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The #H2IQ Hour

Today's Topic:
Caterpillar Hydrogen Fuel Cell Generator Backup System

This presentation is part of the monthly H2IQ hour to highlight hydrogen and fuel cell research, development, and demonstration (RD&D) activities including projects funded by U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office (HFTO) within the Office of Energy Efficiency and Renewable Energy (EERE).

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

HOUSEKEEPING

This webinar is being recorded.

This webinar is being recorded and will be available on the H2IQ webinar archives.

Technical Issues:

- If you experience technical issues, please check your audio settings under the “Audio” tab.
- If you continue experiencing issues, direct message the host, Kyle Hlavacek

Questions?

- There will be a Q&A session at the end of the presentation
- To submit a question, please type it into the Q&A box; **do not** add questions to the Chat

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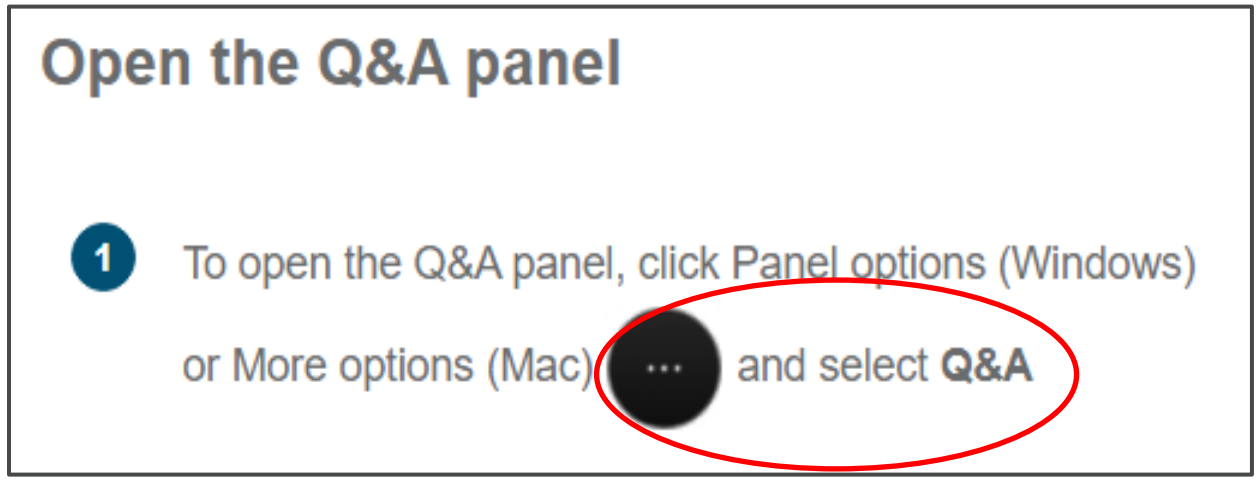
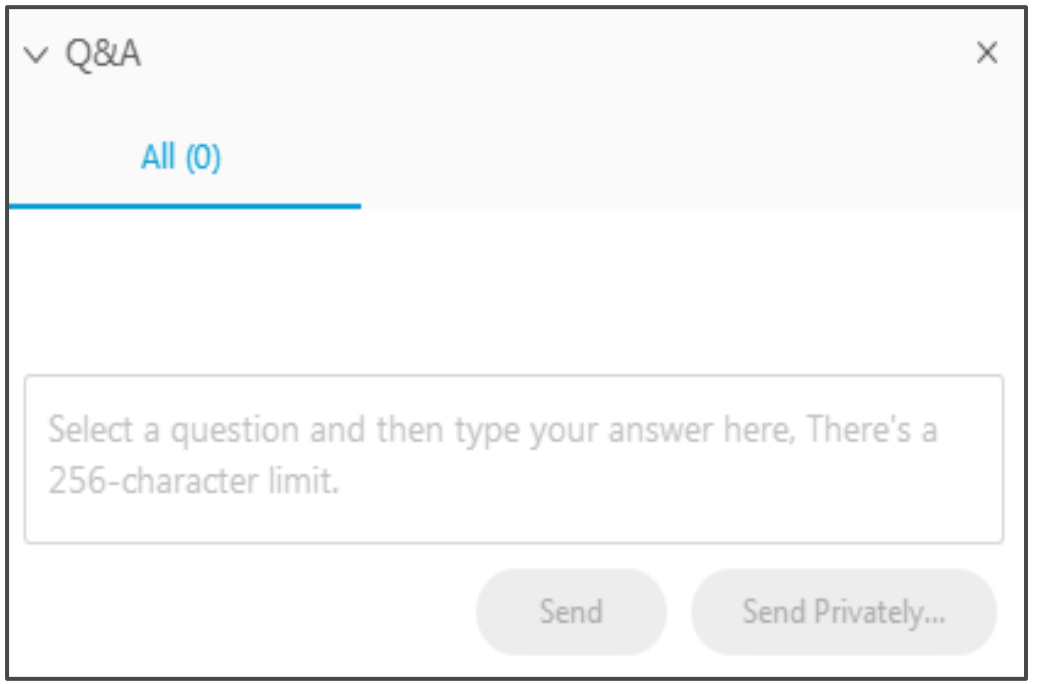
The #H2IQ Hour Q&A

Please type your questions in the Q&A Box





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Hydrogen and Fuel Cell Technologies Office
H2IQ hour webinar

February 23, 2024

DOE AWARD DE-EE009252:

SYSTEM DEMONSTRATION FOR SUPPLYING CLEAN, RELIABLE AND AFFORDABLE ELECTRIC POWER TO DATA CENTERS USING HYDROGEN FUEL

Paul Wang (PI), Ram Manda

CATERPILLAR®

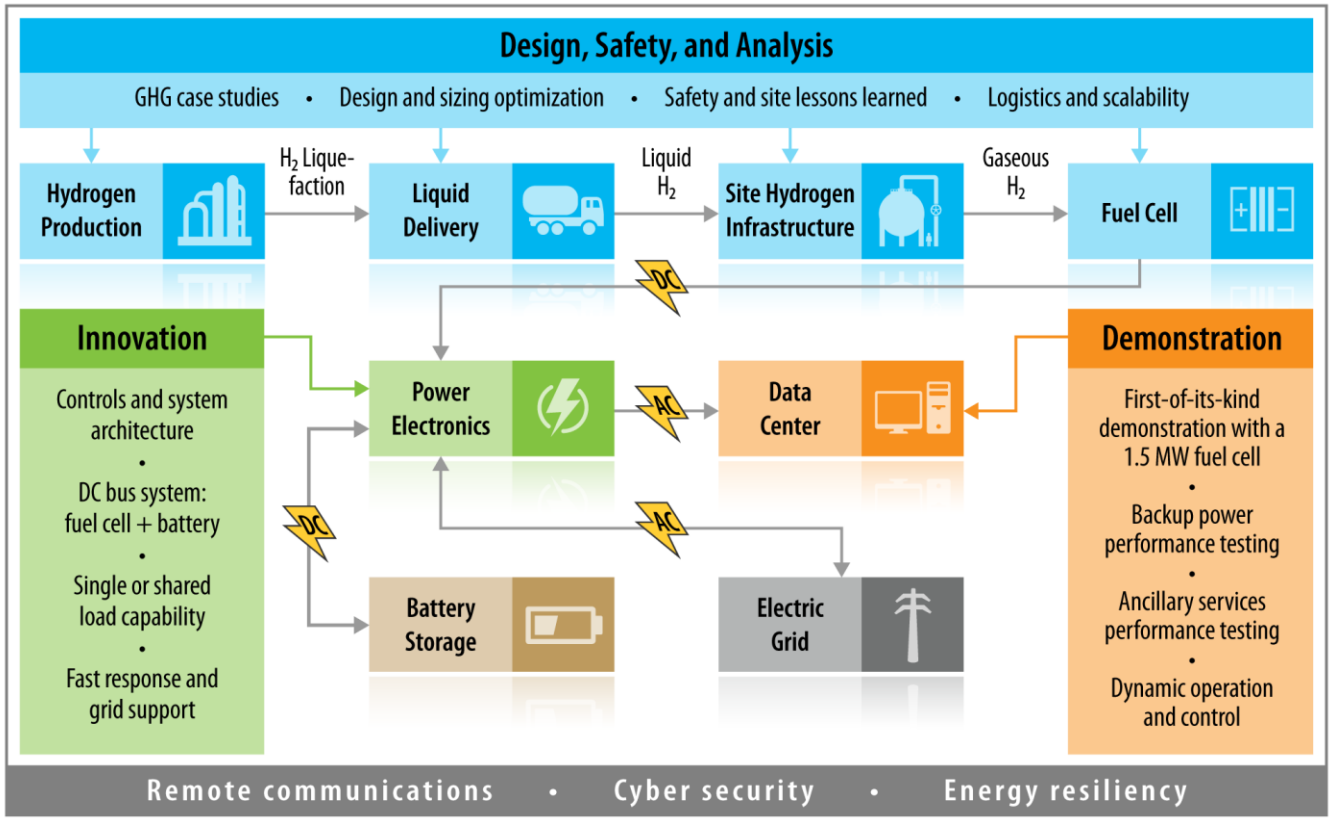
DCPEM – Data Center Proton Exchange Membrane

Can hydrogen power a data center for 48 hours?

1.5 MW fuel cell + battery microgrid

Increased resiliency, lower carbon intensity, integrated system

Project overview and background



Demonstrate 1.5 MW hydrogen fueled data center backup power (Proton Exchange Membrane Fuel Cell, PEMFC)

Total project cost: $11.9 M (Caterpillar share: $6.3 M)

Award Period: 10/01/2020* – 9/30/2024

*effective date of award, Caterpillar acknowledged award on 7/28/2021

Potential Impact and Relevance

Objective

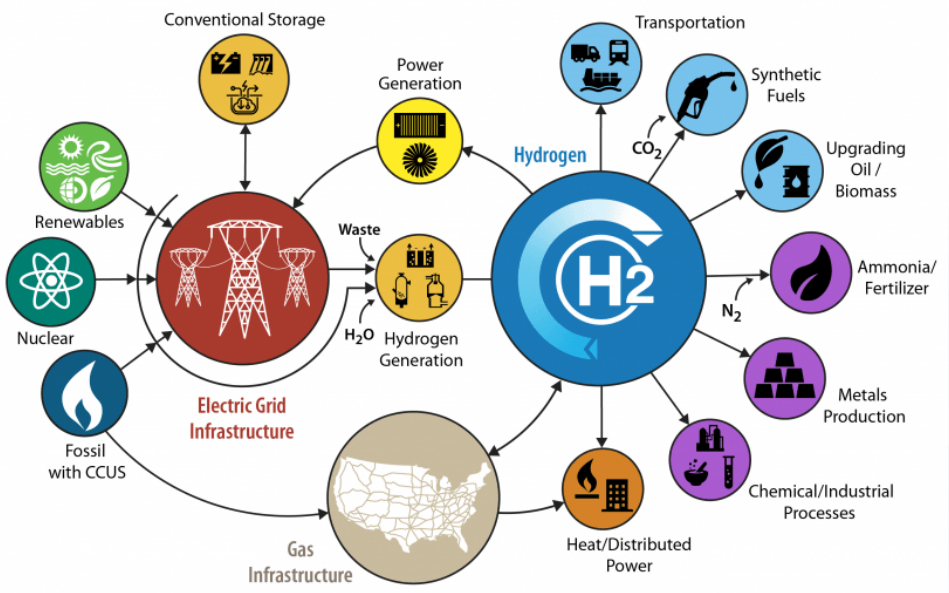
Demonstrate a *first of a kind* megawatt scale stationary fuel cell (FC) to generate electric power and meet the stand-by requirements of a modern data center

