Chapter 18

FOSSIL FUELS AND THE ENVIRONMENT

Lecture Launchers

Sport utility vehicles – 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, s 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.

18.1 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).

18.2 CRUDE OIL AND NATURAL GAS

● Fossil fuel is really organic matter made by plants that was trapped in the earth without a chance to decompose. Most deposits are found at plate boundaries in depositional basins that were buried. Petroleum and natural gas form during 1000s of years of heat and pressure. Petroleum and gas are light and will migrate to the surface 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 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

known 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.

● 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.
2. Proven reserves are about 1 trillion barrels. World consumption is 27 billion barrels/yr. (10^{12}/27 x 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.
3. U.S. oil reserves will be gone by 2090, world oil will be gone by about 2100.
4. Oil exploration will end when the energy cost of exploration approaches the energy content of the discoveries.

● 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 70 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.

● Coat-bed methane – There is a considerable amount of methane associated with coal beds that can be tapped by drilling. The technology is developing. There are significant problems with the disposal of polluted water that is produced when the methane is recovered.

● 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 then known oil, NG and coal reserves. However, these deposits occur at great depths (>1 km), and the technology does not currently exist for extracting methane hydrates.

● Environmental effects of oil and NG 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 other impacts.

18.3 COAL

● Coal is the world's largest conventional source of fossil fuel (See table 18.1). There are different types of coal that vary greatly in energy and sulfur content. The high sulfur content of some types of coal pollute the atmosphere.

● 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. The environmental impacts are severe. They range from acid mine drainage to outright elimination of whole landscapes. Land reclamation practices required by law vary by site. Underground coal mining accounts for 40% of coal production in the U.S.

This method also produces acid mine drainage from the mine tailings and sometimes coal fires that burn for decades.

● 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.

● The future of coal – Coal accounts for about 60% of the electrical energy production in the U.S., about 25% of toal energy consumption, and about 90% of total energy reserves. 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.

● Allowance trading – The DPA 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.

18.4 OIL SHALE AND TAR SANDS

●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. Edward Teller once advocated using nuclear explosives to mine the oil shale. Quoting Teller: "*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*."

● 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.

A CLOSER LOOK: THE ARCTIC NATIONAL WILDLIFE REFUGE

● 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 Bush administration and oil industry favor 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.

A CLOSER LOOK: THE TRAPPER MINE

● The Trapper Mine on the west slope of the Rockies in N. Colorado is a large coal strip mine. 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%. When the mine is abandoned after 35 years in operation, the value of the land will be much greater because of the reclamation.

CRITICAL THINKING ISSUE

● Should the tax on gasoline be raised? In general, if there are "external" costs or benefits or both, economists refer to these as "externalities." The idea is that the decision-maker, who does not pay for the costs, doesn't take them into consideration in deciding how resources shall be used. With respect to gas consumption, the externalities include a number of environmental costs for which the U.S. consumer does not pay. About 60% of the air pollutants emitted into the atmosphere are from autos, and 25% of CO_2 emissions are from fossil fuel combustion. The health costs of treating people for respiratory illness and for time lost from work can be quantified. It is not easy to quantify the cost of global warming, because we cannot predict all of the consequences. But can anticipate that there will be large costs associated with protecting or moving coastal cities as sea level rises, with the spread of tropical diseases to the northern hemisphere, and with disruptions to agriculture. In addition, as discussed in the previous chapter, the cost of a large military presence in the Middle East is not reflected in the price of gasoline. Should the tax on gasoline be raised?

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.