Title:

Beyond the Grid: Clean Hydrogen Pathways for Data Centres

Subtitle:

Exploring Clean Hydrogen Microgrids for Sustainable Data Centres

Preface

This paper emerges from a specialist webinar hosted by Bord Gáis in September 2026 as part of Hydrogen Ireland's EU Presidency Series, a programme designed to advance structured, evidence-based dialogue on Ireland's role within Europe's evolving clean energy and digital landscape. The session brought together policymakers, industry leaders, researchers and legal experts to examine how the rapid expansion of AI, cloud computing and high-performance digital services is reshaping the energy system, and how clean hydrogen can support the next generation of data-centre infrastructure.

The discussion highlighted a central challenge now confronting both energy and digital policy: traditional, grid-centric planning models are no longer sufficient for a world where electricity demand is accelerating faster than system reinforcement. Participants emphasised that powering Europe's digital economy cannot rely solely on a single, centralised electricity system. Instead, new frameworks are required — frameworks that integrate clean hydrogen, long-duration storage, microgrids and diversified energy vectors into the design of digital infrastructure.

This paper synthesises the insights generated during the webinar and situates them within the broader academic, regulatory and market discourse on digital-energy integration. It advances the argument that clean hydrogen is not an optional add-on to Europe's digital future, nor a universal solution to every system constraint, but a strategic enabler: a technology that can provide firm, zero-carbon power, enhance resilience, unlock industrial symbiosis and support the sustainable growth of data-centre ecosystems.

Around us, the world is changing fast. AI, cloud computing, digital payments, streaming and new online services are transforming how we live, work and connect. Ireland is becoming one of Europe's most important digital economies, a place where global ideas are built, stored and powered. With that growth comes a simple, powerful question: how do we fuel this digital world sustainably, securely and responsibly?

By aligning data-centre expansion with diversified energy strategies, Ireland can show Europe what a secure, sustainable and interdependent digital-energy ecosystem looks like in practice not as a distant ambition, but as a functioning model. This is how Ireland moves from being a participant in Europe's energy transition to being a leader of it: proving that digital expansion and decarbonisation can reinforce each other, and that a small nation with the right strategy can shape the future direction of an entire continent.

This paper aims to provide a conceptual foundation for policymakers, investors and practitioners as they navigate the complexities of integrating hydrogen into Europe's digital infrastructure during Ireland's EU Presidency period and beyond.

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1.0 Introduction

Around us, the world is changing fast. AI, cloud computing, digital payments, streaming, and new online services are transforming how we live, work, and connect. Ireland is becoming one of Europe's most important digital economies — a place where global ideas are built, stored, and powered. And with that growth comes a simple, powerful question: how do we fuel this digital world sustainably, securely, and responsibly?

By aligning data-centre growth with diversified energy strategies, Ireland can show Europe what a secure, sustainable, and interdependent energy-digital ecosystem actually looks like in practice - not as a distant ambition, but as a functioning model. This is how Ireland moves from being a participant in Europe's energy transition to being a leader of it: proving that digital expansion and decarbonisation can reinforce each other, and that a small nation with the right strategy can shape the future direction of an entire continent.

1.1 The Challenge: A Grid Under Pressure

Data centres are now essential to everyday life from the apps we use to the services our businesses depend on. But they also consume vast amounts of electricity. In Ireland, they already account for more than one-fifth of our national demand, and that number is rising.

This creates pressure: pressure on the grid, pressure on costs, and pressure on our ability to meet climate goals. And it raises a deeper issue — should our digital future depend entirely on a single, centralised electricity system? Or is there another way?

1.2 The Opportunity: Clean Hydrogen as a New Path

Hydrogen gives us that other way. Clean hydrogen can provide reliable, flexible, zero-carbon power. It can support long-duration storage, strengthen resilience, and help data centres operate without leaning so heavily on the grid.

We're already seeing the first steps. In Dublin, hydrogen fuel cells have powered a data-centre building proving that this isn't science fiction. It's happening now. And across Europe, new rules and new investments are accelerating the shift toward clean hydrogen solutions. Ireland has the renewable resources, the engineering talent, and the digital ambition to lead this transition.

1.3 Ireland's Moment: Leading by Example

If Ireland gets this right powering its data centres cleanly, managing grid demand intelligently, and creating the energy headroom that industry needs, we can do more than solve a domestic challenge. We can set a template for Europe.

We can show how a modern digital economy grows without overwhelming the electricity system. We can demonstrate how hydrogen unlocks flexibility and resilience. And we can prove that coordinated planning between regulators, grid operators, and digital infrastructure providers can turn constraint into competitive advantage.

This is how Ireland moves from being a participant in Europe's energy transition to being a leader of it.

1.4 Conclusion: A Future We Can Build Together

Today's seminar is about imagination and action. It's about asking bold questions and exploring real solutions. It's about recognising that Ireland — a small nation with big ideas, can shape the future direction of an entire continent.

Clean hydrogen gives us a chance to build a digital economy that is sustainable, secure, and proudly Irish. A future where innovation doesn't come at the cost of our climate or our grid. A future where resilience and responsibility go hand in hand.

2.0 The Grid Dependency Challenge for Data Centres

Ireland's data centre sector is at a crossroads. As these facilities now account for roughly 22% (up from 5% in 2015) of the nation's electricity usage (with operational capacity at 1.4 GW and set to rise to 2.6GW by 2030) their dependence on the centralised grid is becoming a strategic risk. Grid reliance exposes operators to escalating energy costs, connection backlogs, and growing concerns over supply reliability, especially as Ireland's electricity demand is forecast to increase by 45% by 2034. The current grid mix (43% fossil fuels, 42% low-carbon sources, and 15% imports) means that data centres are vulnerable to price volatility, emissions targets, and potential supply disruptions.

This mounting pressure prompted a decisive regulatory response. In December 2025 the Commission for Regulation of Utilities (CRU) published its new Large Energy Users (LEU) connection policy, ending the effective moratorium on new data centre grid connections that had been in place since 2021. Under the new rules, new data centres must provide on-site or proximate dispatchable generation and/or storage matching their maximum import capacity and meet at least 80% of their annual demand with additional renewable electricity generated in Ireland, subject to a six-year glide path from energisation. A de-minimis threshold of 1 MVA applies below which these obligations are waived, while system operators retain discretion to refuse connections in constrained regions such as Dublin. By explicitly tying new demand to self-supply and renewable additionality, the policy reinforces the strategic imperative for operators to reduce their reliance on the centralised grid.

The introduction of new EU low-carbon rules, requiring hydrogen to achieve at least 70% lifecycle greenhouse gas savings compared to fossil fuels, is reshaping the landscape. For Irish data centres, these regulations present both a challenge and a catalyst for innovation. Clean hydrogen, produced via low-carbon electrolysis or reforming with carbon capture, offers a credible pathway to reduce grid dependence while enhancing operational resilience. By adopting hydrogen-ready backup systems and leveraging Ireland's expanding renewable capacity (wind: 6.2 GW, solar: 2.1 GW), data centres can mitigate grid risks, meet decarbonisation targets, and reinforce their role as leaders in sustainable digital infrastructure. While the transition demands investment and robust compliance, clean hydrogen stands out as a strategic enabler for the sector's next chapter.

