Developing a Low-Carbon Microgrid on Tribal Lands: A Case Study

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ABSTRACT

The Blue Lake Rancheria (BLR) Tribe is developing a low-carbon, community-scale microgrid that will be completed in late 2016. The project has economic, emergency preparedness, power reliability, emissions reductions, and environmental benefits, and demonstrates a repeatable, scalable solution for similar areas and facilities throughout California and the nation. BLR is located in Humboldt County in Northern California, connected to the statewide electric grid by a single ~70 MW transmission line. Power interruptions and outages are frequent due to technical and natural factors and are an ongoing threat to the region. The BLR microgrid will provide resilient, distributed electrical power supply from renewable power generators on-site. Controllable loads and energy storage will interact via smart controllers to optimize the performance of the overall system, allowing the microgrid to transition from grid-connected to islanded mode. Cost can be a barrier to broader adoption of microgrid technology, including renewable energy generation and energy storage; payback timelines are typically long and uncompetitive, and installations nationwide have been few. BLR's microgrid project helps address cost issues by demonstrating a robust, replicable, cost-effective microgrid package. The lessons learned from implementation will inform and improve the next generation of microgrid hardware/controllers and battery storage to drive down costs and increase reliability.

Introduction

Native American communities have a long history of cultural and economic resilience. Local self-reliance, environmental stewardship, respecting the carrying capacity of the land, and strengthening community are tribal communities' traditional strengths, and are now valued attributes for coping with current and future environmental, economic, and social changes caused by a changing climate and other natural and man-made disasters. The Blue Lake Rancheria (BLR) Tribe, in coastal Northern California (see Figure 1), is continuing this tradition of stewardship and resilience with the development of a low-carbon, community-scale microgrid that will be completed in late 2016. This paper discusses the rationale for the microgrid and the background of BLR, the microgrid components and operations, and lessons learned. This paper is organized as follows:

- Rationale for the Microgrid
- BLR Background
- Microgrid Basics
- Controls and Analytics
- Ratepayer Impacts and Benefits
- Microgrid Partnerships
- Lessons Learned

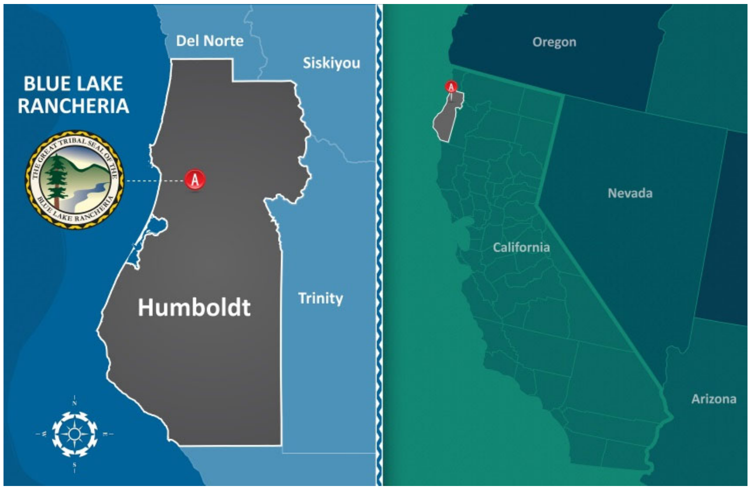

Figure 1. Blue Lake Rancheria Location. Source: Blue Lake Rancheria.

Rationale for the Microgrid

Over the course of millennia, the coastal zones of the Pacific Northwest have been forcibly shaped by the natural world. An area of relative climatic stability, with cool waters creating foggy habitats perfect for redwood and other large tree species, the region is also subject to frequent and catastrophic storms, floods, forest fires, earthquakes and tsunamis (Henderson 2014). In Humboldt County, there is an ever-present risk of isolation from landslides that create impassable road barriers to emergency and other vehicle movement. Non-redundant fiber-optic conduits are frequently damaged by negligence or vandalism, impacting communications. And our widely dispersed, socio-economically disadvantaged populations are, even in the best of circumstances, hard to reach, and have limited resources to respond to calamity. When the Fukushima earthquake struck on April 11, 2011, in the period of uncertainty about the scale of the resulting tsunami, thousands of Humboldt County residents self-evacuated from the Pacific coast and came inland to higher ground. Within an hour, the Blue Lake Rancheria (BLR) Tribe found itself host to over 1,000 vehicles and countless panicked people. That event propelled the Tribe into aggressive action to serve its community and the region as an evacuation center and emergency shelter.

