Westhaven-Moonstone Microgrid Proposal

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Executive Summary of the Westhaven-Moonstone Microgrid Proposal

The Westhaven-Moonstone Microgrid Proposal aims to reinforce the energy security of the unincorporated community of Westhaven-Moonstone, located near McKinleyville, California. This proposal is developed with the collaboration of the local volunteer fire department (VFD) and the community's residents. The primary objective is to establish a renewable energy-based microgrid system to reduce its dependency on traditional utility sources, and ensure a reliable electricity supply during emergencies, especially in the event of wildfires.

Westhaven-Moonstone is characterized by its small scale and vulnerability due to its geographic and environmental conditions. The community is currently powered by a Pacific Gas and Electric (PG&E) 12kV line, which transitions down to 120V to meet residential and commercial energy needs. The proposed microgrid system will utilize a Front of Meter (FOM) setup, incorporating solar power generation and battery energy storage systems (BESS) to maintain power supply consistency and reliability. This system is designed to operate autonomously for up to five consecutive days during utility outages, thus significantly bolstering the community's emergency preparedness. A single line diagram of the proposed system can be found below.

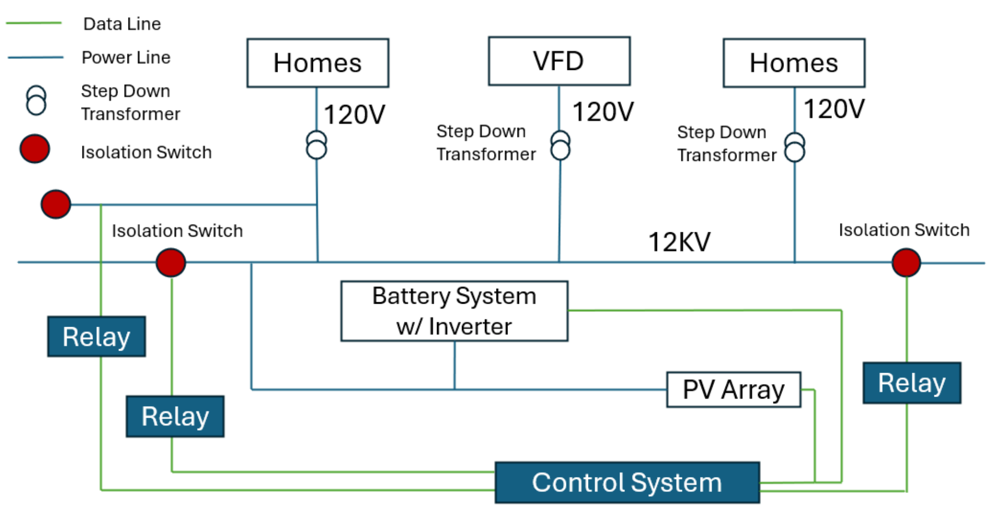

Figure 1: Proposed Westhaven-Microgrid Single Line Diagram

The design includes a 170 kW photovoltaic (PV) system paired with a 741 kWh battery storage unit. This configuration not only supports the community during grid outages but also offers potential financial returns through the sale of excess power back to the grid. The technical feasibility of the project has been determined in conjunction with NREL's ReOpt tool, confirming that the proposed setup can effectively meet the projected energy demands while providing substantial emergency power reserves.

The total cost for establishing the microgrid is estimated at approximately $4280030 USD, which encompasses engineering, infrastructure, equipment procurement, and additional expenditures such as utility upgrades and permitting. While the initial financial investment is significant, the direct economic benefits, although minimal, are supplemented by indirect benefits such as increased property values, improved community resilience, and potential savings on energy costs.

The project is expected to generate an annual revenue of $23343 from power sales and battery capacity. These figures present a modest offset to the initial investment, highlighting the project's long-term economic sustainability alongside its primary focus on safety and resilience.

The microgrid will not only reduce the community's carbon footprint by utilizing renewable energy sources but also enhance overall energy security. This is particularly important for Westhaven-Moonstone, given its susceptibility to natural disasters such as wildfires, which can compromise traditional grid infrastructure and threaten human safety and well being. As can seen in the below graph, the microgrid system will be capable of fully meeting the demands of the structures within its boundaries regardless of time of year.

