U.S. DEPARTMENT OF ENERGY

Hydrogen and Fuel Cells 101

Updated on Jan 2022



Overview

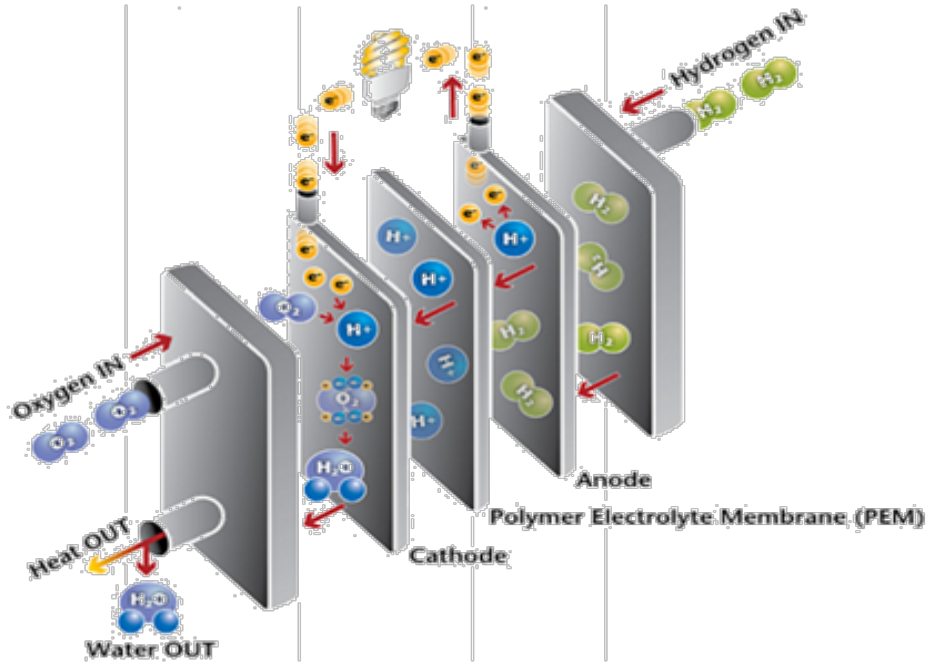
Key Hydrogen Facts:

- 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

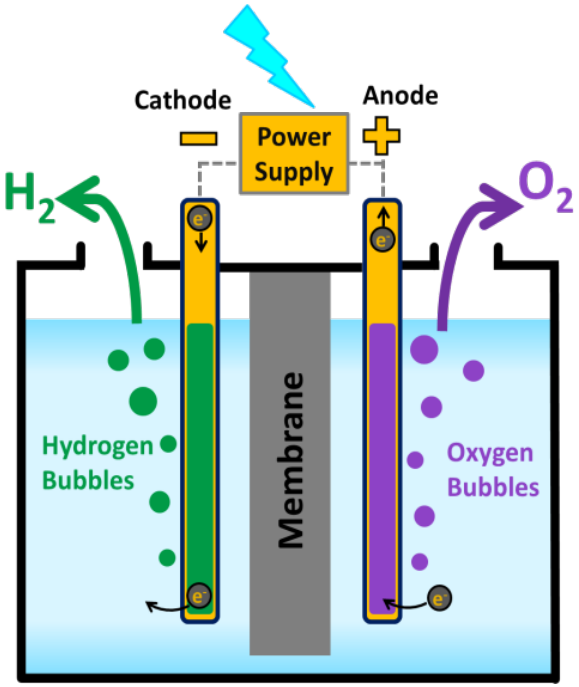
Fuel Cells: Use Hydrogen

- 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

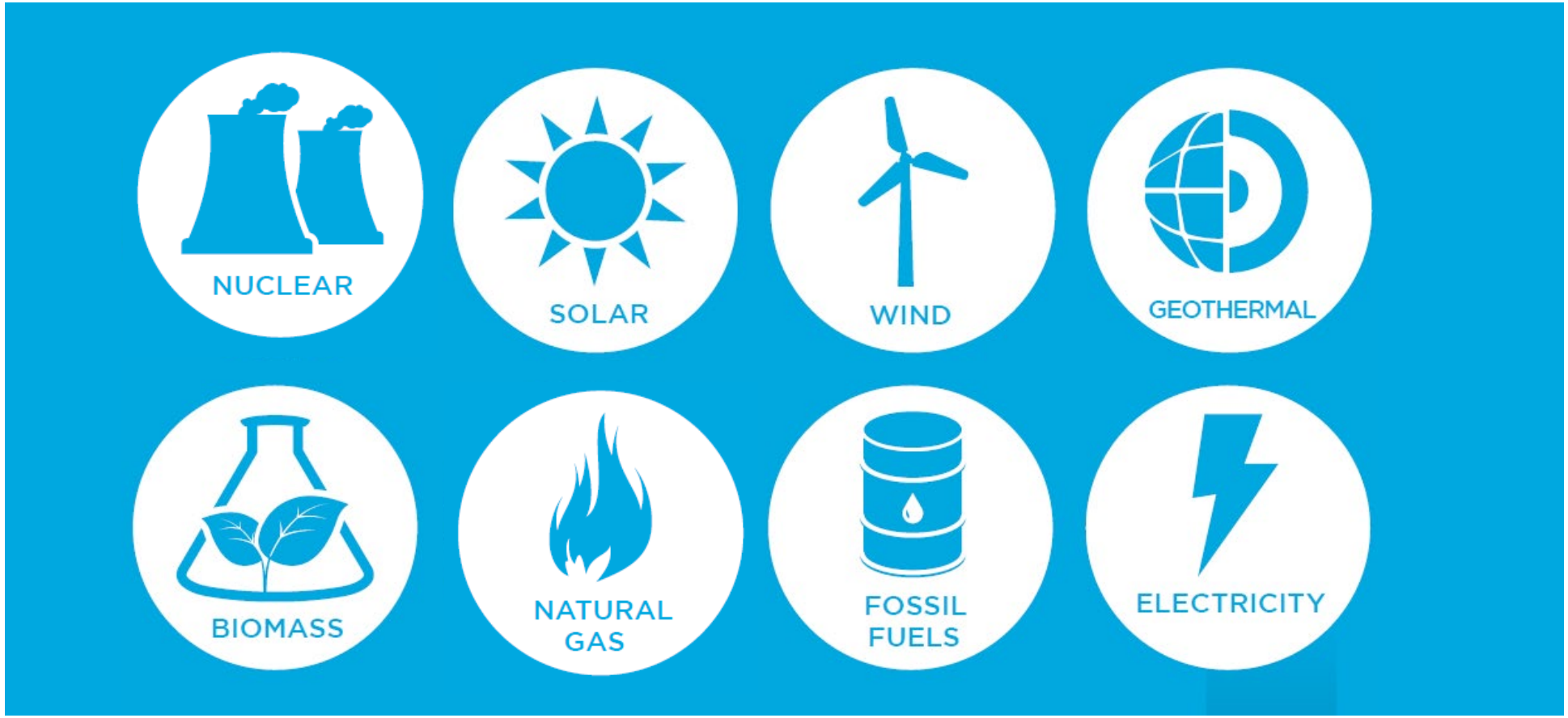
Key Challenges:

- 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



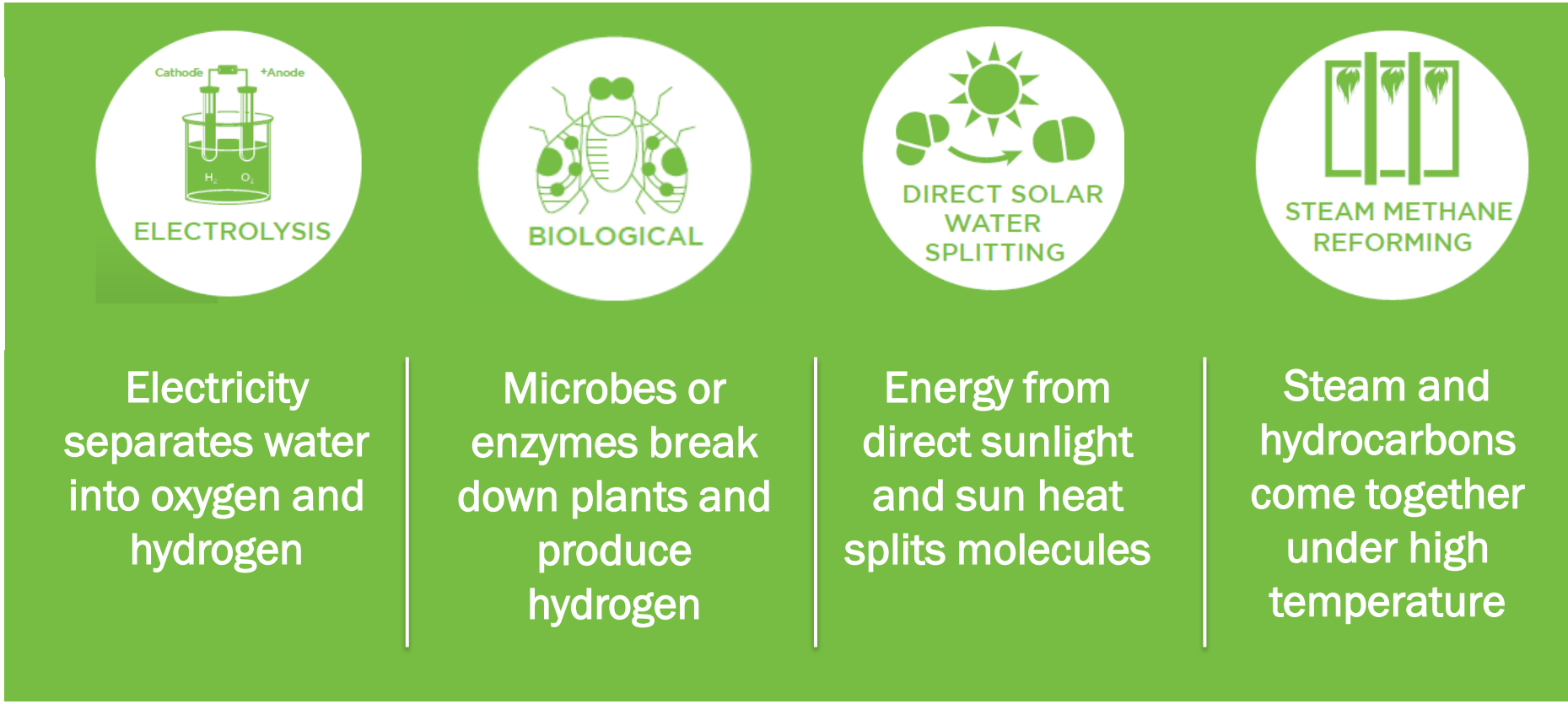
10 million metric tons of hydrogen

produced annually in the United States, mostly for oil refining and fertilizer production