Electric power provides a good illustration of the precarious infrastructure situation along California's North Coast. Humboldt County is connected to the statewide electric grid by a single ~70 MW transmission line. Power interruptions and outages are frequent due to technical and natural factors; past outages have lasted from several days (2005) to several weeks (1964), and are an ongoing threat to the region. The frequent number of weather-related power disruptions impact daily life, health and safety support services, and can cause significant economic impacts. In a disaster, the region's rural isolation makes it prone to "threat amplification," i.e., the cascading impacts of infrastructure failure (e.g., power loss leading to communications loss) that make a coordinated regional response even more difficult. BLR is a certified Red Cross shelter-in-place site (located 5 miles from the Pacific Ocean, outside the tsunami zone), and the project will enable "life, health, and safety-level" power for as long as needed in an emergency.

A Note on Resilience

According to Presidential Policy Directive (PPD) 21: [Resilience is] “the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents” (USWH 2013). Building resilient infrastructure that bends rather than breaks has become an issue of national importance, and guidance and strategies are being developed and promulgated across sectors (e.g., NIST 2015). With today's advanced control technologies, microgrids nested within the larger grid can assess their own operating conditions, isolate from the main grid, and maintain some level of electrical service to their connected facilities (Ton 2014). Indeed, BLR’s microgrid will inform the ongoing discussion about how strategically implementing microgrids can greatly improve national resilience (National Academies 2012).

Resilient strategies actively incorporate uncertainty and recognize how threats can impact infrastructure and system interdependencies. The goal of resilience-related planning is to better understand the nature of these threats, to reduce uncertainty, and to design systems where the probability of low- or no-consequence impacts is increased. Microgrids fit into this strategy by improving the reliability of power supply in times of grid disruption (decreasing high-impact and cascading consequences).

“Resilience-informed” metrics are a relatively new area of research, and worthy of study to help communities anticipate, prepare for, and respond to threat events through “consequence-focused” dispatch and resource commitment (USDOE 2014, SNL 2014). For example, BLR and staff at the Schatz Energy Research Center (SERC, located at Humboldt State University), have focused intently on defining microgrid operational scenarios that anticipate and define certain operational states based on what is happening in the world. A review and quantification of critical infrastructure served by the microgrid resulted in metrics and gap analysis that provide a cornerstone for future planning (SERC 2016). These metrics help BLR answer two key questions: 1) how resilient is BLR? 2) are the resilience decisions/investments making a difference?

Not all resilience measurements are straightforward. For example, a resilience metric that measures “time to recovery of function” may be difficult to define precisely, as recovery times are influenced by multiple factors, including infrastructure design and condition, the extent and distribution of the event’s impact, the availability of resources to deal with post-event restoration, and infrastructure (inter)dependencies, among other variables. Of course, a microgrid is designed to facilitate speedier recovery times both for the larger community affected by the main grid, and for the BLR (or other microgrid-owning) community itself, by maintaining the energy “lifeline sector” throughout the disaster event. By preserving power supply, the microgrid directly impacts economic, social and environmental recovery, both for the tribe and the region, and the metrics used to guide and report on microgrid operations are thus critical to ensure the functionality of interdependent lifeline sectors (communications, water, transportation). BLR will use the analytics from the microgrid operations in combination with other metrics to establish what effectively constitutes a “resilience-oriented, adaptive management system” for tribal operations going forward.

BLR Background

BLR's microgrid development fits into its tribal environmental and energy vision: to provide affordable and environmentally safe energy for BLR members, residents, government, and economic enterprises for the purpose of economic self-sufficiency and environmental protection. The microgrid project is part of an aggressive tribal climate action strategy at BLR. The Tribe began its climate action planning in 2008 and has become a national leader in strategic energy management, greenhouse gas reductions, and community resilience measures. Tribal staff members have been recognized for their energy and climate expertise and are represented on the U.S. Department of Energy's Indian Country Energy and Infrastructure Working Group (ICEIWG), which works with the DOE's Office of Indian Energy to bring government and tribal leaders together "to collaborate and gain insight into real-time tribal experiences representing obstacles and opportunities in energy and related infrastructure development and capacity building in Indian Country" (USDOE n.d.).

