NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Radical Re-Envisioning of Data Centers with Row-Integrated Fuel Cells

November 7, 2019

Fuel Cell Seminar, Long Beach, California

G. Saur[1], S. Hammond[1], J. Kurtz[1](Presenter), T. Cader[2], D. Thoss[3], S. Ecker[3], R. L. Mount[4], R. S. Mount[4], C. Skidmore[4]

[1] National Renewable Energy Laboratory
[2] Hewlett Packard Enterprise
[3] Daimler AG
[4] Power Innovations

Connecting Renewables & Data Centers at NREL

Renewables

Renewable electricity (direct and region specific simulation)

Production

Hydrogen production via electrolysis in grid connect, grid service, and direct renewable operation modes

Storage

Gaseous storage >300 kg

Distribution

Hydrogen pipeline traverses ESIF from north end (hydrogen production, compression, and storage) to data center

Data Center

Fully integrated and operational (~May 2019)

Partner-Driven Proof of Concept

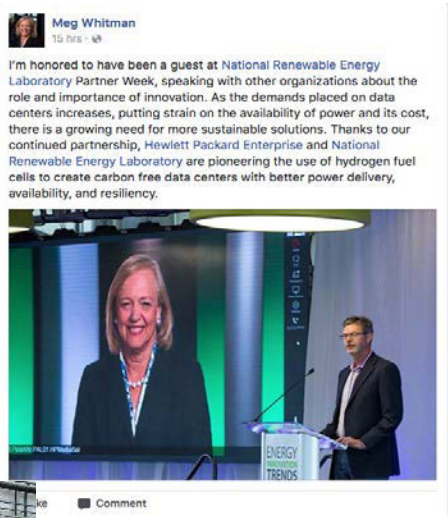
Long-Term Vision Research

