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Solar Energy Implementation Strategies on Picuris Pueblo

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ABSTRACT

Picuris Pueblo is a small tribal community in Northern New Mexico consisting of about 306 members and 86 homes. Picuris Pueblo has made advances with renewable energy implementation, including the installation of a 1 megawatt photovoltaic (PV) array. This array has provided the tribe with economic and other benefits that contribute toward the tribe's goal of tribal sovereignty. The tribe is seeking to implement more PV generation as well as battery energy storage systems. Picuris Pueblo is considering different implementation methods, including the formation of a microgrid system.

This report studies the potential implementation of a PV and battery storage microgrid system and the associated benefits and challenges. The benefits of a microgrid system include cost savings, increased resiliency, and increased tribal sovereignty and align with the tribe's goals of becoming energy independent and lowering the cost of electricity.

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ACRONYMS AND TERMS

Acronym/Term	Definition
AC	Alternating current
BESS	Battery energy storage system
DC	Direct current
DOE	Department of Energy
DNI	Direct normal irradiation
NREL	National Renewable Energy Laboratory
KCEC	Kit Carson Electric Cooperative
kW	Kilowatt
MW	Megawatt
PPA	Purchase power agreement
PV	Photovoltaic

1. INTRODUCTION

1.1. Picuris Pueblo

Picuris Pueblo is located approximately 24 miles southeast of Taos, New Mexico, in a valley of the Sangre De Cristo Mountains. The tribe consists of 306 members and 86 homes. Picuris Pueblo, like many other tribal communities, is a severely underprivileged community. The median 2020 household income in Picuris Pueblo is $35,625 compared to the national average of $67,521. Additionally, as of 2020, Picuris Pueblo has a poverty rate of 25% compared to the national average of 12.3% [1].

Picuris has many motivations for pursuing energy efficiency and renewable energy projects. One motivation is reducing heating and fueling costs. Many members of the tribe have relied on wood stoves for heating which is the home owner's responsibility. Another motivation is to become more energy independent and reduce reliance on third-party utility companies. Historically, Picuris Pueblo and rural utilities have not had the most positive relationship, partially due to trespassing and lease negotiation issues. However, an additional motivation is to expand on public safety service, energy, and economic development and a desire to improve their relationship with Kit Carson Electric Cooperative(KCEC). Picuris, especially as a remote community, sees the significance of providing and caring for themselves and the surrounding community [2].

There is great potential for renewable energy resources in Indian Country or in other words, US tribal lands. Although tribal lands only make up 5% of the US, it is estimated that they contain 10% of all renewable resources [3]. Particularly in the US Southwest, there is great potential for solar energy production as shown in Figure 1. However, these estimates do not take into account the designated land use status or availability within the tribe'sreservations.

