

White paper

Hydrogen fuel cells for data center power

Enabling data center capacity with zero onsite
emission backup power





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Executive summary

- The data center industry faces growing challenges that **demand clean on-site power solutions** to facilitate reliability and environmental responsibility:
- **Environmental air permitting limitations** restrict the use of traditional diesel generators (gensets) due to emissions regulations, making it harder for operators to secure backup power approval.
 - **Responsible business commitments**, including net-zero carbon goals, push companies to phase out fossil-fuel-based power and invest in lower-carbon alternatives.
 - **Power constraints**—from grid instability to local supply shortages—can jeopardize operations, particularly in regions with rapid digital infrastructure growth.
 - Finally, **AI workloads are expected to impose sudden load surges**, which can result in deviations in output frequency and voltage of diesel gensets.
- In contrast, inverter-based hydrogen fuel cell solutions can offer a more responsive backup solution, delivering consistent power without the limitations of mechanical inertia.
- This white paper explores the potential of hydrogen fuel cells as a **zero on-site emission power solution** for data centers, addressing both their technical feasibility and broader impact on energy resilience. We examine fuel cell fundamentals and the steps required to integrate fuel cells into data center backup systems.
- This white paper is intended for:
- **Data center operators, energy managers, responsible business officers, and technology decision-makers** looking for reliable, zero-emission backup power solutions.
 - **Grid infrastructure experts, policymakers, and renewable/alternative energy advocates** may find value in understanding the potential of hydrogen fuel cells for grid support and microgrid integration.
 - **Engineers and researchers** focused on fuel cell technology and hydrogen infrastructure can benefit from insights into data center use cases for hydrogen fuel cell systems.
 - **Investors and corporate leaders** exploring alternative energy investments could use this paper to assess hydrogen's role in future-proofing data center power systems.

Introduction

Increasing demand for cloud computing and Artificial Intelligence (AI) workloads is pushing the rise in data center processing. By 2027, Goldman Sachs Research projects global power demand from data centers to grow 50% with an 165% increase expected by 2030.¹ AI-driven data centers alone could consume 945 terawatt-hours (TWh) of electricity by 2030, surpassing the total electricity use of entire nations such as Japan.²

This surge is challenging the existing power infrastructure, particularly where traditional diesel-based backup solutions face increasing regulatory, environmental, and operational constraints. Proton exchange membrane (PEM) fuel cell technology offers a zero on-site emission, scalable alternative for on-site backup power in data centers and other critical digital infrastructures. Compared to combustion-based systems, PEM fuel cells produce no nitrogen oxides (NO_x), sulphur oxides (SO_x), particulate matter, or Scope 1 greenhouse gas emissions. Their rapid response capability, quiet operation, and modular architecture make them well-suited for high-availability IT environments, particularly where noise and air permitting restrictions limit conventional solutions.

What is a proton exchange membrane (PEM) fuel cell?

A proton exchange membrane (PEM) fuel cell converts hydrogen and oxygen directly into electricity through an electrochemical reaction, producing only water and heat as byproducts. This electrochemical process at the center of the technology eliminates the inefficiencies and emissions associated with internal combustion.

PEM fuel cells generate electricity through an electrochemical reaction between fuel — hydrogen — and an oxidant — oxygen (air). This reaction uses a polymer electrolyte membrane to facilitate the movement of hydrogen ions (protons) from the anode to the cathode.

From this, electrons take an external circuit path, which creates an electric current, while oxygen molecules at the cathode combine with protons and electrons to form the other by-product — water — eliminating nitrogen oxides (NO_x), sulfur oxides (SO_x), and other combustion-related emissions typically associated with conventional fossil fuel-based power generation.

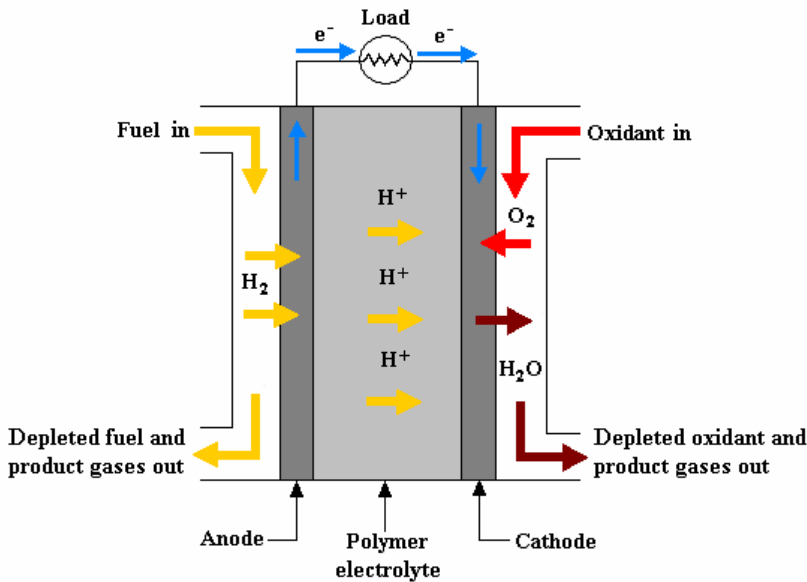


Figure 2. Proton exchange membrane (PEM) fuel cell diagram showing the electrochemical process to produce electricity. Source: The Electrochemical Society ³

PEM fuel cell features

As electrochemical power generators, PEM fuel cells are highly efficient, achieving efficiencies of up to 60%, deliver fast startup times due to their relatively low operating temperature of 60-80°C, and are scalable to meet applications ranging from hundreds of kilowatts to megawatts.

