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# The Looming Power Crunch

## Solutions for Data Center Expansion in an Energy-Constrained World

**A Data Center Research and Strategy Report**

Patrick Donovan

As global IT demand reaches unprecedented levels, dire predictions suggest that electric grids may fail to keep pace and hamper data center industry growth.

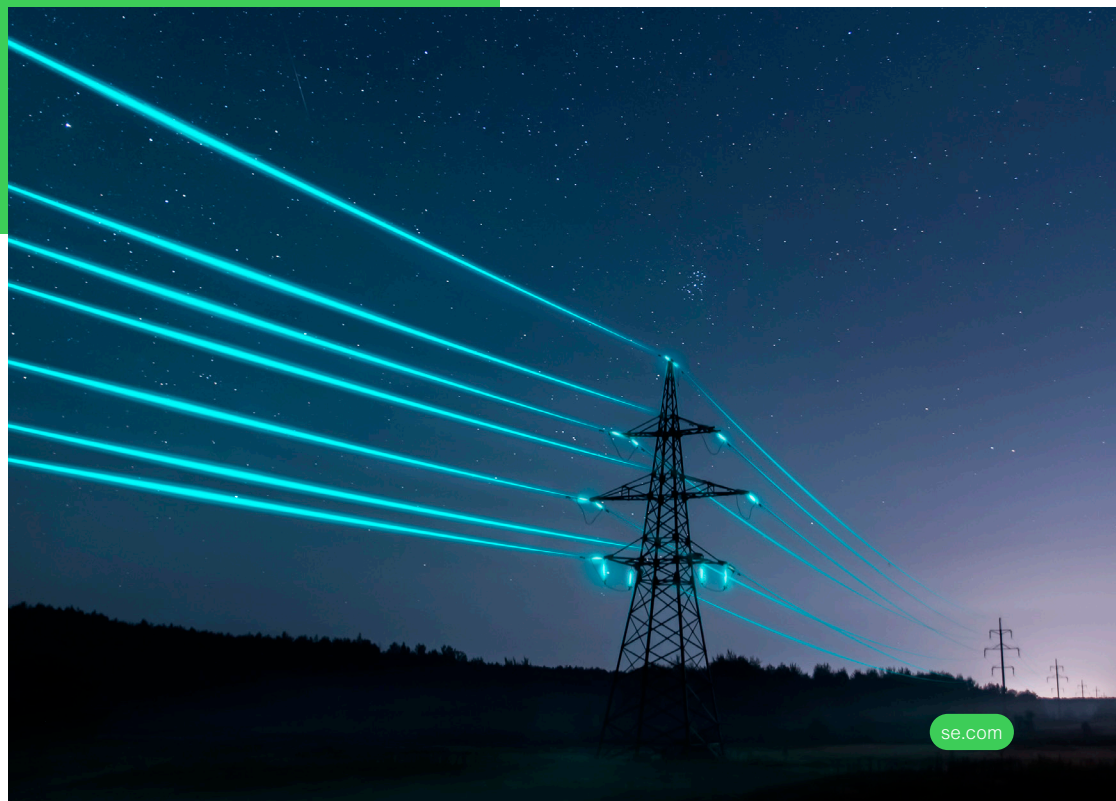
# We believe there are multiple paths to allow continued growth.

**A perfect storm of factors has combined to strain the grid and limit capacity in some regions. However, there are viable options for data centers to keep building as utility companies take steps to mitigate these challenges.**

**In this eBook, we summarize those options and steps, provide helpful guidance, and discuss some considerations for alternative prime and backup power sources. Combined, we aim to help data center owners secure permits, build new data centers with sufficient and reliable power, and operate them more sustainably.**

> “Demand for AI will likely alter the geography of digital infrastructure, but isn’t going to gobble up all the power on the electric grid.[1]”

say government researchers from Lawrence Berkeley National Laboratory (LBNL), part of the Department of Energy.



