

How Microgrids Can Achieve Maximum Return on Investment (ROI) The Role of the Advanced Microgrid Controller



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About this guide

Microgrids are becoming increasingly popular among communities, businesses, universities, hospitals and others seeking reliable and cost-effective energy. But because they are relatively new, complex and different from other forms of alternative energy, investors have yet to establish replicable financing models for microgrids. This guide posits that the financing models will become clear when investors understand how advanced controllers capture a microgrid's full economic value. Here we demonstrate how that is done.



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Chapter 1 Why is Microgrid Financing Difficult?

The microgrid industry is expected to see rapid growth in the coming decade. Some describe it as the next market iteration of solar, which grew eight-fold from 2010 to 2015, and is forecast to expand by another <u>119 percent</u> in 2016.

While many catalysts drive solar industry growth, analysts point to financing as a primary factor. The turning point for the solar industry came when it formulated financing models — such as solar power purchase agreements (PPA) and solar leases — that eased the strain on buyers and offered favorable returns for investors. Before that, solar had advanced slowly. *(See chart below).*

Today, the microgrid industry is much like the solar industry in the early to middle part of the last decade; microgrids have piqued the interest of investors, communities, governments, universities, businesses and others. But customers are unsure if they can afford them, and investors are unsure how to monetize them.

Much of the problem resides within a microgrid's complexity. "There are novel nuances to microgrid projects (such as how to value resilience) that are not yet sufficiently understood by the market, and not

What is a microgrid?

A microgrid is a group of interconnected loads and distributed energy resources in a defined geographic area that can connect and disconnect from the grid. This paper focuses on complex microgrids that are characterized by their sophisticated use of advanced microgrid controllers. The controller orchestrates the microgrid's energy supply, which may come from several on-site energy sources, such as solar, wind, combined heat and power (CHP), energy storage and reciprocating engines, as well as from the central grid.

sufficiently well-vetted to attract larger institutional investors," says Jonathan Strahl, Emily Paris and Laura Vogel of Navigant Consulting, <u>in their paper</u>, "The Bankable Microgrid: Strategies for Financing On-Site Power Generation."



Annual U.S. Solar PV Installations, 2000–2015

Source: GTM Research / SEIA



Greater than the sum of its parts

Consider how microgrids compare with other energy assets, such as power plants or energy efficiency programs. Each of these offers a relatively straightforward product to create value: one provides electricity and the other electricity savings.

An advanced microgrid, however, offers both power supply and energy savings and derives value from each. And that's just the start of the complex stream of economic benefits that can emanate from a microgrid; others include electric reliability, resiliency, energy security, emissions reductions and energy bill savings. In addition, many microgrids incorporate combined heat and power (CHP), which adds thermal economic benefits to the mix.

The microgrid derives its value from an interwoven complexity — and this is what makes quantifying value so difficult.

Perhaps most important, an advanced microgrid creates these benefits through a complex interaction of its distributed assets. (Often the interaction extends to the central grid, as well.) The microgrid derives its value from an interwoven complexity — and this is what makes quantifying value so difficult.

Again, let's compare a microgrid to a power plant. Measuring the power plant's value is like taking a yard stick to a straight line—one asset is considered. By comparison, measuring the value of a microgrid is more like plucking apart strands of a spider's web and putting a ruler to each—but then realizing that length alone does not show the value of the interwoven web to the spider.

For investors, the microgrid value proposition is further complicated because no standard microgrid design exists. Instead, a microgrid is location specific and highly tailored to serve its customers' needs. Customers benefit from tailored solutions, but investors do not, at least in the sense that microgrids become difficult to replicate in financial models.

A microgrid's size also offers an example of a benefit to customers that daunts financial markets. Their 'micro' nature makes microgrids agile and able to serve pinpointed needs on the distributed grid. But financiers generally prefer large capital projects over smaller ones. It is as much work for them to finance a small project as it is a large project, but the large project nets greater profit.

Getting a microgrid down to one number

To be clear, microgrids are being developed and financed now. But no 'killer app' exists for microgrid financing, no one approach that fully realizes microgrids' complexity and value to encourage wide-spread adoption. Instead, for each new microgrid, project partners find themselves engaged in the time-consuming task of figuring out a custom financing package. And while they can solve the problem for that particular microgrid, the solution is not widely replicable.

Government funding typically covers only a portion of costs. For the remainder, microgrids tend to rely on variations of financing models established for related industries.

Like many new clean energy products, microgrids are relying in their early days on government grants for partial funding; the most notable of these programs being the \$40 million <u>New York Prize</u>. However, government funding typically covers only a portion of costs. For the remainder, microgrids tend to rely on variations of financing models established for related industries. These include direct ownership, vendor financing, energy service contracts, power purchase agreements, leasing, debt financing, bonds, Green Banks and other common alternative energy vehicles.

So what will it take for investors to craft a financing model that will accelerate microgrid growth, one that is not piecemeal but takes into account the entirety of the microgrid's value? Is it possible to get a microgrid down to one number?

This guide posits that what's missing is a ready way to establish return on investment (ROI), particularly for advanced or 'optimized' microgrids. It shows how an advanced microgrid controller can help establish ROI, and it offers a method for doing so.

