Alternative Fuels: An Introduction

Fuels are substances that when burned or consumed produce energy. For example, car engines burn gasoline to produce energy. Most fuels in use today are derived from petroleum. Fuels that are not derived from petroleum are known as *alternative fuels* because they provide an alternative source of energy. Alternative fuels include natural gas, propane, hydrogen, biofuels, alcohol, and other fuels. Other sources of alternative energy include solar energy, hydro (water) energy, and wind energy.

Global Energy Crisis

Energy consumption in the world has been growing steadily since the industrial revolution. Most of this energy comes from the burning of fossil fuels like petroleum. Each year millions of vehicles are bought around the world. The majority of these vehicles run on petroleum. In the United States, there are an estimated 230 million vehicles, and that number continues to grow every year. This creates an ever-increasing demand for petroleum. The demand will soon exceed supply. This gap will continue to grow as new vehicles are added to the world's roads and highways. Since fossil fuels are nonrenewable sources of energy, this will create a global energy crisis in the near future.

Vanishing Resources

Nonrenewable energy resources cannot be easily replaced by nature once they are used up. Nonrenewable resources such as coal, oil, and natural gas take millions of years to form naturally. They are therefore in limited supply. These resources are found inside the Earth in solid, liquid, or gaseous form. Petroleum is found in liquid form, coal is solid, and natural gas and propane are gases. The continuous use of these nonrenewable resources is making them slowly vanish from our planet.

The Need to Go Alternative

The increase in global energy consumption has led to a higher demand for energy resources like petroleum. With limited supply, most countries have to import petroleum to meet their energy needs. In the United States, petroleum provides about 40% of all energy needs. However, the burning of petroleum emits large amounts of greenhouse gases such as carbon dioxide. This poses a threat to the environment and contributes to global warming. A possible solution to the problem is to use alternative fuels and invest in natural renewable energy resources.

Why Alternative Fuels Are Better

Replacing conventional fuels like petroleum with alternative fuels helps reduce greenhouse gas emissions. For example, a compressed natural gas (CNG) vehicle emits about 60% to 90% less smog-producing gas, while liquefied petroleum gas (LPG) vehicles emit 30% to 90% less carbon monoxide. This makes alternative fuels safer and cleaner for the environment. The use of other renewable resources such as solar energy, hydro energy, and wind energy is also an easy way to go alternative.

Renewable Energy

Renewable energy resources are natural resources that can be formed and replaced by nature in a short period. Nature is forming these resources constantly. Renewable resources include plants, animals, soil, water, and sunlight. Minerals such as salt or clay are also renewable resources, as they are abundant in nature.

Did you know?

Until the 1950s, the United States produced nearly all the petroleum it needed. In 2000, to meet growing demands, 11 million barrels of petroleum was imported every day.

Vegetable Oil

Vegetable oil is a renewable alternative fuel that can be used to run diesel engines. Vegetable oil is obtained from plants such as corn, soybean, peanut, safflower, sunflower, palm, etc. It is therefore nontoxic, biodegradable, and eco-friendly. Vegetable oil is also one of the most affordable alternative fuels.

Why vegetable oils?

Vegetable oil, a commonly available alternative fuel, provides environmental, economical, and health benefits. Burning vegetable oil does not emit sulfur dioxide, the main component of acid rain. The superior lubricating properties of vegetable oil provide a smoother running engine with less noise. Increased use of vegetable oil has led to an increased demand for vegetable oil crops, thus benefiting the farmers.

Vegetable Oil Limitations

Vegetable oil is thicker than conventional oil. It must be clean and hot. It also needs to be filtered before use. In the winter, vegetable oil does not work properly. Vegetable oils are unreliable at both high and low temperatures. The major drawback of vegetable oil is that it reduces engine life. It is also more expensive than gasoline and diesel.

How to Use Vegetable Oil Properly and Safely

- Mix the vegetable oil with diesel fuel or kerosene and then use.
- Blend vegetable oil with an organic solvent additive or gasoline and then use.
- Use vegetable oil in a properly installed two-tank system. The oil is first preheated and then used.

