# Hydrogen and Fuel Cell Technical Advisory Committee Outreach Modules

Prepared by the HTAC External Communications Subcommittee

# Table of Contents



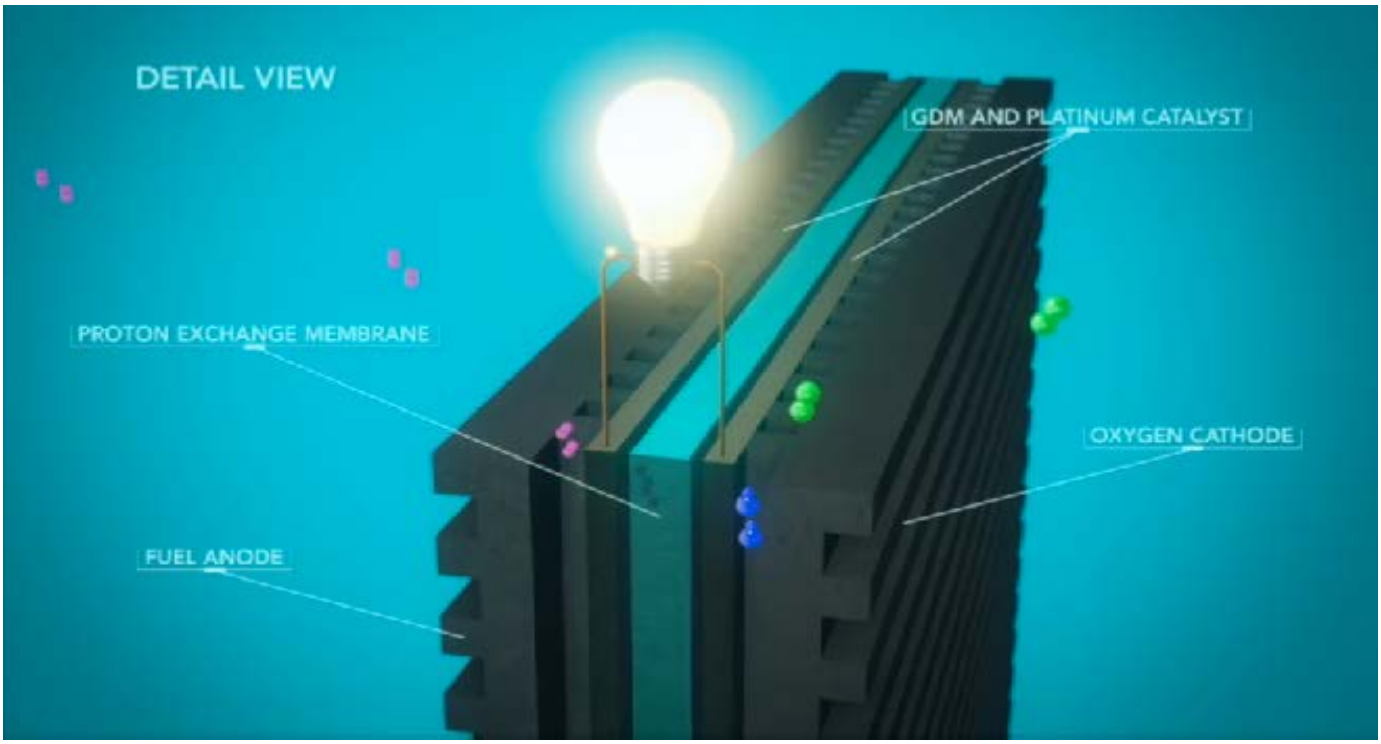
For more information about the Hydrogen and Fuel Cell Technical Committee (HTAC), please visit our website here.

**Contact Us**

# FUEL CELLS

Hydrogen fuel cells provide the power – power to bring renewable energy into transportation, power to keep the lights on in an emergency, power to fuel American technology leadership and American jobs.

Watch the video below to learn how fuel cells work!

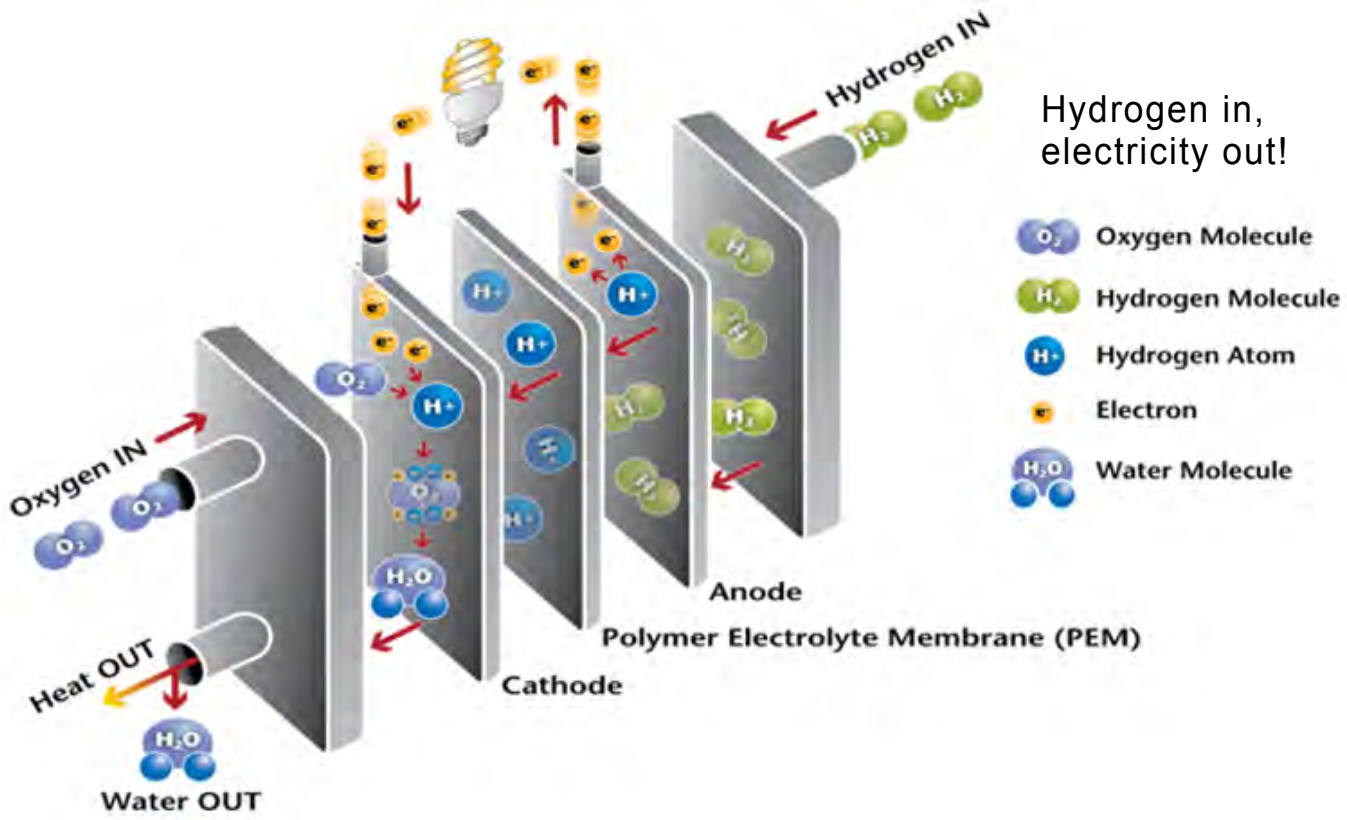



Learn more about fuel cells, their applications, and the industry in the following pages.

