NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Hydrogen Shuttle Bus

Presented

By

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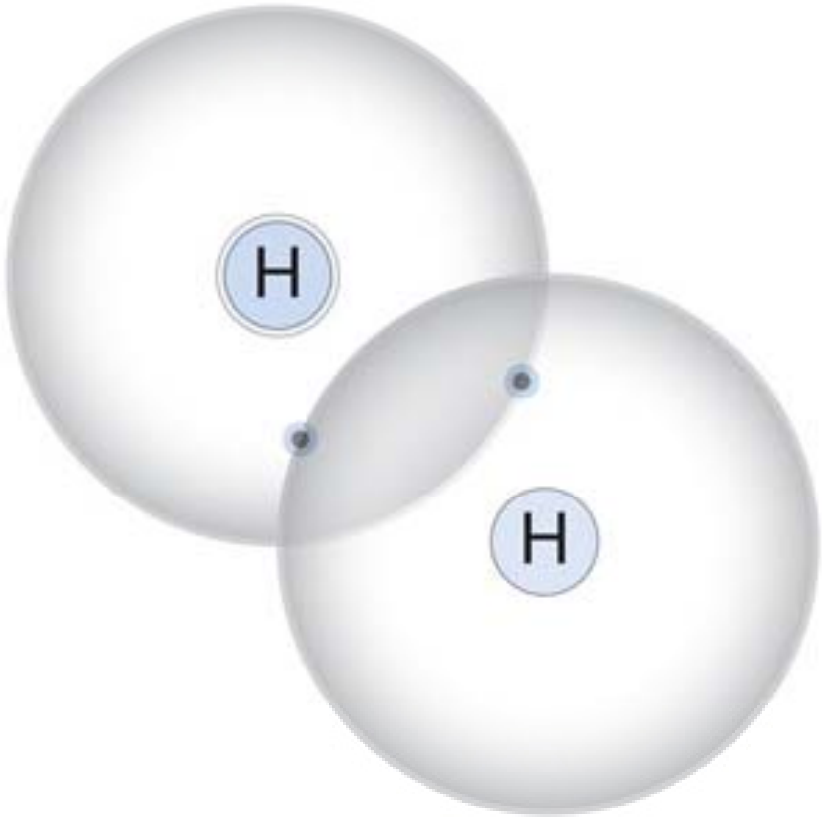
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