Extraordinary Vegetable Oil

Soaking your finger in vegetable oil for a few minutes can remove a splinter. The oil can separate stuck glasses, remove labels and stickers from plastic and glass jars, and can even soften your feet. Vegetable oil also helps in controlling mosquito growth in still water. Pour a few tablespoons of oil onto the water surface and keep mosquitoes away.

Vegetable Oil Versus Petroleum

Compared to petroleum, vegetable oil releases:

- 100% less SO_2
- 78% less CO_2
- 48% less carbon monoxide
- 48% less asthma-causing particulate matter
- 80% fewer cancer-causing hydrocarbons

Vegetable Oil Extracted Per Acre of Crop

- Soybean: 40 to 50 gallons/acre
- Rapeseed: 110 to 145 gallons/acre
- Mustard: 140 gallons/acre
- Jatropha: 175 gallons/acre
- Palm oil: 650 gallons/acre
- Algae: 10,000 to 20,000 gallons/acre

Did you know?

Vegetable oil improves gas mileage by over 3% and reduces smog-forming nitrogen oxide emissions by 75% when used as motor oil.

Peanut Oil

Peanut oil is a clear oil made from crushed peanuts that can be used as an alternative fuel in diesel engines. Peanut oil is a nontoxic, safe, clean, biodegradable, and eco-friendly alternative fuel. In 1900, German engineer and inventor of the diesel engine Rudolf Diesel first used peanut oil as a fuel for his diesel engines. This was the first time that peanut oil was used as an alternative fuel to run diesel engines.

U.S. Peanut Production

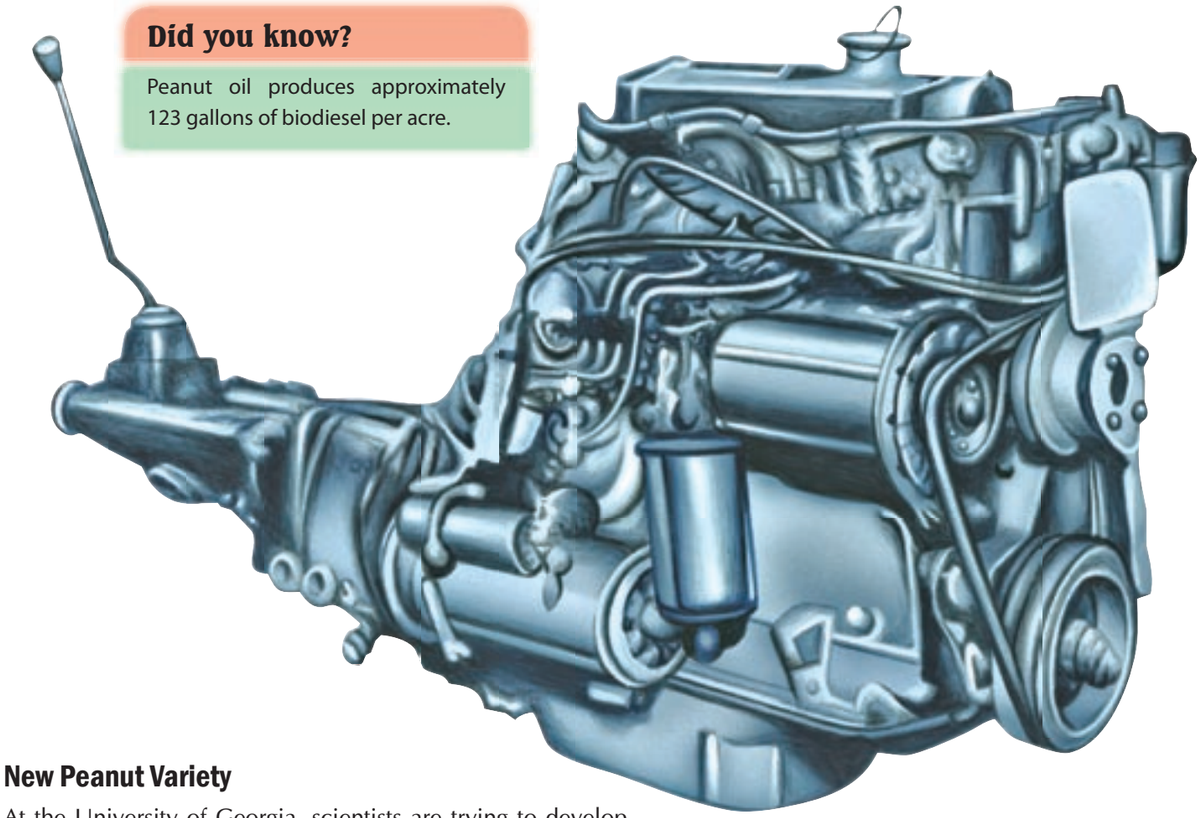
In 2007, the estimated production of peanuts was 3.74 billion pounds, which is 8% more than in 2006. Peanuts are produced in the U.S. southeast, Virginia and the Carolinas, and the southwest. The production of peanuts requires well-drained, light-colored, friable, loose soil with high levels of calcium and moderate levels of organic matter.

