MICROGRID KNOWLEDGE SPECIAL REPORT

The Genius of Microgrids in Higher Education

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Contents

The Genius of Microgrids in Higher Education

Executive summary

The U.S. higher education system ranks as the strongest in the world, besting all other countries because of its breadth of exceptional institutions and its reach to such a large percentage of the nation's youth. Still, it faces some significant headwinds, not the least of which is the increased demand for new infrastructure in the face of leveling enrollment, heightened pressure to reduce costs and the COVID-19 pandemic.

At the same time, U.S. colleges and universities have taken the lead in fighting climate change, and setting ambitious sustainability and renewable energy goals. Now, add a new challenge: the need for reliable and resilient energy.

This paper explains how microgrids help flip these problems into opportunities to prepare the workforce for the emerging new energy economy, while yielding low cost, reliable and clean sources of energy.

Microgrids offer colleges a way to keep critical electricity flowing during power outages, increase use of renewable energy, pursue climate goals, and better optimize energy supplies and campus loads—offering savings potential to free up funds for other priorities. Increasingly, campus microgrids are also being used as an educational and sustainability awareness tool, connecting technology to students and community.

Although microgrids have been deployed for more than a century—and many have been installed at campuses nationwide—broad awareness of the technology is lacking. As a result, too many institutions still rely on less sophisticated control solutions and remain far too dependent on utility or grid supplied power. Microgrid Knowledge prepared this report, in partnership with Siemens, to help college and university decision-makers better understand microgrids and the benefits they provide.

What is a microgrid?

A microgrid is a self-sufficient energy system that serves a discrete geographic footprint, such as a business complex, campus or community. During a power outage, the microgrid can island some, or all, of its buildings away from the utility grid—typically buildings that are critical to the facility's mission. The microgrid's on-site resources then provide power to the islanded buildings. An advanced microgrid also optimizes multiple energy resources and loads to achieve the host's goals for cost, sustainability or efficiency.

This paper is divided into three sections. The first chapter focuses on the energy challenges faced by higher education. The middle chapters explain how microgrids serve as a solution. The final chapter describes microgrids in action, serving not only as an energy solution but also as an educational tool.

This paper is being offered for download free of charge, courtesy of Siemens. We encourage you to share the link widely, particularly among decision-makers in higher education who are seeking more reliable, cleaner and cost-effective energy solutions.

Chapter 1: Energy Choices in an Era of Competing Goals

When it comes to choosing among energy supply options, colleges and universities have three primary goals:

1. Gain greater resiliency in an era of electrical grid power outages
2. Lower energy costs
3. Reduce carbon dioxide emissions

Let's start by examining each of these goals and the challenges they present to energy decision-makers in higher education.

1. Gain greater resiliency in an era of electrical grid power outages

Colleges and universities must increasingly weigh power outages in financial risk assessments because catastrophic events are on the rise. In total, the U.S. experienced 14 separate billion-dollar disasters in 2019, which was the fifth consecutive year to have 10 or more separate billion-dollar disasters, according to the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI).

Indeed, 2020 began ominously with an earthquake in Puerto Rico that caused an island-wide blackout, reminiscent of Hurricane Maria's damage in 2017, which destroyed the electric grid, leaving many without power for over a year. Then, just a few months later, the COVID-19 pandemic put new pressure on hospitals and other critical facilities, underscoring society's need for highly reliable energy.

Power outages are expensive. Exactly how expensive depends on who they affect and their duration. But to get a sense of the financial ramifications, consider that:

- Delta Airlines lost $50 million after equipment failure knocked out power to the world's busiest airport, Hartsfield-Jackson in Atlanta, Georgia, for 11 hours on December 17, 2017.
- Esource looked at eight major industries and found that outages as short as four hours cost, on average, $10,000 to $20,000 per organization.
- A 48-hour power shutoff to 800,000 California utility customers dealt a $2.5 billion blow to the state's economy in October 2019.

Higher education is particularly risk adverse to power outages for several reasons. For example, higher education hosts $80 billion annually in research and development, much of it heavily dependent on electricity. A multi-hour outage could destroy research years in the making.

Colleges that offer room and board have a responsibility to ensure their students' safety and comfort. If they cannot do this when an extended power outage occurs, they face difficult options. Send students home and interrupt the educational program? Take on the expense of arranging for alternative housing? As we have seen this past Spring, a crisis that shuts down a campus can also result in the refunding of housing and dining fees, as well as liabilities associated with student security and safety.

Meanwhile, the risk of power outages at colleges grows for two reasons. First, we've fallen behind in improving our nation's utility and electric grid infrastructure, and now it requires massive investment. Second, campus infrastructure is aging. With deferred maintenance costs now averaging near $100 per gross square foot, many facilities have become vulnerable to equipment related failures. Higher education leaders are becoming increasingly aware of campus vulnerability to power outages and the need for greater resilience, particularly given the accelerating impact of climate change. To that end, more than 100 schools have signed a resilience commitment to overcome their vulnerability.

U.S. 2019 Billion-Dollar Weather and Climate Disasters

This map denotes the approximate location for each of the 14 separate billion-dollar weather and climate disasters that impacted the United States during 2019. Source NOAA

2. Lowering energy costs as financial pressures mount

Higher education faces tremendous pressure to find ways to reduce costs, given the rising expenses for salaries and benefits as well as a large backlog in maintenance expenses. Colleges and universities also face shrinking net revenue, a situation brought about by a combination of factors. Student enrollment is declining in much of the country, and colleges discount tuition as a means to compete for students and assist struggling families.

The COVID-19 crisis has added to the financial challenges and uncertainties facing our institutions of higher learning. Beyond the near-term impact of housing and dining refunds and new investments in on-line learning, longer term uncertainties associated with recruiting, foreign student enrollment, affordability, distance learning, sports revenue, and the potential recurrence of the pandemic are also weighing heavily. Significant credit rating downgrades have occurred year-to-date, and the credit rating outlook for the sector has turned much more negative of late. Hence, financial resiliency is the top priority for many administrators today.

