



## Why Do We Need Hydrogen?

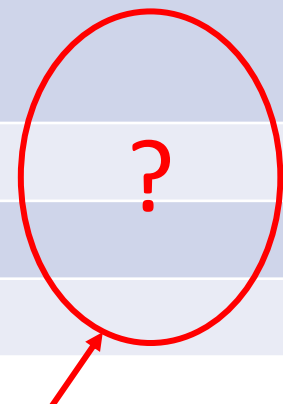
*Part of the Hydrogen Tech Brief Series*

# To Replace Fossil Fuels We Need All The Functions That Fossil Fuels Provide

	Energy Source	Energy Carrier	Storability		Fast Transfer to Vehicles	Hi-Temp for industry (Steel, Cement Glass making)	Long-Distance Energy Transport	High Energy Density (Ships & Planes)
			Short Term	Long Term				
Fossil Fuels	X	X	X	X	X	X	X	X

# Hydrogen Picks Up Where the Grid and Batteries Leave Off

	Energy Source	Energy Carrier	Storability		Fast Transfer to Vehicles	Hi-Temp for industry (Steel, Cement Glass making)	Long-Distance Energy Transport	High Energy Density (Ships & Planes)
			Short Term	Long Term				
Fossil Fuels	X	X	X	X	X	X	X	X
Wind, Solar Geothermal	X							
Electric Grid		X					X	
Batteries		X	X					
Hydrogen	X	X	X	X	X	X	X	



Something else needed

- Geological hydrogen (wells)
- Underground Hydrogen Generation From Petroleum
- Hydrogen from Biomass



# Adding Biofuel to Electricity & Hydrogen Completes the Energy Need

	Energy Source	Energy Carrier	Storability		Fast Transfer to Vehicles	Hi-Temp for industry (Steel, Cement Glass making)	Long-Distance Energy Transport	High Energy Density (Ships & Planes)
			Short Term	Long Term				
Fossil Fuels	X	X	X	X	X	X	X	X
Wind & Solar	X							
Electric Grid		X					X	
Batteries		X	X					
Hydrogen	X	X	X	X	X	X	X	
Biofuel	X	X	X	X	X		X	X

- “Clean” and “Renewable” (net-zero or net-negative)
- Uses the atmosphere to exchange CO<sub>2</sub> between use and source

What is needed



# Hydrogen Sourcing

- Hydrogen needs to be *Clean* (i.e. zero greenhouse gases)
  - If it weren't for the need to eliminate greenhouse gases the world wouldn't bother using hydrogen
- Sources of *Clean* hydrogen
  - Electrolysis of water
  - Natural Hydrogen Wells
  - Generated Underground (GU) Hydrogen (Proton Technology\* process)

\*<https://protonh2.com>.

# Let's Get Clear on Clean and Renewable

- “Clean” Energy
  - Zero GHG (Greenhouse Gas)
    - No emissions
  - GHG neutral
    - Use may emit GHG
    - Production absorbs an amount equal to emission
  - GHG negative
    - Use may emit GHG or not
    - Production removes more GHG from the atmosphere than emitted
- Renewable energy
  - Source is replenished by natural processes
  - Is not depleted

*All Renewable Energy is Clean  
Not all Clean Energy is renewable*

*“Clean” and “Renewable” are Separate Characteristics*

# What About Colors of Hydrogen?

Color is a shorthand to allow us to specify two parameters with one label (color)

- Whether the source of hydrogen *emitted CO<sub>2</sub>* or not
- Whether the source of hydrogen was *renewable* or not

- Natural hydrogen wells (geological) (see: [nh2e.com](http://nh2e.com))
- Hydrogen generated by splitting water with renewable electricity
  - Wind, Solar, Geothermal, Hydroelectric
- Hydrogen from biomass with carbon capture and sequestration

		Emits CO <sub>2</sub>	
		No	Yes
Source	Renewable Energy	Green	Tan
	Non-Renewable (fossil & nuclear)	Blue	Gray

Hydrogen from biomass without Carbon Capture (Tan Proposed)