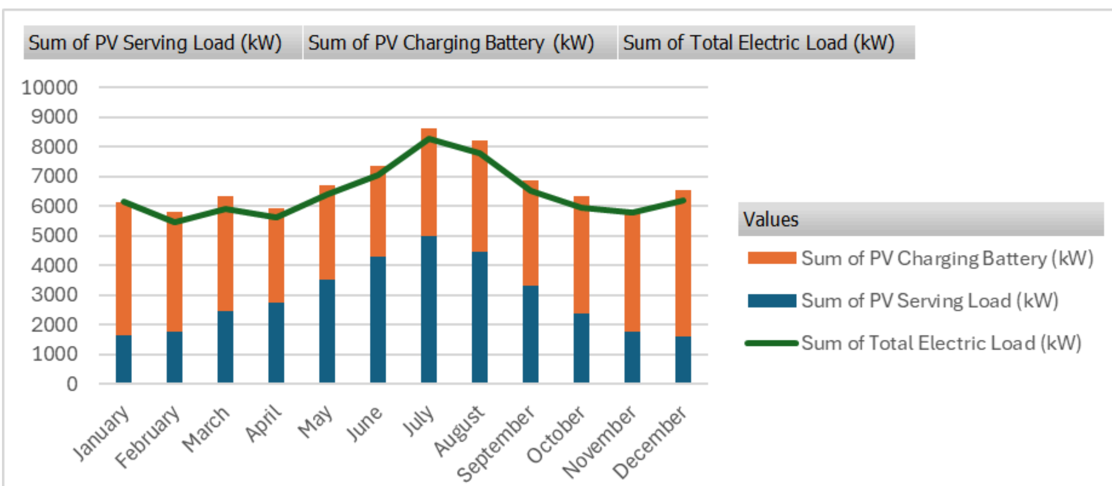

Figure 2: Graph visualizing the demand of the microgrid vs its dispatch capacity

Overall, while the financial returns are limited, the strategic importance of the project for ensuring long-term energy security and supporting local emergency preparedness capabilities should be properly acknowledged. The implementation of the Westhaven-Moonstone microgrid will serve as a critical step towards a more sustainable and resilient future for the community.

Introduction

As technology surrounding renewable energy generation becomes more and more accessible, it brings with it a plethora of opportunities in regards to increasing the energy security of communities around the world. One of these emerging technologies are microgrids, which at their most basic level consist of a renewable energy generation source, a battery energy storage system (BESS), and a series of switches and controls that can help to ensure its reliable and continuous operation.

This proposed project would aim to construct a front of meter (FOM) microgrid system that would serve as both a means to reduce the communities reliance on utility company generated power as well as to boost its ability to provide electricity to those within the microgrid during times of emergency. This project would be a joint venture owned and operated by the VFD in conjunction with the local energy authority Redwood Coast Energy Authority, generating electricity to be purchased by an association composed of the home owners residing within the boundaries.

Project Background and Location

Westhaven-Moonstone is an unincorporated community that houses a small number of homes and restaurants, as well as a volunteer fire department (VFD) that acts as a base of operations for fighting nearby fires. Located around 3 miles from the closest population center of McKinleyville, it is served by a Pacific Gas and Electric (PG&E) 12kV transmission line that steps down to 120V to serve the needs of the households connected to the grid. During times of emergency, the VFD also has the capacity to act as both a gathering point and a logistical center of operations. The transmission lines serving the area have been identified as having the capacity for 1 MW according to the integration capacity analysis map published by PG&E, a more than sufficient value for our desired objectives. However, there are still large swaths of the proposed area that have not been analyzed and would necessitate having these statistics checked. The two figures below detail the project location and proposed developments, in addition to the location as described by the ICA map. The map to the right shows the geographical location of the community in both the state as well as its home county of Humboldt.