Back to Table of Contents

# FUEL CELLS - WHAT AND HOW

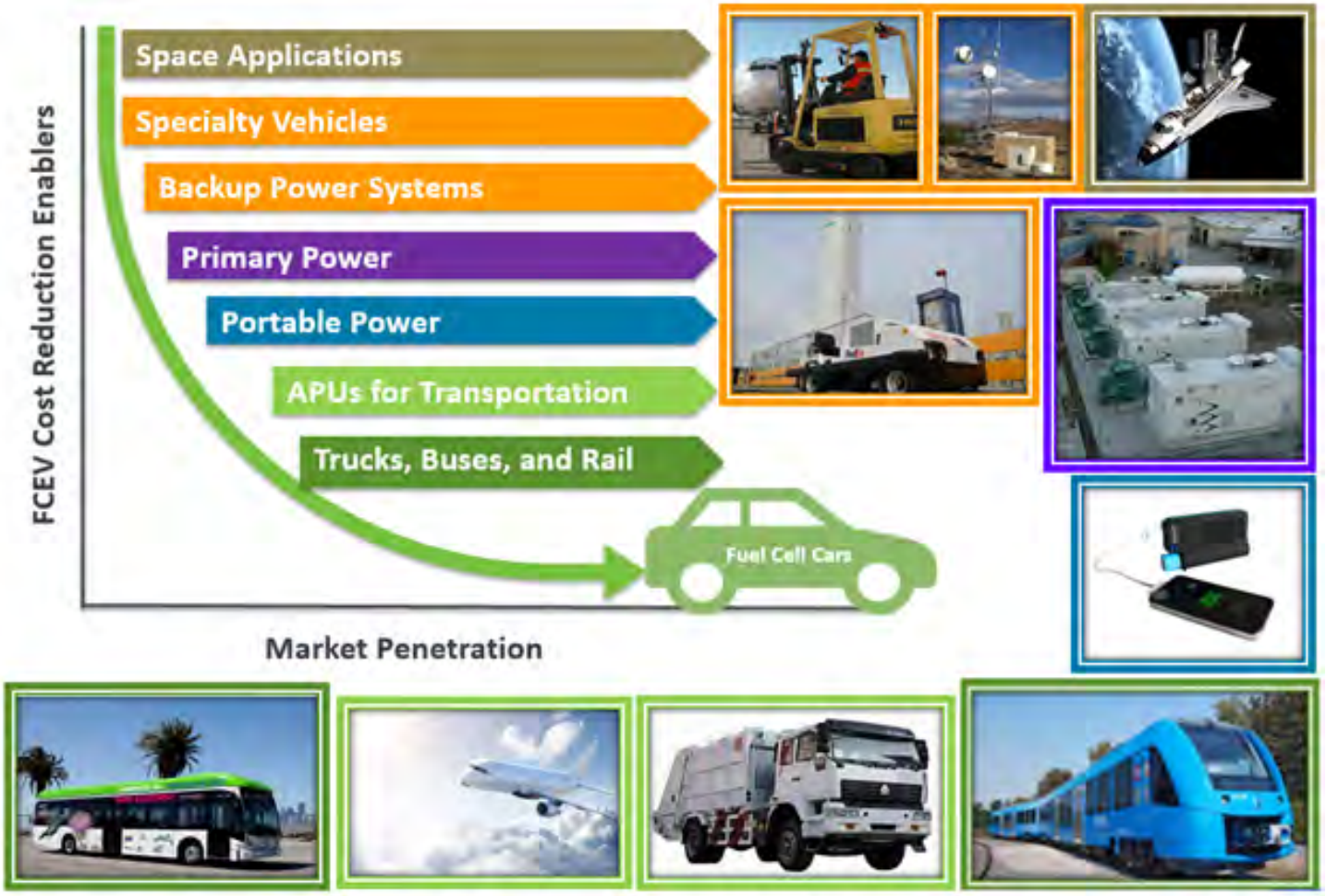
A fuel cell uses hydrogen to produce electricity with no emissions.




Check out this video on how a fuel cell works!

- Electricity is produced directly as needed through a chemical process, similar to a battery
- Only water and heat come out of the tailpipe
- Can be 2 to 3 times as efficient as today's internal combustion engines since they don't burn fuel
- Runs quietly since there are no mechanical gears or combustion

# MANY APPLICATIONS FOR FUEL CELLS




**Lower costs and higher durability are translating to more products.**

The fuel cell stack is the heart of a fuel cell power system. It generates electricity by using hydrogen in an electrochemical reaction that take place in the fuel cell. A single fuel cell typically produces less than 1 volt, but individual fuel cells can be stacked to provide necessary power for many different applications. The larger the stack, the more power it generates, with a typical automotive fuel cell stack consisting of hundreds of fuel cells. The amount of power produced by a fuel cell depends upon several factors, such as fuel cell type, cell size, the temperature at which it operates, and the pressure of the gases supplied to the cell.

# FUEL CELLS FOR SPECIALTY APPLICATIONS

## Forklift applications

**There are now more than 20,000 hydrogen fuel cell forklifts in use with over 12 million refuelings!**

Photo Credit: BMW Manufacturing

- Fuel cell-powered forklifts are currently in operation around the country at manufacturing plants, distribution centers. and grocery warehouses.
- They are replacing battery-powered and combustion forklifts due to their advantages of longer runtime, faster refueling, and higher efficiency.
- Examples of companies using fuel cell forklifts include Amazon, Walmart, Sysco, Procter & Gamble, BMW, Coca-Cola, Central Grocers, FedEx, Lowes, Mercedes, Volkswagen, Honda, Kroger, Wegman's, Whole Foods,WinCo Foods, and many others.

Photo Credit: U.S. DOE

## Airport ground support equipment (GSE) applications

**The world's first zero emissions, hydrogen fuel cell baggage tow tractor demo completed at Memphis International Airport!**

- Fuel cell powered GSE applications such as these aim to reduce consumption of gasoline and diesel fuels and to demonstrate lower carbon emissions with a fuel cell solution in airports.
- In the long term, such early markets could offer the potential for hubs of hydrogen infrastructure for applications such as shuttle buses, fleet vehicles, rental cars, taxis and retail consumer vehicles.
- In two years, the fuel cell GSE at Memphis International Airport have saved 175,200 gallons of diesel while maintaining a towing capacity of up to 40,000 pounds!

