JENBACHER

DATA CENTER SOLUTIONS FOR NORTH AMERICA

The power behind the cloud and beyond the grid

As the data center industry continues its rapid growth in North America, the power grid struggles to meet the increasing demand for electricity. In the near term, the grid's capacity might not be sufficient, potentially leading to power shortages and reliability issues. Thus, many data centers are looking for alternative power supply solutions beyond the grid.

INNIO Group's Jenbacher engine power plants can help solve the problem of providing reliable electricity for the data center industry until the grid is developed or is more reliable. And, with renewable fuels such as hydrogen, Jenbacher solutions can help the data center industry achieve net zero.

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1.

INTRODUCTION

1. INTRODUCTION

Power supply is fundamental to data centers, which are considered critical IT infrastructure that needs to remain operational at all times. A reliable and consistent power supply, then, enables data centers to provide uninterrupted service with minimal downtime to avoid significant business losses. Traditionally, power for data centers was supplied through a combination of affordable grid power and backup diesel generators. The key pillars of this business model, however, have faced challenges in recent years due to the aging of the U.S. power grid and high local emissions from diesel generators, which can limit data center operators' decarbonization efforts.

As a result of these challenges, the following trends have emerged recently in data centers' power supplies:

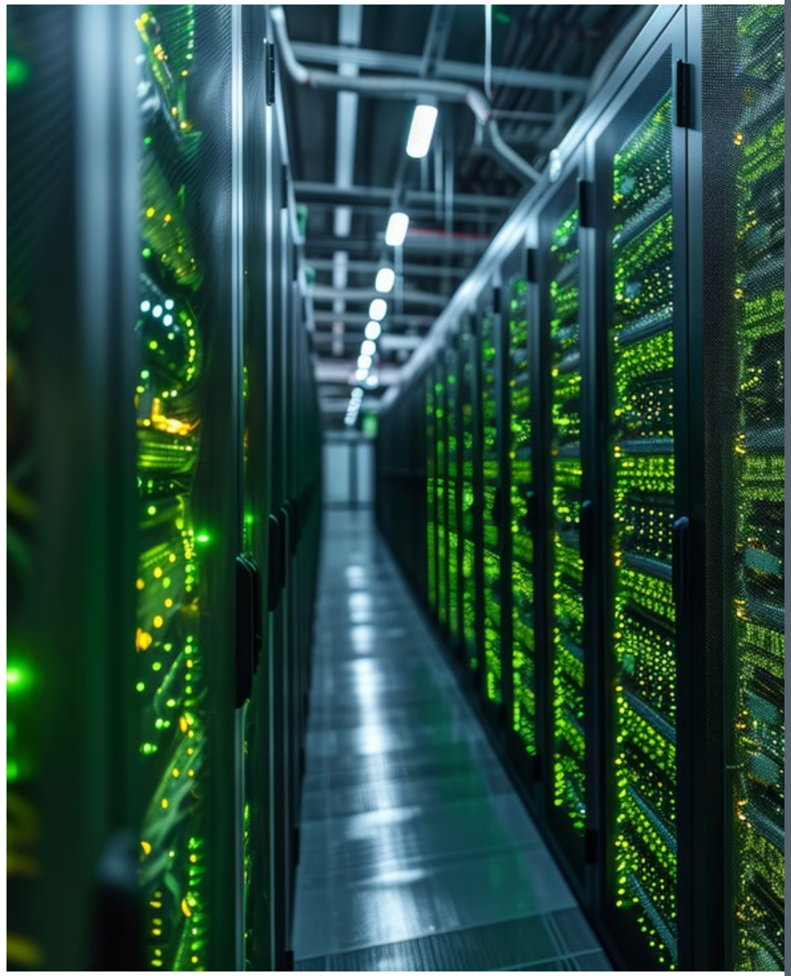
1. **Diesel generators are being replaced for emergency backup with natural gas-operated generators.** One of the cleanest fossil fuels, natural gas can be an excellent backup power choice for companies that set ambitious decarbonization targets.

2. **Gas generators are being used for continuous operations where the grid is under construction or unreliable.** Gas generators can produce reliable power 24/7 to support data centers' high electricity demand. A typical grid expansion project in the U.S. takes up to eight years, and these projects often lag behind electricity demand. Thus, gas engine power plants can bridge data center power needs until the grid is built or its reliability improves.

3. **Gas generators are providing power for several hours a day during peak periods as a cost saving, but also in times of grid curtailment.** A dedicated power generation facility that runs on natural gas can protect the data center operator against the volatility of the electricity prices. Self-generated electricity when power prices are the highest can help save data centers on operating expenses. In times of grid curtailment, self-generated electricity ensures uninterrupted operations.

INNIO Group offers a variety of Jenbacher energy solutions for data center applications to meet individual requirements—whether they are continuous, emergency backup, or hybrid setups with fast and super-fast options, some of which can take on full electric load reliably in under 45 seconds.

This paper focuses on the growing importance of gas generators in the North American data center power supply and the benefits Jenbacher energy solutions offer.



2.

CHALLENGES OF TRADITIONAL POWER SUPPLY FOR DATA CENTERS

2. CHALLENGES OF TRADITIONAL POWER SUPPLY FOR DATA CENTERS

Much of the U.S. electric grid was built in the 1960s and 1970s, and 70% of transmission lines are more than 25 years old and approaching the end of their typical 50- to 80-year life cycle, according to the U.S. Department of Energy (DOE). While the system has been improved with automation and some emerging technologies, U.S. aging infrastructure is struggling to meet rapidly growing electricity needs.

2.1 Grid availability and reliability as a key emerging risk for data centers

Data centers' electricity needs grow amid rapid adoption of AI. Around one-third of the additional electricity demand in the U.S. in the next three years (to 2026) is expected to come from the rapidly growing data center sector, according to recent projections from the International Energy Agency (IEA). Approximately 2,700 U.S. data centers used around 200 TWh of U.S. electricity in 2022, amounting to about 4% of U.S. electricity demand. This share is expected to jump to 6% (260 TWh) of total electricity demand in 2026. Going forward, forecasts show data centers consuming even a larger share of U.S. electricity, as demand from residential and smaller commercial facilities stays relatively flat thanks to steadily increasing efficiencies in appliances and heating and cooling systems.

A major factor behind the surging demand is the rapid innovation in artificial intelligence (AI), which is driving demand for digital services and data centers. Much of this growth occurs in hyperscale data centers that require exponentially more power than traditional data centers.

Grid planners struggle to keep up with the fast-growing load. Rapidly growing electricity demand, especially in already congested areas, is putting an added strain on an already fragile grid. A surge in data center, EV charging infrastructure, and industrial development in 2022 and 2023 caused sudden, large increases in 5-year load growth expectations. The nationwide growth forecast projection of electricity demand in the next five years submitted by major utilities at the end of 2023 increased from 2.6% to 4.7% or by 38 GW (summarized from 2023 Federal Energy Regulatory Commission (FERC) filings). Since the 2023 FERC load forecast filings, several major utilities once again have increased near-term electricity demand forecasts, according to a review of those regulatory filings by the research firm Grid Strategies.

