Energy Research and Development Division

**FINAL PROJECT REPORT**

# Microgrid Analysis and Case Studies Report

## California, North America, and Global Case Studies

**California Energy Commission**

Edmund G. Brown Jr., Governor

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# PREFACE

The California Energy Commission's Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solution, foster regional innovation and bring ideas from the lab to the marketplace. The California Energy Commission and the state's three largest investor-owned utilities – Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company – were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

*Microgrid Analysis and Case Studies Report* is the final report for the Microgrid Support project (Contract Number 300-15-009, Work Authorization Number NAV-15-001) conducted by Navigant Consulting Inc. The information from this project contributes to Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

# ABSTRACT

The Energy Commission seeks to understand the technologies, business models, scale, and vendor landscape supporting microgrids that are commercially viable in the absence of government grants and funding. This report features 26 microgrid case studies from California, North America, and other countries that make innovative business cases and rely on government support for less than 50 percent of project costs. The microgrids profiled range in size from 78 kW (a small demonstration in Michigan) to 112.5 MW (Denmark), and serve commercial, military, municipal, education, agriculture, and utility clients. The majority of projects (93 percent) use solar photovoltaic and energy storage as part of the microgrid generation mix. Diesel and biogas distributed generation technologies are also prevalent.

Analysis of the case studies shows that microgrid business models are still diverse and offer numerous value propositions to hosts. California projects report value propositions of renewable energy integration, resiliency, bill and demand charge savings, and a reduction in carbon footprint. This aligns with California's state renewable energy and carbon reduction mandates, and is also a result of high electricity rates and demand charges. Global microgrids are also deployed to meet clean energy goals; they target renewable energy integration and a reduction in carbon footprint, followed by reliability and resiliency. Notably, North American projects focus more on resiliency and reliability, followed by renewable energy integration; this is likely due to the adverse effect of extreme weather events on the electric grid. Business models appear to be moving towards performance contracting (such as Energy Savings Performance Contract) and shared savings models between the host and project developer, in which bill savings and revenue streams from grid services (for example frequency regulation) are split according to investment and risk tolerance.

**Keywords:** Microgrid, business model, renewable energy, resiliency, grid services

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# EXECUTIVE SUMMARY

## Introduction

A microgrid is 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. According to United States Department of Energy Microgrid Exchange Group A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode. Although the microgrid market is developing rapidly, it is still relatively immature, and microgrid projects tend to be highly customized. Therefore, these projects often require expensive one-off engineering solutions for emerging technologies (such as advanced energy storage) that in many cases still require government subsidies.

However, there are also microgrid projects that are moving forward without significant government support. The California Energy Commission (Energy Commission) seeks to understand the technologies, business models, scale, and vendor landscape supporting microgrids that are economically viable without major subsidies.

## Project Purpose

There has been limited public documentation of economically viable microgrids to support the Energy Commission's needs. This report is intended to help fill the information gap and inform how best to promote and accelerate microgrid adoption in California by learning about how successful projects have been developed without government support. Drawing from existing examples throughout California, North America, and the world helps build a broader understanding of microgrid solutions and guide the industry about best practices for economic viability. The analysis includes a look at resource mixes, market segments, and regional factors that impact commercial microgrid viability as case studies and additional analysis.

Insights gathered from this process will be integrated into the Energy Commission's Microgrid Research Roadmap, as recommendations for growing the market for microgrids through public and private sector actions, and meeting California's energy supply, resiliency, and climate change goals. Results from this study will also guide the Energy Commission's future Electric Program Investment Charge (EPIC) funding for microgrids and DERs.

## Project Process

Navigant, Inc drew on its industry experience and proprietary microgrid market data to select California, North America, and global case studies. Each of the projects was required to be funded by at least 50 percent private investment or non-governmental grant funding, or demonstrate microgrid technology or business model innovation that offers opportunities for repeatable deployments. The projects were also selected to reflect a diversity of microgrid market segments, vendors, use cases, and business models. All projects profiled in this report are either online or will be online by the end of 2018. With input from the Energy Commission for the final selection, Navigant ultimately profiled nine projects in California, 10 projects in North America, and seven projects globally.

The case studies were developed from a variety of data sources, including developer and microgrid host interviews, project data from existing Navigant research reports, and secondary sources such as press releases, company websites, and other public facing reports. During interviews and via written questionnaires, the microgrid developers and hosts were asked the following key questions:

- What were the primary drivers behind the project?
- How did the sponsor determine the value of investment?
- What metrics were used to determine to support development?
- What was total cost (and cost $/megawatt) MW)?
- What was the business model and how was the project financed?
- Did market participation revenue play a role in the business case analysis?
- How many stakeholders were involved with the project?

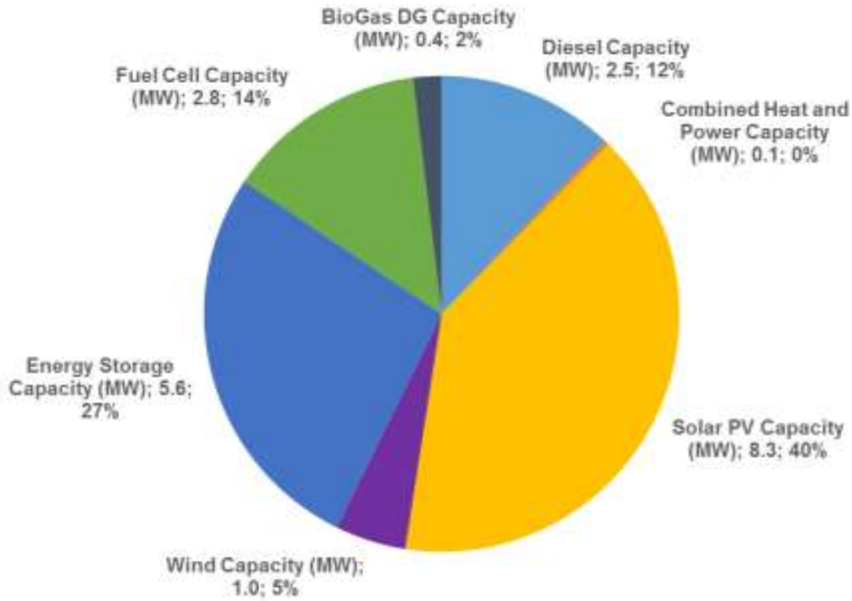
## Project Results

### California Case Study Summary

The nine California microgrids profiled total about 21 MW of peak generating capacity. They range in size from 153 kW (an affordable housing complex in Sacramento) to 13.5 MW (a system serving a public agency wastewater management agency located in San Bernardino).

The DER mix of the California case studies reveals a clear focus on clean energy, but also reliance upon some forms of fossil fuel (Figure ES-1). Solar photovoltaics (PV) and some form of energy storage is used in all nine projects in California. Solar PV represents the largest share at 40 percent of peak generating capacity. Next, energy storage represents 22 percent of the portfolio, followed by fuel cells (14 percent), diesel generators (12 percent), wind (5 percent), and biogas distributed generation (DG) (2 percent). Overall, the California microgrid resource mix is 88 percent clean energy resources (solar, wind, energy storage, biogas DG, and fuel cell) and 12 percent fossil fuel dependent resources (primarily diesel).

**Figure ES-1: DER Mix of Nine California Case Studies, by Capacity**




Source: Navigant

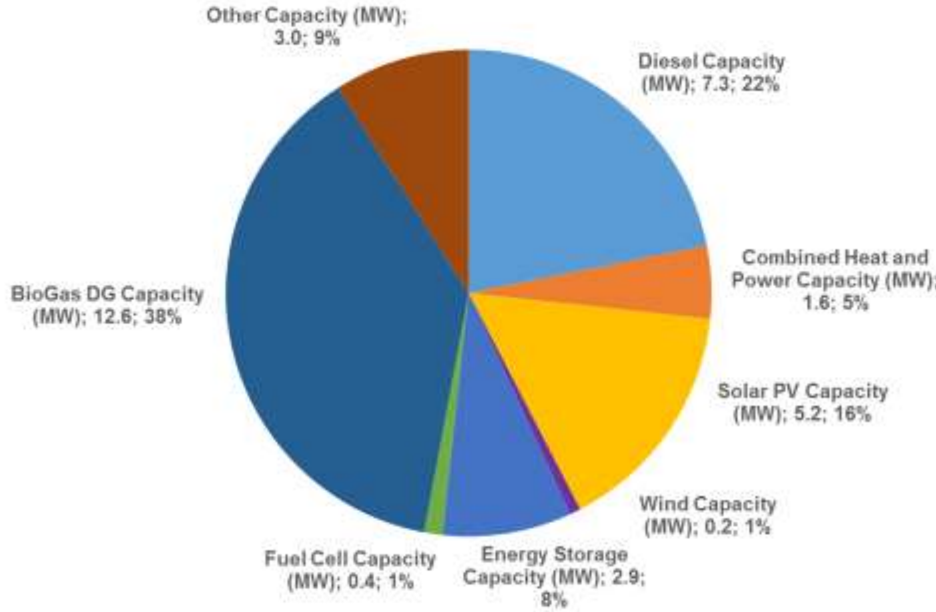
The segment most represented in the California case studies is commercial and industrial, although public agencies are also present. In the commercial and industrial segment, agricultural entities featured prominently, including one avocado operation, one winery, and one farm (with a winery). Microgrid projects for a municipally-owned zoo, a military base, and the wastewater treatment agency reveal that a select group of public entities have also discovered creative financing strategies that leverage relationships with utilities and technology vendors. Additionally, an affordable housing developer in Sacramento incorporated a microgrid into a residential community in partnership with the public utility. Though one commercial customer remains confidential, the project is included because it shows how a commercial entity with multiple sites recognized value in developing a fleet of microgrids across its portfolio in a phased deployment approach. One California case study is a private school in the Santa Barbara are that faces frequent power outages.

**North America Case Study Summary**

The 10 North America microgrids profiled represent approximately 32.4 MW of peak generating capacity. They range in size from 78 kW (a unique data center project leveraging used electric vehicle batteries as energy storage) to 15.6 MW (a US Marine Corps logistics base located in Georgia powered by diverse sources of biogas). The North America case studies also include one of the most unique microgrid use cases of any project—a 450-kW "survivalist" luxury condo constructed in an abandoned missile silo in Kansas (Figure ES2).

The DER mix is diverse; biogas DG represents a large portion of the North America generation mix at 38 percent. solar PV is just 16 percent and energy storage 8 percent of the portfolio. Diesel capacity is at 22 percent and combined heat and power (CHP) makes up 5 percent. The "other" category (9 percent) comprises natural gas generators from two projects.

**Figure ES-2: DER Mix of 10 North America Case Studies, by Capacity**




Source: Navigant

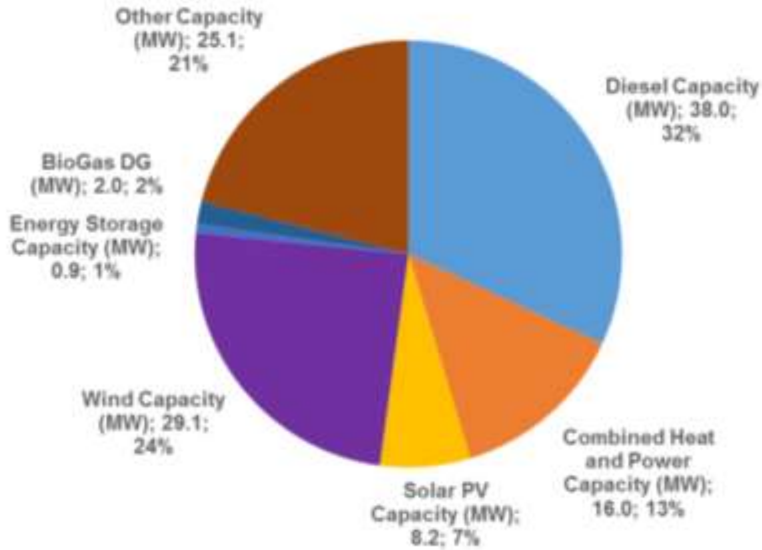
Seven out of the 10 North America microgrids are hosted by commercial customers. These projects include a state-of-the-art data center – a market segment viewed as a potentially huge future market for microgrids integrating renewable energy – and a system integrating three different types of batteries for a single site. One utility distribution microgrid is represented; this microgrid recouped the majority of its costs through utility rates. Finally, two government microgrids showcase new ways to finance microgrid projects by converting what is often viewed as a capital expense into ongoing operating costs that incrementally finance microgrid upgrades.

**Global Case Study Summary**

The seven North America microgrids profiled represent approximately 119.2 MW of peak generating capacity, or 6.7 MW not including the extremely large Bornholm Island system. They range in size from 206 kW (a university-led demonstration in Shanghai) to 112.5 MW (the Bornholm Island EcoGrid in Denmark).

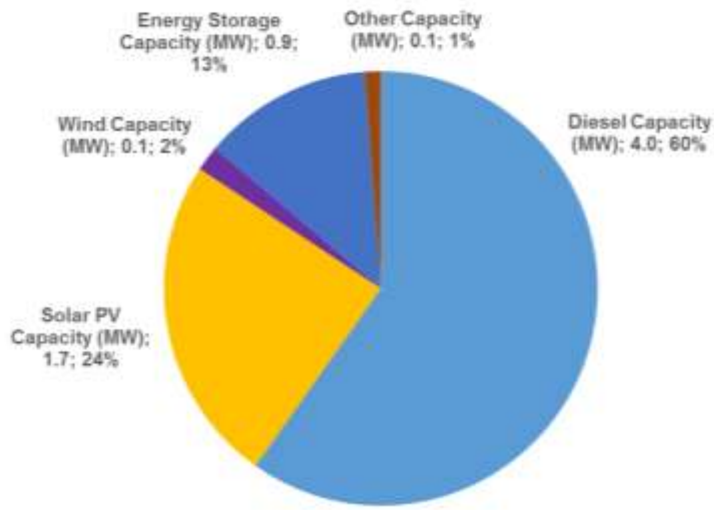
The EcoGrid project includes a large amount of renewable energy, but the other, smaller projects around the world depend more heavily on diesel generation than the California and North America case study portfolios. For the six smaller global projects, diesel generation represents 60 percent of the capacity share, followed by solar PV (24 percent) and energy storage (13 percent) (Figure ES4). With the EcoGrid project, wind capacity has a much larger share (24 percent), but diesel generation is still the largest share at 32 percent of capacity.

**Figure ES-3: DER Mix of Seven Global Case Studies, by Capacity**




Source: Navigant

**Figure ES-4: DER Mix of Six Global Case Studies (Excluding Bornholm Island), by Capacity**

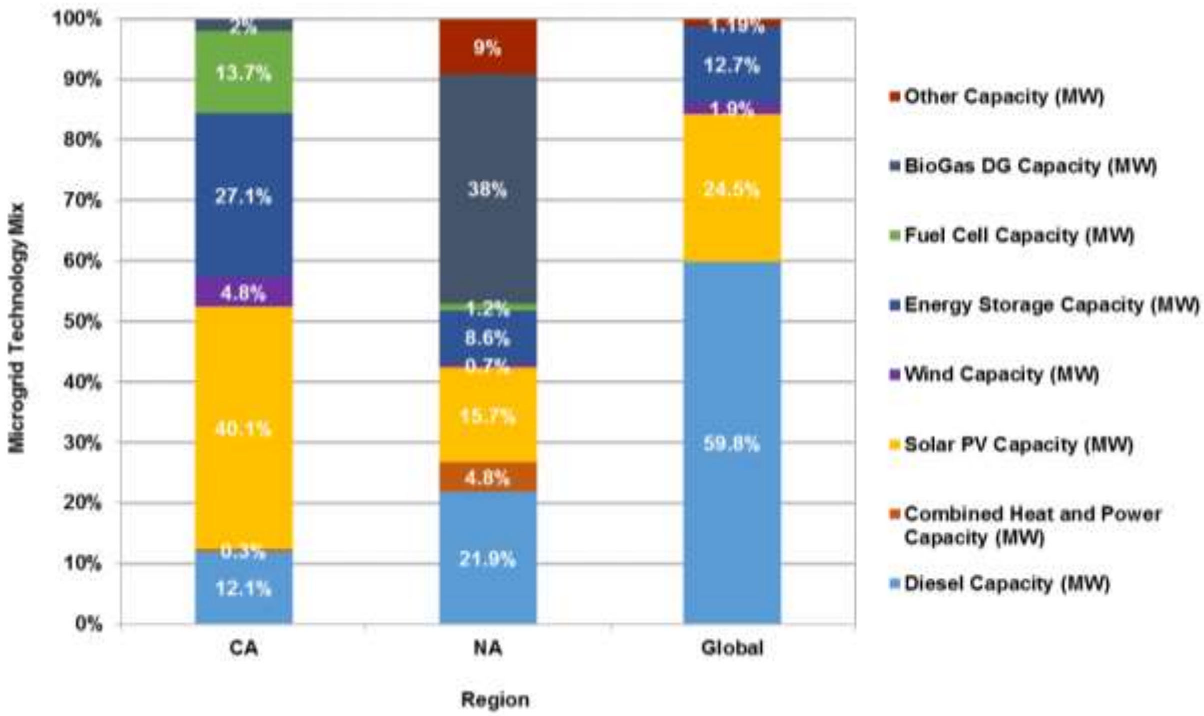



Source: Navigant

The global case studies include several demonstration projects sponsored by governments, public utilities, and universities, but also feature private industry projects for commercial hosts. The portfolio includes projects in India, China, Singapore, Japan, Mozambique, Denmark, and Hawaii – this last project included here as it has more similarities to global projects than the North America case studies which are all located on the continental US.

Comparing the case study regions side by side highlights the clear focus on solar PV in California compared to the rest of the world (Figure ES5). While Navigant purposefully targeted case studies that have a significant amount of renewable energy, results still demonstrate that North America and global case studies more often include fossil fuel generation (diesel and combined heat and power) to achieve resilience and reliability benefits through the ability to completely island from the grid. One factor contributing to this result is a focus on projects not dependent on government subsidies.

**Figure ES-5: Comparison of DER Mix, by Region**

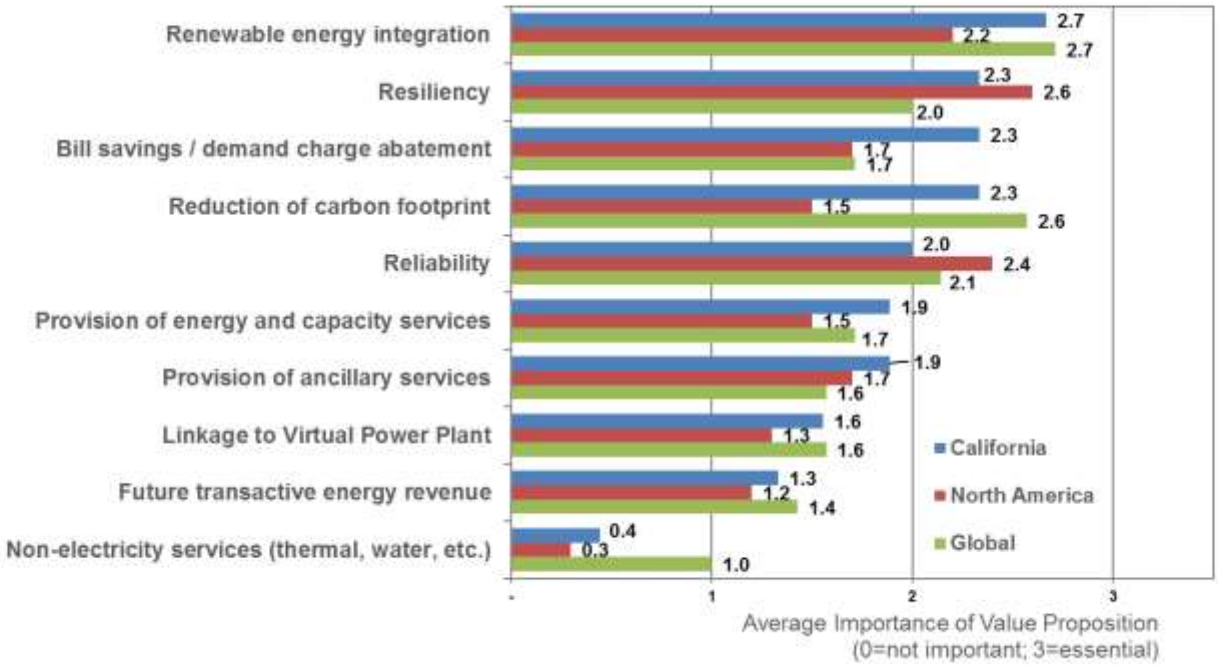



Source: Navigant

### Value Proposition Analysis

The case studies also explored what value propositions are driving commercially viable microgrids. Despite the diversity of use cases and microgrid applications, there are common value propositions driving microgrid adoption in California, nationally, and globally. Ten value propositions were provided to project developers and owners, who then ranked the importance of each value proposition for their projects. Results are shown in the Figure ES6.

**Figure ES-6: Value Proposition Rankings, by Region**




Source: Navigant

Respondents also offered several other interesting value propositions specific to their individual microgrid projects, including:

- EV charging infrastructure and Vehicle-to-Grid integration.
- Cybersecurity.
- Coordination with smart home devices.
- Demonstration of microgrid benefits to the utility and community.
- Secondary use of EV battery packs.

The drivers for microgrids in California, as shown by the value proposition rankings, appear to align with state policy goals for renewable energy and carbon reduction. The rankings also show the value placed on resiliency and microgrid economics, particularly for electricity bill savings and demand charge abatement. This is a driver microgrids share with energy storage systems for commercial customers in California, where electricity rates and demand charges are quite high. In comparison, most of the microgrids profiled from North America are in states with relatively low electricity costs. The North America projects score higher on reliability and resiliency, due (likely) to the effects of extreme weather events on the East Coast.

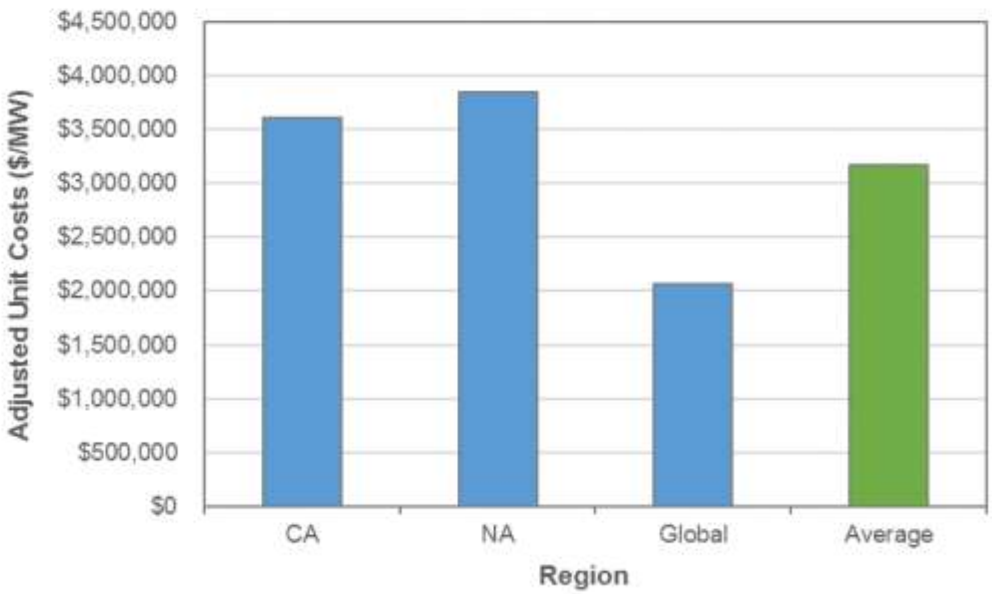
Global microgrids reported value propositions more like California than the rest of North America, signaling a strong interest in renewable energy integration and carbon reduction (despite reliance on legacy fossil fuel generation).

The relatively high scores for the provision of ancillary services and energy & capacity services, as well as interest in the concept of a virtual power plant, (particularly in California and globally) speak to a recent trend of exploring ways for microgrids to offer services to the larger grid in general. California and global projects rank these value propositions higher than do North America projects, pointing to advanced trading markets developing in high-renewables areas. This trend may be worthy of further examination and support from the Energy Commission as it considers future funding of microgrids.