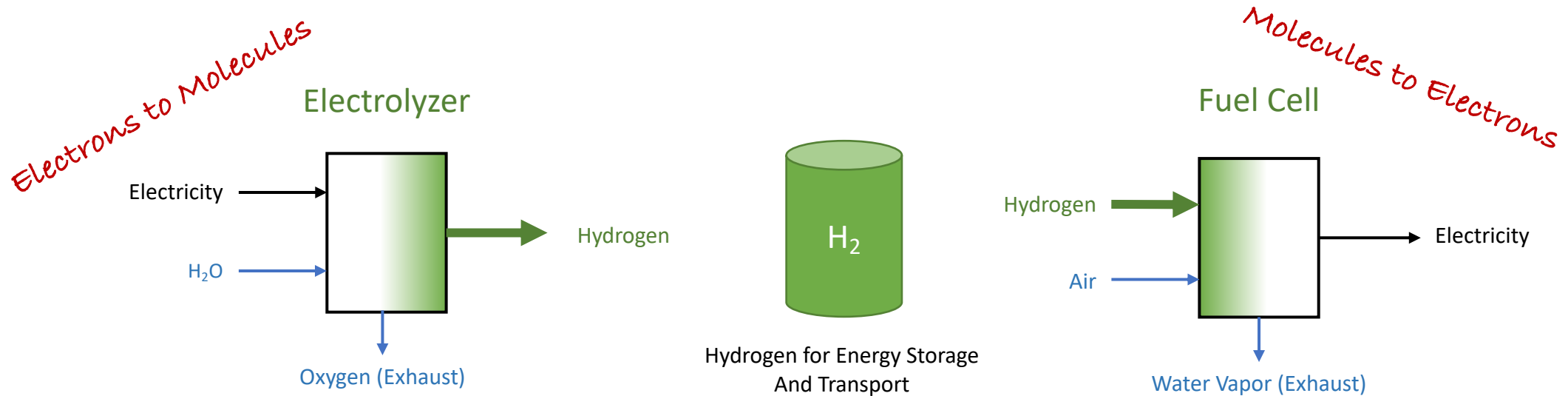
Hydrogen from fossil fuels without Carbon Capture

- Hydrogen from fossil fuels with carbon capture
- In-situ Generated (IG) Hydrogen from petroleum wells with carbon left in the ground (<https://proton.energy>)
- Hydrogen generated using nuclear power

**Only Four Colors Are Needed to Describe Any Hydrogen**  
**A Carbon Intensity (CI) Score is Needed for More Details**

# Why Is Hydrogen So Useful?

Because Electricity and Hydrogen are Interchangeable



*Electricity and Hydrogen Are Two Sides of the Clean Energy Coin*



# Hydrogen is a Useful Fuel for Transportation

- Two types of Electric Vehicles (EV's)
  - Battery EV's – Get their energy by charging
  - Fuel Cell EV's – Get their energy by fueling with hydrogen
- Battery EV's are *different* than petroleum vehicles
  - More convenient for short distances and charged at home or work
  - Far less convenient for long range or hauling loads
- If we are to convince users to adopt something new:
  - It must provide the same performance and convenience as petroleum
  - Fuel Cell EV's provide the same user experience:
    - ✓ 3-Minute Refueling (trucks longer)
    - ✓ Light, Compact, Abundant Energy for Trucks & RV's
    - ✓ Range Undiminished by Cold Weather
    - ✓ Full Driving Range with Heavy Loads and Towing

# Hydrogen Generation Can Help Balance the Grid

- Electricity generated for the grid has to exactly match the demand
- In the past, the grid was balanced by adjusting the generator outputs
  - But switching to wind and solar sources:
    - Eliminates the possibility of generator control other than turning them off (Curtailment)
    - Grid balance is made even worse by the variable nature of wind and solar
- Hydrogen generation can help by being a “dispatchable load”
  - Turned on or off by the utility to balance the grid
    - Using Smart Grid or Smart Meter technology
  - Can absorb excess wind and solar energy.

# Is Hydrogen More Expensive than Battery Charging?

- True, but hydrogen can be competitive with gasoline & diesel
  - From electrolysis of water for light-duty transportation
  - From hydrogen wells and Generated Underground (GU) Hydrogen for MD/HD vehicles, industry and utilities
- Also, users rate products by their **value**, not their **cost**
- *Value* is a combination of cost *and* features *and* performance
  - A product that has twice the performance but only 2% higher cost, is a better value
  - A car costs more to operate than a bicycle, but the car has more value
- Since users can get the same performance, cost and convenience from hydrogen as from petroleum, they will be more likely to switch to a hydrogen EV.

# Won't Battery EV Performance Catch up to Gas & Diesel?

No. Some of the limitations of Battery EV's are insurmountable

- Charge time
  - Not a function of the battery
  - A function of how much power you can practically apply to the vehicle
  - A practical limit is around 300 miles in 30 minutes\*
- Cold performance
  - Use of the heater or air conditioner reduces range 30% to 50% (Colorado AAA study)
  - Lithium-ion batteries cannot be charged when the battery is below 32°F
- Wear out and replacement cost
  - As batteries age, output decreases and therefore vehicle range
  - Replacement cost \$10,000 or more
- Range
  - More than a 10% to 20% improvement in Lithium-ion batteries is unlikely

# Building Heating

- For new construction, electric heat pumps are ideal
  - A heat pump is a reversible air conditioner
- For existing buildings , this is the most difficult sector to decarbonize
  - Huge installed base of furnaces are costly to replace (\$20K to \$40K per home)
  - Some homeowners will refuse to have the modification
- Solution – Biofuels
  - Replace the fuel not the equipment
  - Carbon-Neutral solution
  - Can use existing gas & oil delivery infrastructure.