# Data Centers in an Energy-Constrained World

**Global electricity demand is increasing[2] driven primarily by economic growth, transportation/HVAC electrification, and exploding demand for data centers/IT.**

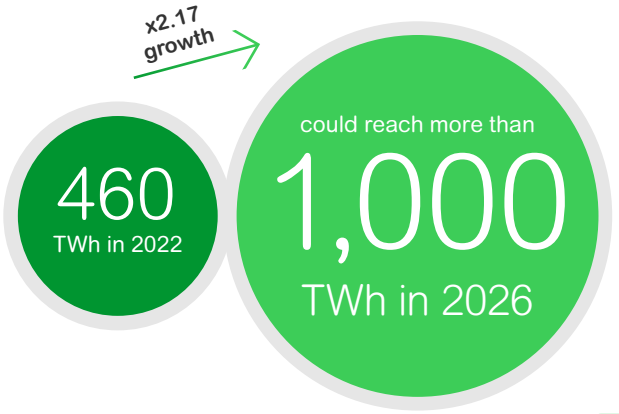
**Given the systemic limitations on reliable power sources, practical solutions are needed. We must address power sustainability, upstream power infrastructure, new data center equipment and trained labor to deliver it all.**

With annual growth rate predictions in the low single digits, the power grid requires large capital investments to modernize, and to accelerate the transition to clean energy.

As a result, some financial analysts, for the first time, are viewing electric utilities as a growth segment with "great potential".[3 4] When massive AI forecasts[5] encounter high profile examples of utility curtailments, it leaves large data center companies struggling to find enough power. And that is where we find the genesis of hyperbolic headlines suggesting the world will soon run out of power.[6 7 8]

Much of the blame for this "looming power crunch" is being placed squarely on the shoulders of the data center industry. Voracious AI models, cryptocurrency mining and the digitization of every aspect of our lives add up to an insatiable need for electricity.[9]

This blame is understandable, given reports of escalating demand forecasts for IT and data centers. For example, the IEA suggests that "after globally consuming an estimated 460 terawatt-hours (TWh) in 2022, data centers' total electricity consumption could reach more than 1,000 TWh in 2026. This demand is roughly equivalent to the electricity consumption of Japan."[10]



The world's largest asset manager, BlackRock, described in their 2024 Midyear Global Outlook report how the race to scale up AI capabilities is already spurring aggressive capital spending. "AI and the low-carbon transition could spur historically large capital spending – and in a much shorter space of time than previous technology revolutions," the report reads.[11]

Data centers, however, are not alone in being called out. Blame for "running out of power" is also placed on the time-consuming and often bureaucratic process of modernizing and building out electrical transmission and distribution capacity. And to pile on, there is the need to connect new generation sources.

Customer grid connection queues are now often in the three-to-five-year timeframe in these energy constrained regions. This regional need for more capacity is rising concomitant with the acceleration of the clean energy transition. This puts everyone in a tough spot. Providers are winding down fossil fuel baseload power anchor for grids worldwide. And they're doing it while adding more and more intermittent, low-inertia renewables. While it seems like a fair trade, swapping traditional baseload for renewables can destabilize the grid. It can cause supply constraints. It can force large customers (like data centers) to take load off the grid for periods of time to maintain overall supply and demand balance.

> "AI and the low-carbon transition could spur historically large capital spending – and in a much shorter space of time than previous technology revolutions."

**Utilities Announce Joint Intent to Invest Over $116B Annually in Grids and Renewables[12]**

Utilities for a Net Zero Alliance
**32**
of the largest utilities and energy companies worldwide

serving
**327M**
customers

announced
**$116B**
each year from 2024

to reach in
**849GW**
in renewables by 2030

# Will the world run out of power?

**Is it true that we will run out of power in a couple of years? Will new data center builds be curtailed over a lack of available power? Is building a large microgrid and is operating in "island mode" forever the last remaining option for many new data centers?**

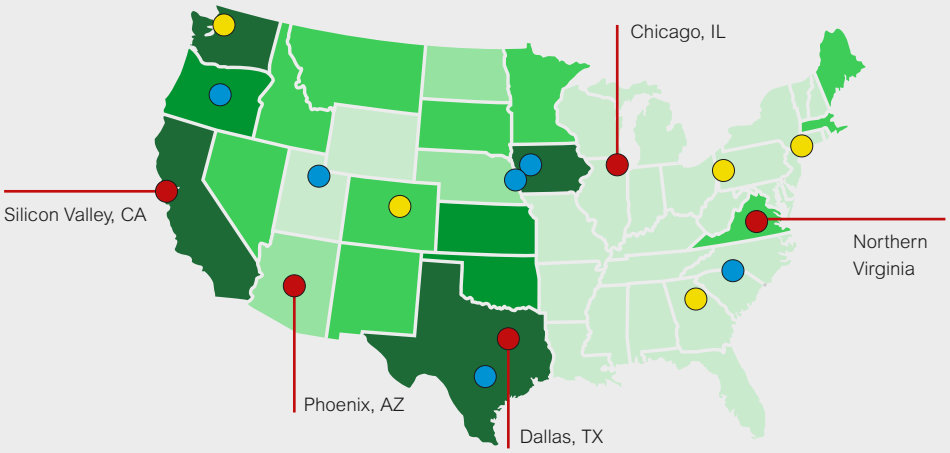
# We believe the answer to each of these questions is "no".

