# Introduction to Oil and Gas

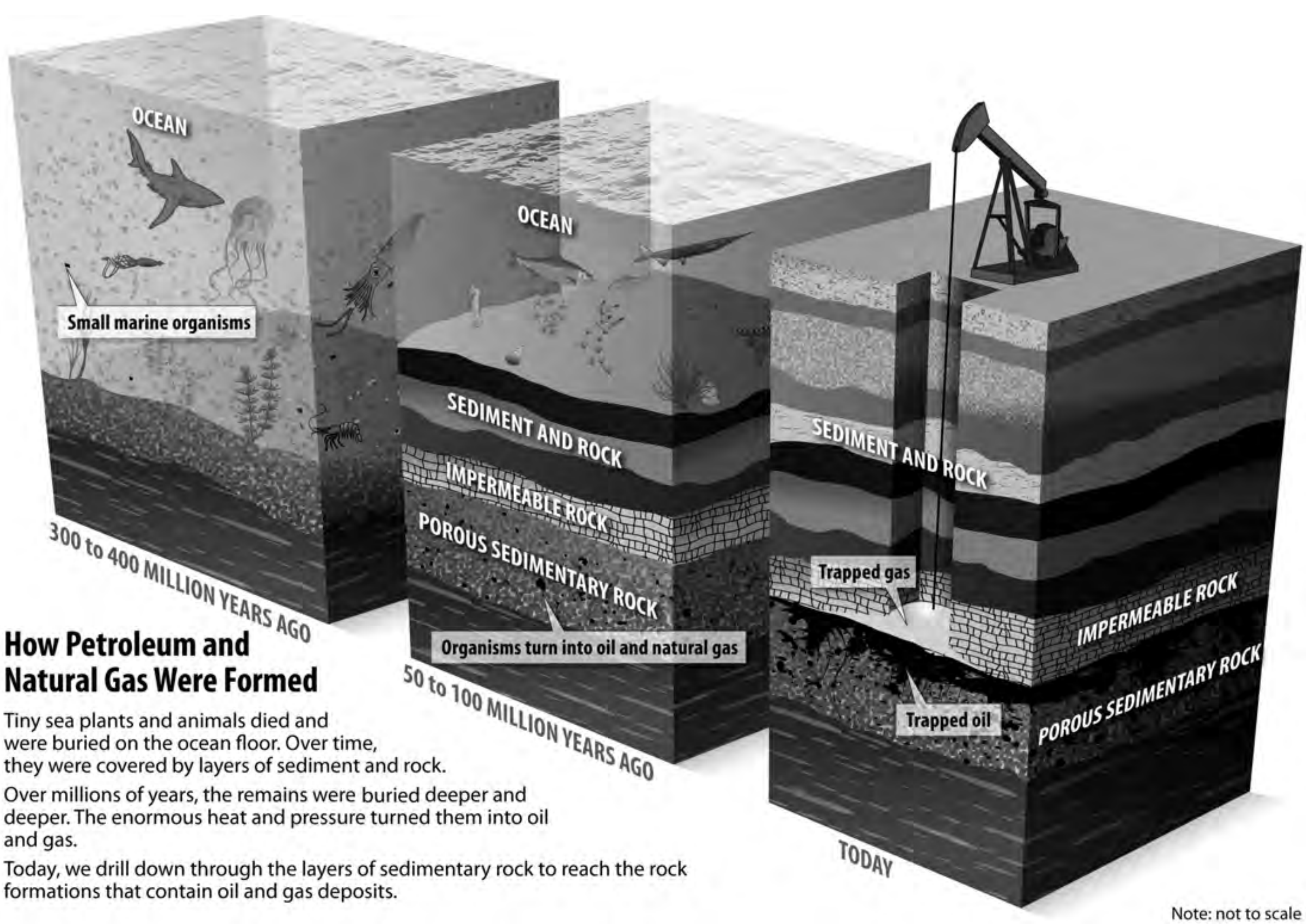
## What is Petroleum?

Petroleum is a fossil fuel. Petroleum is often called crude oil, or just oil. It is considered a fossil fuel because it was formed from the remains of tiny sea plants and animals that died millions of years ago. When the plants and animals died, they sank to the bottom of the oceans. Over time, they were buried by thousands of feet of sand and sediment, which turned into sedimentary rock. As the layers increased, they pressed harder and harder on the decayed remains at the bottom. The heat and pressure eventually changed the remains into petroleum. Petroleum is classified as a nonrenewable energy source because it takes millions of years to form. We cannot make new petroleum reserves in a short period of time.

Even though oil and natural gas come from ancient plant and animal matter, in geologic time, they are young. Most oil comes from rocks that are about 400 million years old or younger. Scientists believe the Earth is over four billion years old, with life existing on Earth for about 3.7 billion years. Dinosaurs first roamed the Earth about 248 million years ago.

Like all living things, petroleum is a mixture made of several carbon compounds such as hydrogen butanes and olefins, and is an excellent source of energy. Because the living things that turned into petroleum did not have the opportunity to complete the decay process, there is a great deal of chemical energy in their molecular bonds.

Petroleum deposits are locked in porous rocks like water is trapped in a wet sponge. Petroleum, just out of the ground, is called crude oil. When crude oil comes out of the ground, it can be as thin as water or as thick as tar. The characteristics of crude oil vary in different locations. Some crude is very clear and moves like water. This is usually called light crude. Other crude is very dark and almost a solid at normal temperatures.




**How Petroleum and Natural Gas Were Formed**

Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sediment and rock.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through the layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.

## History of Oil

People have used petroleum since ancient times. The early Chinese and Egyptians burned oil to light their homes. Before the 1850s, Americans used whale oil to light their homes. When whales became scarce, people skimmed the crude oil that seeped to the surface of ponds and streams. Did you know that oil floats on water? The density of oil is less than the density of water, allowing it to float to the top.

The demand for oil grew and in 1859, Edwin Drake drilled the first oil well near Titusville, PA. At first, the crude oil was refined into kerosene for lighting. Gasoline and other products produced during refining were thrown away because people had no use for them.

This all changed when Henry Ford began mass producing automobiles in 1913. Everyone wanted automobiles, and they all ran on gasoline. Gasoline was the fuel of choice because it provided the greatest amount of energy relative to cost and ease of use.

Today, Americans use more petroleum than any other energy source, mainly for transportation. Petroleum provides almost 39 percent of the total energy we use. Nearly one-third of the oil the U.S. produces comes from offshore wells. Some of these wells are a mile under the ocean. Some of the rigs used to drill these wells float on top of the water. It takes a lot of money and technology to find, explore, produce, and transport oil from under the ocean.

Texas produces more oil than any other state, followed by Alaska, California, North Dakota, and Louisiana. Americans use much more oil than we produce. Today, the U.S. imports about two–thirds of the oil it consumes from foreign countries.

## Oil and the Environment

Petroleum products—gasoline, medicines, fertilizers, and others—have helped people all over the world. Petroleum production and use are not without risk, however; environmental damage can result if oil and its products are not handled correctly. If drilling is not carefully regulated, it may disturb fragile land and ocean environments. Transporting oil may endanger wildlife if oil is spilled into rivers and oceans. Burning gasoline to fuel our cars pollutes the air. Even the careless disposal of motor oil drained from the family car can pollute streams and rivers.