"Every solar company can now quickly crank out a project's value based on a few parameters, such as solar intensity, local utility rates and tax credits. In minutes they can price and produce a power purchase agreement for a customer," says Sally Jacquemin, Siemens Microgrid Business Manager. "The microgrid industry would benefit tremendously from a similar model. Establishing a ubiquitous way to determine ROI would go a long way in helping the financing community develop such a model."

Next, we will describe how to quantify the value of a microgrid.



Chapter 2 Quantifying the Value of Reliability in a Microgrid

Return on investment, or ROI, is a common financial metric used to show the return an investment receives relative to its cost. ROI takes on various forms depending on the industry. For some energy projects, including microgrids, the analysis tends to center on payback — the number of years it takes for the customer to pay back the initial investment and begin seeing a positive cash flow.

At first glance, the idea of establishing ROI for a microgrid seems simple: What did the microgrid cost and what did the customer save on energy bills? How quickly will the savings pay back the investment?

But savings on energy bills alone does not fully value the microgrid. As we pointed out in the previous chapter, microgrids provide value in several ways not readily reflected in bill savings.

Energy reliability — a microgrid's ability to keep power flowing when the central grid fails — is one of the most important, and most difficult, values to prove. Reliability is often a main reason why customers choose to install microgrids. So the question becomes: What will a power outage cost your operation? The answer varies by customer.

For example, a research lab can lose years of research, millions of dollars of work, from a power outage. At the University of Texas, energy reliability is valued highly because 80 percent of the campus space is dedicated to research worth about \$500 million.

"If a professor loses a transgenic mouse with 20 years of research built into it, that's a nightmare. That's what keeps me up at night," says <u>Juan Ontiveros</u>, the university's executive director of Utilities and Energy Management, told *MicrogridKnowledge.com*.

Not surprisingly, the university has invested in one of North America's largest microgrids, a facility with 35-MW (62-MW peak) electric capacity and 1.2 million lb/hr of steam generation (300k peak).

Data centers, supermarkets and certain industrial facilities face similar steep losses from power outages. The military also highly values reliability and has been an early adopter of microgrids. Often the military centers discussion of reliability around energy security, the ability to retain enough power supply to support mission critical responsibilities.

The National Renewable Energy Laboratory (NREL) analyzed the value of electrical energy security at Fort Belvoir military base and pegged it at <u>\$2.2 million to</u> <u>\$3.9 million</u> annually. NREL's range reflected the mission of the respective uses within the base and recent performance metrics of each utility. NREL looked at three approaches to value energy security:

- A macro approach that divided total annual energy consumption into gross domestic product to come up with a \$/kWh outage cost
- A microscopic approach based on a customer survey that looked at duration of outages, the situation under which it occurred and the customer activity
- An analytical method that considered expected energy not supplied and cost

Microgrid Value Grows with Complexity



Economic Value



In deriving the energy security value for Fort Belvoir, NREL employed the microscopic approach, according to NREL researcher Julieta Giraldez.

NREL found that an advanced microgrid — one that continuously optimized its assets — offered greater reliability and greater economic value. While an advanced microgrid may cost more to build than a simple microgrid, the advanced microgrid can provide many more functionalities.

Despite the work of NREL and others, the industry continues to debate the best way to value reliability. As Peter Asmus of Navigant Research says:

"The primary metric that remains a mystery is the value of reliability. Quantifying the benefits of reliability is both art and science. At this point in time, there are no widely recognized financial metrics to monetize the value of energy security and reliability, the key distinguishing feature of a microgrid network." Microgrid developers have been attempting to mold common energy financing models to microgrids. These include:

- The power purchase agreement (PPA), frequently used by independent power generators, solar companies and others that offer energy supply
- The energy savings performance contract (ESPC), a model common to the energy efficiency projects that focuses on sharing cost savings between the contractor and customer

The problem with both of these models is that a microgrid is neither a generator nor an energy efficiency project, but a combination of both — with reliability and other benefits added. Establishing ROI for a microgrid requires understanding the value of reliability, along with the intelligence and abilities of the microgrid controller, which helps create the microgrid's value streams. Until the industry can establish these values, it will be difficult to determine the most effective financing model.

Next, we will more carefully examine the sources of value in a microgrid.

Chapter 3 Inside an Optimized Microgrid: What is the Source of its Value?

Microgrid and microgrid-like projects

Microgrids can be very simple or very complex—and this will influence their ability to derive value and achieve a favorable ROI. So it's important to start this discussion by describing the different types of microgrids and microgrid-like projects that exist.

The U.S. Department of Energy (DOE) defines a microgrid as:

A group of interconnected loads and distributed energy resources (DER) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.

This definition embodies a wide range of energy projects, with various kinds of generation and any kind of customer.

The simplest microgrid might have an elementary microgrid controller governing perhaps one building and at least two forms of generation with no connection to the central grid.

The most complex microgrid in operation today uses an advanced microgrid controller that orchestrates

the energy supply from several generation sources. It supplies multiple loads and is likely to include energy storage, renewable energy, CHP and possibly back-up reciprocating engines. In most cases, the complex microgrid is connected to a central grid, from which it can both supply and derive services.