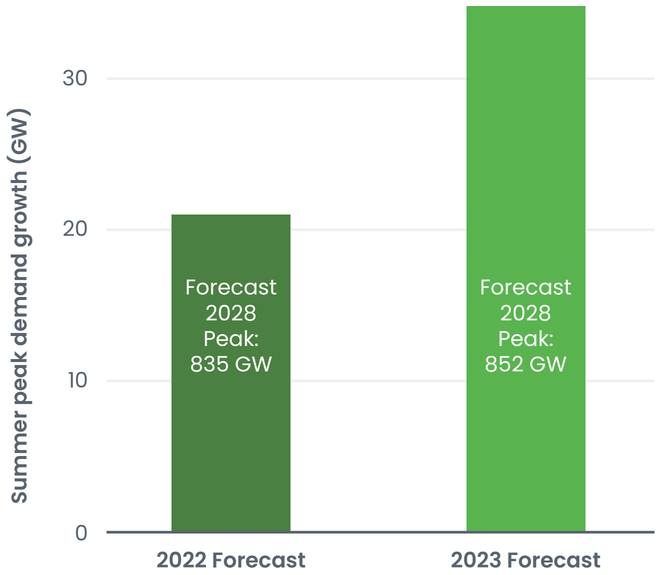


Figure 1: 5-year nationwide growth forecast
Source: Grid Strategies, 2023

2.2 Planned grid expansion projects are not likely to meet growing demand

To reach net zero, the grid must double in length to 23 million kilometers. This requires a rapid increase in annual investment to $150 billion per year by 2030, a tripling from $65 billion in 2022. North American electric utilities and transmission developers are in various stages of development on 556 individual lines that will span more than 18,000 circuit miles. If materialized, these projects would add 380 gigawatts of new transmission capacity by 2030, according to the North America Electric Reliability Corporation (NERC) and BloombergNEF data.

The expansion likely will be fragmented. Looking at the 21 largest transmission projects under way in the U.S. (based on cost of over $400 million each), these projects do not amount to a coordinated national transmission expansion of the U.S. grid but rather represent an uncoordinated expansion of regional power grids. In this unique attribute of the U.S. power grid, regions have a high degree of autonomy. Unless expansion is coordinated at the national level, the progress of upgrading the grid likely will not meet surging demand.

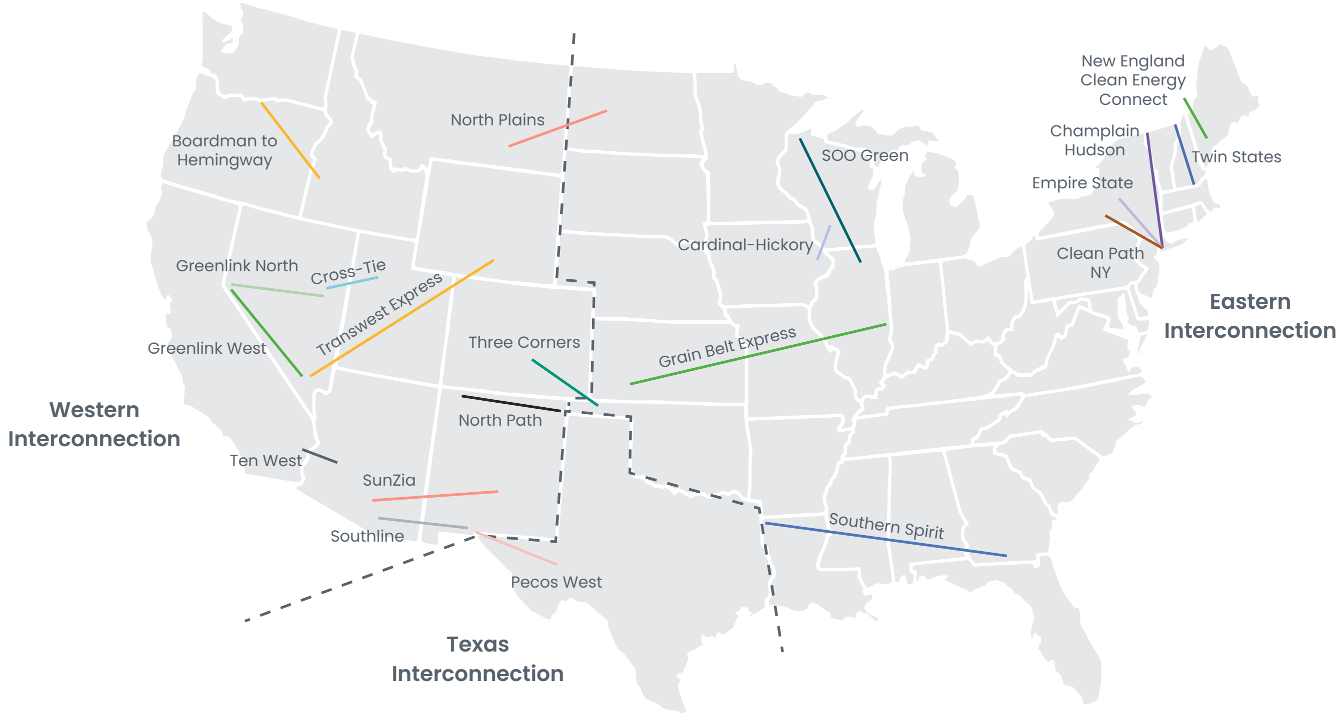


Figure 2: Map of 21 largest grid projects in the U.S.
Source: BloombergNEF, 2024
Note: Colors denote different projects. Dashed lines represent the approximate location of the interconnections.

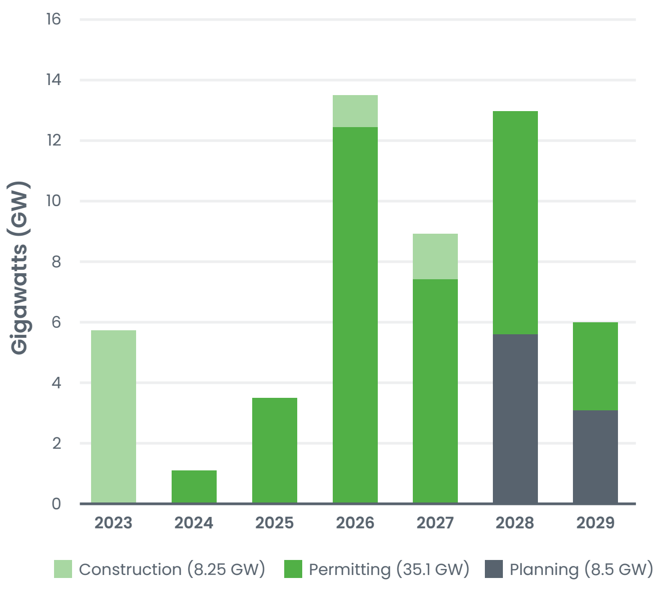


Figure 3: In-service date of analyzed projects categorized by the current development phase
Source: BloombergNEF, Grid United

Major grid expansion projects are stuck in permitting phases. Of the 21 major grid projects, only 8 GW have started construction and 35 GW face a number of barriers, such as obtaining permits and satiating interest groups, with 8.5 GW sitting in planning, which is the most tentative stage (see figure 3).