The petroleum industry works hard to protect the environment. Gasoline and diesel fuel have been processed to burn cleaner, and oil companies do everything they can to drill, process, and transport oil and its products as safely as possible.

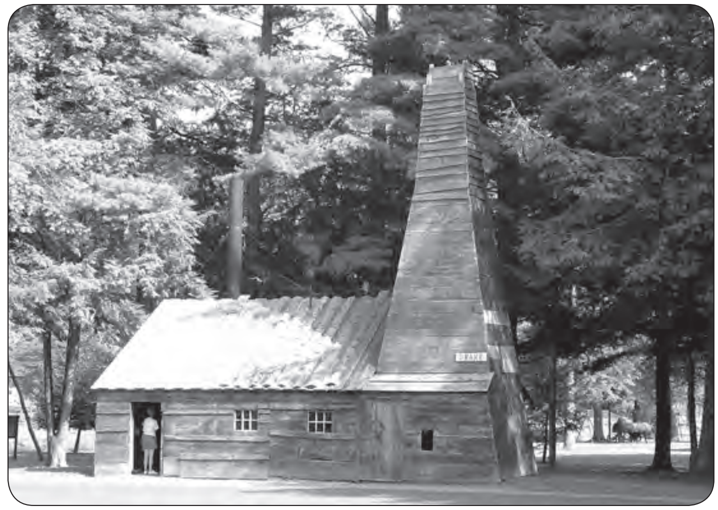
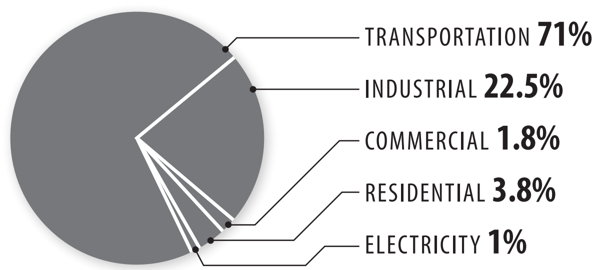


Image courtesy of Doug Stewart, contributor to Wikimedia Commons

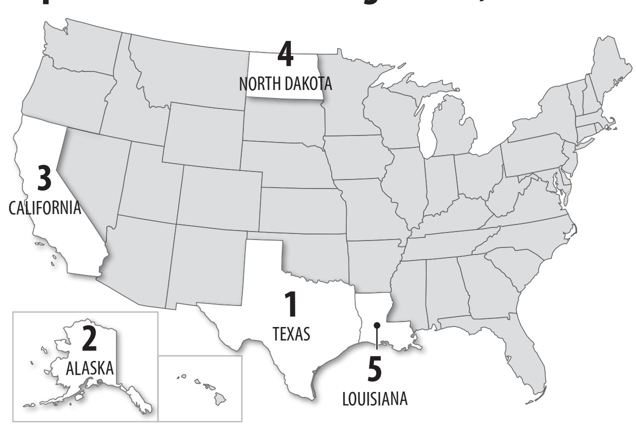
**A replica of the Drake Well in Titusville, PA.**

### Petroleum Consumption by Sector, 2009




Data: Energy Information Administration

### Top Petroleum Producing States, 2009




Data: Energy Information Administration

## What is Natural Gas?

Natural gas is a fossil fuel like petroleum and coal. Natural gas is considered a fossil fuel because most scientists believe that it was formed from the remains of ancient sea plants and animals. When the plants and tiny sea animals died, they sank to the bottom of the oceans where they were buried by sediment and sand, which turned into sedimentary rock. The layers of plant and animal matter and sedimentary rock continued to build until the pressure and heat from the Earth turned the remains into petroleum and natural gas.

Natural gas is trapped in underground rocks, much like water is trapped in the pockets of a sponge. Natural gas is really a mixture of gases. The main ingredient is methane. Methane has no color, odor, or taste. As a safety measure, gas companies add an odorant, mercaptan, to the natural gas that we use in our homes and buildings so that leaking gas can be detected (it smells like rotten eggs). Natural gas should not be confused with gasoline, which is a petroleum product.

Natural gas from underground reservoirs is considered a nonrenewable energy source, which means we cannot make more in a short time.

## History of Natural Gas

The ancient people of Greece, Persia, and India discovered natural gas many centuries ago. The people were mystified by the burning springs created when natural gas seeped from cracks in the ground and was ignited by lightning. They sometimes built temples around these eternal flames and worshipped the fire.

About 2,500 years ago, the Chinese recognized that natural gas could be put to work. The Chinese piped the gas from shallow wells and burned it under large pans to evaporate seawater to make salt.

In 1816, natural gas captured from a coal coking plant was first used in America to fuel street lamps in Baltimore, MD. Soon after, in 1821, William Hart dug the United States' first successful natural gas well in Fredonia, NY. It was just 27 feet deep, quite shallow compared to today's wells. Today, natural gas is the country's second largest source of energy, meeting over 23 percent of our total energy demand.

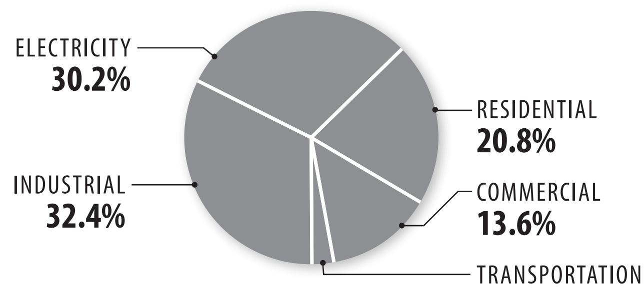
## Who Uses Natural Gas?

Just about everyone in the United States uses natural gas. Industry is the biggest user. Industry burns natural gas to produce heat to manufacture many of the products we use every day. Natural gas is also used as an ingredient, or feedstock, in fertilizer, glue, paint, laundry detergent, and many other products.

Residences, or homes, are the second biggest users of natural gas. Five in ten homes use natural gas for heating, and many also use it for cooking and heating water. Commercial buildings use natural gas too. Commercial users include stores, offices, schools, churches, and hospitals.

Natural gas can also be used to generate electricity. Many utilities are building new power plants that burn natural gas because it is clean burning and natural gas plants can produce electricity quickly when it is needed for periods of peak demand. A small amount of natural gas is used as fuel for automobiles. Natural gas is cleaner burning than gasoline, but vehicles must have special equipment to use it. Many of the vehicles used by the government in national parks operate on compressed natural gas.

### Natural Gas Use by Sector, 2009




Data: Energy Information Administration


**Natural gas is used to power some fork lifts.**

## Natural Gas and the Environment

Burning any fossil fuel, including natural gas, releases emissions into the air, as well as carbon dioxide, a greenhouse gas. Natural gas (and propane) are the cleanest burning fossil fuels because they have fewer carbon atoms to form carbon dioxide. Compared to coal and petroleum, natural gas releases much less sulfur, carbon, and ash when it is burned. Because it is a clean source of energy, scientists are looking for new sources of natural gas and new ways to use it.

## Exploration

### Geology

Oil and natural gas are buried beneath the Earth's crust, on land and under the oceans. To find it, geologists use their knowledge of land and rock formations, the geologic history of an area, and sophisticated technology. Combining all this information, geologists are more likely to be successful when they drill. Even with all this, not all wells produce oil or natural gas. Exploratory wells are drilled if scientists think an area has oil. For every 100 exploratory wells drilled, about 44 of them will find oil.

