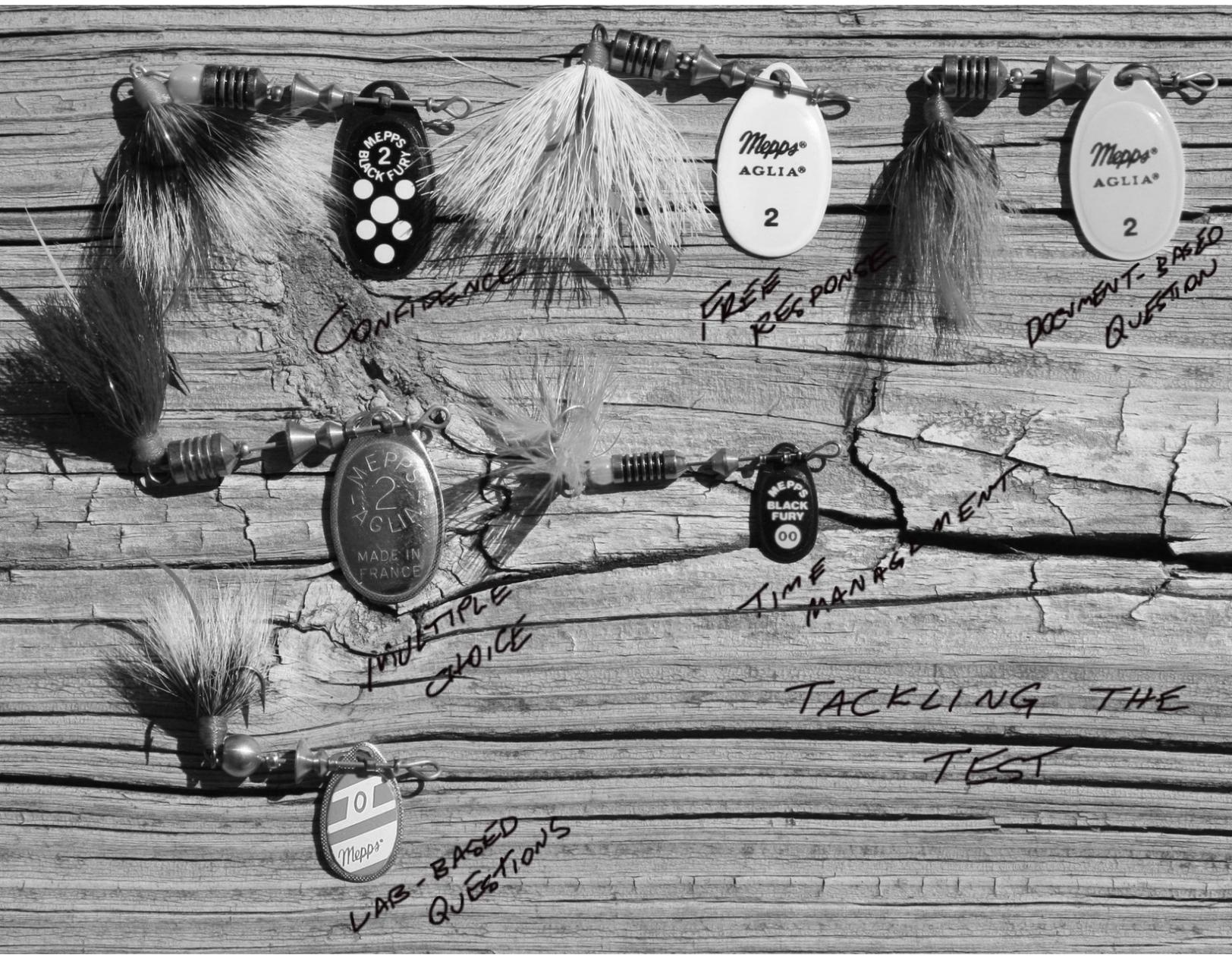


# ENVIRONMENTAL SCIENCE

## Non-renewable Energy



# Non-renewable Energy

## Historical Energy Consumption in the United States and the Rest of the World

Historically, energy use in the United States has been reflective of energy use in the rest of the world. Wood energy was the main energy source from colonial times to late in the nineteenth century. Coal supplanted wood as the main energy source in the United States around 1885.<sup>1</sup> Petroleum and natural gas passed coal around 1950. The US Atomic Energy Commission built a pressurized water nuclear reactor (PWR) in Pennsylvania in 1957. Coal, oil and natural gas are the most important energy sources, but in many of the less-developed countries these sources are not the primary energy source. Draft animals, humans and biomass are the dominant energy sources in these countries. The more these countries develop their economies, the more these countries will rely on coal, oil and natural gas. Energy used in the industrialized world, as well as in the United States, comes from fossil fuels. Fossil fuels account for 84.9% of the United States annual energy use. The worldwide demand for energy is expected to almost double in every category except nuclear by 2050.<sup>2</sup>