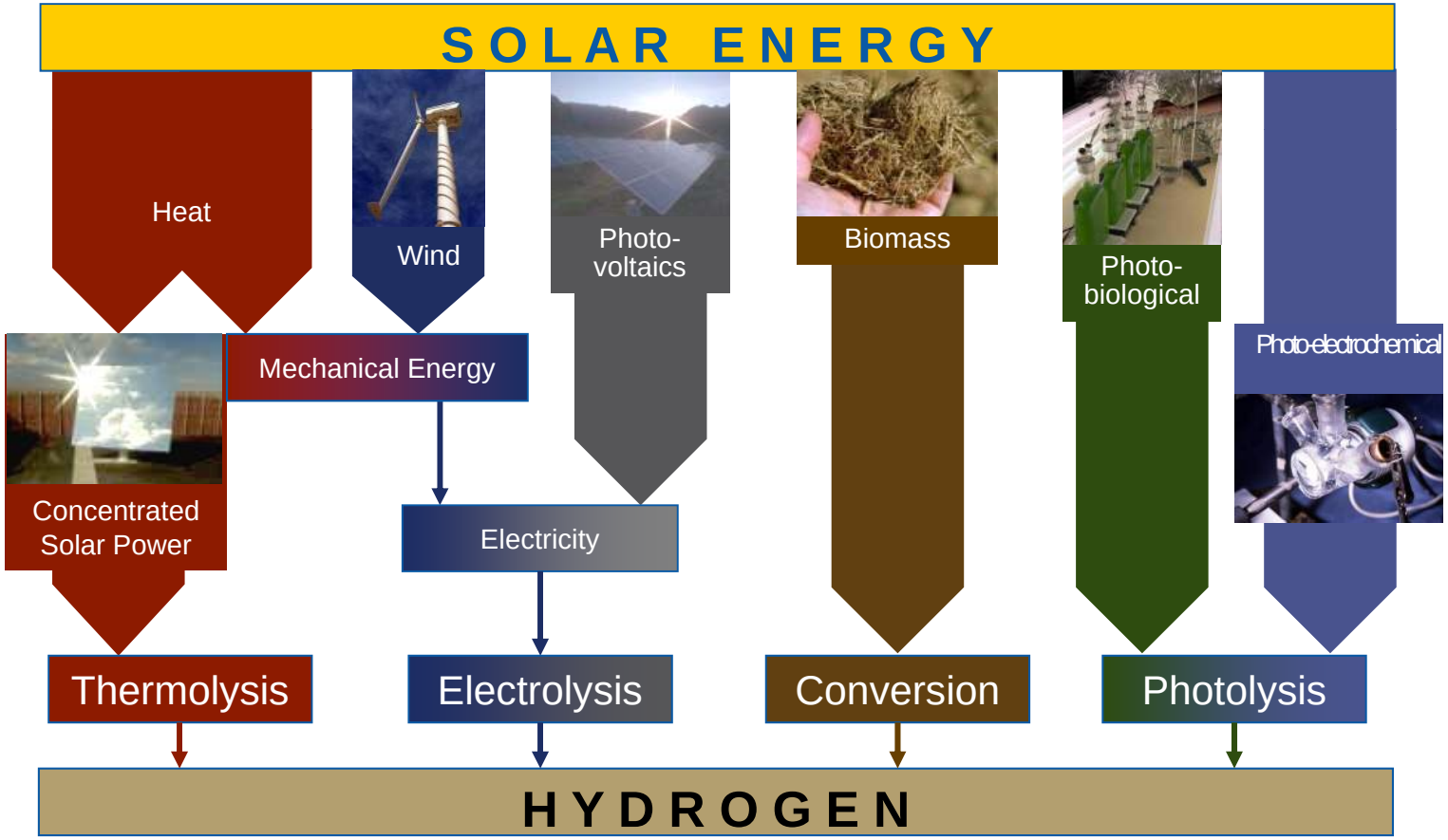
Hydrogen Basics

A hydrogen atom consists of one proton and one electron. A hydrogen molecule consists of two hydrogen atoms, so hydrogen is often abbreviated as H_2. Hydrogen combines easily with other elements. On Earth, it's rarely found in pure form. Instead, it is found in combinations such as water, methane, and biomass.



Hydrogen Basics

Hydrogen isn't a primary energy source. Instead, it's an energy carrier (like electricity), meaning that it can store and deliver energy in an easily usable form. This is an advantage for storing energy generated using variable renewable energy sources such as wind and solar.



Hydrogen Characteristics

At standard temperature and pressure, hydrogen is a gas that human senses can't detect.

Hydrogen gas is

- Odorless
- Tasteless
- Nontoxic
- Colorless
- Noncorrosive
- Fourteen times lighter than air, it rises and disperses rapidly

Photo courtesy of the National Oceanic and Atmospheric Administration

Hydrogen Properties

Like any fuel, hydrogen is a flammable gas, so it must be stored properly away from heat, flames, and sparks.

When hydrogen burns in air, it doesn't produce smoke. Its pale blue flame is difficult to see; in fact, in daylight, the human eye can barely detect it. And although a hydrogen flame burns just as hot as those of other common fuels, it radiates less heat and is less likely to start secondary fires.

Established Hydrogen Applications

Hydrogen is produced and used in many chemical and manufacturing industries such as:

- In ammonia production
- In metallurgical procedures
- As a quenching gas in certain combustion processes
- To hydrogenate oils in food processing
- To upgrade crude oil for gasoline and diesel fuel production

Enough hydrogen is produced and used in the US every year to fuel 34 million fuel cell vehicles.

Fuel Comparison

In general, hydrogen is neither more nor less hazardous than common fuels like natural gas, propane, and gasoline. It is, though, less familiar to most people.

Here's a table that compares hydrogen to other fuels we use today:

	Hydrogen	Natural Gas	Propane	Gasoline
Odorant Added?	No	Yes, if compressed; no, if liquefied	Yes	No
Toxic?	No	No	No	Yes
Vapor Density (% relative to air)	0.07	0.55	1.52	4.00
Autoignition Temperature	1,085°F (585°C)	1,003°F (540°C)	914°F (490°C)	450°F (232°C)
Ignition Energy (mJ)	0.02	0.29	0.26	0.24
Flammability Range (% in gas-to-air volume ratio)	4 – 75	5 – 15	2.1 – 10.1	1.4 – 7.6

1 kg of hydrogen has the same energy content as 1 gallon (3.2 kg) of gasoline

Hydrogen Shuttle Bus

The hydrogen powered bus is one of the newest additions to the alternative fuel vehicle fleet at NREL. The bus is leased from the Ford Motor Company and is used by the Public Affairs office for VIP Tours around the Golden campus. The bus was put into service in May 2010; more than 300 passengers rode the bus by the end of August.

