

Hydrogen

What Is Hydrogen?

Hydrogen is the simplest element known to man. Each atom of hydrogen has only one proton and one electron. It is also the most plentiful gas in the universe. Stars are made primarily of hydrogen.

Like all stars, our sun's energy comes from hydrogen. The sun is a giant ball of hydrogen and helium gases. Inside the sun, hydrogen atoms combine to form helium atoms. This process, called **fusion**, gives off **radiant energy**.

This radiant energy sustains life on Earth. It gives us light and makes plants grow. It makes the wind blow and rain fall. It is stored in fossil fuels. Most of the energy we use today came from the sun.

Hydrogen as a gas (H_2) doesn't exist on Earth. It is always mixed with other elements. Combined with oxygen, it is water (H_2O). Combined with carbon, it makes different compounds such as methane (CH_4), coal, and petroleum. Hydrogen is also found in all growing things—biomass.

Hydrogen has the highest energy content of any common fuel by weight, but the lowest energy content by volume. It is the lightest element and is a gas at normal temperature and pressure.

Hydrogen Can Store Energy

Most of the energy we use today comes from fossil fuels. Hydrogen can be produced using **renewable** or nonrenewable sources. Today 95% of hydrogen produced is made by natural gas reforming in large control plants. Hydrogen is helpful because it can store the energy until it's needed and move it to where it's needed. Hydrogen can be used in many ways once we're ready to use it.

Energy Carrier

Every day, we use more energy, mostly coal, to make electricity. Electricity is a **secondary source of energy**. Secondary sources of energy—sometimes called **energy carriers**—store, move, and deliver energy to consumers. We convert energy to electricity because it is easier for us to move and use.

Electricity gives us light, heat, hot water, cold food, TVs, and computers. Life would be really hard if we had to burn the coal, split the atoms, or build our own dams. Energy carriers make life easier.

Hydrogen is an energy carrier. It is a clean fuel that can be used for transportation, heating, and generating. However, since hydrogen doesn't exist on Earth as a gas, we must make it.

ARTEMIS I SPACE LAUNCH SYSTEM AND ORION SPACECRAFT

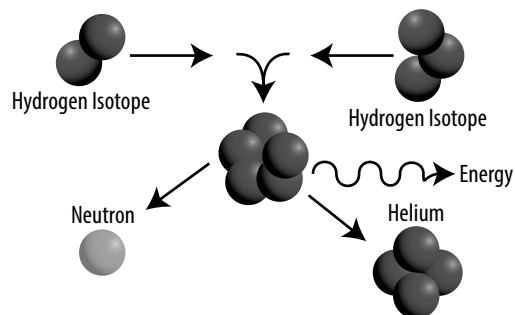


Image courtesy of NASA

Hydrogen was used as the fuel for NASA space shuttles and rockets, beginning in the 1980s. While the U.S. shuttles have since been retired, hydrogen is still used internationally to launch satellites and as a space fuel. The NASA Artemis project will use hydrogen as a propellant. Hydrogen is a perfect fuel for space travel, as it has very high energy density while keeping weight down.

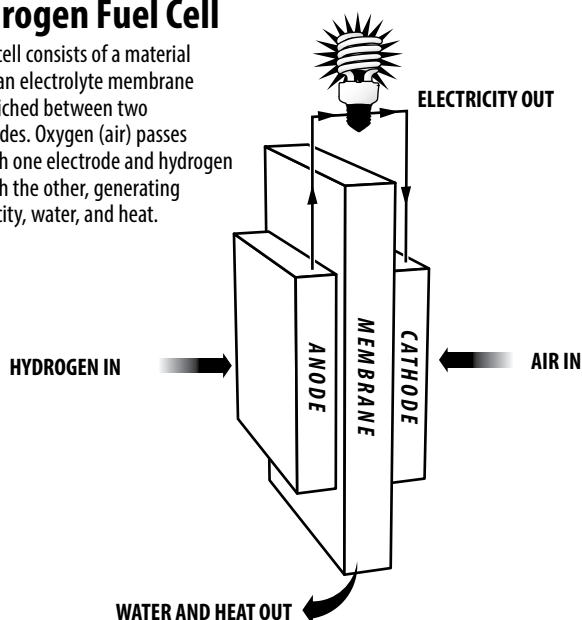
Fusion

The process of fusion most commonly involves hydrogen isotopes combining to form a helium atom with a transformation of matter. This matter is emitted as radiant energy.