- **Zero on-site emissions:** Fuel cells produce no local pollutants that are subject to air permitting restrictions: zero NO_x, SO_x, and particulate matter (PM) emissions. Additionally, no greenhouse gas (GHG) carbon equivalent emissions are generated on-site (zero Scope 1 emissions).
- **Rapid ramp up to full power:** PEM fuel cells can reach their full power output within a minute. This rapid response makes them well-suited for integration with short-bridge energy storage systems like batteries, allowing for seamless switchovers during outages without disrupting critical IT loads.
- **Quiet operation, producing minimal noise pollution:** Compared to diesel gensets, which produce high decibel levels and typically require sound reduction measures, fuel cells operate quietly due to the lack of combustion and mechanical motion. This makes them particularly suitable for installations with strict noise regulations, thereby easing some of the permitting and environmental compliance requirements.

- **High cyclability:** Fuel cells can endure frequent start-stop cycles and long-duration runs without degradation in performance, especially when compared to batteries that experience cycle-based wear or diesel gensets that struggle with wet-stacking during short load cycles.
- **Modular and scalable:** Fuel cell systems are inherently modular. Units can be deployed incrementally based on current load requirements and scaled as demand increases, without changing the core infrastructure. This supports a distributed and fault-tolerant architecture, enabling redundant architecture and simplifying capacity planning in dynamic environments where compute loads are growing or shifting due to cloud and edge expansions.
- **Low maintenance with minimal moving parts:** Diesel gensets require regular oil changes, coolant checks, filter replacements, and periodic load testing. In contrast, fuel cells have fewer mechanical components and experience less wear and tear. Fuel cell maintenance intervals are also longer, more predictable, and generally software-driven, resulting in reduced labor costs and fewer unplanned service events.
- **Limited footprint:** With a scalable and modular approach, fuel cell power solutions enable packaging in a compact solution. A 1MW-system will require 40 m2 space (excluding the hydrogen storage containers). Several systems and modules can be installed on top of each other to reduce space footprint.

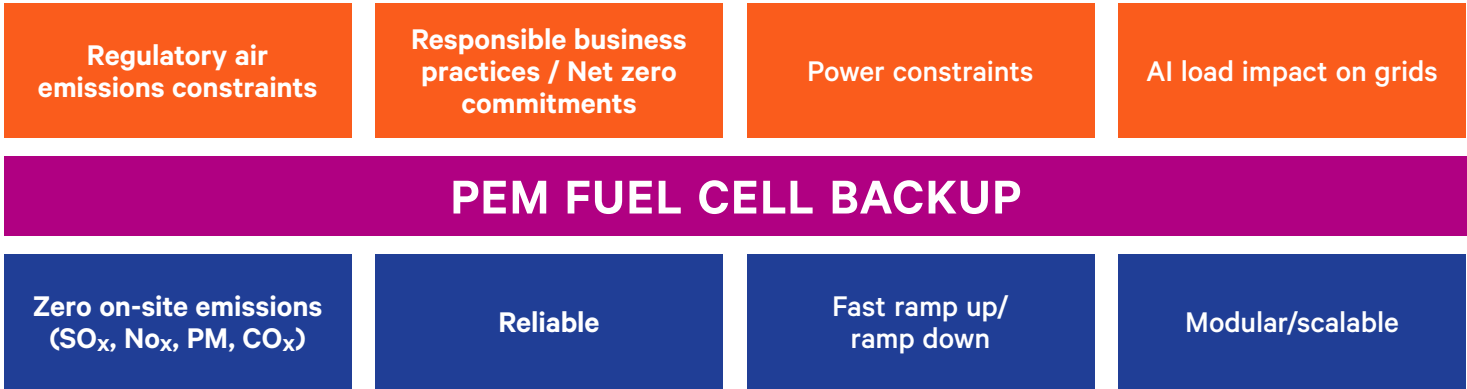


Figure 1. Visualizing the challenges and advantages of PEM fuel cells as a backup energy source.

¹ Goldman Sachs, 2025.
² World Economic Forum, 2025.

³ Baker, R., and Zhang, J., 2011. The Electrochemical Society.

PEM fuel cells for data centers

Beyond emergency power, hydrogen fuel cell systems can be integrated into data center power architectures, including electrical compatibility and dynamic response to AI-induced load fluctuations, offering additional potential for grid support and microgrid applications. However, key challenges—including hydrogen production scalability, infrastructure costs, and evolving regulations—must be addressed to unlock their full potential.

Functional requirements

PEM fuel cells can serve as the core power generation component for data center backup systems, but a complete solution requires additional balance-of-plant (BoP) systems. These include fuel processing, thermal management, power conditioning, enclosure and control systems, making sure the fuel cell protects systems and meets all functional requirements for powering the data center as backup:⁴

- **Black-start capability:** The fuel cell system must be able to start independently without external grid power, facilitating recovery for data center operations even in total blackout scenarios.
- **Startup time, ramp, and ability to withstand transient AI workloads:** The system should rapidly respond to sudden load changes, maintaining stable voltage and frequency during power fluctuations without delays or disruptions.
- **Outdoor placement:** While PEM fuel cells exhibit favorable dynamic properties, they are not inherently capable of full load-following operations. To enhance the system's capability for a dynamic response, some form of energy storage, typically batteries, is integrated to provide bridging power during fuel cell ramp-up and to absorb excess power during ramp-down.
- **Seamless integration in microgrids:** The fuel cell system should support smooth transitions between grid-connected and islanded microgrid operations, enhancing resiliency and supporting grid stability.
- **Integrated solution:** Data center backup systems integrate all internal subsystems with minimal interfaces required for connection to the data center site infrastructure.
- **Prefabricated and factory-tested:** Modular construction should enable fast deployment, with factory-built components that simplify on-site assembly and commissioning, reducing labor and installation time and costs.