**Cost Analysis**

The cost of a microgrid varies greatly depending upon size, the DER resource mix, legacy assets being incorporated into the microgrid, and number and types of vendors involved. The best measure of the cost of microgrids is the cost per unit capacity ($/MW). The average unit costs for each of the case study regions are shown in Figure ES7.

**Figure ES-7: Average Microgrid Unit Costs, by Region**




Acknowledging the limited dataset available from these case studies (26 microgrid projects overall), North America is the most expensive microgrid market, followed closely by California. This is likely due to the focus on smaller, smart-inverter based projects profiled in California (which reduces control costs) as well as a greater emphasis on resilience on the East Coast, requiring larger and more complex systems than would otherwise be considered cost-effective. In California, the relatively high upfront capital cost of solar PV and energy storage technologies is the likely cost driver.

As key enabling technologies such as solar PV and energy storage experience additional price decreases, microgrid costs are expected to continue to decline over time. This trend is already apparent: the average cost of all the case study microgrids is just over $3 million/MW. This average figure represents a significant reduction in costs according to Navigant Research, which four years ago collected cost data for new microgrid projects averaging more than $4 million/MW.[1]

## Benefits to California

Navigant recommends the Energy Commission focus future RD&D investment in technologies that enhance integration and control of diverse DER to limit reliance on back-up diesel generators, which still represent a significant share of microgrid technologies worldwide. Solar plus energy storage microgrids are becoming more prevalent and are now "proven" DER components for microgrids, especially in California. This technology pairing is expected to play a major role in clean energy microgrids going forward. However, to promote diversity in renewable generation – to benefit the larger grid as well as the microgrid – funding should target all renewable technologies. Wind, biogas DG, and fuel cells all feature in the microgrid case studies.

The Energy Commission should also consider benefits outside of electricity when judging microgrid candidates for funding and other support. For example, thermal energy, water, and waste management solutions can be wrapped into microgrid business models as shown in several case studies. These applications are less common today but could be helped by additional government support.

As the microgrid market matures, it is increasingly important to identify sustainable and replicable business models that shift project development risks to market participants with a proven track record and financial stability. Several case studies highlight this trend. However, there are also numerous small companies who still require RD&D funding to validate promising technology or financial solutions. As large technology vendors and utilities increasingly move into the microgrid space, these smaller players merit continued support to be competitive and introduce further innovation. Additionally, there are still many community-based projects – for schools, local governments, and others – that have not yet reached commercial viability and hence require financial support to move forward.

1 "Microgrids: Commercial/Industrial, Community/Utility, Campus/Institutional, Military, Remote and Grid-Tied Utility Distribution and Direct Current Microgrids; Global Market Analysis and Forecast," Navigant Research, 4Q 2013.

# CHAPTER 1: California Case Studies

This chapter contains nine California case studies:

1. Inland Empire Utilities Agency, San Bernardino County
2. Mission Produce Facility, Oxnard
3. 2500 R Midtown Development, Sacramento
4. San Diego Zoo Solar-to-EV Project, San Diego
5. Alpha Omega Winery, Napa Valley
6. Stone Edge Farm, Sonoma
7. US Marine Corps Base Camp Pendleton, Oceanside
8. Thousand Oaks Real Estate Portfolio, Thousand Oaks
9. The Thacher School, Ojai

## Inland Empire Utilities Agency

### Project Background

The Inland Empire Utilities Agency (IEUA) is a regional wastewater utility and wholesale water supplier in southwestern San Bernardino County. Over the last several years, The IEUA has become a national leader in clean energy by building a series of clean energy distributed generation (DG) projects, including wind, solar, and a fuel cell. Recently, the agency decided to optimize its operations using a new system that could maximize economics while also providing revenue opportunities through grid services.

The existing generation assets were installed at different times and operated independently. The IEUA wanted to create an interconnected system, with the ability to island during outages, control resources and costs, and supply energy and services to the regional grid. This "grid interdependence" microgrid structure is emerging as a model that could enable the widespread deployment of DG and microgrid control technology, and enhance grid resiliency (Table 1). This model integrates economic optimization of distributed energy resources (DER) with mission critical reliability requirements. It can provide a more cost-effective approach to resiliency than traditional microgrids, which (typically) completely island all operational load within a given area and can thus be prohibitively expensive.

The IEUA primarily relies on on-site generation resources to serve its operations, with grid power from SCE as a supplementary resource. Battery Energy Storage Systems (BESS) are being installed at facilities as a load control technology allowing each facility to optimize using on-site generation (for example, increasing the capacity value of solar) while providing "warm standby" power in the event of a sudden reduction in on-site generation (such as fluctuations in solar output due to cloud cover or loss of bio-gas digester output). The BESS also allows the IEUA to provide grid services to Southern California Edison (SCE) such as load reduction for demand response programs, congestion management, and voltage support without disrupting operations or stressing equipment. Service fees paid from energy cost savings, in combination with revenue generation from enhanced grid service capabilities, support the costs of deploying the BESS and require no capital outlay by the IEUA.

**Table 1: Inland Empire Utilities Agency Project Overview**

| | |
|---|---|
| **Location** | San Bernardino County, California |
| **Utility** | Southern California Edison (SCE) |
| **Host Organization** | Inland Empire Utilities Agency (wastewater treatment facilities) |
| **Developer/Vendor(s)** | Advanced Microgrid Solutions, Anaergia, Foundation Wind Power, SunPower, Evergreen, FuelCell Energy, Tesla, EnerNOC |
| **Capacity** | 13.5 MW |
| **Installation Timeline** | Initial solar PV installation in 2008; wind turbine and fuel cell installation in 2010; energy storage installation between January 2016 and March 2017 |
| **Total Cost** | Installed under an Energy Management Services Agreement with no up-front cost; costs were converted from a capital expenditure to an operating expense |

Source: Navigant

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Advanced Microgrid Solutions (AMS) holds several contracts with SCE to develop energy storage projects to help replace traditional resources, and approached the IEUA as a host site to develop projects to provide demand response when dispatched by SCE or the grid operator. AMS viewed the IEUA as a viable site to provide dispatchable demand response resources to SCE. AMS and the IEUA partnered to install 3.65 MW of energy storage at six IEUA facilities – four treatment plants and two pump stations – under a 10-year Energy Management Services Agreement.

## Technical Characteristics

The DER listed below represent the portfolio across the six sites. Because special attention is given to Regional Water Recycling Plant No. 5 (RP-5), the DER at that site are also highlighted.

- 3.5 MW solar PV (including 0.99 MW at RP-5), SunPower
- 1 MW wind turbine, Foundation Wind Power

- 2.8 MW fuel cell, powered by locally produced digester gas, FuelCell Energy
- 3.65 MW Li-ion batteries (including 0.5 MW at RP-5), Tesla
- 2.5 MW of back-up diesel generators (including undisclosed capacity at RP-5)
- Load control and demand response software, AMS Armada platform

## Costs

The IEUA's existing DG was installed from 2008-2010 under power purchase agreements (PPAs) with no capital investment, which had a great appeal to a budget-constrained public agency. Similarly, the new energy storage project by AMS is under a 10-year Energy Management Services Agreement; AMS will install, operate, and maintain the energy storage systems at the six facilities, again with no capital investment by the IEUA.

AMS has not provided battery storage system costs. However, for energy storage projects in California qualifying under the Self-Generation Incentive Program (SGIP),[2] the total costs of applicant battery storage projects are between $802/kWh and $1,317/kWh, which provides a reasonable range for the IEUA's installation.[3]

## Business Model

### Financing

Under the 10-year Energy Management Services Agreement, the IEUA will pay AMS fixed monthly equipment fees and performance-based incentive awards ("bonus payments"). Performance is calculated based on net energy cost savings to the IEUA from the operation of the energy storage systems.

The fixed-fee portion of the contract between AMS and IEUA amounts to $65/kW per year. Performance-based incentive awards that accrue to AMS are triggered once net energy cost savings exceed $100/kW, with the savings above $100/kW split between AMS and the IEUA on a 50/50 basis. The contract also includes a savings assurance guarantee of $80/kW for the IEUA, which ensures an annual floor on savings of $55,000. It is estimated that savings could reach a threshold of $230,000 per year.

### Value Proposition

"We are proud of our investments in energy efficiency, renewable generation, and sustainable water management practices," said the IEUA's board president Terry Catlin, when this project was announced. "Energy storage is the key to maximizing the value of those investments, allowing us to use our resources more efficiently, reduce costs for our customers, and participate in building a more resilient electric grid for the whole region."[4]

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2 Self-Generation Incentive Program (SGIP): http://www.cpuc.ca.gov/sgip/, https://www.selfgenca.com/.

3 Data from 25 SGIP battery storage projects in 2017, included in the SGIP Weekly Statewide Report 5/22/2017, https://www.selfgenca.com/documents/reports/statewide_projects.

4 "Inland Empire Utilities Agency and Advanced Microgrid Solutions Launch First-of-its-Kind Energy Storage Project," PR Newswire, October 20, 2016 (http://www.prnewswire.com/news-releases/inland-empire-utilities-agency-and-advanced-microgrid-solutions-launch-first-of-its-kind-energy-storage-project-300348764.html).

The key value stream is demand savings through load control (Table 2). The addition of the battery and controller system provides not only traditional peak demand management capability, but in fact shapes the entire facility's load shape in response to operating needs and grid conditions. The value of storage is enhanced by its ability to support the multiple intermittent renewables present, including solar PV, wind, and the renewable waste-to-energy fuel cell with an intermittent fuel supply. Integrating energy storage with the IEUA's existing fleet of DG is a key way to improve performance under demand response agreements while also meeting SCE's call for energy storage and demand response resources to replace lost nuclear and natural gas peaking capacity in the region (Figure 1).

**Table 2: Inland Empire Utilities Agency Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | ● | | |
| Resiliency | | | ● | |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | | ● | | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | | | ● |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | ● | |
| Other: N/A | ● | | | |

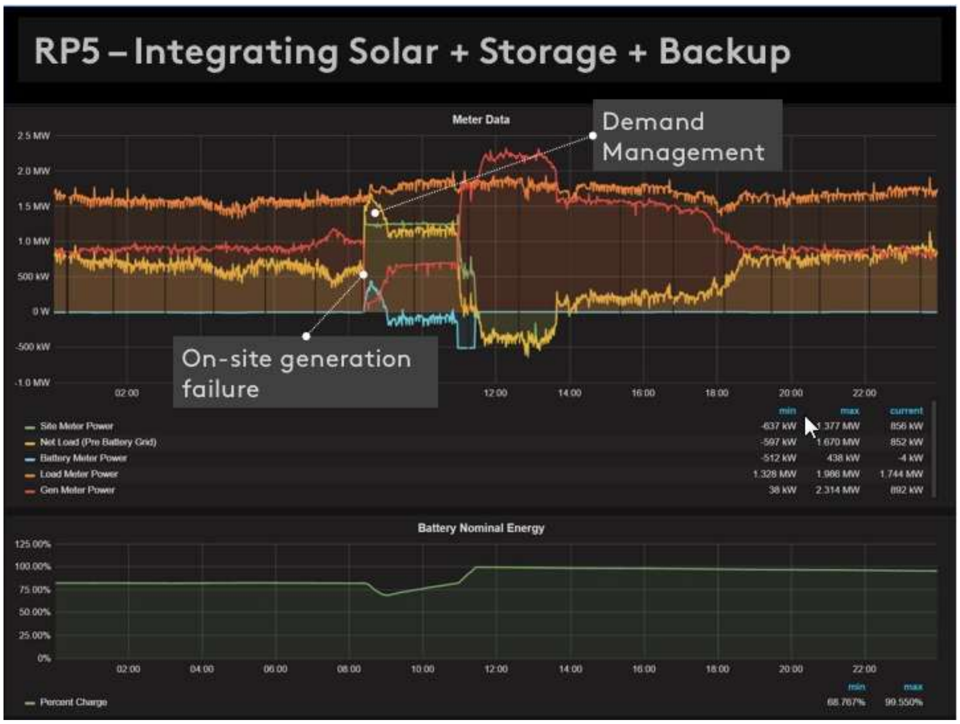
Source: Navigant

### Revenue Streams

Under an agreement with EnerNOC, a demand response provider, a total cumulative curtailment of 1.2 MW for all facilities enrolled in a SCE demand response program is valued at approximately $74,000 per year. Each facility enrolled in the program has a curtailment target, but the IEUA combined total of 1.2 MW is used to determine whether the IEUA will be compensated for its performance during each event. The IEUA's contract with EnerNOC contains a provision that requires the delivered load capacity to be at least 75% of the target reduction. If the delivered capacity falls below 75%, the IEUA does not receive any credit for reducing load during the demand response event. The IEUA strives to reduce its load to match 100% of the target reductions at each facility during every event; however, during the 2013-2014 fiscal year it reached the overall reduction goal in only three out of the six events. AMS estimates that the agency will be able to reduce imports from the SCE grid during peak periods of demand by 14%. In total, the agency is expected to reduce its overall energy spend by a minimum of 10%, primarily through demand savings.

AMS is participating in the Demand Response Auction Mechanism (DRAM), which is the California grid's market for aggregated DER participation.[5] The participation will allow AMS to evaluate bidding and scheduling strategies in California Independ System Operator (California ISO), and will result in capacity and energy payments for participating.

**Figure 1: Typical System Operation at Site RP-5 Within the IEUA Microgrid**




Source: Advanced Microgrid Solutions

## Lessons Learned

The addition of battery storage changed the regulatory status of the existing DG systems, and significant renegotiations were needed to satisfy the owner and utility. The IEUA was on a virtual net energy metering tariff available to public agencies, known as Renewable Energy Self-Generation – Bill Credit Transfer (RES-BCT), but the addition of the battery system added technical and regulatory challenges including a utility-driven requirement for a common disconnect for all onsite DER.

A conflict ensued between the Rule 21 tariff, an interconnection tariff, and the RES-BCT tariff, a tariff advantageous to the IEUA which encourages local governments and campuses to self-generate renewable electricity. AMS and the IEUA worked closely with SCE to revise the tariffs to ensure a seamless integration of battery energy storage with on-site renewable energy

5 "What to expect from California utilities' new aggregated demand response offerings," Utility Dive, January 26th, 2016, http://www.utilitydive.com/news/what-to-expect-from-california-utilities-new-aggregated-demand-response-of/412614/.

generation without injuring the value of the RES-BCT tariff for IEUA's ratepayers. While this presented an administrative burden to the IEUA's project, it helped pave the way for future similar projects at other agencies.

Under SCE's requirements for the RP-5 interconnection, AMS also had to provide a common electrical disconnect with the existing SunPower 0.99 MW solar PV installation at the site. AMS negotiated a tri-party solar agreement with SunPower and the IEUA, which kept both parties "whole" during the time the solar system was down to do the electrical work, in addition to outlining how the O&M requirements would be handled relative to the common disconnect.

One of the keys to scaling deployment of microgrid systems in California will be the development of a clear regulatory and technical path for the combined use of energy storage systems for load management and islanding during grid outages. Battery storage can be used to provide a soft transition to traditional backup generation for facilities that have the controls and switchgear in place to run in isochronous mode off-grid. By instantly picking up critical loads in the event of a grid outage (for a plant equipped for isochronous operation), batteries will be able to provide a "soft load transfer" until the facility's backup utility generators cycle up to come online and support critical loads in islanding mode during longer duration outages.

## Contacts & Sources

Interview with Susan Kennedy, Advanced Microgrid Solutions, May 16, 2017.

Peter Asmus, "Breaking New Ground While Exploring Value of Energy Storage in Southern California," Navigant Research Blog, June 7, 2017 (https://www.navigantresearch.com/blog/breaking-new-ground-while-exploring-value-of-energy-storage-in-southern-california).

# Mission Produce Facility

## Project Background

Mission Produce is one of the leading Hass avocado sellers in the world, with packing facilities in five countries and eight energy-intensive (refrigerated) ripening centers in the US and Canada. The company is focused on sustainability for its agricultural practices as well as its facilities. Mission Produce adheres to the Good Agricultural Practices (GAP) program and good harvesting practices (GHP) for avocados (Table 3). All packing and distribution facilities are built to be energy-efficient, with LED lighting and temperature controls.[6] The Oxnard packing facility is also host to a roof-top solar PV array, now part of the solar and energy storage microgrid.

Economic benefits via electricity bill savings was cited as the primary driver of the microgrid project for the Oxnard facility (Figure 2). The facility is also located in a frequent demand response area – sometimes experiencing two demand response events per day – and where workers are sometimes sent home due to the lack of power. Mission Produce was also

6 Mission Produce, https://www.worldsfinestavocados.com/.

interested in integrating its existing solar PV system, and to continue to expand sustainability efforts.

**Table 3: Mission Produce Facility Project Overview**

| | |
|---|---|
| **Location** | Oxnard, California |
| **Utility** | SCE |
| **Host Organization** | Mission Produce (avocado packing facility) |
| **Developer/Vendor(s)** | Powerit Solutions, UniEnergy Technologies (UET) |
| **Capacity** | 1.5 MW |
| **Installation Timeline** | Not yet installed; typically, 4-6 months from close of contract to completed installation for projects < 1 MW or up to 1-2 years for larger projects |
| **Total Cost** | Approximately $1 million for the flow batteries |

Source: Navigant

## Technical Characteristics

- 1 MW solar PV
- 0.5 MW / 2.0 MWh advanced vanadium redox flow batteries, UET Uni.System
- Cloud-based demand management software platform, Powerit Solutions Spara Hub

## Costs

The estimated total cost of the 0.5 MW / 2 MWh flow batteries is approximately $1 million. This does not include solar PV and other costs. UET's vanadium redox flow batteries are roughly at parity with 4-hour Li-ion batteries, which typically cost $430-$535/kWh (not counting extended warranties). However, flow batteries are less mature than Li-ion batteries, and expect to see a greater decrease in prices over time.

## Business Model

### Financing

The project was developed under a service contract between Mission Produce and UET. UET owns the battery system and receives quarterly service payments from Mission Produce. As the project developer and owner, UET is financing the installation on its own balance sheet as a temporary solution but is also identifying project financiers as a longer-term approach for this and other projects. UET cited Green Charge Networks as a successful example of similar project

**Figure 2: Mission Produce Avocado Packing Facility, Oxnard, California**

Source: Valerie Mitchell

## Costs

The estimated total cost of the 0.5 MW / 2 MWh flow batteries is approximately $1 million. This does not include solar PV and other costs. UET's vanadium redox flow batteries are roughly at parity with 4-hour Li-ion batteries, which typically cost $430-$535/kWh (not counting extended warranties). However, flow batteries are less mature than Li-ion batteries, and expect to see a greater decrease in prices over time.

## Business Model

### Financing

The project was developed under a service contract between Mission Produce and UET. UET owns the battery system and receives quarterly service payments from Mission Produce. As the project developer and owner, UET is financing the installation on its own balance sheet as a temporary solution but is also identifying project financiers as a longer-term approach for this and other projects. UET cited Green Charge Networks as a successful example of similar project financing, having funded its no-money-down energy storage projects through $50 million in non-recourse project finance debt to projects in development.[7]

The project will benefit from funding through the California SGIP, which provides incentives to support existing, new, and emerging distributed energy resources.[8] The current SGIP has allocated 80% of funds to energy storage technologies, and re-opened to energy storage applicants on May 1, 2017.[9] Large-scale energy storage projects will receive $0.40/Wh and total rebates are limited to 40% of the project cost. UET collects the SGIP funds, and is using the award for 30% of the total project cost.

### Value Proposition

The primary value stream is demand charge savings and, to a lesser extent, energy arbitrage. Resiliency and sustainable branding benefits are secondary value streams, although the latter is difficult to quantify (Table 4). Mission Produce has been using Powerit's demand management software at its facilities since 2008, and has saved more than $2 million in electricity costs across its portfolio.

**Table 4: Mission Produce Facility Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | ● | | |
| Resiliency | | | ● | |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | | ● | | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | | | ● |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | ● | | | |
| Other: N/A | ● | | | |

Source: Navigant

7 "Green Charge obtains $20 million in project finance debt from Ares Capital," Stratton Report, January 14, 2016 http://strattonreport.com/news/green-charge-obtains-20-million-in-project-finance-debt-from-ares-capital/.

8 Self-Generation Incentive Program, http://www.cpuc.ca.gov/sgip/.

9 Self-Generation Incentive Program Online Application Database, https://www.selfgenca.com/.

**Revenue Streams**

Market participation in demand response was included as an additional revenue option in the proforma, although the host site is "wary" of demand response from previous experience with more primitive forms of demand response programs cutting into daily operations due to complete curtailments. Despite prior notice about a demand response event, participation would be difficult unless a more sophisticated technology was deployed that was less intrusive to ongoing commercial activities.

### Lessons Learned

UET had originally partnered with Powerit, the provider of the building controls technology (Spara Hub), to complete the project. However, Powerit was acquired by Customized Energy Solutions in early 2016,[10] and the deal to fully integrate UET's new storage system with the existing building controls fell through. For projects with multiple different vendors partnering together to deliver a microgrid solution, it is important to have more than one option for each component. Structuring of contracts should perhaps include the flexibility to switch out vendors as projects evolve, especially when it comes to controls solutions.

### Contacts & Sources

Interview with Russ Weed, UniEnergy Technologies, May 10, 2017.

"UniEnergy, Powerit partner on energy solution for California's Mission Produce," PV Magazine, September 21, 2015 (https://www.pv-magazine.com/2015/09/21/unienergy-powerit-partner-on-energy-solution-for-californias-mission-produce_100021184/#axzz3mTLmVIFR).

## 2500 R Midtown Development

### Project Background

SMUD is the sixth largest municipal utility in the nation, and has been looking for ways to address the high penetration of solar PV on its distribution grid. SMUD partnered with Sunverge Energy to demonstrate integrated solar PV, energy storage, and demand response solutions with benefits for the utility and its customers. SMUD and Sunverge also partnered with Pacific Housing – a nonprofit public benefit corporation providing affordable housing in California – to demonstrate solar plus storage systems in a net zero energy (ZNE) community, to use as a model for California residential zero-net energy (ZNE requirements.[11] The project site, the 2500 R Midtown community development in Sacramento, is the first ZNE community development on the west coast (Table 5).

10 "CES Acquires Powerit – Enhancing Demand Response Services," Customized Energy Solutions, January 21, 2016, http://ces-ltd.com/ces-acquires-powerit-enhancing-demand-response-services/.

11 California's goal is for all new residential construction to be zero net energy by 2020, http://www.californiaznehomes.com/.

The 34 single-family homes range from 1,300 square feet to 1,789 square feet and are designed to be extremely energy-efficient in addition to the rooftop solar PV and Li-ion battery system. The homes also demonstrate the value of smart devices integrated with the solar plus storage system. After construction was completed in 2013, 2500 R Midtown homes sold out in less than one year.

**Table 5: 2500 R Midtown Development Project Overview**

| | |
|---|---|
| **Location** | Sacramento, California |
| **Utility** | Sacramento Municipal Utility District (SMUD) |
| **Host Organization** | Pacific Housing (single-family home affordable housing development) |
| **Developer/Vendor(s)** | Sunverge Energy, BPL Global, Saft, Schneider Electric, Solar World, Granite Bay Energy |
| **Capacity** | 280.5 kW |
| **Installation Timeline** | Project planning in 2010; construction in 2013; residents moved into homes in early 2014 |
| **Total Cost** | $850,000; $25,000 per house for solar plus storage |

Source: Navigant

## Technical Characteristics

- 2.25 kW solar PV (each residence)
- 6 kW / 11.64 kWh Li-ion batteries (each residence)
- Solar Integration System (SIS) hardware and software, Sunverge
- Smart home devices including plug load controllers and programmable thermostats

## Costs

$25,000 per house, or $850,000 in total for the energy infrastructure components. The total project cost for the development of the entire housing project is estimated to be approximately $8 million.

