



Hydrogen and Fuel Cells for Data Center Applications: Workshop Findings

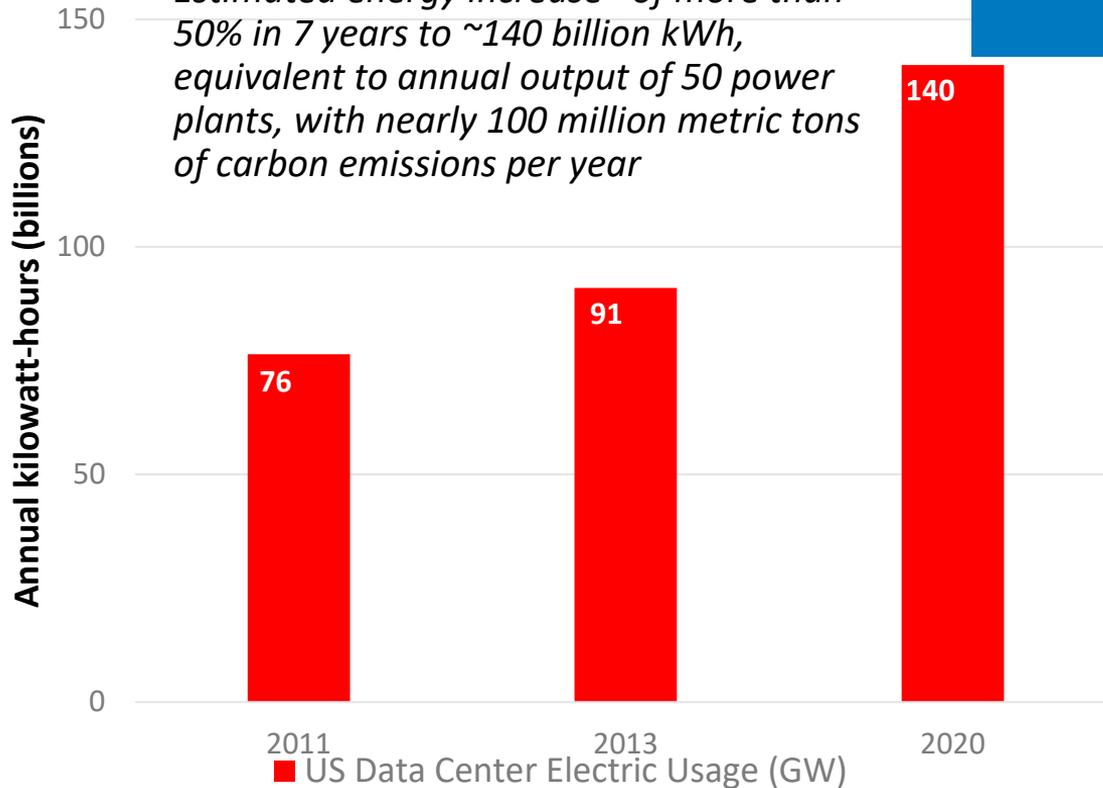
Genevieve Saur
National Renewable Energy Laboratory

DOE FEMP's Better Buildings Data Center Challenge and Accelerator
webinar

January 21, 2020

Estimated Electricity Use

Estimated energy increase of more than 50% in 7 years to ~140 billion kWh, equivalent to annual output of 50 power plants, with nearly 100 million metric tons of carbon emissions per year*



