CALIFORNIA ENERGY COMMISSION

Energy Research and Development Division

FINAL PROJECT REPORT

Constructing a Microgrid for a Wastewater Treatment Facility

Demonstrating Microgrid Elements for Reliability and Resilience

Gavin Newsom, Governor

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The authors herein acknowledge the partners who made this project possible, who demonstrated encouragement, vision and the commitment to bring it to successful completion.

City of Santa Rosa, Laguna Wastewater Treatment Plant (LTP) staff and operations people helped and hosted Trane at the site by providing valuable input into the wastewater plant operations. While the research team performed the project, it was always to provide a safe and environmentally compliant operation at all times. Key contributors were the city of Santa Rosa mayor, city council, and city manager for their support of the project; Mike Prinz the LTP manager; and the plant SCADA operators for their help in integrating the microgrid controller into the plant. The city did not provide its full cost-share commitment of $750,000 to the project.

California Energy Commission provided primary funding to make this project possible, and Commission Agreement Manager Jamie Patterson provided strategic project stewardship.

Electrical Consultants, Inc. (ECI) Bill Young, P.E. provided the technical electrical design and integration of the microgrid system, which included the 126 kilowatt carport solar photovoltaic (PV) system, Nuvation BESS (battery energy storage system), Parker Hannifin inverter and transformer, and the Schweitzer microgrid controller. He was instrumental in providing educational materials to the plant personnel and their consultants.

Nuvation Energy provided the microgrid BESS. Its tireless support and engineering helped develop the battery system. Greg James was key in helping with design and communication of the BESS.

Parker Hannifin provided the 12-kilovolt-to-480-volt transformer and 2 megawatt (MW) inverter system for the microgrid. Casey Butler at Parker was particularly helpful in the design, implementation, and the factory testing of its equipment with the Nuvation BESS system. The project team performed a complete mock-up at the factory with the transformer, inverter, BESS, and microgrid controller tied to the grid at the Tennessee test laboratory that conclusively demonstrated that the system exceeded all applicable national standards and met all project requirements.

Miratech provided the two selective catalytic reduction units for the emission reduction units on the two existing 1.1 MW Cummins combined-heat-and-power (CHP) engines, which allowed them to operate with reduced emissions that the Bay Area Air Quality Management District (BAAQMD) required.

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Pacific Gas and Electric Company (PG&E) is the local distribution utility and was a great partner for this project. Martha Baeli and team helped with the interconnection and provided critical support during the application process.

Trane—Grid Service team provided for the support, insight and ingenuity with the SCADA and software interface to the microgrid controller. They developed and implemented the scenarios with help from the city of Santa Rosa SCADA programmers.

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 solutions, 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.

Constructing a Microgrid for a Wastewater Treatment Facility is the final report for the Laguna Wastewater Treatment Plant microgrid project (Grant Award Number EPC-14-059) conducted by Trane U.S. 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 research website (www.energy.ca.gov/research/) or contact the Energy Commission at 916-327-1551.

ABSTRACT

This project provides a case study of the construction of a microgrid at the city of Santa Rosa's Laguna Wastewater Treatment Plant in Sonoma County. The project documents construction of a microgrid for a wastewater plant using 2 megawatt/480 kilowatt-hours of battery energy storage, a microgrid controller integrated into the supervisory control and data acquisition system of the plant for controllable loads, a 126-kilowatt carport solar photovoltaic array, and the modification of two existing 1.1 megawatt combined heat and power Cummins engines with selective catalytic reduction that are used as dispatchable resources for load reduction. The microgrid project will improve plant operations and grid resiliency for Santa Rosa and the surrounding region.

The microgrid is connected to the Pacific Gas and Electric distribution grid at 69 kilovolts through a computer-controlled circuit breaker and is designed to operate autonomously. The project experienced many hurdles during construction. In October 2017, the Tubbs fire caused major damage to the areas surrounding Santa Rosa. The fire caused delays in the project approvals, while the city dealt with a major catastrophe in the area. Several critical suppliers at the beginning of the project such as Alstom and Tesla quit the project. Nuvation Energy and Parker Hannifin replaced them. Despite project difficulties, the California Energy Commission granted a project extension to March 31, 2019, due to these circumstances, and the project was completed.

Keywords: Microgrids, distributed energy resources, battery energy storage system, microgrid controller, microgrid management system, resiliency, critical facility, controllable loads, PV supplementation, microgrid interconnection process

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EXECUTIVE SUMMARY

Introduction

The City of Santa Rosa's Laguna Wastewater Treatment Plant faces future facility upgrade challenges to respond to population growth and possible new regulations. Microgrids are a technology approach that can improve the reliability and resilience of wastewater treatment plants while achieving economic benefits and help the larger electrical grid by participating in the ancillary electricity markets.

Wastewater treatment in California centers on the collection, conveyance, treatment, reuse and disposal of wastewater. Wastewater passes through nearly 100,000 miles of sanitary sewers and ends up at nearly 900 wastewater treatment centers throughout California. Roughly 4 billion gallons of wastewater are generated in the state each day, according to the Water Education Foundation.

Wastewater treatment plants use a considerable amount of electricity in a process that involves pumping, solids separation, aeration, disinfection, and reclamation. Wastewater treatment plants are usually one of the larger power consumers in a given area, particularly in rural and semirural communities. Power consumption varies and is closely correlated with process flow rates. Power consumption at the Laguna Wastewater Treatment Plant ranges from more than 5 megawatts to less than 2 megawatts, with an average of 3.5 megawatts.

Integrating and adapting the Laguna Wastewater Treatment Plant to an advanced microgrid provide the opportunity to convert a substantial electrical load into a grid resource, which can help maintain power quality, assist in integrating renewables, and generate new revenue for the plant operator. Wastewater facilities that install microgrid technology can also reduce and stabilize related electricity costs while gaining a reliable source of power in the event of a larger grid power outage.

Microgrid technology can help a wastewater treatment plant achieve flexible electrical power consumption by using existing and new resources (such as flow-equalization basins, combined-heat-and-power engines, and demand-reduction scenarios) in a new way. A robust supervisory control and data acquisition system controls the Laguna Wastewater Treatment Plant. A microgrid can be integrated into and implemented with that system with operator input and override capabilities by applying sound supervisory control and data acquisition programming processes. These stages of implementation are required to uphold the mission of the plant to maintain a safe and environmentally compliant operation at all times.

The attribution method used to gauge the grid impact of microgrid operations is of particular concern. Attribution involves calculating what the load would have been in the absence of action (baseline), measuring actual power draw, and reporting the difference. Wastewater treatment plants have highly variable loads that are correlated with flow, but the baseline is not calculated from those data. Instead, the current method looks at data from the same hour of recent days but ignores actual process mass flow. This current California Independent System Operator method results in a less accurate baseline than a real-time data analytics approach could provide. This assessment mirrors results from previous University of California, Davis, research on a similar topic.

Facilities trying to participate in California Independent System Operator markets under current rules face elevated uncertainty that can increase their risk, potentially leading to reduced market participation. Conversely, Trane found that using a proprietary real-time data-driven algorithm to analyze the data opened opportunities to game the system and receive revenue without a change in action. This research indicates a critical gap in market mechanisms for highly variable assets but suggests that possible data-driven solutions exist. This issue deserves further investigation.

Project Purpose

The project team designed, built, and prepared the project to demonstrate an advanced microgrid that can provide ancillary services (operations beyond generation and transmission that are needed to provide grid stability such as frequency control and operating reserves) and some control over the effects to consumers of impacts to the grid; identify barriers to participating in California energy markets and help reduce operational costs at Santa Rosa's Laguna Treatment Plant in Sonoma County.

The technology of the project demonstrates a reliable day-ahead nomination software that curtails key dispatchable electricity-consuming resources for periods of the following day. A microgrid controller installed during the project at the Laguna Wastewater Treatment Plant is connected to the plant supervisory control and data acquisition system (a computer system for gathering and analyzing data) with the ability to control electricity-consuming assets and power generation equipment. This control function had not previously been performed in a wastewater treatment facility. In addition, the project demonstrated the ability to integrate solar photovoltaic electric power with battery energy storage and to use existing combined heat and power engine generators that were otherwise idle, all with the Day-Ahead Nomination system connected to the California Independent System Operator Proxy Demand Resource program.

Another key goal of the project was to transfer the knowledge gained to a broader audience to encourage replication of a scalable solution for similar wastewater treatment plants throughout California and beyond.

Project Approach

Trane U.S. managed the project; coordinated the efforts of the engineers, subcontractors, and vendors; and acted as the technology integrator. Trane ensured that all contractors met their contractual obligations and that their products met project requirements. It also ensured that all technologies used in the project would function as a well-integrated system and that all subcontractors and vendors would work effectively as the project team.

The project team used an integrated design process to develop review packages at 30, 60, 90, and 100 percent levels of completeness for review by the Laguna Wastewater Treatment Plant and the city of Santa Rosa building department for an unusually detailed and thorough building permit approval process. Each review package included design plans, submittals, an engineer's review, and an operational review. To help maintain an agreement on these design documents, each party had input into the process.

The Laguna Wastewater Treatment Plant project used a Schweitzer Engineering Laboratories microgrid controller connected to the existing plant supervisory control and data acquisition system. A battery inverter from Parker Hannifin and a Nuvation Battery connected to the 12-kilovolt electrical in the M2 substation. There were minimal outages during construction.

Prior to installation at the Laguna Wastewater Treatment Plant, the project team performed extensive testing of the Parker Hannifin inverter and Nuvation battery energy storage system at Parker's plant in Tennessee. This testing confirmed that the battery and inverter system met all national standards and project performance specifications. The team also performed a "minicommissioning" (testing to verify the system is operating correctly) with complete load bank tests and operational tests with the Schweitzer microgrid controller. After completion of these tests, all the qualified engineers working on the project cleared the storage system for installation into the microgrid.

To provide ancillary services and enable participation of the microgrid in energy markets, Trane developed the Day-Ahead Nomination software for the microgrid controller. City of Santa Rosa supervisory control and data acquisition system programmers helped interface this software into the on-site system. The team then performed commissioning of the interface and verifying communications protocols. While construction of the microgrid continued, the microgrid controller and software began monitoring plant operations and collecting data, such as plant power, wastewater pumping flows, and other data.

Pacific Gas and Electric Company granted live on-site final commissioning and testing of the microgrid management system on a conditional basis as the final telemetry and interconnection agreement approvals were completed. This allowed commissioning and testing of the microgrid. The city of Santa Rosa is completing its telemetry requirements and pursuing final interconnection with Pacific Gas and Electric.

Project Results

The project team designed, built, and prepared the project to demonstrate an advanced microgrid that can provide ancillary services and some control over the effects to consumers from impacts to the overall grid, identified barriers to participating in California energy markets, and helped reduce operational costs at the Laguna Treatment Plant. Integrating and adapting the Laguna Wastewater Treatment Plant to an advanced microgrid provide the opportunity to convert a substantial electrical load into a grid resource, which can help maintain power quality, assist in integrating renewable energy, and generate new revenue for the plant operator.

This project demonstrated the successful integration and adaptation of the Laguna Wastewater Treatment Plant to a reliable and resilient microgrid that will provide ancillary services to California's electrical grid in the future. This project is the first of its kind in magnitude and complexity. The microgrid makes critical wastewater treatment infrastructure and plants more resilient by being able to adapt to changing conditions and recover from disruptions.

Continued operation of the microgrid system may also provide substantial financial and environmental results for Santa Rosa if it uses the attributes of the microgrid to participate in ancillary energy markets as part of its daily wastewater plant operations. The carport solar photovoltaic system contributes to offsetting electricity use for charging the battery. Selective catalytic reduction systems reduce greenhouse gas emissions when the combined-heat-and-power units are used. Microgrid-controlled demand reduction and participation in the daily electrical California Independent System Operator Proxy Demand Resource market program will provide a source of revenue generation for the plant.

Although project delays required an additional year's grant extension and costs exceeded the original grant amount, the project finished within the grant term and has gained public exposure.

Additional lessons learned from the project include the following:

- Overcoming objections to and concerns about procedural and operational change and achieving early "buy-in" of wastewater plant operators and staff, elected city government officials, and city information technology experts and communications staff are integral to project success.
- Maintaining compliance with regulations is paramount.
- Identifying a qualified individual with microgrid and storage system knowledge to serve as the point of contact promotes efficiency and effectiveness.
- Effective system integration is critical to success. In addition, information technology staff must understand that any postinstallation changes in the network structure or hardware can disrupt communications between microgrid components and cause operational issues.
- Utility interconnection agreements and processes and city and air quality management district permitting require extensive lead times, often of a year or more.

- Wastewater plant legacy equipment and systems create challenges and require inclusion of electricians and other experts familiar with the equipment and systems.

Technology/Knowledge Transfer/Market Adoption (Advancing the Research to Market)

Trane invested heavily in outreach to share knowledge and technology. It delivered microgrid onsite tours to dozens of stakeholder groups, such as the California Water Environment Association, and more than 50 local and out-of-area participants. It also delivered presentations to stakeholder groups and cities throughout California. These high-profile outreach efforts enabled interested parties and the public to see the application of a microgrid at a wastewater plant and educated them about the feasibility and value of microgrids.

This project was the first commercial application for Trane's Day-Ahead Nomination system. The introduction of the system led to further discussions and potential use of this microgrid technology.

Benefits to California

The Laguna Wastewater Treatment Plant microgrid will result in numerous benefits to California ratepayers.

The project will successfully demonstrate that a microgrid can reduce energy costs while improving the resilience of critical facilities and infrastructure. This project will reduce Santa Rosa's energy use and achieve substantial economic benefits for the city and the Sonoma County region, with savings estimated between $85,000 and $125,000 annually. In addition, the city can participate in the California Independent System Operator Proxy Demand Resource day-ahead market program and potentially generate revenue projected at $80,000 to $140,000 per year.

Several local small businesses and contractors worked for the project. In total, about $6.5 million of induced and indirect economic benefits accrued to local, regional, and state economies.

Careful review and assessment of the Laguna Wastewater Treatment Plant microgrid system performance, costs, lessons learned, and benefits realized have and will increase the microgrid knowledge base locally and across the state. This project will have demonstrated a successful microgrid design that not only can be expanded at the site in the future, but is also suitable for replication at other high-energy-use wastewater treatment sites. With more than 900 wastewater treatment plants in the state, installation of additional microgrid systems could dramatically reduce the annual electric load on the grid and offer substantial cost savings and resilience benefits.

CHAPTER 1: Introduction

The Laguna Wastewater Treatment Plant (LTP) microgrid project demonstrated an advanced microgrid at a large wastewater treatment facility that would provide increased reliability and resilience. It consists of a fast responding, battery energy storage system (BESS) and makes use of existing assets such as the flow equalization basins for demand response. Wastewater facilities do not react quickly, and rely on steady treatment of incoming influent flows by using collecting ponds to even out the flow rates. This report documents valuable engineering insights, lessons learned, describes demand reduction scenarios with energy saving measures, and the potential financial benefits of demonstrating the value of a microgrid solution for large wastewater treatment facilities throughout California.

Chapters 2, 3, 4, 5, and 6 provide detail as to how the LTP microgrid project was implemented and can serve as a resource to other project teams working on implementing similar projects. Chapter 10, Production Readiness Plan, addresses key considerations regarding how to replicate microgrids.

This report provides details of the implementation of the project including:

- Project Design Engineering (Chapter 2).
- Project Procurement (Chapter 3).
- Microgrid and Component Interfacing (Chapter 4).
- Construction Activities (Chapter 5).
- Testing, Start-up and Commissioning (Chapter 6).
- System Operation & Observation (Chapter 7)
- Project Benefits (Chapter 8)
- Technology and Knowledge Transfer (Chapter 9)
- Project Pre-production Readiness (Chapter 10)
- Conclusions and Recommendations (Chapter 11)

The remaining sections of this first chapter provide introductions to the city of Santa Rosa, Trane U.S., Nuvation Energy, Parker Hannifin, and Miratech and a brief description of each; a description of the purpose and need for each participant; and a discussion on the project objectives, project benefits summary, and a description of the project team.

The Laguna Treatment Plant

The mission of the Laguna Treatment Plant is to protect public health by sustaining water resources, infrastructure, and the environment. Trane U.S. helped the city of Santa Rosa by designing and implementing a microgrid project for the LTP.

The current LTP is a tertiary-level treatment facility that has an average 17.5 million gallon daily flow. The incoming utility power to the plant includes a 69-kilovolt (kV) utility feed from Pacific Gas and Electric Company (PG&E) to the plant's own substation, a 2.2-megawatt (MW) ultraviolet disinfection system and a co-generation system with four Cummins 1.1-MW engines. Recently a high strength waste project was completed at the plant which provides for a mixed burn fuel for two of the four co-generation engines. The other two co-generation engines were not run except on as rotating run-time engines to even hours on the engines.

The City of Santa Rosa

The City of Santa Rosa is in Sonoma County, in the "wine country" of Northern California, and is the fifth most populous city in the San Francisco Bay Area (Figure 1). Santa Rosa is 55 miles north of San Francisco with a population of around 185,000, which encompasses a Sonoma County population of around 500,000.

Santa Rosa's Laguna Wastewater Treatment plant serves the greater population of Sonoma County, which includes the City of Santa Rosa and outlying communities of Sebastopol, Cotati, Rohnert Park, and other areas within the county. The LTP serves a population of nearly 230,000.

Figure 1: Vicinity Map of Laguna Treatment Plant

Source: Trane U.S.

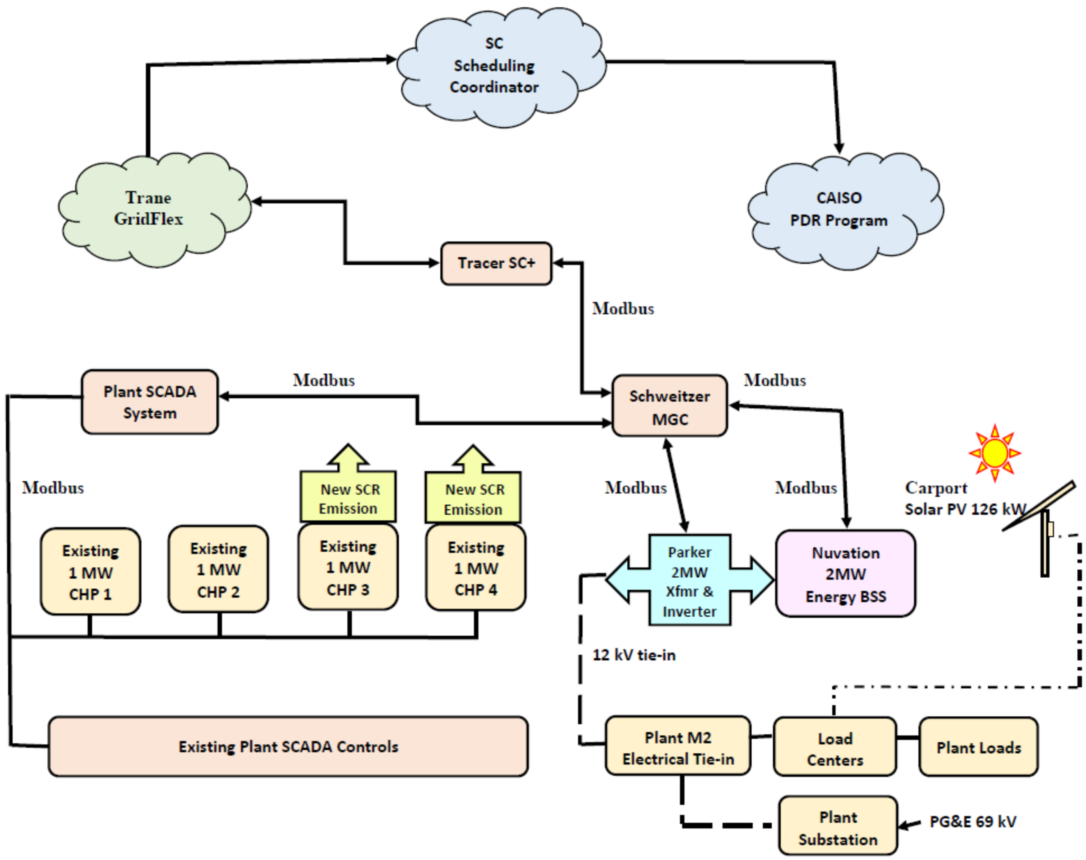
Overview of Project Description

As shown in Figure 2, the Laguna Treatment Plant microgrid project consists of the following:

- 126 kilowatt alternating current (kWAC) carport photovoltaic (PV) array
- 2MW/480 kilowatt-hour (kWh) Nuvation Energy battery energy storage system (BESS)
- 12 kV/480V transformer with a Parker Hannifin 2-MW inverter
- Two (2) Miratech selective catalytic reduction systems implemented onto two existing Cummins 1.1MW co-generation engines

- Schweitzer microgrid controller
- Trane Scheduling Coordinator (SC)+ System Controller to Trane GridFlex™ to SC to California Independent System Operator (ISO) Proxy Demand Resource
- LTP 69-kV substation connected to PG&E utility power

Figure 2: Microgrid Architecture for Laguna Treatment Plant



Source: Trane U.S.

The Laguna Treatment Plant aerial view is shown in Figure 3 with the completed carport solar PV system in foreground and overall view of the wastewater plant.

Figure 3: Aerial View of Laguna Treatment Plant

Source: Trane U.S.

Microgrid Demonstration at Wastewater Treatment Facilities

California has a need for reducing carbon emissions and providing for a reliable and sustainable electrical grid system. Grid reliability is a major concern as California continues to grow yet has to reduce the demand for fossil fuels while still providing reliable electricity to the state's growing economy.

Wastewater treatment facilities (WTFs) not only consume a large amount of power, they also are a large water recycling resource. Both functions are in demand in the State, especially during drought periods.

Microgrids therefore are a viable solution for large electrical consuming wastewater treatment facilities. With nearly 1,000 water treatment facilities throughout the state, it is imperative to look at such potential resources for reducing electrical demand and assisting the utility grid.

This project sought to build a working microgrid for the Laguna Treatment Plant in a mid-size community serving the greater County of Sonoma, California. The project integrated multiple sources of energy generation, some preexisting assets, with a new battery energy storage system and select dispatchable controllable plant loads. The project incorporated a connection with California ISO to provide day-ahead market services in the Proxy Demand Resource program. This program helps reliability needs and reduces electrical utility demand.

While microgrid controllers have not traditionally been applied to wastewater treatment facilities this project demonstrated at a smaller scale the ability to prove the capabilities and move toward widespread commercialization.

Project Objectives

The objectives of this project were to:

- Install a microgrid capable of delivering day-ahead market services while not compromising wastewater plant operations.
- Integrate renewable carport solar PV, battery energy storage, generation, and controllable loads into the microgrid.
- Demonstrate the ability to use existing assets such as flow equalization basins and previously underused existing cogeneration engines with selective catalytic reduction emission controls.
- Demonstrate the ability of the microgrid to participate in the California ISO Proxy Demand Resource demand response program.
- Achieve a reduction in annual electrical energy consumption from the grid and provide for a revenue source from the Proxy Demand Resource participation.
- Make the knowledge gained from this project available to a broad audience.
- Develop a plan to help commercialize the microgrid technologies and strategies demonstrated under this agreement.
- These objectives were largely met as discussed in Chapter 7, System Observation, and Chapter 8, Project Benefits.

Project Benefits

The Laguna Treatment Plant microgrid project has provided benefits to the site host, to the region, and to the California ratepayers. These benefits going forward under its future operation include lower energy costs, revenue generating resources and reduction in pollutants, greater electricity reliability and increased safety, all of which are described in Chapter 8, Project Benefits.

The Laguna Treatment Plant microgrid project has achieved technological advancements and overcome barriers associated with microgrid use. The project demonstrated a successful model of working cooperatively with the local utility (PG&E) to integrate distributed renewable energy resources into California’s electricity grid. The project also successfully demonstrated the technical, potential financial, and regulatory feasibility of integrating renewable energy generation with battery storage, conventional combined heat and power (CHP) engines with emission reduction selective catalytic reductions, microgrid controller technology, and wastewater treatment facility controllable loads into a single microgrid at the scale of a large size wastewater treatment facility.

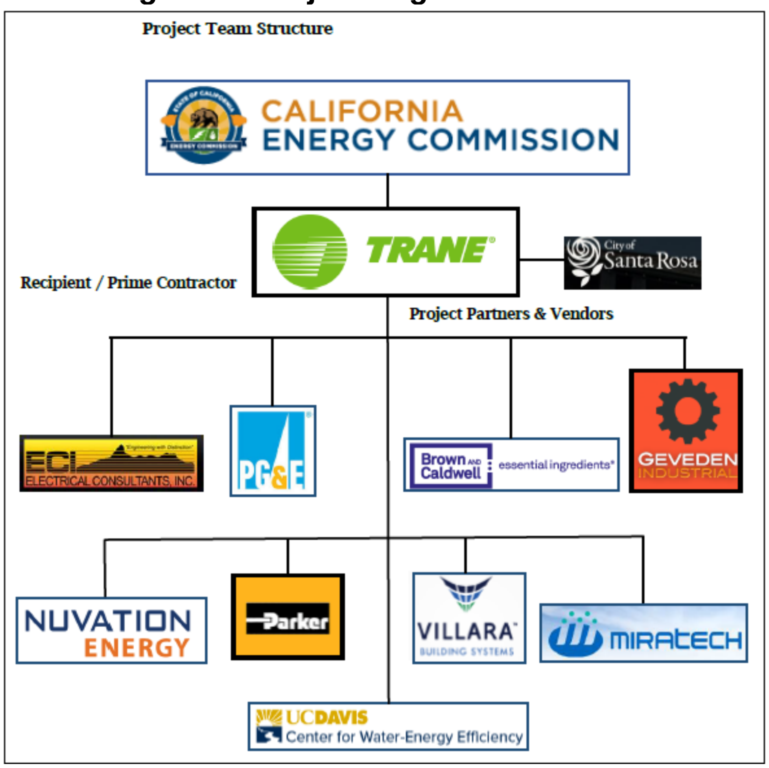
Beyond the benefits associated with this specific project, there is potential for much greater future benefit to be realized via the increased use of microgrids at water treatment facilities throughout California. The lessons learned and the significant outreach conducted as a part of this project will help move the adoption of microgrid technologies forward. Chapter 8 briefly examines the market potential for replication of projects like the Laguna Treatment Plant demonstrated here.

The Laguna Treatment Plant microgrid project has demonstrated beneficial impacts for Santa Rosa and the surrounding communities in terms of providing a functioning microgrid example of a secure, reliable, replicable microgrid for other wastewater facilities.

Project Team

Figure 4 shows the project team organizational chart for the microgrid project at the Laguna Treatment Plant.

Figure 4: Project Organization Team



Source: Trane U.S.

The project was led by Trane U.S., which served as the general contractor and developed the overall design concept. Major subcontractors and their respective roles were as follows:

- Trane
    - Trane provided the project management, coordination and oversight of the microgrid design. Trane also supplied the Trane Grid Services software to interface with California ISO for the Proxy Demand Resource program implementation.
- City of Santa Rosa
    - The City of Santa Rosa was the host client for which the microgrid project was installed at their Laguna Treatment Plant. City staff and plant operators provided valuable knowledge transfer throughout the project. The city's supervisory control and data acquisition (SCADA) programmers provided the required interface and Modbus communications for the microgrid project on their plant. The city provided some match funds for one of the selective catalytic reductions for one of its existing Cummins 1.1 MW CHP engines. However, the City did not provide their full cost share commitment of $750,000 to the project.
- Electrical Consultants, Inc. (ECI)
    - ECI provided the electrical design drawings and details including the Schweitzer microgrid controller programming. ECI provided significant engineering during hardware-in-the-loop testing and onsite testing and commissioning.
- Pacific Gas and Electric Company
    - PG&E is the regional utility and was a critical project partner for granting the project permission to operate after a complex interconnection process.
- Brown & Caldwell
    - Brown & Caldwell provided the engineering for the selective catalytic reductions and the Bay Area Air Quality Management District (BAAQMD) air permit application support.
- Geveden Industrial
    - Geveden Industrial designed and performed the civil work that including excavation, grading and trenching at the selective catalytic reductions and BESS/inverter locations. They also performed the concrete, rebar, and electrical work for both the low and line voltage requirements of the project.
- Nuvation Energy
    - Nuvation provided the design of the BESS container and the battery management system. Their factory testing before shipment to the site helped greatly in reducing the on-site commissioning process and operational validation of the system. A collaborative effort between

    Nuvation, Parker, and Trane greatly helped the final project completion. Nuvation also provided all of their matching funds as part of the California Energy Commission (CEC) grant.

- Parker Hannifin
  - Parker provide the inverter system for the BESS system including the close-coupled 12-kV transformer. Parker provided expertise in the factory testing and field commissioning of the system.
- Villara
  - Villara provided the design and installation of the 126-kilowatt (kW) carport solar PV system. Their engineering support and start-up of the system provided for a complete system and an excellent integration into the project of a renewable resource used for helping re-charge the BESS.
- Miratech
  - Miratech furnished the selective catalytic reduction units for two of the existing CHP engines. They furnished their equipment and engineering support and assisted with the final commissioning and emission testing. They worked with Cummins and their field service personnel for tuning the engines during start-up procedures.
- University of California (UC) Davis – Center for Water Efficiency
  - UC Davis – Center for Water Efficiency helped write a report on the benefits of the microgrid project and its impact on wastewater treatment facilities. A copy of the UC Davis report is found in Appendix F.

CHAPTER 2: Design and Engineering

Engineering Design Process

The engineering design process was a collaborative team effort between the design engineering team and the supplying vendors of the project. Upfront concept and engineering considerations were started with Trane's team, and the key electrical designer, Electrical Consultants, Inc. and the vendors that supplied the products. Once the concepts were established for the design Trane brought in the engineering expertise of Nuvation and Parker for the microgrid energy storage design. The carport PV solar was designed by Villara. The CHP engine selective catalytic reduction units design was completed with Brown & Caldwell and Miratech.

This early on approach helped establish the project goals and implementation strategy. The carport solar PV and selective catalytic reduction units emission systems were performed in separate engineering discussions for the design, engineering and construction details as these components of the microgrid were in separate locations at the wastewater plant.

The engineering and design portions of the project four stages were performed as follows:

- 30 percent design drawing package review by LTP staff completed first
- 60 percent design drawing package review by LTP staff
- 90 percent design drawing package review by LTP staff
- 100 percent design completion and review, then submitted for city of Santa Rosa permit

Throughout the stages, a design drawing package contained the engineering plans and an engineer's notation of progress. The drawing packages communicated the design intent with progressing levels of detail at each stage. Trane provided multiple meetings and discussions on the microgrid operational aspects and buy-in from plant operators and staff for acceptable operational cases or scenarios. The SCADA control functions, operational parameters, and constraints were discussed along the way.

At each review stage, comments were collected from the operators and staff, reviewed and discussed by the design team, then used to make any changes or improvements to the design work for the next milestone.

Due to vendor changes early in the project (Alstom Grid and Tesla quit) Trane required additional time to connect with new vendors and suppliers. The grant timeline was extended to allow for these changes. Other delays in the design and engineering phase were due to long lead times of the batteries and the City-caused delays in the plan/permit reviews.

The project was mostly constructed in 2018 while commissioning occurred in early 2019. This required an early start in 2018 on many of the construction tasks that the City had approved. The delays in 2018 were mostly due to city review delays and the Tubbs Fire that impacted Santa Rosa's ability to process the project plans. Consequently, the final design packages had to be submitted separately for the BESS, the carport solar PV and the selective catalytic reduction units to keep the project moving.

Electrical Design Consultants acted as the electrical engineer of record for the project. They were very helpful in their reviews and made changes to the designs as needed.

Villara handled the complete design of the carport solar PV system including selection of the panels, inverters, and the site work. Baja Construction provided the PV carport structure and support system. Geveden Industrial provided the installation of the main electrical connection to the plant from the PV system including the trenching work and patch paving.

Geveden Industrial included the civil design portion of the work of the selective catalytic reduction units and the BESS system. Brown & Caldwell provided the selective catalytic reduction units design drawings and air permitting support engineering.

Trane performed the engineering selection of the Schweitzer microgrid controller, the Trane software and SCADA interface. Trane's GridFlex™ team at the factory provided software support and testing. The city of Santa Rosa SCADA programmers with Trane and ECI performed the necessary interface software engineering requirements of the microgrid to the wastewater plant systems.

Nuvation Energy designed the BESS system with Parker Hannifin's inverter integration. These two companies worked well together and with Trane's engineers to provide a complete factory tested system before arrival at the site. This system was tested completely and satisfactorily before shipment and clearly met all applicable standards for performance. It included a grid tied charging and discharge test and operational microgrid controller testing! It worked perfectly.

Microgrid Control Strategy and Design

Trane software engineers with engineering support from ECI for the microgrid controller interface developed the microgrid control strategy. The strategy of the project was to run the microgrid system with various scenarios agreeable to the Laguna Treatment Plant personnel. These scenarios included:

1. Use of the flow equalization basins, which consist of two 6-million-gallon concrete ponds for influent flow diversion. This allows the plant to slowly ramp down in kW usage and thereby reduce plant load on the grid.

2. Using the BESS battery system to make up the difference in shortfall kW targets or as a constant instantaneous load reduction component. The BESS is rated at 2 MW for five minutes and then linearly decreases to zero in 15 minutes. The BESS can be used standalone or in conjunction with either the flow equalization basin or the CHP engines.
3. Activation of either one or both of the selective catalytic reduction unit converted Cummins CHP engines as kW load reduction assets. Each engine is rated at 1.1 MW each.

These scenarios allow the plant to participate in the California ISO Proxy Demand Resource program in a day-ahead nomination. The plant operator decides the day before how much and when it wishes to offer a kW demand reduction of energy at the plant. If California ISO accepts the offer the plant is notified in-advance of the event time, and then must perform the energy reduction it was awarded. If successful (such as in meeting the obligation and demand reduction), then city then would be paid for their reduction and participation in the Proxy Demand Resource program. A scheduling coordinator (SC) is required for the program participation. This project was able to demonstrate all the microgrid functions and perform all of the scenarios and some combinations of scenarios. The microgrid has the ability to provide an on-going revenue stream to the City, help the grid in the Sonoma County area by reducing demand on the electrical grid, and act as a load balancing resource during peak times.

The project at the end of the grant period was allowed to commission and facilitate a 30-day test period of the microgrid (as the PG&E telemetry was yet to be installed completely at the time of the grant end date of March 31, 2019. Commissioning of each scenario was performed, tested and energy and flow data was gathered. The outcome of the testing and data demonstrated the attributes of a microgrid integrated and operating with a SCADA system at a wastewater treatment facility with operator *man-in-the-loop* control of the plant assets at all times. This is key for wastewater facilities as they are extremely risk averse.

The following section provides a brief description of the scenarios that will help orient the reader to the modes, design, and function of the microgrid.

Scenario 1 – Flow Equalization Basins: Flow Diversion

The Laguna Treatment Plant has two 6-million gallon flow equalization basins used for influent flow diversion. Typically flow equalization basins are most heavily used in the winter months during rain storms, so that the plant can catch up with the typically higher influent flows. These are then available in the summer months when the flows are typically lower and the flow equalization basins can be used as a resource for demand reduction.

Multiple operational runs of Scenario 1 were performed over a 30-day period in April 2019 with repeatable success. The flow diversion typically would require about an hour in advance to meet the target kW that was offered the day before. In several sample runs the target value was entered at a 500 kW reduction for an event period of two hours. Through some trial and error it was found that if the flow diversion would be started about an hour before the required time to hit the 'target' value the Scenario would closely meet or exceed the 500 kW target amount during the event period. The plant operator could overshoot the target value by diverting more influent flow as it approached the event start time. A lesson learned with this scenario is not only are plant loads constantly varying all the time it is strongly advised to evaluate the flow equalization basin time it takes to meet a target kW reduction amount. This can be done manually via the SCADA control of the flow equalization basin and by monitoring the plant load reduction.

Figure 5 is a picture of one of the flow equalization basins used for Flow Diversion Scenario 1.

Figure 5: Flow Equalization Basin

Source: Trane U.S.

Scenario 2 – Battery Energy Storage System (BESS)

The Nuvation Energy BESS system in conjunction with the Parker inverter provided the ability to instantaneously deliver 2 MW for five minutes and then linearly decline to zero in the following ten minutes. Albeit a small BESS in kWH capacity it was a great resource for peak shaving and making up for other plant assets that were slow reacting (such as flow equalization basin turndown time; CHP engine ramp-up times, and others).

Scenario 2 was tested and operated in various events whereby as a *standalone resource* it would provide 250-kW reductions for nearly two hours. At smaller values it would extend the time of operation.

When the BESS was coupled with either the flow equalization basin or a CHP engine it would help assist hitting the target values once the event time would start and then allow the flow equalization basin or CHP to catch up until they could meet the load reduction desired.

Typically the battery would be used once a day and then re-charged at night after 11 P.M. when electrical demand costs are less expensive and loads are relatively stable. Figure 6 is a photo of the Nuvation Energy BESS and Parker inverter/transformer.

Figure 6: Nuvation Energy and Parker Inverter/Transformer

Source: Trane U.S.

Scenario 3 – CHP Engine #3 or #4 With selective catalytic reduction units

There are four existing Cummins 1.1 MW CHP engines at the LTP. Two engines are dedicated for digester gas operation with a 10 percent natural gas mixture and the other two engines (#3 and #4) were underused natural gas engines for standby use only due to air quality management district (AQMD) permit limitations. This project enabled these two mostly underused engines to now be operated on 100 percent natural gas with Miratech selective catalytic reduction anti-pollution technology applied to them.

During testing of CHP engines #3 and #4 these two assets (as long as they were runnable and without need of maintenance) could easily be called upon and used. Several operational tests and runs with the engines using the day-ahead nomination format were performed and they easily met the desired target kW reduction. Typically, 750 kW would conservatively be offered in a simulated bid as plant loads could be variable and this variability could affect the baseline load.

Lessons learned with CHP engines is that once they are converted with selective catalytic reduction units, the engines required both Cummins and Miratech to be on site for engine tuning and emissions adjustments. This was done several times due to city operational issues with their CHP engines to get them operable and useable as a resource. Running two engines at a time also presents the need for adequate natural gas volumes and pressures to ensure proper fueling of the engines. Figure 7 is of the Miratech selective catalytic reduction units under construction and near completion.

Figure 7: Two Miratech Selective Catalytic Reduction Unit Installations

Source: Trane U.S.

Electrical Design

The electrical design was completed under the supervision and direction of qualified and licensed electrical engineers at ECI, Inc. The design consisted of the following plan sheets:

- Electrical Legend and Abbreviations
- Overall Electrical Site Plan
- Electrical Plan for Battery System/Inverter/Transformer
- Miratech Electrical Plan

- Carport PV System Electrical tie-in Plan
- M2 Switchgear Electrical Plan
- Electrical Details
- M2 Switchgear Single-Line Diagram
- Santa Rosa LTP Single Line Diagram
- Electrical Network Diagram
- Miscellaneous Diagrams

The electrical design reconfigured the plant's existing M2 switchgear to provide 12.5 kV, three phase power to the Parker inverter/transformer. SEL 700 protection relays and customer metering are in the main breaker section. The M2 switchgear is fed from the existing main substation on the plant owned by the City of Santa Rosa, which is powered from a 69-kV PG&E feed to the plant. An air switch in the main substation provides a visible lockable disconnect for PG&E.

From the M2 switchgear, underground conduits feed the new 12-kV service to the Parker pad mounted transformer/inverter, which has a local unit disconnect switch that serves as the visible lockable disconnect. The plant can open this switch if necessary. From the Parker inverter underground feeders enter the Nuvation Energy Battery Storage System. On the exterior of the Battery Storage there is a circuit breaker/disconnect for isolation of the Battery Storage System. The 126 kW_{AC} photovoltaic (Carport solar PV) array is AC coupled at 480 V to the plant site grid.

Two preexisting Cummins CHP generator sets were integrated into the microgrid project. Each CHP engine (#3 & #4) is capable of 1.1 MW each at 4,160-volt, 3-phase. Each engine is tied into the existing on-site electrical grid at the plant.

Under this project, each of the two CHP engines are dispatchable via the Trane GridFlex™ program which provides the SC functions for the California ISO Proxy Demand Resource day-ahead market program. Operators can request these engines to support the reduction of plant load and enable participation in the day-ahead market.

Under the project, these modifications and additions of assets allow for the Trane GridFlex™ program to request the battery storage, the flow diversion, and the two CHP engines to seamlessly perform individually or in a combination of scenarios.

Electrical Studies

Table 1 shows the electrical studies completed during the design phase of the project. These are briefly discussed below.

Table 1: Electrical Studies Completed During Design Phase

Study	Authors
Laguna Treatment Plant Microgrid Study	Trane, ECI, Inc., Nuvation & Parker
Plant Load and Flow Study	City of Santa Rosa, Trane, ECI, Inc.
Electrical Coordination Study	ECI, Inc.
Factory Testing BESS / Inverter Study	Trane, Nuvation & Parker (at the Parker test facility)

Source: Trane U.S.