Disadvantages of Peanut Oil

Peanut oil is more expensive than other alternative fuels. Peanut oil freezes at extremely high temperatures because of its high pour point. *Pour point* is the temperature at which oil no longer flows like a liquid. Peanut oil can also soften and degrade parts of an engine. When not perfectly mixed, peanut oil increases nitrogen oxide emissions.

Did you know?

Peanut oil produces approximately 123 gallons of biodiesel per acre.



New Peanut Variety

At the University of Georgia, scientists are trying to develop nonedible peanuts with high oil content grown specifically for biodiesel production. The production of high oil content peanut varieties would not pose a risk to peanuts grown for cooking purposes in the world market.

Peanut Biodiesel and Fossil Fuel–Based Biodiesel

Peanut biodiesel is compatible with fossil fuel–based biodiesel. They can be mixed in any proportion. Peanut oil shows a 2% to 5% reduction in miles per gallons compared to fossil fuel–based biodiesel, which can be overcome by altering diesel engines.

Rudolf Diesel

Rudolf Diesel was an inventor and engineer. In 1892, he invented the diesel engine, which was named after him. He was interested in using vegetable oil or coal dust as fuel in his engines. He developed the first engine that ran on peanut oil and demonstrated it at the World Exhibition in Paris in 1900.

Wood

Wood is a major source of heat and light and one of the oldest fuels in use today. Wood is also used as an alternative fuel in steam engines and turbines to generate electricity. Wood has many advantages as an alternative fuel, as it reduces carbon dioxide emissions and therefore causes less pollution. It is also a commonly available renewable resource.

Types of Wood Fuel

- *Logs* are the most common and simplest form of wood fuel. They are used as a domestic fuel in open fires and stoves for heating water and cooking.
- *Wood chips* are primarily used as a fuel in commercial-scale boilers. Commercial-scale boilers are used to heat large buildings such as factories, hotels, and offices.
- *Wood pellets* are small, compressed pieces of wood produced as a byproduct of sawmilling. Pellets have very low moisture content and burn efficiently. They can be used in anything from domestic pellet stoves to very large boilers.

Why use wood fuel?

Wood is a renewable resource and emits less carbon dioxide into the atmosphere. Wood fuel is cheaper compared to the costs of fossil fuels. It provides opportunities for new companies to develop sources of income and employment, especially in rural areas. Neglected woodlands can be managed properly and can provide habitat for wildlife. Local production of wood fuel can reduce the transportation costs.

Wood in Africa

People in most parts of Africa use wood as one of the most important forms of domestic energy. For example, in the Giyani area of the Limpopo province in South Africa, 80% of the villagers use wood as the only energy source for cooking and heating.

Did you know?

A unit of wood fuel is called a *cord*. One cord of wood fuel gives about 22,000,000 Btu (British thermal units) of heat, which is second only to coal.

Wood and the Environment

As compared to fossil fuel, wood fuel has many environmental advantages. The amount of carbon dioxide produced during the burning of wood is less in comparison to fossil fuel. The smoke from burning wood is relatively nontoxic to the environment. Wood fuels reduce the amount of airborne sulphur and heavy metals, which contribute to acid rain.

Wood in Europe

In Europe, some countries like Sweden and Austria use wood to generate electricity. Sweden produces 1,490 megawatts of electricity from wood, and Austria produces 747 megawatts. In Finland, people use wood waste, such as pellets, as domestic and industrial sources of energy. Scandinavian countries import firewood from Baltic countries such as Lithuania and Latvia. The cost of manual labor is cheaper in these countries in comparison to Scandinavian countries.