Adding value for microgrid-like projects

Even if a project is not a true 'microgrid' as the defined by DOE, but rather a variation on the theme, it can gain greater value with integration of an advanced microgrid controller. These microgrid-like projects include:

- 1) <u>nanogrids</u>
- 2) solar plus storage
- 3) CHP
- 4) other types of distributed energy resources

Among them, a nanogrid is closest to the microgrid: it can island from the central grid, but it has only one source of generation and only one load to manage (a single building). A true microgrid, by comparison, has more than one distributed energy resource (DER) and multiple loads to optimally manage — this system complexity is where microgrid control drives value.



While distributed energy projects may lack the versatility of a full microgrid (i.e. islanding functionality), they can benefit from similar control technologies that can help them optimize their internal resources, and in some cases leverage against utility rates. Particularly important are the multiple DERs, the advanced controller, and the available utility rate structures. As we'll discuss later in this guide, when these and other aspects of the distributed energy



solution are 'optimized' – used to their fullest value – they offer the opportunity for greatest ROI.

What does a microgrid cost?

Securing value is just one side of the equation to determine project payback. The other is investment cost.

<u>Microgrid costs</u> vary; they depend on the complexity of the installation. The major expenses are:

- Distributed generation assets
- Grid automation
- Microgrid optimization software
- Development and installation costs
- Energy storage (potential)

Distributed generation almost always requires the biggest investment; in fact, generation can account for more than 50 percent of the capital costs, particularly for a greenfield microgrid with multi-megawatt gensets or utility-scale solar, according to Omar Saadeh, Senior Analyst, <u>GTM Research</u>¹.

Meanwhile, the microgrid controller accounts for closer to 15 percent of overall microgrid costs, according to Saadeh.

"A control architecture can be seen as the microgrid's nervous system—the smarts enabling all its



functionality from monitoring and economically dispatching DERs to communicating with the utility or signaling an island disconnect. Development costs do add up when considering a larger portfolio of DERs or more advanced capabilities, but so do additional savings and performance opportunities," he says.

The importance of the microgrid controller

"What's most poignant about this cost breakdown is the low cost of the controller compared with the value it brings to the microgrid project," says Jacquemin. "The controller costs can account for as little as 10 to 15 percent of overall development costs. Yet, the controller is the key differentiator between smart, optimized microgrid or energy generation project and simple, basic control projects, such as a stand-alone solar project that operates under a power purchase agreement or a battery connected via inverter."

In short, the microgrid controller is what drives the financial value streams and enables the technical islanding functionality, when needed.

The controller's ability to derive value will depend on the microgrid's internal complexity, as well as external factors, among them the microgrid's location, which we describe in the next chapter.

¹ The generation investment, however, is not necessarily made all at once. Microgrids often can be developed in phases, an advantage the technology offers since the microgrid can grow with the business operation of its host. Microgrids also can—and often do—leverage existing generation on the site. GTM's Saadeh points out that many of the university campus microgrids in the Northeast include on-site CHP plants that existed prior to development of the microgrid.



Chapter 4 Microgrid Value: Location, Location, Location

Ways microgrids derive value

A microgrid uses its software intelligence to precisely coordinate its energy supply and demand in a way that extracts maximum value and performance from its resources. An advanced microgrid does so with an eye toward the microgrid's internal economics and the outside market. So the level of value the microgrid secures is location dependent; it is influenced by rules, regulations and market conditions that vary by states, regions and countries.

Some ways the controller derives value include:

- Integration and optimization of renewable energy (solar photovoltaics and wind) and battery energy storage systems
- ▶ Utilizing thermal energy from CHP
- Participating in utility-run demand response programs
- Managing controllable loads via Building Automation Systems
- Forecasting weather and managing load and generation accordingly
- Optimizing economic dispatch and unit commitment
- Automating operations and control reducing the need for on-site operators
- Providing energy resiliency/averting power outages

The microgrid controller configures and dispatches the most reliable and economic mix of resources for use at any given time. This might mean integrating on-site renewable energy with other generation resources to overcome the 'variability' of solar and wind — the problem of non-production by these resources when the sun doesn't shine or wind doesn't blow. To make up for any lag in energy production from renewables, the controller can tap into battery storage, reciprocating engines, central grid power (if it is connected to the utility grid) or some other resource. The microgrid can even plan ahead in making these decisions by tracking weather forecasts.

The controller also derives value by tracking market prices for power to determine when it's most advantageous for the microgrid to use its own generation versus buying power from the grid. In some instances, the microgrid may even supply power to the grid, as well



Natural gas prices are one of the location dependent variables that influence a microgrid controller's ability to derive value. Credit: US Energy Information Administration

ancillary services, such as frequency control. The utility or grid operator pays the microgrid for these services, which creates a revenue stream for the microgrid.

The controller also works with Building Automation Systems to analyze energy use in buildings served by the microgrid, and to determine where and what time of day it can 'shave' energy use without affecting the comfort of occupants. During high cost energy periods in summer afternoons, for example, the Building Automation System may increase the temperature by one or two degrees to reduce load per the microgrid controller instruction.

Meanwhile, the microgrid might rely on CHP for continuous operation to serve its base load requirements — the minimum electrical needs of the microgrid host over a 24-hour period. CHP also will offer value by way of thermal energy. CHP uses wasted heat produced in power production for heating buildings, warming and chilling water, producing steam or for some other use valuable to the customer. This distinguishes CHP from conventional power plants, which let the heat waft unused into the air or water. A microgrid controller optimizes CHP systems by ramping up or down capacity to match the forecasted load as well as to maximize economics of the system in relation to utility rates.