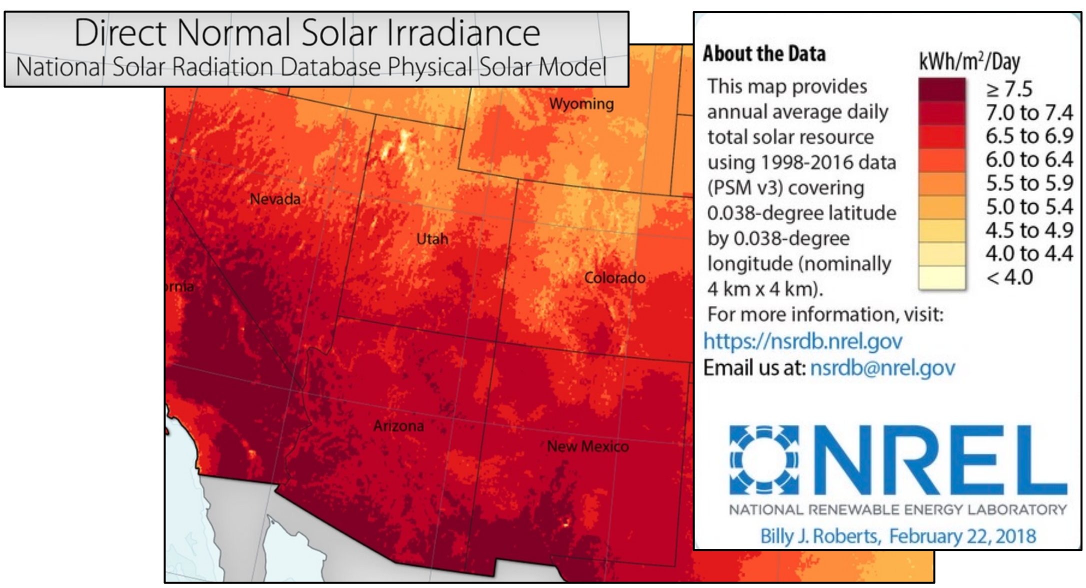

Figure 1. Direct normal solar irradiance resource map of the United States focused on the southwestern United States and surrounding areas

Direct normal irradiation (DNI) is the amount of sun radiation received on a surface [4]. Northern New Mexico, the region where Picuris Pueblo resides, mostly falls into the range of 6.5-6.9 kWh/m^2

per day. This is a high annual average DNI, especially when compared to the rest of the United States.

1.2. Microgrid Technology

A microgrid is a small-scale energy system with the ability to function both independent of the main electrical grid and tied to the grid. In the independent operation, also known as “island mode,” the microgrid can disconnect from the main power grid and provide power to the local load during the day. Island mode operation is beneficial during times of a main power grid outage, as the microgrid still can supply power as long as the interconnection has been disconnected. Microgrids are beneficial in rural situations where the main power grid does not extend out to the desired home, community, etc. Many tribal communities across the United States fall into this category. Extending the grid and transmission lines is expensive, so a microgrid represents an option to establish a reliable power source. Microgrids provide a number of benefits including increased resiliency and economic benefits. [5]

A microgrid can be powered byvariety of energy resources including renewables such as photovoltaic (PV) solar and wind. Battery energy storage systems (BESSs) are often implemented for additional resilience and power. Additionally, gas-powered generators are often used as a backup power source if the main grid is down. Diesel generators are commonly used fuel-based generators [6]. The use of BESSs can reduce and sometimes even eliminate the need for gas-powered generators if sized to meet the energy load.

Another important aspect of a microgrid is the controls system. The controls system is often automated and allows for better communication and electricity flow throughout the microgrid. This system communicates information such as the required load, transition between grid-connected and island mode, BESS status, etc. The controls system can work to optimize and prioritize the use of resources. [5] Blue Lake Rancheria tribe in northern California recently installed a microgrid, in which Siemens Microgrid Management Software is used to manage controls [7].

A basic layout of a PV and BESS based microgrid is shown in Figure 2.

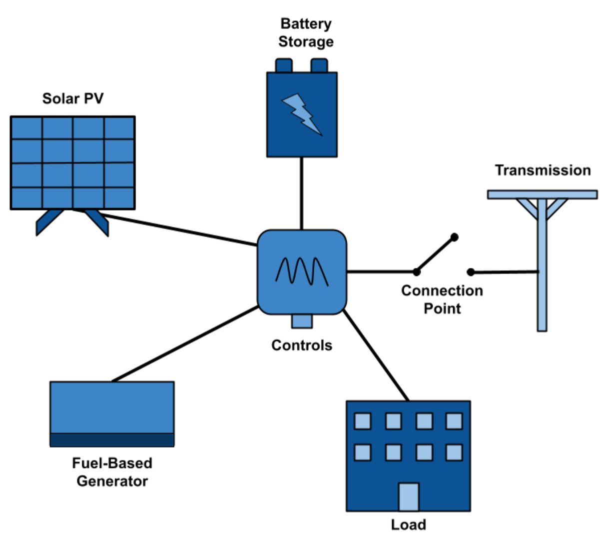

Figure 2. Layout of a sample microgrid system powered by PV, BESS, and fuel-based generators

This microgrid layout can be adjusted for different energy production and storage methods. This includes renewable energy sources such as PV or wind power.