3.0 Hydrogen as on-Site Generation: Microgrids and Autonomy

Clean hydrogen can power microgrids that give data centres autonomy from traditional electricity networks. Here the author can explore hydrogen production via electrolysis, integration with renewables, and the role of hydrogen fuel cells in delivering reliable, zero-carbon on-site power.

There already exist many onsite generation assets used to support data centres, including reciprocating engines, turbines or fuel cells. Historically, facilities have favoured reciprocating engines fuelled by diesel. Some operators have chosen, or in some cases been forced, to adopt gas generation sources. Certain modifications to the grid code are driving these changes to generation assets and their use to deliver compliance. This is particularly needed where long term operation is required to supplement grid supplies and offer grid services as worldwide grids are constrained.

The generation industry has been working hard over recent years to decarbonise assets and facilitate a migration to cleaner fuels. The initial focus is around reducing carbon emissions at the point of use, where fuels are consumed to produce electricity. Some operators have taken the first transitional steps to adopt ethically sourced HVO in place of diesel or biomethane in place of natural gas. Unfortunately, this only offers a reduction in carbon emissions not the elimination. The use of “Green Hydrogen”, produced using curtailed renewable energy sources with electrolysers, can offer the elimination of carbon emissions at point of use.

Conventional fuels are merely refined and then consumed. Carbon free Hydrogen is produced using electrolysers, splitting water into its constituent parts, which consumes excess renewable energy which is otherwise lost to curtailment. The hydrogen produced can then be stored for later use at times of high carbon intensity or grid stress. Generation assets can then consume this stored hydrogen to produce electricity without carbon emissions and ease the grid stress. This offers a unique flexibility not available from other fuels and plays a vital role in offering autonomy from the grid.

There now exist many generation sources that can be powered by hydrogen offering distributed energy sources for microgrids that can deliver flexible clean power. These fall into three main categories: fuel cells, reciprocating engines and turbines. Fuel cells cover a wide range of technologies, but all convert hydrogen electrochemically to electricity. All categories offer a high level of maturity in the market which is beneficial to their adoption into the highly risk averse data centre sector. These generation assets offer limited inertia and typically respond slowly to demand changes. When they are deployed to supplement a grid supply, this is not an issue. This is evident in the trial use of hydrogen in on-site generation to supplement grid supplies.

Case studies show the use of hydrogen powered onsite generation assets is feasible at many scales. In Singapore, DayOne Data Centres broke ground on a 20MW hyperscale facility piloting hydrogen-powered solid oxide fuel cells (SOFCs) for AI workloads.[1] [2] Similarly, South Korea's Doosan Fuel Cell and partners launched a pilot combining hydrogen SOFCs with gas engines to create resilient microgrids for data centres.[3] These examples highlight hydrogen's role in innovation and supports autonomy from the grid.

Data centre power is taken from the grid, distributed to multiple power streams, transformed to low voltage, conditioned through a UPS (uninterruptible power supply), and then distributed to IT cabinets where it is consumed.

Critical to Data Centre power is its reliability, therefore redundancy and resilience are key. The Uptime Institute qualifies that while a grid supply is required, it is also expected to fail and provision for alternative on-site power generation must also be made. Standby reciprocating generation is favoured but can only be operational for <500hrs annually based on the Medium Combustion Plant Directive applicable to facilities with generation <50MWth or <25MWe (subject to efficiency). This run time measure includes both testing/maintenance and actual runtime hours accrued and averaged over 3-5 years.

A microgrid requires greater flexibility to deploy its generation assets in favour of the grid, therefore the running hours cannot be limited. Microgrids combine multiple generation assets, energy stores and loads which must all work together to match demand and supply whether the grid is available or not. The storage assets often include Battery Energy Storage Systems (BESS) offering a medium term (hours) power source. These were normally paired with a grid following inverter, but technology developments are seeing grid forming assets considered to support stability.

As the loads are critical data centres, there is limited or no flexibility to control their demand. It falls to the microgrid generation and storage assets to respond, matching the demand at every step to maintain stability. The microgrid also manages the interconnection with the grid; importing and exporting power, consuming or storage energy as best suits the operational control philosophy. This control bias can be tailored to reducing electricity costs or carbon emissions. The control is key, as it must also manage the stability of the supply given failures of the grid and its own assets. This is where UPS are typically retained in the data centre infrastructure to protect from short term interruptions and poor power quality.

The autonomy of the microgrid refers to its ability to operate without the presence of the grid. The system becomes reliant on its own controlled generation assets and

[1] DayOne breaks ground on first Singapore data centre to trial hydrogen-based power generation - The Business Times
[2] DayOne hydrogen-powered AI data centre takes shape in Singapore - Techgoondu
[3] Hydrogen Fuel Cells Revolutionize Data Center Power In South Korea – Hydrogen Fuel News

storage systems, generally designed and intended to operate for up to 24 hours. Delivering autonomy with hydrogen offers an asset that works to both generate power and store energy benefitting the system in both ways.

The scale of data centres varies from 100's of kW up to 100MW. The available infrastructure to support this migration to hydrogen microgrids is evolving but will see a phased growth. Initially, smaller facilities could be completely transitioned to hydrogen microgrids operating with grid connections. Alternatively, larger scale facilities could decarbonise part of their operations using hydrogen assets to operate with existing carbon rich fuels. Reciprocating engines and turbines offer assets that can work with blended fuel supplies i.e. hydrogen and natural gas mixes. This can enable a pathway for larger facilities to deploy generation assets with a partial use of hydrogen scaling to a full use of hydrogen in the future.

The geographical location is a factor influencing the hydrogen conversion. Excess renewable generation is typically located away from large data centre hubs in city centres - transportation is therefore a key factor. Modern gas networks are a ready-made transport mechanism removing the electricity network constraint in the urban locations.

Balancing the challenges of a constrained power grid with the critical power demands of a data centre, means the microgrid must work hard. This can be achieved with a combination of different assets such as a BESS and conventional UPS. This can be simplified by the integration of a UPS asset that can deliver energy storage (battery and flywheel), improve power quality, deliver a grid forming source, increase system inertia using simple synchronous machine controls. The integration of power conditioning and stabilisation within this microgrid simplifies the infrastructure and enables the transition to hydrogen on-site generation.

4.0 Storage, Flexibility, and Backup Through Hydrogen

Unlike batteries alone, hydrogen offers long-duration energy storage and flexible backup capacity. Section 3 will examine how hydrogen can balance intermittent renewable supply, provide emergency resilience, and support flexible load management for data centres operating at scale, and represents an alternative to using more traditional fuel sources such as natural gas or biodiesel.

Hydrogen excels in long-duration storage, complementing batteries that handle short-term balancing. For data centres, this means backup systems that can sustain operations for days, not just hours.

Hydrogen's technical viability has been studied and confirmed across many applications. Applied to data centres, once an economically viable hydrogen supply

solution is available, hydrogen has the potential to smooth demand curves, reduce peak loads, and provide flexible backup capacity.

4.1 Hydrogen-Based Energy Storage, Grid Flexibility, and Data Centre Backup

Integrating hydrogen fuel cells into digital infrastructure represents a paradigm shift, transforming data centres from passive energy consumers into active, flexible platforms that strengthen the electrical grid. By combining short-duration battery storage with long-duration hydrogen resilience, operators can decarbonize backup power while supporting a highly flexible, low-carbon energy system.

