Fossil Fuels

Definition of Fossil Fuels

Fossil fuels are energy resources derived from the altered remains of living organisms that were buried by sediments and exposed to elevated pressures and temperatures for millions of years. Fossil fuels can be: **solids**, as in the case of coal which is derived primarily from land plants; **liquids,** such as oil or tar sands; or **gas**, such as methane. Oil and gas hydrocarbons are derived primarily from the remains of marine plants.

There are three basic forms of fossil fuels: coal, natural gas, and petroleum (crude oil). Because of the long time it takes to create these materials, they are *non-renewable*, meaning that more will not be made during anyone's lifetime, or even during modern civilization of humanity on the Earth.

How are fossil fuels obtained?

To obtain the raw materials that we make into fossil fuels, we need to find them and then extract them from the ground. Coal is preserved by the earth in a rock layer called a coal seam; mining is the only way to remove it whether it's near the surface or deep underground. Oil and natural gas are preserved inside rocks which contain and trap these fluids in the earth. We locate these fluids using seismic reflections in which vibrations reflect off layers within the earth, and show where there are light fluids such as oil and gas. We gain access to them through drilling and then set up wells to draw them up to the surface. Once all these raw materials are gathered, they are sent to processing plants to become fossil fuels that are usable by consumers.

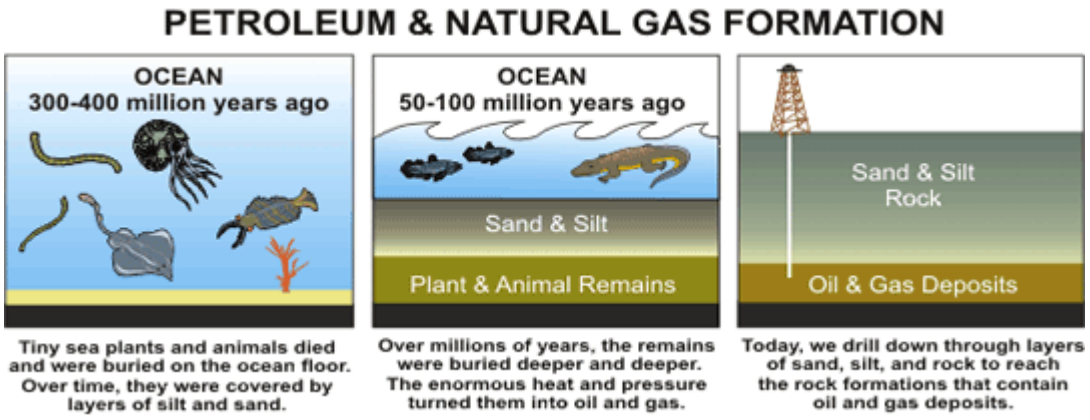
What are fossil fuels used for?

Fossil fuels are used for just about everything. They take the form of many different types of fuels—for heating, cooking, and transportation. Also, they are used to make many everyday products and used as raw materials too!