Performance targets:

- Full load rating at 1.5 MW (electrical out)
- 48 hours of liquid hydrogen storage

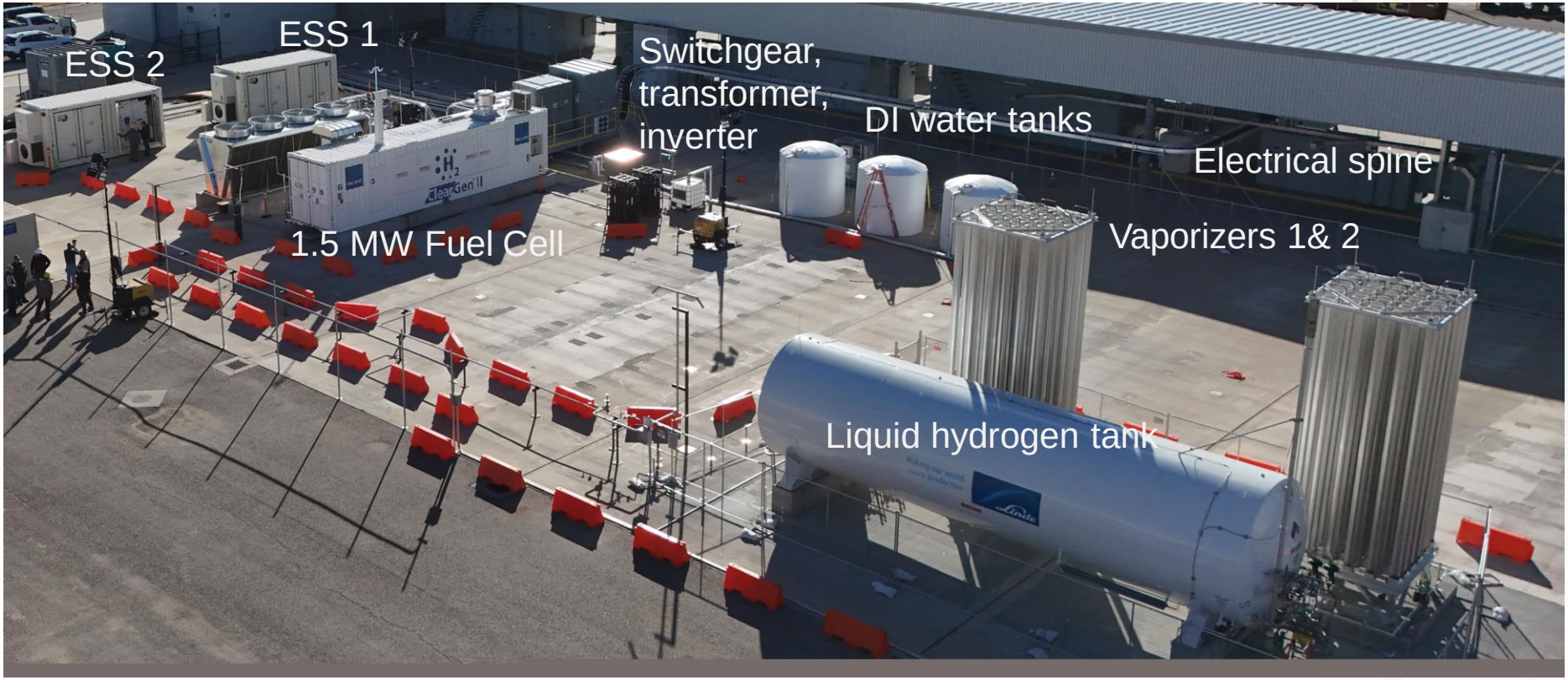
Relevant DOE goals

- System development and integration
- Commercial readiness assessment
- Reduce Greenhouse Gas (GHG) emissions
- Technology validation

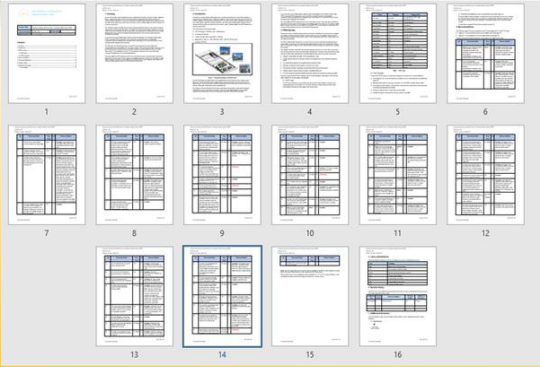


Technology Acceleration: Integrated Clean Energy Systems
Document requirements, progress and identify gaps (scaling of PEMFC, integration, technology, and sourcing)

DCPEM – first of a kind hydrogen data center demo completed!



