THE **MIDWEST HYDROGEN** CENTER OF EXCELLENCE

A Key Initiative of the Renewable Hydrogen Fuel Cell Collaborative

REFUELING SYSTEMS AND INFRASTRUCTURE

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RENEWABLE HYDROGEN FUEL CELL COLLABORATIVE

AGENDA

- Hydrogen
  - Introduction
  - Where Does It Come From ?
- Hydrogen Fueling Stations
  - Make vs Buy – Sourcing H2
  - Station Technologies
- Point of Fueling
  - The Fueling Process
  - H2, CNG, and Diesel
- Infrastructure Considerations
- Operational Station Examples
  - OSU – Electrolysis Stations
  - SATRA – Liquid H2 Vaporization and Compression

BUCKEYE BULLET II

HYDROGEN 101

H2

75% of the Mass of the Universe!

Lightest and Simplest Element Known to Man

Colorless, Odorless, Tasteless (Undetectable by Humans)

9 Mil. Metric Tons Produced In the USA Annually, 50 Worldwide

1 kg H2 Is Roughly Equal (energy) to 1 Gallon of Gasoline

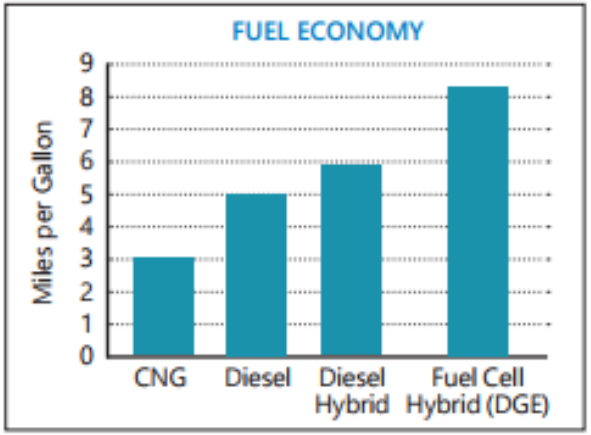
Highly Flammable, BUT Requires and Ignition Source and Oxidizer

WHERE IS H2 USED?

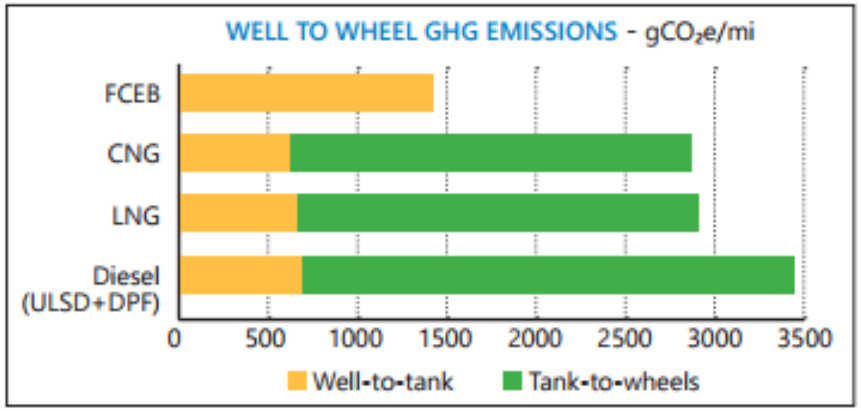
Hydrogen is one of the most important building blocks in the chemical industry.

- Ammonia Production (Fertilizers)
- Methanol Production
- Polymer Production
- Food Processing
- Oil Refining Oil (Sulfur Reduction),
- Metal Processing and Heat Treating
- Welding
- Powering Fuel Cells

Why H2?



