

Hydrogen's Future in Florida

FSEC Advisory Board Meeting
March 31st, 2021

Monjid Hamdan
VP of Engineering, Electrolyzer Systems

Company Profile

- Plug Power, Inc., Founded in 1997
- Based in Latham, NY
- Global leader in the design and development of hydrogen and electrical power generation systems
 - Fuel cells – Mobile & Stationary Power Generation
 - 35,000+ fuel cell systems shipped
 - Hydrogen Dispensers & Refueling Stations
 - 80+ Fueling stations built
 - Customers have completed more than 35 million hydrogen fills into Plug Power fuel cells, 1 fill every 3 seconds
 - Hydrogen Liquification Plants
 - Largest consumer of liquid hydrogen in US
 - 20+ tons of liquid hydrogen used daily
 - **Electrolyzers for Hydrogen production** through water electrolysis
 - Plug Power aims to produce more than 50% of its hydrogen energy from entirely renewable sources by 2024



PLUG
POWER 

Hydrogen Fuel
Plays an important role in
the quest for sustainable,
efficient, energy solutions
in the global move to the
electrification of
everything.

Company Products

**PLUG
POWER** 
GENKEY

(Your turnkey hydrogen and fuel cell solution.)

GENSURE. | **GENFUEL.** | **GENCARE.**

Power.

Fuel.

Service.

Fuel cells
to Power Your
Possibilities.

Our “one call”
hydrogen
refueling solution.

A full suite
of aftermarket
service options.



Worlds first PEM Technology Gigafactory
Driving Scale in the Hydrogen and Fuel Cell Technology

Annual Capacity (2024)