Safety First: maintain safe worksite

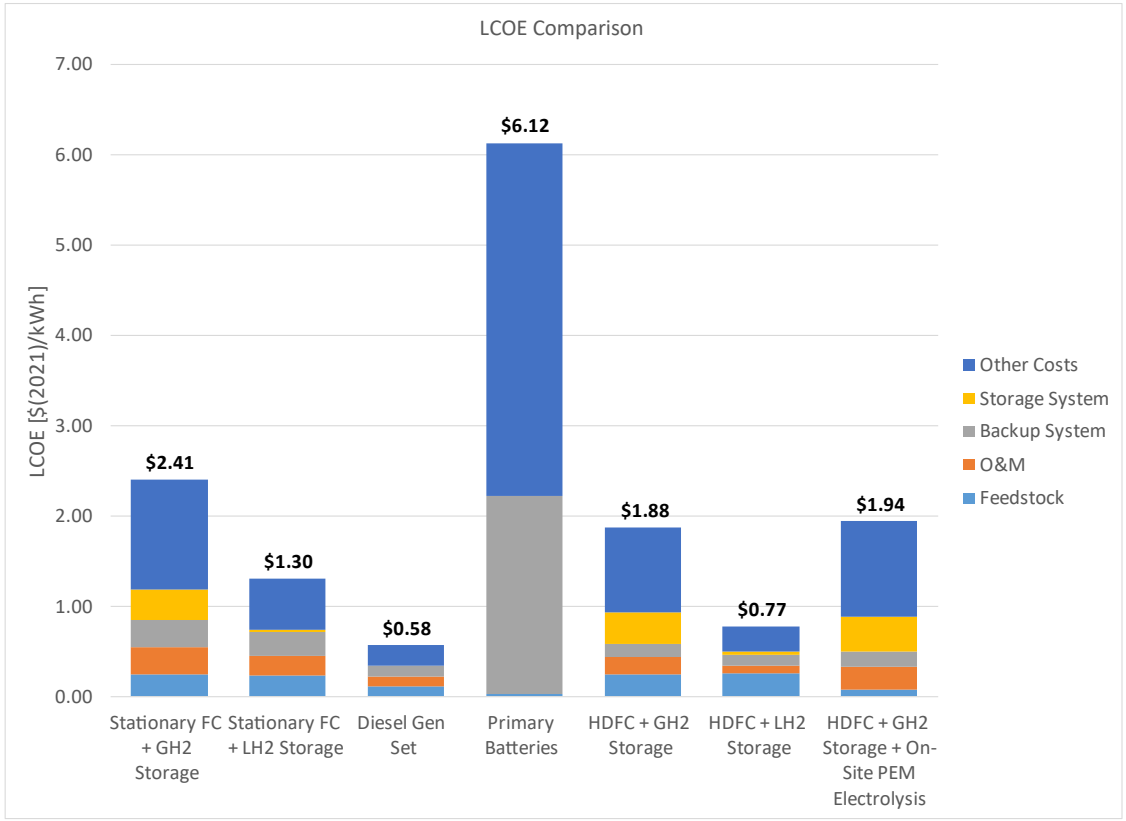


- Hydrogen Safety Plan
- Process Hazard Analysis (PHA)
- Pre-Startup Safety Review (PSSR)
- Training: in person and online
- Safe Job Procedures
- Lessons Learned

Collaboration and coordination

Participant	Role
Caterpillar Inc.	Lead responsible for overall project, requirements, system integration, controls development, installation and demonstration.
Microsoft	Host of demonstration site, data center requirements
Ballard	Supplier for 1.5 MW fuel cell. Support for installation of fuel cell at site, commissioning and tests
National Renewable Energy Laboratory (NREL)	Hydrogen safety, Technoeconomic Analyses, GHG impacts
Linde	Liquid hydrogen equipment and supply for demonstration
McKinstry	Design layout, site preparation and installation, decommissioning

Technoeconomic analysis (NREL)



Levelized Cost of Energy (LCOE, $/kWh) for various cases

Liquid hydrogen has potential to approach cost parity with diesel backup systems

Data Center Assumptions
Peak load for the data center is 1.5 MW
Data center costs were not included in the techno-economic analysis (TEA)
Backup duration is 48 hours per backup event

Seven Backup Scenario Systems

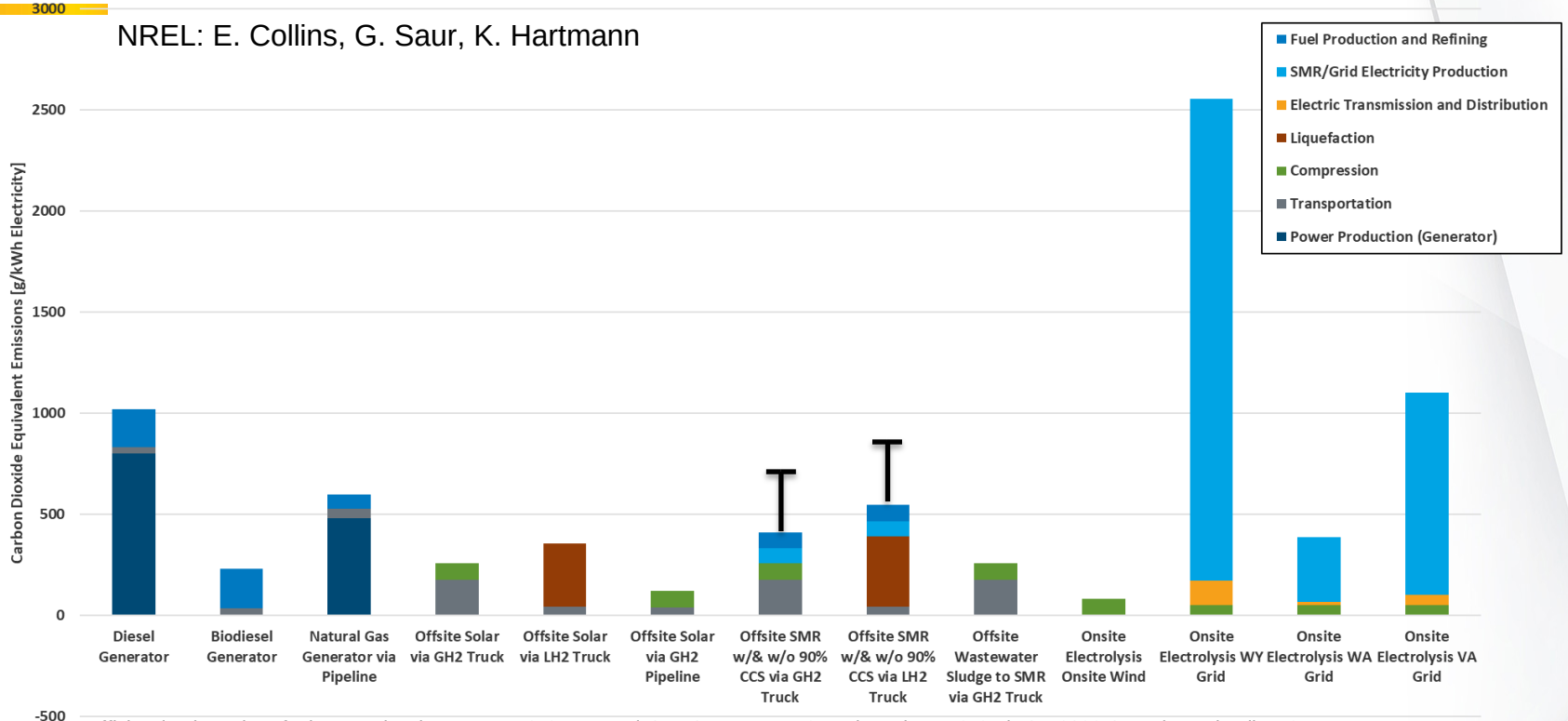
1. Stationary Gaseous Hydrogen (GH2) Storage + Stationary PEM Fuel Cell
2. Stationary Liquid Hydrogen (LH2) Storage + Stationary PEM Fuel Cell
3. Backup Diesel Generator System
4. Primary Backup Li-Ion Battery System
5. Stationary Gaseous Hydrogen (GH2) Storage + Heavy-Duty Vehicle PEM Fuel Cell
6. Stationary Liquid Hydrogen (LH2) Storage + Heavy-Duty Vehicle PEM Fuel Cell
7. On-site PEM Electrolysis for H2 Production + GH2 Storage + Heavy-Duty PEM Fuel Cell