## Business Model

### Financing

Initially, the 2500 R Midtown development did not have any government funding. During the project, however, SMUD contributed $450,000 of its US Department of Energy ARRA funding (of which $200,000 was part of the Solar SMART program), which lasted through the end of 2014, and PG&E awarded $350,000 in California SGIP incentives.[12] According to Pacific Housing, these funds represent under 10% of the total cost of the residential real estate project, with the

12 PG&E provides natural gas service to the housing development; each home has a gas stove, gas-powered water heaters, and gas-fired heat pumps.

balance coming from private capital leveraging special financial structures that take advantage of Pacific Housing non-profit status.

### Value Proposition

The project demonstrates the potential of solar plus storage for ZNE communities. For homeowners, there are immediate benefits in electricity savings through usage reduction and time-based dynamic rates, and power outage protection. Each house fitted with a solar PV system and an integrated battery system stores solar energy generated during the day for use in the early evening during peak electricity hours. Residents with energy storage in addition to solar PV achieved 33% greater savings than residents with only solar PV.

For SMUD, the value was as a research, development, and demonstration project for the future of distributed generation and energy storage in its service territory (Table6). SMUD began collecting data when the first buyers moved into their units in 2014. SMUD is also piloting Critical Peak Pricing (CPP), investigating how to maximize the value of renewable energy using storage, and providing demand reduction. Customers on dynamic time-of-use rates with CPP saved on average more than $50 per month on electricity bills during the test period.

For the real estate developer, Pacific Housing, the value of the project was to market desirable homes using the latest technology – while keeping costs down. This helped differentiate Pacific Housing from the competition, especially in 2011 while housing markets were still recovering. From the success of this project, Pacific Housing has investigated how to replicate this type of integration of new energy technologies into new housing by rolling the costs of energy upgrades into new home mortgages in the Sacramento area. However, Pacific Housing has also run into several barriers that pertain to low-income community energy usage patterns and an increase in construction costs in today's housing market.

### Revenue Streams

The development used an innovative approach by building the additional cost of the solar plus storage system into the cost of the home within its mortgage structure. Home buyers could also take after-tax benefits on the solar and storage equipment. Sunverge is also conducting demand response applications by controlling the programmable thermostats inside homes. During demand response events, 100% of target stored capacity (60% of nameplate capacity) has been dispatched.

To illustrate how these homes managed to also serve as a small Virtual Power Plant (VPP), consider data from a home enrolled in the SMUD program (Figure 3). The demand response services provided back to the grid (in green) during the critical utility peak periods (the grey area between 16 and 19 hours, or 4 and 7 PM).

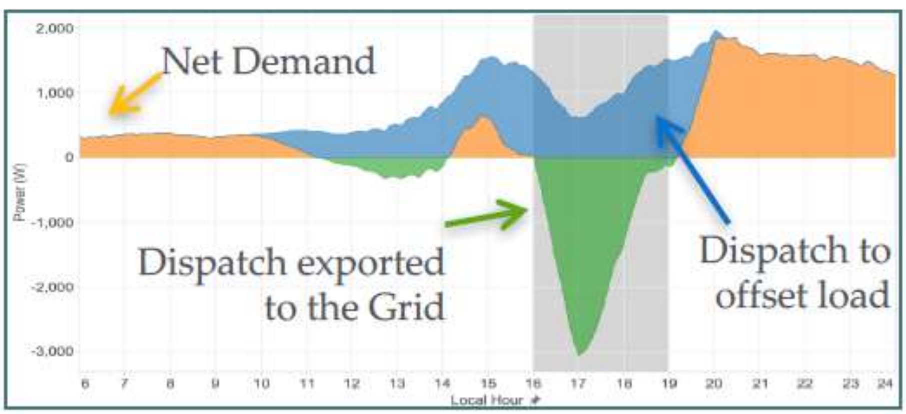
**Table 6: 2500 R Midtown Development Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| **Reliability** | | | ● | |
| Resiliency | | | ● | |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | ● | | | |
| Provision of energy and capacity services | | ● | | |
| Provision of ancillary services | | ● | | |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | | ● | | |
| Linkage to Virtual Power Plant | | | ● | |
| Other: Coordination with smart home devices | | | ● | |

**Transactive energy revenue is not anticipated. SMUD is not prepared for energy & capacity and ancillary services, but may be in the future.**

Source: Navigant

**Figure 3: Sunverge System Demand Response Performance for SMUD**




Source: Sunverge Energy

Though not technically a revenue stream, the homeowners also benefit from resiliency services by having the ability to island in the event of a power outage, both individually (if the home includes a battery) and collectively, with the entire development, as a microgrid. During grid outages, Sunverge SIS platforms are available to dispatch up to 100% of reserve storage capacity and satisfy critical loads.

## Lessons Learned

One challenge was with the permitting process. It was difficult to get the Sacramento Fire Department on board for siting the stationary energy storage systems in homes.

The partners see additional challenges in the future with the question of ownership in the "Energy Cloud" – does the homeowner or developer own the DER system?

Overall, the partners spent a lot of time and resources on the development as a demonstration project. After the success of the project (the 2500 R Midtown development sold out quickly), the partners had been planning similar communities elsewhere in the Sacramento area using the lessons from 2500 R Midtown, but barriers still exist, especially in depressed areas where high unemployment rates impact the viability of pairing solar with energy storage since daily electricity consumption is higher in households with unemployed citizens. (Unemployed people consume the solar generated electricity throughout the day, which means less can be stored for use later after the sun goes down.) This may still be a replicable approach to developing green affordable housing in regions targeting younger homeowners more interested in green and IT technologies, especially as prices for solar PV and energy storage devices continue to decline, while the capabilities and functionality offered up by new software controls increase over time.

### Contacts & Sources

Interview with Ken Munson, Sunverge, May 18, 2017.

"2500 R Street Community Development," Clean Energy Group (http://www.cleanegroup.org/ceg-projects/resilient-power-project/featured-installations/2500-r-street/).

Mark Hand, "Calif. developers spark home-buyer interest with rooftop solar, energy storage," SNL (https://www.snl.com/InteractiveX/Article.aspx?cdid=A-28989356-9767).

Peter Asmus and Mackinnon Lawrence, "Making Sense of New Public Power DER Business Models: The Business Case for Energy Storage," Navigant Research, 2Q 2016.

## San Diego Zoo Solar-to-EV Project

### Project Background

The San Diego Zoo microgrid is officially known as the Solar-to-EV project, a joint initiative between Smart City San Diego and the San Diego Zoo (Table 7). Smart City San Diego is a public-private collaboration that includes the City of San Diego, SDG&E, GE, CleanTECH San Diego, and the University of California, San Diego. The objective of the collaboration is to "improve the region's energy independence, to empower consumers to use electric vehicles, to reduce greenhouse gas emissions, and to encourage economic growth."[13] The Solar-to-EV project includes five solar-to-electric vehicle (EV) charging stations powered by a 90-kW solar array over 10 parking lot canopies.

13 "Smart City," The City of San Diego, https://www.sandiego.gov/sustainability/smart-city.

**Table 7: San Diego Zoo Solar-to-EV Project Overview**

| | |
|---|---|
| **Location** | San Diego, California |
| **Utility** | San Diego Gas & Electric (SDG&E) |
| **Host Organization** | Smart City San Diego / San Diego Zoo |
| **Developer/Vendor(s)** | SDG&E, Independent Energy Solutions, Kokam, Princeton Power Systems, Kyocera, ECOtality |
| **Capacity** | 190 kW |
| **Installation Timeline** | 1 year (2012) including a 6-month development period |
| **Total Cost** | $1,000,000 |

Source: Navigant

The system includes a Li-ion polymer battery system to store solar energy and charge the EVs after sunset. The energy storage system offsets power demands on the grid, and when batteries are full, the excess solar energy is sent to the grid to improve reliability. Because the system's inverters are bi-directional, they can also source energy from the grid during off peak hours to charge the batteries. With the energy storage system, the charging infrastructure can island as a unit in the event of an outage.

The Solar-to-EV project provides essential charging infrastructure, showcases San Diego's commitment to clean energy, and helps improve San Diego's air quality. Independent Energy Solutions served as the lead developer, and brought in San Diego-based architects, engineers, and artists for locally-sourced design and construction (Figure 4). The system is owned and operated by SDG&E (except for the charging stations), with benefits to San Diego ratepayers and to the electric grid.

**Figure 4: Solar Carport and EV Charging at San Diego Zoo**

Source: GreenTech Advocates

## Technical Characteristics

- 90 kW solar PV parking array (420 x 245-watt panels) on 10 stand-alone canopies, Kyocera
- 100 kW / kWh Li-ion polymer batteries (2 x 50 kWh battery banks), Kokam
- Five Level 2 EV charging stations (including one ADA compliant charger), ECOtality Blink
- Bi-directional inverters (with peak shaving, demand response, islanding mode, and other capabilities), Princeton Power Systems

## Costs

The total project cost was approximately $1,000,000 in 2012.

## Business Model

### Financing

The project was financed by SDG&E through ratepayer funds, as a way for the utility to test and validate distributed generation, EV chargers, dispatchable energy storage, and islanding parts of the electrical network to improve stability during transient network conditions. It is owned and managed by SDG&E's Sustainable Communities Program.

### Value Proposition

The value proposition for the community is aligned with the goals of Smart City San Diego providing public EV charging, reduces air pollution and greenhouse gas emissions, supports local businesses (estimated to create 35 jobs during construction), and highlights the City's clean energy leadership. The project is estimated to reduce carbon dioxide emissions by 189,216 pounds, which is equivalent to planting 2,788 trees that grow for 10 years or removing 21 cars from the road each year.

For the utility and its ratepayers, the primary value of the Solar-to-EV project is that it is a first-of-its-kind test bed to investigate direct utility control for smart microgrids of the future (Table 8). It integrates energy production, resiliency for charging infrastructure, peak demand mitigation, and distributed generation with centralized controls.

### Revenue Streams

The San Diego Zoo receives an annual license fee for hosting the system from SDG&E.

## Lessons Learned

The Solar-to-EV project demonstrates successful public-private collaboration, novel DER integration innovation by linking solar PV to EV charging, and linkages to the Smart City concept. Many other investor-owned utilities – including Baltimore Gas & Electric, Commonwealth Edison and PEPCO – have attempted to rate-base microgrids, but such proposals were rejected by state regulators and/or legislators.

This project offers an example where the linkage to the goals of San Diego, and the concept of a "smart city," were clearly aligned with the microgrid. Perhaps its linkage to clean transportation was also key, given that 40% of the carbon footprint of California comes from the transportation sector. The smart city concept is broader than electricity. In the future, microgrids can support the development of smart cities by integrating diverse DERs, including EVs, into the microgrid infrastructure platform.

**Table 8: San Diego Zoo Solar-to-EV Project Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | | | | ● |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | | | ● |
| Reduction of carbon footprint | | | | ● |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | | ● |
| Other: EV charging infrastructure | | | ● | |

Source: GreenTech Advocates

## Contacts & Sources


Correspondence with Neil Bradshaw, Princeton Power Systems, June 9, 2017.

Steven Castle, “Solar PV to EV at San Diego Zoo,” GreenTech Advocates, December 13, 2012 (http://greentechadvocates.com/2012/12/13/solar-pv-to-ev-at-san-diego-zoo/).

“Smart City San Diego & San Diego Zoo Unveil Solar to Electric Vehicle Charging Project,” SDG&E, September 5, 2012 (https://www.sdge.com/newsroom/press-releases/2012-09-05/smart-city-san-diego-san-diego-zoo-unveil-solar-electric-vehicle).

Solar-to-EV Project FAQ, SmartCity San Diego (https://www.sdge.com/sites/default/files/newsroom/factsheets/Smart%20City%20San%20Diego%20Solar%20to%20EV%20Zoo%20FAQ.DOCX).

# Alpha Omega Winery

## Project Background

The Alpha Omega winery is a family-owned Napa Green-certified winery founded in 2006.[14] The winery's strong commitment to sustainability led it to install enough solar PV to supply nearly 100% of its energy needs on five parking lot shade structures, fully integrated with a back-up battery system (Table 9 and Figure 5). Alpha Omega is also planning to add EV charging stations. In addition to environmental benefits and related green marketing, the primary project driver was economic. The microgrid system has already reduced the average monthly electricity bill from $15,000 to $1,000. Renewable energy developer Blue Sky Utility led the project, using BPi as the California-based EPC contractor, and Aquion Energy and Princeton Power Systems as the battery storage and inverter suppliers.

**Table 9: Alpha Omega Winery Project Overview**

| | |
|---|---|
| **Location** | Rutherford Bench, Napa Valley, CA |
| **Utility** | Pacific Gas and Electric Company (PG&E) |
| **Host Organization** | Alpha Omega winery |
| **Developer/Vendor(s)** | Blue Sky Utility, Aquion Energy, Princeton Power Systems, BPi |
| **Capacity** | 500 kW |
| **Installation Timeline** | 2015-2016; including 6 months for development, 3 months for installation, and 3 months for testing & commissioning |
| **Total Cost** | $1,100,000 |

## Source: Navigant Technical Characteristics

- 400 kW solar PV
- 580 kWh / 100 kW Cradle to Cradle Certified™ saltwater energy storage batteries,[15] Aquion Energy[16]
- 100 kW bi-directional inverters (with peak shaving, demand response, islanding mode, and other capabilities), Princeton Power Systems
- EV charging stations (future)

14 Napa Green is a comprehensive environmental certification program for vineyards and wineries in the Napa Valley. https://napagreen.org.

15 Cradle to Cradle Certified™ products are assessed across five quality categories: material health, material reutilization, renewable energy and carbon management, water stewardship, and social fairness. Product assessments are performed by a qualified independent organization trained by the Cradle to Cradle Products Innovation Institute. http://www.c2ccertified.org.

16 Aquion batteries are optimal at low power, so the inverters are sized at 100 kW.

**Figure 5: Aerial View of Alpha Omega Winery**

Source: Photo by Bob McClenahan

## Costs

The total project cost was $1,100,000. Princeton Power Systems also reported that in 4Q 2016, bid results for a different 300 kW PV / 1,142 kWh microgrid varied from $1,500,000 to $1,900,000. Generally, microgrid costs are decreasing significantly, driven by battery pricing, solar PV pricing, and the rise of more modular and pre-engineered technologies which reduce the investment in customized engineering.

## Business Model

### Financing

The microgrid is on a 7-year lease with the winery (where lease costs are less than the utility bill costs). The lease was negotiated using the attributable tax benefits. After the 7-year lease is up, the lease will be retired, and the system will be fully owned by Alpha Omega. The lease structure was compiled by the project developer, Blue Sky Utility. The project also received approximately $180,000 in SGIP funding.

### Value Proposition

The microgrid system has already reduced the average monthly electricity bill dramatically, from $15,000 to $1,000 per month, using solar PV production and demand management with energy storage for energy and demand charge reductions. The backup power aspect of the project is also important for the winery's operations.

The environmental value of the project is quantified as a reduction of 960,750 pounds of carbon dioxide per year, based on the production of 640,500 kWh of solar energy per year (estimated to be equivalent to planting 2,402 trees) (Table 10).

**Table 10: Alpha Omega Winery Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | ● | |
| Resiliency | | | ● | |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | ● | | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | ● | |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | ● | | | |
| Other: EV charging infrastructure | | | ● | |

Source: Navigant

### Revenue Streams

Ongoing revenue streams for the winery will be demand response participation, savings from time-of-use (TOU) rates with solar PV production and energy storage, and the remaining 50% SGIP allowance for five years.

## Lessons Learned

A key lesson learned from this microgrid project is with the right mix of resources and control strategies, a microgrid can be developed for a winery – and by inference other C&I customers – that saves money, reduces carbon footprints and helps meet sustainability and corporate social responsibility targets. Though this project sees the potential to offer DR services to the grid, the prime value proposition is cost effective implementation of energy infrastructure upgrades that take advantage of declining costs of key microgrid enabling technologies – such as solar PV and advanced batteries – while relying on controls embedded in smart inverters, thereby reducing overall system costs. Matching the appropriate controls schemes to project scale and purpose can create microgrids today that not only pencil out, with the help of existing state incentives, but providing ongoing value in terms of resiliency and sustainable energy supplies.

## Contacts & Sources


Correspondence with Neil Bradshaw, Princeton Power Systems, June 9, 2017.

Joseph Bebon, "Napa Valley Winery Installs Solar+Storage Microgrid," Solar Industry Magazine, October 21, 2016 (http://solarindustrymag.com/napa-valley-winery-installs-solarstorage-microgrid).

Elizabeth Pond, "Alpha Omega Winery Surges Ahead with New Solar and Energy Storage Microgrid," Aquion Energy, October 20, 2016 (http://blog.aquionenergy.com/alpha-omega-winery-surges-ahead-with-new-solar-and-energy-storage-microgrid).

# Stone Edge Farm

## Project Background

Stone Edge Farm Estate Vineyards and Winery is a family-owned establishment, producing wine and other products in Sonoma, California since 2004. The McQuown family (the owners) developed Stone Edge Farm as a self-sustaining island that can supply a wide variety of products to the outside world: not just wine and organic fruits, but also energy products including electricity, hydrogen, and biochar.

Wooster Energy Engineering serves as the general contractor and has assembled a wide variety of suppliers and vendors for the project. No less than 10 different DER technologies are employed, most of which can serve as both a load and a generator (Table 11). The guiding principle in developing the microgrid is that all technology must reduce the carbon footprint of the farm.

**Table 11: Stone Edge Project Overview**

| | |
|---|---|
| **Location** | Sonoma, California |
| **Utility** | PG&E |
| **Host Organization** | Stone Edge Farm |
| **Developer/Vendor(s)** | Aquion Energy Inc., DC Systems, Energy Storage Systems Inc., Millennium Reign Energy LLC, PlugPower, SimpliPhi Power, Sony, Tesla Inc., Wooster Energy Engineering |
| **Capacity** | 1.185 MW |
| **Installation Timeline** | July 2013 – June 2018; five years of progressive equipment installations |
| **Total Cost** | Confidential |

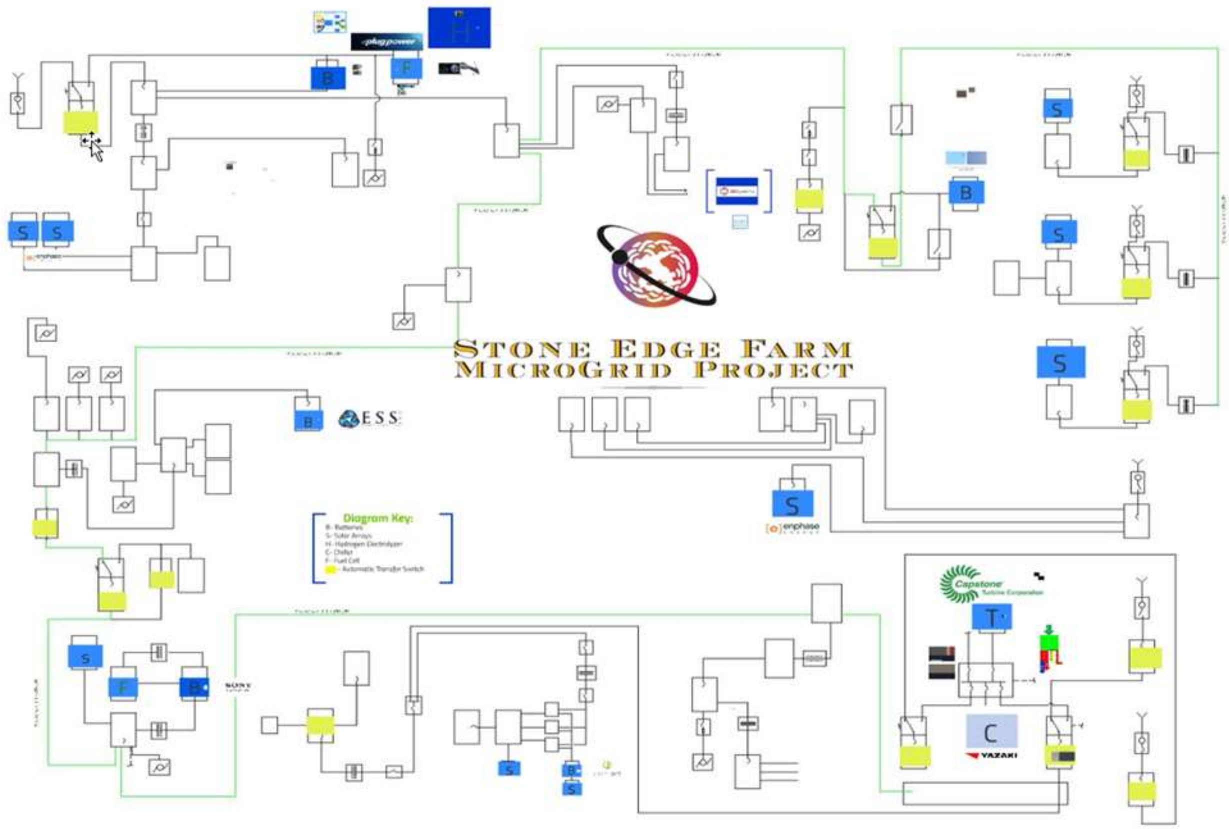
Source: Navigant

## Technical Characteristics

The microgrid consists of a wide variety of DER spread across 6.5 hectares. Most of the DER are positioned on four key nodes of the system (Figure 6).

- 368 kW solar PV with microinverters (+300 kW planned PV), Enphase
- 65 kW natural gas microturbine in trigeneration configuration (combined heat, power, and cooling), Capstone
- 28 kW Fuel Cell Hive, PlugPower ReliOn
- 324 kW battery storage including Aquion Sodium Ion, ESS Iron Flow Cell, Redflow Zinc Bromide Flow Cell, SimpliPhi Lithium Ferro Phosphate, Sony Lithium Iron Phosphate, and Tesla Lithium Cobalt Ion
- 400 kW Electrolyzer, Millennium Reign
- Microgrid management system (with grid interactive ability), DC-SYSTEMS

**Figure 6: Stone Edge Farm Microgrid Line Diagram**




Source: Wooster Energy Engineering

## Costs

The project costs have not been made public. Mac McQuown, the co-owner of Stone Edge Farm, said "this is an experiment so cost is irrelevant and does not matter." The McQuown family is wealthy and saw this project as an opportunity to showcase sustainable energy within an aesthetic showcase for a family farm and winery. Mr. McQuown created the first stock index fund at Wells Fargo in 1964, was successful in many entrepreneurial ventures and co-founded many pioneering wineries, including the Chalone Wine Group and Carmenet Winery.

## Business Model

### Financing

The project was privately financed by the facility owners.

### Value Proposition

The primary directive of the microgrid is to reduce the carbon footprint of the Stone Edge Farm property, while an important secondary directive is to establish a degree of energy independence. The owners intend to see how far below zero an urban farm can reduce greenhouse gas emissions.

Since the microgrid is typically islanded and generates its own power, electric bill energy costs are extremely limited even as the farm benefits from extremely high uptime. The microgrid also generates value through the energy products outlined in the "Revenue Stream" section (Table 12).

**Table 12: Stone Edge Farm Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | ● | | |
| Future transactive energy revenue | | ● | | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | ● | | |
| Reduction of carbon footprint | | | | ● |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | | | | ● |
| Linkage to Virtual Power Plant | | ● | | |
| Other: Fuel cell EV charging infrastructure | | | | ● |

Source: Navigant

### Revenue Streams

Stone Edge Farm began with the goals of emissions reductions and resiliency; however, a variety of quantifiable revenue streams have arisen from creative use of the onsite DER. The evolution of these revenue streams over time (in chronological order) tells the story of this unique microgrid:

- **Demand Charge Management.** First under a simplified NEM tariff, and later through a Rule 21 interconnection at point of common coupling, Stone Edge Farm cut demand charges significantly.
- **CCA Export Models and Wholesale Market Participation**. As the microgrid grew to have significant overproduction capacity, novel models were pursued. Negotiations ensued with Sonoma Clean Power, a community choice aggregator, for sales of excess power (though as the local wires company, PG&E still held negotiating power). CAISO market participation presents high hurdles for small producers including an 11-month minimum interconnection timeline, and requirements for special controls and monitoring including a local weather station. The microgrid's stakeholders aim to lower these barriers by encouraging both a simpler certification process and improved aggregation ability for VPPs.
- **Hydrogen and other Physical Exports**. As an intentionally overdesigned system, the microgrid produces excess power - much like a future high-renewable-penetration grid

might. Thanks in part to high hurdles to electricity exports, physical paths are being opened for exports like hydrogen. Stone Edge Farm has an electrolyzer that can produce up to 12 kg per day, enough to fuel several fuel cell EVs. This represents a profitable "sink" for excess renewable power, as California's hydrogen economy heats up and potentially experiences a hydrogen shortfall by 2020.[17] Additional revenue streams may soon be realized from a new engine prototype that is fed waste biomass and can produce electricity, fertilizer, and biochar, which may have growing market value as carbon sequestration measures are sought.

