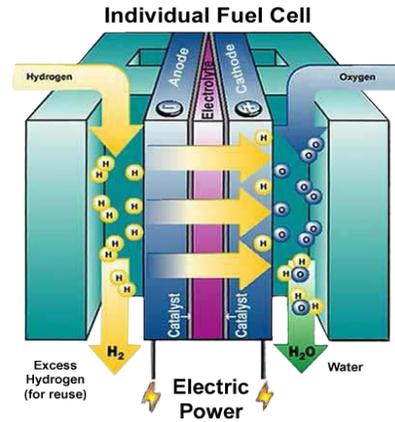




## WHAT IS A FUEL CELL?

Fuel cells are a highly efficient, combustion-less, virtually pollution free source of electricity that can power buildings, automobiles and a host of consumer applications.

A fuel cell is an electrochemical device that produces electricity. In principle, a fuel cell operates like a battery. However, unlike a battery, a fuel cell does not run down or require recharging. A fuel cell uses fuel — usually natural gas to extract the hydrogen and air to extract the oxygen — to produce electricity. It will continue to produce energy in the form of electricity and heat as long as there is a constant source of fuel. The workings of the hydrogen fuel cell are surprisingly simple. Since there are no moving parts, fuel cells operate silently with water as the only by-product

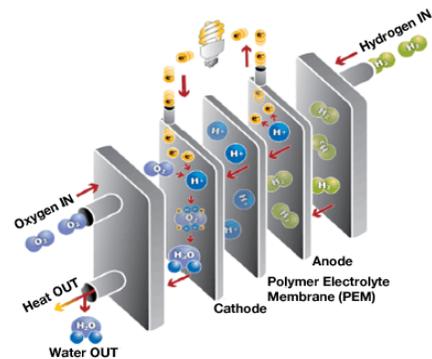


### How Does a Fuel Cell Work?

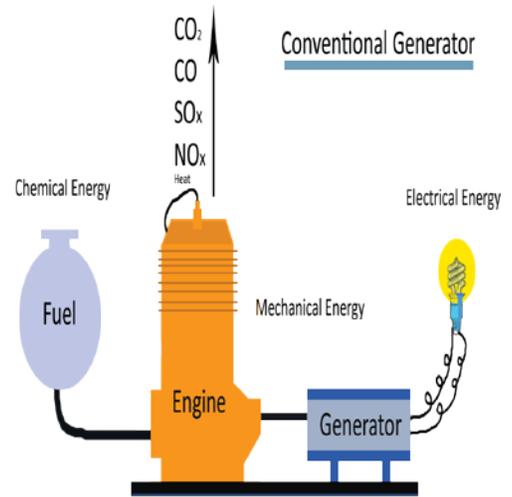
A fuel cell consists of two electrodes sandwiched around an electrically conductive material called an electrolyte. Oxygen passes over one electrode (cathode) and hydrogen over the other (anode), generating electricity, water and heat. A fuel cell system can use the hydrogen from any hydrocarbon fuel. Natural gas — a chemical combination of carbon and hydrogen atoms — is perhaps the most common fuel, but other hydrocarbon fuels, such as methanol and gasoline, can also be used. Oxygen (or air) enters the fuel cell through the cathode. Encouraged by a catalyst, the hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte. The electrons create a separate current that can be utilized before they return to the cathode, to be reunited with the hydrogen and oxygen in a molecule of water.

### The Benefits of Fuel Cells

Fuel cells can be “stacked” to produce voltage levels that match specific power needs for a wide variety of uses. That makes fuel cells one of the most promising technologies for delivering clean and efficient power for automotive, industrial, residential and consumer applications. While some cost and engineering challenges remain, fuel cells hold the potential to provide major environmental, energy and economic benefits that advance critical national goals. Widespread use of fuel cells may hold the answers to some of our most significant energy shortage challenges for the future and could mark a historical turning point, reducing dependence on fossil fuels, improving the environment, and creating a whole new hydrogen-driven economy.

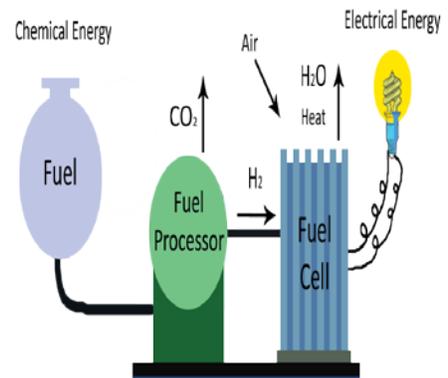


The promise of fuel cells for on-site production of electricity is significant. Many say fuel cells will do for the power industry what desktop computers have done for the computer business. Just as cellular phones and satellite TV have “unwired” their respective industries, fuel cells will herald a new age in electrical power distribution. For developing countries, which have not already made massive investments in electrical utility infrastructure, the rewards are even greater. The stationary fuel cell may well be the vehicle by which the masses learn to think “outside the box” when it comes to electrical power.



Fuel cell systems have a purpose similar to conventional generators already used today for primary or standby power production, e.g. chemical energy from fuel is converted to electrical power. However, in the case of a generator, fuel is converted to mechanical energy by an internal combustion engine. This mechanical energy in turn drives an electrical generator or alternator to produce electrical power. The primary by-products are heat, CO<sub>2</sub> (carbon dioxide), and water. With most fuels, there are also some emissions including CO (carbon monoxide) and various oxides of nitrogen and sulfur. Typically, the energy efficiency of these internal combustion generators is approximately 15% to 20%, as compared to a fuel cell efficiency of 45%. That means that for combustion generators, about 85 to 90 percent of the potential energy in the fuel is not converted to electricity.

Fuel Cell Generator



### Fuel Cell Applications

Advances since the use of fuel cells by NASA for the Apollo programs in 1960's, and fuel cell developments in the past decade have led to increased research and widespread application of fuel cells for power generation and vehicles.

In general, the fuel cell market can be divided into several segments based on the type of application for which the fuel cell is intended.

- Stationary
- Residential
- Transportation
- Portable Power



**Stationary:** Fuel cell systems have been installed for fixed applications in hospitals, nursing homes, hotels, office buildings, schools and utility power plants. In addition to being used as the primary source of power, in some cases, fuel cells are used for standby power to ensure uninterrupted power delivery in hospitals or other businesses that are highly sensitive to power disruptions.

**Residential:** Fuel cells are ideal for power generation, either to provide supplemental power and backup assurance for critical areas, or installed as a generator for on-site service in areas that are inaccessible by power lines. Because fuel cells operate silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be used to provide hot water or space heating for a home. Many of the prototypes being tested and demonstrated for residential use extract hydrogen from propane or natural gas.

**Transportation:** Although many technical challenges remain, automotive industry leaders believe that fuel cell technology is likely to replace the internal combustion engine as the principal power source for automobiles and other vehicles. The U.S. government predicts that fuel cell vehicles may begin to be mass-produced within the next decade, radically transforming the way automobiles are designed and manufactured. In addition, fuel cells are powering buses, boats, trains, planes, scooters and bicycles.

**Portable Power:** Miniature fuel cells will change the world as we know it. Fuel cells can serve as power sources for a limitless array of personal electronics. For instance, fuel cells will power laptop computers and palm pilots for hours longer than batteries. Fuel cells will enable you to talk much longer on a cellular phone without recharging. Other applications for miniature fuel cells include pagers, video recorders, portable power tools, and other devices such as hearing aids, smoke detectors and burglar alarms. These miniature fuel cells generally run on methanol, an inexpensive wood alcohol also used in windshield wiper fluid.