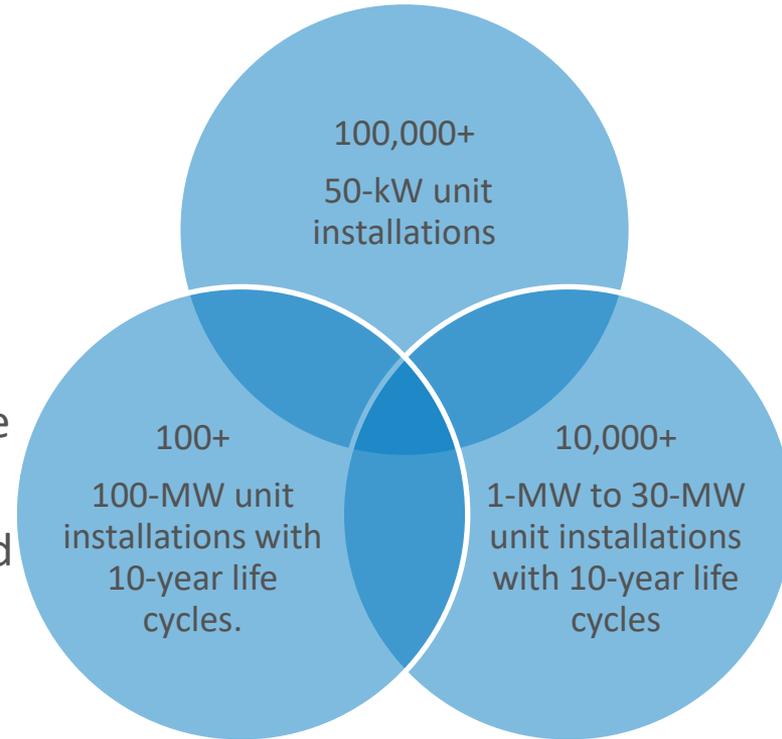
Data center electricity use would be 3.5% of total U.S. electricity use in 2020 according to projections.

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

Types of Data Centers

- **High performance computing**—High-speed computing-intensive application
- **Hyperscale, single customer**—Single company’s business needs. Hyperscale, single customer data centers are modularly designed to allow for the seamless increase of computing capacity. Sizes range from 100 kW to 100 MW.
- **Hyperscale, co-location**—Scaled appropriately based on the individual needs of multiple customers that contract from a third-party data center company.
- **Point of presence servers/mini data centers/micro data centers**—This design is smaller (50 kW to 2 MW).