Biomass

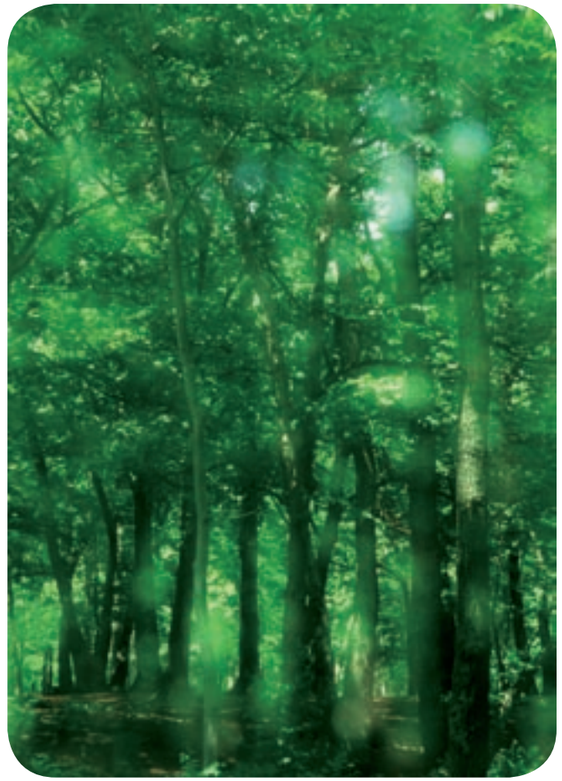
Biomass is organic material derived from plants and animals that can be used as a fuel. It is a clean and renewable energy resource that can be found all over Earth's surface. Biomass can also be converted into other forms of energy such as heat and electricity.

Applications of Biomass Energy

- Biomass is used as an alternative source of energy. Cattle dung is used in India to produce biogas, which is used in cooking.
- The leftovers of a biogas plant are used as fertilizer.
- Leftovers from sugar mills are sold after extracting juice from sugarcane, which is known as *bagasse*. Bagasse is used as a biomass to run electricity-producing turbines.
- Wood, the most abundantly found biomass, is used for room heating and cooking.
- Biomass is used in homes for fireplaces, hot water heating, and space heating, as well as in industries for electricity generation.

What is biomass made of?

- *Wood residues* are the remains of wood derived from woodlands and commercial forests. They include wood chips, slabs, edgings, sawdust, and shavings.
- *Agricultural residues* are obtained from farming activities. They include crop residues, vegetable or food-processing residues, and livestock slurry.
- *Energy crops* are purposely grown to serve as a source of biomass. They include herbaceous grasses, short-rotation tree crops, and cereal crops.



Why use biomass?

Biomass helps in reducing global warming. It emits a lower amount of carbon dioxide and sulfur dioxide, which cause acid rain. The use of biomass reduces the demand for petroleum imported from other countries. Biomass is also used in producing ethanol, which can be used in environmentally friendly cars.

Did you know?

One pound of dry plant tissue can produce energy equivalent to a half pound of coal.

How much biomass is used for energy today?

Biomass is the fourth-largest source of energy after coal, oil, and natural gas. Surveys estimate that biomass is used to generate about 35,000 megawatts (MW) of electricity around the world. About 7,000 MW of that is used in the United States alone. Most of the biomass is used in heat and power systems for the pulp and paper industries. Only 7% of the annual biomass production is used by the total world population.

Biomass Materials Used to Produce Electricity

- Leftover sawmill wood
- Leftover paper and wood waste from paper mills
- Farm waste such as corn stalks, corn cobs, and seed corn
- Paper and cardboard that cannot be recycled
- Fast-growing crops and trees

Wind Energy

Wind energy is a form of energy obtained from moving air. Wind energy can be converted into other useful forms of energy such as electricity. This makes it an important alternative energy resource.

Wind Generates Electricity

Wind energy has been used to produce electricity for many years. Earlier, *windmills* were used to generate electricity, and now *wind turbines* have taken their place. Windmills have a series of blades, while wind turbines have only two or three blades. When the wind blows, the blades turn. The rotating motion of the blades is converted inside a turbine into an electric current.

