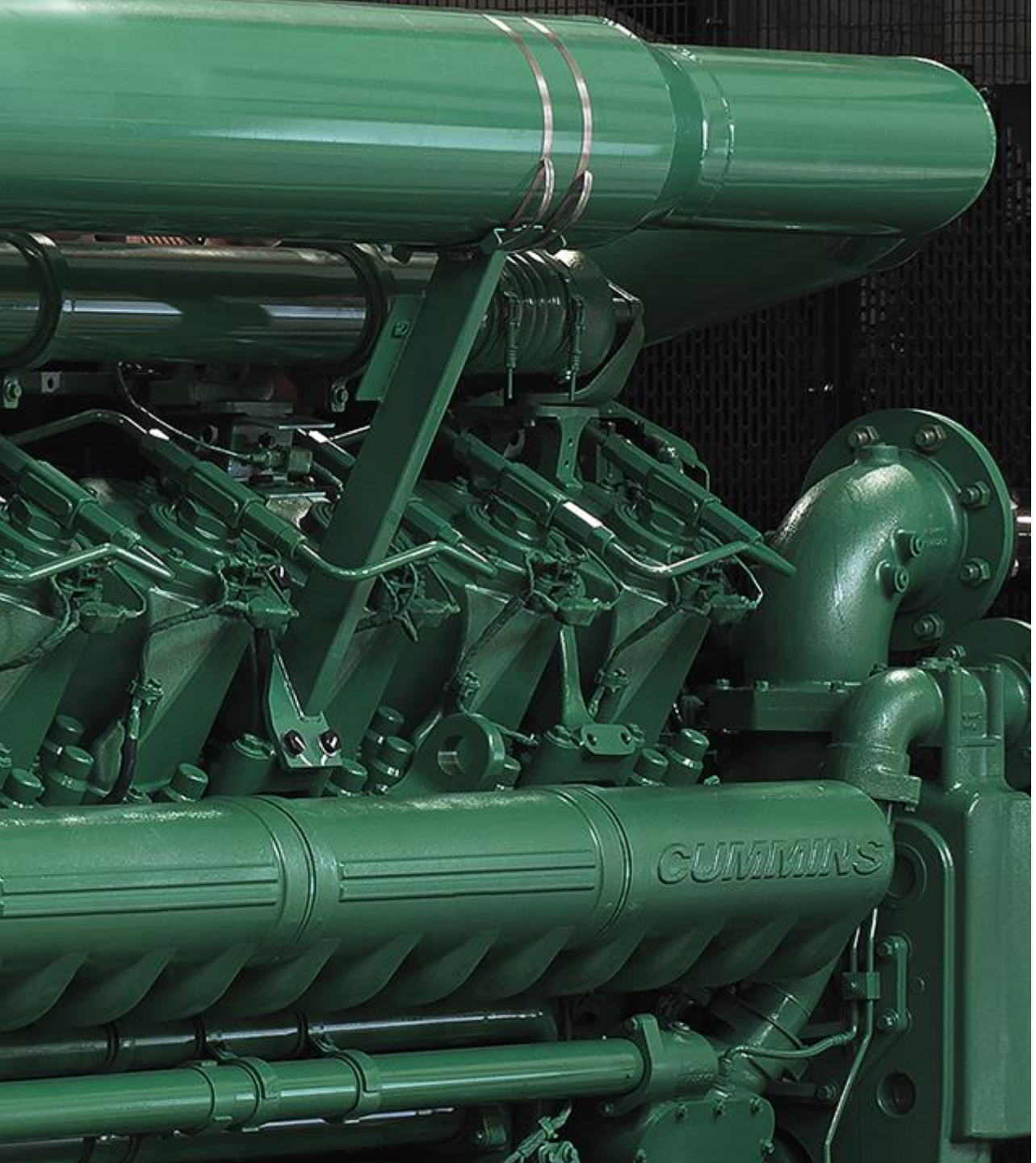

Using Fuel Cells to Address Energy Growth and Sustainability Challenges in Data Centers

PowerHour webinar series for consulting engineers

Experts you trust. Excellence you count on.

April 2, 2020 2:00pm Eastern Time / 11:00am Pacific Time
(1 PDH issued by Cummins Inc.)

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Cummins PowerHour webinar series is designed to help our engineer partners to…

- Keep up to date on products, technology, and codes and standards development
- Interact with Cummins experts and gain access to ongoing technical support
- Participate at your convenience, live or on-demand
- Earn Professional Development Hours (PDH)

Technical tips:

- Audio is available through teleconference or Zoom application.
- Attendees are in “listen only” mode throughout the event.
- Use the Zoom Q&A Panel to submit questions, comments, and feedback throughout the event. Time is allotted at the end of the PowerHour to address Q&A.
- If the audio connection is lost, disconnected or experiences intermittent connectivity issues, please ensure you are connected or troubleshoot your device by clicking the “Join Audio” button in the Zoom panel.
- Report technical issues using the Zoom Q&A Panel.

Meet your panelists

Cummins instructor:

Rich Scroggins
Technical Advisor - Data Center Markets
Cummins Inc.

Cummins facilitator:

Michael Sanford
Technical Marketing Specialist
Cummins Inc.

Your local Cummins contacts:

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- Canada: Ian Lindquist (ian.lindquist@cummins.com)

2020 Supporting Partner of International Data Center Day

“We are confident in our approach in supporting initiatives such as International Data Center Day, to help inspire today’s students to think about a career with the data center industry and Cummins”

Sarah Griffiths, Director – Data Center Markets, Cummins Inc.

Cummins Power Generation

Disclaimer

The views and opinions expressed in this course shall not be considered the official position of any regulatory organization and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Participants are encouraged to refer to the entire text of all referenced documents. In addition, when it doubt, reach out to the Authority Having Jurisdiction.

Course Objectives

Using Fuel Cells to Address Energy Growth and Sustainability Challenges in Data Centers

Data centers are critical to the modern digital infrastructure and an uninterrupted supply of power is critical to their operation; in many cases the demand for reliable power sources that meet stringent performance requirements of a typical data center application drive towards solution that may have long-lasting impacts on energy growth capability and sustainability. This session will explore some of the unique challenges faced in the data center market as related to both energy growth and sustainability while introducing some of the technologies available to the market today. The instructor will review fundamentals of two common fuel cell technologies and will provide key insights into their potential impact in a data center application.

After completing this course, participants will be able to:

- Identify challenges in the data center segment related to energy growth and sustainability
- Describe a fuel cell, the basic functionality of a fuel cell and two examples of modern fuel cell technologies
- Discuss the application and potential impact of fuel cells in data center applications

Data center energy-related pressures

Increasing pressure to lower carbon footprint

- *Tightening emissions regulations*
- *Increased publicity on sustainability initiatives*

[1] Ponemon Institute – Report on Cost to Support Compute

[2] Data Center Knowledge

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Need lower operational costs

- *Energy is 40% of operational costs[1]*
- *Servers and Cooling Loads*

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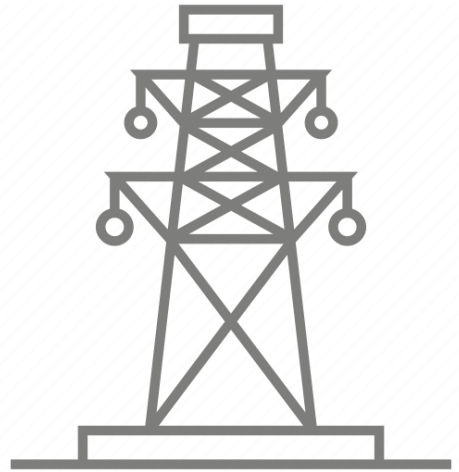