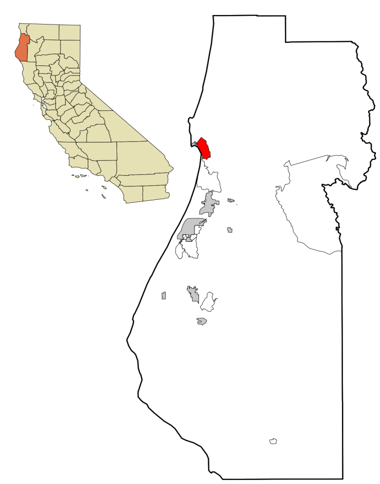

Figure 1: PG&E Integration Capacity Analysis Map for project location

Being located in a densely wooded area that has the potential to see out of control fires risk the safety and well being of local residents, uninterrupted and smooth operation of the VFD is paramount to ensure the greatest level of preparedness for natural disaster situations. The area has a serviceable amount of undeveloped land, but is densely vegetated and would require significant alteration to be made feasible for infrastructure. Solar irradiance in the area is relatively low when compared to the much sunnier southern areas of the state, but would be sufficient in providing the energy required for this smaller scale project. That being said, the climate is also relatively mild, meaning residents generally do not use as much electricity for residential climate control. Figure 3 below shows the single line diagram (SLD) of the proposed microgrid.

The microgrid will be located adjacent to the main 12kV transmission line, having multiple lines that travel through it carrying electricity to homes throughout the area. For this reason, multiple isolation switches will be required in order to fully contain the microgrid. These isolation switches will be located at the intersection of 6th Avenue and Kahlstrom Ave, 6th Avenue and Highland Avenue, and 7th Avenue and Kahlstrom Avenue. During times of regular operation, electricity will be transmitted through the power lines contained within the microgrid boundary. However, in times of emergency and wide scale power outage these isolation switches will close, keeping all energy generated from the PV array and dispatched from the BESS within the boundaries of the microgrid.

The PV arrays will be placed on the western edge of the microgrid boundary, relatively flat but densely vegetated. The installation of the PV array system will necessitate the use of heavy machinery in order to alter the terrain. The battery system will be placed adjacent to the VFD and PV array alongside the controller. Using ArcGIS, the area of the available land was calculated to be 89000 square feet, and the square footage needed for a 170 kW PV array was estimated to be around 85000 square feet using values obtained from the US Department of Energy.[8]

Figure 2: Map of the proposed site with relevant developments and homes labeled

When in its non-isolated state, the energy generated from the PV Array and dispatched from the battery system will not directly fulfill the demand of the structures within the microgrid boundary. However, during times of emergency the PV system and BESS are sized in such a way that almost fully autonomous operation can occur as visualized in the below graph. The amount of energy that the grid must supply to the microgrid during islanding mode It is important to note that the "demand" as specified in the below graph is not demand that will be serviced by the microgrid during times of normal operation, but rather showcases its ability to operate should grid disruption occur.

Desired Outcomes

Resilience

The primary goal of this project is to reinforce the energy security of the community by strengthening its ability to provide electricity to both residents as well as safety management agencies. By the current sizing of the microgrid, the need for grid related generation is quite minimal, limited to just a handful of instances per year. This means that should some sort of catastrophic event occur that knocks out large scale transmission, the community would be capable of meeting its energy demands almost entirely from the PV array and BESS.

In addition to this, the ability to provide energy in the event of an emergency is also a primary consideration. After reviewing the most extreme cases of interruption to electrical services over the past 10 years as published by PG&E, 5 consecutive days was decided on as an appropriate resilience target.[6] Although much longer outages have been observed, it is important to note that this is a small scale microgrid in a community that while rural, is also relatively accessible from larger population centers.

While indeed a critical facility, the main value of the VFD is not necessarily contingent on access to a large supply of energy. While energy is required for pumping water from storage reservoirs into vehicles for usage as fire suppressant, this is not a particularly resource intensive process. Additional energy demands might include specialized equipment that needs to be operated in times of emergency, but it is unlikely that this demand would be comparable to more energy hungry facilities like Hospitals or Airports. This could be considered beneficial, as it means that a longer outage period can be sustained on smaller batteries due to its overall lower consumption.

