E-mail: geo@marin.org
Web: http://geothermal.marin.org

To the Educator:

Over the last three decades world energy consumption has increased threefold, fossil use fivefold and electricity use sevenfold. While energy has contributed greatly to our comfort and social development, indiscriminate use of energy resources has had negative impacts. At risk are our environment, our energy security and our well-being.

Traditionally, energy is presented to students in the context of science, not social studies. But both approaches are important. Earth science and physics principles underlie energy, while social studies can promote informed connections between energy use and the environment. Both are needed to prepare students for responsible citizenship.

This is the time to make changes which will reduce our reliance on fossil fuels and improve environmental health. These changes will take many forms. But they will certainly involve political processes, collaborative decision-making, and community involvement – all issues taught in the social studies and environmental science classrooms.

Understanding energy issues is part of being literate in science, culture and politics. We hope to see energy issues infused throughout the high school curriculum; they are issues crucial to the future.

Marilyn L. Nemzer
Executive Director
Geothermal Education Office

"Americans are confronted increasingly with questions in their lives that require scientific information and scientific ways of thinking for informed decision making. And the collective judgement of our people will determine how we manage shared resources..." National Science Education Standards, 1996

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Geothermal energy is the immense resource of natural heat that is ever-generating inside the earth. It produces clean, reliable power around the world. The use of geothermal energy, like that of other renewables, helps conserve depleting fossil fuels, promotes sustainable economies, and contributes to energy security by decreasing dependence on imported fuels.

Activity One: Making Connections about Energy Sources

When we flip the switch do we really know where our energy is coming from?

OBJECTIVES

- Define energy and energy resources
- Determine where the energy we use comes from
- Categorize energy resources as renewable or nonrenewable
- Compare geothermal energy to other energy sources

SUBJECTS

Social studies, environmental science

TIME

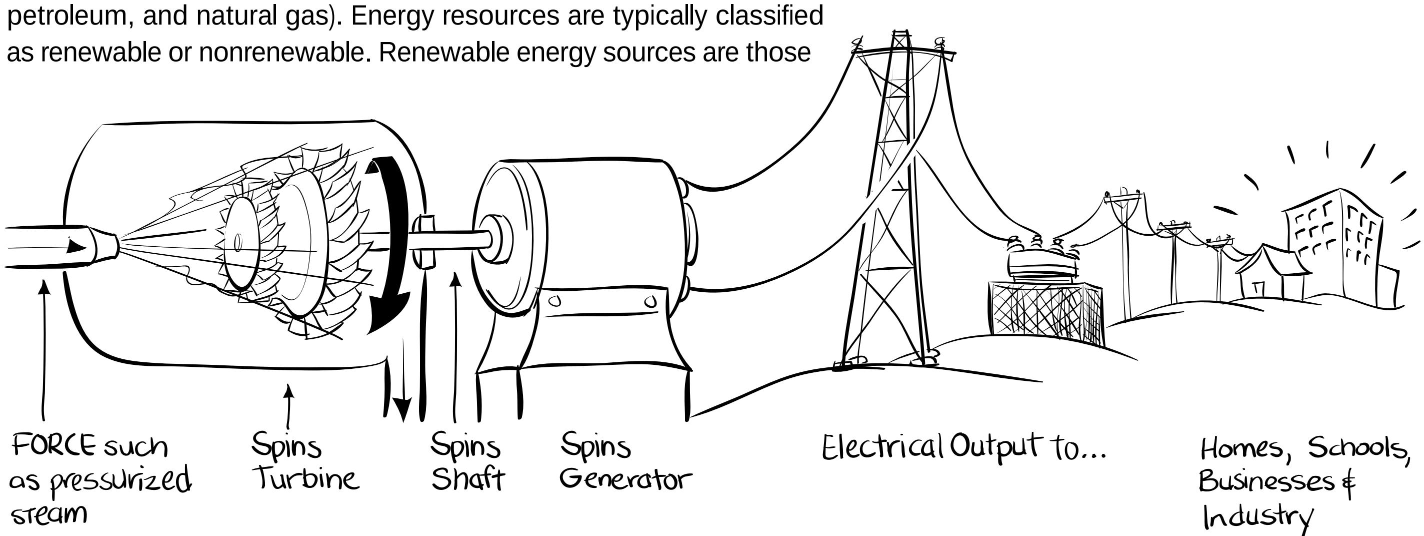
Two 45 minute class periods, separated by two weeks.

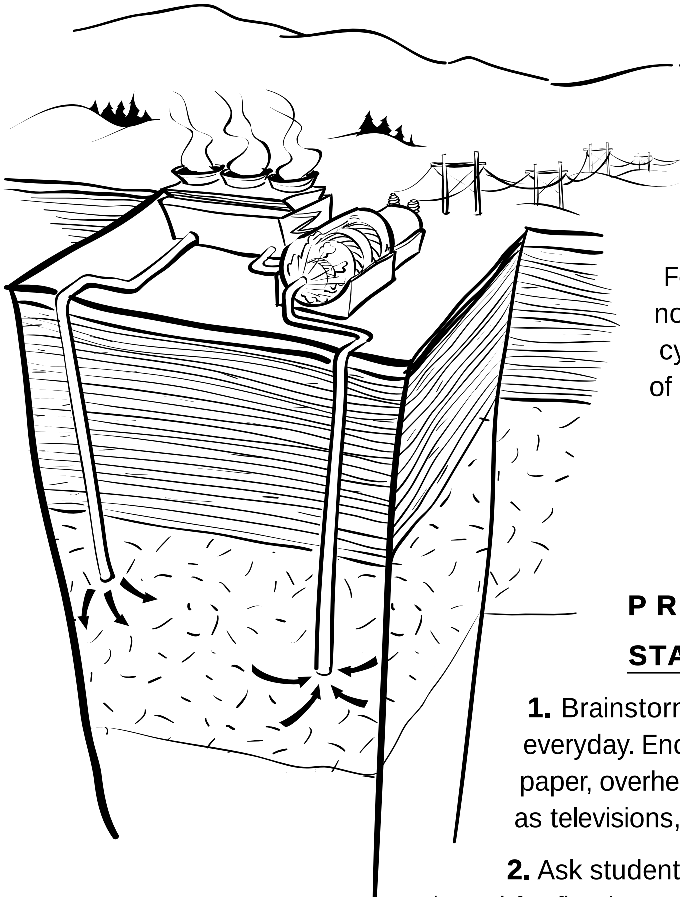
It is assumed that students have viewed the videotape, *Geothermal Energy: A Renewable Option.* (26 minutes).

BACKGROUND

Energy is the capacity to do work. It comes in many forms, some of which are heat, radiant, chemical, mechanical, and electrical energy. Each form of energy can be transformed into another. It is this transformation that allows us to convert energy from a less useful form (such as natural gas or a lump of coal) into a more useful form. For example, burning gas to heat water and make steam is an example of changing chemical energy to heat energy. Using steam to run a turbine involves changing heat energy to mechanical energy. Using the turbine to turn an electric generator involves changing mechanical energy to electrical energy. Using the electricity to turn on a light bulbs changes electrical energy to radiant energy.

We are so used to our everyday conveniences that when we flip the switch to light our homes, we don't often think of the series of changes the energy goes through to produce light. We also may be unaware of the sources of the energy – the energy resources, which include water, geothermal, solar, wind, nuclear, biomass, and the fossil fuels (coal, petroleum, and natural gas). Energy resources are typically classified as renewable or nonrenewable. Renewable energy sources are those





which are replaced by natural processes in an amount of time that is reasonable for human use. For example, wood (biomass) is a renewable resource because of the continuous growth of new trees and other plants. Other renewables include: solar, wind, water, and geothermal. Fossil fuels and, usually, uranium (for nuclear) are classified as nonrenewable energy sources because the regeneration cycle is too long for them to be replaced in a useful amount of time.

PROCEDURE

STAGE ONE

1. Brainstorm with your students about all the ways they use energy everyday. Encourage as many uses as possible, recording them on large paper, overheads, or on the board. You are looking for the end uses, such as televisions, computers, stoves, etc.

2. Ask students to group the lists by the immediate energy source it uses (wood for fireplaces, sunlight or batteries for calculators, gas for cars, and so forth). Put energy users that run on electricity into an "electricity" category.

3. Ask students if they can trace any of the materials used for energy along a pathway back to their original sources. For example, where does the wood come from for their fireplaces? What about the gas for their cars? Where did the natural gas for heating come from? Where does their home or school get its electricity? Can they identify the resource(s) used to produce that electricity? Try to trace the complete pathway back to the original source for each item. Record these "reverse pathways." Examples: wood – home supply store – local wood cutter; computer – electricity – electric company, etc.

4. Identify pathways which don't trace the energy changes back to the initial source. For example, how does the electric company produce the electricity – by making steam using heat from burning fossil fuels? From the force of falling water? From geothermal steam? Put a question mark by each incomplete pathway.

5. Divide the class into teams of 3 to 4 students and challenge each team to pick an incomplete pathway. Their job will be to investigate (using primary sources as much as possible) how to complete their pathway – to trace the energy back to its initial source. Brainstorm together how each group can go about getting the answers (talking to their local gas station managers, having one team per class call their utilities to find how the electricity is produced, etc.). Give the teams two weeks. Decide if you want an informal or formal reporting method. Decide how you want each group to identify, assign, and manage the tasks required.

STAGE TWO

1. After two weeks, have each group report their findings. Complete the unknown pathways on the class chart. An expected example might be: computer – electricity – electrical substation – electric utility – hydroelectric power facility – force of falling water.

2. Ask the class which of the original energy sources can be regenerated in a reasonable amount of time for human use. Explain that these sources are considered renewable. Ask which sources cannot be regenerated in a reasonable amount of time.

3. Remind students of the videotape they watched and ask for definitions of geothermal energy. Ask if students can list some of the ways geothermal energy can be used.

4. Generate a discussion in which students compare geothermal energy to the other energy sources. Be sure to include the advantages and disadvantages of each source discussed.

EXTENSIONS

- Visit a nearby electric power plant.
- Ask a representative from your local utility company to speak to the class.
- If geothermal energy is available in your area, investigate how widely it is being used.
- Have students develop demonstrations of or reports about various energy resources, describing advantages, disadvantages, pollution, byproducts, and so forth.

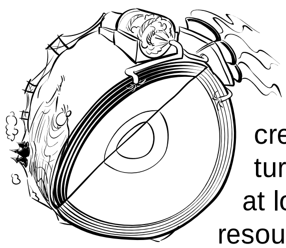
Energy Resources

Energy resources supply the energy needed to do work. The use of energy resources has increased greatly in the last century since the advent of the Industrial Revolution. Prior to that time, wood was the most commonly used energy resource. Today we rely on a number of energy resources. Without them, our lives would be much different – no computers, stereos, electric lights, heart and lung machines, cars, jets, or rockets to the moon.

RENEWABLE RESOURCES

Resources which naturally regenerate themselves within a useful amount of time.

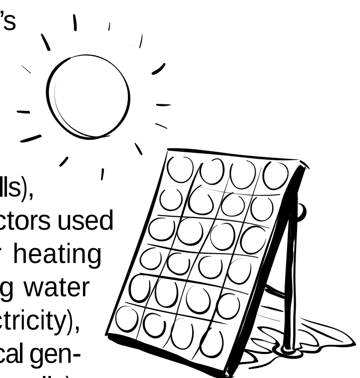
Biomass: All plant material (including wood) or organic waste can be converted to a fuel which is burned to heat water for steam-generated electricity or used to run other machinery (such as autos).



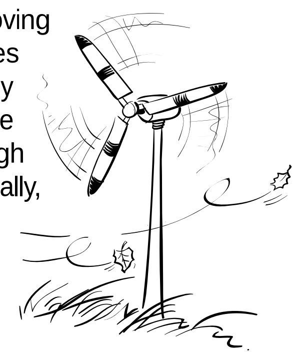
Geothermal Energy: At high temperatures, hydrothermal (hot water) resources are used to create pressurized vapor to drive turbines for electrical generation; at lower temperatures, geothermal resources are used directly for their heat in a wide range of applications.

Hydropower: The force of moving (usually falling) water turns turbine blades for electrical generation; is used most commonly in large power plants; also found as small “run-of-the-river” and “micro” stream systems.

Solar Energy: The sun’s energy is captured in three major ways: **passive solar** (space heating using solar energy through windows and/or heat-absorbent walls), **solar thermal** (solar collectors used for space heating, water heating for direct use, and heating water for steam-generated electricity), and **photovoltaics** (electrical generation using photovoltaic cells).



Wind Power: The force of moving air directly turns turbine blades of electrical generators; normally a large number of these are grouped in a “wind farm,” though they can also be used individually, such as in rural areas.

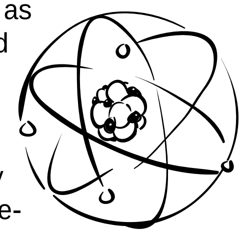


NONRENEWABLE RESOURCES

Resources which are used up faster than more can be naturally replaced.

Fossil Fuels: Main forms are coal, petroleum and natural gas; fuel is burned to produce heat which is used directly or to create steam; wide variety of uses includes electrical generation, internal combustion engines (automobiles), space heating, and factory operation.

Nuclear Fuels: An element (such as uranium) with unstable nuclei is used to generate large amounts of energy liberated by a nuclear reaction; while there are only two forms of reactions (fusion and fission), fission is the only one which has been harnessed usefully at the present time; most common use is for electrical generation.



Activity Two: It's Particulate, Dear Watson

We can detect certain kinds of air pollution by gathering evidence.

OBJECTIVES

- Identify particulate matter (small solid material) as an air pollutant
- Measure the rate at which different sources deposit particulate matter
- Estimate the possible source(s) of the deposited particulate matter
- Identify energy sources that don't contribute to particulate (and other) air pollution which might be used instead of fossil fuels

SUBJECTS

Earth science, environmental science, social studies

TIME

Two 45 minute class periods, separated by one week.

BACKGROUND

In order for the energy in fossil fuels to be beneficial, it needs to changed, or converted into a more useful form. This is done through combustion (burning). The reaction that occurs releases gas such as sulfur dioxide, carbon monoxide, nitrogen dioxide, and unburned hydrocarbons. When these chemicals become concentrated (as in areas with a high density of cars and/or factories) they have effects which include a variety of health problems, acid rain, poor visibility, smog and a reduced quality of life. Another gas emission — carbon dioxide — is also produced by burning fossil fuels. While relatively nontoxic, it is a major contributor to global climate change because it helps trap heat rather than allowing it to escape. These gases are difficult to measure in the ordinary classroom or science lab.

