FACTS.com
Today's Science
Science news written especially for students

Issue: ***September 1997***

Obstacles to Renewable Energy

People in the United States consume vast amounts of energy. In 1996, the United States accounted for less than 5% of the world's population but about 24% of the world's total energy consumption. Fossil fuels, such as oil, coal and natural gas, supplied 84% of that energy. Nuclear power supplied about 8% and renewable sources of energy, such as hydropower, solar power, biomass and geothermal energy, supplied the remaining 8%.

Economists and environmentalists have disagreed sharply about the future of renewable energy. Most economists argue that it is prudent to encourage the use of fossil fuels and nuclear energy. They say that people have not come close to using up the available fossil fuels, and that it would be financially foolish to rely on the more expensive renewables. Environmentalists contend that it would be reckless for people to ignore the ecological damage caused by using fossil fuels and nuclear energy. However, renewable energy faces obstacles beyond cost, including some environmental concerns, that might prevent it from becoming widely used.

Oil crisis

Fossil fuels influence nearly every aspect of modern life. Electricity created by fossil fuels powers every appliance and machine in the home and workplace. Fossil fuels directly power cars, heat houses and cook foods.

Fossil fuels form over millions of years from the decomposed remains of plants. There are finite amounts of fossil fuels available on Earth. Estimates of fossil fuel reserves vary, with environmentalists predicting that Earth could run out of oil by the year 2050, natural gas by the year 2120, and coal by the year 3500. Economists, on the other hand, argue that those estimates are likely too low and that new technologies will develop as needed to access the reserves.

Environmental concerns

Beginning in the 1970s people became increasingly aware of environmental damage and health problems caused by the burning of fossil fuels.

World temperatures have risen an average of 0.5°C (1°F) since the late 1800s. Many researchers believe that the burning of fossil fuels is causing the warming. Greenhouse gases, especially carbon dioxide (CO_2), emitted by burning fossil fuels trap the Sun's heat near the surface of the planet. Others think the warming is a natural trend. [See 1997 Clinton Concedes Pollution Dangers, Holds Off On Curbs; 1996 Record Snowfalls a Product of Global Warming?]

Transporting fossil fuels can sometimes lead to disaster. In 1989, the *Exxon Valdez* tanker dumped 42 million liters (11 million gallons) of oil into the waters and onto the shores of Alaska. In 1994, a ruptured Russian pipeline spewed 323 million liters (85 million gallons) of oil onto previously pristine Arctic tundra. [See 1995 Spring Thaw Unleashes Arctic Oil Spill; 1994 Exxon Ordered to Pay $5 Billion for Alaskan Oil Spill]

Recent studies have indicated that about 64,000 people a year die from ailments caused by particles, such as soot, smoke and tiny acid droplets, emitted by cars, power plants and factories. [See 1996 64,000 Deaths Per Year Tied To Fine-Particle Pollution]

Using renewable energy sources, such as sunlight, wind and moving water, avoids many of the problems associated with burning fossil fuels. Most emit no greenhouse gases or other air pollution. Their almost limitless supply is constantly being renewed by natural processes on Earth. Also, renewables can be produced in the United States rather than having to be purchased from sometimes-hostile foreign nations. However, they remain generally more expensive than fossil fuels. Furthermore, each form of renewable energy has distinct benefits and limitations.

Power from sunlight

The Sun provides the vast majority of energy available on Earth. Heat from the Sun helps create Earth's weather systems. Plants capture the Sun's energy through photosynthesis and use it to grow. Animals obtain that energy by eating plants. Material from plants transforms into coal, oil and other fossil fuels over millions of years.

Three basic technologies have allowed people to capture the Sun's energy directly: solar construction, solar-thermal concentrating systems and photovoltaic cells.

People can build their homes to take advantage of the Sun's heat. Such design is called passive solar construction. Passive solar houses in the Northern Hemisphere have south-facing windows to admit heat and light, and brick and stone work to store heat, among other adaptations. People can also install solar collectors on their roofs. These flat, black devices absorb the Sun's energy and heat water, which can be used directly or to warm the house.

There are three types of solar-thermal concentrating systems: parabolic troughs, parabolic dishes and central receivers. Parabolic troughs are curved sheets of reflective material that focus the Sun's heat on a glass tube filled with a heat-conducting fluid. The hot fluid flows to a power station where it is used to generate steam and electricity. Parabolic dishes are bowl-shaped reflectors that concentrate the Sun's heat on a receiver through which a heat-conducting fluid passes.

Central receivers are made of hundreds or thousands of mirrors, called heliostats, which focus the Sun's rays on a large central receiver. Molten salt circulating within the receiver absorbs the heat energy transmitted by the heliostats. The molten salt can be used to generate electricity and can also be stored in insulated containers for use when the Sun is not shining. In 1996, the U.S. Department of Energy opened an experimental central receiver, named Solar Two, in the Mojave Desert near the town of Daggett, California. Solar Two generates about 10 megawatts of electricity, enough to power nearly 10,000 homes.