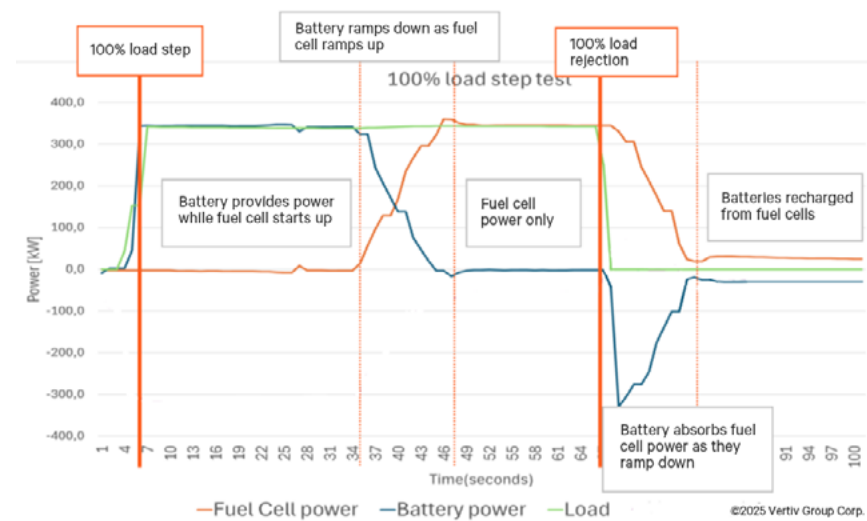


Figure 3. Fuel cell (battery) load sharing.

Balance-of-plant (BoP): From PEM fuel cell to backup system

Balance-of-plant (BoP) components transform a PEM fuel cell into a fully functional bridging backup system capable of supporting data center operations. Especially with high-performance computing (HPC) workloads, auxiliary and non-computing infrastructure such as cooling, power distribution, and safety and environmental controls are crucial for maintaining optimal operating temperatures, advanced monitoring systems, and high availability and accessibility.

- **Power generation:** The system converts stored hydrogen and air into electricity by the fuel cell stack, facilitating consistent fuel delivery, pressure regulation, flow management, stack cooling, and safety shutoff mechanisms.
- **Power conditioning:** This involves converting fuel cell-generated DC power into grid-compatible AC electricity for data center equipment. The process requires inverters, transformers, voltage regulators, and internal power distribution to provide a single bulk output to the data center.
- **Energy storage:** While PEM fuel cells have good dynamic properties, they are unable to act as a load-following source of power. Some form of energy storage, typically batteries, is introduced to the system to improve dynamic response capability: providing bridging power during fuel cell ramp-up and absorbing excess power during ramp-down.
- **Thermal management:** The system controls the temperature within the fuel cell stack and power conversion components to prevent overheating and increase efficiency. This includes cooling loops, heat exchangers, heat rejection, and airflow systems to maintain optimal operating conditions.
- **Control systems:** This is for monitoring and optimizing fuel cell performance, and for managing temperature, airflow, and electrical output based on real-time demand. Automated controls check for smooth grid integration and backup system activation during power outages.
- **Enclosure:** This safeguards components from environmental factors like moisture, dust, and temperature fluctuations. The modular and prefabricated design allows for rapid deployment, simplifying installation, scalability, and maintenance.

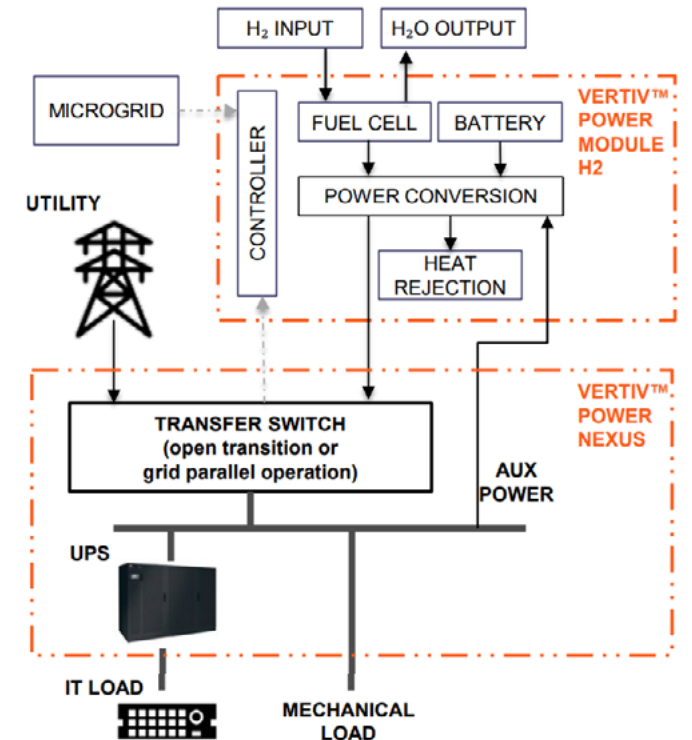


Figure 4. PEM fuel cell backup system block diagram. Source: Vertiv

⁴ Expert summary insights from discussion-interview with Ballard Power Systems and Vertiv.

Where do PEM fuel cells fit into the data center electrical topology?

PEM fuel cells can be integrated into the data center electrical topology in different configurations depending on project-specific requirements:

A. Backup system as an alternative to diesel gensets:

PEM fuel cells can replace traditional diesel gensets for backup power. To enable compatibility with typical data center electrical distribution, the system should have similar interfaces with a diesel generator.

In 2024, Vertiv (in partnership with leading PEM fuel cell company Ballard Power Systems) developed the Vertiv™ Power Module H2, a prefabricated backup power solution that can scale up to 3MW as a single low-voltage system, matching the typical data center generator capacity size.^{5 6}

B. Integration with uninterruptible power supply (UPS) in addition to batteries:

Fuel cells can be directly integrated with the UPS DC bus, operating alongside battery storage to extend runtime and enhance grid-independent backup capacity. This hybrid approach provides long-duration power, ensuring sustained support for critical loads while reducing reliance on fossil fuels.