Energy is a big-ticket expense for campuses. U.S. colleges spend $14 billion on energy annually, according to the U.S. Environmental Protection Agency, with 80% attributable to buildings. Campuses are addressing this problem by making buildings more energy efficient and using advanced building automation and analytics to optimize building and campus operations. In doing so, many are reducing their energy usage and spend. But that's just the start when it comes to "smart campus" energy management.

Most recognize that renewable energy is not inherently resilient. Facility managers understand that their solar panels will not independently meet their energy requirements if the utility grid fails.

3. Reducing carbon dioxide emissions

Higher education institutions act as societal leaders in demonstrating paths to overcome climate challenges and reduce greenhouse gas emissions. Many colleges have sustainability and renewable energy goals; some are even striving for 100% renewables, such as the University of California system, which has set a 2025 goal for this.

In addition, 7,000 institutions of higher education and networks that represent them, from six continents, announced in July 2019 that they are declaring a climate emergency. They agreed to undertake a three-point plan that included going carbon neutral by 2030, or 2050, at the very latest. U.S. higher education, lacking federal leadership, support, or even recognition of the climate crisis, is demonstrating leadership and showcasing the tools available to address climate change. A key parameter involves being more resilient to climate-related challenges and involves focusing on both minimizing energy consumption and provision of reliable, clean energy supplies. To achieve their climate commitments, campuses must be able to manage both on- and off-site renewable and clean energy supply sources.

Most recognize that renewable energy is not inherently resilient. Facility managers understand that their solar panels will not independently meet their energy requirements if the utility grid fails. In fact, in a grid failure, the solar panels will cease to produce power for safety reasons, unless the facility has a microgrid and advanced inverters. So, campuses that center their energy plan solely around renewable energy will find that they may meet climate aspirations but not resilience goals.

In this chapter, we've pointed out three significant energy challenges facing higher education: increase energy reliability, reduce costs and decarbonize. The next three chapters explore one technology that can address all three problems: the advanced microgrid.

Chapter 2: Microgrid Tutorial: What Microgrids are and What They are Not

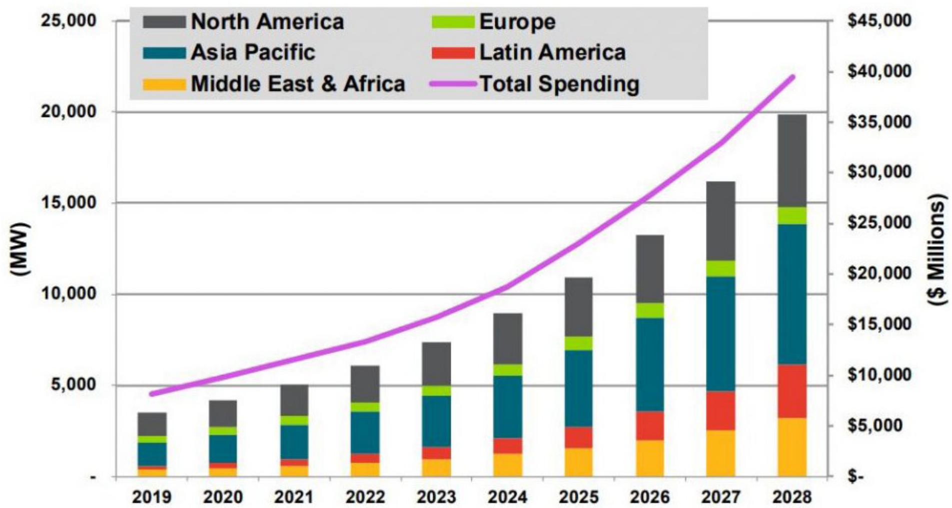
A recent survey of 2,000 U.S. voters by the Civil Society Institute found that most had never heard of the term microgrid, or they had heard of it but had the wrong impression. But when microgrids were explained to them, they showed a strong predisposition to the concept.

"Once people understand microgrids, they see the importance of them in their community," said Andrea Camp, senior project manager at the institute, a nonprofit public policy think tank.

Although microgrids have existed since the electric grid emerged over a century ago, the technology started regaining traction following Superstorm Sandy in 2012. Today, microgrids are viewed as a key component of the emerging smart grid, as well as the "smart campus" vision as defined by Siemens in their new Campus of the Future report. Navigant Research, a Guidehouse company, forecasts 10-fold growth for the microgrid industry from 2019-2028.

So, what is a microgrid, and why is this technology becoming an important part of the U.S. energy landscape?

Annual Total Microgrid Power Capacity and Implementation Spending by Region, World Markets: 2019–2028



Source: Navigant Research

A microgrid is a self-sufficient energy system that runs 24/7/365 and serves a discrete footprint, such as a college campus, hospital complex, business center or neighborhood. In a sense, a microgrid is the electric grid in a compact form because it generally contains the same basic elements: generators to produce energy, a means to distribute the energy, a means to control the energy supply and demand, and customers who use the power. Contemporary microgrids also often include energy storage systems, typically batteries, to help balance and optimize supply and load while providing backup supply capacity. And, microgrids have begun to incorporate electric vehicle charging stations, thus connecting the distributed electricity supply grid to a cleaner transportation fleet.

Intelligent control of your energy assets and use

But a microgrid is more than a mere grouping of energy assets. What sets a microgrid apart is its microgrid controller, the brain of the operation. This is a relatively inexpensive[1] software-driven system that gives the microgrid the ability to undertake various beneficial functions, among them islanding from the central grid. If a power outage occurs on the grid, the controller signals the microgrid to separate from the grid to avoid the disruption. Its generation and storage systems ramp up as needed to become sole providers of power to the buildings the microgrid serves. Islanding can be designed to occur so seamlessly that those within the building are unaware that they are no longer on grid power but are being served by the microgrid controller and associated local generation assets.

