Life Is On | Schneider Electric

How Microgrids for Data Centers Increase Resilience, Optimize Costs, and Improve Sustainability

White Paper 289

Version 1

by Carsten Baumann

Executive summary

As colocation and service provider data center operators explore new ways to improve their facilities' resilience against grid instability, many face continued financial and environmental pressures. The newest microgrid technology can help colocation and service provider data centers further enhance uptime, reduce energy spend, and minimize carbon footprint. This paper introduces how microgrids use advanced analytics to intelligently manage energy assets (gensets, CCHP, renewables, loads), how microgrid design is optimized through feasibility studies, how modular architectures simplify design and installation, and how financing options, incentives, and operational models can help reduce risks and maximize returns.

RATE THIS PAPER ★★★★★

Introduction

Resilient power infrastructure has been a top priority from the very early days of computing capabilities. Computer labs, data network closets, and mainframe computer rooms all evolved their power supply perspectives alongside the compute capability.

As demand for more and more compute flexibility expanded proportionately with the advent of the Internet and dot-com era, the architecture of our former computing infrastructure evolved into what we now call data centers. The Internet, and its associated cloud services providers, make data centers one of society's most critical resources.

Today, the data center industry worldwide faces a number of business and technical challenges. Of these, three energy-related concerns loom large for operators: resilience, costs, and sustainability.

Ensuring uptime and SLA compliance

Resiliency and reliability are often used interchangeably, yet they are distinctly different. By way of example, Microsoft explains that, "Reliability is the outcome cloud service providers strive for – it's the result. Resiliency is the ability of a cloud-based service to withstand certain types of failure and yet remain functional from the customer perspective."[1]

The reliability, i.e., continuity, of electrical supply is paramount for data processing. From an electrical infrastructure point of view, this means not losing power, making sure that critical computing equipment is always operational and in compliance with all service level agreements. To help ensure this, a set of infrastructure standards were developed by the Uptime Institute to guide the design and measure the performance of data center power infrastructures.

Figure 1
Data centers need to meet the challenges of maintaining uptime while controlling energy costs and meeting environmental regulations.

However, increasing power demand, aging electrical transmission infrastructures, more frequent violent storms and other natural or human-caused disasters are all making grid stability issues more common in many regions. Ironically, bolstering generation capacity on the grid by adding renewable energy resources (such as wind and solar) is also causing greater grid power variations, as these sources are intermittent and can lead to voltage and frequency variations.

The typical power resiliency strategy for data centers has always been to provide backup generators, predominantly diesel generators. When grid disruptions have

[1] "Reliability Series #1: Reliability vs. resilience," David Bills, Microsoft

occurred, there have been, unfortunately, cases where data center backup generators did not reliably start up as expected. Due to these factors, relying on the grid for all primary power increases operational risk. And even with traditional diesel-powered backup generation and UPS (uninterruptible power supply) in place, there is a need for higher resiliency over longer, sustained periods.

Budgetary pressures

Beyond 24/7 operation, energy cost is also top-of-mind for data center operators. This is being driven by three realities:

1. Data centers are huge consumers of energy – as much as 2% of grid power is deployed to support them.
2. Many colocation providers are expanding their facilities and adding more clients and cloud services.
3. Roughly 50%[2] of data center OPEX (exclusive of IT equipment) is the cost of electricity, and the price of energy will rise in the short-term and then flatten or decrease in the long term as shown in **Figure 2**.

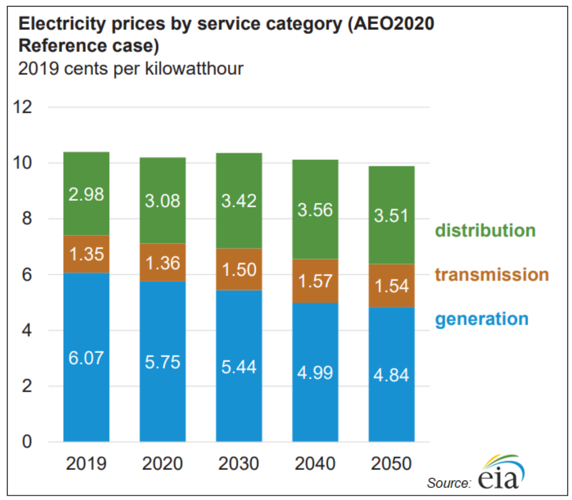


Figure 2
Energy costs are expected to continue to trend upwards worldwide for the next decade, including in the USA.

This is putting limited OPEX budgets under pressure, forcing operators to seek ways to reduce energy-related operating costs. HVAC energy consumption is itself a key contributor to the cost of operating a data center. Power utilization effectiveness (PUE) can only be reduced to a minimum associated with the performance of the cooling system(s) deployed. Even if the very most efficient cooling solutions are used to extract compute power heat, lowering the energy cost to operate a data center cannot be less than the cost of the sum of the computing equipment power being used.

Therefore, to further reduce the cost of data center energy requires reducing the cost of energy from the grid or producing energy below the cost of grid power.

Meeting sustainability goals

As it is for many industries in many regions, meeting self-imposed environmental goals or, in some regions, environmental regulations, is an ongoing challenge for data centers. Electricity and fossil fuel consumption are both part of the formula in calculating greenhouse gas (GHG) emissions. Managing consumption and using

[2] Based on internal Schneider Electric study, the cost of electricity ranged from 40% to 51% depending on the data center type (i.e. enterprise, colocation, and hyperscale) exclusive of IT depreciation.

greener energy sources is often a big part of complying with regulations. But the benefits go well beyond meeting government mandates. Minimizing a building's carbon footprint can also help achieve green building certification and establish a 'greener' image among prospective clients.

