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How new microgrid designs help hospitals increase resilience, cut costs, and improve sustainability

by Markus Hirschbold and Andy Haun

Executive summary

As hospital administrators re-evaluate their facilities' resilience against grid instability, many also face budgetary and environmental pressures. Microgrid technology is increasingly being used to further enhance uptime, while reducing energy spend and minimizing a facility's carbon footprint. The newest of these solutions integrate advanced energy analytics to more intelligently manage energy assets, from gensets and CHP, to renewables and loads.

Introduction

Though the healthcare industry worldwide faces a number of business and technical challenges, three energy-related concerns loom large for administrators: resilience, costs, and sustainability.

Ensuring patient safety

Generator failures at hospitals have made the news in recent years, including failures during U.S. hurricanes Katrina, Irene, and Sandy. This has often resulted in large evacuations of patients. In a few cases, lives were put at risk.[1]

Continuity of electrical supply is paramount for patient safety. From an electrical distribution point of view, this means not losing power and making sure that critical life-sustaining equipment is always operational. At the same time, increasing power demand, aging electrical transmission infrastructures, and more frequent violent storms are all making grid stability issues more common in many regions.

In the past, emergency power has been pre-defined to address only the most critical functions – e.g. operating rooms, intensive care, emergency, etc. – accounting for 20 to 50% of the total services of the hospital. However, as the number and severity of major storms have been increasing, local communities are in greater distress, requiring 100% sustained hospital services, enabled by 100% power availability.

In addition, any disturbances on the supply side can be passed through as power quality problems on a hospital's power distribution network. As facilities add increasing amounts of advanced medical technologies, more power-sensitive equipment is put at risk of failure. Even with traditional diesel-powered backup generation in place, there is a need for higher reliability over longer, sustained periods.

Figure 1

As hospital facilities continue to expand and add more energy-intensive, power-sensitive equipment, they need to ensure a continuous supply of clean electricity while also controlling energy costs.

[1] "Why Do Hospital Generators Keep Failing?", ProPublica, 2012

Budgetary pressures

Re-evaluating the reliability of backup power systems is not the only challenge facing hospitals today. In their 2019 outlook for the healthcare industry, Deloitte notes “Global health care expenditures are expected to continue to rise as spending is projected to increase at an annual rate of 5.4 percent between 2017-2022.” Two of the five key factors impacting the financial performance are listed as “increased use of exponential technologies” and “the demand for expanded care delivery sites”.[2]

Though not mentioned directly in the report, it is easy to understand how energy has, and will continue to, play a key role in hospital facility operations. “Hospitals use 2.5 times as much energy as commercial buildings of the same size. This isn’t surprising given that they must care for patients 24/7, which creates greater demand for lights, heat and cooling, as well as large amounts of hot water and steam for equipment sterilization, and refrigeration for temperature sensitive medications.”[3]

Hospitals also need to maintain a high number of air exchanges in areas such as operating theaters and intensive care units to reduce the risk of infections. This is another major contributor to HVAC energy consumption.

As healthcare organizations respond to the need to expand their facilities and add more energy-intensive equipment, the cost of energy is top of mind for financial teams. As demand for electricity continues to increase and the associated price of energy continues to rise (Figure 2), limited OPEX budgets will be put under pressure.

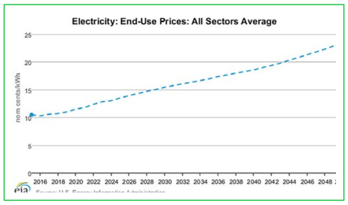


Figure 2

Energy costs are expected to continue to trend upwards worldwide through 2050, including in the USA.

Source: EIA

Meeting sustainability goals

As it is for many industries in many regions, meeting environmental regulations is an ongoing requirement for healthcare facilities. Electricity and fossil fuel consumption are both part of the formula in calculating GHG emissions. Managing consumption and using 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 in the local community.

Green building certifications

Many global and regional certifications are available worldwide. Examples:

- LEED (global)
- BEAM (Hong Kong)
- BREEAM (UK, EU)
- DGNB (Germany)
- CASBEE (Japan)
- EDGE (emerging economies)
- Energy Star (US, Canada)
- Green Globes (US, Canada)
- Green Mark (Singapore)
- Green Star, NABERS (Australia, S. Africa)

“Green Building Standards and Certification Systems”, WBDG

The emergence of the hospital microgrid

Every hospital will have a different balance of the above concerns, depending on the local commercial and regulatory environment. Faced with these multiple challenges, more and more hospitals are building their own microgrids to improve patient safety through better power availability, while relieving budgetary and environmental pressures. 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.