When operating in island mode, there are multiple requirements that the microgrid must meet due to the absence of the main power grid. One requirement is the ability to perform a “black start.” A black start is the ability to start the microgrid on its own without assistance from the main power grid. Another requirement is the ability to meet the surge loads. When certain loads, such as large appliances, start up they require much more power than their regular operating power [5].

A sample operation of a PV, BESS, and generator based microgrid in island mode is shown in Figure 3. This diagram shows the operating strategy. Generators are run through the night and until the morning while there is no sunlight. Once sunlight hits, the BESS begins to be charged. Later in the morning the generators are turned off and the load is powered by the PV and BESS. Eventually there is enough sunlight for the PV to power the entire load, as well as recharge the BESS.

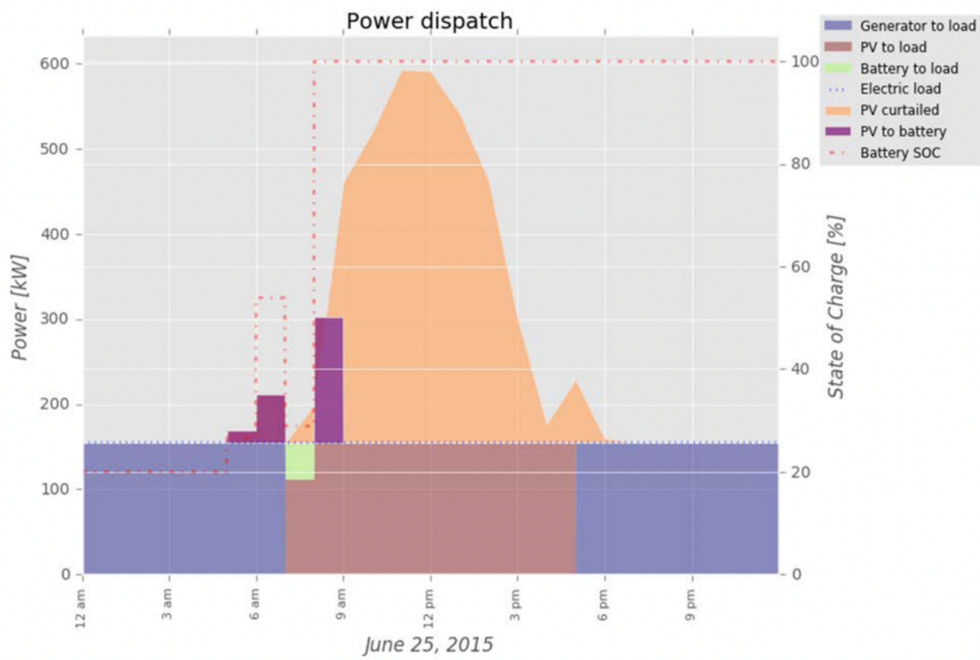

Figure 3. Sample daily operation schedule of a PV microgrid in island mode on June 25, 2015

This schedule demonstrates the importance of the microgrid controls system. Sunlight and other environmental factors are highly variable on a day-to-day basis. Additionally, seasonality changes the schedule and operation times drastically.

When there is an excess amount of energy produced by the PV panels it is referred to as curtailment. This energy is unable to be used because the load demand is lower than the maximum energy production, and the BESS is already fully charged [8]. During a normal grid-tied operation, the PV curtailed energy could be sent back to the grid. Often, through a power purchase agreement (PPA), this electricity is sent to the utility company at a rate per kWh, defined in the PPA.