Data center growth is outpacing electric utility infrastructure investments

- *Data centers account for 2% of global electricity consumption[2]*

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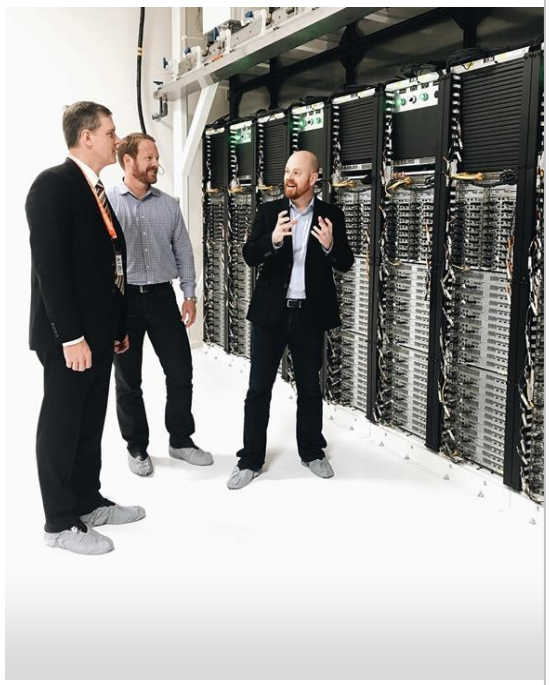
Lots of industry buzz about fuel cells

MICROSOFT-CUMMINS ADVANCED ENERGY LAB

The lab's initial focus will be on powering datacenters with natural gas powered fuel cells. The 20-rack environment in the lab simulates datacenter conditions to evaluate whether the fuel cells have the potential to improve efficiency, reduce emissions and cut costs.

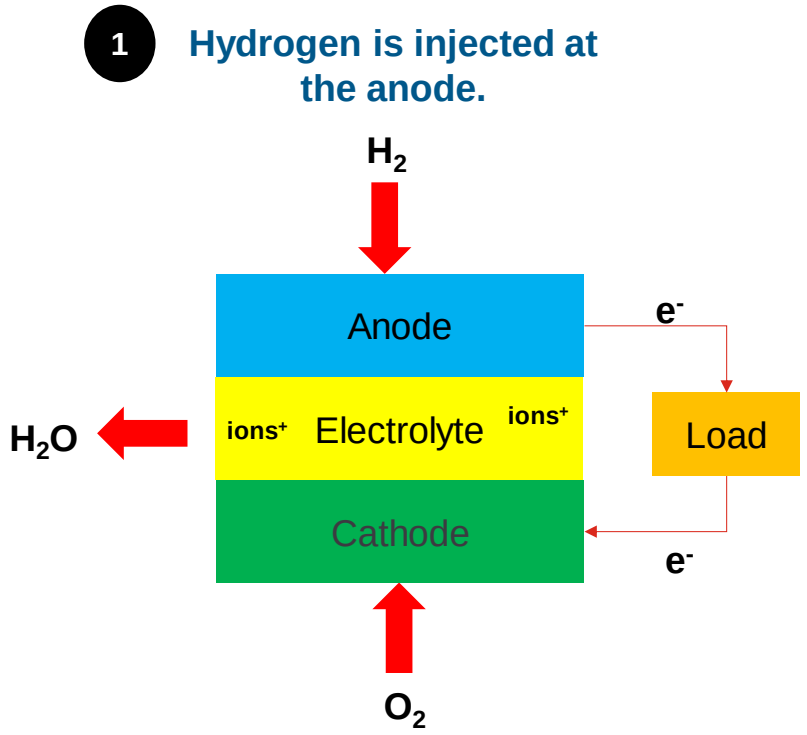
Microsoft



- Equinix installs fuel cells in 12 US data centers
- Apple installs 10MW fuel cell
- CenturyLink installs hydrogen fuel cells at California data center
- Uptime Institute recognizes Fuel Cells as a reliable source of onsite power

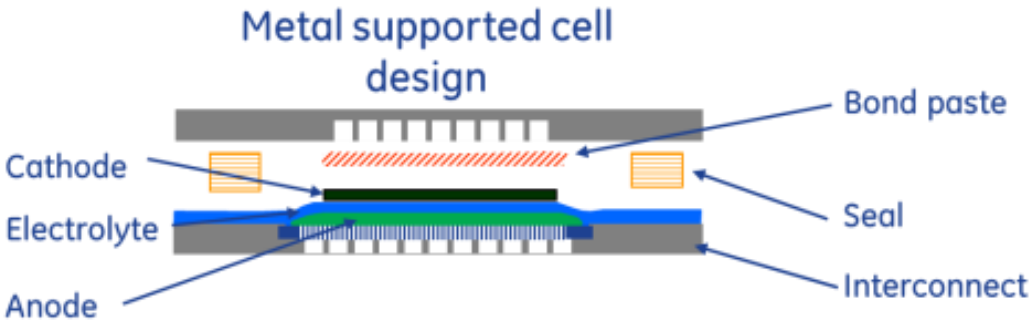
What is a Fuel Cell?

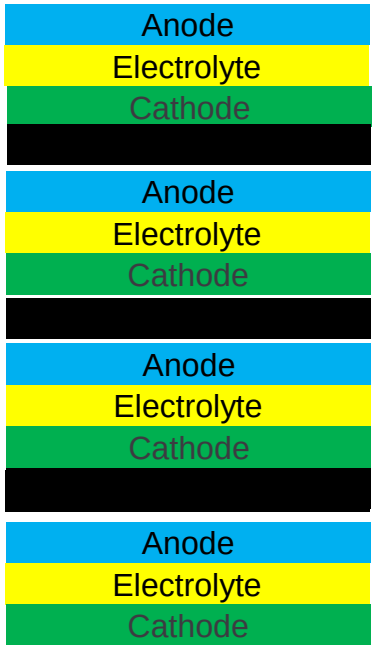
- A fuel cell generates electricity through a **chemical reaction between hydrogen and oxygen**

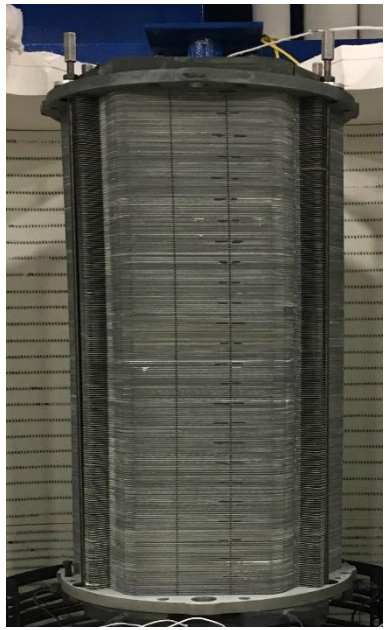


Fuel Cell Stack

- A typical fuel cell generates **06. – 0.7V**
- Cells are stacked and connected in series to **generate higher voltages**



