Electrolyzer Roadmap

September 24, 2020

Hydrogen's Diverse Application Potential

- Electrolysis Compliments a Multitude of Industries

Hydrogen is a versatile energy carrier enabling renewable energy systems

Hydrogen and fuel cells are critical elements in the decarbonization of the transportation sector

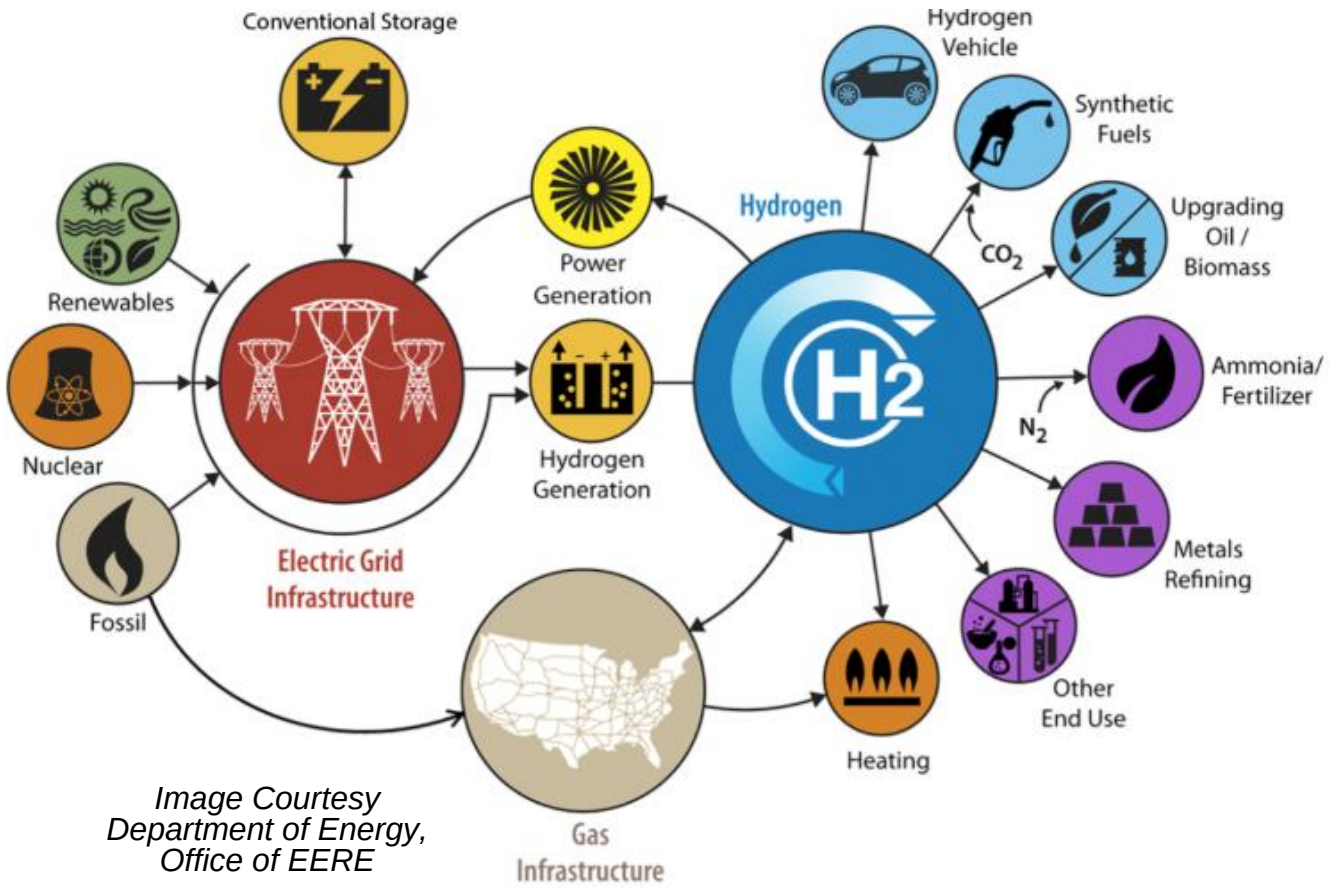


Image Courtesy Department of Energy, Office of EERE

Hydrogen from electrolysis is key in producing large quantities of sustainable energy in various forms

Market Enablers

- Increased Use of Renewables
- Global Decarbonization Initiatives
- Cost Competitive Hydrogen

Cost of H_2 globally determines Market entry points

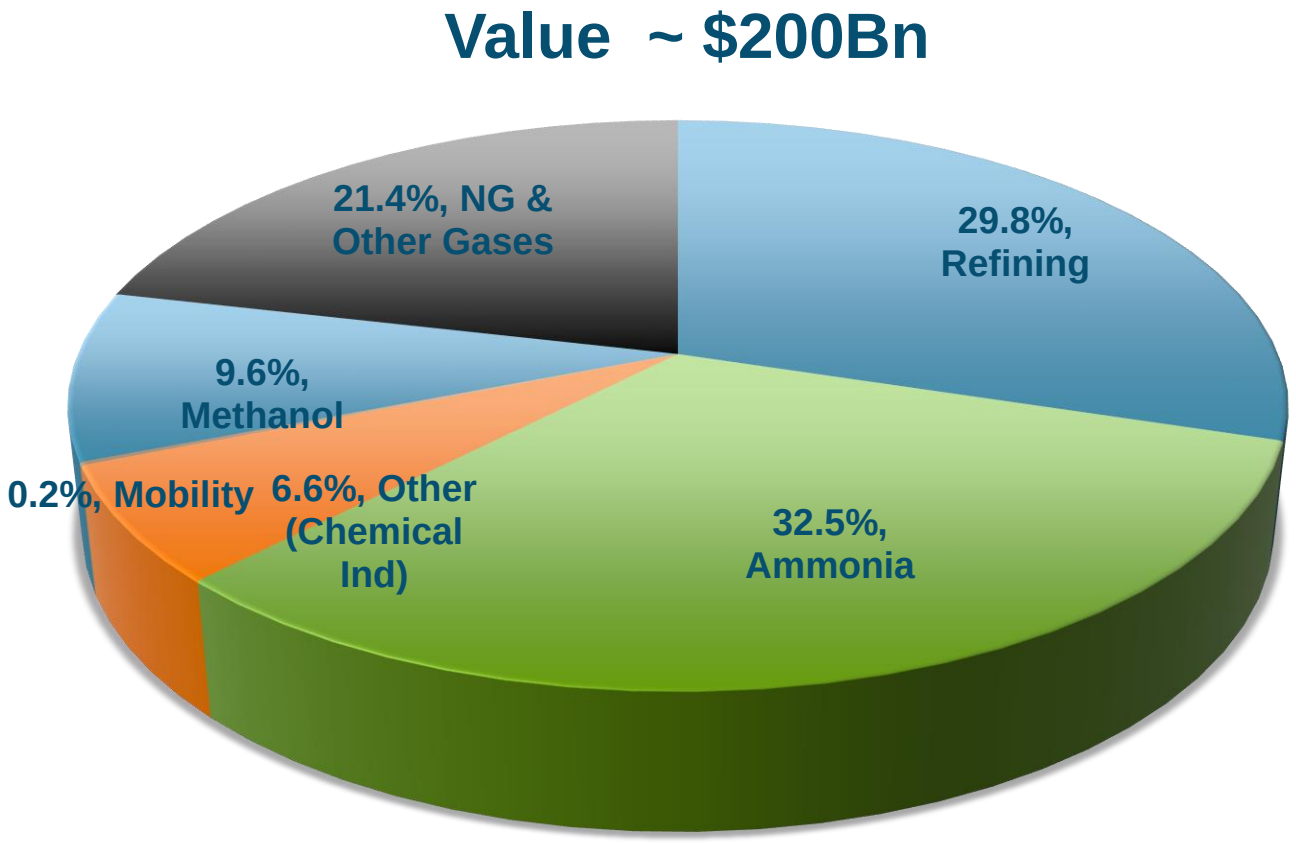
Markets according to price point $/kg H_2