It is important to note that the advanced microgrid controller handles all of this coordination — forecasting, dispatch, interaction with the central grid automatically. No human intervention is required.



Location specific value

How well the microgrid is able to secure some of these values will depend on where it is located geographically. Several external factors influence the ability to fully use microgrid software management, control, and optimization capabilities. In discussing these factors, we will focus on the United States because analysts expect it to be the most active microgrid market in the near term.

Some of these locational factors include:

- ► Utility electric rates
- ► Natural gas prices
- Grid operator rules and markets for ancillary services
- ► Availability of demand response programs
- ► Local rules for net metering
- Renewable energy credits and other financial incentives

Local utility rates are one of the most important influences on microgrid value. Like most distributed energy, microgrids tend to pencil out best in regions where utility rates are high. If utility rates increase over time, as they have historically, the microgrid may be able to show a widening of savings over its lifespan. This is particularly true if at least part of the generation used by the microgrid has fixed, or even zero fuel costs, as does wind or solar energy.

CHP's economic advantage is based on what's known as the spark spread — the difference between gas and electricity prices in a region.

Utility rates vary widely in the United States. For example, in Hawaii, the state with the most expensive electricity, rates for commercial customers were 24.21 cents/kWh as of February 2016. In contrast, Oklahoma has the lowest average rates in the country, at 6.90 cents/kWh, according to the U.S. Energy Information Administration. It's not surprising, therefore, to see early microgrid activity emerging in places like the Northeast and California, where retail electricity rates are high. (See <u>Appendix 2</u> for a list of electricity rates by state in the U.S.)

Natural gas prices also play a role in determining microgrid value, especially since microgrids often include CHP plants, and many CHP plants are fueled by natural gas. CHP's economic advantage is based on what's known as the spark spread — the difference between gas and electricity prices in a region. The CHP plant's heat rate, or efficiency, also is considered in determining spark spread. A CHP plant's best economics generally occur where electricity prices are high and fuel prices low. (See more details on calculating spark spread for CHP <u>here</u>. In addition, the Environmental Protection Agency CHP Partnership offers a <u>spark spread calculator</u>.)

Revenue sources for microgrids

Depending on where the microgrid is located, it may have the opportunity to accrue revenue by selling <u>ancillary services</u>, such as frequency control and black start capabilities, to the local utility or regional transmission organization (RTO) or independent system operator (ISO). RTOs/ISOs manage wholesale power markets that serve two-thirds of electricity customers in the U.S. and more than one-half in Canada. A microgrid's eligibility to sell into these markets, and prices paid for the services, will vary depending on which RTO/ISO the microgrid is located in.

Microgrids also may earn revenue by participating in utility or grid demand response programs, where the microgrid agrees to reduce its power use from the central grid when the grid is under strain. This is commonly a hot summer day when power prices peak and it is more advantageous for the grid operator or utility to pay the customer to reduce energy use than to produce it.

Net metering — a utility credit from the utility for power from on-site generation added to the grid — also can improve the microgrid's bottom line. Most U.S. states have <u>net metering policies</u>, but the value of net metering varies, depending on whether the programs offer the credits based on wholesale or retail rates.

In addition, several states offer various renewable energy credits and emissions credit programs that a microgrid can participate in, if its generation sources qualify. Utilities typically buy the credits to comply with state renewable portfolio standards, requirements that a percentage of their portfolio comes from green energy. Some states, such as Massachusetts and New York, offer incentives for CHP. And finally, microgrids may benefit from federal tax credits, such as the 30 percent investment tax credit now available for <u>solar projects</u> and the 2.3 cents/kWh production tax credit for <u>wind energy</u>.

In the next chapter, we will describe a simulation conducted by Siemens that shows more specifically how to derive value from a microgrid and establish an ROI.



Chapter 5 Optimizing the Microgrid: How to derive maximum value

In this chapter, we describe how Siemens optimized a microgrid system based on an actual customer to achieve best ROI. Siemens modeled an advanced microgrid at a university, running various scenarios that illustrate the complex way a sophisticated microgrid controller derives value.

The microgrid that was modeled contains two CHP units, each with a 2 MW capacity; wind and solar generation, energy storage and controllable and fixed electric and thermal loads.

Five scenarios were modeled. In the first two scenarios, the microgrid does not have an advanced controller. In Scenarios 3-5, where the microgrid is optimized with an advanced controller, new and sophisticated ways to derive value open up. The result is a two- to four-year ROI.

Optimizing CHP

One of the most complex parts of the model involves optimizing the CHP. This is because CHP must take into account both electricity and heat, as well as other input parameters, such as operation and maintenance costs (per kWh), and ramping speed, which is how fast the CHP generators start. (This is necessary to know in order to plan timing in switching between the grid and the on-site generators.)

A CHP plant operates within certain load thresholds. If the facility's power demand falls below a certain level, the plant shuts off for safety reasons. "This shows how important it is to size these generators properly," says Dino Ablakovic, Senior Solutions Architect at Siemens.

The modeled facility has two 2-MW CHP plants. So hypothetically, if load is below 2 MW, one CHP plant operates. If load rises above 2 MW, the second plant kicks in. However, if the plant is optimized with an advanced controller, it quickly becomes apparent that it's not that simple to get the most out of the facility's resources.