Trane / Nuvation Energy / Parker Microgrid Study

The Trane/LTP microgrid study was completed using the Nuvation/Parker/Trane simulation software package. The research team performed steady-state and discharge/re-charge stability analyses. The following scenarios were analyzed:

1. Simulation 1: Charging/Discharging of battery storage system at Parker's live testing facility in Tennessee. Parker connected their inverter to the grid, and all internal system tests were run including voltage, amperage and frequency.
2. Simulation 2: Simulate various discharge stages for the battery storage system with live connection to the Schweitzer microgrid controller and Trane's SC+ controller connected to Trane's GridFlex™ software.
3. Simulation 3: Testing and simulation of on-board battery management system during discharge and re-charge cycling and the Parker inverter system.

The conclusion of the simulation study was that all voltages and thermal loadings in the buses and line sections were maintained within normal criteria and no thermal or voltage violations were found.

The stability analysis was performed to evaluate the ability of the battery storage system and inverter, especially the BESS, to be able to sustain and be disconnected from the grid. Two scenarios were considered: BESS at full state of charge energy; and BESS at minimum state of charge. The results indicated that the BESS was capable of being dispatched and curtailed as needed for the requested capacity (kW) of the design.

The factory acceptance test identified the following:

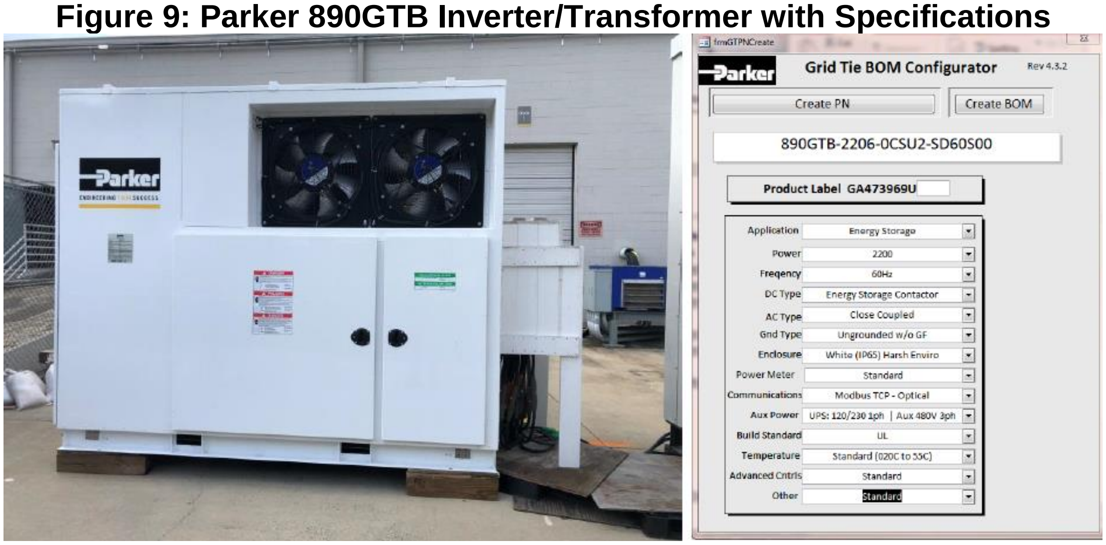
- There were no pre-shipment issues with either BESS or the inverter/transformer.
- All safeties and operation satisfied all test results.
- The BESS was capable of being island remotely.
- The BESS met all system design requirements and applicable standards.

Figure 8, Figure 9, and Figure 10 depict the testing at Parker's Energy Grid-Tie Division testing facility located in Charlotte, North Carolina.

Figure 8: Nuvation Energy Battery Energy Storage System

Source: Trane U.S.

Figure 9: Parker 890GTB Inverter/Transformer with Specifications



Source: Trane U.S.

Figure 10: 2 Megawatt Load Bank

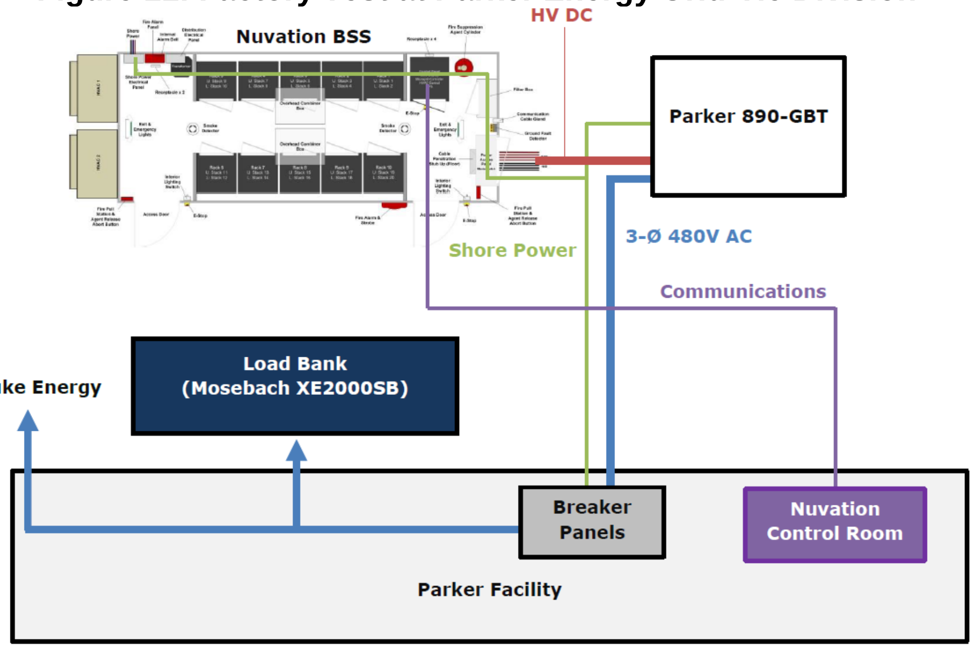
Source: Trane U.S.

Other Electrical Studies

The other studies shown in Table 1 were performed using Trane GridFlex™ program with the Schweitzer microgrid controller and Trane SC+ controller. The integrated controllers and software provided for pre-installation simulation testing of the microgrid system under a live load bank and the Parker inverter/transformer with the Nuvation Energy BESS system interconnection tied to Duke Energy for charging. These tests were performed at the Parker Energy Grid-Tie facility and showed that all performance requirements and standards were met.

Figure 11 shows the actual testing diagram that was performed at the Parker factory with three engineers from Nuvation Energy, Parker engineers, Electrical Consultants, Inc. electrical engineer, and Trane engineers. The controllers (that is, the Schweitzer microgrid controller and the Trane SC+) are located in the Nuvation control room in the BESS container.

Figure 11: Factory Test at Parker Energy Grid-Tie Division



Source: Trane U.S.

At the Laguna Treatment Plant project site the plant electrical load and flow data study and analysis were performed prior and during final testing of the microgrid. These studies provided background for plant operation and historical information.

Prior to making the final 12 kV connections to the Parker transformer and inverter, the electrical tests were performed under the direction of qualified engineers for the protective devices at the first level of connection, where power sources and main load switchboard connect to the microgrid. The Short Circuit Study determined the maximum fault current at the main breaker in the M2 switchgear (LTP-owned service) connected to the microgrid. The Arc Flash Study determined the arc flash category rating at the main bus, where it is connected to the microgrid. This information was then used to develop arc flash warning labels that were affixed to each associated electrical service panel, as appropriate. Figure 12 is of the relay setting and testing performed on the SEL relay.

Figure 12: SEL Relay Settings and Test

Source: Trane U.S.

Civil and Structural Design

The civil engineering design was completed under the supervision and direction of a qualified licensed civil engineer and consisted of the following plan sheets:

- Civil legend and abbreviations
- Civil site plans for carport PV area
- BESS system civil site plan
- Selective catalytic reduction units civil plan for CHP engines #3 & #4
- Civil details by area

Structural engineering was completed under the supervision and direction of a qualified licensed civil engineer. Structural engineering was limited to equipment anchoring and concrete equipment pad design.

Network and Communications

Network and communications engineering was a joint effort among Trane, The City of Santa Rosa Information Technology (IT) department and ECI, Inc. Trane, with ECI, Inc., created a data flow diagram showing each device that has a role in the microgrid communications, control, and generation systems. The dataflow diagram showed the signal paths and characteristics between all devices. From this data flow diagram, Trane created a data flow table to add details such as IP addresses. Next, a network diagram was created by ECI, Inc. and added to the electrical plan set. The data flow diagram, data flow table, and network diagram were created after the 60 percent design review and were revised at 90 percent and 95 percent level of detail. The 100 percent network diagram was used during construction to install the required components for interconnection of device communication, monitoring, and control.

The Trane and City of Santa Rosa team collaborated on a Virtual Private Network (VPN) and cybersecurity assessment as part of the network and communications design. The City of Santa Rosa IT staff provided for the cybersecurity protection methods and made sure that the microgrid network and communications design met their stringent requirements for the facilities.

Concept of Operations

The Concept of Operations for the microgrid evolved over a year and several on-site meetings with plant operators, Trane, and ECI, Inc. and the California ISO to discuss and draft a plan of operations for the project. The research team did a thorough review of the draft concepts of how the microgrid would operate. These meetings narrowed down the possibilities to what the plant operators could understand and were comfortable in allowing the microgrid to control and operate for the day-ahead market.

As the lead system integrator, Trane used their GridFlex™ software platform for integration with the Schweitzer microgrid controller and Trane SC+ controller. Working with ECI, Inc., Nuvation, and Parker closely, Trane developed a plan for the Concept of Operations of how the microgrid should operate that was approved by the plant's operators.

The plant operators limited the full breadth of what the microgrid would be allowed to perform, to limit impacts to the customary operation of the plant. Ultimately, Trane and the equipment providers constrained what the microgrid could and could not do from a technical and contractual perspective (what their system is capable of and what their contract responsibilities are for the project). PG&E requirements defined what the microgrid capabilities needed to be from a regulatory perspective. The Concept of Operations was revised several times to account for the changes the City required for their plant operations to not be disturbed.

Interconnection Process

The interconnection for the project required several key steps in acquiring the approval processes:

1. Approved plans for the interconnection
2. Service connection arrangement
3. Interconnection agreement

These processes were delayed due to a long time for city review and approvals, which delayed the acquiring of the PG&E Interconnection agreement. The city had been dealing with the devastating Tubb's fire aftermath and had several plant personnel issues and concerns with harmonics. To help speed the approval process of the City, the California Energy Commission issued a stop work order (Appendix A) to obtain confirmation of the previous final approvals. PG&E generously allowed for a 30-day commissioning and testing period of the microgrid. The final interconnection requires a telemetry evaluation by PG&E, which is still pending. Once approved, the microgrid may continue to operate as designed to provide grid reliability and load stabilization in the area.

Engineering Plan Set

The engineering plan sets were an integral part of the project development. The preliminary plan sets were developed for the three separate areas: (1) carport solar PV; (2) microgrid BESS/inverter and M2 switchgear 12 kV connection; and (3) selective catalytic reduction units for CHP engines #3 & #4. The city of Santa Rosa required 30/60/90 percent design review by plant staff. Once reviewed and accepted the plans were submitted to the City of Santa Rosa for building permits. During the initial months of the project, the design team added detail to the preliminary plan sets and brought them up to the level of completeness, making them ready for review. Comments from each stage of the design review process were incorporated, and details were added to create a 90 percent complete set of engineering plans. The 100 percent level sets, once approved by the City, permits were issued and work was started in each of the three areas. The carport solar PV was completed first, then the microgrid BESS/inverter set, and lastly the selective catalytic reduction unit plan set. The selective catalytic reduction unit work required an additional permit from the BAAQMD (Bay Area Air Quality Management District) due to the changes required in the plant's operating emission permit. The BAAQMD permit took more than a year to acquire before the City would allow any work to begin for the installation of the selective catalytic reduction units.

Engineering Specifications

Engineering specifications for the project were produced differently than for a typical design-bid-build project, where normally a specification book is part of the bid package. Instead, the specifications were called out on the plans and in the submittal documents, and there was dialog between the City about equipment specifications throughout the design and review process. In that way, vendor-specific requirements could be met to allow for rapid implementation of each technology. Key specifications used for this project are included in Appendix B.

Engineering and Implementation Cost Estimates

The pre-engineering for the grant award was developed at the proposal stage using the preliminary design concepts, and work was delineated into the following divisions:

- Electrical Construction and Commissioning – carport solar PV
- Selective catalytic reduction units Construction, Permit and Commissioning – selective catalytic reduction units for CHP engines #3 & #4
- BESS/Inverter Construction and Commissioning – BESS (Nuvation Energy and Parker)

- Electrical Construction and Commissioning – General

After the project was awarded by the California Energy Commission, contracts between all partners and vendors were finalized using the costs agreed upon during the proposal stage. At this point, the Trane budgets became fixed. The risk in contracting large construction projects in this way is quite high. Normally, the standard method would be for engineers to develop the design and specifications prior to soliciting bids from contractors. This provides for the common method for acquiring accurate cost proposals from the subcontractors and suppliers. In this case the project is a design/build type of project.

Therefore, a fixed price had to be agreed upon when the level of completeness for the design was not finalized. Many things can change as the design develops, and it is challenging to control costs and maintain project quality when the construction costs have to be agreed upon early in the design process. Nonetheless, these were the conditions imposed by the California Energy Commission solicitation process under which the project was developed and proceeded.

This is a new concept for the City of Santa Rosa. Their normal traditional path is the design-bid-build type of contracting. This became evident at certain times in the project when requests for additional work that was not on the approved plans was requested.

In the end, there were cost overruns in the civil construction (due unforeseen underground pipes and soil conditions resulting in about $20,000) and electrical construction and commissioning (about $30,000). These cost overruns were not recovered. The grant amount was for $4,999,804. Given this project was the first-of-its-kind and thus not able to carry a contingency such additional costs cannot be known. The vendor's willingness to work together on issues that were outside of their contracts ultimately made the project successful.

CHAPTER 3: Equipment Procurement and Testing

This chapter presents the procurement methods and processes that were followed to purchase the equipment and services necessary for installing and commissioning the Laguna Treatment Plant microgrid.

Procurement Process

The procurement process started during the initial proposal stage of the project and submission of the grant process. At this early stage, the major microgrid components were depicted in a preliminary design phase with descriptions to show who was responsible for procuring and installing each component of the various parts of the project. These conceptual descriptions were provided to each vendor and contractor on the project team and used to gain agreement on which member would be responsible for procuring and installing each areas components and the associated subsystems.

Once all parties reached agreement on the preliminary design concept, an overall scope of work was developed. Each party provided its proposal for its work which provided the basis of the project costs. These proposal documents were used to add detail and deepen the understanding of how the project would be executed if the grant funding was awarded. The pricing gathered during this proposal stage became the basis for the proposal budget that was submitted to the Energy Commission for the grant.

After the Energy Commission awarded the project to Trane and during the initial issuance of contracts the project team met with each vendor and contractor to concur on the previously provided proposals and the overall scope of work. The Energy Commission budget worksheet help to develop detailed contracts with each of the subcontractors. These detailed contracts included the specific scope-of-work for vendor or contractor, the terms and conditions, and a project schedule.

This process resulted in vendors and subcontracts with the entities listed in Table 2. Of the subcontractors listed, only Nuvation Energy, Parker, and Miratech were responsible for equipment procurement. The remainder of this chapter explains how the major components and subsystems were procured under the project.

Table 2: Trane - Project Subcontractors and Suppliers

Subcontractor/Supplier	Project Role
Nuvation Energy	battery storage system
Parker Hannifin	inverter and transformer
Electrical Consultants, Inc.	electrical engineering & Schweitzer MGC
Villara	carport solar PV system design, engineering, and commissioning
Geveden Industrial, Inc.	civil, structural, and electrical contractor construction and structural and civil drawings
Brown & Caldwell	selective catalytic reduction units engineering and BAAQMD permit application
Miratech	selective catalytic reduction unit equipment and start-up/commissioning
U.C.D. – Center for Water Efficiency	report load shifting at wastewater treatment facilities
Rockwood Communications	outreach

Source: Trane U.S.

Microgrid Management System

The microgrid software platform used in this project is a Trane U.S. product called GridFlex™. This program integrates with the California ISO day-ahead market including inputs from the plant SCADA points, the Schweitzer microgrid controller and a Trane SC+ control for system operation and cloud based storage. The GridFlex™ program provides the plant operator inputs for the Day Ahead Nomination into the California ISO's Proxy Demand Resource program. Plant operators have the ability to nominate the Day Ahead Nomination kW amount into the program and if awarded they then are able to exercise the scenario they wish to operate under (as described previously in Chapter 2). The basic components include the following:

- Interface to plant SCADA system with Schweitzer microgrid controller.
- One Schweitzer GPS clock.
- Access to GridFlex™ software platform for day-ahead market nomination using a Graphical User Interface for proposed kW amounts and durations, including a Baseline Calculation.
- Training and engineering support for plant operators.
- Testing/commissioning/data analysis/operations for final project completion.
- Warranty.

The microgrid system was programmed and tested at Parker's Energy Grid-Tie Division facility in Charlotte, N.C., and then installed and commissioned at the site. After testing, the plant site operators were given a 30-day period of trial operation. Each scenario that they ran provided for kW reductions and simulated the day-ahead market. Trane programmers and engineers hosted operator training at the plant facility and provided support for a 30-day period. The project completed on March 31, 2019 with the succeeding 30-days for operational demonstration of the microgrid system.

Battery Energy Storage System

Trane procured the battery energy storage system (BESS) from Nuvation Energy. A Trane purchase order for various pre-agreed milestones for battery storage system manufacturing and material procurement were used to purchase the BESS, which included:

- BESS outdoor container
- 420 EnerDel Lithium NMC batteries (21 per stack modules).
- Nuvation battery management system and Nuvation stack controller.
- Fire suppression system.
- Engineering/installation support.
- Manufacturer's standard warranty.

The BESS was shipped to the Laguna Treatment Plant after a complete testing regimen, that included the Parker inverter, and Geveden Industrial completed the installation. Once the installation was complete, Nuvation commissioned the system and worked with qualified Trane and Parker engineers to test the system onsite as part of the microgrid.

Inverter and HV Transformer System

Trane procured the 2-MW inverter power conversion system from Parker Hannifin. A Trane purchase order for the high voltage transformer and inverter including manufacturing and material procurement were used to purchase the PCS, which included:

- WEG 12 kV/480V transformer
- Parker 890GTB 2MW inverter
- Engineering/installation support
- Manufacture standard warranty

The Parker transformer and inverter was shipped to Laguna Treatment Plant after a complete testing regimen and Geveden Industrial completed the installation. Once the installation was complete Parker commissioned their transformer and inverter system and worked with qualified Trane and Nuvation engineers to test the system onsite as part of the microgrid.

Carport Solar PV System

Trane procured a turnkey carport solar PV system from Villara. An engineering, procurement, and construction contract was used to procure the turnkey PV system. Villara designed the PV system and hired Baja Construction to install the carport racking structure for the PV panels. Geveden Industrial performed the underground 480V electrical work and tie-in at the electrical distribution point of connection.

Villara performed the parking lot area site work, tree removals and other site work. They installed the PV panels and two inverters for the system. These activities were conducted in compliance with the storm water pollution prevention plan for the site. Trane coordinated the work to prevent conflicts with employee parking from multiple contractors working at the site.

The City of Santa Rosa provided for the SCADA power monitoring of the final installed PV system.

Point of Common Coupling Switchgear

The city of Santa Rosa M2 switchgear had an extra point of common coupling (PCC) switchgear. ECI produced the electrical design including one-line and three-line diagrams of the power connections to the Parker PCS, and Geveden Industrial performed the underground 12 kV feeder from M2 switchgear to the PCS. Information about testing the PCC switchgear is provided in chapters 2 and 6.

Balance of Systems

The balance of systems components for the LTP were mostly for the low voltage communications.

Electrical

Trane procured the balance of systems for the electrical design with ECI and a subcontract with Geveden Industrial for the installation work. Electrical work items not mentioned above included, but were not limited to:

- Installing low-voltage power and communication circuits between the PCS and Nuvation BESS.
- Installing the 480 V electrical for the BESS HVAC units.
- Installing the close coupling electrical between the transformer and PCS.
- Installing various power and communication circuits inside the existing emergency generator building and SCADA system microgrid connections.
- Providing site acceptance testing and relay testing at the M2 switchgear PCC for the pre-energization tests and PG&E inspection.

Trane and the City of Santa Rosa worked together with the PG&E interconnection agreement and relay testing requirements at the PCC.

Microgrid Controller Testing

As part of the procurement, the Schweitzer microgrid controller was installed and tested in a real-time digital simulation, hardware-in-the-loop environment with oversight by qualified engineers at Parker's Energy Grid-tie Division in Charlotte, N.C. This testing is summarized in Chapter 6, Commissioning, and is documented in detail in Appendix C. This demonstrated the microgrid as a complete system at Parker's facility to reduce issues at the site, and increase knowledge and ensure that the system met all requirements and standards before the system was onsite at the wastewater facility.

CHAPTER 4: Microgrid System Interfacing

The LTP microgrid system is composed of a network of systems. These systems operate by and through the Trane GridFlex™ software interface. This chapter summarizes the control hierarchy and basic functions of the various systems.

Microgrid Control Hierarchy

The Trane GridFlex™ software interface (GUI) is the plant operator's interface to the microgrid. The plant operator provides via the Trane GridFlex™ software interface the day-ahead market value in kW, the event start time (including ramp time) and the duration time.

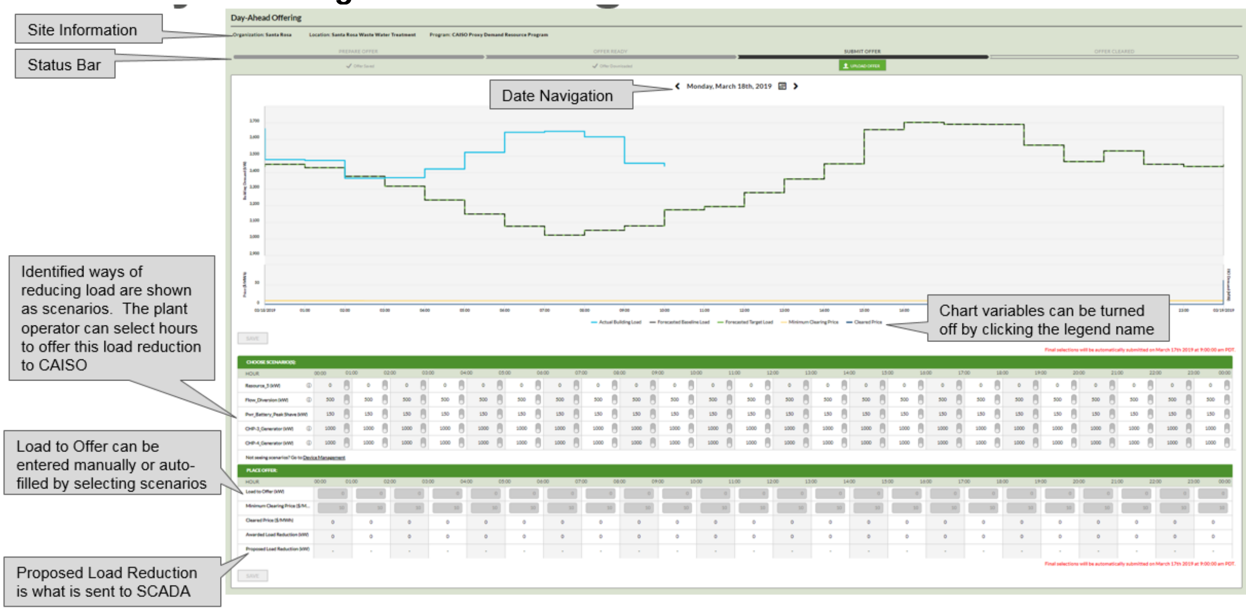
The Day Ahead Nomination control relies on direct action by the plant operator (man-in-the-loop). The plant operator's choices upon which he agreed are non-disruptive scenarios to the Laguna Wastewater Treatment Plant and include the following:

- Scenario 1 – Flow equalization basin or flow diversion of influent flows
- Scenario 2 – BESS (2 MW or incremental values in kW)
- Scenario 3 – CHP engines #3 and #4 (1.1 MW each)

The microgrid control components have primary objectives of monitoring and providing data for the operator to make decisions. Data is exchanged between the Schweitzer microgrid controller, the plant SCADA system and the Trane SC+ controller to the Trane GridFlex™ software interface.

Figure 13 provides for a view of the Trane GridFlex™ operator interface showing plant baseline load and selections for the day-ahead market in the California ISO Proxy Demand Resource program.

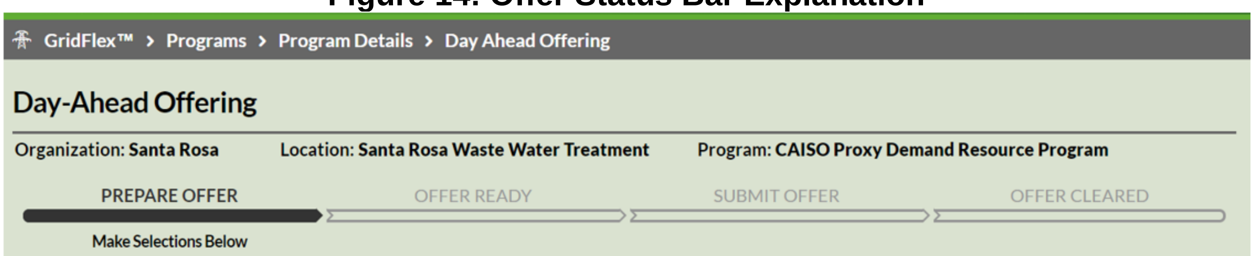
Figure 13: Trane GridFlex™ User Interface



Source: Trane U.S.

The Offer Status Bar shown in Figure 14 advises the plant operator of the offer phase he/she is in each day of the offer. This provides for the day-ahead market sequence of the event offering progression.

Figure 14: Offer Status Bar Explanation

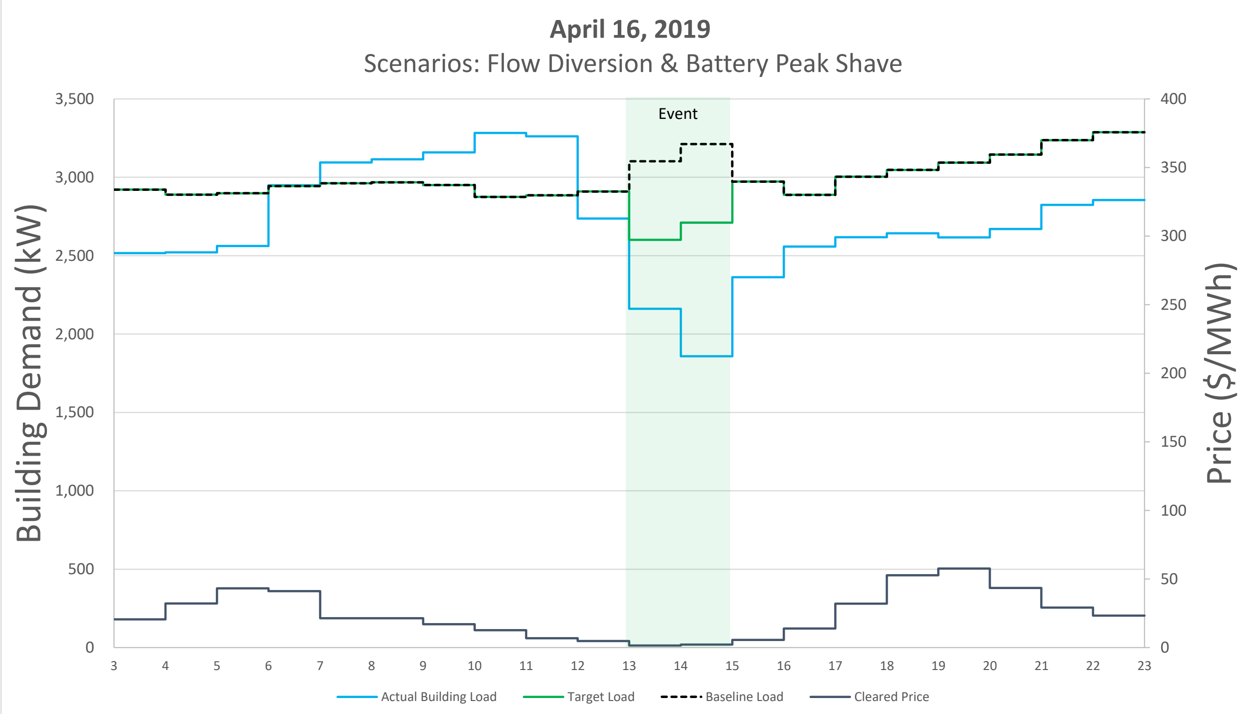


Prepare Offer	Offer Ready	Submit Offer	Offer Cleared
- Select amount and minimum price for hours willing to reduce load - Available until 9am Pacific the day before	- Offer made available to download by Trane's scheduling coordinator - Available 9am-10am Pacific the day before	- Trane's scheduling coordinator submits offer to CAISO - CAISO clears market - Available 9am-10am Pacific the day before	- Trane's scheduling coordinator has uploaded CAISO cleared results prior to 12am Pacific - Awarded offers sent to SCADA system between 12-5am day of event

Source: Trane U.S.

As an example of the Trane GridFlex™ system operation, Figure 15 provides for a Scenario 1 flow diversion and a Scenario 2 with the BESS battery used as a peak shave asset.

Figure 15: Scenarios 1 and 2 Day-Ahead Event April 16, 2019, 1300 – 1500 Hour



Source: Trane U.S.

Figure 15 shows the Event Date and Time as April 16, 2019 from 1300 to 1500 hours Pacific time. The baseline calculation uses the California ISO 10-in-10 method. This event was successful and reduced more than the committed amount as seen from the following bullets:

- 1300 – 1400 hours: Committed Reduction = 501 kW; Actual Reduction = 941 kW
- 1400 – 1500 hours: Committed Reduction = 501 kW; Actual Reduction = 1354 kW
- Note: Cleared pricing is based upon node information and this Event would have provided greater value had it been run either earlier in the day (0500 – 0700 hours) or later in the day (1800 – 2000 hours).

Lessons learned in running the various scenarios was that starting scenarios in the day-ahead market too early (that is, more than an hour before the event time) can skew the baseline load calculation. Plant operators, through running each scenario, have learned that choosing the right event time and day improves the value of the day-ahead market.

Part of the operator training involved teaching what a baseline is and how the baseline is affected in the day-ahead market.

What Is the Baseline?

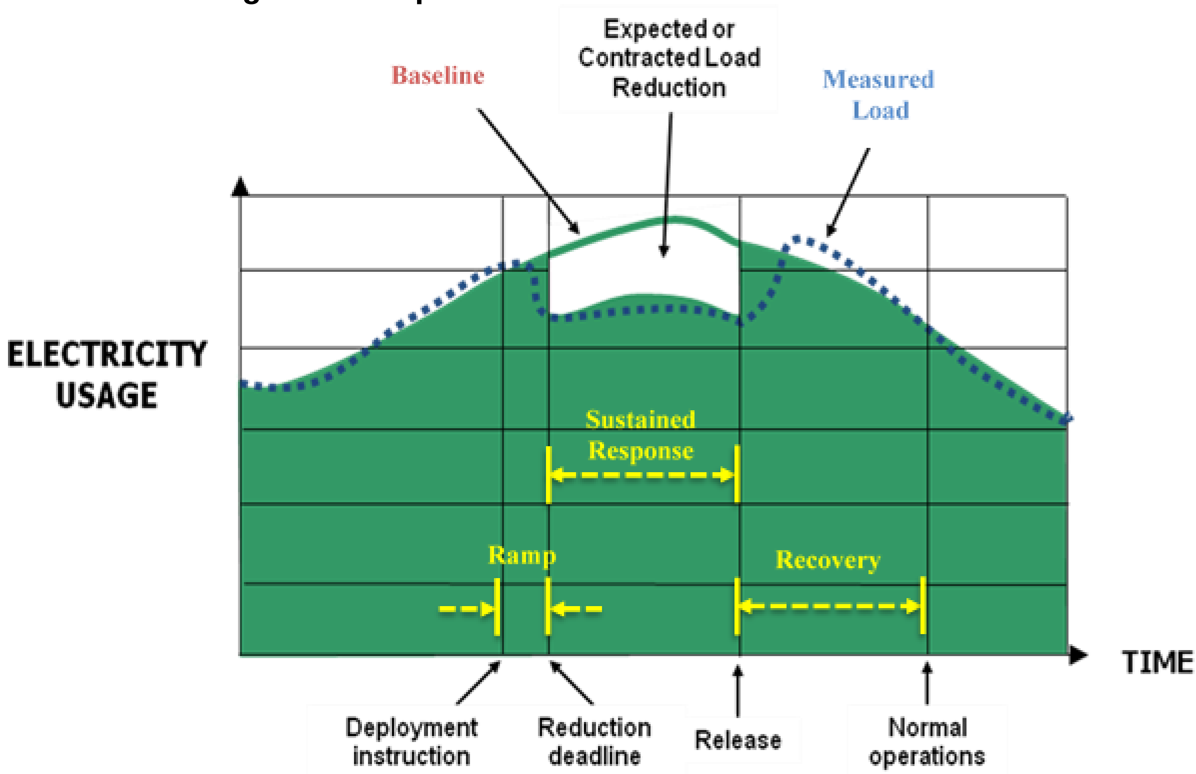
A *baseline* is a method of estimating the electricity that would have been used by a customer or demand resource in the absence of a demand response event.

Energy and capacity programs typically use baselines for their event performance evaluations. These are:

1. Based on historical interval meter data
2. Based on certain required criteria within the calculation, which is defined by the California ISO

Figure 16 depicts a typical baseline with an event ramp, sustained response period, and recovery time based on a time and load period.

Figure 16: Explanation of Baseline Profile and Event



Source: Trane U.S.

CHAPTER 5: Construction

The LTP microgrid project construction and activities are described in this chapter. This is an overview of the construction management process and a description of the major construction and installation work completed to build the LTP microgrid. At the end of this chapter is a discussion of the lessons learned, project challenges, and outcomes.

Construction Management

Trane provided the on-site construction management for the project. Trane has extensive experience with wastewater treatment facilities (WTFs) and with microgrids. The project kick-off was at the California Energy Commission in Sacramento with City of Santa Rosa personnel attending, as well as Trane management and representatives from Villara and Alstom Grid, the at the time BESS/inverter and microgrid partner in fall of 2015.

The design phase required a change in players in that Alstom Grid and Tesla determined they would not be able to participate in the project. Alstom Grid was acquired by General Electric, which complicated the ability to start the design. Trane proposed to the Energy Commission a change in microgrid BESS and inverter vendors and was able to work with Nuvation Energy and Parker Hannifin.

Due to the project changes with Alstom Grid, the on-site project kick-off did not start until the fall of 2016, with the design phase of the project. The Trane management team met with the key design engineers and project subcontractors to discuss the construction schedule, the on-site management, and the construction observation process.

The project began to gain progress once Nuvation and Parker were on board. Then engineering design drawings and details were developed. A list of the suppliers/subcontractors and general scopes of work is provided below.

Electrical Consultants, Inc. – Electrical design drawings

- Design of BESS electrical including high/low voltage and SCADA
- Programming of microgrid controller and plant SCADA interface
- High voltage design at M2 switchgear and underground to PCS
- High voltage design at Parker PCS transformer to inverter to BESS
- Carport solar PV 480V underground design and grid connection
- selective catalytic reduction unit electrical design as it applied to Miratech equipment

Nuvation Energy – Supplier of BESS system

- Design of BESS system
- Selection of Lithium batteries to meet project requirements
- Factory testing of BESS
- Field commissioning and start-up of BESS
- Support for interface to Schweitzer microgrid controller

Parker Hannifin – Supplier of inverter and transformer

- Design of PCS system with interface to Schweitzer microgrid controller
- Selection and design of transformer and inverter to meet project requirements
- Factory testing of PCS
- Field commissioning and start-up of PCS

Villara – Design 126 kW carport solar PV system turnkey

- Supplier of PV system components (carport- rack system, solar modules, inverters, monitoring system, balance of system components, and landscape/tree removals)
- Design of the PV system and monitoring system
- Responsible party for installation and commissioning of the PV system

Brown & Caldwell – Design engineering for Miratech selective catalytic reduction units

- Engineering drawings for the selective catalytic reduction units
- Preparation of the BAAQMD air permits for the City
- Assistance in system commissioning tasks

Miratech – Supplier of the selective catalytic reduction units

- Factory engineering and selection of selective catalytic reduction units to meet emission requirements
- Start-up and commissioning of selective catalytic reduction units

Geveden Industrial, Inc. – Civil, Structural and Electrical Contractor

- Installation and wiring of the BESS
- Installation and wiring of the PV to site electrical grid
- Installation of the PCS inverter and transformer
- Installation and wiring of the point of common coupling (PCC) switchgear
- Installation of the 12.5 kV electrical underground lines
- Installation of the carport PV 480 V bus tie
- Installation of communication wiring, including fiber optic and copper lines

- Installation of balance of system electrical system components

Rockwood Communications – Outreach consultant

- Provided outreach for the microgrid project
- Provide conference set-up and outreach to similar wastewater facilities interested in microgrid applications

U.C. Davis Center for Water Efficiency – Wastewater Facilities Demand Reduction Report

- Provided report on wastewater demand response opportunities

During the project construction, Trane provided on-site management and observation services and documented site work via daily reports and photographs. Trane, the plant operators, and SCADA teams were engaged throughout the construction period to review planned activities and provide input on the construction. Weekly construction meetings were conducted for current and pending future construction activities. Vendor coordination and shipments were also coordinated as needed.

Construction Drawings

The first set of designed and approved drawings were for the carport PV system. This work started in the fall of 2017 and was completed in the spring of 2018. BESS and PCS designs along with the selective catalytic reduction units drawings were submitted for approvals. Both of these design sets were delayed in being reviewed and approved due to the Tubbs fire in October, 2017

The BESS drawings were approved and the civil work began in mid-2018 and proceeded to a completion of this construction work until the end of 2018. The selective catalytic reduction units drawings were approved prior to receiving the BAAQMD air permit. This delay in receiving the air permit only allowed civil work to occur for the selective catalytic reduction units until the permit was approved in December 2018.

The project subcontractors and vendors worked diligently to accelerate the construction phase of each portion of the project until completion. The city plant personnel had hired Kennedy Jenks as their consultant in mid-2018 to provide the expertise that they lacked. This created additional delays as Kennedy Jenks was unfamiliar with the plans and project scope, which required a considerable learning curve. In addition, understanding the grant and its requirements required additional learning time. While Kennedy Jenks was familiar with many aspects of WTFs, they had no prior project work experience with microgrids. They were also not familiar with energy storage. The construction team and suppliers attempted to educate the consultant, enabling the project to proceed.

Environmental Review and Storm Water Pollution Prevention Plan

Early in the project a California Environmental Quality Act (CEQA) exemption determined a finding of no significant impact. There was an additional hurtle to consider during the design phase with the tiger salamander habitat being within the confines and outside of the LTP, which required several relocations of the original ballasted PV system to be changed to a carport PV system where a previously exempt area was available. Also the BESS system original location was moved twice until an acceptable area was agreed to, which was next to the existing emergency generator building.

The Storm Water Pollution Prevention Plan (SWPPP) was applied for the carport PV area, the selective catalytic reduction units, and the BESS. All necessary requirements were adhered to with best management practices during construction. All construction stages required additional time for design and then construction to occur and be completed.

Major Construction and Installation Work

The actual construction and installation period was about 16 months, from December 2017 until March 2019. The first construction activities occurred at the carport PV site and included the removal of trees in a parking lot island area and some irrigation and lighting work. Installation of the carport PV structure work occurred in the first quarter of 2018 and progressed to the final completed by late spring 2018. Final commissioning and intertie into the sites electrical grid were performed.

Most of the construction involved installing three main components within the microgrid project: (1) the carport solar photovoltaic system, (2) the battery energy storage system, and the point of common coupling, and (3) the two selective catalytic reduction units on existing CHP engines #3 and #4. A brief description and key photos of the construction and installation activities for these three main components follow. The electrical work for each of these three areas occurred with communications related connections for the microgrid system. As part of the project grant, the City of Santa Rosa was paid for the SCADA programming, which was a tremendous help as city staff knew best what and how the integration of the microgrid data would be acquired.

Solar Photovoltaic System

The carport solar PV array was located in the main administration parking lot on the LTP site. A site land survey was conducted to identify existing utilities, irrigation, electrical, and storm drains. The construction crews used equipment to clear, and grade the parking lot island area as shown in Figure 17.

Figure 17: Carport Photovoltaic Area Being Cleared for Installation

Source: Trane U.S.

A hydraulic drill rig dug the support structure holes and prepared for the equipment posts to support the carport solar array structure. Figure 18 shows the start of drilling for pier supports of the carport PV structure.

Figure 18: Drilling Preparation for Carport Photovoltaic Supports

Source: Trane U.S.

After the drill rig holes were completed the structural posts were set, the structure began to take shape and concrete and rebar cages placed. Figure 19 shows set carport PV piers.

Figure 19: Carport Photovoltaic Structural Support Post Installation

Source: Trane U.S.