- Today Electrolysis plays in a minute share due to costs above $7.50/kg
- Below **$3.50 /kg** the TAM is approx**imately $69 Bn,**
- **Below $2.00 / kg**, TAM grows past **$130 Bn**,

TAM – How Big? A closer look to H_2 Cost,

While competition is chasing $10/kg
Plug → $2.00 /kg as goal, because at that point the Market opens up

Broad Markets	% Value	Avg $/kg
Refining	29.8%	$ 1.67
Methanol	9.6%	$ 1.70
NG & Other Gases	21.4%	$ 1.75
Ammonia	32.5%	$ 2.23
Other Chemical	6.6%	$ 3.50
Mobility	0.2%	$ 7.50



- CA - LCFS $200/ton = ~ $4.00/kg subsidy
- Europe - Cost of CO2 at 25 Eur/Ton ~ $0.55/kg

Target Markets with large Sales Opportunities

P2P

Power to Power

Stationary Energy Storage, Off-Grid applications

P2X

Power to Product

Ammonia, Steel, Chemicals

P2M

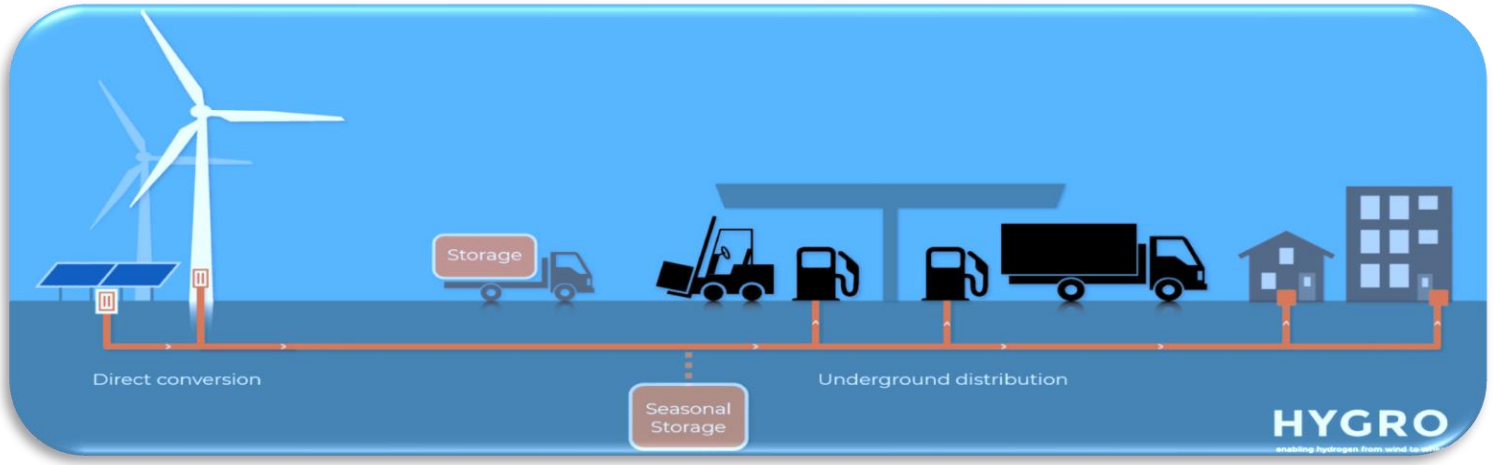
Power to Mobility

Fuel Cell Electric Vehicle, Train, Bus, ..

GREEN HYDROGEN

Wind to Hydrogen

Hydrogen Costs from PEM Already Lowest TCO



- Sustainable hydrogen manufactured at the turbine
- Modeled on DUWAAL project being led by HYGRO in N. Holland with Plug Power
- Directly coupled to wind turbine to reduce capex and optimize system efficiency
- Gas produced supplied to Industry & Mobility below 3.00 €/kg
- Gasunie can transport H_2 600 miles by pipeline @ 0.15 €/kg

Projected cost of hydrogen from the DUWAAL is < € 2.50/kg Larger project and electrolyzer system scale will rapidly drive cost to <$1.75/kg

Other Developing Markets: Power to Gas, Power to Fuel

Bio-methanation, Bio-fuels, & CO_2 Sequestration

Bridge to low carbon fuels: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

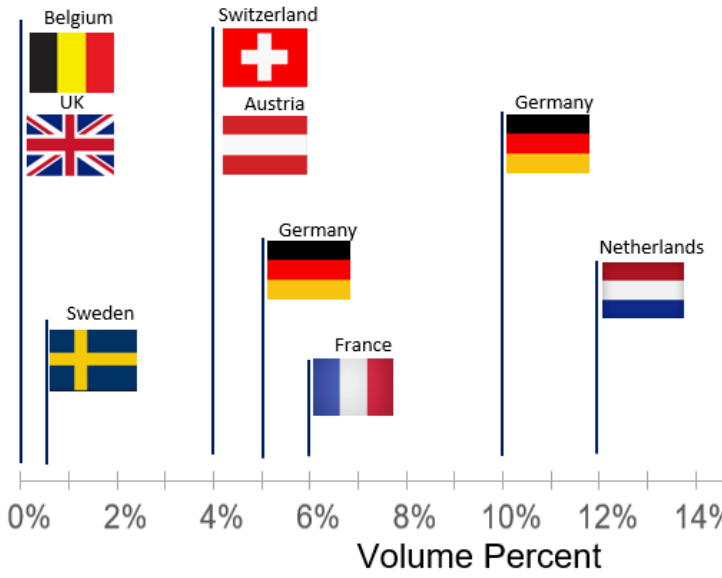
Benefits:

- Reduces greenhouse gas emissions if the hydrogen is produced from low-carbon energy sources, e.g. biomass, solar, wind, nuclear, or fossil resources with carbon capture

Plug Power Electrolyzers. Hydrogen from electrolysis combined with CO_2 captured from air/industrial sources/etc… to produce Biomethane & Biofuels

Available Storage Infrastructure- NG Pipe Lines

- Direct injection of Hydrogen into NG line of 5 to 15% percent hydrogen by volume feasible
- Efficient hydrogen storage solution with existing infrastructure
- Downstream Extraction:
  - Pressure swing adsorption (PSA),
  - Membrane Separation
  - Electrochemical hydrogen separation (hydrogen pumping)



The maximum (local) blend level of hydrogen into the gas grid varies greatly across (and even within) European countries[1]

Current European regulations allow between 0.1–12 percent hydrogen in natural gas lines maximum blend level / H_2 injection limit

Renewable Energy Capture & Storage

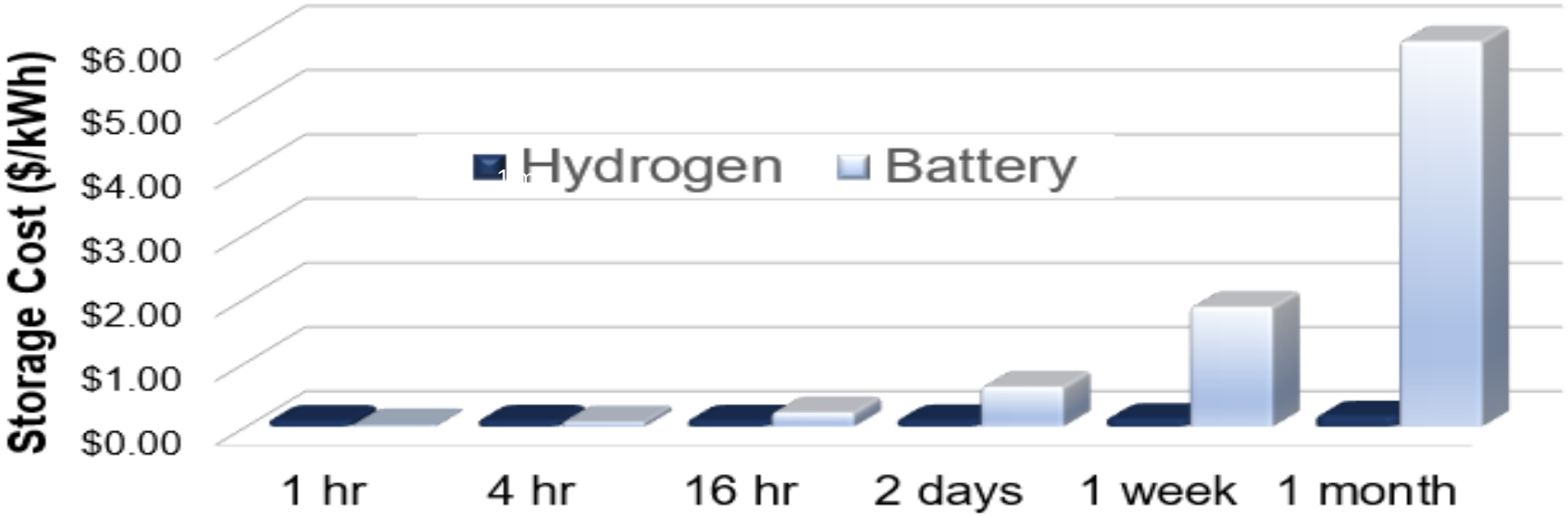
- Hydrogen is the solution, not batteries

Renewables

Electrolyzer

Storage

Fuel Cell



- If storing surplus Renewable Energy for more than ~8 hours, hydrogen is clearly the winner
- If hydrogen is used as a fuel for FCEV or as raw material for industry, the advantages are even greater

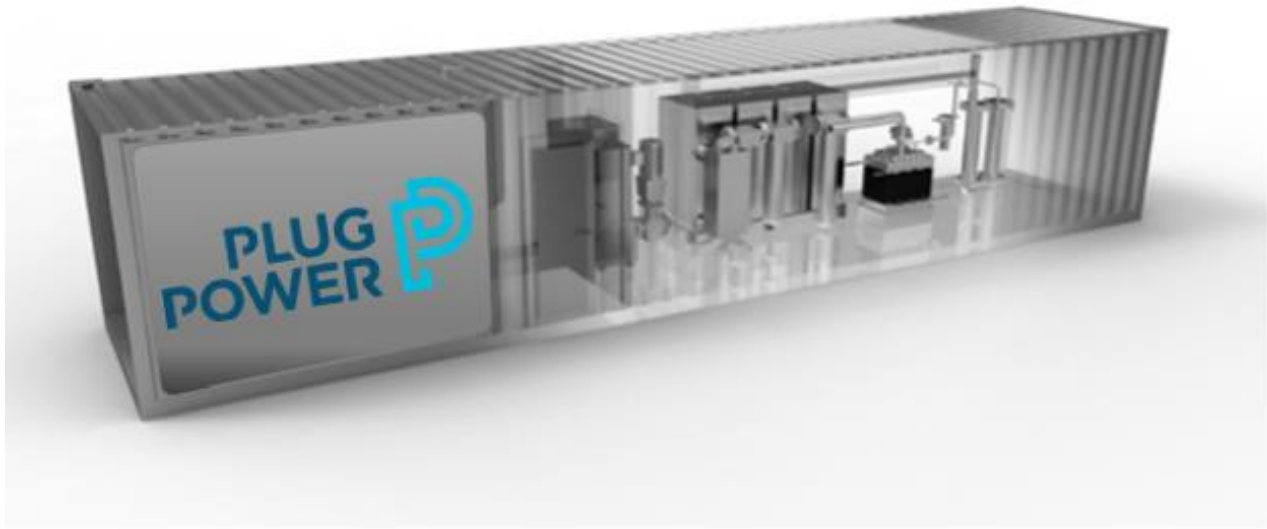
Most Common Electrolyzer Systems Today

150 kW: 65 kg/day H_2

- 10, 20 or 30 Ft containers
- Integrating 1,2, or 3 Merrimack Stacks
- Power conditioning AC / DC
- Water Purification Unit
- Gas Separation & Gas Purification

