Energy Resources

I. A Brief History of Energy Use

A. Charcoal from fires has been discovered at human sites dating back one million years. Wind and water power have been used for about 10,000 years. The invention of the steam engine and the diminishing supplies of wood in industrializing countries, caused a switch to coal in the 19th century. Coal was replaced by oil as the primary fuel because it is easier to ship, store, and burn. World oil use peaked in 1979 when daily production passed 66 million barrels per day.

B. Fossil fuels now account for 85% of all commercial energy in the world.

C. Most energy is used in the form of electricity, which is called a secondary energy because it relies on a primary energy to produce it. Note that electricity is 100% clean at the point of use but causes pollution and environmental damage where it is produced.

II. Fossil Fuels are formed from the remains of living organisms which accumulate under layers of sediment and are converted by pressure and heat to coal, crude oil, and natural gas. It takes 1000 years to produce enough plant material to make the fossil fuels the world uses every day. Is this sustainable? (Ummm . . . I don't think so).

A. **Coal** is fossilized plant material preserved by sediments and compacted and condensed into a carbon-rich fuel. The amount of coal in the world is ten times that of oil and natural gas combined. Coal seams can be 100 m thick and can extend over tens of thousands of square kilometers that were once huge swampy forests up to 400 million years ago.

1. The abundance is not necessarily a good thing as burning coal releases carbon dioxide which contributes to global warming. Also, mining coal is dangerous work. Underground mines are subject to cave-ins, fires, accidents, and accumulation of toxic gases. In some cases, half the coal must be left to support the roof of the mine. Strip mines are cheaper and safer than underground mines cause enormous environmental damage and usually makes the land unfit for any other use. Mining companies are required by law to reclaim the land but efforts are usually superficial and ineffective.
2. Burning coal has several major disadvantages:
    a. It releases radioactive elements and toxic metals such as uranium, lead, cadmium.
    b. It is a very dirty fossil fuel to burn so it produces lots of air pollution.
    c. It cannot be used in cars.

B. **Oil** is also produced from plant and animal material buried millions of years ago. Pumping oil out of a reservoir is like sucking liquid out of a sponge. The first bit comes out easily, but becomes more and more difficult the more you remove. Usually, at least half the oil in a reserve remains underground because it is too expensive to recover it.

1. The 10% rule (not the one in food chains) says that only 10% of the oil remaining in any reserve can be extracted economically each year. This means that reserves can actually increase if the price of oil increases because it becomes feasible to extract more.
2. A continued dependancy on oil imports means a lack of price stability; rather, the price will be determined by OPEC. Oil consumption in the U.S. continues to outpace production, while Canada is a net exporter.

3. The problems of a growing dependency on oil include:
    a. costs of purchasing oil
    b. supply disruptions because of political instability in supply country
    c. finite supply
4. The world currently has supply for approximately 45 years at the current rate of consumption.

C. **Oil (or tar) sands** are usually not included in estimates of oil resources. It is basically thick tar (bitumen) mixed with sand and other sediments. When the tar sand is heated, the bitumen melts out and is released. It is then refined like crude oil.
1. Extraction causes great environmental damage as it is done using strip mining. It uses huge amounts of water and produces huge amounts of waste.

D. **Natural gas** is the world's third largest commercial fuel (after oil and coal). It is a fossil fuel so it does release CO_2 when it burns, but it burns much cleaner than others so using it could help reduce global warming. It is difficult to ship and store but is easy to move by pipeline. The estimated reserve is about 80% as much energy as the recoverable reserves of oil.
1. With modifications, cars could run on natural gas (mostly methane) and it is easily used for heating and cooking.

E. Conservation

III. Alternative and renewable energy sources will be increasingly important in the future if we are to provide energy in a sustainable way. Most of the energy in primary fuels is lost as heat when we convert them to electricity. A good deal of the energy we do get from fuel is used in nonessential ways.

A. Starting in the 1950s, **nuclear power** was believed to be the solution to the predicted shortages of oil and natural gas.
1. It currently provides 14% of the world's power but is the most expensive generation method. The advantages include the fact that it uses much less fuel and produces no emissions.
2. The primary concerns over nuclear power are the radioactive waste that is produced and the chance of a nuclear accident. It should be noted that far more people have been killed and injured by other forms of electricity production. Although most people are afraid of the radiation from a nuclear power plant, in fact, a coal-burning plant produces more radiation. Dismantling the plant actually produces more radioactive waste than is produced during the total active life.
3. The radioactive waste is the main problem with nuclear power. Short term storage of the waste for 10 years reduces the radioactivity by 97%. Waste is usually held in a pool and the water absorbs the heat and radioactivity. Waste must be stored long term, around 10,000 years, to eliminate risk from long-lived radioactive products. This is most often done deep inside stable rock formations.

B. The sun is a giant nuclear furnace, constantly bathing our planet in free **solar energy**. About 1,330 W/m^2 of solar energy reaches the Earth. Half of that is absorbed or reflected by the atmosphere. It is simple to add capacity as the need grows.
1. The main problem with solar energy is that, for most of human history, it has been too diffuse and low intensity to use effectively. Other problems with solar energy include collection (it must be collected over a wide area), conversion (it must be converted to a usable form such as heat or electricity), and storage (it ain't always sunny!).