Industry Partners & NREL

- System concepts, scenarios, economics
- Integrated FC/IT rack proof-of-concept

Industry Partners

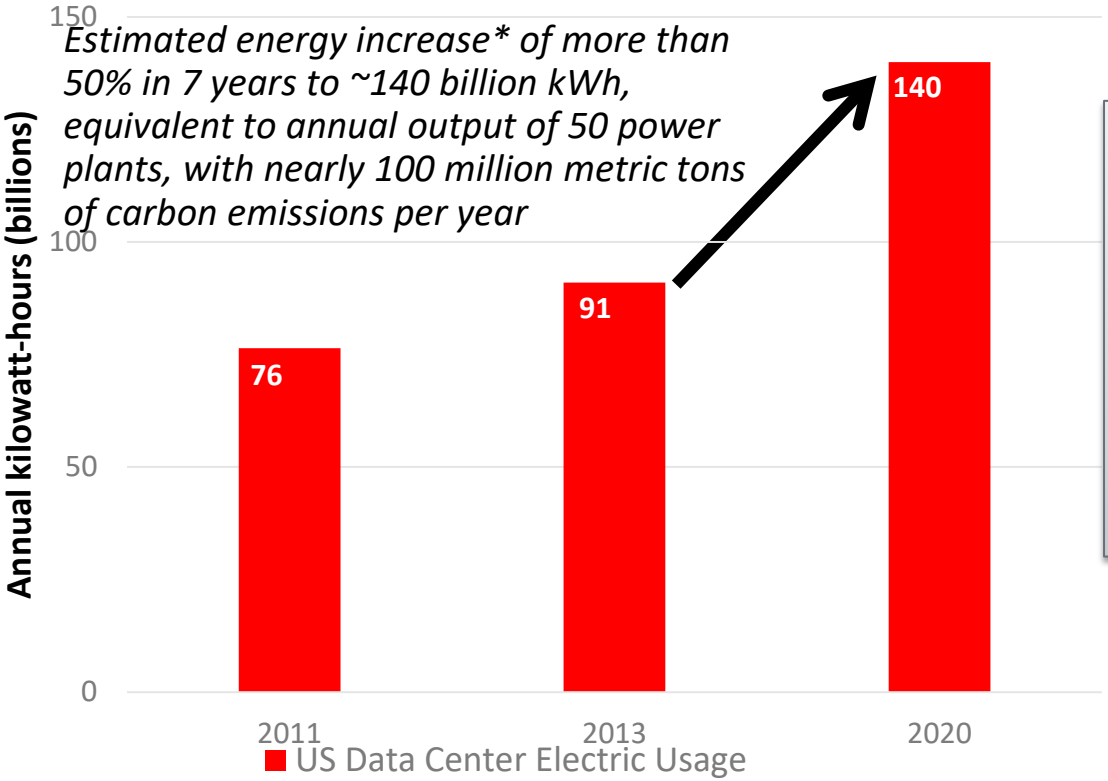
- Business plan, customers, & products



- **HPE**
- **Daimler**
- **Power Innovations**
- **NREL**

Data Center Energy Challenge –

High costs in power infrastructure, inefficiencies, and backup power required

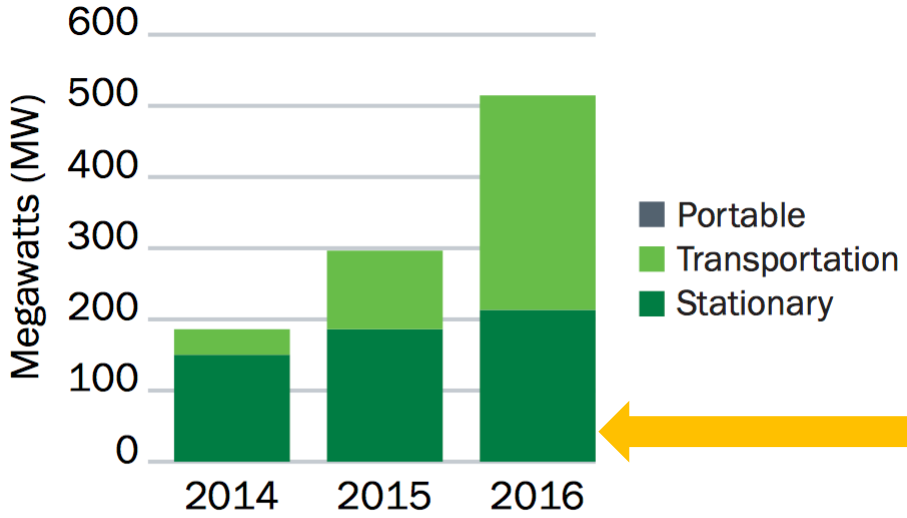


Data center electricity use would be 3.5% of total U.S. electricity use in 2020 according to projections.

Annual Energy Outlook 2019
Table: Electricity Supply, Disposition, Prices, and Emissions
Case: Reference case

* http://www.nrdc.org/energy/data-center-efficiency-assessment.asp

Carbon-Free Data Center Scale Comparison – Megawatts Shipped



Just one large data center is ~25% of worldwide stationary shipments (MW) in 2016

Figure 2: Megawatts of Fuel Cells Shipped Worldwide by Application
Source: U.S. Department of Energy
Fuel Cell Technologies Office, E4 Tech