# FUEL CELLS BRING BACKUP POWER

- Fuel cells can provide power to homes, hospitals, police stations, telecommunications towers, and data centers.
- Backup power is needed to keep critical infrastructure running when grid power goes down such as Hurricane Sandy or the 2003 Northeast Blackout.
- Clean, quiet, and reliable power wherever it's needed.


***Source:*** *"Hydrogen Fuel Cell Performance as Telecommunications Backup Power in the United States" NREL/TP-5400-60730*

Left: Power before Hurricane Sandy


Photo credit: NASA


Right: Power after Hurricane Sandy

# FUEL CELLS POWERING MORE THAN CARS IN TRANSPORTATION

## Industry demonstrates first heavy duty fuel cell truck in CA

Photo Credit: Toyota

Industry unveiled the first fuel cell powered heavy duty truck prototype that will be tested at a California port and emits nothing other than water vapor. It has a 300 mile range, boasting more than 670 horsepower and 1,327 pound-feet of torque.

## Fuel cell buses surpass 19M passengers

Photo Credit: NREL

Fuel cell buses have carried over 19 million passengers and one of the fuel cell buses surpassed a 25,000 hour milestone for durability, exceeding the DOE target. Across California, Illinois, Massachusetts, Michigan, and Ohio, there are 30 buses in operation and 35 more planned.

## World's first hydrogen fuel cell train in Germany


Photo Credit: Hydrogenics and Alstom

Germany is demonstrating the world's first fuel cell-powered train and is transporting passengers on a 62 mile route between 4 cities in Northern Germany. It can travel 600 miles and carry 300 passengers, with a top speed of 87 mph.

## Fuel cell delivery and parcel trucks starting deliveries in CA and NY


Photo Credit: UPS

Photo Credit: FedEx

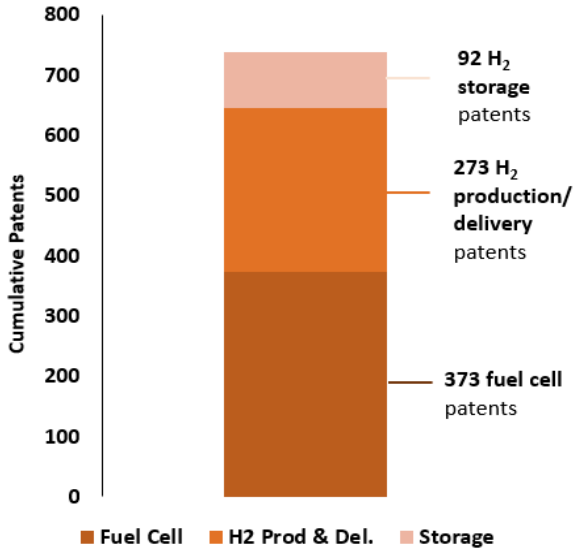
The UPS and FedEx Express are incorporating fuel cells in their delivery trucks. At 125 miles, they double the driving range of battery electric parcel delivery.

# THE FUEL CELL INDUSTRY IS GROWING

**Fuel cells create American jobs and bolster American technology leadership**

- There are over 350 companies in the hydrogen and fuel cell sectors in the U.S.

  Source: HFCNexus




- The U.S. has diverse technology expertise in hydrogen and fuel cells. As of 2017, DOE funding has enabled 750 U.S. patents.

- According to the U.S. Department of Energy (DOE) 2017 Energy and Jobs report, there are currently over 16,500 US employees in the FCEV sector and over 1,500 in the stationary fuel cell sector.

# HYDROGEN FUEL AND INFRASTRUCTURE

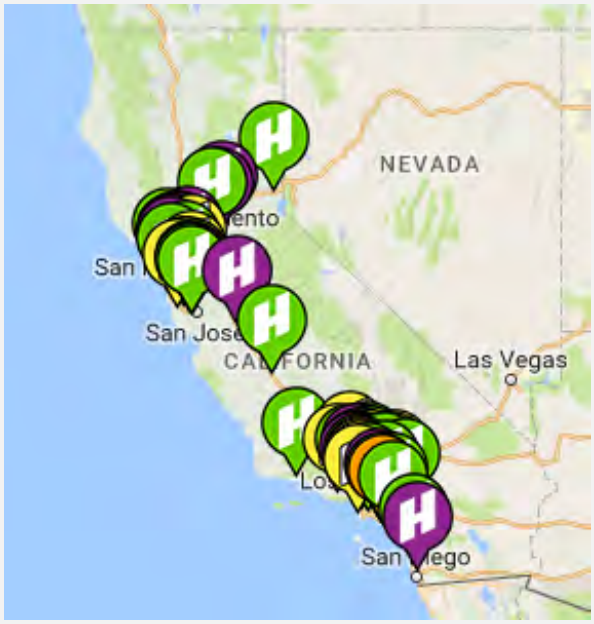
Hydrogen fueling is safe, easy, and available – the hydrogen fuel station network is growing rapidly.

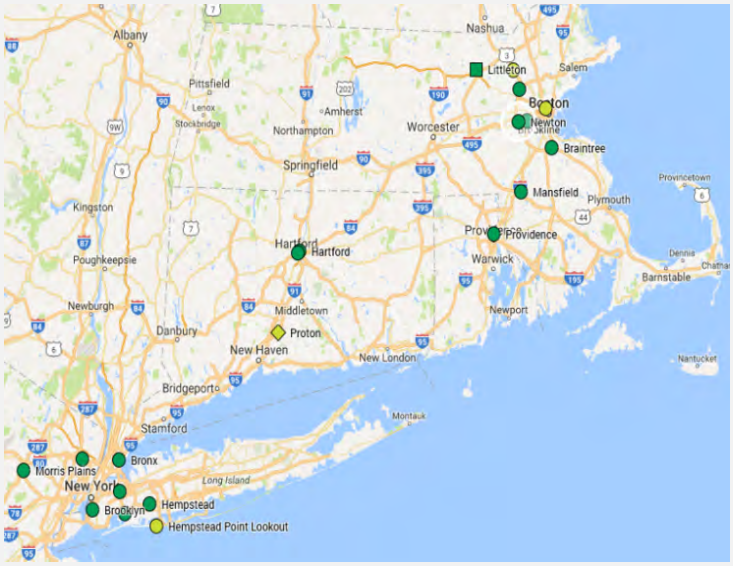
Learn more about hydrogen fuel, where to get it, and the infrastructure for hydrogen in the following pages.

Back to Table of Contents

# WHERE DO I GET HYDROGEN?

- As of December 2018, there are over 35 retail hydrogen stations in the U.S. and quite a few more that are not yet commercial.
- Hydrogen for fuel cell cars is dispensed from a hydrogen pump that looks very similar to a gas pump.
- Plans are underway for over 200 retail hydrogen stations, with California setting goals for 1,000 stations and 1,000,000 fuel cell cars by 2030.