[1] The microgrid controller typically costs far less than the generation portion of the microgrid. By way of example, in a recent winning bid for a microgrid at a California wastewater treatment plant, the controller cost $90,000, while its solar array cost $937,000.

Microgrids as protection from outages

This ability to island produces the hallmark benefits of a microgrid: reliability, grid independence, and resilience. Colleges and universities with microgrids are able to keep the power flowing, at least to critical loads, even when their neighbors are in the dark. This is important as campuses often serve as community shelters during an emergency.

The ability of a microgrid to operate independently from the electric grid is especially important in North America because the magnitude of the grid and its interconnectedness make it particularly vulnerable to power outages. The U.S. grid encompasses hundreds of thousands of miles of high-voltage electricity transmission lines and millions of miles of lower voltage distribution lines that deliver power from thousands of generating plants to hundreds of millions of electricity customers. Because all of these elements are interconnected, a single tree falling on a power line can cause a cascading failure that knocks out power in several states, a lesson the U.S. learned during the Northeast Blackout of 2003.

Microgrids to optimize renewable energy

While islanding may be the most notable characteristic of a microgrid, it is but one of several valuable functions made possible because of the intelligence of the microgrid controller. The controller can optimize for various outcomes. It might be programmed to maximize renewable energy or minimize cost or carbon output. The microgrid's intelligence also can be leveraged to manage building electrical loads efficiently—when electricity prices are high, it can reduce energy flow to buildings or operations that are not essential, such as classrooms not in use at that time. Microgrids can also be designed to capture market opportunities associated with grid integration such as renewables balancing, demand response and spinning reserves. We will review some of these in greater detail in Chapters 3 and 4.

> Microgrids can be designed to capture market opportunities associated with grid integration such as renewables balancing, demand response and spinning reserves.

Microgrid misconceptions

Microgrids are often confused with backup generators; in fact, they are much more. Backup generation, typically fueled by diesel or natural gas, is deployed (by definition) only when needed and typically using simple control systems. Backup generators alone do not enable independent operation from the grid during an outage and are typically limited to supplying short-term emergency power. In contrast, a microgrid combines localized distributed generation assets. As we described earlier, these assets may consist of a combination of reciprocating engines, solar PV, fuel cells, cogeneration, energy storage and other forms of energy supply. They serve a set of interconnected loads by way of a sophisticated controller that enables automated grid islanding and various levels of system optimization

As a result, a robust microgrid has many layers of redundancy. If one asset is too expensive or does not operate—perhaps it's a cloudy day and the solar panels are not producing energy—then another form of generation, imported power and/or energy storage supply comes into play. This redundancy also proves beneficial when certain fuels become scarce. For example, after Hurricane Maria, Puerto Rico found itself short on the diesel required to run many of its backup generators.

But that's not the only reliability advantage of a microgrid over a backup generator. Because most microgrids operate 24/7/365, performance is constantly monitored. Need for repairs or maintenance becomes evident and should be quickly resolved. The same is not true of backup or emergency generators. Since they typically are only run when needed, they sit idle except for periodic required testing. Too often, any malfunction only becomes apparent to a facility manager during a power outage when the backup generator is suddenly called upon to perform. When this happened at a New York hospital during Superstorm Sandy, hospital staff were forced to evacuate patients, and, in some cases, carry them down several flights of darkened staircases.

Case studies

Myriad examples exist of microgrids keeping the power flowing to campuses and communities during power outages. One such example was shared by Princeton University:

Princeton University: Eight million people lost power when Superstorm Sandy lashed the Eastern United States in October 2012. But the university was able to continue to power its essential buildings and operations. Seeing trouble coming as the storm bore down on New Jersey, Princeton's energy facility islanded from the local utility, Public Service Gas & Electric (PSG&E). The campus continued to receive power from its on-site 15-MW combined heat and power plant (CHP), part of a microgrid that includes district heating and cooling, chilled water, thermal storage, a 5.4-MW solar photovoltaic farm, and an advanced microgrid control system. The facility serves a campus community of 12,000 people across about 150 buildings.

Also in Princeton, but separate from the university, Siemens is completing construction of a microgrid at its corporate research campus. Phase 1 of the microgrid consists of an 836-kW solar PV carport, a 500-kW Fluence battery energy storage system and a Siemens VersiCharger electric vehicle charging station. The microgrid will be capable of islanding, and it will be fully integrated with the Siemens building automation system. Plans for Phase 2 include small scale cogeneration.

Like those polled by the Civil Society Institute, colleges and universities like the idea of microgrids once they come to understand them. But it's not just because of the reliability they provide during power outages. As we'll explain in the next two chapters, the microgrid value proposition can offer a dependable and attractive return on investment, as well as a means to deliver sustainability objectives and student learning opportunities.

A range of other colleges and universities, large and small, now operate a set of very diverse microgrids throughout North America, among them:

Algonquin College (Ottawa, Canada)
University of Bridgeport (Connecticut)
Fairfield University (Connecticut)
University of South Florida (Florida)
University of Hartford (Connecticut)
University of Texas (Austin)
University of California (San Diego)
Eastern Mennonite University (Virginia)
Harvard University (Massachusetts)
Illinois Institute of Technology (Chicago)
Saddleback College (California)
Santa Clara University (California)
Santa Fe Community College (New Mexico)
Tufts University (Massachusetts)
Wesleyan University (Connecticut)

Meanwhile, many others are in the process of developing microgrids, including:

Emory University (Georgia)
Georgia Tech (Atlanta)
Northeastern University (Massachusetts)
Santa Rosa Junior College (California)
Sonoma County Jr. College District (Calif.)

Emory University
Photo credit: EQRoy/Shutterstock.com

Chapter 3: Microgrid Tutorial: Why Microgrids Make Financial Sense

The microgrid as revenue producer

In the previous chapter, we described how microgrids can keep electricity flowing to colleges and universities by islanding from the central grid during power outages. Here we'll discuss the financial benefits microgrids can garner.