Source: Public Transit Special Issue 2008 & NREL Reports

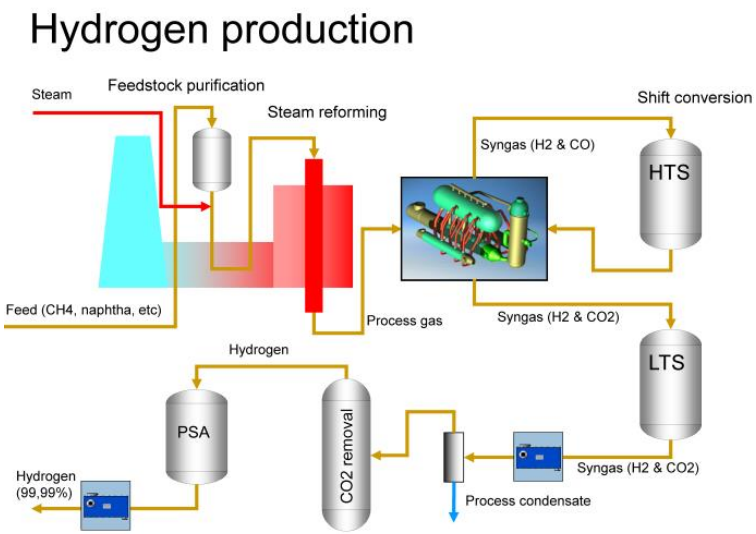


Source: CaFCP analysis using GREET model with support and verification by Argonne National Laboratory and CARB

IS IT SAFE?!

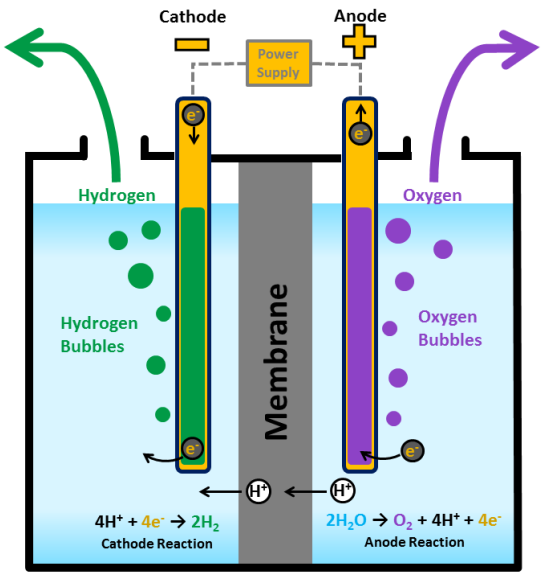
WHERE DOES THE HYDROGEN COME FROM?

Steam Reforming (95%)



Source: Alfa Kaval

Electrolysis (<5%)

