The Hydrogen Data Center Challenge

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Collaborating partners:
Daimler,
Hewlett Packard Enterprise, and
Power Innovations

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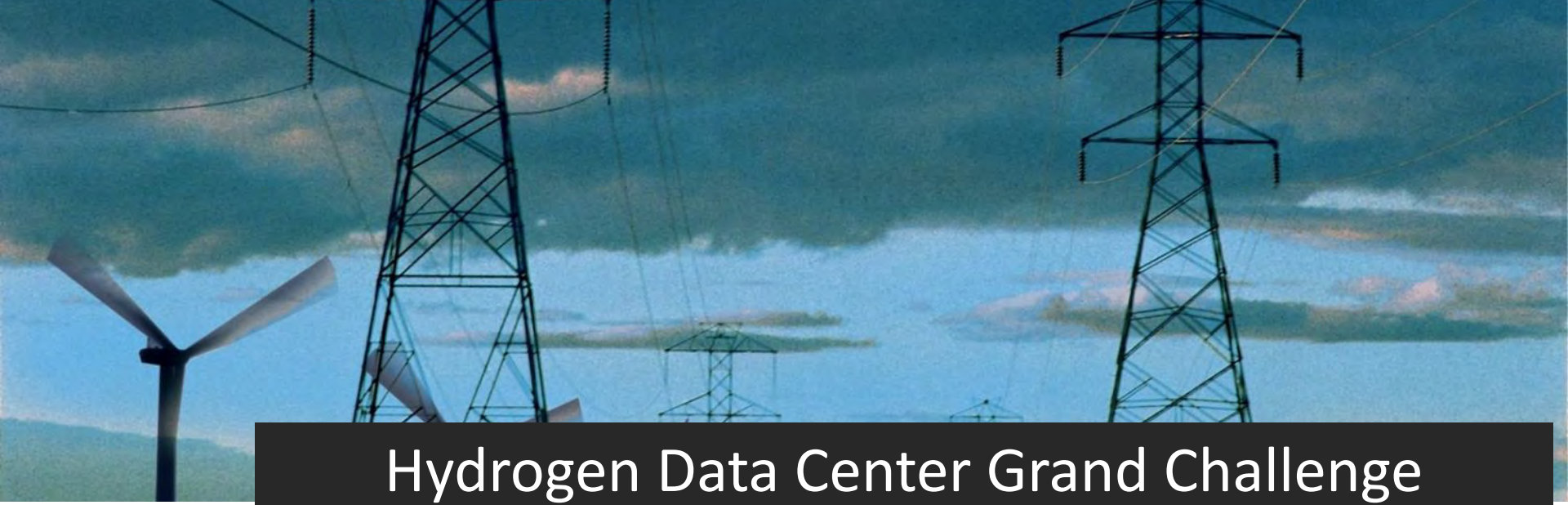
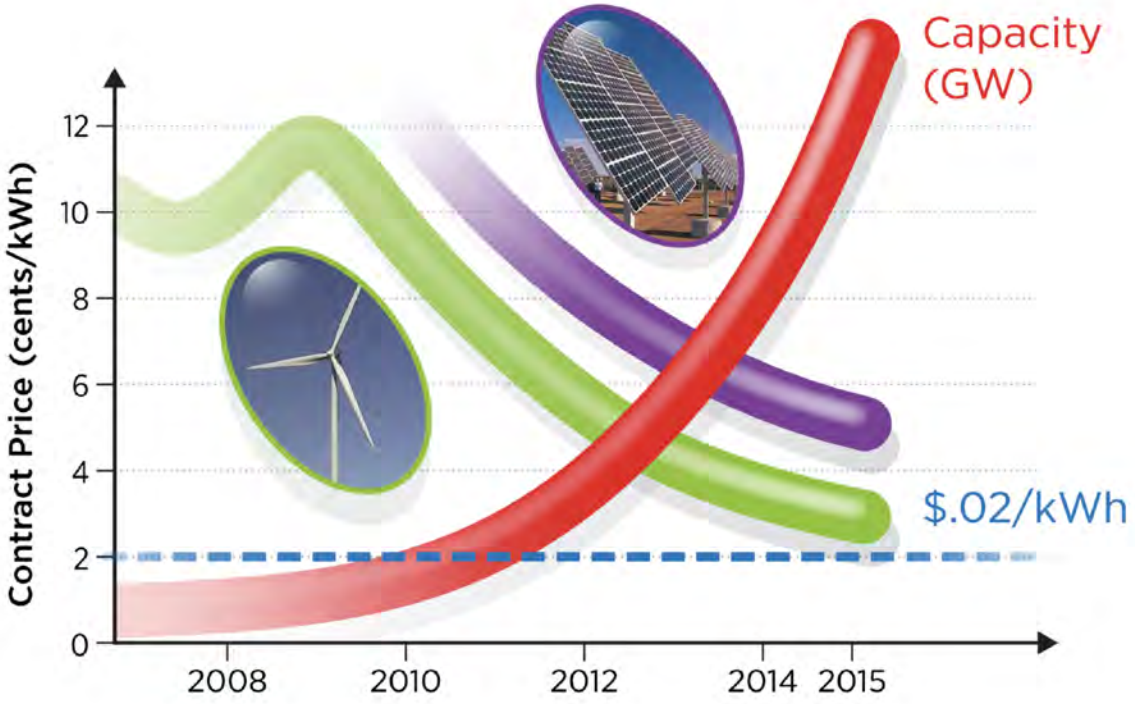