Additionally, customers of data centers increasingly demand greater sustainability of their operations that one can turn into competitive advantages. Up to now, those demands have frequently been met through the acquisition of Renewable Energy Credits (REC) and Power Purchase Agreements (PPA).

The emergence of the data center microgrid

A complete microgrid solution intelligently coordinates a variety of onsite, distributed energy generation assets to optimize costs and power stability, including the option to 'island' from the utility grid to avoid exposure to outages or disturbances. When the cost of grid energy rises, the microgrid can increase consumption of onsite renewable or stored energy. Stored energy can also be sold back to the grid when most economical. And consumption of renewable energy can be maximized to meet greenhouse gas emissions targets.

With their need for large amounts of continuous, clean, and affordable power, data centers are excellent candidates to benefit from microgrids. And there has never been a better time to take this step forward. Microgrid technology has reached a high level of maturity, being adopted in many types of facility and infrastructure applications, such as: utilities, community services, government offices, military bases, large industrials, hospitals, and educational campuses.[3] The latter of these often include research facilities.

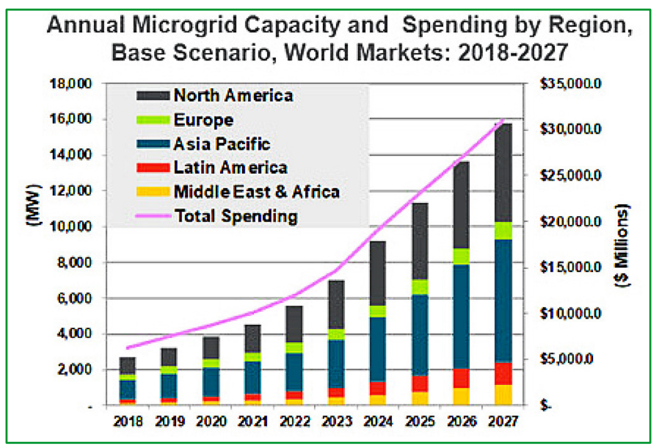


Figure 3
Microgrid technology has reached maturity, with expected continued growth of more than 20% a year.

Source: Microgrid Knowledge and Guidehouse

Worldwide microgrid capacity is anticipated to grow by more than 20% per year (see **Figure 3**). Driven by previous massive growth, the overall cost of installing microgrids has dropped an estimated 25% to 30% since 2014, and is expected to continue on that trajectory.[4] Still, microgrid applications are unique for each organization and, therefore, a feasibility study should be performed to determine the organizational benefits, including the investment versus estimated financial payback and potential operational gains including improvement to resiliency.

This paper offers an introduction to the benefits microgrids can offer colocation providers and data centers, including:

---

[3] "Who Uses Microgrids and Why?", Microgrid Knowledge, 2017

[4] "What's Driving Microgrids toward a $30.9B Market?" , Microgrid Knowledge

- **Smart microgrid architecture**: connecting distributed energy resources (DER) to intelligent control
- **Enhanced resilience**: using multiple energy resources and smart, IoT-enabled controls to ensure the level of operational continuity and redundancy needed, as well as the level of power quality needed, by sensitive equipment
- **Cost-saving opportunities**: maximizing use of renewables while minimizing energy costs using advanced energy analytics

The paper will also briefly overview considerations and options that will help ensure that a microgrid solution is fully optimized:

- **Performing a feasibility study**: to ensure there is adequate return on investment
- **Proper sizing of DER**: to achieve the energy goals of the data center
- **Taking advantage of modular, prepackaged microgrid designs**: to streamline installation, operation, and maintenance
- **Options for financing and operation of the microgrid**: to optimize microgrid investment and management

Smart microgrid architecture

The adoption of microgrids has grown in recent years. They have also gained a significant amount of publicity, such that their nature and purpose are much more widely understood. A microgrid is a localized energy system that interacts with the utility grid, encompassing one or more electric power generating resources and the necessary energy management controls to provide secure electricity to consumers. In contrast to large utility grids, microgrids locate all energy assets – from generation to loads –in close proximity, to serve multiple buildings or even be contained within a single facility or parts of a large data center.

A microgrid is normally connected to the main utility grid, drawing energy from the utility when economically advantageous, using a combination of utility power and on-site energy resources. Microgrids are also configured with the ability to disconnect and run in a self-contained mode when needed. This is appropriately termed 'islanding,' as the microgrid temporarily becomes its own energy island, operating separately from the main grid. This islanding mode is typical for many data center operations, though the mechanism to determine islanding is purely driven by the incoming utility power quality, not by economics or resiliency factors.

First steps in onsite power

All data centers around the world have some form of a backup power system supplying power to computing equipment and critical infrastructure. This is sometimes referred to as an emergency power supply system (EPSS). Most commonly, this takes the form of one or more diesel generators, often supported by a UPS that provides power quality and backup power while generators are starting up.

For the purposes of this paper, backup power systems, while essential to ensure continuity of service, are not considered a microgrid, as they are not intended to run continuously.

Moving toward a true microgrid

In other industries, combined-heat-and-power (CHP) or combined-cooling-heating-and-power (CCHP) systems have become a popular distributed energy resource. These systems are often configured as microgrids, as they include a local energy resource supplying – at least partially – the electricity needs of a facility, as well as delivering useful heat for absorption chillers. Colocation providers and data centers can achieve the same benefits from such systems.

To optimize costs, sustainability, and resilience, a more comprehensive microgrid solution can encompass a variety of DER, including CHP and CCHP, renewables, fuel cells, and energy storage. Choice of DER will depend on economic and environmental considerations.

At the operations level, the coordination of DER is managed by a microgrid control system (see **Figure 4**). In the event of a utility grid outage, the control system is responsible for the safe disconnection from the grid and reliable transition to island mode. In island mode, the system manages all DER to maintain power stability.