In 2023, Vertiv officially unveiled its first- ever UPS-fuel cell microgrid integration in the Delaware Customer Experience Center in Ohio, developed with Ballard Power Systems.⁷

C. Small-scale 48V backup power systems: PEM fuel cells can serve as a high-efficiency emergency backup power source for telecommunications and critical digital infrastructure applications, delivering stable 48V DC power to critical communication infrastructure. The capability to scale down for localized energy needs makes these solutions an ideal low-footprint, long-runtime response where zero emission and low noise are required.

In 2025 and in collaboration with SFC Energy AG, Vertiv will be designing, developing, and manufacturing reliable and climate-neutral UPS for critical locations, integrating with hydrogen fuel cells that can be used for environmentally sensitive areas.⁸

Beyond backup: Utilizing the full potential of fuel cells

While hydrogen fuel cells provide zero-emission backup power for data centers, their full potential can also extend beyond emergency use. In utilizing the system to generate power when it's needed the most, data center operators can unlock additional value and significantly improve the business case for deployment.

- 1 Grid support and demand management:** Hydrogen fuel cells can provide frequency response, demand response participation, and flexible capacity agreements. This stabilizes grids and reduces dependency on fossil-fuel-based backup systems.
- 2 Energy cost optimization:** The system enables peak shaving and demand charge reduction, lowering operational costs by reducing reliance on grid power during high-demand periods.

- 3 Alternative energy integration:** Fuel cells support hourly matching of generation and load for alternative resource purchase agreements, facilitating continuous clean energy availability when alternative power is not generating.
- 4 Advantages over batteries:** Unlike battery energy storage systems (BESS), hydrogen fuel cells offer multi-hour continuous energy generation with the ability to refuel rather than recharge, eliminating energy depletion concerns for long-duration applications.

Unlike diesel gensets, hydrogen fuel cell systems are not subject to environmental restrictions on run hours. PEM fuel cells typically have a 25,000-hour lifespan, allowing thousands of hours of operation per year for backup and additional use.⁹ Main considerations for applications beyond backup include local hydrogen availability, price, and delivery logistics. Bridging battery capacity may need to be upgraded to accommodate more frequent cycling associated with participation in multiple use cases.^{10 11}

Microgrid integration capability

An inverter-based PEM fuel cell system can seamlessly integrate into microgrids for both backup and grid-support applications. Advanced inverter technology enables smooth conversion of the DC output from fuel cells into grid-compatible AC power, establishing synchronization with existing microgrid infrastructure. This allows fuel cells to support island-mode operation to supply continuous power when disconnected from the main grid, or function as a grid-following resource to stabilize voltage and frequency during fluctuations.¹²

Additionally, bidirectional inverters enhance operational flexibility, allowing fuel cells to work in tandem with battery energy storage and alternative energy-generated sources. With fast ramp-up capability and precise power control, fuel cells offer an ideal solution for distributed energy networks, improving microgrid resilience and energy reliability.

Hydrogen as fuel: Storage, delivery, and availability

Hydrogen has a high energy content by weight but not by volume, which makes storage particularly challenging. To store enough hydrogen gas to use as fuel, it is compressed and stored at high pressure or liquefied. Its low weight and density mean hydrogen is usually stored as a gas in fiber-reinforced composite-pressurized tanks or as a liquid in cryogenic tanks at around -250°C (-418°F).¹³

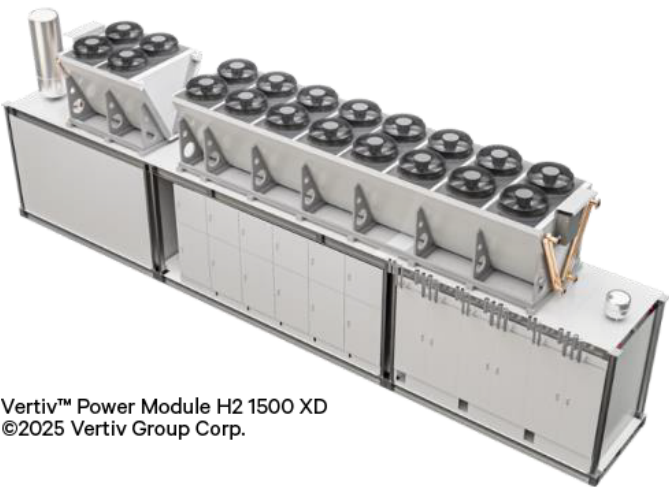
Hydrogen is about 14 times lighter than air. This means that if released in an open environment, it will typically rise and disperse rapidly. This is a safety advantage in an outside environment.

Hydrogen is colorless, odorless, tasteless, non-toxic, and non-poisonous. It is also non-corrosive, but it can cause some metals to become brittle over time. Hydrogen is the lightest and smallest element and exists as a gas under atmospheric conditions.

Hydrogen generation

Though hydrogen is an invisible gas, color codes have become popular to describe the various methods used to produce it, and one can read about green, blue, gray, pink, white, and turquoise hydrogen:

- Gray:** Produced from natural gas through a process called steam methane reforming and emitting carbon dioxide in the process.
- Blue:** Produced from natural gas, through steam methane reforming, but this time the carbon dioxide that would normally be emitted is captured and stored.
- Green:** Produced through electrolysis using electricity from zero direct emissions sources such as wind and solar.
- Pink:** Produced through electrolysis using electricity from nuclear power plants.
- Turquoise:** Hydrogen produced through methane pyrolysis of different types of waste.
- White:** Hydrogen naturally occurring in underground deposits. Research is underway to exploit this resource.



Vertiv™ Power Module H2 1500 XD
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⁵ Vertiv, 2024.
⁶ Vertiv, n.d.

⁷ Di Filippi, 2024. Vertiv.
⁸ SFC Energy AG, 2025.

⁹ Ballard, 2024.
¹⁰ Customers have the option if they need increased battery capacity, evaluated as suppliers/vendors collaborate during design and planning.

¹¹ Battery University, 2023.
¹² Wang, J., 2022. National Renewable Energy Laboratory.
¹³ US Department of Energy, n.d.