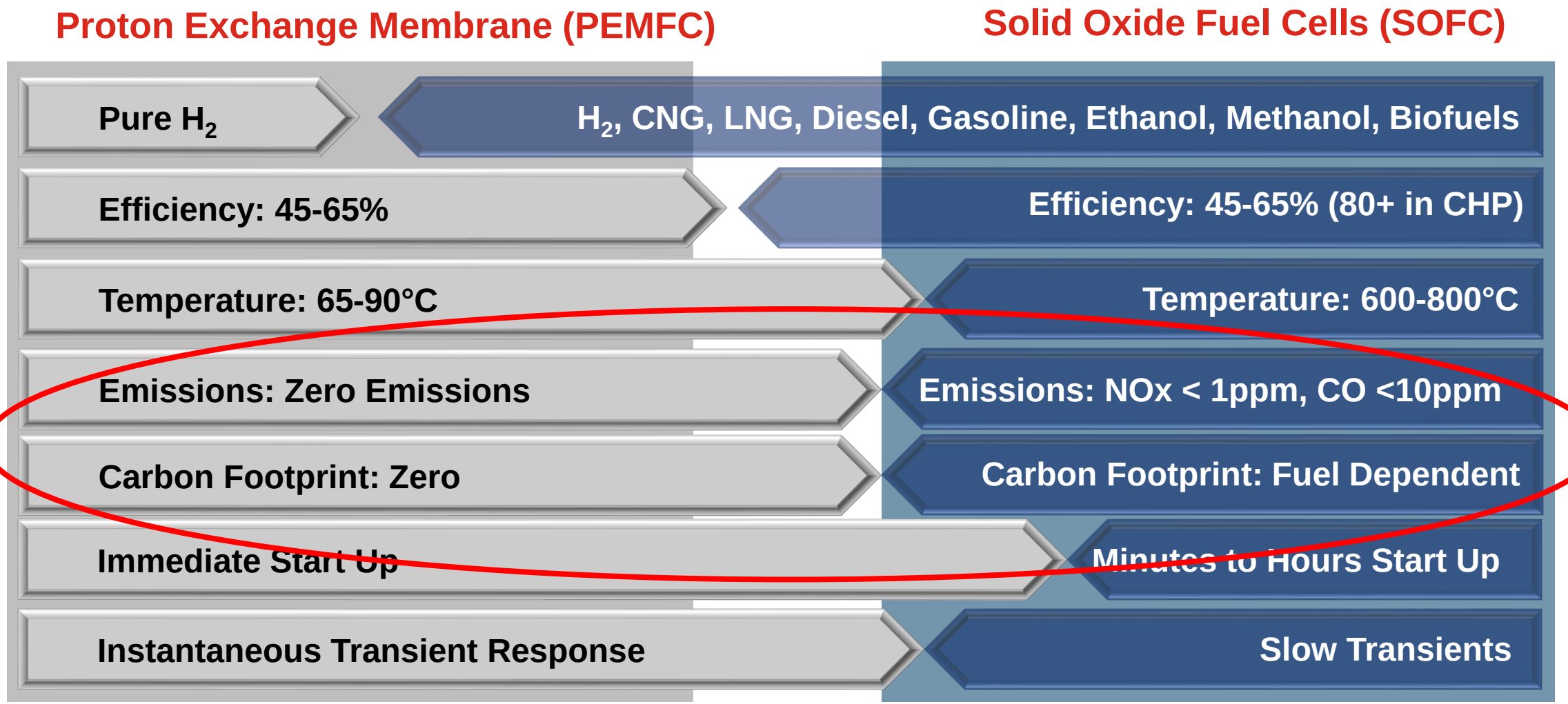




Two primary fuel cell technologies are available today

Proton Exchange Membrane (PEMFC)	Solid Oxide Fuel Cells (SOFC)
Pure H_2	H_2, CNG, LNG, Diesel, Gasoline, Ethanol, Methanol, Biofuels
Efficiency: 45-65%	Efficiency: 45-65% (80+ in CHP)
Temperature: 65-90°C	Temperature: 600-800°C
Emissions: Zero Emissions	Emissions: NOx < 1ppm, CO <10ppm
Carbon Footprint: Zero	Carbon Footprint: Fuel Dependent
Immediate Start Up	Minutes to Hours Start Up
Instantaneous Transient Response	Slow Transients

Two primary fuel cell technologies are available today



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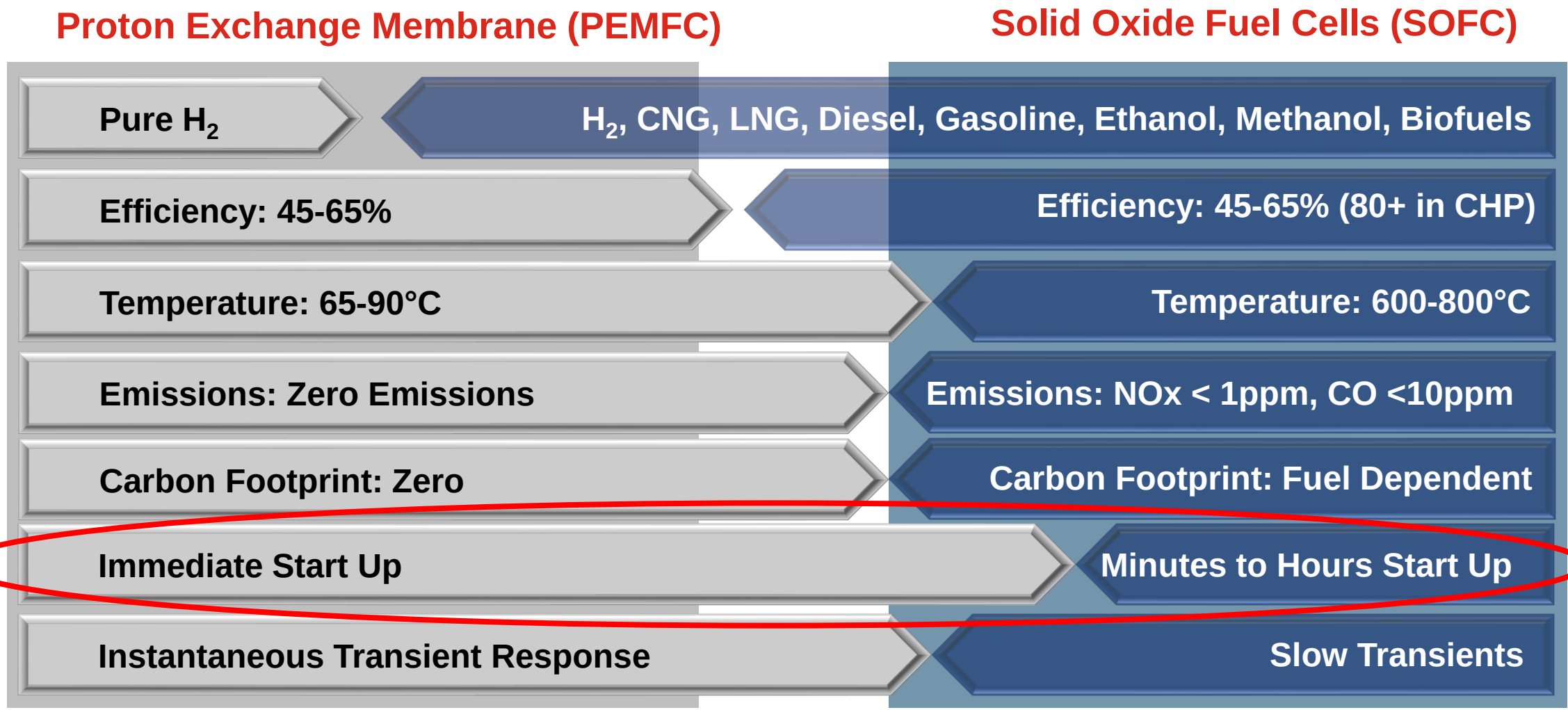

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Proton Exchange Membrane (PEMFC)

- Require pure hydrogen
- Zero emissions
- Fast start up
- Load following, good transient performance
- Suitable for standby power