With their need for large amounts of continuous, clean, and affordable power, hospitals 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

[2] “2019 Global Health Care Outlook – Shaping the future”, Deloitte, 2019

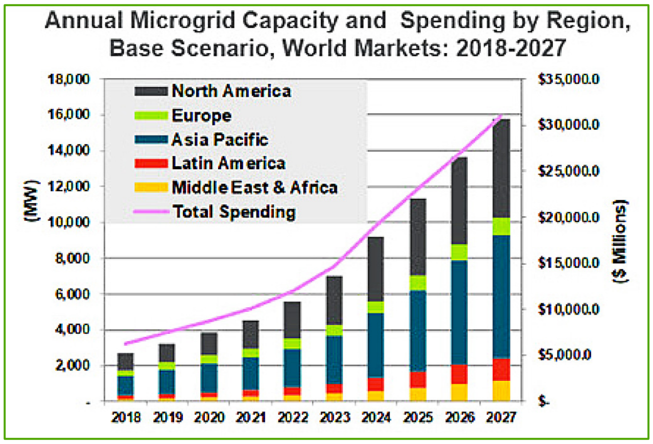
[3] “Healthcare Microgrids - The path to more reliable, clean, lower cost energy in hospitals”, Microgrid Knowledge, 2017

applications, such as utilities, community services, government offices, military bases, large industrials, hospitals, and educational campuses.[4] 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.

Graph courtesy Microgrid Knowledge and Navigant Research



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.[5] 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.

This paper offers an introduction to the benefits microgrids can offer hospitals, including:

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

Smart microgrid architecture

Microgrids have become far more common in recent years and have 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 generators 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.

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 onsite energy resources. Microgrids are also configured with the ability to disconnect and run in a self-contained mode when needed. This is appropriately termed

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

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

'islanding', as the microgrid temporarily becomes its own energy island, operating separately from the main grid.

First steps in onsite power

Almost all hospitals around the world have some form of backup power system supplying power to a portion of the hospital. 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 an uninterruptible power supply (UPS) that provides power quality and backup power while generators are starting up.

In many regions, government regulations require backup power to be in place to ensure that the most critical functions of the facility will be able to ride through an outage on the main grid for a specified length of time.

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

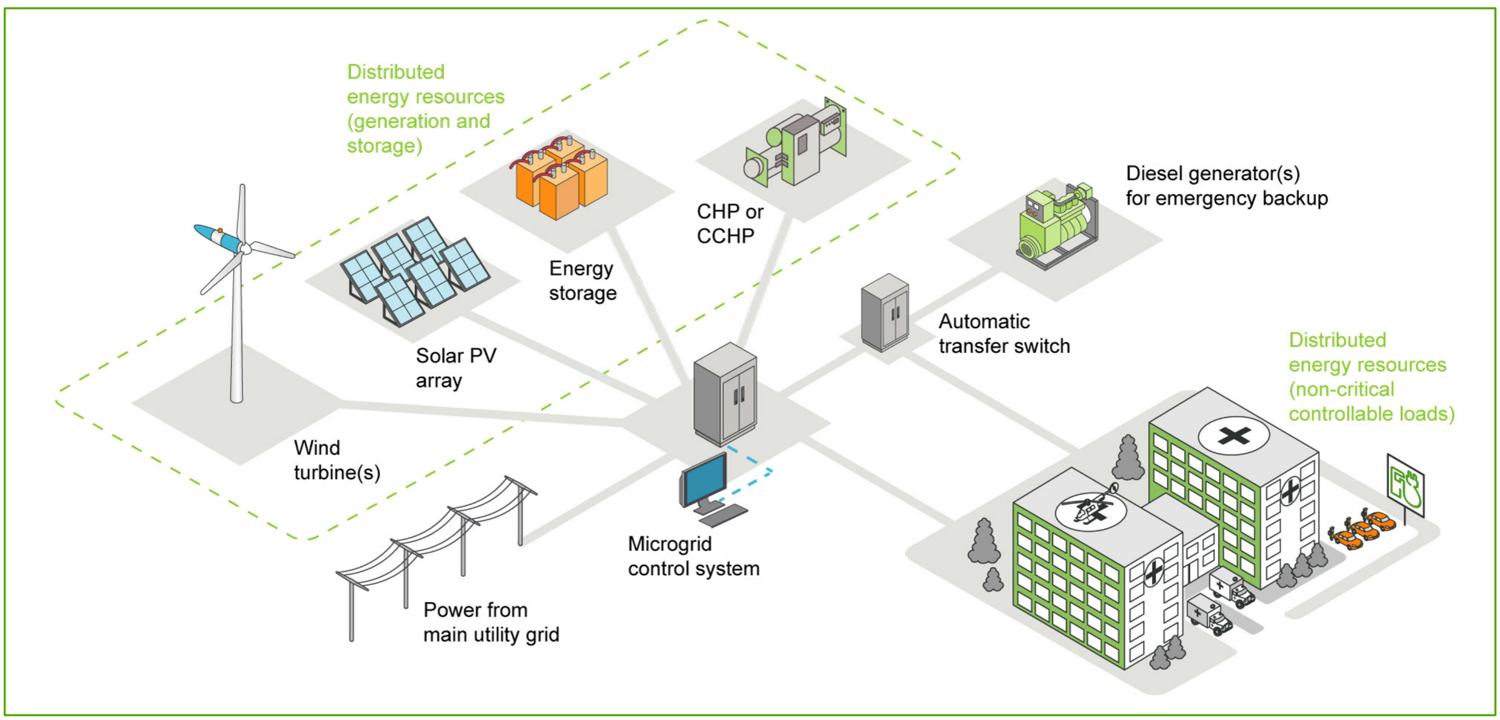
Moving toward a true microgrid

Many hospitals have adopted combined-heat-and-power (CHP) or combined-cooling-heating-and-power (CCHP) systems. These systems are often configured as microgrids, as they include a local energy resource supplying – at least partially – the electricity needs of a hospital, as well as delivering useful heat.