4.2 Real-World Insights: The Dublin 0.5 MW Pilot

Equinix, in collaboration with ESB Generation and Trading, and GeoPura, completed a 15 week on-site 0.5 MW hydrogen fuel cell pilot at the Equinix DB3 International Business Exchange data centre in Dublin, Ireland. This demonstrator pilot successfully proved the technical feasibility of using hydrogen for mission-critical backup.

As data centres scale rapidly to support AI workloads, integrating hydrogen technologies may help operators meet sustainability goals while ensuring uninterrupted operations. Moving from pilot to commercial deployment highlights several key ecosystem barriers:

- **High Capital Costs:** Hydrogen systems carry a significant cost premium over traditional diesel generators, and green hydrogen fuel remains expensive.
- **Supply & Logistics:** Certified green hydrogen availability is currently limited, with unresolved challenges in transport, distribution, and physical space requirements for on-site storage tanks.
- **Regulatory Gaps:** A lack of harmonized safety standards, consistent permitting, and clear operational codes slows down deployment.
- **The Business Case:** To be viable, hydrogen must unlock multiple value streams beyond backup, including participating in grid flexibility markets and capacity mechanisms.

4.3 Grid Flexibility and Long-Duration Energy Storage

- **Seasonal Storage**: Hydrogen energy storage systems (HESS) convert surplus renewable electricity into hydrogen via electrolysis, allowing energy to be stored for weeks or months without self-discharge.
- **Renewable Integration:** By absorbing excess solar and wind power during periods of overproduction, HESS prevents renewable curtailment and stabilizes the grid.

- **Hybrid Systems:** Combining hydrogen with BESS optimizes grid response, using batteries for rapid, short-term fluctuations and hydrogen for long-duration capacity.

4.4 Decarbonizing Data Centre Backup Power

- **Zero On-Site Emissions:** Replacing traditional diesel generators with hydrogen fuel cells eliminates Scope 1 emissions, particulate matter, and nitrogen oxides, producing only water vapor and heat.
- **Scalable Reliability:** Fuel cells offer rapid response times to manage load fluctuations and can scale operational support for multi-day outages by increasing hydrogen storage volume.
- **Grid Support Revenue:** Beyond emergency backup, data centres can utilise fuel cells to participate in demand response programs, generating new revenue streams by supporting the local grid.

4.4 Implementation Challenges

- **Infrastructure & Space:** Widespread adoption requires localized hydrogen transport networks and dedicated physical space for storage tanks and electrolyzers.
- **Utility Participation & Supply:** Energy utility service providers must develop the infrastructure to supply hydrogen at scale to data centre operators across a utility network in a similar manner to the existing gas network.
- **Safety & Cost:** Managing hydrogen safety risks requires specialized monitoring systems, while green hydrogen availability remains a cost factor in many regions.

4.5 The Multi-Tiered Energy Platform

Modern sustainable data centres utilise a hybrid architecture to solve different power and grid challenges simultaneously:

- **Batteries:** Provide immediate, short-duration storage suited for fast-frequency response and rapid grid stabilization.
- **Hydrogen Fuel Cells:** Deliver long-duration resilience and backup power during extended outages lasting hours or days.
- **Grid Integration:** Enables active participation in demand response, power purchase agreements (PPAs) to fund new renewables, and waste heat reuse for local communities.

4.6 Strategic Roadmap: From Pilot to Scale

Unlocking the potential of hydrogen requires a coordinated effort across four strategic pillars:

- **Technology:** Standardise modular, highly efficient hydrogen solutions designed specifically for data centres to drive down capital costs.
- **Infrastructure:** Expand regional green hydrogen production, dedicated distribution networks, and secure refuelling logistics.
- **Policy:** Streamline local permitting, establish clear safety standards, and reward low-carbon resilience solutions.
- **Market:** Create long-term demand visibility to signal investors and develop robust grid-service markets that value flexible capacity.

5.0 Policy, Economics, and Market Signals for Hydrogen Adoption

The transition to hydrogen-powered data centres depends on supportive policy frameworks and market incentives. Section 5 will analyse carbon pricing, renewable hydrogen subsidies, and evolving electricity markets that can make hydrogen integration economically viable and strategically attractive.

Hydrogen adoption requires supportive frameworks. Carbon pricing, renewable hydrogen subsidies, and market reforms can make hydrogen competitive with conventional grid power.

The European Hydrogen Valleys initiative provides a blueprint, with projects across Spain, France, and Germany demonstrating how regional hydrogen hubs can scale production and reduce costs.[4] [5] In Singapore, partnerships between Air Liquide and Aster are developing low-carbon hydrogen with integrated carbon capture, aligning with national hydrogen strategies.[6] These policies and investments show how governments can accelerate hydrogen integration into critical infrastructure like data centres.

[4] Hydrogen Valleys | European Hydrogen Observatory
[5] H2 Valley map | H2Valleys
[6] JTC, NUS to explore setting up new facility on Jurong Island to test green data centre innovations - The Business Times

5.1 Ireland's starting point

The policy case is sharpened by the scale of Irish data-centre demand and grid constraints. The CRU's final Large Energy Users connection policy requires new data centres to provide onsite or proximate dispatchable generation and/or storage matching maximum import capacity, participate in the electricity market, and source at least 80% of annual demand from additional renewable electricity generated in Ireland, subject to the policy's glide path and implementation conditions. [1] These obligations create a role for clean dispatchable assets, but they do not give hydrogen a guaranteed revenue stream or make hydrogen a substitute for the separate renewable-electricity requirement.

Ireland's 2023 National Hydrogen Strategy supplies the framework: renewable hydrogen should be directed towards hard-to-electrify uses, long-duration storage and dispatchable power, while direct electrification remains preferable where practical. [2] That hierarchy is important for data centres. Batteries and grid electricity should serve fast response and routine energy needs; hydrogen should be tested where duration, fuel storage or resilience value exceeds what batteries can provide economically. Peer-reviewed literature similarly finds that power-to-hydrogen-to-power carries material conversion losses, while hydrogen's advantage lies in storage duration and sector coupling rather than round-trip efficiency. [3–5]

5.2 Closing the Irish Hydrogen Viability Gap: Carbon Pricing, Subsidies and Electricity-Market Reform

5.2.1 Carbon pricing: raise the fossil counterfactual, without overstating coverage

Two carbon-price regimes may affect Irish data-centre generation, but their legal incidence differs. The EU Emissions Trading System (EU ETS) applies to covered stationary installations, including qualifying combustion activity, under Directive 2003/87/EC as amended.[6] Whether a particular data-centre generation portfolio is inside the EU ETS depends on its permitted activities, aggregate rated thermal input and applicable aggregation or exclusion rules; standby status does not by itself justify assuming either inclusion or exclusion. Where generation is covered, the allowance obligation increases the variable cost of natural-gas or liquid-fuel operation and makes lifecycle-qualified renewable hydrogen relatively more attractive. Site-specific permitting and legal review are therefore essential.

Ireland's domestic carbon tax applies through excise duties on fossil fuels outside the EU ETS framework, with reliefs intended to avoid double carbon pricing in relevant circumstances. The statutory trajectory is towards €100/tCO_2 by 2030; the applicable rate, commencement date and relief depend on the fuel and use. [7] For non-ETS diesel or natural-gas backup, the tax increases fuel cost but is unlikely, on its own, to close the renewable-hydrogen premium. Its strategic effect is stronger over the life of

new generation assets: it increases exposure to fossil operating costs and the risk of locking in equipment that may face tighter emissions, permitting or customer-carbon requirements.