Wind Farms

Wind farms are flat, open areas with wind blowing at a speed of at least 14 miles per hour. A wind farm has dozens of wind machines to produce electricity. Wind power is the world's fastest-growing technology for generating electricity. The Horse Hollow Wind Energy Center in Texas is the world's largest wind farm. It has 421 wind turbines that power 230,000 homes per year.

Measuring Electricity Produced by Wind Energy

The electricity measured by wind turbines is measured in kilowatts (kW), megawatts (MW), and gigawatts (GW). The production and consumption of electricity are measured in kilowatt-hours (kWh). A kWh refers to electricity produced or consumed in one hour. Electricity produced by a wind turbine depends upon the size of the turbine and the speed of the wind. A 10 kW wind turbine generates 10,000 kWh in a year with average wind speeds of 12 miles per hour.

Wind and Environment

Wind is considered green power technology. It has no harmful effects on the environment. Wind power plants or wind farms produce no air or water pollution. Wind energy is also not responsible for emitting greenhouse gases and thus does not contribute to global warming.

Limitations

Wind turbines create a swooshing sound, which makes noise pollution. Wind can never be predicted. Despite the most advanced equipment, it is not possible to create wind energy all of the time. Wind turbines create problems with TV transmissions. They also are potentially dangerous to birds, as the moving blades can kill them.

Did you know?

A single 1.5-megawatt wind turbine powers about 300 average American homes, year after year.

Hydroelectric Power

Hydroelectric power, or *hydroelectricity,* is power that is generated by the force of flowing water. Hydroelectricity is a renewable source of energy. It is one of the cleanest and cheapest sources of energy. Water from rivers, rapids, waterfalls, and dams is used to generate electricity. Rainwater and melting snow can also be used. Hydroelectricity provides about 24% of the total global electricity requirement. In 2005, about 7% of the total electricity needed in the United States was provided by hydroelectricity.

Itaipu Dam

How is hydroelectricity produced?

Hydroelectricity is produced at a *hydroelectric power station*. Water is stored in a reservoir or artificial lake behind a dam. When the water is released from the reservoir, it passes through a long pipe known as a *penstock*. The water builds up pressure as it travels through the penstock and falls on the blades of a turbine, which is connected to a generator. The force of the falling water rotates the blades of the turbine, which drives the generator and produces electricity. The world's first hydroelectric power plant, on the Fox River in Appleton, Wisconsin, began working in 1882. The United States now has more than 2,000 hydroelectric power plants.

Advantages of Hydroelectric Power

- Hydroelectricity is renewable.
- Hydroelectricity is pollution-free and uses no fossil fuel.
- No greenhouse gases are released by the production and use of hydroelectricity.

Disadvantages of Hydroelectric Power

- Dams often disturb aquatic life.
- Construction of hydropower plants is expensive.
- Dams flood large areas of land, displacing all forms of life from areas where they are built.

Aswan Dam

Grand Coulee Dam

Hoover Dam

Famous Dams

Dam	Place
Aswan High Dam	Aswan, Egypt
Edwards Dam	Augusta, Maine
Folsom Dam	Folsom, California
Grand Coulee Dam	Grand Coulee, Washington
Hoover Dam	Arizona and Nevada
Itaipu Dam	Brazil and Paraguay
South Fork Dam	Johnstown, Pennsylvania
Three Gorges Dam	Three Gorges, China
Niagara Dam	Roanoke County, Virginia

History of Hydropower

Hydropower is an age-old source of energy. The Greeks were one of the earliest known users of hydropower. They used water wheels to grind wheat into flour. These water wheels were very similar to modern-day turbines. Large water wheels were used to generate power during the Middle Ages in different types of mills. The modern-day water turbine was developed from the water wheel. It was invented by Benoit Fourneyron, a French engineer, in 1827.