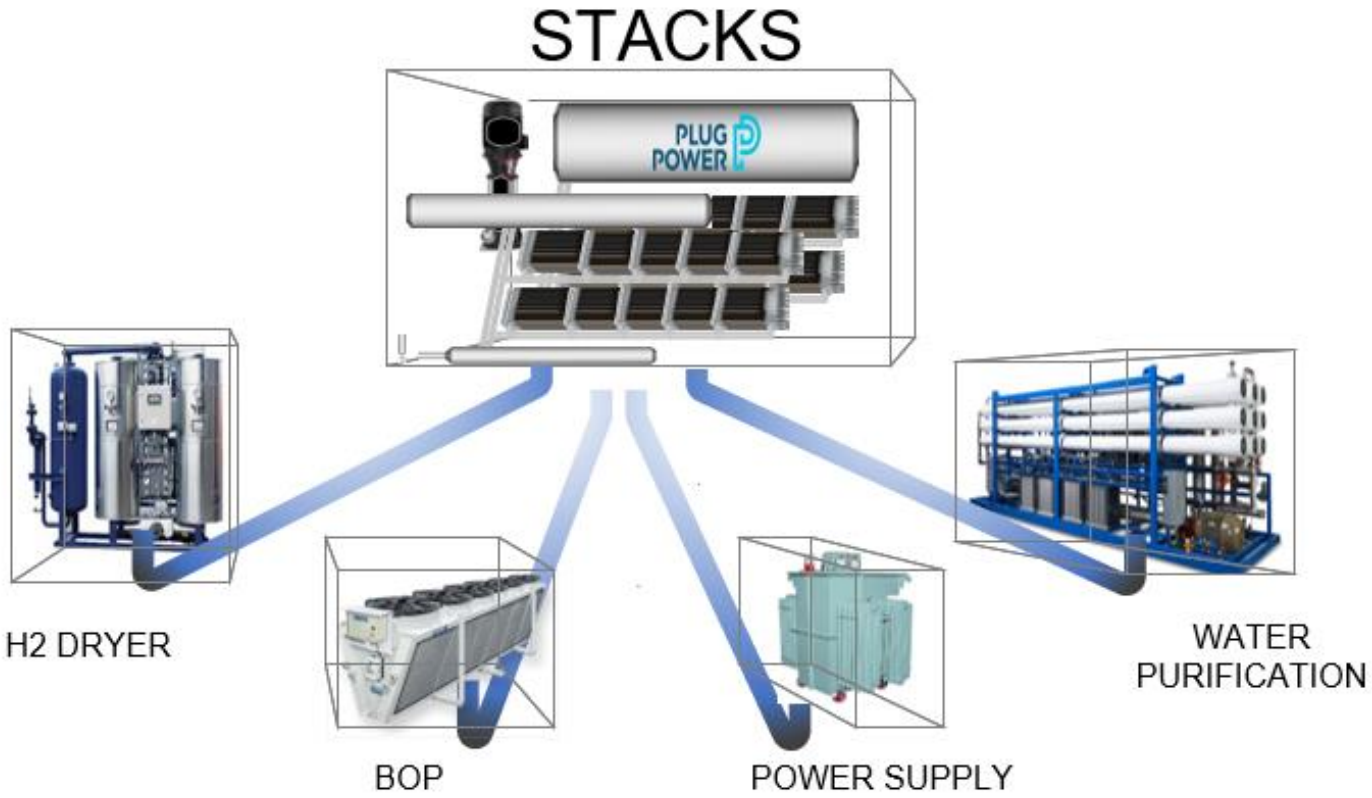
1 MW: 450 kg/day H_2

- 40 ft container
- Integrating 1 – 2 MW Stacks
- Power conditioning AC / DC
- Water Purification Unit
- Gas Separation & Gas Purification

