Chapter 14

ENERGY: SOME BASICS

Case Study: National Energy Policy: From Coast-to-Coast Energy Crisis to Promoting National Independence

The most serious blackout in U.S. history occurred on Aug. 14, 2003 when NYC, eight states and parts of Canada lost power, affecting 50 million people. Rolling blackouts in California in 2001 occurred because production capacity did not keep up with population and economic growth. Planners came to the conclusion that if the United States is to meet electricity demands by the year 2020, over 1,000 new power plants will have to be constructed or about 60 per year. Congress debated a new national energy policy for the first time since the oil embargo of the 1970s and in 2005 the Energy Policy Act was passed into law. The new act acknowledges that we have made improvements in conservation and are continuing development of alternative sources.

14.1 OUTLOOK FOR ENERGY

● Energy Crises in Ancient Greece and Rome

The energy crisis is not new. Ancient Greeks and Romans exhausted the wood supply upon which they depended for heat and cooking. They began to take advantage of solar energy to heat.

● Energy Today and Tomorrow

There has been a succession of primary energy sources throughout the world. Use of wood peaked in the U.S. in the 1880s when coal assumed preeminence as the primary energy source. This was followed by oil, which has dominated since WWII. The use of fossil fuel has improved the standard of living: improved sanitation, medicine, and agriculture are all consequences. The only thing certain about tomorrow's energy resources is that they will change.

14.2 ENERGY BASICS

Energy is the *ability* to do work. **Work** is the product of force times distance. A **force** is a push or pull upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects. When the interaction ceases, the two objects no longer experience the force. Forces only exist as a result of an interaction. So energy is defined by its ability to move something.

A Closer Look 14.1: Energy Units

The **joule** is the fundamental International System energy unit, and equals the force of 1 Newton (N) applied over a distance of 1 m. One Newton is the amount of force required to give a 1-kg mass an acceleration of 1 m/s/s, so 1 Joule is the force of 1 Newton times 1 meter (force times distance).

There are other energy units as well. For example, the calorie is defined as the amount of energy need to raise the temperature of 1 gram of water from 14.5 to 15.5 C (note that a dietary calorie is actually 1 Kcal).

The **Watt** is a measure of the rate at which energy is used. A watt (W) is equivalent to 1 joules per second. A kilowatt-hour, which household bills are based on, is the equivalent of using 1000 Watts for 1 hour.

Conversions:
1 cal = 4.2 joules
1 Wh or 1 Watt-hour = 3600 joules
1 Kcal/hr = 1,163 Wh
1 exajoule = 10^{18} Joule or 1 billion billon Joules

An easy and practical exercise for students is adding up the wattages of a roomful of appliances. Another is to examine devices routinely left plugged in, such as televisions. Also, give the students some problems such as determining the energy used by a light bulb burning for a given amount of hours.

Energy can be classified in several ways: kinetic and potential. **Kinetic energy** is the energy associated with movement, **potential energy** has the potential to move something. Water stored behind a dam is potential energy as is the energy stored in a battery. There are also different fundamental sources of energy: chemical, light, nuclear (a type of chemical energy really) and heat. **Temperature** is a measure of the heat energy of an object or medium.

The First Law of Thermodynamics states that energy can neither be created nor destroyed, but it may be transformed from one type into another type. Solar can be converted to heat and then to electricity, for example.

The Second Law of Thermodynamics states that any conversion of energy from one form to another requires that some of the initial energy input be degraded into a less useful form, usually heat. No energy conversion is 100% efficient. For example, it is impossible to convert electrical energy to light energy with 100% efficiency. There will always be some heat loss.

14.3 ENERGY EFFICIENCY

Two types of efficiencies can be derived from the 1st and 2nd laws. **First-law efficiency** deals with the amount of energy without consideration of the quality or availability, and is expressed by energy delivered/energy supplied. Suppose a furnace delivers 1 unit of heat energy to the house for every 1.5 units of energy supplied to the furnace. This represents an efficiency of 67%. The first-law efficiency may include losses of energy involved in extracting the gas from the ground and transporting it to where it is used (as is done for a full energy analysis of a process), or it may include only the energy actually delivered.