Hydrogen Data Center Grand Challenge

- What IF … hydrogen was available like natural gas?
- Rethink the power delivery to and power distribution within data centers.
- We are developing a proof-of-concept “hydrogen-based” carbon-free data center utilizing renewable energy sources, electrolyzers, hydrogen storage, and hydrogen fuel cells as key building blocks.

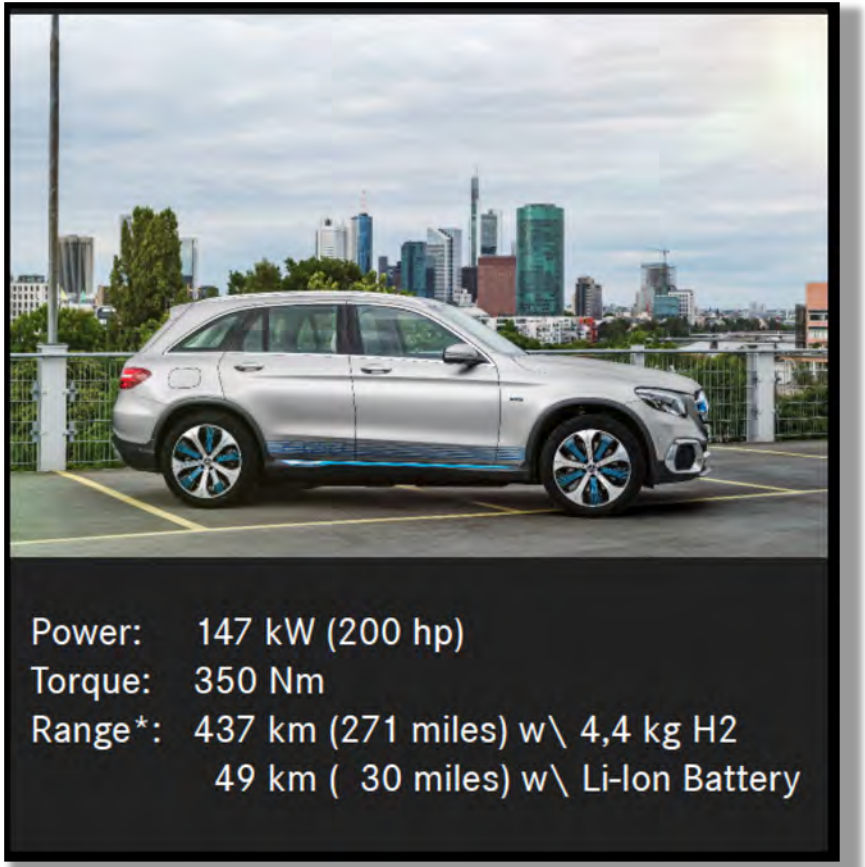
Carbon-Free Electricity Prices

Future Energy Systems are Emerging



Source: (Arun Majumdar) 1. DOE EERE Sunshot Q1'15 Report, 2. DOE EERE Wind Report, 2015

Automotive Fuel Cells & Data Centers



Mercedes Benz GLC F-CELL (IAA Sept 2017)

H2 Fuel Cell Backup Power:

- Robust and modular system, 65kW building block.
- Leverage volume production of automotive industry, e.g. GLC F-Cell available 2020.
- Polymer Electrolyte Membrane (PEM) fuel cell process allows **fast dynamic response** (smaller UPS).
- Low temperature for **long life**.
- **Silent** operation, **zero** local **emissions** (no CO_2)
- **Grid Services**: Depending on utility rates, could use for load shedding, demand response, and resilience.