The assembling of the carport PV structure was next with the galvanized steel racking system. Once erected, the mounting brackets were adjusted along the length of all rows to ensure the framing provided a level surface before attaching the modules. Figure 20 and Figure 21 show the aerial view of the carport PV array mounting structure.

Figure 20: Aerial View of Carport Photovoltaic Array Support Structure

Source: Trane U.S.

Upon completion of the array, the two Canadian solar inverters were mounted and the carport PV system was wired to a total of 620 panels with six strings of 18 modules. Figure 21 shows the installation progress of the PV modules on the racking structures. The installation of the inverters were installed on two of the supports under the structure. Under the canopy area LED lighting was installed for nighttime lighting.

Figure 21: Contractor Begins Panel Installation at Carport Photovoltaic System

Source: Trane U.S.

Figure 22 provides an aerial view of the completed installation of the carport PV system

Figure 22: Aerial View of Completed Carport Photovoltaic System

Source: Trane U.S.

Battery Energy Storage System

The BESS procured from Nuvation Energy was placed next to the LTP emergency generator building at the site. This was an ideal location, about 125 feet south of the M2 switchgear for the 12 kV tie-in. A massive concrete pad was constructed for the 42,000-lb Nuvation Energy BESS and Parker PCS and transformer. Construction and electrical field crews cleared the area, installed the necessary subgrade electrical and communications conduits, and built the heavy-duty reinforced concrete pad. Figure 23 shows contractor excavating pad area for the BESS system, and Figure 24 shows the installation of conduits, concrete pour, and finalizing the concrete slab for the battery energy storage system pad.

Figure 23: Excavation of BESS Concrete Pad Area

Source: Trane U.S.

Figure 24: Conduit Placement Installed and BESS Concrete Pour

Source: Trane U.S.

Figure 25 shows the BESS concrete pad curing in preparation for equipment set, anchoring, and wiring.

Figure 25: Completed BESS Pad Area

Source: Trane U.S.

Once the BESS pad concrete was cured, the equipment was set and anchored to the pad and the electrical contractor began wiring the Nuvation Energy BESS container and Parker PCS inverter. Figure 26 shows the BESS and inverter/transformer set onto the new pad and preparations for connections. Figure 27 and Figure 28 show the final connections to the 12 kV at the transformer.

Figure 26: BESS Set In-Place and Electrical Connections In Progress

Source: Trane U.S.

Figure 27: Power Conversion System Transformer Final Connections Completed

Source: Trane U.S.

Figure 28: Completion of 12 kV Underground Installation to M2 Switchgear Tie-in

Source: Trane U.S.

The 480 V conductors for the BESS were completed and the final communications wiring were performed. This completed the BESS equipment pad installation. Figure 29 shows the fiber optics terminations being installed.

Figure 29: Final Fiber Optics Communication Connections

Source: Trane U.S.

Figure 30 shows the completed BESS and PCS inverter system including the M2 switchgear.

Figure 30: Completed BESS and Power Conversion System

Source: Trane U.S.

Figure 31 shows the existing M2 switchgear that was modified for the 12 kV point of connection and protective relays for the BESS system.

Figure 31: M2 Switchgear Modifications Completed for BESS System

Source: Trane U.S.

Schweitzer SEL3555 Real-Time Automation Controller and SEL2407 Microgrid Management System

The Schweitzer SEL3555 Real-Time Automation Controller (RTAC) and SEL-2407 satellite time clock provide for the interface to the LTP SCADA system and also to the Trane SC+ controller for connection to the California ISO Proxy Demand Resource program day-ahead market. These controllers were installed inside the Nuvation Energy BESS container and connected via fiber optics to the LTP SCADA system. The Nuvation control panel console computer provides for information on the BESS system.

The City of Santa Rosa IT department worked with Trane engineers to install the communications network. This provided for the Trane GridFlex™ connection for remote access through a secure access point external from the BESS. Once these components were installed, Trane engineers worked with Parker and Nuvation engineers to complete the point-to-point testing between the BESS and Parker PCS inverter.

Figure 32 shows the team outside the BESS performing testing and commissioning of the post installation checks of the BESS and PCS systems. This process included Nuvation Energy, Parker, Trane, and the LTP SCADA programmers working together to verify system operational functions.

Figure 32: Commissioning and Testing of BESS System

Source: Trane U.S.

Figure 33 shows the inside of the BESS system after commissioning and testing were performed. Periodic charging and discharging of the BESS system were performed over several days before testing of actual scenarios of the BESS system.

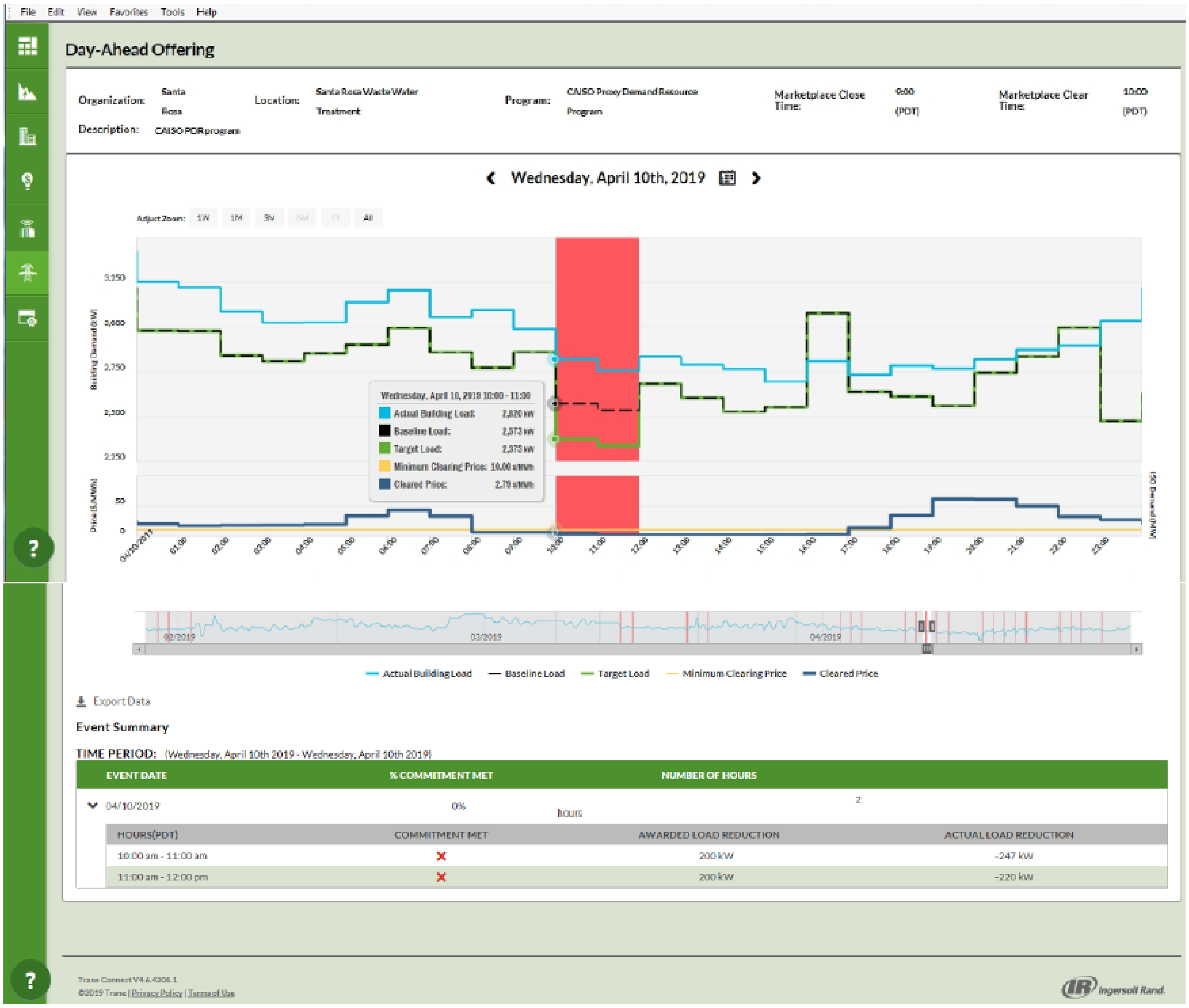
Figure 33: Inside View of the BESS Battery Container

Source: Trane U.S.

The Trane GridFlex screen has multiple selections for viewing the scenarios in which the plant operator may choose from for the day-ahead market participation.

Figure 34 shows an example of an actual scenario run with the program for a two-hour event period on April 10, 2019. The BESS was selected in the day-ahead market and offer was simulated as ”accepted” (or awarded). The offer was for 200 kW from 10:00 A.M. until 12:00 P.M. This was easily met, and the actual load reduction was 247 kW from 10:00 -11:00 a.m. and from 11:00 a.m. to 12:00 p.m. it was actually -220 kW.

Figure 34: Trane GridFlex Dashboard on April 10, 2019



Source: Trane U.S.

The plant operators ran multiple scenarios with the Trane GridFlex™ platform providing successful results of application of the day-ahead market simulation. The scenarios provided operator use and hands-on training during a 30-day period from the last week in March 2019 through April 30, 2019. Many lessons were learned in running each event on the impacts of the plant electrical load and operation.

The BESS was used mostly as a peak saving asset to help other assets such as the flow equalization basin or CHP generators reach their target set point values at the event start time and also to meet the values during the event period or duration.

Challenges Encountered During Construction

A number of challenges arose during the design and construction period. The following are a listing of the events sequentially for this project:

- Acquiring replacement vendors after Alstom Grid pulled out of the project required multiple vendor/suppliers to be able to pull together the project scope and requirements. Fortunately Trane was able to partner with Nuvation Energy and Parker Hannifin. Trane partnered with ECI, Inc. as the electrical designer and consultant and with Geveden Industrial, Inc. These partners helped bring the project back together and move forward with the design and the work.
- The Tiger Salamander habitat on and near the LTP site required relocation of the BESS and PV systems. Multiple site areas needed to be investigated to be able to settle on the final locations. This involved the City and other state and federal agencies to review the newly proposed locations for approval.
- Over the duration of the project several city personnel left their positions and were no longer involved in the project. This created periods of re-establishing new relationships and educating new people on the project and the particulars of the design.
- The 30/60/90/100 percent design reviews required extra time for plant operators to review, comment, and then agree on design measures. The City does not normally follow the traditional design/build concept or project approach, but rather followed a design-bid-build means and takes more latitude in making changes and decisions. The grant process is a design/build method where the City did not hire the designer or builder as they typically would.
- Several times during the construction phase the City wanted to change the scope after plans were already approved. This at times would delay progress of the work as they tried to withdraw their approvals.
- In the fall of 2017 the Tubbs fire destroyed a large portion of the city of Santa Rosa residential and commercial properties. This caused a delay in plan reviews and some personnel of the City being impacted by the tragedy.
- Although each of the challenges mentioned caused various delays, the project team was able to overcome each of them and complete the construction on March 31, 2019. The success of the microgrid and its use going forward relies on decisions by the City. Trane has offered to provide support for a period of time on the possibility of becoming the scheduling coordinator for the day-ahead market.

Monthly Summary of Construction Activity

Table 3 provides a list of monthly construction activities that were carried out to install the LTP microgrid project system. Installation work occurred over a longer period of time than expected due to the challenges discussed previously.

Table 3: Summary of Construction Activity

Date	Construction/Installation Tasks
Dec-2017 to Jun- 2018	Carport PV system installation including clearing of site area, underground utilities, drilling, structural supports, PV arrays, panels and inverters. With final tie-in to 480V connection point of connection.
Jul- 2018 to Dec-2018	BESS excavation work, pad preparations, underground conduits, rebar, concrete pouring, setting of equipment, and electrical installation, excluding final 12 kV energizing.
Feb-Mar 2019	BESS final connections terminated and conditional interconnection approval to operate system.
Sep-2018 to Mar-2019	Selective catalytic reduction units installation occurred beginning in August 2018 with civil work layout, then structural work. Only one selective catalytic reduction unit was allowed to be installed at a time and completely operational, then the second one was installed. Approval of BAAQMD permit was required before setting selective catalytic reduction units onto structural supports, which occurred in December 2018.
Mar-2019	Completion of both selective catalytic reduction units occurred by March 31, 2019 and commissioning and testing were finished.
Mar-2019	PG&E interconnection was approved under a conditional use from April 1, 2019 until April 30, 2019 for commissioning and testing. Final interconnection agreement required additional telemetry that the city is pursuing separate from the project completion.
April-2019	Operational testing of microgrid system were performed throughout the month of April 2019. All scenarios were accomplished and proven as functional.
April 30, 2019	Final closeout of the project and documentation were completed.

Source: Trane U.S.

CHAPTER 6: Commissioning

Overview of Commissioning Process

Goals and Strategy

Commissioning for the project required coordination with the plant operators so that the wastewater plant was not disturbed from its daily operational requirements. A wastewater treatment plant has many processes that require a continual processing of the influent flows into the plant and the effluent flows out of the plant. Plant operators were intricately involved during the commissioning process to ensure that they understood all aspects of the microgrid.

Pre-commissioning checklists were provided for each equipment commissioned. Since this was the first-of-kind equipment in an operating wastewater facility, there were stringent operational requirements.

The LTP operates 24/7/365, so at all commissioning stages, a consideration to maintain plant operations was paramount to avoid any environmental or processing issues. During rain storms activities would need to be curtailed so the plant could handle the influent flows.

As a result, the following wastewater plant operational constraints were required during commissioning:

- No operational tests during heavy rain storms.
- If planned maintenance or equipment failure occur some of the commissioning may need to be suspended until maintenance or equipment repairs are rendered.
- Flow equalization basin flow diversion amounts and durations may fluctuate depending upon influent processing and capacity of the plant to handle processes.

To meet these goals, the commissioning was conducted over a period of time and stages. Whenever possible, components were installed and tested to ensure functionality before efforts were made to integrate them into the overall system, such as the factory testing of the BESS and PCS inverter with the microgrid controller. The timing of each test was planned for plant operators to be available in case of issues with plant operations.

Components Requiring Testing During Commissioning

Table 4 outlines each component and subsystem that was tested, and the party or parties responsible for performing the test. LTP operators participated in and provided oversight and witness of all commissioning tests.

Table 4: List of Components Commissioned

Component	Responsible Party
PV Array	Villara
Battery Energy Storage System (BESS)	Nuvation Energy, Trane, LTP SCADA programmers
BESS Inverter	Parker, Nuvation Energy, Trane, LTP SCADA programmers
SEL Relays and PCC	Geveden Industrial, Inc. / PG&E inspection
CHP Engine #3 & #4 selective catalytic reduction units	Cummins, Miratech, LTP Operators
Power Meters	Trane, Nuvation Energy, Geveden Industrial, Inc.
PG&E Interconnect	PG&E, Trane, city of Santa Rosa
Microgrid Controller / Trane SC+	ECI, Inc., Trane, LTP SCADA Programmers

Source: Trane U.S.

Partial Timeline of Commissioning Process

An abbreviated timeline of some milestones of the commissioning helps one understand the overall flow of commissioning.

- July 2018 – Initial connection of Carport PV
- August 2018 – Commissioning of Carport PV and passed inspection
- December 2018 – BESS installation complete and passed civil, structural inspections
- January 2019 – Selective catalytic reduction units engine #4 installation passed civil inspection
- February 2019 – Selective catalytic reduction units engine #4 installation was completed
- February 2019 – Selective catalytic reduction units engine #3 installation started and passed civil inspection
- February 2019 – Factory Acceptance testing of BESS by city accepted
- March 2019 – Selective catalytic reduction units engine #3 was completed and passed testing

- March 2019 – Conditional PG&E Interconnection allowed less than a 30-day test period
- March 2019 – All work was completed and final testing and commissioning began
- April 2019 – A 30-day final commissioning was performed
- April 30, 2019 – Final project documents were provided and closeout

Subsystem Commissioning

M2 PCC Switchgear and Microgrid Controls

Site acceptance testing of the PCC switchgear and Schweitzer and Trane SC+ microgrid controls included visual and mechanical inspection and electrical testing of switchgear hardware, as well as functional testing of the primary and secondary SEL-700 relays. The site acceptance testing also included functional testing of the Trane GridFlex™ software and the LTP SCADA system in conjunction with the Schweitzer microgrid controller software.

Basic Functionality Acceptance Testing

Basic functionality acceptance testing consisted of passing required PG&E pre-energization tests, performed by Andrew Humphrey Engineering, LLC from Golden, CO and observed by PG&E. These tests confirmed basic safety functionality of the PCC relays and adherence to PG&E interconnect requirements. The testing passed with no issues.

Advanced Software Simulation Testing

To safely test scenarios that could not be tested on a live system without risking damage to hardware or operational disruption, the Trane, Nuvation and Parker teams performed thorough hardware-in-the-loop testing of all advanced SEL software functionality at the Parker Grid-Tie Division in Charlotte, NC and all software features were proven in a simulated environment to meet all requirements and standards.

Testing on-site at LTP began in the later part of March 2019 and concluded the last week of March. LTP personnel, Nuvation and Parker conducted testing under the direction and test plans provided by Trane, with LTP personnel onsite monitoring the tests and Trane communication with the microgrid system. All tests were passed successfully in this environment

Live Site Acceptance Testing

Trane's GridFlex™ software functionality was tested and shown to operate as expected. The plant operators made some adjustments in how they would use the scenarios in the day-ahead market simulation.

Testing of the plant SCADA control interface occurred before and during the simulation testing. This ensured functionality.

PG&E Permission to Operate

The project was issued a PG&E conditional operational permit to operate so that commissioning and testing could occur. PG&E at the close of the project was working with the city of Santa Rosa to finalize the telemetry to meet the interconnection requirements and obtain acceptance approvals.

Photovoltaic System

Site acceptance testing and commissioning of the PV system was conducted by Villara. The process consisted of the following steps:

- Pre-commissioning tests and check procedures
  - DC String Megger Test Report
  - DC Combiner Box Feeder Megger Test Report
  - DC Feeder Megger Test Report
  - AC Feeder Megger Test Report
  - String Voc & Polarity Test Report
  - Planning Checklist - Array Combiner Pre-Commissioning Check
  - Planning Checklist - Remote PV Tie Pre-Commissioning Check
  - Planning Checklist - DC Disconnect Pre-Commissioning Check
  - Planning Checklist - Inverter Pre-Commissioning Check
  - Planning Checklist - AC Disconnect Pre-Commissioning Check
  - Planning Checklist - AC Switchgear/Switchboard Pre-Commissioning Check
  - Planning Checklist - Point of Connection Check
  - Pre-Commissioning Checklist
- Pre-commissioning meeting where the pre-commissioning test results were reviewed and the decision was made as to proceed to the commissioning stage.
- Commissioning checklist
- System performance tests
  - String performance test
  - Combiner box string performance test
  - Inverter performance test
- Testing and commissioning report

Once Villara completed the commissioning of the PV system, the PV system was allowed to operate.

Battery Energy Storage System

Acceptance testing of the Nuvation Energy Battery Energy Storage was performed by Nuvation and observed by Trane engineers, Parker engineer and LTP operators. The system worked flawlessly and demonstrated the value of performing the system testing at the Parker factory as a complete system simulation (that is, Nuvation, Parker and Trane together).

General Testing

Nuvation provided an installation checklist to electrical contractor Geveden Industrial for the wiring and the BESS passed checklist testing in March 2019.

Grid-Connected Testing

Grid-connected testing of the BESS was for charging and discharging purposes. This is a non-export set up for the BESS. Visual and computer monitoring of the testing of the charge and discharge of the BESS was performed on the live system at the end of March 2019. Using onsite metering, Trane confirmed that the BESS imported and exported energy as commanded onto the intragrid at the LTP. Commissioning was considered complete in the last week of March 2019.

Controllable Loads

Controllable loads are entered into the Trane GridFlex™ software program by plant operators. These entries are sent to the Schweitzer microgrid controller that in turn advises the plant operator if the day-ahead offer has been accepted or not. In simulation testing and scenarios the plant operator would request or provide an offering for the next day by 9:00 a.m. of the morning before the event. If the offer was accepted, then the program would advise the operator that the event will be performed. Each scenario was tested and performed as expected.

The initial round of tests in early April 2019 uncovered the operators requesting scenarios at some times when the asset may have needed to be off-line for maintenance or for some repair. This would then create a situation where the offer was not met at the event time. This was good training for the operator to make sure assets are available and can actually occur before making the offer.

Power Metering

The LTP has multiple power meters that were accessed through the SCADA system. Each meter provided for additional data for the microgrid. The power meters in the Nuvation BESS and Parker PCS and the Carport PV system all were monitored and part of the integrated system.

Microgrid Management System Commissioning

The process of the on-site commissioning of the microgrid system was accomplished over a two-week period at the end of March 2019. Having the preceding 30-day period for operational simulation and data retrieval, including hands-on training of LTP operators, was invaluable.

All the microgrid hardware and software testing, de-bugging and commissioning time was reduced at the site by having performed a complete microgrid simulation at the Parker Grid-Tie test facility as previously noted.

The testing at the site only required live assets to be available and operable. The SCADA programming was also vetted out before the on-site start-up, commissioning, and live testing.

Onsite Trane GridFlex™ Testing and Commissioning

SCADA Points Testing

SCADA commissioning for microgrid communication with onsite devices began before March 2019. All active points had been connected and were communicating since early January 2019. In March 2019 the actual on-site points were re-validated and confirmed to be in good working order. The LTP SCADA programmers were very helpful in the testing and confirmation of all the SCADA points.

Trane GridFlex™ Software Functionality Testing

Initial commissioning of Trane GridFlex™ software was completed by early January 2019 and even prior to this time Trane used a Schweitzer microgrid controller for simulation of the software routines. This again saved enormous amounts of time needed in the field so the system commissioned in less time.

Onsite commissioning of the software functionality was with plant operators to train them on its use and simulated day-ahead scenarios. This allowed operators to have hands-on training and experience.

Detailed Testing of Microgrid System Logic and Functions

Full commissioning of the microgrid logic and software control functions were accomplished in the last few weeks of March 2019 and continued into April 2019 for 30 days. Step-by-step operational training and actual assets being used such as the flow equalization basins, the selective catalytic reduction units engines #3 and #4 and the BESS were performed. Multiple scenarios were performed.

Analysis of data collected was performed in the 30-day period of operational testing. This provided valuable data and information on the microgrid functionality and operation.

Interconnection Acceptance Testing

PG&E interconnection was provided on a conditional 30-day basis as previously stated. Final acceptance testing consisted of remains for the following work and inspections:

- A completed pre-energization test, was performed and passed by PG&E.

- Pending is a PG&E study and telemetry requirement due to changes at the plant and the interconnection agreement. There were reliability issues with current telemetry that are being solved between Santa Rosa and PG&E.

The final telemetry will provide for a final approval and utility permission to operate the advanced microgrid features to allow for future operation to proceed.

CHAPTER 7: System Observation

This chapter presents the operational results for the LTP microgrid project that were observed during the March – April 2019 period. The PV system became fully operational in July 2018, and the BESS and microgrid became fully operational in the last two weeks of March 2019, and the entire month of April 2019. As noted previously there were continuing operational observations of data from the plant SCADA system up to two years in advance of the microgrid being operable. In the later part of 2018 the microgrid controller was monitoring actual live plant load data.

There were a few constraining issues back in October 2018 when the plant operators and an outside consultant the city hired felt that the BESS may cause harmonics issues to the LTP. It was later learned they had previous issues with their existing motor drives on their equipment. They were confused and unable to discern the difference between motor drive inverters and PV and storage inverters. The Parker PCS inverter met all the stringent testing and factory testing of UL1741 and IEEE 519 and 1547 standards. This concern extended all the way into early February 2019 at which time the Energy Commission issued a stop work order, spoke with the city representatives and indicated that Trane had city-approved drawings and permits, and that the installed equipment met all required national standards and design requirements. In the later part of February 2019 the BESS and PCS were acknowledged to be accepted and approved by the city. This delayed the project in being commissioned until the matter was resolved.

The following sections describe the data acquisition capabilities of the system and the availability of data. This is followed by the performance of various scenarios, which include the flow equalization basin flow diversion system, CHP engines #3 and #4, PV system, the BESS, operating with the Trane GridFlex™ software and microgrid controller. This includes assessments of system operational functionality, system performance, and system efficiency.

Description of Data Acquisition Capabilities

Introduction

The data acquisition for the microgrid system is performed by retrieving data from several sources: (1) the LTP SCADA system; (2) Nuvation BESS system; (3) Parker PCS inverter system and various other sources such as the California ISO for grid information, and the Trane SC+ controller.

Onsite SCADA Sensors Used for Monitoring

Table 5 through Table 9 summarize the sensors used to collect data. Only primary data points used for monitoring and analysis are listed.

Table 5: List of Key Sensors – LTP Power Meters

Primary Data Collected	Units	Accuracy (Full Scale unless specified)	Collection/Logging Mechanism
Real Power	kW	0.7%	Microgrid Controller Trane GridFlex™ SCADA Historian
Apparent Power	kVA	0.7%	Microgrid Controller Trane GridFlex™ SCADA Historian
Reactive Power	kvar	0.7%	Microgrid Controller Trane GridFlex™ SCADA Historian
Frequency	Hz	0.02%	Microgrid Controller Trane GridFlex™ SCADA Historian
Voltage	V	0.2%	Microgrid Controller Trane GridFlex™ SCADA Historian
Total Energy	kWh	0.7%	SCADA

LTP Power Meters (6) include PCC Utility; BESS; PV Inverters; PCS Inverter; Influent Flow, and Effluent Flow.

Source: Trane U.S.

Table 6: List of Key Sensors – PCC Utility Meter

Primary Data Collected	Units	Accuracy (Full Scale unless specified)	Collection/Logging Mechanism
Energy	kWh	<2%	PG&E Use/Billing Data/PG&E

PCC Utility Meter (PG&E Installed Device)

Source: Trane U.S.

Table 7: List of Key Sensors – PCC SEL-700 Relay

Primary Data Collected	Units	Accuracy (Full Scale unless specified)	Collection/Logging Mechanism
Utility Voltage	kV	1%	SCADA
Microgrid 12.5 kV Bus Voltage	kV	1%	SCADA
1 MW Generator Voltage	V	1%	SCADA
PCC Interchange Current	A	1%	SCADA
Utility Frequency	Hz	±0.01Hz	SCADA
Microgrid 12.5 kV Bus Frequency	Hz	±0.01Hz	SCADA
PCC Breaker State	Boolean	N/A	SCADA
ATS1 Breaker State	Boolean	N/A	SCADA
Utility Voltage Waveform	kV	1%	SEL-700 Internal Event Logging (*triggered by breaker event*)
Utility Current Waveform	A	1%	SEL-700 Internal Event Logging (*triggered by breaker event*)
Microgrid 12.5 kV Bus Voltage Waveform	kV	1%	SEL-700 Internal Event Logging (*triggered by breaker event*)
1 MW Generator Voltage Waveform	V	1%	SEL-700 Internal Event Logging (*triggered by breaker event*)
PCC Breaker State	Boolean	N/A	SEL-700 Internal Event Logging (*triggered by breaker event*)
ATS1 Breaker State	Boolean	N/A	SEL-700 Internal Event Logging (*triggered by breaker event*)
All Internal Variables Used by Relay	Boolean	N/A	SEL-700 Internal Event Logging (*triggered by breaker event*)

Source: Trane U.S.

Table 8: List of Key Sensors – Photovoltaic Inverters (2)

Primary Data Collected	Units	Accuracy (Full Scale unless specified)	Collection/Logging Mechanism
AC Real Power Output	kW	Not specified	SCADA
AC Real Power Output	kW	Not specified	SCADA
AC Real Power Output	kW	Not specified	Canadian Solar

Source: Trane U.S.

Table 9: List of Key Sensors – Battery Energy Storage System

Primary Data Collected	Units	Accuracy (Full Scale unless specified)	Collection/Logging Mechanism
BESS Inverter Real Power Output	kW	Not specified	Schweitzer MGC & Nuvation Energy
BESS Inverter Apparent Power Output	kVA	Not specified	Schweitzer MGC & Nuvation Energy
BESS Inverter Reactive Power Output	kvar	Not specified	Schweitzer MGC & Nuvation Energy
BESS State of Charge	%	Not specified	Schweitzer MGC & Nuvation Energy
BESS Total Available Capacity	kWh	Not specified	Schweitzer MGC & Nuvation Energy
BESS State	N/A	Not specified	Schweitzer MGC & Nuvation Energy
PV Module Temperature (single point)	°C	1%	Schweitzer MGC & Nuvation Energy
Plane-of-array Insolation (thermopile)	W/m2	<2%	Schweitzer MGC & Nuvation Energy
Plane-of-array Insolation (PV reference cell)	W/m2	0.3%	Schweitzer MGC & Nuvation Energy

Some Parker inverter power measurements are read from BESS meter. Note that some data is also logged internally by Nuvation (for troubleshooting purposes.

Source: Trane U.S.

Trane GridFlex™ Data Acquisition and Day-Ahead Market

The Trane GridFlex™ software system data acquisition consists of the plant SCADA subsystem with multiple controllers within the plant. Each device is polled over the site's network by the SCADA system, and collected data are scaled into final values per the plant's requirements. Data read from networked sensors are used for real-time control by the microgrid and are also provided to a data file historian.

Trane GridFlex™ Data Archiving Method

The Trane GridFlex™ system runs as an independent process on the Schweitzer microgrid controller and the Trane SC+ controller. All data are logged to the Trane GridFlex™ system and maintained for a period of six months. Once this period of raw data archiving has passed, the data is overridden or saved to an archival file. The processed data is 5-minute interval data and moved to a long-term archive. Data can be queried from the database in both raw format (all points, at whatever interval that point was recorded at) and interval format (processed internally by the database to specified intervals). Trane performed periodic raw data dumps from the GridFlex™ database to process and analyze the data.

Third-Party Data Logging

Third-party data sources are also available as part of the microgrid system, and these were also used during commissioning and analysis.

PG&E

PG&E collects energy use data from the standard utility meter located at the PCC as part of normal time-of-use and demand billing. Cumulative energy use data on a 15-minute interval are logged and available to the customer via PG&E's Inter-Act data portal. These data were used for performance analysis during some parts of commissioning and were used as an accuracy check on historical data. Trane GridFlex™ has downloaded 15-minute interval PV performance data from the PG&E Inter-Act site.

Laguna Treatment Plant SCADA Data Management

LTP collects data for all of their SCADA points and archives them for years. These data points from the SCADA system were of value in analyzing the performance of the microgrid and were collected beginning in 2017.

Data Processing Procedure

Data processing was performed on the data, supplemented by SCADA data and PG&E billing data for various periods. Processing was performed with visualization and analysis and also performed using Microsoft Excel.

Data Availability During Project Implementation

The data sources described in Data Acquisition Capabilities were commissioned and began recording data as follows.

Laguna Treatment Plant SCADA Data

The LTP SCADA data was available to the project for more than two years. LTP stores historical data for all of the points monitored in the plant. This includes the on-site 69-kV substation, all four CHP engines, the carport solar PV, the BESS, the PCS inverter, and various other SCADA data points for influent flow, effluent flow, and flow diversion. Access to the data that is not monitored directly was available in historical Excel format for analysis.

PG&E Billing Data

PG&E billing data are available for the LTP as standard billing data available which was for the project include monthly energy use and peak demand data, as well as 15-minute interval energy use data.

Microgrid Controller and Trane SC+ Controller Data

Initial data collection using the microgrid controller and the Trane SC+ controller starting three months before commissioning the system was historically saved. Data was collected during the commissioning and testing for monitoring, analysis and direct observation of the system during commissioning. There were no communication issues and fully accurate data was available to the Trane GridFlex™ software and plant operators beginning in the last couple of weeks of March 2019.

Photovoltaic System Observations

This section describes the performance of the carport PV system for the mid-year 2018 until March 2019, compares that performance to the expected performance, and discusses a variety of PV system losses.

The array was designed by Villara and construction began in December 2017 with completion of the array commissioning in July 2018. The as-built array faces due south and has a slope of 20°. It incorporates 372 Canadian Solar CS6U-340M modules arranged in 12 source circuits of 19 modules each and 8 source circuits of 18 modules each. The modules are rated at 340Wdc at STC (1000 W/m^2, 25°C). At the maximum power point, the array is rated at 126.48 kW$_{DC}$. The carport solar structure is by Baja.

The LTP SCADA system monitors the carport PV system and tabulates the production of the system. The output voltage from the PV system is 480V. The analysis in this section is based on a dataset of the two inverter outputs, the plane of the array irradiance, and the module temperature for 15-minute intervals from August 2018 to March 2019.

Carport Photovoltaic System Power Generation

In addition to the battery system and selective catalytic reduction unit equipped engines, Trane installed a 126 kWAC solar photovoltaic system at Santa Rosa. The system has been operational as of December 2018, however the inverters only started collecting calibrated data as of March 16, 2019. The trends collected are in 15-minute intervals and display in the monthly and daily plots. Operation is in line with estimated production and peak demand generation per the panel specifications and operating temperature parameters. Based on the system production in the first two months of recordable operation, the panels appear to be able to meet and exceed the annual production limits, with the peak demand to be realized during the summer months of 2019. Trane will continue to monitor the system to verify total peak generation (kWAC) as well as several other performance points to ensure the system is operating as proposed.

The solar photovoltaic system supplements the microgrid system by offsetting an annual amount of net consumption to the utility meter at this time. This reduces the overall environmental impact of the wastewater plant without affecting daily treatment operations. In the future, this asset may also be used as a demand response asset to further impact peak reduction for utilities and/or to offset the use of peaker plants to meet high instantaneous demands on the utility grid.

Daily Production Subtotals for Solar PV Generation:

Table 10 outlines the daily kWh subtotals for the recorded period from March 16 until mid-April 2019.

Table 10: Observed Carport Photovoltaic Solar kW Daily Production

Row Labels	Sum of
2019	**54,171**
Mar	**18,023**
3/16/2019	1,458
3/17/2019	1,398
3/18/2019	1,357
3/19/2019	823
3/20/2019	954
3/21/2019	1,540
3/22/2019	329
3/23/2019	1,463
3/24/2019	1,234
3/25/2019	366
3/26/2019	1,146
3/27/2019	1,161
3/28/2019	527
3/29/2019	1,250
3/30/2019	1,560
3/31/2019	1,457
Apr	**36,148**
4/1/2019	746
4/2/2019	797
4/3/2019	647
4/4/2019	803
4/5/2019	617
4/6/2019	672
4/7/2019	969
4/8/2019	434
4/9/2019	1,686
4/10/2019	1,688
4/11/2019	1,043
4/12/2019	1,693
4/13/2019	1,647
4/14/2019	1,646
4/15/2019	767
4/16/2019	1,594
4/17/2019	1,701
4/18/2019	1,564
4/19/2019	1,444
4/20/2019	1,579
4/21/2019	1,693
4/22/2019	1,656
4/23/2019	1,651
4/24/2019	1,678

Row Labels	Sum of
4/25/2019	1,746
4/26/2019	1,586
4/27/2019	1,639
4/28/2019	762
Grand Total	**54,171**

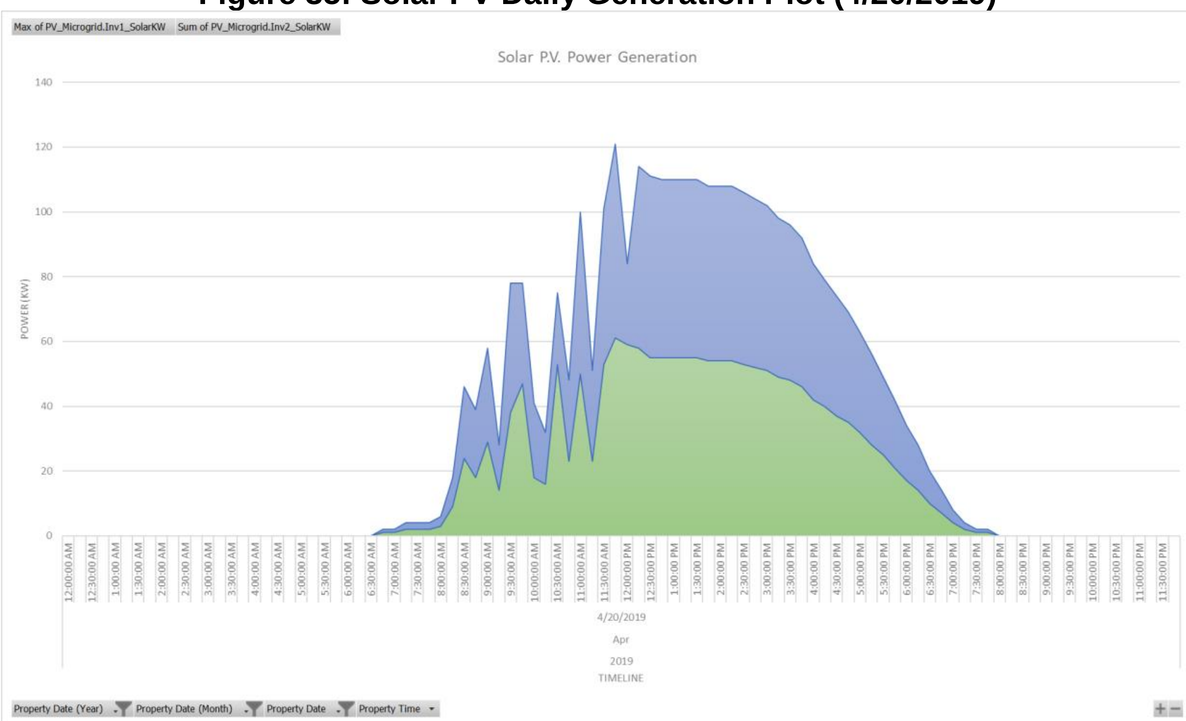
Source: Trane U.S.

Expected Versus Observed System Performance

The PV array design that was originally envisioned and described in the project proposal was developed in July 2017 by Villara. Insolation data for Santa Rosa, CA, estimated that the PV array would produce 675 MWh per year. Figure 35 shows a typical spring day of production. Note that in the morning Santa Rosa frequently experiences partial clouds and patchy fog. This affects the PV output. Figure 36 shows the daily PV output over several weeks. This is also tabulated in Table 11.

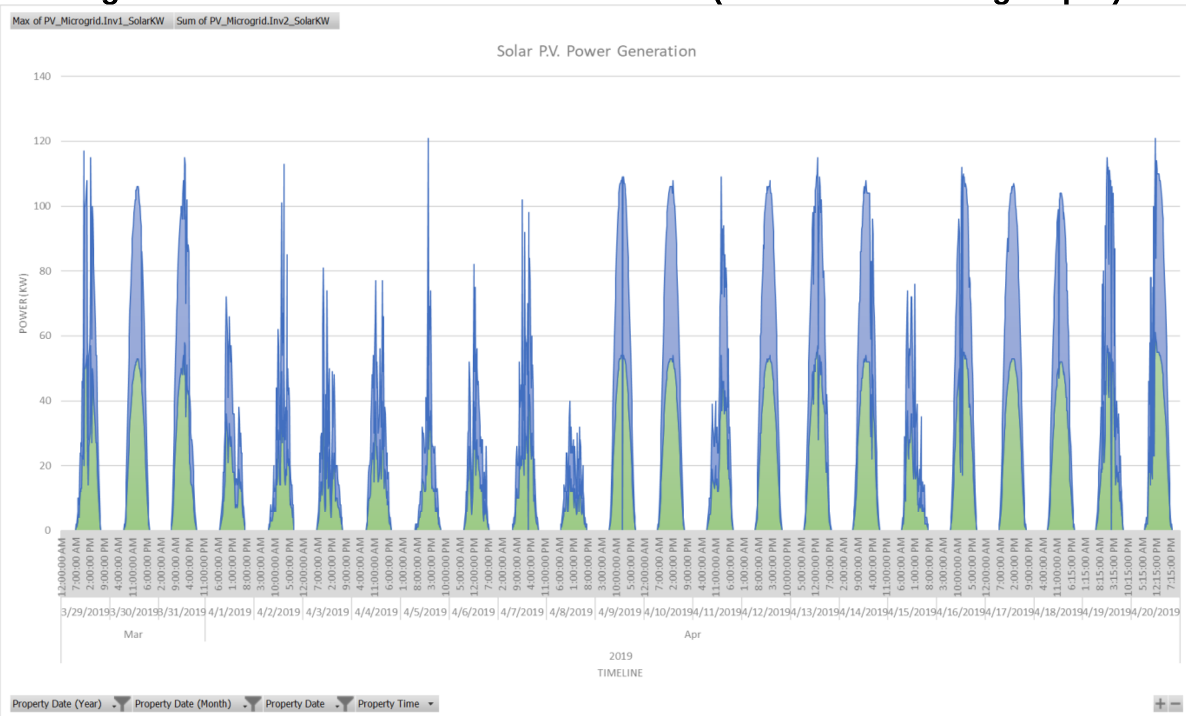
Carport PV System Observations

Figure 35: Solar PV Daily Generation Plot (4/20/2019)



Source: Trane U.S.

Figure 36: Solar Production Stacked Area (Late March Through April)



Source: Trane U.S.

