Case Study: Peak Oil: Are We Ready for It?

The term peak oil refers to the time when we will have exhausted one-half of the Earth's oil supply, which is expected between 2020 and 2050. A more immediate difficult situation occurs when demand exceeds production, and prices rise. Evidence of the instability of gasoline prices in recent years has foreshadowed events of the future when demand increases due to higher population, and when production inevitably slows.

Chapter 15

FOSSIL FUELS AND THE ENVIRONMENT

15.1 FOSSIL FUELS

Fossil energy resources include petroleum (crude oil), natural gas, coal, and some others. Petroleum is a complex mixture of organic molecules that are purified or refined into numerous products like gasoline, kerosene, heating oil, asphalt, synthetic fibers, plastics, etc. Natural gas is also a complex mixture that consists mostly of methane. Fossil fuels were formed millions of years ago from the debris of plants. The energy in fossil fuel originally came from the sun (recall the 1st law of thermodynamics), and is essentially stored sunlight. The major fossil fuels provide 90% of energy consumed in the world, mostly for transportation and industrial uses. Usage is increasing, mostly due to coal burning.

15.2 CRUDE OIL AND NATURAL GAS

Fossil fuel is formed from organic matter made by plants that was trapped in the earth without a chance to decompose. The exact chemistry of the process is not fully understood. Most deposits are found at plate boundaries in depositional basins that were buried (source rock), although several important exceptions exist. Petroleum and natural gas formed during 1000s of years of heat and pressure. Petroleum and gas are light and will migrate to the surface (reservoir rock) and evaporate unless they are trapped by a confining layer of rock or a trap, known as a **cap rock** usually consisting of shale. In other words, the geological requirements are exacting. If the cap develops cracks, the oil will migrate to the surface, the light fractions will evaporate, and the remaining, oily residue is known as **tar sand**. As crude oil ages, it eventually decomposes. The two end products or maturation products are graphite and methane.

● Petroleum Production

Production can be by primary or enhanced extraction methods. **Primary production** involves pumping the oil from wells, a method that can recover only about 25% of the oil in the field. **Enhanced production** methods, in which steam, water, or compressed gases are pumped into the field, can improve the efficiency up to 60%. Most **proven** reserves are located in only a few fields. One percent of all fields contains 65% of the oil, and the largest is located in the Middle East. Enormous trade imbalances have grown as world users purchase this oil.

● Oil in the 21st Century

At present production rates, petroleum will last only a few decades. Consider the following signs:

1. We are approaching the time when 50% of total crude oil from known fields is gone (**peak oil**).
2. Proven reserves are about 1 trillion barrels. World consumption is 27 billion barrels/yr. ($10^{12}/27 \times 10^9$/yr = 37 yr). Forecasts predict the amount of oil that may ultimately be recoverable is in the order of 2-3 trillion barrels. We are not finding new oil as fast as we are depleting known oil.
4. While we can not possibly get all the oil out of the Earth, oil exploration will end when the energy cost of exploration approaches the energy content of the discoveries.
3. U.S. oil reserves will be depleted by 2090, world oil will be depleted by about 2100.

● Natural Gas

Natural gas is a complex mixture of organic gases (e.g. propane) that consists mostly of methane. World reserves of NG, about 155 trillion m^3, will be gone in 60-120 years. Improvements in extraction of NG from know fields accounts for most growth of NG reserves is the U.S. DOE estimates that the current recoverable NG reserves in the U.S. are 11 trillion m^3. They estimate that an additional 19.5 m^3 are undiscovered. At current rates of consumption in the U.S. (0.61 trillion m^3/yr, 2000 U.S. Statistical Abstracts), the known reserves will be depleted in 18 years. Of course the depletion time will be greater because of imported NG and because new supplies (up to 19.5 m^3) will come on line. However, even allowing for undiscovered reserves, it appears that NG reserves will be gone during this century. Increased pressure to utilize natural gas for its clean burning and low pollution contribution may hasten the exhaustion.

● Coal-Bed Methane

There is a considerable amount of methane associated with coal beds that can be tapped by drilling. The technology is developing. This gas is clean burning and produces lower amounts of carbon dioxide than other fossil fuels. There are significant problems with the disposal of polluted water that is produced when the methane is recovered, along with foul smells and nuisance noise.

Methane hydrates are found on the ocean floor in areas where deep, cold water under intense pressure has trapped methane within an ice lattice. This is a potentially large energy source, greater than all known oil, NG and coal reserves. However, these deposits

A Closer Look 15.1: The Arctic National Wildlife Refuge: To Drill or Not To Drill

The Arctic National Wildlife Refuge (ANWR) on the North Slope of Alaska is one of the few pristine wilderness areas remaining in the world. The USGS estimates that the ANWR may hold 3 billion bbl of oil. The oil industry favors drilling for this oil. Environmentalists are opposed. There are valid arguments on both sides of the argument. Regardless of the environmental impacts, which are debatable, one must ask if this oil is more valuable to the nation now, or whether the value of this resource will increase with time. This is a question of short-term profit versus long-term investment.

occur at great depths (>1 km), and the technology does not currently exist for extracting methane hydrates.

● **Environmental Effects of Oil and Natural Gas**

These effects arise from processes associated with the extraction and refining stages, and the delivery and use stages.

In the recovery stage there is a land-use impact, pollution of surface water from leaks and accidents, release of hydrocarbons to the atmosphere, land subsidence (an issue in the Mississippi River delta), and damage to ecosystems. Other impacts specifically associated with marine recovery include seepage from operations, spills, drilling muds, and the aesthetics of drilling platforms.