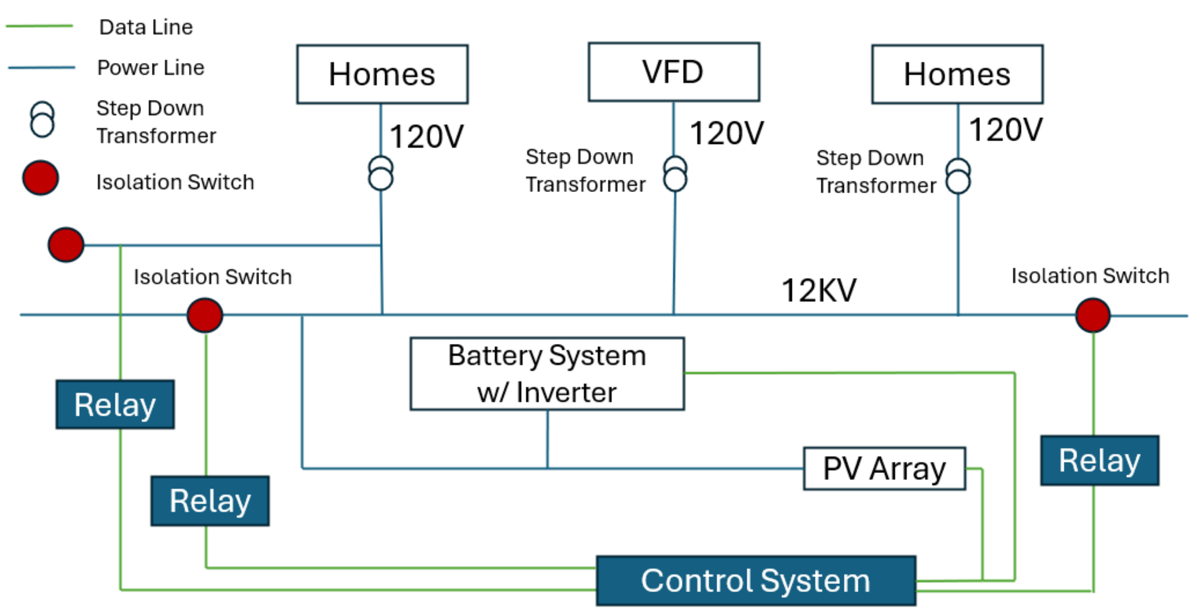

Figure 3: Single line diagram (SLD) of proposed microgrid project

Financial

The power purchase agreement that will be made between the microgrid owners and the utility companies will provide a modest revenue stream, but this is an insignificant sum compared to the total required up front cost of the project.

Methodology

Sizing

To ensure that the completed project is capable of meeting the desired resilience goals of maintaining fully autonomous operation during emergency situations, it is necessary to understand the usage habits of the structures residing within the grid.

Average annual usage of each home was estimated by calculating the approximate square footage of each home contained within the microgrid boundaries via GIS software and then using this square footage in conjunction with data pertaining to energy usage of homes in California by square foot to determine approximately how much energy each household consumes annually. This process was also performed on the VFD, the critical infrastructure located within the grid boundaries. See Table 1 for information pertaining to the structures contained within the microgrid.

Building #	Type	# Floors	Address/Street	Area (Sqft)	Demand (kWh/year)
1	Home	1	683 Kahlstrom Av	2981	2500
2	Home	1	418 7th St	3720	3000
3	Home	2	438 7th St	4600	3500
4	Home	2	415 6th St	2473	2200
5	Home	2	661 Kahlstrom Av	2260	2000
6	Home	1	429 6th St	2244	2000
7	Home	1	435 6th St	990	1100
8	Home	1	443 6th St	1381	1200
9	Home	1	447 6th St	2056	2000
10	Home	1	453 6th St	1690	1600
11	Home	1	471 6th St	4419	3500
12	Home	1	640 Spring Ln	5092	3700
13	Home	1	428 7th St	3110	2700
14	Home	1	414 6th St	3697	2900
15	Home	1	446 6th St	2667	2200
16	Home	1	460 Highland Ave	3298	2700