Table 11: Solar Production Table:

	Sum of PV_Microgrid.Inv2_Solar kW	Sum of PV_Microgrid.Inv1 Solar
2019	**53,409**	**53,440**
Mar	**18,023**	**18,004**
3/16/2019	1,458	1,452
3/17/2019	1,398	1,404
3/18/2019	1,357	1,359
3/19/2019	823	820
3/20/2019	954	950
3/21/2019	1,540	1,535
3/22/2019	329	330
3/23/2019	1,463	1,468
3/24/2019	1,234	1,242
3/25/2019	366	363
3/26/2019	1,146	1,122
3/27/2019	1,161	1,159
3/28/2019	527	525
3/29/2019	1,250	1,228
3/30/2019	1,560	1,597
3/31/2019	1,457	1,450
Apr	**35,386**	**35,436**
4/1/2019	746	749
4/2/2019	797	775
4/3/2019	647	650
4/4/2019	803	813

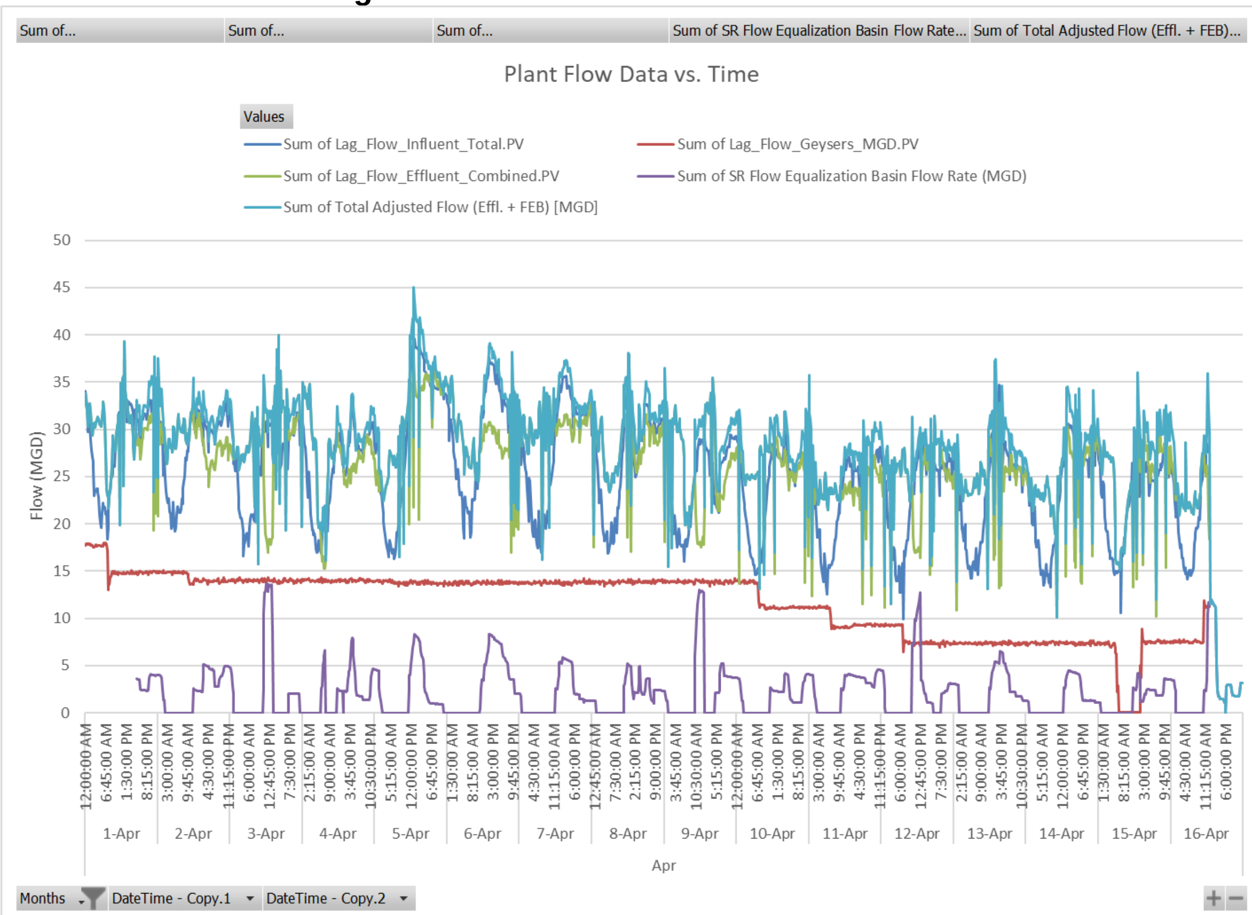
	Sum of PV Microgrid.Inv2 Solar kW	Sum of PV Microgrid.Inv1 Solar
4/5/2019	617	620
4/6/2019	672	669
4/7/2019	969	935
4/8/2019	434	432
4/9/2019	1,686	1,655
4/10/2019	1,688	1,689
4/11/2019	1,043	1,047
4/12/2019	1,693	1,688
4/13/2019	1,647	1,646
4/14/2019	1,646	1,657
4/15/2019	767	770
4/16/2019	1,594	1,612
4/17/2019	1,701	1,705
4/18/2019	1,564	1,613
4/19/2019	1,444	1,386
4/20/2019	1,579	1,656
4/21/2019	1,693	1,744
4/22/2019	1,656	1,653
4/23/2019	1,651	1,646
4/24/2019	1,678	1,633
4/25/2019	1,746	1,769
4/26/2019	1,586	1,595
4/27/2019	1,639	1,629
Grand Total	**53,409**	**53,440**

Source: Trane U.S.

Dynamic Flow Calculation Observations

To further study the dynamic flow model, it was necessary to incorporate the flow equalization basin trends into the effluent information. This flow equalization basin flow is significant as at any given event duration, the flow modeled baseline could be altered based on the diversion of influent which could affect the effluent rates for which the power correlation is seen. In other words, the total effluent flow needs to be considered when constructing the dynamic baseline. Figure 37 is a plot that shows all influent, diversion, and effluent flows for the recorded period.

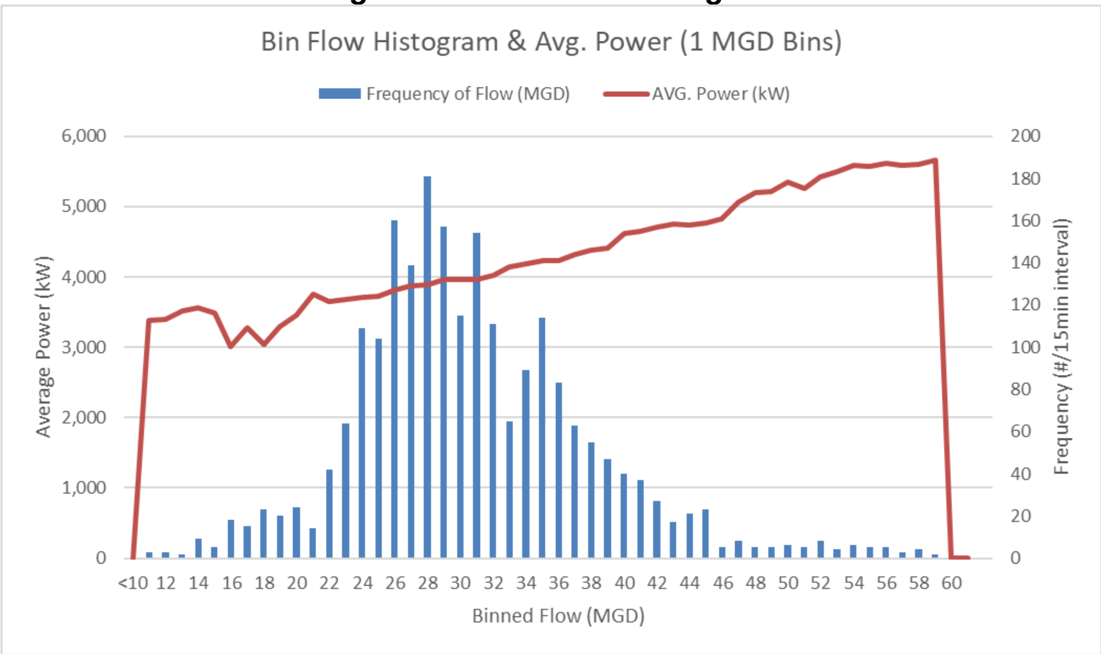
Figure 37: Plant Flow Data Versus Time



Source: Trane U.S.

Once calculations begin on establishing a dynamic baseline from the flow values at the time of demand response events, Trane realized that the data in an analysis bin size of 2 Million Gallons per Day (MGD) as a flow rate had to be refined to 1 MGD. This stemmed from the findings that the average kW per bin was much smoother at the finer interval, leading to more precision when creating the baseline. Table 12 provides the plots and table that show the new 1 MGD bin values and frequency.

Figure 38: Bin Flow Histogram



Source: Trane U.S.

Table 12: Average Power (1 MGD Bins)

Bin Range	Frequency of Flow (MGD)	AVG. Power (kW)
<10	0	n/a
11	3	3,381
12	3	3,393
13	2	3,522
14	9	3,557
15	5	3,487
16	18	3,012
17	15	3,283
18	23	3,040
19	20	3,290
20	24	3,456
21	14	3,748
22	42	3,654
23	64	3,683
24	109	3,704
25	104	3,717
26	160	3,810
27	139	3,875
28	181	3,894
29	157	3,967
30	115	3,964

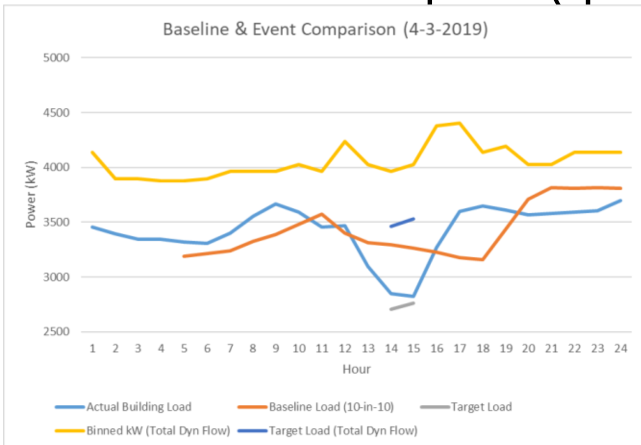
Bin Range	Frequency of Flow (MGD)	AVG. Power (kW)
31	154	3,965
32	111	4,029
33	65	4,136
34	89	4,192
35	114	4,236
36	83	4,234
37	63	4,325
38	55	4,379
39	47	4,407
40	40	4,612
41	37	4,649
42	27	4,707
43	17	4,758
44	21	4,733
45	23	4,761
46	5	4,827
47	8	5,070
48	5	5,199
49	5	5,209
50	6	5,346
51	5	5,258
52	8	5,425
53	4	5,498
54	6	5,588
55	5	5,576
56	5	5,616
57	3	5,581
58	4	5,595
59	2	5,656
60	0	n/a
61	0	n/a
More	0	

Source: Trane U.S.

Baseline Comparisons

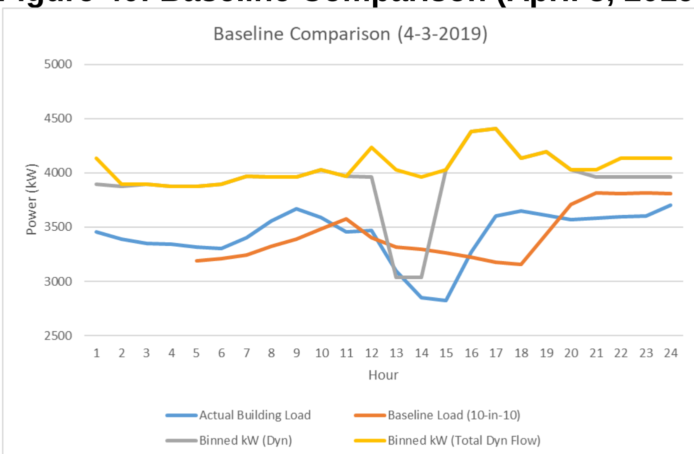
Trane ran several comparisons of baseline data as compared to actual flow and power data to determine the accuracy and interdependencies of each baseline model. To do this, Trane used previous demand response events, using a 10 in 10-baseline method, and overlaid the flow and dynamic baseline data. Figure 39 through Figure 42 show the hourly baseline comparisons for the event day on April 3, 2019.

Figure 39: Baseline and Event Comparison (April 3, 2019)



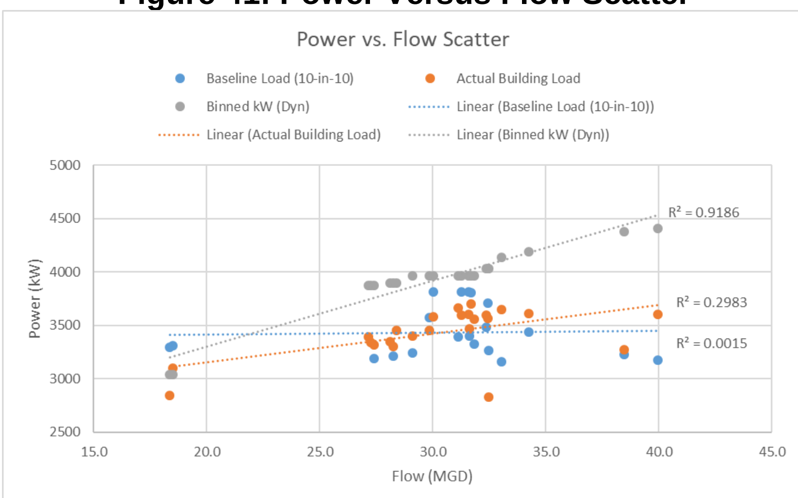
Source: Trane U.S.

Figure 40: Baseline Comparison (April 3, 2019)



Source: Trane U.S.

Figure 41: Power Versus Flow Scatter



Source: Trane U.S.

Figure 42: Actual Load (MW) Versus Flow (MGD) and Dynamic Baseline (kW)

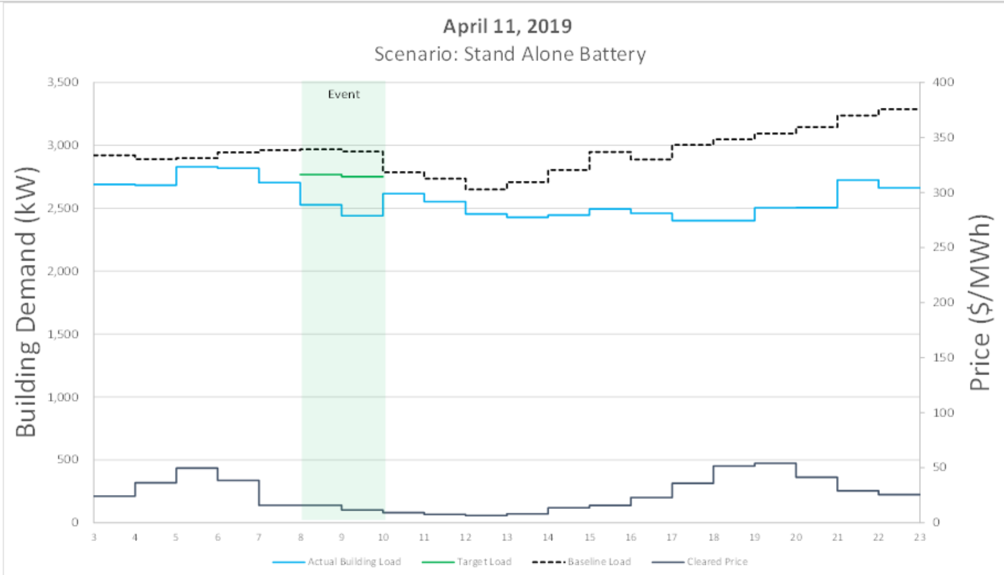
DateTime (HE - Pacific)	Hour (HE Pacific)	Actual Building Load	Baseline Load (10-in-10)	Max Eff. Flow (MGD)	Flow Diversion F.E.B. (MGD)	Max Total Flow (MGD)	Dynamic Baseline (kW)	Committed Demand (kW)	Target Load (10x10)	Target Load (Total Dyn Flow)	Successful 10x10 (Y/N)	Successful ADJ. Dynamic (Y/N)	Power Delta (10x10)	Pwer Delta (Adj. Dyn)	Additional Power (over 10x)
4/3/2019 0:00	HE0	3,454.0	0.0	28.4	4.8	33.2	4,136.3	0.0	0.0	0.0	0	0	0.0	682.3	0.0
4/3/2019 1:00	HE1	3,391.5	0.0	27.2	1.6	28.8	3,894.2	0.0	0.0	0.0	0	0	0.0	502.7	0.0
4/3/2019 2:00	HE2	3,346.3	0.0	28.1	0.0	28.1	3,894.2	0.0	0.0	0.0	0	0	0.0	548.0	0.0
4/3/2019 3:00	HE3	3,342.8	0.0	27.3	0.0	27.3	3,875.0	0.0	0.0	0.0	0	0	0.0	532.2	0.0
4/3/2019 4:00	HE4	3,319.3	3,191.8	27.4	0.0	27.4	3,875.0	0.0	0.0	0.0	0	0	(127.5)	555.7	683.2
4/3/2019 5:00	HE5	3,306.0	3,213.1	28.3	0.0	28.3	3,894.2	0.0	0.0	0.0	0	0	(92.9)	588.2	681.1
4/3/2019 6:00	HE6	3,402.0	3,240.2	29.1	0.0	29.1	3,967.2	0.0	0.0	0.0	0	0	(161.8)	565.2	727.0
4/3/2019 7:00	HE7	3,555.0	3,324.7	31.8	0.0	31.8	3,965.3	0.0	0.0	0.0	0	0	(230.3)	410.3	640.6
4/3/2019 8:00	HE8	3,666.5	3,390.6	31.1	0.0	31.1	3,965.3	0.0	0.0	0.0	0	0	(275.9)	298.8	574.7
4/3/2019 9:00	HE9	3,592.5	3,483.8	32.4	0.0	32.4	4,029.0	0.0	0.0	0.0	0	0	(108.7)	436.5	545.2
4/3/2019 10:00	HE10	3,456.8	3,575.2	29.9	0.0	29.9	3,967.2	0.0	0.0	0.0	0	0	118.5	510.4	391.9
4/3/2019 11:00	HE11	3,468.0	3,403.2	31.6	4.1	35.7	4,236.0	0.0	0.0	0.0	0	0	(64.8)	768.0	832.8
4/3/2019 12:00	HE12	3,099.3	3,313.0	18.5	13.7	32.2	4,029.0	0.0	0.0	0.0	0	0	213.8	929.8	716.0
4/3/2019 13:00	HE13	2,847.5	3,294.0	18.4	13.6	32.0	3,965.3	500.0	2,707.7	3,465.3	Y	Y	446.5	1,117.8	671.2
4/3/2019 14:00	HE14	2,826.3	3,263.7	32.5	0.0	32.5	4,029.0	500.0	2,763.7	3,529.0	Y	Y	437.5	1,202.8	765.3
4/3/2019 15:00	HE15	3,272.5	3,226.2	38.5	0.0	38.5	4,379.2	0.0	0.0	0.0	0	0	(46.3)	1,106.7	1,153.0
4/3/2019 16:00	HE16	3,600.8	3,178.0	40.0	0.0	40.0	4,406.6	0.0	0.0	0.0	0	0	(422.7)	805.8	1,228.6
4/3/2019 17:00	HE17	3,649.3	3,158.3	33.0	0.0	33.0	4,136.3	0.0	0.0	0.0	0	0	(491.0)	487.0	978.0
4/3/2019 18:00	HE18	3,608.8	3,435.6	34.3	0.0	34.3	4,192.1	0.0	0.0	0.0	0	0	(173.1)	583.4	756.5
4/3/2019 19:00	HE19	3,568.8	3,708.0	32.4	0.0	32.4	4,029.0	0.0	0.0	0.0	0	0	139.3	460.3	321.0
4/3/2019 20:00	HE20	3,583.0	3,814.8	30.0	2.0	32.0	4,029.0	0.0	0.0	0.0	0	0	231.8	446.0	214.2
4/3/2019 21:00	HE21	3,595.5	3,811.6	31.3	2.0	33.3	4,136.3	0.0	0.0	0.0	0	0	216.1	540.8	324.7
4/3/2019 22:00	HE22	3,603.5	3,817.4	31.6	2.0	33.6	4,136.3	0.0	0.0	0.0	0	0	213.9	532.8	318.9
4/3/2019 23:00	HE23	3,700.3	3,808.9	31.7	2.0	33.7	4,136.3	0.0	0.0	0.0	0	0	108.6	436.0	327.4

Source: Trane U.S.

Battery System Observations

In the rest of this section the performance of the BESS is evaluated according to several performance characteristics. This evaluation is based on data that were collected during operation of the BESS in the pre- and post-commissioning period of 2019. Figure 43 and Figure 44 demonstrate the microgrid controlling the battery in various scenarios that the plant operator performed during commissioning and the 30-day operational period from April 1, 2019 to April 30, 2019.

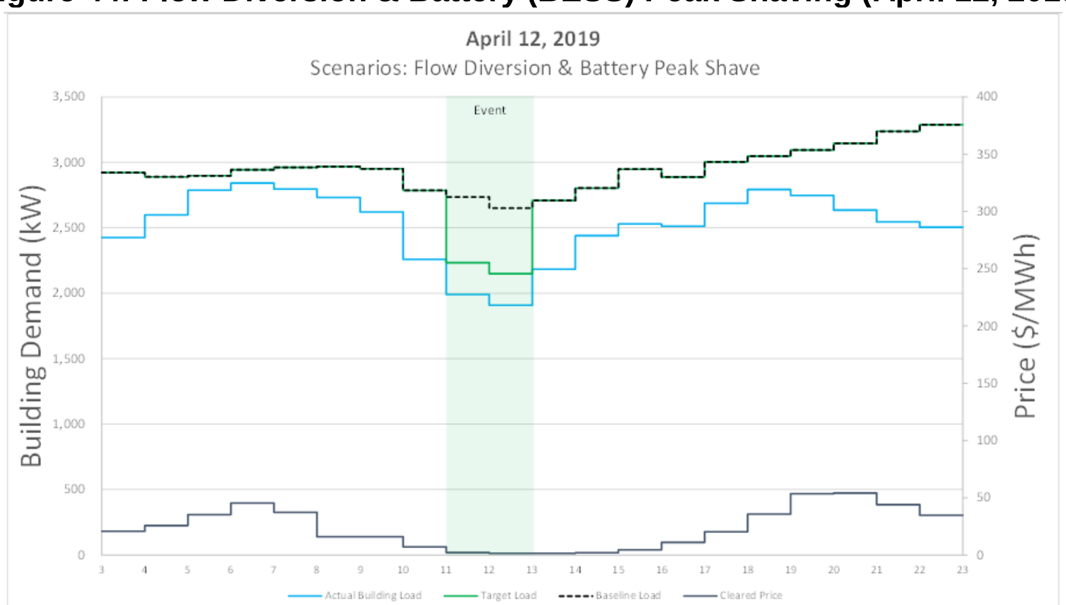
Figure 43: Standalone Battery (BESS) Scenario (April 11, 2019)



Narrative Information:
- **Event Date and Time: April 11, 2019: 8am to 10am Pacific**
- **Baseline used: CAISO 10-in-10 methodology**
- **Event was successful and reduced more than the committed amount**
  - **8-9am: Committed reduction = 200 kW; Actual reduction = 441 kW**
  - **9-10am: Committed reduction = 200 kW; Actual reduction = 511 kW**
  - **Note: The battery is reducing load, but the load variation at the plant itself is causing lower load than the baseline**

Source: Trane U.S.

Figure 44: Flow Diversion & Battery (BESS) Peak Shaving (April 12, 2019)



Narrative Information:
- **Event Date and Time: April 12, 2019: 11am to 1pm Pacific**
- **Baseline used: CAISO 10-in-10 methodology**
- **Event was successful and reduced more than the committed amount**
  - **11-12: Committed reduction = 501 kW; Actual reduction = 744.6kW**
  - **12-1pm: Committed reduction = 501 kW; Actual reduction = 741.1kW**

Source: Trane U.S.

CHAPTER 8: Project Benefits

Project Benefits Overview

The LTP microgrid project has produced a number of benefits. These include benefits to the City of Santa Rosa as the end use customer as cost savings, improved reliability, and improved resilience. The project direct-benefits of energy and cost savings are quantified, and non-energy benefits are discussed.

In the latter sections of this chapter the project goals and expectations are compared with observed results. A discussion regarding opportunities for statewide replication of similar microgrid projects at wastewater facilities and the resulting impacts that could be achieved are also discussed in this chapter.

Direct Project Benefits

Energy Savings

In Chapter 7 the total net energy savings associated with the LTP microgrid project are estimated using the difference in the energy demand on the PG&E grid for the partial few months of operation in 2019. The microgrid at LTP is estimated to save 260 MWh per year of utility power.

Cost Savings

Chapter 7 provides an assessment of the cost savings associated with the LTP project. Total estimated projected annual energy savings are$85,000 to $125,000. The savings are attributable to the microgrid operation.

Non-Energy Benefits

Reliability

The LTP microgrid project provides for several reliability benefits to the LTP and local community electrical grid. The plant typical requires an average of 3.5 MW of continuous energy usage and varies upon time of year and season. The LTP site is at the outskirts of the City of Santa Rosa, and at peak energy needs the plant can curtain in a day-ahead market between 500 kW and up to 2 MW if needed. This resource in the area alleviates the electrical grid, provides for grid reliability in serving the customers in the area, and provides resilience of power.

Market Potential

This project was successfully implemented and performed as expected. As a result, LTP has conducted several dozen tours during the course of this project. Trane has provided several outreach events throughout the State with success and knowledge transfer. Please see Chapter 9 for a full discussion of the technology and knowledge transfer activities. These activities help communicate the benefits and lessons learned to move microgrid technology forward in the market. Almost all members of the project team are engaged with and supporting several developing microgrid projects throughout California.

Economic Development

Microgrids present an opportunity to improve economics and low-carbon power. By developing distributed energy resources, microgrids keep energy expenditures circulating within the local region, and can transfer energy savings into new jobs. Microgrids also provide new opportunities for economic development strategies between local governments and investor owned utilities, to solve energy access issues and improve grid reliability.

Project Performance

Comparison of Project Expectations and Actual Performance

In this section the performance of the LTP microgrid project is compared to initial project expectations and the fulfillment of project goals and objectives is assessed. Table 13 provides a set of project goals and objectives stated at the beginning of the project along with observed results.

Table 13: Comparison of Project Goals and Results

Metric	Project Goal	Result	Comments
Install microgrid capable of demonstrating the technology at a wastewater plant	Yes	Yes	This has been demonstrated
Demonstrate ability of microgrid to participate in demand response market with the California ISO Proxy Demand Resource program	Yes	Yes	LTP will be participating in California ISO Proxy Demand Resource program, the project demonstrated the ability to reduce net site load by discharging the BESS, flow equalization basin flow diversion and CHP engine operation

Metric	Project Goal	Result	Comments
Reduction in annual electrical energy consumption	260 MWh	260 MWh	Trane expects about 260 MWh per year moving forward due to reduction of system losses
LTP energy cost savings	$80,000	$80,000	Could go to $125,000 depending on the market
Make knowledge gained available to broad audience	Yes	Yes	Extensive outreach was performed, numerous awards were received, knowledge transfer was robust and continues
Develop plan for commercializing microgrid technologies and strategies	Yes	Yes	Chapter 10: Production Readiness lays out a clear strategy to allow for replication; numerous follow-on projects are in the works

Source: Trane U.S.

The project goals were met. Despite the inability to perform with live California ISO Proxy Demand Resource participation, the team was able to simulate the day-ahead market opportunity and perform demand resource functions with the microgrid project.

Potential Statewide Microgrid System Benefits

In this section the team examined the broader benefits available from microgrids and considered the opportunity for large-scale market use and the resulting societal benefit that could be generated.

Classifying the Possible Benefits of Microgrids

The benefits of a microgrid can accrue to the project owner, the electric utility, and society. The potential benefits provided by microgrids can be classified into four broad categories: energy, economic, environmental, and emergency.

The benefits are listed under two typical modes of operation: (1) influent flow diversion with plant energy reductions for processing can attribute to between 250 kW to 500 kW reductions, and (2) using microgrid battery for fast response to load shaving to attain desired load reductions while plant assets are reduced in kW. Such load shaving can provide from 250 kW to 2 MW of instantaneous kW demand reductions. Other scenarios have been demonstrated and others are yet to be established.

Assessing the Potential of Microgrids in California

The ability of the LTP microgrid project to provide information on the potential benefits of microgrids at all the wastewater treatment facilities in California is an uncertain process. Individual wastewater facilities are unique and estimations need to be made about the load size of the facilities, and their assets. Very few microgrids have been implemented for such applications and their performance has not been rigorously documented. There are more than 900 wastewater treatment facilities in California of widely varying size and capacity. Each of these facilities could achieve energy savings as shown in this project but the exact amount will vary with the size of the facility.

Identification of a Barrier to Greater Participation by Microgrids in California Energy Markets

The power consumption of the LTP is highly variable, from hour to hour and across the course of a year. Power consumption is directly and highly correlated with flow through the plant, but the current California ISO attribution method is not connected to flow. The difference between actual performance and current attribution method results in a barrier inhibiting greater development of these assets. This research project has performed substantial work in both outlining and validating the issues surrounding the lack of a dynamic baselining method, as well as suggesting technological and regulatory paths that could be used to close the gap. More on this subject is included in Chapter 11- Production Readiness.

CHAPTER 9:
Technology and Knowledge Transfer

Project Fact Sheet

As part of the technology and knowledge transfer activities a project fact sheet was developed and disseminated. The final project fact sheet can be found in Appendix D.

Presentation Materials

Presentation materials were also prepared to share the knowledge gained and lessons learned from the project. The presentation was adjusted as needed to serve the audience.

Technology and Knowledge Transfer Plan

The purpose of the Technology/Knowledge Transfer Plan was to develop a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers.

Microgrids are a new technology area for wastewater facilities that are still in development. The technology offerings, codes and standards, regulatory requirements, utility interconnection requirements, rate tariffs and arrangements, and market opportunities are still evolving.

Microgrid projects, such as the Laguna Treatment Plant microgrid project, are important undertakings to learn about the technology and its related support systems and to test out new ideas to see what works. Then, to maximize the value of early demonstration projects like the LTP project, it is important to share the lessons learned with other stakeholders so they can build on the knowledge gained. That is the purpose of this technology and knowledge transfer plan.

This technology and knowledge transfer plan aimed to reach the following audiences:

- Other wastewater treatment facilities
- Electric utilities and California ISO
- Regulatory agencies
- Public entities and local governments
- Industry
- Academia
- End users (commercial, industrial and institutional electricity users)
- Distributed energy practitioners, engineers and consultants

- Sustainable energy and climate mitigation advocates

The types of information to be shared with stakeholders included the following:

- Description of the Laguna Treatment Plant system design and the technologies that were implemented
- Project performance and project benefits
- Lessons learned

Education, outreach and knowledge transfer activities were to include:

1. In-person and remote participation in workshops, conferences, and other knowledge transfer activities, including:
    a. Presentations at professional energy conferences, workshops
    b. Presentations at wastewater treatment engineer events
    c. Participation in workshops, conferences and meetings as a representative of the project
2. Preparation, publication, and distribution of project documents, including:
    a. Project fact sheets and presentations
    b. Project press releases
    c. Project videos and outreach materials
3. Outreach to interested potential end-users and stakeholders
    a. Project kick-off and outreach events
    b. Site tours
    c. Outreach, discussions and consulting to entities interested in broadening the use of microgrids
4. Educational outreach
    a. Engagement of UC Davis Center for Water Efficiency to contribute to project activities

Education, outreach, and knowledge transfer activities were tracked and recorded throughout the project period.

Technology and Knowledge Transfer Activities

This report documents the efforts and accomplishments regarding project outreach efforts to publicize the project and share knowledge, experimental results, and lessons learned. A Technology/Knowledge Transfer Plan was previously developed; this report documents the results associated with the implementation of that plan.

The Laguna Treatment Plant, Trane and other project partners have worked to disseminate project results and lessons learned from this project to many interested stakeholders. This has included participation in conferences, workshops, onsite tours of the microgrid facility at LTP, and presentations to many interested parties. In addition, there have been press releases and multimedia efforts to publicize the project. Trane has conducted significant outreach activities, including hosting tours and providing information and guidance to stakeholders seeking to build their own microgrids. To support these educational efforts, the LTP has contributed staff time, meeting spaces, teleconferencing, and other resources. Project partners California Energy Commission, PG&E, Nuvation, and stakeholders such as the UC Davis Center for Water Efficiency have put substantial effort and resources into developing reports and resources that feature the benefits of the LTP project.

Stakeholder Engagement

This project has generated publicity and stakeholder interest. To illustrate the interest in microgrids, the following list documents the stakeholder groups who have toured onsite and/or received presentations/consulting regarding the Laguna Treatment Plant microgrid project.

Public Entities

- California ISO
- Utility and special districts

Industry

- Other wastewater treatment facility personnel in the local area
- Private companies

Academia

- University of California Davis

Outreach Activities

Trane executed a significant outreach effort as part of this project. In addition to the Technical Advisory Committee meeting, a total of five separate technology transfer outreach meetings were held across the state, with attendees from dozens of local governments. Technology outreach meetings were held in Chico, Santa Rosa, Visalia, Riverside, and San Diego. The California ISO participated in a majority of these events, further bolstering the understanding of changes in the electric marketplace and how a microgrid approach could be used to meet multiple local needs. This geographically distributed outreach campaign in turn resulted in a follow-on meeting sponsored by the Representatives of California's Rural Communities organization to more than three dozen additional senior county administrators in Sacramento in October 2018.

A record was kept of the LTP outreach activities. Outreach activities started in September 2017 and continued through December 2018 and beyond. Appendix E provides a listing of the outreach activities and agendas of outreach efforts covering the duration of the project period.

Outreach Materials

To support the outreach activities associated with this project the following outreach materials were prepared:

- Project Fact Sheet (Appendix D)
- Project presentations –many project presentations were given over the course of the project.
- Press releases – press releases associated with key milestones in the project were disseminated (for example, receipt of grant award). Appendix D includes an example.

Follow-On Consulting Activities

In addition to the outreach activities, this project has led to numerous microgrid consulting opportunities for the project team. While these additional consulting opportunities are not part of the direct activities associated with this project, they have served the purpose of promoting the replication of similar microgrids. As a result of this project, microgrid feasibility analyses and preliminary design work has been conducted for and/or discussed with the following entities:

- Other wastewater treatment facilities
- Other large facilities

CHAPTER 10: Production Readiness

The production readiness of microgrids is a complex topic because microgrids are a complex blend of carefully integrated systems with components from multiple manufacturers and unique characteristics due to inevitable differences between sites. This chapter attempts to relate the experience of implementing the Laguna Treatment Plant microgrid project to the concept of microgrid production readiness and replicability in general.

This chapter focuses on production readiness, from a technical perspective, for other industrial and wastewater facilities microgrids. Since the focus is technical rather than administrative, the findings are generally applicable to most other similar types of entities.

Required Elements for Microgrid Readiness

In summary, the basic elements needed for preliminary microgrid readiness include:

- A defined boundary between the microgrid and the wastewater treatment facility allowable assets to be controlled.
- Generation/storage components have been sized to meet net microgrid loads and provide the required island-mode run-time capability as may apply.
- An initial study of permitting, environmental review requirements, and cultural resources survey(s).
- A preliminary scaled site plan showing the area requirements for the generation/storage components and controls has been created.
- A preliminary one-line diagram of the microgrid.
- A brief controls narrative of how assets, or which ones, may be controlled.
- A site control plan demonstrating that it will be practical to obtain site control for the required generation/storage components has been created.
- The utility has been made aware of the project, has been provided with the preliminary documentation above, and has not said no to the project.
- Because the economic impacts and associated costs of different monetization mechanisms are distinctly different, potential microgrid owners will often want an economic analysis completed before starting a project.
- While figuring out potential economics and counterparties may seem to be an exclusively administrative element, it is not. Depending upon the grid impact "products" to be sold and who the utility side counterparty is, different rules must be followed for metering, data, communication, and other functions.

> Therefore, if the owner of a potential microgrid project is seeking to monetize the upstream revenues of the grid impact products, then those products and potential counterparties need to be identified early enough in the process so that their inherent needs can be designed in from the start.

With these basic elements in place the microgrid project provider will be in good position to begin working out the details needed to successfully implement the microgrid. The remainder of this chapter discusses other key considerations concerning the replicability of microgrids.

Integrating Existing Equipment Into a Microgrid

Since microgrids are typically implemented with existing facilities, there will likely be pre-existing equipment to account for in the microgrid design. Examples include existing emergency generators, SCADA or energy management systems, existing PV arrays, and the like. Since these pre-existing systems will have been installed with a load-serving purpose that is uniquely related to the role that the system has in serving the same loads, the way that these components operate in the microgrid will have to be carefully evaluated.

An example would be a pre-existing rooftop solar PV array with inverters that have ride-through settings and active anti-islanding. Depending on the size of the PV array relative to the microgrid loads and other onsite generation and storage components, its output may need to be curtailed during island-mode, which would require an interface with the microgrid controller. It is also important to understand the functionality, settings, and intelligence of existing equipment controls, and whether those controls can communicate with an advanced microgrid control system, or whether additional components and upgrades or both are necessary.

The purpose of microgrids is to increase electrical resiliency, which means keeping microgrid loads energized when the utility has an outage. Microgrid loads are intermittent and load profiles will vary from microgrid to microgrid. The system designed to handle load intermittency and any conceivable load profile due to conservative design and interconnection practices, and the presence of large generation sources (power plants). A microgrid operating in island-mode becomes disconnected from these large generation sources and relies on smaller generation and storage components within the microgrid to keep loads energized. In addition, microgrids can drive new revenue for their owners through providing critical grid impacts, either through direct market participation or through providing these services under contract to a utility market off-taker.

Controlling pre-existing loads can be another tool available to designers for maintaining stability and extending run time in island-mode. To incorporate controllable loads into the microgrid, an energy audit should be conducted to characterize microgrid loads and, using the results, a list of non-critical loads that can be shed can be identified and prioritized. Using that list, a control plan can be developed to allow the microgrid controller to use controllable loads as well as controllable generation to maintain stability and extend run time in island-mode.

Installing the Microgrid Controller

There are typically either four or five different levels in a microgrid control system.

1. Component controllers (BESS, inverters, and others)
2. Optimization controller
3. Real-time controller
4. Protection and coordination controller
5. If the plan includes monetization of the grid impacts of the microgrid, then a fifth level of controls is needed: a grid integration control system

The component controllers are provided by the manufacturers of generation and storage devices such as inverters, batteries and generator controllers. Optimization and real time controllers are often packaged together and provided by the same manufacturer. The protection and coordination controller is typically a set of redundant protection relays. In some cases, items 2, 3, and 4 can be provided by the same manufacturer in one integrated controller. The grid integration controls are a combination of sensors, communication gateways, and data links, which may be entirely on-site or at least partly cloud based.

Installing the microgrid control system requires quite a bit of initial research and great care. This is because constructing a microgrid around existing facilities sometimes requires major electrical reconfiguration work at the PCC(s). This requires shutdowns, which are disruptive to the facility and processes. Planned outages are generally more tolerated than unplanned outages and the impacts and duration of unplanned outages can be unpredictable. Important questions to consider are:

- How will the microgrid control system be tested before it is put to use on a live system?
- What is the best construction sequence to minimize cumulative outage duration?
- What are the best initial settings in the component level controllers for interim operations before the entire microgrid control system becomes operational?
- How should the microgrid control system respond to PCC switching as a result of outages?
- How should the microgrid control system respond to the re-energization of the utility power after an outage?
- If monetizing grid impacts, how will the microgrid control system work with a grid integration platform or utility control room?

Based on the experience of implementing the LTP, a microgrid controller implementation plan based on the following outline is offered for consideration:

1. Test the microgrid control system in a digital simulation environment with control hardware in the loop. This is a critical step and its importance cannot be overemphasized for de-risking the system before operating in a live setting.
2. For the main grid-forming generation source's controller, program it to start when the microgrid circuit becomes de-energized. The circuit breaker that connects this generation source to the microgrid circuit should be controllable by the protection and coordination controller, which also controls the PCC circuit breaker.
3. Set the component level controllers for the remaining generation sources to operate in grid-following mode with voltage and frequency ride-through settings as per utility requirements and active anti-islanding turned on.
4. Program the protection and coordination controller(s) with the protection settings required under the interconnection agreement and program an automated foundational microgrid controller into this level.
    a. The foundational microgrid control system should respond to Area Electric Power System (AEPS) faults as per utility requirements and coordinate the switching of the main grid-forming generation source's tie-breaker with the PCC breaker(s) to safely form the microgrid when the PCC is open, provided that the PCC did not open due to a fault that is internal to the microgrid.
    b. The foundational microgrid control system should respond to the utility becoming re-energized with a coordinated reconnection of the microgrid to the utility.
    c. The foundational microgrid control system should have two modes:
        i. Mode 1: Switching commands that are sent by any other external controller (such as the component level, optimization level, or real-time level controllers) are ignored.
        ii. Mode 2: Switching commands for external controllers are processed and acted upon if protection settings allow.