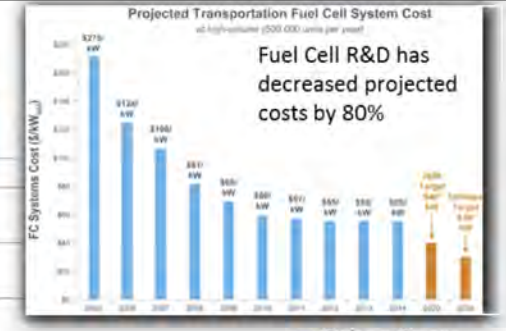
Why Hydrogen?

- Hydrogen is already a critical industrial feedstock.
- Annual U.S. production exceeds 10 million metric tons per year.
- This has an energy equivalent greater than 1% of all U.S. energy use and roughly 1/6th of global
- Primary use is for oil refining and ammonia production (fertilizer).

- 1kg of H_2 is sufficient for a car to drive 100km or 12 hours of electricity for an average U.S. home, assuming 50% efficient fuel cell.
- H_2 has advantages over current battery technology for many applications (seasonal energy storage, heavy-duty long haul transportation, and industrial processes).
- In H_2 based systems, the energy carrier (H_2) is distinct from the energy conversion (fuel cell) offering advantages in refueling rate, footprint, and geographic distribution.

Source: Pivovar, Rustagi, and Satyapal, "Hydrogen at Scale Key to a Clean, Economic, and Sustainable Energy System," Electrochemical Society, 2018.

