

Fuel

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A **fuel** is any material that can be made to react with other substances so that it releases chemical or nuclear energy as heat or to be used for work. The concept was originally applied solely to those materials capable of releasing chemical energy but has since also been applied to other sources of heat energy such as nuclear energy (via nuclear fission or nuclear fusion).

The heat energy released by reactions of fuels is converted into mechanical energy via a heat engine. Other times the heat itself is valued for warmth, cooking, or industrial processes, as well as the illumination that comes with combustion. Fuels are also used in the cells of organisms in a process known as cellular respiration, where organic molecules are oxidized to release usable energy. Hydrocarbons and related oxygen-containing molecules are by far the most common source of fuel used by humans, but other substances, including radioactive metals, are also utilized.

Fuels are contrasted with other substances or devices storing potential energy, such as those that directly release electrical energy (such as batteries and capacitors) or mechanical energy (such as flywheels, springs, compressed air, or water in a reservoir).



Wood was one of the first fuels to be used by humans and is still the primary energy source in much of the world

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History

The first known use of fuel was the combustion of wood or sticks by *Homo erectus* near 2,000,000 (two million) years ago.^[1] Throughout most of human history fuels derived from plants or animal fat were only used by humans . Charcoal, a wood derivative, has been used since at least 6,000 BCE for melting metals. It was only supplanted by coke, derived from coal, as European forests started to become depleted around the 18th century. Charcoal briquettes are now commonly used as a fuel for barbecue cooking.^[2]

Coal was first used as a fuel around 1000 BCE in China. With the energy in the form of chemical energy that could be released through combustion,^[3] but the concept development of the steam engine in the United Kingdom in 1769, coal came into more common use as a power source. Coal was later used to drive ships and locomotives. By the 19th century, gas extracted from coal was being used for street lighting in London. In the 20th and 21st centuries, the primary use of coal is to generate electricity, providing 40% of the world's electrical power supply in 2005.^[4]

Fossil fuels were rapidly adopted during the industrial revolution, because they were more concentrated and flexible than traditional energy sources, such as water power. They have become a pivotal part of our contemporary society, with most countries in the world burning fossil fuels in order to produce power.

Currently the trend has been towards renewable fuels, such as biofuels like alcohols.

Chemical

Chemical fuels are substances that release energy by reacting with substances around them, most notably by the process of combustion. Most of the chemical energy released in combustion was not stored in the chemical bonds of the fuel, but in the weak double bond of molecular oxygen.^[5]

Chemical fuels are divided in two ways. First, by their physical properties, as a solid, liquid or gas. Secondly, on the basis of their occurrence: *primary (natural fuel)* and *secondary (artificial fuel)*. Thus, a general classification of chemical fuels is:

General types of chemical fuels

	Primary (natural)	Secondary (artificial)
Solid fuels	wood, coal, peat, dung, etc.	coke, charcoal
Liquid fuels	petroleum	diesel, gasoline, kerosene, LPG, coal tar, naphtha, ethanol
Gaseous fuels	natural gas	hydrogen, propane, methane, coal gas, water gas, blast furnace gas, coke oven gas, CNG

Solid fuel

Solid fuel refers to various types of solid material that are used as fuel to produce energy and provide heating, usually released through combustion. Solid fuels include wood (see wood fuel), charcoal, peat, coal, Hexamine fuel tablets, and pellets made from wood (see wood pellets), corn, wheat, rye and other grains. Solid-fuel rocket technology also uses solid fuel (see solid propellants). Solid fuels have been used by humanity for many years to create fire. Coal was the fuel source which enabled the industrial revolution, from firing furnaces, to running steam engines. Wood was also extensively used to run steam locomotives. Both peat and coal are still used in electricity generation today. The use of some solid fuels (e.g. coal) is restricted or prohibited in some urban areas, due to unsafe levels of toxic emissions. The use of other solid fuels such as wood is decreasing as heating technology and the availability of good quality fuel improves. In some areas, smokeless coal is often the only solid fuel used. In Ireland, peat briquettes are used as smokeless fuel. They are also used to start a coal fire.



Coal is an important solid fuel

Liquid fuels

Liquid fuels are combustible or energy-generating molecules that can be harnessed to create mechanical energy, usually producing kinetic energy; they also must take the shape of their container. It is the fumes of liquid fuels that are flammable instead of the fluid.

Most liquid fuels in widespread use are derived from the fossilized remains of dead plants and animals by exposure to heat and pressure in the Earth's crust. However, there are several types, such as hydrogen fuel (for automotive uses), ethanol, jet fuel and biodiesel which are all categorized as a liquid fuel. Emulsified fuels of oil-in-water such as orimulsion have been developed a way to make heavy oil fractions usable as liquid fuels. Many liquid fuels play a primary role in transportation and the economy.



A gasoline station

Some common properties of liquid fuels are that they are easy to transport, and can be handled with relative ease. Also they are relatively easy to use for all engineering applications, and home use. Fuels like kerosene are rationed in some countries, for example available in government subsidized shops in India for home use.