17	Home	1	414 Highland Ave	4479	3700
18	Home	1	445 Highland Ave	4605	3700
19	Home	1	470 Highland Ave	2467	2000
20	Home	1	482 Highland Av	3147	2700
21	Home	1	482 6th Ave	5491	4000
22	Home	1	494 6th Ave	1165	1200
23	Home	1	471 6th Ave	1848	1700
24	Home	1	428 6th Ave	1558	1500
25	Home	1	656 Kahlstrom	1759	1700
26	Critical Inf.	1	446 6th St	3504	16121

Table 1: Table showing the estimated load in kWh/year for each building in the microgrid

The VFDs load was estimated using an energy usage intensity statistic for fire departments published by the government of Washington DC. As it is a relatively small fire department serving the needs of a rural community, its energy needs are most likely under that of a traditional fire department. This load was then inputted into the ReOpt tool and fitted to the load demand of a Hospital, another somewhat similar critical facility. The resulting load profile can be seen in table 4 below. The most pertinent concern is with the power rating of the battery during times of critical operation. If an emergency such as a wildfire were to occur, the VFD could act as a potential forward operating base to help rescue and fire mitigation operations. This could require that energy demand peaks for short but significant periods of time to power heavy machinery or specialized equipment.

However, the city of Eureka, Arcata, and the unincorporated community of McKinleyville all possess larger and more appropriate locations that could serve a similar purpose, allowing us to conclude that the energy demand for the Westhaven-Moonstone VFD is important, but does not need to be necessarily high in power rating or duration. Additionally, since the majority of the demand comes from the residential homes within the microgrid, the ability to maintain power to the VFD should remain uncompromised.

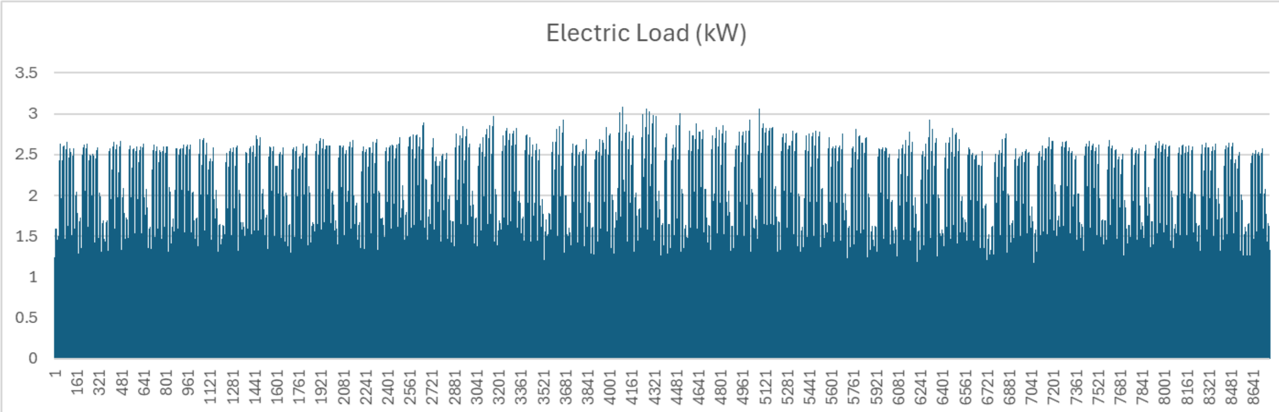

Figure 4: Hourly Load Profile of VFD (Max 3.08 kW demand)

For the estimations, a number of assumptions were made. On-site visits were conducted that allowed for a brief visual inspection of how modern the structure was, likelihood of containing energy intensive appliances, and number of vehicles to estimate the size of the household. A more in depth analysis of each resident via interviews of their home appliances and energy usage patterns was attempted, but residents were all mysteriously not home or present on the scheduled date.

To perform the resiliency simulation, the values as described in table 2 were inputted into the ReOpt tool published by NREL to simulate the cluster of buildings located within our microgrid boundaries. The annual energy demand as determined previously via our estimations were then provided as inputs As there were no load profiles for homes or fire departments in the tool, the parameters for an apartment complex and a hospital were chosen respectively.

