Case Study: Using Wind Power in New Ways for an Old Application

Use of traditional wind power to propel cargo vessels had been pretty much abandoned due to expense and difficulty maintaining equipment as opposed to the general reliability of a diesel engine. A modern cargo ship, the *Beluga SkySails*, has successfully integrated modern machinery and a modified sail/kite to save money and environmental resources.

Chapter 16

ALTERNATIVE ENERGY AND THE ENVIRONMENT

16.1 INTRODUCTION TO ALTERNATIVE ENERGY SOURCES

Alternative energy sources derive from wind, water, solar or biomass. 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 **nuclear** and **deep-earth geothermal**. 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** provide space heating or hot water. Simple designs pass tubing over dark colored panels to heat fluids. More complex **evacuated tube collectors** are more efficient.

A Closer Look 16.1: Fuels Cells - An Attractive Alternative

Fuel cells are highly efficient power plants 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:

$$H_2 + O_2 \rightarrow H_2O$$

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.

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.

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.

● 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 version were not economical, but newly redesigned plants will produce more power.

Other 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 has characteristics like a power tower, but is a hybrid system that uses natural gas as a backup.

● Solar Energy and the Environment

Solar energy production has a very small environmental impact, although some manufacturing processes for solar equipment utilize toxic materials.

16.3 CONVERTING ELECTRICITY FROM RENEWABLE ENERGY INTO A FUEL FOR VEHICLES

Two possible ways to store energy for vehicle use is in **batteries** or by conversion to a **liquid or gaseous fuel**.

Hydrogen gas can be produced by passing an electric current (possibly supplied by solar power) through water to decompose the water molecule into oxygen and hydrogen, a process known as **electrolysis**. It is a clean fuel, as the byproduct of hydrogen combustion is water. It is a concentrated form of energy that can be transported. 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.

16.4 WATER POWER

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. Pumped water can also be used to store energy collected by other means.

● Small-Scale 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).

● 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 in several ways. In areas of extreme tide range, such as the Bay of Fundy, which has a 15 m tide, a dam constructed across the estuary would 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 energy potential is great, and so is the environmental cost. Though proposed, a tidal power plant has not been constructed at Fundy. The La Rance Tidal Power Plant, near St. Malo, France, produces 240,000 kW. (You can see this very clearly on Google Earth.)

16.6 WIND POWER

● Basics of 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 for centuries. Most small modern wind mills generate about 1kW of electricity, which is only practical for decentralized power generation. California has about 17,000 windmills with a capacity of about 1,400 MW. This is about 80% of all windmills in the U.S. 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 they are ugly. They must also have large land areas available, but they can share land use with farms and other facilities.

● The Future of Wind Power

Wind use is very likely to grow. In Western Europe windmill generators are quite common. 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. A 3 kW machine can be found for about $13,000 and a 17.5 kW machine for $31,000 (Forsyth et al. 2000. NREL report). 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. Burning wastes can also be advantageous compared to throwing them away, and renewable firewood will remain a viable source of energy. Some people are concerned about the prospect of fields of corn being used to produce alcohol at the expense of hungry populations, but currently yields by this method are not as high as solar or wind.

● Biofuels and the Environment

Biofuels produced from crops grown specifically for this purpose are being held responsible for increasing food prices worldwide and have many environmental side effects such as increased use of water and fertilizer. While burning natural biofuels may cut pollution, burning waste may increase it.

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** 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.

Critical Thinking Issue: Should Wind Turbines Be Installed in Nantucket Sound?

Spoiling visibility does not seem to be a very important concern when compared to the vast environmental consequences of fossil fuel, but it certainly gets people fired up! Fisherman pose environmental concerns, Native Americans are concerned about ritual practices. This will be a great one for class discussion, especially if you involve some aspects of socioeconomic class and race. Books by Robert Bullard (e.g. *Dumping In Dixie: Race, Class, And Environmental Quality*) are a great reference.

● 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.

Shallow-earth, low-density geothermal energy originates in sunlight, that then warms surface materials (both solids and water), then transmit 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 Energy and the Environment

Wastewater from deep-earth, high-density sources is both corrosive 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.

Web Resources

http://www.users.qwest.net/~rberger1/category.htm This is a portal to alternative energy resource sites.

http://www1.eere.energy.gov/solar/photovoltaics.html A good site devoted to photovoltaics.