Success of future reforms is questionable. Although several permitting reforms are under way, industry is not particularly optimistic based on past reforms that were not particularly successful. For example, FERC does not have jurisdiction to permit interstate power lines as it does for pipelines under the Natural Gas Act. The electric power grid has grown under state jurisdiction, and states remain reluctant to give up that power, although that would enable a centralized and perhaps more efficient buildout. Based on Bloomberg's interviews with developers, the permitting phase is supposed to take four years, but for the largest and most ambitious projects there are instances where it can take up to a decade (see figure 4).

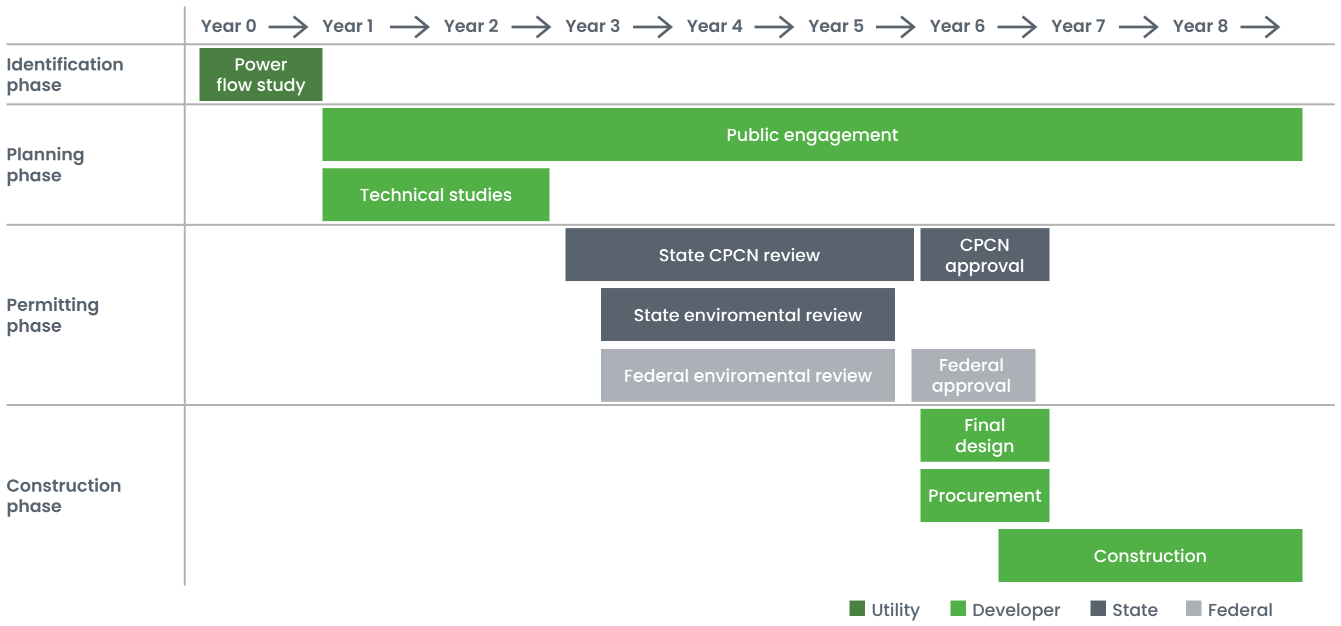


Figure 4: Typical grid transmission project timeline in the U.S.
Source: BloombergNEF
Note: CPCN is Certificate of Public Convenience and Necessity. Timelines based on qualitative BloomergNEF analysis from research calls with developers, third-party reports, and academic publications.

2.3 Grid issues are likely to grow over time

The process of obtaining permits for new infrastructure projects is often lengthy and complex, involving multiple levels of government and various regulatory bodies. These factors can prevent the grid from expanding at a pace that matches the increasing demand for electricity, particularly in areas experiencing rapid data center growth or industrial development. As a result, the grid's capacity may not be sufficient to meet the needs of data centers, leading to potential power shortages and reliability issues.

Scarce resources push data centers to remote locations. Due to rapid data center growth, locations with criteria that traditionally attracted data centers (with major internet infrastructure, a large pool of tech talent, and attractive government incentives) can become depleted. As a result, data center developers are looking at second-choice markets. But power supply and the ability to connect to the grid in some of these areas are already problematic, pushing developers ever farther out, according to JLL, a commercial real estate firm that serves the tech industry. Because the grid is unreliable or perhaps even unavailable in these remote locations, data center developers must turn to other sources to ensure a continuous power supply.

Grid expansion favors middle of the country, but reliability suffers on the coasts. The efforts to build out much-needed transmission lines are focused on the middle of the country, which are second-choice markets for data center development. However, the U.S. east coast, where most data centers are located, has weaker grid stability compared to the rest of the U.S. The system average interruption duration index (SAIDI) for the east coast was over 9 hours compared to a U.S. national average of 6 hours hours (see figure 5). Moreover, more than 60% of new data centers are expected to emerge in the regions where grid reliability already suffers, according to a 2022 study by Boston Consulting Group (BCG) (see figure 6).