Each of these devices must move to follow the Sun's path, which can make them expensive to operate. And they all require direct sunlight. In most cases power generation stops when it gets cloudy or dark. Many regions of the world do not have reliable and abundant sunlight. Consumers generally expect a constant flow of electricity on demand and they cannot always get it with solar power.

Photovoltaic solar cells are somewhat more reliable than solar-thermal concentrating systems because they can provide energy when only diffuse sunlight is available. They also have no moving parts, making them easier to maintain. Photovoltaic (PV) cells were first developed to power spacecraft and are still used for that purpose. They also power calculators, watches and other devices. Materials used in solar cells, generally silicon, convert energy from photons of sunlight directly into electricity.

However, PV cells are enormously expensive to manufacture. The most energy-efficient PV cells are made from a single crystal of silicon cut into thin wafers. These convert into electricity nearly 30% of the energy from sunlight that hits them. But growing and cutting such a crystal is a lengthy and costly process.

In an attempt to cut the cost of PV cells, researchers have used cheaper thin films that contain many small crystals of silicon. The best polycrystalline PV cells are 20% efficient.

Others have made even cheaper PV cells from noncrystalline or "amorphous" silicon. These cells are about 8% efficient. Polycrystalline and noncrystalline PV cells appear to be less efficient than single-crystal PV cells because their molecules contain more unoccupied spaces for electrons. These spaces attract electrons and prevent them from becoming part of the electric current.

However, there are at least three companies that have successfully made amorphous PV cells more efficient--perhaps as high as 14%. They used multiple layers of amorphous silicon and added hydrogen to the silicon. The hydrogen's electrons fills vacant spaces, making it easier for other electrons to flow.

Another type of relatively cheap PV cell was discussed at the 1996 Photovoltaic Specialists Conference. This cell was made not of silicon, but of a material called CIGS, which is composed of copper, indium, gallium and selenium. CIGS PV cells are about 18% efficient--nearly as efficient as the best polycrystalline PV cells.

Despite the drawbacks of PV cells, the cost of generating electricity with them has dropped more than 90% since 1976. Many observers expect the price to drop even further as the technology develops, perhaps one day approaching the cost of fossil-fuel energy.

And, although generating electricity with PV cells in many locations is expensive, the method is currently economical in remote regions that are not connected to a centralized power grid.

Wind power

Heat energy from the Sun sets the wind in motion. People have been harnessing wind energy for thousands of years, to blow their ships across the oceans or to spin windmills that helped pump water. Modern-day electricity-generating windmills are called wind turbines. They look somewhat like airplane propellers stuck on top of long poles. Blowing wind causes the blades, and the shaft to which they are attached, to turn. This transmits power to an electricity generator.

After the energy shortages of the 1970s, many wind farms sprang up, especially in California and Denmark. But wind turbines could not generate electricity as cheaply as fossil fuels, and they began to fall out of favor.

Technological advances in the 1990s have made wind power much cheaper. In 1992, the U.S. National Renewable Energy Laboratory in Colorado redesigned the wind turbine blade. Previously the blade had been slanted at a consistent angle along its length. The new blade had a different shape at its base, middle and tip. This allowed it to catch the wind more effectively at every section. The new design was 50% more efficient than the old one. [See 1993 Wind Power Gets a Second Chance]

The new wind turbines were also controlled by a computer that helped them run more efficiently when wind speeds were unusually high or low. The cost of generating electricity with wind has dropped 80% since 1980 thanks to these advances.

There are many regions of the country, such as the Great Plains, in which the wind blows often and strongly. Many wind power advocates have suggested the Great Plains as an area especially suited to the technology. However, there are some significant problems with wind power. First of all, the wind does not blow constantly. This can lead to gaps in the power supply. Many critics complain about the appearance of wind turbines and the noise they make. Perhaps worst of all, wind turbines have been known to kill endangered birds. A 1992 study sponsored by the California Energy Commission found that 500 birds of prey, including 78 threatened golden eagles, were killed during a two-year period at a large wind farm in California.

Proponents of wind energy contend that wind turbines have become much quieter in recent years. And, defenders say, they can be made safer for birds if they are carefully placed to avoid migratory paths. Soren Krohn, executive director of Denmark's wind industry trade association, Vindmolleindustrien, told *The Nation*, "Far more birds die on transmission wires than at properly sited windmills, where the casualties are virtually nil."

Moving water

Hydropower is the form of renewable energy that people have most thoroughly utilized. It also provides some of the cheapest electricity available. And, unlike wind and solar power, the energy of rivers is relatively constant.

Hydroelectric dams hold back huge reservoirs of water. This water is released and allowed to fall hundreds of feet over arrays of electricity-generating turbines.

The dams emit no pollution, but they do greatly disrupt local ecosystems. The lakes created by the dams displace animals and plants. The dams prevent nutrients from flowing downstream, disrupt natural flooding patterns, and change water temperatures and currents.