Yes, it is true for some regions – regions that have seen data center companies concentrate – that a "perfect storm" of factors can strain, destabilize, and limit utility grid capacity. But, as argued in this blog by data center construction company, Rosendin, we believe this will largely be a short to mid-term challenge (next 3 to 5 years or so).

Grid capacity will be constrained or exhausted in some locales while more remote power-rich areas will experience increasing pressure from a rapidly growing number of buildouts. Vacancy rates at existing colocation companies will continue to decline across the board as well,[13] with prices rising at existing providers in energy-constrained regions.[14] Power availability has become the key determining site selection factor for many data centers.

Over the longer term, we expect new grid capacity investments (new builds and modernization programs) will reach completion. Closure of fossil-fuel plants will be deferred; it will be balanced in line with customer demand in these more congested areas. At the same time, efforts are being made to streamline permitting processes to reduce interconnection queues.[15]

POCKETS OF RISK BALANCED BY NEW EMERGING ZONES ('24-'28)




Source: EMRC/Data Center Strategy analysis, October 2024

# Data centers can bridge the gap

> “In the near term, the U.S. power grid is not in danger of running out of capacity, but investments need to be made in expanding the existing and adding new substations in critical areas for data center development.[16]” added Cvengros. “The process of power procurement needs to be greatly improved administratively and in the field. Egregious power load requests and significant transformer delays are curtailing future data center growth.”

**In the meantime, data center companies building in grid-constrained regions are adjusting their energy procurement strategies, starting with consideration of alternative prime and backup power sources. A host of options can be considered for on-site generation and energy storage tech: natural gas turbines, HVO-fueled generators, wind/solar, fuel cells, and battery energy storage systems.**

Utilities, aggregators, and governments are going further, providing incentives and markets to help monetize and improve the ROI of these assets. On-site generation sources and energy storage can work together to provide prime power until the grid connection becomes available. Once grid connected, these resources could be used to provide local grid or market services. This increases the overall share of renewables in the grid mitigating the rising cost of energy for both data centers and the energy system.

If it appears that power-constrained areas also tend to be population dense, it’s because they are. After all, providers desire these dense, more expensive locations to reduce network latency so that they can competitively serve local markets.

And so, atop power constraints, data center owners often face additional local scrutiny and pushback from authorities and the public at large over generator noise/pollution, land and water use.[17] [18]

In this eBook, we provide advice for navigating these challenges. We provide helpful guidance and discuss some considerations for alternative prime and backup power sources. Combined, we aim to help data center developers secure permits and build new data centers faster with sufficient, clean and reliable power in energy-constrained areas.

# Rethinking site selection

**Whether you're building a new site or choosing a provider, the key consideration factors for choosing where to build or collocate remain unchanged.**

Availability and price of power, connectivity, land, and skilled labor, as well as proximity to the users you serve, service costs, natural disaster risks, economic incentives, security risks, energy procurement strategy, contribution to sustainability goals, and so on.

However, you're forced to consider local build challenges including competition for power, space, and water or the tradeoffs of moving to an energy-constrained region, how you weigh those factors becomes vital.

Power availability becomes the crucial factor. The obvious alternative is building somewhere not energy-constrained, if possible. You can expect this to force a change in your energy procurement strategy.

Developers will take care to consider alternative energy sources and the tradeoffs between lower latency and/or higher labor availability and what it would take (cost and timewise) to obtain enough power at that energy-constrained location versus somewhere more remote.

When facing this circumstance, key questions need to be considered, such as the ones opposite and on the following page.

01

Can you afford to wait for the desired capacity to become available, and will you be willing to incur a potential increase in land and energy costs?

02

Is it possible to enhance the network design to mitigate the latency challenges of a more remote site by, for example, using an interconnection platform in the form of distributed and data center-neutral Internet Exchanges?[19]

03

While there may be enough bulk generation capacity, is there enough transmission and distribution capacity going to the specific site under consideration?