Model

NREL's H2FAST was used for this analysis

Greenhouse Gas Emissions (GHG) Analysis

NREL: E. Collins, G. Saur, K. Hartmann



Efficiencies based on fuel LHV: Diesel generator: 34%; Natural Gas Generator 45%; Electrolyzer: 61% (DOE 2022 Status); Fuel cell: 55%.
Liquefaction: 72% efficiency; 90% carbon capture for SMR scenarios; Delivery truck driving distances and payload (GH2: 1 ton; LH2: 4 ton).
Hydrogen scenarios (including via SMR): Ontario, CA to Cheyenne, WY (1065 miles). Diesel scenario: Houston, TX to Cheyenne, WY (1250 miles).
Primary fuel source for grid power: WY: Coal, WA: Hydroelectricity, VA: Natural Gas.

Gaps and barriers to adoption

- Hydrogen cost and availability
- Power density of fuel cells
- First cost for fuel cell and systems
- Space requirements: cooling, setback distances, other subsystems

Conclusions

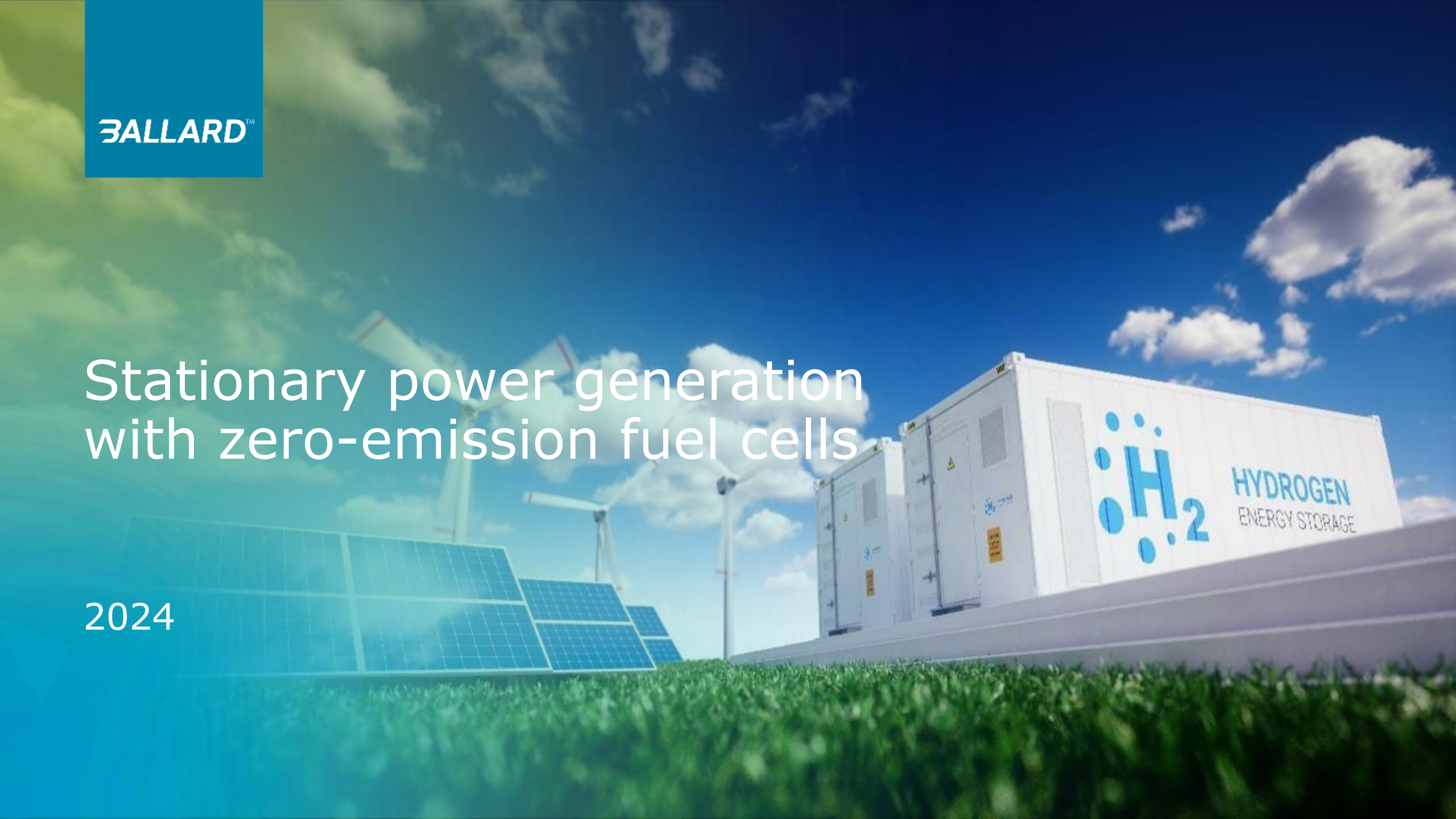
Successful demonstration of hydrogen backup power at data center

