

## **Environmental Benefits of Hydrogen**

*Part of the Hydrogen Tech Brief Series*

# Why Do We Need Hydrogen?

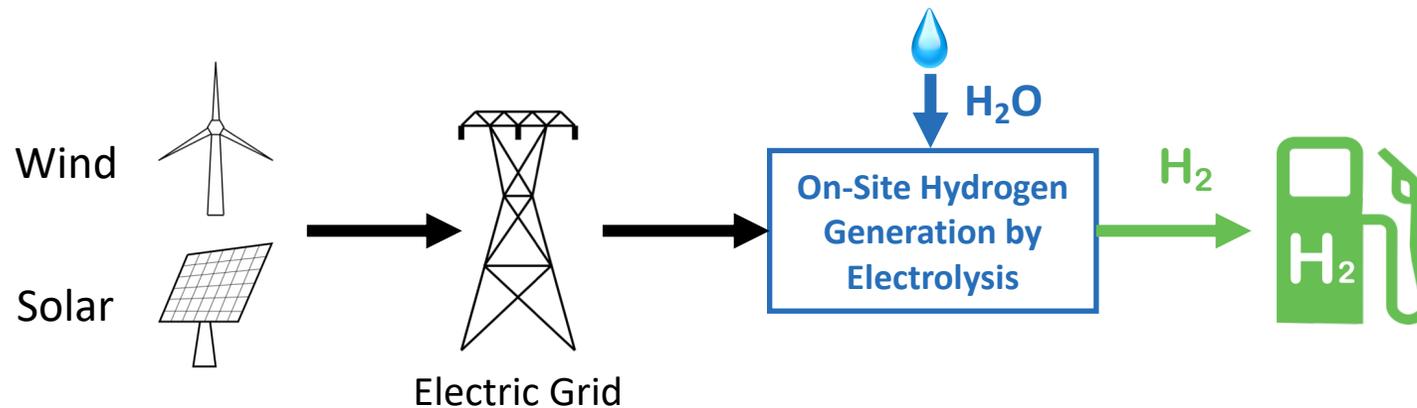
*To Replace Fossil Fuels  
Hydrogen Can Do More than the Grid and Batteries Alone*

	Energy Source	Energy Carrier	Storability		Fast Transfer to Vehicles	Steel, Cement Glass making	Long-Distance Energy Transport
			Short Term	Long Term			
Fossil Fuels	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

- Geological hydrogen
- Zero-carbon hydrogen from oil wells

# Doesn't Hydrogen Come From Fossil Fuels?

- In the past, both our electricity and hydrogen came from fossil fuels
  - Starting now, neither will
- Hydrogen is generated by splitting water molecules with renewable electricity
  - *Colorado electric rates make hydrogen competitive with gasoline*



# 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
- 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)
    - ✓ Range Undiminished by Cold Weather
    - ✓ Light, Compact, Abundant Energy for Trucks & RV's
    - ✓ Full Driving Range with Heavy Loads and Towing

# Why Can't we Just 'Electrify Everything'?

- Today the grid handles a third of our energy needs
- To electrify everything, the grid has to **triple**
  - Tripling the number of transmission lines
  - Most efforts to build transmission lines have been rejected