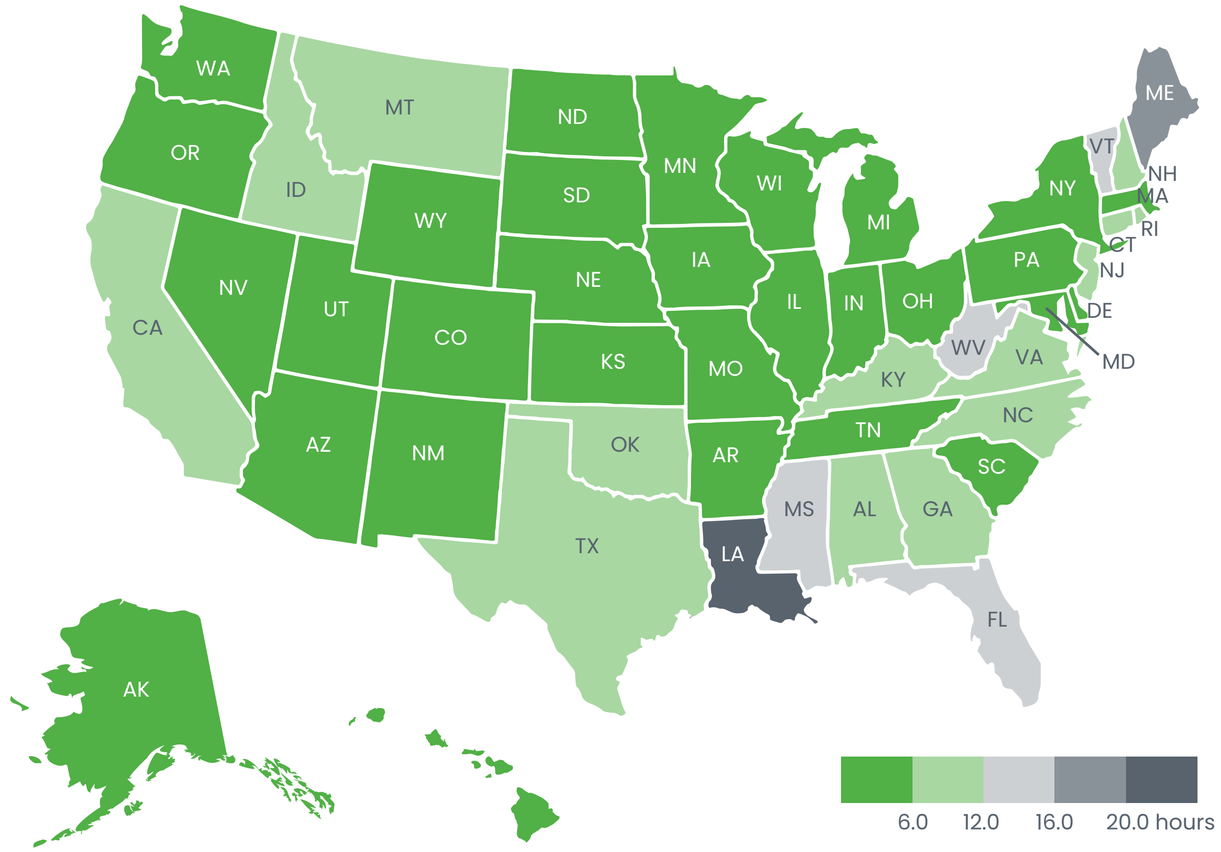


Figure 5: System average interruption duration index (SAIDI) from 2017-2021. Higher number means more disruptions and less reliability.
Source: EIA Form-861

> 60% of total U.S. data center capacity expected in MISO, CAISO, PJM and Southeast by 2027

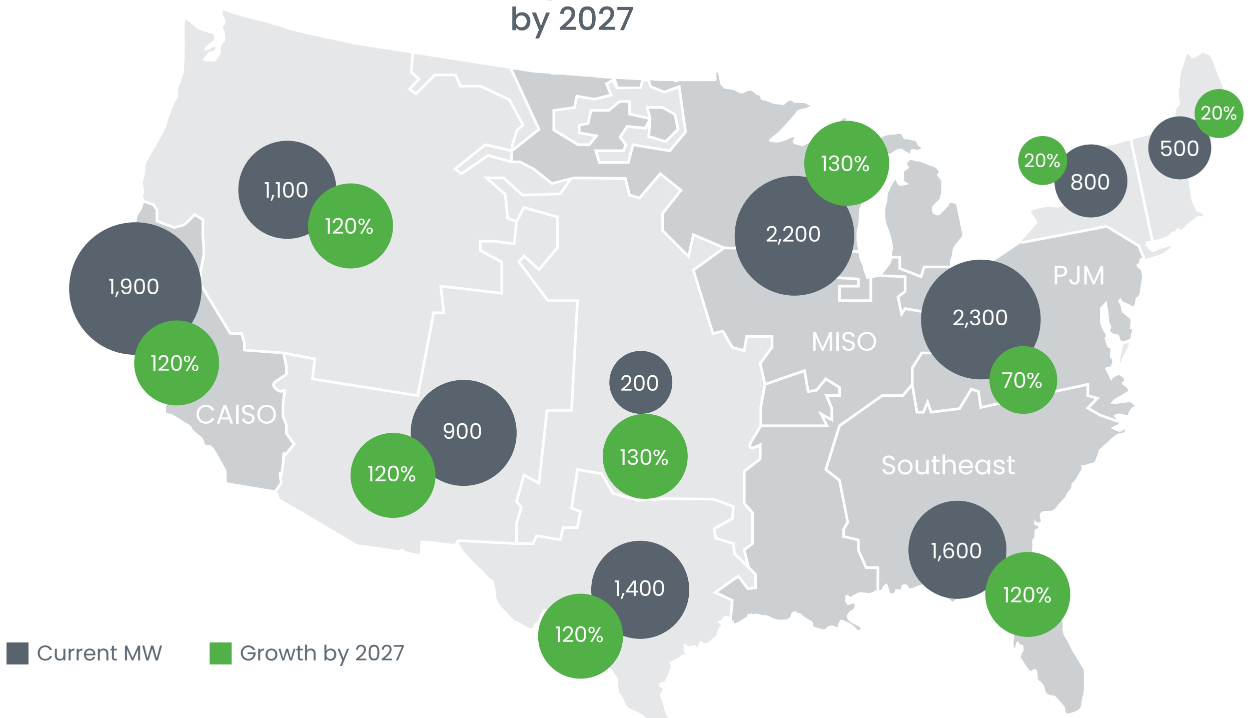


Figure 6: Expected data center growth in the U.S.
Source: BCG Analysis, 2022

Independent System Operator (ISO)	Total build by 2027 (MW)	Share of total build	Top markets
MISO	5,100	19%	Ohio, Illinois
CAISO	4,200	16%	California
PJM	3,900	15%	Pennsylvania, Virginia
Southeast	3,500	13%	Florida, Georgia
ERCOT	3,100	12%	Texas
Northwest	2,500	10%	Washington, Oregon
Southwest	1,900	7%	Arizona, Colorado
NYISO	900	3%	New York
ISO-NE	600	2%	Conneticut, Maine, Massachusetts
SPP	500	2%	Kansas
Total	**~26,200**	**100%**	

Table 1: Expected data center growth in the U.S.
Source: BCG Analysis, 2022
Note: MISO = Midcontinent Independent System Operator, CAISO = California Independent System Operator, PJM = PJM Interconnectio, ERCOT = Electric Reliability Council of Texas, NYISO = New York Independent System Operator, ISO-NE = Independent System Operator New England, SPP = Southwest Power Pool

2.4 Solving grid availability and reliability issues with gas engine power plants

Given all the grid challenges mentioned in the previous sections—the surge in electricity demand due to rapid expansion of AI, lengthy grid expansion times and permitting hurdles, fragmented grid expansion without a coordinated national effort, and the need for outsized investment—data center operators must find alternative power supply solutions. Gas engine power plants can bridge the gap, providing reliable electricity for data centers until the grid is built up or its reliability improves. Reliable, low emission gas generators can supply continuous power 24/7. When the grid is available to meet data center power needs, gas generators previously used for continuous power supply can transition to a backup solution.