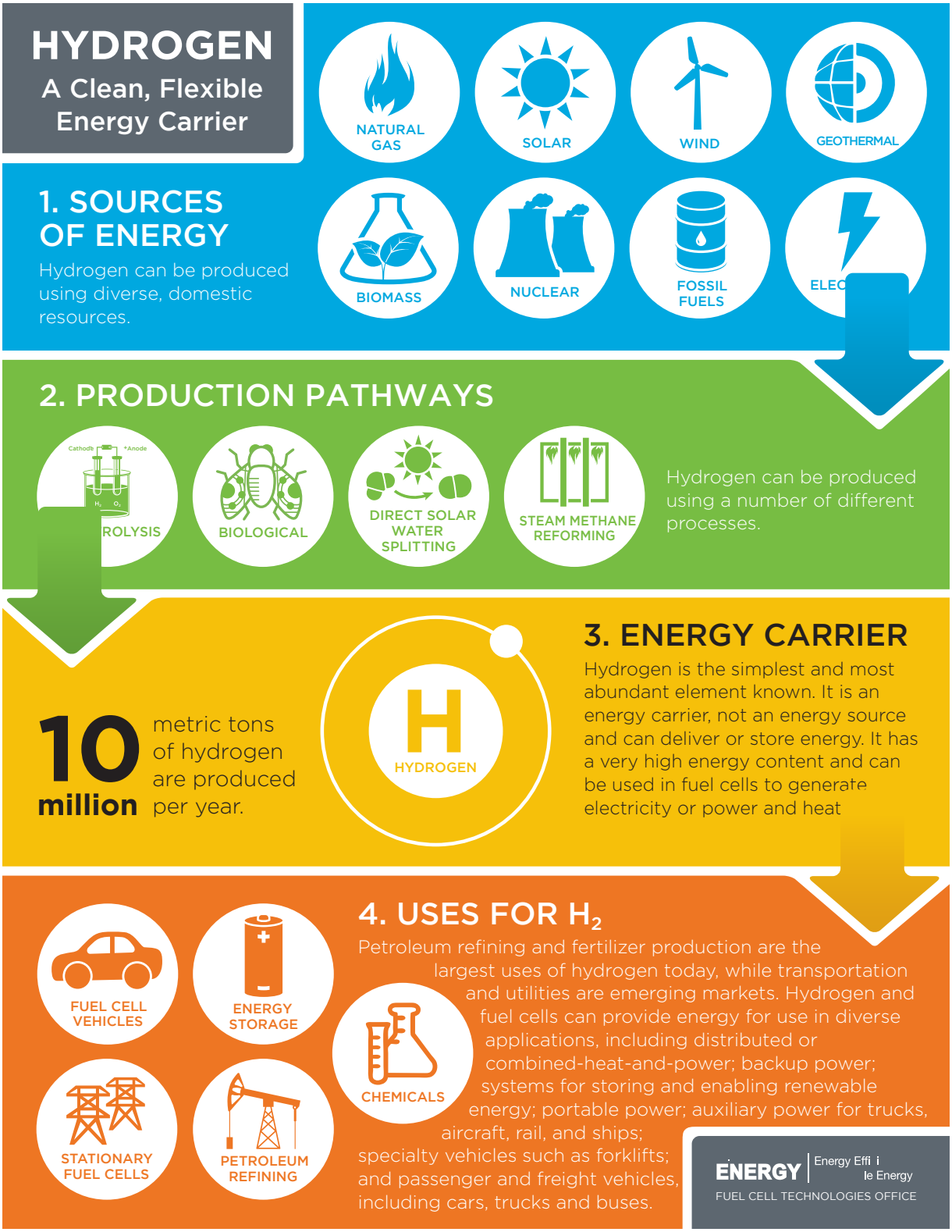





You can find a list of hydrogen stations here

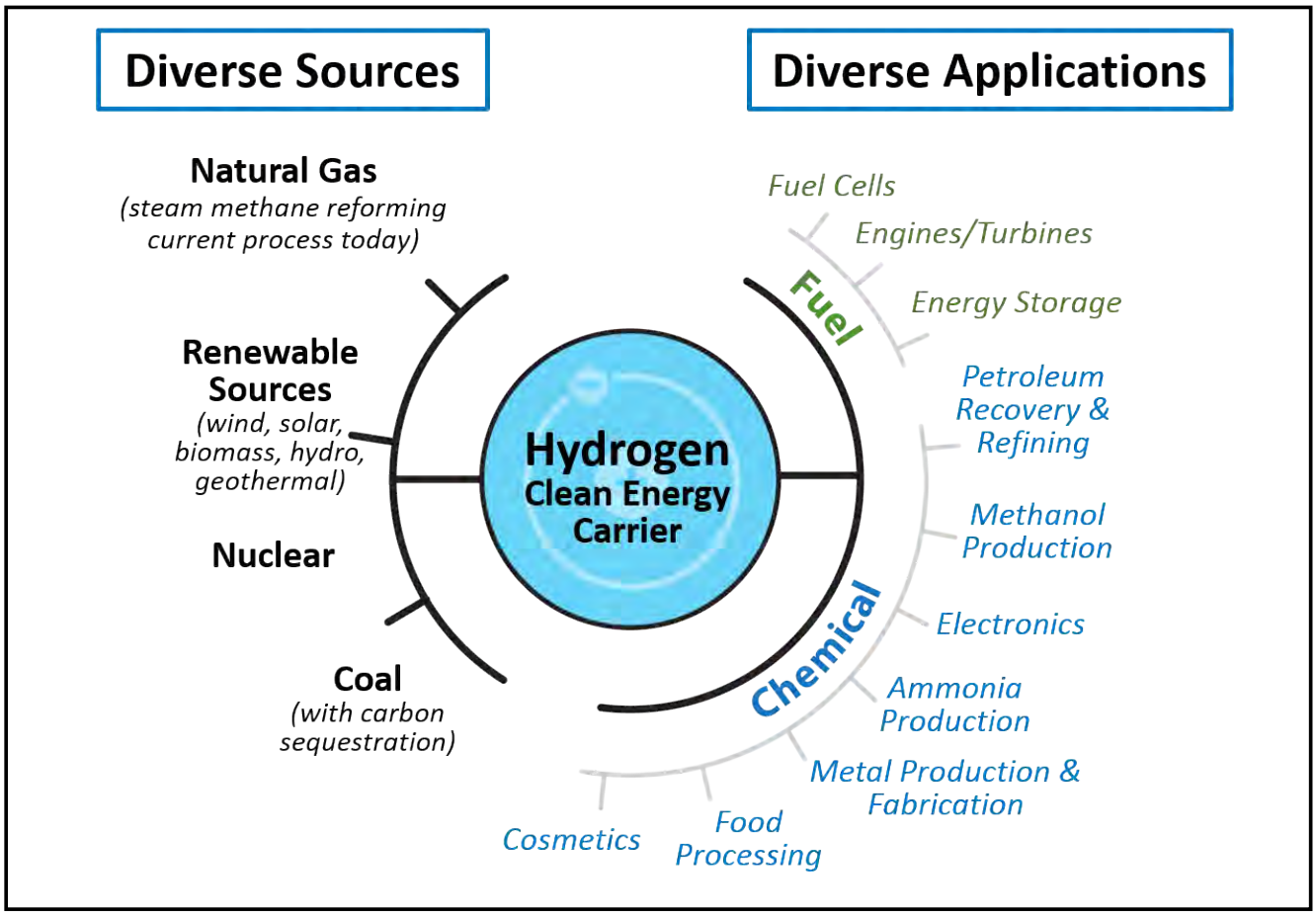
Type in your zip code to find the nearest station
on the Alternative Fuels Data Center