    If the control system is operating in Mode 2 and for any reason the microgrid circuit becomes de-energized for an unexpectedly long period, then it should automatically switch to Mode 1 and energize the microgrid with the main grid-forming generator.
5. With the PCC and the control system operational, the optimization and real-time controllers can be deployed and tested on the live system with the foundational control system being in Mode 1 until these controllers have been tested successfully for all functions that do not require switching of the PCC or main generation source tie breakers. At that point the foundational control system can be switched to Mode 2 and live testing can continue with the optimization and

real time controllers being allowed to attempt switching of the PCC and main tie breakers for applicable control sequences.

6. Test any newly installed communication links and grid integration platform elements needed for market participation

Once the optimization and real time controllers are proven, a final step is to coordinate ramp rates and component-level controller settings so that components will revert to a safe operating state if the optimization and/or real time controllers go offline. The final state should be optimal economic performance if all controllers are online, commissioned well, and meeting the design intent, with fail-safe operation at the component-level controllers if the optimization and/or real time controllers are offline.

Critical Processes, Equipment, and Expertise

Developing a microgrid is a complex process that involves several key processes, technologically advanced equipment, and specialized expertise. Information relevant to these topics has been provided previously in this chapter. This section summarizes several key aspects that cannot be overemphasized when considering development of a microgrid.

Based on the experience of the LTP project, the most critical process for implementation is technology integration. With multiple contractors and vendors involved in implementing the project, there is a tendency for each entity to be narrowly focused on their scope of work, schedule, and budget. This creates risks because the work items and technical systems being provided must be able to interact with the overall integrated system for the design intent of the microgrid to be realized. Care must be taken to avoid gaps in the divisions of responsibility between contractors and vendors, which will become more apparent in the latter stages of the project as budgetary and schedule pressures increase. To mitigate as much of this risk as possible, the prime contractor should select a qualified technical integrator to set up a contractual framework to empower the project's integration team so that when uncertainty arises about the division of responsibilities, there is a licensed engineer with responsible charge of the work that can provide direction that is reinforced by contracts that were carefully negotiated at the beginning of the project. Other critical processes include:

- Interconnection process with the utility
    - Take the necessary time to fully understand this process early in the project and account for the various steps and necessary review periods in the master project schedule
    - Pre-energization testing will be required for any new switchgear at the PCC

- Engineering design process
  - Include development and review of the following at the 30 percent, 60 percent, 90 percent, and 100 percent level of completeness
    - An integrated plan set showing design plans for each system in one plan set. Every piece of hardware should be included with divisions of responsibility for procurement and installation noted on the plan sheets.
    - A complete listing of any performance metrics required of the equipment, sensors, control system, communication links, or grid integration platform required to allow monetization of grid impacts
    - A Concept of Operations document written in lay-person's terms that outlines the goals and objectives of the microgrid. It defines the use cases for the microgrid and describes the control actions that will be active to support each use case. It specifies the actors that have a role in the control system and describes how they will influence the operational characteristics of the integrated system, and describes each control function that will be used to meet the design intent.
    - An engineer's opinion of probable costs, which is used at each design review stage to check to make sure that the estimated construction cost of the system is still within the project budget. If not, a value engineering step can be included in the work to achieve the next level of design completeness milestone.
- Hardware-in-the-loop testing in a digital simulation environment
  - A digital blueprint of the microgrid should be created in a suitable real-time digital simulator.
  - All four or five levels of microgrid controllers listed above should be included whenever possible. If it is not practical to integrate a certain component level controller, a simulated model may be used as a substitute but the amount of risk that can be retired through this critical process will be reduced in that case.
  - Hardware-in-the-loop testing system can be used to train microgrid operators.
- Deploy a fully tested foundational microgrid controller implemented in the protection and coordination hardware at the time that the PCC construction occurs
  - This control system will include all of the protection requirements that the utility requires at the PCC as well as control functions to transfer the microgrid loads between the AEPS and the main grid-forming generator in

    the microgrid and back in response to outages on the utility or operator commands for planned islanding events.

- Commissioning
    - This process will involve making sure that all of the interfaces between the various actors in the microgrid are functioning and that the four levels of control listed above are coordinated and functioning to meet the design intent of the microgrid.
- System Observation
    - After commissioning, the system should be observed for at least one year with data analysis conducted at regular intervals. Due to the complexity of the integrated system there will likely be deviations from expected behavior that will require effort to diagnose. The project team should plan for this observation period by making sure there is budget for data analysis and diagnostics and by making sure that warranty documentation supports any fixes that are deemed necessary.

In addition to these critical processes there are several critical pieces of equipment that are necessary for the microgrid to function safely, reliably, and optimally from an economic perspective. The list of critical equipment includes:

- Advanced protection relays that can be programmed to provide basic control, coordination, and protection for the microgrid.
- A grid-forming generator that is capable of black starting the entire microgrid and that can:
    - Generate enough current to handle reactive load spikes and inrush current from starting large motors.
    - Generate enough fault current to maintain the selectivity of fault interruption devices on the main circuits in the microgrid.
- A microgrid controller that provides real-time control of generation sources and storage in the microgrid on a time scale of milliseconds to seconds to enforce constraints within the control scheme.
- A microgrid controller that provides optimal dispatch of generation sources and storage to minimize operational costs and maximize economic benefits.
- Component level controllers (for example smart inverters) that provide adequate control and protection functions to enable fail-safe operation in the event that communication with the real time or optimization controller is lost.
- For microgrids looking to monetize grid impacts that are highly variable in nature (such as a waste water treatment plant), a grid integration platform that can

develop an accurate and precise dynamic baseline, and communicate that to the grid impact counterparty

Key expertise for implementing microgrids includes:

- A project management team who can lead the implementation team to keep the project on schedule and under budget, and ensure environmental and permitting processes are closely managed
- A grid product integration specialist or firm for analyzing the economics of the saleable grid impacts, whether directly to the California ISO or to a load serving entity, as well as for communicating the associated performance and data requirements to the design and construction team.
- A licensed engineer to act as the lead technical integrator with responsible charge over the integration process and who has been empowered through contracts to direct work as needed
- A controls expert who can program advanced protection relays with control functions necessary for microgrid operation, participate in the development of the real-time and optimization control programming, and who can coordinate the settings of the component level controllers
- A licensed electrical engineer who has responsible charge over the electrical design of the microgrid and who can develop a power flow model of the microgrid to evaluate stability under various conditions
- A protection engineer who can program protection relays, complete short circuit coordination studies, and who has responsible charge over the selectivity of the fault interruption systems in grid-connected and islanded modes
- An energy modeler who can verify the optimal component sizing and consult with the controls team to ensure that the necessary functions are in place to achieve optimal economic performance
- Utility interconnection engineers who can evaluate the proposed project to clarify requirements and ultimately inspect and approve of the project
- A licensed electrical contractor with experience with medium-voltage systems
- A network technology expert who can design the communications network needed for microgrid control and data acquisition
- A cyber security expert who can evaluate the design plans, identify any vulnerabilities, and recommend mitigation measures to harden the microgrid against cyberattack
- A testing team with facilities to conduct hardware-in-the-loop testing of controls in a digital simulation environment so that the microgrid control system can be tested before being deployed on a live system

- A construction management team to document construction and help mediate any disputes that arise
- A commissioning agent who is responsible for testing all of the functionality included in the final Concept of Operations document, which should contain a common understanding among all project participants as to how the system should operate upon completion
- A data analysis specialist who can efficiently analyze large operational data sets during the system observation period and provide summary reports to the project management team

The information provided in this section is not intended to be exhaustive but should provide a sense of the types of processes, equipment, and skills needed to successfully implement a microgrid.

Key Cost Considerations

Microgrid implementation is very capital intensive. Certain components are commercially mature from both an economic and technical perspective, such as solar PV systems, natural gas and other fossil fueled generators, and advanced protection relays. Battery energy storage systems are often essential to microgrid operability because they are able to absorb as well as generate energy in quantities that are useful in supporting microgrid operation in island-mode. Battery storage is still relatively expensive in 2018, but capital costs are declining steadily.

On an individual basis, procuring each of these types of assets and installing them at a facility with a connection to the utility is relatively straightforward, and in isolation the "soft costs" (such as engineering, permitting, testing, construction management, commissioning) of each are in line with a typical public works project. However, for a microgrid project, some combination of these assets must be deployed in an integrated system and a dynamic PCC with the AEPS must be managed as well, which is likely to create significant design, engineering, commissioning, and utility interconnection requirements that can add considerably to the cost.

Key cost considerations for microgrid implementation are:

1. The soft costs for the expertise needed during design, testing, interconnection, construction, and commissioning of the microgrid.
2. The interconnection costs with the utility, including potential service reconfigurations.
3. The microgrid controller system costs covering the four level of controls described above.
4. Additional revenues and marginal costs, both up front and continuing, of monetizing grid impacts.

These four cost considerations generally amount to a significant fraction of the overall project cost and should be evaluated early during the project budgeting phase. Estimating the amount of effort that should be budgeted for items one and two is difficult and can vary widely from project to project. From a cost management perspective, an experienced design team and a utility that has a clear interconnection process and experience with microgrids are two desirable attributes for any microgrid project.

Thoughts on Replicability

Regarding replicability of microgrids in California and general, a primary consideration is the perspective of the utility on any proposed project. Any type of microgrid will always require utility interaction, and the local distribution utility will always be the expert in the room when it comes to safely and reliably operating the local electricity grid. When a microgrid project is proposed, the local distribution utility has the ultimate authority to either approve or deny the terms for interconnection for any project. If a project fails to meet the utility's requirements at a reasonable cost, it may be unable to obtain permission to operate regardless of whether construction has been completed.

Single-customer microgrids with a single PCC (that is, a campus), that are well-designed according to utility requirements, should be able to obtain unconditional permission to operate from the utility. There may be restrictions on the types of transfers that are allowed (break-before-make or seamless) and/or the amount of power that is allowed to be exported from the microgrid to the AEPS. However, these are points of discussion that can be addressed using sound engineering design practices and clear communication to obtain mutual agreement.

Multi-customer microgrids will likely require that the utility's distribution circuit be modified and special cost recovery methods and tariffs will probably apply. It is easier to standardize these types of microgrids from a technical perspective, especially if the generation and storage assets are owned by the utility, because the protection and control hardware and software for switching on medium voltage circuits is mature. The more complicated aspects are the contractual and financial details that will govern cost recovery and the creation of special tariffs.

Need for Standardization

Standardization of equipment, communication protocols, control sequences, interconnection pathways, and primary circuit switching protocols in the context of microgrid use is an admirable and elusive goal. There are industry efforts to pursue standards that, if adopted by enough manufacturers, could make it easier to integrate component-level controllers and optimization, and real-time controllers.

The LTP project did not benefit from any such standardization. Most of the interfaces and much of the control software required custom development. This required significant effort by highly skilled engineers to develop and test the interfaces and software. These "soft costs" increased the overall project cost and timeline considerably. At present and for the near future, it is likely that teams working to develop a microgrid project will have a similar experience.

In an ideal scenario, a set of microgrid interface and communication standards would exist that component manufacturers would adopt to allow devices from different manufacturers to communicate with each other over a secure TCP/IP network with reduced customization requirements by the engineers deploying the equipment.

One approach is to try to implement a microgrid using hardware and software from a single vendor. There are several large companies that are capable of providing this type of umbrella solution. However, there are pros and cons with this approach. On the plus side, one experienced firm can provide the components for much of the control system and, in some cases, the generation sources and energy storage systems as well. Experienced engineers from that same company can design, test, and commission the equipment. Custom interfacing and controls work is minimized.

However, with this approach the microgrid design, functionality, and innovative characteristics could become somewhat limited by what the "umbrella" company sees as the "best" way to implement a microgrid. Also, being able to fully grasp the operational characteristics of the completed microgrid during the sales period with a large company offering a turnkey microgrid could be challenging. Once the sale has been made, the selected company will implement the project and along the way details about how the system will be deployed and operate will become clear to the owner. There is a risk that the owner's expectations will not be met and options to remedy the situation may be limited.

Where monetization of grid impacts is a key goal of the project, the development of an accepted and well-understood method for determining the 'but for" baseline of a highly variable asset like LTP is critical. The need for a dynamic baselining method is detailed elsewhere in this report

Need for Plug-and-Play Architecture

The phrase "plug-and-play" describes a case where a "child" device can be plugged into a "parent" device for the first time and after a brief communication period, the child device works perfectly the first time it is used. One example of this is when a keyboard (child) is plugged into a computer (parent) for the first time. The child device is designed with a standardized interface protocol, and as long as the port that it is plugged into complies with this protocol and the operating system on the computer has a standardized discovery mechanism for this protocol, meeting the plug-and-play standards, the child's driver will be installed on the parent and it will operate as designed.

While it is conceivable that an analogous system could be implemented to speed wider use of microgrids with components from multiple manufacturers, the practicalities of such an endeavor are daunting. The types of components that could be used in a microgrid, potentially with multiple manufacturers involved, are many — inverters, automatic transfer switches, protection relays, internal combustion engine generators, microturbines, fuel cells, battery energy storage systems, energy management systems, meters, and others. From this perspective alone, it appears unlikely that standards to enable plug-and-play operation for multi-manufacturer microgrids will ever be widely adopted. It is much more likely that single-manufacturer microgrids may achieve plug-and-play functionality as competition drives down cost for turnkey microgrid solutions.

One note of caution regarding the concept of plug-and-play solutions for microgrids is that there could be significant risk in allowing any component that is connected to the microgrid circuit to operate as a plug-and-play device. For safety, any device that is connected to the microgrid circuit should be carefully configured to operate within the constraints of the site-specific control system by the engineering team. These components need to operate in a coordinated fashion with other grid-connected components.

Some grid-following components that are connected to the microgrid circuits such as solar PV inverters are essentially plug-and-play. Solar PV inverters are a good example of how grid-following generation sources can be designed to be plug-and-play because their initial settings are fail-safe and can be customized during commissioning as needed for microgrid duty. Also, components that are not directly connected to and have no direct influence on the microgrid circuit, such as power meters, weather station instrumentation, data loggers, and others, could be made plug-and-play, which could definitely reduce microgrid implementation time.

Need for a Dynamic Baselining Capability

For a wastewater treatment facility the best predictor of power consumption at any given time is the amount of liquid waste being processed through the facility, as the change in flow results in a change in need for pump operation, mechanical grinder/separator operation, aeration blower operation, and other actions. Unfortunately, this is not how the system currently works with respect to compensation.

When participating in electric markets through monetization of grid impacts, one of the most important elements is the baseline. The California ISO defines it as follows:

> *A baseline is an estimate of the expected consumption-i.e. the electricity that would have been consumed-had there not been a demand response event. The difference between the baseline and the actual consumption is the actual energy reduction a demand response resource delivered during the event. Because only the physical load can be metered (and not the demand response quantity), the result of the baseline calculation compared against the actual load during the idea so dispatch time arise and serves as the demand response energy*

management use by the ISO to financially settled the energy delivered (i.e. Energy not consumed) from a demand response resource.[1]

The North American Energy Standards Board (NAESB), responsible for developing and promoting industry standards, published a standard for demand response performance methodologies in 2012. It provided standard terminology and identified five broad types of performance evaluation methodologies:

Baselining Type-I, Baselining Type-II, Maximum Base Load, Meter Before/Meter After, and Metered Generator Output. The California ISO tariff currently provides for three of these five NAESB approved performance evaluation methodologies (Type-I, Type-II, and MGO).

According to California ISO "*Type-I metering is the most commonly used baseline method for performance measurement of demand response resources among ISOs and regional transmission organizations*." This method looks at energy consumption at the same time of previous days in order to predict the energy consumption for a given time block, with a minor adjustment available (up to plus or minus 20 percent) based on the hours immediately before a potential event. Type-II uses statistical sampling where appropriate metering technology may not be present. Metered generator output (MGO) is just what it sounds like: measurement of the actual output of a device like a generator or battery.

Type-II metering does not apply because settlement quality interval metering devices will always either be in place or installed as part of a microgrid project. MGO does not apply to a project like LTP because it is a load modifying grid impact, not a generating device that pushes a measurable quantity of electrons onto a grid. Because of this, Type-I is the default method for potential microgrid assets seeking to monetize their ability to provide firm, dispatchable grid impacts.

For many potential market participants, a Type-I baseline method would be entirely practical. For loads such as those at data centers, hospitals, or office buildings, there is relatively little change in total power/energy consumption from one day to the next. Even while the power consumption of some internal systems of the building may change dramatically (such as the power draw of a cooling plant during a major heat storm), so long as the method focuses only on the power consumption of the building as a whole, the variance between one days energy usage and another is relatively predictable.

This is not the case for wastewater treatment facilities like Laguna. Depending upon flow, the power draw of the Laguna treatment plant during the period of this study ranged from more than 5 MW to less than 2 MW as the hourly flows through the plant ranged from more than 50 MGD to less than 15 MGD. The Laguna treatment plant is an

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[1] California ISO Demand Response User Guide, 2017, page 149)

episodic, highly variable load. It is episodic in that load variations can and do change from day to day, and the timing of those load changes is random. It is highly variable in that the difference in power for any given block of time can vary tremendously, particularly when compared to more static loads such as the building types mentioned above.

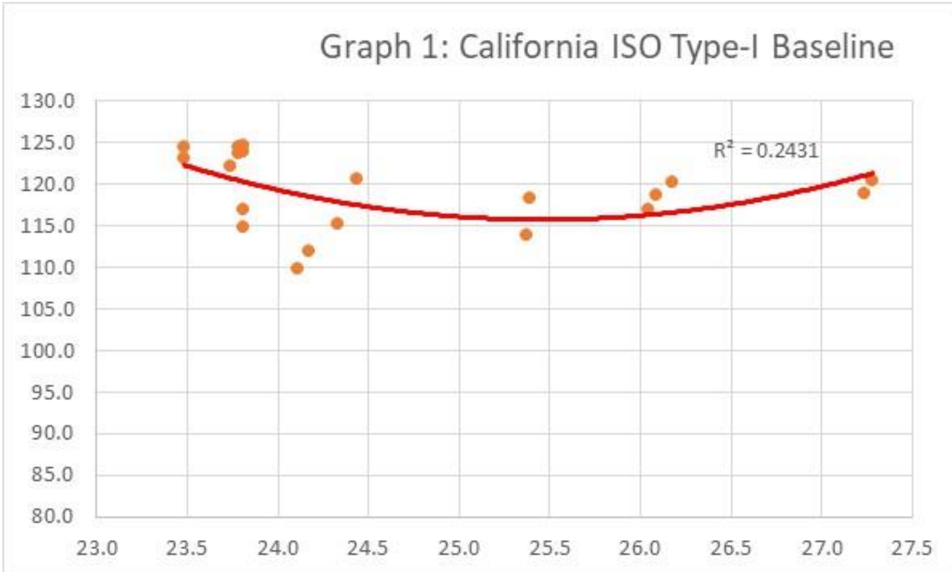
An alternative approach would be to develop a dynamic baseline using a variant of the NAESB Meter Before/Meter After method. Even with the relatively limited amount of data gathered during the testing period, the Trane dynamic baselining method appeared to have a considerable edge over the Type–I method currently mandated by California ISO.

Impacts of the Absence of a Dynamic Baselining Method

Due to delays caused by variables listed elsewhere in this report, the actual runtime of the project prior to the conclusion of the grant period was relatively limited. However, even during this limited run time, data collection and operation was able to provide some confirmation of the potential superiority of a dynamic baseline approach over the current Type-I standard.

Operational data from the test period appears to confirm that a Type-I baseline can be both imprecise and inaccurate compared to Trane's dynamic baseline approach, and this imprecision is particularly noticeable during variable weather. Variable weather during the test period meant several days of high flow following several days of low flow, as well as the reverse of this situation. When several consecutive low flow days preceded a high flow day, plant kW would be higher than anticipated by a Type-I baseline. Where several consecutive high flow days preceded a low flow day, plant kW would be lower than the baseline before any load modifying behavior had taken place. This high variability would be more likely to occur during the "shoulder" Figure 45 and Figure 46 are provided to illustrate this point.

Figure 45: California ISO Type-I Baseline

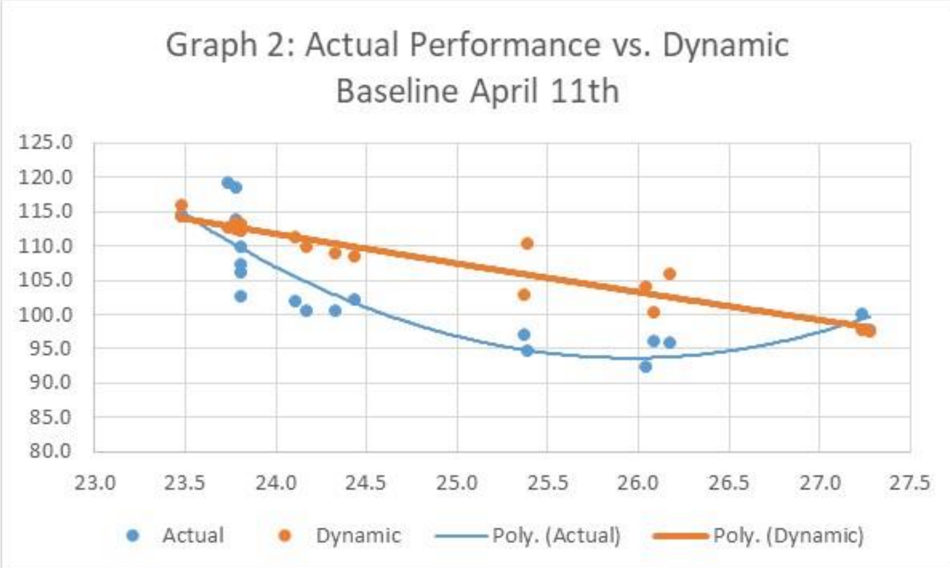


Source: Trane U.S.

The graph in Figure 45 comes from the plant data gathered on April 11. On this day plant flow ('x' axis) was fairly steady in the range of 23 to 27 MGD, but the previous 10 weekdays had experienced much higher average flows due to weather. Because the Type-I baseline only used data from those dates (with a minor modification due to "day of" power), the predicted baseline power consumption of the plant was neither precise nor accurate. The attached graph shows the Type-I calculated baseline, with kilowatts per MGD on the vertical axis and hourly flow (in MGD) on the bottom axis.

The graph in Figure 46 compares the same metrics for both a dynamic baseline and actual power readings at the plant.

Figure 46: Actual Performance Versus Dynamic Baseline (April 11, 2019)



Source: Trane U.S.

During the test period Trane and Santa Rosa ran a series of simulated market participation events. These test events included diversion of flow to a flow equalization basin, operation of the battery, and operation of the motor driven generator set.

Using a Type-I attribution method, eight of the 16 test events would have been deemed unsuccessful by the California ISO, while using a dynamic baseline method would have demonstrated that all 16 of the events would have met their targeted load modification goals. During these events both the plant operator and Trane understood that they were providing a real curtailment of grid load compared to what the normal operation of the plant would have drawn from the grid at that moment. However, several of these test events occurred during weather related high flow time blocks, while the Type-1 baseline was based upon previous lower flow time blocks. In these cases there is no combination of actions that a plant operator could have taken that would have resulted in a successful event when compared to the Type-I baseline.

This is important for several reasons. First, energy market participation is not core to the mission of this facility. Market participation is something that may be done so long as the perceived risk is low, and the reward is reasonable. For assets that have highly variable loads a Type-I baseline method thus brings on risk. This negatively affects the risk-reward calculation on the reward side as well. A "no way to make it" failure event deprives a potential market participant of remuneration they would otherwise receive, while some monetization mechanisms punish a failure with an actual penalty. For a highly variable load the uncertainty and risk inherent in a Type-I Baselining method will probably continue to dissuade market participation.

Market Gaming

This research validated that it is possible to game the demand response market through data analytics by using flaws in the Type-I method. A specific example showed how a demand response market actor with an advanced data analytics engine like Trane's dynamic baselining algorithm could produce revenue in the California ISO demand response market without actually changing equipment operation.

The morning of Monday, April 15, was dry, and flow into the plant dropped below 20 MGD for several hours in the morning. This flow reduction was the first time that this had occurred during a weekday in roughly two weeks. The Type-I baseline method for April 15 was based on the previous 10 weekdays, all of which had higher flows than that morning. Knowing both recent flow and the flow anticipated for that day it was possible to know in advance that the California ISO Type-I method would be artificially high. The Type-1 baseline for 8 a.m. was more than 4 MW, the dynamic baseline was estimated at less than 2 MW, and actual power consumption was less than 2 MW. Had a 2 MW curtailment been bid in to the California ISO it would have appeared to have been successful without needing any change in plant operation.

Because of the way that Type-I baselines work, this would not necessarily be limited to being a one day market gaming event either. Under a Type-I baseline method any day that an asset participates in the market is not included in the basket of hours that are used to calculate the next day's baseline. In this case, if the Laguna plant had participated on Monday and then elected to participate again on Tuesday, the same days would have been used for establishing the Tuesday Type-I baseline: because Monday was a "participation event day," Tuesday, April 16 would have used the 10 previous week days, but excluding Monday. The result effectively "freezes" the abnormally high baseline of April 15 in place for another day of potential "no change" kW harvesting, an exploit that could have continued for more than a month.

This gaming vulnerability is not going away. The amount of data collected and available for analysis by current or potential market actors is large and growing. This data includes the ability to anticipate flow before it gets to a plant, see flow rates at various locations as it moves through the process stream, and also gather real time data on instantaneous power consumption. With this data in hand the ability for market actors to calculate and act upon the monetization opportunities provided by the differential between the actual power predicted by dynamic baselining engines and the artificial baseline calculated through a Type-I method will only grow.

Finally, it is worth noting that the lack of a fair dynamic baselining method also negatively affects the ability of entire classes of important distributed energy resources from reaching their potential.

For example, the Laguna plant has what is called a flow equalization basin, which allows incoming process flow to be diverted and held for processing at a later time. Use of a flow equalization basin could allow a plant to artificially reduce its power consumption at one block of time and then artificially increase its power consumption at another, at least when compared to the same plant without a process flow storage capability. When properly metered and controlled, an integrated flow equalization basin could become a valuable, predictable, and dispatchable grid asset. By providing a morning ramp up, mid-day beneficial load, afternoon ramp down, and evening curtailment, a flow equalization basin equipped plant could provide multiple different grid impacts throughout the day to help counter "duck curve" events. However, in the absence of a dynamic baselining method it would be difficult for a wastewater treatment facility to be able to reliably monetize these altered and beneficial grid impacts.

Not all wastewater treatment facilities have flow equalization basins. When considering whether to invest in a flow equalization basin a plant owner would look at first cost, additional marginal operating cost, tariff based electric bill savings, and finally any "upstream" utility facing revenue produced by the operation of this grid integrated asset. Since the absence of a dynamic baselining method effectively neuters the ability to reliably monetize these beneficial grid impacts, it effectively de-monetizes an important cash-flow mechanism for any plant considering this piece of infrastructure. Many microgrid projects that could work economically in an environment that has a dynamic baselining method would not be able to make economic sense in its absence.

Wastewater facilities are not the only types of potential microgrid loads that are negatively affected by the absence of an accepted dynamic baseline method. Potable water systems in many locations across California have the ability to install significant tankage in areas where elevation provides the ability to drive needed system pressure. Sufficient tankage at elevation would allow the instantaneous energy usage of a water system to be effectively de-coupled from instantaneous water usage. Similarly, the grid impact of an HVAC system (when isolated from the load of the rest of the building) is also a highly dynamic load, where instantaneous power draw is closely correlated to ambient air temperature. A thermal energy storage system coupled to a highly variable HVAC load could also benefit from a dynamic baselining method and would do so for the same reasons. Highly variable loads like these represent a significant portion of overall annual electric energy consumption, with water estimated at around 18 percent of California's annual energy consumption and HVAC not far behind.

Functional energy storage systems (flow equalization basins, water tanks, thermal energy storage, and others) share common characteristics. They can provide reliable grid impacts that are needed to help California reach its renewable integration goals. They can be applied to systems representing a significant portion of annual energy consumption. They are well understood technologies that have historically seen relatively small deployments compared to their market potential, and all of their advancement in the market would be helped by the market monetization opportunities presented by the development of a dynamic baseline.

This research into the challenges faced by highly variable grid loads when trying to use a Type-I baselining method, particularly when compared to the results possible from a data driven dynamic baselining method, indicates that this is an important area for additional research. It appears that there is an important market gap, a large potential market, potentially workable technologic solutions, and an existing regulatory framework that this concept could fit into. Trane believes that attention to the issues surrounding the lack of a dynamic baseline method for highly variable grid loads by researchers, public servants, industry, and decision makers has the ability to rapidly, meaningfully, and equitably help move California toward a greener electric future.

CHAPTER 11: Conclusions and Recommendations

Conclusions

The LTP microgrid project was successful in the integration and installation of a microgrid system. This allows the LTP to participate in the day-ahead market. A new opportunity for wastewater treatment facilities. The project was completed at the end of the grant period, March 31, 2019, and was operated over a 30-day period using simulations. The project was recognized for its technology and ability to control certain assets in a wastewater treatment facility.

The project met its design intent and achieved full functionality, including:

- A secure, reliable, wastewater treatment facility microgrid deployed at the Laguna Treatment Plant
    - This provides critical resiliency for the plant and surrounding areas.
- Four levels of operator day-ahead market assets for programmed demand response:
    - Flow equalization basin flor diversion
    - BESS
    - CHP engine #3 with selective catalytic reduction unit
    - CHP engine #4 with selective catalytic reduction unit

The LTP supports academic, government, public, and private industry groups and students visiting the microgrid site to tour and learn about solar energy, battery storage, distributed energy resource integration, demand response, peak shaving, and other details.

The telemetry and data recording system on the microgrid are extensive and the project represents a valuable resource to the State of California for studying grid dynamics and smart-grid strategies under a variety of real-world scenarios on a live system. Committed partners such as Trane, PG&E, and others are providing ongoing support for the microgrid, which enables growth as the technology improves. The economic benefit to the LTP going forward will be dependent upon its use of the microgrid and the assets it controls. Subsequent years going forward will provide further system performance and results of the microgrid project.

Lessons Learned

Some of the key lessons learned include:

- Implementing a microgrid project requires an empowered technical integration team, including the owning entity.
- A microgrid control system has four levels of control:
    - Component controllers
    - Optimization controller
    - Real-time controller
    - Protection and coordination controller
- Advanced protection relays have control capabilities that can be used to make sure that the protection and coordination controller is at the top of the control hierarchy, which aids with construction sequencing and avoids significant risk when deploying the optimization and real-time controllers.
- The electric utility is a critical partner in any microgrid project. Microgrid interconnection processes are especially complex and establishing a collaborative relationship with the utility is essential.
- Network latency and control cycle times must be accounted for, especially when solar output is large relative to loads.
- Hardware in the loop testing in a real-time digital simulation environment is valuable for de-risking and providing a venue for operator training.
- During live testing, use detailed test plans with contingencies for all failure modes.
- Include SCADA programmers and electricians with prior knowledge of the microgrid site on the project team.
- IT upgrades can disrupt communications between microgrid components causing operational issues, so ensuring system/sitewide IT coordination is important.
- Make sure to account for large reactive loads during design.
- Implementing a microgrid over an existing built environment is challenging. Any reluctance to change by plant personnel must be carefully considered.
- Owner/operator ability should determine system complexity and the appropriate level of automation.
- After commissioning, closely monitor system performance to verify functionality and expected results.

- Involvement of the IT and communications department is critical to project success.
- Do not underestimate the amount of time it will take to commission the microgrid control system.

Recommendations

Chapters 2, 3, 4, 5, and 6 provide detail as to how the LTP microgrid project was implemented and can serve as a resource to other project teams working on implementing similar projects. Chapter 10, Production Readiness Plan, addresses key considerations regarding how to replicate microgrids in a general sense. The top five recommendations for project developers are as follows:

1. Engage and empower a qualified technical integration team in the early stages of project development.
2. Engage and cultivate a cooperative relationship with the electrical utility to which the microgrid will connect as early in the project development process as possible.
3. Use advanced protection relays at the point of common coupling with the utility to create a foundational microgrid control system that is at the top of the microgrid control hierarchy.
4. The site host should be prepared to accept risks associated with both planned and unplanned electricity outages, potential equipment damage, and cost overruns.
5. Ensure that there is enough budget after initial commissioning for a system observation period (ideally at least 12 months) during which data analysis results will lead to opportunities to improve system performance, sometimes dramatically.

Suggestions for Further Research

The following is a set of research topics that the authors think are worth further research:

- Schemes to optimize microgrids
- Use of thermal storage in a microgrid
- Front-of-the-meter multi-customer microgrids integrated into a distribution utility's control network
- Simplified microgrid control – how simple and low-cost can a microgrid control system be and still serve basic microgrid needs?

- Deployment of microgrid controllers that can provide seamless transitions during unplanned outages, like an uninterruptible power supply
- Grid distribution services that can be provided by microgrids
- Exploration of distributed, rather than centralized, smart grid control architectures
- Control and protection strategies for low-inertia operation of inverter-based microgrids with high penetrations of renewable energy

GLOSSARY AND ACRONYMS

Term	Definition
1 MW CHP	Cummins combined heat and power (CHP) engines 1.1 MW capacity located in the CHP plant that was retrofitted with selective catalytic reduction technology used as demand response resources.
BESS	battery energy storage system; in the context of this project, specifically refers to the Nuvation 2MW /480 kWh battery energy storage system the project used.
BMS	Battery management system
CPUC	California Public Utilities Commission
EPIC	Electric Program Investment Charge
ECI	Electrical Consultants, Inc.; project partner.
IT	information technology
LTP	Laguna Treatment Plant
ME&E	McKeever Energy and Electric; project subcontractor.
MGD	Million gallons per day
MSB	main switchboard
PCC	point of common coupling; the point at which a microgrid is connected to the wider utility grid.
PCC relay	the primary SEL-700 & PCC breaker control and protection relay located in the PCC.
PTO	permission to operate
PV	photovoltaic
RTDS	Real-Time Digital Simulation; a digital simulation system that operates in real time, often including hardware-in-the-loop components.
SCADA	supervisory control and data acquisition
SEL	Schweitzer Engineering Laboratories, Inc.; project vendor.
SEL-700	specific model of protection relay device, manufactured by SEL, Inc., used to monitor and control the point of common coupling breaker control.

Term	Definition
smart grid	The thoughtful integration of intelligent technologies and innovative services that produce a more efficient, sustainable, economic, and secure electrical supply for California communities.
SOC	state of charge; the amount of energy stored in the battery system (synonym of SOE).
SOE	state of energy; the amount of energy stored in the battery system (synonym of SOC).
SWPPP	Storm Water Pollution Prevention Plan
UPS	uninterruptable power supply; device capable of powering attached loads from stored energy (usually batteries) for a short period of time after normal input power is interrupted, and of transferring quickly enough that connected loads are not affected by the transfer.

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Water Education Foundation . 2019. *Wastewater Treatment Process in California.* Accessed 2019. https://www.watereducation.org/aquapedia/wastewater-treatment-process-california.

APPENDIX A: CEC Stop Notice

The California Energy Commission issued a Partial Stop Work Order on February 2, 2019, for the second selective catalytic reduction unit installation until the city accepted in writing the project's BESS inverter and PV inverters. These project components were previously reviewed and approved by the city; however, plant operations personnel were unsure of the harmonics these devices may impose upon the plant's equipment.

The notice was released on March 3, 2019, only after the city accepted the previously approved plans and equipment specified for the project. A copy of the Stop Order follows.

CALIFORNIA ENERGY COMMISSION
1516 NINTH STREET
SACRAMENTO, CA 95814-5512
www.energy.ca.gov

February 13, 2019

Richard Swank
TRANE
4145 Del Mar Avenue
Rocklin, CA 95677

Re: **STOP WORK ORDER**
Agreement Number EPC-14-059
Laguna Subregional Wastewater Treatment Plant Microgrid

Dear Mr. Swank:

This letter provides notice that we are issuing a Partial Stop Work Order on EPC-14-059 pursuant to Exhibit C, Terms and Conditions, Section 16, Stop Work. Notice is hereby given to stop work effective upon receipt of this letter on the installation of the second Selective Catalytic Reduction (SCR) equipment excluding the civil work under the above referenced agreement between the California Energy Commission (Energy Commission) and Trane. Actual installation of the second SCR shall not be performed unless and until the Energy Commission notifies you in writing to resume work. This Stop Work Order provides both you and the Energy Commission time to evaluate the project.

The Energy Commission approved funding for this project to demonstrate a wastewater treatment plant using a microgrid with a solar photovoltaic system using inverters, an energy storage system using inverters, and a microgrid controller to provide increased resiliency and allow greater use of renewable energy.

As of February 1, 2019, the City of Santa Rosa permitted all of the equipment as detailed in the design documents used for permitting by the City. The microgrid has been designed, reviewed by the City, all permits were issued by the City to allow for the installation of all equipment, and construction is almost complete representing the current expenditures of $3.4M (75 percent of total budget). However, the City Wastewater Treatment Plant Personnel have not accepted the UL testing and certification to IEEE standards for the PV and Storage inverters and is not proceeding with the commissioning and use of the inverters. This threatens the completion of the project.

Under the Terms & Conditions, the Energy Commission retains title to all equipment and without completion and commissioning of a microgrid, is exploring options for equipment removal and/or cost recovery.

The Energy Commission will only consider removal of the Stop Work Order after:

- The Commission receives written confirmation that the City of Santa Rosa has completed all reviews of the microgrid including equipment and design and accepts and approves the microgrid for commissioning and operation by February 20th.
- Scheduling for commissioning of the storage system by February 20th.
- A letter from the City of Santa Rosa that demonstrates the City's commitment to continue microgrid operation beyond the end of the agreement.
- Beginning collection of measurement and verification data by March 1st.
- A CPR is held by the Commission to review and approve the performance to date, the budgets, and a schedule and plan for completion of the project.

If I can be of any assistance or provide you with clarification, please contact me at (916) 327-1521 or Jamie Patterson, the Commission Agreement Manager at (916) 327-2342.

Sincerely,

Laurie ten Hope
Deputy Director
Energy Research and Development Division

APPENDIX B:
Project Specifications

The microgrid project specifications are consolidated into the following areas:

a. Carport solar PV
b. BESS (Nuvation & Parker)
c. Selective catalytic reduction units - Miratech

The following pages provide for the specifications of each of the above microgrid major components.

EQUIPMENT SPECIFICATIONS

Carport Solar PV System (126 kW D.C.)

MATERIAL LIST			
QTY.	MANUFACTURER	PART#	DESCRIPTION
372	CANADIAN SOLAR	CS6U-340M	MODULE
2	CANADIAN SOLAR	CSI-60KTL-CT	INVERTER
1	SIEMENS	P1E18ML250CTSN	PANELBOARD
22	ALEO	LSC-40	LED LIGHTS
1	INGENIEURBURO	SI-RS485-TC-T	IRRADIANCE SENSOR
124 (20FT)	IRONRIDGE	XR10	MOUNTING RAIL
558	IRONRIDGE	FM-LFT-003	RAIL ATTACHMENT
CONSTRUCTION TYPE		IIB	
BUILDING OCCUPANCY		U	
TOTAL AREA OF CANOPY		7,960 SQ FT.	