Forty-eight of every 100 exploratory wells drilled find natural gas. By the time production wells are drilled, the success rate has risen to about 85 percent. To increase the success of drilling, petroleum geologists must be knowledgeable in a number of areas.

### Rock Formation

The field of stratigraphy is the study of rock layers (or strata) to determine the type of rock formation, the age of the layers, the radioactivity of the formations, and other information to determine the composition, origin, and location of rock strata.

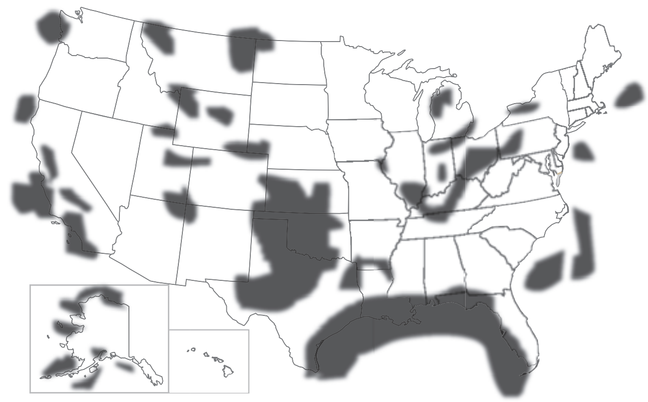
Compiling information on rock formations is an important part of oil and gas exploration. Different types of rock have varying potential for holding oil or gas in a reservoir. There are three different types of rock: sedimentary, metamorphic, and igneous. Every rock fits into one of these three categories.

**Metamorphic rock** began as either sedimentary or igneous rock that was exposed to increased pressure and heat that eventually transformed it into metamorphic rock. Usually metamorphic rock is found near other types of rock. It is also usually denser than sedimentary rock since heat and pressure have removed many of the pores from it.

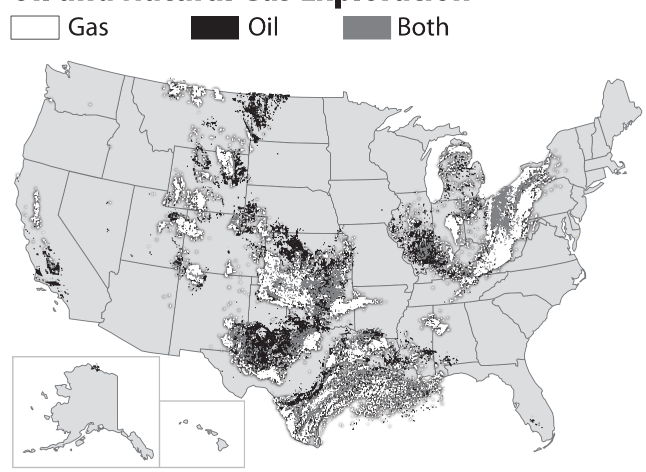
**Igneous rock** is formed from magma, or liquid rock, that exists in the Earth's core. Sometimes where cracks or faults occur in the Earth's crust, magma can seep up and cool, creating igneous rock. Igneous rock can also be created when magma makes its way to the Earth's surface in the form of lava. Igneous rock is usually the densest of the three rock types.

**Sedimentary rock** is formed by the build-up of layers of sand and sediment over time. These layers are created as materials on the Earth's surface are eroded and washed downstream. Over thousands of years, these particles are compressed to create rock. Most oil is found in sedimentary rock. Since sedimentary rock often has many pores, it is an ideal formation to contain oil and natural gas.

### Oil and Gas Basins

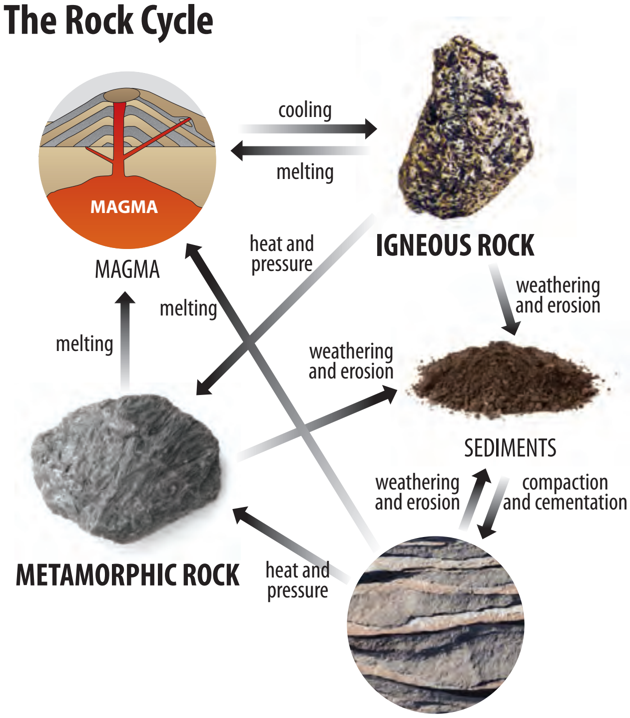


### Oil and Natural Gas Exploration




Data: Energy Information Administration

### The Rock Cycle



## Permeability

Oil and natural gas occur naturally in the Earth's layers, inside of rocks. Rocks are not completely solid; they have tiny holes, or pores, in which air or other fluids were trapped during formation. The porosity of a rock formation is a measure of the number and kind of pores it has.

Fluids can move between rock pores in varying degrees. Permeability is a measure of the ability of a rock to move fluids through its pores. Permeability is a very important feature for finding oil and gas. Being successful at finding oil is partially determined by locating porous rock, as well as locating other fluids, such as water, that are contained in rock formations.

## Geologic History

An important factor in finding oil and gas is understanding the environment that existed in an area millions of years ago. Since oil and natural gas are the remains of ancient sea life, the first step in locating oil is finding areas where ancient seas once existed.

## Seismic Technology

Seismic technology uses sound waves to reveal what lies deep in the ground. Sound waves can travel through some materials more easily than others. When sound waves are directed into the ground and they hit something they cannot penetrate, they bounce back, returning to the surface. Equipment on the surface records the returning waves. Once the waves have all been recorded for an area, the information is taken back to a lab where geoscientists read the waves. A map can then be created of the underground terrain.

The first seismic instruments were used in the mid 1800s to detect earthquakes. Seismic equipment began being used in the oil fields in the 1920s. In those days, dynamite was used to create the sound waves. The data collected had to be read by hand. In the 1960s, digital technology allowed the information to be read by machine. Three-dimensional seismic data was first used in the late 1960s and changed the way seismographs were used. Today, machines called thumpers are used to create shock waves instead of dynamite. To create a 3D image of the layer of ground, not one, but many seismic instruments are used. They are placed in holes around a site. Each of these instruments records sound waves. Then scientists can combine all of these images to get a better understanding of what lies underground.

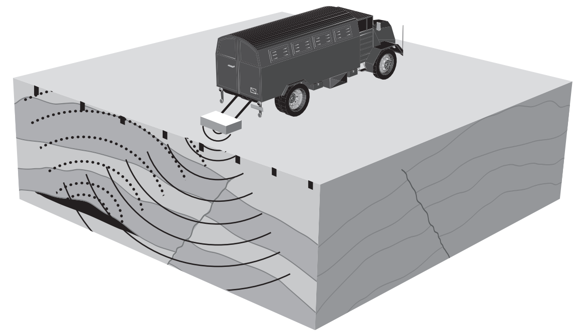
When searching for oil under the sea floor, seismic equipment must be adapted for the marine environment. Seismic systems are placed on ships and the listening devices are attached to long streamers. Many ships have four or five streamers, but some larger ships may have up to 16 streamers.