### Lessons Learned

As a prototypical microgrid, one of the farm's key "products" is learning, and a number of lessons have come forth. They include:

- Interconnection requirements can be prohibitively expensive to meet, at both the utility and ISO levels. Continued active engagement among all interested parties can help streamline those processes and encourage the aggregation of DER.
- Where electrical interconnections are too burdensome, other energy exports beyond electricity are becoming viable. These include hydrogen, biochar, and thermal energy.
- Revenue streams associated with microgrids are undergoing continual change (as explained in the previous section) and DER with more flexibility are more likely to capture those opportunities.

### Contacts & Sources

Correspondence with Craig Wooster, Wooster Energy Engineering, June 9, 2017.

Stone Edge Farm Microgrid Technical Overview, March 2017 (http://sefmicrogrid.com/wp-content/uploads/2017/03/SEFMG-Tech-Overview.pdf).

## US Marine Corps Base Camp Pendleton

### Project Background

The United States military is actively pursuing microgrids as part of a wide-reaching effort to achieve energy security and minimize risks for critical infrastructure by increasing resilience. In 2015, the Marine Corps Base Camp Pendleton contracted with CleanSpark to install a solar + storage microgrid at one of its facilities in Southern California, as part of a larger Military Construction (MILCON) procurement effort (Table 13). The project currently continues to move forward with a Design-Build contract, under which CleanSpark is responsible for design, engineering, system optimization, and deployment of the microgrid.

17 Joint Agency Staff Report on Assembly Bill 8: 2016 Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California, California Energy Commission and California Air Resources Board, January 2017. https://cafcp.org/blog/cec-and-arb-release-joint-staff-report-2017.

**Table 13: US Marine Corps Base Camp Pendleton Project Overview**

| | |
|---|---|
| **Location** | **Oceanside, California** |
| **Utility** | SDG&E |
| **Host Organization** | US Marine Corps Camp Pendleton |
| **Developer/Vendor(s)** | CleanSpark, others not yet disclosed |
| **Capacity** | 202 kW |
| **Installation Timeline** | Begun in 2015; project design review in progress |
| **Total Cost** | $1,035,000 |

Source: Navigant

Although the project was initiated in 2015, the project design is only now under review. CleanSpark has experience with the defense community and government contracting process, so approximately 1.5 years of procurement disputes and other complications was no surprise. In fact, CleanSpark has previously completed the advanced 'FractalGrid' demonstration at Camp Pendleton.[18]

## Technical Characteristics

- 152 kW solar PV
- 50 kW / 400 kWh energy storage
- Connection to a larger 3.2 MW system with backup diesel generator sets
- Parallel grid connection to export excess solar generation
- "Blinkless" transition to islanding mode

## Costs

The total cost of the project is $1,035,000. The largest component of this is the microgrid installation at $800,000, with additional costs for project development ($160,000) and testing & commissioning ($75,000).

## Business Model

### Financing

The project is funded through government MILCON appropriations. There was no specific appropriation for the microgrid, but it was proposed and accepted as a "betterment" through the MILCON Design-Build procurement method under the prime contractor. There is precedent for microgrids being funded under specialized MILCON procurements directly, but CleanSpark expects the "betterment" approach to become more common for military microgrids, as many projects already include DER and can be expanded to include intelligent controls and energy storage.

18 Camp Pendleton FractalGrid Demonstration, CleanSpark, http://microgridmedia.com/grid-edge-marine-corps-base-camp-pendletons-fractal-microgrid/.

### Value Proposition

Energy security/resilience is the primary driver for the Camp Pendleton microgrid (Table 14). To win funding, the project had to qualify as Design-Build Best Value Procurement, follow government life-cycle cost analysis guidelines, and determine the Cost of Unserved Energy for mission critical loads.[19] The microgrid will serve a subset of loads at the critical facility, in part to demonstrate the high level of critical power security it can provide. If results are favorable, the military may further rely on microgrids as uninterruptible power supply (UPS) systems.

Since the facility's loads are large, it has direct agreements with local utilities, including rates with no demand charges. Additionally, it is a government facility that cannot take advantage of the federal ITC. Consequently, it was more of a challenge to make the microgrid cost effective. The payback period is estimated to be 9-11 years. However, the lifetime of the system should be well over 20 years.

### Revenue Streams

The microgrid installation will help reduce long-term operating expenses at Camp Pendleton for the government; however, economic revenue streams will not be optimized because energy security is the primary project driver.

## Lessons Learned

The primary lessons learned from the project relate to the lengthy government contracting process required to develop the project and the effective communication/education process with all stakeholders. CleanSpark, as the microgrid developer, engineer, integrator, and operator, partnered with a prime contractor to navigate the process—and had existing government contracting experience itself. Although the numerous challenges and delays were not surprising in this situation, they could be very off-putting to an inexperienced vendor.

**Table 14: US Marine Corps Base Camp Pendleton Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | ● | | | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | ● | | |
| Renewable energy integration | | | ● | |

19 The Cost of Unserved Energy is used to provide an economic value to the cost of electricity interruptions to electricity customers and the economy as a whole." Ulrich Minnaar, "Cost of Unserved Energy," SAIEE WattNow Magazine, October 2015, https://www.researchgate.net/publication/292617097_Cost_of_Unserved_Energy.

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | ● | | | |
| Other: N/A | ● | | | |

Source: Navigant

Under the Design-Build structure, CleanSpark was also able to engineer a highly optimized microgrid system for the facility, including an extensive analysis of 53 energy storage vendors. Efficiency, cost, O&M needs, and other factors were all important considerations in this process, as no single energy storage technology fits every situation. CleanSpark employed its proprietary Dynamic Network Analysis (DNA) tool to optimize the implementation for maximum lifetime savings while still meeting the energy surety requirements. CleanSpark found that communicating the overall costs and benefits of the microgrid project to stakeholders was straightforward; however, educating the government client and prime contractor about the intricacies of the different energy storage technologies was more of a challenge.

### Contacts & Sources

Interview with Bryan Huber, COO of CleanSpark, June 23, 2017.

## Thousand Oaks Real Estate Portfolio

### Project Background

CleanSpark is currently developing a microgrid pilot project for a confidential commercial client with a large portfolio of properties (Table 15). The client is very progressive when it comes to clean energy solutions, having tried various clean technologies, and won multiple awards. However, it did not yet have a comprehensive solution linking together its discrete systems. The microgrid pilot project will ensure the client's systems are working in coordination and that no value streams are "left on the table."

**Table 15: Thousand Oaks Real Estate Portfolio Project Overview**

| **Location** | **Thousand Oaks, California** |
|---|---|
| **Utility** | SCE |
| **Host Organization** | Confidential |
| **Developer/Vendor(s)** | CleanSpark, Jacobs Engineering, others not yet disclosed |
| **Capacity** | 2.4 MW |
| **Installation Timeline** | In progress, expected operation in December 2017 |
| **Total Cost** | $7,900,000 |

Source: Navigant

CleanSpark was contracted to complete its PowerPlan[20] service for the customer's entire portfolio, including a historical energy consumption and cost analysis, technology selection, system sizing and optimization, engineering estimates, and business cases. The pilot program starts with five of the company's 90 properties, which were ranked by priorities.

## Technical Characteristics

- 1.96 MW new rooftop and carport solar PV
- 1.70 MW legacy solar PV
- 440 kW / 900 kWh new energy storage: hybrid configuration of li-ion and flow batteries
- Energy Operating Platform for Microgrid Control and Market Participation, CleanSpark mPulse
- Legacy Building Energy Management System (BEMS)

## Costs

The total cost of the project is $7,900,000. The largest component of this is the microgrid installation at $7,680,000, with additional costs for project development ($120,000) and testing and commissioning ($100,000).

## Business Model

### Financing

The pilot project is cash-funded by the customer. Financed solutions were also considered.

### Value Proposition

The confidential client is primarily interested in (1) cost savings, (2) orchestrating existing DER and legacy systems such as installed solar PV and the BEMS, and (3) sustainability (Table 16). After completing its PowerPlan service for the customer portfolio, CleanSpark worked with the client to refine each business case and potential near-term implementation plan to quantify the value and priority of each opportunity. Together, they identified five "low-hanging fruit" opportunities, one of which is now being pursued as the pilot. The metrics used in the complete cash-flow analysis included payback period, IRR, technical metrics such as asset efficiency and lifetime, and dollar amounts for engineering estimates.

To deliver value, the project utilizes a blended model of existing DER operational improvements, additional self-generation, energy storage, and demand management.

20 CleanSpark PowerPlan. http://cleanspark.com/powerplan/.

**Table 16: Thousand Oaks Real Estate Portfolio Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | ● | | |
| Resiliency | | ● | | |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | | ● |
| Provision of ancillary services | | | | ● |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | ● | |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | | ● |
| Other: N/A | ● | | | |

Source: Navigant

### Revenue Streams

In normal operation, the microgrid system will be optimized for cost savings through demand management for utility bill reduction, with additional near-term opportunities for ancillary service market participation to generate revenue. Operation of the microgrid for economic outcomes is driven by CleanSpark's mPulse Energy Operating Platform. The business case required a payback period (post-tax) of 4 to 9 years and returns exceeding 12% (post-tax unlevered IRR).

## Lessons Learned

After the priority pilot project is complete, CleanSpark will do a deeper dive for all the client's properties to prepare a portfolio-wide microgrid rollout utilizing lessons learned from the pilot. However, this customer is not necessarily indicative of the broader market because it has an experienced sustainability team composed of energy professionals.

So far, CleanSpark has identified the greatest challenge to be striking the right balance in terms of communication to different customer stakeholder groups. Working with the sustainability team to understand project benefits has been easier than usual, but it can still be a challenge to communicate at the different levels of a large organization. For example, detailed technical materials used with the sustainability team cannot be duplicated for business executives, who require high-level work products with costs and benefits.

## Contacts & Sources

Interview with Bryan Huber, COO of CleanSpark, June 23, 2017.

# The Thacher School

## Project Background

The Thacher School is an independent boarding school with approximately 250 students, located in Ojai, California. Sustainability and power resiliency are important to the school. The school is located near the end of a remote utility feeder, and suffered a major outage of 10 days due to wildfires in 2007. The microgrid is a solar-plus-storage system that can island from the grid during outages (Table 17).

**Table 17: The Thacher School Project Overview**

| | |
|---|---|
| **Location** | Ojai, California |
| **Utility** | SCE |
| **Host Organization** | The Thacher School (private boarding school) |
| **Developer/Vendor(s)** | JLM Energy |
| **Capacity** | 1 MW |
| **Installation Timeline** | Mid-2016 – mid-2017; approximately 1-year planning, permitting and installing the storage & microgrid controls; 9 weeks for installation and commissioning. The PV system was an earlier 3-year project, first operational in June 2016. |
| **Total Cost** | $4.33 million |

Source: Navigant

JLM Energy led the development of the microgrid, installing its Gridz product which provides battery storage and control. Previously, Sullivan Solar Power installed the solar PV system (Figure 7).

**Figure 7: The Thacher School Solar PV Array**

Source: The Thacher School

## Technical Characteristics

- 750 kW solar PV (265 W panels), Kyocera
- 250 kW Li-ion battery and microgrid controls, JLM Energy Gridz

## Costs

The total cost of the project was $4,330,000. The PV system was $3,400,000 plus $250,000 for permitting and related costs. The storage and microgrid controls portion were $580,000 plus $100,000 for additional surveys and related costs.

## Business Model

### Financing

The system was paid for in cash by the school, thanks in part to alumni donations. Novel financing options were considered but ultimately dismissed. As a non-profit organization, the school is not eligible for all the tax incentives available to for-profit entities.

### Value Proposition

The microgrid reduces carbon emissions, enhances energy resiliency, and provides a learning opportunity for the students (Table 18). Additionally, the system provides approximately $175,000 per year in energy bill savings. More than 90% of the electricity is provided through solar, or around 1.2 million kilowatt-hours of clean energy each year. The system offsets approximately 1.4 million pounds of carbon dioxide annually.

**Table 18: The Thacher School Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | ● | |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | ● | | |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | ● | | | |
| Reduction of carbon footprint | | | | ● |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | | ● |
| Other: N/A | ● | | | |

Source: Navigant

### Revenue Streams

The solar and storage system reduces both energy and demand charges on the monthly electric bill, in the amount noted above. The power resiliency benefits were more difficult to quantify, but are still important to the school. The simple payback period for the system was around 18 years, although this number does not capture the power resiliency, emissions reductions, and learning benefits from the system.

## Lessons Learned

Proactive communications with local authorities are important for speedy permit approvals, especially where relatively few DER have been installed. In this new jurisdiction, authorities considered the container battery system to itself be a structure, necessitating additional approvals. A proactive approach to approvals is likely to pay dividends, as processes gradually standardize and stakeholders continue to get up to speed.

The local utility installed a switch that does not allow for seamless islanding. Instead, the solar PV system trips offline and is powered on manually, one string at a time as needed. While seamless islanding has its advantages, this topology works for the host site.

JLM is interested in allowing such systems to become VPPs in the future by providing grid services. In the long term, JLM hopes to aggregate multiple systems and sell into CAISO markets under a revenue sharing business model.

## Contacts & Sources

Correspondence with Ed Bennett of the Thacher School, and Roman Couvrette of JLM Energy, July 7, 2017.

# CHAPTER 2:
# North America Case Studies

This chapter contains the 10 North America case studies:

1. Montgomery County Public Safety & Correctional Facility, Montgomery County, Maryland
2. Kansas Survival Condo, Glasco, Kansas
3. US Marine Corps Logistics Base, Albany, Georgia
4. OATI Microgrid Technology Center, Bloomington, Michigan
5. General Motors E-Motor Plant, White Marsh, Maryland
6. Peña Station NEXT, Denver, Colorado
7. EaglePicher Power Pyramid™ Demonstration, Joplin, Missouri
8. Marcus Garvey Apartments, Brooklyn, New York City
9. General Motors Milford Data Center, Milford, Michigan
10. Ameren Distribution Microgrid, Champaign, Illinois

## Montgomery County Public Safety & Correctional Facility

### Project Background

Montgomery County is moving forward with two microgrids that help it meet its policy goals to dramatically increase resiliency, efficiency, and sustainability without exposing the local government to large capital expenses (Table 19). Solar PV and natural gas and diesel generators allow these critical facilities to operate independently of the electrical grid, ensuring uninterrupted public services during emergencies. The microgrid also includes a Combined Heat and Power (CHP) system which saves energy by using waste heat from on-site power generation to heat buildings and to provide chilled water via absorption chilling.

**Table 19: Montgomery County Project Overview**

| | |
|---|---|
| **Location** | Montgomery County, Maryland |
| **Utility** | PEPCO |
| **Host Organization** | Montgomery County Public Safety Building and Correctional Facility |
| **Developer/Vendor(s)** | Schneider Electric, Duke Energy Renewables |
| **Capacity** | 7.6 MW for both microgrids (2.8 MW for the Correctional Facility and 4.8 MW for the Public Safety building) |
| **Installation Timeline** | Design began in February 2017; construction was planned to begin in September 2017; planned to be completed in 2018 |
| **Total Cost** | No upfront cost under the “Microgrid-as-a-Service” business model |

Source: Navigant

Montgomery County sought developers from the private sector because it wanted to address aging infrastructure issues, but was highly budget-constrained. Additionally, since it is a governmental entity, it could not take advantage of available tax credits to reduce overall capital costs of the system. Duke Energy Renewables and Schneider Electric served as the microgrid owner and solution provider, respectively.

## Technical Characteristics

- 2 MW solar PV
- 2 MW continuous duty-rated natural gas generators
- 2.55 MW legacy diesel generators
- 1 MW CHP
- Critical Infrastructure Upgrades (i.e., medium and low voltage gear)
- Advanced cybersecurity solution

## Costs

Since the cost of two microgrids is rolled into a new "Microgrid-as-a-Service" (MaaS) business model, it is difficult to disaggregate the actual cost of each microgrids. The estimate for necessary distribution system upgrades was $4 million.

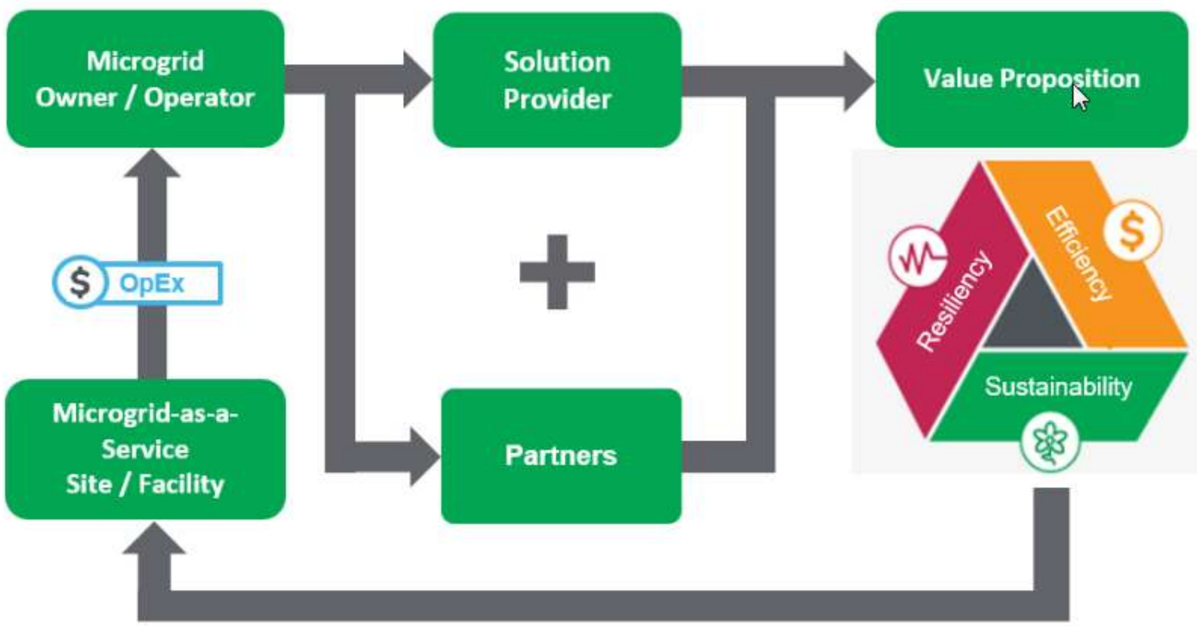
## Business Model

### Financing

Duke Energy Renewables is the owner of the microgrid. The project is funded through a PPA partnership with Schneider Electric, which eliminates the requirement for upfront capital expenditure from Montgomery County. The PPA incorporated into the MaaS contract includes a unique capacity payment to cover the capital expenses for the microgrid component, in addition to a volumetric energy charge that serves as the basis for a standard PPA.

The basic structure of the new Schneider Electric MaaS is depicted in Figure 8. For the Montgomery County project, Montgomery County is the MaaS facility, Duke Energy Renewables is the owner/operator, and Schneider Electric is the solution provider.

**Figure 8: Microgrid-as-a-Service Business Model**




Source: Schneider Electric

### Value Proposition

Montgomery County's two microgrids will provide the following benefits (Table 20):

- Produce nearly all energy necessary on-site (>80%) or 3.6 million kilowatt-hours of solar energy each year, enough to power more than 200 homes.
- Reduce greenhouse gas emissions by 3,629 metric tons each year, which translates to removing over 767 cars from the road or planting 94,000 trees.
- Allow the County to avoid $4 million in outright capital expenditures for mid and low voltage distribution upgrades.
- Lock in known price of energy for 25 years under the MaaS model.

**Table 20: Montgomery County Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | ● | | | |
| Provision of energy and capacity services | ● | | | |
| Provision of ancillary services | ● | | | |

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | | | ● | |
| Linkage to Virtual Power Plant | ● | | | |
| Other: Cybersecurity | | | | ● |

Source: Navigant

**Revenue Streams**

The project is not yet online, but it is not anticipated that this microgrid will capture revenue streams from the provision of grid services. Beyond electricity, the project will provide value via thermal energy and improved cybersecurity.

### Lessons Learned

The primary lesson learned is that new microgrid business models, such as MaaS, can allow public agencies to move forward with microgrid projects that previously would have required federal or state government grants. Schneider Electric's MaaS offering allows the private sector to help fund public infrastructure that can provide broad resiliency, efficiency, and sustainability benefits to communities that would otherwise be unable to afford it. Microgrids can also be rolled into broader infrastructure upgrades and lock in energy costs for public agencies over long periods of time, providing budget stability and supporting long-term planning goals.

### Contacts & Sources

Interview with Trish Starkey, Sales Enablement Manager, NAM Microgrid Competency Center, Schneider Electric, June 16, 2017.

Peter Maloney, "Duke, Schneider pair up to build two microgrids in Maryland," UtilityDIVE, February 2, 2017 (http://www.utilitydive.com/news/duke-schneider-pair-up-to-build-two-microgrids-in-maryland/435398/).

## Kansas Survival Condo

### Project Background

A project developer in Kansas converted a missile silo (built in the 1960s) into luxury survival condominiums (Figure 9). The silo has 14 below-ground stories to shelter 10 families in the event of a major disaster. The average electrical load drawn by the condo complex (which includes a swimming pool, hydroponic and aquaculture food production, bar and lounge, and general store) is 85 kW, equivalent to the load of about 70 average American households. The total capacity of diesel, wind, and battery storage technologies to support the microgrid is 450 kW (Table 21).

**Figure 9: Diagram of the Luxury Condo Microgrid in Former Missile Silo**

Source: Sustainable Power Systems

**Table 21: Kansas Survival Condo Project Overview**

| | |
|---|---|
| **Location** | Glasco, Kansas |
| **Utility** | Rolling Hills Electric Cooperative |
| **Host Organization** | LAH Cubed, LLC (luxury survival condominiums) |
| **Developer/Vendor(s)** | Sustainable Power Systems, Halus Wind |
| **Capacity** | 0.45 MW |
| **Installation Timeline** | 6 months; commissioned in 2013 |
| **Total Cost** | ~$800,000 |

Source: Navigant

This commercial facility is connected to an unreliable utility distribution feeder in rural Kansas. The microgrid responds instantly to any voltage disturbances or outages on the utility, acting as a large Uninterruptible Power Supply (UPS) for the facility. Unlike a UPS, however, the microgrid allows the wind turbine to stay online while the facility is islanded. Since its commissioning in 2013, the microgrid has successfully responded to numerous utility disturbances. At one point, Kansas experienced severe ice storms that brought down the utility's distribution lines, cutting off the condo's access to utility power for over five hours. The microgrid immediately took over without any disruption in power to the facility.

The condo's developer and owner Larry Hall states, "Energy security is a top priority for our community. We needed a microgrid to ensure that our power stays on and that our wind turbine continues to produce, regardless of what is happening out on the electric grid. Ours is a complex facility, and Sustainable Power Systems overcame some significant system integration challenges to provide us with true energy security – we now have power no matter what."

## Technical Characteristics

- 200 kW diesel generator
- 100 kW wind turbine, Halus Wind
- 150 kW lead-acid battery
- Grid-Forming Inverter, Sustainable Power Systems
- Universal Microgrid Controller™, Sustainable Power Systems

## Costs

The project cost approximately $800,000 (or $500/kW if calculated based on the size of the grid forming inverter, according to Sustainable Power Systems). Calculated in the same way as other projects profiled in this report (based on total peak capacity), the cost is $1,777/kW. This figure was used in the data analysis.

## Business Model

### Financing

The microgrid was financed directly by those who purchased the condos. The condo developer – LAH Cubed, LLC – financed the project be selling the units in advance of actual construction.