Microgrids operate in two modes: connected to the central electric grid or islanded from it. This ability to toggle back and forth between the two modes allows microgrids to not only provide maximum electric reliability, but also to save money or earn revenue for the campus through intelligent management of resources and participation in grid programs.

Reduce demand charges

Microgrids can help campuses reduce peak demand charges, which for some institutions can be onerous, accounting for as much as 30%–70% of total monthly electric charges. Demand charges are difficult to manage because they are based on how much energy an institution uses at particular moments, typically when grid demand reaches its peak. For some, these momentary peak demand charges increase the monthly charges for the entire year.

Peak demand charges affect a wide range of users. Therefore, most users strive to reduce their power demand (as seen by the utility) during these periods so that their demand charges will be set at a lower level. However, this is a difficult task, requiring control of power supply and usage during the peak periods. Solar PV by itself may reduce demand charges, but solar power is intermittent, hence unreliable. Battery storage is a major addition to peak load management. However, a microgrid offers a far more reliable solution. The microgrid controller provides a combination of microgrid demand forecasting and reliable reaction—reducing load or ramping up supply (via generation or storage assets). Sophisticated microgrid controllers offer predictive capabilities based on grid communications and simulation. Such microgrid control systems can also be programmed to coordinate reduction of the facility's use of utility energy while managing on-site generation and energy storage to avoid a demand ratchet.

Demand response

A microgrid offers the means for campuses to participate in demand response programs—where a utility pays its customers to reduce their energy use during periods of peak electric demand. Those without microgrids or on-site generation participate by shutting off lights, adjusting room temperatures, reducing their operations or even sending employees home. But those with microgrids can accrue the benefits of demand response without cutting back on energy use; instead, they curb use of utility power and rely on their microgrid generation or energy they have stored in its batteries. For maximum benefit, they activate the microgrid generation *and* cut back on energy use for nonessential services. This process—balancing supply and demand by reducing energy use—is known as load management, and it is another ability of an advanced microgrid system.

> The Brattle Group estimates that load flexibility programs alone could triple demand response in the U.S., creating savings of more than $15 billion per year by 2030.

Demand response is becoming an important grid management tool, one beneficial to both the participant and society at large. By participating, a college or university helps reduce strain on the grid at crucial periods and averts the need for utilities to install and use peak generators, which are generally less efficient and often rely on fuels that produce higher emissions. So, participation in demand response makes economic sense and can produce environmental advantages.

Not surprisingly, use of sophisticated demand response and load management is on the rise. This is, in part, because of the recent reduction in the cost of battery storage and the ability to combine such assets with a microgrid controller. The Brattle Group estimates that load flexibility programs alone could triple demand response in the U.S., creating savings of more than $15 billion per year by 2030.

Ancillary services

Depending on market rules where the microgrid is located, it may be able to sell what are known as ancillary services to the electric grid. For example, grid operators are constantly balancing supply and demand, keeping them within an acceptable range of tolerance. When the equilibrium starts to move beyond an acceptable range, the grid operator may seek a quick injection of power from an outside source, such as a microgrid. The grid operator pays the microgrid owner for this service. The need for such balancing is expected to increase with the rise of renewable energy on the grid because wind and solar create conditions that can lead to a sudden supply/demand imbalance. Their energy output can suddenly stop based on weather conditions: The sky might cloud up or the wind cease to blow.

Electric grid operators engage in real-time, moment by moment orchestration to keep supply and demand in balance, and their ability to do so determines power availability and prices. Loss of too much supply can send power prices skyrocketing and even lead to power outages. So, they need resources that can respond quickly.

Grid stabilization based ancillary services vary by market, but can include demand response, frequency regulation and spinning reserves. A microgrid's ability to respond in milliseconds enables it to supply value-added grid resources in return for financial compensation.

Because microgrids assist with grid balancing, they pave the way for greater use of renewable energy on the grid. This capability creates not only a revenue stream for the microgrid, but also an environmental benefit for society. When used to balance and optimize supply of intermittent renewable resources to service a campus load, the microgrid directly contributes to the campus' sustainability and greenhouse gas reduction goals.

Leverage grid pricing

Wholesale power prices can fluctuate dramatically on the electric grid. For example, during a heat wave last summer in Texas, prices jumped to $9,000/MWh, while the average day-ahead, around-the-clock price was only $38/MWh. This is an extreme situation, but it demonstrates the volatility of real-time market pricing.

Every generation resource on the grid and associated with a microgrid offers a different operational and variable cost profile. Because load varies economically based on weather, time of day, day of week, and other factors, it is optimal to access supply using the lowest cost generation and storage resources. Advanced microgrids can be programmed to continuously simulate and optimize supply based on the characteristics and fuel pricing for each distributed generator and the market signal for real-time grid pricing. The microgrid is typically programmed to use market supply when it is cheaper than on-site generation. Further, during extreme pricing, such as the Texas example above, the microgrid can be programmed to shed load to avoid the need to purchase super-premium power supply.

Sophisticated microgrid controllers are designed to optimize complex scenarios to meet changing conditions and customized owner objectives, in an operationally simplified manner. And, as battery storage prices have come down dramatically in recent years, they've been increasingly incorporated into microgrids. Advanced microgrid controllers can help leverage the value of the energy storage devices. They effectively implement energy arbitrage to minimize the cost to supply the microgrid loads. The microgrid controller uses energy price prediction, weather forecasts and renewable generation forecasts to optimize the load shifting to achieve maximum energy cost savings. A common example is optimizing solar PV by using a battery to store excess power during peak periods, which will balance the power supply to match the load. Additionally, such a solar-plus-storage setup can be utilized to offset peak demand when the sun is not shining.

During extreme pricing, the microgrid can be programmed to shed load to avoid the need to purchase super-premium power supply.