https://energy.gov/sites/prod/files/2017/10/f37/fcto_2016_market_report.pdf

Carbon-Free Data Center Vision

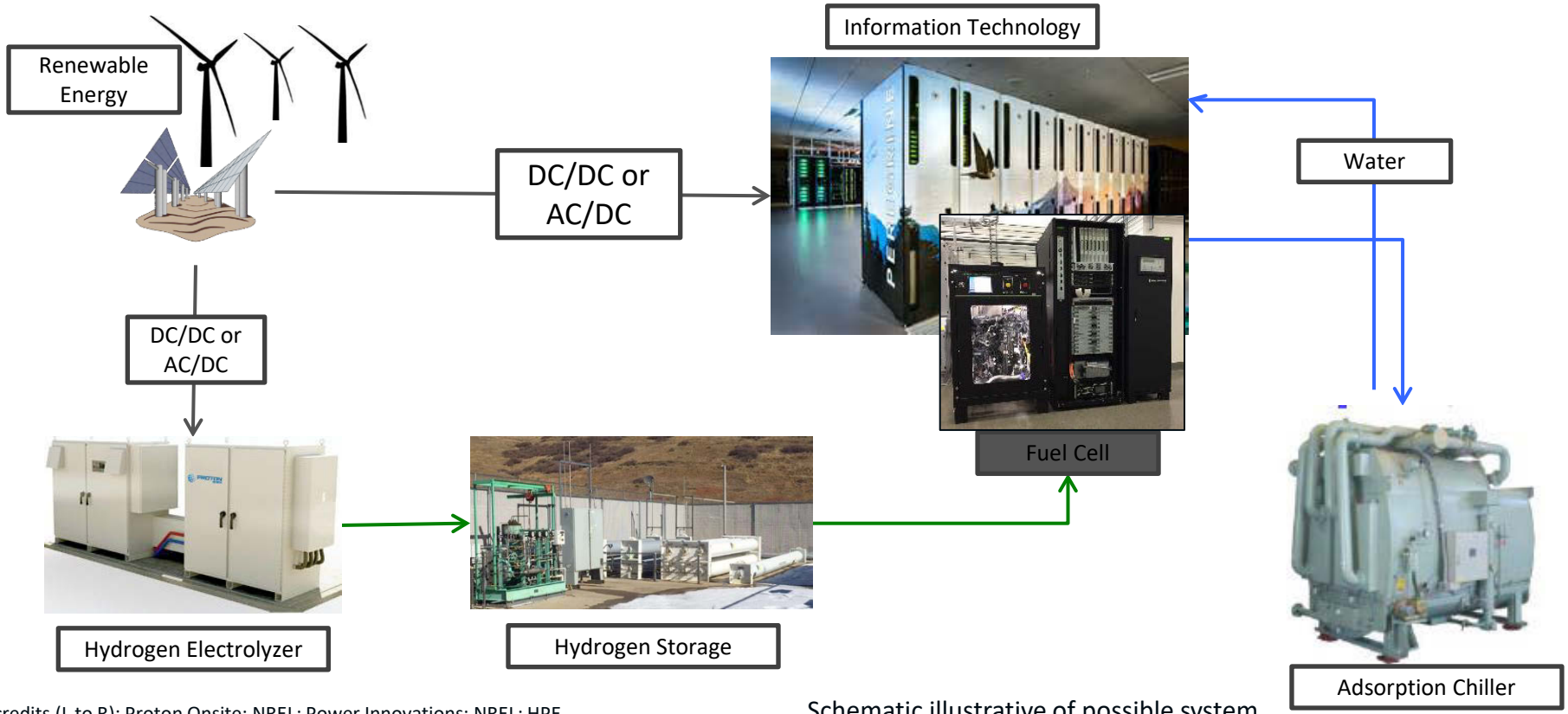
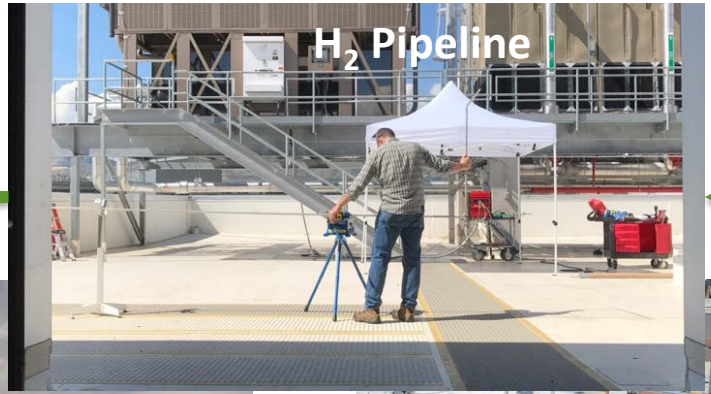
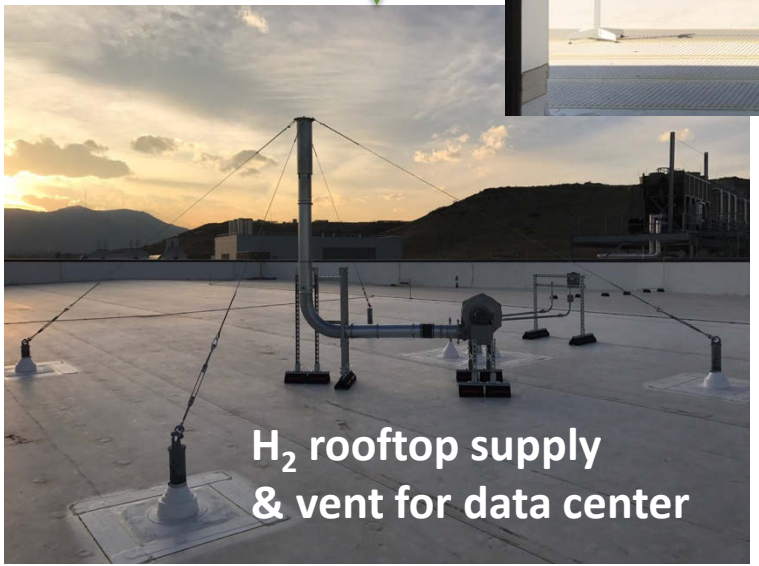