Fuel cell + battery microgrid solution provides applicability beyond standby

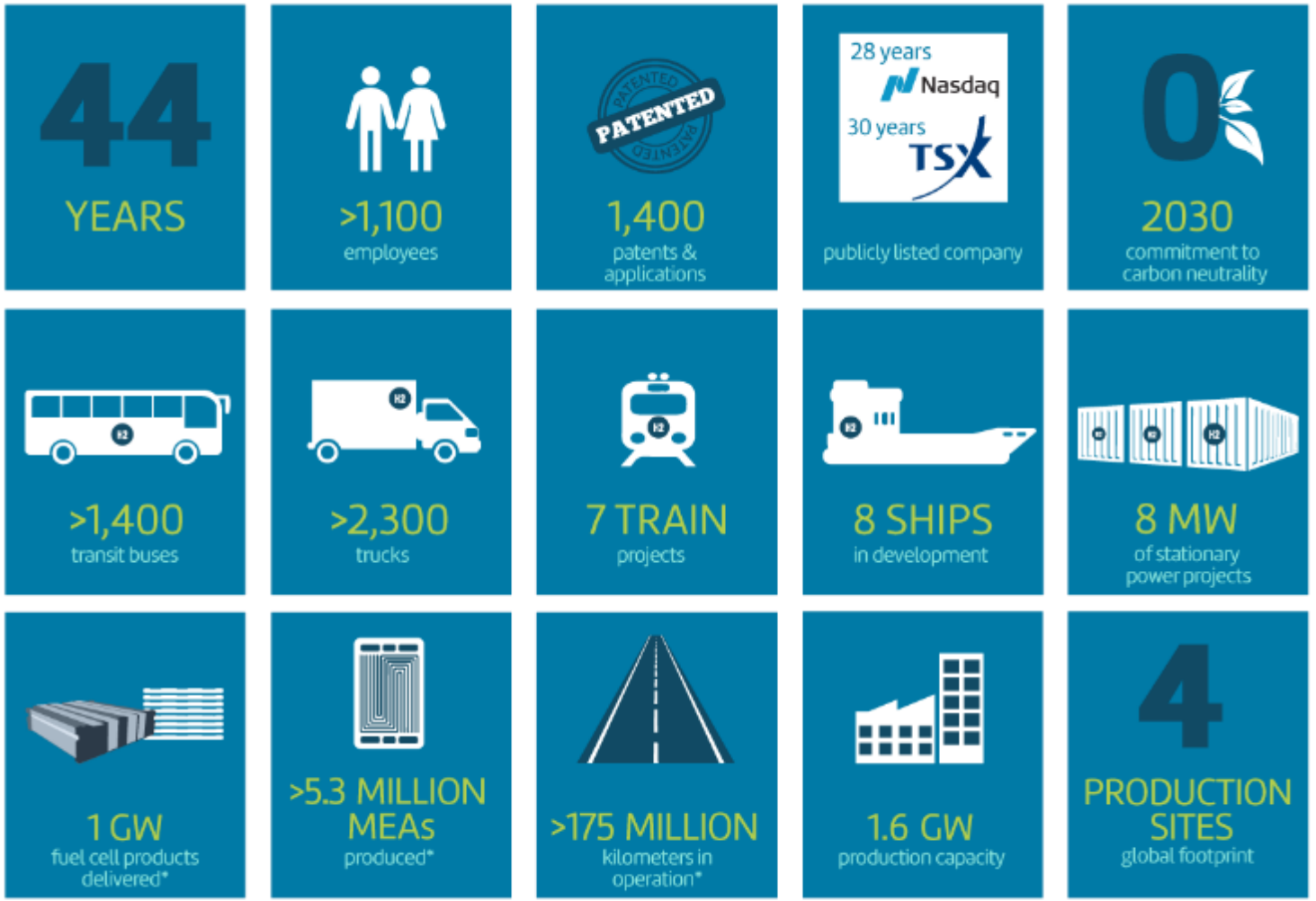
Increased resiliency, lower carbon intensity, integrated system

Stationary power generation with zero-emission fuel cells

2024



Ballard by the numbers



*compiled from 2015

Ballard Power Systems

We are dedicated to accelerate the adoption of fuel cell technology

Proven

8 MW successfully deployed

Products certified to stationary fuel cell power generator requirements per EU, ATEX and CSA standards

Performance

99.9% reliability

50% efficiency

Excellent availability

Exceptional durability

Promise

End to end support throughout the whole customer journey

Sustainable zero-emission solutions from stack supply to turnkey power solution for the end users

Ballard offers PEM fuel cells

PEM fuel cells have a faster ramp rate

PEM is a proven technology

PEM is truly zero emissions

PEM cost will be comparable to diesel by 2030

Aspect	PEM Fuel Cells	Solid Oxide Fuel Cells (SOFCs)
Operating Temperature	Low (50-100°C)	High (600-1000°C)
Efficiency	Range of 50%	Range of 60%
Start-Up Time	Quick start-up time	Longer start-up time due to high operating temperatures
Fuel Flexibility	Limited to pure hydrogen	Can utilize various fuels including hydrogen, natural gas
Durability	Typically requires stack refurb at midlife	Higher durability due to robust ceramic materials
Cost	Typically, higher cost	Lower cost per kW
Size and Weight	Lighter and smaller	Bulkier and heavier
Applications	Mobility, non base load stationary applications	Base load Stationary power generation,
Sensitive to Impurities	H2 quality needs to meet ISO 14687	Less sensitive to impurities