Another way scientists analyze the ocean floor is with ocean bottom cables. These cables are sent to the ocean floor from a stationary platform. Then, a ship towing air guns passes by. The air guns, directed down, are used to create the sound waves.

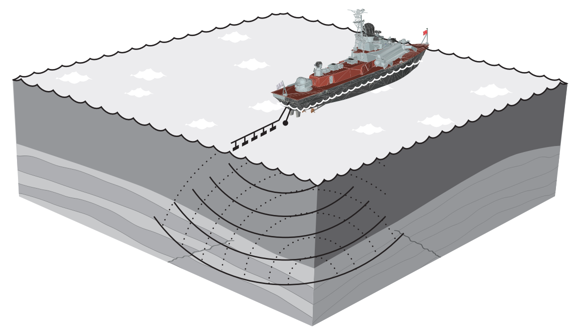
## Interpreting Seismic Output

Today, seismic data is interpreted in high tech ways. 3D visualization puts seismic information into a three-dimensional format that people can more easily understand. One of the most advanced 3D visualization projects is known as the CAVE (Cave Automatic Virtual Environment). The CAVE is an entire room used for visualization. In this virtual reality environment, the walls and floor are used as projection surfaces, giving the appearance of filling the room and allowing scientists to walk into the data.

### Land-based Seismic



### Ocean-based Seismic



THE CAVE 3D SEISMIC VISUALIZATION ROOM

The newest type of seismic technology is 4D seismic. The fourth dimension is time. 4D seismic uses a number of 3D images taken over time to see how they change. This technology is often used in areas that are already producing oil to see how production is affecting the reserve.

Other surveying techniques include gravitational, magnetic, and radioactive processes, all of which measure physical properties of a site and use that information to determine whether oil or gas is present.

# Retrieving the Oil

## Permitting and Leasing Land

Once a site has the potential for oil extraction, companies must get permission to drill. In some areas, this means acquiring the needed permits from state government and leases from landowners to drill on private land. In other cases, the land is federal land and require leases and permits from the U.S. Bureau of Land Management (for onshore drilling) or the Bureau of Ocean Energy Management, Regulation and Enforcement (for offshore drilling). There are also environmental protection measures that must be in place before drilling can begin.

## Drilling

Since the first oil well was drilled in 1859 by Edwin Drake, oil production has become an increasingly complex and precise process. The original methods of drilling for oil were based on ancient methods for finding water and salt. As wells have gotten deeper and more complex, drilling technology has also become more complex.

To drill a well, a large drilling rig is brought to the site. Once it is situated above the desired location, drilling can begin. Roustabouts work on the rig and handle many of the different elements of drilling.

Drill bits have sharp teeth that rotate to tear apart rock while the well is drilled. As the well gets deeper, lengths of 30-foot pipe are attached to the top of the drill. Each 30-foot section must be lifted above the last section into the sky and screwed onto the previous section. This is one of the reasons drilling platforms are very tall.

When drilling an oil well, the rock that is torn by the drill bit (called debris) does not come easily to the Earth's surface. As the hole gets deeper, debris can get in the way, blocking the hole. For this reason, drillers use mud to lift debris out of the well. Drilling mud originally was actual mud found on the drill site. Today, mud is a complex material specifically made for its purpose. Because it is so complex, mud is one of the biggest expenses in drilling.

Mud flow is controlled by the mud engineer. It is pumped down the hollow drilling pipe. It comes out near the drill bit, cooling the bit. The mud then carries debris up through the well as it is pumped, to be collected above ground. One of the reasons mud is so expensive is that it must be formulated with precise density. Since less dense materials float on top of more dense materials, the mud must have a greater density than the rock that is being cut. Drilling mud also keeps the formation, or walls of the well, from collapsing inward.

Once a well has been drilled to the depth of the oil reservoir, the workers move into the next stages—well completion and production. The drilling rig is removed from the site and the well is prepared to begin producing oil.

## Well Completion

After a well is drilled, it must be completed before it can begin producing. There are three main steps in the completion process. The first step is allowing oil into the well so that it can be brought to the surface. The second is making sure that water does not get into the well, and the third is keeping underground rock out of the well.

Completion is not done the same way for all wells. Deciding what to do depends on a number of factors, including the size and shape of the oil reservoir, the surroundings of the reservoir, and the kinds of rocks and oil the reservoir contains.

**DRILL PIPE**

**ROUSTABOUTS**

Image courtesy of StatOil

Oil is contained within rock formations. The nature of these formations affects the way oil is pumped from the ground. There are two characteristics that are very important to predicting how the oil will flow. The first characteristic is porosity. Porosity pertains to the gaps, or pores, between the grains in the rock where oil is stored. Permeability is the second important characteristic; it measures how many of those pores connect to each other. Knowing if the pores connect is important, since these connections are what allow oil to flow to the well. Even though a rock formation is very porous, if it has no permeability, the oil will be difficult to extract.

Most oil formations also contain water, or saturation, near or mixed in with the oil. Producers must be sure to separate this water out of the formation. They must also be sure to avoid contaminating nearby ground water, land, and underground aquifers.

The amount of pressure in a formation is another factor that is very important. Since oil extraction removes mass from the Earth, the stability of the reserve is something that must be considered. While some formations can maintain their shape when oil is removed, others cannot. These formations must be stabilized, allowing them to remain open for fluids to flow.

The last issue to be considered is how well the reserves are connected. Compartmentalization is a situation in which the oil from one part of the reserve cannot flow to another part of the reserve. There may be faults in the ground that disconnect the layers, or pores from one section may not be connected to other sections because of low permeability. There can also be streaks of other types of rock that the oil cannot easily pass through between the well and the oil, or there may be other barriers in the way of the flow.

Once all these issues are taken into consideration, completing the well may begin. To start completion, the well must be open so that oil can flow into it.

### Casing the Well

Drill pipe does not stay in the well after it is drilled. It is replaced with longer, wider casing pipe, which is used to line the well. Usually, casing a well begins before the end of the drilling process. Casing the top of the well occurs as the drill continues to dig deeper into the ground. The final and deepest casing is placed in the well after drilling is complete.

The rock around the well is crushed to allow the oil to flow freely. Shooting nitroglycerin and shattering the rock in the immediate area can crush the rock. The side of the well, or the casing, blocks oil from getting into the well itself. At the levels where oil is present, the casing is perforated to let oil flow. Perforating the casing is done by shooting a very thin, fast jet of gas to penetrate and perforate the casing.

### Cementing

Once casings are in place, cement is used to fill in the gap between the casing pipes and the well wall. Drilling mud is pumped out of the well as cement is pumped in. As the cement is pumped in, the casing is slowly rotated to create a better bond with the cement.

**CHRISTMAS TREE**

**HORSE HEAD PUMP**

**OFFSHORE RIG**

## Production

Once the wells have been completed, they can go into production. Production wells do not have the complex, above ground structures that are in place during drilling. Instead, the wells are capped with smaller units. Ideally, oil is extracted using natural drive, which means there is enough pressure in the well to move the oil and no pumping is needed. Wells with natural drive have christmas trees above ground. A christmas tree, in the petroleum industry, is a series of valves and gauges used to measure and control the flow and pressure of the well.