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

Hydrogen Production

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

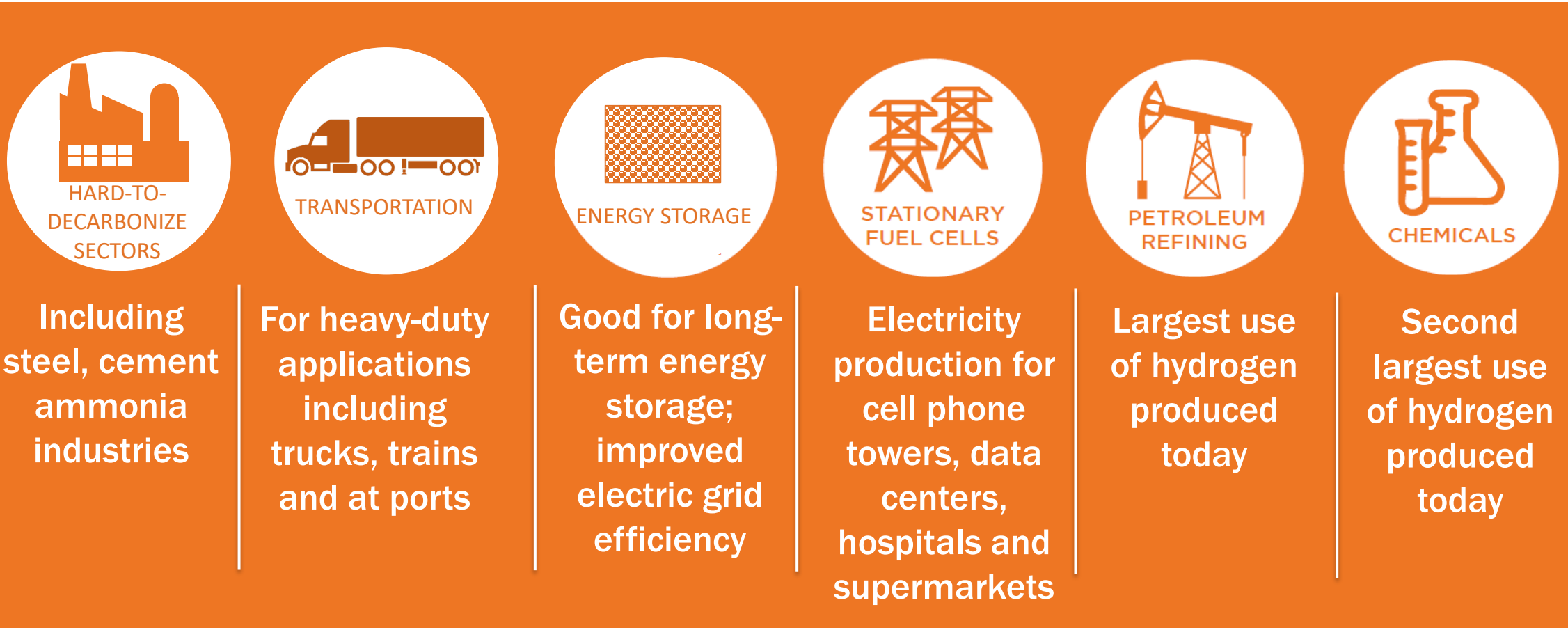


Learn more at: http://www.energy.gov/eere/fuelcells/hydrogen-production-processes