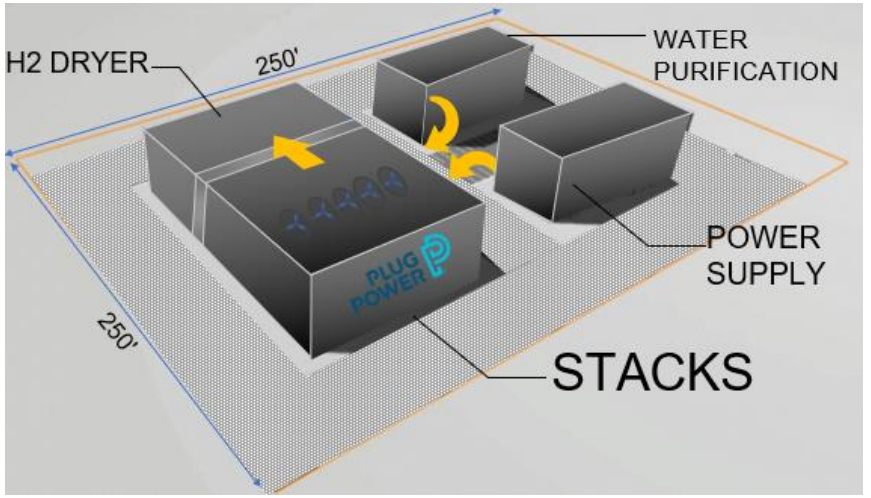


Large System Architecture

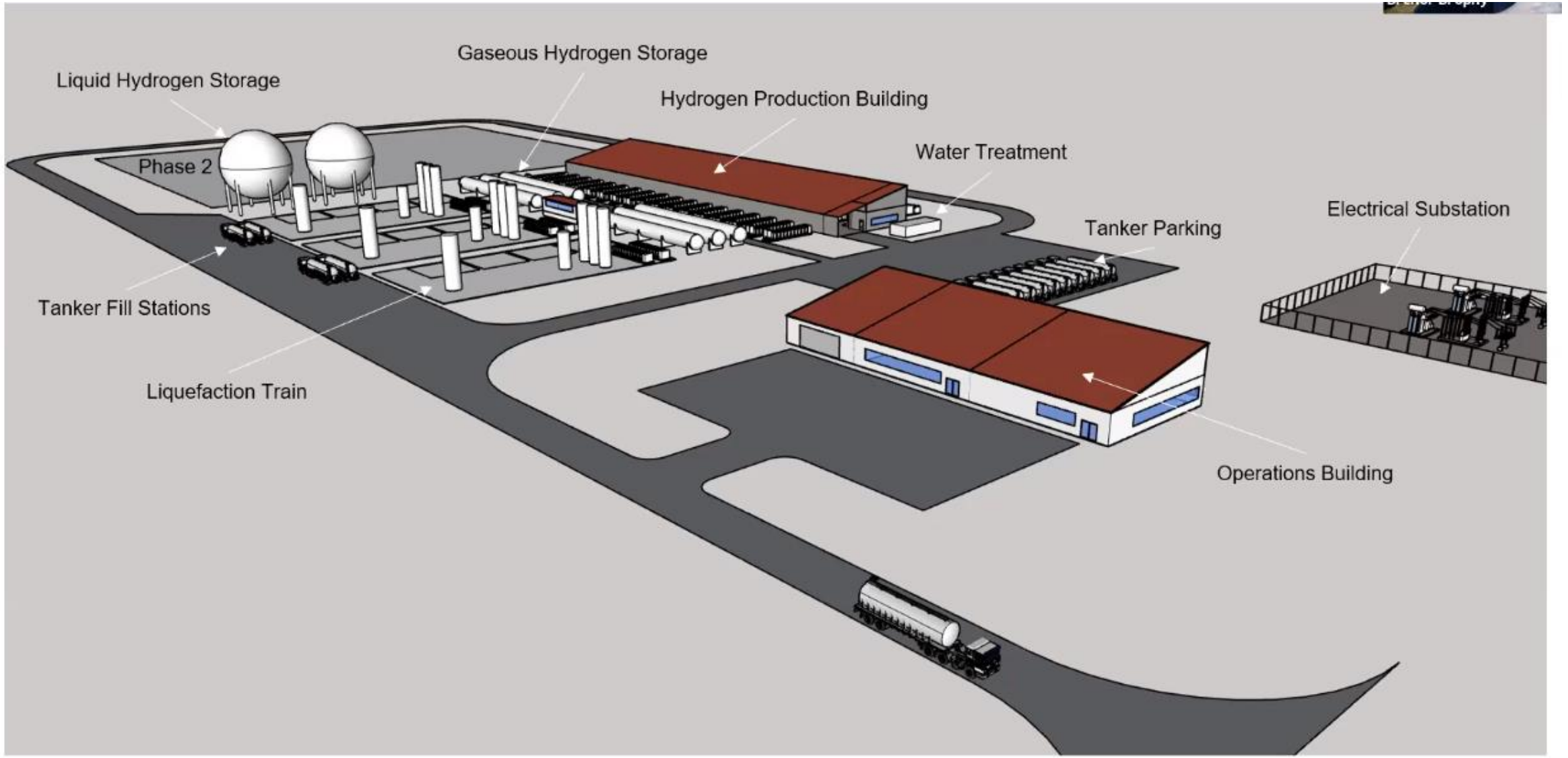
IMPORTANT SLIDE BASED ON CONTENT



- 5+ MW system designed with standalone sub-systems (vs. containerized solution for 1-3 MW systems)
- Key Sub-systems:
  - Stack enclosure and related components
  - H2 Dryer and purifier
  - Water purification plant
  - Power supply and power filters
  - BOP (dry cooler, pumps, sensors, plumbing, etc..)
- Additional cost reduction via fabrication of sub-system components at Plug Power (e.g. H2 Dryer, water purification plant)

