SOLARIZING THE ISLAND OF CULEBRA, PUERTO RICO:
RATE-DESIGN MODEL AND ANALYSIS

by

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Executive Summary

Power on the island of Puerto Rico has historically been served through a centralized generation system that has largely failed to provide reliability— ability of the grid to provide the right quantity and quality of electricity needed and operate in times of stress — and resilience— the ability of the grid to come back online quickly and for all consumers after a major disruption. This master's project team is working with the *Fundación Comunitaria de Puerto Rico* (FCPR; Puerto Rico Community Foundation) to support the Caribbean's first community-owned solar utility in Culebra, Puerto Rico to improve grid reliability and to foster community energy independence.

The idea behind Culebra's solar utility is simple: 50 businesses, non-profits, and critical facilities will pay for the energy service provided by the utility through rooftop solar and battery systems that have been fitted to meet the individual facility energy needs. These entities that purchase this utility electricity become subscribers to the service, and these payments will allow for operation and maintenance (O&M), equipment replacement, system expansion and any other necessary services to be sustained. A SWOT analysis is provided to identity the different Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T) for the project.

The core objective of this project is the development of a rate-design model to evaluate the optimal rate to charge the subscribers of this solar utility. This rate-design model has three parts – Revenue, Costs and Financial Statements. For the revenue calculations, a load curve for an average subscriber was fitted based on historical consumption data. This information was used in a Monte Carlo simulation to model subscriber demand on a monthly basis. This simulated subscriber demand was compared with solar production forecasts to compute monthly revenue per subscriber. Four types of costs were considered in this analysis: Operations and Maintenance, Administrative, Insurance and Correction costs. All costs are increased annually with inflation.

An analysis of the cost-breakdown results shows that correction cost is the largest cost component, however this declines over time. Operations and maintenance is the second largest component, followed by administrative and insurance costs. The results from the revenue and

cost analysis were used to compute an Income Statement and Statement of Cash Flows for the solar utility.

A set of sensitivity analyses were conducted to assess the effect of input parameters such as inflation, PREPA electricity rate, solar utility electricity rate, and taxes on output metrics such as net income, profit margin, subscriber savings, annual revenue and costs. A combination of the rate-design model and various sensitivity analyses suggest an ideal rate of $0.19/kWh for FCPR to charge to subscribers for the solar utility project. FCPR has already submitted an electricity rate of $0.21/kWh to the Puerto Rico Energy Bureau. This team's analysis shows that the $0.21/kWh rate will help realize significant subscriber savings and ensure the viability of the solar utility project over its initial lifespan of 10 years and beyond. This project is expected to yield $2,600 of annual savings in electricity payments for subscribers and lead to the abatement of 1076 MT CO_2e annually.

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Figures and Tables

List of Acronyms

EDA	Economic Development Administration
FCPR	Puerto Rico Community Foundation (*Fundación Comunitaria de Puerto Rico*)
FCPRS	Puerto Rico Community Foundation Services (*Fundación Comunitaria de Puerto Rico Servicios, Inc*.)
IRP	Integrated Resource Plan
NGO	Non-Governmental Organization
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
PREB	Puerto Rico Energy Bureau
PREPA	Puerto Rico Electric Power Authority
PV	Photovoltaic
REC	Renewable Energy Certificate

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Introduction

A movement toward a decentralized power grid is happening in Puerto Rico. Recent storms in 2017, Hurricane Irma and Hurricane Maria, significantly damaged the island's already-aging energy infrastructure and turned up the volume on the call for grid alternatives (DOE, n.d.; Mazzei et al., 2020). Hitting just two weeks apart, Hurricanes Irma and Maria led to 80% of the transmission and distribution network being rendered inoperable and corresponding power outages that affected over 1.5 million of the island's electricity customers (EIA, 2021b; McArdle, 2019). In what is considered the longest blackout in US history, a quarter of electricity customers of the island were without electricity for over 100 days following Hurricane Maria's landfall (Marsters & Houser, 2017). Many who live in difficult to reach areas, such as the mountainous corridor in the central region of the island, waited even longer to see power restored (Chasteen, 2018).

Power on the island of Puerto Rico has traditionally been served through a centralized power generation system that has largely failed to provide grid reliability— ability of the grid to provide the right quantity and quality of electricity needed and operate in times of stress — and resilience— the ability of the grid to come back online quickly and for all consumers after a major disruption. Additionally, the electricity rates seen in the territory are the third highest when compared to the US fifty states due to heavy fossil fuel dependence, further increasing inequities in energy access (EIA, 2021b). Now, new methods of generating and managing energy generation are being imagined with the hope that grid alternatives can increase reliability and resilience for residents, as well as electricity affordability. Such a movement will help safeguard energy availability during the aftermath of natural disasters, such as tropical storms and earthquakes, and during the frequent main grid outages that are all too common.

This master's project team is working with the *Fundación Comunitaria de Puerto Rico* (FCPR or Puerto Rico Community Foundation in English), a community-based nongovernmental organization (NGO) that has a history of successful grid alternative projects throughout the island. FCPR is currently working on a project focused on a small island off of the main Puerto Rico island called Culebra. Culebra receives its energy service through an underwater transmission cable that connects the mainland Puerto Rico to the larger island Vieques first

(Campbell et al., 2017). This transmission system was left damaged following the 2017 hurricanes, leaving Culebra residents in the dark for 3 months, and highlighting the small island's energy grid vulnerability (Salasovich & Mosey, 2019).