*Energy Can be Transported as Hydrogen*

# Does Hydrogen Generation Use a Lot of Water?

- No. A medium-sized fuel station uses the same water as two homes

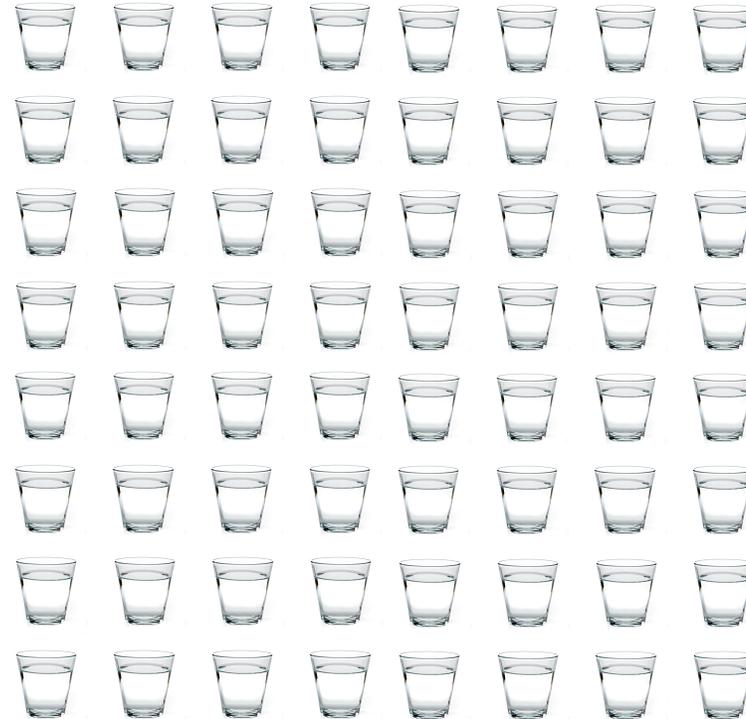
Typical Home  
90 Gallons/day



Hydrogen Station  
180 Gallons/day



Average Restaurant  
5,800 Gallons/day



# 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

# Aren't Hydrogen EV's Less Efficient than Battery EV's?

	Vehicle Efficiency	Vehicle + Fueling System
Gasoline	1	0.8
Fuel Cell EV	2.5	1.3
Battery EV	4.1	3.9
Battery Motorcycle	12.8	12.2

- True, but if this is our deciding metric, we should all drive motorcycles
- More important metrics to achieve universal adoption of EV's are:
  - Performance, cost and convenience the same or better than gasoline
  - Fuel Cell EV's achieve this

# Isn't Hydrogen More Expensive than Battery Charging?

- True, but hydrogen is around the same cost as gasoline (in Colorado)
  - Wind and solar are dropping electricity cost everywhere
- Also, systems are rated on 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 gasoline, they will be more likely to switch to an EV

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

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 safely apply to the vehicle
  - A safe limit is 400 Volts and 450 Amperes which limits charging to 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 10% to 20% improvement in Lithium-ion batteries is unlikely

# Should We Exclude the Oil Industry?

- Will endorsing hydrogen encourage the oil industry to make Gray or Brown Hydrogen?
- The right way to prevent this is policies to discourage *all* CO<sub>2</sub> emitting processes, not to discourage hydrogen
- We need hydrogen, let's not throw out the baby with the bath water

Source	Emits CO <sub>2</sub>	
	No	Yes
Renewable Energy	Green	
Extraction (Fossil fuels)	Blue	Gray-Brown

CO<sub>2</sub> is Captured and Sequestered

# The Customer's Perspective – Comparing Options

Characteristic	Battery EV	Petroleum Vehicles	Fuel Cell EV
Fuel cost per mile	3.5¢ (warm weather) 5.8¢ (cold weather)	11¢	11¢
Fueling Time Long Trips (450 mile example)	1 hour (2 stops, 30 minutes)	3 minutes	3 minutes
Refueling Temperature	Charge only when battery above 32° F	Any Temperature	Any Temperature
Range at Hot and Cold	Reduced 20% to 50%	Unaffected	Slight effect
Suitability for Large SUV Trucks and RV's	Battery weight, bulk & cost become limiting	Unlimited	Unlimited
Impact of Towing	Decreased Range	Decreased Mileage	Decreased Mileage
Range Over Vehicle Life	Range decreases as the batteries age	No Change	No Change
Fueling / Recharging	Charge at home or public chargers	Gas stations	Hydrogen Fuel Stations

← Sweet Spot for Battery EV's

⎵ Sweet Spot for Fuel Cell EV's

*Both EV Types Are Needed to Satisfy All Users*

# Hydrogen Transportation and Environmental Justice

- EJ = “Fair distribution of environmental benefits and burdens”
  - Benefits: Clean air and water, and Climate Change impacts
  - Burden: Cost of the Energy Transition
- Electric vehicles
  - Battery EV’s
    - Vehicle charging will continue be an issue for people without garages or in apartments
    - Lower-income people are less likely to have vehicle charging available at work
  - Cost
    - Vehicle costs eventually expected to be at parity for gasoline, battery and fuel cell
    - “Fuel” cost per mile
      - Battery – 3.5¢ to 5.8¢
      - Fuel Cell – 11¢ (Colorado)

# Summary

- It's clear that we need to eliminate ALL petroleum vehicles to improve air quality and save the climate
  - Therefore, we need to entice ALL vehicle users to switch to electric
- In order to do that, we have to offer options which provide the same or better cost, performance and convenience
  - *Both* Battery and Fuel Cell EV's are required to satisfy all users
- Beware of Confirmation Bias
  - Selecting only information that supports existing views
  - Ignoring contrary information
  - Interpreting ambiguous evidence as supporting your existing position