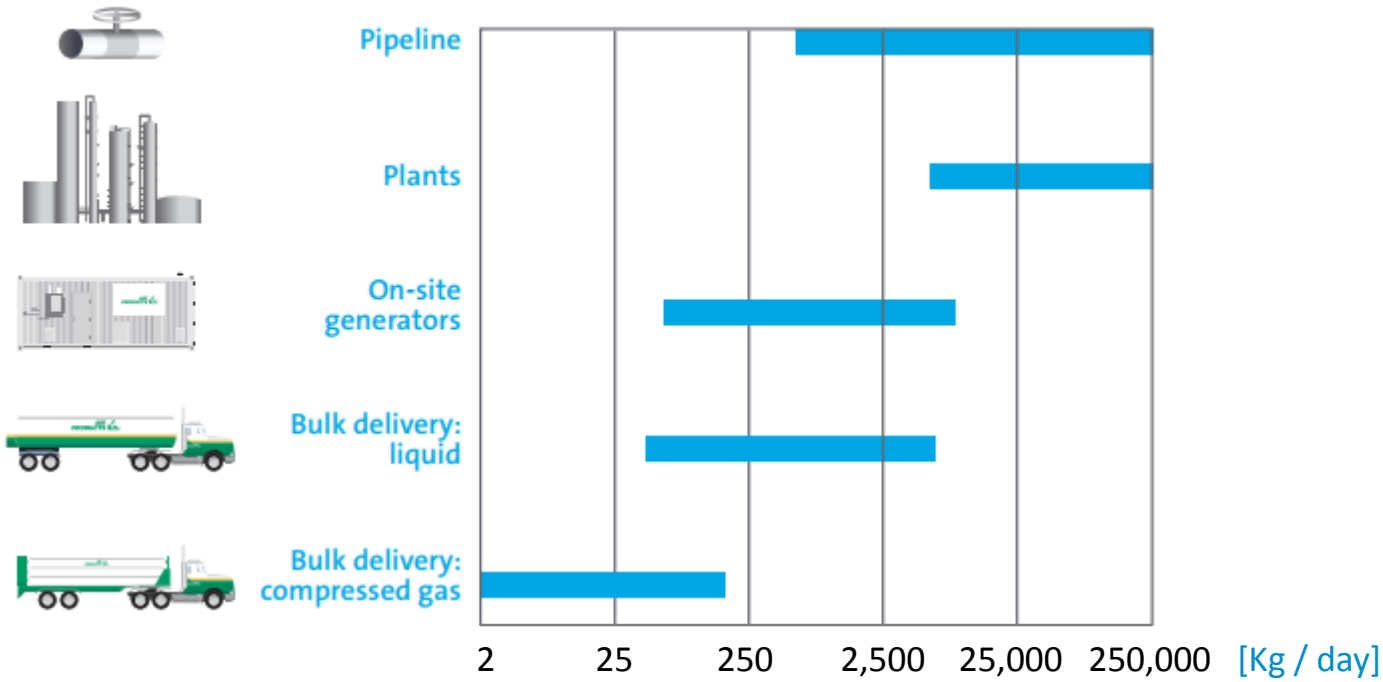


Source: US DOE

HYDROGEN FUELING STATIONS

Make vs Buy

WHICH SOURCE IS FOR ME?



Source: www.airproducts.com

DELIVERY: PRESSURIZED GAS VS CRYO LIQUID

Gaseous Storage

- 350-700 bar (5,000 – 10,000 psi)
- Large heavy tanks
- Can be directly pressure balanced to a vehicle tank
- Can be compressed to intermediate high pressure storage
- Low % utilization of transportation mass

Liquid Storage

- More efficient transport
- Cryogenic temps (-250 C / -420 F)
- Must be vaporized (1:851)
- Must be compressed to vehicle or storage tank
- Leak rate (up to 1% per day)

PRODUCTION: PRESSURIZED GAS VS CRYO LIQUID

Steam Reforming

- Most cost effective (today, in large scale)
- Variety of source feed fuels
- Waste heat recovery / co-generation possible
- Greenhouse gas emissions always present
- Requires use fossil fuels
- Technology to efficiently scale down is developing

- Gaseous hydrogen
- Steam methane reformer (SMR)
- 200–500 kg/day
- Purity levels 99.999% or better
- Compact, modular design

Source: Air Products

Electrolysis

- Very simple process
- Equipment is cost effective
- Requires significant electricity
- Can be 100% renewable (solar / wind power)
- Excellent solution to wind curtailment
- No byproducts / emissions