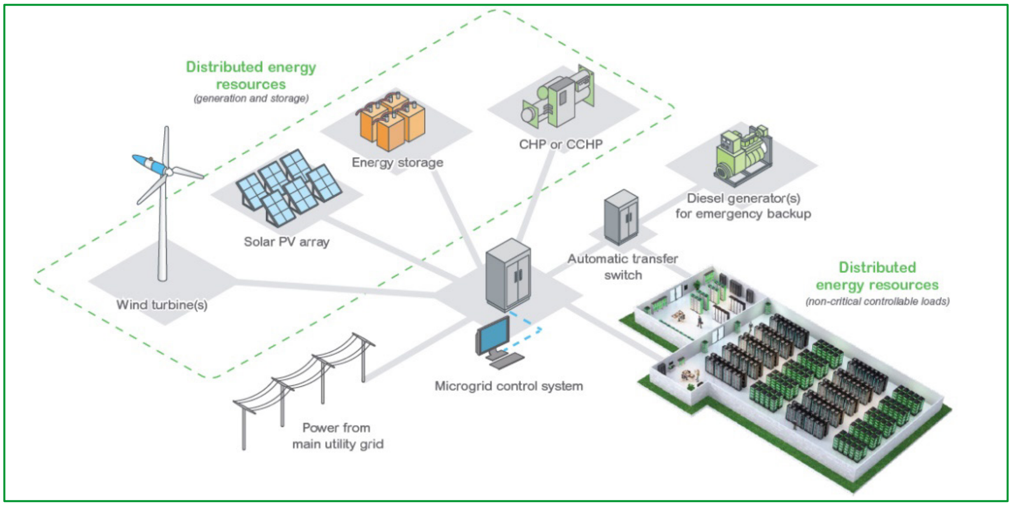


Figure 4
A modern microgrid takes advantage of a variety of distributed energy resources, coordinated by a smart microgrid control system.

With this level of digital connectivity and control, it's crucial that communication networks are secure against cyber threats. A microgrid solution should comply with end-to-end cybersecurity best practices, including alignment with standards such as IEC 62443-4-2 and IEC/ISA 62443-3-3 and the use of cyber-secure components from trusted vendors.[5]

Choices of distributed energy resources

As seen in **Figure 4**, a microgrid can include a wide variety of distributed energy resources. The choice of DER will depend on several factors.

Backup generators
As noted previously, diesel generators are ubiquitous in data centers for backup requirements. They will typically be required to meet service level agreements as well as Uptime Institute's Tier Classification System requirements. Diesel is a reliable fuel source that can be easily stored onsite. However, diesel generators have three potential weaknesses:

1. There are limits to how much fuel can be stored, and therefore the total runtime a data center can expect is often limited to a few days.
2. Environmental emissions regulations will restrict how long a diesel generator can be run during the year.
3. Although many data center operators test their backup generators regularly, it is not a 100% guarantee that generators will reliably start up in the event of a

[5] "Get Secure: End-to-End Cybersecurity Lifecycle Frameworks", Schneider Electric, 2017

utility grid blackout. For diesel generators, this primarily means addressing insufficient maintenance, including regularly testing fuel quality, loading, and starter battery conditions.

CHP and CCHP

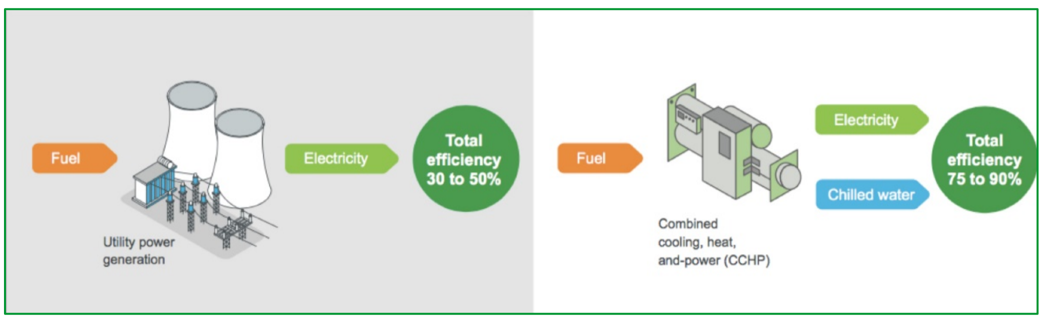
Sometimes referred to as cogeneration, these systems combine electrical generation with the production of heating or cooling. Combined heat and power (CHP) technology has been available for decades and typically use a reciprocating engine or combustion turbine as the prime mover, fueled most often by natural gas. The greatest benefit of CHP and CCHP is efficiency. The system generates electricity at the same time as the prime mover produces heat, which is captured and put to use (see **Figure 5**).

For powering a data center, a more interesting and related solution, combining cooling, heat, and power (CCHP) – also known as trigeneration – is similar to CHP, except with the ability to also provide cooling. Using absorption chillers, the waste heat from the prime mover provides the energy to produce chilled water, which is then used for cooling.

A CCHP system would typically run continuously and would be better maintained than standby generators, meaning it is ready and able to provide power in the event of a blackout. Further, according to the U.S. Department of Energy, “Natural gas infrastructure is typically not impacted by severe weather.”[6] This makes CCHP a good candidate for a data center microgrid. In some cases, depending on energy and fuel pricing as well as local regulations or policies, CCHP can be sized to provide primary power to the facility, with the utility acting as backup.

Figure 5
Energy efficiency of CCHP compared to traditional electricity and cooling supply.

Source: MDPI



Of course, any emissions produced by the CHP system will need to be considered. And the microgrid system will need to continuously balance requirements against costs. This includes determining, at any given time, what the difference is between the cost of grid electricity and natural gas, also called ‘spark spread’ (keeping in mind there is no peak demand charge for natural gas). Likewise, it is important to understand the balance of cooling against electricity output, and determining at what point you should buy extra electricity from the utility versus selling it back to the grid. These points will be covered in more detail further on in this paper.