Ireland should therefore avoid a data-centre-specific carbon exemption. Instead, policy should maintain predictable fossil-carbon escalation while preventing overlapping EU ETS and domestic-tax liabilities. Operators should model three counterfactuals - diesel backup, natural-gas generation and hydrogen/fuel-cell resilience - using the legally applicable carbon regime, expected operating hours and lifecycle emissions. Renewable hydrogen must also satisfy EU sustainability and greenhouse-gas-accounting rules; zero emissions at the point of use do not establish zero lifecycle emissions. [8]

5.2.2 Renewable-hydrogen subsidies: reduce price and offtake risk.

The EU Hydrogen Bank uses competitive auctions under the Innovation Fund to award a fixed premium per kilogram of verified renewable hydrogen for up to ten years. The premium is intended to close part of the gap between production cost, and the price buyers will pay, while competition reveals the minimum support requested. [9] For Ireland, the replicable lesson is auction-based price-gap support; the necessary adaptation is scale and use-case design. A national top-up or ring-fenced demonstration window could support Irish production serving strategic resilience loads, but payment should attach to certified hydrogen actually produced and contracted, with safeguards against subsidising inefficient continuous power generation.

The UK Hydrogen Production Business Model, implemented through the Low Carbon Hydrogen Agreement (LCHA), is a stronger template for bankability. It provides long-term contractual revenue support through a strike-price/reference-price structure and includes mechanisms addressing qualifying volume risk. [10] Scotland benefits from this UK-wide framework while using devolved policy to develop regional production, export and infrastructure propositions. [11] Ireland should adapt - not copy wholesale - the LCHA approach: a competitive Irish Renewable Hydrogen Agreement could provide a time-limited price premium and limited volume protection for early projects, conditional on certified supply, additional renewable electricity, firm offtake and transparent subsidy control. For data centres, contracts should normally sit with the hydrogen producer or cluster, not subsidise individual fuel-cell assets indefinitely.

5.2.3 Electricity-market reform: pay for the service, not merely the molecule.

Hydrogen-to-power becomes more credible when its value is measured against the complete fossil-resilience alternative, not only against wholesale electricity. Potential value includes avoided diesel use, connection optionality, capacity availability, balancing or system-service revenue, renewable-curtailment capture and reduced exposure to extended outages. The Single Electricity Market already contains energy,

capacity and system-service arrangements, but participation is subject to technical qualification, availability and market rules; the CRU policy creates an obligation to participate, not guarantee revenue. [1,12]

Three reforms are practical. First, CRU, Eirgrid and SONI should publish a technology-neutral route showing how hydrogen fuel cells or engines can qualify as dispatchable generation, capacity and system-service providers, including testing, metering, minimum run-time and fuel-security evidence. Second, Irish private-wire and co-location rules should enable additional or constrained renewable generation to supply electrolysers and shared storage where this is efficient and consistent with EU rules. Third, a demonstration auction should reward verified availability, duration and performance of emissions rather than energy throughput alone. This avoids encouraging unnecessary hydrogen combustion while valuing the resilience service that batteries or grid reinforcement may not provide at the required duration.

5.3 Transferability of external mechanisms to Irish data-centre hydrogen

Mechanism	Market failure / operation	Irish data-centre relevance	Verdict	Irish action and owner
EU Hydrogen Bank auction	Fixed €/kg premium awarded competitively to narrow the renewable-hydrogen production-cost gap. [9]	Can lower upstream fuel cost, but Irish projects may be too small or fragmented to compete alone.	**ADAPT**	DECC/SEAI: aggregate demand; create an Irish top-up or strategic demonstration window aligned with EU certification and State-aid rules.
UK HPBM / LCHA	Long-term strike/reference-price support plus defined volume-risk provisions improve producer bankability. [10]	Addresses the two risks most relevant to a new Irish supply chain: uncertain price and uncertain early offtake.	**ADAPT**	DECC/Department of Finance: competitively award time-limited Renewable Hydrogen Agreements to producers or clusters; require firm data-centre and third-party offtake.
Scottish regional hubs and export planning	Coordinates production, users, ports/pipelines and skills around regional demand; UK support remains a separate layer. [11]	A cluster can share electrolysis, storage and logistics across data centres and other hard-to-abate users, improving utilisation.	**REPLICATE**	Government/IDA/local authorities/GNI: designate one data-centre-linked Hydrogen Valley demonstrator; complete spatial, safety and network planning before major infrastructure.
CRU LEU policy + SEM arrangements	Requires generation/storage and market participation; SEM can value energy, capacity and services if assets qualify. [1,12]	Creates demand for dispatchability but no hydrogen-specific revenue floor.	**REFINE**	CRU/Eirgrid/SONI: publish qualification pathway; procure technology-neutral duration/availability demonstrations; prevent double recovery across grants and market payments.

Table 1: Integrated economic test for Irish data centres

Hydrogen is commercially credible only where the combined value stack closes the gap against the best alternative. The assessment should compare total annualised cost and service quality, not fuel price alone:

Fossil counterfactual: generator capital and maintenance, diesel or gas, legally applicable EU ETS or carbon-tax exposure, emissions permitting, testing, fuel security and expected replacement risk.

Hydrogen system: fuel-cell or hydrogen-ready generator capital, certified hydrogen delivered cost, storage and safety infrastructure, efficiency losses, maintenance and contracted fuel availability.

System value: capacity and system-service revenue that the asset is demonstrably qualified to earn; avoided connection or network costs; curtailed-renewable capture; and the value of longer-duration resilience.

Subsidy: transparent, competitively awarded support net of EU or Irish grants, with no double recovery and a defined route to declining support.

This framework is most favourable for backup and long-duration resilience because annual hydrogen consumption can remain low while the value of dependable capacity is high. It may also support flexible peaking where market revenue and renewable fuel supply are contractable. It remains weak for continuous prime power: electrolysis and reconversion losses mean that direct renewable electricity is normally more efficient, while high utilisation magnifies fuel-price exposure. [3–5] Carbon pricing improves the relative position of hydrogen, but support and market value must still do most of the work in early projects.

5.4 Prioritised Ireland action plan

5.4.1 Create a competitive Irish Renewable Hydrogen Agreement pilot (2027–2029).

DECC, supported by SEAI and the Department of Finance, should adopt the EU auction and UK LCHA principles: a declining, time-limited price premium with narrowly defined volume protection, awarded to certified producers or multi-user clusters. The market failure is revenue and offtake uncertainty; dependencies are State-aid compliance, additional renewable supply, lifecycle certification and firm counterparties.

5.4.2 Establish one data-centre-linked Hydrogen Valley demonstrator.

Use the EU Hydrogen Valleys model and Scottish hub approach to combine data-centre resilience demand with other suitable users, shared electrolysis, storage and logistics. [11,13] The market failure is fragmented demand and underutilised infrastructure. Selection should be competitive and location-led, with no assumption that Dublin is optimal.

5.4.3 Publish a hydrogen-to-power market and connection pathway.

CRU, Eirgrid and SONI should state how certified hydrogen assets can meet LEU generation/storage obligations and qualify for energy, capacity and system services. The objective is regulatory clarity - not preferential dispatch or guaranteed revenue. Operators should be required to demonstrate start performance, duration, availability, emissions and secure fuel inventory.