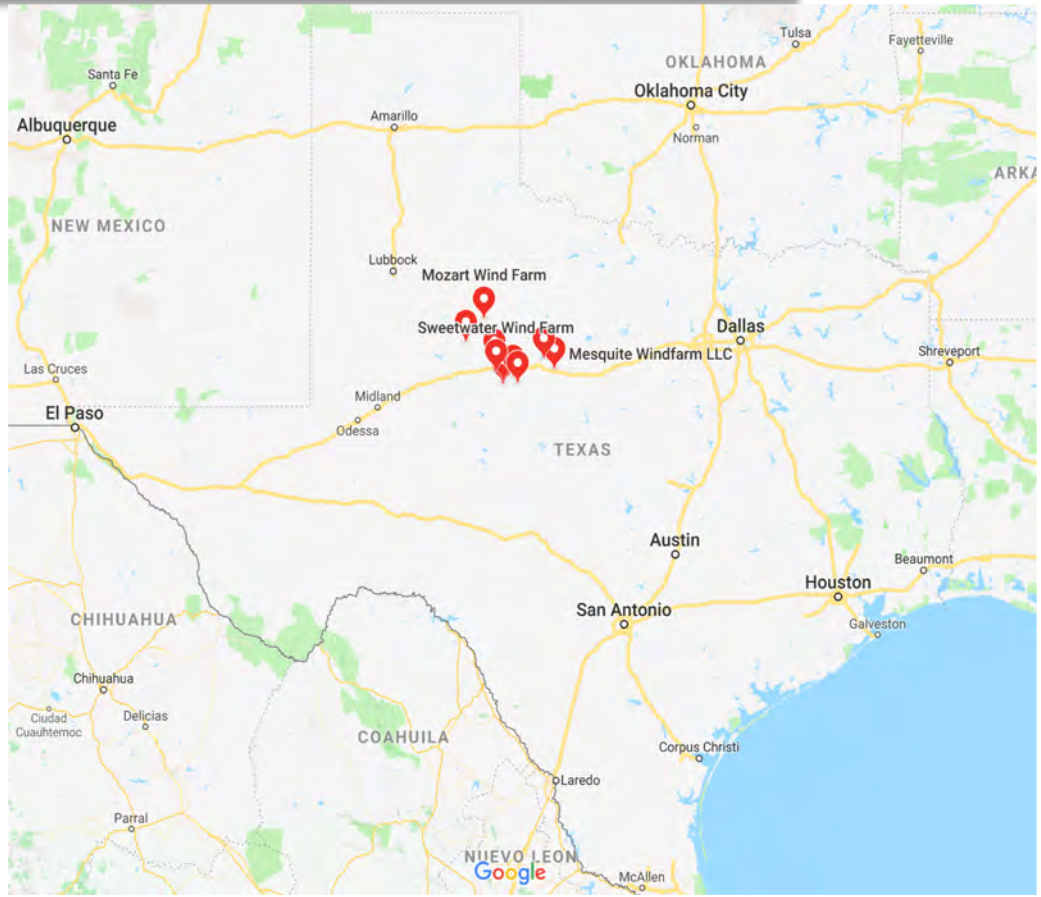
Improving Economics of Renewable H2



Source: Pivovar, Rustagi, and Satyapal, "Hydrogen at Scale Key to a Clean, Economic, and Sustainable Energy System," Electrochemical Society, 2018.

Hydrogen Pipeline

- There are about 1600 miles of H2 pipeline in the U.S.
- Five of the worlds largest wind farms are situated in central Texas*
- This is ~400 miles from approx. 1200 miles of hydrogen pipeline along the US Gulf of Mexico coastline.

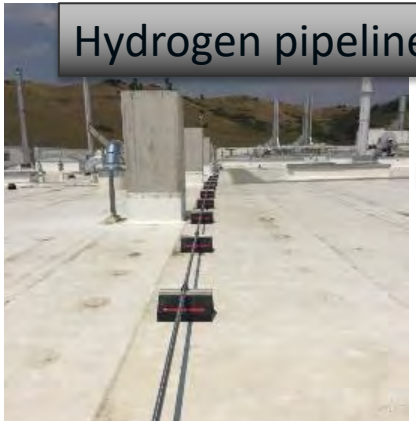


Source: http://www.power-technology.com/features/feature-biggest-wind-farms-in-the-world-texas/.

NREL's Unique Role

- At NREL, we have PV, electrolyzers, H_2 storage yard, the data center, and H_2 technical expertise.
- Establish codes and standards necessary to safely use H_2 in a data center.
- Support industry partner interest in H2FC for data center & other stationary applications (backup power, grid services, defense, resilience, disaster recovery, remote villages, etc.)
- Identify additional H_2 applications to accelerate FC to scale faster
- Techno-economic Analysis: Determine trade-offs for large scale 100% renewable hydrogen systems
  - Realistic capacity factors, storage, cost, etc.
  - Understand cross-over point for batteries vs. FC as f(MW)
- Demonstrate H_2 in use in highly visible HPC at NREL to further promote the flexibility/resiliency of hydrogen to a broad audience of visitors.