BLR's tribal council has set ambitious energy use and greenhouse gas (GHGs) reduction goals, including a 40% reduction in GHGs community-wide by 2018 from a 2014 baseline. Since 2008, BLR has implemented a wide range of projects to improve tribal and regional resilience and security, including: 1) maximizing energy efficiency, 2) implementing energy resilience measures, 3) working aggressively to transition from fossil to renewable energy sources, and 4) taking actions to ensure continual critical infrastructure operations in business-as-usual and short- and long-term emergency situations. As a result of its efforts, BLR has positioned itself as a leader in clean energy and climate action. In acknowledgment of its achievements in greenhouse gas reductions and community resilience, BLR was recognized by President Obama and the Department of Energy as a 2015-16 White House "Climate Action Champion," one of only 16 communities across the nation to receive this distinction (including Boston, Portland (Oregon), San Francisco, and Seattle, among others).

Microgrid Basics

Microgrids can play a key role in a more resilient, distributed electric grid, where electrical power supply will come more from smaller, renewable generators located near where power is needed. Controllable loads and energy storage will interact via smart controllers to optimize the performance of the system. The goal is to lower greenhouse gas emissions, lower prices, provide more secure, reliable, and resilient power, and allow local choice and control.

A microgrid is a defined group of interconnected electric loads and distributed power generation resources that acts as a single controllable entity with respect to the larger grid. A microgrid includes distributed energy resources (DER)—distributed generation (DG) and distributed storage (DS)—and loads, connected through a physical network. Advanced controls and demand-response technologies control the distribution of energy flows and provide energy usage information to system operators. The load(s) of a microgrid are controllable, with discretionary, flexible controls that can be manipulated to control demand and supply in both business-as-usual and emergency situations. DS is critical for a microgrid where intermittent DG power sources (such as wind generators and photovoltaics) cannot be perfectly matched to load demands. Storage options stabilize load and generation fluctuations by absorbing excess generation and/or making up for insufficient generation.

There are many resilience-related benefits to microgrids, including: 1) increasing the efficiency and reliability of the electric delivery system, 2) reducing the vulnerability of the electric power system to threats, 3) reducing peak price and price volatility of electricity, 4) increasing asset utilization, 5) providing accessibility to a variety of energy sources, including onsite baseload and intermittent renewables, 6) strengthening grid stability, and 7) reducing the frequency and duration of operational disturbances (ensuring that critical loads will be met).

BLR's Microgrid

At the outset of the BLR microgrid project, a goal was set to design, build, and demonstrate a renewable and self-sustaining microgrid. In pursuit of this goal, the project design sought to achieve the following objectives:

- install a microgrid capable of powering the nationally recognized American Red Cross disaster shelter on BLR land in times of emergency,
- integrate renewable generation, battery storage, diesel generation, and controllable demand into the microgrid,
- achieve renewable energy generation exceeding 40% of annual energy production,
- demonstrate the ability to island and supply uninterrupted electric power for at least 7 days during a real or simulated grid outage,
- demonstrate the ability of the microgrid to participate in one or more Pacific Gas and Electric's (PG&E) demand-response programs,
- achieve a reduction in annual electrical energy consumption from the grid of at least 680MWh over Year 1 of operation,
- achieve at least 25% energy cost savings over Year 1 of operation,
- achieve a reduction in annual greenhouse gas emissions of at least 195 metric tons CO2e over Year 1 of operation, and
- make the knowledge gained from the project available to a broad audience.