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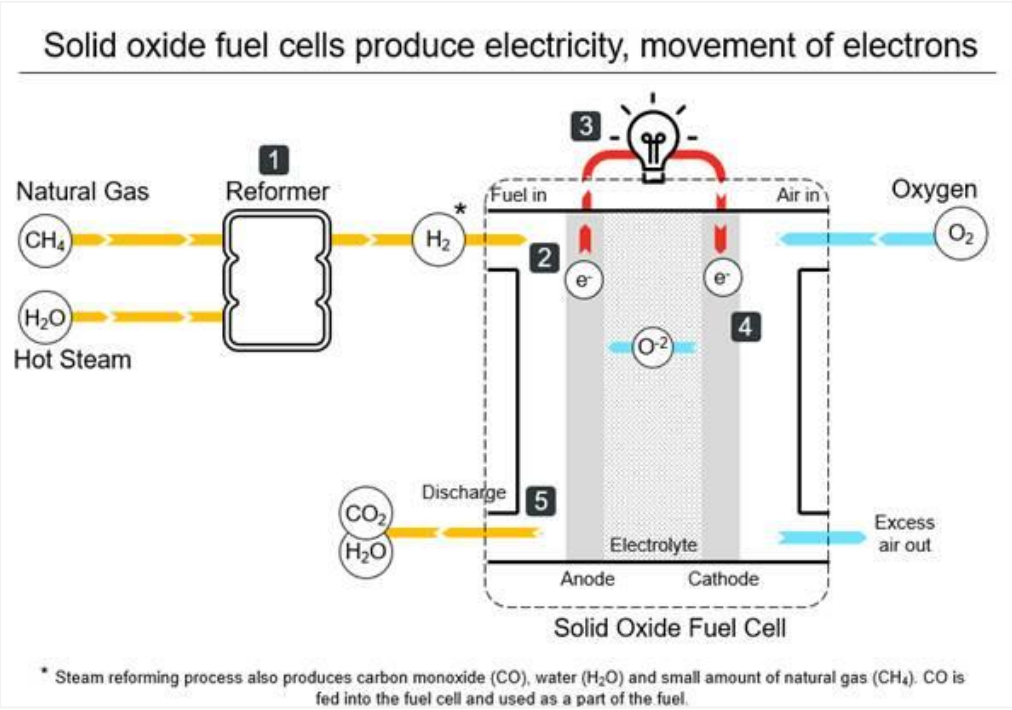
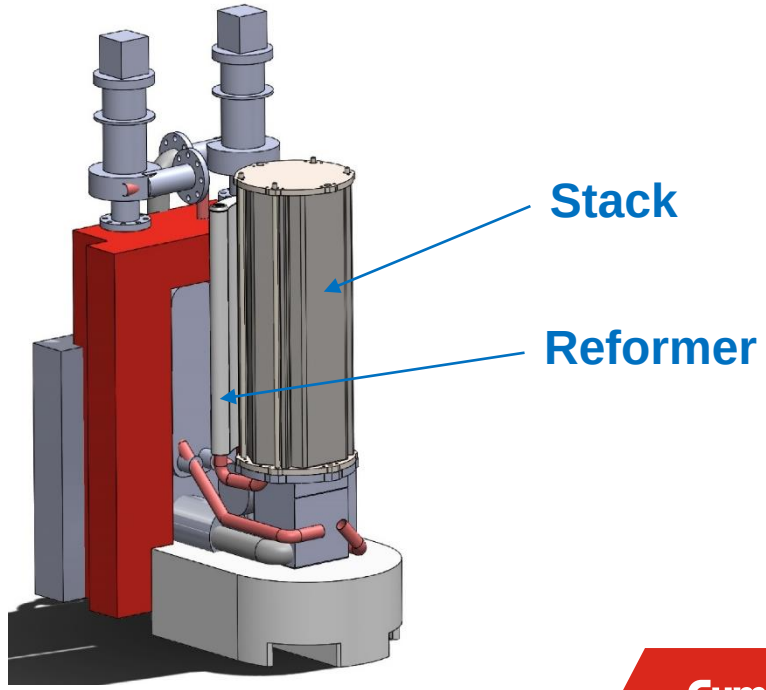
Solid Oxide Fuel Cells (SOFC)

- Run on any hydrogen rich gas
  - Reformer extracts hydrogen from natural gas or other fuel
- High operating temperature, cogen opportunity
- Low emissions
- Slow start up and transient performance
- Suitable for prime power

Extracting Hydrogen for a SOFC

- **A reformer extracts hydrogen from natural gas or other fuel**
- Produces high grade usable heat
- CO_2 and H_2O are byproducts





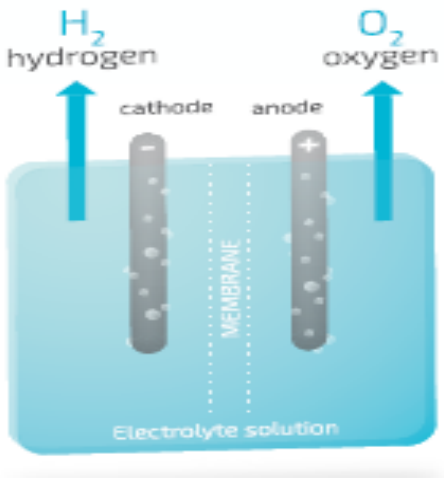
Producing Hydrogen for a PEMFC

- Availability of Hydrogen is currently a barrier to widespread adoption of PEM fuel cells
- **Hydrogen can be produced though electrolysis**
- Electrolysis uses electricity to separate water into hydrogen and oxygen

WATER (H_2O) + **POWER** ⇄ **HYDROGEN (H_2)** + OXYGEN(O_2)

Electrolyser

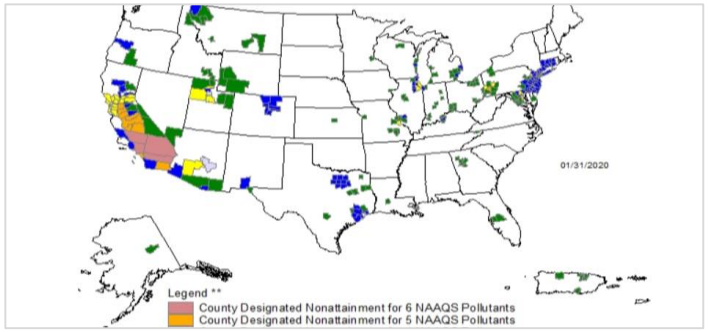
Fuel Cell



What factors make fuel cells a practical solution?

Emission restrictions

PEM fuel cells have no emissions, SOFC have very minimal emissions



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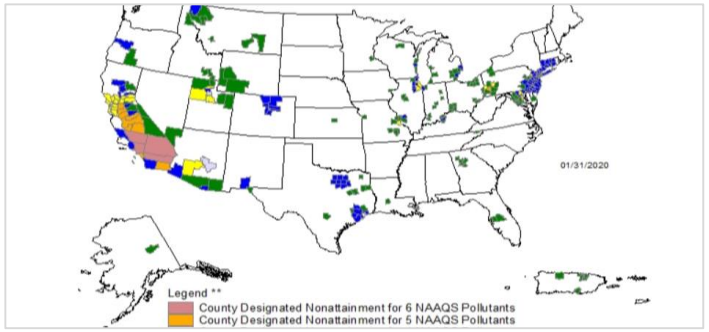

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PEM fuel cells have no carbon footprint other than that generated by H_2 creation

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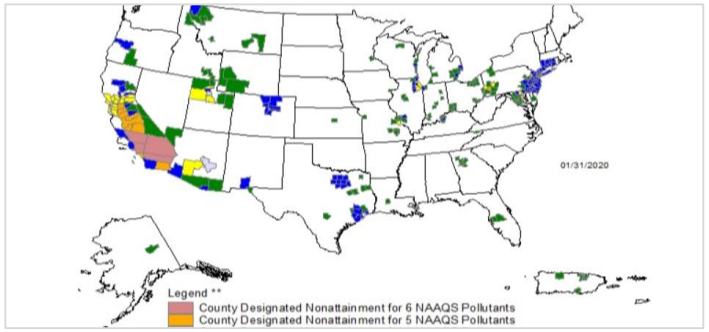

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Highly desirable for Data Centers located in urban areas