Moreover, a hybrid setup involving both backup and prime power supply could be an attractive option for a data center. With a hybrid setup, gas generators can act not only as a backup power source but also can supply power continuously as a primary energy source when the grid cannot supply enough power. Gas generators also can be used for grid curtailing during peak periods when the data center is disconnected from the grid and power is supplied internally.

The design of the data centers' power supply system almost always involves some redundant capacity to help ensure the availability of its critical load during maintenance. As the grid decarbonizes with an increasing use of renewables, the need will be greater for fast-start resources to provide balancing and ancillary service solutions. Once the grid becomes available, redundant capacity also can become a source of additional revenue rather than sitting idle. The redundant capacity could generate electricity to sell on the market when prices are at their highest level. That way, the cost of the emergency power source is replaced by revenue from the electricity sales. In addition, those generators can offer their services to the capacity markets. For example, the PJM, ISO New York, and ISO New England wholesale markets all have a capacity market.

Advantages when running in island mode, disconnected from the electricity grid (self generation on site):

- Local power in remote or congested grid areas
- Cost savings due to lower grid connecting power
- Avoidance of coincident peak charges for electricity or demand charges
- Easily expandable due to grid independence
- Participation in curtailable tariffs and/or as emergency standby
- Utilization of heat or cold produced in combined heat & power or trigeneration applications

Advantages when running in parallel to the electricity grid:

- Fast-start resource—providing balancing and ancillary service to the grid
- Grid value—accommodating intermittent renewable generation
- Demand response—when needed
- Peak shaving—with the ability to sell electricity when retail or wholesale prices are high
- Utilization of heat or cold produced in combined heat & power or trigeneration applications

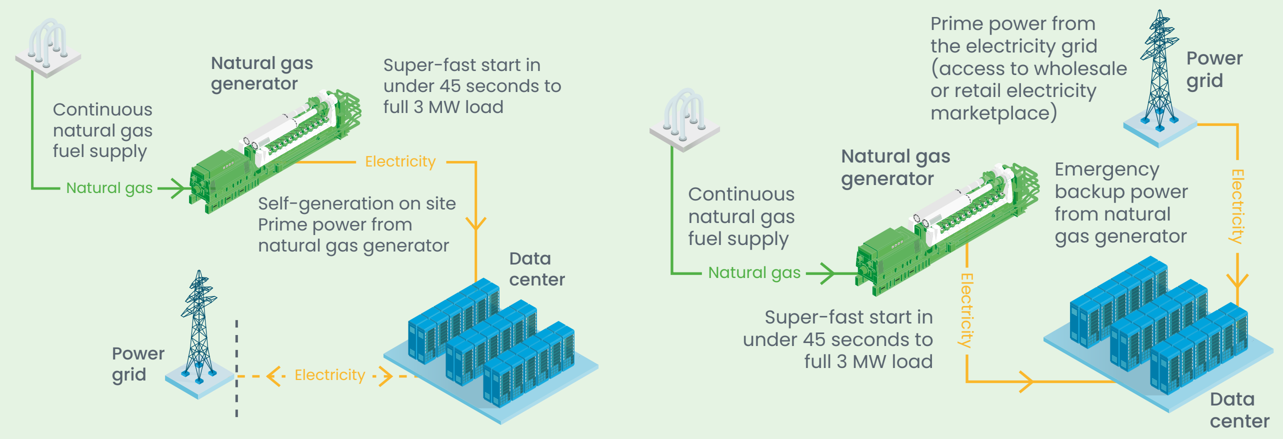


Figure 7: Comparison of advantages of prime on-site power self-generation vs. running in parallel to the grid

2.5 Jenbacher solutions for continuous operations and hybrid plant setup

INNIO Group offers a variety of Jenbacher solutions based on individual data center needs. Depending on the data center's operating system, the appropriate start option is selected. Jenbacher Type 6 engines are available with super-fast, fast, and standard start options.

Fast-start options also allow data center customers to offer ancillary services. As mentioned before, to help ensure electricity supply security, certain regions in the U.S. have capacity markets where the Jenbacher energy solutions also come into play.

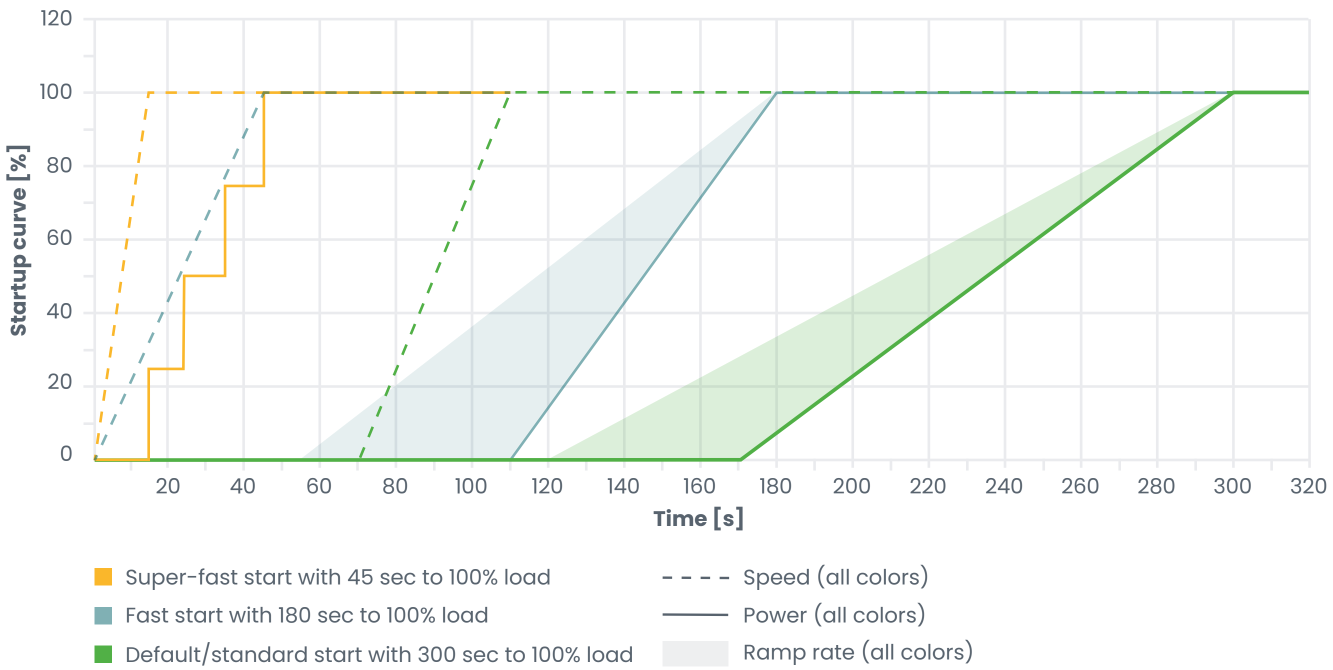


Figure 8: Jenbacher Type 6 generators: broad bandwidth of different start times
Note: Example profile for pre-heated/-lubricated; without synchronization; 480 V configuration; power quality within +/- 10% voltage, +/-5% frequency

For prime power supply of a data center, whether in island- or grid-connected mode, reliable, highly efficient Jenbacher Type 6 engines offer the advantages of outstanding high-power density with low installation costs and low emissions due to the pre-combustion chamber.