2. PAST ENERGY PROJECTS ON PICURIS PUEBLO

2.1. 1995 Project

In 1995, Picuris Pueblo completed an energy study for their community center that was being expanded. Through this energy study, energy enhancement features for the center were identified and implemented. This enhancement sought to improve energy efficiency and better utilize natural resources like solar energy. Implemented features include a solar hot water system and ventilation heat recovery, clerestory windows, better insulation, and high-intensity discharge lights. The community center is 9,050 square feet and named Tol-Pit-Tah (The Sun Center). [9]

2.2. 2016 Project

In 2016, the tribe began implementation of a 1 megawatt (MW) grid-tied solar PV array, which was completed in December 2017. The array is a 1.2 MW direct current (DC) array; but due to energy losses through the inverter, it produces 1 MW alternating current (AC). Additionally, the array is ground-mounted and has a fixed-tilt (not an adjustable tilt to maximize the angle of the panels to the sun). This project was partially funded through a DOE Indian Energy grant received through a competitive application process. The 1 MW PV system has 18 modules per string of PV panels and 199 strings in parallel. Each PV module is rated at 325 W. A single central inverter is used to convert the current from DC to AC. [2] The layout of the solar array and transmission lines is shown in Figure 4.

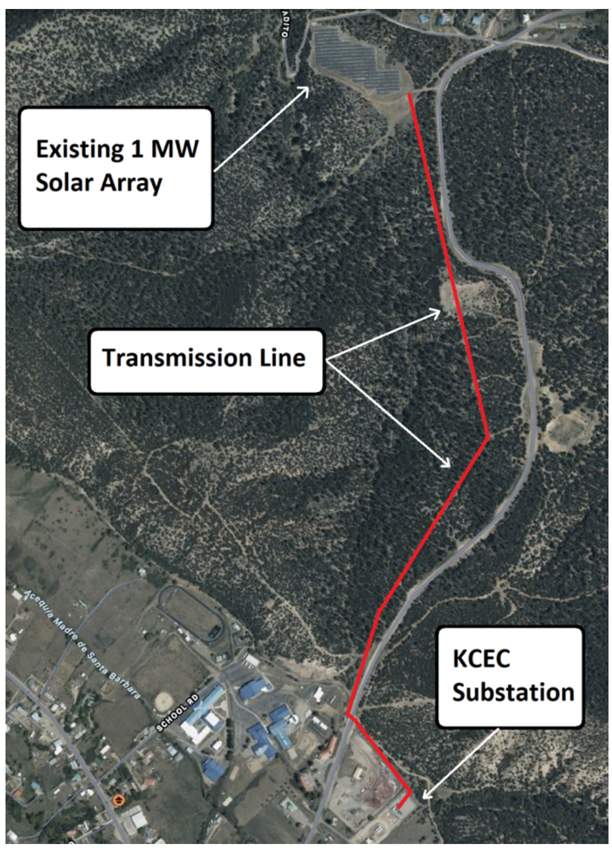

Figure 4. Arial view layout of the existing 1 MW solar array and transmission lines to a KCEC substation on Picuris Pueblo

The tribe has a 25-year PPA with KCEC, which began in 2015. Through this PPA, KCEC purchases the energy generated by the solar array at a rate of $0.09/kWh. The energy and money generated by the 1 MW solar array from January 2018 to March 2020 is shown in Table 1.

Table 1. Power output and PPA revenue of Picuris Pueblo 1 MW solar array

Month	kWh	PPA Revenue ($0.09/kWh)
Jan-18	53,451	$ 4,811.00
Feb-18	98,853	$ 8,897.00
Mar-18	137,280	$ 12,355.00
Apr-18	214,689	$ 19,322.00
May-18	235,691	$ 21,212.00
Jun-18	83,745	$ 7,537.00
Jul-18	128,927	$ 11,603.00
Aug-18	200,514	$ 18,046.00
Sep-18	195,997	$ 17,640.00
Oct-18	149,142	$ 13,423.00
Nov-18	140,677	$ 12,661.00
Dec-18	103,348	$ 9,301.00
Jan-19	96,186	$ 8,657.00
Feb-19	90,733	$ 8,166.00
Mar-19	149,337	$ 13,440.33
Apr-19	176,355	$ 15,871.95
May-19	203,726	$ 18,335.34
Jun-19	203,956	$ 18,356.04
Jul-19	50,786	$ 4,570.74
Aug-19	190,542	$ 17,148.78
Sep-19	156,388	$ 14,074.92
Oct-19	65,623	$ 5,906.07
Nov-19	32,301	$ 2,907.09
Dec-19	25,496	$ 2,294.64
Jan-20	76,276	$ 6,864.84
Feb-20	45,829	$ 4,124.61
Mar-20	173,951	$ 15,655.59