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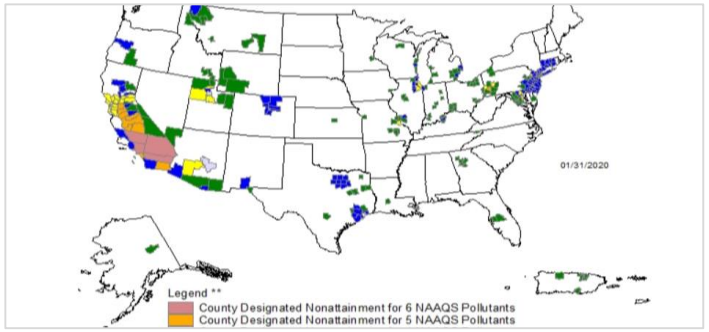

Hydrogen Availability

Where hydrogen is available or hydrolysis using renewable energy is practical

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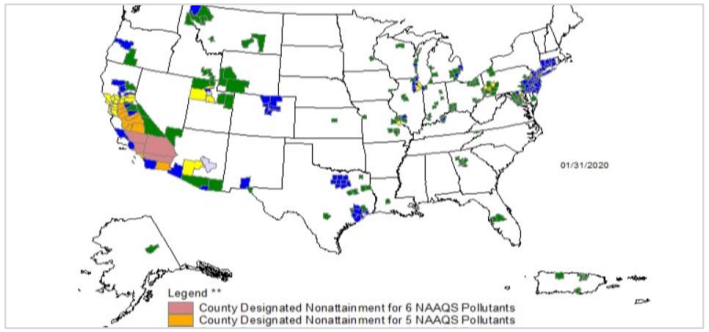

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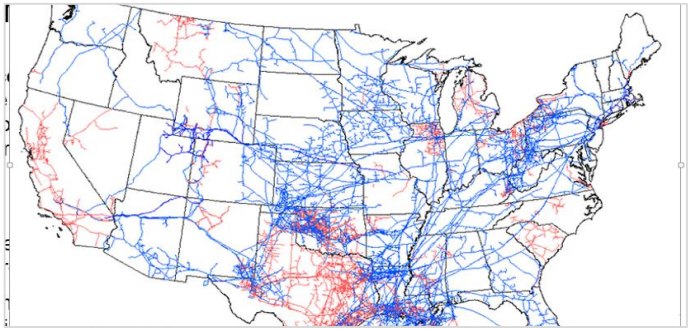

Reliable Gas Utility

In some locations the gas utility is more reliable than the electric utility

PUE – Power Usage Effectiveness

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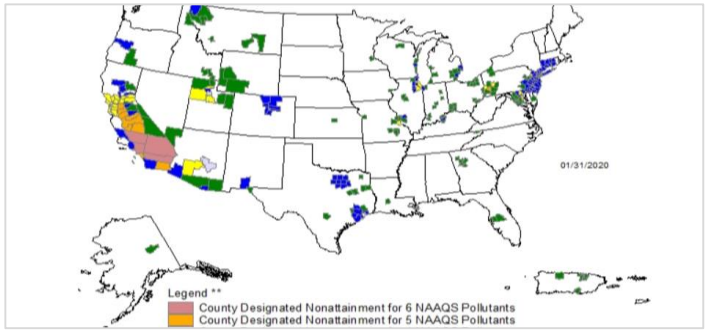

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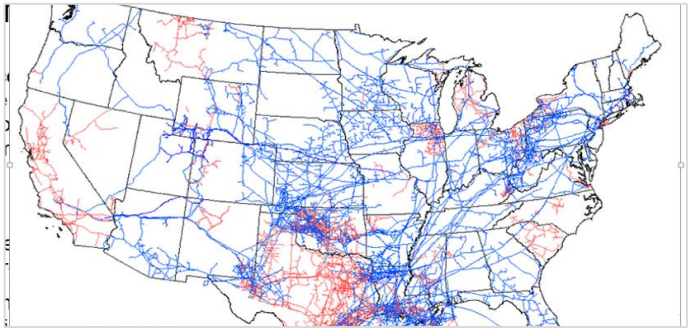

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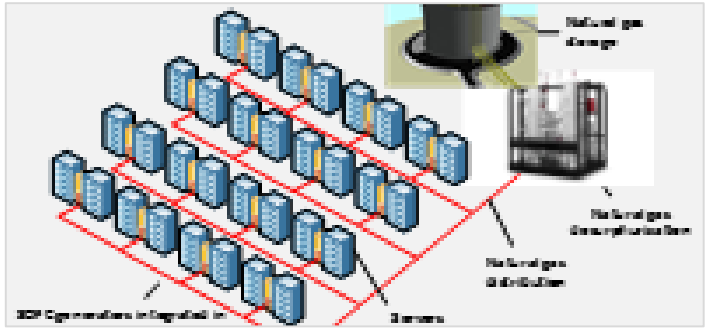


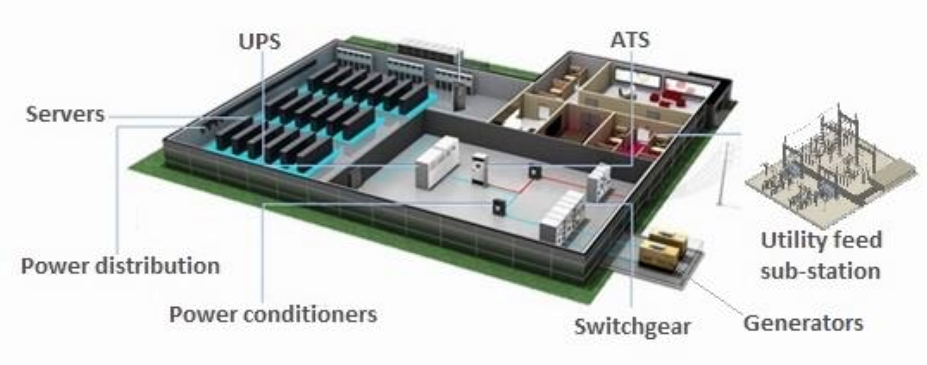
Infrastructure Cost Reduction

Low noise and emissions allow fuel cell location close to loads enabling electrical infrastructure cost reduction