Jenbacher Type 6 generators:

Loaded with features that enhance heat recovery and stable combustion, reduce emissions, and increase efficiency, the Jenbacher Type 6 generator takes performance to a new level.

- A centrally located purged pre-combustion chamber for excellent ignition conditions.
- The spark plug ignition energy is amplified in the pre-combustion chamber, supporting stable and reliable combustion.
- Miller valve timing creates reduced compression end temperature and an increased safety margin to knocking limits, allowing improved ignition timing resulting in high efficiency.

Jenbacher J620

- 20-cylinder version
- Electrical output: 3,331 kW
- Electrical efficiency up to 45.2%

Jenbacher J624

- 24-cylinder version and two-stage turbo charging
- Electrical output: up to 4,459 kW
- Electrical efficiency up to 46.4%

When it comes to a **hybrid setup** in a data center, where backup emergency power supply is required along with continuous operations, the Jenbacher Type 6 fast-start option (180 seconds until full load) might be the most suitable fit. It combines fast-start capabilities with high electrical efficiency coupled with fast transient responses.

For data center applications where grid availability is a concern, highly efficient Jenbacher Type 6 engines offer a reliable bridging solution for **continuous power supply** during the initial period when the data center cannot be connected to the grid. Later, when the grid becomes available, Jenbacher generators also can act as emergency backup generators.

The flexibility provided by Jenbacher technology is a significant advantage for data center customers. By providing both continuous and emergency backup power, Jenbacher technology helps to prevent unnecessary costs, and to save space on the data center's premises that otherwise would be used for emergency backup diesel systems.

3.

BACKUP SOLUTION: DECARBONIZATION WITH NATURAL GAS AND RENEWABLE FUELS

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3.1 Switching from diesel to natural gas: decarbonization of emergency backup operations

Diesel generators traditionally have been the preferred backup solution option for data centers, but many data center operators are rethinking this strategy amid mounting pressures to decarbonize. Natural gas is one of the cleanest fossil fuels and can be an excellent backup power choice for companies that set ambitious decarbonization targets.

As discussed in the previous section, on-site data center power generation is changing from simply providing backup power to acting as a local power plant, which also means more operating hours per year for engines. Therefore, the traditional concept of diesel generators with a fuel tank is no longer viable due to the major increase of needed fuel and, along with it, the larger data center carbon footprint.

Natural gas is delivered through pipelines on demand, which allows data center managers to closely control their supply and budget. Natural gas supply and delivery networks are extremely reliable, since pipelines are typically underground and protected from the natural elements, although human error or natural disaster-induced disruptions sometimes occur. By converting from diesel generators to gas generators, data center operators can access the huge capacities of these networks as opposed to on-site diesel tanks.

3.2 Reliable backup power with Jenbacher technology's super-fast-start option

Primarily used for **emergency backup**, the Jenbacher J620 generator with a super-fast-start option is a highly efficient 3 MW class Jenbacher engine for data center applications that can take on load within 15 seconds and reach full load in under 45 seconds.
With their fast-start capabilities and transient performance when ramping up and down or applying loads, Jenbacher generators with fast-start option offer diesel-like performance for emergency backup with the main advantage of reduced emissions.
The load steps that can be supported by the Jenbacher J620 super-fast-start depend on the permissible frequency and voltage deviations together with the required recovery time. It can take 35% of nominal load in a first step complying with ISO 8528-5 class 3, which represents stringent limits on voltage and frequency requirements.

Figure 9 below shows the load adding and shedding sequence of the J620 super-fast-start for a customer-specific requirement of +/-10% voltage and +/- 5% frequency deviation, which is even more stringent than the limits stated in ISO 8528-5 class 3. In this example, within 15 seconds after receiving the start command, the Jenbacher generator reaches stable rated speed and is ready to take the first 25% load step. With four steps, the generator set reaches nominal output, keeping the requested limits on power quality. In addition, 100% load step and shed is possible.

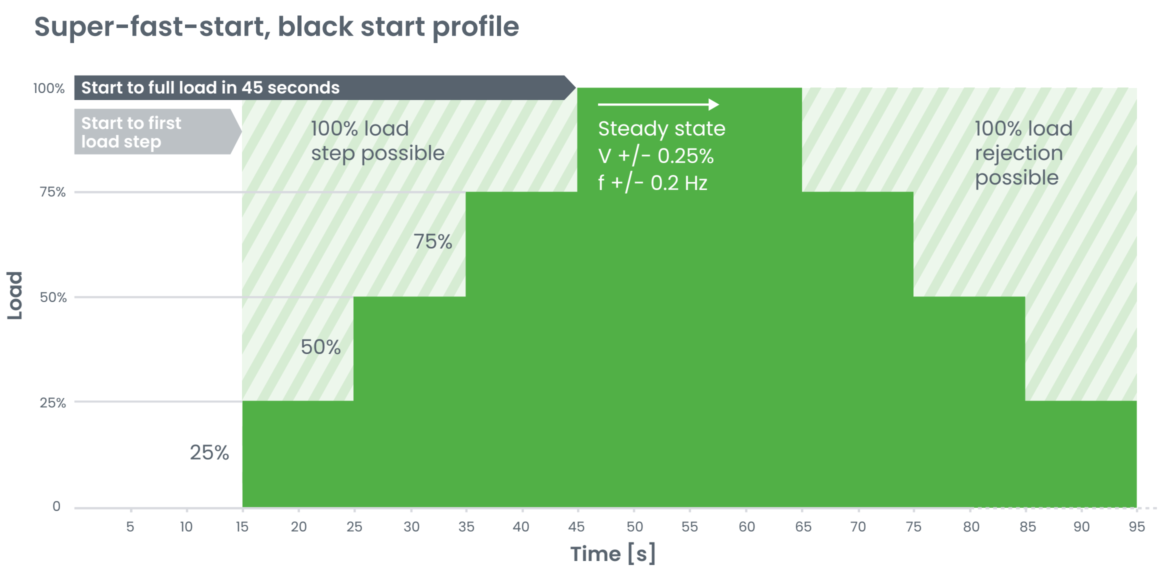

Figure 9: Jenbacher J620 super-fast-start generator: example of load adding and shedding sequence for a customer-specific requirement.
Note: Example profile for pre-heated/-lubricated; without synchronization; 480 V configuration; power quality within +/- 10% voltage, +/-5% frequency

4.