HYDROGEN
A Clean, Flexible Energy Carrier
1. SOURCES OF ENERGY
Hydrogen can be produced using diverse, domestic resources.
NATURAL GAS
SOLAR
WIND
GEOTHERMAL
BIOMASS
NUCLEAR
FOSSIL FUELS
ELEC
2. PRODUCTION PATHWAYS
ROLYSIS
BIOLOGICAL
DIRECT SOLAR WATER SPLITTING
STEAM METHANE REFORMING
Hydrogen can be produced using a number of different processes.
10 million metric tons of hydrogen are produced per year.
H
HYDROGEN
3. ENERGY CARRIER
Hydrogen is the simplest and most abundant element known. It is an energy carrier, not an energy source and can deliver or store energy. It has a very high energy content and can be used in fuel cells to generate electricity or power and heat
4. USES FOR $H_2$
Petroleum refining and fertilizer production are the largest uses of hydrogen today, while transportation and utilities are emerging markets. Hydrogen and fuel cells can provide energy for use in diverse applications, including distributed or combined-heat-and-power; backup power; systems for storing and enabling renewable energy; portable power; auxiliary power for trucks, aircraft, rail, and ships; specialty vehicles such as forklifts; and passenger and freight vehicles, including cars, trucks and buses.
FUEL CELL VEHICLES
ENERGY STORAGE
CHEMICALS
STATIONARY FUEL CELLS
PETROLEUM REFINING
ENERGY
Energy Efficiency Energy
FUEL CELL TECHNOLOGIES OFFICE

# A CLEAN ENERGY FUTURE

Hydrogen can enable an affordable, reliable, clean and secure energy future by:

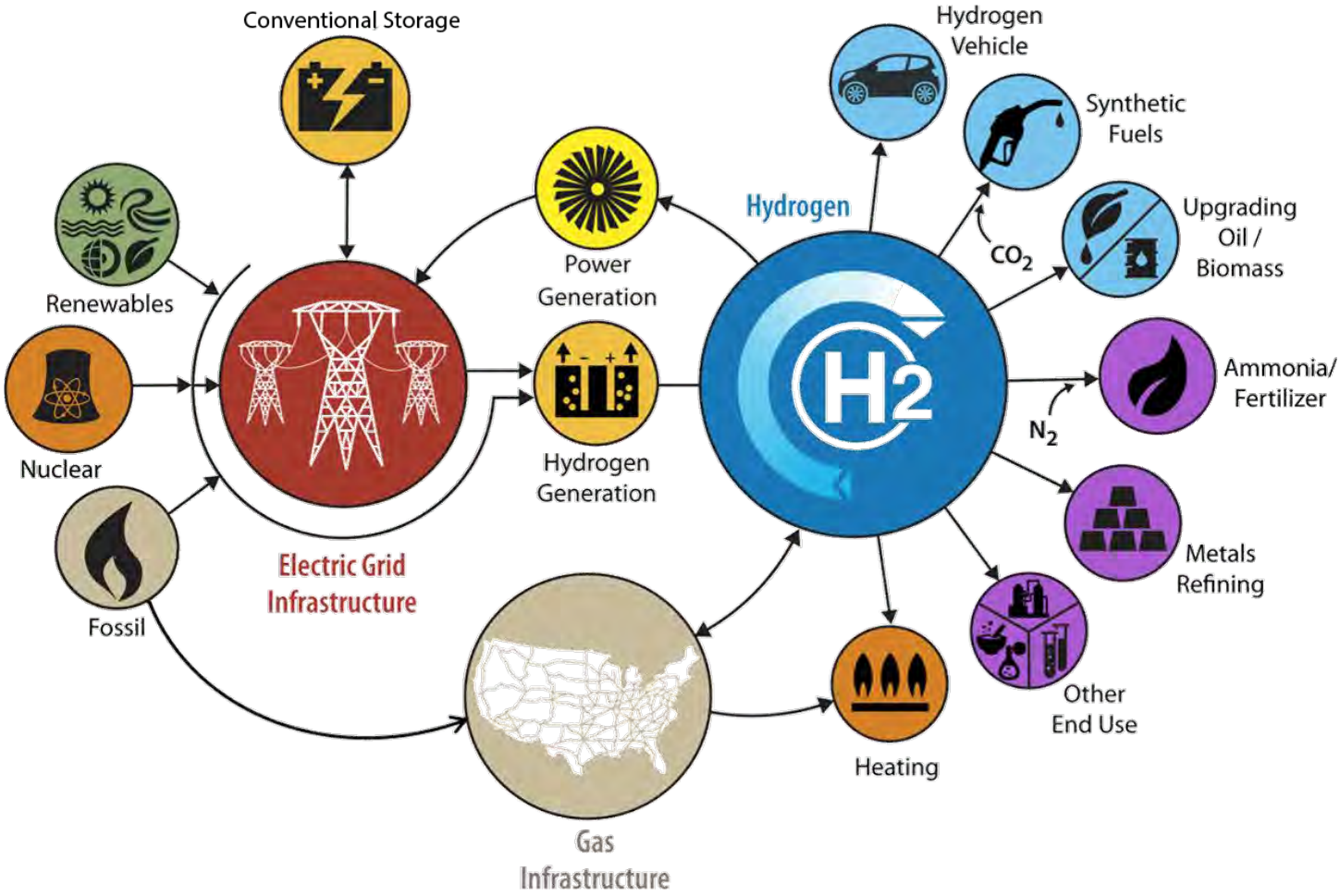
- Uniting all our nation's diverse energy resources: natural gas, coal, nuclear, and renewables.
- Producing completely zero or near zero emissions when used in transportation, stationary or remote power, and portable power applications.
- Serving as a critical feedstock for the entire chemicals industry, including liquid fuels.
- Enabling grid services, gigawatt-hour energy storage, and energy generation through multiple technologies that can be geographically widespread.




- Click here for a webinar presentation about "H2@Scale" – the concept of uniting all our nation's energy resources and unlock value across multiple sectors in the economy.