In extreme cases like the Texas heat wave, the microgrid also can be programmed to shed load (reduce nonessential building energy use). This reduces how much energy the campus needs so that it can avoid purchasing high cost power.

Microgrids becoming more affordable

As you can see, microgrids are an energy asset that can both save money and earn revenue for a campus, which makes them an appealing energy investment. In addition, they have dropped in price roughly 30% in recent years, according to Navigant Research. Their more favorable price point stems from the falling costs of two main components found in many contemporary microgrids: solar panels and batteries. The price of solar panels has fallen 70% over the last decade and energy storage 87% over the same period. As mentioned earlier, the cost of the advanced microgrid controller is relatively minor in comparison to electricity generators and storage systems.

That said, the capabilities offered by advanced microgrids have escalated significantly in recent years, and features and functionality previously reserved for utility scale controllers can now be found in microgrid controllers.

Microgrids also are made affordable by various government incentives, such as the federal investment tax credit for solar or the state renewable energy credit programs. Some states, including California, Connecticut, Maryland, Massachusetts, New Jersey and New York, also have made grants available for microgrids. Hawaii and California are considering microgrid service tariffs to help foster their development.

Traditionally, colleges and universities have expanded their campus utility systems over time to meet growth requirements, using a range of traditional financial approaches including bonds, debt, capital budgets, grants and energy savings performance contracting. While traditional financing and funding continue to lead, more higher education institutions are questioning the rationale for being in the utility business, at least as related to new asset investments. The power purchase agreement (PPA) model is dominant for solar PV investments, largely driven by the ability of the private sector to capture lucrative federal tax credits and offer a resulting lower rate for solar power. The PPA model is being expanded to support microgrids or hybrid power systems that might consist of solar PV, battery storage and electric vehicle charging that are operated with a microgrid controller. The same systems might be delivered using an energy-as-a-service (EaaS) model. While it is beyond the scope of this report to dive into alternative financing and contracting methods, both of these models (PPA and EaaS) involve a third-party owner who assumes performance risk.

For larger, more complex campus generation plants and microgrid systems, DBOOM and DBFOM (design, build, own or finance, operate and maintain) models continue to grow in popularity. The avoidance of upfront capital requirement and transfer of risk to a private sector partner are the main drivers for these models. The landscape of higher education suggests continued acceleration of this energy asset outsourcing (sometimes referred to as P3 or public-private-partnership) trend. We expect that it will apply to microgrid systems as well, offering institutions a variety of ways to take advantage of this powerful technology.

Given that generating resources typically represent the largest cost within a microgrid, using existing resources can significantly reduce a project's price tag.

And, last, it's important to note that microgrids are modular in structure, so they can be improved incrementally as budget allows. Not all generating assets need to be added at once; a college or university can gradually expand the microgrid to reach sustainability goals. In many cases, the institution may already have on-site generators that can be incorporated into the microgrid, such as solar panels or a CHP plant. Given that generating resources typically represent the largest cost within a microgrid, using existing resources can significantly reduce a project's price tag.

Fred James, National Business Director for Higher Education at Siemens, pointed out that this modularity also enables microgrid owners to adopt the latest technology as it becomes commercially available.

"It is hard to predict which technologies will prove optimal to meet a university's carbon neutrality goal, often 30 years in the future. Microgrids enable you to achieve your long-term goals in a natural evolutionary manner by adding components over time and having the advanced controls to optimize those new technologies," said James.

Energy cost savings are valuable for any organization, but especially so for higher education at this time, given the many pressing financial needs faced by colleges and universities. Spending less on energy frees up capital for other priorities.

Campus microgrids for student recruitment and workforce development

By initiating a campus microgrid, an institution communicates its commitment to the next generation of energy solutions. In an era of faltering enrollment, microgrids, as an enabler and optimizer of renewables, better position schools to draw more students. More than half (63%) of students surveyed for the *Princeton Review*'s 2018 "College Hopes & Worries Survey" reported that information about a college's commitment to the environment would influence their application or enrollment decisions. A microgrid on campus makes the college a draw for today's climate conscious students.

Equally significant, an on-site microgrid translates easily into a learning laboratory for STEM students. Learning associated with both the physical microgrid assets and operations, as well as the simulation capabilities offered by an advanced microgrid controller, provide a range of learning opportunities and give students an opportunity for hands-on work with a cutting-edge energy technology — one that is expected to grow rapidly over the next decade, opening up new job opportunities. Microgrid living laboratories also provide opportunities to study cyber security, machine learning and large-scale software integration. Microgrids provide humanities students with the real-world challenges of creating new public policy and communications strategies. The campus microgrid can be a popular stop on the campus tour, helping a college brand itself as sustainable and technically advanced.

Eastern Mennonite University (EMU)

This liberal arts college in Harrisonburg, Virginia, decided to install a microgrid after realizing that it could help cut costs related to its distribution demand charges by as much as $7/kW.

The microgrid powers the school's 650,000 square feet with three 500-kW natural-gas-fired generators. EMU also has a solar panel array located on its library roof. Together, the energy assets allow the campus to supply all of its own energy when needed.

In addition to installing the microgrid, the college entered into a performance contract with Siemens Building Technologies for capital improvements designed to save energy.

Fiscal prudence is an important part of the mission of any college or university, yet so is environmental prudence, given today's climate crisis. Sometimes one competes with the other; environmental upgrades can be costly. Fortunately, microgrids offer a way to achieve both. The next chapter explores microgrids and environmental stewardship.

Chapter 4: Microgrid Tutorial: How Microgrids Boost Decarbonization Efforts

Higher education has become a standard bearer for climate action. More than 400 colleges and universities have pledged to become carbon neutral between now and 2050 (or earlier) through Second Nature's Climate Leadership Network program and over 40 currently get all of their electricity supplies from renewable energy. And of the 180 schools that have reported their renewable energy data to the Association for the Advancement of Sustainability in Higher Education's (AASHE) Sustainability Tracking, Assessment & Rating System (STARS), 91% use some renewable energy, according to Environment America.