MORE ON NEXT PAGE

## 04

To connect with the grid, will the utility mandate demand response and grid services participation that includes taking data center load off the grid for periods of time?

(This would be prevalent in energy-constrained areas.) And are you and your tenants willing to embrace that operating model? This requirement will impact your electrical and backup design.

## 05

If your situation requires on-site generation and/or energy storage to connect to the grid or have prime power until the grid becomes available, have you evaluated your options (e.g., own, lease, or sign an EaaS contract) given site constraints (e.g., is natural gas pipeline nearby, what are utility generator connection standards, etc)?

## 06

Have you evaluated the local regulatory and political landscape and public willingness to host data centers and the energy infrastructure required? Data center owners trying to build in resource-constrained, population-dense areas tend to have a higher bar for gaining approval.

## 07

Should you consider outsourcing to existing service providers to avoid building given cost, time, and/or supply chain constraints? Can you find capacity?

## 08

Have you considered the impacts of operating new on-site generating equipment? Should you consider outsourcing the power generation (aka near site vs on-site)?

**Answers to these questions should factor heavily into your site selection decision.**

The next recommendation is to work closely with electric utility company early in the planning phase of the site selection process and new build project. The utility will be a helpful partner in navigating the challenges of both and in answering many of the questions above.

# Data centers and utility companies should collaborate as early as possible to align goals and expectations

**The economic opportunity of growing demand compels utility companies in grid-constrained regions to modernize, increase capacity, streamline permitting, and add renewable generation sources. This brings grid owner goals into alignment with data center developers trying to build a new site sustainably with sufficient power.**

Before the AI boom, large data centers could accept the longer lead times for utilities and transmission operators to conduct necessary studies. However, skyrocketing demand now drives data center developers to build with great immediacy.[20] Understanding the utility's baseline situation and challenges can allow a data center operator to pursue creative solutions.

The grid is a much larger and more complex machine than a single data center. Operators have little room for error as they continuously work to balance supply and demand. Myriad regulatory bodies and reams of regulations are involved, along with political and public scrutiny. This raises the stakes for utilities, particularly in grid-constrained areas.

Yet the utility views and evaluates projects in time scales that extend well beyond the life of a data center. They must also consider the long-term impacts on land, right of ways, the larger grid, and on customers every time they need to make additions or upgrades.

Electric utilities have been dealing with monumental changes in the last few years. For many, this period brings more change in a more compressed period than they have faced in the previous 50 years combined. And so, utility companies cannot respond to new demand and requirements as quickly as data center developers expect or might have been used to before.

Working together early and understanding the process, however, should improve the efficiency and success of new data center builds. Early collaboration allows data centers and utilities to develop plans together, integrating each other's needs and capabilities from the start with full knowledge of all the options for getting the data center up and running as soon as possible.

> "In the 1950s, electricity demand grew at a staggering 9 percent compound annual growth rate (CAGR). The 60s saw 7 percent, the 70s 5 percent, and even in the 80s, it was still at 3 percent before settling to 2 percent or less in recent decades... Current forecasts from utilities suggest a more modest growth rate of 1.5-2.5 percent CAGR through 2035 – numbers we routinely surpassed for four straight decades while fueling unprecedented economic expansion.[20]"

# How collaboration helps with site selection

**Utilities can provide data centers with accurate information needed to make better decisions. Data on cost, current and future power capacity, carbon intensity, power quality, and reliability for the specific locations can be provided. Within their grid, utilities can help pinpoint optimal locations based on their intimate knowledge.**

For example, a data center real estate team identified a low-cost piece of land in a tier one metro area near a local highway that turned out not to have the necessary transmission capacity. The utility was able to quickly find a better site in a nearby tier two metro area that was much more suitable. The town had once hosted a manufacturing center in this location. The data center was the beneficiary of the installation of a strong transmission backbone.[21] Although abandoned by manufacturers, it is an ideal location for new data centers.

Based on the specific needs of the data center, the utility will provide details on what the requirements are for connection (e.g., contract requirements, mandatory demand response participation, etc) and help data centers understand what all the options might be for getting the required energy if not yet available. Utilities can also make clear where economic incentives exist and what rate structures are for a given area. This information sharing will help set the stage for the eventual energy procurement contract negotiations that typically comes at the end of the site selection process. And all this helps data center developers make informed decisions about where to build and ultimately the design of the data center.