Number of sites for size range



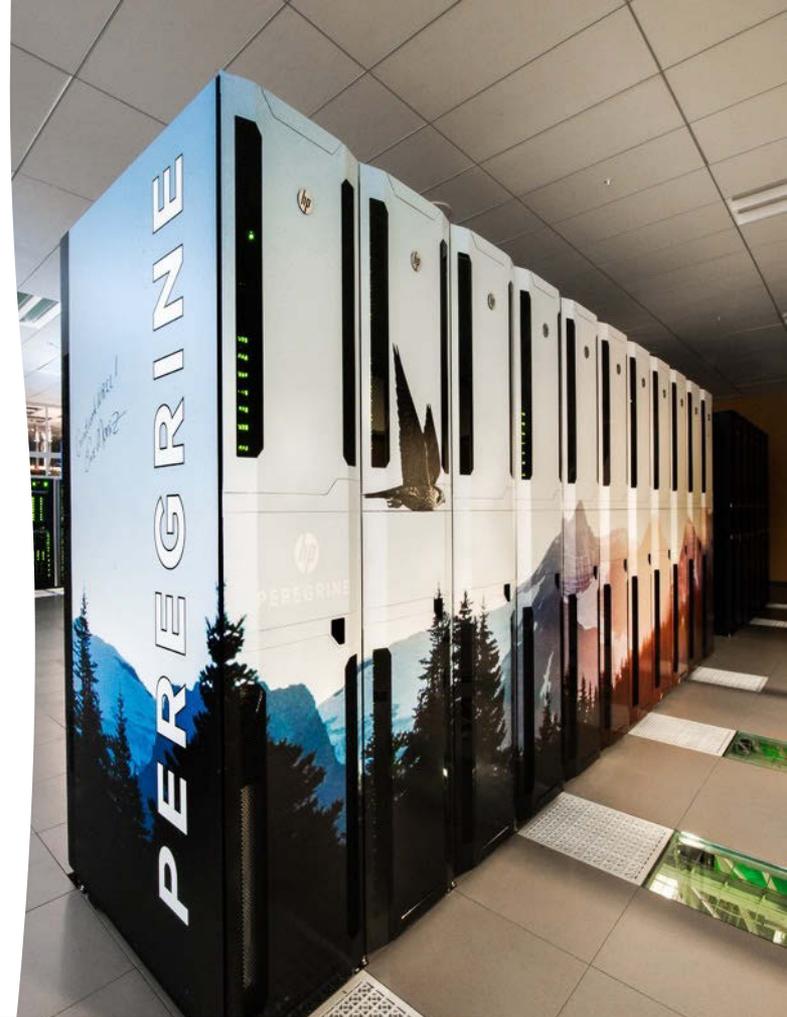
Power Scenarios

	Thermal Integration	Frequency of Use	Incumbent Technology
Prime	Y	24/7/365	Grid + Diesel/battery backup
Backup	N	~ 100 hrs/yr	Diesel/battery backup
Backup + Grid	N	6 weeks of services + 100 hrs/yr	Grid + Diesel/battery backup

- **Prime**—A large capacity fuel cell outside or smaller fuel cells integrated at the rack/row level inside the data center to meet the critical loads with optional thermal integration.
- **Backup**—Either a larger capacity fuel cell or distributed fuel cells used as backup and sized to meet the critical loads of the center.
- **Backup/Prime + Grid Services** - Services could include peak shaving, frequency regulation, and increased demand response.

Integration Considerations

- ❑ Footprint and electrical infrastructure
 - Estimated 40% of the building footprint is electrical infrastructure
 - Multiple points of power conversions from the outside to IT racks
 - Each rack can be powered by up to four *copper*-based electrical cables that are several inches in diameter
 - Redundancy achieved using duplicate electrical infrastructure
 - AC power distributions more standardized options for IT racks and auxiliary data center systems
- ❑ Thermal systems
 - Higher quality heat might provide cooling through an adsorption chiller or other thermal systems like humidity control
 - Greater total efficiency



Scenario Thoughts - Backup

Advantages

- Complete redesign of data center not necessary*
- Option if diesel cannot be permitted
- Fuel cells can offer robust durability and fast startup times

Hurdles

- Upfront capital cost (FC, H2 storage, and H2 supply) likely more expensive than diesel
- Is regional hydrogen supply adequate for anticipated need?

- ## Grid support offers opportunity for improving the economics and leveling hydrogen supply requirements.

* If fuel cells used as direct replacement of diesel generators



Scenario Thoughts – Large Prime

- ❑ Advantages
 - Thermal integration possible for both high- and low-temperature fuel cells
 - Redesign of electrical infrastructure not required
 - Potential for grid independence
 - Some UPS backup may be eliminated
- ❑ Hurdles
 - Relative price of natural gas/hydrogen to electricity
 - How are combined heat and power options incorporated
 - Design of redundancy and backup
- ❑ Grid support opportunity
 - Maintenance of grid connection would need to be investigated

Information collected from workshop participants and represents their views and opinions.



Scenario Thoughts – Distributed* Prime

Advantages

- Elimination of significant power electronics inside data center for stainless steel H₂ pipelines and exhaust vents
- Elimination of significant thermal load
- Switch to DC power could improve metrics like power usage effectiveness (PUE)
- Can be integrated with liquid cooled IT racks
- Built in redundancy with design

Hurdles

- Radical redesign of data center power
- Options for standardized DC powered IT racks and equipment are limited
- Technicians required specialized training for work with DC power

Elimination of grid connection

* Distributed design
also compatible with
backup power

Shifting to DC Power

- ❑ Potential advantages
 - Fuel cells output DC power
 - Could simplify power electronics infrastructure
 - Could decrease thermal loads
- ❑ Hurdles
 - DC power options for IT equipment are scarce and not standardized
 - Technician training required for working with DC power



Onsite Storage and Flow Rates

	Power Range	Module Size	For Specified Module Size			
			Onsite Storage 48-72 hrs (H ₂)	Annual H ₂ - Prime (50% LF)	Annual H ₂ - Backup (50% LF)	H ₂ Flow Rate at module peak power
Hyperscale Computing	100 kW - 100 MW	20 MW	60-90 tonne H ₂	5,500 tonne H ₂ /y	100 tonne H ₂ /y	15,000 nm ³ H ₂ /h
Micro datacenter	50 kW - 2 MW	100 kW	300-450 kg H ₂	27 tonne H ₂ /y	0.3 tonne H ₂ /y	38 nm ³ H ₂ /h

Estimated to demonstrate the scales required for onsite storage and flow rates.