Second-law efficiency is the minimum amount of energy required/actual energy input. The second-law efficiency tells us how efficient a process is relative to how efficient it could be. Essentially the second-law efficiency tells us how efficient it *could* be, the first-law tells us how efficient a process actually *is*.

To use high quality energy for low-quality energy tasks is wasteful, and the second-law efficiency gives information on this. Power plants, for example, produce enormous amounts of waste heat, as do the transmission lines.

14.4 ENERGY SOURCES AND CONSUMPTION

The U.S. has 5% of the world's population and accounts for 25% of world energy consumption. A peak in oil production (extraction) is expected to occur in 2020-2030, followed by a decline. However, the demand for oil may occur sooner, which will raise the price of oil significantly, reducing the growth rate in demand, stimulating the development of **alternative energy sources** and **conservation**, and possibly extending the supply of oil.

● Fossil fuels and Alternative Energy Sources

About 90% of energy consumed in the U.S. today are from nonrenewable fossil fuels: petroleum, natural gas and coal. Alternative energy sources include geothermal, nuclear, hydropower and solar, some of which are renewable.

Since 1980 energy consumption in the U.S. has increased from about 20 exajoules to more than 95 exajoules. About 50% was wasted. Energy conservation is one of our greatest untapped energy sources! The Table in the text gives energy consumption by sector (residential, industrial and transportation) and by source. Go the to the DOE web page (see web resources) for the latest statistics.

14.5 ENERGY CONSERVATION, INCREASED EFFICIENCY, AND COGENERATION

Conservation of energy simply means using less. Energy may also be conserved by increasing the energy **efficiency** (1^{st} and 2^{nd}-law efficiencies) of devices and processes. **Cogeneration** is a means of increasing the efficiency of our energy delivery processes by taking advantage of wasted heat energy. For example, the hot water that created by condensing the steam in electric power plants is now discharged into lakes or rivers in the U.S. In Europe it is common to pipe this hot water into the cities to heat homes.

To understand where we need to focus our efforts, we need to examine how we use energy. For example, the transportation sector accounts for about ½ of the petroleum consumed in the U.S., and the majority of this is accounted for autos. The transportation sector offers our greatest opportunity for conservation through conservation (driving less) and efficiency of engines and design as well as better roads with less congestion.

The Energy Policy and Conservation Act of 1975 (P. L. 94-163) established corporate average fuel economy (CAFE) standards for new passenger cars. The CAFE standards are applied on a fleet-wide basis for each manufacturer; i.e., the fuel economy ratings for a manufacturer's entire line of passenger cars must average at least 27.5 mpg for the manufacturer to comply with the standard. If a manufacturer does not meet the standard, it is liable for a civil penalty of $5.00 for each 0.1 mpg its fleet falls below the standard, multiplied by the number of vehicles it produces. Congress included a number of exceptions. For example, a manufacturer whose light truck fleet was powered exclusively by basic engines which were not also used in passenger cars could meet standards of 14 mpg and 14.5 mpg in model years 1980 and 1981, respectively. There are lower standards for light trucks, defined on the basis of vehicle weight. Manufacturers found a way to dodge the standards for cars and satisfy the American appetite for large autos by making SUVs, which are classified as light trucks. The fleet of light trucks is required to average 20.7 mpg. SUVs emit 30-100% more CO_2 per mile than standard autos.

● **Building design**
Building designs offer opportunities for energy conservation. Better insulation, use of active and passive solar designs, and appropriate landscaping can help.

● **Industrial Energy**
Usage of the principle above has allowed US industries to increase production without increasing energy use in direct proportion.
In terms of **automobile design and regulation**, hybrid cars are becoming more common. It may be possible to tax inefficient autos such as SUVs and to raise the tax on gasoline. Europeans have been paying a high tax on gasoline for many years.