It was featured at a booth during A Taste of Colorado in downtown Denver which helped educate people from a wide variety of backgrounds about advanced technology vehicles and hydrogen. We had 5,559 people visit the booth over the four days of the event.

Hydrogen Internal Combustion Engine (H_2ICE)

Ford was one of the first automakers to develop commercially available H_2ICEs, which use the same basic technology as gasoline-powered engines but run on hydrogen fuel. The bus has a 6.8-liter supercharged Triton V-10 engine. Only modest design adjustments are needed to switch a basic gasoline-powered engine to a hydrogen-powered engine, such as using alternate materials for valve seats and other parts that may become brittle when exposed to hydrogen and specially designed spark plugs.

Jack Nicholson's Hydrogen Powered Car

View clip online

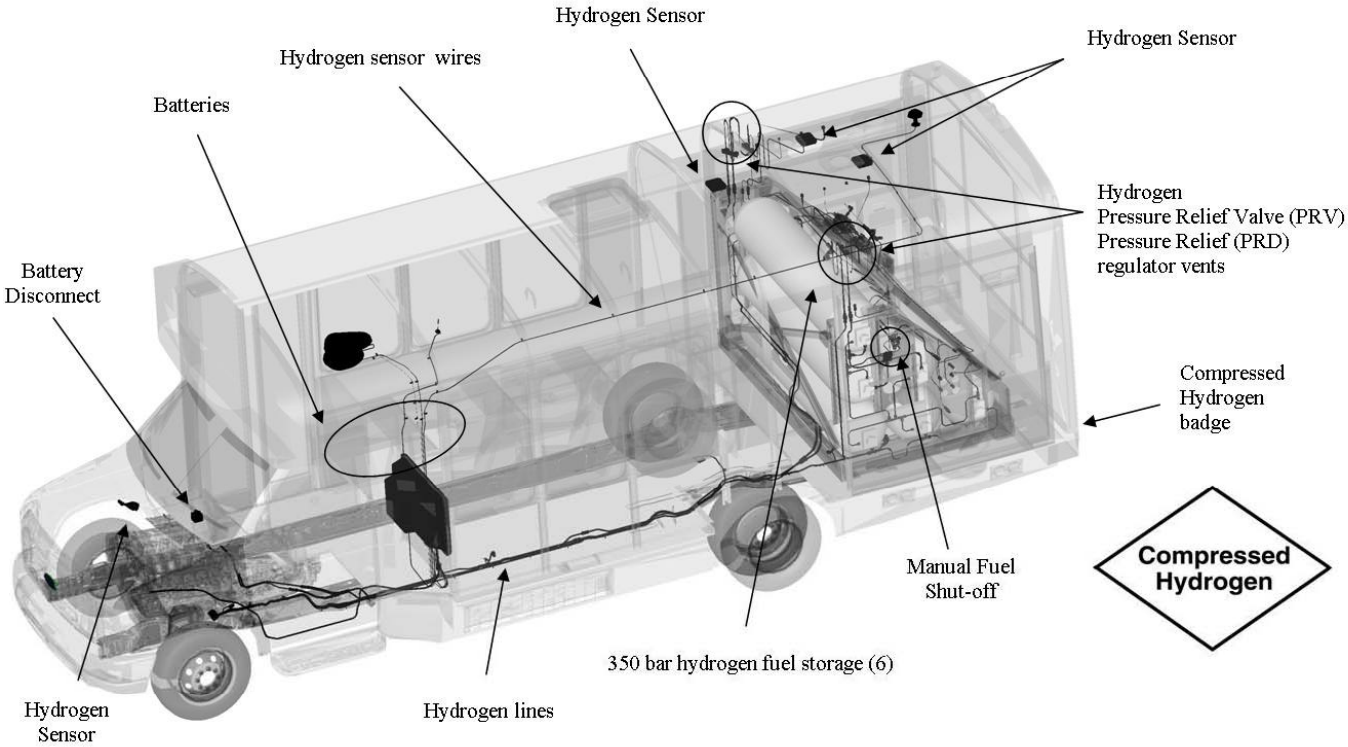
Courtesy of www.jack-nicholson.info

Vehicle Modifications

- Gaseous fuel injection system
- Modified ignition & electrical systems
- Iridium dipped spark plugs
- Super charger and intercooler
- Compressed H_2 storage tank package 5,075 PSI (350 bar)
- Low pressure hydrogen fuel lines 70-80 PSI
- Hydrogen Management System (H_2MS)