## Fossil Fuel Resources and Use

### Coal

Coal is a fossil fuel that exists in a solid, rock form. Coal is formed from the remains of ancient Carboniferous (290 MYA) plants that were subjected to pressure and heat over many millennia. Coal's major component is carbon. It also contains sulfur, water and other materials. Carbon content and heat content increase with the age of the coal.

There are three types of coal:

**Lignite** - lowest carbon content ( $\leq 35\%$ ) and lowest heat value; called "brown coal"

**Bituminous** - coal with carbon content from 45% to 86% and a moderate heat value; most abundant form of coal in U.S.

**Anthracite** - highest carbon content (up to 98%) and highest heat value

In the late 1990's, the United States produced over one billion short tons of coal. This was second only to China. This coal is extracted in a variety of ways from the lithosphere. **Subsurface** mining employs adits and tunnels to reach the coal below the surface. This is generally more "environmentally-friendly"; however, it is considered by many as the world's most dangerous occupation. Coal is also extracted through **surface** mining. Surface mining falls into two categories. **Open-pit mining** is used when a bed of coal is wide and deep. **Overburden** is removed from the top of the ore and digging is continued until the ore is gone. **Strip mining** is the second type of coal mining. This is used when the bed is wide but not deep. The coal is removed in rows or strips. As additional rows are excavated, the overburden is used to fill previous strips.

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<sup>1</sup> <http://www.eia.doe.gov/emeu/aer/eh/frame.htm>

<sup>2</sup> History: Energy Information Administration, International Energy Annual 2005, <http://www.eia.doe.gov>

Coal is used to produce 41% of the world's electricity.<sup>3</sup> Electricity is generated by coal in a **coal-fired power plant**. To produce electricity, the coal is pulverized and burned. The burning coal is used to boil water and generate steam. This steam is used to spin a turbine, which drives a generator to produce electricity. The steam is then condensed, and the resulting hot water is sent to a cooling tower or cooling ponds. The burning of coal produces toxic emissions. Emissions can be passed through an **electrostatic precipitator**. As it passes through an electrostatic precipitator, particulate matter is removed by induced electrostatic charge. Once the particulate matter is charged, it falls into a collection chamber and the toxic ash is disposed. The emission gases can also pass through **wet scrubbers** to remove pollutants. When the smoke passes through a wet scrubber, the particulates are removed by passing through a watery mist that traps the pollutants. This results in a liquid waste product that must be removed.

Advantages of coal include its relative abundance and its high net energy yield. Disadvantages include habitat destruction, land subsidence, soil erosion, leaching of toxic materials, high CO<sub>2</sub> emissions. Coal-fired power plants are major contributors of **sulfur dioxide**, a major contributor to acid rain. U.S. coal-fired power plants owned by utilities emitted an estimated 50 tons of **mercury** in 2000, the largest source of man-made mercury pollution in the U.S. Coal is considered the “dirtiest” of the fossil fuels. Due to the abundance of coal, many advocates propose the conversion of coal to **synfuel**. This can be easily transported and is an alternative to oil; however, it has a low net energy yield when converted and produces large amounts of pollution.

## Oil

Oil is also a fossil fuel produced by the decomposition of organic matter from plants and animals subjected to high temperature and pressure over millions of years. Oil or **petroleum** consists mainly of hydrocarbons (simple organic compounds that consist only of hydrogen and carbon). It also includes small amounts of sulfur, oxygen and nitrogen. When extracted from the ground it is called **crude oil**. This crude oil has to be refined to produce diesel, gasoline, heating oil and other fuels. Crude oil is also used in the manufacturing of petrochemicals. These are used to produce pesticides, cosmetics and nylon.

Oil is not evenly distributed. The major oil **reserves** (identified deposits that can be extracted at a profit with current technology) are controlled by OPEC or the Organization of the Petroleum Exporting Countries. These thirteen countries account for 67% of the world's reserves with Saudi Arabia having the most. Reserves are expected to be depleted in 40 to 80 years depending on consumption and technology.