U.S. INTERCONNECTION QUEUES, ALREADY JAMMED, GREW

**30%**

in 2023[22]

# How collaboration helps with design, permitting, and construction

**The utility company and grid operator's intimate knowledge of the grid and their local regulatory, governmental, and political landscape makes them critical partners in the design, permitting, and construction phases of a new data center project.**

Their input will guide the electrical design to be more efficient and sustainable, will secure the necessary power faster, and will accelerate and simplify the permitting process, all to ultimately build more quickly. The following examples show how collaboration helps in these areas.

**Efficient electrical system design**
Utility energy engineers can provide insights on energy-efficient and cost-saving infrastructure design, potential influencing plans and helping data centers better optimize their power consumption. By designing together from the utility substation down to the power at the IT rack enclosure level, there may be opportunities for transformer, switchgear, and power bus sizing to be better optimized for efficiency and lower cost. *Note, designing a highly efficient, sustainable data center is now "table stakes" for permitting and minimizing public concerns over new data centers in energy and resource-constrained communities.*

**Load management and grid stability**
Planning together allows utilities to better prepare for the significant power demands of new data centers to maintain grid stability and minimize the use of more carbon-intensive "peaker" plants. This can involve updating strategies for load balancing at the grid level, peak demand management, and integrating data centers into demand response and grid services programs. This early planning and buy-in by data centers to manage their demand on the grid can mean that new data centers can be built and connect sooner than they would otherwise. This participation would also mean lower energy costs through time-of-use arbitrage and by avoiding costly demand charges, and by earning income from services rendered to the utility. *Note, in more energy-constrained regions, participation in demand response and grid services is sometimes mandatory for grid connection.*

**Alternative prime power and backup design support**
The participation described above will likely lead to non-traditional data center designs. Taking the data center off the grid and putting it back on again, multiple times a year for significant periods of time, means a large amount of on-site energy storage (typically lithium-ion battery energy storage systems) will be necessary. And if there's not enough grid capacity for long enough, data center developers will consider designs with on-site alternative prime power sources such as natural gas turbines, fuel cells, and eventually, small modular reactors (SMRs).

**Permitting support**
Aside from providing a "will-serve" letter that verifies utilities have the electricity and water required by the data center, utilities can provide valuable input during the permitting process, helping data center operators navigate local regulations and requirements related to power infrastructure and environmental impact. Collaborative planning on energy use demonstrates the data center developer is being responsible which will have a positive impact on gaining approvals and permits. With their established presence in local communities, utility companies will often work with developers to help explain and promote the benefits of new data center projects while helping address any public concerns.

**Accelerated equipment procurement**
Early collaboration can possibly streamline the procurement process for critical utility grid equipment during the construction phase. Utilities will likely order necessary equipment earlier if data centers agree to cover costs in case of project cancellation, reducing potential delays. Typically, utilities won't procure necessary equipment to build out new capacity or to make a new connection until that project has been fully approved.[24] For data centers willing to cover these costs ahead of time, several months can be saved in the grid connection process.

The global smart demand response market size was valued at USD 23.81 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 17.4% from 2023 to 2030. Advancements in technology in the utility vertical and the introduction of regulatory frameworks are expected to increase smart grid deployment, which is estimated to drive industry growth.[23]

GLOBAL RESPONSE MARKET VALUED AT

**$24bn**

in 2022

EXPECTED CAGR OF

**17.4%**

from 2023 to 2030

For data centers building a microgrid, utility companies are well positioned to help with:

- Feasibility studies to understand capability of integrating a microgrid in terms of power capacity, interconnection points, and its impact on wider-grid stability.
- Microgrid design in terms of selecting on-site generation sources based on local conditions, helping size energy storage systems, and ensuring compatibility with grid interconnection standards.
- Financial and regulatory support by helping data centers navigate the complex microgrid regulatory environment (e.g., interconnection, islanding, power quality regulations) while identifying potential financial incentives and rebates.

# Considerations for alternative prime and backup power sources

**As mentioned earlier, data center developers and designers who are planning to build in energy-constrained regions, will likely have to consider deploying alternative prime power sources and/or energy storage systems to get new data centers up and running.**

Until recently, most data centers that have deployed on-site microgrids have used them grid connected as a backup solution and as a means to help decarbonize their energy consumption.

Now in grid-constrained areas, some data centers are considering deploying them as off-grid solutions.[25]

At a fundamental level, we can characterize two basic use cases when data centers are trying to build in energy-constrained regions:

- Electrical capacity exists, but to connect, the utility or grid operator requires the data center owner to agree to mandatory demand response and grid services participation.
- Electrical capacity does not yet exist and there's a need to build and operate before that capacity is available.