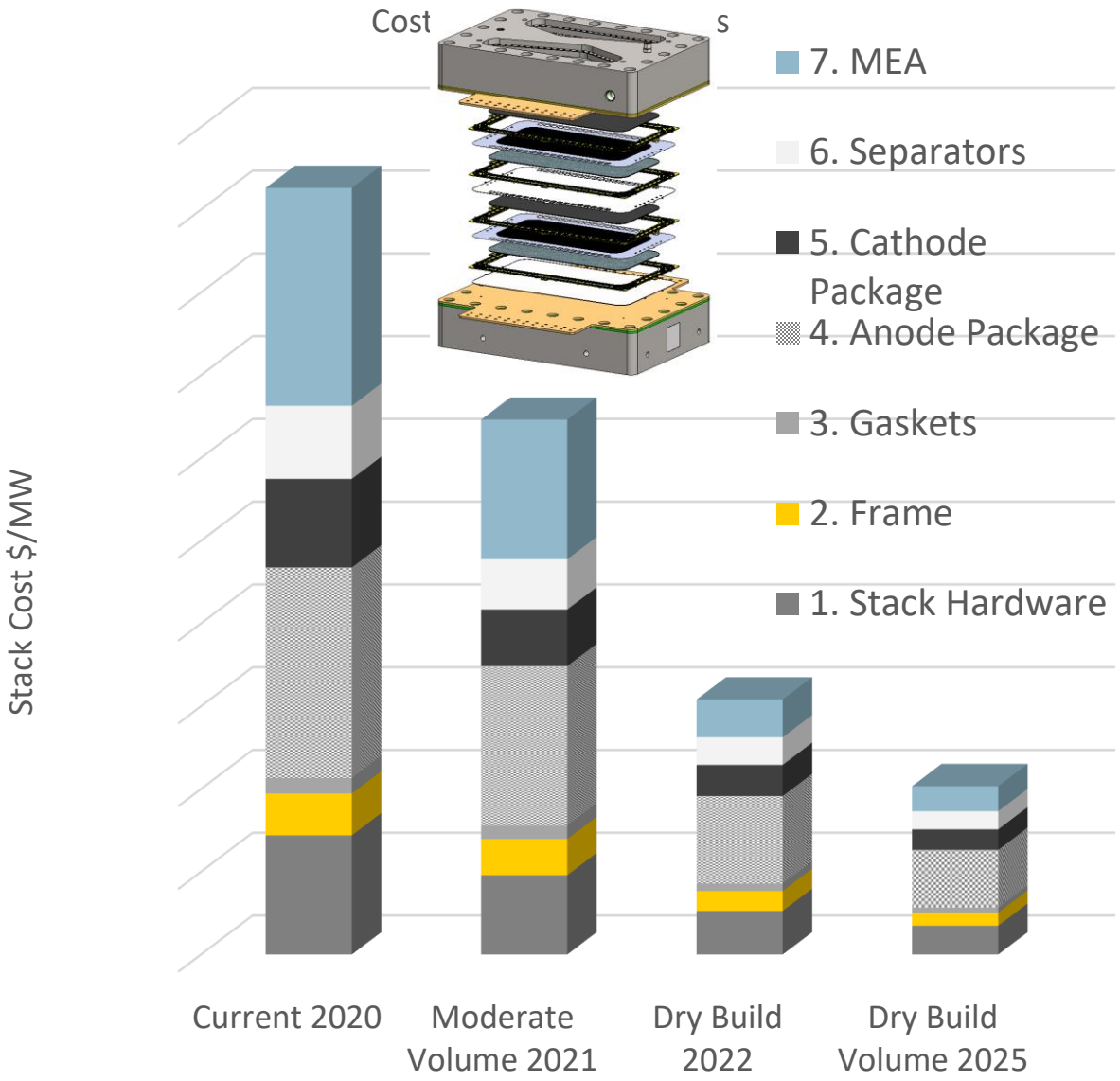


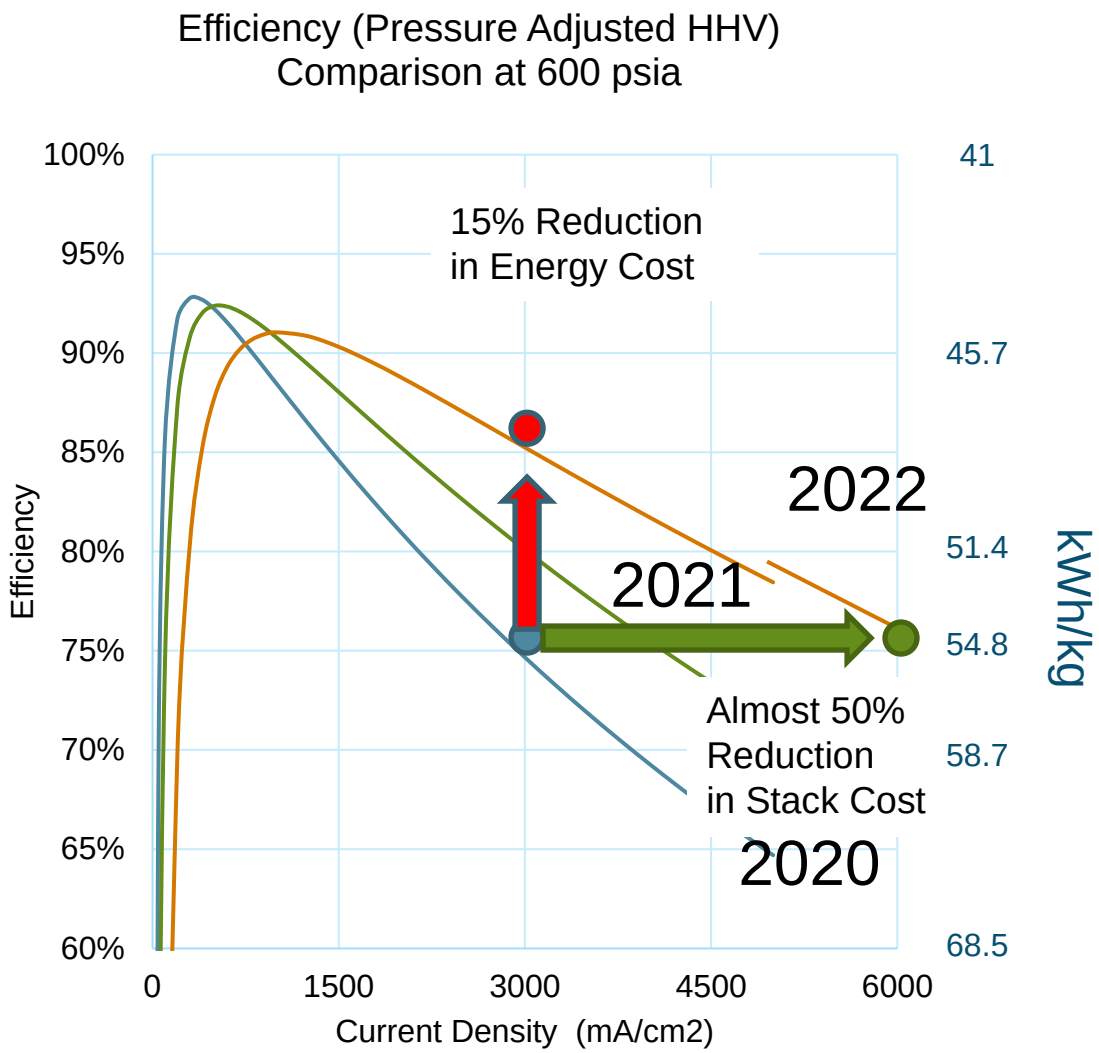
Large Scale Centralized Stations: Plug's New York 120 MW Facility