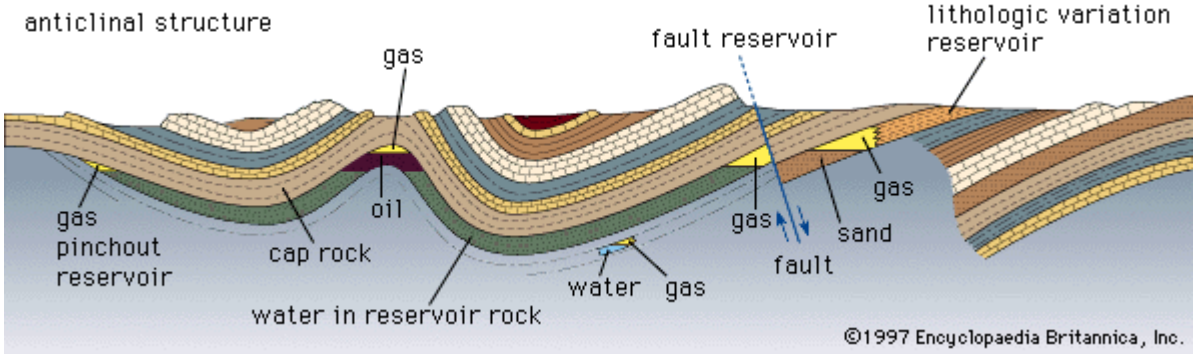
Petroleum (Crude Oil): An Introduction

Petroleum, otherwise known as crude oil (and often referred to as oil), is the altered remains of marine micro-organisms, or *plankton*. Buried under millions of years of sediment, petroleum (crude oil) needs to be extracted from the earth through drilling.

Millions of years ago, micro-organisms died, settled to the sea floor, and were buried by sediment. As time passed, the thick piles of sediments buried the remains so deeply that they were subjected to high pressures and temperatures. The heat and pressure drove off oxygen and left behind petroleum (crude oil) consisting mostly of hydrogen and carbon, or *hydrocarbon*.



Petroleum (crude oil) forms in broad areas called *source rock*. In order for petroleum—once formed—to be useful, it must be accessible for drilling from oil wells. So, the petroleum (crude oil) has to migrate and become concentrated in a much smaller space called a *reservoir*. Oil companies drill into these areas to pump out the petroleum (crude oil).



Because petroleum (crude oil) is less dense than water and the ground is saturated with water, the petroleum (crude oil) and gas move up the slopes of deformed sedimentary layers to get caught under structural domes, adjacent to faults, or against impermeable rock layers in *stratigraphic traps*.

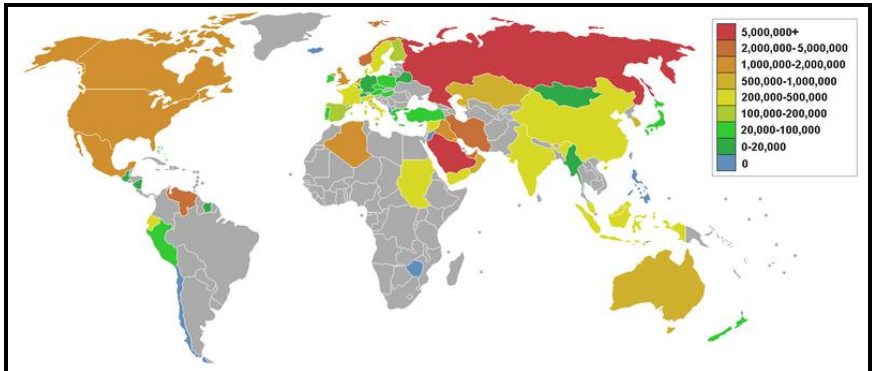
DID YOU KNOW? Petroleum (crude oil) does not come from dead dinosaurs, despite some perceptions, cartoons, and commercial ads.

Petroleum (Crude Oil): Production and Consumption

In order to use the petroleum (crude oil), it must be refined. Once refined, it can be used in a variety of items including gasoline and diesel fuel.

Changing petroleum (crude oil) into gasoline is done in large refineries such as the one pictured here. In a refinery, the petroleum (crude oil) is chemically altered so the gasoline will burn in predictable ways. Basically, the chains of carbon atoms with attached hydrogen atoms are forced to change shape into specific forms.

Fuels are the most common use of petroleum (crude oil). However, petroleum is also used in plastics, wax, asphalt, and many other products.



Oil Exports

Today, petroleum (crude oil) is found on most of the world's continents, but is unevenly distributed. The processes that form petroleum (crude oil) are very specific and lots of conditions must be satisfied. Ideally, there needs to be good proximity of a source rock to a reservoir rock and a good stratigraphic or structural trap. Most of the world's oil is found in the Middle East where conditions for petroleum (crude oil) formation are the most ideal.