Microgrids help campuses further their climate and clean energy goals in several ways.

For example, a microgrid controller can optimize the system for maximum use of low carbon energy. The microgrid controller determines the optimal mix of energy sources, including grid power, so that the campus uses the cleanest possible configuration available at a given time.

Microgrids also are often built as part of a larger energy performance contract. This means that the contractor starts the project by evaluating the campus for energy efficiency opportunities. This lowers energy use (and, therefore, costs) and reduces the campus' carbon footprint. As the saying goes, the megawatt not used is the cheapest and cleanest megawatt. In addition, lowering campus energy demand can reduce the amount of generation that needs to be installed for the microgrid, which, in return, lowers costs.

Another way microgrids achieve efficiencies—and therefore lower carbon production—is by reducing what's known as electric line loss. When electricity travels from power plants over transmission and distribution lines, an average of 5% dissipates in transit, according to the U.S. Energy Information Administration. The energy is produced, and consequent carbon created, but the power is never used; it is wasted energy. Microgrids help overcome this inefficiency because they are located in or near the buildings they serve. The electricity has little distance to travel so little, if any, is lost.

And, as we discussed in Chapter 3, microgrids help green the entire grid by efficiently orchestrating grid resources. When wind or solar energy suddenly ebb, microgrids can quickly inject energy onto the grid to help keep supply and demand in balance. Without such balancing services available, grid operators would need to limit the amount of renewable energy added to the grid. By allowing for use of more renewable energy, microgrids help lower the carbon footprint for the broader society.

Even as tried and true forms of renewable energy, such as solar and wind, are added to the grid, researchers are developing new clean technologies, among them hydrolysis for hydrogen production and renewable natural gas from landfill waste. These technologies are particularly important, given the recent drive for electrification in some parts of the U.S. In an effort to curb carbon emissions, cities such as San Jose, California, and Berkeley, California, have established rules to make new buildings all electric. As new technologies commercialize and government policies evolve, microgrids can add or exchange generation resources.

Examples of decarbonization with campus microgrids

Northeastern University says it is developing a microgrid that sets the bar for higher education, using a self-funded approach to bolster its campus resiliency while achieving sustainability goals.

Now in the planning stages, the integrated microgrid will serve the university's 73-acre campus in Boston, Massachusetts, a city that experiences urban power congestion and coastal challenges caused by increasingly severe storms.

Photo credit: Northeastern University

The university sees the microgrid as a means to not only ensure reliable power, but also to reduce its carbon dioxide emissions 80% by 2050 (and possibly reach complete carbon neutrality), a goal Northeastern set several years ago as a signatory to the American College and University Presidents' Climate Commitment (ACUPCC), which has transitioned to the Second Nature Climate Leadership Network. (More recently, the university has decided to move more aggressively and align itself with the City of Boston to become carbon neutral.)

Tufts University, also in Massachusetts, commissioned a microgrid to provide electricity, steam and hot water to around 60 buildings, and chilled water to an initial four, on Tufts' Medford campus.

The university saw the microgrid as a way to not only reduce costs by 20%, but also cut greenhouse gas emissions 14% annually. The microgrid, which employs highly efficient CHP, contributes to achievement of university, city, state and federal sustainability, as well as carbon and other greenhouse gas emissions reduction goals.

Chapter 5: Vision for the Future

Microgrids acting as teaching tools & community partners

This chapter offers real world examples of how microgrids assist colleges and universities in managing their energy assets, while also educating the energy engineers of tomorrow and serving local communities.

Solar panels on Dearborn Homes Development in Chicago's Bronzeville neighborhood. Photo credit: ComEd

The Bronzeville Microgrid: A Chicago neighborhood offers a glimpse of the future

Microgrids are impressive on their own, but what if they could work together? What if they could communicate and share resources via market participation—automatically with no human intervention—to achieve even greater efficiencies than they accomplish alone? In fact, what if the electric grid eventually became a grid of self-supporting, super smart and highly predictable microgrids?

It may sound futuristic, but the idea of clustering microgrids is already being explored on the southside of Chicago in a partnership that includes Siemens, a technical college and a local utility.

Known as the Bronzeville Microgrid, the project will pair a microgrid already in operation at the Illinois Institute of Technology (IIT) with a microgrid being developed by Commonwealth Edison (ComEd) for the Bronzeville community.

With $5 million in grant funding from the U.S. Department of Energy, the $25 million project is the first utility-operated microgrid cluster being developed in the nation.

Illinois Institute of Technology
Photo credit: Joe Ravi/Shutterstock.com

Spurred by Bronzeville community members eager to make their backyard a showcase for clean technology, the project will demonstrate how microgrids support the integration of renewable energy into the grid, enhance grid security, and keep power flowing during emergencies. The Bronzeville community will use its microgrid to ensure reliable energy for 10 facilities that provide critical services, including the Chicago Public Safety Headquarters, the De La Salle Institute and the Math & Science Academy, a library, public works buildings, restaurants, health clinics, public transportation, educational facilities and churches.

"The Bronzeville community is well-known for innovation and entrepreneurship and commitment to building a bright future," said Paula Robinson, president of the Bronzeville Community Development Partnership. "A secure energy infrastructure and greater access to renewable sources are central to our vision…. It's time to put this technology to the test, and Bronzeville is the perfect place to do it."

The project has two phases:

Phase 1: The project will include 2.5 MW of load, require reconfiguration of an existing feeder, and installation of battery storage and solar PVs. It will directly serve approximately 500 customers.

Phase 2: The project will add more than 550 customers and an additional 4.5 MW of load and 7 MW of distributed energy resources, which is calculated to be enough to meet the peak electricity demand of customers within the microgrid footprint and maintain service when the microgrid is islanded from ComEd's grid. The complete project is expected to serve more than 1,050 residential, commercial and industrial customers.

Siemens is providing an advanced microgrid controller and developing the algorithmic logic to handle the complex cluster.