Photo credits (L to R): Proton Onsite; NREL; Power Innovations; NREL; HPE

Schematic illustrative of possible system

Pipeline Connecting Hydrogen and the Data Center





Hydrogen in NREL's Data Center

Advantages

- **Potential to lower up-front capital costs**
  - *Eliminate traditional power distribution and conversion*
  - *Negate need for back-up generators and traditional UPS*
  - *Reduce expensive copper wiring*
- **Reduce and re-use thermal load**
  - *Reduce power electronic heat loads*
  - *PEM FC connected to water loop*

FC System Components

Monitoring & System Control

70kW Fuel Cell *

*250 kW system in development at Power Innovations

Exhaust
(Water Vapor)

EPO/EMO

Control Systems

Heat Exchanger Interconnect
(70kW of Heat / Cooling Capability)

POWER INNOVATIONS
Building a Safer & Greener Future

Demonstration Results and Lessons Learned

System shake-out and testing began May 2019

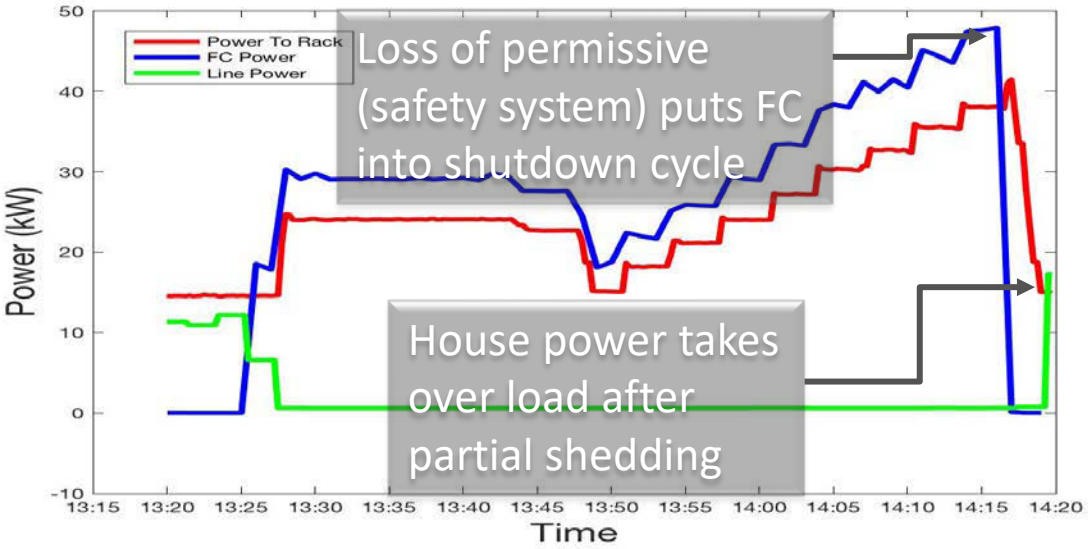
Test Matrix

- Performance data of the system in different situations
- Range of back-up and primary power scenarios
- Demonstrate automotive fuel cell in stationary application

Test name	Test Time (hr)
High power	6
Transient	6
Low power	4
Ramp (Results follow)	*2*
Start/stop	6
Soak Test I - Weekend	5
Soak Test II - 2 week	5
Endurance Test I - Low Power	18
Endurance Test II - High Power	18

Lessons Learned 1

Wireless safety system not likely solution going forward; wired systems more reliable