For example, a problem can occur in certain circumstances when heat and electric demand do not correspond — at least if the facility does not have an optimized controller.

Consider a situation where the amount of heat needed requires operation of both plants, but the amount of electricity needed is much lower, below 2 MW. Under these circumstances, both CHP plants would automatically shut down since the electric load has fallen below the safety minimum. A power outage would result.

"There is clearly a need for some type of advanced controller there," Ablakovic explains.





An optimized controller would avoid the outage by calculating the mix of resources to keep the facility running, taking into account load requirements, the price of electricity and the efficiency level of the CHP plants.

Because of the many calculations the controller makes, the mix it decides upon at any given moment may even be somewhat counter intuitive.

For example, imagine a winter day that creates a need for more heat than just one of the plants can supply. You may think the controller would solve the problem simply by turning on the second plant — especially since electricity prices on the grid happen to be high at this time, higher than the cost of electricity generated by the CHP.

But the microgrid controller determines that it is more cost-effective to buy power from the grid than to run the second CHP plant. Why? CHP plants lose efficiency when they do not run to full capacity, Ablakovic says. Operating the second plant at partial capacity is not as cost-effective as buying the extra electricity from the grid, when CHP efficiency factors are taken into account. The CHP is most efficient if it is running at 2 MW — at that level it uses the least amount of fuel per kWh.

Flexible and inflexible resources

CHP is just one aspect of the microgrid that can be optimized to improve pricing and increase efficiency.

"A microgrid has both fixed and flexible energy resources. The controller is able to optimize all of the flexible energy resources within a microgrid," Ablakovic says.

For example, a research lab may require a constant temperature, so is inflexible. A lecture hall may be flexible—the controller can reduce air conditioning in the room when it's empty, increase it when it's not.

Real-time pricing

For this microgrid, hourly electricity pricing is available, so based on those numbers, the controller is able to fine tune in any given hour whether it is most cost-effective to use its own generation versus buy power from the grid.

The controller automatically calculates a range of parameters to determine optimization. Some of these parameters change in real-time, which can cause a re-arranging of the facility's energy configuration at any given point in time.



This chart provides an example of the spikes in electricity prices that occur over a year (top) and over the course of the (day) bottom in Ontario. An advanced controller will take these price changes into account as it determines the best use of resources to use at any give time.



Energy shifting

The advanced controller also can help the facility manage electric tariffs. This is especially important because in some places a utility bases annual pricing on a facility's peak load. If the rate threshold is say 2 MW, and the customer hits that peak only a once a year, it still is moved to the higher rate for the entire year.

"If based on the historical data we see that there are only a few cases where this price level is reached, we try to isolate these cases, and through load optimization and energy shifting, see if we can avoid going over this price range," he says.

The controller also provides the ability to plan the best mix of future resources. It can run analytics based on various different forecasted gas and electric prices, along with decreases or increases in load.

Forecasting of future prices

The controller also provides the ability to plan the best mix of future resources. It can run analytics based on various different forecasted gas and electric prices, along with decreases or increases in load. These forecasts can help in planning the optimal mix of resources for the future.

For example, perhaps the plant plans to install a diesel generator for use when grid prices peak. If electricity prices are going to rise over the years, the analysis may show an increasing need for the diesel generator in the future years. That might suggest resizing the diesel generator in preparation for the later years. Or once downtime is considered for the maintenance of the diesel generator, it may prove optimal to install a second generator.

Conclusion

The bottom line is that an advanced microgrid or distributed energy project has many resources at its disposal. When an advanced controller is used to manage the resources, it can derive value unavailable to simple generation-only projects. For example, a facility that uses CHP alone, or solar plus storage, without this advanced optimization and control, offers less flexibility and fewer pathways to maximum efficiency and best pricing. As the industry searches for ideal financing models, it is important to consider the abilities of an advanced controller and how it derives value for the microgrid. Microgrids and distributed energy projects achieve best ROI when their resources are deployed to their maximum.

With an advanced controller, it is possible to get a microgrid's value down to one number — down to a true ROI — that reflects the uniqueness of a microgrid's abilities. With that calculation done, it becomes easier to design financing packages that are based on the true and clear value of a microgrid.

A path to find the 'killer app' of microgrid financing, a model that will encourage more rapid adoption of microgrids, does exist. And it is the advanced microgrid controller that offers the signposts to get there.

Microgrid optimization

Some of the parameters influencing the microgrid's ability to fully optimize include:

- Current electricity and gas contract costs
- Hourly electricity prices
- ► How much fuel cost savings the microgrid can derive from CHP at any given time
- ► The availability of controllable loads, which can shift
- ► The influence of load shifting on utility charges
- How load profiles change over time
- ► How energy contract prices change over time
- The size of the generation resource; how it might change over time
- The variability/output of renewables and how energy storage is used
- ► The value of resiliency (See <u>Appendix 1</u>)
- ► Generator efficiency and ramping ability
- Diesel fuel costs



Chapter 6

Case Study: Algonquin College Leads the Way in Benefiting from an Optimized Microgrid

Background

Algonquin College in Ontario, Canada is modeling how to become a showcase for sustainability—and earn a positive return on investment—through exploration of a cutting-edge 'optimized' microgrid.