### Value Proposition

"As far as SPS is concerned, the fact that it is a survivalist condo is incidental," said Steve Drouilhet, CEO of Sustainable Power Systems. "For us, it is simply a behind the meter commercial grid-tied microgrid (Table 22). I'd like to see a lot more funding for microgrids in this market sector. The message I would send to Energy Commission is that ancillary services are NOT really drivers in this market. It is all about energy security, being green, energy charge reduction, demand charge reduction, TOU Rate reduction, and in some cases, making distributed customer-owned renewables more grid-friendly so that they can get an interconnection agreement."

**Table 22: Kansas Survival Condo Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | ● | | | |
| Provision of energy and capacity services | ● | | | |
| Provision of ancillary services | ● | | | |
| Reduction of carbon footprint | | | ● | |

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | ● | | | |
| Other: N/A | ● | | | |

Source: Navigant

**Revenue Streams**

There are no revenue streams.

### Lessons Learned

Perhaps the most important lesson learned is that while microgrids for residential applications are often touted for energy access in developing world markets, there may also be a market for luxury condos. Markets for similar microgrids – absent the abandoned missile silo – could exist in places such as Humboldt, Mendocino, or Trinity counties in California as well as desert locations in the southwestern corner of that state. If such a remote, grid-tied segment grew significantly, stakeholders may need to review standards for remote interconnections of microgrids.

### Contacts & Sources

Interview with Steve Drouilhet, President & CEO, Sustainable Power Systems, Inc., June 27, 2017.

Peter Asmus, "Zombie Dread Fuels Microgrid Market," Forbes, August 2, 2013 (https://www.forbes.com/sites/pikeresearch/2013/08/02/zombie-dread-fuels-microgrid-market/#772ded5b4845).

## US Marine Corps Logistics Base

### Project Background

Energy security and resiliency is a priority for military installations tasked with keeping personnel safe and maintaining cybersecurity for the increasing sophistication of military radar, sensing, monitoring armament, and weapons technology. These concerns are driving energy innovation in overseas deployments and for stationary bases located in the United States.

Last October, the Naval Facilities Engineering Command (NAVFAC) selected Constellation, a subsidiary of Exelon Corporation, to implement a $170 million, 24.9-year energy savings performance contract (ESPC) designed to increase energy efficiency and install DG for the Marine Corps Logistics Base in Albany, Georgia. NAVFAC spent almost five years planning for this major system upgrade (Table 23). The logistics base covers 3,600 acres and hosts nearly 400 facilities, 61 miles of electricity distribution lines, and 19 miles of natural gas pipelines. This infrastructure is owned and operated by the US Marine Corps.

**Table 23: US Marine Corps Logistics Base Project Overview**

| | |
|---|---|
| **Location** | Albany, Georgia |
| **Utility** | Georgia Power |
| **Host Organization** | US Marine Corps Logistics Base |
| **Developer/Vendor(s)** | Constellation, Schneider Electric, Proctor & Gamble, Georgia Power |
| **Capacity** | ~15.6 MW |
| **Installation Timeline** | Contracts awarded in late 2016 and Spring 2017; full implementation is expected to take approximately 1 year, with online date scheduled for September 2018 |
| **Total Cost** | $4.2 million of a $170 million, 24.9-year energy savings performance contract |

Source: Navigant

Among the goals of this long-term ESPC contract was the installation of an 8.5 MW biomass-fueled steam-to-electricity generator. Additional upgrades include high-efficiency transformers, industrial air compressors, building automation, lighting and boiler upgrades. The new DG installation and efficiency measures are estimated to reduce energy consumption by 15%. The biogas generator will use steam purchased from an adjacent Procter & Gamble cogeneration plant, and sell electricity to Georgia Power.

Additionally, system controls were needed to optimize the new 4.1 MW landfill gas project and six diesel generators, and for the monitoring and operation of electricity for the entire base. Constellation turned to Schneider Electric to design and install the new controls architecture to help the base achieve "net zero" resiliency – consuming net annual energy from on-site renewables – while simultaneously providing cybersecurity, ongoing maintenance, and optimization services. Schneider Electric first came onto the project during the investment grade audit of the microgrid, when it was discovered that a previous vendor failed to adequately address cybersecurity requirements and the architecture required to manage complex data flows from a myriad of generators. Schneider Electric's real-time enterprise data historian helped resolve these issues, integrating data management throughout the entire base.

## Technical Characteristics

- 8.5 MW biogas electric generator
- 4.1 MW landfill gas project
- 3 MW diesel generators (6 units)
- High efficiency electricity transformers
- High efficiency advanced lighting systems
- Boiler upgrades
- Industrial Air Compressors
- New control scheme based on data warehousing software capable of "islanding" the base from the larger utility grid, allowing for remote stop/start commands and provision of real and reactive power management
- Real-time data historian to manage data flows from all DER deployed at the base

## Costs

The microgrid cost approximately $4.2 million. If we assume the $/MW is based on the new DG installed – a total of 12.6 MW – the cost per MW is $333,333/MW. Note that this analysis does not include the 3 MW of existing diesel generation in the $/MW cost calculation.

## Business Model

### Financing

Military microgrids have unique contractual parameters due to capital budget limitations, vetted vendor pre-qualifications, and a prohibition on paying any price premium for infrastructure upgrades. One of the most common vehicles for microgrids is the ESPC format, whereby infrastructure upgrades are financed through the savings generated by energy efficiency upgrades, which include reductions in the purchase of power from the utility grid through on-site power generation. The only government funding involved was a modest DOE grant for a steam turbine.

The reliance upon the ESPC contracting vehicle mimics the benefits of Schneider Electric's MaaS concept, with ongoing upgrades being financed through operational revenue generation. In this project, however, Constellation is the prime contractor and the microgrid is a subset of a much larger infrastructure upgrade, with incremental improvements extending over 23 years. While government funding originally served as the basis of the overall infrastructure project upgrades, the actual microgrid portion of the project is financed by savings generated through reductions in energy consumed from the utility power grid, via the ESPC.

### Value Proposition

The value proposition is the creation of a microgrid embedded with cybersecurity, that supports critical facilities without any capital costs and uses a control framework to manage assets across the entire base. The cost per megawatt is remarkably low, since the project was designed to fit within the ESPC parameters. In other words, no bells and whistles.

**Table 24: US Marine Corps Logistics Base Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | ● | | | |
| Future transactive energy revenue | ● | | | |
| Provision of energy and capacity services | ● | | | |
| Provision of ancillary services | ● | | | |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | ● | |
| Services beyond electricity (thermal, water, etc.) | ● | | | |

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Linkage to Virtual Power Plant | ● | | | |
| Other: Cybersecurity | | | | ● |

Source: Navigant

#### Revenue Streams

The revenue streams are captured energy savings, which are then given back to the project, underwriting the microgrid deployment. Demand response may be possible down the road, but is not vital to the economics of this microgrid.

### Lessons Learned

Ensure the preferred microgrid provider is engaged early and often! Up-front planning can pay dividends by limiting expensive changes later. In these early discussions, cybersecurity is a critical component. It is best not to add cybersecurity considerations during the final stages of the project, but rather integrate into the upfront design.

Tapping experience from past projects is another key to success. Constellation has since partnered with Schneider Electric on five military microgrid projects. Getting a good team together in the design phase will speed up the development cycle and offer opportunities to reduce costs.

### Contacts & Sources

Interview with Trish Starkey, Sales Enablement Manager, NAM Microgrid Competency Center, Schneider Electric, July 18, 2017.

Interview with Dave Reed, Schneider Electric, July 18, 2017.

Interview with Russel McNair, Constellation, July 18, 2017.

“US Marine Corps, Constellation, P&G collaborate to achieve Navy’s first ‘Net Zero’ energy military base,” Constellation, October 27, 2016 (https://www.constellation.com/about-us/news/archive/2016/US-Marine-Corps-Constellation-PG-collaborate-to-achieve-Net-Zero.html).

“Schneider Electric to Help Enable Energy Resiliency at USMC Logistics Base,” PR Newswire, March 14, 2017 (http://www.prnewswire.com/news-releases/schneider-electric-to-help-enable-energy-resiliency-at-usmc-logisitics-base-300423278.html).

## OATI Microgrid Technology Center

### Project Background

Open Access Technology International, Inc. (OATI) is a leading provider of advanced application software, security solutions, data center operations, and hardware technologies in the North American energy industry. OATI was an early leader in software-as-a-service (SaaS) solutions, providing SaaS from its NERC CIP compliant data centers for more than 20 years. OATI’s services span the entire breadth of the energy industry, from transmission and distribution to trading. OATI serves more than 1,800 customers. The OATI Distributed Energy Management System (DERMS) integrates DER into distribution utility operations, successfully mitigating their impacts while harnessing many grid services for reliability and resiliency purposes.

OATI began planning a new data center development in 2014. As a critical facility, the data center required significant equipment and infrastructure to meet OATI's resiliency requirements. During the planning phase, it became apparent that a microgrid would be a superior solution to a traditional data center design. Given the high costs to develop mission-critical data center infrastructure (such as diesel generators and switchgear), a microgrid provides greater resiliency and reliability, and is a more economically viable solution to the traditional data center model because of less redundancy and more efficient networking of DER. The OATI team of in-house developers and engineers defined the requirements, assembled the external design and construction team, and oversaw the development and construction of the project.

The project is the OATI Microgrid Technology Center, which includes one of the company's data centers that host its SaaS solutions (Table 25). The Microgrid Technology Center is also a Class-A office building, with large meeting facilities, an on-site gym, and more than 80,000 square feet of office space (Figure 10). The microgrid also serves as showcase for OATI microgrid products and services.

**Table 25: OATI Microgrid Technology Center Project Overview**

| | |
|---|---|
| **Location** | Bloomington, Minnesota |
| **Utility** | Xcel Energy |
| **Host Organization** | Open Access Technology International, Inc. (Office building and datacenter) |
| **Developer/Vendor(s)** | USA Microgrids, Inc., EnSync Energy Systems, Agile Hybrid Energy Storage, Capstone Turbine Corporation |
| **Capacity** | 2.4 MW |
| **Installation Timeline** | April 2015 – April 2017 (data center commissioned, and start of production operations) |
| **Total Cost** | $1.5 million for the microgrid-specific costs, excluding the diesel generator |

Source: Navigant

Following the success of the project, OATI created USA Microgrids, Inc. (its subsidiary), which is focused on turn-key development, design, construction, and ongoing operation of microgrids and DER in North America, with particular emphasis on integration with utility operations.

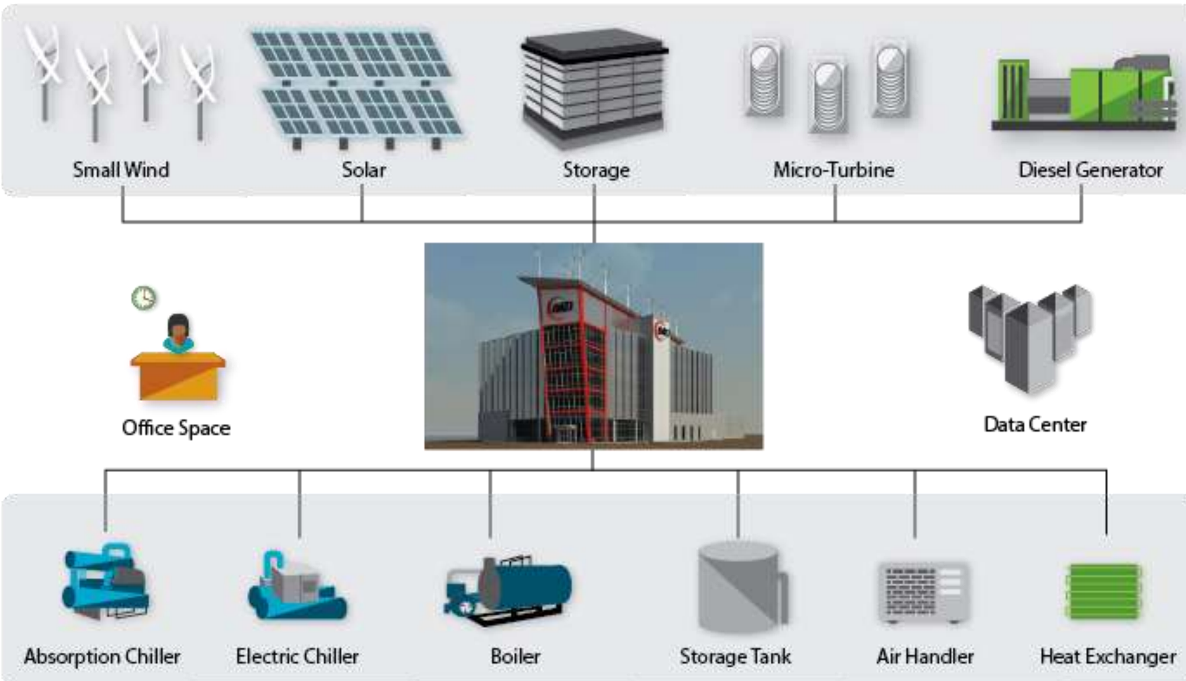
**Figure 10: OATI Microgrid Technology Center**


Source: OATI

## Technical Characteristics

- 150 kW solar PV (Figure 11)
- 24 kW vertical axis wind turbines
- 600 kW natural gas microturbine in trigeneration configuration (combined heat, power, and cooling), Capstone C600
- 125 kW / 231 kWh battery, EnSync
- 1,500 kW diesel backup generator
- Microgrid control system, OATI GridMind

Figure 11: OATI Microgrid Technology Center Integrated Distributed Energy Resources




Source: OATI

## Costs

The project costs are divided into three categories:

- Typical building costs for any construction project such as site acquisition, permitting, design fees, and the overall construction of the building shell and finishings.
- Costs specific to the microgrid, including the CHP plant, PV, energy storage system, wind turbines, and enhanced electrical Power Line Communication (PLC) controls.
- Data center specific costs such as specialized and redundant cooling and electrical systems, fire suppression systems, raised floor, enhanced security, and backup generation. These costs are significant in any data center construction project.

OATI estimates the microgrid aspects of the building were an approximately $1.5 million up-front investment. These costs can be offset with savings achieved through microgrid optimization strategies and the avoidance of “stranded” assets. Additionally, many of the traditional data center costs were offset by the microgrid components. For example, the building has only one backup diesel generator, which is required by city code. The microturbine provides the remaining generation.

It is important to note that every microgrid project is different. In OATI’s case, the microgrid infrastructure replaced the backup generation needed to support a critical facility. In a non-critical facility that does not have a data center’s enhanced resiliency requirements, the microgrid infrastructure cost can be considerably less.

## Business Model

### Financing

The OATI Microgrid Technology Center was privately financed.

### Value Proposition

The primary objective of the Microgrid Technology Center is to ensure resilient and reliable power for OATI's mission-critical data center (Table 26). The microgrid infrastructure is even more resilient and reliable than traditional data center designs, because the DG assets are regularly utilized—in contrast to the traditional model of using backup diesel generators that are very seldom used. Regular use of the assets increases reliability and staff understanding. The value of enhanced reliability alone justifies the minimal incremental cost of the microgrid.

The Microgrid Technology Center also serves as a demonstration of the GridMind control system and other technologies,[21] and as a showcase for consumers and utilities interested in developing and operating microgrids. For example, each DER, and the microgrid as a whole, can offer grid services such as demand response, load shedding, and other services to the local utility and even the surrounding buildings.

### Revenue Streams

The primary revenue streams offered by most microgrids relate to business continuity for critical business and emergency services as well as utility demand-side relief and ancillary services (kVAR, frequency control, and more). OATI has had multiple conversations about opportunities for market participation and is interested in participating in the future. Hurdles to market participation exist, including up front communications costs and geographic constraints, although the company notes that the various DER do not present any technical challenges. That is, DER technologies are ready to participate in markets, if regulatory and other hurdles can be overcome.

**Table 26: OATI Microgrid Technology Center Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | | ● | |

21 The OATI GridMind microgrid control system optimizes the performance of all DER concurrently, to operate the microgrid in the most economical fashion. Solar forecasts, current and future cost of utility gas & electricity, and current and forecasted temperature are input into the model. The system is configurable on a 5-minute basis.

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Renewable energy integration | | | ● | |
| Services beyond electricity (thermal, water, etc.) | | ● | | |
| Linkage to Virtual Power Plant | | | ● | |
| Other: Demonstration of microgrid benefits for the consumer and utility | | | | ● |

Source: Navigant

### Lessons Learned

The marginal cost to include a microgrid in a mission-critical facility like a data center can be relatively minimal, pointing to growing commercially viability in this segment as best practices are refined and economies of scale lower costs further. The cost of integration and routine operations and maintenance on diesel generators and batteries can help “fund” the microgrid, and as a bonus, those resources can be used in economically advantageous ways. OATI, like many other microgrid owners, is turning energy resources from liabilities into revenue-providing assets.

### Contacts & Sources

Correspondence with David Heim, OATI Chief Strategy Officer, June 21, 2017.

“Advanced Microgrid Deployment, OATI, 2017 (https://www.oati.com/about/microgrid-technology-center).

## General Motors E-Motor Plant

### Project Background

TimberRock Energy Solutions partnered with OnStar and General Motors (GM) to develop a microgrid demonstration project, exploring the next generation of energy infrastructure at large commercial and industrial facilities. The objective of the project was to quantify how a microgrid comprising DER such as solar PV, EV charging infrastructure, stationary li-ion storage, and a small fleet of GM’s Chevy Volts (or other EVs) could deliver an economic "benefit stack" to participating stakeholders. The resulting microgrid is a relatively small but advanced demonstration of complex energy management and integration technology with a focus on Vehicle-to-Grid (V2G) applications (Table 27).

**Table 27: General Motors E-Motor Plant Project Overview**

| | |
|---|---|
| **Location** | White Marsh, Maryland |
| **Utility** | Baltimore Gas and Electric Company |
| **Host Organization** | General Motors (manufacturing plant) |
| **Developer/Vendor(s)** | TimberRock Energy Solutions, OnStar |
| **Capacity** | 610 kW |
| **Installation Timeline** | Approximately 18 months (commissioned in 2014) |
| **Total Cost** | Confidential; order of magnitude ~$1 million |

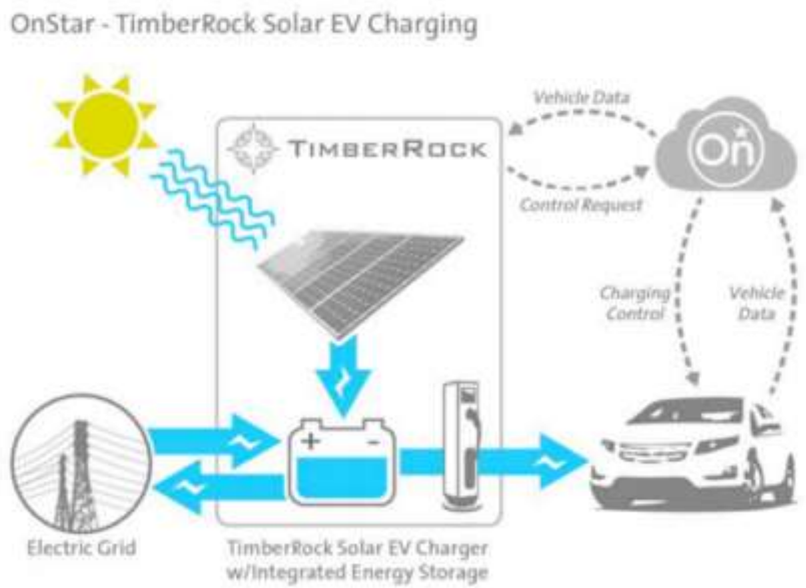
Source: Navigant

The GM manufacturing site is rated as a LEED Silver building because of the solar array, LED lighting, and other improvements. Six percent of the facility's electricity comes from renewable sources (including a larger ground-mounted solar array). Before developing the microgrid project, TimberRock Energy Solutions was already working with GM to build out EV charging stations when GM became interested in testing the Chevy Volt as a grid resource. At the same time, OnStar was developing a smart grid product for V2G integration. The two technology vendors partnered to complete a cloud-based software integration for controlling the Volts for demand response, load curtailment, and real-time grid balancing (Figure 12).

## Technical Characteristics

- 580 kW solar PV rooftop (non-islanding) and canopy (islanding) arrays
- 30 kW / 30 kWh Li-ion stationary energy storage (integrated into solar parking lot canopies)
- Distributed Energy Resources Management System, TimberRock DE-MAP
- EV charging stations in solar parking lot canopies
- Four Chevy Volts (16.5 kWh each in the 2014 model – 18.4 kWh each in the 2017 model)
- Advanced bi-directional inverters
- Transactive Energy Router – embedded control hardware, telecommunications and software required for optimization, aggregation, and dispatch

**Figure 12: General Motors E-Motor Microgrid Solar EV Charging Diagram**




Source: TimberRock Energy Solutions

## Costs

Confidential; order of magnitude ~$1 million.

## Business Model

### Financing

GM, TimberRock Energy Solutions, and the Maryland Energy Administration all funded a portion of the project. The Maryland Energy Administration provided some grant funding (less than 50% of the total cost) to support the technology demonstration. GM entered into a long-term lease agreement for the system, with a partial upfront payment, and continues to accrue savings through electricity bill reductions. TimberRock also invested in the project, and earns returns from GM's lease payments and revenue from grid services through the PJM Interconnection. This financing arrangement suited the stakeholders well; GM was comfortable with the straightforward economic value of energy and demand savings, whereas TimberRock was willing to take on the "riskier" (less proven/guaranteed) revenue from grid services.

### Value Proposition

The primary driver for the project was as a demonstration of advanced V2G integration with DER and software for optimization, aggregation, and dispatch; demonstrating how an intense level of integration drives down costs while maximizing functionality and total revenue generating potential (Table 28). While reliability and resiliency are not the primary value drivers of the microgrid, it is interesting to note that the bi-directional inverters do provide EV charging-specific islanding capabilities, which may be even more valuable in the future when a larger EV population is adversely affected by grid outages.

**Table 28: General Motors E-Motor Plant Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | ● | | |
| Resiliency | | ● | | |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | | | | ● |
| Provision of energy and capacity services | | | | ● |
| Provision of ancillary services | | | | ● |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | ● | |
| Other: EV charging and V2G integration | | | | ● |

Source: Navigant

### Revenue Streams

Despite utilizing some grant funding as a technology demonstration project, the business model is a replicable one without public funding because revenues and risks are split fairly between the customer and the developer. The revenue stream for GM is ongoing utility bill savings from energy and demand reductions (renewable electricity, solar firming, and peak shifting), while the revenue streams for TimberRock are lease payments from GM and revenue from PJM grid services. This enables both entities to invest some amount of money upfront in return for ongoing revenue. The model also accommodates a partial "pay as you go" structure for the customer via the long-term lease.

The microgrid generates revenue in the PJM market managing and dispatching the aggregated DER as a single block of capacity (using DE-MAP), which can provide services such as spinning reserve, dynamic load shedding, and frequency regulation. For example, the charging of the Volts can be modulated across their charging range in direct response to a frequency regulation signal.

## Lessons Learned

TimberRock Energy Solutions learned several valuable lessons during the development and ongoing operation of the E-Motor Plant microgrid project. Two important lessons relate to software and hardware components: (1) software is the key enabling technology for the microgrid, and existing software solutions can meet advanced DER and V2G requirements, and (2) existing hardware solutions cannot yet meet the requirements of these advanced applications. TimberRock discovered that, at the time, there were major gaps in the power hardware needed to operate this type of microgrid configuration.

On the business model side, the project showed that the stakeholders can share financing risks according to their level of understanding and willingness to take on revenue streams with different risk levels. The customer and developer can both realize value from the project by entering into an agreement that balances their requirements.

Finally, during this project TimberRock solidified its view of microgrids as part of a larger customer energy strategy rather than standalone projects. A microgrid is a "tool in a toolbox" that can be used to meet targeted customer demands in their larger retail energy portfolio. Customers like GM do not necessarily want a "microgrid" specifically – they want a comprehensive energy supply agreement with onsite (including demand management) and offsite (larger-scale renewables) resources to meet their 100% renewable energy and/or greenhouse gas emissions reduction goals. The business model is evolving towards a single supply and demand-side solution, with microgrids playing a part.