BESS (Nuvation Energy)

Mfg. Part number	Manufacturer	Description	Quanity per Stack	Total Quantity
		Control Tray		
S8VK-C12024	OMRON	24V 120W Power Supply	1	20
HX241CAX	GIGAVAC	1500 Vdc 400A Contactor	3	60
90-447-25-.200	SIBA	1500 Vdc 200A Fuse	2	40
RSB-500-50	Riedon	500A Shunt 50mV	1	20
OTDC315EV12	ABB	Manual Disconnect Switch	2	40
2903361	Phoenix Contact	RELAY GEN PURPOSE SPST 6A 24V	1	20
774059	Pilz	E-Stop Safety Relay	1	20
NUV100-PI-HE	Nuvation	Power Interface	1	20
NUV100-SC	Nuvation	Stack Controller	1	20
SM50-30-101L-M	HVR	100 Ohm Precharge Resistor	1	20
		Battery Rack		
NUV100-CI-12-1	Nuvation	12 Channel Cell Interface	21	420
4715MS-12T-B20-A00	NMB Technologies Corporation	FAN AXIAL 119X38MM 115VAC TERM	9	180
MP320-049 Moxie+	EnerDel	Lithium NMC battery module	21	420
		Control Panel		
ML500G-50	Logic Supply	PC	-	1
PMM4410	BSI	Monitor	-	1
CP1L-EL20DR-D	OMRON	PLC	-	1
NUV100-GBC	Nuvation	GBC	-	1
EKI-7526I-AE	Advantech	Ethernet switch	-	2
S8VK-C12024	OMRON	24V 120W Power Supply	-	1
		Container		
W72A2/W72L2	BARD	HVAC	-	2
NFS-320	Honeywell	Fire Supression Control	-	1
NBG-12LX	Honeywell	Fire Pull Station	-	1
FST-851	Honeywell	Thermal Detector	-	3
87941	Honeywell	E-Stop	-	3
iso685-D	Bender	Ground Fault Detector	-	1
20505	JANUS Fire Systems	Clean Agent Suppression Systems	-	1
SMC1500	APC	900W UPS	-	1
44YV22	DAYTON	3 phase 480VAC to 208VAC Transformer	-	1

Parker

PCS - Inverter

Technical specifications

Specifications	Units	890GTB-1200	890GTB-1450	890GTB-1800	890GTB-2200
DC Input					
Input Voltage Range	VDC	400 - 1200			
Input DC Bus Voltage (Max)	VDC	820	1200	820	1200
Overvoltage Protection		Included - Type 2 surge arrestor			
DC Disconnection Method		Contactor or Circuit Breaker Options			
Surge Protection		Type 2 surge arrestor			
AC Output					
Rated Output at up to 40°C	kVA	1200 (1)	1450 (2)	1800 (1)	2200 (2)
Rated Output at 50°C	kVA	1080 (1)	1305 (2)	1620 (1)	1980 (2)
Output Voltage Range	VAC	270 - 480			
Nominal Output Frequency	Hz	50/60			
Power Factor Range		+/- 1.0			
Current Distortion	%	< 3			
Overvoltage Protection		Included - Type 2 surge arrestor			
AC Circuit Breaker		65kA Interrupt Rating			

(1) Based on AC Voltage of 400V at 800 VDC (2) Based on AC Voltage of 480V at 1000 VDC

Performance Data	
Efficiency (Max, estimated)	98.7%
Auxiliary and Cooling System Losses	< 6 kVA typical, 9kVA maximum
Sensors and User Interface	
User Interface	10.4" TFT LCD Touch-screen
Communications Options	Modbus TCP (Optional: Ethernet IP, CANopen, DNP3, EtherCAT, PROFIBUS)
Control and Monitoring System	Included
Stored Data History	31 days
Monitored Internal Temperatures	Up to 112 - Including busbars, ambient, choke, IGBTs
External Auxiliary Supply	120/230V single phase or 380-480V three phase
Control Power Breaker	65kA Interrupt Rating
Auxiliary Power Breaker	65kA Interrupt Rating
Mechanical User Interface	EPO Button, On/Off Switch, Local/Remote Switch, Light Switch
Humidity Sensor	Included
Anti-Condensation Heaters	Included
Ground Fault Monitoring/Protection	Optional
Specifications are subject to change	
Compliance and Certification to Standards	
European Certifications	CE: LVD,EMC, G5/4 & G59/1 (pending)
North American Certifications	UL1741 Second Edition, 2010, NFPA70
Grid Interconnection and Power Quality	IEEE1547 (2003), IEEE1547.1 (2005) and IEEE1547a -2014 Amendment to IEEE1547 (2003), IEEE 519
EMC	EN61000-6-2, EN 61000-6-4

EQUIPMENT SPECIFICATIONS

Selective Catalytic Reduction (SCR) Miratech

Application & Performance Warranty Data

Project Information

Site Location:	Santa Rosa CA
Project Name:	Santa Rosa Microgrid
Application:	Prime Power
Number Of Engines:	2
Operating Hours per Year:	8000

Engine Specifications

Engine Manufacturer:	Cummins
Model Number:	C1100 N6C 1 gm
Rated Speed:	1200 RPM
Type of Fuel:	Natural Gas
Type of Lube Oil:	0.6 wt% sulfated ash or less
Lube Oil Consumption:	0.1 % Fuel Consumption
Number of Exhaust Manifolds:	2

Engine Cycle Data

Load	Speed	Power	Exhaust Flow	Exhaust Temp.	Fuel Cons.	NO_x	CO	O_2	H_2O
%		*kW*	*acfm (cfm)*	*F*	*btu/bhp-hr*	*g/bhp-hr*	*g/bhp-hr*	%	%
100	Rated	1,132	7,350	779	5,000	0.75	2.3	9	15

Emission Data (100% Load)

Emission	Raw Engine Emissions						Target Outlet Emissions						Calculated Reduction
	g/bhp-hr	*tons/yr*	*ppmvd @ 15% O_2*	*ppmvd*	*lb/MW-hr*	*g/kW-hr*	*g/bhp-hr*	*tons/yr*	*ppmvd @ 15% O_2*	*ppmvd*	*lb/MW-hr*	*g/kW-hr*	
NO_x*	0.75	10.04	65	132	2.22	1.006	0.07	0.94	6	12	0.21	0.094	90.7%
CO	2.3	30.79	329	663	6.8	3.084	0.1	1.34	14	29	0.3	0.134	95.7%
NH_3							0.06	0.85	15	30	0.19	0.086	N/A

System Specifications

SCR/Oxidation System Specifications (EM25.120-20, ACIS II, SP-IQ2-36-17120071-EH2, 20" Mixing Section (2 Mixer), BL220-20PF1-20PF2-120-2)

Design Exhaust Flow Rate:	7,350 acfm (cfm)
Design Exhaust Temperature[1]:	779°F
Housing Model Number:	SP-IQ2-36-17120071-HSG
Element Model Number:	IQ-RE-36EH, ROM.1300.46.C3.C5.S150.045.255, SCRC-084-150-300
Number of Catalyst Layers:	2
Number of Spare Catalyst Layers:	0
Total Catalyst Volume:	18 cubic feet
SCR Catalyst Volume:	12.0 cubic feet
SCR Catalyst Space Velocity:	15,494 1/hr
Ammonia Reduction Catalyst Volume:	6 cubic feet
Ammonia Reduction Catalyst Space Velocity:	30,987 1/hr
System Pressure Loss:	12.0 inches of WC (Clean)
Sound Attenuation:	25-30 dBA insertion loss
Exhaust Temperature Limits:	572 – 977°F
Reactant:	Urea
Percent Concentration:	32.5%
System Dosing Capacity:	3 L/hr
Estimated Reactant Consumption:	0.6 gal/hr (2.2 L/hr) / Per Engine

APPENDIX C: Microgrid Commissioning

The microgrid project commissioning involved the following areas:

a. Carport Solar PV
b. BESS (Nuvation & Parker)
c. Selective catalytic reduction units - Miratech

The following pages provide for the commissioning of each of the above microgrid major components.

WWTP Carport - As-Built Santa Rosa WWTP, 38.3687732,-122.7681317

Report

Project Name	Santa Rosa WWTP
Project Address	38.3687732,-122.7681317
Prepared By	Michael Ketcham mketcham@trane.com

TRANE BUILDING ADVANTAGE

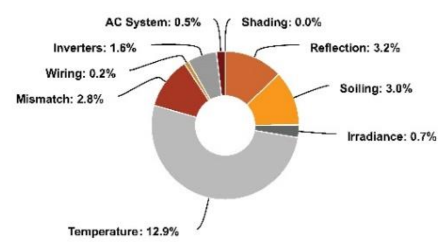
System Metrics

Design	WWTP Carport - As-Built
Module DC Nameplate	126.5 kW
Inverter AC Nameplate	120.0 kW Load Ratio: 1.05
Annual Production	176.3 MWh
Performance Ratio	77.0%
kWh/kWp	1,393.9
Weather Dataset	TMY, SANTA ROSA (AWOS), NSRDB (tmy3, II)
Simulator Version	9a48172b35-98a3557fac-5d8c9dbf0d-bca5500d7c

Project Location

Monthly Production

Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,693.7	
	POA Irradiance	1,809.4	6.8%
	Shaded Irradiance	1,809.4	0.0%
	Irradiance after Reflection	1,751.1	-3.2%
	Irradiance after Soiling	1,698.6	-3.0%
	Total Collector Irradiance	**1,698.6**	**0.0%**
Energy (kWh)	Nameplate	214,808.7	
	Output at Irradiance Levels	213,315.9	-0.7%
	Output at Cell Temperature Derate	185,715.5	-12.9%
	Output After Mismatch	180,470.4	-2.8%
	Optimal DC Output	180,027.3	-0.2%
	Constrained DC Output	180,023.2	0.0%
	Inverter Output	177,143.0	-1.6%
	Energy to Grid	**176,297.0**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		17.1 °C
	Avg. Operating Cell Temp		37.3 °C
Simulation Metrics			
		Operating Hours	4378
		Solved Hours	4378

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, SANTA ROSA (AWOS), NSRDB (tmy3, II)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters	Rack Type	a	b	Temperature Delta
	Fixed Tilt	-3.56	-0.075	3°C
	Flush Mount	-2.81	-0.0455	0°C

Soiling (%)	J	F	M	A	M	J	J	A	S	O	N	D
	3	3	3	3	3	3	3	3	3	3	3	3

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations	Module	Characterization
	CS6U-340M (Canadian Solar Inc.)	CS6U-340M-AG_MIX_CSI_EXT_V6_52_1500V_2016Q4.PAN, PAN

Component Characterizations	Device	Characterization
	CSI-60KTL-GS (Canadian Solar)	Spec Sheet

Components

Component	Name	Count
Inverters	CSI-60KTL-GS (Canadian Solar)	2 (120.0 kW)
AC Panels	2 input AC Panel	1
AC Home Runs	1/0 AWG (Aluminum)	2 (438.0 ft)
AC Home Runs	350 MCM (Copper)	1 (675.6 ft)
Home Runs	500 MCM (Copper)	4 (141.8 ft)
Combiners	4 input Combiner	2
Combiners	6 input Combiner	2
Strings	10 AWG (Copper)	20 (1,430.0 ft)
Module	Canadian Solar Inc., CS6U-340M (340W)	372 (126.5 kW)

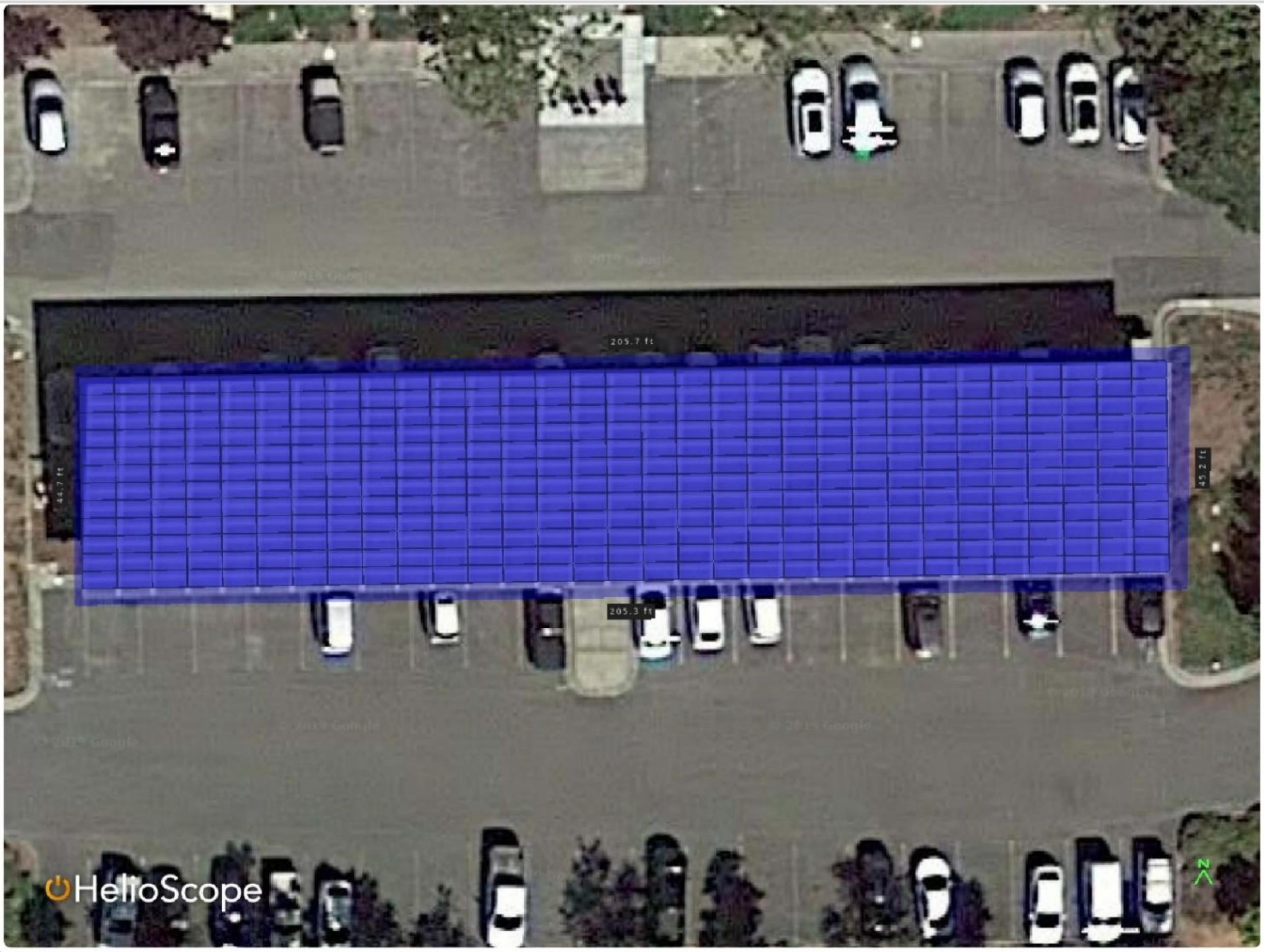
Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	12	18-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Flush Mount	Landscape (Horizontal)	10°	179.1°	0.1 ft	12x1	31	372	126.5 kW

Detailed Layout



TRANE

It's Hard To Stop A Trane.

Santa Rosa WWTP

7-18-18

Date	Time	Inverter Size	Inverter SN	System	IRR (W/m2)	Amb Temp (C)	Cell Temp (C)	WS (mph)	Psys KW-AC (kW)	Number of Panels	Contract Power (kW)	Actual Power (kW)
7/18/2018	12:30	60		1	855	32	46	-	47.400	186	54.4	57.3
7/18/2018	12:30	60		2	855	32	46	-	47.100	186	54.4	56.9
Total										372	108.9	114.2

Meter Information	
Anemometer	2%
Power Meter	2%
Pyranometer	2%
Temp Meter	2%

System	# Panels
1	186
2	186
	0
	0

STC Standards	
IRR (W/m2)	1000
Cell Temp	43

Year Placed in Service	2018

Bosch Panel Rating	
Watt/Panel	340

	Contract	Actual	
Contract Power Total (kW)	108.9	114.2	
Guaranteed kW-AC	108.9	114.2	100%

PV Module Derates		
Nameplate	0.00%	
Diodes	1.00%	
Mismatch	2.00%	
Incident Angle	1.00%	
Efficiency Loss due to Reduced Irradiance from STC	0.33%	
Age	0.75%	per operating year
Cell Operating Temp Loss	0.41%	per degree C
Inverter Efficiency	1.50%	
DC Wiring Loss	2.00%	
AC Wiring Loss	1.00%	
Intermediate Transformer Loss	0.00%	
Interconnection Transformer Loss	0.00%	
Soiling	2.00%	
System Down Time	0.00%	
Desing/Site Conditions	4.00%	

Panels Canadian Solar CS6U-340

Inverters Canadian Solar CSI 60KTL CL

IR Ingersoll Rand
Industrial Technologies

ELECTRICAL DATA | STC*

CS6U	330M	335M	340M	345M
Nominal Max. Power (Pmax)	330 W	335 W	340 W	345 W
Opt. Operating Voltage (Vmp)	37.5 V	37.8 V	37.9 V	38.1 V
Opt. Operating Current (Imp)	8.80 A	8.87 A	8.97 A	9.06 A
Open Circuit Voltage (Voc)	45.9 V	46.1 V	46.2 V	46.4 V
Short Circuit Current (Isc)	9.31 A	9.41 A	9.48 A	9.56 A
Module Efficiency	16.97%	17.23%	17.49%	17.74%
Operating Temperature	-40°C ~ +85°C			
Max. System Voltage	1500 V (IEC) or 1500 V (UL)			
Module Fire Performance	TYPE 1 (UL 1703) or CLASS C (IEC 61730)			
Max. Series Fuse Rating	15 A			
Application Classification	Class A			
Power Tolerance	0 ~ + 5 W			

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m², spectrum AM 1.5 and cell temperature of 25°C.

MECHANICAL DATA

Specification	Data
Cell Type	Mono-crystalline, 6 inch
Cell Arrangement	72 (6×12)
Dimensions	1960×992×40 mm (77.2×39.1×1.57 in)
Weight	22.4 kg (49.4 lbs)
Front Cover	3.2 mm tempered glass
Frame Material	Anodized aluminium alloy
J-Box	IP68, 3 diodes
Cable	4.0 mm² (IEC), 12 AWG (UL), 1160 mm (45.7 in)
Connector	T4 series
Per Pallet	26 pieces, 635 kg (1400 lbs)
Per Container (40' HQ)	624 pieces

ELECTRICAL DATA | NMOT*

CS6U	330M	335M	340M	345M
Nominal Max. Power (Pmax)	242 W	246 W	250 W	253 W
Opt. Operating Voltage (Vmp)	34.5 V	34.8 V	34.9 V	35.1 V
Opt. Operating Current (Imp)	7.03 A	7.08 A	7.16 A	7.23 A
Open Circuit Voltage (Voc)	42.7 V	42.9 V	43.0 V	43.2 V
Short Circuit Current (Isc)	7.52 A	7.60 A	7.66 A	7.72 A

* Under Nominal Module Operating Temperature (NMOT), irradiance of 800 W/m², spectrum AM 1.5, ambient temperature 20°C, wind speed 1 m/s.

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.41 % / °C
Temperature Coefficient (Voc)	-0.31 % / °C
Temperature Coefficient (Isc)	0.05 % / °C
Nominal Module Operating Temperature (NMOT)	43 ± 2 °C

PERFORMANCE AT LOW IRRADIANCE

Outstanding performance at low irradiance, with an average relative efficiency of 96.5 % for irradiances between 200 W/m² and 1000 W/m² (AM 1.5, 25°C).

PARTNER SECTION

Ingersoll Rand
Industrial Technologies

<table>
<tr><th>INPUT (DC)</th><th>CSI-50KTL-CT</th><th>CSI-60KTL-CT</th></tr>
<tr><td>Max. PV Power</td><td>75 kW (25 kW/MPPT)</td><td>90 kW (30 kW/MPPT)</td></tr>
<tr><td>Nominal DC Input Power</td><td>51 kW</td><td>61 kW</td></tr>
<tr><td>Max. DC Input Voltage</td><td colspan="2">1000 V_{DC}</td></tr>
<tr><td>Operating DC Input Voltage Range</td><td colspan="2">200 - 950 V_{DC}</td></tr>
<tr><td>Start-up DC Input Voltage/Power</td><td colspan="2">330 V / 300 W</td></tr>
<tr><td>Number of MPP Trackers</td><td colspan="2">3</td></tr>
<tr><td>MPPT Voltage Range</td><td>480 - 850 V_{DC}</td><td>540 - 850 V_{DC}</td></tr>
<tr><td>Operating Current (Imp)</td><td>108 A (36A per MPPT)</td><td>114 A (38 A per MPPT)</td></tr>
<tr><td>Max. Input Current (Isc)</td><td colspan="2">180 A (60 A per MPPT)</td></tr>
<tr><td>Number of DC Inputs</td><td colspan="2">15 inputs, 5 per MPPT</td></tr>
<tr><td>DC Disconnection Type</td><td colspan="2">Load rated DC switch</td></tr>
<tr><td>OUTPUT (AC)</td><td></td><td></td></tr>
<tr><td>Rated AC Output Power</td><td>50 kW</td><td>60 kW</td></tr>
<tr><td>Max. AC Output Power</td><td>50 kVA</td><td>60 kVA</td></tr>
<tr><td>Rated Output Voltage</td><td colspan="2">480 V_{AC}</td></tr>
<tr><td>Output Voltage Range*</td><td colspan="2">422 – 528 V_{AC}</td></tr>
<tr><td>Grid Connection Type</td><td colspan="2">3Φ/PE/N</td></tr>
<tr><td>Nominal AC Output Current @480 Vac</td><td>60.2 A</td><td>72 A</td></tr>
<tr><td>Rated Output Frequency</td><td colspan="2">60 Hz</td></tr>
<tr><td>Output Frequency Range*</td><td colspan="2">57 – 63 Hz</td></tr>
<tr><td>Power Factor</td><td colspan="2">> 0.99 (±0.8 adjustable)</td></tr>
<tr><td>Current THD</td><td colspan="2">< 3 %</td></tr>
<tr><td>AC Disconnection Type</td><td colspan="2">Load rated AC switch</td></tr>
<tr><td>SYSTEM</td><td></td><td></td></tr>
<tr><td>Topology</td><td colspan="2">Transformerless</td></tr>
<tr><td>Max efficiency</td><td colspan="2">98.8 %</td></tr>
<tr><td>CEC efficiency</td><td colspan="2">98.5 %</td></tr>
<tr><td>Stand-by/Night Consumption</td><td colspan="2">< 30 W / < 2 W</td></tr>
<tr><td>ENVIRONMENT</td><td></td><td></td></tr>
<tr><td>Protection Degree</td><td colspan="2">NEMA 4X</td></tr>
<tr><td>Cooling</td><td colspan="2">Variable Speed Cooling Fans</td></tr>
<tr><td>Operating Temperature Range</td><td colspan="2">-22 °F to +140 °F / -30 °C to +60 °C (derating from +113 °F / +45 °C)</td></tr>
<tr><td>Storage Temperature Range</td><td colspan="2">-40 °F to +158 °F / -40 °C to +70 °C</td></tr>
<tr><td>Operating Humidity</td><td colspan="2">0 – 95 %, non-condensing</td></tr>
<tr><td>Operating Altitude</td><td colspan="2">13,123.4 ft / 4000 m (derating from 6,561.7 ft / 2000 m)</td></tr>
<tr><td>Audible Noise</td><td colspan="2"><50 dBA @ 1 m and 25 °C</td></tr>
<tr><td>DISPLAY AND COMMUNICATION</td><td></td><td></td></tr>
<tr><td>Display</td><td colspan="2">LCD + LED</td></tr>
<tr><td>Communication</td><td colspan="2">Standard: RS485 (Modbus), optional: TCP/IP Card</td></tr>
<tr><td>MECHANICAL DATA</td><td></td><td></td></tr>
<tr><td>Dimensions (WxHxD)</td><td colspan="2">600 × 1000 × 260 mm (23.6 × 39.4 ×10.24 in)</td></tr>
<tr><td>Weight</td><td colspan="2">Inverter: 123.5 lbs / 59 kg; Wirebox: 33 lbs / 15 kg</td></tr>
<tr><td>Installation Angle</td><td colspan="2">0 – 90 degrees from horizontal</td></tr>
<tr><td>Fused String Inputs (5 per MPPT)</td><td colspan="2">15 A standard (20, 25, 30 A acceptable)</td></tr>
<tr><td>SAFETY</td><td></td><td></td></tr>
<tr><td>Safety and EMC Standard</td><td colspan="2">UL1741:2010, UL1699B, CSA-C22.2 No. 107.1-01, IEEE1547;FCC PART 15</td></tr>
<tr><td>Grid Standard</td><td colspan="2">IEEE1547, Rule 21, HECO/Rule14</td></tr>
<tr><td>Smart-Grid Features</td><td colspan="2">Voltage-RideThru, Frequency-RideThru, Soft-Start, Volt-Var, Frequency-Watt, Volt-Watt</td></tr>
</table>

"Engineering with Distinction"
ECI ELECTRICAL CONSULTANTS, INC.
BILLINGS OFFICE: 3521 GABEL ROAD, BILLINGS, MONTANA 59102 • PHONE: 406-259-9933 • FAX: 406-259-3441

TRANE®

SCADA Commissioning Plan

For

Santa Rosa WWTP Microgrid SCADA System

Prepared By:
Electrical Consultants, Inc.

V1 – 10/31/18

COMMISSIONING PLAN

ECI "Engineering with Distinction"
ELECTRICAL CONSULTANTS, INC.

COMMISSIONING PLAN
SANTA ROSA BSS MGC

SANTA ROSA BSS MICROGRID CONTROLLER

COMMISSIONING PLAN
SANTA ROSA BSS MGC

1. PURPOSE

The purpose of this procedure is to test and demonstrate functionality of the new BSS Microgrid Controller (MGC) at the Santa Rosa WWTP.

2. PERSONNEL REQUIREMENTS

2.1. ECI Quality Representative — Bill Young
Name

2.2. Controls — ECI, Nuvation, Parker, Trane, & Santa Rosa WWTP
Company

2.3. Wiring — Geveden
Company

3. SAFETY

3.1. Dangerous voltages and stored mechanical, electrical, and chemical energy exist on the WWTP site and in BSS area. All necessary precautions shall be taken to prevent injury to operators and observers.

3.2. Pre-job briefing and job safety analysis discussion with all participants shall be conducted at the beginning of each shift in which testing is to be conducted. Additional briefings may be necessary as dictated by change in conditions or revision of this test plan.

3.3. In no event shall any protective relaying setting be changed or protective relay be operated by anyone for this test.

3.4. In no event shall any wiring be modified by anyone except the representative identified in item 2.3 above or an individual designated and given explicit direction by that representative.

3.5. All jumpers used by test personnel shall be numbered or color coded to ensure that all jumpers are accounted for at the completion of testing.

3.6. Any wires temporarily removed during testing shall be independently verified for proper reconnection.

4. DOCUMENTATION

4.1. The MGC points list shall be used to identify SCADA points and determine the most efficient, safe, and effective method to simulate required conditions. When the site is energized, live values will be used to verify scaling of data.

4.2. The attached MGC checklist shall be used to complete all steps of testing with any issues noted.

4.2. Exceptions to this procedure and required data shall be recorded on the appropriate attachments.

5. INITIAL CONDITIONS

5.1. BSS installation and commissioning shall be complete or substantially complete before commencement of SCADA testing.

5.2. Protective relay panel installation and commissioning shall be complete before the commencement of SCADA testing.

5.1. SCADA hardware, software, and com cables shall be installed and ready for testing.

5.2. Necessary personnel, tools, computer hardware and software are on site. Personnel have participated in the pre-job briefing and job safety analysis and have been familiarized with this procedure.

5.3. Any exceptions to items 5.1 through 5.4 shall be noted.

6. PROCEDURE

6.1. START-UP

6.1.1. Energize or verify energized all components of the SCADA system. Verify proper indications and record any abnormal indications.

6.1.2. Establish or verify communications with all peripheral equipment. Ensure that all relevant communications settings, protocols, addresses, baud rates, parities, etc., are documented.

6.1.3. Verify or set the time and date, location, time zone, and daylight saving settings as applicable. Verify correct region, language and dialect as applicable.

6.1.4. Perform a preliminary check of screens making note of any inoperable controls or unexpected indications. Correct any such indication before proceeding.

6.2. TESTING

6.2.1. Testing of SCADA points shall proceed in a systematic manner using documentation noted in Sections 4.1 and 4.2.

6.2.2. If during testing any condition is identified that requires a change or correction to wiring, software, settings, or communications configuration all related and affected data objects and controls shall be retested.

6.2.3. Each analog data object shall be tested by simulating, injecting, or forcing the condition at the source of the data if possible. If it is not possible or safe to access the source of the data then the most remote accessible point shall be used.

6.2.4. Each digital data object shall be tested by causing the desired condition if such an operation is safe and possible, otherwise by installing jumpers or by temporarily removing wires. The condition shall be simulated at the apparatus or equipment that originates the signal. If it is not possible or safe to access the source of the signal then the most remote accessible point shall be used.

6.2.5. All control outputs shall be tested to perform the correct operation when active if safe and possible. If it is not safe and possible to operate the affected apparatus or equipment then the control output shall be verified at the most remote accessible point using continuity checks.

6.2.6. All HMI animations shall be observed to operate as expected. Animations shall be tested to indicate correctly for abnormal conditions.

6.2.7. All equations shall be tested to produce and indicate the expected output.

6.2.8. All screens shall be checked for clarity and lack of ambiguity.

6.2.9. All navigation controls shall be tested for proper operation.

6.2.10. Upon completion of items 6.2.1-6.2.9 system functional testing shall begin.

6.3. SYSTEM FUNCTIONAL TESTING

6.3.1. Follow the TRACER-MGC-INVERTER-BMS communication site test plan checklist for the following sections:

6.3.1.1.Pre SCADA Commissioning
6.3.1.2.SCADA Commissioning - Pre Energization
6.3.1.3.SCADA Commissioning - Post Energization Manual Power Testing
6.3.1.4.SCADA Commissioning - Post Energization Scenario Simulation
6.3.1.5.SCADA Commissioning - Go Live

7. FINAL CONDITIONS

7.1. BSS & M2 Switchgear

7.1.1. Any condition that was altered or forced for testing shall be restored to its normal operating state.

7.1.2. Verify that no abnormal alarm or unexpected conditions are indicated on the SCADA system.

7.2. SCADA System

7.2.1. All software installed during development or testing that does not have value for maintenance of the system shall be uninstalled.

7.2.2. Any passwords, "work-arounds", "back doors", or similar items and features used during development or testing shall be removed from the system. No password shall be left active without documentation on the appropriate attachment to this procedure.

7.2.3. All applications, ladder, code, settings, configuration files, etc., shall be downloaded in their as-left condition.

7.2.4. Final as-left screen configurations shall be recorded as "screenshots" or digital photographs. As-left screen images shall be amended as attachment 3 to this procedure.

7.2.5. If all testing was successful, MGC will be left enabled and ready for operation.

7.3. Any exceptions to items 7.1.1. through 7.2.5 shall be noted.

8. ACCEPTANCE

8.1. The ECI Quality Representative's signature indicates that the SCADA system was tested in accordance with this procedure and that, to the extent the testing was observed, the system performed to expectations.

8.2. ECI Quality Representative ________________________ ____________

Signature Date

COMMISSIONING PLAN
SANTA ROSA BSS MGC
ATTACHMENT 1:
EXCEPTIONS

Section	Exceptions

Attach additional sheets as necessary

Page ______ of _______

COMMISSIONING PLAN
SANTA ROSA BSS MGC
ATTACHMENT 2: DATA

Section	Data

Attach additional sheets as necessary Page ______ of _______

COMMISSIONING PLAN
SANTA ROSA BSS MGC
ATTACHMENT 3
SCREENSHOTS

Tracer-MGC-INVERTER-BMS COMMUNICATION SITE TEST PLAN CHECKLIST

Item	Name	Description	Complete	Comments
Pre SCADA Commissioning				
1	Nuvation Commissioning	All nuvation commissioning tasks are complete.	NO	
2	Parker Commissioning	All parker commissioning tasks are complete.	NO	
3	Gevedan Commissioning	All electrical system testing & commissioning is complete.	NO	
4	Remote Access	Verify city provided VPN works to access MGC	NO	
SCADA Commissioning - Pre Energization				
5	MGC - TRACER COM CHECK	MODBUS Connection online.	NO	
6	MGC - PARKER COM CHECK	MODBUS Connection online.	NO	
7	MGC - BMS COM CHECK	MODBUS Connection online.	NO	
8	MGC - BMS PLC COM CHECK	MODBUS Connection online.	NO	
9	MGC - CITY PLC COM CHECK	MODBUS Connection online.	NO	
10	MGC-Tracer Points	MODBUS points check between MGC and Tracer SC+	NO	
11	MGC-Inverter Points	MODBUS points check between MGC and Inverter	NO	
12	MGC-BMS Points	MODBUS points check between MGC and Nuvation BMS	NO	
13	MGC-PLC Points	MODBUS points check between MGC and City PLC	NO	
14	MGC- HMI	Check HMI screen and operation	NO	
15	SAT CLOCK	Verify proper time sync with sat clock	NO	
16	TURN ON Sequence	MGC to command Battery contactor then inverter	NO	
17	TURN OFF Sequence	MGC to command inverter off then contactor	NO	
18	BMS Clear Faults Check	MGC TO issue clear faults command	NO	
19	Clear Inverter Alarms Check	MGC to issue clear faults to inverter	NO	
20	Freeze Heartbeat Check	MGC to freeze heartbeat to ensure systems respond correctly.	NO	
21	Hard Reboot Test	MGC is hard reboot. Verify correct status and state on reboot.	NO	
22	PRE TEST Scenarios	Simulate the various scenarios to verify overall system logic operates as expected.	NO	
SCADA Commissioning - Post Energization Manual Power Testing				
23	Manual Discharge Testing	Issue P set point to Inverter an confirm operation as intended.	NO	
24	Manual Charge Testing	Issue -P set point to Inverter an confirm operation as intended.	NO	
SCADA Commissioning - Post Energization Scenario Simulation				
25	FULL TEST Scenario 1	Force scenario 1 to verify overall system logic operates as expected on live system.	NO	
26	FULL TEST Scenario 2	Force scenario 2 to verify overall system logic operates as expected on live system.	NO	
27	FULL TEST Scenario 3	Force scenario 3 to verify overall system logic operates as expected on live system.	NO	
28	FULL TEST Scenario 4	Force scenario 4 to verify overall system logic operates as expected on live system.	NO	
29	FULL TEST Scenario 5	Force scenario 5 to verify overall system logic operates as expected on live system.	NO	
SCADA Commissioning - Go Live				
30	GO Live	Put system into normal operation state ready to react to scenarios.	NO	
31	GO Live - 1 day check	Verify system operating as expected.	NO	
32	GO Live - 5 day check	Verify system operating as expected.	NO	
33	Commissioning Complete	System is now fully operational.	NO	

VILLARA™
BUILDING SYSTEMS

Heating and Cooling
Plumbing
Home Automation
Fire Sprinklers
Solar
Energy Saving Products

July 19, 2018

Santa Rosa Waste Water Treatment Plant – Testing PV System
4300 Llano Road
Santa Rosa, CA 95407

Date of Testing:	**July 18, 2018**
Start Time of Testing:	**10:05**
Components:	**(372) Canadian Solar CS6U-340**
	(2) Canadian Solar CSI-60ktl-60
Strings:	**Test 1 – 12 strings of 19, 228 modules**
	Test 2 – 8 strings of 18, 144 modules

Azimuth:	**170 degrees**
Tilt:	**10 degrees**
Windspeed:	**1.4 m/s**

Sincerely,

Curtis R. Wylie

Curt Wylie
General Manager
Villara Corp – Solar Division
916-646-2700 x1453
Cell: 916-240-5695
wyliec@villara.com

VILLARA BUILDING SYSTEMS

BUILDING PEOPLE, BUILDING TRUST

SEAWARD

Module Canadian Solar CS6U-340M

Maximum Power (Watts)	339.963
Open Circuit Voltage (VDC)	46.2
Short Circuit Current (Amps)	9.48
Voltage at Maximum Power (Vmpp)	37.9
Current at Maximum Power (Impp)	8.97
Beta (%/°C)	-0.1544
Alpha (%/°C)	0.003138

Technician	C. Wylie
Report Date	July 19, 2018
Data taken on	July 18, 2018

String Data - STC

Power =	6459.297	Watts
String	19	in series
Isc =	9.48	Amps
Voc =	877.8	VDC
Voc (0 °C) =	911.7	VDC

Offset from STC

LID	1.00%	of Voc & Isc
Sorting/Quality	1.50%	ol
Soiling	2.50%	Vc
Degradation	1.00%	Vc

Acceptable Li

Delta (-) Isc =	7.50%	(low)
Delta (+) Isc =	7.50%	(high)
Delta (-) Voc =	2.50%	(low)
Delta (+) Voc =	5.00%	(high)

	String Index	Voc (VDC)	Isc (Amps)	Irradiance (w/m²)	Ambient T (deg. C)	Time (local - Euro format)	Date	BOM-Temp (deg. C)	Expected Voc	Expected Isc
Test passed	5	795	7.23	808.0	26.5	10:38:55	18/7/2018	42.9	809.1	7.06
Test passed	6	796	7.25	808.1	26.6	10:39:08	18/7/2018	42.9	809.1	7.07
Test passed	7	796	7.24	808.7	26.2	10:39:25	18/7/2018	43.8	807.9	7.07
Test passed	8	797	7.27	810.6	26.1	10:39:38	18/7/2018	43.2	808.7	7.09
Test passed	9	796	7.22	808.1	26.3	10:39:55	18/7/2018	43.6	808.2	7.07
Test passed	10	797	7.23	807.4	25.9	10:40:08	18/7/2018	43.5	808.3	7.06
Test passed	15	791	7.36	822.7	26.8	10:45:11	18/7/2018	43.4	808.5	7.19
Test passed	16	800	7.33	826.8	27.6	10:45:28	18/7/2018	43.1	808.8	7.23
Test passed	17	792	7.39	826.5	27.1	10:45:45	18/7/2018	43.0	809.0	7.23
Test passed	18	790	7.39	827.2	27.6	10:46:04	18/7/2018	43.0	809.1	7.23
Test passed	19	791	7.38	828.6	27.0	10:46:23	18/7/2018	42.9	809.1	7.24
Test passed	20	791	7.41	825.4	27.1	10:46:38	18/7/2018	42.7	809.3	7.22

SEAWARD

Module Canadian Solar CS6U-340M

Maximum Power (Watts)	339.963
Open Circuit Voltage (VDC)	46.2
Short Circuit Current (Amps)	9.48
Voltage at Maximum Power (Vmpp)	37.9
Current at Maximum Power (Impp)	8.97
Beta (%/°C)	-0.1544
Alpha (%/°C)	0.003138

Technician	C. Wylie
Report Date	July 19, 2018
Data taken on	July 18, 2018

String Data - STC

Power =	6119.334	Watts
String	18	in series
Isc =	9.48	Amps
Voc =	831.6	VDC
Voc (0 °C) =	863.7	VDC

Offset from STC

LID	1.00%	of Voc & Isc
Sorting/Quality	1.50%	of
Soiling	2.50%	Vc
Degradation	1.00%	Vc

Acceptable Li

Delta (-) Isc =	7.50%	(low)
Delta (+) Isc =	7.50%	(high)
Delta (-) Voc =	2.50%	(low)
Delta (+) Voc =	5.00%	(high)

	String Index	Voc (VDC)	Isc (Amps)	Irradiance (w/m²)	Ambient T (deg. C)	Time (local - Euro format)	Date	BOM-Temp (deg. C)	Expected Voc	Expected Isc
Test passed	1	756	7.14	798.5	25.3	10:36:34	18/7/2018	41.8	767.9	6.98
Test passed	2	759	7.13	797.7	26.0	10:37:17	18/7/2018	42.0	767.6	6.97
Test passed	3	756	7.19	798.3	25.3	10:38:10	18/7/2018	41.7	768.0	6.98
Test passed	4	762	7.16	800.1	26.1	10:38:32	18/7/2018	42.7	766.7	7.00
Test passed	11	749	7.40	821.3	27.0	10:44:13	18/7/2018	43.7	765.5	7.18
Test passed	12	748	7.40	819.5	27.6	10:44:28	18/7/2018	43.8	765.4	7.16
Test passed	13	747	7.39	818.8	27.1	10:44:41	18/7/2018	44.0	765.2	7.16
Test passed	14	751	7.42	823.2	27.1	10:44:58	18/7/2018	43.8	765.5	7.20

CERTIFICATE OF CALIBRATION

ISSUED BY SEAWARD ELECTRONIC

DATE OF ISSUE 20 March 2018 **CERTIFICATE NUMBER** SEA30278SS

SEAWARD

SOLAR

Seaward Group
Bracken Hill
South West Ind. Estate
Peterlee
Co. Durham
SR8 2SW
Telephone: 0191 5863511 Fax: 0191 5860227

CALIBRATED BY

S. BESTFORD

Requested By:	SEAWARD ELECTRONIC - NEW BUILD
Order Number:	
Manufacturer:	Seaward Electronic
Model:	SS200R
Serial Number:	11K-0639
Calibration Date:	20/03/2018
Calibration Category::	A: NEW BUILD

The measurements reported in this certificate were carried out using equipment whose measured values are traceable to National Standards, where these exist.

All procedures employed and management controls are in conformance with BS EN ISO9000: 2015

The ambient temperature and relative humidity throughout the calibration were 21°C +/-3°C and 50% RH +/-20%

For customer use only:
The Seaward Group provides its products through a variety of channels, therefore it is possible that the calibration date on this certificate may not represent the actual date of first use. Experience has indicated that the calibration of this instrument is not effected by storage prior to receipt by the user. We therefore recommend that the recalibration period be based on the date that the unit is placed into service.