2. The simplest way to use solar energy is **passive heat absorption**. This system uses thick stone walls or floors to collect heat all day and release it at night. Greenhouses and windows on the sunny side of a house employ the same idea. In our climate, we would need a back-up source of heat for days when it is too cold to rely on solar heat alone.
3. **Active solar heating** involves pumping a heat-absorbing fluid (usually air or water) through a small collector and then through the space to be heated. In its simplest form, this is like a little greenhouse on the roof or side of a house. Water (or air) circulates through tubes in the "greenhouse" and is heated by the sun. This can then be used to heat a building.
4. **Photovoltaic cells** capture solar energy and convert it directly to electricity (as in solar calculators). Although the amount of electricity produced from a single cell is small, they can be wired together to create as much electricity as is desired. The lack of light at night may not be a huge problem because most electricity is used during the day. Some kind of efficient storage is necessary.
5. **Solar concentrators** use mirrors to track the sun and reflect the light to a tower. In the tower, steam is generated to turn a turbine and generate electricity.

C. **Fuel cells** can be powered using hydrogen produced using solar energy.
1. A fuel cell basically combines hydrogen and oxygen to produce electricity and water. Depending on the source of the hydrogen, the only waste product is pure water. Hydrogen can be obtained from splitting water using electricity (electrolysis). To do this economically, solar energy could be used to produce the electricity needed to split the water and produce hydrogen. Hydrogen can be obtained by splitting water or from agricultural waste or methane from landfills or water treatment plants.
2. The problem with hydrogen as a fuel source is that there is virtually no hydrogen gas on Earth.
3. One huge advantage of fuel cells is they can be scaled for a variety of uses. Small fuel cells can be used in buildings where the waste heat can be used for water heating or space heating.

D. Plants store solar energy as chemical compounds using photosynthesis. This **biomass** could be used as a primary energy source. Biomass includes such things as wood, bark, branches, leaves, and manure.
1. **Wood** has long been the source of energy for most cooking and heating throughout human history. As recently as 1850, it supplied 90% of the fuel used in Canada and the US. In many poor countries, wood and other biomass still provides 95% of all energy used. In most cases, the burning of wood is not sustainable and contributes to deforestation, although it is possible to do sustainably by using twigs, branches and crop residue.
    a. Wood stoves are generally inefficient and incomplete burning of the wood produces ash and smoke that carry pollutants into the air. Many jurisdictions are banning the installation of new wood stoves and enforcing tough, new regulations on efficiency.
    b. An advantage of burning wood is that it does not contribute global warming. Tress absorb CO_2 as they grow and that CO_2 is released when they are burned.

2. Where wood and other fuels are not available, people often dry and burn **animal manure**. This is unsustainable as it effectively removes nutrients from the soil, leading to more intense food shortages. Although more expensive, it is much more efficient to convert the dung to methane to be used as a fuel. When dung is converted by bacteria to methane, more heat can be produced than burning the dung itself, and the sludge leftover is an excellent fertilizer as the nutrients are not lost. Sources of organic matter for producing methane include farm waste, landfills, and sewage treatment plants.
3. Ethanol and methanol can be produced by fermenting grain or sugarcane waste. Ethanol can be mixed with gasoline to be burned in cars. This reduces CO_2 production because ethanol produces more energy.

E. **Hydroelectric power** basically uses the power of falling water to produce electricity. Hydroelectric power is renewable, 100% clean, and a continuous source of energy but is not without its drawbacks.
1. We discussed the loss of wildlife, habitat destruction, and human displacement of large dams in the Water Unit. One additional danger of large dams is the catastrophic flooding that can occur if the dam fails. Sedimentation is also a problem as the dam reservoir fills with sediment, reducing the life of the dam or increasing costs as dredging becomes necessary.
    a. Other problems include the growth of aquatic vegetation which requires herbicides to control, evaporative water loss, and breeding of aquatic parasites.
2. Low-head hydropower and run-of-the-river flow technology can avoid most of these problems because they are small scale and do not cause the damage that large dams do. Micro-hydro generators are small enough to provide power to a single home.

F. As the atmosphere absorbs solar energy, the air is differentially heated and this causes currents. This **wind energy** can be used to produce electricity. Like any other source of energy, wind power has advantages and disadvantages.
1. The main advantages of wind are that it is limitless, non-polluting, and causes minimal environmental disruption. It also has the benefit of being able to add capacity on a small scale quite cheaply. The main disadvantage is the same as with solar - power must be stored when it is not windy. Where conditions are favorable, wind power is cheaper than all other sources.
2. A wind farm is a large concentration of wind generators producing commercial electricity. They are usually located in areas where wind and weather are too severe for residential development. Also, the land under the towers can be used for other purposes such as grazing.
3. Additional complaints are that wind turbines are not very aesthetic and have, in the past, posed a danger for birds, especially when they are in migratory routes.

G. **Geothermal energy** uses the internal temperature of the planet. At places where magma is close to the surface, the heat can be used to produce steam to drive turbines to generate electricity. Ideally, the steam is then condensed and pumped back into the ground to be reheated. Alternatively, water can be pumped deep underground to warm it and then used to heat buildings.

H. **Tidal power** uses the enormous energy of ocean tides and waves to produce electricity. The basic principal is the same as that used in hydroelectric dams. The twice daily rise and fall of the tides turns turbines and produces electricity. Problems include the fact that most

tides are not high powerful enough to turn the turbines and the deposition of silt. There is also some concern that interfering with water flow will affect the mixing of fresh and salt water in estuaries as well as interfere with fish migration and feeding.

1. Several smaller technologies exist that could use small floating bars which rise and fall with waves or small rotating cylinders that generate electricity as water flows through them.

I. **Ocean thermal energy conversion** (OTEC) is a technology that exploits the temperature difference between surface and deep water. Heat from the surface water is used to evaporate a fluid with a low boiling point (like ammonia or Freon - sound familiar). The resulting gas turns a turbine to produce electricity. Deep, cold water is then used to condense the gas.

1. Water temperature differences can also be used to cool and heat buildings. In winter, heat can be extracted from warm ocean water to heat buildings. In summer, cool ocean water can be used to cool buildings.