However, we can detect some materials that are released during the combustion of fossil fuels. These are tiny solid and liquid particles called particulate matter that are suspended in the air. It is normal to have some particulates in the air (as from volcanic eruptions, lightning-set fires, and dust). In fact, without airborne particles, we wouldn't have rain. (Water vapor needs to condense on something to form a drop. In the air, water condenses on tiny particles.) However, since the Industrial Revolution, the activities of humans have been producing an excessive amount of particulates from combustion, contributing to poor air quality.

Acting as detective teams, students can identify possible sources of particulate-matter pollution by collecting samples. While they won't be able to determine whether the particulates are necessarily the result of a polluting source (such as a fossil fuel using factory), a high amount of deposition in that vicinity may lead to the conclusion that the source is contributing to particulate pollution.

MATERIALS

- list of major air contaminants & chart of particulate matter per square inch (see page 8)
- wax pencils
- glass microscope slides
- petroleum jelly or double-sided tape
- clean jar lids or petri dishes (larger than the slides)
- cellophane wrap if using jar lids
- microscopes, or hand lenses (make sure that all examinations of particle samples are done with the same magnification or the same type of magnifying lenses)
- maps of your city or area
- information on industry in your area from Chamber of Commerce
- optional: information about prevailing wind patterns (available from your local weather service)

PROCEDURE

STAGE ONE

1. Share the list of major air pollutants (p. 8), and conduct a discussion about air pollution. Define term "particulate matter." Explain what is meant by naturally-occurring particulates and discuss their increase since the early 1800's. Talk about why.

2. Ask students if they consider their local area to have sources of particulate matter pollution. Even if your area does not have a high concentration of cars or factories, there may be other causes – wood burning stoves, coal, and gas for space heating, charcoal production plants. Your very school may be one of the "culprits."

3. Divide your class into teams. Explain that each team is to form a detective agency. Their assignment: to determine if there are any major particulate matter polluters in your area. You might allow time to have each team develop a name for their agency, as well as pseudonyms for each detective participant.

4. Provide each team with a map of the community and information from the Chamber of Commerce. Ask each team to identify five places from which they would like to gather evidence of particulate air pollution. Some teams will pick the same location. This is okay.

5. Have each team report which places they have identified. Create a master list of locations. Pick the top five most suspected locations. Assign a location to each team. (These may include a home which burns wood for heating, a factory, the school, and so forth)

6. Each team must develop a plan for getting permission to leave two or more collection devices in the vicinity outside of the identified source. Each team must develop a feasible plan to leave their collection devices for one week (where they won't be disturbed).

Provide support as needed. Doing this during dry weather is optimal. (The more slides each team leaves at one location, the more accurate the data.)

7. Provide each team with a wax pencil, slides, tape or petroleum jelly, and jar lid/cellophane wrap or petri dishes. (Each team should get the same number of slides, etc.) Have them write the location on the back of each slide (i.e. Bob's home, Milltown Gas & Electric, Miller Furniture plant,etc.]. They then place each slide in the lid or dish, smear with thin layer of petroleum jelly (or affix tape) and cover. Their homework for this project is to obtain permission and then leave the slides in a safe place outside the identified source. They uncover the jar lids or dishes and leave them for one week. They may choose to check on their devices periodically during the seven days.

8. Have a volunteer prepare two or more collection devices for use in the classroom, leaving the lids on. These are the controls.

STAGE TWO

1. After seven days, teams retrieve the slides and bring them to class. They should cover them en route, taking care not to touch the slides' surfaces. (If covered, then there shouldn't be a problem if a day or so elapses before the next steps of the project.)

2. Each team carefully examines their slides with a microscope or hand lens. They make a drawing of what they see and then compare it to the chart provided on page 8 to derive an estimate of the amount of particulate matter collected. (The chart shows the number of particles per square inch.) Have them calculate an average amount of particles deposited. Meanwhile, have volunteers check the control slides, making an average for them as well.

3. Have each team report their findings and record the results on the master list. Identify which source produced the most particulates. Discuss whether or not this met with their expectations. Talk about ways to do an even more extensive test to be sure that that source is the culprit. Teams who accomplished their mission may be given Master Detective status (as well as a good grade.)

4. Discuss how feasible it would be for the pollution source(s) to change the form of energy they use. Using information from the video (or video transcript), identify renewable energy sources which don't contribute to air pollution. Include geothermal energy (or geothermal heat pumps in areas without direct geothermal energy) in the discussion.

NOTE: If your students aren't able to go out into the field to collect samples, you may wish to simulate the conditions which might be found in various locations by burning paper, cheap paraffin candles, or kerosene lanterns and comparing the particles gathered to those gathered in a "cleaner" location in your room or lab.

EXTENSIONS

- Research the feasibility of the electric utility company substituting other energy sources which don't contribute to particulate matter pollution.
- Discuss the idea that some of the evidence collected may have blown in from another source. Brainstorm how to make sure that the particles collected actually come from the source identified.
- Contact the EPA for information about how scientists determine the levels of air pollutants.
- Learn about how industries try to control air pollution.
- Contact your local air quality control board for more detailed information on particulate air pollution in your region.

Major Air Pollutants

Pollutants can enter the air through both natural and human activities. Up until the Industrial Revolution, nature was able to dispose of or disperse enough pollutants to restore the air to a natural balance. However, the recent activities of humans – burning fuel for industry, power and transportation and crowding together in urban areas – have resulted in an imbalance in the air. In the last twenty years, humans have made significant decreases in air pollution*; however, the amounts produced by human activities are still high enough to require continued concern, especially regarding the following air pollutants.

carbon dioxide (CO_2): a generally non-toxic gas; produced by human activities such as combustion of wood and fossil fuels, as well as by nature through forest fires, respiration and volcanic activity; is thought to be a major contributor to the trapping of excess heat in the atmosphere, resulting in global climate change (greenhouse effect).

carbon monoxide (CO): highly toxic gas; produced by incomplete combustion of fossil fuels; greatest source is gas-powered vehicles; other major contributors are industry and solid waste burning; also produced naturally by forest fires and other natural processes.

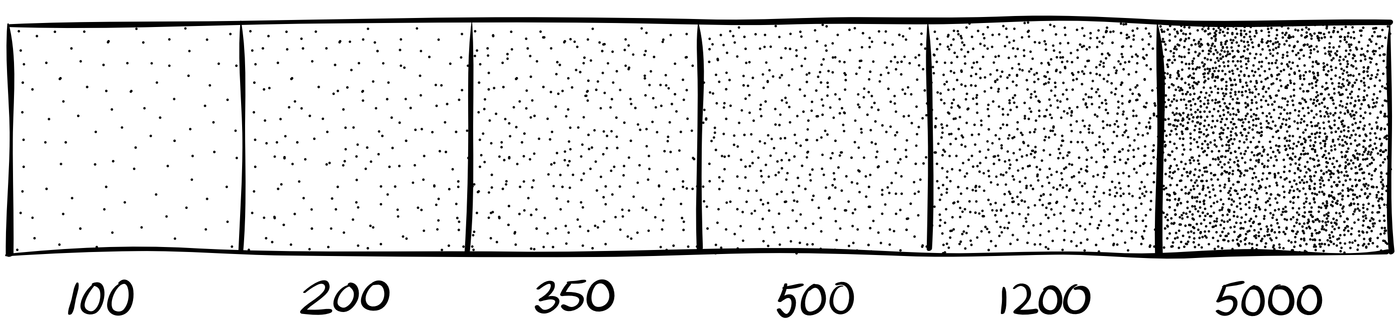
sulfur dioxide (SO_2) & hydrogen sulfide (H_2S): the “smelly” gases; produced as a result of the combustion of sulfur-containing fuels (coal and fuel oil). If not captured, these gases release sulfur into the air where they can join with oxygen and other chemicals. Major sources which also use fossil fuels are power plants, industry (especially the smelting of ores) and space heating; also produced naturally by volcanoes and natural decay. Some geothermal power plants have H2s requiring capture.

nitrogen oxides (NOx): gases mainly produced as a result of gas-burning engines, fuel-burning power generation, and space heating; produced naturally by lightning, biological processes and decay; when combined with other chemicals in the presence of sunlight, nitrogen oxides form photochemical smog.

ozone: a special form of oxygen formed by the reaction with other chemicals including nitrogen oxide; in the lower atmosphere ozone is a pollutant; in the upper atmosphere, it is necessary to block the sun’s harmful rays.

particulates: all solid particles suspended in the air; produced by combustion of fossil fuels, waste burning, construction, and mining; also produced naturally by forest fires, volcanoes, dust; one of the most harmful of the particulates is soot; harmful chemicals which result from combustion can become attached to soot and then easily breathed into the lungs.

* Some of the major reasons for reduction in human-produced air pollution include: improved engine design (including systems which lower emissions and improve fuel efficiency); reduction of emissions from power plants through use of filters, scrubbers and other devices; incentives for and heightened public awareness about the use of non-polluting energy alternatives; convenient and efficient mass transit systems; car pooling; enforced government regulations; and “watch-dog” groups.



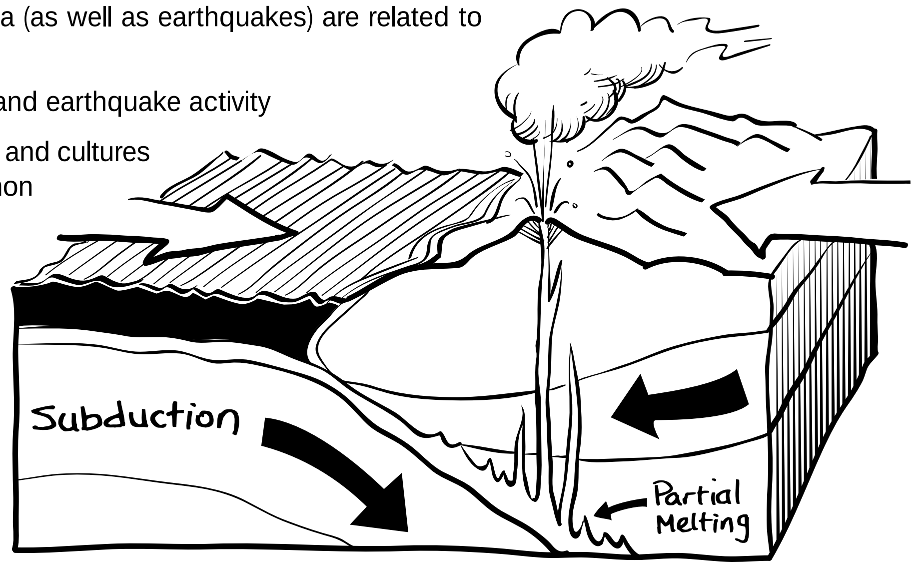
Thanks to Grolier for permission to adapt this particulate chart from
Martin Gutnik’s Ecology Projects for Young Scientists, New York: Franklin Watts, 1984

Activity Three: When Plates Collide (and Divide)

Geography, geology and cultures collide when students study geothermally active locations.

OBJECTIVES

- Understand how geothermal phenomena (as well as earthquakes) are related to plate tectonics and hot spots
- Identify geographic belts of geothermal and earthquake activity
- Research and describe specific locations and cultures which experience geothermal phenomenon



SUBJECTS

Earth Science, Social Studies

TIME

Two 45 minute class periods, separated by an interval determined by teacher

BACKGROUND

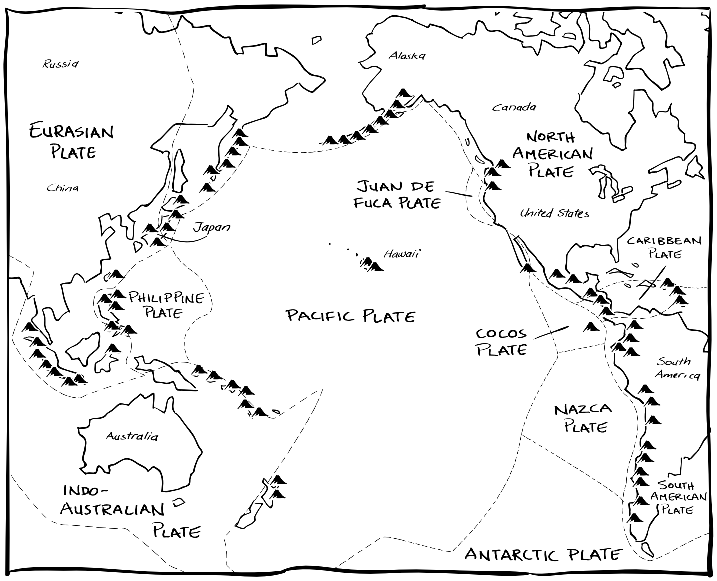
Geothermal phenomena - volcanoes, hot springs, geysers, underground geothermal aquifers - (see glossary) are fueled by heat energy (thermal energy) from the earth's interior. This interior heat is also thought to produce huge, slow, circular movements in the mantle – convection currents – which drive the movements of enormous plates of Earth's crust, the lithospheric plates (the study of which is called plate tectonics). These movements are among the causes of stress in crustal rock, resulting in fractures and faults, and hence earthquakes. Plate movements are also among the causes of volcanic activity.

Most volcanoes and earthquakes occur along specific belts of activity found where the plates meet or separate – often referred to as plate margins. These are found: (1) along ocean spreading centers or continental rift zones where upwelling magma pushes apart the enormous lithospheric plates along great cracks in the crust or (2) along subduction boundaries – places where the lithospheric plates are colliding (slowly but very forcefully) with each other. Here one plate slides up over the other, pushing down the latter, creating great heat and pressure which results in even more magma – hence even more volcanic activity.

Geothermal phenomena also occur within lithospheric plates. From deep in Earth's mantle, extremely hot upwellings of magma surge up through the surrounding semi-molten or molten rock toward the surface, creating hot spots. As a continental plate moves over a hot spot over millions of years, there is a higher incidence of volcanoes and other geothermal occurrences on the surface. When the moving plate is an oceanic plate, the resulting volcanoes create a series, or chain, of islands; the most famous chain forms the Hawaiian Islands.

Geologists estimate that for any given amount of magma expelled by a volcanic explosion, a volume ten times greater remains beneath the crust. Because hydrothermal (hot water) resources are heated by these underground magma chambers, the study of volcanoes goes hand in hand with the search for and study of geothermal energy resources.