The revenue generated from the 1 MW solar array is used partially for personal tribal household energy subsidies. In the four winter months, each household gets a $75.00 subsidy toward energy costs with an average winter household monthly energy bill of $132.35. In the eight non-winter months, a $50 subsidy is received with an average household monthly energy bill of $86.23. [10] This 1 MW PV array has proved to be successful for the tribe, as all residential tribal members receive economic benefits.

2.2.1. Technical Analysis on 2016 Project

Technical performance analysis was performed on the 2016installed 1 MW solar array in Picuris Pueblo. The analysis modeled the power output of the solar array based on the surface tilt of the solar modules. Currently the solar array is fixed mount at 30°. The power output was modeled at various tilt angles ranging from 25 - 45°, including the latitude angle of 36.45°. This analysis was performed using Sandia's PVlib library in the software code Python specifically using thethe National Renewable Energy Laboratories (NREL)'s PVWatts model method. Parameters from the solar modules and central inverter were input into the code. Weather data from nearby Taos, NM was input through a typical meteorological year. Results from the analysis are displayed in Figure 5.

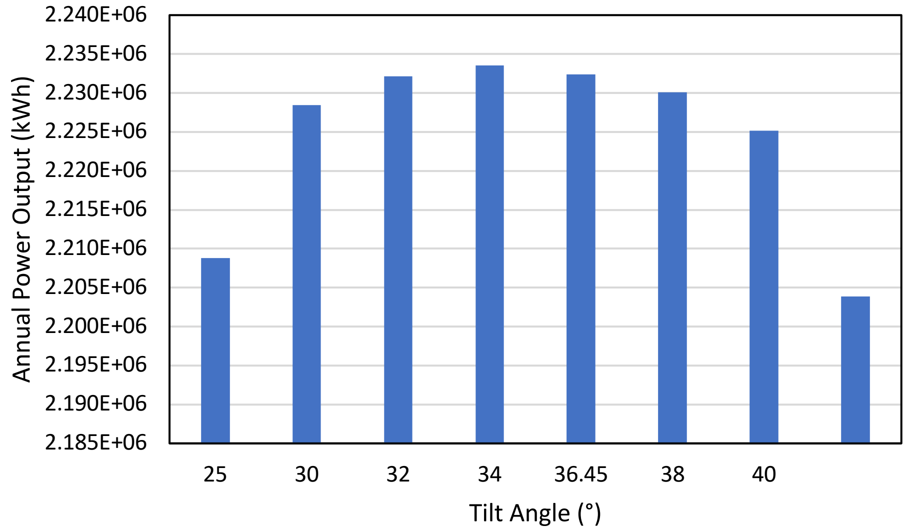

Figure 5. Annual power output of 1 MW solar array on Picuris Pueblo with varying tilt angles

As shown in Figure 5, the highest estimated annual power output occurs at a tilt angle of 34° with 2,233,566 kWh. This is slightly higher than the output at 30°, the current fixed tilt. Tilting the PV modules at 34° could potentially show a slight increase in power output compared to a 30° tilt based on the PVWatts model. Other modeling methods should be tested and analyzed to make any decisions for future PV arrays. The cost to modify an existing PV array is not feasible or realistic as the system is in operation. A different tilt angle designs should be considered for future projects.

3. CURRENT SOLAR PROJECT

Picuris Pueblo is currently seeking to implement another PV project as well as energy storage for the community. The tribe has already secured a DOE grant to help fund this project. Additional funds from Wells Fargo and 11th Hour Project have been approved [10]. The tribe must decide on placement of the PV energy plant. One placement option is to form a microgrid with the PV and BESS. The other placement strategy would be to create another grid-tied solar array, similar to the first 1 MW solar array project.