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

Figure 4

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



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.

Further gains can be achieved by connecting the microgrid control system to the hospital's building management system (BMS) and energy management system (EMS). Advances in digitization and the Internet-of-Things are making power and building systems more intelligent and connected. Integrating these systems with the microgrid control system enables the 'flexibility' of DER, including non-critical controllable loads (e.g. electrical vehicle charging stations), to be fully exercised to optimize costs and reliability.

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.[6]

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 hospitals for backup requirements and will typically be required to meet local regulations. 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 hospital can expect is often limited to 48 hours.
2. Environmental emissions regulations will restrict how long a diesel generator can be run during the year.
3. Though regulations require that a backup generator be regularly tested, it is not a 100% guarantee that generators will reliably start up in the event of a utility grid blackout. The examples in the introduction should be a wakeup call that steps to improve the reliability of backup systems are prudent.

CHP and CCHP
Sometimes referred to as 'cogeneration', these systems combine electrical generation with the production of heating or cooling. CHP technology has been available for decades and has often been the first step toward creating a microgrid for many hospitals.

The U.S. Department of Energy reported in 2016 that 368 healthcare sites had installed a CHP system, yet this represents only about **12% of the technical potential hospitals should be taking advantage of**.[7] As noted by the DOE, "Hospitals have the coincident electric and thermal loads that match CHP capabilities and drive project economics. Hospitals need continuous power and have a large demand for domestic hot water, sterilization and laundry. In addition, hospitals are considered critical facilities in the event of a natural disaster or emergency, so the backup reliability of CHP is a good match for their needs."

Case Study: CHP

"[The] CHP system at the Texas Medical Center in Houston allowed the hospital to retain power during Hurricane Harvey in August 2017. As the largest medical center in the world, the results of a total power outage there could have been catastrophic. Instead, the hospital was able to continue to operate the largest chilled water district energy system in the United States, as well as meet crucial air conditioning, refrigeration, heating, sterilization, and laundry needs."

Alliance for Industrial Efficiency

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

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

CHP systems typically use a reciprocating engine or combustion turbine as the prime mover, fueled most often by natural gas. The greatest benefit of CHP is efficiency. The system generates electricity at the same time as the prime mover produces heat, which is captured and put to use. Compared to traditional power plant electricity production and boiler-based heat production, which are at best a combined efficiency of 50 to 58%, CHP can be 75 to 90% thermally efficient,[8] depending on climate. Less losses mean less money wasted and fewer emissions. It also means that, unlike backup generators, CHP delivers benefits on a continuous basis.

Usually, a CHP system runs continuously and is 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. DOE, "Natural gas infrastructure is typically not impacted by severe weather."[9] In some cases, depending on energy and fuel pricing as well as local regulations or policies, CHP can be sized to provide primary power to the facility, with the utility acting as backup. If the system provides excess energy, there may also be the possibility of selling that power back to the grid. Of course, any emissions produced by the CHP system will need to be considered.