● **Values, Choices, and Energy Conservation**
Many of us routinely practice conservation, and there are many ways that we can all contribute (the text gives an extensive list). Experience in European nations indicates that Americans could greatly improve on our energy conservation efforts and still maintain a high quality of life.

A Closer Look 14.2: Micropower

Sustainable energy will likely include the emerging concept of micropower- smaller, distributed systems for production of electricity. In nations with a high degree of industrialization, micropower may emerge as a potential replacement for aging electric power plants. For micropower to be a significant factor in energy production, a shift in policies and regulations to allow micropower devices to be more competitive with centralized generation of electrical power is required. Distributive power systems will probably play an important role in our goal of achieving integrated, sustainable energy management for the future.

14.6 SUSTAINABLE ENERGY POLICY

President Nixon's Project Independence, started after the first oil shock of 1973, proclaimed that the U.S. would be self-sufficient by the end of the decade. Today we rely more on imported energy than ever before. The U.S. has spent $110 billion on energy research, most of it on nuclear energy, which supplies only 11% of our total energy. Only 18% of the energy research budget has targeted renewable energy resources. In a typical year, the U.S. spends $2 billion on energy R&D, and $45 billion for military R&D (including R&D for weapons used in the mid-east). Yet energy is no less important for the survival of the U.S. than is the military for our defense.

Our energy policy may lead to two alternative futures, a **hard path**, which is the continued development of fossil fuel and nuclear energy (favored during the 2000-2008 Bush administration), and a **soft path**, which relies heavily on renewable and alternative energy resources and decentralized energy production, as envisioned by Lovins (see text for details of this plan - an interesting student project would be to match Lovins' principles to society today).

● **Energy for Tomorrow**

By the year 2030, energy consumption in the U.S. Could reach 120 exajoules (20% higher than today), if growth in consumption continues unabated, or it could be as low as 60 exajoules if we move aggressively toward conservation. The choice will have an impact on climate and air quality. A move to conservation will require more energy efficient land-use planning that minimizes the need for personal transportation, changes in agriculture, industry, and behavior. Changes in government policy will also be required.

The concept of **integrated, sustainable energy management** recognizes no single energy source, but a mixture of energy sources that are reliable, environmentally benign, and sustainable. To move in this direction will require an energy policy that favors sustainable energy development, encourages conservation and efficiency, allows diversity, balances economic health and environmental quality, and uses 2nd-law energy efficiency as a policy tool.

Critical Thinking Issue: Use of Energy Today and in 2030

Current uses of energy per person are between 46 billion joules per year (low income countries) and 210 billion joules per year (high income countries). Increases in population and per person consumption have to be considered if we are to have sufficient energy in the future.

Dependence on fossil fuel is also a security issue. The United States spends tax dollars to keep standing armies in areas of the world where oil and gas resources are of strategic importance. The first Gulf war to turn back the Iraqi invasion of Kuwait is widely acknowledged to have been primarily about energy resources; it could not have been about protecting a democratically elected government in Kuwait. The motive behind the second Gulf war may also be about energy. Regardless, the fact is we expend enormous resources to safeguard our oil supply. Should this cost be passed along to the consumers at the pump?

Web Resources

www.eia.doe.gov A comprehensive collection of statistics covering energy consumption by source, sector, and time. Also available are production and importation statistics.

http://energy.usgs.gov/ Natural oil and gas resource assessments.

http://web.ornl.gov/info/news/pulse/pulse_home.htm Highlights work being done at the Department of Energy's national laboratories.

http://www.whitehouse.gov/energy/ The United States' current energy policy.

http://energy.senate.gov/ The U.S. Senate's energy web page with discussion of major issues and current energy legislation.

http://www.eere.energy.gov/ This is the portal to DOE's alternative energy programs, and information about energy efficiency.

www.ase.org/powersmart Energy consciousness and tips for saving energy around the home.