POINT OF FUELING

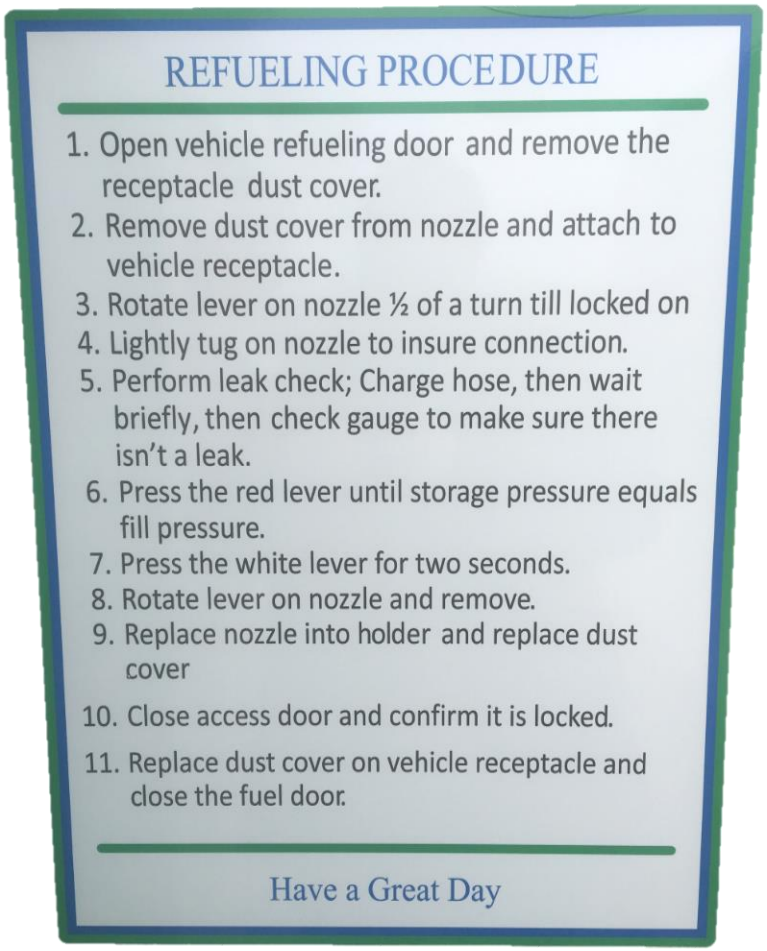
FUELING STATION

FUELING NOZZLE



	DIESEL	H2	CNG
Nozzle	SAE J285	SAE J2600	SAE J1616
Flow Rate [GPM Eq.]	10 / 40	~ 4	~4
Leak-proof / Spill-proof	No	Yes	Yes
Storage Pressure [bar]	Atmospheric	350 / 700	200 / 250
Breakaway Safety	Yes	Yes	Yes

THE PROCESS



REFUELING PROCEDURE

1. Open vehicle refueling door and remove the receptacle dust cover.
2. Remove dust cover from nozzle and attach to vehicle receptacle.
3. Rotate lever on nozzle ½ of a turn till locked on
4. Lightly tug on nozzle to insure connection.
5. Perform leak check; Charge hose, then wait briefly, then check gauge to make sure there isn't a leak.
6. Press the red lever until storage pressure equals fill pressure.
7. Press the white lever for two seconds.
8. Rotate lever on nozzle and remove.
9. Replace nozzle into holder and replace dust cover
10. Close access door and confirm it is locked.
11. Replace dust cover on vehicle receptacle and close the fuel door.