Low-carbon hydrogen production capacities commissioned or to be commissioned in the next 3 years

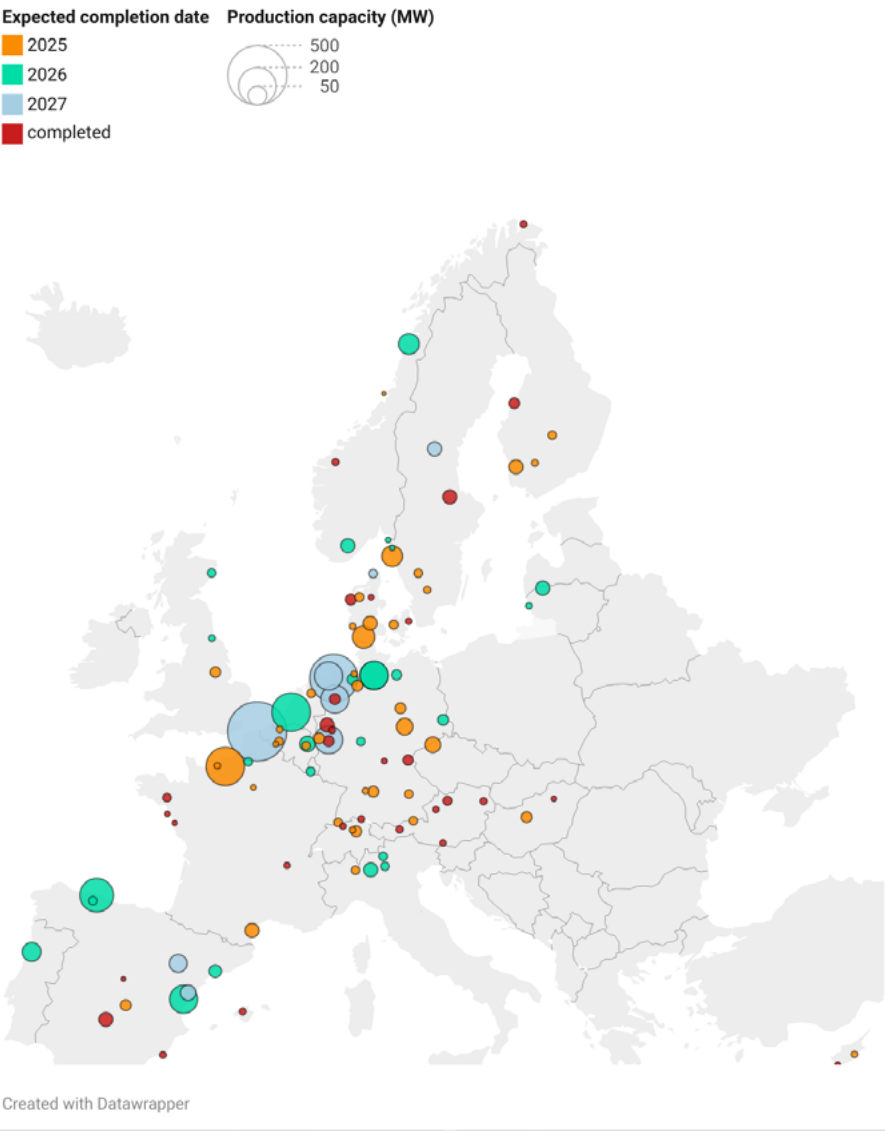


Figure 5. Hydrogen production capacities in Europe. Source: Ballard Power Systems.

These classifications occur and apply during production and therefore occur from upstream the data center.¹⁴ While the color codes have no impact on the data center and facility operators simply receive the hydrogen for consumption, the classification has an impact on the carbon-intensity of the fuel.

While these color definitions are popular, they may vary from one region to another, and do not match the legal definitions enacted across the world. For instance, in the European Union, the legislation distinguishes between “renewable fuels on non-biological origins” (RFNBOs) and low-carbon hydrogen:¹⁵

Renewable fuels of non-biological origins (RFNBOs): Hydrogen and derivatives produced with electricity coming from new renewable sources, located close to the electrolyzer, and can generate electricity at the same time as the hydrogen is produced.

Low-carbon hydrogen: Hydrogen produced while saving at least 70% greenhouse gas emissions compared to hydrogen made from fossil fuels.

In the U.S., a general definition of “clean hydrogen” is found under section 45V of the Internal Revenue Code, with tax credits up to \$3/kg related to the emission intensity of the hydrogen produced.^{16 17}

¹⁴ No methane onsite or near the PEM fuel cell module/s. PEM fuel cells can operate on hydrogen regardless of how it was made, as long as the fuel complies with purity requirements.
¹⁵ Dulan, M., and Erbach, G., 2025. European Parliament.
¹⁶ US Department of Energy, 2025.
¹⁷ US Department of the Treasury, 2025.

Hydrogen availability map

While gray hydrogen is the main source of hydrogen today and is generally available in all advanced economies, future production facilities will primarily supply green and blue hydrogen.¹⁸ In Europe, the largest planned capacity of electrolyzers can be found (in descending order of supply availability) in Germany, Sweden, France, the Netherlands, and Denmark. This should result in production capacity of renewable and low-carbon hydrogen increasing 10 to 20 times by 2030, greatly improving the availability of zero-emission fuels for stationary power applications.¹⁹

Hydrogen is commercially produced and used across the US and Canada. Most hydrogen produced today in the United States is gray hydrogen. But a growing number of low carbon hydrogen production site are being developed.²⁰