### Contacts & Sources

Interview with Brent Hollenbeck, TimberRock Energy Solutions, July 7, 2017.

"Case Study: Solar Microgrid Integrates Solar PV, Energy Storage, Smart Grid Functionality and Advanced Vehicle-to-Grid Capabilities," TimberRock Energy Solutions (http://timberrockes.com/docs/TRES-MEA.pdf).

"Spark EV Motor Plant Fueled by Green, Clean Energy," General Motors, May 18, 2015 (http://www.generalmotors.green/product/public/us/en/GMGreen/energy_efficiency.detail.html/content/Pages/news/us/en/2015/may/0518-baltimore.html).

## Peña Station NEXT

### Project Background

Peña Station NEXT is a 382-acre transit-oriented development adjacent to the Denver International Airport (DEN). The project is a public-private partnership with contributions from a variety of stakeholders, including Xcel Energy (Xcel), Panasonic, Younicos, and the city, county, and airport of Denver. The development showcases a variety of smart city and energy technologies, including smart street lighting, EV charging stations, and a unique microgrid (Table 29).

**Table 29: Peña Station NEXT Project Overview**

| | |
|---|---|
| **Location** | Denver, Colorado |
| **Utility** | Public Service Company of Colorado (a subsidiary of Xcel Energy) |
| **Host Organization** | Panasonic, Denver International Airport |
| **Developer/Vendor(s)** | Younicos, Panasonic, L.C. Fulenwider, Inc. |
| **Capacity** | 2.86 MW |
| **Installation Timeline** | Approximately 2 years, 2015- 2017; the core of the microgrid (storage and controls) took 20 weeks from initial order to final commissioning |
| **Total Cost** | $10.3 million, not including the 259 kW of building-mounted solar PV |

Source: Navigant

Xcel's distribution feeder has about 30% solar penetration, and the microgrid will help the utility integrate that intermittent energy source while also supporting the grid through other use cases like peak demand reduction and frequency regulation. Panasonic's facility, requiring uninterruptible power, will receive power resiliency benefits from the battery storage system. This pilot is a technology showcase for the stakeholders and a test bed for future microgrid business models.

## Technical Characteristics

The microgrid consists of multiple DER installed on multiple properties with multiple owners. Since there are several stakeholders involved, the DER are presented in Table 30.

In addition to the DER, there are advanced microgrid and battery controls supporting the microgrid system. Importantly, the solar carport is not behind the microgrid islanding switch, although the battery energy storage system that anchors the microgrid – and which is owned and operated by the utility – performs its use case operations by including real-time data from the solar carport to evaluate when and how to charge and discharge.[22] (Figure 13)

**Table 30: Peña Station NEXT Microgrid DER Stakeholders**

| Distributed Energy Resource | DEN | Xcel Energy | Panasonic | Younicos |
|---|---|---|---|---|
| 1.6 MW carport solar PV | Hosts (location) | Owns, Operates | | |
| 259 kW rooftop solar PV system | | | Hosts, Owns, Operates | Operates when system Is islanded |
| 1 MW / 2MWh Li-ion battery system, Younicos | | Owns, Operates | Hosts, Operates, Maintains | Operates, Maintains |

Source: Navigant

22 A Portfolio Microgrid in Denver, Colorado: How a multi-use battery energy storage system provides grid and customer services through a public-private partnership, Panasonic, Xcel Energy, and Younicos, January 2017, https://www.younicos.com/wp-content/uploads/2017/02/201702-Microgrid-White-Paper.pdf.

**Figure 13: Peña Station NEXT Microgrid Aerial View**

Source: Younicos

## Costs

The project cost an estimated $10,320,000 million.[23] This does not include the building-mounted 259 kW solar PV array. The battery systems cost an estimated $2.3 million, while the carport PV cost $3.4 million. The carport structure itself added another $2,5 million. The remaining $2.12 million covered ancillary equipment, integration costs, warranties, and O&M.

## Business Model

### Financing

The stakeholders will pay the following estimated amounts: DEN pays $2.5 million for the carport structure; Panasonic pays $1.1 million for preferential pricing, maintenance, and labor; Xcel pays the remaining $6.72 million. In addition, Panasonic maintains a special contract for backup power from Xcel. The creative financing approach was required, in part, due to the inability of Xcel to rate-base (or recover the costs via the customer rate base) this project due to the mixture of customers, vendors, and use cases all combined into a single project.

### Value Proposition

The microgrid serves five major use cases, the benefits of which accrue to the various stakeholders (Table 31).

1. **Solar PV Grid Integration**. This includes ramp control (for smoothing brief fluctuations) and solar time shifting (to manage feed loads throughout the day). The battery system monitors both PV systems and charges/discharges to provide the most benefit. This

23 "Xcel, Panasonic and Denver Airport to Team on $10.3M Solar Microgrid," Microgrid Knowledge, November 3, 2015 (http://microgridknowledge.com/xcel-panasonic-and-denver-airport-to-team-on-10-3m-solar-microgrid/).

allows Xcel to integrate renewables more effectively, and helps both Denver and Colorado meet their aggressive renewables goals.

2. **Grid Peak Demand Reduction.** Unlike some behind-the-meter storage facilities, the battery is under the utility's control. Thus, it will be dispatched at times known by Xcel to historically exhibit highest feeder demand, like hot summer afternoons. Xcel expects to call upon this use case 10 to 15 times per year.
3. **Energy Arbitrage**. Like the previous two use cases, energy arbitrage is a form of energy time shifting – although it's applied solely based on price, rather than PV generation or grid congestion. Any financial benefits accrue to Xcel, the owner of the battery.
4. **Frequency Regulation.** The battery provides frequency regulation as part of ancillary services to the local grid operator. The battery responds when frequency deviates from specified limits, and can provide relatively high value without compromising other use cases for the battery.
5. **Resilience Through Backup Power**. Panasonic's collocated network operations center, which monitors nationwide network of PV assets, has a need for a source of high-uptime power. In an outage, an islanding switch puts the battery, Panasonic's rooftop PV, and Panasonic's facility into grid-forming mode. Approximately 20% of the battery's capacity is reserved to provide about four hours of backup power to the facility. Panasonic receives this service from Xcel, which is provided under a special contract.

**Table 31: Peña Station NEXT Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | ● | |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | ● | | | |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | | ● |
| Provision of ancillary services | | | | ● |
| Reduction of carbon footprint | | ● | | |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | | ● |
| Other: N/A | ● | | | |

Source: Navigant

### Revenue Streams

The microgrid is operating on a 2-year pilot basis, with the goal of examining and optimizing the revenue streams available. To this end, the system is testing different use case hierarchies to determine optimal battery settings. The pilot's findings may suggest new business models for future deployments of energy storage as stand-alone systems or integrated into microgrids.

### Lessons Learned

The 2-year pilot is just underway, and is expected to inform business models associated with multi-use-case microgrids. The project stands out for its large number of stakeholders, novel revenue stacking, and unique method of applying backup power. In particular, this backup power scheme – a utility-connected battery that deploys power back to the customer in an outage – holds promise as a business model of the future, especially for projects featuring utility/vendor partnerships.

### Contacts & Sources

Interview with Bjoern Lang, Younicos, July 7, 2017.

"A Portfolio Microgrid in Denver, Colorado: How a multi-use battery energy storage system provides grid and customer services through a public-private partnership," Panasonic, Xcel Energy, and Younicos, January 2017 (https://www.younicos.com/wp-content/uploads/2017/02/201702-Microgrid-White-Paper.pdf).

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## EaglePicher Power Pyramid™ Demonstration

### Project Background

EaglePicher installed this microgrid at its facility to demonstrate its proprietary Power Pyramid™ technology and to provide a business case proof-of-concept for a mixture of battery technologies optimized for different use cases (Table 32). The Power Pyramid™ solution can reduce costs by managing onsite DER (including solar and wind) and grid power to optimize TOU rate differentiation. For example, low cost / low cycle batteries are used for low occurrence peak demand events, whereas high cost / high cycle batteries are included for everyday use (Figure 14). Leveraging multiple energy storage technologies is designed to minimize the shortcomings associated with any single electrochemical system. The microgrid project accumulates data on different configurations to measure system efficiencies.

**Table 32: EaglePicher Power Pyramid™ Demonstration Project Overview**

| | |
|---|---|
| **Location** | Joplin, Missouri |
| **Utility** | Empire District (Liberty Utilities) |
| **Host Organization** | EaglePicher Cross Roads Facility (microgrid demonstration facility) |
| **Developer/Vendor(s)** | EaglePicher Technologies, Princeton Power Systems |
| **Capacity** | 1.03 MW |
| **Installation Timeline** | Completed in February 2012 |
| **Total Cost** | $2,628,000 |

Source: Navigant

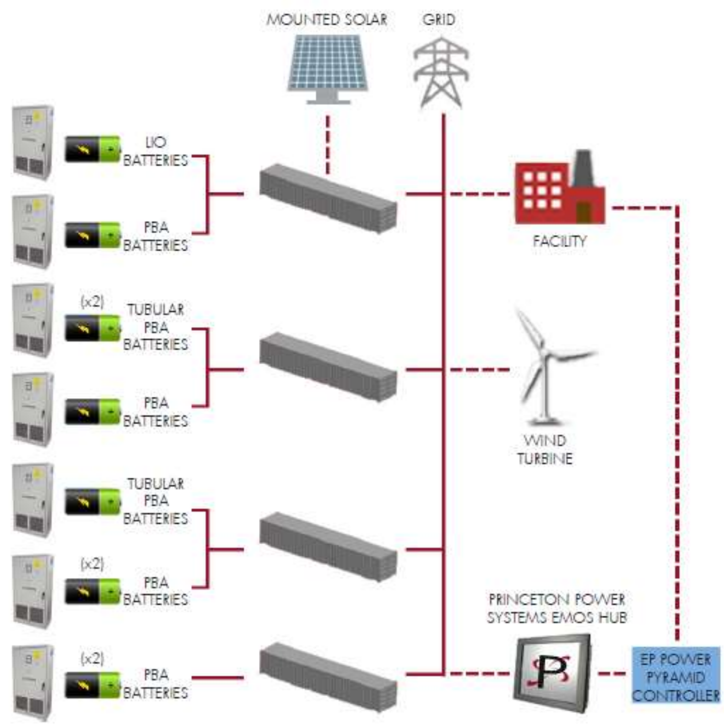
## Technical Characteristics

- 1 MW / 2 MWh lead acid (tubular lead acid and AGM lead acid) and Li-ion batteries
- 20 kW solar PV
- 10 kW wind turbine
- GTIB-100 inverters, Princeton Power Systems
- Site Controller, Princeton Power Systems
- Power Pyramid™ controller, EaglePicher

## Costs

The total project cost was $2,628,000.

**Figure 14: EaglePicher Power Pyramid™ Diagram Featuring Three Battery Technologies**




Source: Princeton Power

## Business Model

### Financing

As a technology demonstration project, EaglePicher financed the installation because they are the manufacturer the Power Pyramid™ controls that can manage multiple types of batteries and other DER and saw value in a successful project showcasing multiple use cases centered around economic optimization.

### Value Proposition

The primary value of the project is as a demonstration of an optimized energy storage system with a mix of battery technologies integrated with renewable energy, which is able to reduce energy demand and provide services to the grid through intelligent dispatch (Table 33). The system charges at low-cost energy times (specifically at night) and discharges batteries at peak times to reduce the facility's load. It can also operate in islanded mode during outages.

**Table 33: Power Pyramid™ Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | ● | | |
| Resiliency | | ● | | |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | ● | | | |
| Provision of energy and capacity services | | | | ● |
| Provision of ancillary services | | | | ● |
| Reduction of carbon footprint | ● | | | |
| Renewable energy integration | ● | | | |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | ● | | | |
| Other: N/A | ● | | | |

Source: Navigant

### Revenue Streams

The system can power facility loads and perform functions including peak demand shaving, frequency regulation, and other grid services. The project is currently shaving ~200 kW from the 500-kW daily demand of the EaglePicher facility. Depending on the host facility's tariff structure/demand charges, a 4 to 7-year rate of return (ROI) can be achieved.

## Lessons Learned

The technology vendors learned several lessons throughout the demonstration project. They discovered that the battery containers required special air-handling considerations to ensure cooling for the different battery types, and used this lesson to improve cooling system methods going forward. The vendors also gained experience integrating their technology solutions together to optimize the dispatch of different battery banks at different times.

## Contacts & Sources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"EaglePicher Energy Storage System," Princeton Power Systems, 2015 (http://www.princetonpower.com/images/casestudies/pdfs/EaglePicher_CaseStudy_September_2015.pdf).

# Marcus Garvey Apartments

## Project Background

Consolidated Edison identified a substation that had to drop 53 MW by 2018 to avoid investing $1.2 billion in traditional grid upgrades to address peak demands for electricity—peaks which occur for just 48 hours each year. The utility, under its Brooklyn-Queens Neighborhood Program, investigated "non-wires alternatives," of which a microgrid at a low-income apartment complex emerged as one of the viable options to help mitigate peak demand and grid issues at a lower cost than traditional options.

Marcus Garvey Apartments is a 10-city block complex consisting of 32 low-rise apartments totaling 625 units. The grid infrastructure serving the complex was built in the 1970s at the lowest possible cost with aluminum distribution wiring. The facility had two master meters fed by two separate feeders, which is typical for coupling with the Consolidated Edison grid. Since it was constructed during the oil embargo, all units used electric heat, which increased load on the grid. The complex represents a 3 MW winter heating peak load and a 1.5 MW summer air conditioning peak load. Its peak demand period is from 8 pm to midnight, long after the solar PV systems are generating electricity (Table 34).

**Table 34: Marcus Garvey Apartments Project Overview**

| | |
|---|---|
| **Location** | Brownsville Brooklyn, New York |
| **Utility** | Consolidated Edison |
| **Host Organization** | Marcus Garvey Apartments |
| **Developer/Vendor(s)** | Demand Energy, Bright Power, Consolidated Energy, Bloom Energy, LG Chem, L+M Development Partners, Princeton Power |
| **Capacity** | 1.1 MW |
| **Installation Timeline** | ~ 2 years |
| **Total Cost** | $190 million for total apartment renovation and refinancing, including approximately $3 million for the microgrid |

Source: Navigant

Along with upgrading the electric distribution system to modern standards, the project also upgraded kitchens, bathrooms, and other amenities. The focus of the upgrades was a microgrid that features the first lithium ion battery installed under new rules issues by the local fire department in New York City.

## Technical Characteristics

- 400 kW rooftop solar PV array
- 400 kW fuel cell, Bloom Energy
- 300 kW/1.2 MWh Li-ion battery
- Distributed Energy Network Optimization System (DEN.OS), Demand Energy

## Costs

The estimated cost of the microgrid is approximately $3 million for the solar PV and energy storage system. The fuel cell is being installed under a purchase power agreement (PPA).

## Business Model

### Financing

The solar PV was directly purchased by L+M Development Partners. The fuel cell was installed under a PPA. The energy storage system is provided under a shared savings model. Hence, the microgrid combined several funding sources to move forward.

Low income housing projects have complex financial structures that leverage various tax benefits. Since L+M Development Partners had used up its appetite for tax benefits on the solar PV system, a creative solution had to be developed to finance the energy storage component. Demand Energy secured a 10-year project loan from the nonprofit New York City Energy Efficiency Corporation, based on a shared savings model that was applied to the energy storage system whereby the owner and developer will pay off financing using energy bill savings once the system is operating (Figure 15). Other sources of funding include some level of utility rate-basing investment under the Brooklyn-Queens Neighborhood Program, of which the microgrid was just one element.

**Figure 15: Storage-as-a-Service Business Model for Microgrids**


Source: Demand Energy

### Value Proposition

The primary value proposition was to reduce energy usage and to use the savings to finance upgrades (Table 35). Additionally, rolling blackouts frequent this region. Rather than develop a microgrid that would provide back-up power for the entire apartment complex, instead the system provides back-up power specifically for a security system, the central office, and a large community room where residents can gather during an emergency and that hosts an area for phone charging. Furthermore, the project helps Consolidated Edison meet its goals of reducing demand on the problematic substation through the optimization of DER that includes solar, a fuel cell and an advanced battery.

**Table 35: Marcus Garvey Apartments Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | ● | |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | | ● | | |
| Provision of energy and capacity services | ● | | | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | ● | | |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | ● | |
| Other: N/A | ● | | | |

Source: Navigant

### Revenue Streams

Though the project is not allowed to export excess capacity back to the Consolidated Edison grid, it can provide demand response services. Any revenues generated via demand response will be shared between L+M and Demand Energy. The shared savings model for the energy storage system and overall microgrid could also be considered a revenue stream: it is fundamental to the viability of the project development.

## Lessons Learned

The key lesson learned is that multiple value streams are essential to cover the installed cost of a microgrid. The biggest challenge in developing this project was the equipment location due to antiquated zoning laws, especially set-back requirements. These are important lessons that could/should shape the New York Reforming the Energy Vision process. Utilities have incentives to pursue expensive and capital-intensive projects, since they earn a rate-of-return (ROI) on such investments. The larger the capital cost, the greater the ROI. New York is looking to reform this traditional approach, but the rules have yet to be finalized. This project shows that microgrids can offer equivalent benefits as traditional capital-intensive upgrades, at much lower cost.

## Contacts & Sources


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"Marcus Garvey Village Microgrid," Demand Energy (http://demand-energy.com/wp-content/uploads/2017/04/Marcus-Garvey-Fact-Sheet-Final-LowRes.pdf).

Elisa Wood, "Marcus Garvey Microgrid Begins Operating as a First for NYC Affordable Housing," Microgrid Knowledge, June 9, 2017 (https://microgridknowledge.com/marcus-garvey-microgrid/).

# General Motors Milford Data Center

## Project Background

For its new data center completed in 2015, General Motors (GM) decided to seek Leadership in Energy and Environmental Design (LEED) certification and continue to demonstrate its commitment to energy efficiency and renewable energy (Table 36). GM is committed to a 20% reduction in energy use by 2020,[24] and to using 100% renewable electricity across its global operations by 2050 (RE100).[25] The administrative building for the data center is a net-zero energy building, and hosts the solar, wind, and storage (used Volt battery pack) microgrid. The Milford data center project demonstrates GM's broader sustainability efforts, as well as the value of secondary use for EV batteries. GM's Battery Lifecycle Management team is actively pursuing solutions for battery reuse (Figure 16).

The project was led by GM's internal Global Facilities group, which contracted the design-build of the microgrid to Superior Electric and Empower Energy.

## Technical Characteristics

- 74 kW ground-mounted solar PV
- 4 kW (2 x 2 kW) wind turbines
- Five used Chevy Volt battery packs (16.5 kWh each)

## Costs

Less than $1 million in total.

**Table 36: General Motors Milford Data Center Project Overview**

| | |
|---|---|
| **Location** | Milford, Michigan |
| **Utility** | DTE Energy |
| **Host Organization** | General Motors (Milford data center) |
| **Developer/Vendor(s)** | General Motors, Superior Electric, and Empower Energies |
| **Capacity** | 78 kW |
| **Installation Timeline** | Completed in 2015; approximately four months to install during the new data center construction |
| **Total Cost** | Less than $1 million |

Source: Navigant

24 GM Earns ENERGY STAR Award for Environmental Leadership," GM Press Release, April 10, 2017 (http://media.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2017/apr/0410-energy-star.html).

25 RE100: General Motors (http://there100.org/general-motors).

## Business Model

### Financing

100% owner-financed (GM) as a demonstration project.

### Value Proposition

GM is interested in further integrating batteries, and potentially fuel cells, with on-site renewable energy in pursuit of its RE100 goal and net zero energy facilities (Table 37). In using retired Volt batteries, which typically have at least 70% battery life remaining when taken off the road, GM is also demonstrating the beneficial reuse of EV batteries and gathering data to identify the best use cases.

Although it is still too early in the demonstration project to conclude whether commercial, industrial/manufacturing, or residential use cases may be the best application of used Volt batteries, the administrative building has already achieved net zero energy with 12 months of operational data. The energy storage system can provide four hours of backup power for the administrative building.

### Revenue Streams

The system is not currently generating revenue other than electricity and demand savings from zeroing out the administrative building's load. However, GM is working with DTE Energy to identify and gather data for grid services. The small size of the demonstration project means that it does not have a major impact on the grid today, but GM and DTE are working with the data to determine what could be possible at a larger scale in the future with this technology.

GM is also exploring the commercialization of 100 kWh used Volt battery packs as modular energy storage solutions for customers.

**Figure 16: General Motors Milford Data Center Benefit Stack Summary**


Source: General Motors

**Table 37: General Motors Milford Data Center Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | ● | |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | ● | |
| Other: Secondary use of EV battery packs | | | | ● |

### Lessons Learned

The primary lesson learned from this demonstration project is designating repurposed EV batteries still requires clarification at state and federal levels since the guidelines for reusing EV batteries in a stationary storage application is not well defined. Even though the EPA sets guidelines for battery waste, recycling, and reuse it does not yet adequately address the complexities of beneficial reuse outside of the original purpose of the battery (in this case, no longer being part of an EV). The Milford data center project shows that an EV battery can be a valuable asset in a secondary application.

### Contacts & Sources


Interview with Rob Threlkeld, General Motors Global Environmental Compliance & Sustainability, July 20, 2017.

Greg Gardner and Chris Woodyard, "GM poised to challenge Tesla in battery storage," Detroit Free Press and USA TODAY, June 16, 2015 (https://www.usatoday.com/story/money/cars/2015/06/16/gm-tesla-power-storage-batteries/28815023/).

Melissa Burden, "GM using EV batteries to power Milford data center," The Detroit News, June 16, 2015 (http://www.detroitnews.com/story/business/autos/general-motors/2015/06/16/gm-ev-batteries/28800549/).


## Ameren Distribution Microgrid

### Project Background

The Ameren microgrid installed at the utility's Technology Applications Center in Champaign, Illinois, serves an active utility distribution feeder and can provide more than 1 MW of power to local customers when paralleled with the distribution grid, improving reliability and resiliency

(Table 38). It is one of the few microgrids in the world that operates at utility-scale / medium voltages (4-34.5 kV), is the first investor-owned utility microgrid to island customers on an active feeder, and employs a unique military-grade cybersecure microgrid control system and intelligent automation scheme to seamlessly transition power from microgrid mode back to grid connected mode for the entire distribution circuit. The system features solar, wind, natural gas generator and battery (Figure 17).

**Table 38: Ameren Distribution Microgrid Project Overview**

| | |
|---|---|
| **Location** | Champaign, Illinois |
| **Utility** | Ameren Corporation (Ameren Illinois) |
| **Host Organization** | Ameren Technology Applications Center |
| **Developer/Vendor(s)** | Ameren, S&C Electric Company, Schneider Electric, Northern Power Systems, Yingli, Caterpillar |
| **Capacity** | 1.475 MW |
| **Installation Timeline** | June – December 2016 |
| **Total Cost** | Approximately $5 million |

Source: Navigant

S&C Electric Company provided a complete EPC solution to Ameren, with design, engineering, and interconnection studies, while supplying the cybersecure controller, energy storage, communications system, and distribution switchgear and other equipment.

## Technical Characteristics

- 125 kW solar PV, Yingli
- String inverters, ABB
- 100 kW wind turbine, Northern Power Systems
- 250 kW / 500 kWh li-ion battery storage, S&C Electric Company (PureWave®SMS-250 Storage Management System and LG batteries)
- 1 MW (2 x 500 kW) natural gas generators, Caterpillar
- GridMaster® military-grade cybersecure controller, S&C Electric subsidiary IPERC
- Microgrid Economic Advisor, Schneider Electric

**Figure 17: Ameren Microgrid Featuring Wind, Solar, Natural Gas Generator, and Battery**


Source: S&C Electric

## Costs

Approximately $5 million.

## Business Model

### Financing

Funding for the project was enabled by the Energy Infrastructure Modernization Act which authorized Ameren Illinois to invest $643 million to modernize its energy delivery system over the 10-year life of the program.