Conventional diesel is similar to gasoline in that it is a mixture of aliphatic hydrocarbons extracted from petroleum. Kerosene is used in kerosene lamps and as a fuel for cooking, heating, and small engines. Natural gas, composed chiefly of methane, can only exist as a liquid at very low temperatures (regardless of pressure), which limits its direct use as a liquid fuel in most applications. LP gas is a mixture of propane and butane, both of which are easily compressible gases under standard atmospheric conditions. It offers many of the advantages of compressed natural gas (CNG), but is denser than air,

does not burn as cleanly, and is much more easily compressed. Commonly used for cooking and space heating, LP gas and compressed propane are seeing increased use in motorized vehicles; propane is the third most commonly used motor fuel globally.

Gaseous fuels

Fuel gas is any one of a number of fuels that under ordinary conditions are gaseous. Many fuel gases are composed of hydrocarbons (such as methane or propane), hydrogen, carbon monoxide, or mixtures thereof. Such gases are sources of potential heat energy or light energy that can be readily transmitted and distributed through pipes from the point of origin directly to the place of consumption. Fuel gas is contrasted with liquid fuels and from solid fuels, though some fuel gases are liquefied for storage or transport. While their gaseous nature can be advantageous, avoiding the difficulty of transporting solid fuel and the dangers of spillage inherent in liquid fuels, it can also be dangerous. It is possible for a fuel gas to be undetected and collect in certain areas, leading to the risk of a gas explosion. For this reason, odorizers are added to most fuel gases so that they may be detected by a distinct smell. The most common type of fuel gas in current use is natural gas.



A 20-pound (9.1 kg) propane cylinder

Biofuels

Biofuel can be broadly defined as solid, liquid, or gas fuel consisting of, or derived from biomass. Biomass can also be used directly for heating or power—known as *biomass fuel*. Biofuel can be produced from any carbon source that can be replenished rapidly e.g. plants. Many different plants and plant-derived materials are used for biofuel manufacture.

Perhaps the earliest fuel employed by humans is wood. Evidence shows controlled fire was used up to 1.5 million years ago at Swartkrans, South Africa. It is unknown which hominid species first used fire, as both *Australopithecus* and an early species of *Homo* were present at the sites.^[6] As a fuel, wood has remained in use up until the present day, although it has been superseded for many purposes by other sources. Wood has an energy density of 10–20 MJ/kg.^[7]

Recently biofuels have been developed for use in automotive transport (for example Bioethanol and Biodiesel), but there is widespread public debate about how carbon efficient these fuels are.

Fossil fuels

Fossil fuels are hydrocarbons, primarily coal and petroleum (liquid petroleum or natural gas), formed from the fossilized remains of ancient plants and animals^[8] by exposure to high heat and pressure in the absence of oxygen in the Earth's crust over hundreds of millions of years.^[9] Commonly, the term fossil fuel also includes hydrocarbon-containing natural resources that are not derived entirely from biological sources, such as tar sands. These latter sources are properly known as *mineral fuels*.

Fossil fuels contain high percentages of carbon and include coal, petroleum, and natural gas.^[10] They range from volatile materials with low carbon:hydrogen ratios like methane, to liquid petroleum to nonvolatile materials composed of almost pure carbon, like anthracite coal. Methane can be found in hydrocarbon fields, alone, associated with oil, or in the form of methane clathrates. Fossil fuels formed from the fossilized remains of dead plants^[8] by exposure to heat and pressure in the Earth's crust over millions of years.^[11] This biogenic theory was first introduced by German scholar Georg Agricola in 1556 and later by Mikhail Lomonosov in the 18th century.



It was estimated by the Energy Information Administration that in 2007 primary sources of energy consisted of petroleum 36.0%, coal 27.4%, natural gas 23.0%, amounting to an 86.4% share for fossil fuels in primary energy consumption in the world.^[12] Non-fossil sources in 2006 included hydroelectric 6.3%, nuclear 8.5%, and others (geothermal, solar, tidal, wind, wood, waste) amounting to 0.9%.^[13] World energy consumption was growing about 2.3% per year.

Fossil fuels are non-renewable resources because they take millions of years to form, and reserves are being depleted much faster than new ones are being made. So we must conserve these fuels and use them judiciously. The production and use of fossil fuels raise environmental concerns. A global movement toward the generation of renewable energy is therefore under way to help meet increased energy needs. The burning of fossil fuels produces around 21.3 billion tonnes (21.3 gigatonnes) of carbon dioxide (CO₂) per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tonnes of atmospheric carbon dioxide per year (one tonne of atmospheric carbon is equivalent to 44/12 or 3.7 tonnes of carbon dioxide).^[14] Carbon dioxide is one of the greenhouse gases that enhances radiative forcing and contributes to global warming, causing the average surface temperature of the Earth to rise in response, which the vast majority of climate scientists agree will cause major adverse effects. Fuels are a source of energy.

Energy

The amount of energy from different types of fuel depends on the stoichiometric ratio, the chemically correct air and fuel ratio to ensure complete combustion of fuel, and its Specific energy, the energy per unit mass.