Renewables

As noted by the U.S. Department of Energy, determining whether renewables make sense for a particular facility will depend on availability and costs, policies and incentives, and local market factors such as electricity pricing and regulations. A number of renewable options are worth considering.

As data centers operate 24/7, solar-based energy generation can be a good choice, as consumption can be maximized. However, it takes about 4-5 acres of space to

[6] “Combined Heat and Power for Resiliency”, U.S. DOE, 2016

generate one megawatt of solar electricity. For those that have the roof space or surrounding land available, dropping solar prices make it a good choice. According to Energy Sage, "10 years ago, in 2009, the cost of a solar panel installation was $8.50 per watt… [in 2019] the price of solar has fallen by over 60 percent, to just $3.05/watt."[7]

Wind power can be a potential choice. However, the use of large stand-alone turbines must take into account any local community concerns. They must also be located far enough from existing structures to avoid noise and safety issues, which can make connection to the data center challenging. Smaller vertical wind turbines can be mounted on a roof. Consistently good wind conditions will be imperative. Similar to solar, connection to the utility grid to sell excess energy may be an option.

Biomass energy can be a good choice if there is availability of resources, which could include plant matter, residues, or waste. Important considerations are cost of the resource as well as the level of particulate emissions that some types of biomass can produce when burned.

Fuel cells
According to the Fuel Cell & Hydrogen Energy Association, "Fuel cells can provide primary power, backup power, or combined heat and power (CHP)."[8] Rather than using combustion, fuel cells generate electricity based on a chemical reaction that combines hydrogen and oxygen. The only fuel cell byproducts are water and heat.

Hydrogen for fuel cells is most commonly produced from natural gas or biogas (methane) using a process called natural gas reforming[9]. However, hydrogen can also be produced from water using a process called electrolysis that can be powered by a renewable energy source, such as solar or wind. In this case, the resulting hydrogen fuel can be considered a renewable resource. Fuel cells are considered by policy and regulation to be renewable resources (even with natural gas reforming) in five U.S. states: Connecticut, New York, Ohio, Indiana, and Oklahoma. They are often exempt from air permitting due to their ultra-low emissions.

Fuel cells have a much smaller footprint and weigh less than competing alternatives. Depending on financing, incentives, and fuel costs, these systems may deliver some savings over alternatives. For this reason, more and more data center operators are exploring fuel cell technology.

Energy storage
Having the ability to store energy onsite has a wide range of benefits for data centers. First, acting as part of a UPS, energy storage can help support resilience against a utility grid outage, in coordination with backup generators, CCHP, and renewables. Second, it can maximize the value of renewable energy generation by saving excess energy for use when solar or wind generators are not producing electricity. Finally, stored energy – both within the UPS system and dedicated battery energy storage systems (BESS) – can be dispatched for peak demand management, helping reduce the amount of energy consumed from the utility grid during periods of high energy cost. Though capital intensive, energy storage is a good option to address load peaks, while other DER (such as CCHP or fuel cells) are more suited to support the base load.

[7] "How solar panel cost and efficiency have changed over time", Energy Sage, 2019

[8] "Fuel Cells and Hospital Applications", FCHEA

[9] "Hydrogen Production: Natural Gas Reforming", Energy.gov

Enhancing resilience

A microgrid system can be thought of as a three-layer architecture (see **Figure 6**). The first layer includes all smart (IoT-enabled), connected products, including monitoring and control devices, distributed energy assets, etc. The middle layer is where local 'edge control' takes place in real time. This is the combination of microgrid controller and associated software that monitors all assets, makes critical decisions, and takes cost-optimized action to control generation and consumption assets to enhance resilience and maximize use of renewables.

The top layer includes applications, analytics, and supporting services that augment the microgrid solution. Often hosted in the cloud, advanced energy analytics help optimize when and how to produce, consume, and store energy to minimize costs and maximize sustainability. This is detailed later in this paper.

At the control level, the microgrid system supervises all DER and uses artificial intelligence-supported algorithms[10] to take the appropriate actions as required:

- **Manage grid connection**: The system must be able to disconnect from the grid, support critical loads, and reconnect after an event.
- **Manage DER during island mode**: The system must ensure the amount of energy production is balanced against consumption.
- **Ensure microgrid safety**: The microgrid system must manage facility-wide electrical network protection, in grid-connected and island mode, for every combination of DER. This is done to ensure that circuit breaker coordination is maintained and, in turn, impact is minimized if an electrical fault occurs anywhere in the facility.
- **Manage DER in grid-connected mode**: The controller needs to be programmed to maximize the use of renewables when possible. Weather forecasting needs to be automatically considered to properly predict future energy production of renewable resources, in particular wind and solar. Excess energy needs to be saved to an energy storage system or sold back to the grid, or both. The microgrid system must manage the level of authorized energy export to the utility grid. This can be in reaction to a demand response utility signal, third party signal, or predefined threshold.