Three Gorges Dam

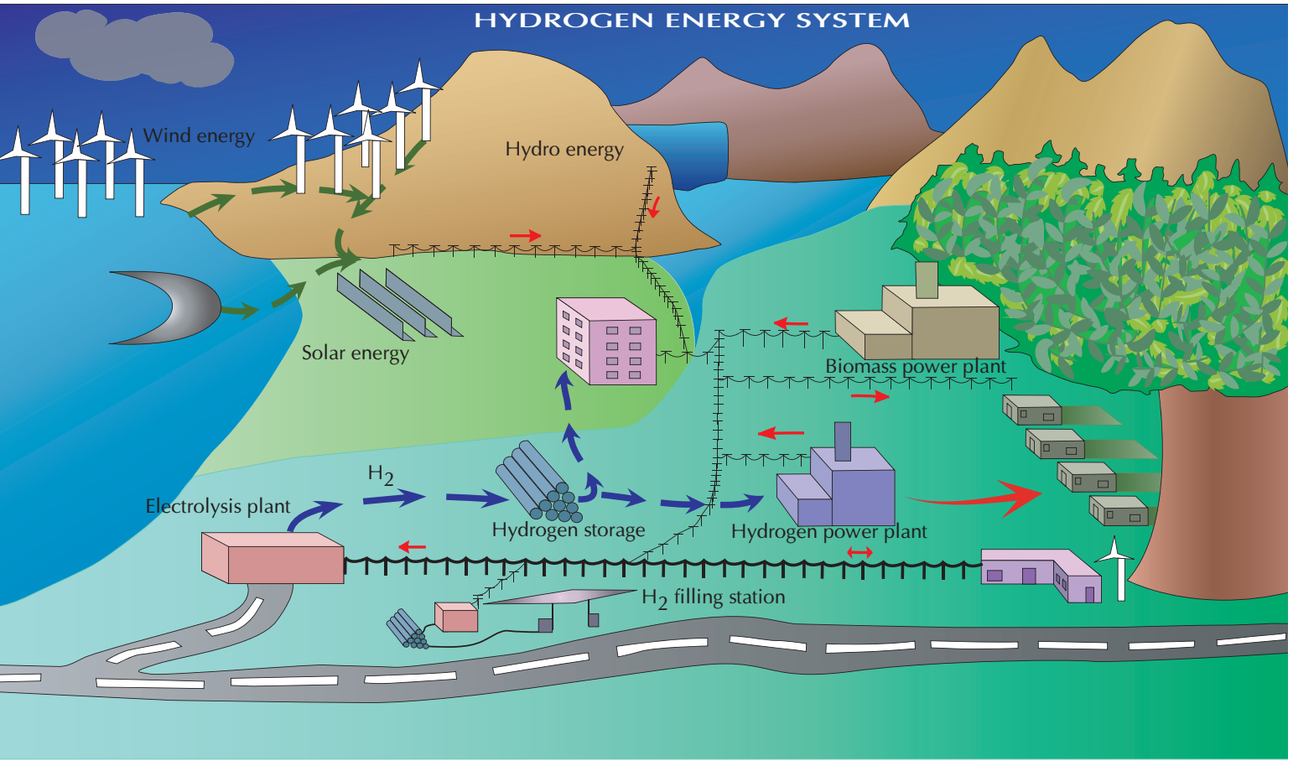
The Three Gorges Dam on the Yangtze River in China is the world's largest dam. The dam is still under construction and will be ready to operate by 2011. The construction of the dam will benefit many people, but it may also cause serious problems as it will submerge 13 cities, 140 towns, and 1,352 villages and displace 1.9 million people. The dam water will immerse several historical sites and animal species, too.

Top Ten Hydroelectric Power Producing Countries

- China
- Canada
- Brazil
- United States
- Russia
- Norway
- India
- Japan
- Sweden
- France

Did you know?

The Grand Coulee Dam on the Columbia River in the state of Washington is the largest hydroelectric power facility in the United States.