Energy capacities of common types of fuel

Fuel	Specific energy (MJ/kg)	AFR stoich.	FAR stoich.	Energy @ $\lambda=1$ (MJ/kg (Air))
Diesel	48	14.5 : 1	0.069 : 1	3.310
Ethanol	26.4	9 : 1	0.111 : 1	2.933
Gasoline	46.4	14.7 : 1	0.068 : 1	3.156
Hydrogen	142	34.3 : 1	0.029 : 1	4.140
Kerosene	46	15.6 : 1	0.064 : 1	2.949
LPG	46.4	17.2 : 1	0.058 : 1	2.698
Methanol	19.7	6.47 : 1	0.155 : 1	3.045
Nitromethane	11.63	1.7 : 1	0.588 : 1	6.841

1 MJ \approx 0.28 kWh \approx 0.37 HPh.

Nuclear

Nuclear fuel is any material that is consumed to derive nuclear energy. Technically speaking, All matter can be a nuclear fuel because any element under the right conditions will release nuclear energy, but the materials commonly referred to as nuclear fuels are those that will produce energy without being placed under extreme duress. Nuclear fuel is a material that can be 'burned' by nuclear fission or fusion to derive nuclear energy. *Nuclear fuel* can refer to the fuel itself, or to physical objects (for example bundles composed of **fuel rods**) composed of the fuel material, mixed with structural, neutron moderating, or neutron reflecting materials.



CANDU fuel bundles Two CANDU ("CANada Deuterium Uranium") fuel bundles, each about 50 cm long and 10 cm in diameter

Most nuclear fuels contain heavy fissile elements that are capable of nuclear fission. When these fuels are struck by neutrons, they are in turn capable of emitting neutrons when they break apart. This makes possible a self-sustaining chain reaction that releases energy with a controlled rate in a nuclear reactor or with a very rapid uncontrolled rate in a nuclear weapon.

The most common fissile nuclear fuels are uranium-235 (^{235}U) and plutonium-239 (^{239}Pu). The actions of mining, refining, purifying, using, and ultimately disposing of nuclear fuel together make up the nuclear fuel cycle. Not all types of nuclear fuels create power from nuclear fission. Plutonium-238 and some other elements are used to produce small amounts of nuclear power by radioactive decay in radioisotope thermoelectric generators and other types of atomic batteries. Also, light nuclides such as tritium (^3H) can be used as fuel for nuclear fusion. Nuclear fuel has the highest energy density of all practical fuel sources.

Fission

The most common type of nuclear fuel used by humans is heavy fissile elements that can be made to undergo nuclear fission chain reactions in a nuclear fission reactor; *nuclear fuel* can refer to the material or to physical objects (for example fuel bundles composed of fuel rods) composed of the fuel material, perhaps mixed with structural, neutron moderating, or neutron reflecting materials. The most common fissile nuclear fuels are ²³⁵U and ²³⁹Pu, and the actions of mining, refining, purifying, using, and ultimately disposing of these elements together make up the nuclear fuel cycle, which is important for its relevance to nuclear power generation and nuclear weapons.



Nuclear fuel pellets are used to release nuclear energy

Fusion

Fuels that produce energy by the process of nuclear fusion are currently not utilized by humans but are the main source of fuel for stars. Fusion fuels tend to be light elements such as hydrogen which will combine easily. Energy is required to start fusion by raising temperature so high all materials would turn into plasma, and allow nuclei to collide and stick together with each other before repelling due to electric charge. This process is called fusion and it can give out energy.

In stars that undergo nuclear fusion, fuel consists of atomic nuclei that can release energy by the absorption of a proton or neutron. In most stars the fuel is provided by hydrogen, which can combine to form helium through the proton-proton chain reaction or by the CNO cycle. When the hydrogen fuel is exhausted, nuclear fusion can continue with progressively heavier elements, although the net energy released is lower because of the smaller difference in nuclear binding energy. Once iron-56 or nickel-56 nuclei are produced, no further energy can be obtained by nuclear fusion as these have the highest nuclear binding energies. The elements then on use up energy instead of giving off energy when fused. Therefore, fusion stops and the star dies. In attempts by humans, fusion is only carried out with hydrogen (isotope of 2 and 3) to form helium-4 as this reaction gives out the most net energy. Electric confinement (ITER), inertial confinement(heating by laser) and heating by strong electric currents are the popular methods used. ^[15]

World trade

The World Bank reported that the USA was the top fuel importer in 2005 followed by the EU and Japan.

See also

- Alcohol fuel
- Alternative fuels
- Ammonia
- Battery (electricity)



Fuel imports in 2005

- Bitumen-based fuel
- Biofuels
- Compressed natural gas
- Cryogenic fuel
- Emulsified fuel
- Fuel card
- Fuel cell
- Fuel management systems
- Fuel oil
- Fuel poverty
- Filling station
- Hydrogen economy
- Hydrogen fuel
- Liquid fuels
- List of energy topics
- Marine fuel management
- Propellant
- Recycled fuel
- Solid fuel
- World energy resources and consumption

Footnotes

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Further reading

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- Council Directive 80/1268/EEC Fuel consumption of motor vehicles (<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31980L1268:EN:NOT>).



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