Date received into service __________

S. Besser

Approved Signatory

CERTIFICATE OF CALIBRATION

DATE OF ISSUE 20 March 2018

Uncertainties:

Earth Bond	0.1%
Insulation	0.5%
Flash	0.5%
Load	1.0%
Leakage	0.5%

Traceability Information:

All calibration undertaken is traceable through one or more of the following company test standards:-

Transmille 3041 TS933 UKAS Certificate No:	35012
Transmille 3200 TS930 UKAS Certificate No:	32556
Racal 1992 UKAS Certificate No:	2491670003
Wavetek 1281 TS1151 UKAS Certificate No:	33674
1 Mohm Std Resistor TS877 UKAS Certificate No.	147126
100 kohm Std Resistor TS902 UKAS Certificate No.	34723
10 kohm Std Resistor TS878 UKAS Certificate No.	34722
1 kohm Std Resistor TS879 UKAS Certificate No.	33937
100 Ohm Std Resistor TS880 UKAS Certificate No.	33935
10 Ohm Std Resistor TS881 UKAS Certificate No.	33934
1 Ohm Std Resistor TS882 UKAS Certificate No.	34724
0.1 Ohm Std Resistor TS883 UKAS Certificate No.	U85929-17
0.01 Ohm Std Resistor TS884 UKAS Certificate No.	U85922-17
0.001 Ohm Std Resistor TS885 UKAS Certificate No	U85941-17

CALIBRATION RESULTS

Model: SS200R **Serial No:** 11K-0639

CERTIFICATE NUMBER

SEA30278SS /1

FUNCTION	ACTUAL	READING BEFORE	READING AFTER	LIMITS	
PANEL TEMPERATURE (°C)	-24.5	-25		-25.5	-23.5
	20.3	20		19.3	21.3
	70.3	70		69.3	71.3
	120.2	121		119.2	121.2
AMBIENT TEMPERATURE (°C)	-24.5	-25		-25.5	-23.5
	20.3	20		19.3	21.3
	70.3	70		69.3	71.3
	120.2	121		119.2	121.2
IRRADIANCE (W/sqM)	145.00	146		133	157
	227.00	221		211	243
	440.00	440		413	467
	1007.00	1008		952	1062
TILT	0	0		-2	2
	45	44		43	47
	90	90		88	92
COMPASS (Degrees)	NORTH (0)	354		352	8
	EAST (90)	93		82	98
	SOUTH (180)	174		172	188
	WEST (270)	276.0		262	278

CERTIFICATE OF CALIBRATION

ISSUED BY SEAWARD ELECTRONIC

DATE OF ISSUE 17 April 2018

CERTIFICATE NUMBER SEA30655SS / 1

ilac-MRA

UKAS CALIBRATION 0809

SEAWARD
TESTED. TRUSTED... WORLDWIDE.

PAGE 1 of 2 PAGES

Approved Signatory
A. Taylor

Seaward Electronic Limited
Bracken Hill, South West Ind. Estate
Peterlee, Co. Durham, England
SR8 2SW

Telephone: +44 (0)191 586351 email: sales@seaward.co.uk

Tested By: S. BESTFORD

Requested By	SEAWARD ELECTRONIC NEW BUILD
Order Number:	
Manufacturer:	Seaward Electronic
Model:	Solar Utility Pro
Description:	Solar Installation Meter
Serial Number:	14K-0527
Seaward Reference:	
Date Received:	17 April 2018
Calibration Date:	17 April 2018
Calibration Category	A: NEW BUILD

The ambient temperature and relative humidity throughout the calibration were 21 +/-3 degrees and 50% +/-20% RH

The unit was allowed to stabilise in a temperature controlled area prior to calibration. The unit was calibrated by connecting to an automatic test fixture which applied various load resistance values to simulate test conditions across a number of ranges.Current Clamp measurement by by mV simulation. All measurements were gathered electronically, the display functionality was checked as part of the process but not used in the data collection process.

For customer use only:
The Seaward Group provides its products through a variety of channels, therefore it is possible that the calibration date on this certificate may not represent the actual date of first use. Following a study of product performance, it is our opinion that the calibration of this instrument is not effected by storage for periods of up to six months from the date of calibration. We therefore recommend that the recalibration period be based on the date that the unit is placed into service if it falls within this time period. Note: this is our opinion and does not form part of our UKAS

Date received into service: ______________

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=2, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements

CALIBRATION RESULTS

CERTIFICATE NUMBER

SEA30655SS /1

Model: Solar Utility Pro **Serial No:** 14K-0527

FUNCTION	MEASURED	READING BEFORE	READING AFTER	LIMITS		UNCERTAINTY
OPEN CIRCUIT PANEL VOLTS (V)						
	28.59	28.6		28.3	28.9	+/-100mV
	98.71	98.7		98.0	99.4	+/-100mV
	299.0	299		297	301	+/-1.0V
	599.4	600		594	604	+/-1.0V
	1000.0	1000		993	1007	+/-1.0V
	1200.2	1200		1192	1208	+/-1.0V
	1480.8	1481		1471	1490	+/-1.0V
SHORT CIRCUIT CURRENT (A) ***						
	1.02	1.0		0.8	1.2	+/-10mA
	5.02	5.0		4.8	5.3	+/-10mA
	10.00	10.0		9.7	10.3	+/-10mA
	20.00	20.0		19.6	20.4	+/-10mA
	38.01	38.0		37.4	38.6	+/-10mA

*** S/C current above 20A are not covered by the UKAS schedule but are shown to complete the certificate

APPENDIX D:
Project Fact Sheet

The microgrid project 'Fact Sheet' discusses the following areas:

a. The Issue: Wastewater Treatment Facility acceptance of microgrid technology
b. The Project: Mircogrid application at a wastewater treatment facility
c. Benefits for California
d. Project Highlights
e. Project Specifics

Santa Rosa Laguna Treatment Plant Microgrid

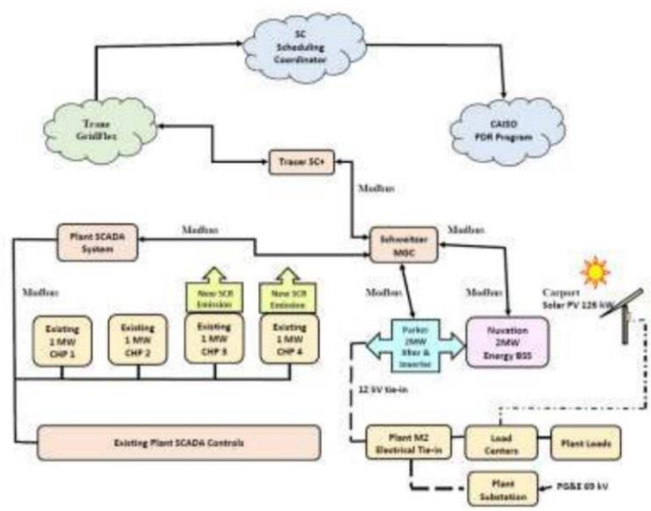
Project Fact Sheet

The Issue

Wastewater treatment plants are large energy users subject to processing constant influent flows and providing safe and compliant water treatment. These types of plants do not like to have intermittent power fluctuations or changes in plant operations. The challenge is having plant operators understanding and accepting microgrid technology as an asset to their day to day operations, while providing a reliable resource and revenue generator for the City. Besides the grid resiliency is impacted by such large electrical fluctuations and demands.

The Project

The Santa Rosa Laguna Treatment Plant (LTP) is a demonstration project for an advanced microgrid application at a critical wastewater treatment facility combining battery storage, solar PV, CHP engines with SCR emission controls and existing flow equalization basins as flow diversion assets for energy reduction in peak periods. Besides having four 1.1 MW CHP engines, two were modified with SCR emission controls, these assets are operator dispatchable. The overall microgrid system provides for multiple new and existing assets controllable via existing SCADA controls by the microgrid controller.



Component Specifications	
Carport PV	126 kW, 620 Canadian Solar PV modules, two Canadian Solar inverters
Battery Storage	Nuvation Energy 2MW / 480 kWh, 420 EnerDel Lithium NMC batteries (21 per stack modules)
Parker Hannifin	890GTB, 2MW inverter
Microgrid Controller	Schweitzer 3555



System Operation

Microgrids allow for the flexible man-in-the-loop control of plant assets such as flow diversion, battery storage for peak shaving or load reduction and CHP assets for load curtailment when dispatched. The project demonstrated Day Ahead nomination into the CAISO market where plant operators would elect next day scenarios of various combination of assets to reach desired load reductions. In peak times such ability and assets provides for electrical grid load reductions and revenue generation to the City. The LTP plant averages 3.5 MW in a typical daytime period and the microgrid provided for electrical load reduction from 250 kW to 1 MW.

Benefits for California

- Impact on Load and Duck Curve – Provides fast ramping capabilities while providing grid stability
- Increased grid resilience – Provides for battery storage and solar PV assets to the grid
- Demonstrated a Microgrid at Wastewater Treatment Plant – first of its kind and integrated with plant

Project Highlights

- Projected energy savings between $85K to $125K with further demonstration of microgrid use
- Carport PV system provides for 126 kW of renewable energy production
- Improved plant emissions of greenhouse gases with retrofit of two CHP engines with SCR's
- Microgrid demonstration of man-in-the-loop plant operator control at a wastewater plant
- Demonstrated Day-Ahead market opportunity with CAISO PDR program
- Provided for local grid resiliency with load reductions
- Generated media attention in the north bay area, public outreach and education opportunities
- Provides for peak shaving and load reduction scenarios in multiple new and existing assets

Project Specifics

Contractor:	Trane U.S., Inc.
Partners:	Nuvation Energy, Parker Hannifin, Villara, Miratech, Geveden Industrial, ECI, City of Santa Rosa
Funding:	$5,000,000 – Energy Commission Agreement: EPC-14-059
Timeline:	August, 2015 – March, 2019
Energy Commission Agreement: EPC-14-059	
Contact: Richard Swank, Trane U.S. Email: Richard.swank@trane.com	



APPENDIX E:
Outreach Activities

Trane performed numerous Outreach Activities throughout the State of California. A compilation of these activities is described in following pages.

2016 EPIC Symposium:
Innovative Solutions for Reaching California's 2030 Energy Goals

Thursday, December 1, 2016 | Sacramento Convention Center

PG&E | SOUTHERN CALIFORNIA EDISON An EDISON INTERNATIONAL® Company | SDGE A Sempra Energy utility® | CALIFORNIA ENERGY COMMISSION

Opening Plenary

9:00 – 9:15	**Welcome and Opening Remarks -** Robert B. Weisenmiller, Chair, California Energy Commission
9:15 – 9:45	**Keynote Address** - TBD

Panel Sessions

10:00 – 11:15

Energy Efficiency Track

Session: Getting to Zero Net Energy Buildings

This session will explore the challenges of implementing ZNE in homes and commercial and municipal buildings. Each project uses a different ZNE strategy, but all will document the process, measure the outcomes and share the lessons learned with the building community.

Moderator: David Hungerford

Building Affordable Zero Net Energy Homes (Stockton, CA)
Presenter: Larry Brand & Rob Kamisky, Gas Technology Institute

Demonstrating a Cost-Competitive Zero Net Energy Community (Chino)
Presenter: Garth Torvestad, Consol

Innovative Strategies to Achieve Zero Net Energy in Grocery Stores (San Francisco)
Presenter: Aaron Daly, Whole Foods

Electricity Generation Track

Session: Planning for a Clean and Resilient Electricity System

This session will highlight research on the pathways for the electricity system to reach California's clean energy goals and reduce greenhouse gas emissions, and share how one utility is using the information to make their system less vulnerable to climate impacts.

Moderator: Guido Franco

Low Carbon Energy Scenario Insights for a Robust Electricity System
Presenter: Max Wei, Lawrence Berkeley National Laboratory

Technology and Risk Assessment in GHG Mitigation Pathways
Presenter: Snuller Price, Energy and Environmental Economics, Inc.

Tackling Climate Vulnerability in San Diego
Presenter: Andrew Petrow, ICF & SDG&E (invited)

Power System Modernization Track

Session: Advancing Field Safety and Securing Power Systems

This session will include presentations pertaining to power system electrical safety and fault detection. It will also include a presentation on pilot testing new communication architecture standards for power systems.

Moderator: Julie Cerio

PG&E: 1.09A Close Proximity Switching
Presenter: Rudy Movafagh

SCE: High Impedance Fault Detection System
Presenter: Bryan Pham

SDG&E: Smart Grid Architecture Demonstrations
Presenter: Gabriel Leggett

Break

11:30-12:15

Thought Leaders Discussion
Leveraging Emerging Technology to Meet California's Advancing Energy Landscape

Dr. Ernest Moniz (invited), Secretary, US Department of Energy
Dr. Robert Weisenmiller, Chair, California Energy Commission
Ahmad Ababneh, Director of Asset Management and GIS at Pacific Gas and Electric Company, Pacific Gas & Electric
Doug Kim, Director of Advanced Technology, Southern California Edison
Jonathan Woldemariam, Director of Electric Transmission and Distribution Engineering, San Diego Gas & Electric

Moderated by: Cassandra Sweet, Wall Street Journal/Dow Jones Newswire correspondent

12:15-1:15	Lunch					
1:15-1:45	EPIC Showcase					
1:45-3:00	Energy Efficiency Track	**Session: Bringing Emerging Energy Efficiency Technologies to Low Income or Disadvantaged Communities** This session will explore projects and strategies that target disadvantaged communities and how the projects will help these communities and its occupant's lower energy costs and provide other benefits, such as building improvements and access to education and training opportunities. This session will also discuss how best to reach this sector to ensure long lasting and sustainable benefits. Moderator: Felix Villanueva **Maximizing Energy Efficiency in an Existing Low-Income Mixed Use Residential and Commercial Building (San Francisco)** **Presenter: Tim Minezaki, Prospect Silicon Valley** **Integrating Smart Ceiling Fans and Communicating Thermostats to Provide Energy Efficient Comfort** **Presenter: Abhijeet Pande, TRC Companies Inc.** **Discussants:** **Sekita Grant, Greenlining Institute (invited)** **Samara Larson, Linc Housing** **Cindy Wu, Chinatown Community Development Center**	Electricity Generation Track	**Session: Microgrids Accelerating Adoption of Renewables** This session will showcase five low carbon microgrids from design to construction with the goal of demonstrating the microgrids' ability to utilize local renewable resources, provide grid resiliency in emergency situations, and provide repeatable solutions that can be tailored for use in similar areas in California. Moderator: Fernando Pina **Kaiser Richmond Microgrid Focusing on Resilient Hospital Services** **Presenter: John Harding, Charge Bliss, Inc.** **Fremont Fire Station's Low-Carbon Microgrid Maintaining Emergency Services** **Presenter: Vipul Gore, Gridscape Solutions** **Laguna Subregional Wastewater Treatment Plant Microgrid – Sustainable Water Treatment and Ancillary Services** **Presenter: Michael Day, Trane U.S., Inc.** **Anchoring Downtown Berkeley's Urban Energy Community** **Presenter: Timothy Burroughs, City of Berkeley** **Designing Santa Monica's Municipal and Mixed-Use Advanced Energy District** **Presenter: Garrett Wong, City of Santa Monica**	Power System Modernization Track	**Session: Enabling Distributed Energy Resources (DER) Growth** This session will include presentations on demonstrations to advance infrastructure for electric vehicles, high penetration of photovoltaics, and advanced power system protection. Moderator: Frank Goodman **PG&E: 1.25 DC Fast Charging Mapping** **Presenter: Morgan Metcalf** **SCE: Advanced Distribution Analytic Services Enabling High PV Penetration** **Presenter: Araya Gebeyehu** **SDG&E: Modernization of Distribution System and Integration of Distributed Generation and Storage** **Presenters: Zoltan Kertay/Kirsten Petersen**
3:00-3:15	Break					

Time	Energy Efficiency Track	Electricity Generation Track	Power System Modernization Track
3:30-4:45	**Session: Increasing California's Water Supply through Energy Innovation** This session will explore novel technologies and strategies that provide an integrated approach to addressing both California's energy and water saving needs. Technologies and strategies that leverage both energy and water savings simultaneously provide a dual benefit to California and help maximize the potential value of investments. Moderator: Brad Williams **California's Groundwater Pumping: The Energy Perspective** **Presenter: Larry Dale, Lawrence Berkeley National Laboratory** **Accelerating Drought Resilience Through Innovative Technologies** **Presenter: Laurie Park, Water Energy Innovations** **Demonstrating a Low Energy Biofiltration System for Groundwater Contaminant Removal** **Presenter: Joon Min, BKT** **Improving Water and Energy Efficiency in California's Dairy Industry** **Presenter: Theresa Pistochini, UC Davis**	**Session: Creating Advanced Energy Communities** Local jurisdictions are increasingly looking to emerging energy technology solutions to help meet their community goals. This session will explore creative approaches being taken at the local levels to increase community-wide deployment of emerging energy technologies. Moderator: Erik Stokes **Piloting an Integrated Energy Financing Platform for Fresno's Blackstone Corridor** **Presenter: Neil Matouka, Local Government Commission** **Creating a Zero Net Energy Farm in the Central Valley** **Presenter: Russ Teall, Biodico, Inc.** **Transforming Lancaster into a Zero Net Energy City** **Presenter: Richard Schorske, ZNE Alliance** **From the Community Up: Building a Clean Energy Model for San Diego's Encanto Neighborhood** **Presenter: Srinivas Sukumar, Groundwork San Diego-Chollas Creek**	**Session: Demonstrating System Simulation** This session will include presentations on demonstrations of new concepts for modeling, simulation, visualization and situational awareness to support power system operations. Moderator: Ryan Blaney **PG&E: 2.10 Restoration Workplan** **Presenter: Greg Molnar** **SCE: Power Factory & Triangle Microworks Hardware/Software in the Loop** **Presenter: Christopher Clarke** **SDG&E: Visualization and Situational Awareness Demonstrations** **Presenters: Aksel Encinas & Subburaman Sankaran**
4:45-5:00	**Closing Remarks**		

Registration and Information Desk is available 8:00 AM – 5:00 PM

To register, go to the following link: http://bit.ly/2016EPICSymposium

August 15, 2018

MEETING SUMMARY

Energy Market Symposium
Courtyard by Marriott Chico
2481 Carmichael Drive, Chico
August 15, 2018

Outreach Goals and Purpose

The purpose of the meeting was to disseminate information about changes occurring in California electric markets as well as to provide information about the Santa Rosa Microgrid project itself. The goal of the meeting was to educate while building trust. While learning about the grid impacts from the measures installed at the Santa Rosa plant, attendees would be provided information, tools, and resources to help them understand and identify opportunities of similar controllable load specific to their agencies or districts and how that could be monetized. But trust is a key component for an agency or district to considering the feasibility of this concept. Both wastewater and potable water system operators are constrained by rigorous safety regulations. By bringing in the management and operations staff of the Santa Rosa project, attendees would feel much more comfortable with the concept—novel grid participation strategies could be enabled while still maintaining safety standards.

Stakeholder Outreach

The project team targeted districts and agencies that provide water and/or wastewater services, located within Colusa, Sutter, Glenn, Tehama, Shasta, Butte, Nevada, Placer, Yuba, Sacramento, Plumas, Lassen, and Sierra counties. Key decision makers from these districts and agencies were identified and compiled in a stakeholder database that totaled 157 contacts. *To reference the entire stakeholder database, see* **ATTACHMENT A.**

Multiple rounds of contact was made with each stakeholder in the database in an effort to inform these agencies and districts of upcoming changes to the California electric markets as well as to invite them to the August 15 Symposium. A series of email invitations were sent on July 27 and August 13. Reminder phone calls were made to stakeholders between August 1 and 6. *To reference the initial email invitation, see* **ATTACHMENT B.**

Five representatives from five different agencies and districts attended the Energy Market Symposium held in Chico on August 15. Following is a list of presenters and attendees:

Project Team/Presenters

Michael Day, Utilities/Smart Grid Team Lead, Trane Ingersol Rand
Peter Klauer, Senior Advisor/Smart Grid Technology Cal ISO (by phone)
Frank Gill, Senior Vice President, Holeman Capital
Kristy Day, Principal, Rockwood Consulting

Meeting Attendees

City of Roseville
Bryan Buchanan, Wastewater Treatment Manager for Operations and Maintenance
Greenville Community Service District

Robert Heard, Board Member

Indian Valley Community Services District

Chris Gallagher, General Manager

Yuba County Water Agency

Mary Gabel, Power Systems Administrator

Shasta Environmental/Fall River Valley Community Services District

Stephen Rooklidge, Board Member

Trane Ingersol Rand

Katherine Drewes, District Marketing Manager

Meeting Summary

Michael Day welcomed attendees, followed by self-introductions. Michael Day then, reviewed the agenda (referenced below) and discussed electric market changes, project goals, and project components. Michael continued with a discussion about the Santa Rosa Mirogrid project. Peter Klauer provided an overview (by phone) of the CalISO market, followed by Frank Gill discussing Capital Project Impacts. Michael finished the presentation with lessons learned from the Santa Rosa project and opened the meeting to questions and comments. *To reference the full PowerPoint presentation, see* **ATTACHMENT C.**

Meeting Agenda

1. Introductions
2. Drivers: electric market changes
3. Goals of the project
4. Project components
5. Plant Operator's perspective
6. Day ahead load nomination system
7. CAISO market access
8. Capital project impacts
9. Lessons learned

The following is a compilation of comments and questions generated during the meeting:

- How does the change in time of use periods affect customers on net energy metering?
- I thought that net energy metering operated on a 1 kWh to 1 kWh basis, doesn't it?
- Would energy storage effectively allow you to shift solar production from off peak to on peak cost?
- There does not appear to be a great amount of transparency in the values paid for capacity and energy in bilateral Resource Adequacy contracts.
- What's the contractual vehicle that would be used for someone who has an asset to contract with the CCA or another load serving entity?
- What's the difference between the CaISO PDR, NGR, and DERP markets for behind the meter resources?
- If the investor owned utilities are moving their peak time of use periods later into the evening will the municipal utilities do the same thing?
- For CaISO do you bid in a day ahead or a shorter timeframe?
- What's the advantage of participating in the realtime market as opposed to the day ahead market?

- When looking at the economics of a battery energy storage system are there costs associated with maintenance or battery replacement?
- Are future revenues for a municipality left to the whim of the market, or are there more secure ways to lock in a revenue over a longer period?
- Could hydraulic systems set up to store water for firefighting also have a secondary use as an energy storage asset?
- How can a disadvantaged community pay for a study to do the analysis to participate in advanced energy markets?
- Can I get a copy of the presentation?

August 22, 2018

MEETING SUMMARY

Energy Market Symposium
Courtyard by Marriott Riverside UCR/Moreno Valley
1510 University Avenue, Riverside
August 22, 2018

Outreach Goals and Purpose

The purpose of the meeting was to disseminate information about changes occurring in California electric markets as well as to provide information about the Santa Rosa Microgrid project itself. The goal of the meeting was to educate while building trust. While learning about the grid impacts from the measures installed at the Santa Rosa plant, attendees would be provided information, tools, and resources to help them understand and identify opportunities of similar controllable load specific to their agencies or districts and how that could be monetized. But trust is a key component for an agency or district to considering the feasibility of this concept. Both wastewater and potable water system operators are constrained by rigorous safety regulations. By bringing in the management and operations staff of the Santa Rosa project, attendees would feel much more comfortable with the concept—novel grid participation strategies could be enabled while still maintaining safety standards.

Stakeholder Outreach

The project team targeted districts and agencies that provide water and/or wastewater services, located within Los Angeles, San Bernardino, Riverside, Orange, and Ventura counties. Key decision makers from these districts and agencies were identified and compiled in a stakeholder database that totaled 198 contacts. *To reference the entire stakeholder database, see* **ATTACHMENT A.**

Multiple rounds of contact was made with each stakeholder in the database in an effort to inform these agencies and districts of upcoming changes to the California electric markets as well as to invite them to the August 22 Symposium. A series of email invitations were sent on August 1 and 13. Reminder phone calls were made to each stakeholder on August 6 and 7. *To reference the initial email invitation, see* **ATTACHMENT B.**

Seven representatives from five different agencies and districts attended the Energy Market Symposium held in Riverside on August 22. Following is a list of presenters and attendees:

Project Team/Presenters

Michael Day, Utilities/Smart Grid Team Lead, Trane Ingersol Rand
Peter Klauer, Senior Advisor/Smart Grid Technology Cal ISO (by phone)
Mike Prinz, Deputy Director Public Works, City of Santa Rosa (by phone)
Frank Gill, Senior Vice President, Holeman Capital

Meeting Attendees

Irvine Ranch Water District
Joe Lam, Automation Manager
Jose Zepeda, Director of Recycling Operations
City of Redlands

Jason Montgomery, Civil Engineer
Paul Toor, Director Municipal Utilities and Engineering
City of Chino Hills
Jarrod Manuel, Facilities Maintenance Supervisor
City of Palmdale
Benjamin Jucha, Environmental and Technology Manager
City of San Jacinto
Tom Prill, Finance Director
Trane Ingersol Rand
Katherine Drewes, District Marketing Manager

Meeting Summary
Michael Day welcomed attendees, followed by self-introductions. Michael Day then, reviewed the agenda (referenced below) and discussed electric market changes, project goals, and project components. Mike Prinz continued (by phone) with a discussion about the Santa Rosa Mirogrid project. Frank Gill reviewed Capital Project Impacts. Peter Klauer followed by providing an overview (by phone) of the CalISO market. Michael finished the presentation with lessons learned from the Santa Rosa project and opened the meeting to questions and comments. *To reference the full PowerPoint presentation, see* **ATTACHMENT C.**

Meeting Agenda
1. Introductions
2. Drivers: electric market changes
3. Goals of the project
4. Project components
5. Plant Operator's perspective
6. Day ahead load nomination system
7. CAISO market access
8. Capital project impacts
9. Lessons learned

The following is a compilation of comments and questions generated during the meeting:
- Why is the duck curve an issue in the spring and not in the summer?
- How fast can combined-cycle plants ramp up and down, and how does that impact the duck curve?
- Do CCAs want to buy smaller and more local grid assets than the IOUs?
- When the Laguna Wastewater Treatment Plant swings its flow rate do you see a big KW offset?
- Can you be both an SCE rate payer and a CAISO market participant?
- Can we get a copy of the presentation?

August 23, 2018

MEETING SUMMARY

Energy Market Symposium
Springhill suites by Marriott Mission Valley
2401 Camino Del Rio North, San Diego
August 23, 2018

Outreach Goals and Purpose

The purpose of the meeting was to disseminate information about changes occurring in California electric markets as well as to provide information about the Santa Rosa Microgrid project itself. The goal of the meeting was to educate while building trust. While learning about the grid impacts from the measures installed at the Santa Rosa plant, attendees would be provided information, tools, and resources to help them understand and identify opportunities of similar controllable load specific to their agencies or districts and how that could be monetized. But trust is a key component for an agency or district to considering the feasibility of this concept. Both wastewater and potable water system operators are constrained by rigorous safety regulations. By bringing in the management and operations staff of the Santa Rosa project, attendees would feel much more comfortable with the concept—novel grid participation strategies could be enabled while still maintaining safety standards.

Stakeholder Outreach

The project team targeted districts and agencies that provide water and/or wastewater services, located within San Diego and Imperial counties. Key decision makers from these districts and agencies were identified and compiled in a stakeholder database that totaled 84 contacts. *To reference the entire stakeholder database, see* **ATTACHMENT A.**

Multiple rounds of contact was made with each stakeholder in the database in an effort to inform these agencies and districts of upcoming changes to the California electric markets as well as to invite them to the August 23 Symposium. A series of email invitations were sent on August 2 and 13. Reminder phone calls were made to each stakeholder on August 7. *To reference the initial email invitation, see* **ATTACHMENT B.**

One representative from one agency attended the Energy Market Symposium held in San Diego on August 23. Following is a list of presenters and attendees:

Project Team/Presenters

Michael Day, Utilities/Smart Grid Team Lead, Trane Ingersol Rand
Peter Klauer, Senior Advisor/Smart Grid Technology Cal ISO (by phone)
Mike Prinz, Deputy Director Public Works, City of Santa Rosa (by phone)
Frank Gill, Senior Vice President, Holeman Capital

Meeting Attendees

City of Encinitas
Carl Quiram, Public Works Director
Trane Ingersol Rand
Katherine Drewes, District Marketing Manager

Meeting Summary

Michael Day welcomed attendees, followed by self-introductions. Michael Day then, reviewed the agenda (referenced below) and discussed electric market changes, project goals, and project components. Mike Prinz continued (by phone) with a discussion about the Santa Rosa Mirogrid project. Frank Gill reviewed Capital Project Impacts. Peter Klauer followed by providing an overview (by phone) of the CalISO market. Michael finished the presentation with lessons learned from the Santa Rosa project and opened the meeting to questions and comments. *To reference the full PowerPoint presentation, see* **ATTACHMENT C.**

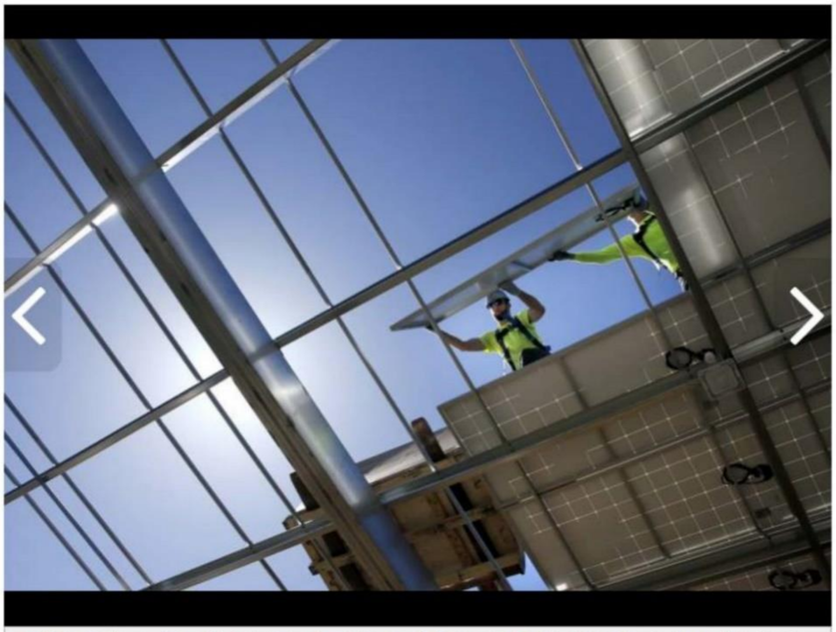
Meeting Agenda

1. Introductions
2. Drivers: electric market changes
3. Goals of the project
4. Project components
5. Plant Operator's perspective
6. Day ahead load nomination system
7. CAISO market access
8. Capital project impacts
9. Lessons learned

The following is a compilation of comments and questions generated during the meeting:

- What does CAISO control? What is their domain?
- Can I get a copy of the presentation?

Solar panels to help power Santa Rosa micogrid



(1 of 5) Eric Johnson, left, and Alex Vavrynyuk, employees of Villara Solar, install solar panels over the parking lot of the Laguna Subregional Water Reclamation Plant on Tuesday, May 8, 2018. (Beth Schlanker/ The Press Democrat)

(2 of 5) Eric Johnson an employee of Villara Solar, installs solar panels over the parking lot of the Laguna Subregional Water Reclamation Plant on Tuesday, May 8, 2018. (Beth Schlanker/ The Press Democrat)

(3 of 5) Eric Johnson, top, and Alex Vavrynyuk, employees of Villara Solar, install solar panels over the parking lot of the Laguna Subregional Water Reclamation Plant on Tuesday, May 8, 2018. (Beth Schlanker/ The Press Democrat)

(4 of 5) Employees of Villara Solar, install solar panels over the parking lot of the Laguna Subregional Water Reclamation Plant on Tuesday, May 8, 2018. (Beth Schlanker/ The Press Democrat)

KEVIN MCCALLUM
THE PRESS DEMOCRAT | May 8, 2018, 6:43PM

When California's energy grid gets stressed out during heat waves, energy managers send out so-called flex alerts asking people to conserve energy.

An innovative energy project underway in Santa Rosa aims to take that flexibility to new levels by helping a huge energy user — the city's water treatment plant — quickly reduce its energy usage while still performing its core mission of cleaning water.

A 125-kilowatt solar array popping up above the parking lot of the Laguna Subregional Water Reclamation plant on Llano Road is the first visible sign of a yearslong effort to turn the plant into a microgrid capable of reducing its use of electricity from the grid.

"Increasing our flexibility to produce energy on-site allows us to adjust our demand on the macro grid, and doing that is worth money," said Mike Prinz, deputy director of Santa Rosa Water.

Microgrids, as the name implies, are small electric networks that can operate, to varying degrees, independently of the larger electrical grid managed locally by Pacific Gas & Electric Co.

The solar panels are not the core of the new system, but will help recharge the batteries that are being installed later this year as part of the project.

"These are icing on the cake," Prinz said.

The 372 panels are mounted on steel supports above the parking lot, a technique becoming common for commercial-scale solar installations.

The panels will help recharge the storage batteries that, combined with upgrades to the plant's four large gas generators, will allow the plant, when asked by grid managers, to reduce its demand on the grid.

"They'll get a call that says, 'You need to reduce. How much do you want to reduce?' It's voluntary," said Richard Swank, a program manager with Trane.

The energy company in 2015 won a highly competitive $5 million grant from the California Energy Commission to test the viability of a microgrid on such a large facility.

The treatment plant cleans and recycles an average of 17.5 million gallons of wastewater daily from 250,000 customers in Santa Rosa, Sebastopol, Rohnert Park and Cotati. The plant's pumps, aerators and ultraviolet disinfection system consume an average of 4.4 mega-watts of electricity, enough to power nearly 3,000 homes.

The plant has recently increased its ability to produce electricity from biogas from both human waste and commercial sources such as food, oil and grease. Today it can generate more than 1 megawatt of electricity on-site through this method. But that still leaves a lot of electricity to buy from its provider, Sonoma Clean Power.

The microgrid project will enhance the self-generation capacity further by installing large catalytic converters on two of those large gas generators, allowing them to operate on up to 100 percent natural gas and still remain within strict air quality regulations, Prinz said.

The expectation is that because of the low cost of natural gas, the plant will be able to generate its own electricity less expensively than what the utility would charge, Prinz said.

The city may benefit further by getting paid for reducing its energy use during these peak periods, but how much remains to be seen, Prinz said. Once the project is up and running, the city will operate the plant with an eye toward maximizing value for ratepayers, he said.

The treatment plant solar installation avoided the fate of a recently canceled Sonoma Clean Power solar project. That far larger project sought to build 12.5 megawatts of power on six Sonoma County Water Agency holding ponds, but fell victim to a number of challenges, including President Donald Trump's tariff on imported solar panels.

But the solar panels at the treatment plant were purchased before the tariffs went into effect, Swank said, from an Ontario-based company called Canadian Solar.

You can reach Staff Writer Kevin McCallum at 707-521-5207 or kevin.mccallum@pressdemocrat.com. On Twitter @srcitybeat.

July 29, 2018

MEETING SUMMARY

Energy Market Symposium
Laguna Subregional Wastewater Treatment Plant
4300 Llano Road, Santa Rosa
June 28, 2018

Outreach Goals and Purpose

The purpose of the meeting was to disseminate information about changes occurring in California electric markets as well as to provide information about the Santa Rosa Microgrid project itself. The goal of the meeting was to educate while building trust. While learning about the grid impacts from the measures installed at the Santa Rosa plant, attendees would be provided information, tools, and resources to help them understand and identify opportunities of similar controllable load specific to their agencies or districts and how that could be monetized. But trust is a key component for an agency or district to considering the feasibility of this concept. Both wastewater and potable water system operators are constrained by rigorous safety regulations. By bringing in the management and operations staff of the Santa Rosa project, attendees would feel much more comfortable with the concept—novel grid participation strategies could be enabled while still maintaining safety standards.

Stakeholder Outreach

The project team targeted districts and agencies that provide water and/or wastewater services, located within Yolo, Solano, Lake, Marin, Sonoma, and Napa counties. Key decision makers from these districts and agencies were identified and compiled in a stakeholder database that totaled 107 contacts. *To reference the entire stakeholder database, see* **ATTACHMENT A.**

Multiple rounds of contact were made with each stakeholder in the database in an effort to inform these agencies and districts of upcoming changes to the California electric markets as well as to invite them to the June 28 Symposium. A series of email invitations were sent on June 8, 21, and 26. Reminder phone calls were made to each stakeholder between June 13 and 21. *To reference the initial email invitation, see* **ATTACHMENT B.**

The outreach effort generated a significant amount of interest, however, a local fire prohibited some from attending and the timing of the Symposium (June 28) proved to be a challenge due to summer vacation season. Nonetheless, **seven representatives from five different agencies and districts attended the Energy Market Symposium on June 28 at the Laguna Subregional Wastewater Treatment Plant in Santa Rosa.** Following is a list of presenters and attendees:

Project Team/Presenters

Michael Day, Utilities/Smart Grid Team Lead, Trane Ingersol Rand
Peter Klauer, Senior Advisor/Smart Grid Technology Cal ISO
Frank Gill, Senior Vice President, Holeman Capital
Mike Prinz, Deputy Director Public Works, City of Santa Rosa
Joe Schwall, Wastewater Treatment Superintendent
Richard Swank, Microgrid Program Manager, Trane Ingersol Rand
Matt Bye, Trane GridFlex Platform Development Manager

Kristy Day, Principal, Rockwood Consulting

Meeting Attendees

City of Santa Rosa

Tasha Wright, Energy and Sustainability Coordinator

Sonoma County Water Agency

Dale Roberts, Principle Engineer

Hannah Salafia, Water Agency Engineer II

N. Marin Water District

Robert Clark, Operations/Maintenance Superintendent

City of Vacaville

Travis Kuhn, Assistant Engineer

Marin Municipal Water District

Kristin Arnold, Associate Engineer

Trane Ingersol Rand

Trevor Joelson, Trane Energy Supply Services

Reggie Ingram, Regional Executive-Client Solutions

Adam Wittwer, Director of Energy Services-California

Meeting Summary

Michael Day welcomed attendees, followed by self-introductions. Michael Day then, reviewed the agenda (referenced below) and discussed electric market changes, project goals, and project components. Mike Prinz (Plant Manater/Deputy Director) and Joe Schwall (Senior Operations Supervisor) discussed the project from their own perspectives. Matt Bye then covered day ahead load nomination system. Peter Klauer provided an overview of the CalISO market, followed by Frank Gill discussing Capital Project Impacts. Richard Swank discussed lessons learned from the Santa Rosa project, then Michael Day invited further questions and comments. *To reference the full PowerPoint presentation, see* **ATTACHMENT C.**

Meeting Agenda

1. Introductions
2. Drivers: electric market changes
3. Goals of the project
4. Project components
5. Plant Operator's perspective
6. Day ahead load nomination system
7. CAISO market access
8. Capital project impacts
9. Lessons learned

The following is a compilation of comments and questions generated during the meeting:

- Will the new Time of Use Periods align better with peak prices?
- Why not just put in batteries or energy storage for solar voltaic projects that will now have decreased revenue due to the time of use period change?
- For most projects, the consideration of risks to cash flows and proformas from later year changes to electric rate structures is an afterthought at best. How can a microgrid like this help preserve out-year value through optimization?
- Is there a plan where the Santa Rosa plant can be completely off the grid?

- Assuming you charge the battery off the PV system when the sun is shining, does the battery allow you to move the discharge of that power to when it is more valuable under the new TOU periods?
- Are you charged by solar for tax credit?
- How does microgrid respond to negative energy price events?
- So, PG&E or a CCA purchasing that gird impact is better off than buying the same grid impacts from a peaker plant?
- So, a water system with storage tanks on hills and grid connected pumps and in-conduit generation could be a grid asset both by increasing and curtailing its load?
- How many hours in the last few years were there with negative pricing?
- Are you doing anything different with the plant from a sequence of operations standpoint, or is this more just a way to document and monetize it?
- For some small wastewater plants, anytime you use the flow equalization basin there is labor involved for cleaning. How do you handle this?
- If you are setting it up for microgrid operations does any of the capital equipment change?
- If you bid into the day ahead market at CalISO, and then for some reason you are unable to actually do what you bid in because of an emergency, what are the financial impacts?
- What is the MW and MW-Hr rating of the batteries being used?
- All new construction homes in California will have to have solar, wont this greatly increase the chance of critical duck curve events?
- As soon as electric rates change water agencies are going to change their operation, which in turn will also impact the duck curve. Have the CalISO Forward Planners considered this change in behavior when anticipating what the future grid will look like?
- Are all residential customers being moved to TOU, if so, when?
- Besides participating in the CalISO PDR market, what other options are there for an agency to monetize its grid impacts?
- Who owns what in the Santa Rosa project?
- Considering how the market has changed between the time of designing the project and today, what would you do differently?
- Because each site is specific, I'm wondering what microgrid hardware you installed for the Santa Rosa project?
- So, projects can be hardware heavy, software heavy, or a combination of both?
- Does the addition of the microgrid controller change the eligibility of any energy storage?

August 16, 2018

MEETING SUMMARY

Energy Market Symposium
Visalia Marriott at the Convention Center
300 South Court Street, Visalia
August 16, 2018

Outreach Goals and Purpose

The purpose of the meeting was to disseminate information about changes occurring in California electric markets as well as to provide information about the Santa Rosa Microgrid project itself. The goal of the meeting was to educate while building trust. While learning about the grid impacts from the measures installed at the Santa Rosa plant, attendees would be provided information, tools, and resources to help them understand and identify opportunities of similar controllable load specific to their agencies or districts and how that could be monetized. But trust is a key component for an agency or district to considering the feasibility of this concept. Both wastewater and potable water system operators are constrained by rigorous safety regulations. By bringing in the management and operations staff of the Santa Rosa project, attendees would feel much more comfortable with the concept—novel grid participation strategies could be enabled while still maintaining safety standards.