1.5 Gigawatts Output

7M+ MEAs

7M+ Bipolar Plates

500+ MW of Electrolyzers

60,000+ Fuel Cell Stacks

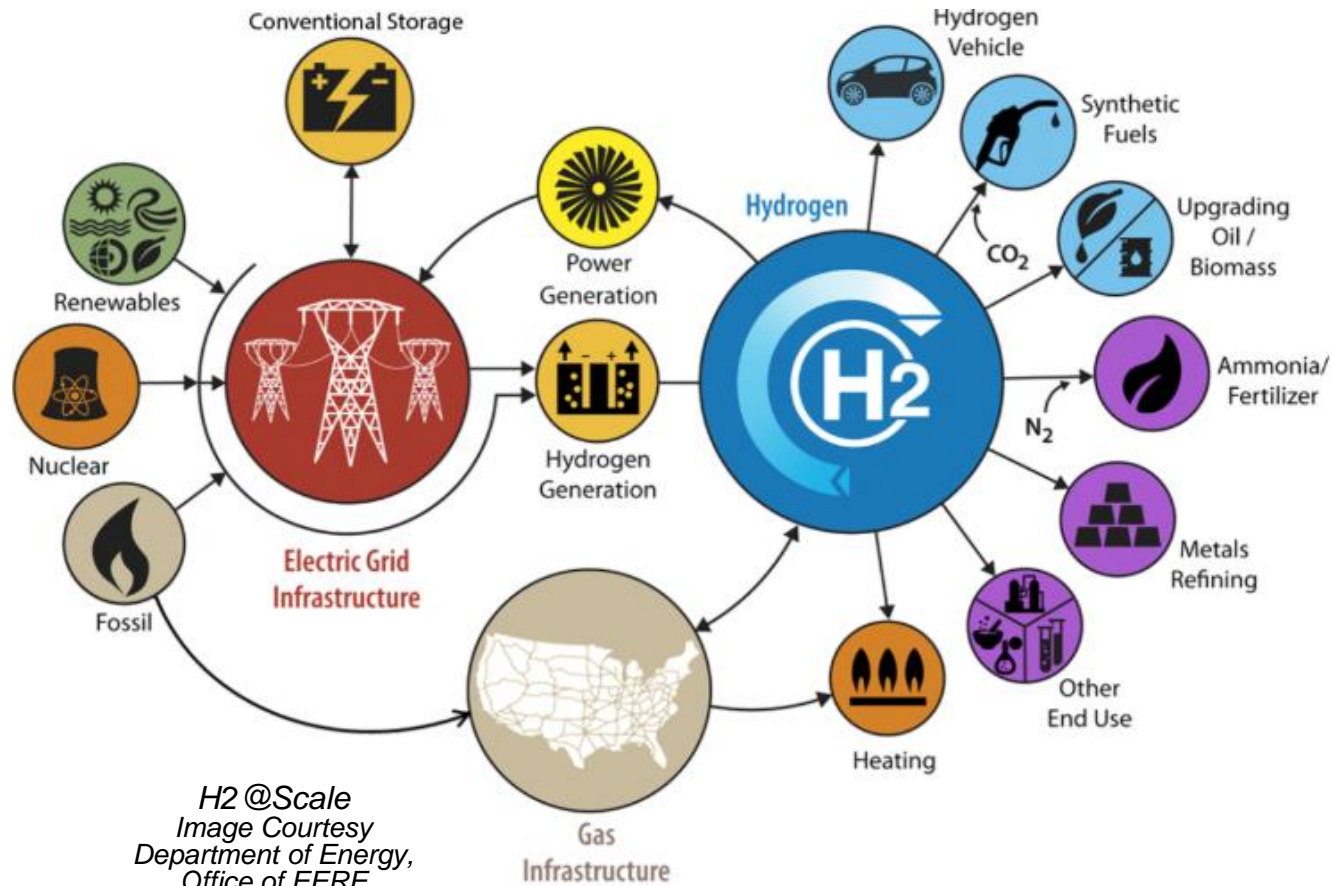
Green H₂ Onsite generation

Hydrogen's Diverse Application Potential

Hydrogen and Electrolysis Compliments a Multitude of Industries

Hydrogen is a versatile energy carrier enabling renewable energy systems

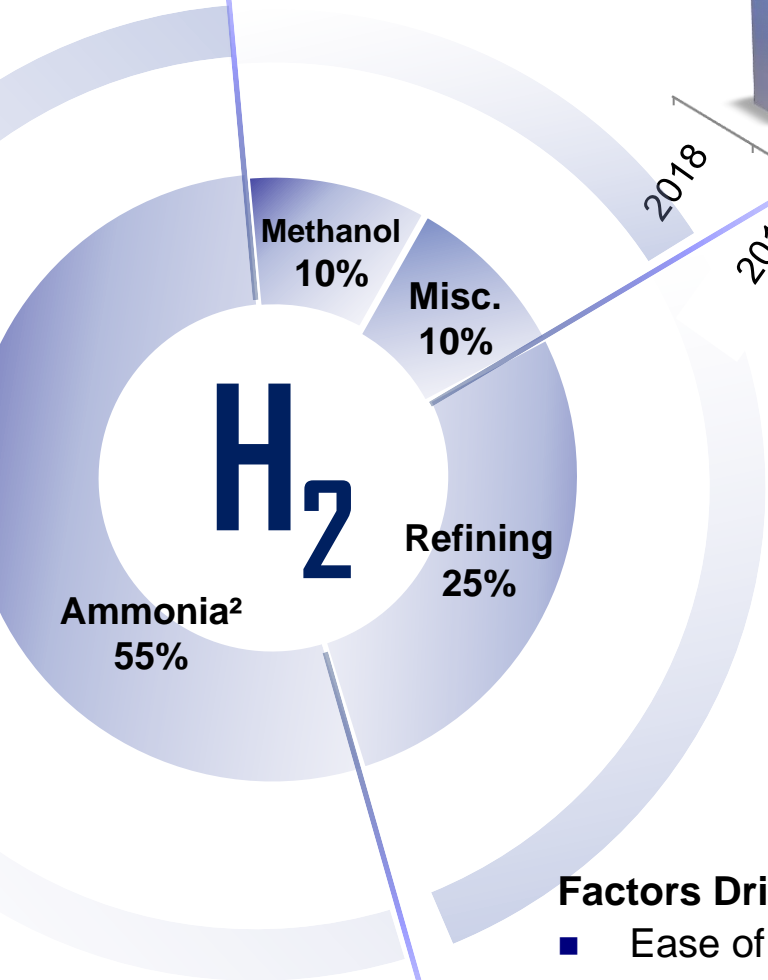
Hydrogen from electrolysis is key in producing large quantities of sustainable energy in various forms



Market Enablers

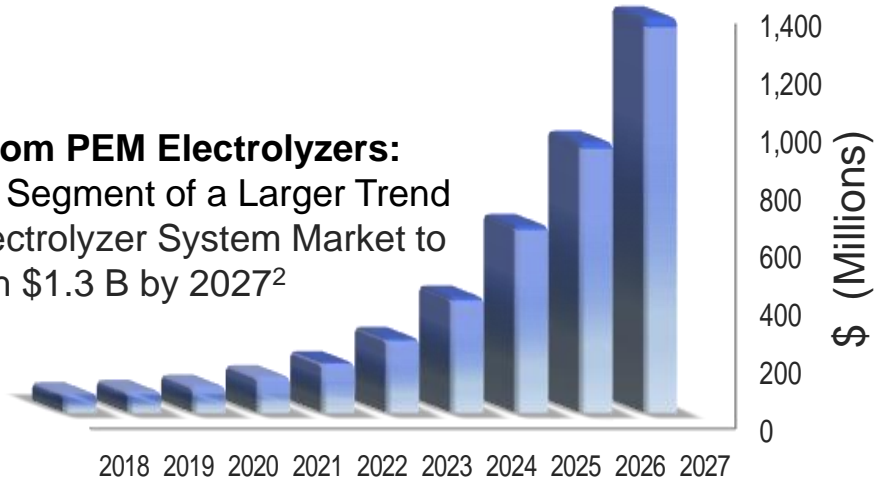
- Increased use of Renewables
- Global Decarbonization Initiatives
- Cost Competitive Hydrogen

Hydrogen Markets



Global Hydrogen Generation Market Expected to Grow at 8.0% CAGR from 2018 to 2023¹

Hydrogen from PEM Electrolyzers: A Concentrated Segment of a Larger Trend
Global PEM Electrolyzer System Market to Reach \$1.3 B by 2027²



Factors Driving Growth in PEM Electrolyzers

- Ease of integration for renewable energy applications
- Government regulation for desulphurization of refinery activities
- Increased demand for hydrogen in the transportation sector

¹Kansas State University
²U.S. DOE.

Hydrogen Economy on the Horizon

Countries move to Hydrogen to meet emission standards

The EU is leading in Hydrogen

€ 65bn

Investment by 2030

€ 20bn

EU investment in funding initiatives
Green Deal, Horizon2020, EU
Innovation Fund, Green Ports &
Airports, IPCEI



Holland has committed to close its Groningen gas field by 2030 and end the sale of all gas- and diesel-powered vehicles; In Northern Holland there are initial plans for 500 MW of water electrolysis



UK: The H21 Leeds City Gate pilot project is converting the entire city's **heating grid to 100% hydrogen**, testing a concept that could eventually span the entire UK



Germany: Demonstrating how to convert carbon-rich exhaust gases of a steel plant to **green chemical products by using electrolysis** and chemical synthesis technologies