Other wells do not have enough natural drive to move oil out of the Earth. They must use pumps to lift the oil to the surface. Typically, this is done with a sucker-rod pump, sometimes called a horse head pump because of its shape. Using one-way valves underground near the oil formation, the pump draws, or sucks, oil to the surface. As the horse head pump above ground goes up and down, valves below lift the oil. Pumps may run for only a few hours each day to avoid distorting the way the fluids are distributed underground. Many wells produce only a few barrels of oil a day.

In a well that has a lot of pressure, a blow out preventer, or BOP, is used to avoid explosions. A BOP includes monitors to ensure the well is operating correctly and a set of controls that react to any unexpected pressure change. If there is too much pressure, the man-made elements of the well could be forced out the top of the well or fire could occur.

To monitor a well's progress, comprehensive data logs are kept that track a number of different factors. Radioactive, electric, mechanical, and sonic tools are just some of the ways wells are studied. If monitors indicate unusual well behavior, engineers investigate and attend to the problem.

### Subsea Operations

In offshore operations, well completion and production are similar to onshore, but they take place below hundreds or thousands of feet of water. Well caps must be resistant to corrosion by saltwater and must be able to withstand the pressure deep in the ocean. Well operators do not regularly visit the ocean floor to check on the well caps. Instead, sensors are placed on the well caps so that the wells can be monitored from the platform. Advanced technologies such as Remote Operating Vehicles, or ROVERS, can make robotic repairs to the well by operators on the platform using remote controls.

The oil is piped to an offshore processing platform where it is combined with oil from other wells before being cleaned and sent to a refinery. There is a limited amount of space on an offshore platform to store new oil, so all of the operations must be carefully coordinated. Production supervisors oversee the entire operation of an offshore rig to make sure operations are moving smoothly.

### Cleaning the Oil

Once oil has been brought to the surface, it must be cleaned. Refineries have specific standards that they require suppliers to meet before they will accept the oil. Producers usually clean their oil on site, near the pump. If a producer has multiple wells near each other, there may be one processing facility for a number of wells.

Field processing is used to separate out oil, gas, and saltwater. All of these materials can come up through the well mixed together. The simplest way to separate out the different materials is in settling tanks. Oil from the ground is pumped into a tank through one pipe and allowed to settle. Each layer of oil, gas, and saltwater is then pumped out through its own pipe. The downfall of this method is that settling can take a long time.

Pressurized separators that have a higher capacity and separate more quickly can also be used. Inside these separators, pressure is used to collect liquids at the bottom, while oil and gas are piped out the side. Separators do a good job of separating oil and gas, but more processing is needed to remove all of the saltwater.

When oil and water are mixed together, they can be difficult to separate. This is true for household vegetable oil and tap water and it is true for crude oil and saltwater. Refineries require that the oil contain no more than one percent water.

To remove excess water, heat is applied with a heat-treater. The heat-treater causes the droplets of water that are suspended in the oil to come together, creating larger drops that can be more easily removed from the oil. Water-free oil is removed from the top.

**OIL TANKER**

**OIL PIPELINES**

## Shipping Crude Oil

Oil wells are located above oil-bearing formations, wherever they are found. Refineries are usually near oil consumption markets, though many are located near major oil producing areas as well. There are different ways to get the oil from well to refinery.

Much of the oil we use is shipped via pipeline. Oil pipelines move crude oil from oil platforms offshore in the Gulf of Mexico to refineries onshore. Pipelines can also move petroleum products between regions of the U.S. Pumping stations along the pipelines are located every 60 to 100 miles to keep the oil flowing.

A pipeline must be kept clean. To clean the inside of a pipeline, an instrument called a pig is used. This instrument is shaped like a bullet and scrubs the wall of the pipeline. More advanced pigs, called smart pigs, use cameras to monitor the pipe for flaws.

For longer distances, oil is put in tanker trucks or moved by sea on oil tankers. Crude oil produced in Venezuela, for example, is carried to the U.S. in oil tankers. This oil is off-loaded at a refinery to be turned into useful products. Oil tankers have two hulls, or shells, to help prevent oil spills.

In most cases when oil is shipped by tanker, the crude oil travels though both pipeline and tanker. One example is crude oil produced on the Northern Slope of Alaska. This oil field is very far north, near the Arctic Ocean. Instead of building a port to bring tanker ships into these treacherous waters, a pipeline was built to carry the oil to a more easily reached port in the southern part of Alaska.

After transportation by oil tanker or pipeline to a refinery, much of the crude oil is placed in storage facilities or tank farms. These large cylinders hold the crude oil until the refinery is ready to process it.

## Refining

### Distillation

In its crude form, petroleum is of little use to us. To make it into products we know and use, petroleum must be refined—separated into its many parts. Those parts are what we use to fuel our world. Petroleum is made of hydrocarbons. Hydrocarbons are chemical compounds containing only hydrogen and carbon. These two elements combine in different ways to make hundreds of different compounds that we use to make thousands of products.

To separate petroleum products, oil is refined. The first and most important step in the refining process is distillation. Distillation has been around since ancient times. Stills were set up by many cultures to produce alcohol. The first distillation of oil was done at the world's first oil refinery in Romania in 1856.

Distillation is the separation of substances based on their boiling range. Petroleum is not the only thing that is distilled. The chemical industry and the beverage industry also distill their products. Basic distillation follows the same steps regardless of what is being separated.

A mixture is heated. As parts of the mixture begin to boil, they rise as gases. These gases are captured in a fractioning tower. While the bottom of the tower is very hot, the temperature at the top of the tower is cooler. Trays are placed at different levels inside the tower. These trays have holes in them so that gases can pass through. But as the gas meets a plate that is cooler than the temperature of that gas, it condenses, or turns back into a liquid. The condensed liquid that forms on each plate is sent to a pipe. Each plate has its own pipe that carries only the liquids collected on it. The separated liquids move to other machines for further processing.

OFFSHORE PRODUCTION PLATFORM

STORAGE TANKS

There are a number of products that come from the refining process. Hydrocarbons with simple molecular structures have lower boiling temperatures. As the molecular structures become more complex, the boiling temperature increases—more energy is required to break the intra-molecular forces between the molecules, which allows for the phase changes.

Once distillation is complete, the light, higher value products are cleaned and put to use. Heavy, lower value products are subjected to additional processes to either extract higher value products or alter their chemical make-up to produce higher value products.

### Processing

These different parts are sent through chemical processing to be turned into useful products. There are three main types of processes. Cracking breaks long hydrocarbon chains into smaller ones. Unification combines small chains into longer ones. Alteration rearranges pieces of hydrocarbon chains to make different hydrocarbons.

Cracking can be done in a number of different ways. One method is thermal cracking. Thermal cracking uses very high temperatures to break apart long chains of hydrocarbons. This can be done using high temperature steam.