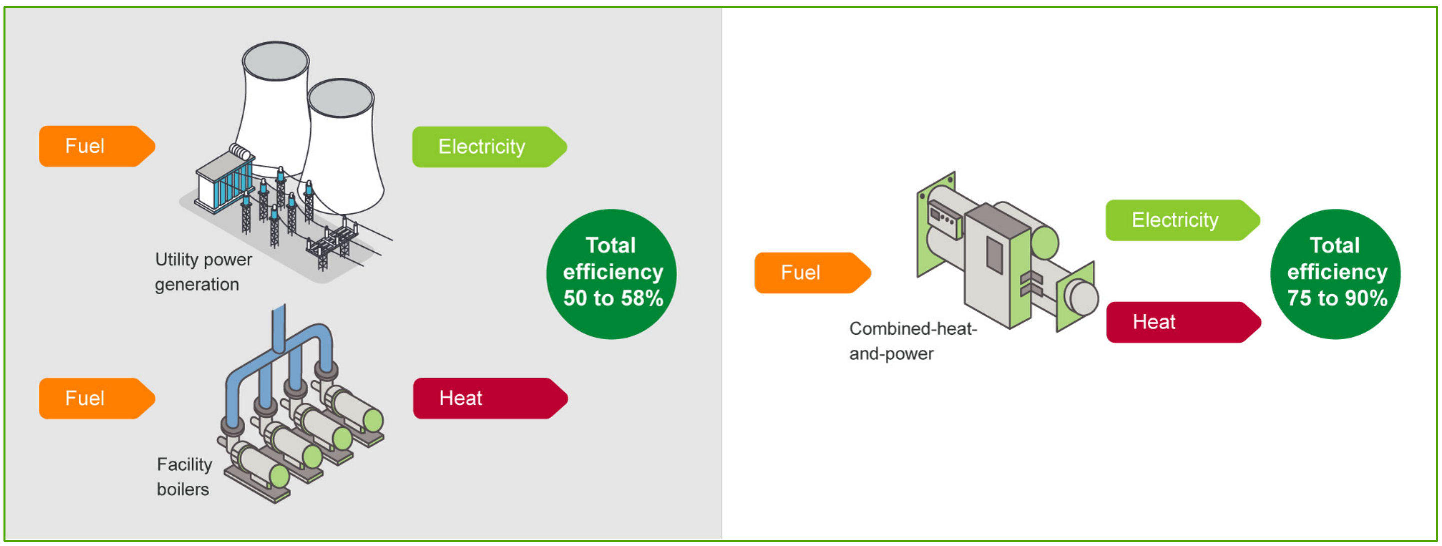


Figure 5

Energy efficiency of CHP compared to traditional electricity and heat supply.

Based on data from U.S. DOE and Coenergy Canada

Another related solution, combined 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. Depending on the local climate, CCHP may be a better choice over CHP, and can provide all the same benefits of efficiency and reliability.

For both CHP and CCHP systems, 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 (keeping in mind there is no peak demand charge for natural gas). Likewise, it is important to understand the balance of heating and cooling against electricity output, and determining at what point you should buy extra electricity from the utility versus

[8] "What Is CHP", Coenergy Canada

[9] "Combined Heat and Power for Resiliency", U.S. DOE, 2016

selling it back to the grid. These points will be covered in more detail further on in this paper.

> "Rapidly rising energy costs and tightening regulations on carbon emissions are making renewable energy increasingly compelling to hospitals. Renewables were once viewed as niche technologies, but improved funding, incentives, and technology have positioned renewable energy to enter the mainstream."
>
> *U.S. DOE*

Renewables

In the US, healthcare represents 10 percent of national emissions, with hospitals representing 39 percent of that total. The industry is expected to grow from $3.4 trillion nationally in 2016 to $5.5 trillion by 2025,[10] and we can expect emissions to grow equally fast, unless controlled.

As noted by the U.S. DOE, determining whether renewables make sense for a particular hospital 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.

Solar energy generation is a perfect fit for most hospitals. Roof space can often be plentiful. If not, adding solar canopies in parking areas can provide the double benefit of renewable energy and welcome shade. Also, hospital facilities operate 24/7, meaning solar energy self-consumption can be maximized. And the price of solar is continuing to drop. 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."[11]

Solar energy comes in two forms: *photovoltaic* (PV) that directly converts solar energy to electricity, and *solar thermal* that produces steam to drive a turbine to generate electricity or to provide hot water for requirements like hospital laundry or showers. The viability and efficiency of solar panels depends greatly on mounting, orientation/tracking, shading, and weather. Where utility side interconnection is possible, a net metering arrangement allows excess solar-generated energy to be sold to the grid.

Wind power is another potential choice. For a stand-alone turbine, it depends on available location far enough from existing structures to avoid noise and safety issues, as well as taking into account any local community concerns. However, building-integrated designs – such as roof mounting – are also emerging as a viable alternative.[12] For these, weight and vibration must be considered. Of course, for either design, consistently good wind conditions will be imperative. Similar to solar, there may be opportunity for connection to the utility grid and to sell excess energy.

Biomass energy can be a good choice if there is availability of resources, which could include plant matter, residues, or waste. Examples are waste wood chips from a mill or the spent grain from a brewery. Burning biomass is often used for CHP, producing both electricity and heat. 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

Fuel cell technology has been advancing and gaining global market share quickly. Valued at USD 3.21 billion in 2016, with continued massive growth being projected[13], fuel cells are finding a wide scope of application, from transportation to onsite stationary power generation. According to the Fuel Cell & Hydrogen Energy Association, "Fuel cells can provide primary power, backup power, or combined heat

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[10] "Can the healthcare sector match big tech in going 100 percent renewable?", GreenBiz, 2018

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

[12] "Wind energy: building-integrated turbines", ClimateTechWiki

[13] "Fuel Cell Market Size, Share & Trends Analysis Report", Grand View Research, 2016

CASE STUDIES: Fuel Cells

Hartford Hospital (Connecticut) – 1.4 MW fuel cell supplies about 60% of the hospital's power and most of the facility's heat requirements. Excess heat is harnessed and utilized by a nearby school system.

Sutter Santa Rosa Hospital (California) – new facility, operates a 375 kW fuel cell system to generate about 70% of the hospital's electricity needs.

Fuel Cell & Hydrogen Energy Association

and power (CHP)."[14] 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.

As hydrogen is not a naturally occurring fuel, it needs to be manufactured. Today, hydrogen is most commonly produced from natural gas or biogas (methane) using a process called natural gas reforming.[15] 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: CT, NY, OH, IN, OK. 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. As such, they can be situated outside, inside, or on rooftops. Depending on financing, incentives, and fuel costs, these systems can also deliver significant energy savings. For these reasons, many hospitals have adopted fuel cells to supply electricity, heat, and hot water to their facilities (see Case Studies: Fuel Cells).