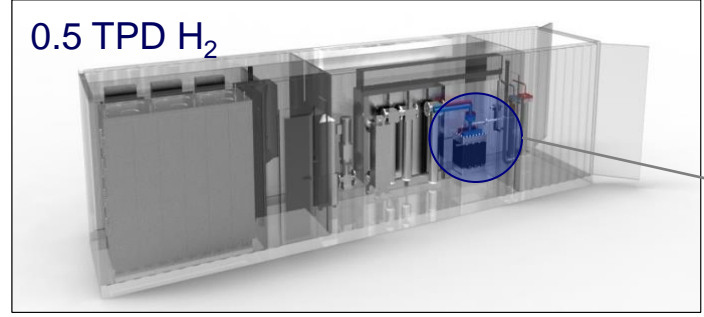


Tokyo's governor has designated hydrogen as the "energy star" of the 2020 Olympics - with the Olympic Village powered by fuel cells and athletes shuttled throughout the games by **hydrogen-powered vehicles**

Advancements in Electrolyzers

Stacks for H₂ @ Scale

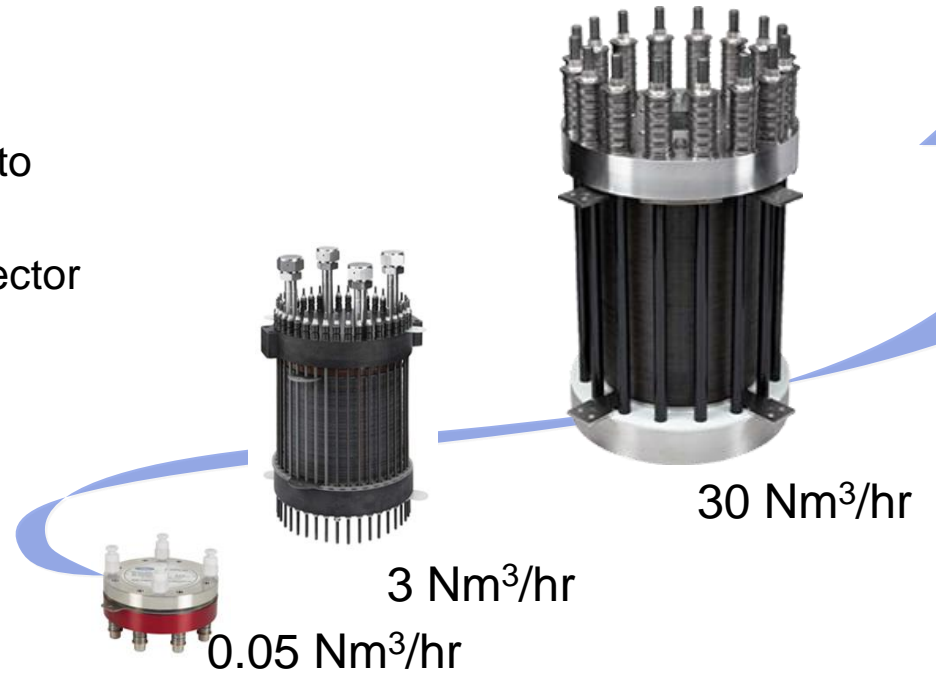
1 MW



220+ Nm³/hr
(MW Scale)

Emerging Markets & Drivers

- Power to Mobility (**P2M**)
- Power to Gas/Fuel (**P2G/F**)
 - Vast opportunities in Biogas/CO₂ sequestration
- Power to Hydrogen (**P2H**)
 - Integration of Renewable Energy Sources
 - Large reserves of stranded energy (need to store/shift)
 - Ongoing broad developing wind energy sector
- Power to Power (**P2P**)
 - Backup power for grid outages
 - Regenerative Fuel Cell Systems
 - Grid load leveling
- Power to Product (**P2X**)
 - Ammonia, Steel, Chemicals

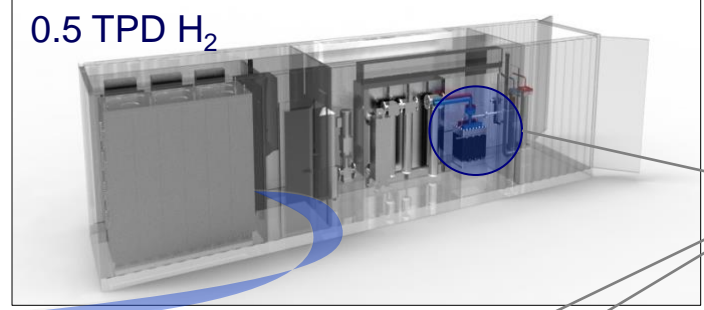


Advancements in Electrolyzers

Systems for H₂ @ Scale

Clear development roadmap to green hydrogen at a cost of <\$1.50 per kilogram (RES power at \$0.02/kWh) based on technology advances already being demonstrated at Plug Power

1 MW

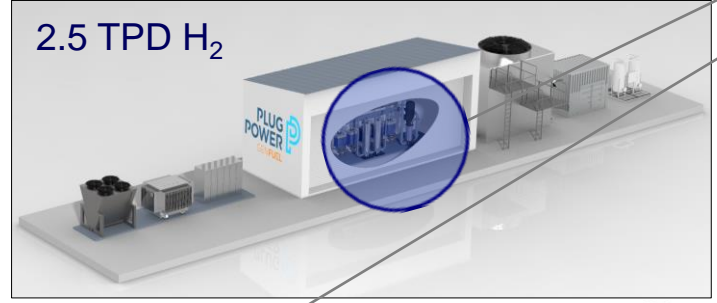


0.5 TPD H₂



220+ Nm³/hr
(MW Scale)