Hydrogen Uses

Multiple industries

Multiple applications



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

Key Hydrogen Benefits

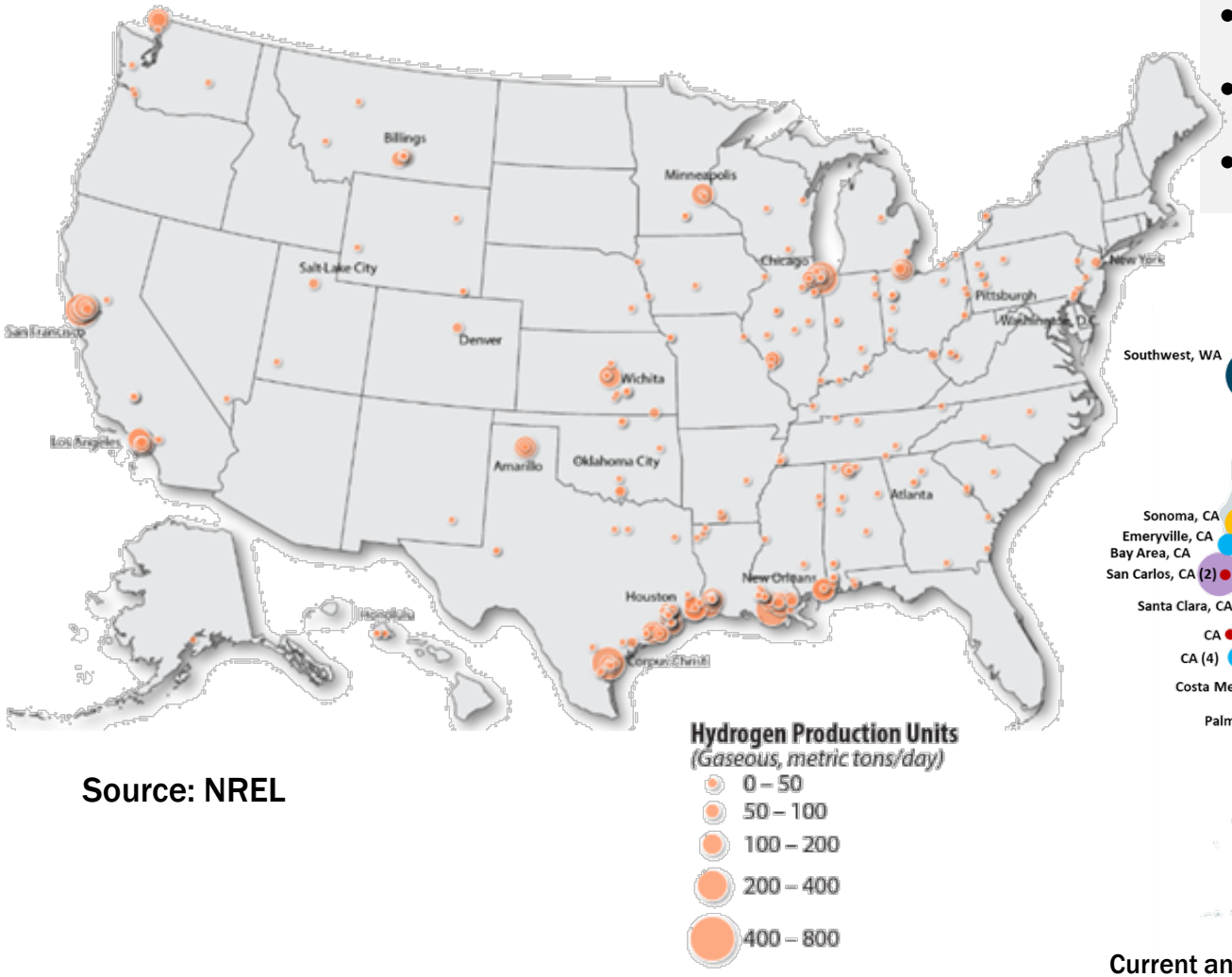
- Reduced greenhouse gas emissions
- Reduced oil consumption
- Ability to store renewable power
- Ability to use for industry and transportation
- Reduced air pollution
- Reliable grid support

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.