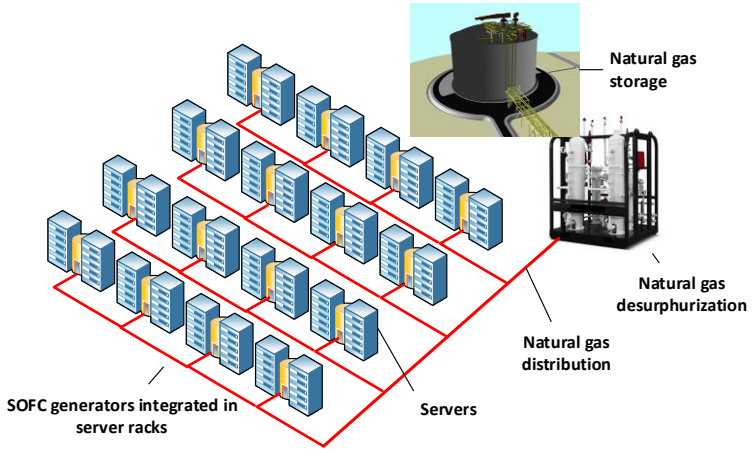
PUE – Power Usage Effectiveness

Data Center Design with Fuel Cells

Grid Model



Fuel Cell Distributed Model



TODAY → **TOMORROW**

Minimal emissions and noise allow fuel cells to be located close to loads

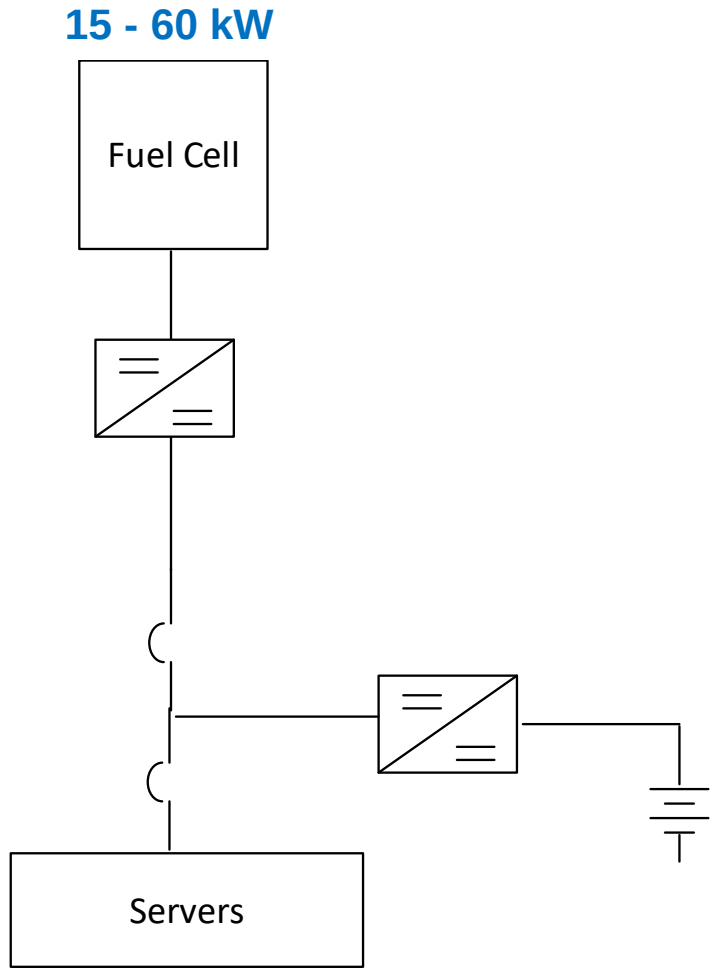
- Infrastructure cost reduction
- Simplifies the operation and construction
- Reliability improves due to simplicity
- Data Center efficiency (PUE) improves

Data Center Design with Fuel Cells

Fuel cell at the rack

Fuel cell at the rack level can power server loads directly:

- Eliminates substantial switchgear costs
- Battery at rack mitigates transients in server loads
- Transient at servers are more severe for high compute lower storage loads as will be common in Edge applications

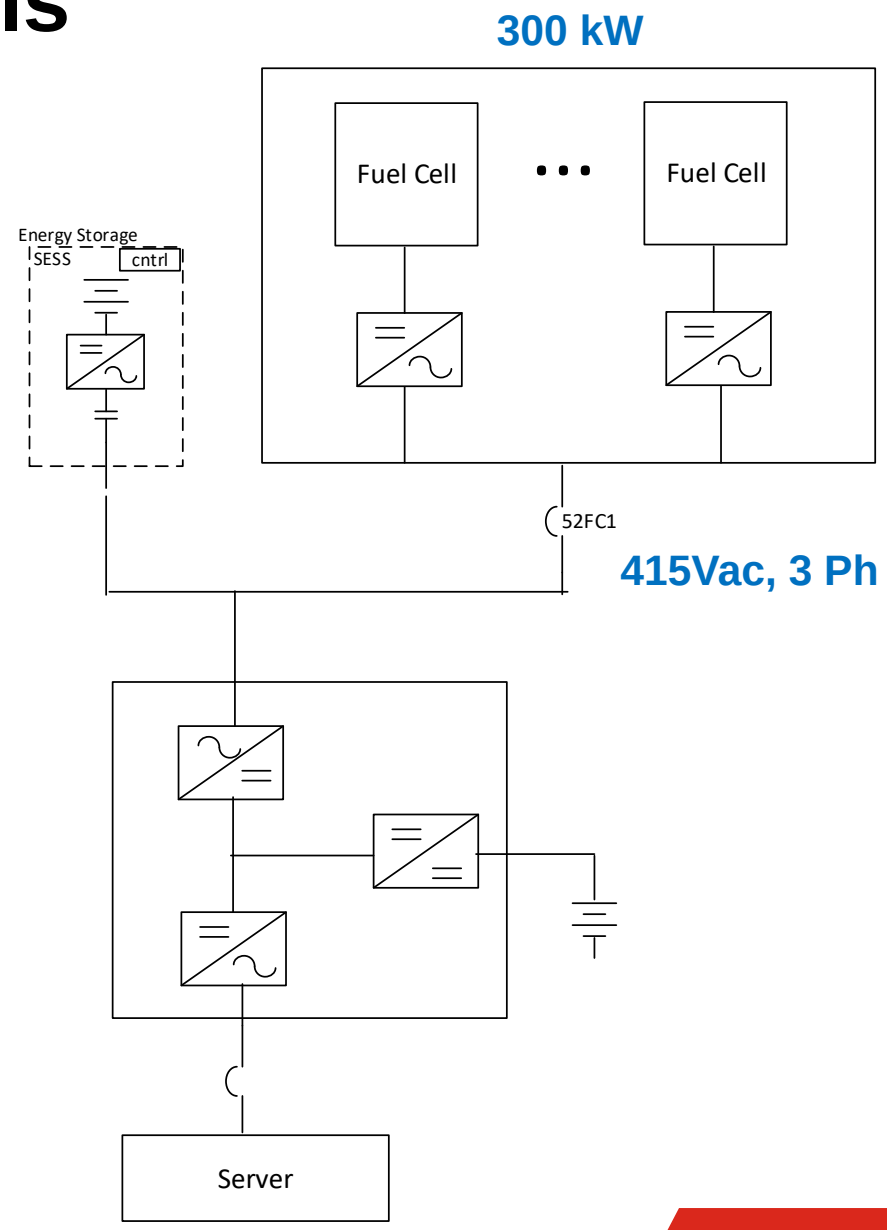


Data Center Design with Fuel Cells

Fuel cell at the row

Paralleled fuel cell modules allow for redundancy and maintainability of fuel cells