The search starts with a map of the globe showing belts of volcanic and earthquake activity stretched like crooked stitches along the spreading centers and subduction



Ring of Fire

boundaries. Here, for example, one can find the Ring of Fire, a zone of volcanoes and earthquakes which circles the entire Pacific basin. On the other side of the globe, Iceland – so well known for its hot springs and geysers – straddles a rift zone and is literally being stretched apart.

Using the maps as a starting point, student groups locate areas along one of these belts of activity. After conducting research, student groups create a story which takes place in a specific geothermally active region, without identifying the spot. Classmates use the cultural, geographic and geological clues, along with the story line itself, to identify the location.

By assembling the stories, and placing their location on a world map, students will have a greater understanding of the convergence of geothermal geology, geography, and culture.

MATERIALS

- large world map which can be marked
- reproducible maps (see p. 12) of tectonic plates and earthquakes & volcanoes
- story example (see p. 11)
- access to research materials

PROCEDURE

STAGE ONE

1. Ask students to brainstorm various famous volcanic eruptions and earthquakes. As the list grows, have a volunteer plot their locations on a world map. You may wish to provide some examples if students are unfamiliar with this topic.

2. Provide students with a copy of the world maps Tectonic Plates and Earthquakes & Volcanoes. Have them describe what they see.

3. Generate a discussion about plate tectonics and its relationship to geothermal phenomena (including volcanoes, geothermal aquifers, hot springs, geysers, etc.) and earthquakes, using the background information and any other sources.

4. Organize students into groups of 3-5.

5. Read the example story, “Diablo’s Visit,” then ask students to guess the geographical location of the story. Allow them to use atlases and maps. When the location is ascertained, ask how they figured it out. Look for answers which include cultural and geographical hints. Plot the location on the large world map.

6. Brainstorm a list of other places along the geothermal activity belts which might be interesting to learn more about. Your list may include (but not exclusively): Alaska; Cascade Mountains (Mt. St. Helens); Yellowstone National Park; Hawaiian Islands; Iceland; Japan; Philippines; Mexico; Central America; Peru; Himalayas; Indonesia; and so on.

7. Each student group will secretly pick a location. They will then research the area. They will be looking for:

- An interesting geothermally-related event or story (you may include earthquakes, if you choose)
- Descriptions of the local geology and geography

- Cultural details about the area, such as language, celebrations, life styles, food, legends/myths and so on

8. Students then develop the information into a short story without including the name of the place where it occurs. You may choose to suggest a size limit. Ask students to write their information references on a separate paper, along with the name of the location.

STAGE TWO

1. Develop a management plan for session two, where students will share their stories with fellow classmates. The expected outcome is that students will guess where each story takes place, based on the clues.

2. Once guessed, the location is plotted on the world map. After everyone's stories, students compare the plotted large world map with their small map of volcanic and earthquake belts. They then discuss how plate tectonics affects not only the geology, but also the geography and the culture of an area.

STORY EXAMPLE

EL DIABLO'S VISIT

Pedro told me about the smell in my field when we returned from the fiesta at our friends in Uruapan. Pedro had tended my farm in my absence and told his story at supper that evening. "Señor, yesterday I started smelling something very bad at the end of a field of maize. And I thought I saw smoke. Could it be El Diablo coming to visit?" Pedro was known for his tendency to stretch a story, so I paid little attention. Anyway, we were so full of our own tales that a little smell in my field didn't seem very important.

When I returned to work the next day, I realized that Pedro, for once, had not been exaggerating. Not only was there a bad smell and smoke coming from my rows of maize, there was a great crack bubbling with grey-white stuff...as if El Diablo was coming up from below. I was sure that the world was coming to an end, so I fled with my family to the village. After describing what I saw, all the villagers hid in the church.

After a while, nothing seemed to be happening. So Pedro along with my friends Raul and Miguel went back to my field with me. I'll never forget that day in 1943 – because before our eyes, we saw a huge smelly hole exploding smoke, ash and sparks. It was hurling red-hot rocks through the air. It might as well have been El Diablo himself, we ran so fast.

Back at the church, we found some books that explained what was happening. We had not seen El Diablo – we had seen the birth of a volcano! All night the volcano roared. A cone-shaped hill began to form and within two days, lava started to flow from a crack nearby.

Lava and ash soon covered my farm, and then the entire village. Only the church steeple showed. Our country's government had to move us all away. In just a year the volcano grew into a small mountain.

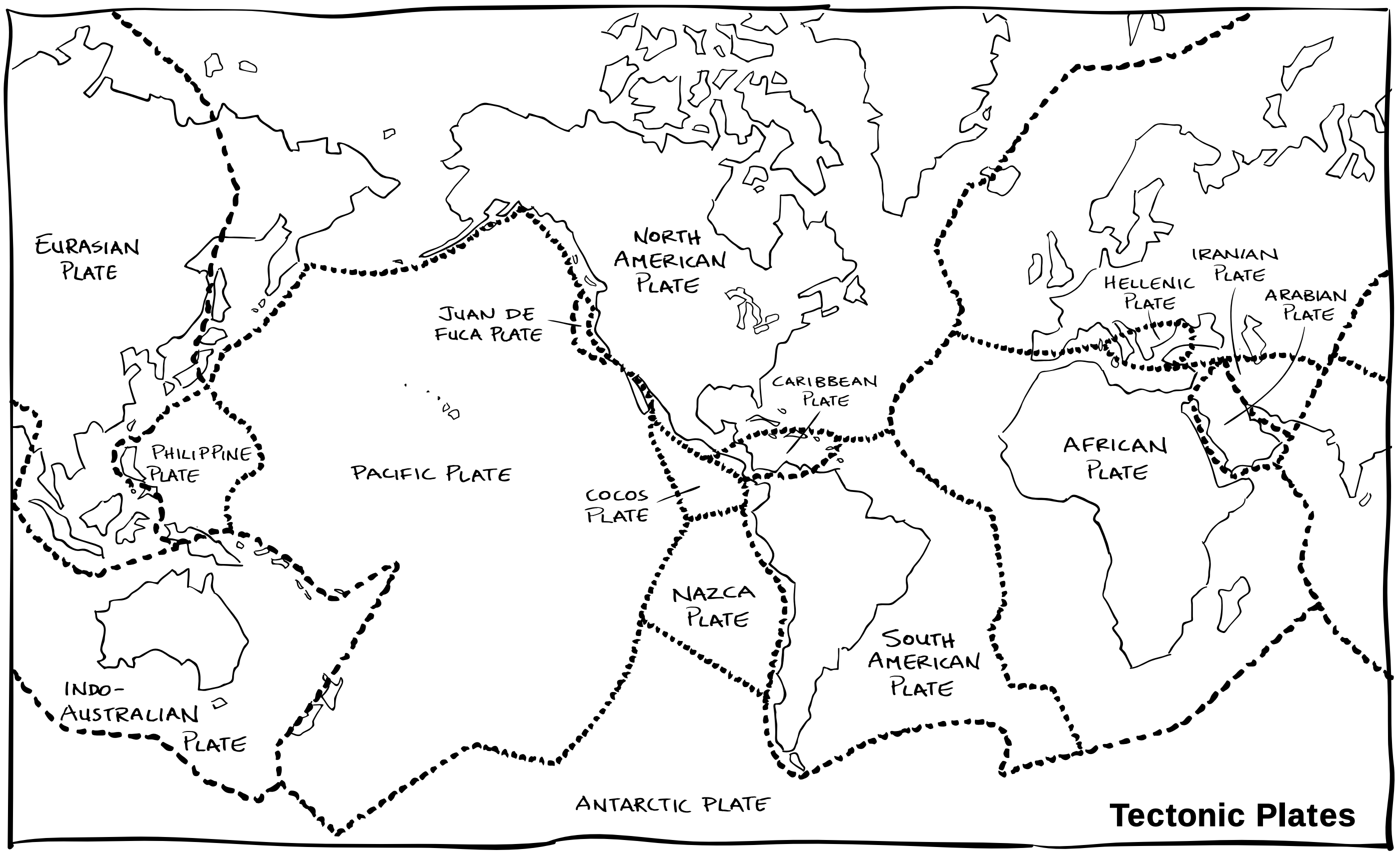
Now I am no longer known as a great grower of maize, but rather, Dionisio the Volcano Grower.

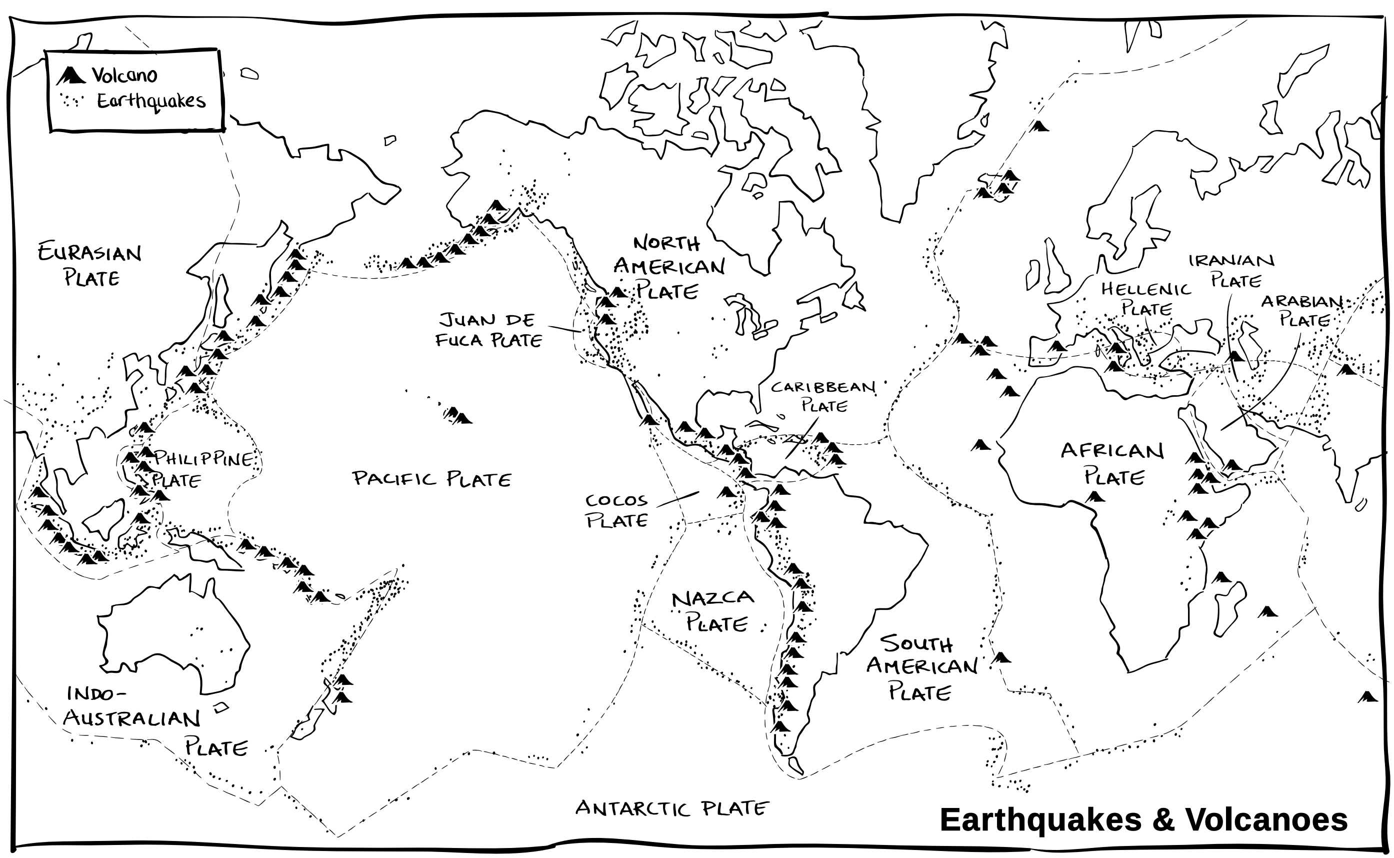
Question: Where is this volcano?

Answer: Dionisio Polido's cornfield, Paricutín, Mexico. First erupted Feb 20, 1943

EXTENSIONS

- Continue this activity by having students bring in actual articles as they find them about geothermal events or earthquakes worldwide. Proceed with plotting these points on the large world map.
- Invite a geothermal expert to speak about geothermal development in developing countries along the Ring of Fire.
- Invite a geothermal geologist to speak about the search for geothermal resources in volcanically active areas.
- Learn more about what makes volcanoes explode and why there are different types of volcanoes.


Eurasian Plate
North American Plate
Juan de Fuca Plate
Iranian Plate
Hellenic Plate
Arabian Plate
Caribbean Plate
Philippine Plate
Pacific Plate
African Plate
Cocos Plate
Nazca Plate
South American Plate
Indo-Australian Plate
Antarctic Plate
Tectonic Plates


Volcano
Earthquakes
Eurasian Plate
North American Plate
Juan de Fuca Plate
Iranian Plate
Hellenic Plate
Arabian Plate
Caribbean Plate
Philippine Plate
Pacific Plate
African Plate
Cocos Plate
Nazca Plate
South American Plate
Indo-Australian Plate
Antarctic Plate
Earthquakes & Volcanoes

Activity Four: Geo Journey

Students can mentally journey above and below ground to understand how hydrothermal systems work.

OBJECTIVES

- Identify the components of a hydrothermal system
- Describe above ground hydrothermal phenomena and explain their causes
- Design a model or demonstration which illustrates an aspect of a hydrothermal system

SUBJECTS

Earth science, environmental science

TIME

Two 45 minute class periods, separated by a time interval determined by teacher

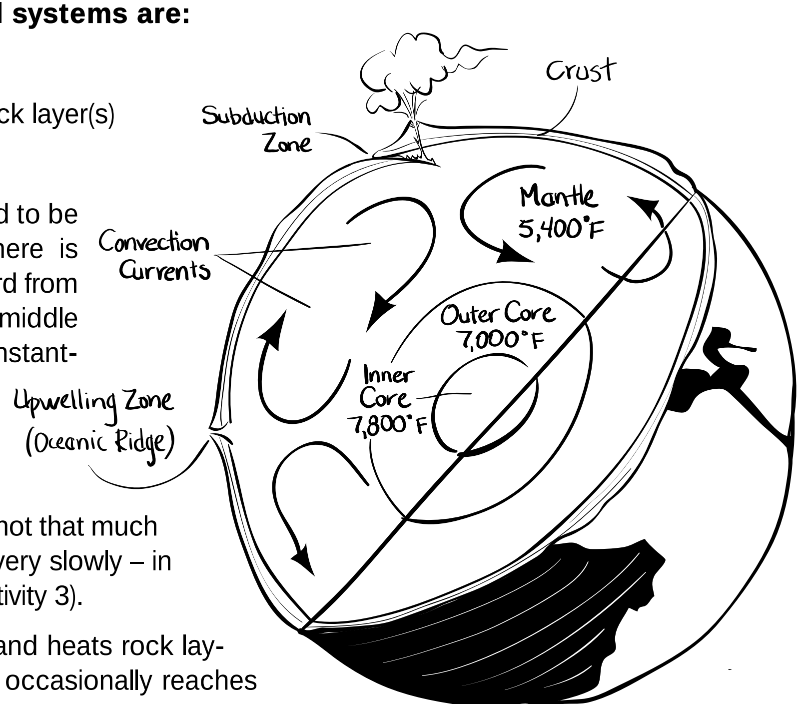
BACKGROUND

Most geothermal phenomena are easy to identify – geysers, hot springs, volcanoes. Understanding their causes is not as easy, since much of the story lies below the surface.