Examples of Hydrogen Production Locations

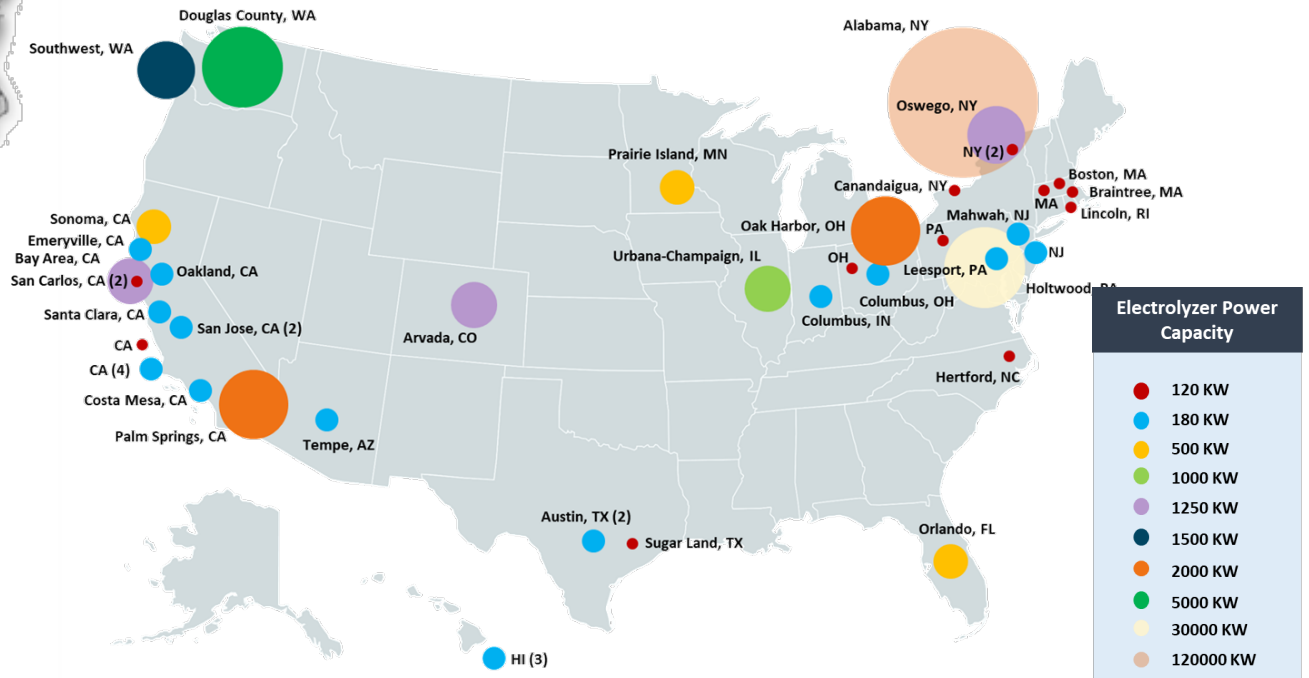


Source: NREL

In the United States:

- 10 million metric tons (MMT) H_2/yr
- Over 1,600 miles of H_2 pipelines
- World's largest H_2 storage cavern

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.

Examples of Applications in Use

- **>550MW** — Stationary and Backup Power
- **>50,000** — Forklifts
- **>172 MW** — PEM* Electrolyzers
- **~70** — Fuel Cell Buses
- **~50** — H_2 Retail Stations
- **>12,000** — Fuel Cell Cars

PEM: Polymer electrolyte membrane

Photo Credit: UPS

Fuel cell delivery and parcel trucks operating in CA and NY

Photo Credit: FedEx

Increasing orders of fuel cell forklifts by warehouses and stores in the U.S.

Photo Credit: BMW Manufacturing

World's first fuel cell for maritime ports in Hawaii

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.

Photo Credit: BMW Manufacturing

Hydrogen fuel cell ferry set to operate in the West Coast

Over 550 MW of fuel cell stationary power deployed and on order across the country

Photo Credit: NREL

Approximately 50 public hydrogen stations open to refuel cars and trucks

Approx. 70 hydrogen buses operating for public transit

Examples of Real-World Applications Abroad

World's first 4-seater fuel cell plane takes off at German Airport

Photo Credit: Christoph Schmidt/dpa via AP and phys.org.