Hydroelectric dams have been blamed in large part for plummeting fish populations in dammed rivers. Salmon in the Pacific Northwest have been especially hard hit. Young salmon get fatally sucked into turbines as they swim downstream. Adult fish attempting to swim upstream to spawn are blocked by the dams. Some dams have installed "fish ladders" for adult salmon to swim over. But fish frequently die of exhaustion trying to get up the ladders. [See 1997 Sharks and Fisheries in Danger; 1994 Wild Salmon Declining in Pacific Northwest]

One attempt to repair ecological damage caused by a hydroelectric dam was partially successful. In 1996, officials purposely flooded the Colorado river with water from behind the Glen Canyon Dam. The deluge created new beaches and sandbars and improved the conditions of some shallow breeding areas. [See July 1997, page 155; 1996 Scientists Deliberately Flood Grand Canyon]

Biomass

Biomass, burnable organic matter, has been the power source of choice for almost all of human history. People have burned wood, oils from animals and plants, and even dried animal feces. One advantage that biomass has over other sources of renewable energy is that it exists everywhere. Not all regions of the country have strong rivers, winds or sunlight. In fact, a 1995 report by the Center for Energy and Economic Development and Resource Data International, Inc. concluded that there is "no practical non-combustible energy potential for the U.S. east of the Mississippi." But most regions of the world produce some sort of biomass.

Biomass includes sewage and trash; byproducts of logging and paper making, such as diseased trees, sawdust, bark and paper pulp; and waste from farms and food processing plants, such as straw, corn stalks and cobs, fruit pits and nut shells. Some crops, such as grains and certain fast-growing trees, can be cultivated specifically for use as biofuels, such as methanol (wood alcohol) and ethanol (grain alcohol).

Biomass can be burned directly to create heat in power plants. A sugar cane byproduct, *bagasse*, provides about 9% of Hawaii's power. Biomass can also be processed to release oils, gases or alcohol. These fuels can be used as alternatives to standard gasoline in cars.

However, unlike other renewable energy sources, biomass emits pollutants, such as CO_2 and particles.

Geothermal energy

One renewable energy resource that does not derive all its power from the Sun is geothermal energy. Some of Earth's internal heat was trapped underground in rock formations when the planet formed. Most of the heat is produced by the radioactive decay of mineral elements. People have tapped this geothermal heat source for millenia, using natural hot springs as baths. Geothermal heat has been used to produce electricity since the early 1900s.

Water seeps through cracks in Earth's crust to the hot rocks deep underground. That water becomes extremely hot, creating pressure that forces steam and hot water back to the surface in the form of geysers and hot springs.

Power companies drill into underground steam pockets. They use the steam to turn turbines, which produce electricity, or to heat buildings directly. Geothermal energy accounts for about 6% of the electricity generated in California. Iceland heats about 80% of its buildings with geothermal heat.

However, geothermal heat is not limitless; energy production from geothermal wells usually subsides after many years of use. Geothermal wells can also pollute ground water with minerals and metals leeched from the soil. If the steam were allowed to naturally disperse, it would carry away the minerals and metals. However, when it is condensed in a plant, the toxins precipitate into a sludge.

And some environmentalists believe that accessing geothermal sources might endanger some fragile habitats. For example, government officials have discussed building a geothermal plant in Hawaii, in an area called Wao Kele o Puna. The site sits within the largest untouched rain forest in the United States and is sacred to native Hawaiians.

Easily accessible steam pockets form only in a few places. Most of Earth's heat is trapped in rocks so far below the surface that no water can reach it. Researchers are exploring methods of exploiting this deep geothermal heat, called hot dry rock. For example, scientists at Los Alamos National Laboratory in New Mexico drilled wells into these deep areas. They pumped cold water down into one well. The water heated up in the hot rock, and then came shooting up another well. [See 1992 Drilling Deep for Hot Rocks]

Other researchers think it may one day be possible to harness the nearly limitless heat energy stored in molten magma within the Earth's mantle.

Creativity

During the oil crisis of the 1970s, a reporter asked science-fiction author Arthur C. Clarke to comment on the energy shortage. Clarke responded, "There is no shortage of energy, there is a shortage of intelligence." The Sun and Earth provide people with abundant energy sources. Further research will likely make fossil fuels less harmful to the environment and will help renewable energy resources become more affordable.

Science, May 19, 1995, page 955.

"Sea Power." Mariette DiChristina. *Popular Science*, May 1995, page 70.

"Thin-Film Photovoltaic Cells." Ken Zweibel. *American Scientist*, July/August 1993, page 362.

Cool Energy. Michael Brower. The MIT Press, 1992.

The Green Encyclopedia. Irene Franck and David Brownstone. Prentice Hall General Reference, 1992.

Internet Sites

"Rocky Mountain Institute FAQ" (www.rmi.org/faq/) Informative site answering frequently asked questions about the Rocky Mountain Institute, a nonprofit environmental research and education foundation; site provides numerous links to other sites.