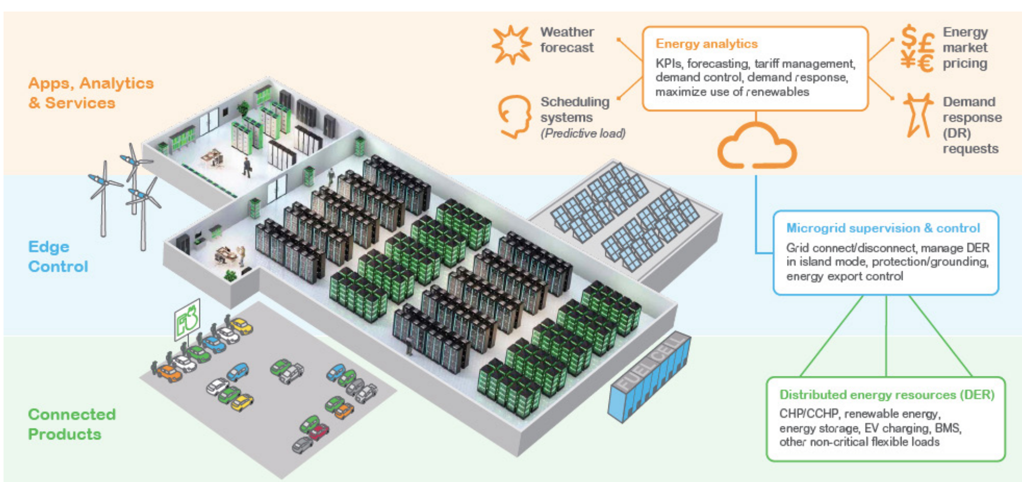


Figure 6
The three functional layers of a microgrid architecture work in tight coordination to maximize resilience, cost savings, and use of renewable energy, including other DER.

[10] The Schneider Electric EcoStruxure Microgrid Advisor (EMA) is an example of a control system that uses AI to support predictions.

The microgrid system requires exceptional speed and performance. Fast switching response helps ensure the stability of the facility's power by balancing load demand with available generation from DER assets.

Implementing microgrid control system redundancy can further support reliable operation under any conditions. Additionally, a microgrid system should provide options for automatic versus manual control, in case it is necessary to override the system's control algorithms under special circumstances.

Similar to most existing data center power infrastructures, in the event of a main grid interruption – possibly due to storm damage or a grid overload issue – the microgrid will automatically island from the grid to protect the quality of power in the facility and continuously serve all critical loads. If not active already, generation assets need to have the ability to start up immediately and independently from the grid, operating without a grid signal. And, of course, there must be enough generation capacity to support all critical loads.

The most advanced microgrid solutions also provide proactive protection capabilities. In response to weather data and alerts, a microgrid system can 'look ahead' to approaching conditions and prepare to island from the grid prior to the arrival of a major storm, giving enough time for facility personnel to take precautionary measures.

Disconnection from the grid does not, necessarily, need to be in response to a complete utility grid outage. If there is instability on the main grid, islanding can help protect sensitive equipment against harmful effects of poor power quality. For example, a local lightning storm can cause massive voltage transients that can be passed through as disturbances along the facility's power distribution network.

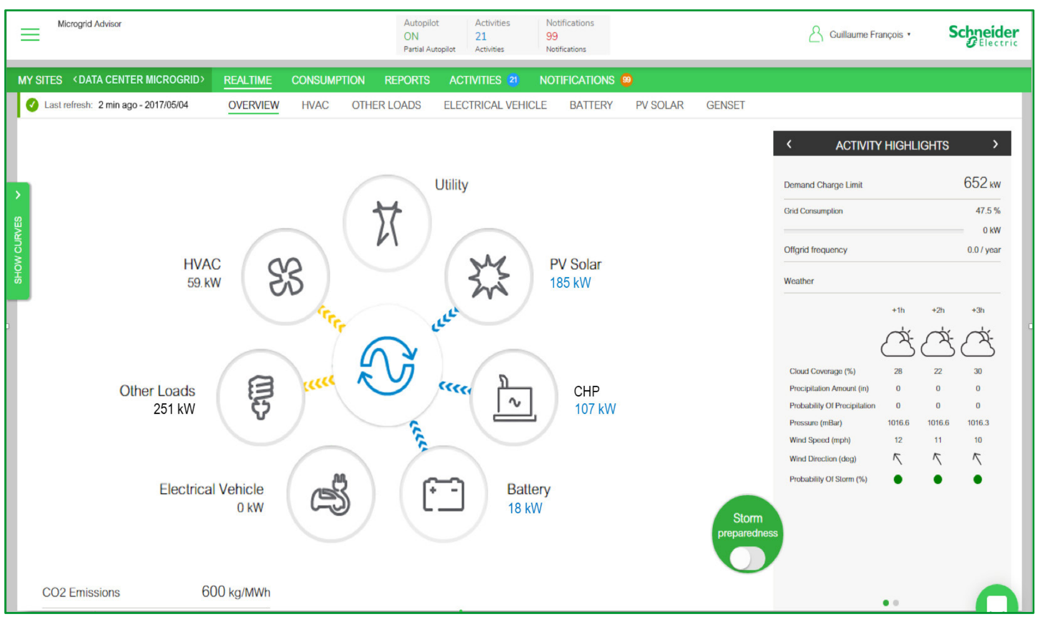


Figure 7
The microgrid control system takes the appropriate actions to disconnect the data center from the utility grid, then manage DER to balance generation against demand, and ensure safe

Depending on the level of capability currently in place, a data center microgrid can respond to a utility supply-side issue as appropriate. With increasing levels of DER, a greater level of resilience is possible. For example:

- **No microgrid - backup power only**: If the facility has backup generators and a UPS is in place, power is not interrupted, as the UPS supplies critical load power until gensets are online. The backup system is engaged through automatic transfer switches (ATS) to supply critical circuits. If the gensets fail to start up, or fail to continue to run, power to the entire facility will be lost. Also, due to the need for diesel fuel, gensets have limited duration capability.

