HYDROGEN FACTS

Power to change the world®

Ballard's PEM fuel cell products create electrical energy from the combination of hydrogen and air. But, what is hydrogen, where does it come from, how available is it and where can I learn more about it? Read on…

WHAT IS HYDROGEN (H_2)?

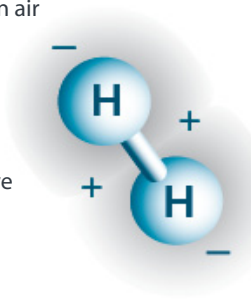
- Simplest element on earth – made up of one proton and one electron
- Third most abundant element on the earth's surface – makes up 98% of the universe
- An energy carrier – like electricity, H2 stores and delivers energy in an easily usable form

WHY HYDROGEN?

- **Renewable** – H_2 can be produced from renewable esources (e.g. wind, solar, and hydro-electric power)
- **Efficient** – H_2 fuel cell products are significantly More efficient than internal combustion engines
- **Clean** – H_2 is a carbon-free fuel
- **Safe** – H_2 is safer than conventional hydrocarbon fuels

HYDROGEN CHARACTERISTICS

- Colorless
- Odourless
- Tasteless
- 14x lighter than air
- Carbon-free
- Non-toxic
- Non-corosive
- Non-irritating
- Non-radioactive



REFORMATE-CAPABLE FUEL CELL PRODUCTS

Many industrial gas suppliers are working with the fuel cell industry to make significant progress toward establishing the required infrastructure to refuel hydrogen storage tanks installed at distributed sites. In locations where hydrogen distribution is challenging, a fuel cell product can be coupled with a reformer, which expands the choice of fuel options to more widely available fuels, such as natural gas, propane or methanol.

FCgen®-LCS

PRODUCTION OF HYDROGEN

Hydrogen is one of the most abundant elements, but it is rarely found in its purest form. Hydrogen is almost always found as part of some other substance, such as water, plants, methanol, kerosene, natural gas, or other hydrocarbons. The base substance dictates the production process chosen.

Hydrogen can be produced in large "central production" plants and transported to the point of end-use. Liquid hydrogen is the most cost-effective form of hydrogen to transport. Hydrogen may also be produced in smaller "distributed production" facilities, very near or at the point of end-use.

In North America today, more than 95% of hydrogen is produced by large-scale steam methane reforming (SMR). This is the most cost-effective method of hydrogen production.

MAJOR HYDROGEN PRODUCTION PROCESSES (Source: National Hydrogen Association)

METHOD	PROCESS	SUBSTANCE	ENERGY	CO_2 EMISSIONS	LOCATION
Thermal	Steam reformation	Natural gas	High temperature steam	Yes	Central or Distributed
	Thermochemical water splitting	Water	High temperature heat from advanced gas-cooled nuclear reactors	Zero	Central
	Gasification	Coal and biomass	Steam and oxygen at high temperature and pressure	Yes	Central
	Pyrolysis	Biomass	Moderately high temperature steam	Yes	Central
Electrochemical	Electrolysis	Water	Electricity from wind, solar, hydro and nuclear	Zero	Central or Distributed
	Electrolysis	Water	Electricity from coal or natural gas	Yes	Central or Distributed
	Photoelectrochemical	Water	Direct sunlight	Zero	Central
Biological	In exploratory R&D phase				

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COST OF HYDROGEN

The choice of a hydrogen production strategy greatly affects the cost and method of delivery. Central production plants can produce hydrogen at relatively low cost due to economies of scale, but the delivery costs are significant since the point of use is farther away. In comparison, distributed production facilities have relatively low delivery costs, but the hydrogen production costs are likely to be more significant than centralized production, as lower production volume means higher equipment costs on a per-unit-of hydrogen basis.

COMPRESSED HYDROGEN

- Compressed hydrogen tube trailers are typically used in low-volume commercial applications or temporary demonstration projects.
- Tube trailers provide convenient and portable fuelling solutions but are typically more expensive than permanent liquid hydrogen installations.

LIQUID HYDROGEN

- Liquid hydrogen installations are typically used in high-volume, permanent commercial installations, such as fuelling stations for fuel ell transit bus fleets and fuel cell forklift truck operations.
- The energy density of liquid hydrogen (LH2) is considerably higher than that of compressed hydrogen. Therefore, LH2 is generally a more cost-effective solution for large-scale use, as fewer journeys are necessary to transport the same quantity of energy.

STEAM METHANE REFORMING

- On-site steam methane reforming is the most cost-effective and common form of hydrogen production today, usually reserved for large-scale capvtive markets, such as petroleum refining.
- Medium-scale SMR products are also now available for producing on-site hydrogen from natural gas for hydrogen bus fleets and commercial warehousing operations.

HYDROGEN SAFETY (Source: National Hydrogen Association)

Hydrogen is no more or less dangerous than other flammable fuels. However, its unique characteristics should be viewed as advantageous. Hydrogen is lighter than air and therefore it rapidly disperses in the event of a leak. This minimizes the possibility of accumulation and ignition. In the event that hydrogen does ignite, its flames generate low radiant heat due to the absence of carbon. This makes hydrogen substantially safer than conventional hydrocarbon fuels (such as gasoline) for users and first responders in the event of any accident.

Photo from a video that compares fires from an intentionally ignited hydrogen tank release to a small gasoline fuel line leak.

- 60s after ignition: they hydrogen flame has begun to subside, while the gasoline fire is intensifying
- 100s after ignition: all of the hydrogen is gone and the car's interior was undamaged. The gasoline car continued to burn for several minutes and was completely destroyed

H2 FUELLING

H2 fuelling stations use industry standard designs for indoor and outdoor solutions. H2 fuelling is simple, safe and does not requirespecialized equipment or labour.

Ballard Power Systems, Inc. is recognized as a world leader in the design, development, manufactureand sale of clean energy fuel cell products. Our **FCgen** family of stationary power products and **FCvelocity** family of motive power products offer important business benefits not available from traditional power sources. To learn more contact us at:

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