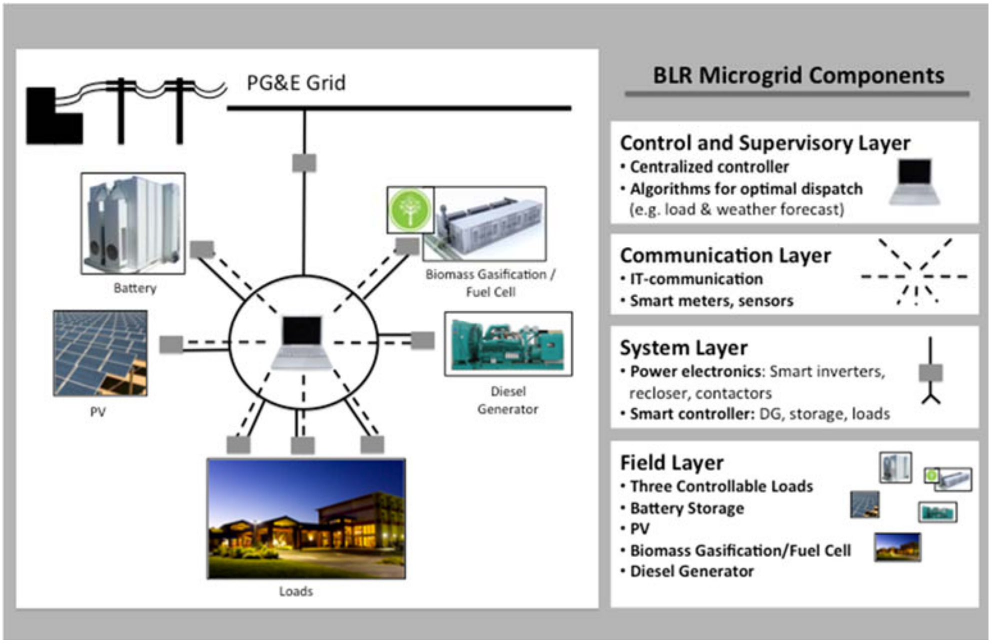

Figure 2. Blue Lake Rancheria low-carbon microgrid components.

At BLR, the physical network (See Figure 2) that distributes the power between the DG, DS, loads, and the main grid is the first layer of the power system. Loads are supplied via service wires that connect to DERs and the main grid from a medium voltage (MV) distribution feeder. The MV feeders are typically connected to a utility distribution substation via an interconnection switch, which is the central point of common coupling (PCC) where synchronization with the main grid occurs. This network architecture provides for power distribution via intelligent electronic devices (IED), including circuit breakers and digital protective relays, remotely operated switches, current and voltage sensors, and condition monitoring units for switch gear and transformers.

To actively operate and control DG units together with DS and controllable loads, advanced electronic conversion and control capabilities are needed to integrate communication between all components into a coordinated microgrid management system. This requires specialized hardware and software control systems (such as digital protection relays) to detect, isolate, and repair faults quickly.

Because direct current (DC) DER (from solar generation and batteries) is employed, an inverter interface is needed to convert DC to alternating current (AC) at the appropriate voltage level. Distribution supervisory control and data acquisition (SCADA) software is also an essential control component, along with advanced microprocessor meters and meter reading equipment to create transparency and optimize and balance supply and demand in real time.

The integrated components of BLR’s microgrid project include:

- 0.5 MW ground-mounted solar array (1.8-acre site),
- 1 MWh battery storage system,
- underground conduit utility and power connections between the solar and battery systems and existing power infrastructure onsite,
- ground-mounted recloser and associated equipment,
- new and modified electrical equipment within existing structures at the tribe’s government offices, casino, hotel, and event center,
- purchase and management of PG&E’s electrical infrastructure, and
- potential expansion of the microgrid to incorporate more infrastructure, increase the solar array to 1 MW, and expand the battery storage banks to 1.6 MWh.

Because microgrid composition will vary depending on location, components, and optimization goals, each will have different challenges and barriers, including: technology choice, switching from grid-connected to islanded mode, and power quality and control. Microgrids aggregate and integrate the quality, variation, and safety of distributed energy resources. The size of BLR’s microgrid was based on peak demand and on available generated/stored energy. The size and voltage level, and network configuration and components were determined by the load characteristics; the amount of storage, for example, depends on peak demand, variability (demand response level) of the loads, and requirements for reliability.

Since 2002, the Tribe has participated in demand response programs with PG&E, reducing power in both mandated and voluntary situations when peak demands place pressure on the larger regional power grid. With the microgrid and the addition of renewable power and battery storage, the Tribe will be able to respond by taking even more electric load off the grid demand.

The microgrid is a sub-system within the larger PG&E electrical grid system, with each subsystem contributing to the resilience and reliability of the greater, “smarter” grid. At the core of BLR’s microgrid is its ability to transition from grid-connected mode to island mode—either intentionally or owing to a fault event—and to have enough generation to provide reliable power on-site. This conversion to island mode can be from a “black start” (starting with no grid power), after a period of outage, or through a seamless transition (i.e., negligible transition time after grid disconnection). One issue with a black start is energy reliability during the transition to off-grid mode and before back-up generators can re-energize the system. Reconnecting to the main grid also poses challenges. Re-synchronizing the grids after a fault event requires voltage and/or frequency controls in the islanded microgrid. These operational scenarios will be addressed during the course of the project and lessons learned will be comprehensively documented and communicated to a wide stakeholder audience.