Energy storage

Having the ability to store energy onsite has a wide range of benefits for hospitals. First, acting as part of an uninterruptible power supply (UPS) system, energy storage can help support resilience against a utility grid outage, in coordination with backup generators, CHP, and renewables. Second, it can maximize the value of renewable energy generation by saving excess energy for use when photovoltaic panels or wind generators are not producing electricity output. Finally, stored energy 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 CHP) are more suited to support the base load.

Energy storage can come in many forms, from batteries to mechanical flywheels to thermal. Solid-state batteries are the most common choice for hospital applications, with lithium-ion overtaking lead-acid technology due to longer life and greater density. However, increasing lithium costs and recycling challenges are causing the market to consider other new technologies.[16]

Dedicated energy storage solutions for critical power applications are also emerging. As reported by Navigant Research, "Advanced batteries for critical infrastructure (ABCI) solutions using distributed energy storage system (DESS) technology…can help mitigate the effect of electrical service outages for mission critical facility operations by providing grid ancillary services and electrical demand charge reduction."[17]

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

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

[16] "Are lithium batteries still leading the way?", Power Technology, 2018

[17] "Advanced Batteries for Critical Infrastructure", Navigant Research, 2019

Enhancing resilience

A microgrid system can be thought of as a three-layer architecture (see Figure 6). The first layer includes all smart, 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 action to control generation and consumption assets to enhance resilience and maximize use of renewables.

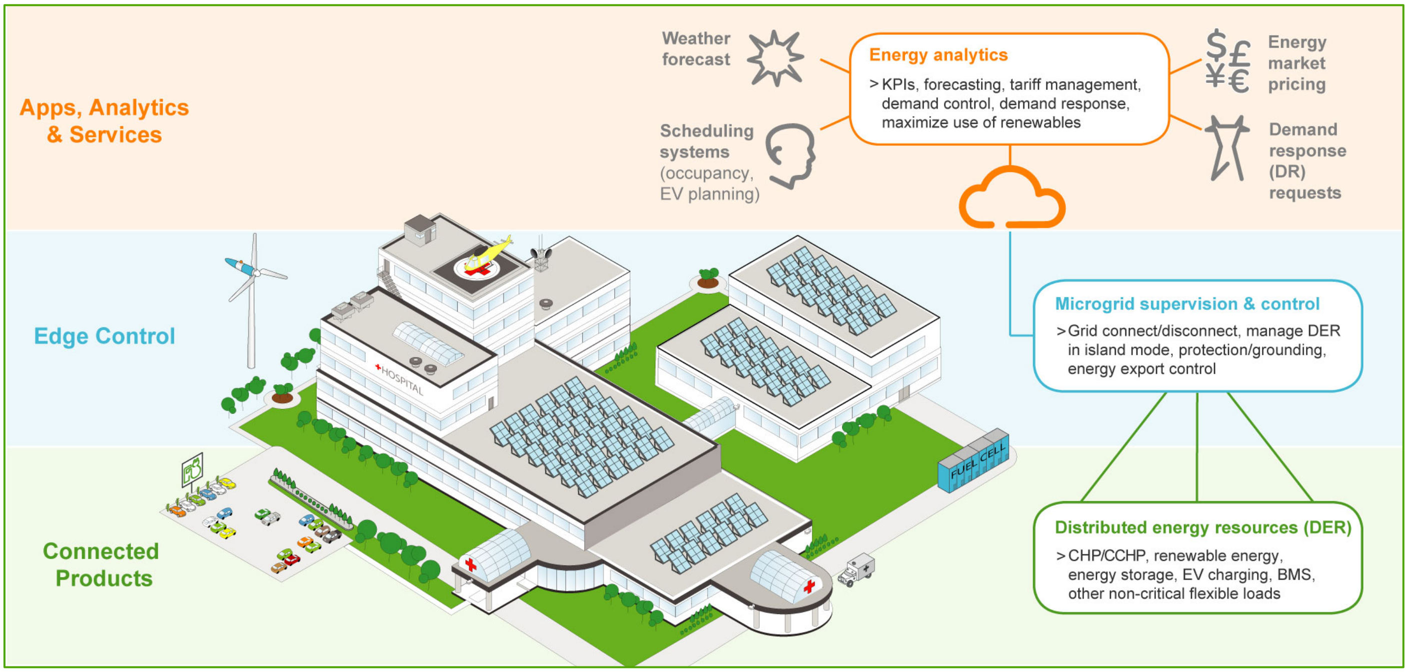

Figure 6

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

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 intelligent, predefined algorithms 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 ensures the amount of energy production is balanced against consumption. If necessary, the system will shed non-critical loads to ensure production can meet consumption requirements.
- **Ensure microgrid safety:** The microgrid system manages 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 can be programmed to maximize the use of renewables when possible. Excess energy can be saved to an energy storage system or sold back to the grid. The microgrid system manages the level of authorized energy export to the utility grid. This can be in response to a utility signal, third party signal, or predefined threshold.

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.

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.