The results specified that a 170 kW PV system coupled with a battery with a power rating of at least 65 kW and a capacity of at least 741 kWh would be sufficient in both supplying power to the community over a 5 day outage as well as generating enough power to exceed the maximum demand by a factor of 3. This factor was selected due to the nature of the safety measures in place requiring a battery to be able to deliver 3 times the peak demand of power in case of emergency surges.

Parameter	*Input*
Site Location	Westhaven-Moonstone
Electricity Rate	PG&E E-1 Residential Baseline
Total Energy Consumption	(79% VFD, 21% Residents)
Electrical Load Adjustment	100%

Parameter	*Input*
Critical Load Factor	200%
Outage Duration	120 hours
Number of outages	Single outage model
Outage start date	October 17th
Outage Start Time	12 AM
Minimum Battery Capacity	65 kW

Table 2: Table detailing the inputs utilized for ReOpt tool analysis

Components

Being a technically complex piece of infrastructure, a microgrid requires many specialized components that must be specced accordingly to the determined project requirements and parameters. In addition to the PV array and battery system outlined in the above section, isolation switches and a microgrid controller must also be installed to allow for safe operation of the microgrid. The price for the BESS was calculated utilizing a $/kWh function with values retrieved from the NREL website.

PV Panels: Solartech Solar panels will be utilized, with the overall price of the PV array system being calculated by a $/kW all-in value as published by NREL.

BESS: The Tesla Powerpack system integrates DC battery packs with a bi-directional inverter for power management and energy distribution.

Switchgear: The Eaton ATS1 is an automatic transfer switch capable of isolating the microgrid in a way that will allow for islanded operation powered by the battery and PV array in times of need. The controller will be an automatic, utility-generator, closed transmission type in order to ensure safe and autonomous operation. 3 of these must be purchased to account for the 3 isolation points.

Controller: The controller is a Siemens Spectrum Power all in one inclusive system, with included software that would be customized for this specific project. Siemens would also be responsible for writing the software that dictates the controllers parameters.

Table 3 details which components would be acquired for the project as well as price and quantity.

Component	*Model Number*	*Quantity*	*Price (USD)*
PV Panels	550 watt Axitec	340	$180,200 (170000W @ $1.06 /W)[9]
BESS	65 kW / 770 kWh, Tesla Powerpack System w/ built in Inverter	1	$450000[3] ($600/kWh)
Switchgear	Eaton ATS1	3	$250000[3] /Unit
Controller	Siemens Spectrum Power Microgrid Management System + Software	1	$33000 (Hardware 25000 + Software 8000)
Total Cost	N/A	N/A	$1413200

Table 3: Equipment Cost Breakdown

Costs

Many costs will be incurred over the duration of the project, ranging from acquisition of tangible components to providing compensation for engineering and other planning/logistical services, as well as to utilities and governmental entities to satisfy demands for large scale projects. A full breakdown of estimated and predicted costs is listed below.

Engineering: This phase will encompass a comprehensive assessment of the site, energy needs, and system integration challenges. The project will necessitate the engagement of specialized engineering firms with expertise in microgrid technology who can handle the complexities of integrating solar panels, battery storage systems, and control mechanisms. The logistics of bringing heavy machinery to a possibly remote or difficult-to-access site adds another layer of complexity. Given the specialized skills and equipment required, the project management will opt for a contractual agreement where payment is disbursed upon successful completion of the project, ensuring accountability and quality in construction.

Infrastructure: Installing the microgrid infrastructure involves several critical steps beginning with site preparation, which in this case means significant land clearing due to dense vegetation. This initial step is crucial to create a suitable environment for installing photovoltaic panels and the Battery Energy Storage System (BESS). The BESS will be installed on a specially prepared concrete slab to ensure stability and longevity. High-value components like PV panels and storage batteries will necessitate additional security measures, including fencing and adequate lighting, to protect the investment from theft or damage. The labor-intensive nature of this phase includes intricate electrical work and physical construction, both requiring precision and adherence to safety standards.

Equipment: This includes not only primary components like PV panels and batteries but also ancillary supplies such as electrical wiring, piping for protective casing, and weather-resistant sealants. Each piece of equipment must be chosen to ensure compatibility with the rest of the system and to meet the expected energy demands and efficiency standards of the microgrid.