Each case has different implications in terms of the need for on-site generation and energy storage.

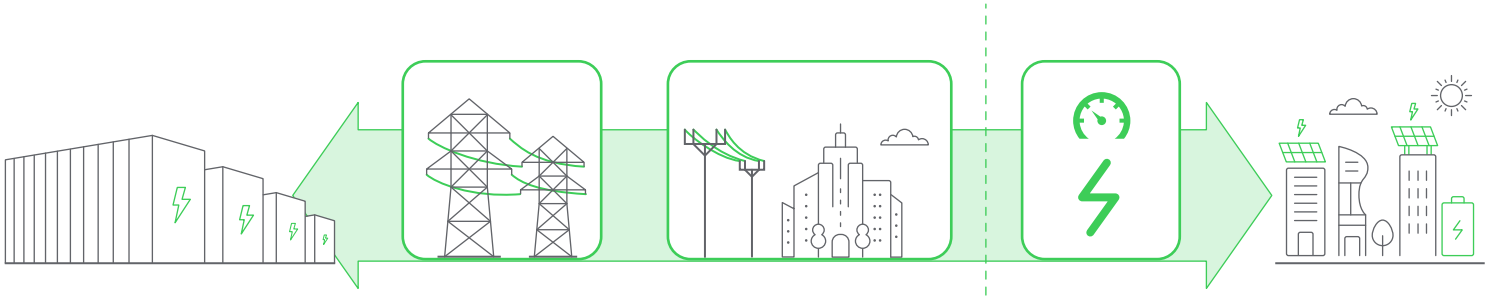
CONSIDERATIONS FOR ALTERNATIVE PRIME AND BACKUP POWER SOURCES CONTINUED

## Use case #1:

Electrical capacity exists, but to connect, the utility or grid operator requires the data center owner to agree to mandatory demand response and grid services participation.

A perfect storm of factors has combined to strain the grid and limit capacity in some regions. However, there are viable options for data centers to keep building as utility companies take steps to mitigate these challenges.

This requires having enough on-site energy storage (e.g., generators and/or battery energy storage systems) to take the data center load (in the amount required by the grid operator) off the grid as directed.




Traditional data centers tend to have diesel generators as backup to the utility; with uninterruptable power supplies (UPSs) to power critical loads when power switches from utility to the gensets.

Whether traditional backup diesel generators can be used or not for demand response and grid services depends on fuel availability and local regulations. Recent moves from localities have seen a drop in diesel gensets driven by noise, air pollution and carbon emission concerns.

There are places, however, where it is allowed or even encouraged.[26] In those cases, developers may be able to deploy more traditional data center designs. To address the negative environmental impacts of diesel gensets, it's worth noting that more sustainable hydrotreated vegetable oil (HVO) fuels exist as an alternative to diesel fuel. It reduces related carbon emissions by about 90%. However, HVO is in shorter supply and costs significantly more (15-100% more according to Kohler). Nor does it fully abate concerns of increased tailpipe emissions or air quality impacts.

Some generator manufacturers also have improved environmental performance through efficiency improvements, less frequent maintenance schedules that require no load for no noise or smoke during tests. These improvements may make generators more viable to local authorities as a tool for demand response participation.

For those areas where diesel gensets cannot be used for demand response and grid services, other energy storage systems must be considered. Lithium-ion battery energy storage systems (Li-ion BESS) has become the leading choice for this behind-the-meter application. Li-ion BESS is mature technology, has an established safety regulatory framework in place, and has benefited from the technology improvements and cost reductions that the lithium-ion battery industry has been experiencing for many years now. With economically feasible runtimes of one to four hours, an on-site BESS system can provide enough energy storage to meet grid operator requirements for demand response and grid services.