Controls and Analytics

To achieve reliable, low-carbon microgrids, advanced control is required, with technical and software capabilities that handle power quality issues and maximize the value of clean energy. Diverse energy sources such as battery, solar PV, and biomass can now be integrated to provide reliable, low-carbon power under all circumstances (NREL n.d.). The BLR microgrid uses the latest developments and innovations in microgrid control. The microgrid is complex in that it involves different energy generation technologies (e.g., PV array, diesel generators), separate energy storage media (e.g., lithium ion battery, diesel fuel), and the integration of a portion of PG&E’s 12 kV distribution grid.

Using Siemens microgrid management software, BLR can “see into” the microgrid system, accurately predicting and automating power load needs and dynamically managing and controlling its distributed power generation through integrated weather and load forecasting. BLR will use this insight to provide its critical infrastructure with reliable, high-quality power with significantly more resilience to outages or power interruption.

Siemen’s Microgrid Management Software (MGMS) will automate many functions. The MGMS is built on a utility-grade SCADA platform, giving it the ability to handle any microgrid application (demand response, balancing generation and distribution, etc.) and ensure interoperability with other load control systems. The user interface provides a detailed dashboard view of all microgrid components and allows BLR staff to manipulate a variety of operational states (load shedding, demand response, and prioritizing sources of power). In situations of larger grid failure, critical facilities at BLR need to be operational, and the software allows BLR to automatically and/or manually curtail non-essential loads to concentrate power where it will be needed most to keep people safe.

Since the MGMS is scalable, additional distributed energy resources may be incorporated and additional economic value may be realized from planned functionality such as the expansion of the microgrid to include more critical infrastructure and/or residents, and California Independent System Operator (CAISO) market participation. Additional functions—such as SaaS (Software as a Service) or managing multiple, geographically dispersed microgrids from one central location—are in planning stages to ensure that this solution is always on the leading edge of distributed energy technology advancement.

When the microgrid is commissioned, BLR will have incorporated over five years of 15-minute interval data for the vast majority of their onsite loads. This data will establish the baseline operation of the Rancheria’s critical facilities. The MGMS will also receive real-time data from power transducers and other high-resolution monitoring equipment installed throughout the microgrid. Based on data logs from the MGMS, all power flows internal to the microgrid will be captured at whatever interval is practical for accurate system verification and analysis. The entire microgrid will interface with the PG&E grid through a single 12-kV primary energy meter. Data from this meter will be used to verify aggregated system measurements.

Ratepayer Impacts and Benefits

The BLR microgrid will result in the following ratepayer benefits: greater electricity reliability, lower costs, and increased safety. The microgrid will be capable of islanding, providing greater electricity reliability to the site host. This increased reliability will extend past the confines of the Rancheria by making BLR a flexible load, capable of participating in a variety of demand response programs or by providing ancillary services to the grid. These services benefit all ratepayers through lower costs and higher reliability as the grid becomes incrementally more robust and responsive to peak day conditions.

The microgrid will result in multiple forms of cost savings to the site host, which could be replicable in other sites. The PV system will offset energy purchases from PG&E, lowering BLR's bills for the lifetime of the array. By purchasing the PG&E transformers and converting from a secondary voltage to a primary voltage customer, BLR will be moved to a different rate schedule (E19-P), which has lower pricing and will result in long-term savings. Finally, the strategic use of the battery system will lower annual energy costs by allowing BLR to peak shave and load shift from peak and partial peak periods to off peak periods. The project provides increased safety by providing an indefinite power generation capability to a nationally-recognized American Red Cross emergency shelter in a natural disaster-prone region.

Microgrid Partnerships

BLR developed its microgrid as part of a highly collaborative and creative partnership among a diverse, motivated group of professionals, including local, state, and federal entities, major technology players in energy, university research groups, and international engineering firms. The project illustrates the value of ongoing learning, innovation, and collaboration in the development of a resilient technology system. The collaborative microgrid effort has been led by the Schatz Energy Research Center (SERC), a research and educational institute associated with the Environmental Resources Engineering (ERE) Department at Humboldt State University.