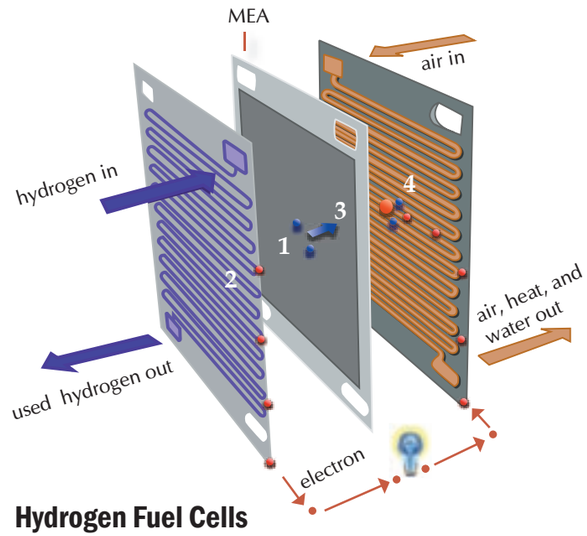
Hydrogen Energy

Hydrogen is a colorless, odorless gas that can be used as an energy source. Hydrogen has many advantages as an alternative fuel. It is one of the most abundant elements found in nature. It is renewable and efficient. Hydrogen reduces greenhouse gas emissions and improves the quality of air.

Sources of Hydrogen

Hydrogen is found almost everywhere on Earth. Hydrogen can be produced from a variety of easily available resources:

- *Primary energy sources:* water, sunlight, wind
- *Traditional or conventional energy sources:* natural gas, gasoline, diesel, propane
- *Renewable/alternative fuels:* methanol, ethanol, landfill gas, biogas, methane
- *Other sources:* ammonia, sodium borohydride, algae, peanut shells



Hydrogen Fuel Cells

Hydrogen contains chemical energy. A *hydrogen fuel cell* uses this chemical energy contained in hydrogen to generate electricity. A hydrogen fuel cell is very much like a battery. It uses hydrogen and oxygen from the air to generate electricity. A hydrogen fuel cell produces no waste except heat and water. The advantage of a hydrogen fuel cell is that it can provide a continuous supply of energy. A hydrogen fuel cell is safe and produces almost no pollution.

Hydrogen in the United States

Hydrogen is most widely used to generate electricity in the United States. It is commonly used in the metal refining, waste treatment, and food processing industries. It is also used in households and in fuel cells to power vehicles, laptops, and cell phones. The National Aeronautics and Space Administration (NASA) uses liquid hydrogen fuel to launch the Space Shuttle into space. Hydrogen fuel cells provide power to electrical equipment in the Space Shuttle. The states of California, Louisiana, and Texas are leaders in hydrogen production.

Bio-Hydrogen

Bio-Hydrogen is hydrogen produced from biomass or by any other biological process. Dark fermentation reaction is a biological process used to produce hydrogen. Dark fermentation reaction uses bacteria to ferment organic waste, which produces hydrogen.

Did you know?

Hydrogen is the lightest element on Earth, yet it has the highest energy content per unit weight of any fuel.

World's Largest Hydrogen-Powered Electricity Generation Plant

Each year the United States imports 55% of its crude oil. By 2025, imports are expected to rise to 68%. To meet its growing energy needs, the United States is going to build a low-carbon electricity power plant in California. It will be the world's largest hydrogen-powered electricity generating plant. The plant will generate enough energy to supply power to 325,000 homes in southern California.

HydroGen3 Minivan

Hydrogen as an Alternative Motor Fuel

Hydrogen can also be used as an alternative motor fuel. Most vehicles around the world run on internal combustion engines. The biggest advantage of hydrogen is that it can be directly used as a motor fuel in internal combustion engines. Another advantage is that the engines require little modification when hydrogen is used as a fuel. Hydrogen also provides three times the energy per pound of gasoline. However, it has one disadvantage: Liquid hydrogen has one-tenth the density of gasoline. This means that vehicles running on hydrogen need to have larger fuel tanks.

Tidal Power

Ocean tides are moving water masses that rise and fall periodically over most of the Earth. Ocean tides are a potential source of clean, alternative energy. When a tide flows in or out, it carries along with it a large amount of energy. If all tidal energy could be tapped, we would be able to generate about 64,000 megawatts of electricity. However, tides at all coastlines around the world cannot be used to generate electricity. Only coastal areas where the difference between high and low tides is at least 16 feet can be used to generate tidal power. Potential sites for generating tidal power can be found in the United Kingdom, New Zealand, Turkey, Australia, and Canada.