## CONSIDERATIONS FOR ALTERNATIVE PRIME AND BACKUP POWER SOURCES CONTINUED

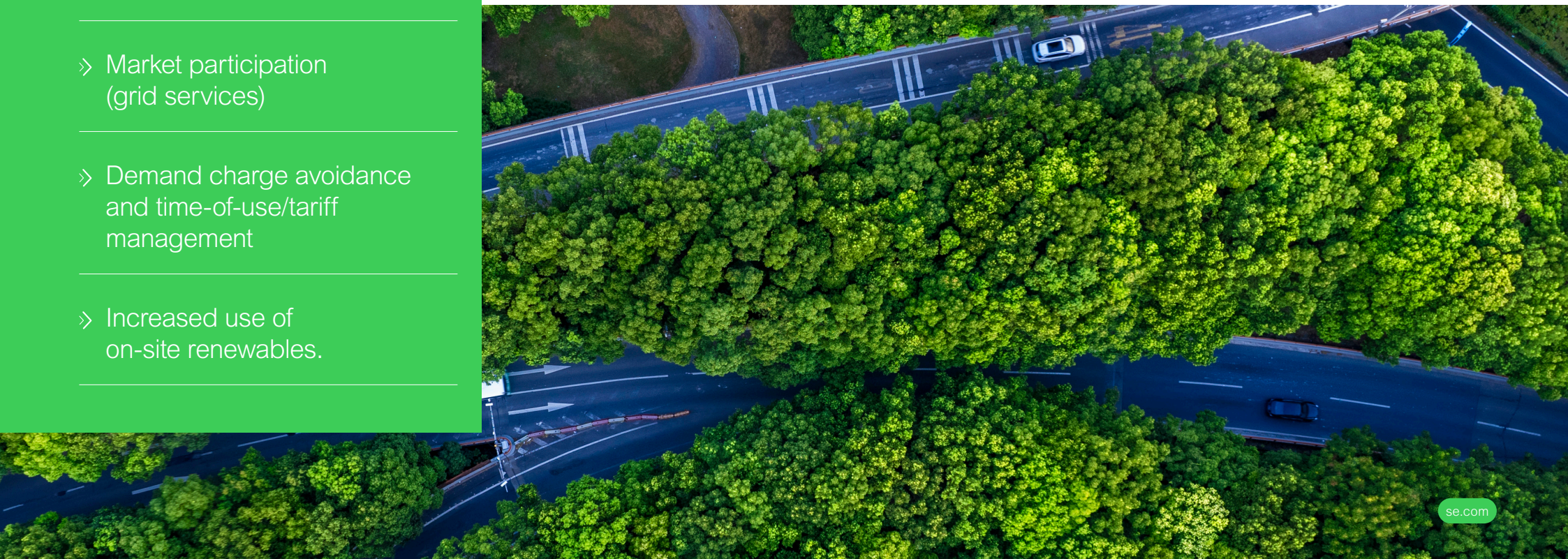
In addition to meeting requirements for connecting to the existing grid, a BESS system can provide data centers with five key outcomes:

- Additional backup power and greater independence from the grid
- Decreased reliance on, or elimination of the need for, diesel generators
- Market participation (grid services)
- Demand charge avoidance and time-of-use/tariff management
- Increased use of on-site renewables.

To learn more about what a li-ion BESS[27] is, how it works, drivers for adoption, and how it achieves these five outcomes, see Schneider Electric White Paper 185, Understanding BESS: Battery Energy Storage Systems for Data Centers.

Some may consider using their UPS systems to meet grid requirements for demand response and grid services. However, most UPSs do not have a bi-directional inverter needed to both charge and dispatch power to the grid. And most UPSs only have five to fifteen minutes of runtime which is often insufficient to meet grid connection requirements in this use case. Also, many risk-averse data center operators may not want their mission critical UPSs changing states to perform services other than their intended functions – being there for the IT loads when there's a power outage.

Energy storage systems aside, other alternatives include natural gas generators (turbine and synchronous generator) and fuel cells. However their cost and complexity rules them out as an option for use case #1. This is where the electrical grid has capacity to connect, but the utility or grid operator has mandatory demand response and grid services participation. When on-site prime power generation sources are needed, however, these options become much more viable.



CONSIDERATIONS FOR ALTERNATIVE PRIME AND BACKUP POWER SOURCES CONTINUED

## Use case #2:

Electrical capacity does not yet exist and there's a need to build and operate before that capacity is available.

**For a data center to realistically consider operating off grid using alternative prime power generation sources, certain key considerations must be addressed or confirmed:**

**Reliability** – Prime power generation needs to be reliable and consistent. Is redundancy required?

**Fuel availability** – Secure and consistent fuel supply is essential, especially for non-renewable options. For example, is the site close to a natural gas supply pipeline trunk?

**Environmental impact and efficiency** – How does the chosen tech compare to other options? Does it enable or hinder you from meeting sustainability goals and operations budget?