With more than 54,000 full- and part-time students, the college is renowned for integrating technology into learning. Its living laboratory of green technologies is designed to not only improve the campus environment, but also serve as an educational resource for students and faculty.

The campus already includes four state-of-the-art green buildings – one which has attained Platinum Leadership in Energy and Environmental (LEED) certification and three others either at or moving toward LEED Gold certification.

In addition, the college recently unveiled a high-efficiency microgrid, with a combined heat power (CHP) plant at its core.

Developed by Siemens, the project has drawn delegations of international visitors to the campus, according to the college president Cheryl Jensen.

The CHP plant is being constructed as part of a longterm Strategic Partnership aimed at Transforming the Algonquin College Campus to a model of Energy Management and Sustainability, which includes:

- Reducing campus energy expenses
- Keeping the power flowing during a central grid outage
- ► Addressing major deferred maintenance issues
- Offering students and faculty new learning and research opportunities

Next phase in sustainability leadership

The first 2-MW CHP plant is currently in operation. The next phase calls for a 2-MW CHP expansion and adding scaled solar PV, power storage and EV charging stations — all controlled by a new level of software intelligence to create a cutting-edge 'optimized' microgrid.

This new Energy Center makes the college a showcase for advanced microgrid control; software intelligence that uses complex algorithms to network on-site generators



to each other as well as the campus buildings, and even the outside electric grid.

Developed by Siemens, 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.

Perhaps most significant, the project demonstrates how such intelligence brings about an impressive return on investment for the college's microgrid, in this case a twoto four-year ROI.

By modeling how to achieve microgrid ROI for each individual customer, Siemens is at the forefront of advancing microgrid deployment.

"This project helps solve one of the most daunting issues facing the microgrid industry — how to finance a microgrid," says Jacquemin.

She points out that because an 'optimized' microgrid is a relatively new advancement, enabled by the latest software technology, it is not yet widely understood by investors. They are intrigued, but unsure how to structure a repeatable microgrid package that is able to be monetized.

"By showing how to solve for ROI, this project opens the way for innovation in financing, which in turn will make microgrids more accessible to businesses, institutions and communities," she says.



The modeling details

The financial system modeling called for doubling the CHP plant's capacity — from two to four megawatts. This gives the college the opportunity to secure all of its power onsite. The microgrid also incorporates solar power, energy storage, demand response, heat recovery, controllable loads, forecasting of load and generation, automated operation and control, and optimal economic dispatch and unit commitment.

While the college will be able to operate entirely off grid, it will only do so at times when a power outage occurs or when being off grid offers economic advantage.

Other times, the microgrid will operate in parallel with the local utility grid, entering into buy or sell contracts based on real-time grid prices. Automatically, and with no human intervention, the microgrid controller will decide the best mix of these resources at any given time.

Modeling CHP is particularly complex because it couples both power and heat, and has several input parameters.

Examples of some ways the microgrid can derive value include:

- Storing energy in batteries and then using that energy to respond to a demand response event.
- Controlling load in response to market signals. For example, a swimming pool's energy use is flexible. 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 low, the college may instead tap into the grid for the necessary power.
- Forecasting 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.

Modeling CHP is particularly complex because it couples both power and heat, and has several input parameters. The controller must decide at any given time if it's best to operate both CHP units, or just one and then purchase grid power.

"In Ottawa, electricity prices change every hour, so based on near real-time signals, the microgrid controller can decide which energy mix to plan," says Ablakovic.

Determining ROI

Siemens modeling shows the optimized microgrid earning a two- to four-year ROI. Siemens determined the ROI by:

- 1. Replicating the customer's energy usage and costs over a year based on past historical data.
- 2. Determining how new generation types (such as CHP) will influence the calculation; for example, how will replacing grid power with CHP influence economics using a simple controller?
- 3. Applying an advanced Siemens microgrid controller to optimize the mix, then determining how much money the optimized controller saves versus a simpler, non-microgrid controller.

Siemens also modeled a price for resiliency — the ability to keep the power flowing when the central grid fails. (See <u>Appendix 1</u>: Placing a Price on Resiliency.) This is an important value because power reliability is a major reason many customers install microgrids; yet determining its value is tailored to each customer and not easy to apply generically across the industry.

Conclusion

By moving toward an optimized microgrid, the Algonquin College will create a highly advanced learning lab for its students and researchers. Even more, Algonquin College is helping to open the door for communities, businesses and institutions worldwide that can benefit from this cutting-edge clean technology.

Special thanks to Siemens for making this guide possible.

About Siemens

Siemens Corporation is a U.S. subsidiary of Siemens AG, a global technology powerhouse that has stood for engineering excellence, innovation, quality, reliability and internationality for more than 165 years. With 343,000 employees in more than 200 countries, Siemens reported worldwide revenue of approximately \$98 billion in fiscal year 2014. Siemens in the U.S. reported revenue of \$22.2 billion, including \$5.2 billion in exports, and employment of approximately 50,000 people throughout all 50 states and Puerto Rico.

For further information on Siemens microgrid solutions, please see <u>www.usa.siemens.com/microgrids</u>.



Appendix 1

Placing a Price on Resiliency

To determine what an outage cost a facility, or more precisely to give reliability a specific value, Siemens undertook the following calculation. (The numbers are hypothetical.)