ComEd will report its data from the project over a 10-year period to help the energy industry better understand what some see as an eventual retooling of today's centralized electric system into a grid-of-microgrids.

Algonquin College demonstrates the economic ingenuity of the microgrid

Algonquin College, located in Ottawa, strives to be a model for exceptional energy management and sustainability and is ranked as one of the top 50 research colleges in Canada.

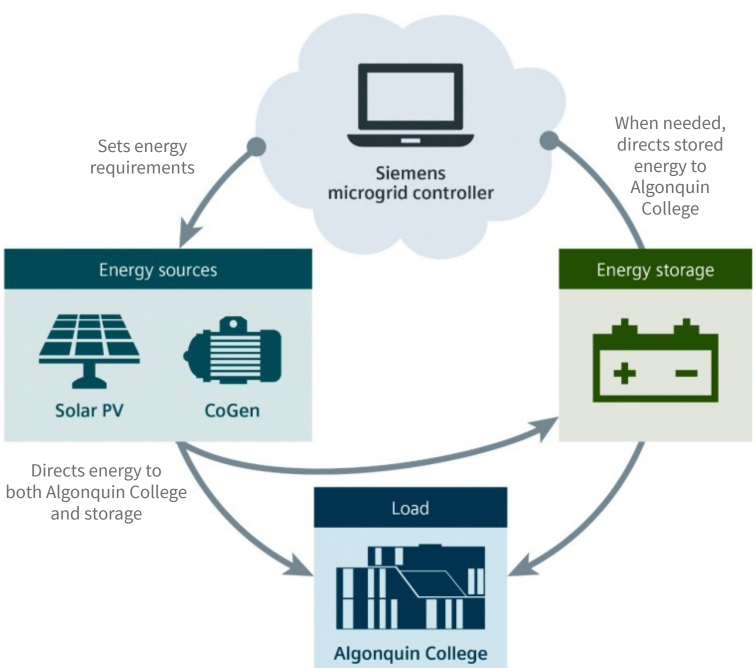
So it's fitting that the college operates an advanced microgrid, which includes a 4-MW CHP plant, 500 kW of solar, 500 kW (3-hour) battery energy storage and electric vehicle charging stations—all controlled by a new level of software intelligence to create a cutting-edge "optimized" microgrid.

The college uses an advanced Siemens microgrid controller to network on-site generators to each other as well as the campus buildings and the outside electric grid. The controller continuously reconfigures use of microgrid resources based on their availability and energy market prices. It achieves this feat minute by minute. In doing so, the controller minimizes emissions, increases efficiency and reduces energy costs.

The expanded microgrid allows the college to operate entirely off grid when a power outage occurs or when being off grid offers economic advantage.

Driving to total energy independence, Algonquin College currently creates and directs part of its energy requirements. Photo credit: Siemens

Other times, the microgrid operates connected to the local utility grid, making valuable decisions based on real-time grid prices and the thermal requirements of the college. Automatically, and with no human intervention, the microgrid controller will decide the best mix of these resources at any given time.



When needed, the microgrid controller can direct stored energy to Algonquin College. Infographic credit: Siemens

Examples of some ways the microgrid can derive value include:

- Store energy in batteries and then use that energy to respond in a demand response event.
- Control load in response to market signals. For example, the campus heating requirements are seasonal and dynamic. If demand is low on the microgrid, the microgrid controller may choose to use on-site generators to heat the water. But, if the on-site generators are in demand, or if grid electricity prices are low, the college may instead tap into the grid for the necessary power.
- Forecast what is ahead for load and generation. The microgrid can look ahead to determine what mix of distributed generation resources will be most economical based on forecasted fuel prices.

The optimized microgrid creates a highly advanced learning lab for Algonquin students and researchers. Even more, the college is helping to open the door for communities, businesses and institutions worldwide that can benefit from this cutting-edge clean technology.

The Santa Fe Community College microgrid: preparing the next generation

Microgrids also provide community college students outstanding opportunities for training in technical jobs in the new energy economy. They have the potential to attract students back to the vital hands-on workforce. In an era of rapid-fire technological change, it's not always easy for engineering students to train on the latest real-world tech. Campus microgrids, however, allow them to do just that, doubling as both teaching tools and clean energy generating assets serving the school.

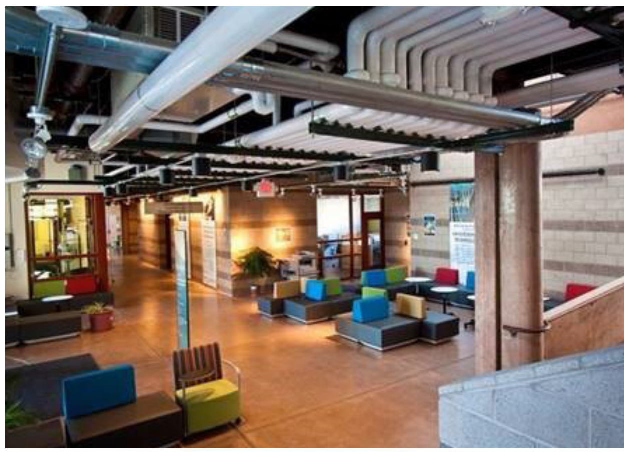
A gold star example is emerging at Santa Fe Community College (SFCC) in New Mexico, which is building a microgrid training center in partnership with Siemens. Like Bronzeville, SFCC's project demonstrates the value of linking disparate microgrids. In SFCC's case, a nanogrid will power its greenhouse and link to a planned campuswide microgrid.

Its Building Energy Automation and Microgrid Training Center (BEAM TC) provides students with the critical training that links advanced building automation technology to microgrid energy control. This way, students learn how to manage the building's heating, cooling and lighting, while simultaneously training in microgrid managed power generation and controls.

The microgrid will expand the reach of the building automation system so that it can integrate multiple energy systems, add resiliency to the grid in the event of power disruptions, optimize the energy systems and enable advanced cybersecurity.