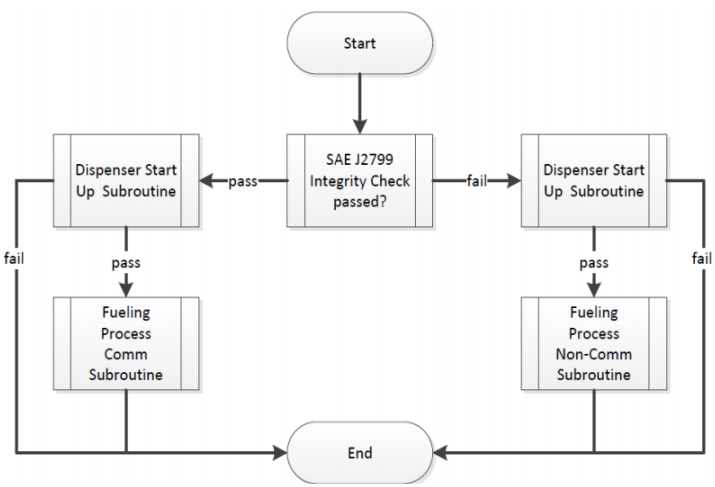
Have a Great Day

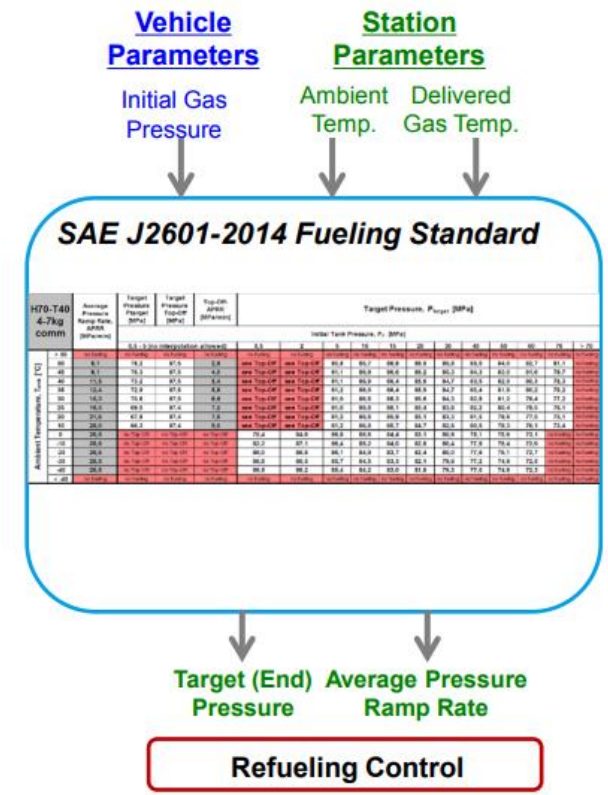
STANDARDIZATION

- SAE J2600 - Compressed Hydrogen Surface Vehicle Fueling Connection Devices
- SAE J2601 – Light Duty Hydrogen Vehicle Fueling Protocol
- SAE J2601/2 - Hydrogen Bus Fueling Technical Information Report
- SAE J2601/3 - Fueling Protocol for Gaseous Hydrogen Powered Heavy Duty Vehicles
- SAE J2578 - Recommended Practice for General Fuel Cell Vehicle Safety
- SAE J2579 - Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles
- SAE J2719 - Hydrogen Fuel Quality for Fuel Cell Vehicles
- SAE J2799 - FCEV to Hydrogen Station Communication

Learning from J2601 AND J2799

- Fast fuel 3-5 minutes
- “Smart” fueling (communication)
- Wireless communication





Source: US DOE / SAE Int.

INFRASTRUCTURE & SITE REQUIREMENTS

- Footprint
- Utilities: Power / Water / Natural Gas
- Permitting
- Safety Measures: Inerrant Design
- Safety Measures: Training and Protocol
- Emergency Response