The following sections look at the outcomes and benefits of implementing the PV and BESS in a microgrid. Unlike the previous utility-scale PV array, this microgrid will directly power various tribal buildings (including the new tribal travel complex) and homes. The microgrid will be used as the primary power source, and any additional needed power will be purchased from the main grid or Kit Carson. This microgrid project will use PV for power generation and BESS for power storage.

3.1. Microgrid Outcomes and Benefits

There are three major outcomes with implementing a microgrid project:

- Economic benefits of a microgrid and energy production.
- Increased resiliency.
- Increased tribal sovereignty.

3.1.1. Cost Savings

A primary goal of implementing a microgrid is to obtain and utilize the economic benefits of a microgrid and energy production. This includes the goal of lowering the cost of electricity. With the previous 1 MW solar array, community members already saw over 50% of their electric bill covered. A goal of the new project is to cover 100% of tribal member's electric bill with the additional power and revenue generation. [10]

The price of solar energy has dropped significantly in recent years. From 2010 to 2020 the price of utility-scale PV energy dropped 85%. Once a luxury, solar energy is now a realistic and cost-effective option for many. For most areas, renewable energy including PV is the least expensive and most cost-effective energy option [11].

The prices of electricity will drop with the transition to more PV power. These cost savings come from less energy being purchased off the main grid and more energy being generated. Estimates suggest that the price per kW will be decreased by 60-67% through general solar implementation [10].

The implementation of energy storage through BESS will further save on energy costs. BESS allows additional solar energy to be utilized. When the solar energy generation exceeds the desired load, such as during some daytime hours, any excess solar energy is be stored in the BESS. This stored solar energy can be used in a time when the solar energy generation does not meet the required load, such as during evening and nighttime hours. Using stored power allows for less power to be purchased from the main power grid.

BESS can also save money through a technique called peak shaving. Peak shaving reduces the amount of energy used from the grid during peak energy demand hours (when energy prices are highest). This can be done through strategic charge and discharge of the BESS. [12] An example of peak shaving is shown in Figure 6.

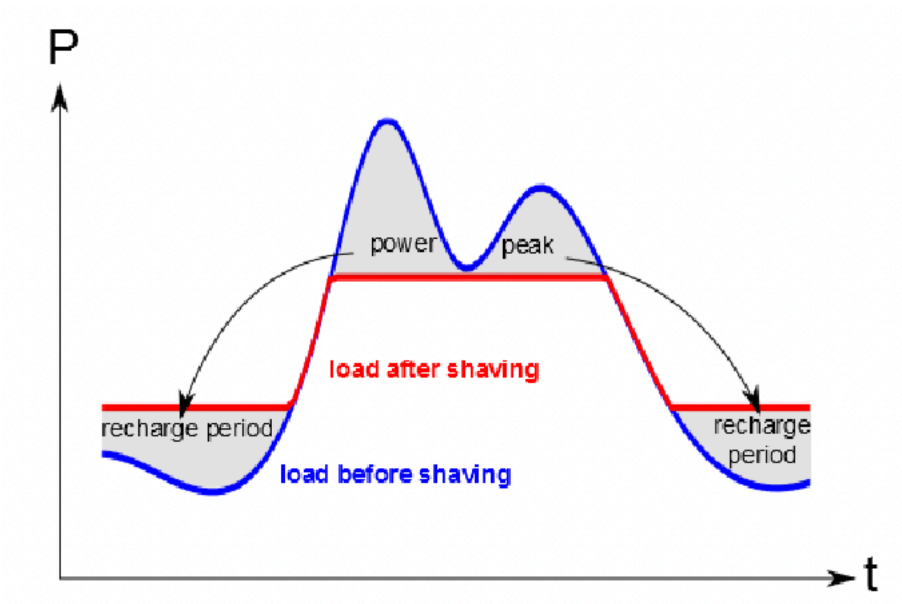

Figure 6. Example of peak shaving in a power load schedule – y axis power, x axis time

To maximize the cost saving benefits of BESS, optimized sizing and operation is significant [12]. Optimized BESS can have additional savings such as lowered demand-related charges and reduced generator fuel costs during island mode operation.