- **Microgrid with renewables - no CHP/CCHP**: The microgrid system does not conflict with the emergency backup generators, which will still be engaged as a first line of defense against any failure of the main grid. Renewables can be used to supplement the emergency backup generators to preserve fuel consumption. In addition, if backup generation operates reliably to supply critical circuits, the microgrid can use DER to supply other circuits in the data center to keep some services up and running during the grid outage. This can be extremely important in the event of a large-scale natural disaster.
- **Microgrid with CHP/CCHP**: The CHP/CCHP system will be running continuously, serving the partial electrical needs of the data center. Typically, CHP/CCHP is sized to meet demand. Electricity demand can be grid augmented and if CHP/CCHP is sized large enough to supply the entire facility, backup gensets will not need to be engaged at all in case of a grid outage.
- **Microgrid with CHP/CCHP, plus renewables**: With additional DER, the microgrid can achieve almost unlimited autonomy, depending on fuel supply for CHP/CCHP. The additional renewable resources – such as solar, wind, and energy storage – can be used to augment the electrical energy supply of the CHP/CCHP to serve loads throughout the facility.

Cost saving and sustainability opportunities

Beyond helping a data center improve resilience against the possibility of a grid blackout or power instability, a microgrid can help optimize energy costs and maximize the use of renewable energy. Ten years ago, resiliency was the only reason one would buy a microgrid, as energy self-generation was purely cost prohibitive – it was never cheaper than a grid. Today, with photovoltaics (PV), and CHP and CCHP with natural gas, in many states [within the USA] you can generate energy cheaper than you can buy it. And as prices for battery energy storage systems (BESS) continue to become more cost effective, installing such BESS helps optimizing a Microgrid while also creating financial incentives by participating in grid services, offered by utility companies.

Even in regions where energy from the grid is not always more costly, a microgrid offers many opportunities to achieve cost savings. This is due to how microgrids are enabling a new, dynamic model between a utility and its customers. In other words, a cost-optimized utility interdependency. IEEE stated that non-utility microgrids shift a centralized, one-way power system to a bidirectional system with new supply and load variables at the grid's edge.[11]

Advanced energy analytics

The supply variables referred to by the IEEE are the distributed energy resources of the microgrid. With sophisticated tools and methods, the energy flexibility and functional value of DER can be fully monetized.

To create the best ROI (return on investment), the most advanced microgrid solutions provide analytic intelligence that integrates external data:

- Weather prediction
- Availability of solar and wind
- Energy market pricing, including pricing for grid electricity as well as other fuel sources such as natural gas, hydrogen, and diesel

[11] "Utility and Other Energy Company Business Case Issues Related to Microgrids, …", IEEE, 2014

The analytic layer tracks and visualizes all relevant key performance indicators listed above. Some vendors use advanced AI modeling where the application predicts facility demand based on weather forecasts and historical energy usage. It then determines the best times and means to generate, use, store, or sell energy (see **Figure 8**). Some example scenarios may include:

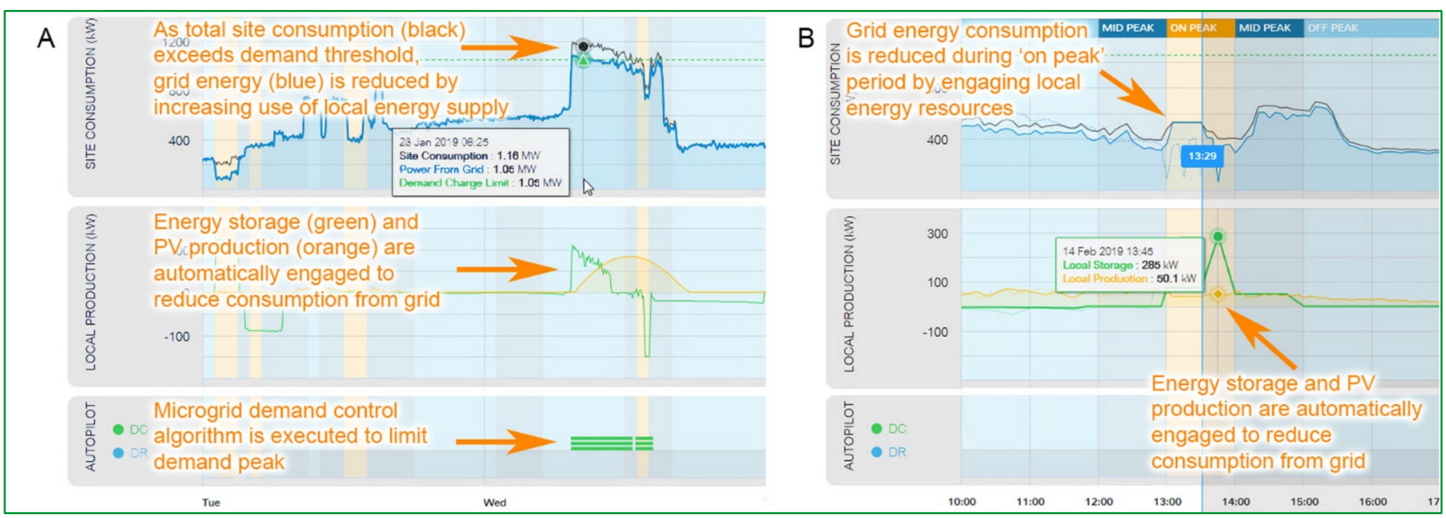
- Avoid demand penalties
- Tariff management
- Participate in demand response (DR) program
- Optimize self-consumption of renewables

The more flexibility its microgrid has in terms of onsite generation, energy storage, and controllable loads, the more optimization opportunities can be taken advantage of by the data center. Additionally, the greater the variety of DER, the greater the resiliency against a single mode of disruption.

The microgrid system provides an intelligent, transparent way to manage a data center's distributed energy resources, as well as a simple, automated way to participate in smart grid programs as an energy prosumer. A *prosumer* is an operation that can both produce and pro-actively consume energy. The microgrid platform takes into account the energy, environmental, and economic needs of the data center, and then automatically proposes the optimal arbitrage between the different opportunities.