BLR has actively built partnerships to obtain critical expertise for moving a diverse array of energy and other projects forward in a relatively short time. Local engineering and energy expertise comes from SERC and the Redwood Coast Energy Authority (RCEA), a local energy joint powers authority. At the state level, the California Energy Commission, Pacific Gas & Electric, and project partners (e.g., GRID Alternatives) have provided strategic funding and operational assistance for a variety of BLR projects. And on the national level, the U.S. Department of Energy, Office of Indian Energy Policy and Programs, U.S. Department of Interior, Bureau of Indian Affairs, National Renewable Energy Laboratory, Idaho National Laboratory, U.S. Department of Agriculture Rural Development, the National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, and the U.S. Department of Transportation—among many others—have provided significant and ongoing support and guidance.

The Tribe has been fortunate in its public/private partnerships as well, with several private technology partners who have contributed financially, technically, and operationally to various projects. The microgrid project in particular involves several technology partners, including: Siemens (microgrid controls), Tesla Energy (energy storage), Pacific Gas & Electric (electric infrastructure), REC Solar (photovoltaics), Johnson Controls (energy management system), Colburn Electric (electrical contractors), Kernen Construction (site work), and GHD Engineering (electrical engineers).

Lessons Learned in Microgrid Project Development

As noted above, the grant-funded BLR microgrid project includes a large number of partners, and a key project management task has been to coordinate project workflow through assiduous communication and careful contract development. To facilitate efficient project development, the project was designed with multiple design-phase “check-ins” at the 30%, 50%, 90% and 100% stages, making sure at each stage that scopes and budgets were on track. Additional lessons learned during project development (as of this writing) include:

- equipment connection compatibility: many vintage inverters and other points of connection to a microgrid are not “smart enough” to communicate with the microgrid management systems hardware and software,
- utility interconnection requirements regarding total size of generation source(s); to avoid a significant cost increase, the BLR microgrid is less than 1 MW,
- electrical engineer, electrician, facilities manager: It can make sense to train and/or hire specific personnel in-house for these multi-year projects,
- utility communication: the microgrid project has benefitted from proactive and consistent communications with utilities; utilities can be extraordinary project partners on cost-effective equipment alternatives (especially at points of common coupling) and safety, interconnection, and compliance requirements and strategies, and
- a project manager (PM) with engineering and communication expertise: a key role of the PM is to foresee, identify, and solve issues relative to a microgrid environment; ideally the PM has a technical power systems background.

Recommended tools for microgrid project management include a “concept of operations” document that that clearly documents microgrid operational scenarios. Developing a shared understanding among project partners of operational descriptions is essential for keeping the project on time and within scope and budget, and ensuring required functionality. As noted above, the process involves staged reviews. For the BLR microgrid grant proposal to the CEC, the 30% design-stage was used to develop reasonable cost estimates (quantities of materials, types of equipment, etc.); project partners were critical in helping develop defensible cost estimates. The staged review process also helped answer questions among project partners. For example, if at the 90% review someone has a question, it is possible to point to the 60% review drawings and say “this is what we decided.”

A Step toward Resilience

The Blue Lake Rancheria—a tribal government and community with a tradition of building resilient infrastructure, a nationally recognized Climate Action Champion, steward of a nationally recognized Red Cross shelter, and its partners—is pioneering its low-carbon microgrid to serve as an example of what progressive community resilience efforts can achieve. The BLR microgrid project has demonstrable beneficial impacts for the BLR community, the greater Humboldt County region, and California in terms of critical facility emergency preparedness/resiliency and environmental sustainability. It also demonstrates a repeatable, scalable solution for similar areas and facilities throughout California and the nation.

Cost is the main barrier to adoption of microgrid technology—including innovative renewable energy generation, and energy storage—into the general California market. Payback timelines are typically long and uncompetitive, so installations are few. The microgrid project helps to address concerns about cost issues by demonstrating a robust, replicable, cost-effective microgrid package. The project will inform and improve the next generation of microgrid hardware/controllers and battery storage to drive down costs and increase reliability.

As California makes a concerted effort to add distributed generation to its grid, to increase the reliability and decrease the cost of electric power delivery, and to increase the amount of renewable power serving the state, projects such as the microgrid system make a crucial contribution. When its microgrid system is operating, BLR will be providing energy and financial information that will help prove the value of a microgrid solution for any distributed generation site and/or critical facility in California and elsewhere (including hospitals, emergency operations centers, office and residential complexes, and schools and universities, among others). That value will accrue not only through the business case, but also through the value placed on increased emergency preparedness, power reliability, community and global health due to emissions reductions and positive environmental action, and a successful model of working cooperatively with multiple partners to achieve positive results.

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