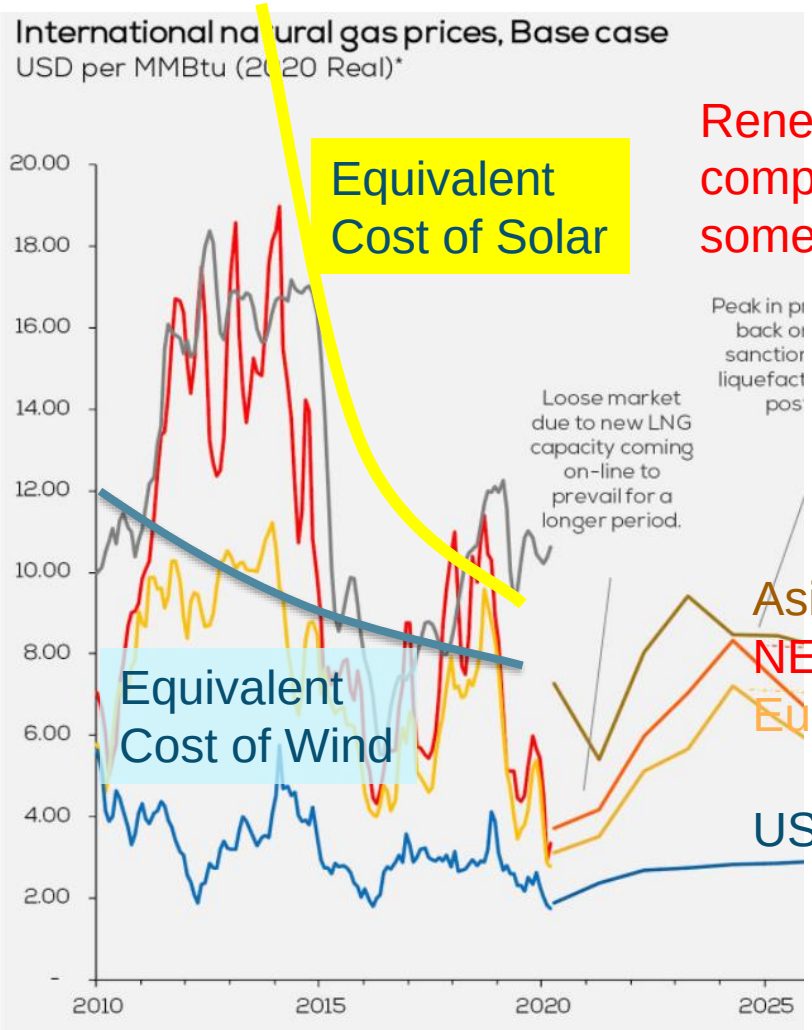
Technology

Strong Reduction in Cost while Improving Performance in the Near Term



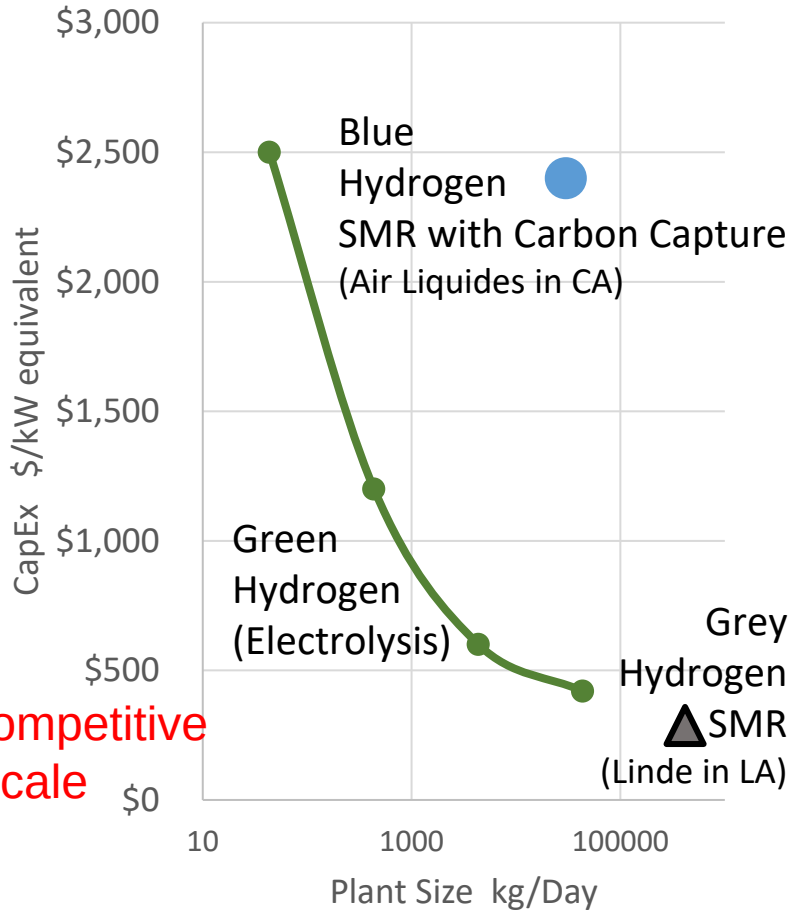


Competing Against Steam Methane Reform in CapEx and OpEx



Rystad Energy

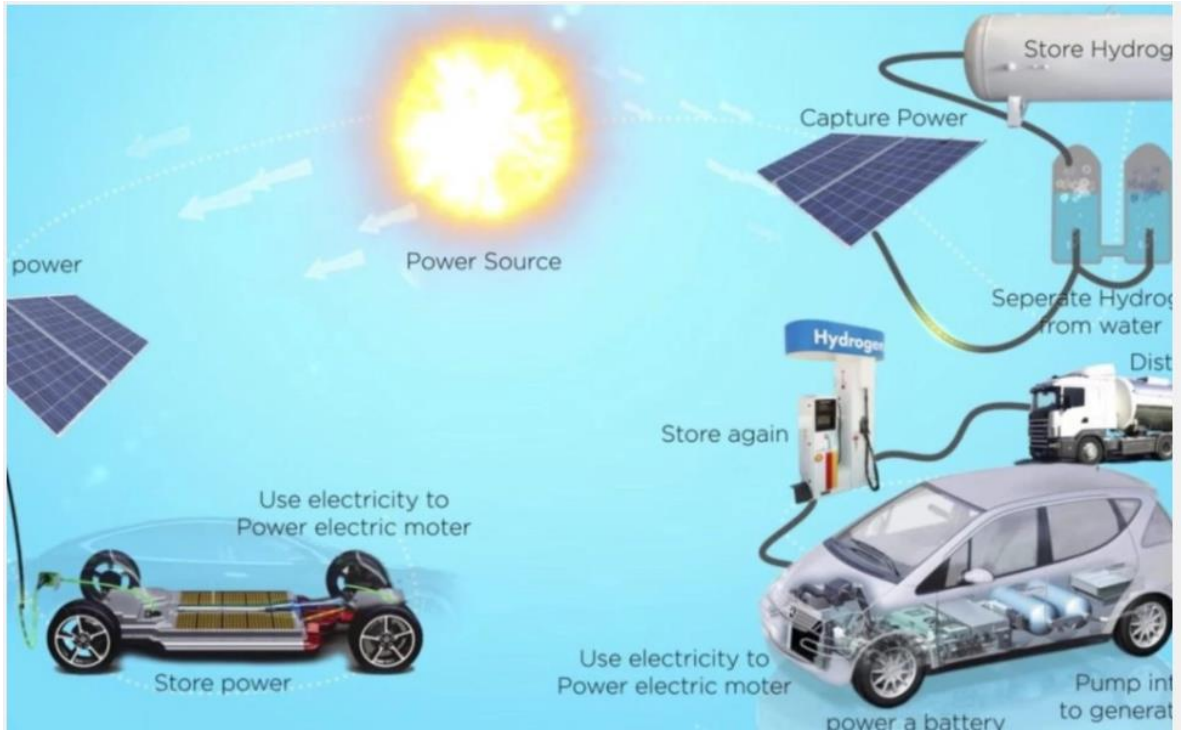
Renewables are already competitive with feed costs in some regions