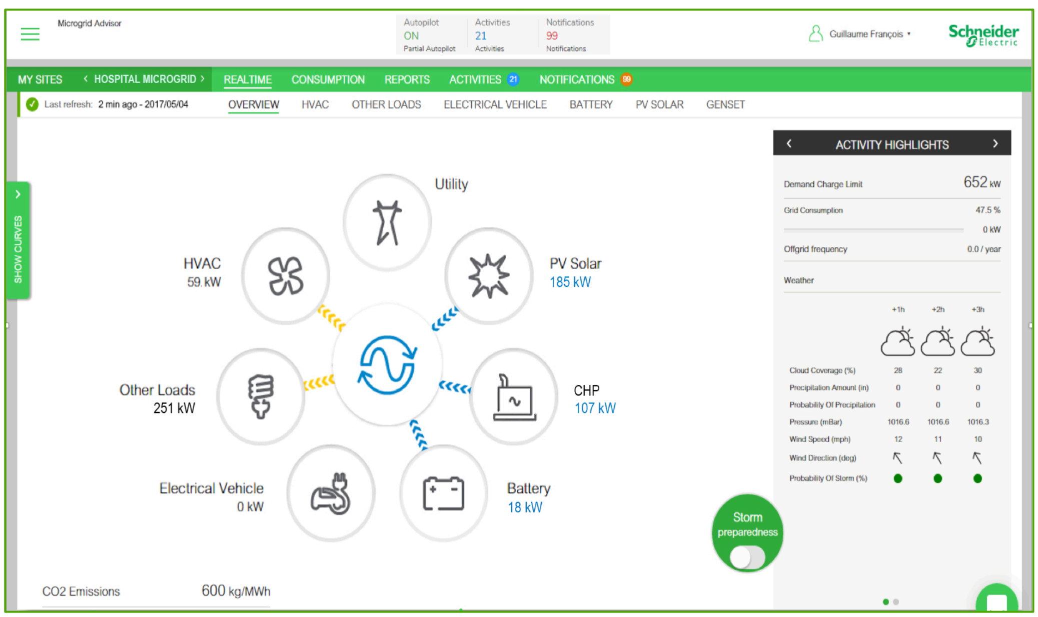

Figure 7

The microgrid control system takes the appropriate actions to disconnect the hospital from the utility grid, then manage DER to balance generation against demand, and ensure safe operation.

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 through the facility's power distribution network.

With the increasing number of advanced technology instruments and appliances in hospitals, in addition to the number of new load types (e.g. variable speed drives, LED lighting, etc.) it is important to carefully monitor electrical conditions and be aware of the power quality thresholds that need to be maintained for reliable operation of equipment. If conditions are trending toward exceeding those safe operating thresholds, the microgrid control system can activate islanding mode to protect the facility.

Depending on the level of capability currently in place, a hospital microgrid can respond to a utility supply-side issue as appropriate. With increasing levels of DER, a greater level of resilience is possible (see Table 1).

Table 1

Levels of resilience offered by increasing amounts of distributed energy resources.

	Microgrid control capabilities
LEVEL 1: **No microgrid - backup power only**	If the facility has backup generators, but no UPS, the hospital will suffer short term downtime until the gensets are online. If 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, e.g. operating theatres, intensive care units, other miscellaneous critical life safety equipment, data center, etc. If the gensets are sized large enough, they can supply the entire facility. 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.
LEVEL 2: **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. However, in the event that backup generation fails to start up, or reaches the limit of its run time due to expending all fuel, the microgrid controller can engage DER assets, such as solar and energy storage, to help power critical circuits. In addition, if backup generation operates reliably to supply critical circuits, the microgrid can use DER to supply other circuits in the hospital to keep more hospital services up and running during the grid outage. This can be extremely important in the event of a large-scale natural disaster.
LEVEL 3: **Microgrid with CHP/CCHP**	The CHP/CCHP system will be running continuously, serving (at least) the partial electrical needs of the hospital. Typically, CHP/CCHP is sized to meet thermal demand, so electricity is augmented from grid. When a grid outage occurs, the microgrid system can use CHP/CCHP for a 'flicker-free' transfer from grid connection to island mode. However, to ensure CHP/CCHP can supply all critical loads, there may be a need for the microgrid controller to use a fast load shedding scheme to enable non-critical loads to be shed in the short term until backup generators are online to meet additional demand. This will avoid the risk of the CHP/CCHP system becoming overloaded and tripping offline. If CHP/CCHP is sized large enough to supply the entire facility, backup gensets will not need to be engaged at all.
LEVEL 4: **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 additional loads throughout the facility.

Cost saving and sustainability opportunities

Beyond helping a hospital 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 you would buy a microgrid, because the energy would cost too much to create -- it would never be cheaper than a grid,” said Mark Feasel, Vice President of Smart Grid at Schneider Electric. “Now with PV and CHP with natural gas, in many states [within the USA] you can generate energy cheaper than you can buy it.”[18]

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. As noted by the IEEE, “…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.”[19]

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.