**Economic factors** – Consider upfront and ongoing costs, including fuel, maintenance, and potential revenue from excess power generation.

**Regulatory compliance** – How does the considered tech adhere to local, state, and federal regulations regarding emissions, noise, and land use?

**Permitting and construction** – Does the timeline meet requirements? How does it compare to waiting for an electric utility connection to become available at the capacity required? Depending on the specific circumstances, permitting, and building out a natural gas generation plant can be shorter or longer than getting a connection to an electric utility. Two to three years is not uncommon for natural gas turbines.

## CONSIDERATIONS FOR ALTERNATIVE PRIME AND BACKUP POWER SOURCES CONTINUED

Some alternative power sources are more mature or better suited for some scenarios than others. It is also a moving target as these technologies are constantly evolving through investments and on-going innovation. Utility companies and energy procurement companies like Schneider Electric will help you navigate these choices based on local conditions at the considered site and your business priorities (i.e., cost, availability, efficiency, sustainability, and so on).

Data center operators are considering multiple paths to sourcing energy. This includes a new application in Virginia in the U.S. for a "natural gas power plant and data centers." The plans call for 70 data center buildings, with mobile gas turbines, each generating 30 MW power, giving the project a total of 450 MW.[28]

In general, we believe that natural gas turbines, in many cases, will be the most commonly used prime power alternative in the short term from a technology maturity, cost, fuel flexibility, reliability, deployment speed, and scalability perspective. While it does produce more emissions than a fuel cell, there is the opportunity to retrofit green hydrogen fuel in the future. So, in cases where you need to build where there's no grid power available for many years, the most likely solution will be to use a natural gas turbine as prime power with BESS and diesel or HVO generators as backup until grid eventually becomes available. Once it does, that prime power infrastructure could then be switched to being backup with utility power now being the prime source.

Fuel cells are another prime power alternative for regions where no grid power exists. Although having lower emissions than natural gas turbines, they are more expensive, have longer startup times (particularly solid-oxide fuel cells), and can have difficulty following larger load swings and, therefore, require additional infrastructure. The constrained supply of green hydrogen is also a big challenge for fuel cells.

In either case, these alternative prime power sources can be coupled with on-site renewables like wind and solar and energy storage to help increase resiliency, independence, and energy cost optimization while reducing emissions. Once grid connected, these assets can then be used to participate in demand response and grid services.

SMRs – Small Modular Reactors – are an emerging power source receiving serious attention by large data center owners trying to build in energy constrained areas.[29] These nuclear-powered generation sources promise constant, carbon-free energy in a very compact footprint. However, regulatory hurdles, public concerns over nuclear fuel, and high upfront costs are currently hindering their adoption. To learn more, see Schneider Electric White Paper 186, "Small Modular Nuclear Reactors Suitability for Data Centers".

It might be worth investigating any options available from microgrid providers in the area. There are companies building massive megawatt industrial parks involving both renewables and prime power generation sources like natural gas generators and fuel cells in the 300 MW to 600 MW range[30] that could serve larger data centers and help them avoid grid connection queue lines. These industrial parks of power may be grid connected already with microgrids as a backup or they may be permanently islanded. These microgrid companies will provide power as a service. Their full lifecycle expertise and established supply chains can make these organizations a viable alternative for data centers trying to get ahead of connection queues and/or improve resiliency, sustainability, and lower energy costs.

# The economic opportunity of growing demand compels utility companies in grid-constrained regions to modernize, increase capacity, streamline permitting, and add renewable generation sources.

**While headlines may paint a picture of an impending "power crunch" to cripple data center growth, we argue for a more nuanced perspective.**

**Yes, a "perfect storm" of factors has strained or exhausted grid capacity in SOME regions, but plenty of viable solutions exist. Here's a brief, high-level summary of the guidance we've offered:**

- Re-consider your site selection strategy… power/water/space availability and latency/ labor tradeoffs become focus area
- Bond with your utility company early to align on goals and objectives
- Engage utility companies to participate/ advise on-site selection and design
- Support and fund utility company modernization and expansion efforts for faster connections
- Encourage utility companies to promote data center projects and address public/ government concerns for faster permitting
- Design for sustainability to improve performance and public acceptance
- Consider and evaluate alternative prime power and backup architectures for faster new data center startups.

# Appendix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**Data center lifecycle $CO_2e$ calculator: Estimate and see key drivers of carbon footprint over the entire lifecycle.**
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