Generation of Tidal Power

Tidal fences, turbines, or barrages are used to generate tidal power. The simplest method of producing tidal power is by constructing a *barrage* or a dam. A barrage has a sluice gate that opens to let water in. This raises the water level in the barrage. When the tide recedes, the water is emptied into a turbine system. The force of falling water rotates a turbine that drives a generator, which produces electricity. *Tidal fences* are turbines mounted vertically on fences, and *tidal turbines* are large heavy turbines similar to wind turbines.

Why use tidal power?

- Tidal power is renewable, reliable, and non-polluting.
- Tidal power produces neither greenhouse gases nor any other waste.
- Tidal power is predictable, as tides occur twice every day.
- Building tidal power plants on the shore may protect coastlines against high storm tides.

Largest Tidal Power Plant

The world's largest tidal power plant is situated at the estuary of the La Rance River in France. It was built in 1966, generates 600 million kilowatt-hours every year, and can supply energy to almost 250,000 homes.

Energy Island

Energy Island is a concept of constructing a floating island capable of generating electricity using renewable sources like waves, ocean currents, wind, and solar energy. The idea of Energy Island is based on the Danish island of Samso, which is self-sufficient in its energy requirements. The island of Samso gets 100% of its electricity from wind power and heat energy from the sun and biomass. It is estimated that 50,000 such energy islands would be sufficient to meet the world's total energy requirements. Along with generating electricity, they could also provide enough drinking water, as a byproduct of the process, for the entire world population.

Highest Tides (Tide Ranges) Around the World

Country	Site	Tide Range (feet)
Canada	Bay of Fundy	53.1
France	Port of Ganville	48.2
England	Severn Estuary	47.5
France	La Rance	44.2
Russia	Penzhinskaya Guba (Sea of Okhotsk)	43.9
Argentina	Puerto Rio Gallegos	43.6
Russia	Bay of Mezen (White Sea)	32.8

Did you know?

The Bay of Fundy in Nova Scotia, Canada, has the highest tides in the world and can produce up to 14,000 MW of tidal power.

Geothermal Power

Earth is also a source of heat energy. Earth's mantle and core produce tremendous amounts of heat. Geothermal power converts hot water or steam from deep inside the planet's surface into electricity. For example, in the United States, the state of California meets most of its electricity demands from geothermal energy. Geothermal reservoirs are usually found near volcano and earthquake sites. Most geothermal reservoirs in the world are located in an area surrounding the Pacific Ocean known as the "Ring of Fire."

Hot Springs

Hot springs are natural springs that have a continuous flow of hot, bubbling water. The water in a hot spring is naturally heated by geothermal energy. Hot springs are found all over the world. Some hot springs are present even under the seas and oceans. Hot springs are geothermal energy resources.

The Geysers Geothermal Field

The Geysers geothermal field in California is the largest geothermal power plant. It is spread over an area of about 120 miles and is the largest dry steam field. The Geysers Field has been generating electricity since 1960. It generates enough electricity to light up more than 22,000 homes. Presently, it supplies electricity to 1.1 million people.

Geysers

Geysers are hot springs that expel fountains of hot water and steam. Geysers are geothermal energy resources. The word *geyser* is derived from the Icelandic term *gjósa*, which means "to gush." Geysers are formed when the pressure of groundwater becomes high due to geothermal heating. For example, thousands of gallons of water are released into the sky every day by the Old Faithful Geyser of Wyoming.

Early Use of Geothermal Energy

Geothermal energy has been used since ancient times for various purposes. The Romans, Chinese, Icelanders, and New Zealanders have used it over the years for heating and cooking. People of many early civilizations used hot water springs for bathing. In North America, geothermal energy was used 10,000 years ago by Paleo-Indians. They used it as a source for cleansing and healing.

Geothermal Power Plants

Geothermal power plants are built near geothermal reservoirs. They are similar to any other power plant except that they do not burn fuels to generate electricity. In a geothermal power plant, cold water is pumped down into the Earth's crust through pipes and the Earth's heat converts the cold water into heat and steam. The steam is used to propel turbines to generate electricity. The heat generated is used directly in heating systems installed in buildings. The Larderello geothermal power station in southern Tuscany, Italy, was the world's first geothermal power station. It was established in 1911. The site of the power station was the *Valle del Diavolo* (Devil's Valley).

Did you know?

Italy's Larderello was the first place in the world to use geothermal electricity, in 1904.