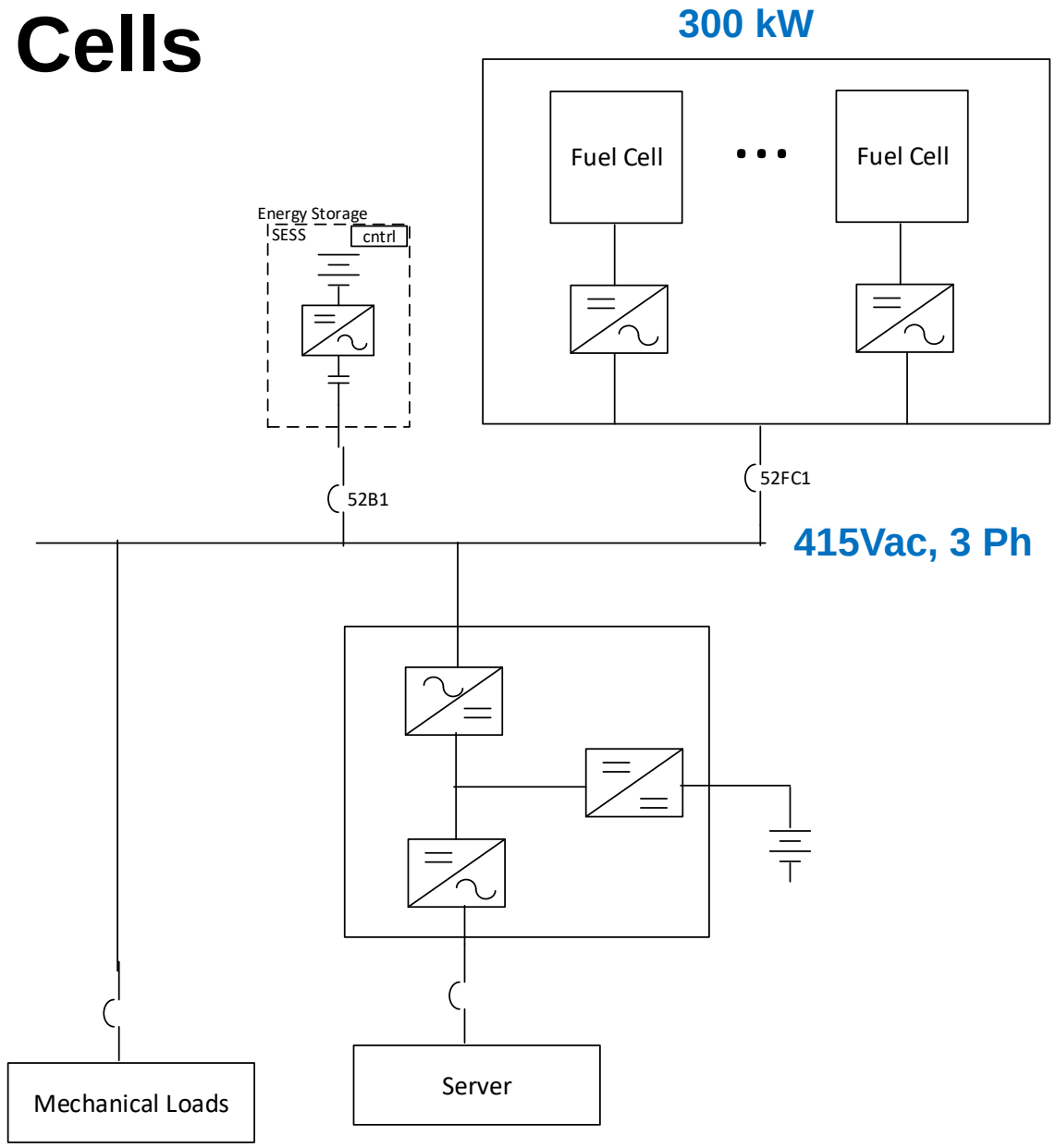
- Energy storage systems will help mitigate transients and clear faults
- Common requirement of low-inertia, inverter based power sources



Data Center Design with Fuel Cells

Mechanical Loads

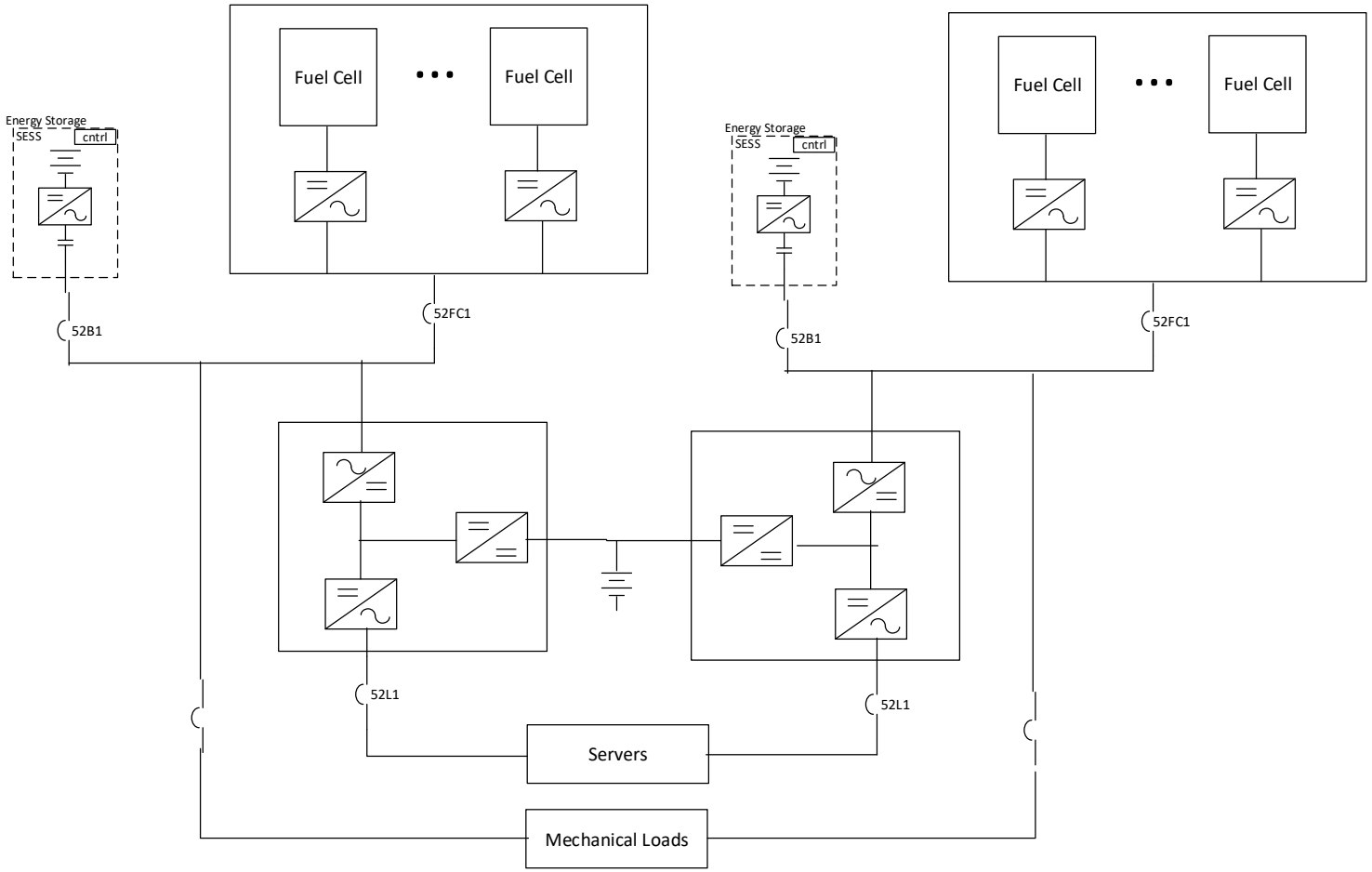
UPS will stabilize voltage in the event of mechanical load transients



Data Center Design with Fuel Cells

Distributed Redundant Design

UPS walk in function can **minimize** transients on a failover condition in a distributed redundant design

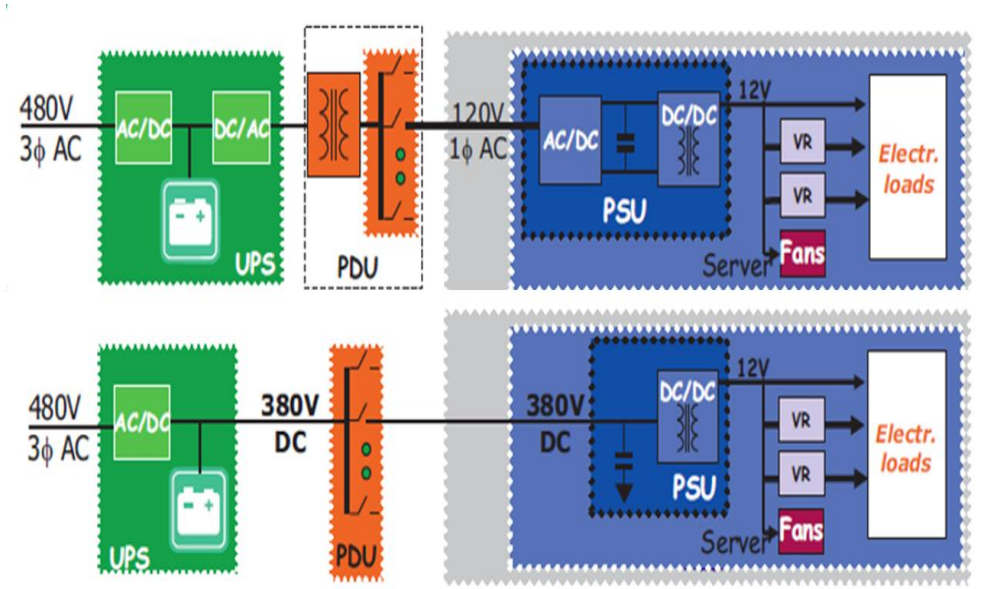


DC Power in Data Centers

Will data center power distribution systems migrate towards DC?