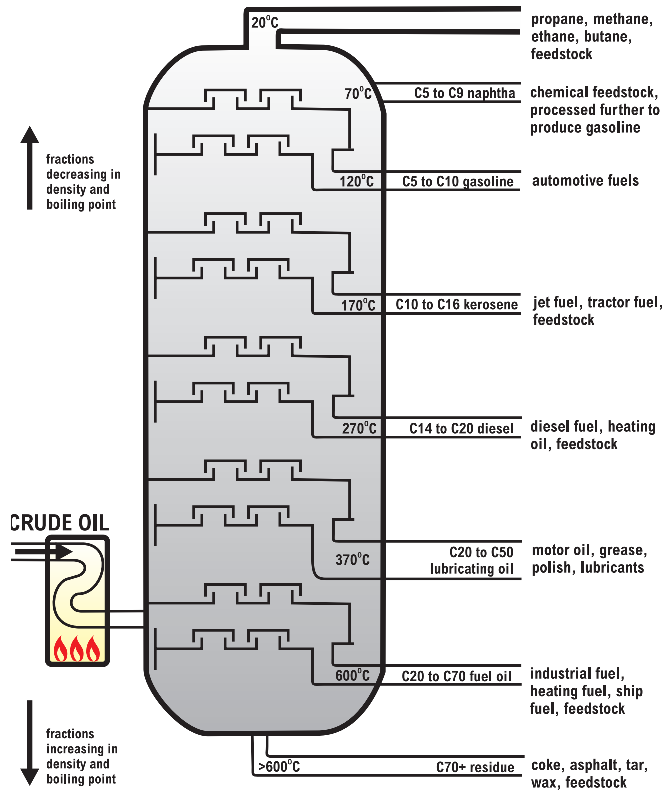
Cracking can also be done by heating the residue from distillation towers to very high temperatures until it separates into useful parts. This process is also known as coking, since the material that is left after all of the useful hydrocarbons are removed is coke, a hard, porous carbon material. Coke is used by heavy industry, such as iron and aluminum manufacturing.

Another way that long hydrocarbon chains are broken is through catalytic cracking. A catalyst is a material that increases the rate of reaction. Catalytic cracking is used to change heavy diesel oils into diesel oil and gasoline.

When smaller hydrocarbons are combined to make larger ones through unification, they usually undergo a process of catalytic reformatting, a process that converts naphtha into aromatics. Aromatics are cyclic hydrocarbons—meaning the carbons form a ring rather than the simpler straight chain of hydrocarbons. Aromatics are typically used to make chemicals and blend gasoline. The main by-product of catalytic reforming is hydrogen gas.

Alteration is the rearrangement of molecules in a hydrocarbon to create a more useful hydrocarbon. Usually this is done with

## Fractioning Tower




alkylation, a process in which hydrocarbons are mixed with a catalyst and an acid to create hydrocarbons that are high in octane. These high-octane hydrocarbons are blended into gasoline.

### Preparation to Market

Once all the products have been separated from the crude oil that went into the refinery, the products must be prepared to go to market. This last step is known as treatment. Gasoline, for example, is treated with additives that help engines operate more smoothly and burn cleaner.

From the refinery, different petroleum products make their way to a variety of places. Almost half of every barrel of oil is made into gasoline. Another 10–15 percent is refined into other transportation products such as jet fuel, diesel fuel, and motor oil. Many of these products are produced by further chemical processing.

## Shipping Petroleum Products

After the refinery, most petroleum products are shipped to markets through pipelines. Pipelines are the safest and most cost effective way to move big shipments of petroleum. Gasoline is transported around the country through pipelines, most of which are buried underground. There are about 230,000 miles of underground pipelines in the U.S. It takes about 15 days to move a shipment of gasoline from Houston, TX to New York City.

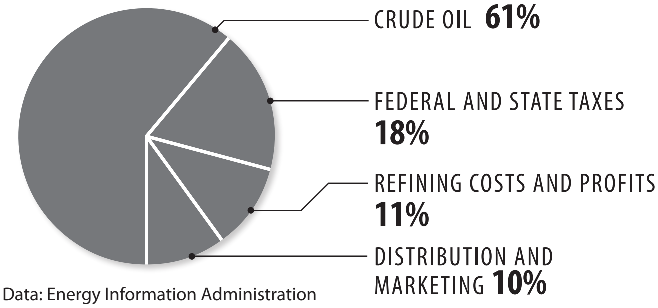
Special companies called jobbers buy petroleum products from oil companies and sell them to gasoline stations and to other big users such as manufacturers, power companies, and large farmers.

# Petroleum Based Transportation Fuels

Driving is an important part of Americans' daily lives. In fact, Americans drive their personal vehicles about 3 trillion miles a year. Commercial trucks drive 145 billion miles, public transit buses drive 2.3 billion, and school buses drive nearly 6 billion miles. There are a lot of vehicles racking up that kind of mileage—249,000,000 personal vehicles, 9,000,000 commercial trucks, 83,700 public transit buses, and 480,000 school buses.

## Factors in Gasoline Pricing

In 2009, the average retail price for a gallon of regular grade unleaded gasoline was $2.34. The biggest factor in the total price is the cost of crude oil that is used to produce the gasoline.




Data: Energy Information Administration

## Gasoline as a Transportation Fuel

Today, gasoline is the fuel used by a vast majority of passenger vehicles in the U.S. There are about 249 million vehicles that use gasoline to travel an average of 12,000 miles per year. There are 162,000 fueling stations that provide convenient accessibility for consumers. The production and distribution infrastructures are in place. Most Americans consider gasoline the most sensible transportation fuel for today, even if it is not an ideal fuel.

Consumers are concerned about price fluctuations. During World War I, the cost of gasoline was about $0.25 a gallon. The price of gasoline has averaged about $2.00 a gallon in inflation-adjusted dollars for the last 80 years, until the shortages caused by Hurricanes Katrina and Rita, and the unrest in many oil producing areas, such as Iraq, Iran, and Nigeria. In 2009 the average cost for a gallon of gasoline was $2.34.

## Diesel as a Transportation Fuel

Diesel fuel plays a vital role in America's economy, quality of life, and national security. As a transportation fuel, it offers a wide range of performance, efficiency, and safety features. Diesel fuel contains between 18 and 30 percent more energy per gallon than gasoline. Diesel technology also offers a greater power density than other fuels, so it packs more power per volume. Since 2004 diesel prices have been higher than gasoline prices. Diesel is more expensive due to higher refining costs and higher federal taxes. In 2009 the average retail price for diesel was $2.46 per gallon.

Diesel fuel has a wide range of applications. In agriculture, diesel powers more than two-thirds of all farm equipment in the U.S. because diesel engines are uniquely qualified to perform demanding work. The construction industry also relies heavily on diesel fuel to operate heavy machinery. Diesel power dominates the movement of America's freight in trucks, trains, boats, and barges; 94 percent of our goods are shipped using diesel-powered vehicles. No other fuel can match diesel in its ability to move freight economically. In addition, it is the predominant fuel for public transit buses, school buses, and intercity buses throughout the U.S.

Diesel fuel is not just for large vehicles. There are five million diesel cars, pickups, and sport utility vehicles (SUVs) on the road today. A new generation of clean diesel cars, light trucks, and SUVs are now available and offer consumers a new choice in fuel-efficient and low-emissions technology. Clean diesel is a proven technology that is clean, quiet, and fun to drive. Many new diesel options are available for car consumers in every state. Thanks to their inherent fuel efficiency, diesel engines also offer a viable and readily available strategy for reducing greenhouse gas emissions as they produce 20 percent fewer carbon dioxide emissions than gasoline vehicles. American drivers who purchase cleaner-burning diesel cars, trucks, and SUVs are eligible for similar tax incentives as purchases of gasoline-hybrid electric vehicles.