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
- Facility occupancy forecast and activity schedules (e.g. electric vehicle charging)

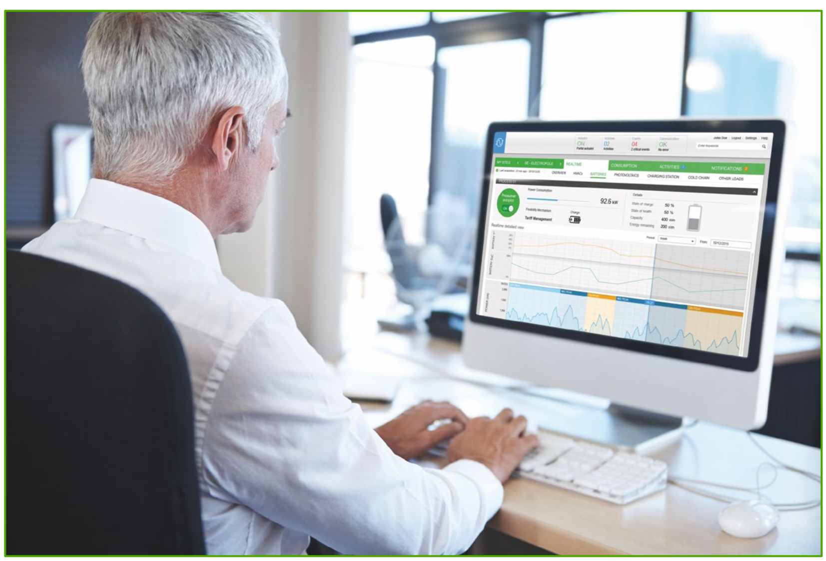

Figure 8

Advanced microgrid energy analytics integrate external and internal data inputs to support decision making and automated control schemes.

The energy management analytics layer is most often provided as a cloud-hosted service. Integration of the microgrid analytic application with the facility BMS system will enable coordinated optimization of sources and loads. In this way, the microgrid becomes an integral part of a complete intelligent building, allowing it to leverage

[18] “Microgrids On The March…”, Greentech Media, 2017

[19] “Utility and Other Energy Company Business Case Issues Related to Microgrids, …”, IEEE, 2014

smart BMS consumption functions – e.g., heating, cooling, automation of blinds for control of daylighting and passive solar, etc. – to optimize the facility's energy profile.

The analytic layer tracks and visualizes all relevant key performance indicators listed above. Using advanced modelling, 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.

The analytic layer works together with the microgrid control layer, using predefined algorithms and control schemes to optimize the use of renewable energy while achieving the most economical energy spend (see Table 2). The more flexibility the microgrid has in terms of onsite generation, energy storage, and controllable loads, the more optimization opportunities can be taken advantage of by the hospital.

Table 2

Microgrids with DER offer a range of effective cost-saving opportunities.

Savings opportunity	Microgrid control capabilities
SCENARIO 1: **Avoid demand penalties**	If the hospital energy billing from the local power utility includes penalties for incurring excessive demand peaks, the microgrid system can be used to dynamically manage demand. If the system forecasts that the total facility demand is trending upward and may exceed the penalty threshold, the microgrid controller can reduce energy consumption from the grid in one of two ways: 1. **Consume more energy from onsite resources**. This can include renewable resources, stored energy, or CHP. 2. **Temporarily turn off non-critical load(s).** Which loads are considered non-critical will, of course, need to be carefully predefined. These could include EV charging stations or hot water boilers for laundry, for example. Integration with BMS may offer additional options.
SCENARIO 2: **Tariff management**	If the hospital is in a region with an open energy market experiencing significant price fluctuations, or is subject to some form of variable tariff structures (e.g. time-of-use), the microgrid system can respond to pricing signals to optimize the facility's energy consumption profile. It can do this in a number of ways: 1. **Determine when it makes economic sense to consume each energy resource** (or combination), comparing grid pricing versus CHP, renewable, etc. 2. **Shift some load to 'off-peak' periods**. This could include programming the BMS to pre-cool some areas of the facility depending on forecasted solar heating, without affecting comfort. It could also include helping the hospital administration team decide to reschedule some non-critical activities. 3. **Store energy during periods of low grid energy pricing**. Consume the stored energy during periods of high grid pricing. Energy to store can come from the grid when prices are low, or from onsite renewable sources.
SCENARIO 3: **Participate in demand response (DR) program**	If the hospital is in a region where the grid operator is offering 'smart grid' programs such as demand response, participation can result in significant economic benefits. The hospital will need to agree to reduce a portion of their energy consumption when the supply of electricity on the grid is threatened. Load reduction typically needs to be exercised within two or less hours of notice from the grid operator. Participants receive upfront payments for the amount of load capacity they can reduce. The microgrid and its flexible DER can be used to optimize participation in a DR program by providing a choice of using local generation or load management to comply with a curtailment request. This is where energy storage offers a great advantage. Stored energy can be consumed to respond to load curtailment requests to effectively consume less energy from the grid. In some cases, the grid operator may ask for increased consumption. In that case, batteries can be charged from the grid.

	Stored energy can also be used to provide ancillary services to the grid, such as frequency or voltage support.
SCENARIO 4: **Optimize self-consumption of renewables**	Optimizing sustainability will include reducing energy-related GHG by self-consuming low-carbon, low-cost energy when it's available. The microgrid system controls energy storage and onsite solar or wind generation to maximize consumption from those renewable sources. If the hospital has a 'net metering' contract with the utility, the microgrid system optimizes when it is most economical to consume or store locally-generated energy versus selling it to the grid.