3.1.2. Resiliency

A second major outcome of a microgrid project is an increase in resiliency. Resilience describes the ability to prepare and respond to changing energy conditions. A microgrid can mitigate the effects of a drastic change such as a main power grid outage by supplying a select amount of power to the community. Alternatively, a grid-tied PV system without energy storage cannot provide any power during a main grid outage; when the grid goes down, the PV system goes down [13].

Grid outages are often caused by natural disasters such as wildfires, floods, ice, and snow. Natural disasters have seen an upward trend in frequency, with climate change being a major factor. Consequences of this include a longer fire season, and more frequent and intense storms [8]. Additionally, the number of outages caused by such weather has doubled over the past two decades [14]. Particularly in northern New Mexico, fires are frequent and pose a threat to the electric grid. A microgrid can provide more resilience to a community if the system can independently generate electricity when the rest of regional system has an outage due to a threat like a fire.

There are different ways of quantifying resilience. This includes outage time, percentage of customers affected, and critical services affected. Additionally, there are ways to economically value resilience such as the cost of grid damages, cost of business interruptions, and avoided outage costs. [15].

NREL conducted a resilience case study on a microgrid project. This study looked at an 845 kW PV, 155 kW and 172kWh BESS, and 305 kW diesel generator microgrid system. The sizing of the PV and BESS were optimized completely on economics and not on resiliency. The study found during a grid outage, the microgrid system could supply the critical load for 3.5 days at 90% probability. This is compared to a 305 kW diesel generator system that could supply the critical load for 1.7 days at 90% probability. The assumption was made that no additional diesel was supplied or imported after the outage. Ninety percent probability means the critical load will be met for 90% of outages. Additionally, the microgrid system would be able to supply some or all the critical load during daylight hours. The results of this study clearly show microgrid technology can have a significant positive impact on the resilience of an energy system (during a fire), especially when compared to grid-tied solar. Grid-tied PV provides no additional resilience when the power grid goes down and is not functionable [8].

3.1.3. Tribal Sovereignty

A third major outcome of a microgrid project is an increase in tribal sovereignty. Tribal sovereignty is the tribe's ability to be self-sufficient and reliant. A microgrid project will lead closer to true tribal sovereignty for Picuris Pueblo. An important aspect of tribal sovereignty is being able to provide power to its own people [16]. A microgrid project will not only power the tribe but will be a large source of revenue as well. This project will make the tribe more energy independent and will decrease their reliance on third-party rural utilities. These benefits lead to better long-term sustainability for the tribe.

3.2. Engineering Considerations

An important step in the microgrid planning process is appropriately sizing the features of the microgrid such as the main energy source (PV), energy storage (BESS), and back up fuel-based generators. The appropriate sizing of these aspects will optimize the use of renewable energy resources[12]. The tribe's main goal is seeking economic benefits, so optimization should be primarily based on costs.

Mathematical optimization algorithms are often used to maximize the benefits of microgrid systems. Mixed-integer quadratic programming and mixed-integer linear programming are two methods that can be used to optimize the use of BESS [12].

When operating in island mode, there may not be enough power from PV and BESS to provide the required load to the whole community. This issue is often resolved by use of back up diesel generators, which provide additional support in such critical situations. Microgrid technology, if properly sized and optimized, can have the ability to reduce the usage of diesel generators during island mode operation.

4. CONCLUSION

Based on the benefits, a PV and BESS microgrid project is more beneficial for Picuris Pueblo than implementing additional grid-tied PV with better economic benefits, resilience, and positive impacts on tribal sovereignty. Economically, a microgrid is better because the power goes directly to the tribe as opposed to being purchase of power from the electrical provider. A microgrid also has resiliency benefits that grid-tied solar does not. In cases where the grid is down a microgrid can still provide for periods of time power to the tribe, whereas grid-tied solar cannot. Through better energy independence and additional revenue, the tribe will become less reliant on third-party rural utility electric cooperatives.

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