## Characteristics and Environmental Impacts of Gasoline and Diesel Fuels

Gasoline is a nonrenewable fossil fuel that produces criteria air pollutants—carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide—when it is burned. Since the 1960s, stricter environmental standards have led to gasoline formulations and vehicle designs that have reduced vehicle exhaust emissions by 95 percent.

The Clean Air Act Amendments of 1990 mandated that reformulated gasoline be used in areas of the country that do not meet air quality standards, as well as reductions in nitrogen compounds ($NO_X$) and volatile organic compounds (VOCs). More than a dozen different formulations of gasoline are now required by law in the U.S. Blending ethanol with gasoline was originally targeted in areas that did not meet air quality standards. Now, it is common place to find up to 10 percent ethanol blended into gasoline.

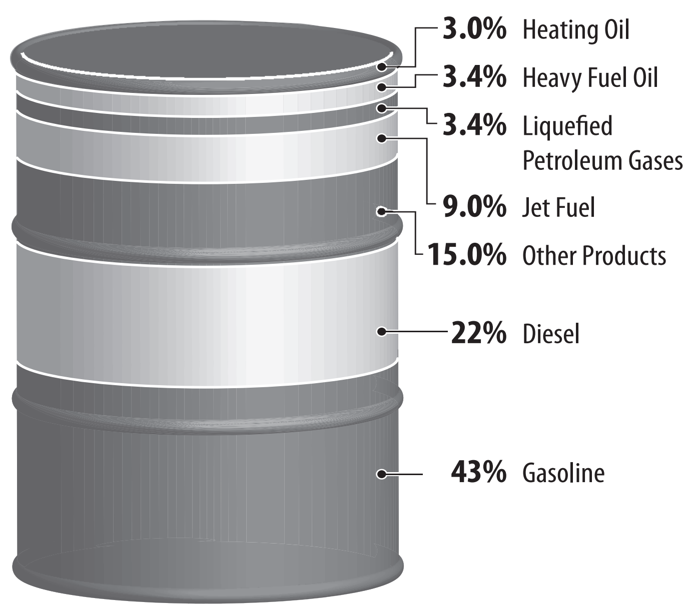
Significant progress has been made in reducing emissions from diesel engines. With new clean diesel technologies, today's trucks and buses are eight times cleaner than those built just a dozen years ago. As of 2010, new trucks and buses have near zero emission levels.

## Chemical Manufacturing

Petroleum goes into much more than just the tanks of our cars and airplanes. Petroleum is part of many of the products we use every day. It is well known that plastics are made from petroleum products, but that is only the beginning. Your toothbrush, toothpaste, shampoo, and even your contact lenses contain petroleum, as do carpeting, CDs, the ink in your pen, and medical devices such as prosthetic heart valves.

Chemical plants take refinery products and turn them into the products we use. There are many different kinds of chemical plants. Some are small and produce one or two items. Some are very large and produce a number of items. The largest plants can produce over 5 billion pounds of product each year. Large chemical plants operate all the time. They run 24 hours a day, every day of the year. Many of these plants are automated with new technology and need fewer people than in the past to run them.

### Products Produced From a Barrel of Oil




Data: Energy Information Administration

## Plant Equipment and Processes

Cracking in a chemical plant is very similar to cracking in a refinery. Heat is used to break apart the chemical bonds of the hydrocarbon molecules in feedstocks. Feedstocks are the raw materials used to make products in chemical manufacturing plants.

### Boilers and Furnaces

Both boilers and furnaces are important parts of chemical plants. Often feedstocks are brought to a chemical plant in solid form, such as powder or pellets. To work with these materials, they must be heated and melted into liquids or sometimes gases.

**FURNACE**

### Cooling Towers

Cooling towers are used to return the water used in chemical processing back to normal temperature before it is returned to the river or lake from which it was taken. To do this, water is sent through a maze-like structure that allows as much air as possible to come into contact with the water. Gravity pulls the water down through this maze, cooling it as it goes.

The air inside a cooling tower heats up as it comes into contact with the warm water being fed into the tower. The warming air rises, collecting a tiny bit of water vapor in the process, and is released from the top of the tower. As you drive by a chemical plant, you can sometimes see a cloud of water vapor rising from the cooling tower.

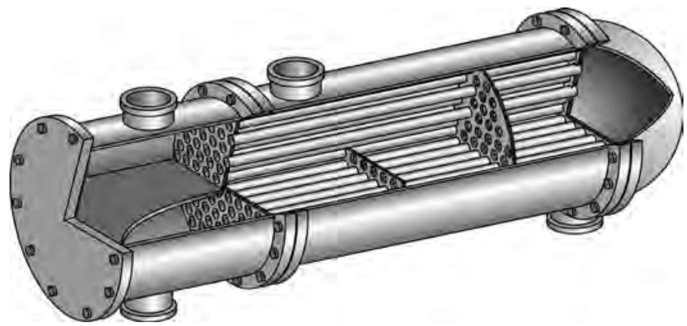
### Heat Exchangers

Heat exchangers are devices that can speed up production and cut down on the need to process waste heat at the same time. Heat exchangers use fluids that contain waste heat, or heat that is no longer useful from a previous step, to heat materials that must be warmed in another step.

Heat exchangers are large pipes with smaller pipes inside. The small pipes carry cool liquids that need to be heated. The small pipes do not completely fill the large pipes, and the space around the small pipes is where the waste-heat fluid (liquid or gas) flows.

As the cool liquid and the hot fluid flow past each other, heat is transferred from the hot fluid to the cool liquid. At the end of the heat exchanger, the cool liquid has warmed in preparation for its next step. The hot fluid has cooled and requires less processing.

### Heat Exchanger



### Wastewater Treatment

Processing chemicals can use large quantities of water. Water is present in nearly every step. Boilers, cooling towers, and heat exchangers all use water. To ensure that the water leaving the plant is as clean as the water coming into the plant, wastewater treatment facilities are located on site.

### Laboratory

One important part of a chemical plant is the laboratory. Chemists constantly monitor the product at each step to make sure it meets the required specifications. If the chemistry is not just right, plastic bags could be too weak to hold groceries or nylon thread too brittle to sew. Chemists also monitor waste products to make sure the land and water is not being polluted.

### Loading Station

Once the final product is complete, it is stored in a warehouse or storage tank, depending on the type of product. When needed, the product is taken from the storage facility to a loading station to be transported to market or to another chemical plant for further processing. Depending on the product, it may be transported by road, rail, air, water, or pipeline.

## Transportation

Refineries and chemical plants are located all over the country and feedstock is often moved long distances between the two. Sometimes, chemicals are moved in small 50-pound bags or 400-pound drums. Feedstocks that must be transported in large quantities may be moved by barge, ship, or pipelines, which can carry larger quantities of product.

## Products

To get the products that are familiar to us, feedstocks must be processed. Different products have different steps that are needed. Many products are made from more than one feedstock, which are combined in different ways to produce a variety of products.

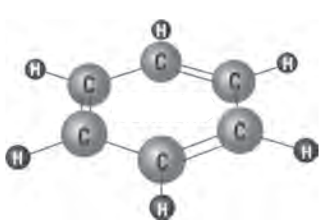
There are two general types of chemicals produced from petroleum that are used to create most everyday items—aromatics and olefins. Aromatics are a group of petrochemicals with a distinctive sweet smell that are characterized by ring structures, and are produced in refineries and petrochemical plants. The most common aromatics are benzene, toluene, and xylenes.