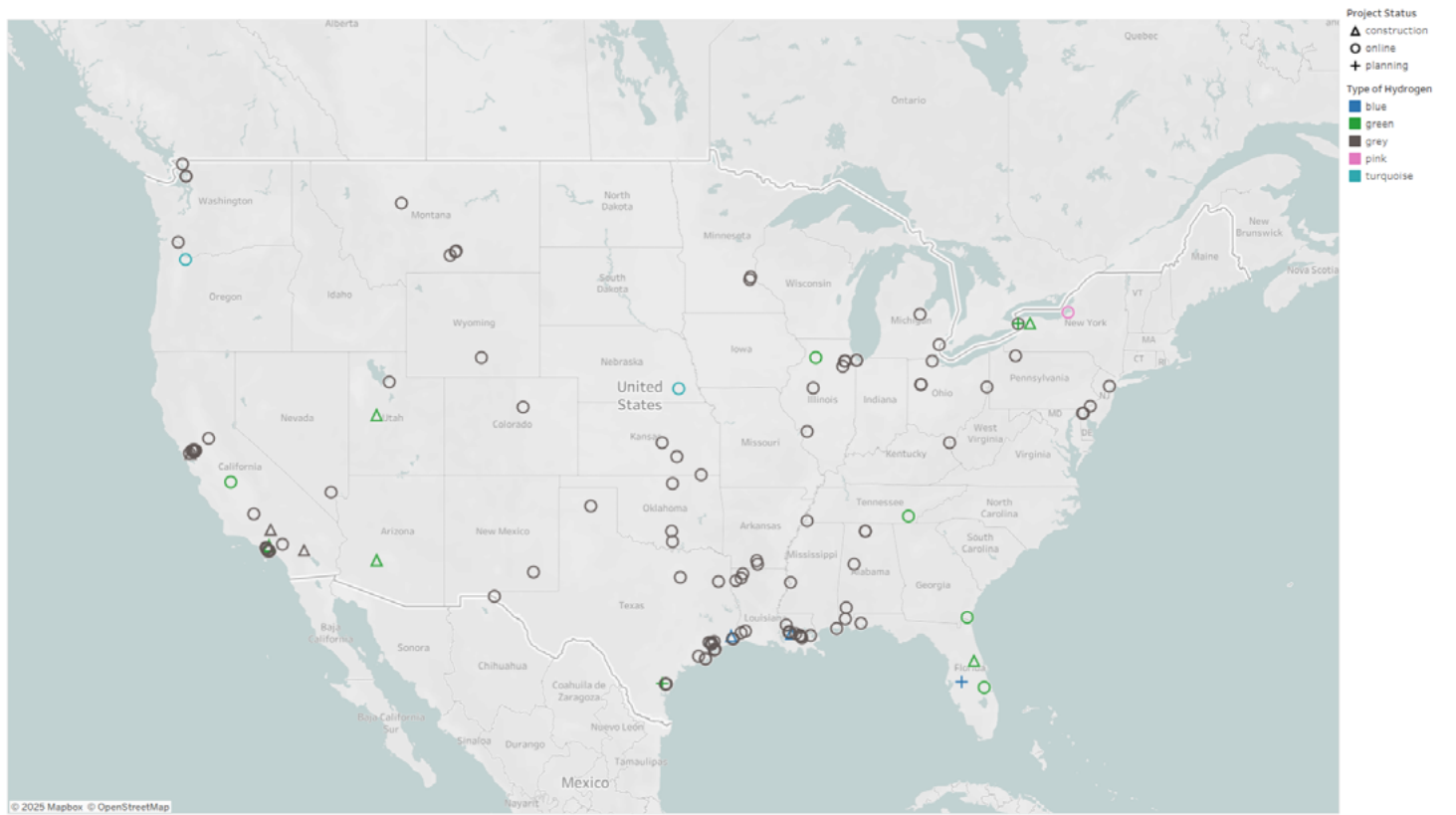


Figure 6. Hydrogen production capacities U.S. Source: Clean Energy Group.

¹⁸ From a business perspective, using blue or green hydrogen fuel cells will capture a lower carbon footprint count compared gray hydrogen.
¹⁹ Ballard Power Systems internal tracking database.
²⁰ Ballard Power Systems internal tracking database, and insights from Ballard Power Systems and Vertiv experts.

Hydrogen delivery and storage

There are two main pathways to get hydrogen onsite:

- 1 Delivered hydrogen, or
- 2 On-site hydrogen production through electrolysis (green hydrogen) or steam methane reforming (SMR, with gray hydrogen), including various combinations of the two.²¹

The development of large hydrogen production plants, and hydrogen hubs and valleys, will allow transit agencies to consider hydrogen pipelines as another pathway to the molecule delivery in specific geographical areas where hydrogen production and storage plant/s are in proximity to hydrogen consumers.

For back-up power applications, the off-site production of hydrogen is the preferred solution. Hydrogen can be delivered and stored onsite as gas or liquid. The choice between gas and liquid will depend on the quantity of hydrogen required to support the site's operation.

- **Liquid hydrogen** offers a smaller storage footprint compared to gaseous hydrogen, making it a more space-efficient option for high-volume on-site storage. This makes it particularly suitable for applications requiring large quantities of hydrogen to be readily available. However, one key drawback is **boil-off**, where hydrogen naturally evaporates at a rate of up to **0.5% per day**, leading to gradual losses over time.

Boil-off hydrogen can either be vented to the atmosphere or recycled for on-site use, but repurposing it requires additional compression and processing infrastructure to bring it to the correct pressure for fuel cell consumption. This challenge is especially pronounced in intermittent-use scenarios, such as backup power and grid support, where hydrogen stored remains largely unused for extended periods. Liquid hydrogen is typically transported in trailers with a capacity of up to five tons, translating to approximately 70 MWh of usable electrical output of a PEM fuel cell backup system.

- **Compressed gas hydrogen** provides a versatile storage solution, particularly for applications requiring on-site fuel reserves without the complexity of cryogenic infrastructure. Compared to liquid hydrogen, compressed storage operates at high pressures (typically 350–700 bar). One advantage of compressed hydrogen is its straightforward handling and transportability. However, the lower volumetric energy density compared to liquid hydrogen means storage footprints tend to be larger, requiring more physical space to hold equivalent energy quantities.