5.4.4 Preserve carbon-price credibility and avoid technology-specific fossil relief.

Government should maintain the legislated domestic carbon-tax trajectory, implement EU ETS requirements correctly and avoid duplicate charging where statutory relief applies. [6,7] Data-centre investment appraisals should disclose whether the fossil counterfactual is EU ETS-covered, carbon-taxed or otherwise relieved.

5.4.5 Require operator-led bankability evidence before scale.

Data-centre developers should aggregate offtake, run competitive supply procurement and publish comparable pilot metrics: delivered hydrogen cost, lifecycle intensity, availability, start time, autonomy, utilisation, maintenance and verified market revenue. Public support should proceed from pilot to repeat deployment only where hydrogen demonstrates incremental duration or system value over batteries, direct electrification and grid reinforcement.

5.5 Conclusion

Ireland can replicate the competitive discipline of the EU Hydrogen Bank, adapt the bankability features of the UK LCHA, and use Scotland's cluster-led planning as a model for shared infrastructure. The Irish innovation should be to connect those mechanisms directly to CRU large-energy-user obligations and the Single Electricity Market. Carbon pricing alone will not make renewable hydrogen competitive; subsidies alone risk supporting inefficient use; and market access alone does not guarantee bankable revenue. Together, however, predictable fossil-carbon exposure, competitively awarded hydrogen support and payment for verified duration and availability could make hydrogen strategically attractive for selected data-centre resilience applications. The policy test should remain strict: hydrogen should be supported where it provides additional, low-carbon system value - not simply because the technology is available.

6.0 Future Pathways: Hybrid Models and Global Hydrogen Lessons

The future lies in hybrid energy models where hydrogen complements renewables and limited grid reliance. The final section will draw on global case studies of hydrogen valleys and pilot projects, showing how data centres can pioneer hydrogen adoption and set new standards for sustainable digital infrastructure.

As Europe's digital economy accelerates, data-centre energy demand is rising faster than traditional electricity systems can accommodate. Grid congestion, renewable intermittency, and the escalating power requirements of AI are converging to create a new strategic challenge: how to power digital infrastructure sustainably, reliably, and at scale. The answer increasingly lies in hybrid energy models, systems where hydrogen complements renewables and reduces dependence on constrained grids. These models are no longer theoretical. They are emerging globally, backed by real-world pilots, hydrogen valleys, and early commercial deployments.

The future of data centre energy lies in hybrid models where hydrogen complements renewables and limited grid reliance. This blended approach optimizes costs, hedges risks, and maximizes sustainability.

Hydrogen Europe's 2025 briefing highlights how hydrogen can secure reliable energy for data centres amid grid congestion.[7] The Equinix data centre trails in Dublin, Microsoft's trials in Ireland and Wyoming, Singapore's hydrogen-ready testbeds, and South Korea's pilots all demonstrate scalable pathways. Together, these global lessons suggest hydrogen can become a cornerstone of sustainable digital infrastructure, ensuring resilience in the age of AI.

As data-centre demand accelerates and electricity systems across Europe face mounting pressure, the future of digital infrastructure will depend on new energy models that combine resilience, sustainability, and flexibility. Hybrid systems where hydrogen complements renewables and reduces dependence on constrained grids are emerging as the most credible pathway for powering the next generation of digital services, AI workloads, and cloud expansion. This section explores how hybrid hydrogen-renewable models are evolving globally, what lessons can be drawn from early adopters, and how Ireland can position itself at the forefront of this transition.

6.1 The Emergence of Hybrid Energy Models

For two decades, data centres have operated on a simple formula: grid electricity plus diesel backup. That model is now under strain. Across Europe, grid capacity is tightening, connection queues are lengthening, renewable penetration is increasing variability, decarbonisation targets, and the operational requirements of AI are forcing

[7] Hydrogen-powered data centres: securing reliable and sustainable energy HYDROGEN EUROPE'S BRIEFING September 2025

operators to rethink their energy strategies. At the same time, AI workloads are driving unprecedented spikes in demand, with hyperscale operators forecasting multi-gigawatt growth over the next decade. Hybrid systems blend renewable generation, hydrogen production and storage, on-site generation, and limited but strategic grid reliance. This integrated approach optimises costs, hedges against volatility, and provides long-duration resilience that conventional systems cannot match.

Hybrid models also enable data centres to operate flexibly, drawing from the grid when conditions are favourable, and switching to hydrogen or stored renewable energy during peak-demand periods or grid constraints. This flexibility is becoming essential in markets like Ireland, where grid capacity is increasingly scarce.

Hybrid energy models are emerging as the most credible response. These systems combine:

- On-site renewable generation (solar, wind, bioenergy)
- Hydrogen production and long-duration storage
- Flexible on-site generation (fuel cells, hydrogen turbines)
- Strategic, limited grid reliance
- Advanced energy-management systems and microgrids

This integrated architecture allows data centres to operate dynamically - drawing from the grid when conditions are favourable, and switching to hydrogen or stored renewable energy during peak-demand periods, curtailment events, or grid constraints. The result is a more resilient, cost-optimised, and sustainable energy profile.

For Ireland, where grid capacity is increasingly scarce and data-centre growth continues, hybrid models offer a pathway to expansion without exacerbating grid pressure.

6.2 Hydrogen as the Flexibility Layer

Hydrogen offers capabilities that complement and enhance renewable energy. It provides dispatchable, firm power; long-duration storage measured in days or weeks; and a pathway to off-grid or near-grid operation.

Hydrogen effectively becomes the “flexibility layer” in hybrid systems. It stabilises renewable-heavy energy portfolios, supports microgrid operation, and enables data centres to maintain uptime even when the grid is constrained. As AI workloads grow and demand becomes more volatile, this flexibility will be indispensable.

Hydrogen’s role in hybrid systems is not to replace renewables, but to enable them. It provides the flexibility and stability that intermittent generation cannot deliver alone.

Hydrogen offers:

- Firm, dispatchable power capable of supporting critical loads
- Long-duration storage measured in days or weeks, not hours
- Peak-shaving capability during grid stress events
- A pathway to off-grid or near-grid operation
- Zero-carbon backup, replacing diesel entirely

Hydrogen Europe's 2025 briefing underscores this point: hydrogen can secure reliable energy for data centres during periods of grid congestion, ensuring continuity of service even when the electricity system is constrained. secure reliable energy for data centres during periods of grid congestion, a critical insight for countries facing infrastructure bottlenecks.

As AI workloads become more volatile and mission-critical, this flexibility becomes indispensable.

Hydrogen effectively becomes the stability layer in a renewable-heavy energy system, smoothing variability, enabling microgrids, and supporting continuous digital operations.

6.3 Lessons from Global Hydrogen Valleys

Hydrogen valleys, regional ecosystems that integrate production, storage, distribution, and end-use, offer a blueprint for how hydrogen can be deployed at scale. Europe, Asia, and North America are already demonstrating how these ecosystems can support industrial clusters, transport networks, and critical infrastructure.

Hydrogen valleys regional ecosystems integrating production, storage, distribution, and end-use provide a real-world blueprint for how hydrogen can be deployed at scale. They demonstrate how coordinated planning, shared infrastructure, and anchor customers can accelerate hydrogen adoption.