Petroleum (Crude Oil) and the Environment

Currently, in the United States, we rely on petroleum (crude oil) as our primary energy source. Unfortunately, obtaining, transporting and using petroleum (crude oil) all have costly consequences on the environment.

Drilling

Extracting petroleum (crude oil) from the ground is not only a costly process but can be environmentally damaging. Drilling on land requires a lot of land use which can disturb local habitats. Two major concerns are that drilling mud is stored in ponds and industrial roads are built in natural areas. Off shore drilling impacts the surrounding marine ecosystem. Specifically, artificial islands are often built in shallow offshore areas.

Spills

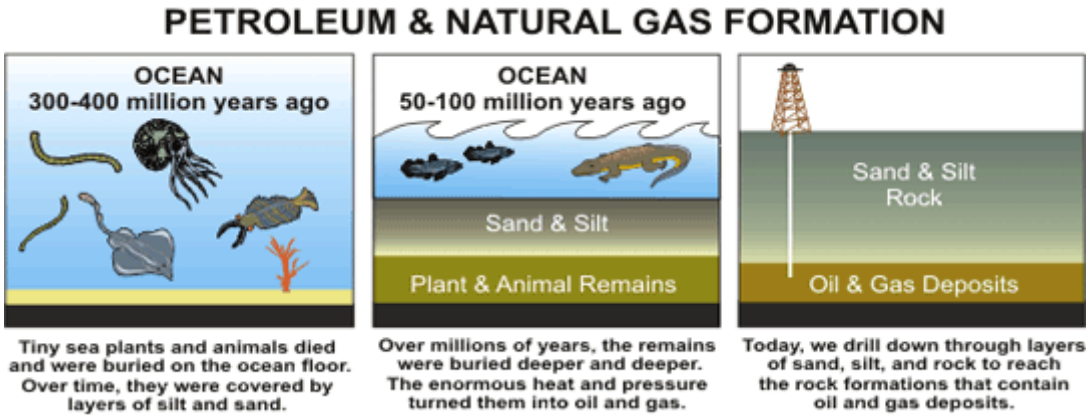
Since petroleum (crude oil) is toxic and not biodegradable, any type of spill has a harmful effect on the environment. Oil spills are responsible for destroying numerous ecosystems around the world. When an oil tanker spills at sea, oil slicks spread easily over the water killing lots of plant and animal species. The only way to repair the problem is months—or sometimes years—of human intervention.

Pollution

Refineries emit toxins into the air and water as they process petroleum (crude oil) into usable oil. Then, as they are used, the burning of petroleum products emits toxic substances into the air. The carbon dioxide that is released is contributing to global warming. Other byproducts have been connected to heart disease and respiratory illnesses in humans. The polluted air also affects our plants and animals.

Natural Gas: An Introduction

Natural gas occurs underground when petroleum (crude oil) matures further under high pressure and intense heat. Just like petroleum (crude oil), which is buried under millions of years of sediment, natural gas needs to be extracted from the earth through drilling.



When petroleum (crude oil) matures further under high pressure and temperature deep underground, the carbon atoms no longer bond to each other. Each carbon atom is surrounded only by hydrogen atoms. This makes natural gas, or methane. The gas rises to the top of reservoirs, gets trapped by the cap rock, and often sits on top of the liquid petroleum (crude oil) beneath it.

Drilling is used to find trapped gas underground. Then, a well is built. The gas naturally flows up to surface level.

From the well, the natural gas is transferred into pipelines which transport the gas to a processing plant.

A processing plant may be connected to over a 100 wells in the area through a complex system of interconnecting pipelines.