First, it looked at the total annual value at risk (VAR). This took into account an entity's revenue that could be lost by a power outage.

Calculating the amount of revenue at risk during a power outage is a difficult task and involves averaging out various values, some precise, some not. For a college campus, a wide range of activities must be valued

Assumptions							
Value at Risk VAR (Opex for year)	\$344,000						
Value at Risk VAR (Assets)	\$0						
Total Value at Risk	\$344,000						
Operational Hours per year (hrs/year)	6,000						

and then averaged to one number. Some examples might be financial loss from an experiment destroyed in a research lab due to a power outage, which can bring deep economic loss, to financial loss to students and lecturers when classes are canceled, which will likely be less substantial.

After determining revenue loss, Siemens established the operational hours per year of the facility. A college may not operate fully all year; its energy needs are minimized during school vacations, where the impact of blackouts would not be as significant. The VAR calculation needed to take into account this variability. So Siemens considered three scenarios of (A, B, C) with different percentages of VAR at risk.

Value of an Unserved Hour (VUH)								
VAR scenarios	% of Value at Risk Scenarios	Operational Hours (hrs/year) at risk	Value of Unserved Hour (VUH) per scenario (\$/hr)					
Scenario A	40 %	6,000	\$2,293,000					
Scenario B	60%	6,000	\$3,440,000					
Scenario C	100%	6,000	\$5,733,000					

Next, Siemens took into
account the number of
blackouts per year and how
long they last. In industry
parlance, these values are
known as System Average
Interruption Frequency Index

Reliability Statistics							
Type of Interruptions	SAIDI	SAIFI	Expected Outage Hours				
			0				
Total (including all forms of outage)	2.34	1.78	4.1652 (5 year average)				

(SAIFI) and System Average Interruption Duration Index (SAIDI).

Finally, Siemens calculated the expected outage and put a value to it. This is called the annual value of unserved hours (AVUH) — the resiliency value. In this hypothetical, the AVUH was \$99,600,000 to \$249,000,000 per chart below. The range varies based on whether the VAR was 40 percent, 60 percent or 100 percent.

Annual Value of Unserved Hours (AVUH)									
VAR scenarios	VUH (\$/Hr) per scenario driven (hrs)		AVUH non-storm driven (\$/yr)	Expected Outage Hours per year – storm driven (hrs)	AVUH storm driven (\$/yr)	Present Value storm driven AVUH (\$)			
Scenario A	\$2,293,000	0	\$0.00	4.1652	\$9,552,000	\$99,600,000			
Scenario B	\$3,440,000	0	\$0.00	4.1652	\$14,328,000	\$149,400,000			
Scenario C	\$5,733,000	0	\$0.00	4.1652	\$23,880,000	\$249,000,000			



Appendix 2

Table 5.6.B. Average Price of Electricity to Ultimate Customers by End-Use Sector, by State, Year-to-Date through March 2016 and 2015 (Cents per Kilowatthour)