### Value Proposition

Ameren's primary drivers for the project included: greater reliability for customers, better understanding the integration of DER, improving energy security for customers and achieving a continuous energy supply during islanding events. Ameren must demonstrate these expected benefits for its customers (Table 39). To provide a true benefit that reduces the overall number of outages (on a medium voltage system), the microgrid must be able to seamlessly transition to and from the grid – a major focus of this project and the purpose of its advanced technologies. Without seamless transitions, the system undergoes a minor outage when it reconnects with the grid which would be detrimental to customer reliability metrics. The Ameren microgrid synchronizes the two power systems (the microgrid and the utility grid) so that there is no loss of power at any time during the return to grid power. This seemingly minor change was a significant engineering undertaking and the successful implementation of this synchronization scheme will allow for an improvement in overall customer reliability metrics.

The microgrid also provides greater reliability to the customers it serves in the event of an outage on the main grid. In the event of an outage on the main grid, the more than 190 customers served by the microgrid would continue to receive power supplied by the microgrid.

The microgrid is helping Ameren prepare for the grid of the future, which will have a high penetration of DER and incorporate all the improvements of the smart grid. This project is a proactive exploration of how Ameren can continue providing value to its customers far into the future.

A secondary benefit to the utility is capital deferral – a microgrid on a distribution feeder can take care of certain power quality and other issues, and help the utility avoid installing new capacitor banks, reconductoring lines, etc.

**Table 39: Ameren Distribution Microgrid Value Proposition Ranking**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | ● | | | |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | ● | | |
| Renewable energy integration | | ● | | |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | ● | | |
| Other: N/A | ● | | | |

Source: Navigant

### Revenue Streams

Since this microgrid is a utility distribution microgrid, no revenue streams are generated for any third-party during operations.

## Lessons Learned

S&C Electric Company had an extremely short timeline to complete this project. Because Ameren Illinois is a distribution-only utility, S&C Electric Company had to find a leasing company for the generation equipment to make the project market compliant. The important lesson is that the regulatory environment can have a major impact on the financing plan, the project plan, and the project timeline.

The project has also provided several technical lessons. S&C Electric Company developed new control schemes and new protection schemes for frequency regulation and voltage management, which were two use cases of interest identified by Ameren. These capabilities are particularly important to optimize a system with intermittent (wind/solar) generation in microgrid mode, to avoid unnecessarily operating the natural gas generators.

## Contacts & Sources


Interview with David Chiesa, Senior Director of Business Development, S&C Electric Company, July 24, 2017.

Input from Tamer Rousan, Supervising Engineer-DA Technology, Ameren Illinois, Aug. 10, 2017.

"S&C Completes Ameren Microgrid Project near University of Illinois Urbana-Champaign," S&C Electric Company, May 23, 2017 (https://www.sandc.com/en/news/sc-news/SandC-Completes-Ameren-Microgrid-Project-near-University-of-Illinois-Urbana-Champaign/).

Elisa Wood, "Ameren Microgrid Goes Live as First in Utility Cybersecurity," Microgrid Knowledge, May 18, 2017 (https://microgridknowledge.com/ameren-microgrid-utility-cybersecurity/).

"Ameren unveils advanced distributed energy microgrid," Electric Light & Power, May 18, 2017 (http://www.elp.com/articles/2017/05/ameren-unveils-advanced-distributed-energy-microgrid.html).

# CHAPTER 3:
# Global Case Studies

This chapter contains these seven global case studies:

1. Shanghai Microgrid Demonstration, Shanghai, China
2. Singapore Renewable Energy Integration Demonstration, Singapore
3. Palama Holdings Facility, Oahu, Hawaii
4. Bornholm Island EcoGrid 2.0, Bornholm Island, Denmark
5. Chennai Campus, Tamil Nadu, India
6. Nagoya Landfill Microgrid, Nagoya, Japan
7. Medjumbe Island Eco Resort, Mozambique, Africa

## Shanghai Microgrid Demonstration

### Project Background

This demonstration project is a collaboration between Aalborg University in Denmark and Tsinghua University in China. This project developed a "demonstrative, research-oriented platform, which aims to ease integrating distributed generation (DG) units, hierarchical and multilevel control strategies, and multiple microgrid configurations with the help of standard-based communication technology, resulting in a set of complete microgrid solutions." Table 40) To achieve its objective, the demonstration will develop, test, and assess the microgrid's performance, including the performance of individual components in the integrated system. For this project, important components include AMI and smart grid technologies.

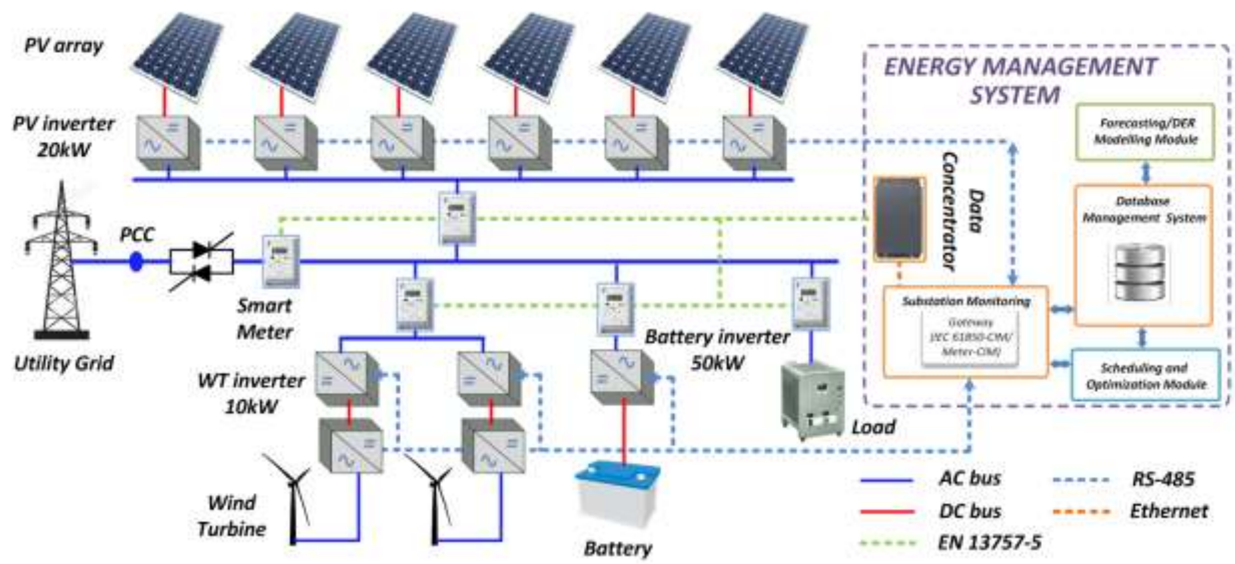
**Table 40: Shanghai Microgrid Demonstration Project Overview**

| | |
|---|---|
| **Location** | Shanghai, China |
| **Utility** | STATE GRID Corporation of China |
| **Host Organization** | Plant B HT-Shanghai Solar (manufacturing plant) |
| **Developer/Vendor(s)** | Aalborg University, Tsinghua University, Kamstrup A/S, Shanghai Solar Energy Science & Technology Co. |
| **Capacity** | 206 kW |
| **Installation Timeline** | September – December 2013 installation; 2014 – 2017 testing and commissioning |
| **Total Cost** | 2,300,000 DKK[26] ($371,400 USD at a 0.16 conversion) |

26 Danish krone.

Tsinghua University, in partnership with Shanghai Solar and Kamstrup A/S, installed the 200 kW microgrid on a Shanghai Solar manufacturing plant. At the lab in Aalborg University, researchers are modeling the microgrid implemented in Shanghai. They are working to optimize the AMI and Energy Management System (Figure 18).

**Figure 18: Shanghai Microgrid Demonstration Project Schematic**




Source: Aalborg University

## Technical Characteristics

- 136 kW rooftop solar PV
- 20 kW (2 x 10 kW) wind turbines
- 50 kW energy storage system
- Energy Management System (EMS)
- AMI and smart grid communication technology

## Costs

The total cost of the project was 2,300,000 DKK; or $371,400 USD at a 0.16 conversion rate in September 2017. Public funding provided 1,000,000 DKK and private funding provided 1,300,000 DKK for the project (56.5% private).

## Business Model

### Financing

The demonstration project was financed by the Denmark and China Renewable Energy Development (RED) Programme (1,000,000 DKK) and HT-Shanghai Solar (1,300,000 DKK) together.

### Value Proposition

The proposed solutions will facilitate planning and operational analyses. Robust stability and power quality by the proper control of the power electronics interfaces and integrating advanced metering infrastructure (AMI) and smart-grid ready communication technologies will be considered as well (Table 41).

**Table 41: Shanghai Microgrid Demonstration Project Value Proposition**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | ● | |
| Resiliency | | ● | | |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | | ● | | |
| Provision of energy and capacity services | | ● | | |
| Provision of ancillary services | | ● | | |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | ● | |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | ● | | |
| Other: N/A | ● | | | |

Source: Navigant

### Revenue Streams

As part of the demonstration project, the researchers developed a cost and revenue model to analyze and estimate the ROI of the microgrid. The ROI is calculated based on the efficiency and operating life of the microgrid. In operation, the microgrid generates revenue from the sale of electricity to the utility.

## Lessons Learned

Organizationally, it was important for the project collaborators to be able to coordinate across large distances and time differences. A central management group was established to supervise the project progress, and a project group for each participant organization was formed independently. The contact person in each group is responsible for coordinating with the other groups and the supervisor of the central management group.

Another important lesson is the importance of planning for changes over time. Policy and facility changes should be considered in depth in the project planning phase.

### Contacts & Sources

Dr. Kai Sun, Tsinghua University, August 21, 2017.

Microgrid Technology Research and Demonstration, Aalborg University (http://www.et.aau.dk/research-programmes/microgrids/activities/microgrid-technology-research-and-demonstration/).

## Singapore Renewable Energy Integration Demonstration

### Project Background

This Renewable Energy Integration Demonstration (REIDS) microgrid in Singapore is a research and development site designed to test out various, cutting-edge integration strategies to create 100% renewable energy microgrids (Table 42). It is being touted as the largest microgrid demonstration platform in the tropics. The project is led by ENGIE, a large energy company based in France. Formerly known as GDF Suez, it was France's natural gas utility and was heavily invested in large centralized plants. However, realizing that the energy industry was changing, and responding to deregulation trends sweeping across Europe, the company took on a new name, made a series of acquisitions, and refocused its business strategy as a global developer of DER, including microgrids

**Table 42: Singapore Renewable Energy Integration Demonstration Project Overview**

| | |
|---|---|
| **Location** | Semakau Island, Singapore |
| **Utility** | Energy Market Authority, Singapore |
| **Host Organization** | Nanyang Technological University, Singapore Economic Development Board |
| **Developer/Vendor(s)** | ENGIE, Schneider Electric, REC Solar, Trina Solar, XANT, McPhy Energy, Symbio Fuel Cell |
| **Capacity** | 2.8 MW |
| **Installation Timeline** | 2 years of upfront development; 2 months installation; 12 months testing for research purposes; commissioning in 2018 |
| **Total Cost** | > $3 million |

Source: Navigant

ENGIE has acquired several firms to bolster its microgrid capabilities:

- *Tractebel Engineering*: An engineering and consulting firm that has developed a resource sizing tool for microgrids.
- *Green Charge Networks:* A distributed energy storage company focused on software optimization and integration of electric vehicles into utility grid to provide ancillary services.
- *Opterra*: Formerly Chevron Energy Solutions, a system integrator for DER projects, including microgrids such as the Santa Rita Jail in Alameda County, California.

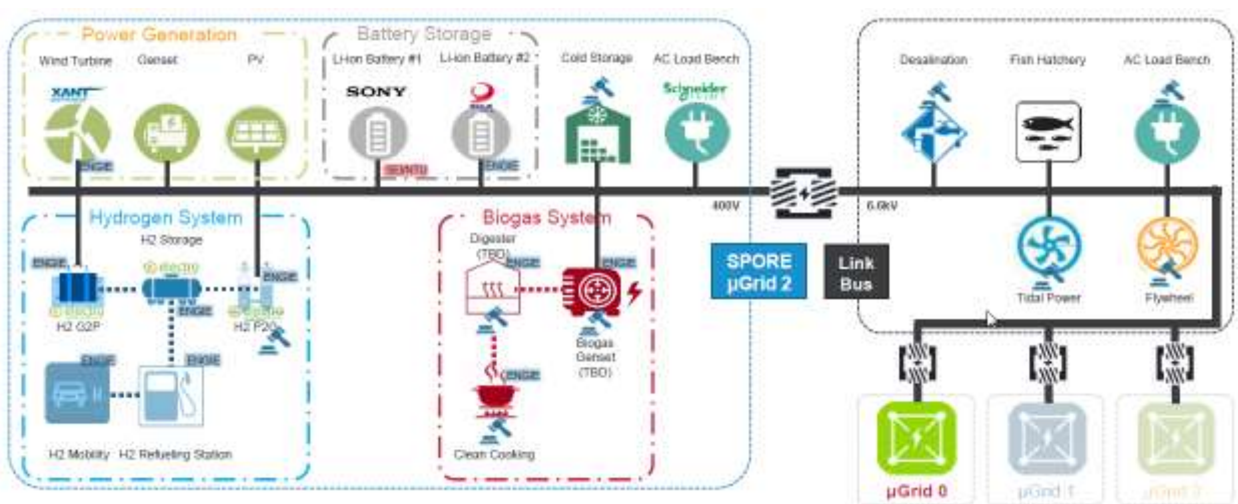
Located about eight kilometers south of Singapore's main island, Semakua is a site for landfill waste that is increasing the size of the island over time. The island is not connected to the utility grid. As such, it provides a laboratory to resolve grid stability and renewable integration issues. The demonstration is targeting a “multi-fluid” solution, pairing renewables with batteries, and using technologies based on hydrogen and biogas. The project is designed to generate not only clean electricity, but clean water, clean cooking, and clean mobility services that will have wide applications in remote communities around the world. The project is also focused on ease of deployment, infrastructure robustness, and low ongoing operational costs.

The entire REIDS microgrid project will consist of four distinct, modular microgrids that can use different components (grow or shrink) based on the use case (Figure 19). The first microgrid will be completed in 2017 and commissioned in early 2018. The remaining three microgrids are also expected to come online in 2018.

## Technical Characteristics

- 200 kW solar PV
- 100 kW wind turbines
- 50 kW Hydrogen Power to Power System
- 30 kW natural gas generator
- 2.2 MW diesel generator
- 200 kW Li-ion battery
- Other energy storage: redox flow battery, supercapacitors, flywheel, and compressed air storage

**Figure 19: Singapore Renewable Energy Integration Demonstration Diagram**




Source: ENGIE

## Costs

The microgrid demonstration cost is confidential, but ENGIE shared that it will be more than $3 million, for scale.

## Business Model

The ENGIE "Center of Excellence" Lab in Singapore features ENGIE employees working on cutting-edge energy research in conjunction with Nanyang Technological University. All told, 1,600 ENGIE employees now reside in Singapore. While ENGIE funded this R&D venture, the project's purpose is to demonstrate replicable microgrid concepts which can then be used throughout southeast Asia, with a total population of 625 million, the majority of which do not have access to traditional utility grade power services. This lab is one of 11 research centers ENGIE has created across the globe.

This microgrid demonstration is designed to define and validate technical use cases, economical models, and integration concepts for multiple DER. The end goal is to replicate the microgrid using a similar design throughout the region.

### Financing

The project is financed directly by ENGIE with supplementary support from the Economic Development Board. Nanyang Technological University and National Environmental Agency of Singapore played supporting roles.

### Value Proposition

Perhaps the most innovative aspect of this microgrid is using hydrogen as an energy storage medium (Table 43). Excess renewable energy generated from wind and solar is converted into hydrogen via electrolysis. Some of this hydrogen is diverted to motor vehicles, with the residual hydrogen combusted in a fuel cell. ENGIE is also testing the performance of its energy management system (EMS). The power controls that make up the power management system (PMS) from Schneider Electric are capable of instant optimization based on weather and energy consumption data to minimize operating costs and environmental impacts. The EMS is also designed to address mid-term and long-term optimization goals, such as a maintenance schedule designed to extend the life of DER assets while minimizing replacement costs.

### Revenue Streams

Because the system is targeting off grid customers, there are no available opportunities for traditional grid-tied microgrid revenue streams. However, the ability to use excess renewable energy to create hydrogen fuel for transportation is a potential revenue stream for other applications. Additionally, the provision of thermal energy is an additional benefit attributable to the microgrid.

## Lessons Learned

The partnership between ENGIE and Schneider Electric was designed to validate a package of infrastructure services revolving around electricity, but also to integrate with mobility and other requirements for remote islanded applications. ENGIE served as the equipment integrator and provided the EMS; Schneider Electric also contributed to the microgrid control system solution with its PMS software and controls products.

**Table 43: Singapore Renewable Energy Integration Demonstration Value Proposition**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | | | ● | |
| **Provision of energy and capacity services** | | ● | | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | | | ● |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | | | | ● |
| Linkage to Virtual Power Plant | | | ● | |
| Other: N/A | ● | | | |

Source: Navigant

Both companies learned how to overcome scalability challenges with both greenfield and brownfield plug-and-play microgrid solutions. An important innovation resulting from this R&D collaboration is an algorithm associated with a virtual synchronous generator, allowing for the microgrid to reach 100% renewable supply at points in time. Also, a multi-fluid optimization module was developed to enhance synergies between variable and decentralized DER in a cost-effective manner.

### Contacts & Sources

Interview with Etienne Drouet, ENGIE, June 28, 2017 and August 28, 2017.

"ENGIE chooses Singapore for its green-energy R&D centre of excellence in Southeast Asia," ENGIE press release, July 11, 2016 (https://www.engie.com/wp-content/uploads/2016/07/pr-engie-lab-singapore.pdf).

## Palama Holdings Facility

### Project Background

Palama Holdings is a 13-year old, local Hawaiian company that owns a meat processing plant and H&W Food Services, which delivers food to restaurants, military bases, and other customers. Palama Holdings had been looking at investing in a microgrid for several years, but at first found costs to be prohibitive. As the cost of solar PV and batteries kept falling, the microgrid project finally hit a price point that, when paired with available incentives, allowed the project to pencil out (Table 44).

The cost of electricity for commercial and industrial (C&I) customers in Hawaii are extremely high. The demand charge component is particularly problematic. Unlike the US mainland, where demand charges are typically based on a 30-day peak, HECO imposes its demand charge based on a 12-month rolling peak. As a result, a facility such as Palama Meats pays twice as much for electricity as a similarly sized meat processing facility based in Los Angeles, California. Though costs have declined over the past two years, the cost per kWh still falls in the 22-23 cents per kWh range.

**Table 44: Palama Holdings Facility Project Overview**

| | |
|---|---|
| **Location** | **Oahu, Hawaii**[27] |
| **Utility** | Hawaiian Electric Company (HECO) |
| **Host Organization** | Palama Holdings (Palama meat processing; H&W Food Services) |
| **Developer/Vendor(s)** | EnSync Energy, Holu Energy (subsidiary of EnSync) |
| **Capacity** | 0.62 MW |
| **Installation Timeline** | 1 year total (including 5 months up-front planning and design; 6 months installation; 1 month testing and commissioning) |
| **Total Cost** | $2.53 million |

Source: Navigant

Beyond cost drivers for microgrids, Hawaii is also vulnerable to hurricanes, tsunamis, and earthquakes. In 2006, the power was out for areas of Oahu for more than 24 hours because of island-wide generator automatic shutdowns from an earthquake. In 1992, the island of Kauai was hit with a Category 4 hurricane that knocked out power for weeks. On an island, the provision of food becomes a vital service to the community, so resilience at this C&I facility could also provide community benefits during emergencies.

## Technical Characteristics

- 410 kW solar PV
- Total battery capacity is 214 kW/424 kWh
    - Two 65 kW/44 kWh Li-ion "power" batteries
    - Two 42 kW/84 kWh Li-ion "energy" batteries

## Costs

The total cost was $2,532,070.

## Business Model

### Financing

The owner – Palama Holdings – considered direct financing for the project, but opted for a purchase power agreement (PPA) to minimize risk and capital requirements, and to better align with the structure of the company itself. The decision was based on a pro forma model

27 This project is included in Global Case Studies rather than North America because it has greater similarities with remote and island-based microgrids that are more common globally.

developed by the vendor team. The project was financed by the system owner on its balance sheet, using debt for operational funding.

**Value Proposition**

The two primary value propositions were cost reductions and resilience (Table 45). In the long term, the customer is interested in being able to participate in grid service revenue opportunities as well as energy arbitrage opportunities available with future TOU electricity rates. The key technology to realizing value propositions is EnSync's DER Flex platform, which optimizes the internal resources of the microgrid and sets the stage for export of grid services externally (Figure 20).

**Table 45: Palama Holdings Facility Value Proposition**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | | ● |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | | | ● |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | ● | |
| Other: N/A | ● | | | |

Source: Navigant

**Figure 20: EnSync DER Flex Platform**


Source: EnSync

**Revenue Streams**

At present, the microgrid reduces costs by prioritizing lower-cost renewable energy to service the customer's electrical loads and by enabling demand charge abatement strategies. However, Hawaii is revamping its energy markets. Current proposals from HECO to the Hawaii state regulators would create a "grid service purchase agreement" (GSPA) contract structure. The theory behind these proposed contracts is to integrate additional energy storage systems and smart inverters into the power grid. The costs of these devices may be able to be put into the utility rate base if they are determined to be necessary equipment for the creation of grid services. If such a market opens up on Oahu, this microgrid would be capable of generating revenue by delivering grid services such as demand response and frequency regulation through the DER Flex controller.

## Lessons Learned

It is critical to install monitoring to understand how to best match solar PV and storage with the facility load to achieve ongoing cost savings and the level of resiliency required by the facility. Such data was critical for optimizing system size as well as for prioritizing value streams to achieve customer objectives, and for positioning the system for future participation in the grid services market to further optimize system value.

Effective and efficient solar plus storage project planning, design, and financial viability all rely on innovative modeling capabilities. EnSync Energy has built integrated models that consider the myriad of variables when designing for "right-size" design and optimal financial performance. EnSync Energy had previously been unable to source modeling software that met its requirements, so it built a proprietary model that considers all variables, such as load characteristics, back-up requirements, optimal solar generation, and the appropriate ratio of hybrid energy storage applications ("power" and "energy" batteries). The resultant model informs a system that utilizes all available energy resources to provide the most cost-effective, highest value, and reliable electricity.

The timing of project development was also heavily impacted by available state incentives. State credits for DER assets such as solar PV have a cap. Phase 1 of this project had to be online by end of 2018 to qualify for these state incentives. The microgrid is scheduled to be completed by the second quarter of 2018.

### Contacts & Sources

Interview with Ted Peck, Holu Energy, August 11, 2017.

Interview with Dan Nordloh, EnSync Energy, August 11, 2017.

## Bornholm Island EcoGrid 2.0

### Project Background

EcoGrid 2.0 is a demonstration project on the Danish island of Bornholm (Table 46). EcoGrid EU, its predecessor, has ended. The Bornholm Island system is larger than a typical microgrid, but is capable of islanding from the main grid (the Nordic interconnected power system)—and does, when the undersea cable to Sweden requires repairs. Under normal conditions, the system has a high penetration of wind and some solar power. When islanded, it depends significantly on fossil fuel generation.

**Table 46: EcoGrid 2.0 Project Overview**

| | |
|---|---|
| **Location** | Bornholm Island, Denmark |
| **Utility** | Bornholms Energi og Forsyning / prev. Østkraft |
| **Host Organization** | Various locations and homes on Bornholm Island |
| **Developer/Vendor(s)** | Danish Energy Association (Dansk Energi), Technical University of Denmark (DTU), Bornholms Energi og Forsyning (Bornholm's Energy & Supply), IBM, Insero Software, Uptime-IT, Krukow, Copenhagen Business School, and 2+1 Idebureau |
| **Capacity** | 112.5 MW |
| **Installation Timeline** | January 2016 – June 2019 |
| **Total Cost** | DKK 98 million |

EcoGrid 2.0 involves the participation of 1,000 families on the island (compared to 2,000 families in EcoGrid EU) (Figure 21). EcoGrid EU tested ways to control consumption through price signals in a load shifting and demand response type model; residents would receive price signals directly and respond by modifying their home electricity consumption. EcoGrid 2.0 is leveraging the previously installed equipment from EcoGrid EU, but is introducing a market for flexibility, where EcoGrid 2.0 acts as an aggregator controlling household heating for residents. The goal is to create a market where the aggregator responds to bid requests from the Transmission System Operator (TSO) and Distribution System Operation (DSO). For demonstration purposes, EcoGrid 2.0 is a parallel trading platform to existing markets.