# HYDROGEN FOR ENERGY STORAGE

H2@Scale: Enabling affordable, reliable, clean, and secure energy across sectors



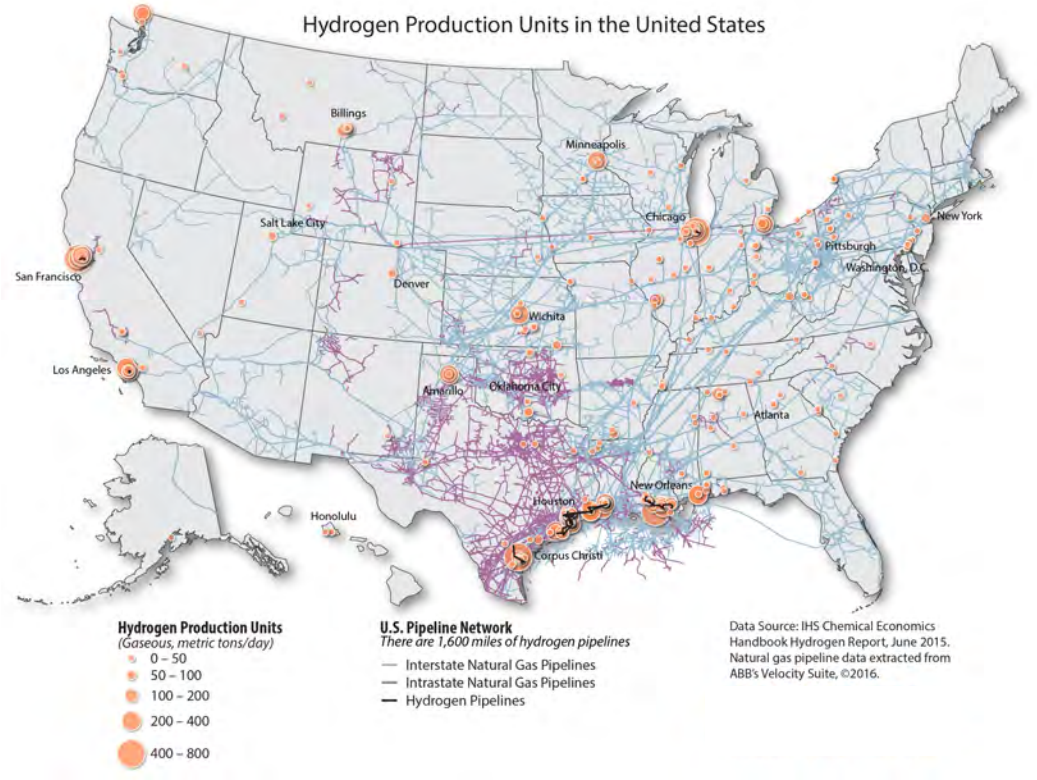

H2@Scale is a concept regarding the potential for wide-scale impact of hydrogen produced from diverse domestic resources to enhance U.S. energy security and enable growth of innovative technologies and domestic industries.

Image source: NREL

# WHAT'S THE BOTTOM LINE?

**Hydrogen production facilities in the United States**

The United States already produces over **10 million tons of hydrogen per year.** That's enough to power roughly 50 million fuel cell cars!




Over 1,600 miles of hydrogen pipelines distribute $H_2$ from production sites to major users primarily on the Gulf coast.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

- Fueling is safe, easy, and available in certain areas, with an expanding network.
- Today we're rapidly adding retail and transit stations to the existing US hydrogen production and distribution system.
- DOE's H2@Scale concept brings renewable, nuclear and fossil fuel (with carbon sequestration) energy into transportation and other sectors – it allows us to use hydrogen to store energy when the electric grid doesn't need it.

# FUEL CELL ELECTRIC CARS
# AND
# BATTERY ELECTRIC CARS

Which one you need depends on how far you're going and what kind of energy you are using.


Learn more about fuel cell electric and battery electric cars, including refueling and charging times, in the following pages.