Aromatics are used for chemical production or as high-octane components for gasoline blending. Aromatics are used to make plastics and polymers. These go into products such as paint, textiles, building materials, and leather alternatives.

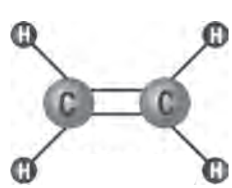
Olefins are a class of hydrocarbons recovered from petroleum that contain one or more pairs of carbon atoms linked by a double bond. Typical examples include ethylene and propylene. Olefins are obtained by cracking petroleum fractions at high temperatures. Another word for olefin is alkene.

The simplest olefins—ethylene, propylene, butylene, butadiene, and isoprene—are the basis of the petrochemicals industry. They are used to produce plastics, industrial solvents, and chemicals that are used in other applications. A number of familiar products come from these petrochemicals, including plastic bags, paint, tires, and plastic bottles.

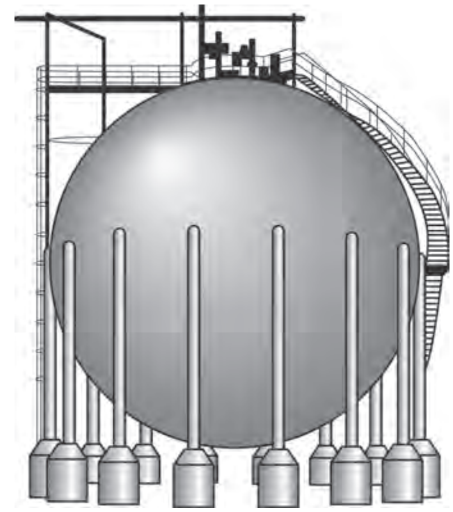
### Benzene



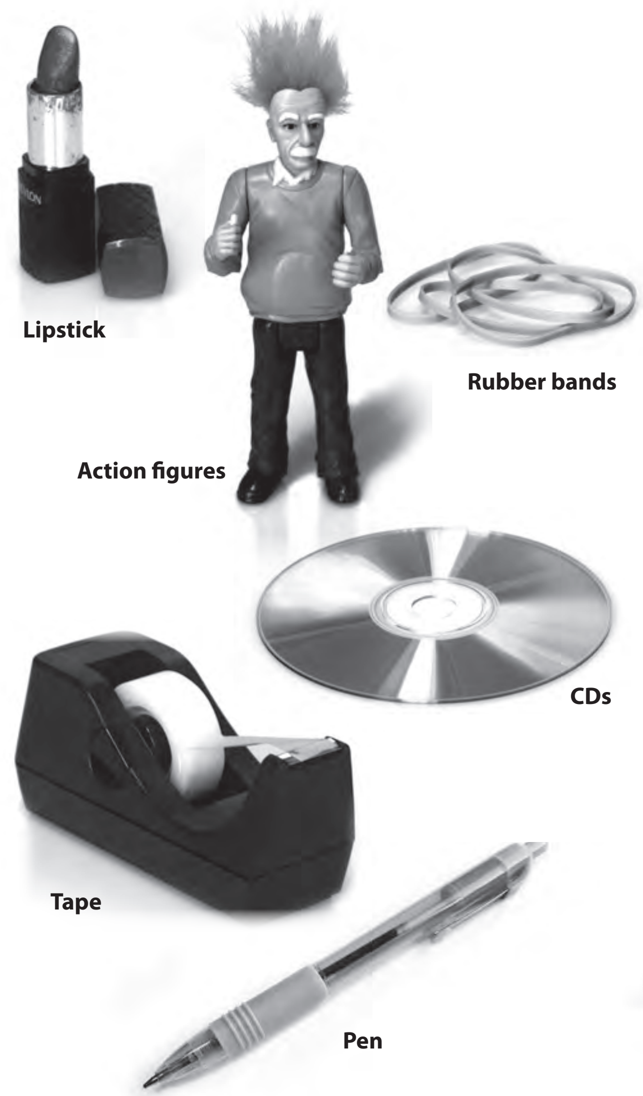
### Ethylene



### Sphere Storage Tank



### Products Made From Petroleum



## Health and Safety

Worker health and safety are top priorities in all process industry facilities. To help ensure that workers are safe on the job, all manufacturing plants follow OSHA (Occupational Safety and Health Administration) rules and guidelines.

In many work settings, for example, OSHA guidelines require that workers wear hardhats, ear protection, eye protection, or other safety gear.

Chemical plants are continuously making their operations as safe as possible. Spill kits are located throughout a plant so that if there is a spill, clean-up can be accomplished quickly. Plants also work hard to replace any materials used in their processes that are toxic with alternatives that are safer for workers and for the environment.

One safety feature at a chemical plant is the fire pond. A pond of water is kept on site ready to be pumped if a fire were to erupt. There are usually a number of ponds scattered around each plant site so that one is never far away if it is needed. Since fire pond water does not need to be as clean as the water we use in our everyday lives, storm water is often collected to fill the ponds.

## Into the Future

As the demand for petroleum products grows and the issues become more and more complex, energy companies are using advanced technologies to design and deliver next generation fuels and products. The skills used by all workers in the petroleum product industry are transferable to these new technologies. New opportunities are emerging every day.

Consumers can make a real difference by recycling petroleum–based products and buying products that conserve energy.

To take a tour of a chemical plant, go to the Center for the Advancement of Process Technology's Virtual Chemical Plant at http://capt.com.edu/virtualchemplant/.

**OIL WORKER**


Image courtesy of StatOil

# Careers in the Oil and Gas Industry

The oil and gas industry offers a variety of careers for individuals to work at its refineries, chemical plants, or on exploration and production onshore/offshore facilities. The following are an example of some of the career options available:

**Process Technicians** - member of a team of people that control, monitor, and troubleshoot equipment and focus on safety and environmental considerations.

**Instrumentation Technicians** - maintain, calibrate, adjust, and install measuring and control instruments necessary to ensure the safe, efficient operation of equipment.

**Electricians** - read blueprints that show the flow of electricity and maintain and repair the electrical and electronic equipment and systems that keep the facilities up and running.

**Machinists** - install, maintain, repair, and test rotating mechanical equipment and systems.

**Geologists** - explore the nature and structure of rock layers to piece together a whole picture of the subsurface in order to determine the best possible places to drill for oil and natural gas.

**Petroleum Geologists** - gather, process, and analyze seismic data and well data in order to locate drill sites for their companies.

**Geoscientists** - study the composition, structure, and other physical aspects of the Earth and are involved in exploration and production of oil and natural gas.

**Petroleum Engineers** - play a key role in determining the reservoir capacity (how much oil it might hold) and productivity (how much it produces) to design systems that move the petroleum from the wells (production process) through refining, where it gets cleaned up and converted into the energy we use.

**Chemical Engineers** - design chemical plant equipment and develop processes for manufacturing chemicals and products like gasoline, detergents, and plastics.

**Mechanical Engineers** - deal with the design, manufacture, and operation of the machinery and equipment used to improve oil drilling, and the processing of petroleum or chemical products.


Image courtesy of Shell

Image courtesy of Shell