5 MW

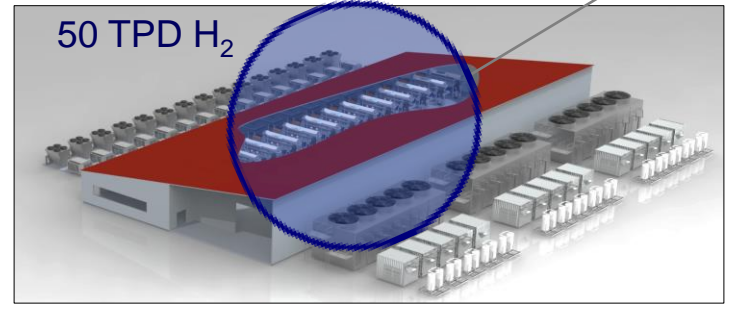


2.5 TPD H₂



30 Nm³/hr

100+ MW



50 TPD H₂



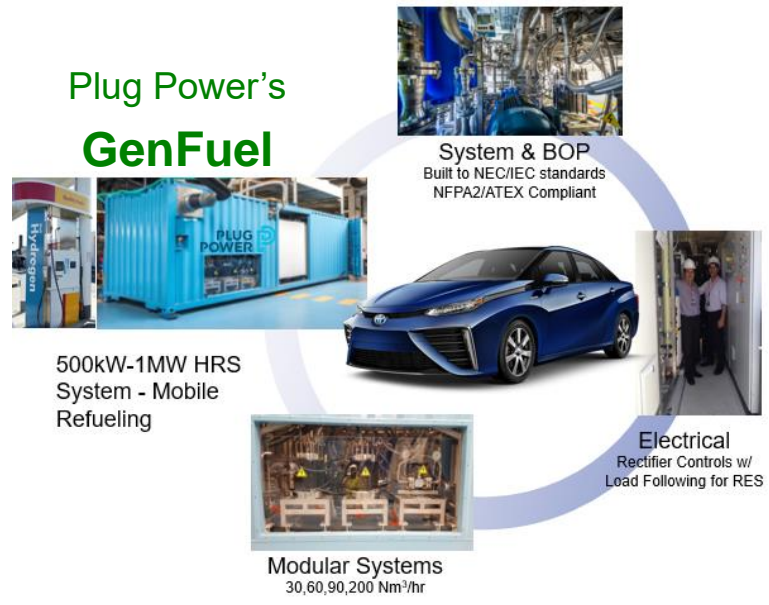
3 Nm³/hr



0.05 Nm³/hr

P2M: Mobility

Plug Power's GenFuel



Plug Power's ProGen Fuel Cell Engines



- 20 Years of Field Experience, 35,000+ units shipped
- High utilization applications (7x24)
- Greater than 500 million run hours in the field
- Flexible FC Engine Designs for 'Plug and Play' integrations

P2M Market Drivers

- Emissions reduction from the transportation sector. Fuel Cell Electric Vehicles (FCEV) release zero greenhouse gas (GHG) emissions
- Tax rebates and developments in hydrogen refueling stations (HRS)