Onsite Hydrogen Storage Requirements

❑ Factors

- Capacity of 2-3 days of backup
- Footprint considerations
- Cost considerations
- Trade-offs between size of storage and frequency of delivery

❑ Bulk Storage options

- Gaseous tank storage - Cost and footprint considerations. More appropriate for backup power.
- Cryogenic tanks – for >500 kg of hydrogen. Cost and boil-off considerations. More appropriate for prime power.
- Geologic cavern storage - regional option
- Other chemical carriers – R&D phase. Mechanism of release and flow rates would need evaluation.

Information collected from workshop participants and represents their views and opinions.

Hydrogen Supply

Currently the merchant market* is about 260 tonnes/day for liquid and 15,000 tonnes/day for gaseous.

The flexibility of the merchant market has tightened in recent years due to 1) new markets for FCEV's and forklifts 2) aging liquefaction equipment retiring**.

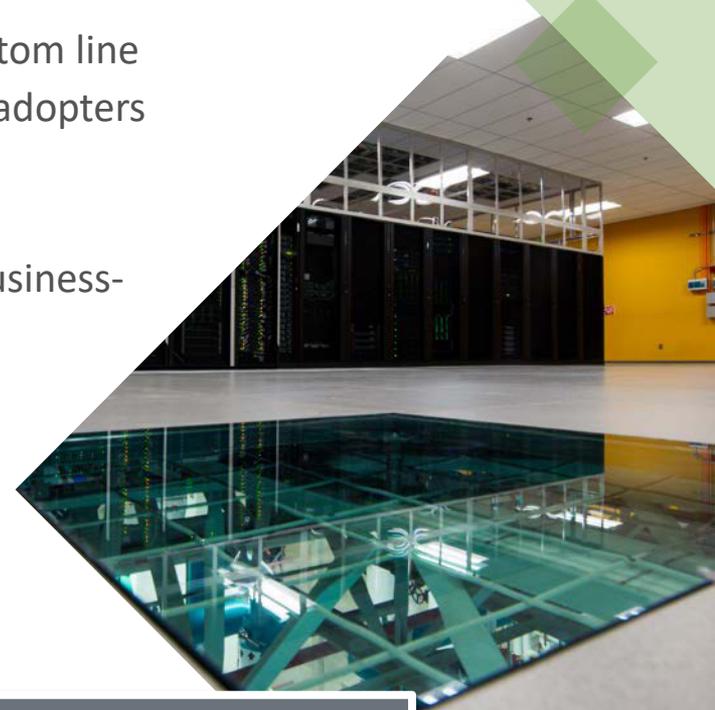
Backup Scenarios may be limited to merchant market unless scenarios or synergies with other H2 users can be realized.

*Onsite production an option for large, regular usage

**4 new liquefaction plants announced in 2018/2019.

Adoption Barriers

- ❑ Data center owner/operators
 - For-profit businesses in data, not energy
 - Conservative around technologies that may affect bottom line
 - Will look to large/established industry leaders as first adopters
- ❑ Factors in siting
 - Large space and power requirements
 - Regional conditions favorable to power, labor, land, business-friendly governments
 - Redundancy is important
- ❑ Obsolescence times (replacements/upgrades)
 - 3 years for IT equipment
 - 5 years for batteries
 - 5–10 years for power distributors
 - 30 years for generators



Information collected from workshop participants and represents their views and opinions.

Incumbent Technologies

- ❑ Prime power competes against grid electricity
 - Delivered power at 3¢/kWh (5¢/kWh for green)
 - Durability, efficiency, cost important over data center lifetime
- ❑ Backup power competes primarily against diesel generator/battery UPS
 - \$1,000/kW delivered power
 - Cost main driver, durability and efficiency not as important

BUT

- ❑ Air permitting of diesels becoming harder
- ❑ Corporate strategies to increase the use of non-carbon/green fuels



What is first step?