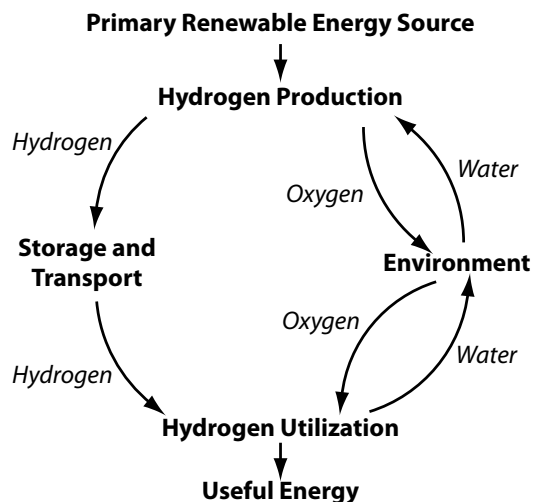


Hydrogen Fuel Cell

A fuel cell consists of a material called an electrolyte membrane sandwiched between two electrodes. Oxygen (air) passes through one electrode and hydrogen through the other, generating electricity, water, and heat.



Hydrogen Life Cycle



How Is Hydrogen Made?

Hydrogen is made by separating it from water, biomass, or natural gas—from domestic resources. Scientists have even discovered that some algae and bacteria give off hydrogen. It can be expensive to make hydrogen right now, but new technologies are being developed.

Hydrogen can be produced at large central facilities or at small plants for local use. Every region of the country (and the world) has some resource that can be used to make hydrogen. Its flexibility is one of its main advantages.

Uses of Hydrogen

Over eight and a half billion cubic feet of hydrogen are produced in the U.S. each day. Most of this hydrogen is used by industry in refining, treating metals, and processing foods.

NASA was once the primary user of hydrogen as an energy fuel; it recently began using hydrogen in the space program again. Hydrogen fuel is used to lift the spacecraft into orbit. Hydrogen batteries—called **fuel cells**—can be used to power spacecraft electrical systems. The only byproduct of hydrogen use is pure water.

Hydrogen fuel cells make electricity. They are very efficient but can be expensive to build. Small fuel cells can power electric cars. Large fuel cells can provide electricity in remote areas.

Hydrogen as a Fuel

Because of cost, storage, and distribution concerns, hydrogen power plants may not be built for a while. Hydrogen could be added to natural gas, to reduce pollution from existing plants.

Hydrogen could also be added to gasoline to boost performance and reduce pollution. Adding just five percent hydrogen to gasoline could significantly lower emissions of nitrogen oxides (NO_x), which contribute to ground-level ozone pollution.

HYDROGEN-FUELED VEHICLE



Image courtesy U.S. Department of Energy

An engine that burns pure hydrogen produces almost no pollution. However, there are only five hydrogen fuel cell models available for purchase in the U.S. Sales are limited to areas where hydrogen fueling stations exist, which is mostly in California.

The Future of Hydrogen

Before hydrogen becomes a significant fuel in the U.S. energy picture, many new systems must be built. We will need systems to produce hydrogen efficiently and to store and move it safely. We will need many miles of new pipelines and economical fuel cells. Consumers will need the technology and the education to use it. More infrastructure and fueling stations will need to be added.

With advancements in hydrogen and fuel cell technologies, hydrogen has the potential to provide a large amount of clean, renewable energy in the future.