Volcanoes are a form of geothermal energy which are almost impossible to control. But another form, hydrothermal activity, is not only amazing, but also controllable and useful as energy.

The key components of most hydrothermal systems are:

- magma
- permeable rock layer(s)
- fractured &/or faulted rock
- hot rock
- impermeable rock layer(s)
- water



The internal temperature of Earth's core is estimated to be over seven thousand degrees F (1548°C). There is tremendous energy (thermal energy) flowing outward from Earth's interior, heating the rock of the mantle (the middle section of Earth's interior). Furthermore heat is constantly regenerated by the radioactive decay of elements in rocks of the interior. This heat energy can cause solid rock to become so hot it melts into magma – molten rock. Not all of the rock in the mantle is molten, but all of the rock is very hot – so hot that much of it is not rigid. Rather, this rock is able to flow – very slowly – in circular motions called convection currents (see Activity 3).

Less dense than surrounding rock, magma rises and heats rock layers; some relatively close to the surface. Magma occasionally reaches the surface as lava erupting from volcanoes or oozing from openings in the surface. More magma remains below the surface under and in Earth's crust.

Surface water percolates down from the surface through fractured and/or faulted rocks in the crust, sometimes for miles. Sometimes this water penetrates a layer of permeable rock which has been heated from magma or hot rock below. If this layer is capped by a layer of impermeable rock, then the water can accumulate in (saturate) this layer of hot rock. The heat energy is transferred (moves) from the hot rock to the water. This water is now in a hydrothermal (geothermal) aquifer (also referred to as a geothermal reservoir).

The heated water might make its way back up to the surface as a geyser, hot spring, fumarole (small vent shooting out gas and steam), or mud pot or remain hidden underground. This depends on various combinations of underground conditions, including the geologic structure and the reaction of water in its various phases to the great pressure of the ground above it.

In the following activity student groups will research different aspects of hydrothermal resources which will include learning more specifics about the principles described above, as well as others such as heat transfer, pressure and water phases.

They will then create a model or demonstration which they set up for the class to experience. By "journeying" through the series of demonstrations, all students should develop a greater understanding of the forces that work to create hydrothermal systems.

MATERIALS

- For Stage One: various generic materials (see #7 below)
- For Stage Two: handout, "Hydrothermal Systems" (p. 16)

PROCEDURE

STAGE ONE

1. Show pictures of volcanoes and geysers, then generate a discussion about these phenomena. Springboards might include Mt. St. Helens, Pompeii, Hawaii, Yellowstone National Park, local geothermal phenomena, or a geothermal energy project such as The Geysers, CA.

2. Ask students to describe the difference between a geyser and a volcano. Explain that both volcanoes and geysers are forms of geothermal energy – they both bring heat up from the earth's interior. But, because geysers are dependent on water, they (and hot springs, fumaroles and mudpots) are hydrothermal surface phenomena. Explain that hydrothermal phenomena also are found underground as geothermal reservoirs.

3. Challenge the class to explain exactly what causes geysers. After making note of their answers, list the components of a hydrothermal system on the board. Explain that all these ingredients, in combination with certain science principles, are necessary to make a geyser blow. Point out that other types of hydrothermal activity use the same ingredients and principles, but in different combinations. Compare the natural activity of geysers to that of humans drilling wells down to a geothermal reservoir and using the geothermal water and steam to drive turbines for electrical generation.

4. Explain that they will be working with partners or small groups of 3-5 to research and demonstrate an aspect of hydrothermal systems. Each group will then bring their explanation and demonstration/model to class for the others to experience. The class will "journey" through all the projects, and come out with a deeper understanding of what is happening below the surface.

5. Assign any or all of the following, one aspect per group: a) Models or demonstrations of: hot spring, geyser, fumarole, mud pot, groundwater flow, aquifer, permeable vs. impermeable materials and b) Demonstrations of various principles: heat transfer, convection, and conduction (see Activity 5).

6. Describe the expected outcome: 1) a written explanation of their topic, printed clearly or typed, and easily displayable 2) a model or demonstration of their topic. Provide support for research and projects. Establish a time interval, such as two or three weeks.

7. If you wish, you may anticipate needs by having some generic materials available, such as tubes, sand, gravel, pumice and other types of rock, glass and plastic bottles/beakers of various sizes, hot plates, pots and pans, aluminum pie pans, alcohol burners, tools,oven mitts, safety goggles, tongs, posterboard, art materials, and so forth. IMPORTANT: Review all safety rules regarding the use of heat and hot water. Advise students who are working with heat to do so with adult supervision.

Option: You may choose to dedicate some other class time(s) to the research, development and/or creation of projects.

STAGE TWO

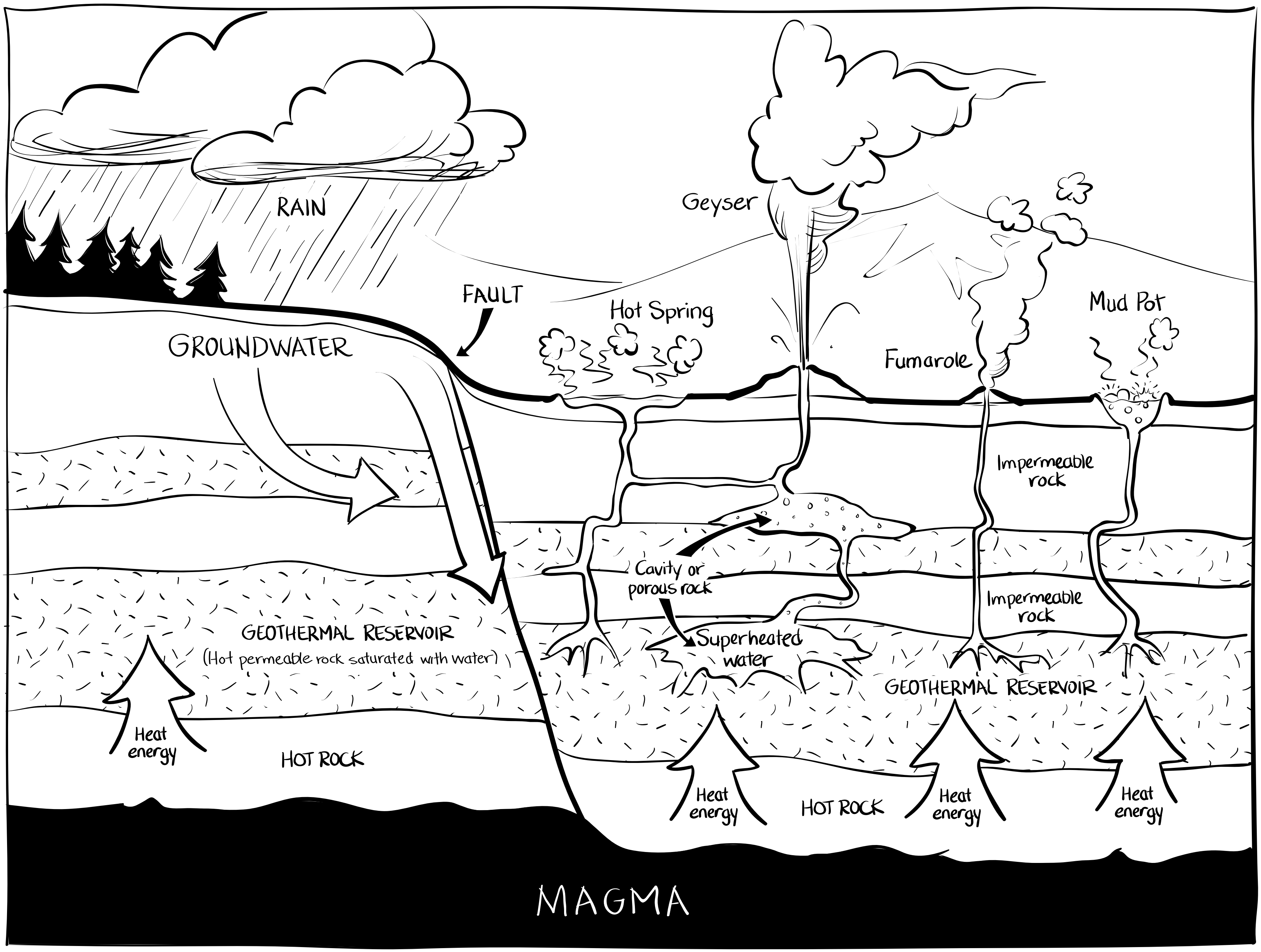
1. Create a management plan for the day of the "journey," so that all students will see each project. Because some projects will need to be attended by their creators (e.g. demonstrations), develop a plan which will allow one member of the group to remain while the rest "tour." They then rotate so that each member has a turn to participate in the journey.

Option: Have each group demonstrate their project to the entire class.

2. Use the handout "Hydrothermal Systems" to guide a discussion about the various components the class demonstrated. Relate this information to how hydrothermal phenomena occur, e.g. how the components all work together as a whole.

EXTENSIONS

- Challenge your class to develop a cut-away model of the entire hydrothermal process.
- Invite a geophysicist or geologist to speak to the class on this topic.



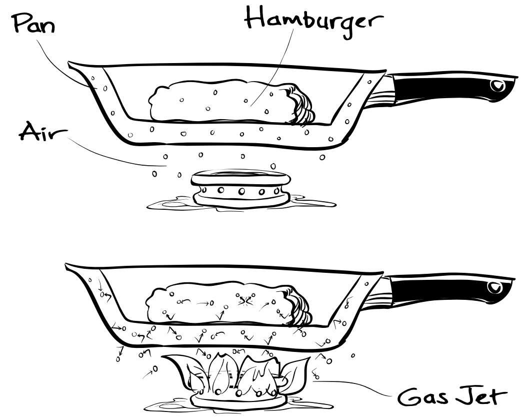
Hydrothermal Systems

Activity Five: Thermo Dynamic

What do geothermal electrical generation and roses have in common?

OBJECTIVES

- Define heat energy and describe the three means of heat transfer
- Define the first and second laws of thermodynamics
- Describe how various geothermal technologies make use of heat over a wide range of temperatures
- Create models demonstrating uses of geothermal which apply heat transfer and the first two laws of thermodynamics



Conduction

SUBJECTS

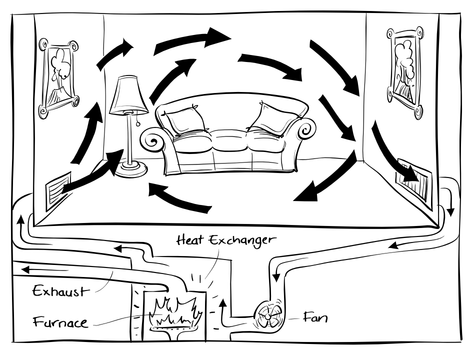
Physics, environmental science (use of energy sources])

TIME

Determined by teacher; but at least two 45 minute class periods

BACKGROUND

Geothermal technology uses heat energy, also called thermal energy. The temperatures at which geothermal energy can be used ranges from as low as 55°F/13°C (the fairly constant temperature of Earth just a few feet underground) all the way to up to 700°F/371°C (geothermal water). All uses of geothermal – from ground source heat pumps to electrical generation plants – rely on the same fundamental principles: thermal energy transfer and thermodynamics.



Convection

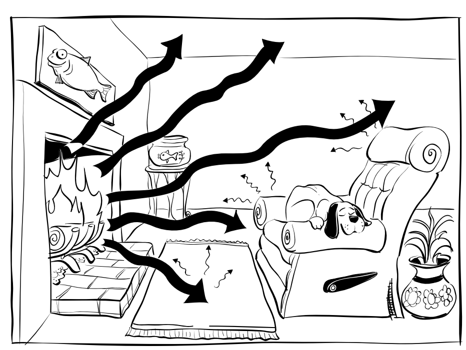
Thermal energy is the form of energy that results from the random motion of molecules. In any given amount of matter, thermal energy is the total energy contained in its molecular motions. When thermal energy is added to a medium, its molecules vibrate faster and move farther apart (expand).

Thermal energy can be transferred from one material to another by:

1. **conduction:** as the particles of a heated medium vibrate with more energy, they cause the particles of another medium with which they are in contact to also vibrate faster and farther, transferring more thermal energy to the other material.

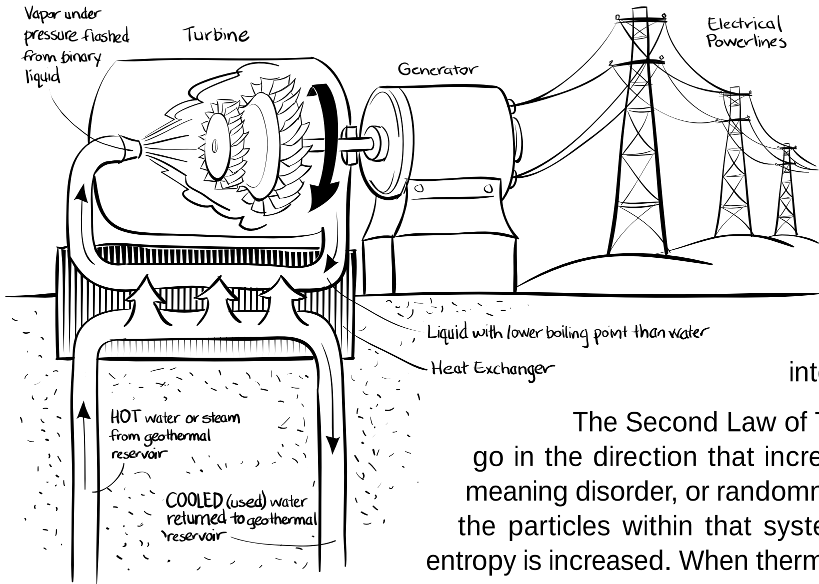
2. **convection:** in a liquid or gas, differences in temperatures result in different densities – the particles in a hotter portion of a fluid will bounce farther apart, becoming less dense than the cooler ones. As the cooler particles are pulled down by gravity (since they are more dense), they displace the warmer (less dense) particles, which are then pushed up. As the particles mix, the warm ones will cool off, becoming more dense, causing them to sink. This results in a cycle of rising and sinking called a convection current.