Key global lessons include:

- North Netherlands Hydrogen Valley: A model for coordinated regional planning, where industrial clusters anchor demand and create economies of scale. It shows how hydrogen can support both mobility and stationary power.
- German and Austrian Hydrogen Valleys: These valleys demonstrate multi-sector integration, linking transport, manufacturing, and energy systems. They highlight the importance of cross-sector collaboration and regulatory alignment.

- Japan's Fukushima Hydrogen Valley: A renewable-heavy region where hydrogen stabilises the energy system and supports critical infrastructure. It illustrates hydrogen's role in resilience and disaster-preparedness.

Across all valleys, one insight stands out: hydrogen deployment accelerates when anchor customers exist. Data centres, with their predictable demand profiles and need for resilience, are ideally positioned to play this role in Ireland.

6.4 Data Centres as Early Hydrogen Adopters

Around the world, data-centre operators are already testing hydrogen systems. Microsoft's trials in Ireland demonstrate feasibility within a European regulatory environment, while its Wyoming project shows scalability in remote and colder climates. Singapore's hydrogen-ready testbeds prove adaptability in dense urban regions with limited land availability. South Korea's digital campus pilots integrate hydrogen with microgrids to support high-density data-centre clusters.

These pilots collectively show that hydrogen systems can be modular, scalable, and climate-agnostic. They also demonstrate that hydrogen can support partial or full off-grid operation, a critical capability for markets facing grid constraints and they also show that hydrogen can replace diesel backup, provide long-duration storage, and support partial or full off-grid operation.

The global momentum is clear: hydrogen is moving from experimental to operational, and data centres are among the earliest adopters.

6.5 Strategic Advantages of Hybrid Hydrogen Systems

Hybrid hydrogen-renewable systems deliver a balanced portfolio of strategic benefits. They optimise costs by reducing exposure to volatile electricity markets and peak-pricing events. They hedge risks by diversifying energy sources and reducing dependency on any single supply chain. They enhance sustainability by enabling deep decarbonisation of backup systems and long-duration storage. And they create energy headroom, new capacity that can support digital expansion even when grid upgrades are slow or politically constrained.

For Ireland, these advantages are particularly relevant. With a grid under pressure and data-centre demand continuing to rise, hybrid systems offer a credible pathway to growth without compromising national energy security.

6.6 Ireland's Opportunity to Lead Europe

Ireland is uniquely positioned to lead Europe in the development of hydrogen-enabled digital infrastructure. The country's strong data-centre ecosystem, ambitious renewable targets, and emerging hydrogen strategy create the conditions for leadership. By integrating hydrogen into data-centre energy strategies, developing hydrogen-enabled digital clusters, and leveraging offshore wind to produce green hydrogen, Ireland can demonstrate scalable, commercially viable hybrid models.

Ireland and Europe can:

- Integrate hydrogen into data-centre energy strategies
- Develop hydrogen-enabled digital clusters
- Leverage offshore wind to produce green hydrogen at scale
- Create hydrogen valleys centred on digital infrastructure
- Demonstrate commercially viable hybrid models
- Export expertise and standards across Europe

If Ireland gets this right powering data centres cleanly, meeting grid demands smartly, and building the energy headroom required for AI it can set the European standard for secure, sustainable, and interdependent digital-energy ecosystems. Ireland can move from being a participant in Europe's energy transition to being a leader of it.

If Ireland gets this right, powering data centres cleanly, meeting grid demands smartly and building the energy headroom required for AI, it can set the European standard for secure, sustainable, and interdependent digital-energy ecosystems. Ireland can move from being a participant in Europe's energy transition to being a leader of it.

Conclusion

Clean hydrogen is emerging as the most promising alternative to grid dependency for data centres, offering autonomy, resilience, and sustainability. Real-world pilots in Ireland, Singapore, South Korea, and across Europe show that hydrogen is not just theoretical, it is already reshaping the future of digital infrastructure.[8]

7.0 Life Cycle Assessment and Hydrogen Storage Selection for Data Centres

7.1 Environmental performance beyond the point of use

Hydrogen can contribute to data-centre resilience and the replacement of fossil-fuelled backup generation. However, low emissions at the point of electricity generation do not, by themselves, establish the environmental performance of a hydrogen-based system. Hydrogen production, conditioning, transport, storage and conversion to electricity must be considered alongside equipment manufacture, replacement and end-of-life treatment. Life cycle assessment (LCA) provides a framework for evaluating these contributions and comparing configurations delivering an equivalent service.

[8] https://doi.org/10.1007/s11356-025-36924-0

Storage is central to this assessment because it connects hydrogen supply with the timing and duration of electricity demand. Celestine et al. [9] discuss hydrogen storage technologies for large-scale data-centre applications, identifying storage as a key component of fuel-cell backup systems. Kurtz et al. [10] examine four renewable-hydrogen infrastructure scenarios for a fuel-cell-powered data centre, demonstrating the importance of coordinated production, storage and generation design.

Storage selection also requires attention to scale. Saberi Mehr et al. [11] review technologies ranging from material-based storage to compressed and cryogenic hydrogen and underground storage. Their assessment highlights differences in technical maturity and economic viability across applications. For data centres, this supports distinguishing between storage installed at the facility and bulk storage supporting the wider hydrogen supply chain.

The relevant question is therefore which combination of hydrogen production, storage and conversion can meet the required service with acceptable environmental impacts, cost and operational risk. Storage should be evaluated from the outset rather than selected after the generation technology has been specified.

7.2 Establishing a consistent assessment framework

An assessment should distinguish emergency backup, routine peak support and continuous electricity generation. These applications involve different fuel requirements, storage durations and cycling frequencies. Equipment maintained for occasional outages may remain inactive for extended periods, whereas systems supporting regular dispatch must accommodate repeated withdrawal and replenishment. Findings obtained for one operating profile should not automatically be transferred to another.

For electricity-supply comparisons, a suitable functional unit is one kilowatt-hour of net electricity delivered at a specified data-centre electrical boundary. This should be accompanied by explicit requirements for critical load, autonomy, availability and operating hours. For standby applications, an additional indicator should describe the annual environmental burden of maintaining a specified backup capacity and duration. Reporting both perspectives would distinguish the impacts of maintaining readiness from those associated with electricity delivery.

The system boundary should include hydrogen production, conditioning, transport, storage, fuel preparation and electricity conversion. Auxiliary energy, equipment manufacture, replacement and end-of-life treatment should also be included. Storage losses, unusable residual inventory and carrier regeneration must be represented where applicable.

[9] https://doi.org/10.3390/su132212654
[10] https://doi.org/10.1016/j.seta.2023.103357
[11] https://doi.org/10.1016/j.ijhydene.2024.05.182

Boundary selection can influence the comparison substantially. Agostini et al.[12] found that, when hydrogen compression electricity was included, the investigated solid-state storage tank exhibited greenhouse-gas emissions and primary energy demand similar to Type III and IV compressed-gas tanks. This finding illustrates why storage comparisons should encompass both the storage equipment and the processes needed to operate it.

Alternative configurations must also provide equivalent services. Batteries or uninterruptible power supplies retained for immediate response should remain within the assessed system. Assumptions about fuel delivery during an extended outage should explicitly describe replenishment timing and availability.

7.3 Selecting storage for the required application

The storage options reviewed by Saberi Mehr et al.[11] encompass different scales, operating conditions and supply-chain requirements. This diversity makes a universal technology ranking inappropriate. For data-centre applications, assessment should focus on the complete installation, including usable capacity, hydrogen delivery rate, auxiliary equipment, site requirements and replenishment arrangements.