The greenhouse nanogrid consists of a 100 kW (85 kWh) lithium ion battery and a 25 kW dual axis solar PV array, which will share power with a campus microgrid that will contain 1.5 MW of solar PV (existing), a 500 kW (500 kWh) lithium ion battery, and advanced Siemens microgrid controls. The 1.5 MW of existing solar PV, because of the addition of microgrid controls and advanced switchgear, will be able to remain connected to the campus during power outages. Like nearly all solar PV arrays connected to buildings, the array must be automatically disconnected during outages unless connected to a microgrid controller.

The new BEAM TC will be the first of its kind to train students in building automation and microgrids and how the two complement each other to allow interaction with the utility grid. SFCC's new greenhouse (for advanced hydroponics and aquaponics) was designed to be powered by a fully integrated nanogrid, optimized for microgrid training opportunities. The nanogrid will become a node for the proposed campuswide microgrid.



SFCC as a Living Laboratory. Photo credit: Siemens

The college is leveraging a $351,000 grant from the U.S. Economic Development Administration (EDA), $326,000 in state appropriations, and $111,661 in donated equipment and engineering expertise from Siemens and other industry partners. Santa Fe Community College President Rebecca "Becky" Rowley, Ph.D., said:

"SFCC is proud to partner with Siemens Industries as well as U.S. EDA to be on the forefront of education and research in microgrid technology. The college has been a leader in workforce development in the sustainability arena by developing educational programs and training in solar (thermal and PV) electricity, controlled environment agriculture (both hydroponics and aquaponics), algae production and biofuels. Developing an educational and training program in microgrid technology was the next logical step to prepare our students to become a part of the new energy economy."

U.S. Congressman Ben Ray Luján foresees the training center as making SFCC a statewide leader in building a green energy workforce and economy. "This grant recognizes their smart, forward-looking approach to ensure that students graduate with the skills to get good jobs in the renewable energy sector," Luján said.

The project is expected to attract jobs and businesses to the region and position engineering students for employment in the rapidly growing microgrid industry. BEAM TC will be housed in the college's Trades and Advanced Technology Center. It will serve the entire North Central New Mexico Economic Development District, which encompasses seven counties (Colfax, Los Alamos, Mora, Rio Arriba, San Miguel, Santa Fe and Taos) as well as nine pueblos and tribes.

The energy industry faces a skills gap similar to the talent gap in the manufacturing sector. A U.S. Department of Energy report found that the nation lacks enough workers to fill 1.5 million new energy jobs by 2030.

"Our goal is to have students move on from this program and find good and fulfilling jobs in the future of technology, energy and energy distribution," said Camilla Bustamante, Dean of the School of Trades, Technology, Sustainability and Professional Studies and of the School of Business and Education.

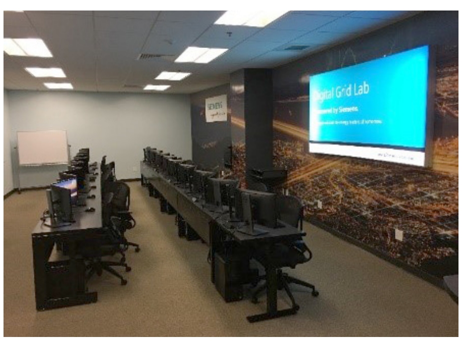
"We are achieving the cutting edge with facilities projects that relate to training and education. But we're also doing things that will help the college improve energy resilience in addition to operating more efficiently and sustainably as an organization. It's not only an educational program, it's an inherent fabric of the college," said Henry Mignardot, executive director for plant operations and maintenance at the college.

Siemens Digital Grid Lab at the University of Central Florida

In a partnership that has spanned three decades, Siemens and the University of Central Florida (UCF) have engaged in 100 research projects, representing a $10 million investment. Now, together, they are also educating the next generation in microgrids and smart grids at the specially designed Digital Grid Lab.

Siemens Digital Grid Lab at UCF.
Photo credit University of Central Florida

The Orlando, Florida, lab, which includes data links to the UCF campus microgrid, offers the opportunity for researchers to work on a range of power systems, including optimal operation of transmission and distribution systems with high penetration of renewable energies, stochastic modeling of power systems, protection of PV farms, real-time monitoring of transmission and distribution systems, distribution system automation, and power system restoration and resilience analysis.



Siemens Digital Grid Lab at UCF.
Photo credit: University of Central Florida

It is equipped with cutting-edge technology used by many utilities, including utility-grade software and hardware, such as Siemens Spectrum Power Microgrid Management System (MGMS), Spectrum Power Advanced Distribution Management System (ADMS), Power System Simulator for Engineering (PSS/E) and PSS/SINCAL, and Siemens Distribution Feeder Automation (SDFA).

Students are able to test real-world scenarios with simulated models of the UCF microgrid, while commercial energy customers seek insight into how to use their on-site assets. Led by Engineering Professor Wei Sun, the lab accommodates about 120 students a year.

"The strategic partnership between Siemens and UCF is an excellent example of a collaborative relationship that has produced and continues to produce notable accomplishments in the areas of STEM, social responsibility and leadership development. Siemens is very fortunate to have UCF as one of its key partners in the areas of advanced smart grid research, recruiting and continuing education," said Rafael Ozaki, president of Siemens Digital Grid U.S.

Conclusion

U.S. colleges and universities are world leaders, not only in education, but also in proving advanced technologies and taking on the climate change challenge. But pursuit of sustainability can be costly, and higher education already faces financial headwinds. Microgrids are an energy solution for the times, given that they can help infuse more renewable energy onto our grid while also reducing costs.
In addition, a campus microgrid becomes a teaching tool to prepare future engineers on some of the most cutting-edge energy technology now available. We encourage higher education decision-makers to examine their energy infrastructure to see how a microgrid might improve their energy system, advance their environmental goals and enrich their educational mission.