- ❑ Hyperscale computing application wants scalability of 20–30 MW module designs
- ❑ Testing mini data centers between 100 kW and 2 MW had wider acceptance.
- ❑ Natural gas was also seen as a potential bridge to green hydrogen
- ❑ Biggest potential benefit from most radical redesign (distributed prime power)
- ❑ Some options may not provide much/any economic benefit



Information collected from workshop participants and represents their views and opinions.

Actions Going Forward

- ❑ A techno-economic analysis of specific scenarios
- ❑ Pilot project(s) by a major industry entity where the government takes the initial risk
 - Backup power less disruptive
 - Micro data centers lower-risk options in backup or prime
 - Distributed prime many advantages but the most disruptive
 - Collaboration with Indian Tribes or underserved people
- ❑ Reliable hydrogen supply is key
 - Buildout plan leverages multiple sectors and applications
- ❑ Utility companies engaged for impacts on the grid.
- ❑ Industry panel on safety and standards for DC power
- ❑ Training programs for handling DC power equipment
- ❑ System integration R&D for balance of plant and system cohesion.
- ❑ R&D into low-cost bulk storage options is needed



Information collected from workshop participants and represents their views and opinions.

Information for this presentation from:
G. Saur, V. Arjona, A. Clutterbuck, E.
Parker. 2019. *Hydrogen and Fuel Cells
for Data Center Applications Project
Meeting: Workshop Report*. NREL/TP-
5400-75355.

Thank You

www.nrel.gov

NREL/PR-5400-75877

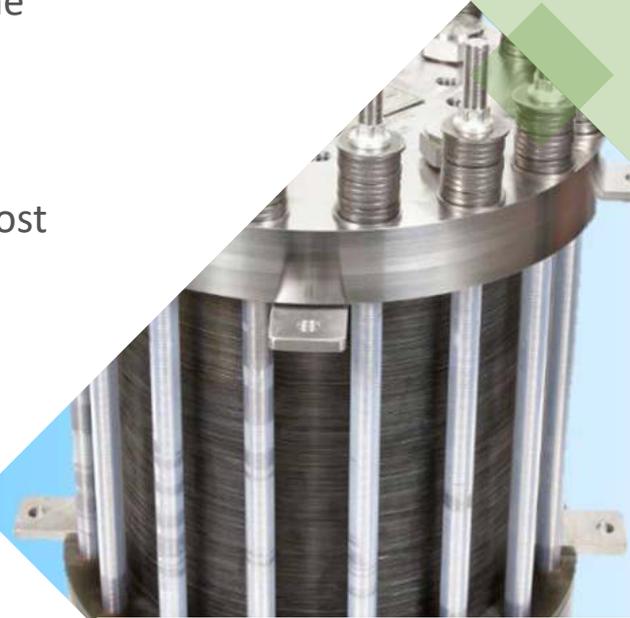
This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Fuel Cell Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.



Backup Slides

Key Considerations

- ❑ Implicit assumption in previous estimates that hydrogen is the key end-product
 - Dependent on fuel cell type used
- ❑ H2 Carrier
 - Onsite space requirements (energy density) and vessel cost
 - Onsite weight not likely an issue for this application
- ❑ Delivery requirements and considerations
 - Frequency of deliveries
 - Time for off-loading of carrier
- ❑ Process for onsite hydrogen release
 - Response time of system start-up important for backup scenarios
 - Redundancy to reduce compressed hydrogen storage
 - Thermal integration a possibility in prime power applications



Information collected from workshop participants and represents their views and opinions.

Key Challenges/Opportunities for Alternate H₂ Carriers

- ❑ Compressed hydrogen
 - Large space requirement for quantities needed
- ❑ Liquid Hydrogen
 - Not suitable for purely backup application
- ❑ Alternate H₂ Carriers
 - Competes against traditional H₂ storage *and* incumbent technologies
 - Application requires reliable supply and large quantities
 - *Green/renewably-sourced H₂ an industry priority, but fossils fuels can be part of the transition*