3. **radiation:** all objects radiate some energy in the form of waves, but hotter materials radiate more than cooler ones. When electromagnetic radiation strikes a material, the molecules move faster, heating up that material.



Radiation

Thermodynamics is the study of the movement of thermal energy and the ways in which this energy can be converted into mechanical work. The First



Binary Power Plant

Law of Thermodynamics states that anytime you change the internal energy in a system, you change that system's temperature. For example, the heat energy in Earth's core is transmitted mostly by conduction and convection to rock or groundwater. When thermal energy is transferred to water, the water molecules move faster and the temperatures rise...changing the internal energy of the system.

The Second Law of Thermodynamics says that natural processes go in the direction that increases the total entropy of a system, entropy meaning disorder, or randomness. As thermal energy is added to a system, the particles within that system move more quickly and randomly – the entropy is increased. When thermal energy from a geothermal source comes in contact with a cooler source, the heat energy transfers (by conduction) to the cooler system...increasing the entropy (and increasing the temperature of the cooler matter).

In a binary power plant, the geothermal water is drawn up through pipes to a heat exchanger. Here the thermal energy is transferred to a second liquid in completely separate but physically bonded pipes, increasing the system's internal energy. The second liquid has a low boiling point and quickly flashes to vapor, expanding rapidly, causing a rise in pressure. This high-pressure vapor is used to drive turbines for electrical generation.

On the other end of the temperature spectrum, geothermal greenhouses may not use the sophisticated technology of a binary power plant, but the principles are the same. Using geothermal water circulating in pipes, thermal energy is transferred to warm soil and the air in the greenhouse. At the same time, the entropy of the system increases as the energy transfers from warmer to cooler materials.

Looking at the chart provided and reviewing the video and video transcript, students can identify how thermal energy transfers and how thermodynamic principals are used in geothermal technologies, from home heating to raising alligators to producing electricity.

MATERIALS (PER TEAM)

- Copy of chart of geothermal uses
- 6 pipe cleaners or lengths of soft wire
- 12 straws
- 20 toothpicks
- Glue sticks and white glue
- Copy of video transcript
- 3 -4 sheets of colored paper (variety)
- 1 sheet aluminum foil (approx. 12" x 12")
- Ten 12" strips of masking tape
- Permanent black marker
- Shoe box, or other box (can be used as part of the model)

Optional:

- Hot glue gun, if available
- Other work materials of your choice
- You may wish to contact one or more of the sources found in the Resources section for additional information on geothermal technology

PROCEDURE

1. Brainstorm with students everyday experiences with hot and cold (cats seeking a high shelf to nap on a winter day, the warmth (in the summer) at the surface of a pond,etc)

2. Generate a discussion about all the ways thermal energy is transferred. List the three main ways on the board (radiation, convection, conduction).

3. Illustrate the laws of thermodynamics with a simple demonstration. For example, you might heat a fairly large piece of metal in a flame for one minute, then place it in a small measured amount of water, having first recorded the starting temperature of the water. Have volunteers measure and record the temperature of the water at 30 second intervals. Discuss the rise in temperature in terms of heat transfer and the two laws of thermodynamics.

4. Review the video segment on geothermal technologies and /or provide the video transcript. Give students the chart of geothermal uses at various temperatures. Discuss the applications of thermal energy transfer and thermodynamics in these technologies.

5. Present students with the following challenge:

Your spaceship has crashed on an unknown planet. Your propulsion system is ruined. You and your team have the bare necessities you need to survive for 6 months – water, food rations, tools, seeds, and the materials that are on your ship. You were able to beam a message to Earth before the crash and you know that you will be rescued...but it could be quite a few months or years.

You find that the planet has an atmosphere you can breathe, rich soil, and water. Most of the water is underground – in fact, some of it is geothermal water. Scans of the planet tell you that the air temperatures go down to at least 32° F in winter and up to about 95°F in summer (the planet rotates around a central star).

Design a model of a system using geothermal energy which will make your stay much more pleasant, as well as aiding your survival. For example, you might create a living space which is heated with geothermal sources in some way. You might add a sauna or hot tub. You might warm up soil in a greenhouse to make your seeds germinate and grow faster. The chart of geothermal uses and the video transcript will give you more ideas.

Use only the materials provided to create your geothermal designs – which will not be working models. Be prepared to explain how they utilize thermal energy transfer and the laws of thermodynamics.

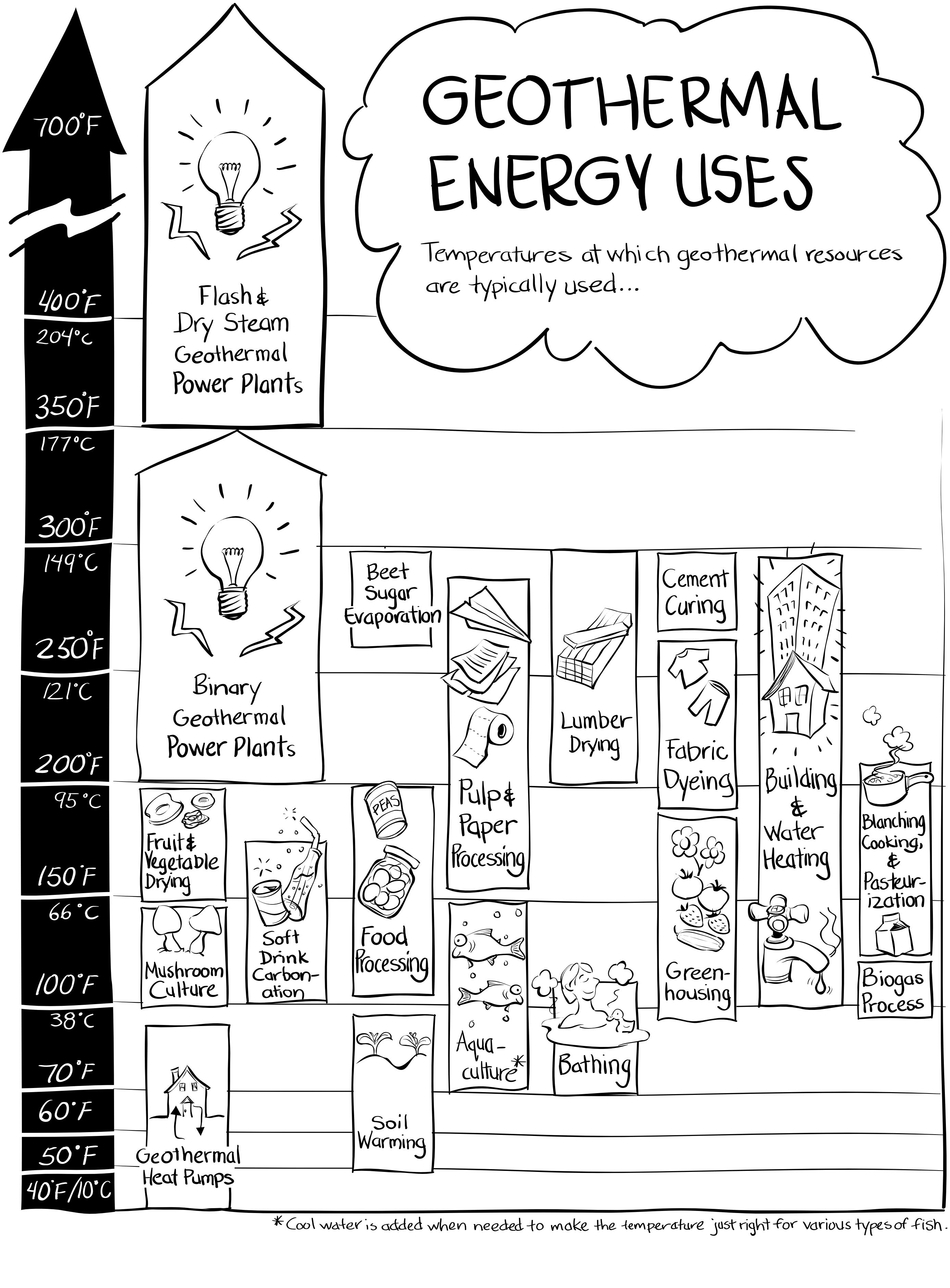
6. Divide the class into teams and provide materials. Explain that they may use only the materials given, so they should plan ahead. Remind them to use the video transcript and chart for ideas (as well as any other materials you have procured ahead of time). Provide scratch paper for sketches and brainstorming.

7. Set a time limit which fits your schedule (two class periods, for example, plus time to present their models). Optional: students may wish to name their team, their planet and so on.

8. Allow time at the end for each group to present their geothermal model and explain how it uses thermal energy transfer and thermodynamics principles.

EXTENSIONS

- Conduct experiments with plants to ascertain the difference in growth and vigor when optimum heat is used.
- Invite an engineer to explain how a heat exchanger works and to discuss their many applications (space heating/ cooling, refrigerators, etc.).
- Invite a geothermal engineer to talk about an aspect of geothermal technology such as power plants or district heating systems.
- Brainstorm other ways geothermal energy might be used other than the ones they already know.


GEOTHERMAL ENERGY USES
Temperatures at which geothermal resources are typically used...
700°F
400°F
204°C
350°F
177°C
300°F
149°C
250°F
121°C
200°F
95°C
150°F
66°C
100°F
38°C
70°F
60°F
50°F
40°F/10°C
Flash & Dry Steam Geothermal Power Plants
Binary Geothermal Power Plants
Beet Sugar Evaporation
Pulp & Paper Processing
Lumber Drying
Cement Curing
Fabric Dyeing
Building & Water Heating
Blanching, Cooking, & Pasteurization
Fruit & Vegetable Drying
Soft Drink Carbonation
PEAS
Food Processing
Greenhousing
Mushroom Culture
Aquaculture*
Bathing
Biogas Process
Soil Warming
Geothermal Heat Pumps
*Cool water is added when needed to make the temperature just right for various types of fish.

Activity Six: The Dogtown Dilemma

When it comes to energy use, can you really teach an old dog new tricks?

OBJECTIVES

- Identify issues which affect decisions about energy use
- Research various energy sources' advantages and disadvantages
- Develop an energy use plan which will promote public and environmental health, without negatively impacting commerce

SUBJECT

Social Studies, Environmental Science

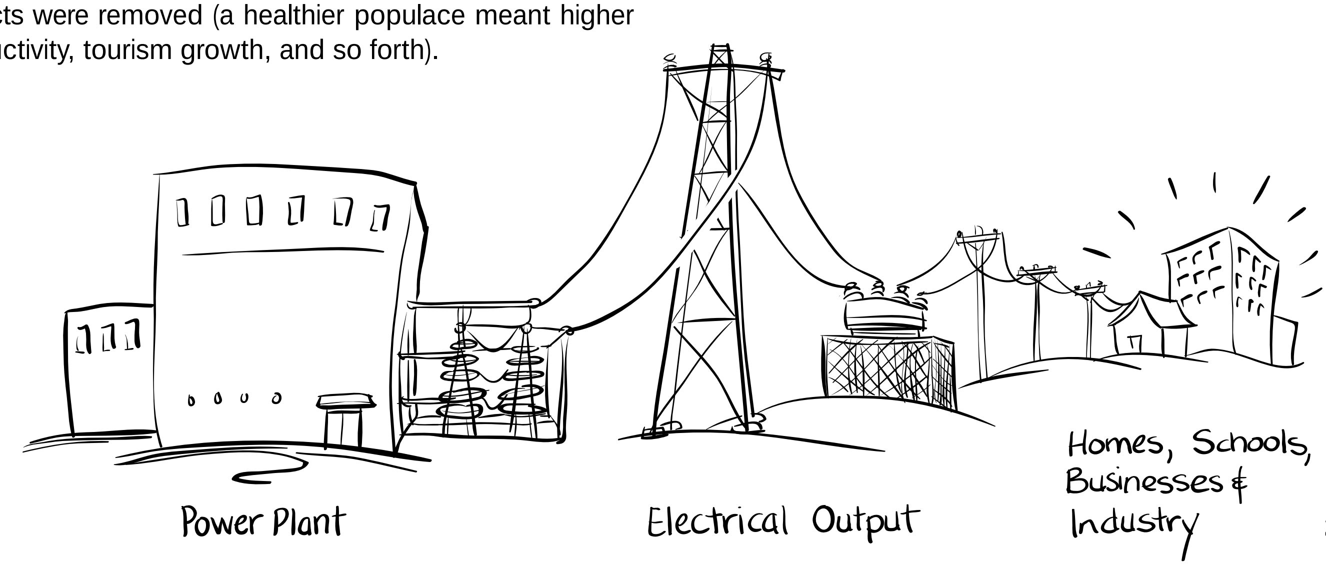
BACKGROUND

Fossil fuels account for 85 percent of all the fuel use in America. In most communities, fossil fuels drive not only your cars, but also power plants and various businesses. This is understandable since fossil fuels have been readily available, easy to use, and technological advances have been designed to utilize them. Today we now know that their use has had harmful effects on many aspects of our life: oil embargoes and shortages, dirty cities, polluted waters and air, respiratory ailments, and the threat of global warming. Some would add foreign wars to protect our fuel supplies. Many scientists now question how long fossil fuel reserves will last at the current rate of usage.

In many communities, the ability to switch to new energy sources may seem far away. Industries which rely on fossil fuels are well-established. Renewable energy is not as widely available and seems more expensive at the outset. Fossil fuel use appears cheaper because its price does not take into account all its hidden costs: diplomatic and military demands, health and environmental impacts, to name a few.

"Younger" renewable energy operations require start-up capital, as well as access to research and development funds. And lacking of familiarity with new renewable technologies, public demand isn't always high enough to attract investors.

However, it has been shown that communities can develop programs which allow them to make changes in how they use energy without adversely affecting the local economy. In some cases, the economy has improved because some of the hidden impacts were removed (a healthier populace meant higher productivity, tourism growth, and so forth).



The generation of electricity consumes almost 45 percent of all the energy used in the U.S. Therefore, it is crucial to scrutinize what resources electricity suppliers use. In some states customers can now choose their electrical supplier. Some customers opt for suppliers which use renewable energy resources.