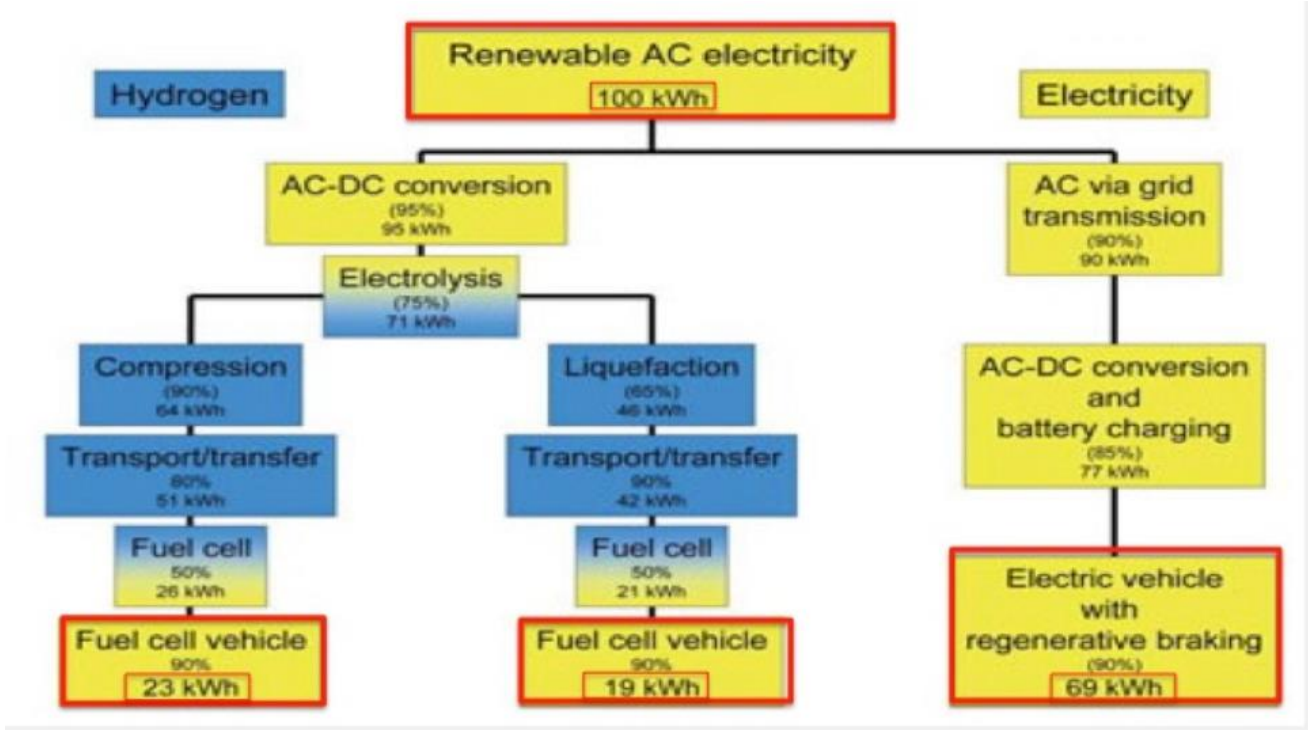


Electrolysis will be competitive with SMR OpEx at Scale

Vehicles

Energy Transfer





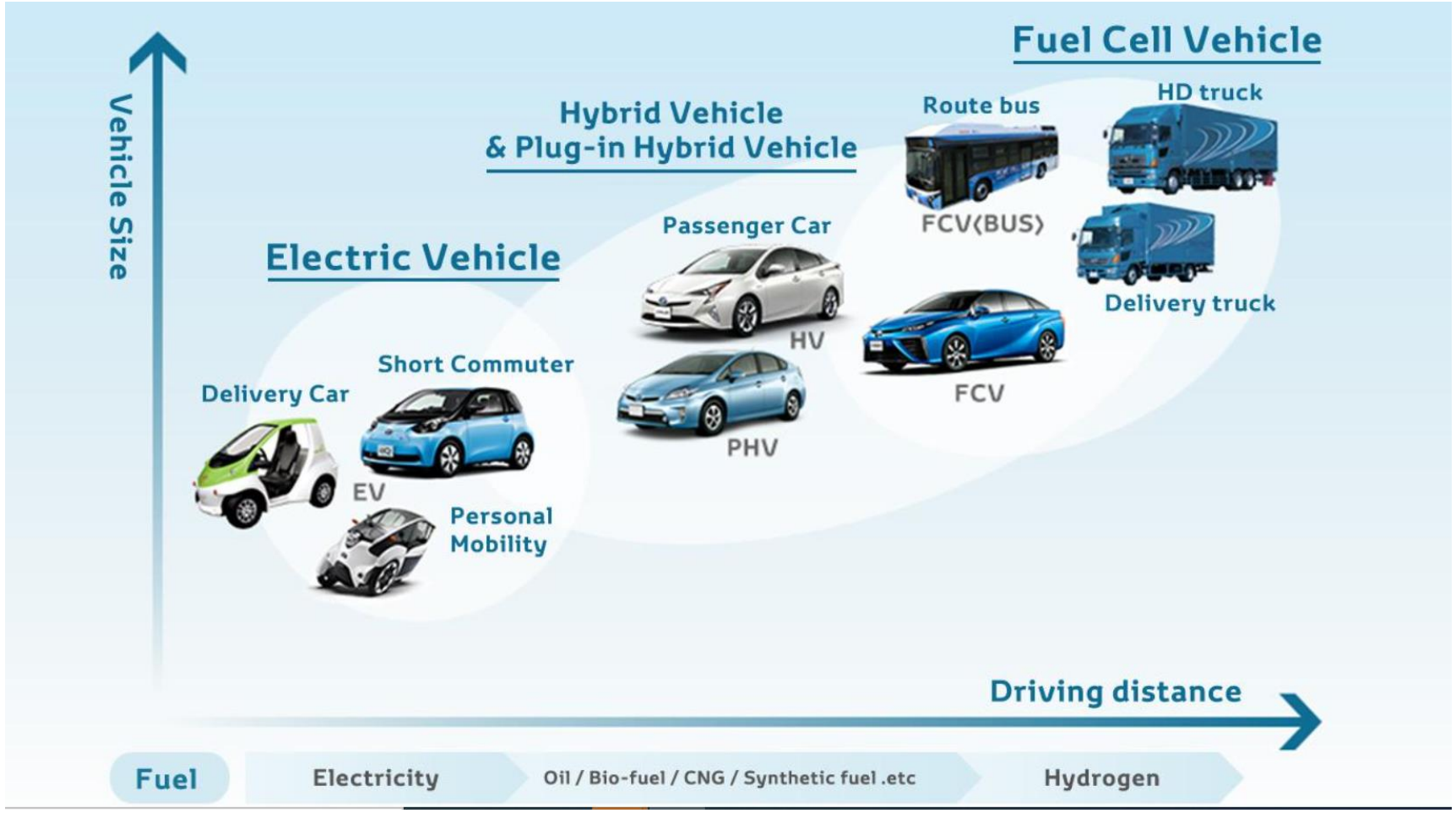
What is missing from this story?

Batteries
- $150/kWh today
- $100/kWh Goal

STORAGE!

Hydrogen
- $20/kWh in tanks
- <$1/kWh underground

Fuel Cell Vehicles: Where do they make sense:

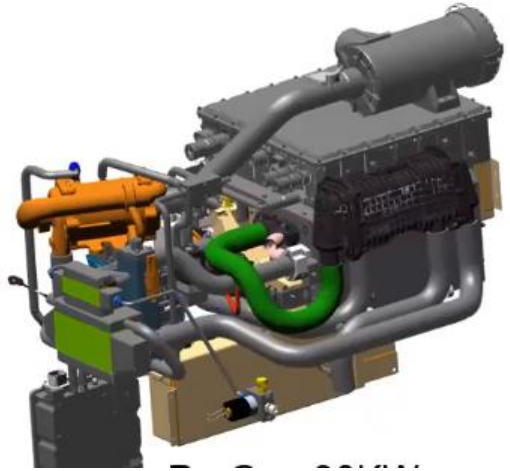


Fuel Cells win for:

- Heavier Load
- Longer the trip
- Greater the Utilizations
- Fleet Markets

Plug Power's Approach: Targeting Fleet Vehicles, Renault JV

- High degree of integration
- FC system under the hood
- Tanks in floorplan/chassis
- 30 KW ProGen powertrain
- Next Gen Master = 47 KW powertrain



Master

50,000 Vehicles by 2024