- Servers require DC power
- Most renewable sources are inverter based
- Cost and efficiency improvements associated with removing AC/DC conversions

AC Data center system



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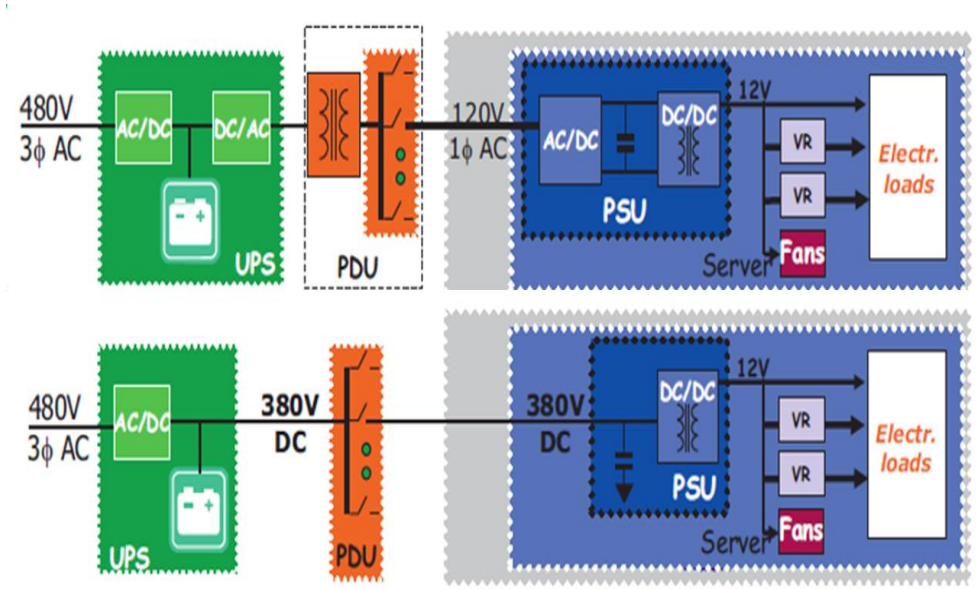
Limitations to mass-adoption of DC distribution

- Voltage conversions still needed between DC levels
- Few suppliers of DC distribution equipment
- DC circuit breakers are more expensive than AC circuit breakers
- DC is perceived as more dangerous than AC
- AC power will still be required for cooling and mechanical loads

AC Data center system



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Keys to Fuel Cell Adoption at Scale

Regulations and Incentives

- Will drive investments in fuel cell technology
- Emissions regulations may limit conventional generation
- Carbon reduction goals drive development of low carbon technologies

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Technology Improvements

- Necessary to make fuel cells feasible at scale
- Fuel cells costs ($/kW) need be competitive with other forms of generation or subsidized
- Improved transient capability of energy storage

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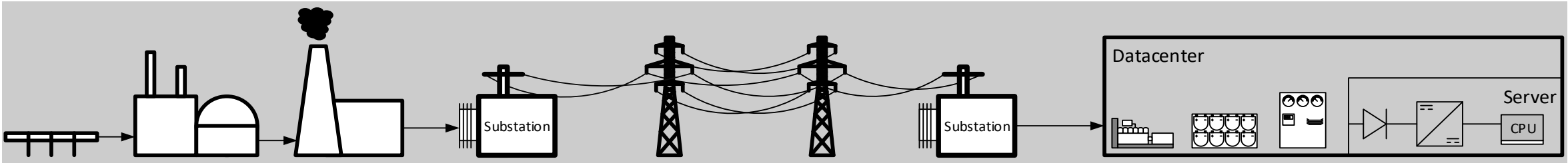
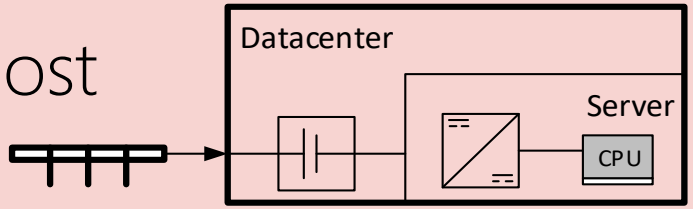
Ecosystem

- Mature supply chain for infrastructure and hydrogen
- Development of a skilled workforce
- Development of hydrogen infrastructure

Smaller, distributed fuel cell systems can disrupt the data center power model



Less Infrastructure + Less Complexity = Reduced Cost & Risk



50% decrease in physical infrastructure on-site

5-10% decrease in total DC COGS rate

24-40% efficiency improvement

22-50% CO2 reduction (more w/ RNG)

SIMPLICITY

Streamlined Design
Reduces Risk
Minimal customization
Reduced failure zone

LOWER COST

Elimination of electrical distribution
Less site equipment to maintain
Waste heat reuse
Simple energy supply chain

IMPROVED EFFICIENCY

Dramatic improvement in efficiency
Lower PUE, Reduced losses
Reduced TTM- construction time down 6 months

SUSTAINABILITY

Lower Emissions
Reuse of waste heat

Cummins is innovating to deliver the Power of Choice

SERVICE & SUPPORT

SYSTEM OFFERINGS

IC Engine (Diesel, Natural Gas)

Stationary Energy Storage

Solid Oxide Fuel Cell

PEM (Hydrogen) Fuel Cell

Battery Materials, MEA's & Cells

H_2 O_2 fuel cells + battery pack + power electronics + controls +

motor generator, engines, gear boxes, accessories, cooling, wiring +

H_2 storage =

system integration & aggregation

Battery/Stack Reuse or Recycle

COMPONENTS

CHARGING , CONNECTIVITY, HYDROGEN GENERATION & SUPPLY

Images are illustrative

Course Summary

Using Fuel Cells to Address Energy Growth and Sustainability Challenges in Data Centers

- Identify challenges in the data center segment related to energy growth and sustainability
- Describe a fuel cell, the basic functionality of a fuel cell and two examples of modern fuel cell technologies
- Discuss the application and potential impact of fuel cells in data center applications

Key Takeaways

Fuel cells could potentially help data centers reliably meet carbon reduction goals

Two types of fuel cells are available in the market

- **Solid Oxide Fuel Cells**
  - Run on natural gas
  - Suitable for prime power
- **PEM fuel cells**
  - Run on pure hydrogen
  - Suitable for standby power

Cummins is investing in both **SOFC** and **PEMFC technologies**

Additional Resources

Cummins White Papers

- Data Center Continuous (DCC) Ratings: A Comparison of DCC Ratings, ISO Definitions and Uptime Requirements (Nov 2019)
- Understanding ISO 8528-1 Generator Set Ratings (Nov 2019)

Cummins On-Demand Webinars

- Generator Set Ratings for Data Centers and Other Applications
- Common Failure Modes of Data Center Back Up Power Systems

Q&A

Please type your questions, comments and feedback in the **Zoom Q&A** window.

After the PowerHour, a complete list of questions and answers will be published on powersuite.cummins.com.

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Please complete the brief survey before exiting the webinar!

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Closing

Watch out for a follow-up email including:

- A link to the webinar recording and copy of the presentation
- A certificate issuing one professional development hour (1 PDH)

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- Gaseous Generator Set Installations and Case Studies, April 28
- Considerations for Specifying Generator Set Fuel Sources, May 20
- The Role of a System Level Control in a Power System, May 21

Please contact Michael Sanford if you have any questions related to the PowerHour webinar (michael.sanford@cummins.com)


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