Compressed gaseous hydrogen provides a useful reference configuration. Its evaluation should include compression electricity, vessel manufacture, delivery arrangements and usable inventory. The findings of Agostini et al.[12] demonstrate that including conditioning energy can alter the apparent environmental advantage of competing storage systems. For a data centre, nominal tank capacity must additionally be distinguished from the hydrogen inventory that remains deliverable at the required pressure and flow rate. Increasing storage pressure should therefore be evaluated against its implications for footprint, energy consumption and equipment requirements.

Liquid hydrogen warrants consideration where storage volume is a significant constraint [9,11.] Its assessment should incorporate liquefaction, insulated storage, handling and boil-off management. For infrequently operated backup systems, the ability to maintain the required reserve during prolonged inactivity is particularly relevant. Any recovery, consumption or replenishment strategy should be represented in both the operational model and the environmental inventory.

Metal-hydride storage requires attention to material production and thermal integration. Alves et al. [13] assessed the HyCARE prototype, including construction, operation and end of life. The hydride material, particularly titanium, was a major contributor to environmental impacts. Among the alternatives investigated, the configuration without integrated phase-change thermal storage had the lowest impacts. The study therefore illustrates that additional thermal-management equipment does not necessarily improve life-cycle performance.

[12] https://doi.org/10.1016/j.apenergy.2018.01.095
[13] https://doi.org/10.1016/j.jclepro.2025.145836

For data centres, hydrides should be assessed through the complete storage reactor and its supporting systems. Relevant criteria include hydrogen-release conditions, delivery rate, thermal demand, cycling performance and start-up requirements. Material-level storage capacity alone is insufficient to establish the suitability of the installation.

Chemical carriers and chemical hydrides broaden the available options. Saberi Mehr et al.[11] identify ammonia borane as a promising candidate for medium-scale storage while highlighting the importance of effective hydrogen release. Its consideration for data centres should therefore remain conditional on the performance of the complete process. Depending on the pathway, assessment should include release and purification equipment, consumables, spent-material handling, regeneration and return transport. High hydrogen content should not be interpreted as evidence of favourable life-cycle performance without evaluating these contributions.

7.4 Underground storage and the wider hydrogen supply chain

On-site storage and regional bulk storage fulfil different functions. The former provides an immediately accessible inventory at the facility, while the latter could support longer-duration supply balancing across multiple users. Assessing a data centre supplied through shared hydrogen infrastructure therefore requires consideration of storage beyond the site boundary.

Murray et al. [14] compared salt caverns, saline aquifers and depleted gas reservoirs across twelve scenarios involving different hydrogen production pathways and cushion gases. Within the study's assumptions, salt caverns exhibited the lowest environmental impacts across the assessed categories. Hydrogen losses and cushion-gas selection were important determinants of performance. Switching from grey to green hydrogen reduced global warming impacts by approximately 40%, while some toxicity impacts increased because of renewable infrastructure contributions. These results demonstrate that underground storage performance depends on both reservoir characteristics and the upstream hydrogen pathway.

For data-centre planning, the implication is that regional storage should be assessed as part of the delivered-hydrogen supply chain. The comparison in [14] does not establish that salt caverns are universally preferable or suitable at every location. Geological availability, infrastructure requirements and the ability to deliver hydrogen to the facility remain separate considerations. Nevertheless, transporting hydrogen from large-scale storage facilities into the site would still be challenging, and the proper method is questionable as well.

A potential configuration would combine regional bulk storage with an on-site buffer. This is a design proposition requiring evaluation rather than a demonstrated outcome of the cited study. Its assessment should include transport, compression, any

[14] https://doi.org/10.1016/j.ijhydene.2026.154907

necessary purification, and interruption risks between the storage site and the data centre. A large regional inventory cannot substitute automatically for local autonomy if the connecting supply infrastructure is unavailable.

7.5 Integrating storage with start-up and resilience requirements

Hydrogen storage provides resilience only when fuel can reach the generation system at the required time, quality and rate. Storage selection must therefore address start-up and transient operation as well as steady-state capacity.

Wang et al. [15] examine metal-hydride configurations for stationary backup power, including an arrangement in which gaseous hydrogen initiates fuel-cell operation before its waste heat supports hydrogen release from the hydride. This addresses a practical integration issue: thermally dependent storage may require an initial hydrogen or energy source before recoverable heat becomes available.

Hybrid storage may consequently merit consideration, but its environmental assessment must include both storage components and their supporting equipment. Waste-heat integration should be evaluated using the available temperature and heat flow during the relevant operating period. Heat used internally to release hydrogen should not simultaneously receive a credit for external use.

Storage capacity must also be translated into electrical autonomy using recoverable hydrogen inventory, net conversion efficiency, auxiliary demand and an operational reserve. Where the system supports both electricity-market participation and emergency backup, routine dispatch should preserve a defined minimum inventory. Replenishment assumptions should be tested against credible interruptions to production or delivery.

7.6 Implications for environmental assessment and deployment

The literature supports an integrated approach to hydrogen infrastructure [9,10], an application-specific assessment of storage scale [12], and explicit consideration of conditioning energy, material production and upstream supply [12-15]. These findings favour a selection process in which operational suitability and environmental performance are evaluated together.

Candidate technologies should first be screened against minimum requirements for autonomy, start-up, delivery rate, site constraints and replenishment. Those meeting these requirements can then be compared using consistent life-cycle boundaries and economic assumptions. This avoids selecting an apparently favourable technology that cannot provide the required service.

Sensitivity analysis should examine hydrogen production emissions, conditioning energy, transport distance, storage losses, equipment lifetime and annual utilisation. For regional supply configurations, it should additionally consider bulk-storage

[15] https://doi.org/10.1002/advs.202415736

operation and the infrastructure connecting storage to the user. Environmental assessment should extend beyond climate impacts where material requirements or other impact categories could alter the interpretation.

For Irish data centres, conclusions should reflect the proposed supply chain and site conditions. The evidence supports evaluating specific configurations rather than assuming that hydrogen's low on-site emissions establish its overall sustainability. Combining LCA with operational modelling would clarify where storage enables a defensible environmental benefit and where alternative configurations warrant consideration.

7.7 Conclusion

Hydrogen storage selection is integral to the environmental performance and reliability of hydrogen-powered data centres. Existing research shows that comparisons depend on conditioning energy, material production, supply pathways and operating assumptions [11-15]. On-site storage and regional underground storage should be evaluated according to their distinct roles within the supply chain. Integrating LCA with explicit requirements for autonomy, start-up and replenishment provides a stronger basis for selecting appropriate storage and identifying where hydrogen can support lower-impact, resilient electricity supply.

8.0 Solid Oxide Fuel Cells in Hydrogen Enabled Data Centre Energy Systems

8.1 On site power for growing digital loads

AI and data-centre growth is increasing demand for continuous electricity and cooling. US data centres used 176 TWh in 2023; a national study projects 325–580 TWh in 2028 [16]. Building enough grid capacity may take longer than building computing facilities. A solid oxide fuel cell (SOFC) plant can supply firm power at the site using pipeline gas or a qualified local fuel store. This reduces the electricity drawn through a constrained grid connection while retaining the possibility of grid support. The plant still needs fuel treatment, thermal management and electrical protection. Fast storage is needed to bridge sudden AI load changes.

