Chapter 16

ALTERNATIVE ENERGY AND THE ENVIRONMENT

> Case Study: Alternative Energy on Public Lands in The American Southwest: Good Idea or A Conflict Among Environmentalists?
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> Continuing a theme from the last chapter, this essay addresses conflict between two key environmental issues: the need to provide more energy from sustainable sources and the need to protect valuable open spaces. Building solar and wind devices for harvesting power can interfere with migration routes, views, and habitat. Decisions on where to locate sustainable power systems and how large to make them remain key environmental issues.

16.1 INTRODUCTION TO ALTERNATIVE ENERGY SOURCES

Alternative energy sources derive from wind, water, solar or biomass, as opposed to fossil fuels and nuclear power which are considered conventional sources. Note that wind, water and biomass are indirect sources of solar energy, and since they are derived from solar energy, their rate of renewal depends on the sun and they may be temporarily depleted. Nonrenewable alternatives include deep-earth geothermal energy. The renewable alternatives are low quality energy in the sense that the energy is not concentrated and not easily portable nor economical compared with fossil fuels (for now), but the total energy available from renewable sources is extremely large.

16.2 SOLAR ENERGY

The amount of solar energy reaching the earth's surface exceeds our current total Earth energy consumption by 7,000 times, averaging 177 W/m^2. Passive solar energy systems attempt to enhance the absorption of light from surfaces using special materials or designs. Active solar designs involve moving materials such as air or water with machinery or the conversion of solar into other forms of energy.

● Passive Solar Energy

Buildings can be designed to take advantage of solar energy in a passive way. These are directed either at collecting heat more efficiently in cooler climates, or blocking/reflecting it in warmer ones. Collection of light can be enhanced through window and skylight positioning. Clever use of plants (hopefully native varieties) can assist greatly.

● Active Solar Energy

Active solar designs require mechanical power of some type to circulate air or water, such as in the use of solar collectors to provide space heating or hot water. Simple designs pass tubing over dark colored sunlit panels to heat fluids. More complex designs such as the evacuated tube collectors are more efficient.

Photovoltaics convert sunlight directly into electricity, and are the world's fastest growing energy source. Use of photovoltaics in the U.S. increased by 90% between 2007 and 2008, and total solar electric installations from 2000 MW to 3000 MW (about 50% growth) between 2008 and 2011.

~~Their~~ 1st-law efficiencies used to be about 1-2%, but today are as high as 20%. Household photovoltaic systems can provide enough energy for lighting and simple appliances, but larger systems can power small communities or remote stations and can feed into energy grids.

> A Closer Look 16.1: Fuels Cells - An Attractive Alternative
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> Fuel cells are highly efficient power systems that produce electricity by combining fuel and oxygen in a electrochemical reaction. Experimental fuel cells have been developed that can power automobiles. Hydrogen is the most common fuel type. It's reaction is essentially the opposite that of electrolysis:
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> $2H_2 + 1O_2$ yields $2H_2O$
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> Natural gas can also be used in fuel cells. Powering a car with natural gas fuel cells only produces 1% of the pollution as a car using gasoline. Currently using this technology is expensive but it is bound to become less pricey in the future.

● Solar Thermal Generators

Solar thermal generators utilize sunlight to boil water, producing steam to run an electric generator, essentially substituting sun for the role of burning fossil fuel. Power towers are centralized electric generation plants where a field of mirrors focus the solar energy on a collector. Early versions were not economical, but newly redesigned plants reflecting light onto pipes produce more power and are cheaper and more reliable.

Another solar electric-generating system utilizes a system of solar collectors (curved mirrors) to heat a synthetic oil that flows though a heat exchanger that drives steam turbines. It is a hybrid system that uses natural gas as a backup.

● Solar Energy and the Environment

Use of solar energy production equipment has a very small environmental impact, although some manufacturing processes for the equipment utilize toxic materials and, as stated in the chapter opening, locations can be controversial.

16.3 CONVERTING ELECTRICITY FROM RENEWABLE ENERGY INTO A FUEL FOR VEHICLES

Two possible ways to store energy for vehicles is to convert the electricity to rotating motion right away or store it in batteries. Electricity can also be converted to a liquid or gaseous fuel.

● Producing Liquid and Gaseous Fuels from Electricity

Hydrogen gas can be produced by passing an electric current (possibly supplied by solar power) through water to split the water molecule into oxygen and hydrogen, a process known as electrolysis. Hydrogen is a clean fuel, as the byproduct of its combustion is water, and it can be transported in pipelines. Hydrogen can also be produced from hydrocarbons, including natural gas. The nation of Iceland is attempting to become the first hydrogen-based energy economy using its abundant geothermal energy resources.

It is possible that hydrogen produced by solar processes could be used to make methane or alcohol, but this is not yet in use.

16.4 WATER POWER

Water power is a form of stored solar energy. (This is a good time to revisit the hydrologic cycle.) Hydroelectric power plants use the water stored behind dams. Generally a controlled flow of water passes

through a turbine to produce electricity. In the U.S., hydroelectric plants account for about 10% of total electricity production. Water pumped to higher locations and allow to flow down when needed can be used to store energy collected by other means.

● Small-Scale Hydropower Systems
Areas suitable for large scale dams and power production are pretty much exhausted, so develops are turning to small scale systems that use turbines or other machinery in exiting streams (especially mountain streams). Environmental issues will likely arise as more of these come into use.

● Water Power and the Environment
Hydroelectric power has a number of environmental costs. For example, fish migrations are disrupted. Another cost is the loss of scenic rivers, the flooding of valuable land, and the displacement of people. Evaporation and infiltration causes water losses at dams, and sediment tends to clog reservoirs.