Those utilities which have been using hydropower have been investing in one type of renewable energy all along. However, there are other alternatives which may not have such a major impact on the landscape, fish and other wildlife as does a large hydropower dam.

In communities across the nation, alternative energy sources are being implemented in creative ways. Some would say the incentives to change from fossil fuels were strong enough to overcome the entrenched "old guard." The incentives included concerns about life quality (health,environmental degradation), strong leadership with long-range vision, tax credits, and a utility with a conservation program. Creating a municipal (city-owned) utility helped. Local renewable resources were identified and analyzed. And funding needed to be secured.

In the following simulation, students will make crucial decisions about energy use in fictional Dogtown, USA – a town lucky enough to attract a large grant for the purpose of helping them reinvigorate their economy while creating a brighter, cleaner future. Students endeavor to create the best plan for Dogtown and answer the question, "Can you teach an old dog new tricks?"

PROCEDURE

1. Explain to students that they are going to participate in a simulation in which they are citizens of the fictional community, Dogtown, USA. Each student will participate on a consulting firm team and some will also be members of a Dogtown Energy Commission which will make decisions regarding energy use in the community.

2. Distribute copies of "The Dogtown Dilemma Scenario," and read it over with students. Identify the steps the community has already taken to attract the grant money and the future steps they must take in order to procure the next portion of the grant money.

3. Generate a list of all the energy sources which should be investigated. It will look something like: biomass, fossil fuels (including coal and natural gas), geothermal, hydropower, nuclear, solar, and wind. Divide the entire class into seven consulting firms and assign an energy source to each.

4. Each firm conducts an investigation into their energy source. They must:

- Learn how it is used to produce electricity
- Ascertain its advantages and disadvantages
- Remember that they are not representatives of that source, but rather impartial observers
- Be prepared to give a brief public presentation on their resource.

5. Give the teams a time limit for preparation (one week, for example). Alternative: you might wish to procure the research materials before hand so that students can conduct their research in class.

6. Prior to the presentations, ask one member of each team (or have teams vote) to form the Dogtown Energy Commission. This commission will listen to each presentation and then prepare an energy use plan for the community.

7. The commission may appoint a leader and decide on rules of conduct and schedule of presentations if you have time.

8. After listening to all the presentations, the commission will:

- Debate the advantages and disadvantages of each energy resource
- Select the resources which they feel will work best, in accordance with the purpose of the grant.
- Create an outline of how the resources will be recommended to the community or implemented by the utility over the next ten years.
- Justify how these decisions will help both the quality of life and the environment, without negatively impacting commerce
- Decide how to mitigate the closing of the coal mine, the loss of those jobs, and the loss of revenue to railroads for shipping coal (if they decide to no longer use coal to produce electricity.)
- Decide how to encourage other possible polluters to use cleaner resources (for example, education, tax incentives, etc.)

9. While the commission is deliberating, various members of the class may chose to don an identity, such as Big John, Fred Manley, or the President of Pioneer JC. They should develop the position of their persona in regard to these issues. Other students might develop their own plan and be ready to compare them with the commission's plan. Others might create a map of Dogtown and environs.

10. The commission then presents its plan to the community. Decide ahead on rules of order for the public debate which will follow. Allow time for the commission to make adaptations to the plan as they see fit after listening to the debate.

11. Afterward, generate a discussion about the plan. Did it meet the criteria of the grant? Is it feasible? How could a community make these kinds of changes in real life? How could your community benefit from making these kinds of changes?

EXTENSIONS

- Invite a member of your town council to speak on city plans for improving environmental and health quality.
- Have a representative from your local utility speak about the various resources they use to generate electricity.

Note: Those familiar with large-scale grant awards may also be aware of a different approach than that proposed in this scenario. In some cases, initial grants are limited to awards for studies and establishing infrastructure, such as creating an energy commission. Then a separate grant may be awarded for the actual project.

THE DOGTOWN DILEMMA SCENARIO

The Setting

- Dogtown resides in a valley below Beartooth Mountain, a dormant volcano.
- Dogtown has been a prosperous community since its origin as a gold mining town in the mid-1800's; just recently the economy has begun to decline.
- Mining operations shifted to coal mining in the late 1800's. The coal mine, owned and operated by Manley Mining Co, is located on upper south face of Beartooth Mountain.
- Besides Manley Mining, the largest privately owned businesses in Dogtown are Big John's Smelting, Pioneer Junior College, and Dogtown Gas & Electric. All buy and use coal from Manley Mining. Dogtown Gas & Electric and Big John's Smelting are both located along the banks of the Buffalo River.

The Resources

- The area's coal field has been mined for over 100 years. While the coal field appears to be sizeable, recently Manley Mining has needed to blast into new areas.
- Untapped underground geothermal reservoirs are believed to exist under the north base of Beartooth Mountain, and in a forested area 10 miles east of Beartooth Mountain. The area nearby is dotted with hot springs.
- Meteor Lake, once a popular area for tourists, sits on the lower south face of Beartooth Mountain.
- Meteor Lake feeds Buffalo River, the area's principal river, which flows to the valley floor and through the heart of Dogtown. Two other smaller rivers, Crane Creek and Mill River, are fed by runoff and snowmelt from Beartooth Mountain.
- Elk Pass is located just below Beartooth's peak and experiences steady winds.
- The area receives an average of 6 - 7 hours of sun at levels strong enough to be useful for solar power.

The Problems

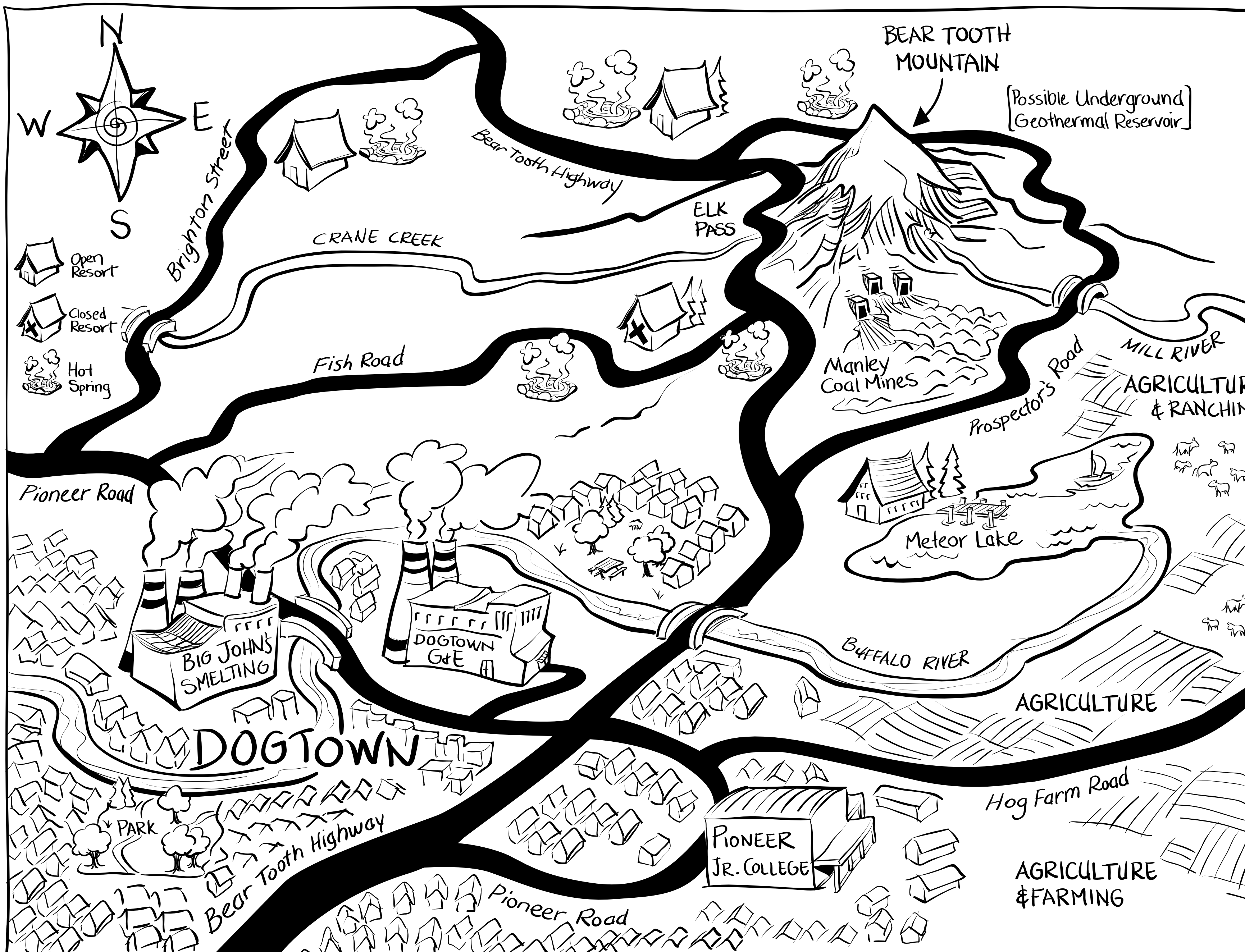
- In the past, tourism has kept many of Dogtown's smaller business alive and prospering. Lately, tourism has declined. Many community members have begun to suspect that the causes for the decline include the pollution of the Buffalo River and Meteor Lake, the growing unattractive mining site on Beartooth Mountain, along with increasingly poor air quality.
- Several mountain resorts on the lake have closed, but one remains open. A once successful hot spring resort has also shut down. Two hot spring resorts remain, but one is considering closing.
- The local HMO (health maintenance organization) has recently raised its premiums because of increased hospital and doctor visits, mostly due to respiratory and heart ailments.
- In response to community concerns about loss of tourism, the reduced visual appeal of the area, and increased health problems, city leaders have decided to take steps to improve the quality of life in Dogtown. The mayor, Lillian Hughes, former owner of Hot Spot Health Spa, has spearheaded many of the changes:
    - They passed legislation which gives tax incentives for energy efficiency and for use of solar energy and geothermal heat pump technology.
    - They have been working with Dogtown Gas and Electric on a program which encourages conservation.
    - They passed a bond creating green space and parks in undeveloped areas of town.
    - They have applied for and received help from the EPA (Environmental Protection Agency) to identify types and sources of pollution in the area's water and air.

The Dilemma

- Several very influential business owners have begun speaking out against the recent work of Mayor Hughes and other city leaders. They are most concerned about the recent findings regarding pollution and air quality. These include John ("Big John") Wilson, Fred Manley, and Sylvia Steadwell of Dogtown Gas & Electric. They claim that moving from coal to a less polluting energy source will not only reduce profitability, but also affect many jobs in town. Big John was overheard saying, "There's plenty of coal up on Beartooth. Why not keep using it?"
- Pioneer Junior College – now heated with coal – is open to the possibility of switching energy sources, but just doesn't have the financial resources to do so.
- In spite of protests from influential business owners, Mayor Hughes and her staff have responded to the general community support for change and have applied for a grant from the Grand Corporation*, a nonprofit philanthropic firm that promotes wise use of energy resources (*established by Cleo Grand, heiress to the Megasoft millions left her by her father, the late Will Wates).

The Opportunity

- The Grand Corporation provides grants to promising communities who need to make changes in their energy use in order to improve the environmental and health quality of their city.
- Grand Corporation provides upfront money to communities who implement "stage one" of the grant, which entails:
    - Replacing polluting energy sources with renewable, nonpolluting energy sources, by at least 50 percent.
    - Improving environmental quality with little or no adverse effect on commerce.
    - If the city successfully completes "stage one" within 10 years, it will receive a "stage two" matching grant to undertake further improvements.
- The Grand Corporation has just awarded the first stage of the grant money to Dogtown mostly because of recent, positive environmental efforts.
- Community leaders have decided to buy Dogtown Gas & Electric with a portion of the money to create a municipal utility. Aging Sylvia Steadwell says she is glad to pass her troubles on to someone else and is moving to Boca Raton.
- Community leaders have held a special election to create the Dogtown Energy Commission, which now must decide what energy resource(s) to use.
- The commission must investigate each energy resource available to them, and choose which ones to use at the utility. They will hire individual consulting firms to investigate each resource. After hearing each firm's report, the commission must create a conversion plan explaining how their resource conversion will positively impact the environment and public health and follow the grant guidelines.
- Further, the commission needs to decide how to encourage other polluters to use cleaner resources. These might include education, tax incentives, fines, community pressure, and so forth.
- Before enacting the plan, the commission must present its plan and invite public debate. Modifications may be made based on the public debate.



Dogtown & Environs

Video Transcript: Geothermal Energy: A Renewable Option

Introduction

From the very beginning people have used energy sources, first to survive, then to make their lives better. Until 200 years ago, our main sources of energy, other than our own muscles, were domesticated animals, fire, the sun, the wind, and running water.

Then, in the 1700's, a new way to use energy was invented, creating a force that could move ships against the wind, and up rivers, and carry us across the land. It was an engine powered by steam!

A steam engine harnesses the force that's created when water is heated and expands to steam. A steam engine could power the wheels of a train, the paddles of a ship, the machines in a factory.

The steam engine brought the Industrial Revolution. With steam we could excavate minerals from the earth, farm millions of acres, and produce electric power...power that would change the world.

The first long distance power line served the gold mining town of Bodie, California. When pioneers built the 13-mile line in 1892, they made it perfectly straight — for fear that electricity couldn't turn corners! When people learned that electricity could not only turn corners, but travel tremendous distances along wires, down city streets and into homes and offices, everyone wanted electricity!

That demand created a new and urgent need for fuel — fuel to burn, to boil water into steam. Steam to spin turbine generators in electric power plants. The stage was set for fossil fuels. By the early 1900s, coal had already replaced wood as the main fuel. And coal was soon joined by oil and gas.

Today we take electricity for granted. It lights our homes and powers our ovens and stoves, refrigerators, television sets and thousands of other useful devices. Electricity powers our factories, schools, hospitals and all the large and small businesses we depend on. We rely on abundant, affordable energy. Without it our economy would collapse and our standard of living would take an alarming nosedive.

Worldwide, our energy use keeps going up. In fact, it's expected to double within fifty years. But fossil fuels are not inexhaustible. The more we use, the faster our fossil fuel reserves disappear. But that's not all. Fossil fuels come with hidden costs — costs to the environment.

"Energy production and energy consumption cause more environmental damage than any other peacetime activity on earth." (Christine Irvin, U.S. Department of Energy, 1997).