Back to Table of Contents

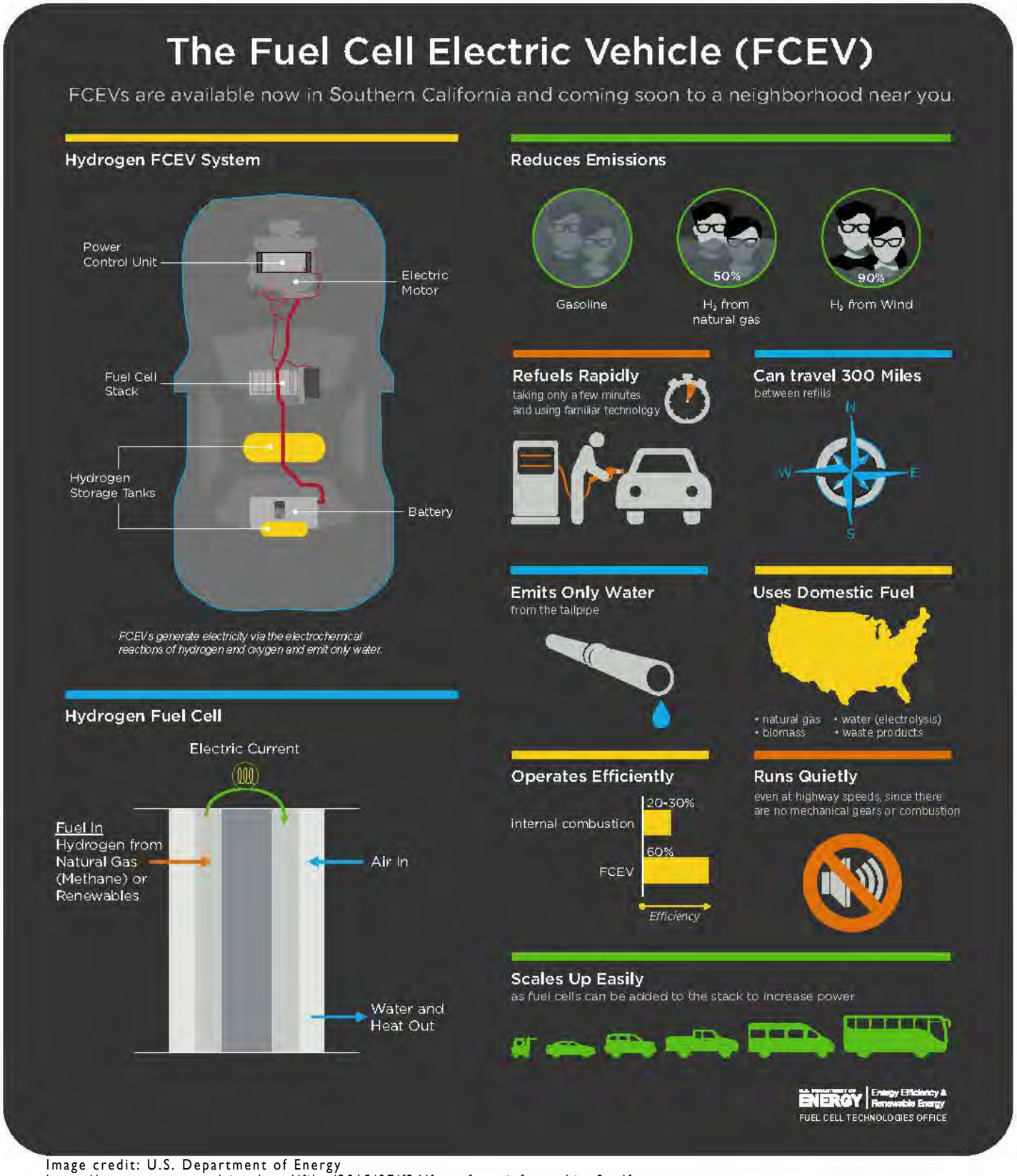


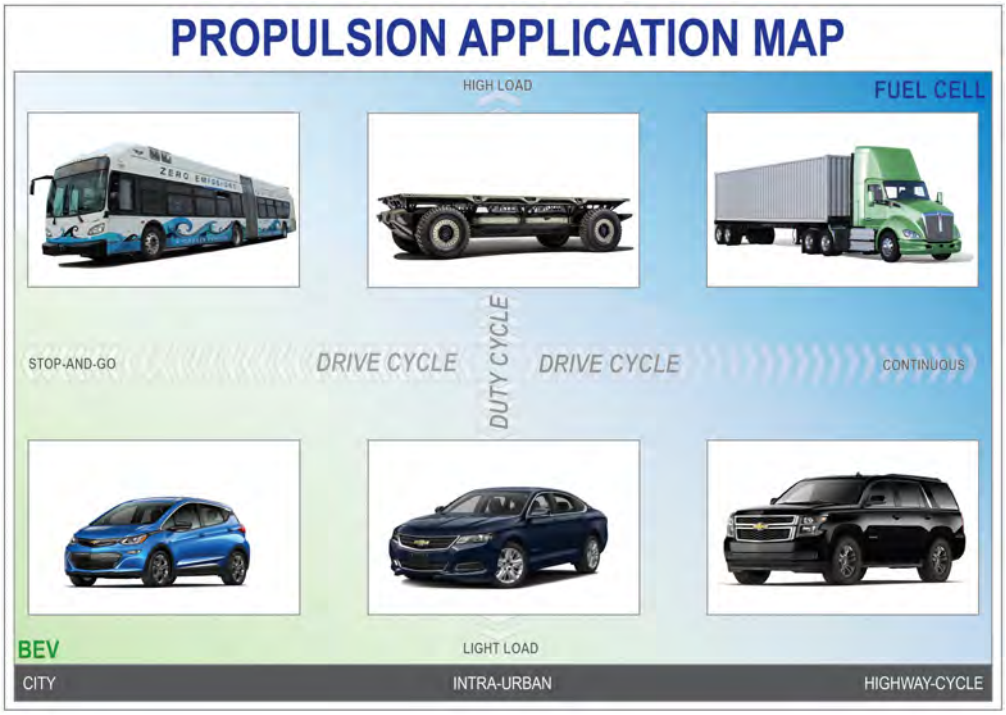

Image credit: U.S. Department of Energy
https://www.energy.gov/sites/prod/files/2015/07/f24/fcto_fcev_infographic_0.pdf

# FUEL CELL ELECTRIC CARS AND BATTERY ELECTRIC CARS

## Electric vehicles are driving the way to the future

When is it better to fill up and when is it better to plug in?
Both fuel cell cars and battery electric cars have a role in clean energy transportation.

**Both types of cars will work together to reduce emissions and meet customer needs**




- Battery electric cars work well for smaller vehicles and shorter trips. Battery electric cars have a range of 100-300 miles and it takes roughly half an hour to several hours to charge the battery depending on the type of charging system.
- Fuel cell electric cars provide the same experience drivers are used to today, working well for larger vehicles (including trucks) and longer trips. A fuel cell electric car can fill up in 3 to 5 minutes.

# REFUELING AND CHARGING TIMES

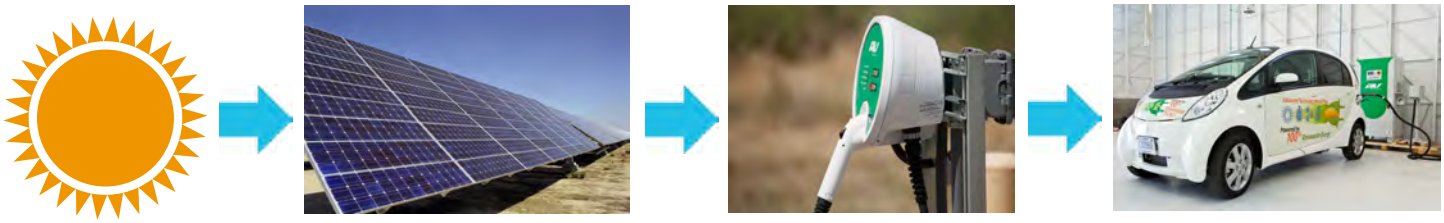
| Energy Source | Rate (miles of travel per minute spent filling) | Percent of your trip you'll spend filling |
|---|---|---|
| Gasoline | 150 | 1-2% |
| Hydrogen | 100 | <2% |
| EV Supercharger | 6 | 15% |

Source: General Motors

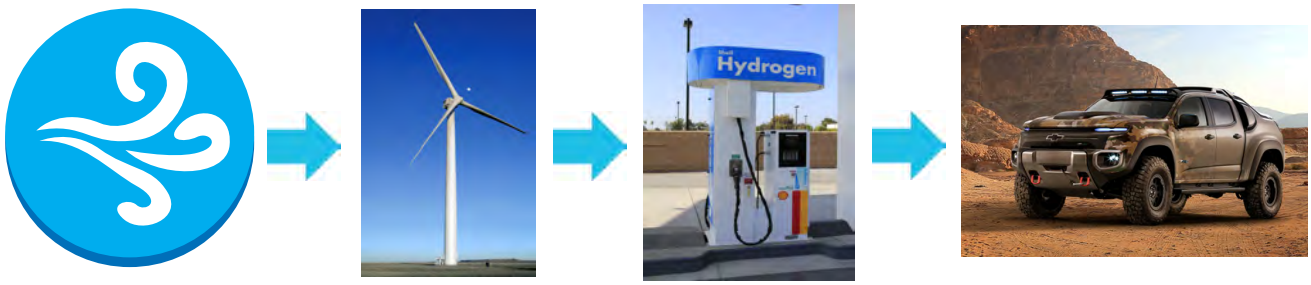
Filling up a fuel cell car with hydrogen is a lot like filling your current car with gasoline. Watch it now!

## Efficiency and Energy Storage

- Charging a battery and then using it to run an electric motor is more efficient than running an internal combustion engine. However, storing large amounts of electricity is difficult.



