Hydrogen and Fuel Cells 101

Updated on Jan 2022
Overview

Key Hydrogen Facts:

- Most abundant element in the universe
- Present in common substances (water, sugar, methane)
- Very high energy by weight (3x more than gasoline)
- Can be used to make fertilizer, steel, as a fuel in trucks, trains, ships, and more
- Can be used to store energy and make electricity, with only water as byproduct
- Can be produced from multiple abundant fuel sources in the U.S.
Key Hydrogen Technologies: Fuel Cells and Electrolyzers

**Fuel Cells: Use Hydrogen**
- Hydrogen and Oxygen IN
- Electricity and Water OUT
- Makes electricity using hydrogen
- No combustion involved

**Electrolyzers: Make Hydrogen**
- Electricity and Water IN
- Hydrogen and Oxygen OUT
- Makes hydrogen using electricity
- Operates like a fuel cell “in reverse”
Hydrogen Challenges

Key Challenges:

- High cost
- Needs energy (like solar, wind, nuclear) or fuel to produce
- Difficult to store and transport
- Limited infrastructure to move and use hydrogen
Hydrogen Sources

Clean and domestic energy sources can be used to produce hydrogen

Most of today’s hydrogen comes from natural gas

Learn more at: http://www.energy.gov/eere/fuelcells/hydrogen-resources

10 million metric tons of hydrogen produced annually in the United States, mostly for oil refining and fertilizer production.
Hydrogen Production

Any of the previously mentioned energy sources can produce hydrogen through these processes:

- **Electricity** separates water into oxygen and hydrogen.
- **Microbes or enzymes** break down plants and produce hydrogen.
- **Energy from direct sunlight and sun heat** splits molecules.
- **Steam and hydrocarbons** come together under high temperature.

Hydrogen Uses

Multiple industries
Multiple applications

Including steel, cement ammonia industries
For heavy-duty applications including trucks, trains and at ports
Good for long-term energy storage; improved electric grid efficiency
Electricity production for cell phone towers, data centers, hospitals and supermarkets
Largest use of hydrogen produced today
Second largest use of hydrogen produced today

Learn more at: https://energy.gov/eere/fuelcells/fuel-cell-technologies-educational-publications
Key Hydrogen Benefits

- Reduced greenhouse gas emissions
- Reduced oil consumption
- Ability to store renewable power
- Ability to use for industry and transportation
- Reduced air pollution
- Reliable grid support
Key Fuel Cell Benefits

- Quiet operation
- Low-maintenance; no recharging required
- High reliability
- Can provide power from a variety of fuels (not just hydrogen)
- 2-3x more efficient than internal combustion engines
- Zero emissions at point of use
Hydrogen Production and Electrolyzers in the U.S.

**In the United States:**
- 10 million metric tons (MMT) H₂/yr
- Over 1,600 miles of H₂ pipelines
- World’s largest H₂ storage cavern

**Examples of Hydrogen Production Locations**

**Examples of Electrolyzer Installations**

Current and under construction installations over 120 kW as of Jun. 2021

*Source: Arjona, et al, DOE HFTO Program Record, June 2021*
Examples of Real-World Hydrogen Applications in the U.S.

- **Stationary and Backup Power**: >550MW
- **Forklifts**: >50,000
- **PEM* Electrolyzers**: >172 MW
- **Fuel Cell Buses**: ~70
- **H₂ Retail Stations**: >50
- **Fuel Cell Cars**: >12,000

*PEM: Polymer electrolyte membrane*

- **Increasing orders of fuel cell forklifts** by warehouses and stores in the U.S.
- **World’s first fuel cell for maritime ports** in Hawaii

Photo Credit: UPS
Photographs: BMW Manufacturing
Photo Credit: FedEx
Examples of Real-World Applications in the U.S.

- Fuel cells provided backup power during Hurricane Sandy in the U.S. Northeast
- Increasing orders of fuel cell forklifts by warehouses and stores in the U.S.
- Over 550 MW of fuel cell stationary power deployed and on order across the country
- Hydrogen fuel cell ferry set to operate in the West Coast
- Approximately 50 public hydrogen stations open to refuel cars and trucks
- Approx. 70 hydrogen buses operating for public transit

Photo Credit: BMW Manufacturing
Photo Credit: NREL
Examples of Real-World Applications Abroad

- **World’s first 4-seater fuel cell plane takes off at German Airport**
- **A town in Fukuoka, Japan running on hydrogen**
- **World’s first hydrogen fuel cell train in Germany**
- **Fuel cell cab fleet launched in Paris, France**

Photos:
- World’s first 4-seater fuel cell plane: Photo Credit: Christoph Schmidt/dpa via AP and phys.org.
- A town in Fukuoka, Japan: Photo Credit: Fukuoka Pref.
- World’s first hydrogen fuel cell train in Germany: Photo Credit: Hydrogenics and Alstom.
- Fuel cell cab fleet launched in Paris, France: Photo Credit: Hyundai.
Secretary of Energy Jennifer Granholm Explains Clean Hydrogen