PEM fuel cells + Batteries

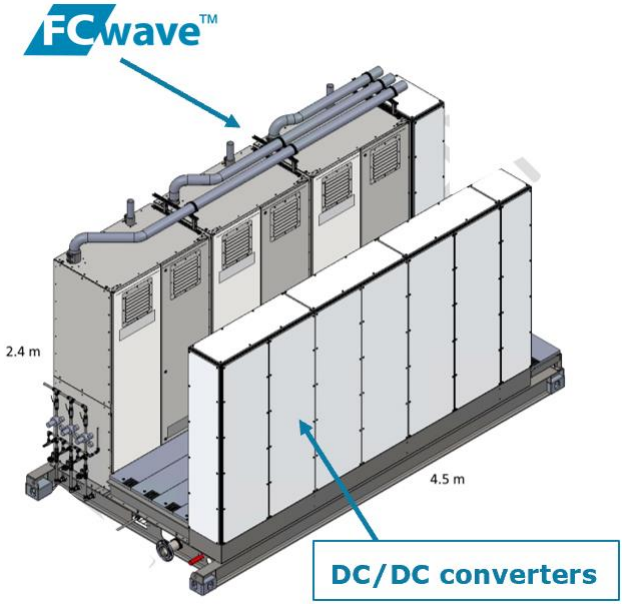
- Batteries are the jam: Short sprints of energy, high power and instantaneous transient response
- Hydrogen storage is the peanut butter: long-term steady energy supply via Fuel Cells

The perfect solution for a healthy supply of energy and a full belly!

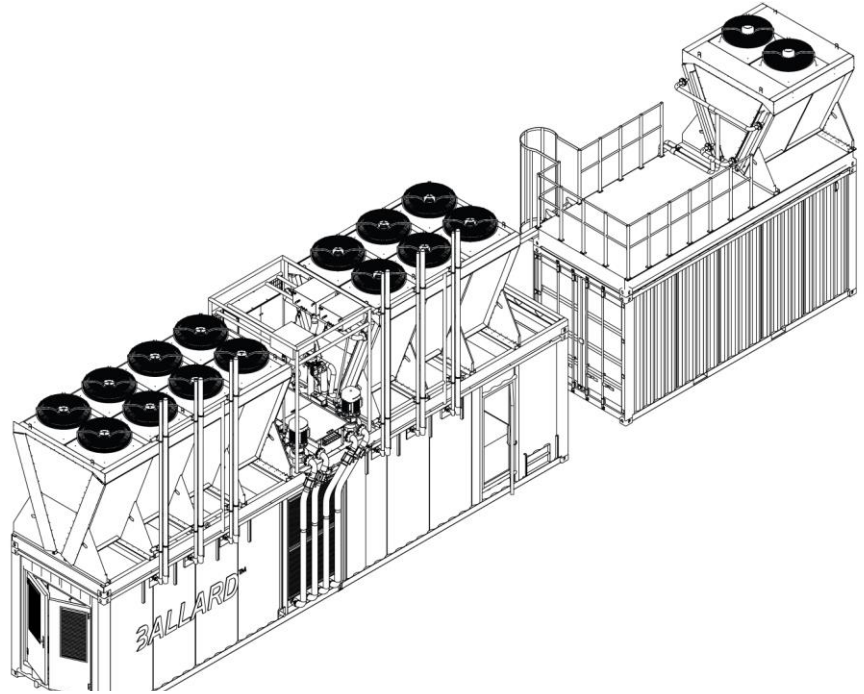
FCwave: from module to solution

Module | Systems | Solution

FCwave™
200 kw building block
Module only



FCwave™-Megablock
3x 200kW systems with interconnection, skid and DC/DC
Indoor solution

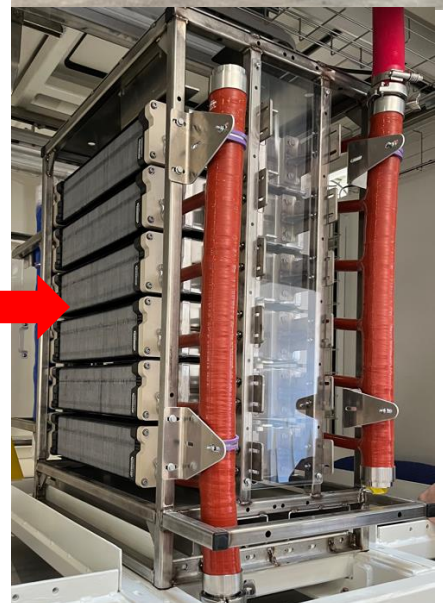


FCwave™- Container
Configurable Product solution up to 6 x 200kW modules integrated into container with DC/DC and cooling (1) option for DC/AC and battery scope (2)