16.5 OCEAN ENERGY
Oceanic areas are prone to storms, severe tides, and corrosion due to salt, so harvesting ocean energy is a challenge. Tidal power can be harnessed by dams across estuaries that let water enter on the incoming tide, then release the water through turbines at low tide (at least an 8 m tide difference is needed). The La Rance Tidal Power Plant, near St. Malo, France, produces 540 GWh. (You can see this very clearly on Google Earth.) The energy potential of tidal power is great, and so are the environmental costs, which include biodiversity damage and silting.

● New Ocean Energy Technologies
In the Bay of Fundy, which has a 15 m tide, a horizontal turbine was constructed that went online in September, 2012. This was the first project supply power to the US electrical grid. Another application of ocean power is the conversion of wave motion to forward craft motion. Both the Suntory Mermaid and the robotic Wave Glider make use of this technology.

16.6 WIND POWER
Wind power is essentially secondary solar power. Solar heat produces uneven heating of the atmosphere, causing movements as convection and wind that have been gathered by windmills and ships for centuries.

● Basics of Wind Power
Most small, farm-based wind mills generate about 1kW of electricity, which is only practical for decentralized power generation. Modern windmills can be 70 m high ~~and~~ and generate enough electricity to 500 US homes. "Wind farms" with many turbines generate much more electricity. Currently the two largest onshore wind farms are in China (Gansu Wind Farm, 5,000 MW) and the US (the Alta Wind Energy Center, 1,020 MW, is clearly visible on Google Earth). Wind farms are also constructed offshore.

Wind is the cheapest source of alternative energy, although it only supplies 1.4% of US energy. Because wind is variable in direction, duration, and strength, and is generally fed into a grid that can compensate for low production times.

● Wind Power and the Environment
Wind mills can kill birds, and people complain they are ugly. They must also have large land areas available, but they can share land use with farms and other facilities.

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● The Future of Wind Power

Wind use is very likely to grow. In Western Europe windmill generators are quite common. It is predicted that wind may supply 10% of energy in future years. Several states in the U.S. offer incentives for wind power. For grid-connected systems, Minnesota offers a 1.5 cent/kWh payment for net excess generation for small wind energy projects. Cost varies with capacity. At $0.08/kWh, the payback time of these machines would be about 3-6 years.

16.7 BIOFUELS

Biofuel is from the energy recovered from biomass. This can take a number of forms ranging from direct combustion of biomass to fermentation of alcohol, which can be mixed with gasoline. Biofuels can be vegetable oil, vegetation, waste, and even algae.

● Biofuels and Human History

Biofuels, especially wood burning, are the oldest methods by which humans have extracted energy. Wood, peat, and dung are all viable fuels still in use today for heating and cooking. Modern methods of burning wood pellets for energy can release less carbon dioxide than coal or oil, but the overall carbon debt may be higher. (Interesting study of externalities here.) Burning wastes for energy can also be advantageous compared to throwing them away.

● Biofuels and the Environment

Biofuels produced from crops grown specifically for this purpose are being held responsible for increasing food prices worldwide. Some people are concerned about the prospect of fields of corn being used to produce alcohol at the expense of hungry populations. Current yields by this method are not as high as solar or wind and have many environmental side effects such as increased use of water and fertilizer. While burning natural biofuels may cut pollution, burning waste (especially urban waste) may increase it as well as land degradation and habitat loss, as in Indonesia. On the plus side, some fuels can be grown in areas not suited for other crops.

16.8 GEOTHERMAL ENERGY

Geothermal energy is natural heat from the interior of the earth that can be harnessed to produce electricity or heat buildings. Geothermal energy that is deep-earth, high-density energy originates deep in the Earth, mainly from radioactive decay. Water originating from or pumped through deep wells can gather this energy and be used for heating or generating electricity. Total installed capacity worldwide is approaching 9,000 MW, with 40 million people depending on geothermal energy for their electricity.

Shallow-earth, low-density geothermal energy originates in sunlight that then warms surface materials (both solids and water), then transmits usable energy into the ground. This is valuable for heating buildings and pools. Most groundwater can also be a source of heat regulation, for both cooling and heating.

● Geothermal Systems

Average heat flow is low from geothermal systems, and can be considered nonrenewable if used too fast, but the source is virtually inexhaustible. Unfortunately, geothermal energy is not uniformly distributed and is only available where hot rocks are in reach of drilling equipment or where steam rises to the surface.

● Geothermal Energy and the Environment

Wastewater from deep-earth, high-density sources can be both corrosive (due to salinity) and a cause of thermal pollution. Land use and the destruction due to facility construction and exploration are further concerns.

● The Future of Geothermal Energy

The potential for geothermal energy to contribute more than a minor contribution to world energy use is slim, but the quantities available are very useful.

Plans for ocean thermal energy conversion (OTEC) would use the temperature gradient in tropical oceans to produce electricity. In theory, warm water at the surface could vaporize a gas such as ammonia, which would turn a turbine, and cold water from depth would condense the gas. A prototype was constructed in Hawaii. There are many problems associated with this technology and unknowns, including effects on ocean circulation and biofouling.

Critical Thinking Issue: Should Governments Support Renewable Energy?

This essay cites the success of legislation implemented in Germany in encouraging small residential and commercial renewable energy generators. Renewable energy now accounts for 22% of Germany's power. In contrast, growth in the United States has not been as rapid. One reason is that laws and incentives are not sufficient to make renewable energy attractive. While renewables are subsidized to some degree in the US, traditional forms of energy use are also subsidized, in some cases to a higher degree. It may be that by adopting Germany's model the US could make more progress.