Operation and Maintenance: Regular checkups and continued upkeep of critical components will be vital in ensuring the continued operation of the microgrid. Should a highly advanced component of the system malfunction, specialist assistance will most likely be needed to conduct repairs.

Utilities Upgrade: Integrating the microgrid with the existing utility infrastructure requires significant upgrades to ensure compatibility and safety. This includes enhancing the local grid's capacity to handle new energy inputs and potentially modifying transmission lines to manage the additional flow of electricity. These upgrades, carried out in collaboration with Pacific Gas and Electric (PG&E), are financially substantial. They must be planned and executed to meet regulatory standards and to ensure that they complement the existing grid infrastructure without compromising its integrity or performance.

Permitting: Securing the necessary permits for a microgrid is a complex process that involves detailed knowledge of regulatory requirements. This includes environmental impact assessments, zoning approvals, and electrical system compliance checks. Given the innovative nature of microgrid technology, local regulatory bodies may not have established guidelines, which can complicate the permitting process. Understanding and fulfilling these requirements is essential to avoid legal and operational hurdles, necessitating skilled legal and technical input.

Training: For the efficient operation and maintenance of the microgrid, specialized training for the technical staff is required. This training will cover the specific technologies used in the microgrid, such as the management of the BESS and the photovoltaic system, along with routine maintenance and emergency response protocols.

Expenditure	*Description*	*Estimated Cost (USD)*
Engineering	Logistical planning, schematic design, technical analysis	$1000000[3]
Infrastructure Installation	PV array, BESS and related components, controllers, switches, wiring, safety equipment	$250000
Equipment	Critical microgrid components as described in previous section	$1413200
Operation and Maintenance	Ensuring that proper checkups and repairs are conducted in a timely manner.	$750000
Construction Supplies	Ancillary supplies like wiring, piping, sealant, etc. etc.	$200000
Utilities Upgrade	Cost to utility operator PG&E to upgrade transmission lines to be able to accommodate the microgrid.	$500000[3]
Permitting	Necessary municipal and state permits, local zoning approvals, electrical and building permits, environmental impact assessments, and any fees associated with regulatory compliance.	$5000[3]
Personnel Training	Cost of training staff and personnel on the operation, maintenance, and monitoring of the microgrid. Calculated at 5% of total cost.	$161830[3]
Total Cost	N/A	$4,280,030

Table 4: Breakdown of Total Cost of Microgrid Installation

Revenue/Savings Summary

According to the ReOpt tool, PV generated energy would amount to 218674 kWh. With a power purchasing agreement (PPA) in place, this energy could be sold back to the utility and the revenue used to help maintain the microgrid infrastructure. At $80 a MWh[3], this would amount to $11040, a relatively insignificant sum compared to the overall cost of the project. The battery capacity would add a bit more, generating an additional $5850 a year at $90/kW/year with the system's 65kW battery.[3]

Revenue Component	Revenue	Capacity	Total Revenue/year (USD)
Power Purchase Agreement	$0.08/kWh	218,674 kWh	$17493
Battery Capacity	$90/kW/yr	65 kW	$5850
Total Annual Revenue			$23343

Table 5: Annual Revenue Streams from PV Based Energy Generation

Since this is an entirely FoM system, this means that the utility bills of the structures within the microgrid will not be altered. Ultimately during the 20-year projected lifespan of the microgrid, the owners and operators of the microgrid will incur a $4013936 cost assuming that all future revenue is committed to paying off the initial investment. The final LCoE was calculated as $18.97, which seems appropriate considering the significant financial loss that would be incurred with this project.