**Figure 21: Bornholm Island**

Source.

Another recent project on Bornholm Island is ACES, a Vehicle-to-Grid (V2G) demonstration between Bornholm's Energy & Supply, NUVVE, Nissan, and DTU's Department of Electrical Engineering. This project will simulate a full-scale penetration of EVs on Bornholm to assess how the fleet can be integrated into the grid, and deploy a small real-world pilot project with up to 50 Nissan EVs on Bornholm.

## Technical Characteristics

- 29 MW wind
- 6.5 MW solar
- 2 MW biogas
- 16 MW CHP
- 25 MW oil-fired steam generators
- 34 MW backup diesel generators
- 22 EVs (ACES)

## Costs

EcoGrid 2.0 has a total budget of DKK 98 million. The ACES project has a total budget of DKK 10.2 million.

## Business Model

### Financing

As an R&D effort, EcoGrid depends on funding from a variety of partners. Partners contribute funds based on how large the organization is. Bornholm's Energy & Supply, as a "large" (publicly-owned) company, funded approximately 50% of the project. The Danish Energy Agency's Energy Technology Development and Demonstration Program provided DKK 49 million.

The ACES project received 5.5 million DKK in public funding from the same program.

### Value Proposition

EcoGrid EU learned two valuable lessons related to the value proposition for residents of Bornholm Island (Table 47). First, the power bill in Denmark is constructed from many taxes and fees, and actual power consumption is only 15-20% of the total. This means that families who reduced energy consumption in response to price signals – sometimes waking up at 2 AM to do laundry with low electricity prices – saw very little economic benefit. Accordingly, participation was low. Second, Bornholm families are nonetheless very interested in clean energy and sustainability – they *want* to participate, they just don't want to be inconvenienced or uncomfortable (i.e., the program must keep their homes heated within comfortable limits and no 2 AM wake-up calls). EcoGrid 2.0 is attempting to find the right value proposition through the flexible market approach where households can participate under the control of the aggregator.

The ACES project is investigating the value proposition for participating EVs to sell frequency regulation services to the grid, which is the underlying service of NUVVE's platform. Currently, there are 22 EVs on Bornholm Island preparing to test this concept in the small pilot with Bornholm's Energy & Supply. A large fleet of EVs could also potentially provide peak shaving and balancing services to the grid.

**Table 47: EcoGrid 2.0 Value Proposition**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | ● | | |
| Resiliency | | ● | | |
| Bill savings / demand charge abatement | ● | | | |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | | ● |
| Provision of ancillary services | | | | ● |
| Reduction of carbon footprint | | | | ● |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | | | | ● |
| Linkage to Virtual Power Plant | | | | ● |
| Other: N/A | ● | | | |

Source: Navigant

### Revenue Streams

EcoGrid 2.0 is operating a flexible market, aggregating the heating load of the 1,000 participating families to respond to respond to the needs of the TSO and DSO (either load increase or reduction). When there are differences between the predicted energy consumption and predicted renewable generation, the operators request bids demand response services. EcoGrid bids into the market with the amount of renewable energy it can export to the larger grid; if

EcoGrid must reduce the amount of renewable energy on the grid, it will use the excess to heat homes on Bornholm.

EcoGrid is also investigating other products and services (focused on electric heating) that could be offered by the aggregator that would encourage households to participate. One example would be "heating as a service," where the aggregator would install a heat pump in the customer's home, and the customer would pay only for the heat delivered. Other examples are to offer a heat pump service plan or to provide an app for residents to control the temperature of their homes remotely.

### Lessons Learned

The lessons learned in EcoGrid EU directly influenced the design of EcoGrid 2.0. One of the biggest challenges is that because the power component of the electricity bill is so small, it creates very little economic benefit for the end-user to participate in EcoGrid. But EcoGrid EU also learned that Bornholm residents are very willing to be flexible with power consumption to help the environment – without economic benefit – as long as they can remain within their comfort zones. Accordingly, EcoGrid 2.0 controls the heat in homes automatically within the allowed temperature range, to provide flexible load to the system operators.

Another major lesson involves communications infrastructure. As part of the project, all the 2,000 active households in EcoGrid EU received smart meters from Østkraft, intended to collect 5-minute interval data using the DSO's network infrastructure. However, the infrastructure was not capable of handling the vast quantity of data. Two full-time staff were required to keep the meter system running. Even with 1,000 homes in EcoGrid 2.0, the infrastructure is still not sufficient. EcoGrid 2.0 is collecting 12-hour interval data, but would need to use much smaller intervals for a real-world project. The current model is not scalable in terms of staffing, either. Future projects should address communications infrastructure needs at the beginning.

### Contacts & Sources


Interview with Kim Kock-Hansen, Bornholm's Energy & Supply (https://beof.dk/), September 6, 2017.

EcoGrid website (http://www.ecogrid.dk/en/home_uk).

"About EcoGrid," EcoGrid (http://ecogridbornholm.dk/om-ecogrid/).

ACES website (https://sites.google.com/view/aces-bornholm).


## L&T Chennai Campus

### Project Background

Larsen & Toubro (L&T) is a large engineering, technology, construction, manufacturing, and financial services conglomerate valued at $17 billion and with customers in over 30 countries around the world. L&T Construction is the construction arm of L&T; it is India's largest construction organization offering engineering, procurement, and construction (EPC) solutions with single-source responsibility for executing large industrial and infrastructure projects from concept to commissioning.[28] The company has proven capabilities for executing all types of mega-projects on a turnkey basis (design and construction services including procurement, supply, installation, testing and commissioning).

L&T Construction's solar business is one of India's largest solar EPC players, with approximately 1 GW of projects incorporating various technologies. The company offers services for Utility Scale Solar PV & CSP projects and DER projects such as rooftop solar PV, fuel cells, solar pumps, microgrids, and energy storage.[29]

L&T Construction's campus headquarters at Manapakkam in Chennai is a hub for developing solutions for a range of business applications, among which renewable energy initiatives are prominent. Acquired in 1961, the campus is spread over 27 acres. Almost every campus structure has won prestigious awards for excellence in construction and features green designs. The Engineering Design and Research Centre, Technology Centre II, and Technology Centre III all meet LEED green building standards.

The entire campus has grid-connected solar PV systems on rooftops; this was the company's first solar pilot project installed in 2008 (Figure 22). The approximately 1 MW system has been operational since 2009, and features different modules, inverters, and balance of system component technologies (Table 48). It features a unique east-west wave configuration that generates 6% more electricity than a standard south-facing solar array. Solar street lighting is also provided on campus. L&T has also developed an 8.7 MW wind farm in Tamilnadu, which provides electricity to the campus.

Along with other recent advancements in energy systems, L&T's Solar Business has also initiated a pilot microgrid project at the Technology Centre II building.

28 L&T Construction contains eight related business lines: Buildings & Factories, Metallurgical & Material Handling, Transport Infrastructure, Heavy Civil Infrastructure, Power Transmission & Distribution, Water & Effluent Treatment, Smart World & Communications.

29 http://www.lntecc.com/homepage/RenewableEnergy/home.html

**Figure 22: L&T Chennai Campus Micro-Wind Turbines**

Source: L&T Construction

**Table 48: L&T Chennai Campus Project Overview**

| | |
|---|---|
| **Location** | Chennai, Tamil Nadu, India |
| **Utility** | State Electricity Board |
| **Host Organization** | Larsen & Toubro (commercial campus) |
| **Developer/Vendor(s)** | L&T Construction (construction arm of Larsen & Toubro) |
| **Capacity** | 1.82 MW |
| **Installation Timeline** | 12 months |
| **Total Cost** | < $2 million |

Source: Navigant

## Technical Characteristics

- 130.5 kW solar PV
- 7.2 kW micro-wind power
- 10 kW/32kWh Li-ion battery energy storage system
- 2 x 808 kW diesel generators

In addition to the energy generated from this pilot microgrid project, the campus also benefits from a 569.5-kW solar PV installation and a 15-kW biogas plant (Figure 22).

## Costs

L&T Construction estimates the total cost of the microgrid is less than $2 million.

**Figure 23: L&T Chennai Campus Technology Centre II Microgrid Features**


Source: L&T Construction

## Business Model

### Financing

The microgrid was 100% financed by L&T Construction.

### Value Proposition

The primary drivers for L&T Construction to develop the microgrid included:

- Piloting the microgrid inside its own campus with a detailed study and monitoring.
- Increasing the renewable energy portion of the campus generation portfolio.
- Increasing campus power reliability and sustainability.

The internal metrics used to determine whether to proceed with the microgrid included all standard value proposition evaluations, including ROI, IRR, NPV, and payback period (Table 49).

**Table 49: L&T Chennai Campus Value Proposition**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | | ● |
| Resiliency | | | | ● |
| Bill savings / demand charge abatement | | | ● | |
| Future transactive energy revenue | | ● | | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | ● | | |
| Reduction of carbon footprint | | | | ● |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | ● | | |
| Other: N/A | ● | | | |

Source: Navigant

**Revenue Streams**

The power generated from on-site assets is consumed by the campus; none is exported back to the grid.

## Lessons Learned

The integration of the microgrid into the existing power infrastructure of the Technology Centre II building enhanced the overall power stability, efficiency, and resilience of the facility. It also enabled faster control and monitoring of loads and generation sources. The microgrid has enabled L&T to power the building with renewable sources at times when they are abundant, thereby reducing the reliance on conventional DG sources and deferring consumption from utility power. Load "controllability," which is one of the key microgrid offerings, facilitates load distribution, shedding, and shifting with regards to utility supply availability, renewable supply availability, and peak demand, thereby reducing the onus on the power system. Since this microgrid was a brownfield project, the technical complexities were significant. The constraints were identified and tackled in the engineering and design phase, ensuring smooth execution and operation of the system.

## Contacts & Sources

Interview with Harshitha Kumar, Microgrid and Energy Storage Business, Solar Business Unit, Power transmission & Distribution Vertical, L&T Construction, June 15, 2017.

# Nagoya Landfill Microgrid

## Project Background

The Nagoya Landfill Microgrid is a solar PV plus energy storage system built atop a completed landfill (Table 50). The landfill owners wanted to increase the value proposition of the property, and considered a microgrid to accomplish this goal. Thanks to Japan's rapid adoption of distributed renewable energy systems, the local feeders are saturated with solar PV, so a special feed-in tariff (FiT) provides incentives for exporting dispatchable renewable power using energy storage. Since Japan is phasing out large centralized nuclear power plants, and seeking to reduce reliance upon imported fossil fuels, "firming up" distributed solar PV is a top priority for utilities and regulators.

**Table 50: Nagoya Landfill Microgrid Project Overview**

| | |
|---|---|
| **Location** | Nagoya, Japan |
| **Utility** | Chubu Electric Power Company, Inc. |
| **Host Organization** | Local Landfill |
| **Developer/Vendor(s)** | Optimal Power Solutions |
| **Capacity** | 0.7 MW |
| **Installation Timeline** | Commissioned in December 2014; installation took less than one year |
| **Total Cost** | $1,500,000 |

Source: Navigant

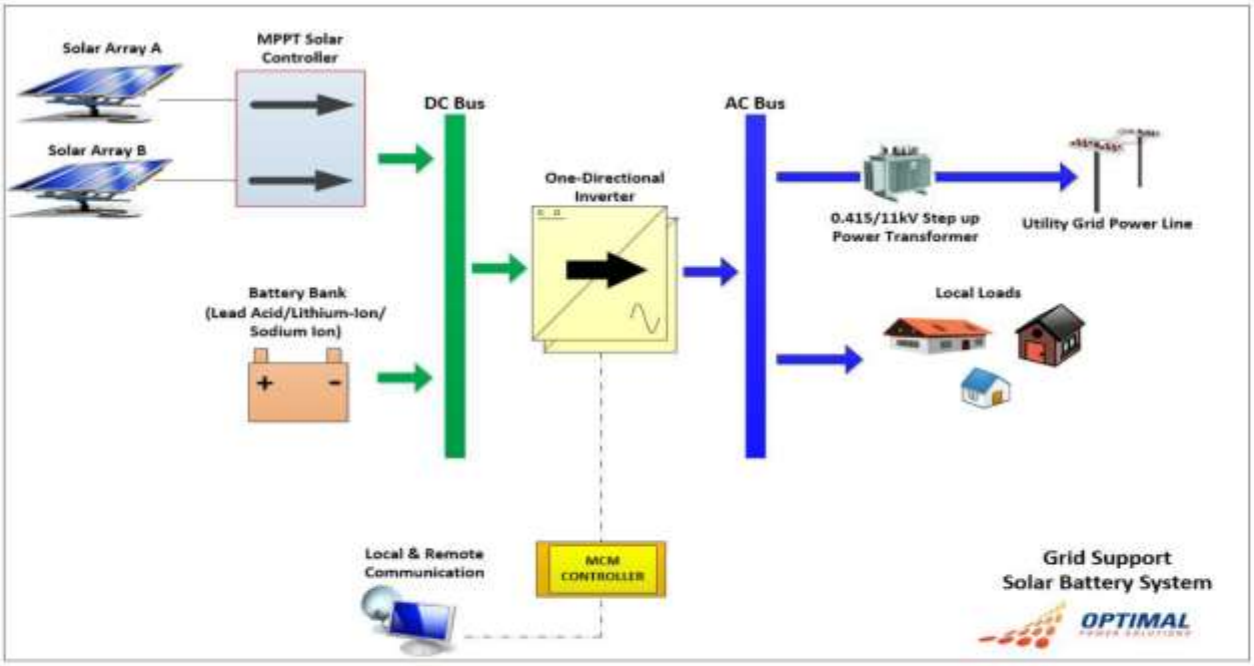
Optimal Power Solutions (OPS) of Australia, offers one-way and bi-directional inverters, microgrid controls, and system integration services, and was the lead developer for this project (Figure 24). Because the host site is a landfill – covered with about six feet of soil and paved over – it cannot be used for most types of construction. The microgrid installation is an opportunistic use of the approximately 2-acre site.

## Technical Characteristics

- 0.5 MW solar PV
- 0.2 MW/1.2 MWh lead-acid battery bank

Lead-acid batteries were chosen for their low cost. However, with lithium-ion battery prices falling rapidly, the project investors envision ultimately replacing the battery bank with low-cost li-ion batteries at the end of the battery bank's life – or approximately six years after initial commissioning.

**Figure 24: Nagoya Landfill Microgrid Project Schematic**




Source: Optimal Power Systems

## Costs

The total cost of the project was approximately $1,500,000.

## Business Model

### Financing

The primary project investor provided approximately 10% of the funding. The remainder was financed by a third party, in return for routine payments over the 15-year lifetime of the project. Many banks in Japan are "cash rich," since the economy in Japan does not offer many lucrative short-term financial opportunities. Though returns on a project such as this one may seem modest by US standards, such projects appear attractive within the context of the Japanese economy. One of the challenges facing financiers is that the FiT is not fixed, and may go up and down over time. This uncertainty adds another layer of complexity to the financing.

### Value Proposition

The microgrid provides battery-based, long-duration dispatch of solar PV energy to provide firm capacity during peak demand periods, and offers a resilient power source to local properties in case of a grid outage (Table 51).

The local utility feeders are saturated with solar PV, limiting the value of additional solar output in the late morning and early afternoon. However, in part to drive continued adoption of renewable power, regulators instituted a special FiT that provides incentives for solar PV plus energy storage systems that can dispatch to the grid during the peak load times. To do this, the solar PV system charges the battery bank during the day. Grid import is not allowed, so a onedirectional inverter (as seen in the diagram) is sufficient. The battery bank then discharges, typically during the peak net load period (4 PM to 9 PM), though sometimes as late as 2 AM. The battery bank is rated for six hours, but sometimes discharges for 8-10 hours in total.

**Table 51: Nagoya Landfill Microgrid Value Proposition**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | ● | | |
| Resiliency | | | ● | |
| Bill savings / demand charge abatement | ● | | | |
| Future transactive energy revenue | | | ● | |
| Provision of energy and capacity services | | | ● | |
| Provision of ancillary services | | | ● | |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | | ● |
| Services beyond electricity (thermal, water, etc.) | ● | | | |
| Linkage to Virtual Power Plant | | | ● | |
| Other: N/A | ● | | | |

Source: Navigant

**Revenue Streams**

The primary revenue stream is in the form of special tariffs, paid by the utility. There is potential for future aggregation of multiple such systems into a single virtual power plant, though this project currently functions on its own.

The simple payback of the system is expected to be around 4 years, or possibly sooner given optimal tariff paybacks.

## Lessons Learned

The biggest lessons from this project for the Australia-based developer were the intricacies of Japanese utility interconnection requirements, which continue to become more complex as the grid takes on more DER. The local utility in Nagoya details several documents that restrict reverse power flow alone, including “Interpretation of technical standards for electrical equipment,” “Grid-interconnection Technical Requirements Guidelines on Electric Power Quality,” “Grid Interconnection Code,” and others.[30]

The keys to a successful microgrid project in Japan are a thorough understanding of the local utility requirements and an understanding of the customs and culture. Japanese utilities have historically been quite conservative, having been highly dependent on large baseload resources. In response, they have often sought to make variable renewables more dispatchable, though

30 http://www.chuden.co.jp/english/corporate/ecor_releases/erel_other/__icsFiles/afieldfile/2013/06/26/0509e.pdf

developers have described some of the utilities' efforts in this regard to be "pedantic" and prohibitive toward microgrid development. The special FiT that enabled this project is just one example of how utilities are adapting to a new world where DER dominate new supplies.

### Contacts & Sources

Interview with Stephen Philips, Optimal Power Solutions, August 22, 2017.

## Medjumbe Island Eco Resort

### Project Background

The owners of the Anantara Holiday Resort (Figure 25) wanted to install a renewable generation source to displace expensive diesel fuel, lessen the local environmental impacts of diesel generation, and showcase the island to eco tourists. The remote island is 150 kilometers from the nearest shore, which also makes the delivery of the drums of diesel an expensive undertaking.

**Figure 25: Anantara Holiday Resort, Medjumbe Island**

Source: Optimal Power Systems

On the island, wind resources are not sufficient for electric generation. Biomass resources are also too limited to be a sustainable energy source. Furthermore, cutting down trees on the small island for electricity generation would also detract from the goal of providing an upscale eco-tourism experience. The only viable renewable resource was solar energy. The microgrid consists of a new solar PV array, battery bank, and hardware and controls that are used to supplement the diesel generator and cut its diesel consumption. Optimal Power Solutions (OPS) of Australia is the developer of the project (Table 52).

**Table 52: Medjumbe Island Eco Resort Project Overview**

| | |
|---|---|
| **Location** | Medjumbe Island, Mozambique |
| **Utility** | None (private island) |
| **Host Organization** | Eco Resort Group (Anantara Holiday Resort) |
| **Developer/Vendor(s)** | Optimal Power Solutions |
| **Capacity** | 0.675 MW |
| **Installation Timeline** | 1 year for initial design and approvals; 3 months for procurement & manufacturing; 2 months for international sea shipping; 7 weeks installation; 2 weeks commissioning and startup; operational in 2016 |
| **Total Cost** | Approximately $1 million |

Source: Navigant

## Technical Characteristics

- 275 kW solar PV
- 220 kW diesel generator
- 180 kW/720 kWh lead-acid (VRLA gel type) battery bank
- Power electronics solutions, Optimal Power Parallel-PIM inverters, high-power MPPT chargers, and the Prescient U10 micro-grid controller platform

## Costs

The cost of the microgrid was approximately $1 million for the solar PV, energy storage system, and other hardware, including logistics and planning. The diesel generator existed before the microgrid, and therefore is not included in these costs.

## Business Model

### Financing

The project was financed with a debt and equity contract from the owner's European bank. The owner contributed approximately 25% of the funding, with the bank contributing the remainder.

### Value Proposition

The key value propositions are related to cutting costs, cutting carbon and other emissions, and enhancing the brand of the eco resort (Table 53). Cost reduction is primarily driven by displacing diesel fuel that would have otherwise been burned for power. By the same token, the project avoids carbon dioxide and criteria pollutant emissions, along with the sound pollution of the diesel generator on the small island.

Reducing diesel generator operating time also allowed for "quiet periods" in the evening, which enhance the resort experience. These types of intangible benefits, not captured by traditional metrics, were the primary attractions to the resort owners and let them to move forward with the solar PV and energy storage remote microgrid.

**Revenue Streams**

The revenue streams are based on avoided diesel power generation costs. Total diesel displacement is approximately 30%. Beyond the diesel fuel savings, the lowered demand on the generator can help reduce maintenance costs, which is of significant value on this remote island. The payback timeframe for the project is about 3.5 years, even with the current low cost of oil. (When the project was first conceived, the price of oil was much higher.)

## Lessons Learned

The key hurdle the project had to overcome was conveying both the value and obligations associated with the new microgrid to the operators. In much of the developing world, many power users simply accept that power will be available for just a few hours per day, so the value of 24/7 power can require a sales pitch. Future microgrids for eco resorts under similar circumstances will benefit from clear communication of all benefits and costs up front.

**Table 53: Medjumbe Island Eco Resort Microgrid Value Propositions**

| Category | Not Important | Somewhat Important | Very Important | Essential |
|---|---|---|---|---|
| Reliability | | | ● | |
| Resiliency | | ● | | |
| Bill savings / demand charge abatement | | | | ● |
| Future transactive energy revenue | ● | | | |
| Provision of energy and capacity services | ● | | | |
| Provision of ancillary services | ● | | | |
| Reduction of carbon footprint | | | ● | |
| Renewable energy integration | | | ● | |
| Services beyond electricity (thermal, water, etc.) | | ● | | |
| Linkage to Virtual Power Plant | ● | | | |
| Other: N/A | ● | | | |

Source: Navigant

Additionally, the operators required training to understand the additional O&M requirements of the system. Developers must recognize the limits of available human capital and then design a microgrid with appropriate technology. Developers should ask: What is the available skilled labor on such a remote island, and how does it impact the selection of inverters, mini-SCADA systems, and other microgrid enabling technologies? Such projects are generally custom-engineered for specific applications. Typical considerations such as warranties and performance guarantees must be carefully structured under these market conditions.

## Contacts & Sources

Stephen Philips, Optimal Power Solutions, 8/22/2017

"Medjumbe Island, Mozambique for Anantara Holiday Resort," Optimal Power Solutions (http://optimal-power-solutions.com/blog/2016/03/ops-delivers-advanced-solar-hybrid-system-to-island-resort-in-mozambique/).

# GLOSSARY

| Term | Definition |
|---|---|
| CHP (Combined Heat and Power) | Also known as cogeneration. It is the concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy. |
| DER (Distributed Energy Resources) | Smaller power sources that can be aggregated to provide power necessary to meet regular demand. |
| DG (Distributed Generation) | The generation of electricity for use on-site, rather than transmitting energy over the electric grid from a large, centralized facility (such as a coal-fired power plant). |
| EPIC (Electric Program Investment Charge) | The Electric Program Investment Charge, created by the California Public Utilities Commission in December 2011, supports investments in clean energy technologies that benefit electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company. |
| PPA (Power Purchase Agreement) | A contract between two parties, one which generates electricity (the seller) and one which is looking to purchase electricity (the buyer). |
| SGIP (Self-Generation Incentive Program) | The California Public Utilities Commission's program providing incentives to support existing, new, and emerging DER. |
| TOU (Time of Use) | Time-of-use rates better align the price of energy with the cost of energy at the time it is produced. |
| UPS (Uninterruptible Power Supply) | An electrical apparatus that provides emergency power to a load when the input power source or mains power fails. |
| VPP (Virtual Power Plant) | A smart grid network that links retail markets to wholesale markets. The primary goal of a VPP is to achieve the greatest profit for DER asset owners while maintaining the proper balance of the electricity grid at the lowest economic and environmental cost. |