Cleargen II 1.5 Hydrogen Fuel Cells

Typical Ballard scope

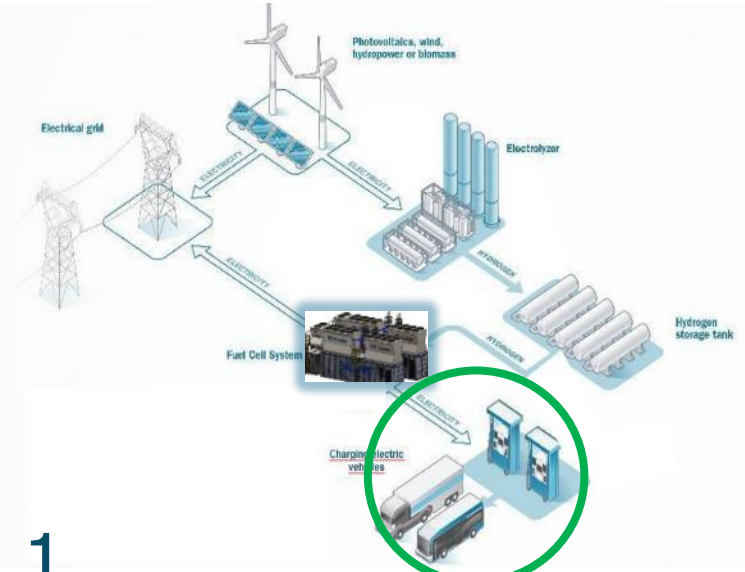
- Single balance of plant equipment fitted into a 40ft ISO Container
- True Output 1.5MW DC Power
- Includes cooling pump skid and heat management
- Outdoors Solution
- Multiple Containers can be connected without any changes to the product
- 11 strings of stacks, 6stacks/string of approximately 50kW/stack

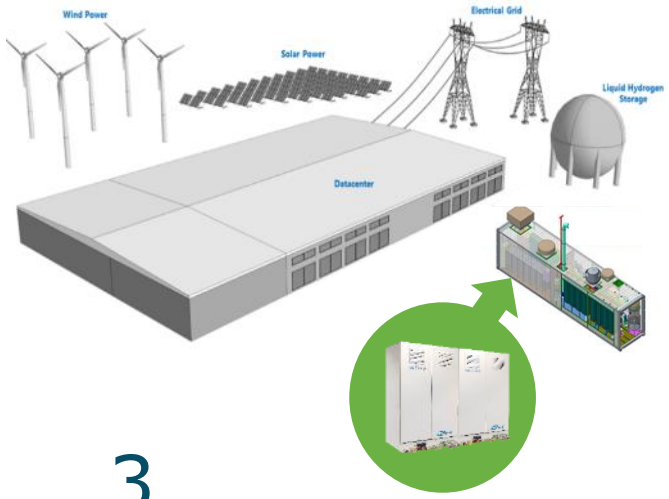


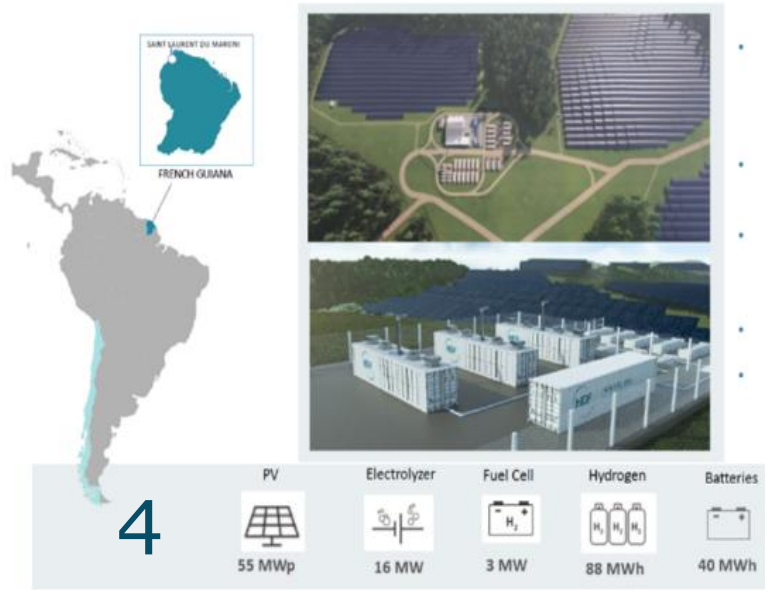
Fuel cell applications

1. EV Charger: Grid constraints
2. Shore Power: Emissions reduction
3. Data center: Emissions reduction
4. Micro grid: Cyclical power required

Illustration by CS Electric







Hydrogen fuel cells for EV charging

- Grid not ready to support growth in EV vehicles
- Using hydrogen fuel cells to fuel EV charging stations will ensure access to zero-emission reliable power for EVs
- Will avoid costly and timely grid delays

	Zero Emissions 50% efficiency	99.9% reliability Exceptional durability

Fuel cells for shore power

- Fuel cells can power hotels and other shiploads with land-based zero-emission electricity
- Reduce emissions without compromising operations
- Eliminating diesel consumption and reducing the auxiliary engine’s operational hours resulting in maintenance cost savings and reduced maintenance frequency
- Hydrogen fuel cell systems can meet various power levels and run-time requirements

	Zero Emissions 50% efficiency Low CAPEX	99.9% reliability Exceptional durability

Uninterrupted power supply for datacenters

- Unrestricted hours of zero-emission backup power
- Unrivalled reliability
- Reduces customer CO2 footprint
- Products developed to meet ESG standards
- Design and service model optimized for low maintenance costs
- Close couple to the battery for smooth operation between battery and fuel cells

	Zero Emissions 50% efficiency	99.9% reliability Exceptional durability

Hydrogen fuel cells for peak shaving, microgrids

- Levels out peaks in electricity use
- Ensures reliable access to the power needed
- Secures grid stability
- The fuel cell system eliminates or complements other energy sources (e.g., batteries)

	Zero Emissions 50% efficiency Low CAPEX	99.9% reliability Exceptional durability

Here for life™

Thank you

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This project was supported by the Hydrogen and Fuel Cell Technologies Office

DE-EE0009252 – Caterpillar, Inc.

1.5 MW PEMFC for Data Center Power: Development and Demonstration

Federal Funding - $6,154,667

Cost Share - $6,322,133

DOE Technology Manager – Peter Devlin

Principal Investigator – Paul Wang

Click for Annual Merit Review

For questions about this webinar, please contact us at HFTOInquiries@ee.doe.gov.

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