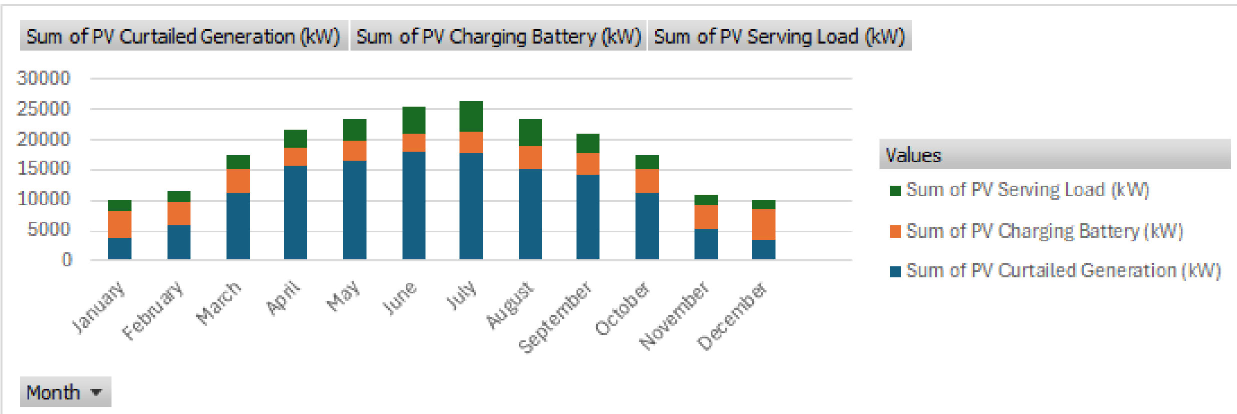

Figure 5: Total annual energy generation capable of being sold back to utilities company

Summary and Conclusion

The proposed microgrid configuration comprises a 170 kW photovoltaic (PV) array coupled with a 741 kWh Tesla Powerpack battery storage system. This system is designed to meet the critical load demands for a minimum duration of up to five days during utility power outages. The energy generation capacity, when paired with the storage system, ensures a continuous supply of electricity to critical infrastructure, primarily the local volunteer fire department (VFD), and mitigates the community's vulnerability to power disruptions caused by natural disasters, with a particular emphasis on wildfire-induced blackouts.

Financially, the total upfront cost for the microgrid installation is projected at approximately $4,256,687 USD. This investment encompasses various facets of the project including engineering services, infrastructure setup, equipment procurement, and associated costs such as utilities upgrades and personnel training. It is important to note that while the economic return on investment is minimal, the value proposition of the microgrid extends beyond direct financial returns to encompass community safety, energy autonomy, and environmental sustainability.

From a revenue perspective, the ReOpt tool simulation predicts an annual income of $23343. The microgrid is anticipated to generate 218,674 kWh in generation to sell as revenue through a power purchase agreement (PPA) with the utility provider. The potential revenue from the PPA and battery capacity payments is estimated to be $17,493 and $5,850 per year, respectively.

While the microgrid is technically feasible and sufficient physical space exists for construction to take place, it is a project that will require a large donation or windfall to be able to economically justify. However, the indirect benefits of the microgrid in its ability to serve as a case study as well as the direct benefit it will have in enhancing community resilience and protecting the well being of local residents must be taken into consideration as well.

Assumptions

A number of assumptions were made when compiling the report, as listed below.

Geospatial Components: Much of the proposed microgrid lies in an area that is difficult to access with heavy machinery, and its location next to the coast suggests that salt-related degradation of critical components may occur more rapidly than a more inland location. Factoring for these variables was considered outside the scope of this analysis, and was thus not considered.

Energy Demand: The inability to acquire exact energy usage data means that the total demand of the structures within the microgrid was calculated utilizing average energy usage of homes of comparable size obtained from an EIA report detailing energy usage in California. For the VFD, kWh/square footage was determined by multiplying the observed square footage by the average energy use intensity reported by the Department of Energy.

Equipment Selection: Due to the relatively nascent status of microgrid technology, specialized components are difficult to source and research. Many of the components selected are of the same make as the equipment as described in the Blue Lake Rancheria microgrid project report, as it is a comparable project.

Expenditures: Due to the complexity of calculating out feasible estimates for the service related costs, heavy assumptions were made with the final determination of various costs. This is included but not limited to the cost of the BESS, the cost of labor, the cost of engineering, energy savings, permitting, and transmission line upgrade costs.

ReOpt Tool: While an excellent way to acquire additional information, the ReOpt tool is not capable of providing site specific outputs, meaning that the values obtained from it are approximations rather than concrete calculations.

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