For backup and grid-support applications, compressed hydrogen does not suffer from boil-off, making it more suitable for intermittent use cases where long-term fuel storage is needed without frequent replenishment. Typically, tube trailers carry 500–1,000 kg of hydrogen, corresponding to seven to 14 MWh of fuel cell electrical output, though larger stationary storage tanks can scale capacity as required.

- **Hydrogen delivered via pipeline infrastructure** provides a continuous, on-demand fuel supply, eliminating the need for on-site storage and refueling logistics. Unlike compressed or liquid hydrogen, pipeline-delivered hydrogen facilitates stable pressure and flow rates, reducing operational constraints associated with storage capacity limits or fuel depletion concerns. However, the feasibility of piping hydrogen to a data center is highly site-specific: this requires a nearby hydrogen production/storage facility that is open to engage in such arrangements.

While considering a fueling model with delivered hydrogen, the cost of a kilogram of hydrogen will likely be calculated by the distance to the hydrogen production facility and according to the production process. In specific cases where the production is close enough to the fuel cell site, hydrogen pipelines could be considered feasible but would require a minimal daily consumption threshold to justify the investment.

Challenges associated with hydrogen fuel cells

Can PEM fuel cells be used for prime power?

PEM fuel cells are well-suited for backup and grid-support applications, but face challenges when used for prime power generation.

- 1 **Hydrogen cost and availability:** Commercial scale hydrogen production remains expensive, particularly when sourced from green hydrogen.
- 2 **Supply and processing:** Hydrogen infrastructure for an uninterrupted supply is still under development in many regions, complicating fuel supply logistics.
- 3 **Stack refurbishment:** PEM fuel cell stacks degrade over time and typically require refurbishment every 25,000 hours (approximately the equivalent of three years of continuous use), adding to long-term maintenance costs.

Considering its use for critical digital infrastructure, Vertiv and Ballard Power Systems see data center facilities being able to maximize the benefits of hydrogen fuel cells as a backup energy resource, offering the flexibility and scalability of up to 500h/year.

- **Permitting:** Permitting complexity varies based on local regulations and jurisdictional familiarity with hydrogen technologies. Some Authorities Having Jurisdiction (AHJs) may need more experience with hydrogen systems, leading to extended review timelines. The permitting process is typically smoother in locations where regulators have pre-existing frameworks for hydrogen storage, safety standards, and grid integration. Early engagement with local permitting authorities, as well as partnering with experienced consultants, can significantly reduce approval challenges and streamline the regulatory pathway.²²

- **Safety:** Hydrogen is highly flammable, with a wide ignition range and an invisible flame, demanding strict leak detection and ventilation protocols. Proper handling of compressed or liquid hydrogen requires specialized storage materials and site separation measures to minimize risks.

- **Novel technology:** This technology is still in an early phase of adoption for data centers. Unlike traditional diesel backup systems, hydrogen-based solutions require new operational frameworks, trained personnel, and customized infrastructure to support long-duration power applications. The level of trust in the technology may be improved by conducting smaller scale pilot projects with results shared between industry stakeholders.²⁴

- **Fuel delivery and intermittent hydrogen demand:** The feasibility of using hydrogen as the data center's backup power source ultimately depends on local supply chains, transportation costs, and proximity to hydrogen production facilities. Fuel delivery Service Level Agreements (SLAs) need to be able to support continuous fuel supply delivery in case of an extended outage.²⁵

An additional challenge is the intermittent hydrogen offtake by the data center for backup and flexibility use-case (estimated up to 500h/year), creating challenges in hydrogen generation planning by the hydrogen producer.

- **Footprint:** Compared to diesel generators, hydrogen fuel cells require approximately twice as much space on site, excluding the space requirements for hydrogen storage, and the additional distance and physical barriers required by local mandates from the nearest location of facility personnel and operations.²⁶

- **Cost:** Upfront costs remain a significant barrier, both for fuel cell system capital expenses (CapEx) and hydrogen fuel operational expenses (OpEx). However, the higher cost may be justified by the ability to deploy increased power capacity in areas where diesel generators cannot be installed or where clean on-site generation is a prerequisite for utility connection.

²¹ As of writing this white paper, steam methane reforming (SMR) is the most practical method for producing hydrogen.

²³ Draeger, 2021.

²⁴ Vertiv and Ballard Power Systems technical experts.

²⁵ Draeger, 2021.

²⁶ Vertiv, 2025. Also from interview with a Vertiv technical expert in 2024 on fuel cell requirements in Ohio as an example.

Early-stage feasibility assessment of hydrogen fuel cells as data center backup

Hydrogen fuel cells offer a viable solution for data centers where their unique advantages provide critical value, particularly in locations constrained by regulatory requirements or limited utility availability. To determine whether this technology can effectively address site-specific challenges, the following key considerations should be evaluated early in the planning process:

- **Are there air permit restrictions (SOx, NOx, PM emissions) preventing the use of diesel or gas generators?**

Hydrogen fuel cell operations do not emit any SOx, NOx, and particulate matter, which are limiting factors for diesel generator permitting and deployments.²⁷ However, hydrogen leakage risks may be evaluated as part of the permitting process.²⁸

- **Is your data center deployment constrained by noise limitations?**

Hydrogen fuel cell systems do not involve combustion processes; the main source of noise is the heat rejection equipment.

- **Does your utility connection require the reduction of power use and loads at certain times?**

Flexible, dispatchable on-site power can help support grid utility connections, especially in geographically facility-dense areas, when capacity is not available.

- **What are the power flexibility services that the system could provide to the grid?**

Utilizing the system for grid balancing provides a revenue stream that improves business case for fuel cells. Moreover, leveraging the value stack brought by regional and local incentives with the production and use of clean energy can bring the data center facility additional savings for reallocation to crucial operational and business concerns.

- **What is the hydrogen availability and cost in the area?**

Ideally, a nearby hydrogen production and storage facility can support the site with reliable fuel deliveries. If feasible, a piped connection to hydrogen storage reduces the on-site footprint and complexity. Local incentives and subsidies may be available for hydrogen systems.