15 kW



15 kW



30 kW



85 kW

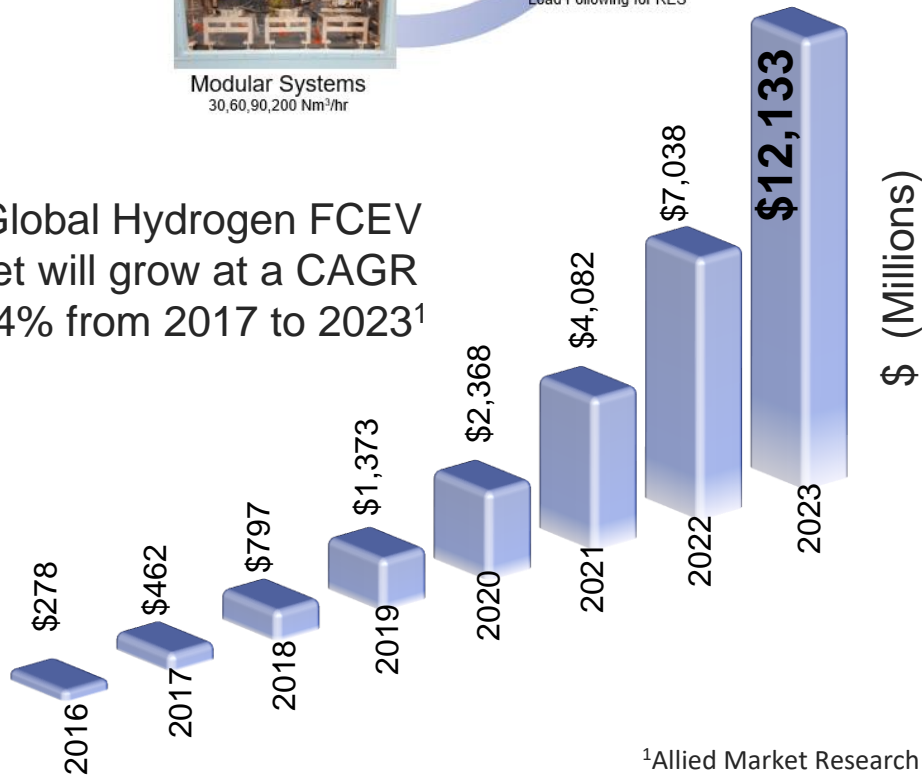


85 kW



125 kW

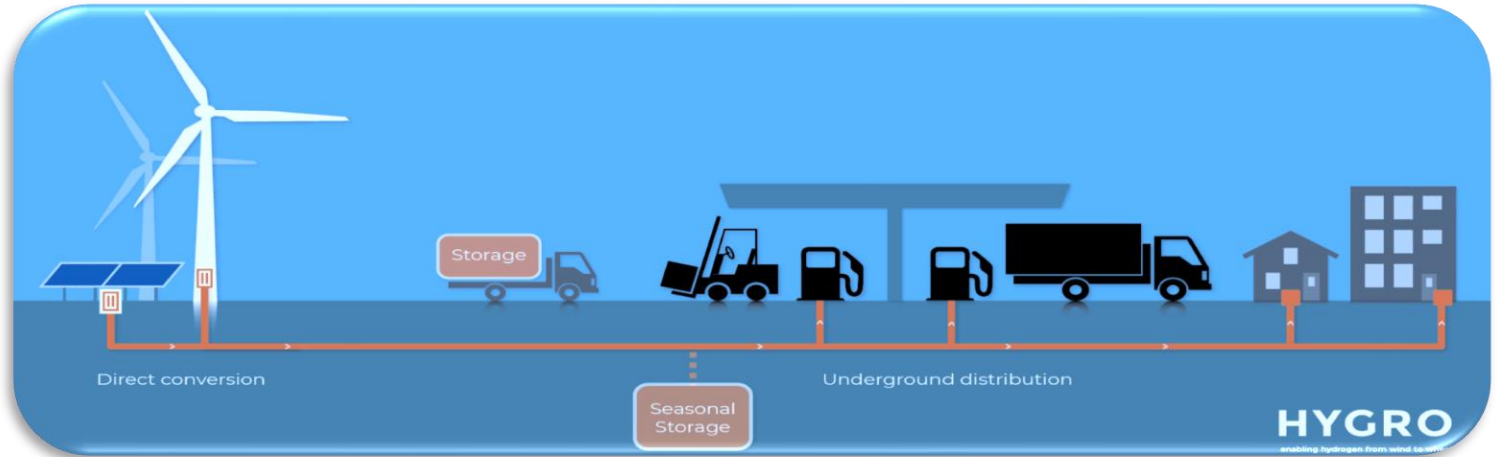
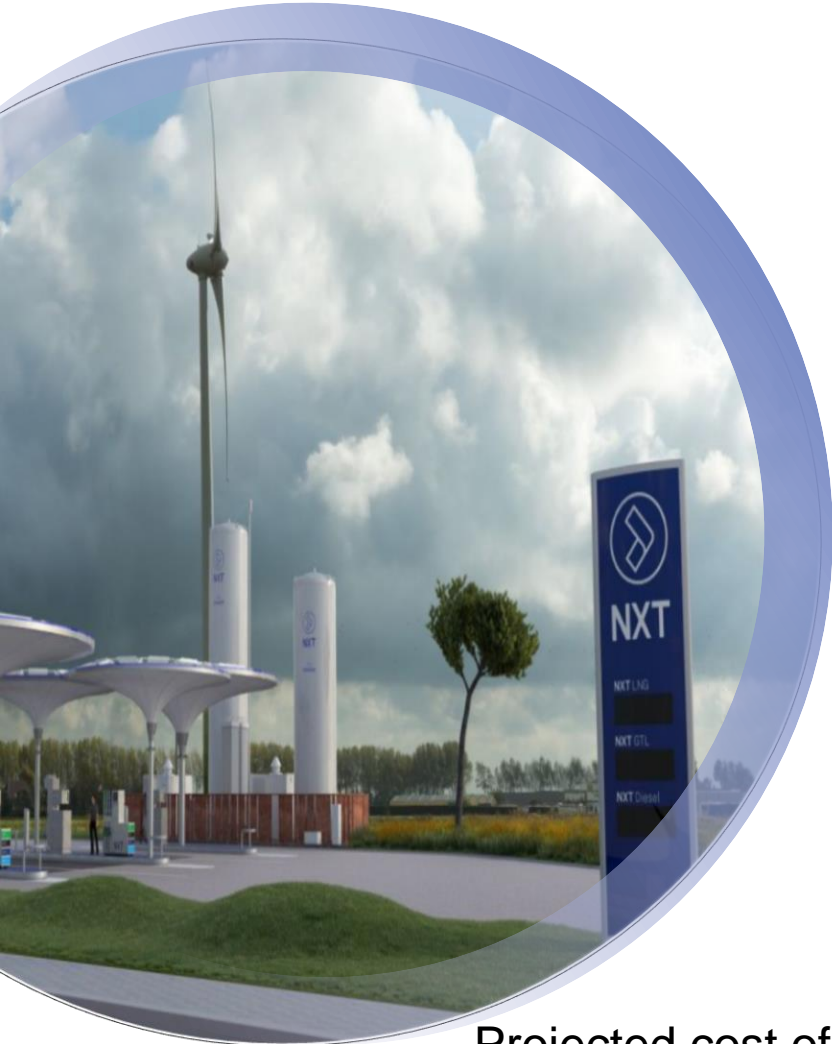
The Global Hydrogen FCEV Market will grow at a CAGR of 72.4% from 2017 to 2023¹



¹Allied Market Research

P2H (Wind to Hydrogen)

Hydrogen Costs from PEM Already Competitive



- Sustainable hydrogen manufactured at the turbine
- Modeled on DUWAAL project being led by Plug and HYGRO in N. Holland
- 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 H₂ 600 miles by pipeline @ 0.15 €/kg

HYGRO directly couples Plug Power system to wind turbines to reduce capex and optimize system efficiency
 Plug Power will supply a 2 MW electrolyzer for our collaborator HYGRO's DUWAAL project in Northern Holland in 2019



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

P2G (Power to Gas), P2F (Power to Fuel), P2X (Power to Product)

Bio-methanation, Bio-fuels, & CO₂ Sequestration

Bridge to low carbon fuels: $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$

Benefits:

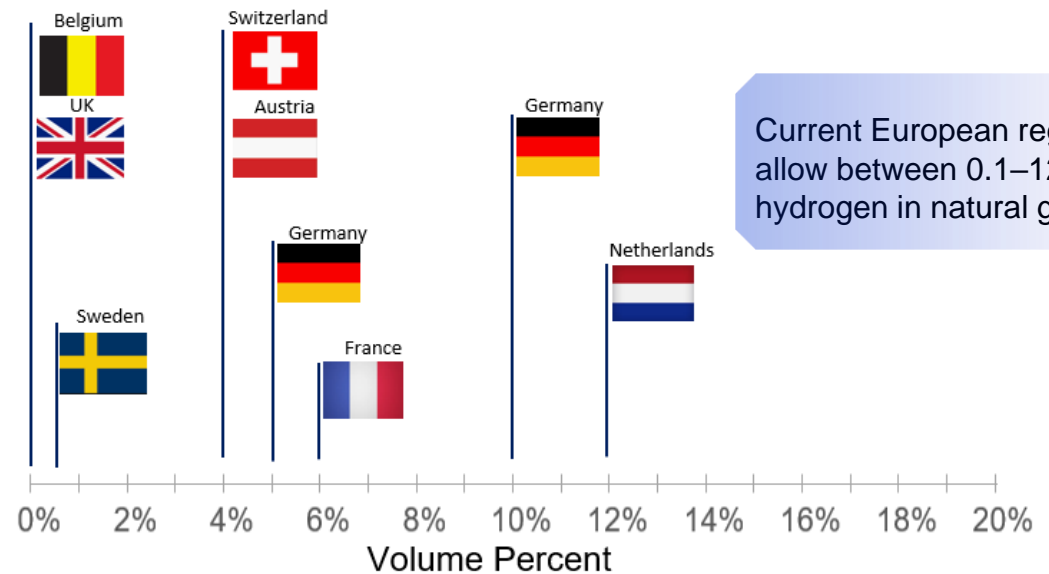
- Reduces greenhouse gas emissions if the hydrogen is produced from low-carbon energy sources, e.g. biomass, solar, wind, nuclear, or fossil resources with carbon capture



Plug Power Electrolyzers: Hydrogen from electrolysis combined with CO₂ captured from air/industrial sources to produce Biomethane & Biofuels

Available Storage Infrastructure- NG Pipelines

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

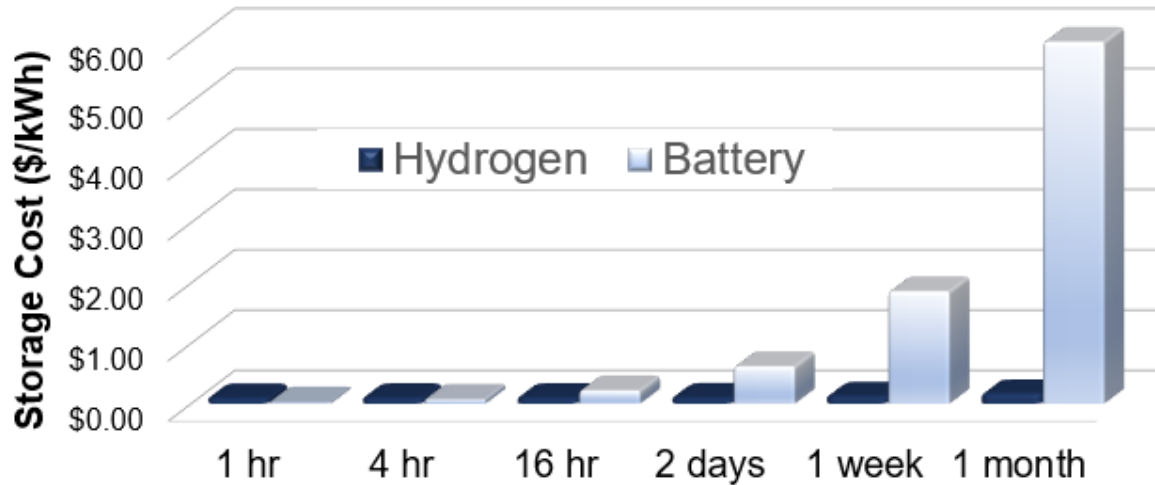


Current European regulations allow between 0.1–12 percent hydrogen in natural gas lines¹

¹Source: FCH 2017

P2P - Renewable Energy Capture/Storage

H₂ is the Solution, not Batteries

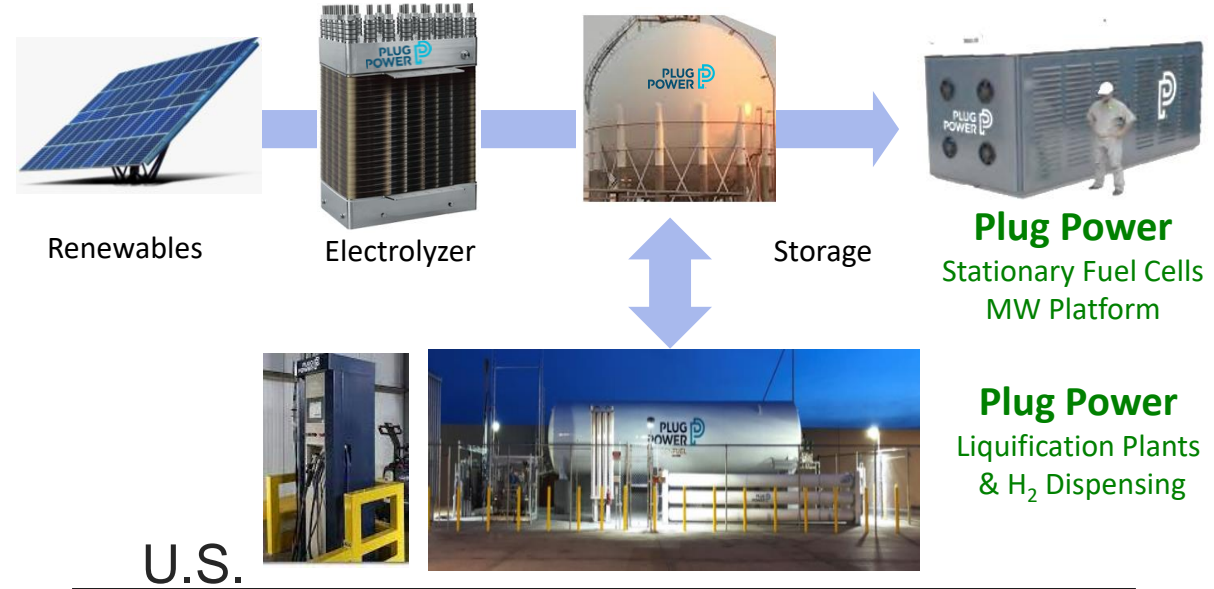


- If storing surplus Renewable Energy for more than ~6 hours, hydrogen is clearly the winner
- If hydrogen is used as a fuel for FCEV or as raw material for industry, the advantages are even greater