CUSTOMIZABLE SOLUTIONS TO MEET DATA CENTER NEEDS

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4.1 Containerized solution for a modular, scalable data center layout

INNIO Group's modular Jenbacher containerized solution is tailored to the data center's specific requirements. This pre-installed package includes all required auxiliaries to enable a quick site installation with a compact footprint. The bottom container houses the heart of the system—the Jenbacher genset. The upper module houses the large auxiliaries such as radiator, ventilation system, and exhaust silencer.

Standards: ASCE, IBC, UL, DIN, EN, ISO
Width < 4 m/13 ft; length < 20 m/65 ft; height[1] < 3.5 m/11.5 ft
Ships in 59 t/130 tlb (lower) + 30 t/66 tlb (upper)

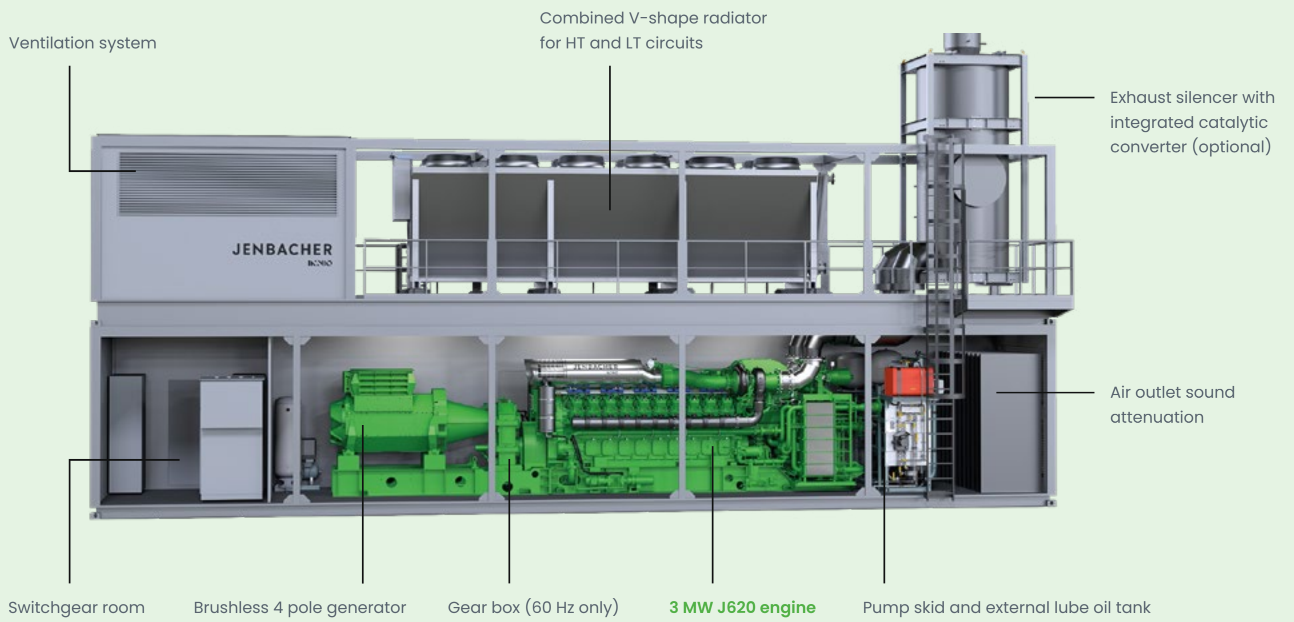


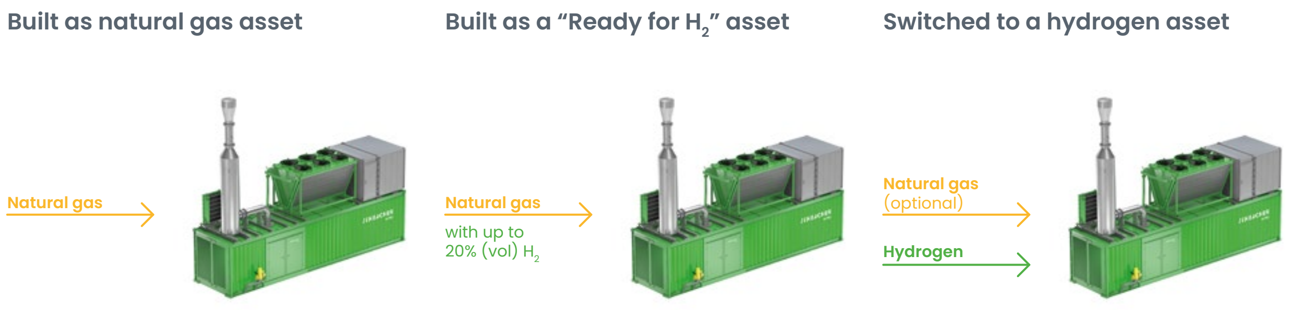
Figure 10: Fully customizable, easily transportable 2-module Jenbacher concept
[1] Per module

4.2 Fuel flexibility and hydrogen power generation solutions for data centers

INNIO Group's "Ready for H_2" engine portfolio, including also selected Jenbacher engine technology that can be operated on 100% hydrogen, is built on a long history of innovation with more than 30 years of experience and expertise in the use of renewable and hydrogen-rich fuels, such as syngas and process gases, for power generation.

The energy solutions from INNIO Group's Jenbacher product line offer the key advantage of fuel flexibility while helping to protect customers from stranded investments in their decarbonization strategy.

All new Jenbacher power plants are "Ready for H_2." In addition, engine variants with a corresponding option can be operated with up to 25% (vol) of H_2 in the pipeline gas. As hydrogen availability increases, all new plants and most of the currently installed Jenbacher natural gas-powered generators can be converted to operate on 100% hydrogen.



Natural gas with <5% (vol) of H_2 content
Current standard

Natural gas with up to <25% (vol) of H_2 content
Pipeline gas can have up to 20% (vol) of hydrogen content

Required:
- NO_x-sensor
- H_2 signal integrated into LeanoxPlus
- H_2-ready compensation software

Low-cost package

Hydrogen fuel (natural gas optional)
When hydrogen becomes available

Required:
- Hydrogen conversion package
- NO_x-sensor
- H_2 signal integrated into LeanoxPlus
- H_2-ready compensation software

Medium-cost package

Figure 11: Demand-oriented conversion of INNIO's Jenbacher generators to hydrogen operation

An overview of the Jenbacher "Ready for H_2" product portfolio with timelines is provided in the following table.

Power output (kWel) 0 – 1,000 – 2,000 – 3,000 – 4,000 – 5,000 – […] – 10,000		H_2 in pipeline gas		Gas/H_2 engine	H_2
		< 5% (vol)	< 25% (vol) optional	0-100% (vol)	100%
Type 9	J920 FleXtra	✓	✓	25	2025+
Type 6	J612, J616, J620, J624	✓	✓	60	2025
Type 4	J412, J416, J420	✓	✓	100	✓
Type 3	J312, J316, J320	✓	✓	60	2025+
Type 2	J208	✓	✓	60	2025+

Table 2: Jenbacher "Ready for H_2" product portfolio

Data center design can be significantly improved with the integration of renewable energy sources to achieve net zero. By leveraging renewable energy, such as solar, wind, or bioenergy, data centers can significantly reduce their carbon footprint. It involves strategically placing solar panels or wind turbines to harness a significant amount of available renewable energy, and integrating hydrogen production, the gas network, energy storage systems, and bridging solutions such as 100% hydrogen or hydrogen-ready engines.