- **Is there sufficient space onsite?**

Hydrogen systems require more white and gray spaces compared to diesel generators, with setback distances required from neighboring sites and buildings.

The figure below shows footprint requirements for a 1MW IT data center with a 2N electrical topology, utilizing two Vertiv™ Power Module H2 1500' XD systems as a backup solution. It is a reference to help inform early-stage planning.

Hydrogen storage consists of two 1000kg compressed hydrogen trailers at approximately 500bar pressure, providing 24 hours of backup power duration at a 1.2MW load. There is a space provision for a third trailer to support refueling: As one of the trailers is depleted, a delivery truck will bring in and position a full trailer. The authorized and trained delivery operator will make the required connections, disconnect the empty trailer, and bring it back to the hydrogen storage/production facility.

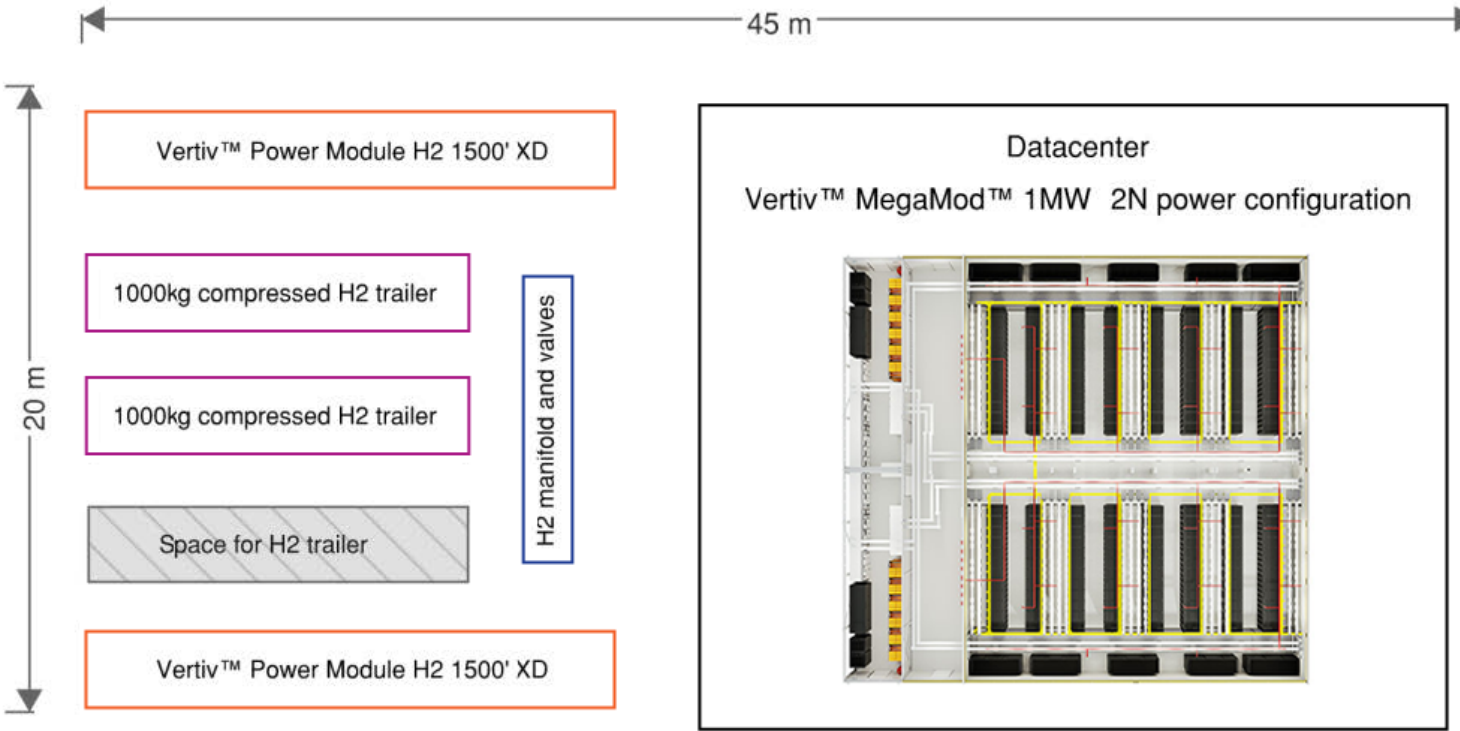


Figure 7. 1MW data center reference

Conclusion

PEM fuel cell systems offer a technically viable, highly scalable, low-emission alternative to conventional diesel generators for data center backup power, bringing fast ramp-up capability, grid integration flexibility, and resilience against load fluctuations. The technology's ability to seamlessly integrate with microgrids, systems, and crucial HPC infrastructure to drive and support increased demand for AI-driven workloads makes fuel cells a future-ready solution for critical digital infrastructures, especially relevant in regions facing permitting constraints or grid limitations.

In addition to backup functionality, PEM fuel cells unlock additional value through grid support services, including frequency response, peak shaving, and demand charge reduction, helping data centers optimize energy costs and environmental responsibility commitments. PEM fuel cells' potential to participate in energy matching for 24/7 clean power agreements further enhances their role in decarbonizing large-scale computing operations and contributing to maximizing total cost of ownership (TCO) if used as a multifunctional asset. Low maintenance requirements and potential for modular deployment also align with the distributed and scalable nature of today's data center architectures. Moreover, technology's long-term viability will likely improve with continued advances and cost reduction in fuel cell stack production, improved hydrogen costs and availability, and supportive environmental and energy policies driving competitive advantages. As the industry shifts toward net-zero objectives, PEM fuelcell solutions present a resilient and adaptable pathway for data centers seeking clean, scalable, and grid-interactive backup systems.

²⁷ Data Center Dynamics, 2024.

²⁸ Frazer-Nash Consultancy, 2022.

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