- Making hydrogen and running a fuel cell is 2-3 times as efficient as an internal combustion engine with 2 key benefits:
  1. Hydrogen can be made, stored, and used later to fill a vehicle, allowing hydrogen to be made from renewable energy.
  2. Can quickly fill your car in 5 minutes with enough fuel for more than 300 miles and provide a fuel economy of over 60 miles per gallon of gasoline equivalent.



# HYDROGEN AND FUEL CELL SAFETY

Hydrogen fuel can be used safely just like other fuels.

Learn more about the safety of hydrogen fuel, hydrogen stations, and fuel cell electric cars in the following pages.

Back to Table of Contents

# HOW DOES HYDROGEN FUEL COMPARE?

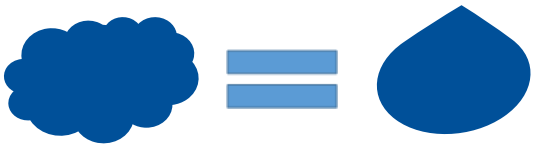
With decades of experience using hydrogen as rocket fuel, NASA has established rigorous safety guidelines for using hydrogen and the systems involved in storing, transporting, and operating with hydrogen fuel.

Hydrogen fuel is an energy carrier used in a fuel cell to produce electricity for vehicles, buildings, and backup power systems.

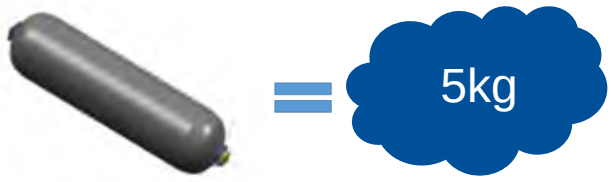
Hydrogen fuel is produced and shipped all over the world for use in industry. Just like systems for handling natural gas, gasoline, and diesel fuel, modern hydrogen production, storage, transportation, and dispensing systems include multiple safety systems to guard against leakage and shut down if any problems occur.

Currently there are three main transportation methods for delivering hydrogen:

- gaseous pipelines
- pressurized tube trailers
- cryogenic liquid tankers



Hydrogen fuel is in gaseous form and is measured in kilograms (kg). 1 kg of hydrogen has about the same energy content as a gallon of gasoline.




A typical fuel cell car carries about 5kg of fuel – the equivalent of a 5 gallon can of gasoline for your lawn mower. Because fuel cell cars are twice as efficient as gasoline cars, you can travel twice or even three times as far on a kg of hydrogen versus a gallon of gasoline depending on the vehicle.

Fuel cell cars meet all of the same Federal Motor Vehicle Safety Standards (FMVSS) requirements and tests as gasoline or battery cars.

# HYDROGEN FUEL 101

You can't see it – it's colorless. But hydrogen has very well known properties and behaviors after being used in many different applications for several decades years.

- It is colorless, odorless, and non-toxic.
- It is the lightest of all gases. It rises and dissipates very rapidly.
- It is flammable like all fuels, but the flame is nearly-invisible to the naked eye and doesn't radiate much heat.
- Knowledge of these properties is used to design all the vehicle and station systems.
- Can be used to store energy from many sources including wind and solar.
- Most abundant element in the universe.

Firefighters and first responders everywhere are being trained how to respond to accidents involving fuel cell cars and hydrogen stations.

For information on training and the safety features of specific vehicles, click here.

# HYDROGEN REFUELING INFRASTRUCTURE

Hydrogen station challenges can be overcome. Gasoline was inevitable... despite several early challenges.

Photo credit: John Vachon

There were road challenges and refueling infrastructure challenges



The infrastructure followed the technology

Hydrogen fuel use is rapidly expanding because:

- $H_2$ has the appeal
  Clean, fast fueling, long range electric driving
- $H_2$ has the momentum
  More stations opening
- $H_2$ has the demand
  More cars on the road
- $H_2$ has the investment
  Corporate, International, Federal, State

As more hydrogen is used, the price of $H_2$ and stations will come down.

# TAKE A LOOK AT THIS HYDROGEN STATION


Find the hydrogen station map here

- It dispenses hydrogen fuel as a compressed gas. The tanks, compressors, dispenser, hose, and nozzle are all sealed for safety.
- The dispenser checks everything for leaks every time you use it – it won't even turn on if it thinks there's a leak.
- Notice how the nozzle locks onto the fuel cell car with a tight seal. And it stays locked – as long as there's hydrogen fuel pressure in the hose, the nozzle won't unlock and it can't be pulled off.
- If you look above you will see that just like gasoline stations, there are fire detectors, fire extinguishers, and other safety features available on common fuel dispensers today.

SAFETY FIRST!

# TAKE A LOOK AT THIS FUEL CELL ELECTRIC CAR

- Fuel cell cars have smart technology in place to prevent any hydrogen from leaking and to safely dissipate the fuel in the event of an accident.

- Safety interlocks prevent accidental hydrogen leakage. Fuel cell cars will not move as long as the fill hose is attached, so you can't accidentally drive the car away and damage the hydrogen pump.

Watch here
https://vimeo.com/194298093

- Fuel cell cars have hydrogen sensors (you can't smell hydrogen fuel) that shut off valves if they ever detect any hydrogen.

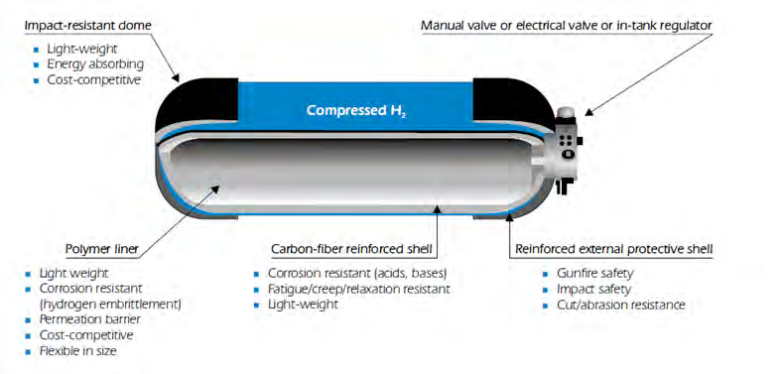
- In an accident, while the airbags are busy protecting passengers, the fuel cell car is busy isolating all the tanks, valves, and hoses so that even in a severe crash no hydrogen can escape.

- Fuel cell cars have been crash tested just like all vehicles. From the front, rear, sides, and even upside down.

**As of November 2018, over 5,900 fuel cell cars have been sold in the U.S. Find the most up-to-date numbers from Argonne National Lab here.**

# TAKE A LOOK AT THIS HYDROGEN TANK

- It is made of carbon fiber –one of the strongest materials on Earth.
- It is a cylinder – the more hydrogen (the more pressure) in it, the stronger it gets




- Hydrogen tanks are extensively tested for safety – tanks are dropped, burned, crushed, impacted, and even ballistics tested with gunfire.

Drop test

2-ton drop impact test on pressurized tanks


Gunfire penetration test

Environmental and chemical effects

Hydraulic crush test

.50 BMG gunfire test