Oil has certain economical advantages. It is easily transported. Oil has a high net energy yield. Oil is also a relatively cheap fuel. The disadvantages of oil include low reserves and pollution. Habitat destruction is also a problem encountered throughout the extraction process. Carbon dioxide is also produced in great quantities with the combustion of fuels derived from oil. Hydrocarbons that could potentially be used for energy are also found in **oil shale** and **tar sands**.

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<sup>3</sup> <http://www.worldcoal.org/pages/content/index.asp?PageID=188>

## Natural Gas

Natural gas is a mixture of methane, propane and ethane. It was created by the breakdown of long hydrocarbon chains into smaller chains. It is generally found near crude oil reserves. To transport natural gas internationally it has to be liquefied (**LPG**). This is often costly and dangerous. Russia and Kazakhstan have the largest supply of natural gas. Natural gas is cheaper than oil and has estimated reserves that exceed oil. Natural gas also has a high net energy yield. Furthermore, when compared to the other fossil fuels it burns the cleanest. The disadvantages include the cost in energy of conversion to a liquid. It also contains methane which when released is a more effective greenhouse gas than carbon dioxide.

## Nuclear Energy

When nuclear power plants were developed in the United States in the 1950s, the government thought this would provide a cheap, dependable source for the production of electricity. However, the high cost of operation, disposal of radioactive wastes and incidents like Three Mile Island have kept nuclear energy at a small percentage of electricity production in the United States and in the world (17%).

Nuclear reactors produce electricity when **uranium-235 isotopes** undergo controlled nuclear fission, which in turn produces heat that converts water into steam. The steam produced turns a turbine attached to a generator that produces electricity. The nuclear power plant can be broken down into three parts. (Figure 1)

**Containment structure** – Houses the steam generator and the reactor core

Core contains **fuel rods** of uranium fuel. It also contains **control rods** made up of neutron absorbing material that control the rate of fission.

**Steam generator** – Coolant from the reactor passes through this area heating a clean-water loop to produce steam.

**Generator** – Steam produced from the steam generator turns a turbine attached to a generator to produce electricity

**Cooling system** – The cooling tower receives and cools the water from a closed loop after it is used to cool and condense the steam used to turn the turbine

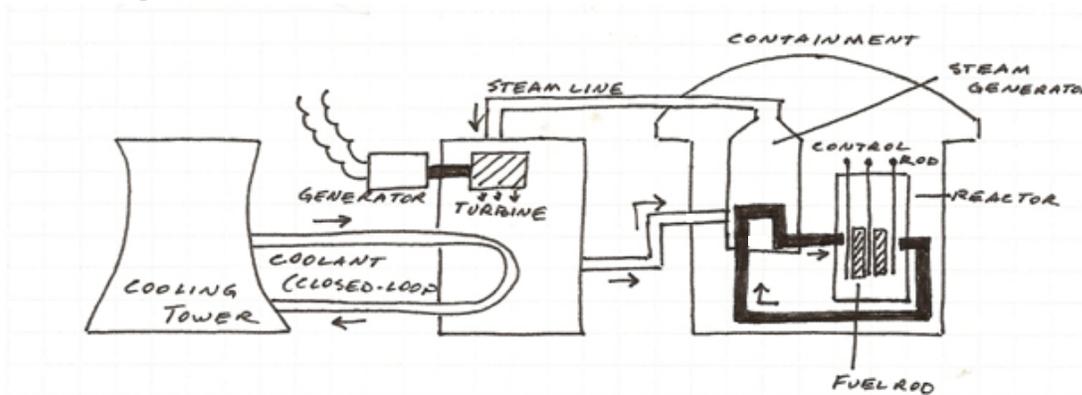


Figure 1

After 15-40 years of operation, the plant must be decommissioned. This is accomplished by dismantling the plant or by enclosing the plant in a containment structure that will last several thousand years.

The advantages of nuclear power include no air pollution, minimal water pollution and minimal land degradation. However, the disadvantages are great. Plant safety is a serious issue with not only the Three Mile Island incident in the United States, but also Chernobyl in the former Soviet Union. The disposal of the radioactive waste is also a huge deterrent of nuclear energy. High-level radioactive waste has to be stored for thousands of years. Ultimately, the United States wanted to construct a deep geologic repository for disposal of high-level radioactive waste at Yucca Mountain, Nevada. This project has been grounded with many obstacles.