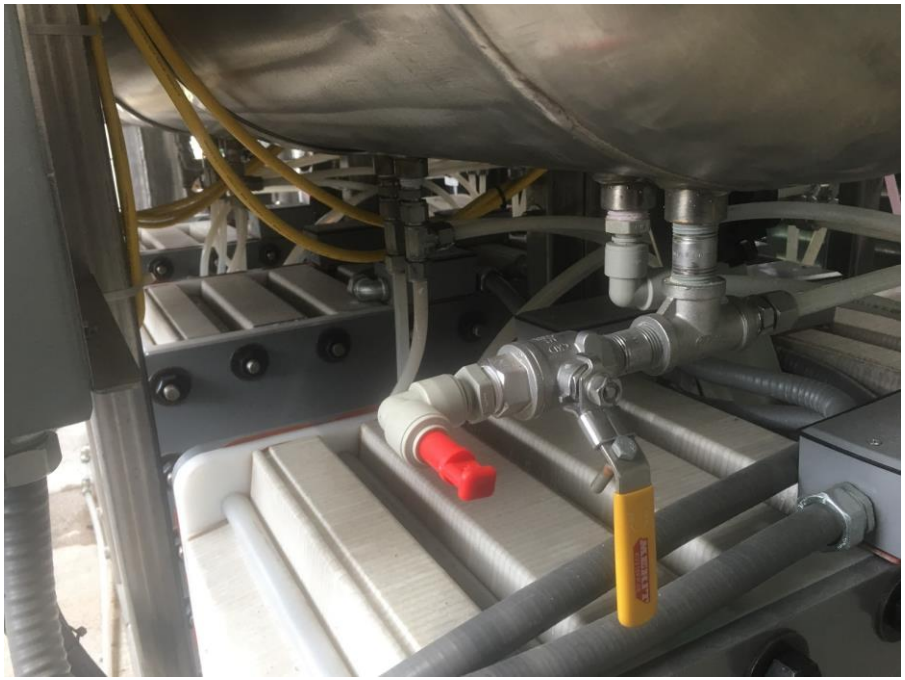
EXAMPLES OF STATIONS IN OPERATION

SARTA and OSU

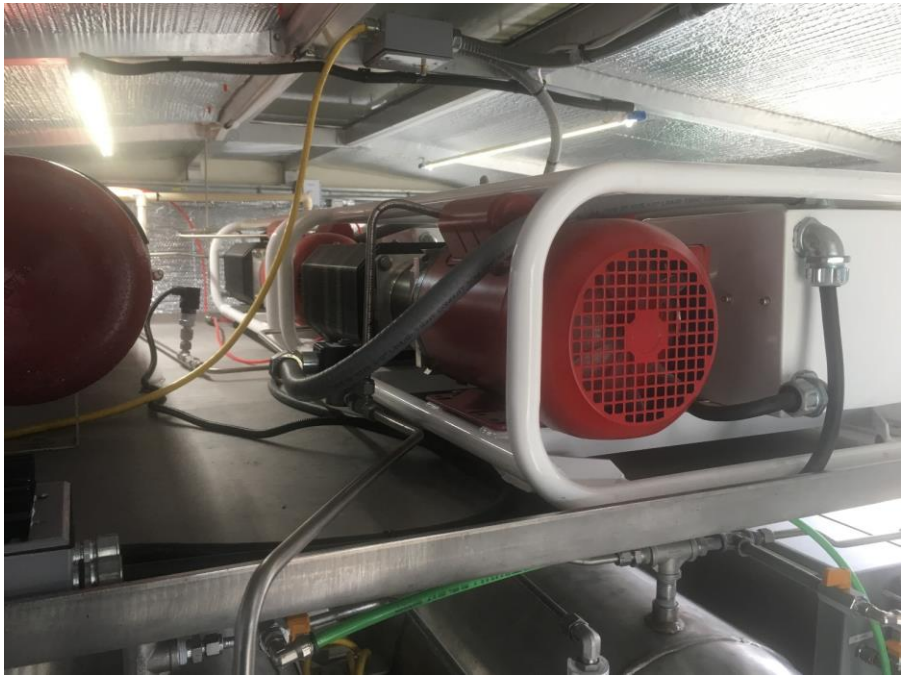
OSU ELECTROLYSIS STATION

MRE Triple Twin System

ELECTROLYSIS STACKS AND H2 PURIFICATION



COMPRESSION AND HIGH PRESSURE STORAGE



POINT OF FUELING

SARTA LIQUID H2 SATION

- Built in 2016
- Built by Air Products
- Largest H2 Station Outside of California
- ~$1.6 Million Capital Cost
- ~$2.20 per Gallon Eq.

LIQUID H2 STORAGE TANK

HIGH PRESSURE VAPORIZERS

COMPRESSORS

HIGH PRESSURE STORAGE

POINT OF FUELING

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WHAT QUESTOINS DO YOU HAVE?

RENEWABLE HYDROGEN FUEL CELL COLLABORATIVE