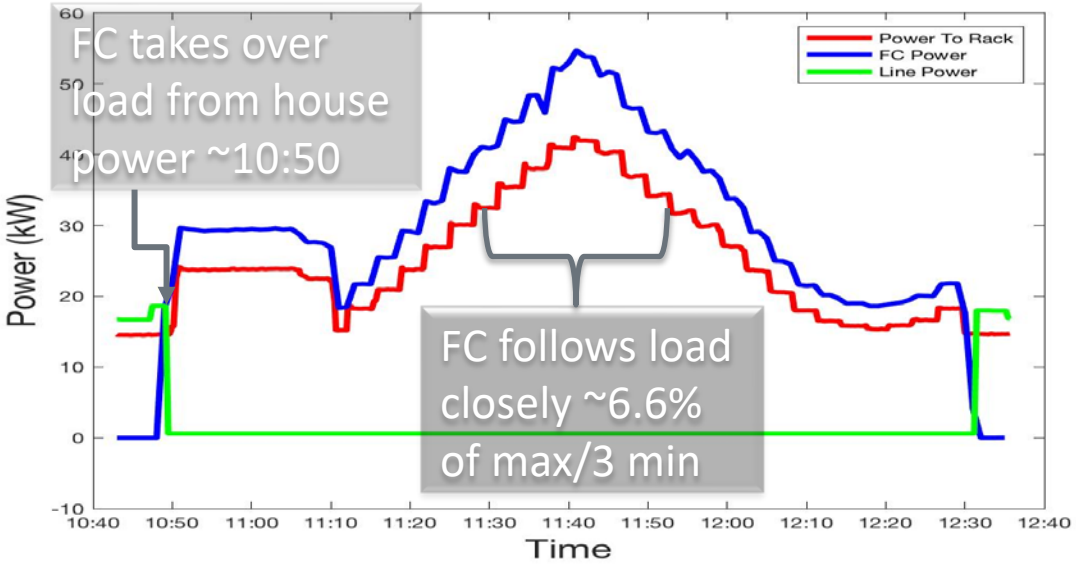


- Unexpected loss of permission to run fuel cell
  - System handled unexpected scenario well
  - Battery took over as load was shed
  - House power (future: redundant fuel cell) took over load
- Wireless remote watchdog causing problems
  - RF interference in data center causing wireless systems to intermittently time-out
  - Moved antenna outside; resolved for now

Lessons Learned 2

Successful Ramp Test

- Next up: Shake-out of other test protocols



- Fuel cell provides power for system
  - IT rack, battery, auxiliary equipment
- PEM fuel cell can ramp closely to load
  - Allow smaller battery subsystems than typical UPS
- IT load maintained 10 kW–40 kW for duration of test
  - System switched seamlessly between house line power and FC system with no impact to load on IT rack
  - Load ramped ~6.6% of max every 3 min

Main takeaways:

- The first steps to scale-up to large data centers (20 MW+, 24/7 operation), while a challenge, are currently being tested
- Safety systems need to provide branch isolation and failure management for paralleled fuel cell systems

Exhaust vent now insulated to reduce condensation/water back flow problem; alternate condensate systems installed*

Two demonstrations being tested, a 70-kW system at NREL and a 250-kW system at Power Innovations.

- Testing and shake-out providing valuable data
- Systems have been safe even in unexpected events
- Learning new ways to improve system dynamics and support systems

* Water recovery can be an important consideration. Future improvement could be separating the negative safety pressure fan from the water exhaust.

Benefits of Fuel Cell-Powered Data Center

- Savings from grid independent operation
  - On-site generation with behind the meter electricity price
  - Avoid demand charges
  - FC electric power directly used by computer for low power usage effectiveness (PUE)
  - Stable load and controlled environment favor higher fuel cell efficiency and longer servicer life.
- Energy savings:
  - Overall efficiency with heat recovery to drive chiller for building heating and equipment cooling needs
  - Data center of low cost and small footprint by FC racks
  - No H_2 distribution cost needed as H_2 is consumed locally
- Increase fuel cell production and accelerate its deployment.

Summary

Holistic Vision

- Conceptual models for size, performance, and economic estimates
- Economically viable near-term option includes natural gas
- Lowest up-front costs may not be lowest total cost of ownership options

Product Acceleration

- Verify proof-of-concept in a functional data center
- Identify codes and standards for hydrogen fuel cells in data centers
- Automotive fuel cell in a new application => increase quantity and decrease cost
- Partners include product developers and end users

What's Next

- Identify systematic solutions for challenges
- Refine and define system
- Improve estimates
- Validate system and install at scale
- Will continue to work closely with DOE in detailing improvements for stationary H2 FC for data centers.

With the sustained drop of the cost for renewable power, long-term renewable hydrogen to supply fuel cells for powering a data center can realize both decarbonization and economic returns.

Acknowledgements also to the following for support of the project:
K. Regimbal,[1] D. Sickinger,[1] R. Fraley,[1] O. Smith,[1] M. Mann,[1] M. Ruple,[1] S. Gilleon,[1] J. Izquierdo,[2] J. Ladra,[3] P. Muench,[3] D. Papageorgopoulos,[4] N. Stetson[4]

[1] National Renewable Energy Laboratory
[2] Hewlett Packard Enterprise
[3] Daimler AG
[4] U.S. Department of Energy

Thank You

www.nrel.gov

NREL/PR-5400-75401

NREL
Transforming ENERGY