Refining oil and natural gas impacts include spills, leaks, and air pollution as well as leaks of chemicals used in the refining processes.

Delivery and use impacts result from failure of pipelines and storage tanks as well as spills from ships and trucks.

15.3 COAL

Coal is the world's largest conventional source of fossil fuel. There are may different types of coal that vary greatly in energy and sulfur content. Those most commonly used a fuel, in order of increasing energy per ton, are **lignite**, **bituminous**, and **anthracite**. The high sulfur content of some types of coal pollute the atmosphere. Sulfur can be removed from coal as it burns, but this produces toxic pollutants as well.

● **Coal Mining and the Environment**

The environmental impacts of coal use are severe. They range from acid mine drainage to outright elimination of whole landscapes. Land reclamation practices required by law vary by site, but so far only about half of all land disturbed by coal mining have been reclaimed. Open pit and strip mines are surface mining processes in which the overlying soil and rock is stripped off to reach the coal. This accounts for over ½ of the coal mining in the U.S.

● **Mountaintop Removal**

A Closer Look 15.2: The Trapper Mine
The Trapper Mine on the west slope of the Rockies in northern Colorado is a large coal strip mine is a "new generation" strip mine in that recovery and reclamation processes are being planned according to higher standards. It will produce 68 million metric tons of coal from a 5-6 $mile^3$ area. Land reclamation, which has been successful, increases the cost of the coal by 50%, but when the mine is abandoned after 35 years in operation, the value of the land will be much greater because of the reclamation.

This special strip mining technique involves just what it sounds like. Any tree cover is removed, followed by the topsoil, and then the coal is excavated. Environmental consequences are particularly severe due to ecosystem destruction and from runoff. Mountains are also particularly difficult to reclaim. An interesting class discussion can revolve around using a program such as Google Earth to find places where this type of mining has taken place.

● **Underground Mining**
Underground coal mining accounts for 40% of coal production in the U.S. This method also produces subsidence as well as acid mine drainage from the mine tailings and sometimes coal fires that burn for decades. Underground coal mining is also associated with human disease and great danger from cave-ins and other other hazards.

● **Transporting Coal**
The transport of coal, usually by train, from the mines to electric power plants also has environmental costs and energy costs that reduce the efficiency. Alternative transport methods often require large amounts of water.

● **The Future of Coal**
Coal accounts for about 50% of the electrical energy production in the U.S., and about 25% of total energy consumption. Clean air legislation has forced utilities to seek cleaner types of coal and new technologies to remove pollutants before the coal is combusted and before the combustion products are released to the atmosphere. Coal is a lower quality of energy than the liquid and gaseous forms of fossil fuels, and it has a much greater environmental impact. As oil and NG supplies become limiting, the pressure to consume more coal will increase.

The EPA grants utility companies **tradable allowances** for polluting. This is a market approach to regulating pollution. For example, they are allowed to release a given amount of sulfur dioxide. If they release less than their allotment, they are allowed to sell the credits. This provides an incentive to use clean technology.

15.4 OIL SHALE AND TAR SANDS
These are currently being explored for future use but currently do not contribute much to overall energy production.

● **Oil shale**

Critical Thinking Issue: What Will Be the Consequences of Peak Oil?

This Issue presents a graph of world oil production versus time and several statistics regarding oil and grain. A set of critical thinking questions addresses the relationship between oil and food prices. The second question, making the link between food supplies and energy, should be thoroughly addressed.

Oil shale is a sedimentary rock containing a type of organic matter called kerogen. When heated to 500°C the shale yields up to 60 liters of oil per ton of shale. This is one of the **synfuels**. There are large deposits of oil shale in Colorado, Utah and Wyoming. Oil shale is not yet economically viable, and the environmental costs of developing oil shale are huge.

Interesting point of discussion could be a quote from Edward Teller, who worked on the Manhattan Project, who once advocated using nuclear explosives to mine the oil shale. "*What you can do here is to drill down under the shale, blow up a nuclear explosive, maybe 50 kt., maybe 100 kt. There would be an earthquake on the surface, so you better move the people out. But it is a desert area where for one shot you have to move out maybe 50 people. And the damage found afterwards in the few buildings is quite small. It's a moderate earthquake, not a very big one*." (Dr. Edward Teller, in a presentation at Hillsdale College as part of the Center for Constructive Alternatives seminar titled "Energy or Exhaustion: The Planet as Provider.") (http://www.hillsdale.edu/news/imprimis/archive/issue.asp?year=1975&month=07)

● **Tar sands**

Tar sands are sedimentary rocks or sands impregnated with tar oil asphalt, or bitumen. The oil in tar sand is recovered by mining the sand and extracting the oil with hot water. Some 75% of the world's known tar sand deposits are in the Athabasca Tar Sands near Alberta. Current production of the Athabasca Tar Sands is about 10% of North American oil production. Again, the environmental cost is enormous.

Web Resources

http://tonto.eia.doe.gov/dnav/pet/pet_crd_top.asp A link to the most recent annual data on U.S. oil and gas reserves.

http://www.hubbertpeak.com/gas/eia/ Natural gas statistics

http://www.census.gov/prod/2001pubs/statab/sec19.pdf U.S. Energy Statistics from 2000 from U.S. Statistical Abstracts (Census Bureau).

http://energy.usgs.gov/oilgas.html USGS site with statistics on hydrocarbons, coal, inventories, etc.