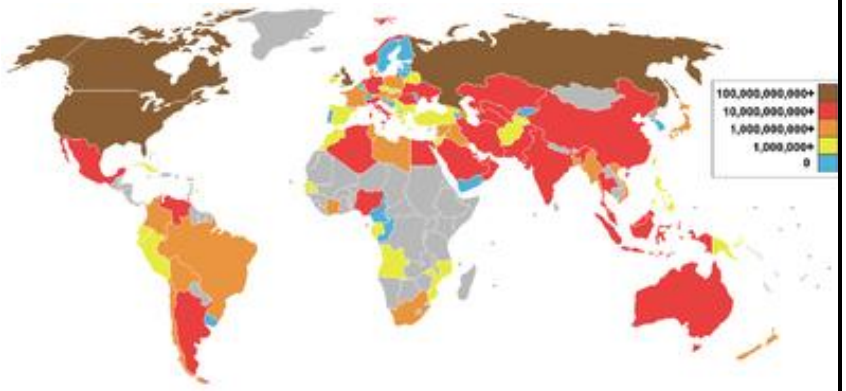
DID YOU KNOW? Natural gas is difficult to transport across oceans and does not sell at as high a price as petroleum (crude oil). For this reason, for many years, it was simply burned off from the tops of petroleum (crude oil) reservoirs so that oil companies could get to the more valuable petroleum (crude oil) beneath.

Natural Gas: Production and Consumption

In order to use natural gas as fuel, it must undergo some type of processing. Once refined, it can be used for a variety of things including electricity generation, heating, and cooking.

Changing raw gas into sales gas is done in processing plants such as the one pictured here. In a plant, the raw gas is purified into almost pure methane, which is then used by customers as consumer-grade gas. During purification, some of the by-products that are derived are also commercially usable, such as ethane, butane and propane.

Many homes use natural gas for heating and cooking. Natural gas also supplies our economy with a variety of commonly used fuels. Additionally, natural gas is used in the manufacture of many common products including fabric, glass and paper. It's also used as a raw material in paints, plastics, and fertilizer.



Natural Gas Production

Russia has the world's largest gas reserves. Qatar and Iran are home to the world's two largest gas fields. The USA, a large producer of natural gas, was able to produce enough for the country's consumption needs until 1986. Since then, gas imports have been necessary to meet demand. 90% of those imports arrive via pipeline, mainly from Canada. The remaining 10% arrive via tanker from overseas.

DID YOU KNOW? Gas is odorless and colorless so—during processing—they add a chemical to the gas which smells like rotten eggs.

Natural Gas and the Environment

In its raw form, natural gas is a greenhouse gas. After it's been processed, natural gas burns cleaner than other fossil fuels. It's currently considered an important fuel source, but it's still a substantial contributor to global warming.

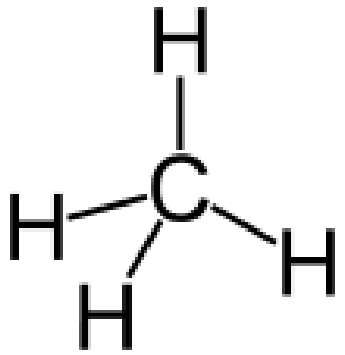
Drilling

Looking for natural gas deposits and drilling for them is harmful to habitats on both land and sea. New horizontal and directional drilling procedures are trying to maximize the amount of gas obtained from a single source and minimize the impact on the surrounding environment.

Leaks

If released into the atmosphere in its raw form, natural gas can be much more potent and dangerous than carbon dioxide. Unfortunately, small leaks can sometimes occur in the storage and transportation infrastructure such as wells, tanks or pipelines. A leak can lead to an explosion.