Stakeholder Outreach

The project team targeted districts and agencies that provide water and/or wastewater services, located within Mono, Santa Clara, San Luis Obispo, Santa Barbara, Ventura, Tuolumne, Mariposa, Madera, Kings, Fresno, Tulare, Inyo, Kern, San Joaquin, Calaveras, Stanislaus, Merced, San Benito, and Monterey counties. Key decision makers from these districts and agencies were identified and compiled in a stakeholder database that totaled 251 contacts. *To reference the entire stakeholder database, see* **ATTACHMENT A.**

Multiple rounds of contact was made with each stakeholder in the database in an effort to inform these agencies and districts of upcoming changes to the California electric markets as well as to invite them to the August 16 Symposium. A series of email invitations were sent on July 27 and August 13. Reminder phone calls were made to each stakeholder between August 3 and 6. *To reference the initial email invitation, see* **ATTACHMENT B.**

Five representatives from four different agencies and districts attended the Energy Market Symposium held in Visalia on August 16. Following is a list of presenters and attendees:

Project Team/Presenters

Michael Day, Utilities/Smart Grid Team Lead, Trane Ingersol Rand
Peter Klauer, Senior Advisor/Smart Grid Technology Cal ISO (by phone)
Mike Prinz, Deputy Director Public Works, City of Santa Rosa (by phone)
Frank Gill, Senior Vice President, Holeman Capital

Meeting Attendees

City of Visalia
Devon Jones, Economic Development Manager

City of Bakersfield

Zachary Meyer, Wastewater Manager

Sean Caral, General Services Superintendent

West Kern Water District

Troy Turley, Operations/Engineering Administrator

Westlands Water District

Jose Rangel, Associate Resources Analyst

Trane Ingersol Rand

Katherine Drewes, District Marketing Manager

Doug Walker, Senior Sales Executive

Meeting Summary

Michael Day welcomed attendees, followed by self-introductions. Michael Day then, reviewed the agenda (referenced below) and discussed electric market changes, project goals, and project components. Mike Prinz continued (by phone) with a discussion about the Santa Rosa Mirogrid project. Frank Gill reviewed Capital Project Impacts. Peter Klauer followed by providing an overview (by phone) of the CalISO market. Michael finished the presentation with lessons learned from the Santa Rosa project and opened the meeting to questions and comments. *To reference the full PowerPoint presentation, see* **ATTACHMENT C.**

Meeting Agenda

1. Introductions
2. Drivers: electric market changes
3. Goals of the project
4. Project components
5. Plant Operator's perspective
6. Day ahead load nomination system
7. CAISO market access
8. Capital project impacts
9. Lessons learned

The following is a compilation of comments and questions generated during the meeting:

- Will the change in time of use periods affect non IOU customers as well?
- How much in the way of resource adequacy assets do the CCAs need to buy?
- Do flow changes affect effectiveness of the UV system at Santa Rosa?
- Is Santa Rosa flaring digester gas while operating the microgrid system?
- Did Santa Rosa need to replace their motor driven generating sets, if so, was that an important element in the economics of this project?
- Who maintains the new equipment?
- Are there investors who are looking to do this type of project?
- Can we get a copy of the presentation?

APPENDIX F:
UC Davis Report

UC Davis performed an initial report of the LTP microgrid opportunity and the effects upon water treatment at a wastewater plant. A copy of the report may be found in this Appendix.

Load Shifting at Wastewater Treatment Plants: A Case Study for Participating as a Demand Resource

Authors: Erin Musabandesu[a], Frank Loge[a]

[a] Center for Water-Energy Efficiency, University of California Davis
2015 Sage St. Suite 200
Davis, CA 95616, United States

[b] Corresponding author, fjloge@ucdavis.edu

Abstract

Energy load shifting can allow for increased renewable energy integration and reduction of greenhouse gas emissions. Recent research has demonstrated that wastewater treatment plants (WWTPs) have considerable potential to implement energy load shifting and act as a demand resource due to their energetic flexibility and energy production capacity. This paper presents a case study of a WWTP in California participating as a demand resource on the wholesale energy market through the Proxy Demand Resource (PDR) program. This case study identifies opportunities and barriers for wastewater treatment plants to perform energy load shifting. A preliminary cost-benefit analysis was conducted based on projected program participation and estimated energy load shifting capabilities. It was determined that the Laguna WWTP facility could load shift between 200 and 1020 MWhs annually, leading to between 1% and 7% energy cost savings through the PDR program. This analysis shows that there is revenue potential for WWTPs participating as a demand resource. As a supplement to the case study, a roadmap outlining the technology necessary for WWTPs to participate in general demand resource programs through energy load shifting and a summary of the requirements for WWTPs in California to participate in the PDR program were developed and are presented.

Keywords: Energy Management, Load Shifting, Wastewater Treatment Plants, Automated Demand Response

1.0 INTRODUCTION

Rising concerns over global warming and climate change have resulted in aggressive renewable energy integration commitments to reduce the greenhouse gas (GHG) intensity in the energy sector. California has committed to 60% renewable energy integration by 2030 and 100% clean energy by 2045 [1]. Europe has also committed to 45% renewable integration by 2030 with additional integration projected in order to meet carbon neutrality by 2050 [2] [3].

However, the integration of renewable energy has caused new operational challenges for energy systems, particularly when integrating wind and solar due to their intermittent, variable, and non-dispatchable nature [4] [5] [6] [7]. A significant contributing factor to these challenges is that large scale energy storage is currently infeasible: most energy produced must be consumed immediately. Dispatchable energy generation sources such as hydropower, geothermal, natural gas, and coal are required to fill increasingly substantial temporal gaps left by renewable energy generation to meet customer demand [4] [5] [6] [7].

Utilizing customers as an energy demand resource by incentivizing energy reductions, also known as curtailment, at particular time periods can help to mitigate these operational issues. In practice, customers can act as demand resource by shifting their energy load out of time periods when demand on dispatchable resources are the greatest or when the grid is unbalanced. This can help smoothen the net energy load that must be provided by dispatchable resources and ease renewable energy integration [8] [9] [10]. Furthermore, if customer energy load can be shifted into times of the day when renewable generation is readily available, renewable integration should increase and GHG emissions can be reduced. Customers who can more significantly shift their energy load, or are energetically flexible, are well suited to act as a demand resource.

Energy utilities have utilized several different time-based pricing mechanisms to incentivize customers to participate as a demand resource and promote load shifting. Static time-of-use (TOU) rate structures based on historical energy load patterns incentivize customers to avoid using energy during historical peak usage hours. Demand response programs motivate customers by sending day-ahead requests to reduce load during times of peak energy use or at times which will improve the reliability of the grid. Some customers can also access dynamic energy markets, either through energy utility programs or directly, which incentivize customers with near real-time energy prices based on the locational needs of the grid.

As large energy users worldwide, wastewater treatment plants (WWTPs) possess a significant opportunity to participate as a demand resource. In Europe, WWTPs account for approximately 1% of total energy consumption [11]. In China, that number is 0.3% [12]. Data for the United States shows wastewater treatment represents 0.6% of total energy consumption [12], while in California that number is approximately 0.8% [13]. Additionally, the potential of WWTPs to co-generate energy as a byproduct of the treatment process allows for increased energetic flexibility [19].

Energy research at WWTPs has typically focused on increasing energy efficiency [14] [15] or optimizing energy production [16] [17]. However, recent studies have begun to evaluate the energetic flexibility of wastewater treatment plants, their ability to perform energy load shifting, and their potential as a demand resource. Several wastewater treatment processes have been identified as main areas of energetic flexibility for energy load shifting. Table 1 presents a summary of the processes identified by previous studies as areas of energetic flexibility within wastewater facilities and related requirements and concerns.

Anaerobic digester operations are of particular interest for load shifting because of their potential for energy generation [18] [20]. Electricity is generated from the digester gas, supplemented with natural gas, using combined heat and power engines (CHPs). CHP operations can be shifted to generate energy during different time periods and offset energy usage from the electricity grid [19] [20] [21] [22]. The operation of the heat pumps that maintain digester temperature can also be load shifted. Because insulated digester tanks do not lose more than 1° C of temperature when heat pumps are turned off for less than 24 hours, the impacts of load shifting on final effluent quality are minimal [21] [19].

Pumps used to transport wastewater within WTTPs can also be utilized for energy load shifting if the facility has sufficient storage to retain untreated wastewater while pumps are not operating [19] [20] [21] [22]. However, additional research is needed to understand the effects of intermittent pump operations on treatment efficacy [22] [18]. Excess facility capacity in general has been identified as an area that can allow for increased energetic flexibility [22] [18]. If additional capacity exists within a facility, or before the wastewater enters the facility in the sewer system, operators can delay treatment operations and shift energy load. However, depending on the level of additional capacity and projected future facility requirements, operators may be hesitant to utilize excess capacity for this purpose [20] [22].

Despite interest in load shifting aeration blower operations due to their high energy usage, there is conflicting evidence on whether delays in aeration cause degradation of final water quality. While Schafer et al. found that shutting down aeration blowers for a limited amount of time with specified control parameters had no effect on effluent quality [19] [21], a study conducted by Lawrence Berkeley National Laboratory revealed that intermittent aeration operations did affect key operating parameters and water effluent quality [20][22]. Further research is needed to determine how effluent quality is affected by intermittent aeration operations and if additional controls or treatment techniques might make load shifting feasible. Monitoring of oxygenation levels or over oxygenation are two strategies that might mitigate the effects of intermittent aeration on water quality [18] [22].

Table 1: Previous Research on Wastewater Treatment Process Energetic Flexibility

Treatment Process	Previous Studies	Requirements	Concerns
Combined heat and power generation	[18] [19][20]	Digester (anaerobic preferred to aerobic), gas storage, and CHP units.	-
Digester heat pump operations	[19][20][21]	Digester (anaerobic preferred to aerobic).	-
Pump operations	[20][21][22]	Storage facilities to store wastewater while pumps are not operating.	Further research needed on effects to effluent quality.
Aeration blower operations	[20][21][22]	No additional requirements.	Further research is needed on how intermittent blower operations effect effluent water quality and what controls or techniques might mitigate these effects.
Excess capacity	[18][20][21][22]	Requires oversized facilities.	Further research needed on effects to effluent quality.

The level of automation at a WWTP can also have a significant impact on how effectively a WWTP can load shift operations [20] [22]. Load shifting at manually operated facilities may require adjustments to processes at levels that staff typically cannot adequately or easily provide [19] [20].

Despite this array of unique opportunities, knowledge is still lacking around the specific technologies or steps required for WWTPs to participate in demand response programs. Research in this area has been limited in general, and only a few full scale case studies have analyzed WWTP energetic flexibility [19] [22]. The main purpose of these studies was to analyze the feasibility of load shifting for different WWTP assets and understand the limits of energetic flexibility at WWTPs.

To help identify the technologies and steps required to perform load shifting, a case study was performed for a WWTP in California that has recently begun participating as a demand resource for the California energy grid. The primary objectives of the study were to 1) interview WWTP operators to determine barriers and opportunities for participating as an energy demand resource, 2) measure their participation in the demand response program and compare these results to projected participation from a preliminary cost-benefit analysis, 3) analyze the effects of load shifting on wastewater operations and effluent quality and, 4) calculate the GHGs reduced through these operational changes. A supplementary goal of the study was to provide a roadmap for other WWTPs to participate in energy markets as a demand resource. Unfortunately, due to delays in permitting, the WWTP was not able to participate in the demand resource program prior to the completion of the case study. As a result, only interview and preliminary cost-benefit analysis results are presented here, in addition to the roadmap outlining how WWTPs can participate as a demand resource.

2.0 METHODS AND APPROACH

This case study examines the Laguna Wastewater Treatment Plant, located in Santa Rosa, California. The Laguna facility serves nearly 230,000 customers and treats an average daily flow of 17.5 million gallons for recycled water reuse. Wastewater at the Laguna WWTP undergoes primary, secondary, and tertiary treatment (see Figure 1). These treatment processes all consume energy and are considered within the system boundary of this study. Primary treatment includes screens, grit removal, primary clarification and anaerobic digestion. Methane is captured from the anaerobic digesters and used for cogeneration by four CHPs at the facility. After anaerobic digestion, the sludge is dewatered and composted for agricultural use. Secondary treatment includes aeration and secondary clarification. Tertiary treatment involves a coal filter and ultraviolet disinfection system. The treated water is classified as recycled is used to irrigate agricultural lands and urban landscaping, or to recharge the steamfield feeding the Geysers geothermal energy production facility. Water not reused for these purposes is discharged to surface waters during the allowable discharge period, October 1st through May 14th. Before participating as a demand resource, the Laguna WWTP experienced a typical peak energy load of approximately 5 megawatts (MW).

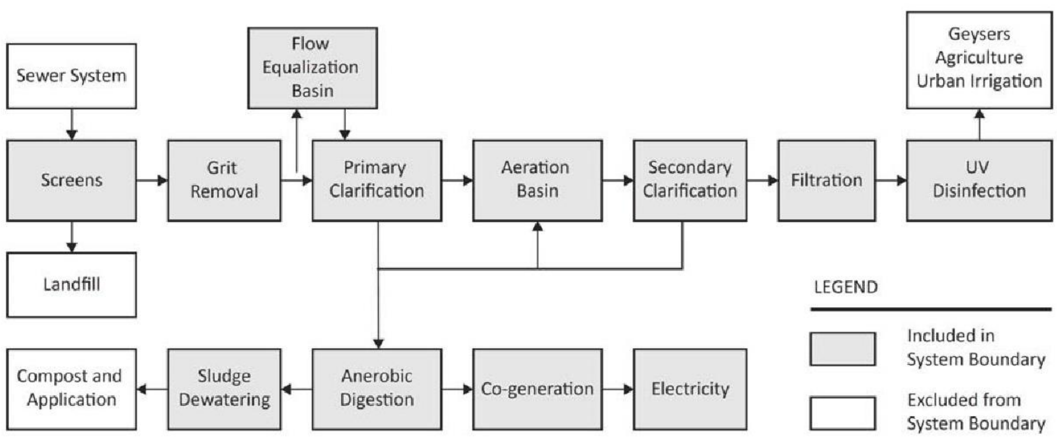


FIGURE 1: Laguna Wastewater Treatment Plant Treatment Process Diagram

2.1 Participation in the Proxy Demand Resource Energy Program

The Laguna WWTP receives energy from the California statewide energy grid as a Pacific Gas & Electric Company customer.

As seen in other regions, several issues are complicating the ability of the California statewide grid to meet demand with the introduction of increasing supplies of renewable energy sources. As non-dispatchable renewable integration increases, the unpredictable nature of renewables has more significant impacts. It has become progressively more challenging for system operators to match supply to demand accurately in order to maintain grid reliability. In addition, as a result of increased solar procurement, the majority of renewables on the California statewide grid are generated during the middle of the day [10]. Two large energy system ramps must be supplied by dispatchable energy sources; one in the morning when renewable generation is ramping up and one in the evening when renewable generation is ramping down (see Figure 2; [10] [23]). As the rate of ramping steepens, it becomes increasingly difficult to reliably meet energy demand with dispatchable resources because of operational facility constraints.

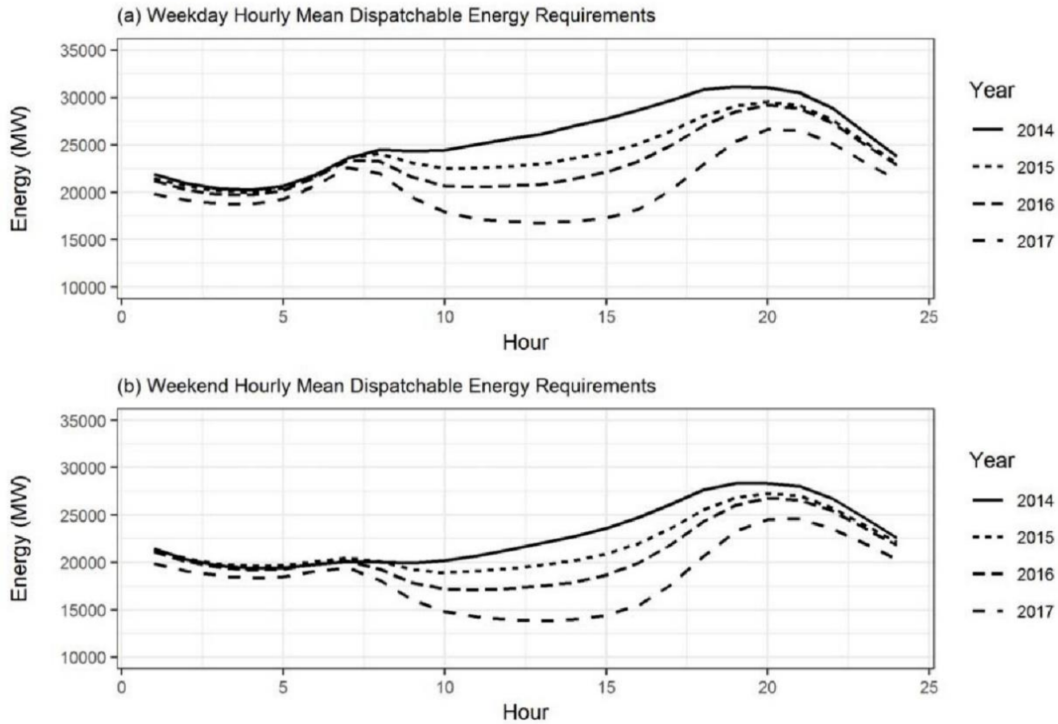


Figure 2: California Statewide Historical Dispatchable Energy Requirements

The California Independent System Operator (CAISO), manages the California energy grid using a wholesale energy market which promotes the purchase and sale of energy through locational marginal pricing (LMP); energy is bought and sold at real-time energy prices based on the locational value of energy.

The Proxy Demand Resource (PDR) program, also managed CAISO, is one of several time-based incentive programs designed to mitigate operational grid issues by leveraging customers as a demand resource. The PDR program allows participants to bid into California's day-ahead and real-time wholesale energy markets as a demand resource, providing energy "supply" by curtailing their load by a promised amount. A minimum bid of 0.1 megawatts (MW) is required to participate in the program; smaller loads can be aggregated. Once all bids are placed, CAISO determines which bids to accept and notifies the participants. For each participation day, a moving average is calculated from the most recent non-participation days, which is then used as a baseline load. Once the event has concluded, metered data is compared to a calculated baseline to determine the amount of energy that is curtailed during PDR events. A final settlement amount is determined by multiplying the load curtailed by the real-time LMP prices during the PDR event. LMP pricing is only utilized to determine revenue for supplying energy, PDR participants continue to pay for their electricity at based on their selected energy rate.

In 2018, the Laguna WWTP upgraded its facilities to increase the load shifting capacity of the site to more effectively participate as an energy demand resource through the PDR program (see Table 2). Automated Demand Response (ADR) capability was incorporated into the system, allowing operators to divert flow into two, pre-existing 12.8 MG flow equalization basins (FEBs), within certain operational limits, to shift operations and energy load. Additionally, two pre-existing CHPs were retrofitted with selective catalytic reduction (SCR) emissions control units to allow four units to operate simultaneously. At previous emissions levels, state air regulations only allowed one unit to be active at a time mixing digester gas with natural gas. The remaining two CHPs now will only run off of pure digester gas, and will be operated as gas is produced from the anaerobic digester.

To increase Laguna WWTP's ability to smoothen and control energy load several energy infrastructure assets were installed onsite. A 2-MW battery was installed at the on-site energy grid substation, allowing the WWTP to stabilize energy load that is required by the electricity grid. An inverter was also installed to connect the battery and the grid and control the timing and rate at which the battery stores or releases energy. These assets facilitate rapid energy load reduction, easing the demand on the grid while maintaining minimum energy requirements to sustain operations and maintain adequate water quality.

Table 2: Assets at Laguna Wastewater Treatment Plant That Facilitate Energy Load Shifting

Asset	**Quantity**	**Make and Model**	**Size/Capacity**
Additional Infrastructure			
Selective Catalytic Reduction Emissions Control Unit	2	Miratech[1]	NA
Battery	1	Tesla	2 MW
Outdoor Power Conversion System (Inverter)	1	Parker 890GTB-2206	2200 kVA (480 AC); 60 Hz
Existing Infrastructure			
Flow Equalization Basin	2	NA	12.8 MG
Combined Heat and Power Engines	2(of 4)[2]	Cummins QSK60G	Maximum power output: 1100 kw; Power Factor: 0.89

[1] Custom built Selective Catalytic Reduction Unit by Miratech.

[2] Only the two engines fitted with SCR emissions control units are utilized for load shifting.

2.2 Data Collection and Analysis

The master energy meter for Laguna WWTP was used to collect time series energy data from May 2017 to October 2017. LMP data was collected from CAISO for the nearest sub-load aggregation point associated with the Laguna WWTP [24] for this same time period.

Anecdotal evidence was also collected through interviews with Laguna WWTP operators and program implementers to identify opportunities and barriers to participation as a demand resource in the PDR program.

2.3 Preliminary Cost-Benefit Analysis

A preliminary cost-benefit analysis was performed to estimate the potential revenue from participating in the PDR program using historical five-minute interval energy load data from Laguna WWTP from May 2017 to October 2017 and corresponding CAISO real-time Locational Marginal Prices [24]. For purposes of this study, it was assumed that PDR bid placement would be chosen to optimize revenue and all bids placed would be accepted.

Wastewater treatment operators projected that they would be most likely to participate in the PDR program during the dry season from May to October. Based on staffing restrictions, they anticipated bidding into the market Tuesday through Friday, once a day, for a four-hour time block. They did not plan on participating during the wet season because of system constraints; the WWTP experiences higher and more variable flows that limit plant energetic flexibility and require additional staff oversight.

For the analysis, it was assumed that diverting flow to the two FEBs would reduce plant-wide energy load by 500 kWh for approximately four hours, and operating the two CHP engines fitted with SCR units would result in another 1 MWh of energy reduction per engine. These assets could be combined in different ways to achieve different levels load reduction at the site. The load reduced during the PDR event hours is based on the combination of assets selected for energy reduction. The revenue from the PDR program for each combination was determined for this analysis. It was also assumed that the battery would be able to fill in any gap between the projected energy loads and actual energy produced for the PDR event period. For analysis purposes, projected energy load was defined as the baseline minus the projected reduction in load during PDR event hours; the actual energy produced was defined as the actual historical energy load minus the projected reduction in load during the PDR event hours.

The baseline was calculated using the 10-in-10 methodology presented in the CAISO PDR Project Implementation Plan [25]. A brief summary of this methodology is provided here. For each participation day a baseline is calculated from an hourly average of the last ten non-participation days within a 45-day window. If there are fewer than 10 non-participation days in the last 45 days, then a minimum of 5 days may be used. If the minimum is not met, then the participation days with the highest load during a demand response event are substituted for use in the baseline calculation. On the day of participation, the raw baseline can be adjusted by up to 20% using a multiplier based on a comparison of the recorded energy load for the four hours prior to the event, excluding the hour directly before demand response [25]. Figure 3 provides an example of the results of the adjusted baseline calculation for a single day, showing the raw baseline, the actual energy load and the final adjusted baseline, as well as the adjusted baseline limitations and the time period that the adjusted baseline multiplier was calculated within.

In the PDR program, distinct baselines are calculated for weekdays and weekend/holidays. However, for the preliminary cost analysis only a weekday adjusted baseline was calculated as weekend participation was not anticipated.

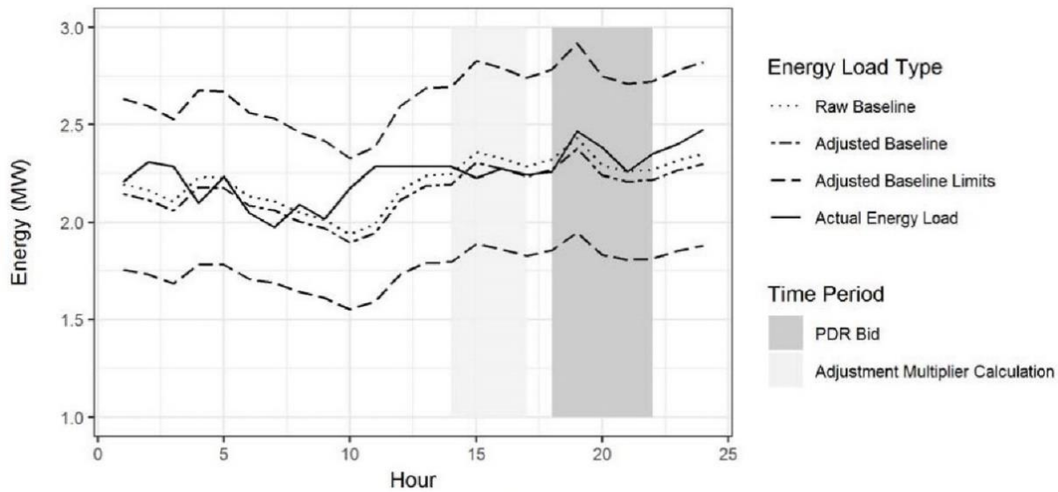


Figure 3: Adjusted Baseline Calculation for Preliminary Cost-Benefit Analysis

For the analysis, differences between the adjusted baseline and the actual energy load for participation days were calculated by transforming hourly adjusted baseline data into 5-minute interval data and comparing it to measured 5-minute interval data for the PDR event. For the Laguna system, this difference reflects the amount of curtailment that must be provided by the battery.

Projected PDR revenue was calculated by multiplying the load curtailed during the event by real-time prices during the event bid period. Additionally, because participants in the PDR program still purchase electricity from their supplier at static TOU rates, changes in electricity costs due to participation in the PDR program were also included in the cost-benefit analysis.

3.0 RESULTS & DISCUSSION

3.1 Operator Interview Results

Performing energy load shifting is not a typical part of wastewater operations. Operators at Laguna WWTP identified several barriers to implementing load shifting at their facility as well as opportunities that would allow for energy load shifting to be integrated more smoothly.

One of the main difficulties this facility encountered was navigating the design, permitting, and construction process under the time constraints of grant funding. In particular, there were delays permitting the SCR units through the California Air Resources Board and processing the interconnection agreement with the energy utility. Delays for this project were compounded by the 2017 wildfires in this region, which put unanticipated strains on regulatory agencies reacting to emergency conditions. Future implementations should consider working within the framework of municipal capital infrastructure development programs, which provides time for the administrative procedures required by municipal agencies such as WWTPs and allows design and construction to follow established processes.

Prior to implementation, WWTP operators voiced concerns over a fragmented understanding of the PDR program. There was uncertainty on how baselines would be calculated and how settlements would be determined. This may have been heightened by the fact that the PDR program is currently being updated and procedures and requirements are changing [26]. Operators expressed a need to either develop in-house expertise or to contract private consultants to interpret energy data and market information required for operational decision making. Additional outreach by energy utilities to educate wastewater treatment facilities about demand resource programs might increase participation.

There was also concern about how load shifting would impact the efficacy of wastewater treatment operations. Biological systems at treatment facilities perform best under stable conditions [22]. Operators were cautious when determining which operations to load shift at the Laguna WWTP. The primary goal of WWTPs is to treat wastewater to safe levels based on effluent use or discharge location; optimizing energy use is secondary. Based on previous experience at the site, Laguna WWTP personnel determined an extent and timing of flow diversion that would have minimal impacts on effluent quality. Since CHP operation has no impact on wastewater treatment processes there are no constraints. These two assets were the only operations that Laguna WWTP was comfortable altering to perform energy load shifting. Once participation in the PDR program commences, water quality parameters will be monitored to ensure load shifting did not negatively impact effluent standards. Additional research in this area could give WWTP operators more confidence in altering WWTP operations to perform energy load shifting.

3.2 Preliminary Cost-Benefit Analysis Based on Projected PDR Participation

Results for the preliminary cost-benefit analysis are provided in Table 3. Based on projected participation, the facility could save between $18,000 to $94,000 dollars annually by participating in the PDR program depending on which assets are used to perform load shifting. This includes revenue from both PDR participation as well as projected savings from shifting out of peak and partial peak TOU pricing time periods. Given that the total cost of electricity for 2017 was approximately $1,400,000, this represents a reduction of energy costs from 1% to 7%. If participation could be increased year-round larger percent reductions could be achieved.

Image of Laguna Wastewater Treatment Plant, Final Research Article, Page 1.

Table 3: Preliminary Cost-Benefit Analysis Based on Projected PDR Participation

Operation Changes for Load Shifting Event	Energy Load Shifted	PDR Revenue	TOU Savings[1]	Total Revenue
Flow Diversion with FEB[2]	204 MWh	$15,429	$3,365	$18,794
Run One Additional CHP[3]	408 MWh	$30,857	$6,730	$37,587
Run Two Additional CHPs[3]	816 MWh	$46,286	$13,460	$59,746
Flow Diversion with FEB[2] and Run One Additional CHP[3]	612 MWh	$61,715	$10,095	$71,810
Flow Diversion with FEB[2] and Run Two Additional CHPs[3]	1020 MWh	$77,144	$16,825	$93,969

[1]Energy cost taken from PG&E Tariff E-20T
[2]Flow Equalization Basin
[3]Combined Heat and Power

The total daily adjusted baseline energy over the retrospective study duration is presented in Figure 4a and the variation of the baseline energy load by hour is presented in Figure 4b. There is an observable variation in the calculated adjusted baseline energy load over time; the adjusted baseline varies both by total daily energy use (see Figure 4a) and by hourly energy use (see Figure 4b). The total daily energy use falls within the range of 48.7 MW to 71.5 MW per day. For any given hour, the calculated baseline energy load is within the range of 1.5 to 3.7 MW.

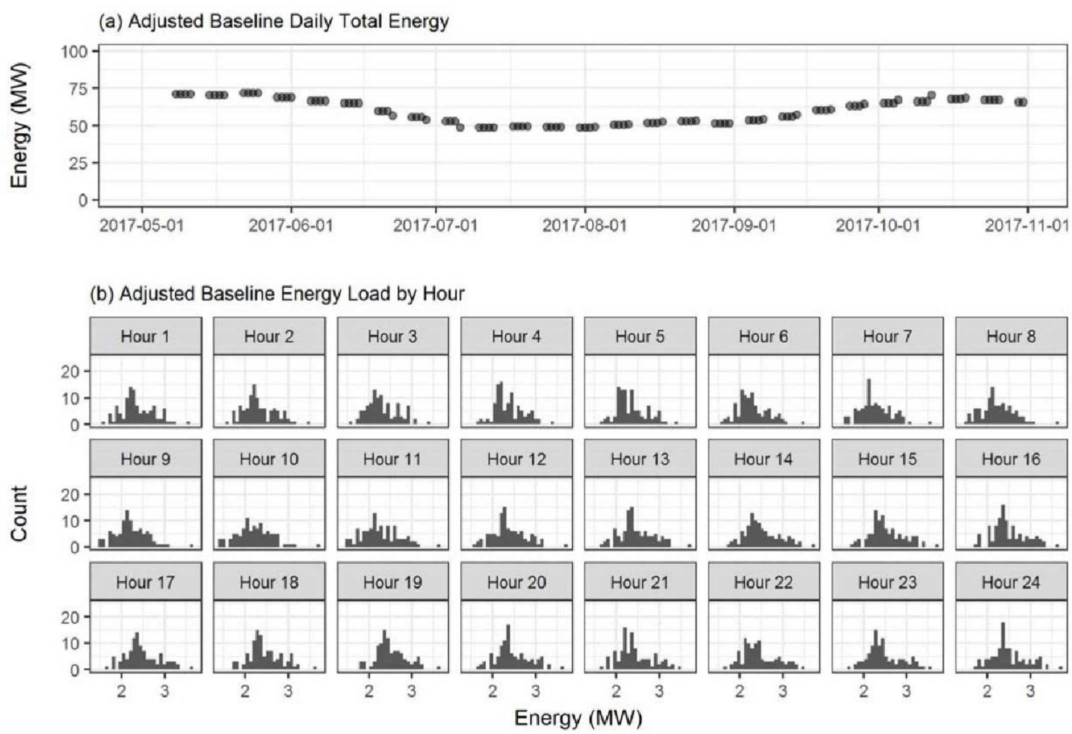


Figure 4: Calculated Adjusted Baseline for Preliminary Cost-Benefit Analysis

Figure 5 presents the differences between the calculated adjusted baseline and the actual energy load at the 5-minute interval level that is used to determine financial settlements in the PDR program. If the difference is equal to zero then the adjusted baseline matches the actual energy load, meaning that the baseline accurately predicts the actual load and can be used to accurately determine curtailment. For the analysis period the maximum monthly mean difference was 0.13 MWh and the maximum monthly lower and upper quartiles were 0.20 MWh. This shows that for most of the intervals the adjusted baseline is a somewhat good prediction of actual load. However, there are several outlying data points that were as high as 1.31 MWh above or as low as 2.27 MWh below the calculated adjusted baseline, revealing that the adjusted baseline can sometimes greatly mispredict the energy load of this WWTP. There may be some concern that the battery will be able to provide energy load to make up the positive differences between the adjusted baseline and the actual energy load so that the WWTP can provide the agreed load curtailment. The battery should undergo a testing period to determine whether it can sufficiently make up the difference. If the battery cannot provide the necessary energy, projected energy loads can be reduced to ensure that the WWTP can meet the promised load curtailment.

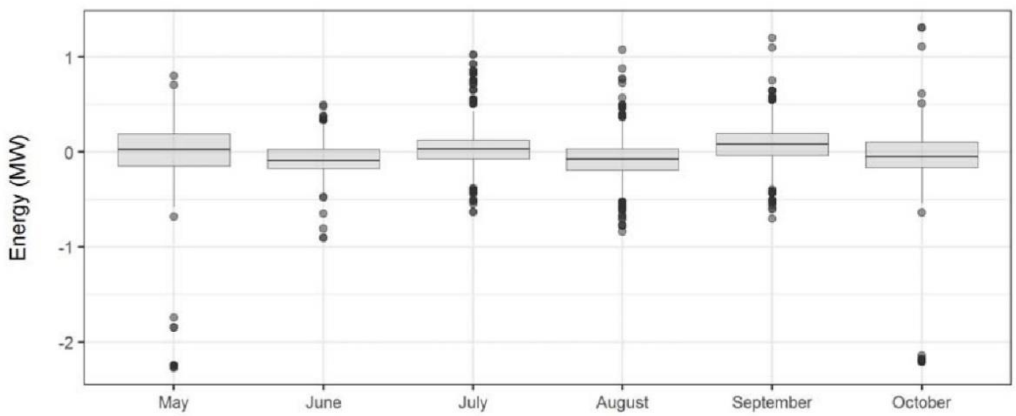


Figure 5: Difference Between Actual Energy Load and Adjusted Baseline at the 5-Minute Interval

3.3 Roadmap for Wastewater Treatment Plants to Participate as a Demand Resource

As a part of this study a roadmap was developed as a guide for WWTPs to participate as a demand resource through energy load shifting (see Table 4). Three main requirements were identified for WWTPs to perform load shifting to the standards required to participate in typical demand resource programs: instrumentation and automation infrastructure, assets providing energetic flexibility, and infrastructure for stabilizing energy load.

Time-series energy metering is required to calculate baseline energy use and determine the amount of energy actually load shifted [26]. Control systems and measurement instrumentation allow for remote optimization of operations and reduced effort. Without a certain level of automation, load shifting tasks may require excessive staff time [20].

Additionally, water quality measurement instrumentation provides assurance that load shifting operations are not affecting wastewater effluent quality [22].

In order to perform energy load shifting, assets must be selected whose operations do not negatively affect effluent quality. Most demand response programs require a minimum energy load to be shifted for a minimum time period. Based on the site-specific requirements of each facility, WWTPs may choose to perform energy load shifting using one or a combination of several assets within their facility to meet the minimum requirements of a particular demand response program.

Adding infrastructure that can stabilize energy load also allows WWTPs to more accurately project bids, reducing the possibility of failure to meet minimum load requirements or load curtailment commitments. WWTPs have variable energy load profiles that are largely dependent on inflow. Building in the ability to more precisely alter this load with residually stored energy is an important component for WWTPs to participate in energy load shifting.

Table 4: Roadmap for WWTPs Performing Energy Load Shifting

Requirements	Recommended Assets
Instrumentation/automation infrastructure	Time series energy metering[1] SCADA control system SCADA measurement instrumentation Water quality measurement instrumentation
Assets that can provide energetic flexibility	Combined heat and power engines Digester heat pumps Flow Diversion using equalization basins Flow Pumps Aeration Blowers[2]
Infrastructure for stabilizing energy load	Battery Power conditioning system Microgrid controller (interfaced with SCADA systems)

[1]The PDR program requires 5-minute interval energy metering.
[2]Additional research is needed regarding the intermittent operation of aeration blowers to determine its effects on wastewater effluent quality.

Additional information is also provided in Table 5, which summarizes the requirements for participation in CAISO's PDR program. This is to serve as an introduction to the PDR program and should not be considered a comprehensive set of all processes. Full and current details are available directly from CAISO.

Table 5: Requirements for Participation in the Proxy Demand Resource Program

Category	Requirement
Infrastructure requirements	Energy metering - 5 minute interval data Telemetry is required for a PDR with a rated capacity greater than or equal to 10 MW.
Minimum bidding requirements	100 kW minimum curtailment sustained for the duration of bid (smaller loads may be aggregated to achieve the minimum)
CAISO PDR process requirements[1]	Execute a Demand Response Agreement Submit a new Demand Response Provider ID request Receive a Demand Response Provider ID Assign a certified Scheduling Coordinator [2] Receive Demand Response Registration System access Submit contacts to be added to the Demand Response Registration System Demand Response Registration System training - user guide Submit performance evaluation forms

[1] Additional details provided CAISO Demand Response User Guide [26]
[2] A list of certified Scheduling Coordinators is maintained on the CAISO website.

3.4 Study Limitations

The results of the preliminary cost-benefit analysis are subject to several limitations. First of all, assumptions were made on when and how Laguna WWTP could participate in the PDR program that if altered could either increase or decrease the fiscal impact of participation. Similarly, it was assumed that all bids placed into the PDR program would be accepted, but because PDR is a competitive market some bids might not be accepted which would reduce earnings. Additionally, increases in energy required to divert flow into FEBs and increases in natural gas required to run additional CHP units were not included in the study. Changes in energy use based on changes in flow through the treatment plant also were not considered. Data analysis of actual participation in the PDR program should provide insight into fiscal potential and increases in energy and natural gas as a result of load shifting.

This case study outlined the predominant baseline methodology utilized in the PDR program and applied it as part of a preliminary cost-benefit analysis to illustrate how the baseline varies over time and to analyze its accuracy at predicting energy load. It was observed in the preliminary cost-benefit analysis that in some cases there was a significant difference between the adjusted baseline and actual energy load during PDR event time periods. Such discrepancies lead to inaccuracies in determining the amount of load curtailed. Although the impacts of these discrepancies may be mitigated by the onsite battery that has been installed to stabilize energy load, additional research should be performed to determine a baseline methodology that can accurately predict load at WWTPs for a true evaluation of curtailment. The PDR program has recently added two additional methodologies for calculating baselines for non-residential customers: the weather matching baseline and the day matching baseline [26]. Further research should be conducted on whether an alternative baseline methodology would be better suited to predict energy load at WWTPs or if a new methodology should be created for this specific use case.

3.5 Future Research

Additional analysis is planned once participation in the PDR has begun and data can be collected. The following is an outline of the proposed analysis:

- Evaluate PDR participation, including baseline data, and it's financial impacts
- Compare hourly WWTP operational data from the study duration to historical operational data collected prior to PDR implementation
- Evaluate WWTP water quality results from the study including biological oxygen demand, suspended solids, turbidity, coliforms, pH, and UV transmittance.
- Compare monthly average GHG emissions before and after implementation of the PDR program.

Greenhouse gas (GHG) emissions of wastewater operations will be calculated using two methodologies:

- The 2016 average emissions factors from the Climate Registry (TCR) for the Western Electricity Coordinating Council of California eGRID [27].
- The California electrical grid historic hourly emissions factors reported by the California Independent System Operator.

Historic hourly emissions factors are reported to the California Air Resource Board as a part of the California Cap-and-Trade program and should better capture GHG emissions savings from reduced energy use based on load shifting energy at the Laguna WWTP. By incorporating the dynamic schedules, internal resources, net imports, and transfers from the energy imbalance market, the use of hourly emissions factors should more accurately consider the impacts that the time variance of energy sources on the statewide energy grid have on GHG emissions [28].

4.0 CONCLUSION

WWTPs have been identified as energetically flexible resources that can be leveraged by energy grids to act as a demand resource [19] [21]. The results presented in this case study further illustrate that WWTPs have the opportunity to reduce energy costs through participation in demand resource programs.

However, several barriers make load shifting and participation in demand resource programs less attractive to WWTPs. The main concerns identified by operators at the Laguna WWTP were a lack of understanding of the PDR program and the impacts of load shifting on wastewater quality. The results of the preliminary cost-benefit analysis, the roadmap for WWTPs performing energy load shifting and the summary of PDR requirements serve as a resource for how WWTPs can safely load shift operations to participate in energy demand programs with time-based incentives such as the PDR program. Additional research should be conducted to determine how to accurately predict the diurnal energy load profile of a wastewater facility for use as a baseline. This will allow WWTPs to more confidently predict the financial impacts of load shifting energy. Similarly, concerns regarding the impacts of load shifting on wastewater quality effluent should be

Image of Laguna Wastewater Treatment Plant, Final Research Article, Page 1.

addressed by continued research, particularly for more sensitive energy intensive components, such as aerators.

Although additional research will better enable WWTPs to perform energy load shifting and act as a demand resource, there are several WWTP assets that operators can utilize with little or no concern for the negative effects on wastewater treatment processes. As renewable energy integration increases, the value of energetic flexibility in energy market will increase. As such, WWTPs should take advantage of the opportunities they currently have to participate as a demand resource and continue to expand those capabilities.

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