Most air pollution is caused by energy use. Carbon dioxide and other gases do occur naturally in the air. But soon after the start of the Industrial Revolution, the levels of these gases began to go up. Many climate scientists believe that we are causing the increase — mainly by using fossil fuels. Many also believe that these gases are trapping heat — causing global warming. They say global warming may lead to extreme weather events, dislocation of agriculture and commerce, flooding of low-lying or coastal lands, and the spread of tropical diseases.

Burning fossil fuels can also cause acid rain. And, right at ground level, air pollution is a serious threat to health...especially to the health of children.

You and I can reduce our own energy use by conserving. We can insulate our homes and use energy-efficient light bulbs. But the demand for electricity keeps on going up. And as more countries become industrialized, that demand will go up even faster. We'll have to build more power plants. And that means we have some choices to make. We all want to meet those future energy demands, to supply a good life for our children and grandchildren, without leaving a legacy of polluted air and vanishing resources.

Fossil fuels may always be part of our energy mix. But we can reduce our reliance on them by using more renewable energy sources — like the sun, the wind, or the heat of the earth — sources we can use today that will still be here tomorrow. And with these resources we can generate electricity without burning fossil fuels.

We're using many kinds of renewable resources to make electricity right now: mostly hydropower, which uses rushing water from dammed-up rivers to turn turbines, and biomass — the burning of wood and other organic materials to make steam. But the renewable resources that have the greatest promise for sustainability with the least environmental impact are wind energy...solar energy...and geothermal energy.

Wind Energy

From very early times, sailors used wind energy to power their sailing ships. On land, people used wind to mill grain, and pump water. Today, we use wind power to generate electricity. Wind turbines now provide significant amounts of electrical power in the United States and Denmark. And people are starting to use them in lots of other places around the world.

Solar Energy

People have used energy from the sun throughout history, as a source of heat and light. Today, we can convert solar energy directly into electricity using photovoltaic cells. We see them in remote places where they provide power for telephones and traffic signals. And photovoltaic cells generate electricity in some sparsely populated areas where there aren't any transmission lines.

A second solar technology, solar thermal, uses an array of focusing mirrors to concentrate the sun's light energy. The resulting heat boils water to create steam to generate electricity.

Another clean, renewable source of power is geothermal energy.

Geothermal Energy

Geothermal energy is the natural heat of the earth — a remnant of the fiery consolidation of gases and dust that forged our planet more than four billion years ago. Geothermal energy is the force that moves continents, builds mountains, produces volcanic eruptions.

At the earth's core, about four thousand miles deep, temperatures may reach over nine thousand degrees Fahrenheit. This tremendous heat flows outward, melting huge masses of rock. The molten rock is called magma. It isn't as dense as the solid rock around it, so it rises slowly toward the earth's crust. And carries with it the earth's heat. Sometimes the magma emerges above ground — where we know it as lava. But most of it stays below ground — where, over time, it creates vast regions of hot rock.

When geothermal heat combines with water, we might see hot springs, fumaroles, geysers, or other fascinating surface features. Geothermal water begins its journey on the surface of the earth, as rain or melted snow. It seeps slowly downward, following cracks in the earth's crust, sometimes for miles, to places where it can be heated by hot rock to as much as 700°F.

When the hot water is trapped within porous and fractured hot rock, the result is a geothermal reservoir. Much hotter than a surface hot spring, a geothermal reservoir is a powerful source of energy.

The most abundant, accessible geothermal reservoirs are in the countries bordering the Pacific ocean — the area known as the Ring of Fire. Others form along rift zones, in countries such as Iceland, and Kenya. Geothermal energy concentrates within our reach in many parts of the world.

These areas can be rich in geothermal reservoirs.

Locating Geothermal Reservoirs

Locating economically viable reservoirs takes the expertise of geologists, geochemists, and geophysicists. Geologists, with help from satellite images and photos taken from aircraft, identify rock types and pinpoint fault locations. Geochemists analyze the chemistry of the soil and nearby surface and groundwaters. Geophysicists use magnetic, electrical, and gravity surveys to detect minute differences in the underground rock and water.

Only when all these data are analyzed together can the geologists and reservoir engineers recommend drilling. And only by drilling can we discover a geothermal reservoir.

We begin exploring by drilling wells a few inches in diameter and up to a mile deep. Drillers and geologists take rock samples and measure temperatures. If they find encouraging signs of deep heat, they'll drill larger and deeper wells. And if they find a large high-temperature reservoir, we have a new supply of energy...to generate electricity in a geothermal power plant.

Generating Electricity in Geothermal Power Plants

Geothermal power plants have no smoky emissions. Instead, they give off water vapor.

Dry Steam Power Plants

The reservoirs we value most produce steam and little or no water. They're known as dry steam reservoirs. From the reservoir, the natural steam rushes up the well and is piped into a turbine. The force of the steam spins the blades. The blades turn the turbine generator, producing electricity. Then the steam is condensed and the water is pumped back into the reservoir to be heated up again.

Dry steam was first used to generate electricity in 1904, at the Lardarello steam field in Northern Italy. In the 1930's the field went into commercial production. Sixty years later, it's still a major source of electrical power. The Geysers steam field in Northern California was put to work making electricity in 1960 and remains the world's largest producing dry steam reservoir.

Flash Power Plants

Only a few reservoirs produce dry steam. Most produce hot water, and can be used in "flash" power plants. Here, the water shoots up the well, where it's released from the pressure of the deep reservoir and some of it "flashes," or expands, to steam. This steam spins the turbine generator in the power plant, and the remaining water, along with condensed steam, is returned to the reservoir.

This flash technology was first developed in New Zealand in the 1950s and has dominated geothermal electricity production ever since. There are now geothermal flash plants in Iceland, Japan, Mexico, Indonesia, the Philippines, Kenya, Italy, the United States and over a dozen other countries.

Binary Power Plants

Some geothermal power plants don't flash the water to steam. They use geothermal water to generate power through binary technology. In a binary power plant, the geothermal water passes through a "heat exchanger." The heat of the water transfers to a second, or binary liquid, such as isopentane. Isopentane boils at a lower temperature than water, so it flashes to vapor at a lower temperature. The binary vapor, like steam, spins the turbine blades. Then the vapor is condensed back to a liquid and the process is repeated over and over.

In the United States there are now binary plants in California, Utah, and Nevada. Hawaii, which depends heavily on imported fuels, now uses a combination flash and binary plant. The plant produces a quarter of the electricity used on the Big Island. Binary plants are also generating clean power in the Philippines, New Zealand, Thailand, Mexico, Iceland, and several other countries. And the use of binary technology is increasing worldwide.

Today, there are more than two hundred and fifty dry steam, flash, and binary plants running day and night around the world. These plants reliably serve the electrical needs of well over sixty million people.

Direct Uses of Geothermal Water

Geothermal energy isn't always used to generate power. Sometimes we use the hot water "directly." In ancient Pompeii, geothermal water heated buildings. Medieval armies fought over lands that had valuable hot springs. And Native Americans, the Maoris of New Zealand, and other early cultures throughout the Pacific and the Mediterranean have long used geothermal waters for bathing, healing, and cooking.

We still use geothermal water directly in all these ways...and some new ways. Geothermal water helps grow flowers, vegetables, and other crops in greenhouses, shortens the time needed for growing fish, shrimp, and alligators to maturity, dries vegetables and fruits, processes minerals, and heats buildings. In Klamath Falls, Oregon, geothermal water is piped under roads and sidewalks to keep them from icing over in freezing weather. Our use of geothermal water is limited only by our ingenuity.

The oldest and most common use of nature's hot water...apart from hot spring bathing, is to heat individual buildings, and sometimes entire commercial and residential districts. District heating allows many buildings to be heated from a central plant which gets its geothermal heat from one or more wells.

The first geothermal district heating system in America dates back to 1893, and it still serves Boise, Idaho. In the western United States there are a dozen such systems now in use, and there are over two hundred and seventy communities that are close enough to geothermal reservoirs to develop geothermal district heating.

Modern district heating systems also warm homes in many other countries, including Iceland, France, Sweden, Bulgaria and Hungary. The world's largest geothermal district heating system is in Reykjavik, Iceland — where over ninety percent of the homes, apartments and commercial buildings use geothermal heat. Reykjavik was once very polluted. Since it started using geothermal energy, it has become one of the cleanest cities in the world.

Geothermal Heat Pumps: GeoExchange Systems

We can also use geothermal energy to help keep indoor temperatures comfortable almost anywhere in the world, without a geothermal reservoir. Animals have always known to burrow underground to protect themselves from winter's cold and summer's heat. And humans have sought shelter from extreme weather in underground caves and in cliff dwellings.

Today, with a geothermal heat pump — also known as a "GeoExchange" system — we can use the earth's almost constant temperature to heat — and even cool — our homes, schools and offices. With a geothermal heat pump, water or another liquid circulates through loops of pipe buried next to a building. During cold weather, the circulating liquid transfers heat from the earth to help warm the building. During hot weather, the liquid carries the heat from the building into the ground.

Geothermal heat pumps use very little electricity and are easy on the environment.

These energy-saving systems keep 300,000 buildings comfortable in the United States, and hundreds of thousands more worldwide. The U.S. Environmental Protection Agency has rated geothermal heat pumps as among the most efficient heating and cooling technologies available today.

Who Chooses?

Now...who chooses which energy sources we use? Every day, when we decide to turn on our lights, washing machines, or air conditioners — or when we buy products that required energy to manufacture — we participate in deciding how much power will be produced. But historically, in most countries, the government has decided which energy sources would be used to generate that power. And it's been the governments that have owned and operated the power plants and transmission lines.

The United States has been different. Here, federal and state governments have regulated energy, but have not generally owned the equipment. Instead, utility companies have been granted exclusive territories within which they built and owned the power plants and transmission lines. There was no competition within their service territory, and their costs, including fuel costs, were passed on to their customers. These regional utility monopolies decided which sources of energy would be used to make electricity.

The United States geothermal industry originated within this utility structure. Small independent companies, not the utilities, explored for geothermal reservoirs, drilled the wells, and made the first major commercial steam discoveries. But only utilities built power plants. So the steam developers had to persuade the regional utility to build a geothermal power plant and to buy the steam to run it. The first contract to sell steam to a utility was signed in 1958 and the first American utility-owned geothermal power plant began operating at The Geysers in 1960.

That first steam sale established a formula: the geothermal companies drilled the wells to supply steam, and the utilities built, owned and operated the power plants — a pattern that was to continue for nearly two more decades.

Then, in 1978, shaken by the the global economic effects of the energy crisis, Congress passed legislation that changed the utility world forever. The new law required utilities to purchase electricity from non-utility power-generating companies...and that created a new force — the independent power producer. Now private companies could build renewable-energy power plants and the utilities had to buy that electricity.

Implementation of the new federal laws was left largely to the states. Nowhere was the effect as dramatic as in California, where the result was the equivalent of an electrical generation gold rush.

Thousands of megawatts of power were offered to utilities throughout the 1980's by wind, solar and geothermal power producers. With an assured market for power, geothermal and other renewable energy companies were able to overcome many financial and technical problems. In the geothermal industry, these new government policies got results. Geothermal energy output tripled in ten short years.

Over the last three decades, governments in many countries, including the U.S., have implemented aggressive programs to conserve power and fossil fuel resources, to make energy use more efficient, and to limit pollution. Geothermal, solar, and wind power have played major roles in meeting these goals.

As we enter the 21st Century, over two billion people — almost half of the world's population — still don't have electricity. And in highly industrialized areas, the demand for electricity keeps going up. And yet, in the United States, private investment and research into renewable energy technologies has actually slowed down.

What will the consequences be if the increasing demand for power is met with fossil fuels? And when these fuels get scarcer and their costs go up, will we be ready with clean energy alternatives?

It's up to us.

Within the next few years, U.S. electricity suppliers will be required to identify the resources they use. And you and I will be able to choose our electricity supplier, the way we now choose our long-distance telephone company. We'll be able to choose electricity made from clean renewable sources, such as geothermal energy.

And, while governments will continue to set energy and environmental policy, each of us can contribute to a sustainable energy future: We can choose conservation, energy efficiency...and energy from clean renewable resources.

Within the last two centuries, access to energy has changed our world. Ordinary people now lead lives richer than kings of ancient times.

If we use energy responsibly, it can continue to spread its benefits to all parts of the world. If we misuse it, we can create economic and environmental disasters.

In another 200 years, what will people say about the way we used energy?

What will be our energy legacy?

GLOSSARY

acid rain: nitrogen oxides and sulfur oxides combine with water vapor in clouds, forming sulfuric and nitric acids and precipitated as rain or snow; accumulation of acids in lakes and rivers makes the water too acidic for plant and animal life. Acid rain also dissolves building materials and leaches nutrients out of soil resulting in crop damage.

boiling point: temperature at which a substance changes from a liquid to a gas under normal atmospheric pressure. Some liquids boil at a lower temperature than does water – a principle utilized in binary geothermal power plants. Boiling point is also affected by pressure. The greater the pressure, the higher the boiling point. This principle accounts for the superheated (rather than boiling) geothermal water found at depth, which flashes to steam when it rises to the surface and the pressure is released, resulting in such features as geysers. The principle is also put to work in geothermal (flash) power plants.

carbon dioxide: non-toxic gas produced in nature by respiration, forest fires, volcanic action; human activities produce carbon dioxide by burning fuel such as wood, fossil fuels; excess quantities are thought to be contributing to global climate change.

carbon monoxide: gaseous molecule formed as a byproduct by the incomplete combustion of fossil fuels; exposure can cause headaches and place stress on those with heart disease; toxic at high concentrations.

chemical energy: energy that is stored in the chemical bonds which hold molecules together.

conduction: the transfer of heat as a result of the direct contact of rapidly moving molecules within a medium or from one medium to another.

convection currents: the currents caused by hot air or fluid rising. Hot air or fluid expands and therefore is less dense than its cooler surroundings, thus it rises; as it cools it contracts, becomes more dense and sinks down.

density: the amount of mass (material) in a given volume of a substance; two materials can have the same size, but have different densities.

deregulation: in public policy, the preference to rely less on government control and more on buyer/seller choice.

earthquake: the vibration or movement of the ground caused by a sudden shift along faults in the Earth's crust. The largest are set off by movement of the lithospheric plates.

electric utility restructuring: the separation of the various utility functions (generating, selling, and distributing power) into individually-owned and -operated facilities.

core (outer and inner): the extremely hot center of the Earth. The outer core is probably liquid rock and is located about 3,200 miles (5,100) kilometers down from the earth's surface; the inner core may be solid iron and is found a the very center of the Earth – about 4,000 miles (6,400 kilometers) deep.

crust: the solid outermost layer of the Earth, ranging from 5 - 35 miles (8 - 56 kilometers) thick; comprises the topmost portion of the lithosphere (see lithospheric plates).

electric energy: energy in which there is a flow of electrons.

energy conversion (transformation): the process of changing energy from one form to another.

energy efficiency: the measure of the amount of energy which any technology can convert to useful work; technology with a higher energy efficiency will require less energy to do the same amount of work.

energy resource: a fuel or other source of useable power which can be drawn on when needed.

energy: the ability to do work, such as making things move and heating them up. Energy can take many forms, including electrical, chemical, radiant, mechanical, and heat.

entropy: the measure of disorder or randomness in a closed system.