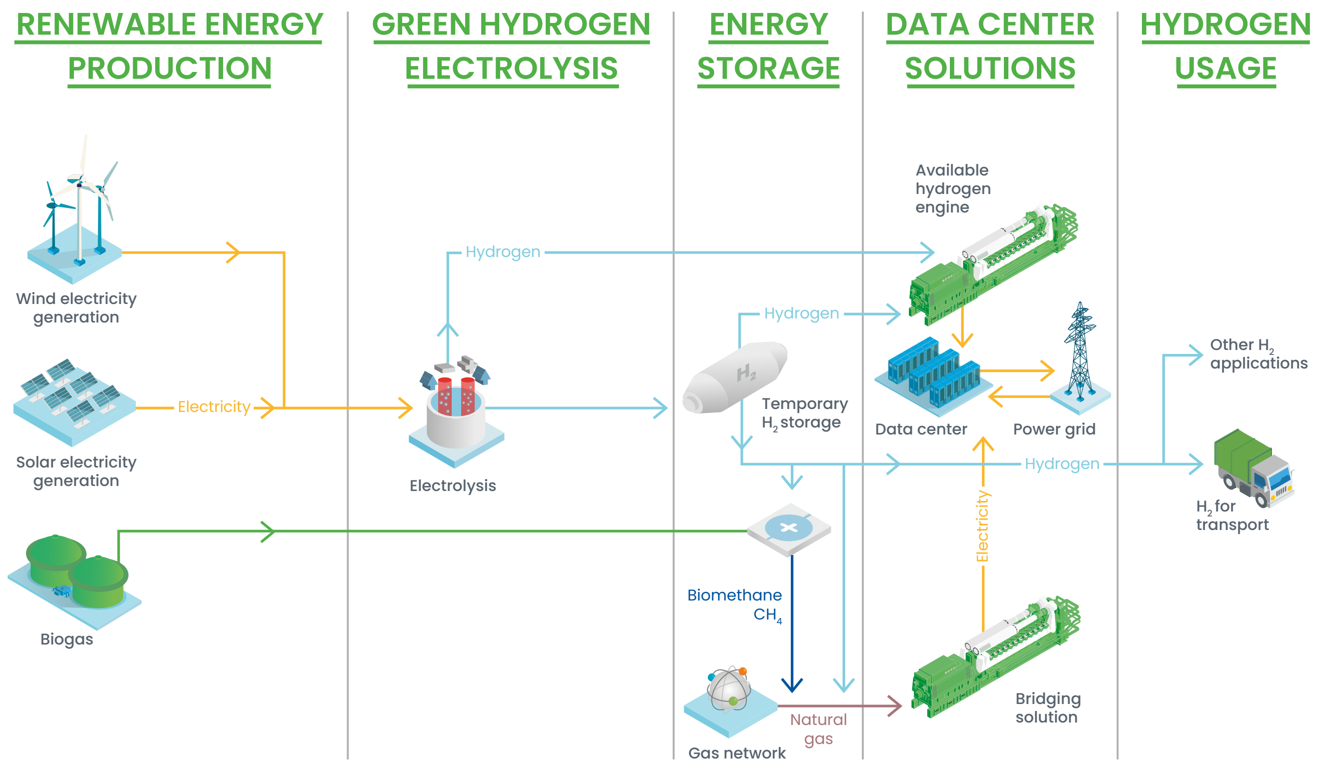


Figure 12: Possible data center layout with renewable energy sources and green hydrogen

5.

CONCLUSION

5. CONCLUSION

The traditional power supply model for data centers, which relies on a combination of grid power and backup diesel generators, faces challenges due to the aging of the U.S. power grid and high local emissions from diesel generators. Given all the headwinds mentioned in this paper, grid issues are likely to grow in the coming years. Delays in permitting and regulatory hurdles can prevent the grid from expanding at a pace that matches the increasing demand for electricity, particularly in areas experiencing rapid data center growth or industrial development. As a result, the grid's capacity may not be sufficient to meet the needs of data centers, leading to potential power shortages and reliability issues.

Jenbacher energy solutions are sustainable technologies that can meet individual customer requirements in the data center industry for backup generation with the same performance as diesel generators, continuous operation until the required grid capacity becomes available, or continuous operation in remote areas without a grid connection. Jenbacher generators also can provide power for several hours a day during peak periods for either cost savings or in times of grid curtailment.

Therefore, Jenbacher solutions are well-suited to provide reliable power supply, reduce the carbon footprint of data centers, and offer the potential for additional savings and revenue. Jenbacher gas generators are built on proven and established engine technology that enables INNIO Group's customers to decarbonize and flexibly move to 100% hydrogen operation over time without having to invest in another asset. Investing in Jenbacher gas generators helps to prevent data center operators from having a stranded asset on the books, which might be the case with diesel generators.

LITERATURE

LITERATURE

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About INNIO Group

INNIO Group is a leading energy solution and service provider that empowers industries and communities to make sustainable energy work today. With its Jenbacher and Waukesha product brands and its AI-powered myPlant digital platform, INNIO Group offers innovative solutions for the power generation and compression segments that help industries and communities generate and manage energy sustainably while navigating the fast-changing landscape of traditional and green energy sources. INNIO Group is individual in scope, but global in scale. With its flexible, scalable, and resilient energy solutions and services, INNIO Group enables its customers to manage the energy transition along the energy value chain wherever they are in their transition journey.

INNIO Group is headquartered in Jenbach (Austria), with other primary operations in Waukesha (Wisconsin, U.S.) and Welland (Ontario, Canada). Through a service network in more than 100 countries, a team of more than 4,000 experts provides life-cycle support to the more than 57,000 engines that INNIO Group has delivered globally.

INNIO Group's ESG strategy has been recognized and awarded by esteemed rating agencies such as Sustainalytics and EcoVadis. Additionally, the company's near-term climate targets until 2030 have been validated by the Science Based Targets initiative (SBTi).

For more information, visit INNIO Group's website at innio.com

Follow INNIO Group and its brands on X (formerly known as Twitter) and in

ready for H_2

ENERGY SOLUTIONS.
EVERYWHERE, EVERY TIME.

Digital version available

In general, "Ready for H_2" Jenbacher units can be converted to operate on up to 100% hydrogen in the future. Details on the cost and timeline for a future conversion may vary and need to be clarified individually.

Jenbacher is part of the INNIO Group

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PLATINUM Top 1% 2023 ecovadis Sustainability Rating

MORNINGSTAR | SUSTAINALYTICS ESG 2024 INDUSTRY TOP RATED