Figure 8

The microgrid automatically performs demand control (A) and tariff management (B) by engaging DER as necessary. Energy storage is recharged at optimal times, from renewables or the grid.



Microgrid clusters: greater demand for greater leverage

In some regions of the globe, grid operators are using commercial 'aggregators' to help effectively combine energy-consuming customers into larger blocks of demand referred to as 'virtual power plants' (VPP).

As more colocation providers and data centers begin to implement onsite DER, combining together with other DER owners creates microgrid clusters. These provide a potential economy of scale that can offer further opportunities to monetize energy flexibility by working with grid aggregators and operators.

Designing the optimal data center microgrid

A new era in microgrid design

Microgrids have been around for decades, though we may not have called them microgrids. Constraints of past microgrid designs and implementations were due to the complex and static control schemes of multiple DER. They all lack the dynamic modeling that are now possible due to IoT-enabled devices, powerful analytics, and reduced cost.

Due to the need to meet operational and financial goals, along with selecting from many possible system architectures, microgrid designs are still challenging. Fortunately, design tools are emerging that use advanced modeling algorithms to assist in the feasibility analysis of multiple design choices.

A microgrid system design tool creates a microgrid model by taking into account constraints such as existing equipment, costs, functionality, and project execution. To develop the most complete and accurate model, it should also include as inputs:

- Site physical limitations and local weather forecasting
- Base energy utilization and load profiles
- Electricity tariff structures and demand surcharges
- Access to different fuels and their costs (e.g., natural gas, diesel)
- Cost of electrical generation and storage assets
- Operation and maintenance costs
- How the site plans to use its energy – buy, self-generate, store, sell, and participation in ancillary service markets
- Energy export limits or net zero agreements (see sidebar)
- Future expansion plans

Net zero agreements

Net zero does not mean zero energy import from the utility grid. Rather, as the balance calculation is typically made annually, net zero can be accomplished by exporting at levels that exceed consumption during periods of peak PV production (i.e., summer months) to offset periods of low or no production (i.e., winter months) when energy is consumed from the utility grid. Renewable production and storage should be sized to best meet the intent of the net zero agreement.

Using advanced control algorithms and simultaneous analysis of multiple types of DER, a design tool needs to ensure that the electrical and thermal demand of the facility throughout the year is satisfied. This also helps optimize the size, type, and mix of DER to meet resiliency requirements and achieve the highest financial performance and, in turn, the shortest payback period.

When planning a microgrid project, it is advantageous for the design tool to apply the same algorithms used in the final microgrid control systems. Compatibility between the model and the installed operational system helps ensure optimal microgrid performance is being met.

Additionally, the design model can be used in the operation phase as a ‘digital twin’ to compare real and simulated data to validate performance, check potential adaptation of the control solutions to site evolution, and support ‘what if’ studies (e.g., tariff optimization).

Modular microgrid architectures

Due to the maturing of the microgrid market, advancements in knowledge and technology have spawned a new breed of microgrid solutions based on standardized, prepackaged system components. These building blocks, together with predefined architectures, enable configured-to-order microgrid systems. This is helping minimize microgrid delivery time and costs while maximizing ROI, due to simplified design, installation, support, and maintenance. Designs are also more reliable due to tested and validated architectures, and are easier to adapt over time.
Pre-engineered control centers

Pre-engineered microgrid control centers allow for selected components to be pre-installed during manufacturing to then deliver a ready-to-use solution. The newest designs typically include:

- Microgrid controllers and power management that oversee distribution and control of electric power flow between the electric utility grid, DER, and all critical and flexible loads.
- Protection and monitoring, such as protective relays, circuit breakers, intelligent energy metering with power quality monitoring capability, and front panel touchscreen interface.
- Scalability and adaptability, to meet requirements of small or large sites, and to allow for future expansion and fast integration of additional DER.

Predefined control algorithms

In addition to modular switchgear designs, prepackaged microgrid management software includes pre-engineered, AI-driven algorithms to support all important decision-making and control applications, including: managing grid connection, managing DER in grid-connected and island mode, and safety assurance. It will also include a variety of decisions and actions to minimize cost and maximize sustainability, including: avoiding demand penalties, tariff management, demand response participation, and optimizing self-consumption of renewables. Traditional sequence-of-operations (SOO) in data center designs are replaced by these new and more sophisticated algorithms.

Microgrids made affordable

Guidehouse anticipates that the "evolving power sector and customer factors will increase demand for innovative DER financing options" and that "C&I energy users will increasingly seek cost-effective, customized, and comprehensive energy solutions [that] guarantee energy use reduction and cost savings without CAPEX or an impact on their day-to-day operations to meet sustainability and operational efficiency needs."[12]

Convinced by the many benefits outlined in this paper, the decision to move forward with implementing a data center microgrid will still include a variety of financial considerations.

For example, the management team should evaluate the current state of its energy infrastructure. Are chillers nearing end of life in need of replacement? If yes, this may be the perfect time to replace with a CCHP-based microgrid. And, as noted in the previous section, the local tariff and demand penalty structure, along with local natural gas pricing, will influence whether onsite energy resources make economic sense.

If factors point positively toward a microgrid solution, the final step will be to determine the best way to finance and operate the new infrastructure. Part of the financing questions will include the investigation of all available government incentives.
Microgrid financing options
Today, there are two primary types of financing and operation models for microgrids:

1. Customer-owned
Some organizations prefer to own their microgrids outright using cash or loans. In this scenario, the operator retains complete control over the system and benefits

[12] "Leaderboard: Energy as a Service Solutions Providers", Guidehouse, Q1 2019

from the financial returns. In this model, the microgrid is a capital expense; however, all financial, technical, and operational risk is on the data center manager.