by State, Tear-to-Da	ate through mart	2010 anu 201	5 (Cents per Ki	owatthour)						
Residential		Commercial		Industrial		Transportation		All Sectors		
Census Division										
and State	March 2016 YTD	March 2015 YTD	March 2016 YTD	March 2015 YTD	March 2016 YTD	March 2015 YTD	March 2016 YTD	March 2015 YTD	March 2016 YTD	March 2015 YTD
New England	19.37	20.43	15.30	16.92	12.20	13.18	9.01	11.61	16.50	17.90
Connecticut	20.43	21.65	15.85	17.14	13.28	13.93	11.20	16.86	17.65	18.98
Maine	18.06	15.93	12.26	14.58	9.16	10.63			13.95	14.11
Massachusetts	19.64	21.50	15.64	17.19	13.18	14.04	7.29	8.45	16.80	18.50
New Hampshire	18.27	19.39	14.64	16.21	12.60	13.69			15.84	17.26
Rhode Island	18 73	19.24	15.82	19.03	13 79	17.01	18 24	17.67	16.83	18.92
Vermont	16.86	16.56	14.30	14.00	10.19	10.29	10.21		14.28	14 31
Middle Atlantic	15.00	15.00	11.00	13.07	7.05	7 90	10.88	12 12	19.20	13.17
New Jersey	15.20	15.77	11.92	10.07	1.00	1.30	10.00	12.12	12.21	13.17
New Jersey	15.50	15.51	11.93	12.00	10.00	11.43	9.13	10.65	13.05	13.04
New York	16.72	19.37	13.35	15.21	5.85	7.20	11.83	13.27	13.60	15.77
Pennsylvania	13.98	13.05	9.49	9.83	7.05	7.62	8.07	8.10	10.48	10.54
East North Central	12.51	12.22	9.63	9.72	6.75	6.87	6.90	7.55	9.66	9.71
Illinois	11.92	11.77	8.50	8.84	6.32	6.67	6.68	7.01	8.95	9.19
Indiana	10.69	10.67	9.41	9.64	6.57	6.74	9.74	9.93	8.63	8.83
Michigan	14.73	13.72	10.40	10.27	6.83	6.96	11.39	11.53	10.81	10.55
Ohio	12.16	12.08	9.76	9.75	6.83	6.75	7.45	12.02	9.73	9.77
Wisconsin	14.01	13.84	10.78	10.74	7.57	7.58	14.17		10.76	10.73
West North Central	10.62	10.24	8.86	8.57	6.65	6.49	8.49	8.02	8.90	8.63
lowa	10.91	10.56	8.40	8.30	5.35	5.46			7.89	7.85
Kansas	12.46	11.67	10.18	9.74	7.44	7.38			10.17	9.78
Minnesota	12.11	11.54	9.49	8.98	7.01	6.71	10.19	9.31	9.69	9.19
Missouri	9.42	9.35	8.02	7.87	5.93	5.52	6.57	6.51	8 34	8.16
Nebraska	9.80	9.50	8.55	8.48	7.55	7 30	0.01	0.01	8 69	8.52
North Dakota	0.00	9.51	0.00	0.40	9.07	0.05			0.00	0.02
South Dakota	10.44	10.14	0.70	0.13	7.21	7.10			0.03	0.04
South Dakota	10.44	10.14	0.90	0.73	1.31	7.10			9.23	9.04
South Atlantic	11.42	11.37	9.38	9.66	6.16	6.55	1.10	0.00	9.76	9.96
Delaware	13.17	12.73	10.39	10.51	8.31	8.96			11.31	11.35
District of Columbia	12.99	12.33	11.88	12.11	9.20	8.55	9.28	9.24	12.00	12.00
Florida	11.39	11.88	9.47	9.98	7.84	8.38	8.66	9.26	10.33	10.83
Georgia	10.66	10.58	9.48	9.75	5.17	5.70	4.38	5.11	8.95	9.20
Maryland	14.11	13.12	10.95	11.45	8.02	9.61	7.76	9.11	12.27	12.20
North Carolina	10.88	10.80	8.60	8.62	5.84	6.29	7.93	7.81	9.14	9.28
South Carolina	12.08	11.99	9.96	10.12	5.65	5.94			9.37	9.47
Virginia	10.88	10.92	8.15	8.50	6.78	7.30	7.88	8.48	9.15	9.49
West Virginia	10.76	9.25	9.34	8.16	6.48	5.92			8.88	7.84
East South Central	10.36	10.34	9.98	10.21	5.48	5.78			8.69	8.90
Alabama	11.50	11.29	10.92	10.90	5.46	5.72			9.04	9.14
Kentucky	9.84	9.59	9.26	9.16	5.27	5.29			8.01	7.91
Mississippi	10.55	11.08	9.89	11.00	5.75	6.56			8.71	9.60
Tennessee	9.82	9.87	9.82	10.07	5.59	5.97			8.91	9.14
West South Central	10.35	10.67	7.65	8.05	5.06	5.69	5.63	5.53	7.81	8.41
Arkansas	9.19	8 94	7.93	7 79	5.54	5.68	8.96	11 25	7.63	7.65
Louisiana	8.68	8.81	8.56	8.77	4 95	5.46	8.52	8 11	7 18	7.60
Oklahoma	0.00	0.01	6.84	7.18	4.00	5.08	0.02	0.11	7.10	7.30
Toyaa	9.20	11.62	7.50	1.10	4.44	5.00	5.42	5.24	9.10	1.55
Meuntein	11.07	11.02	7.59	8.00	5.13	5.87	0.42	0.07	0.10	0.00
Nountain	11.03	11.31	9.00	9.36	5.01	6.16	9.35	9.97	0.72	9.02
Arizona	11.32	11.35	9.73	9.62	5.37	5.92	8.21	7.75	9.38	9.49
Colorado	11.18	11.60	8.73	9.52	6.61	6.87	9.03	10.23	9.00	9.50
Idaho	9.66	9.56	7.56	1.12	5.86	5.84			8.03	7.96
Montana	10.51	10.58	9.86	10.41	4.84	5.08			8.72	9.01
Nevada	11.90	13.18	8.37	9.64	4.97	5.93	7.84	8.71	8.06	9.13
New Mexico	11.38	12.27	9.43	10.24	5.53	6.10			8.77	9.55
Utah	10.60	10.42	8.24	8.18	5.93	5.76	10.05	10.07	8.23	8.02
Wyoming	10.60	10.43	9.21	8.87	6.85	6.81			8.12	7.97
Pacific Contiguous	14.13	13.69	12.21	12.22	7.98	7.99	8.65	8.79	12.08	11.85
California	17.71	17.22	13.79	13.91	10.43	10.73	8.63	8.78	14.54	14.43
Oregon	10.32	10.40	8.80	8.81	5.86	5.84	9.19	9.18	8.85	8.78
Washington	9.16	8.46	8.43	8.02	4.47	4.36	9.87	8.85	7.77	7.22
Pacific Noncontiguous	23.50	25.54	20.91	23.07	18.47	21.83			20.93	23.46
Alaska	19 75	19 43	17.63	17.38	14 39	14 55			17.68	17.55
Hawaii	27.01	31.58	24 14	28.84	20.11	24 73			23.35	28.02
U.S. Total	12.22	12 24	10.08	10.46	6.42	6 78	9.46	10 52	20.00 9 08	10.22
					0.72		0.40		0.00	

Source: U.S. Energy Information Administration, Form EIA-826, Monthly Electric Sales and Revenue Report with State Distributions Report