Environmental Protection Agency (EPA): Federal government agency that develops and enforces specific regulations (based on laws made in Congress) designed to protect the environment.

fault: a crack or break in the Earth's crust along which movement has occurred; the expected site of earthquakes.

fission, nuclear: the splitting of a heavy nucleus into two lighter nuclei, which releases a large amount of energy.

fracture: a crack in the Earth's crust or in rocks.

fumarole: small vent in the Earth's crust which shoots out gas and steam.

fusion, nuclear: the formation of a heavier nucleus from two lighter ones, which releases a large amount of energy.

generator: a machine which converts mechanical energy to electric energy.

geothermal (hydrothermal) aquifer/reservoir: a large volume of underground water collected in porous and permeable rock, heated by hot rocks and/or magma.

geothermal (ground source) heat pump: a space heating/cooling system which moves heat from and to the earth, as opposed to making heat or cold using a fuel source. (see video transcript)

geothermal phenomena: an observable event whose occurrence is the result of the Earth's internal heat; includes volcanoes, geysers, hot springs, mud pots, and fumaroles.

geothermal power plant: a facility which uses geothermal steam to drive turbine-generators to produce electricity. Three different types make use of the various temperature ranges of geothermal resources: dry steam, flash steam and binary. (see video transcript)

geyser: a natural hot spring that periodically sends up a fountain of water and steam.

global warming: the warming of the atmosphere beyond levels which are healthful to people and the environment, due to air pollution.

groundwater: water that collects underground, mostly from surface water that has seeped down through faults, cracks, and pores in the earth.

heat exchanger: a device used to transfer heat from a liquid on one side of a barrier to a separate liquid or to air on the other side of the barrier (a highly conductive material). In the case of binary power plants, the purpose is also to transfer the heat to a low boiling point working fluid which then flashes to steam. (see video transcript)

heat transfer: the transmission of heat energy from one material to another due to the differences in temperature between the two materials. There are three forms of heat transfer: conduction, convection, and radiation. (see the latter three terms)

heat energy: a form of energy possessed by a material because of the motion of its molecules.

hot springs: a natural spring that puts out water warmer than body temperature and therefore feels hot; may collect in pools or flow into streams and lakes.

hot spot: areas of geothermal activity found in the middle of lithospheric plates, caused from an upwelling of concentrated heat in the mantle. Hot spots remain stationary while the plates move over them, often leaving behind a chain of extinct volcanoes as the plate moves away from the hot spot; examples include the Hawaiian Islands and Yellowstone National Park.

hydrocarbons: a broad category of pollutants made up of hundreds of compounds containing hydrogen and carbon; many react with nitrogen oxides to form smog; can result in shortness of breath and, over time, permanent lung damage.

impermeable: does not allow liquids to pass through easily as in certain rock types and clay soil.

Industrial Revolution: the shift to large-scale factory production brought about by the extensive mechanization of production and the use of steam engines; generally thought to occur between the 1750's to the mid to late 1800's; brought about dramatic social and economic changes.

lithospheric (tectonic) plates: huge, rigid sections of the Earth's outer shell – made of the crust and the upper layers of the mantle – which vary in thickness from just a few miles under the oceans to 186 miles (300 km) in some places under the continents. (see plate tectonics)

magma: hot, thick, molten rock found beneath the Earth's surface, formed mainly in the mantle.

mantle: the soft interior of the Earth that lies between the core and the crust making up nearly 80% of the Earth's total volume; extends down to a depth of about 1800 miles (2,900 kilometers) from the surface and is so hot that it is often partially molten.

mechanical energy: the energy an object has because of its motion and the forces acting on it.

megawatt (MW): a unit of power, equal to a thousand kilowatts. The watt is a unit of power (energy/time), a measurement of the rate at which energy is consumed or converted to electricity.

mud pot (paint pot): thermal surface feature which occurs where there is not enough water to support a geyser or hot spring even though there may be some hot water below. Steam and gas vapors bubble up through mud formed by the interaction of gases with rock.

municipal utility: utility owned by a city, a district or another public entity, rather than by private stockholders.

nitrogen dioxides: formed in combustion; appear as yellowish-brown clouds; can irritate lungs, cause lung diseases, and lead to formation of ozone (which is harmful in the lower atmosphere, but necessary as protection from UV rays in the upper atmosphere).

nonrenewable resource: a source of power which is not replaced or regenerated within a period of time that is useful, including fossil fuels, uranium, and other minerals.

particulates (particulate matter): dust, soot, smoke, and other suspended matter; can be respiratory irritants.

permeable: able to transmit water or other liquids; for example, rock with tiny passageways between holes is permeable.

photovoltaic: able to convert sunlight directly into electricity. Photovoltaic cells generally are made of layers of semiconductor material in which electrons are excited by photons in sunlight, causing them to move, creating an electrical charge.

plate tectonics: the study of the movement of large crustal plates (lithospheric plates) of the Earth's shell. The continents are embedded in continental plates and much of the sea floor is found in oceanic plates. Plate tectonics helps to explain continental drift, seafloor spreading, volcanic eruptions, other geothermal phenomena, earthquakes, and mountain formation.

pollution: a condition in which some part of the environment is no longer healthful for human, plant or animal use; includes air, land, and water pollution.

radiant energy: energy that is transferred by rays or waves, especially electromagnetic waves.

radiation: the transfer of heat in the form of waves, usually electromagnetic.

renewable resource: a source of power which regenerates itself within a useful amount of time; examples include water (hydro) and wind power, solar energy, biomass, and geothermal energy.

rift zone: long narrow fractures in the crust found along ocean floor or on land, from which lava flows; often associated with spreading centers from which tectonic plates are diverging, such as the mid-Atlantic Ridge.

Ring of Fire: a belt of intense geothermal and earthquake activity found all around the Pacific Rim caused by tectonic activity.

solar thermal: several strategies for concentrating and collecting enough solar energy for heat to make large quantities of steam – mostly used for turbine electrical generators. Sunlight is concentrated using either huge parabolic troughs or computer-guided mirrors which can track the sun.

subduction boundary: region where one tectonic plate plunges under another overriding plate; one of two types of converging plate boundaries.

sulfur oxides: pungent, colorless gases (including sulfur dioxide); formed primarily by the combustion of fossil fuels; may damage the respiratory tract, as well as plants and trees.

sustainable: material or energy sources which, if managed carefully and used at current levels, will provide the needs of a community or society indefinitely.

thermodynamics: Physics that deals with the movement of heat and the ways that heat can be converted to other energy forms, especially mechanical.

turbine: a bladed rotating engine driven by the pressure or force of steam, falling water, or wind.

volcano: an opening in the earth's crust from which lava, steam, and/or ashes erupt or flow, either continuously or at intervals.

water phases: the change of water from one state to another. The change from ice to liquid is melting; the reverse process is freezing. The change from liquid to gas is evaporation and the product is water vapor or (when above the boiling point) steam; the change from water vapor to liquid is called condensation. Evaporation and condensation are both important functions in geothermal phenomena and in geothermal technology.

RESOURCES

ORGANIZATIONS

Geothermal Education Office. Provides posters, videos, maps, booklets, curricular materials, referrals to other information sources. 664 Hilary Drive, Tiburon, CA 94920. 1-800-866-4436 or 415-435-4574; geo@marin.org; http://geothermal.marin.org/

California Energy Commission. Look for "Energy Quest," an online site which offers dozens of activities and information sources for students and educators on energy, including energy resources, how energy is produced, energy conservation, and energy and the environment. 1516 Ninth Street, MS-29, Sacramento, CA 95814-5504. 1-916-654-4287; http://www.ca.gov/education/quest

Environmental Protection Agency. Information on specific environmental projects; general information on environmental topics. EPA, Ariel Rios Bldg., 1200 Pennsylvania Ave., N.W., Washington, D.C. 20460; 1-202-260-2090; http://www.epa.gov/.

Geo-Heat Center. Information about geothermal energy, particularly low-temperature resources and their use worldwide. Oregon Institute of Technology, 3201 Campus Dr., Klamath Falls, Oregon, 97601-8801. 1-503-885-1750; geoheat@oit.edu; http://www.oit.osshe.edu/

Geothermal Energy Association. Provides posters, videos, maps, booklets, curricular materials, referrals to other information sources. 664 Hilary Drive, Tiburon, CA 94920. 1-800-866-4436 or 415-435-4574; geo@marin.org; http://geothermal.marin.org/

Geothermal Resources Council. Information about the geothermal industry & geothermal energy; website has many links to other sites. P.O. Box 1350, Davis, California, 95617-1350. 1-916 -758-2360; http://www.geothermal.org/

International Geothermal Association. Information about geothermal activities worldwide. http://www.demon.co.uk/geosci/igahome.html

National Geographic Society Educational Services. Offers many educational services; look for "Kids Network" - interactive investigations on earth science topics. 1145 17th St., N.W., Washington, D.C., 20036. 1-800-368-22728; http://www.nationalgeographic.com/

U.S. Dept. of Energy, Office of Energy Efficiency & Renewable Energy. General information on geothermal energy, including geothermal energy; technical information about current renewable energy (including geothermal) projects; U.S. Dept. of Energy, Headquarters, Forrestal Bldg., 1000 Independence Ave., S.W., Washington, D.C., 20585; 1-202-586-5340; Website has links to geothermal division; "Ask an Energy Expert," "Education" and "Kids" sites: http://www.eren.doe.gov/

Yellowstone Association/Yellowstone Institute. Provides educational products, services, and classes related to Yellowstone National Park, including its ecosystem, geology and geothermal manifestations. P.O. Box 117, Yellowstone National Park, WY 82190; Office:1-307-344-2293; Institute: 1-307-344-2294; http://www.YellowstoneAssociation.org/

TEACHING RESOURCES

Energy Education Resources: Kindergarten Through 12th Grade. Annual directory of energy resource organizations and materials. Energy Information Administration, U.S. Dept. of Energy, Washington, D.C., 20585. 1-202-586-8800: http://www.eia.doe.gov/

Geothermal Resources: Supplement to the Project WET Teacher Guide. Inquiry-based, interdisciplinary curriculum supplement on geothermal resources designed to accompany the Project WET teacher's guide; includes energy use and energy issues, environmental science, geology, physics, geography, and literature tie-ins. A*nticipated availability, Spring 2002.* Contact: Marilyn Nemzer, Geothermal Education Office, (See contact info under "Organizations"), or Project Manager at University of Idaho, Water Education Coordinator, 800 Park Blvd., Plaza 4, Suite 105, Boise, ID 83712, 1-208-422-0737. A joint project of The Watercourse, Bozeman, MT and the Geothermal Education Office, Tiburon, CA.

Geology – The Active Earth. Ranger Rick's NatureScope. (Grades K-7) Geology background and activities including the Earth's structure, plate tectonics, rocks & minerals, landforms, fossils, resource use; focus is on environmental awareness. For the National Wildlife Federation by Learning Triangle Press (McGraw Hill), New York, NY, 1997. http://www.mcgraw-hill.com/

Pollution – Problems & Solutions. Ranger Rick's NatureScope. Identifies many forms of pollution while showing students how to get involved in creating a cleaner environment; includes environmental science, planning community cleanups, reducing everyday pollutants, writing lawmakers. For the National Wildlife Federation by Learning Triangle Press (McGraw Hill), New York, NY. http://www.mcgraw-hill.com/

Project Earth Science. Geology. Part of a four-volume Earth Science series from the National Science Teachers Association. In-depth investigations include student and teacher background information and classroom-ready activities covering the earth's structure, plate tectonics, earthquakes, volcanoes, natural resources and rocks/minerals. National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000; 1-800-722-NSTA; http://www.nsta.org/

Planet Earth Series. Video series developed by the Corporation for Public Broadcasting. Topics include, The Living Machine (plate tectonics), The Climate Puzzle (looks at changes in climate), Gifts from the Earth (Earth's mineral and energy resources), and others. Corporation for Public Broadcasting, The Annenburg/CPB MultiMedia Collection, P.O. Box 2345, South Burlington, VT 05407-2345; 1-800-532-7637; http://www.learner.org/catalog/science/plseries/

Renewables are Ready: People Creating Renewable Energy Solutions. Guide to renewable energy technologies as well as the politics and economics of energy use; contains general overview of all renewable energy sources and technologies; discussion of how to establish grassroots local community projects; specific case studies from all the U.S. The Union of Concerned Scientists, Chelsea Green Publishing Co., White River Junction, Vermont, 1995. Teacher's guide and student handouts also available; contact: Union of Concerned Scientists: 2 Battle Square, Cambridge, Massachusetts, 02238.
1-617-547-5552; http://www.ucsusa.org/

Resources for Teaching Elementary Science. Comprehensive list with descriptions of outstanding science teaching resources; coordinated with the National Science Education Standards (Many suitable for middle school/senior high). National Science Resources Center, National Academy of Sciences & Smithsonian Institution, National Academy Press, Washington, D.C., 1996. 1-800-624-6242 or 202-334-3313; http://www.nap.edu/

The Sun's Joules & School Energy Doctor. Educational CD-ROM about renewable energy & the environment; includes School Energy Doctor which lets student perform an energy and water audit in their school. Center for Renewable Energy & Sustainable Technology, 1200 18th St., NW Suite 900, Washington, DC, 20036; 1-800-346-0104; http://www.solstice.crest.org/

U.S. Geological Survey. Free curricular packets on volcanoes, ecology, and maps. 790 National Center, Reston, Virginia, 22092. For teaching packets call 1-800-USA-MAPS. http://www.usgs.gov/

GEOTHERMAL EDUCATION OFFICE

664 Hilary Drive, Tiburon, CA 94920 USA
1-800-866-4436
Fax: 1-415-435-7737
E-mail: geo@marin.org
Web: http://geothermal.marin.org