Target markets

- Intermittent Renewable Energy Source (RES) integration
- Backup power for grid outages and load shedding
- Increase RES ratio and ensure grid stabilization

RFC Systems



France



Plug Power's Electrolyzer System utilized for Solar-to-Hydrogen conversion in Japan

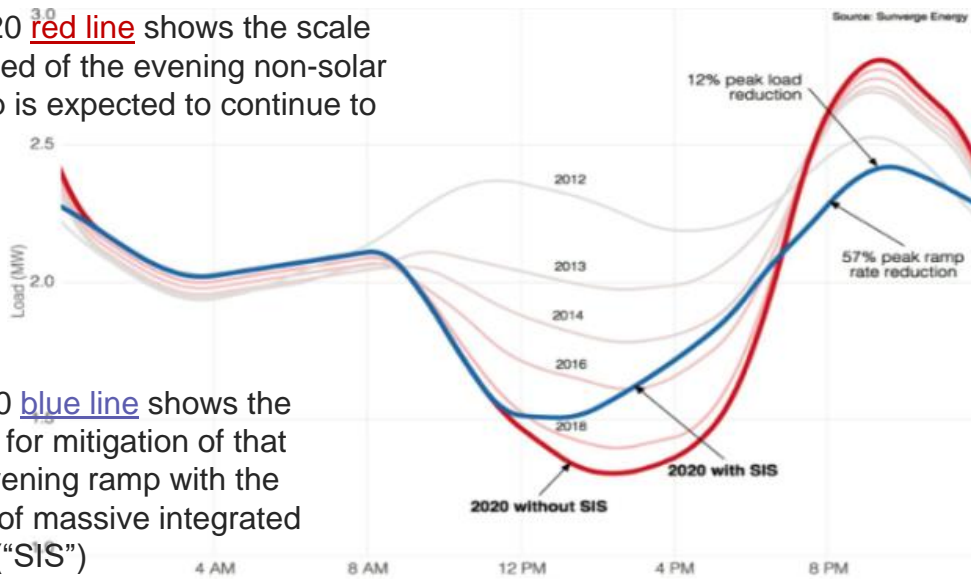
Japan

Grid Stabilization

-Hydrogen Offers a Green Solution to Intermittent renewables

- Rapid implementation of solar has led to storage needs more quickly than anticipated
- Solution: PEM Electrolyzer with fast response time, and be scalable to TWh
 - Electrolyzers can provide grid services & renewably generated hydrogen with fast response time as a controllable load
 - The ability to provide stability to overburdened-RES grids has already been marketed at a value of \$50/MWh, not including benefits from the sale of hydrogen; an additional financial incentive¹

The 2020 **red line** shows the scale and speed of the evening non-solar ramp-up is expected to continue to grow



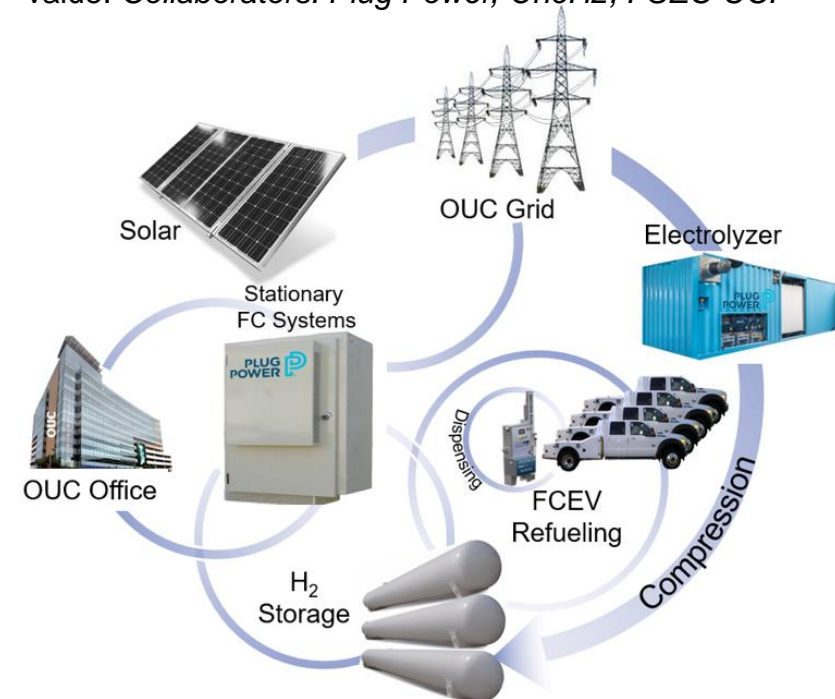
The 2020 **blue line** shows the potential for mitigation of that costly evening ramp with the addition of massive integrated storage (“SIS”)

The “California Duck” Chart:
Non-solar generation required over a 24-hour period (2012 to 2020)



‘Integrated Hydrogen Production and Consumption for Improved Utility Operations’ Orlando Utility Commissions (OUC) has been awarded a grant from the U.S. Department of Energy to make solar energy a more reliable, affordable, and sustainable resource

Ensures that the hydrogen is produced at the lowest electricity cost, and consumed for the greatest possible value. Collaborators: Plug Power, OneH2, FSEC-UCF