2. Energy-as-a-Service (EaaS)
This model offers a flexible ownership structure, which is essentially a power purchase agreement model that may leverage an equity and debt financing structure. Parties involved could include a vendor, a financier, and sometimes the utility. An EaaS agreement can incorporate a range of financing and contracting concepts and innovations, including:

- Equipment leases/loans
- Power purchase agreements
- Efficiency savings agreements
- Energy savings performance contracts
- Shared savings agreements
- Energy asset concession agreements

The data center operator will pay a monthly fee for operational expenses to the third-party owner of the microgrid. This model eliminates the data center owner's capital investment and reduces financial risk. Operational risk can be structured flexibly to ensure operational continuity within the comfort level for each facility's administration. It also allows the facility to benefit from the expertise of developers who specialize in power system design and modeling.

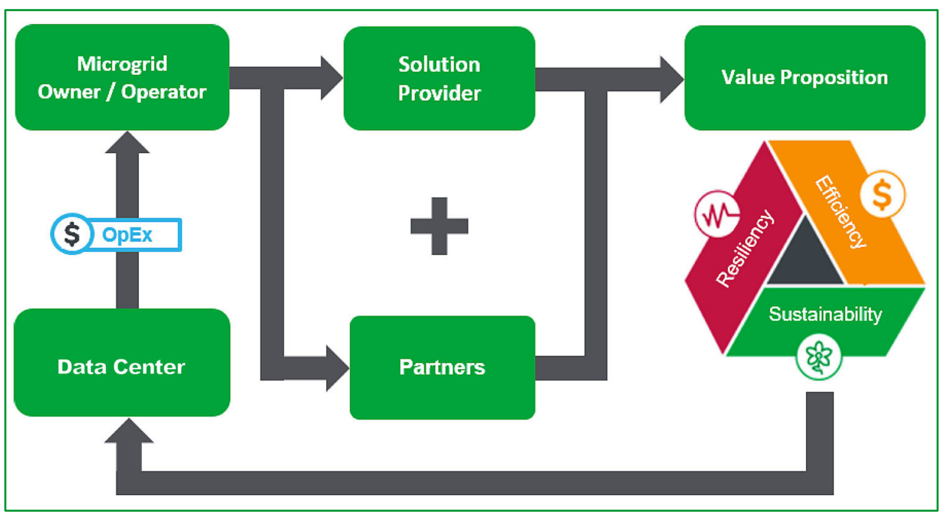


Figure 9
Typical value chain delivered by an energy-as-a-service financing and opera-

Incentives for microgrid, renewables, and energy storage including demand response programs

Depending on what region of the world the data center is operating within, there may be a variety of national and local government policies and incentives that promote investment in solar generation and microgrids. Some examples include:

- **Tax credits**. These can cover a significant portion of solar and microgrid installation costs.
- **Renewable portfolio standards**. Regions with such commitments will be more likely to support solar-friendly policies and incentives.
- **Net metering**. These policies allow the data center to get paid for the solar it produces, sometimes offsetting the cost of installation in a matter of years.

- **Interconnection policies**. Some regions may exempt a data center from pricey interconnection study fees that are part of developing a microgrid.
- **Grant programs**. These can provide partial funding of microgrids, solar, and other generation and storage technologies.
- **Demand Response programs**. Many utility companies are offering financial incentives when participating in demand reduction or frequency stabilization measures.

Conclusion

For colocation providers and data centers, microgrids provide value every day, and not just when the power goes out. Microgrids go beyond diesel-based power backup systems by enabling use of CCHP, renewables, fuel cells, and energy storage. They help increase resilience against grid disruptions, reduce energy-related operational costs, and ensure sustainability, with advanced energy analytic capabilities. Compliant with all applicable national and local regulations, a microgrid helps optimize and balance the use of grid versus onsite energy resources.

Ultimately, a microgrid increases a data center operator's confidence in uptime, ensuring tenants' needs for computing continuity are met. Now is the perfect time for data center infrastructure managers to adopt a microgrid solution. The technology is mature, making solutions more affordable and easier to implement than ever before. To ensure an optimized solution, seek a trusted expert that can offer the newest microgrid planning tools, modular architectures, along with EaaS options to reduce financial risks while maximizing return on investment.

About the author

Carsten Baumann (Electrical Engineer)
Carsten is the Director and Solution Architect at Schneider Electric. Carsten helps data center customers to evaluate Microgrid opportunities. He has developed and taught many classes on a diverse set of technical subjects in the fields of data centers, IT, telecommunications, signal processing and data compression. His technical papers have been published in peer-reviewed journals and he frequently speaks on national and international venues.

RATE THIS PAPER ★★★★★

Resources

Microgrids for Data Centers

"Data Centers and Advanced Microgrids - Meeting Resiliency, Efficiency, and Sustainability Goals Through Smart and Cleaner Power Infrastructure", Guidehouse, Q4 2017

Microgrid DER

"The Evolution of Distributed Energy Resources", Microgrid Knowledge, 2018

"Combined Heat and Power (CHP) Technical Potential in the United States", US DOE, 2016

"How solar panel cost and efficiency have changed over time", Energy Sage, 2019

Microgrid financing and operation

"Leaderboard: Energy as a Service Solutions Providers", Guidehouse, 1Q 2019

"The Financial Decision-Makers Guide to Energy-as-a-Service Microgrids", Microgrid Knowledge, 2018

Cybersecurity

"Get Secure: End-to-End Cybersecurity Lifecycle Frameworks", Schneider Electric

Browse all
white papers
whitepapers.apc.com

Browse all
TradeOff Tools™
tools.apc.com

Contact us

For feedback and comments about the content of this white paper:

Data Center Science Center
dcsc@schneider-electric.com

If you are a customer and have questions specific to your data center project:

Contact your Schneider Electric representative at
www.apc.com/support/contact/index.cfm