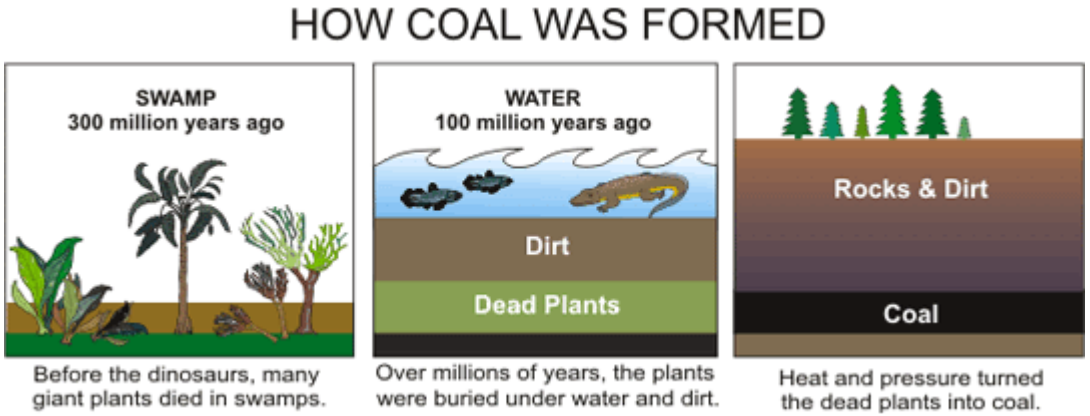
"Cleanest" Fossil Fuel



Natural gas is the most evolved fossil fuel because it contains only carbon and hydrogen. Compared to coal and oil, it has fewer emissions. In fact, it burns the most cleanly forming only water and carbon dioxide in the process. Almost no ash particles are left behind. Lastly, because of its chemistry, natural gas provides the most energy per carbon dioxide molecule emitted.

Coal: An Introduction

Coal is not derived from marine micro-organisms, but is the compressed and baked remains of land plants. Unlike petroleum (crude oil) and natural gas, coal is often located near the surface and can be extracted from the earth through mining.



Usually when plants die, they rot and oxidize. Ultimately, they turn into carbon dioxide and water. However, if the plants are quickly buried by other plants, sediments from a flood, or in a swamp that has no oxygen dissolved in the water, they do not oxidize and are preserved. Over millions of years, high pressure and temperature drives off both the hydrogen and oxygen from the dead plant material, leaving only the carbon behind. This leftover carbon becomes a coal seam.

The only way to extract the coal from the earth is to establish a coal mine. The design of a coal mine is based on a number of environmental factors as well as the depth and quality of the coal seam. There are two main types of coal mine designs: surface mines and underground mines. In the United States, surface mining is more frequently used since it is less expensive.

Surface mining is used when the coal seam is close to the surface. A surface mine can be used if the coal seam is less than 200 feet underground.

Underground mining is used when the coal seam is deep underground. About 60% of the world's coal is extracted through underground mining.

Hobet mine in West Virginia

1984 2009

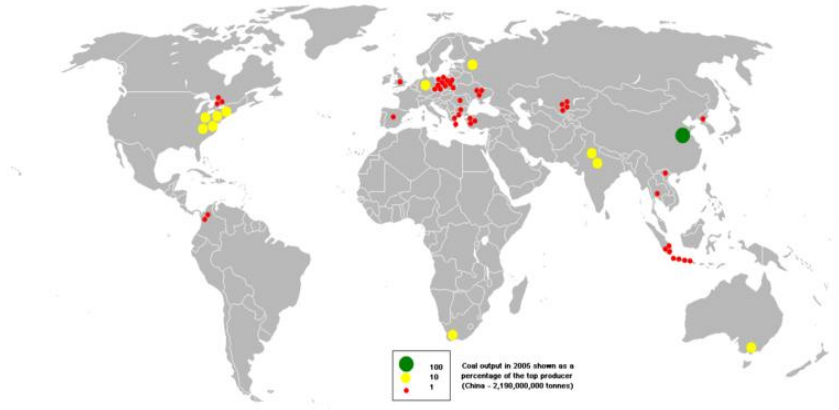
Mountaintop mining is a type of surface mining where entire coal seams are removed from the summit of a mountain. The impacts can be severe to be human health and the environment.

Coal: Production and Consumption

Once coal is mined, it goes through a cleaning process to increase its heating value. Then, it is transported and ultimately burned to release its energy.