The microgrid system gives the hospital an intelligent, transparent way to manage its distributed energy resources, as well as a simple, automated way to participate in smart grid programs as an energy *prosumer*. The microgrid platform takes into account the energy, environmental, and economic needs of the enterprise, then automatically proposes the optimal arbitrage between the different opportunities.

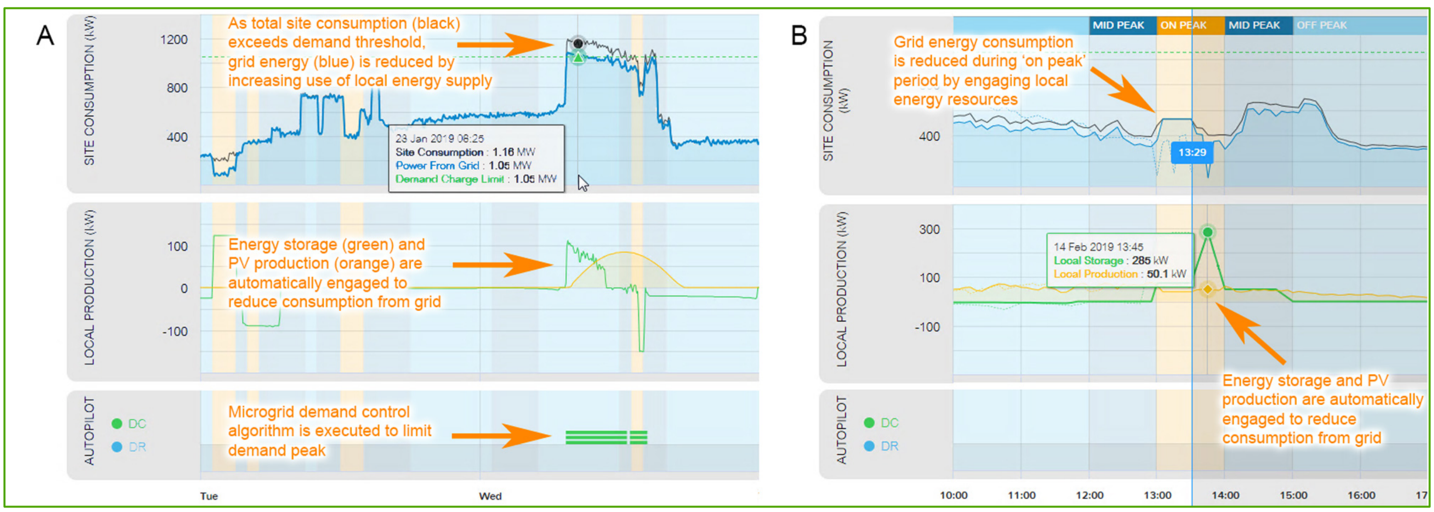

Figure 9

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 customers 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. "Via sophisticated controllers, multiple microgrids communicate and exchange services to improve efficiency or price or achieve other predetermined goals."[20]

The advanced analytic layer of the microgrid system offers an effective two-way portal to emerging smart grid VPP platforms used by grid operators and commercial aggregators.

[20] "The Evolution of Distributed Energy Resources", Microgrid Knowledge, 2018

Next Steps

Hospital management teams considering a microgrid solution should look for vendors that offer:

- **Extensive experience in microgrid design and operation**, with solutions that include all forms of distributed energy resources, robust microgrid controls, and advanced energy management intelligence.
- **Advanced microgrid design tools** that validate the feasibility of DER assets for a hospital in any region of the world.
- **Packaged, pre-engineered microgrid architectures** that make it easier and more affordable to implement, operate, and maintain a solution.
- **A choice of financing and operating models** (e.g. customer-owned, or energy-as-a-service), as well as available incentives, that can make a microgrid affordable while reducing financial risks and maximizing returns.

Conclusion

For hospitals, 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 CHP, CCHP, renewables, fuel cells, and energy storage. They help maximize resilience, reduce costs, and ensure sustainability, with advanced energy analytic capabilities that help optimize and balance the use of grid versus onsite energy resources. They also meet all applicable national and local regulations. Now is the perfect time for hospital teams to adopt a microgrid solution. The technology is mature, making solutions more affordable and easier to implement than ever before.

Resources

Microgrids for Hospitals

"Building resilient, efficient microgrids for hospitals: from design to financing", Schneider Electric, 2019

"Healthcare Microgrids - The path to more reliable, clean, lower cost energy in hospitals", Microgrid Knowledge, 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

"Fuel Cells and Hospital Applications", FCHEA

Microgrid financing and operation

"Leaderboard: Energy as a Service Solutions Providers", Navigant Research, 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

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The authors also wish to thank the following contributors:
From Schneider Electric: Patrick Beguery, a Simulation Group Senior Expert with the Analytics & Artificial Intelligence team, Francois Borghese, Smart Grid Marketing Manager, Francois Guillaume, Global Microgrid Business Developer, and Jake Friedman, Project Development & Engineering Manager. From Expleo Group: Yassine Saad, Simulation Engineer.