Vehicle Diagram

FORD HYDROGEN V-10 E-450 SHUTTLE



OPERATOR TRAINING

Special Features

Telematics System

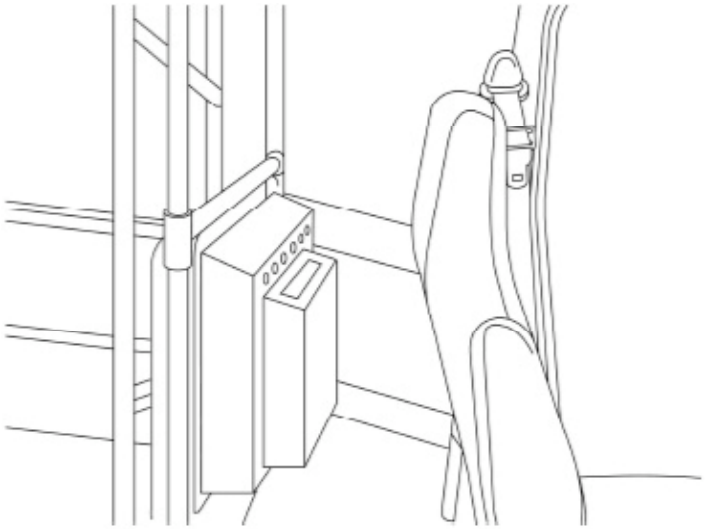
- Collects data, remotely diagnoses components and sends electronic notifications for service

Fuel System

- equipped with an inertia switch which disconnects the battery voltage from the fuel system under impact conditions

Hydrogen Management System

- Monitors the sensors for hydrogen concentration, tank temperature and pressure during fueling events



Operation is completely automatic. The telematics system (excluding antennas) is located on a panel behind the driver's seat.

Hydrogen Fueling Station

NREL recently outfitted the hydrogen dispensing station at the National Wind Technology Center near Boulder with cascading storage tanks, which decrease the time required for refueling. This is particularly beneficial for vehicles with large onboard storage systems like the H_2ICE bus, which can take up to 30 kg of hydrogen in a single fueling. The station has a 130 kg storage capacity at 413 bar (6,000 psi), so filling the bus takes about 20-30 minutes.

Hydrogen Fueling Station

The hydrogen dispensed at the station is produced via water electrolysis as part of a wind-to-hydrogen demonstration project. A partnership between NREL and Xcel Energy, this project integrates wind turbines and photovoltaic arrays to power electrolyzer stacks that split water into hydrogen and oxygen. This process produces some of the greenest hydrogen in the world The hydrogen is then compressed and stored for later use.

Wind-to-Hydrogen Project Video at www.nrel.gov/hydrogen/proj_wind_hydrogen_video.html

Why H_2ICEs?

H_2ICE Vehicles

- Hydrogen can be made from a wide variety of domestic, renewable resources such as solar, wind, and geothermal energy.
- Compared to conventional gasoline engines, they have very low criteria emissions and near-zero greenhouse gas emissions when the hydrogen is produced from low carbon resources.
- Are fuel efficient – up to 25% more efficient than gasoline in conventional spark ignition engines
- Only modest design modifications to standard ICE technology are necessary, so the engine technology is familiar to mechanics and fleet personnel.
- With very few cost and technical issues limiting commercialization and deployment, H_2ICE vehicles can help create the demand needed to support the build out of a hydrogen infrastructure

Ford Hydrogen Shuttle Bus

The U.S. Department of Energy funded the lease for NREL's hydrogen-powered internal combustion engine (H_2ICE) bus, along with 12 other buses at federal facilities across the country, to:

- Demonstrate product feasibility
- Educate customer & promote acceptance of H_2 as an alternative fuel
- Support the development of the hydrogen economy
- Demonstrate capability of meeting future emission levels
- Provide technological development opportunities
- Stimulate development of H_2 infrastructure, safety, codes & standards

Questions?

U.S. DEPARTMENT OF ENERGY

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