100% Renewables, H2 Fuel Cell Data Center Proof-of-Concept at NREL

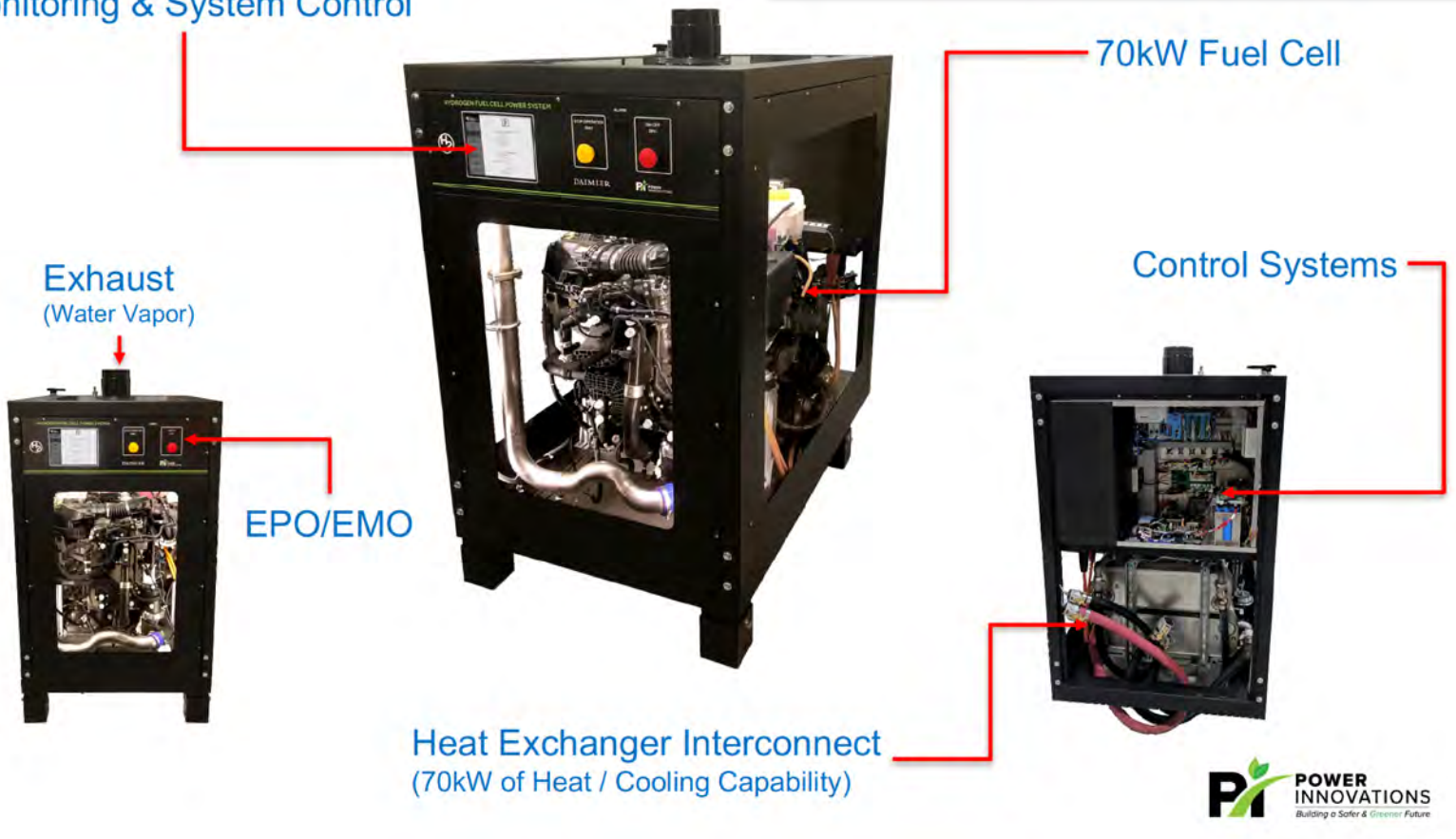


Proof-of-concept of the integrated system for verification of safe operation in data center

- Status: Integrated FC IT rack at NREL's Energy Systems Integration Lab; completing safe operation verification.
- Operation of production version of FC in data center planned in 2019.

Photos from NREL (top row) and Power Innovations (bottom)

Fuel Cell System Components



H2 Fuel Cell Data Center Proof-of-Concept at NREL

Planned Fuel Cell Demonstration:

- Provide continuous H_2 to fuel cell.
- FC provides 380V DC to 2 IT racks.
- Demonstrate load following for variety of typical workloads.
- Capture 65C waste heat from H_2 fuel cell in “CHP” approach.
- Possible Future H_2 Data Center
  - Short runs of DC
  - N+1 FC redundancy
  - Eliminate UPS & backup generator

FC & IT racks
in NREL data center

Safety is Paramount

- Data Center roof vent stack and fan unit keep fuel cell enclosure under slight negative pressure.
- Fuel cell enclosure has sensors to detect concentrations of H_2.
- Safeguards include ability to stop H_2 flow and evacuate fuel cell enclosure.

Next Steps

- Early production H_2 fuel cell is being tested.
- Plan to operate fuel cell in NREL data center this spring.
- Completing technical-economic analysis, multiple scenarios
  1. Replace diesel generators with H_2 fuel cell backup generators.
  2. Off grid with renewable power + H_2 storage.
  3. Siting on H_2 pipeline.
- Develop specifications and requirements for stationary data center fuel cell, rather than retrofitting automotive Fuel Cell.
- Consider larger-scale demonstration.

Breakouts: Required & Desired Characteristics

Purpose-built stationary fuel cell requirements:

- Life expectancy, 40K Hours?
- Primary vs backup power?
- “Optimal” building block size?
- Serviceability
- Response time 1s, 10s, ?
- Thermal management
  - Combined heat and power
  - Waste heat capture

Data Center needs:

- H2 source (on prem?)
- SCADA, Sensors and Safety
- Where is it best to provide resilience (N+1 at the row?)
- On site generation?
- Storage?
- For “backup” solution, how many MW hours of storage needed?
- IT load characteristics.


NREL
NATIONAL RENEWABLE ENERGY LABORATORY
For 40 years, NREL has delivered innovation impact enabling the emergence of the U.S. clean energy industry.
Many thanks to our colleagues at Daimler, HPE, PI!
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