¹cleantecnica.com 08/21//2018

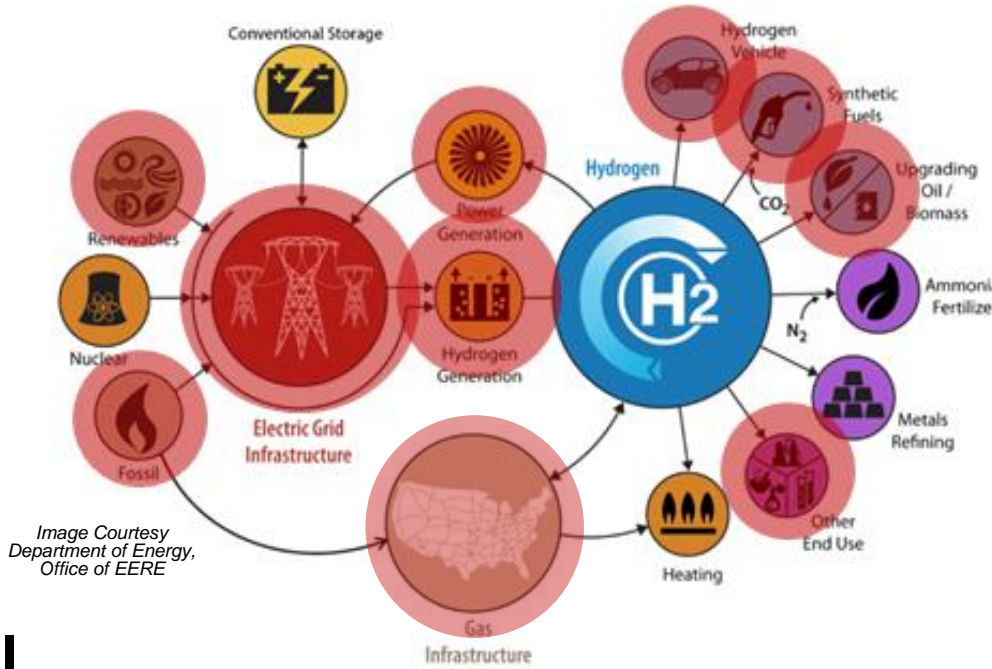
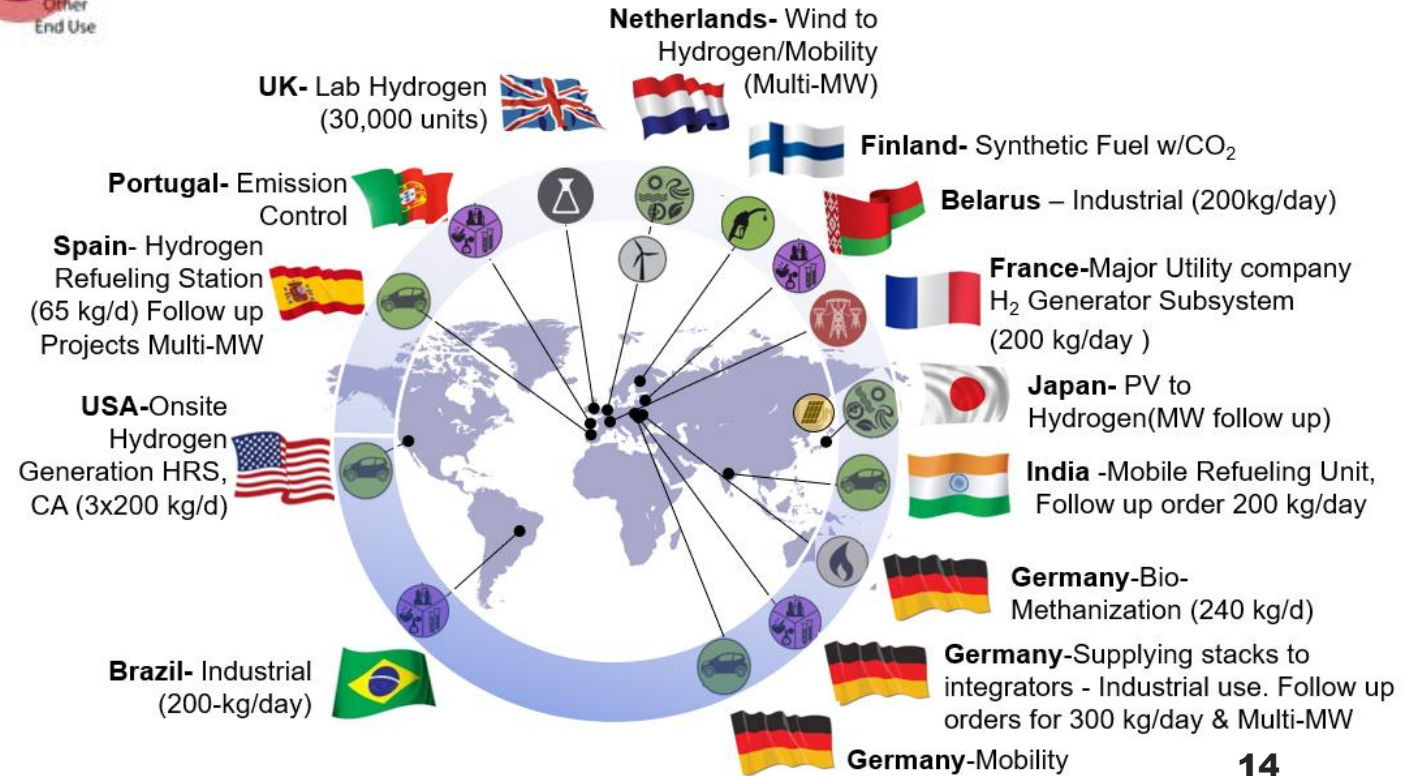


Image Courtesy Department of Energy, Office of EERE

Renewable Energy Applications
 Plug Power PEM **Electrolyzers** have penetrated many of the hydrogen production utilization activities mentioned in H2@Scale

Recent Commercial 'System' Activities





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www.Plugpower.com

Thank You!

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