[16] https://eta-publications.lbl.gov/publications/2024-lbnl-data-center-energy-usage-report

US projects show how this arrangement is being used. eBay made Bloom Energy fuel cells its primary on-site supply at a Utah data centre connected to the gas network [17]. Bloom reported about 75 MW operating and 30 MW under construction across 19 Equinix data centres in February 2025 [18]. Its April 2026 Oracle announcement described 1.2 GW contracted and deployment underway, within a framework of up to 2.8 GW [19]. Contracted capacity is not operating capacity. A Bloom publication also identifies a 1 MW Equinix installation in San Jose [20]. These projects establish a gas-fed deployment route, not pure-hydrogen service.

The US hydrogen roadmap considers hydrogen blending, pipeline reuse and synthetic methane made from hydrogen and carbon dioxide [21]. California's proposed hydrogen hub includes production, connective infrastructure and stationary fuel cells [22]. Together with existing Bay Area SOFC activity, these plans suggest a possible regional data-centre microgrid linked to future hydrogen supply. That remains a design opportunity contingent on local fuel delivery, grid rules and project investment.

8.2 A fuel pathway that preserves useful assets

The emerging US and European gas systems will contain more than one fuel. Natural gas remains available today; biomethane can enter existing gas networks after upgrading; hydrogen may be delivered through approved blends or dedicated infrastructure; renewable hydrogen can also be converted to synthetic methane for storage and transport [21,23,24]. The EU gas-market framework supports renewable gases and potential reuse of some natural-gas assets for hydrogen [23]. These are parallel supply options, not a fixed sequence that every site must follow.

[17] https://www.ebayinc.com/stories/news/new-utah-data-center-advances-our-commitment-greener-commerce/

[18] https://investor.bloomenergy.com/press-releases/press-release-details/2025/Bloom-Energy-Expands-Data-Center-Power-Agreement-with-Equinix-Surpassing-100MW/default.aspx

[19] https://www.bloomenergy.com/news/bloom-energy-and-oracle-expand-strategic-partnership-to-deploy-up-to-2-8-gw-to-accelerate-ai-infrastructure-build-out/

[20] https://resources.bloomenergy.com/hubfs/Whitepapers/Bloom%20Data%20Center%20Overview_2023_Feb.pdf

[21] https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap

[22] https://www.energy.gov/nepa/doeeis-0570-california-hydrogen-hub

[23] https://energy.ec.europa.eu/topics/markets-and-consumers/hydrogen-and-decarbonised-gas-market_en

[24] https://energy.ec.europa.eu/news/focus-hydrogen-2025-10-14_en

SOFC fuel flexibility gives operators a way to adapt a power asset as this supply mix changes. Methane-rich fuel, hydrogen-rich fuel and reformates impose different requirements on fuel processing, temperature control and gas flow [25]. A plant specified for natural gas cannot be assumed to accept an arbitrary hydrogen blend. Before procurement, the operator should establish the manufacturer's permitted fuel composition, impurity limits, blend-change rate and required modifications to piping, metering and controls. Raw biogas needs further cleaning before it can be treated as a candidate fuel.

This approach supports staged investment. A site may begin with a qualified pipeline fuel, contract certified biomethane where available, and later introduce an approved hydrogen blend or separate hydrogen feed. Surplus renewable electricity can be converted to hydrogen and stored for longer periods; synthetic methane offers another storage route where a suitable carbon source and gas infrastructure exist. Both routes lose energy in conversion. Reusing pipes or SOFC modules therefore depends on demonstrated compatibility and the delivered cost and emissions of the complete fuel chain.

8.3 Coordinating electricity cooling and heat

Fuel flexibility matters only if the power system can protect the data-centre load. Local SOFC controls maintain stack conditions. At building level, the uninterruptible power supply and battery cover power quality, switching and rapid load steps. At campus level, an energy manager schedules SOFC blocks, storage, renewable generation, grid exchange and cooling. At regional level, fuel producers and networks replenish local reserves. Bloom's load-following tests used an inverter and supercapacitors alongside SOFCs [26]; the response belongs to that combined package.

In grid-connected operation the SOFC can reduce imports and follow slower changes. During an intentional island, a qualified grid-forming source must establish voltage and frequency while storage bridges disturbances and SOFCs supply sustained energy. Black start additionally requires independent power for controls, fuel equipment, cooling and SOFC warm-up. These capabilities require separate engineering and tests; ordinary on-site generation does not establish them.

[25] https://doi.org/10.1002/fuce.202100037
[26] https://www.bloomenergy.com/wp-content/uploads/load-following-solid-oxide-fuel-cell.pdf

SOFC heat can support an absorption chiller or another useful heat load when the purchased system provides the required temperature and flow [27]. Data-centre server heat is a separate, lower-temperature stream; a heat pump may raise its temperature for residential district heating or nearby industrial use [28]. Where temperatures and operating hours match, recovered SOFC heat could preheat water or steam for high-temperature electrolysis [29]. The controller must prioritise electricity and critical cooling, then allocate remaining heat to these uses. Independent heat rejection and cooling are needed when external demand stops. This allows the campus to provide computing and potentially heat or hydrogen services without counting the same energy twice.

8.4 SOFCs as traceable energy conversion nodes

An SOFC campus links upstream fuel production with electricity, cooling and exported heat. That position makes it a useful measurement point for decarbonisation, but using an SOFC does not itself make data-centre power zero carbon. The carbon result changes with natural gas leakage, biomethane origin, the electricity used to produce hydrogen, synthetic-fuel processing and the amount of heat actually used.

A credible claim therefore follows each fuel batch or contracted attribute to a measured output. Operators should record fuel origin and composition, metered fuel input, net power delivered to IT and essential auxiliaries, heat supplied to cooling or external users, and losses in storage and conversion. Shared-network biomethane or hydrogen claims require recognised chain-of-custody rules and retirement of the corresponding attributes. EU certification rules for renewable hydrogen and renewable fuels provide one established model for checking production electricity and lifecycle emissions [30]. Section 6's lifecycle boundary can then compare the SOFC system with grid supply and other backup options on the same basis.

This accounting also clarifies the wider industrial value. A data centre could purchase renewable fuel, offer dependable power services, supply usable heat and, when surplus electricity and suitable equipment are available, participate in hydrogen production. Each service needs its own meter and contract. The SOFC is then a conversion node within a regional energy system: it can support resilient computing while making the fuel transition and its emissions independently verifiable.

[27] https://www.bloomenergy.com/waste-heat-recovery-for-chp/
[28] https://www.iea.org/commentaries/opportunities-for-district-heating-in-the-changing-energy-landscape
[29] https://www.energy.gov/cmei/fuels/hydrogen-production-electrolysis
[30] https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen/renewable-hydrogen_en

8.5 Conclusion

SOFCs can provide continuous on-site power while allowing data centres to adapt to a changing fuel supply. Current US projects demonstrate deployment mainly with gas; a shift towards biomethane, hydrogen blends, dedicated hydrogen or synthetic methane requires verified fuel quality and compatible equipment. At site level, SOFCs provide sustained electricity, while batteries and power electronics manage rapid load changes and protect critical cooling. Islanding and black start require separately qualified controls and reserves. Heat recovery can add value where demand and temperature are suitable. The climate benefit depends on the full fuel chain and measured net outputs. Under these conditions, SOFCs can connect reliable digital infrastructure to a developing hydrogen energy system.

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