Fuel cell cab fleet launched in Paris, France

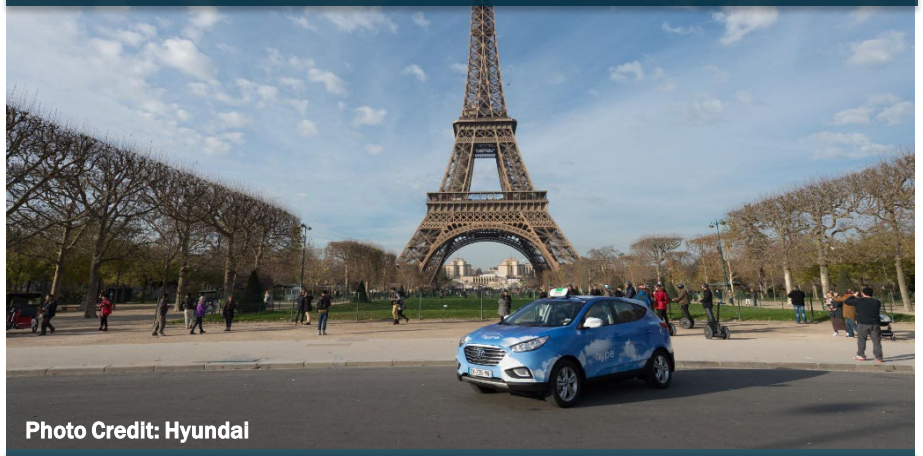


Photo Credit: Hyundai

A town in in Fukuoka, Japan running on hydrogen

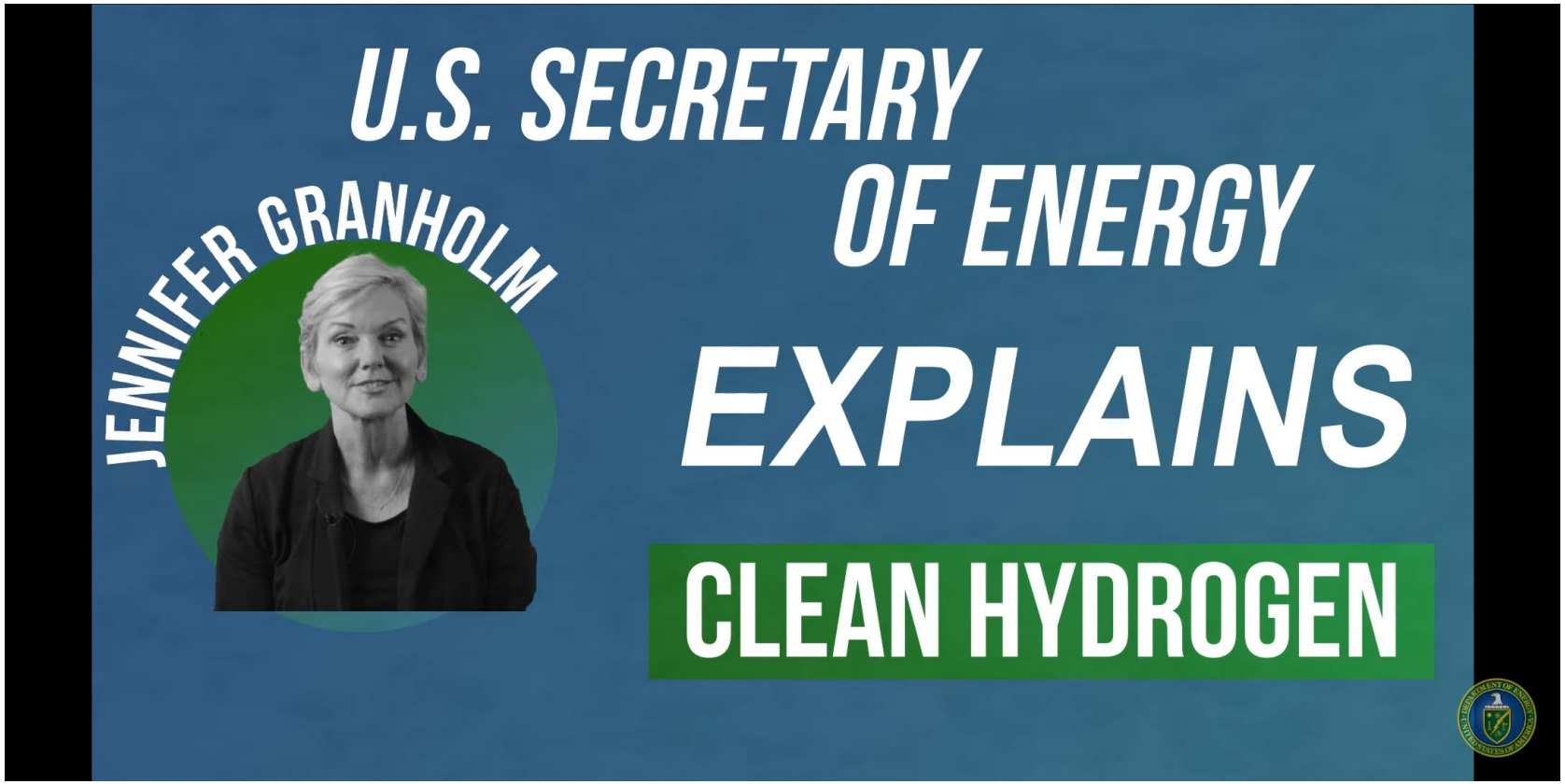
Photo Credit: Fukuoka Pref.

World's first hydrogen fuel cell train in Germany

Photo Credit: Hydrogenics and Alstom

Watch

Secretary of Energy Jennifer Granholm Explains Clean Hydrogen



Watch Secretary Jennifer Granholm Explain Clean Hydrogen | Department of Energy