Once the coal is extracted from the ground, it usually goes to a preparation plant located near the mine similar to the one pictured here. The plant washes the coal to clean away unwanted materials—like rocks, dirt, and ash—which increases the coal's heating value.

Coal is most commonly burned in electric power plants to provide electricity to the grid. Most of the US coal is used for electricity. A small amount is exported. The remaining coal is used in a variety of industries—such as steel, paper, and cement. These industries use not only the coal's heat but also some of its byproducts.



Global Distribution of Coal Output

50 countries around the world mine coal. It's found almost everywhere in the world, and remarkably, is almost absent from the Middle East. The purest, hardest form of coal—anthracite—is found in Pennsylvania. So much has been extracted over the years that there is very little left. However, there are large amounts of lesser types of coal throughout America and all over the world.

DID YOU KNOW? Because coal is so plentiful, it is relatively cheap… if you do not account for the environmental damage it creates.

Coal and the Environment

Industry has found ways to reduce the pollutants emitted by burning coal. The media refers to this as *clean coal technology*. However, the fact remains that, of all fossil fuels, coal produces the least energy per carbon dioxide molecule emitted to the atmosphere, thus enhancing the greenhouse effect and leading to global climate change.

Impact on Land

Surface mining severely changes the natural landscape. Existing vegetation is eliminated. The soil profile is drastically altered. Animal habitats are destroyed which means local wildlife either die or get displaced. Further, the general topography of the landscape changes and loses aesthetic appeal. The mining of coal has led to denudation of large areas of the countryside in places like West Virginia and Pennsylvania.

Impact on Water

Coal mines produce an outflow of acidic water called *acid mine drainage*. Throughout the country, streams and rivers that flow past coal mines become contaminated with acids that make them uninhabitable for fish and other wildlife as well as impossible for people to drink. Acid mine drainage is exacerbated when a mine is abandoned because the mine will flood creating more acidic outflow. Even liquid that drains from coal during storage and transport is also highly acidic and impacts water resources.

Impact on Air

The nitrogen and sulfur oxides emitted from burning impure coal react with water in the air producing acid rain. Acid rain can negatively impact the surface waters, aquatic animals, soils, forests, and other vegetation. Coal burning releases carbon dioxide into the air which is a main contributor to global warming and climate change. Even worse, coal mining produces methane which is even more potent than carbon dioxide. For these reasons, using coal for energy is troubling for human health and the sustainability of our planet.

DID YOU KNOW? Coal is considered the "dirtiest" of all fossil fuels because there are usually large amounts of sulfur and nitrogen in it. When those elements are burned they make sulfuric acid and nitric acid which cause acid rain and other forms of pollution.

Transportation of Fossil Fuels

Despite their negative environmental impacts, fossil fuels are still in high demand.
This means they need to be transported around the country--and sometimes—around the world.

Petroleum (Crude Oil)

Petroleum (crude oil) is relatively easy to transport, but can cause catastrophic damage if spilled. The safest and cheapest way to transport large amounts of petroleum (crude oil) over land is via pipelines. Construction, placement of the pipeline and control of the pipeline often figure heavily in politics between states and countries. When petroleum (crude oil) needs to travel overseas, oil tankers are used.

Natural Gas

Natural gas is easy to transport over land in pipelines, but difficult to transport over oceans due to its low density and thus large volume. Increasingly, countries are importing and exporting natural gas in a liquefied form. If natural gas is chilled to about -260°F, it changes to liquid form and can be easily transported and stored. It takes up much less space and can be loaded into domed tanks, like the ones pictured on the tanker above. The tanks hold the gas in liquefied form until it's needed, then it is converted back into gas and sent through pipelines to consumers.

Coal

Transporting coal can be costly but there are many ways to do it. Most of the coal in the USA travels by train, at least for part of its journey from mine to market. Near the mine, coal can be moved around by trucks and conveyors. River barges and ships are often a cheaper means of transport than trains but are obviously limited in where they can go. Finally, if the coal is crushed and mixed with water, it can even travel through a pipeline!