FCPR's project is to establish a renewable energy utility which will provide businesses, NGOs, and critical facilities (hereon collectively referred to as "businesses") with an energy service that is more reliable, resilient, and affordable than the energy service they currently receive. The technology used will be rooftop solar photovoltaic (PV) panels and battery storage, and as such, the project is being referred to as a solar utility. At this time, the project is expected to start construction in 2022 and have 50 initial energy customers subscribed to the solar utility.

This master's project seeks to develop a rate-design model to suggest a solar utility rate to be charged to the subscribers in Culebra. This rate will be determined with the objective of making the solar utility financially sustainable for the initial project period of 10 years and onward. Additionally, several sensitivity analyses are performed to assess the impact of varying model inputs on utility finances and project benefits. These results will provide FCPR with insights on key decision-making aspects of the business.

Objectives

This master's project seeks to achieve the following objectives:

1. **Rate-Design Model:** Develop a rate-design model to determine the optimal rate to charge subscribers of the solar utility for a period of 10 years.
2. **Cost Breakdown Analysis:** Estimate a breakdown across different cost headers to ensure financial sustainability of project operations.
3. **Benefits:** Estimate direct benefits to subscribers in terms of subscriber savings and co-benefits in terms of emissions abated with the displacement of the existing generation mix with solar energy generation.
4. **Sensitivity Analysis:** Assess the effect of changes to the input parameters of the rate-design on the benefits and financial sustainability of the project**.**

Background

Energy Grid Owners and Operators

Puerto Rico's energy grid is centralized, meaning that large-scale energy generation occurs at centralized locations and is distributed outward to energy customers throughout the island via a transmission and distribution system. Combined, these three components—generation, transmission, and distribution—make up the electric system. For scale, Puerto Rico's electric system contains 2,400 miles of transmission lines, 30,000 miles of distribution lines, and 300 sub-stations (Task Force Power Restoration (PR), 2018). There are two main entities that current own and operate these components of the system in the territory.

Historically, Puerto Rico's sole electric utility provider has been the Puerto Rico Electric Power Authority (PREPA), a publicly-owned utility that owns transmission, distribution, and approximately 86% of generating capacity for Puerto Rico (EIA, 2021b). In 2017, PREPA filed for bankruptcy after accumulating over $9 billion in debt (Hirsch & Brown, 2017). The following year, the Puerto Rico legislature approved measures to restructure PREPA and to allow parts of the agency to be privatized, to help PREPA overcome bankruptcy (EIA, 2021b).

In 2020, PREPA and Puerto Rico Public-Private Partnership Authority chose LUMA, a private joint venture company, to manage the transmission and distribution components of the grid (AFAF, n.d.). This public-private partnership between PREPA and LUMA was intended to facilitate the energy sector transformation on the island(*The Transformation of the Puerto Rico Electric Power Authority (PREPA)*, 2020). LUMA's 15-year transmission and distribution contract was implemented in 2021. In sum, PREPA continues to *own* generation, transmission, and distribution, while LUMA now *operates* transmission and distribution.

Puerto Rico Energy Landscape

Energy generation in Puerto Rico is fossil fuel dominated. Currently, Puerto Rico has an installed capacity of 5,839 MW, out of which only 2% comes from renewable energy (NREL, 2020). In 2020, 97% of all generation came from petroleum, natural gas, and coal. Natural gas generation accounted for 44% of total generation while petroleum contributed to 37%. The island's only coal plant in Guayama was responsible for 17% of all generation while renewables lagged behind at 3% (EIA, 2021b). The island's generation mix between January 2019 to March

2020 can be referred to in Figure 1. This heavy dependency on fossil fuels comes at a substantial cost as all of them need to be imported. Puerto Rico spends around $3.54 billion on fossil fuel imports, accounting for 3.5% of its GDP (NREL, 2020).

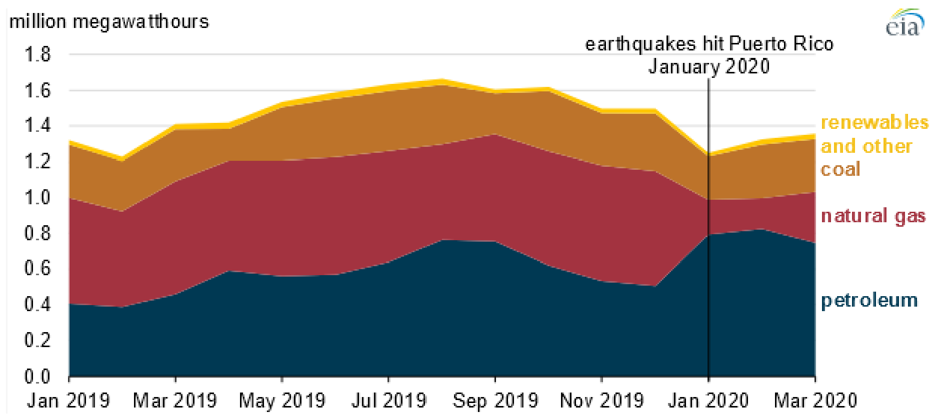

Figure 1. Monthly Puerto Rico net generation by fuel type (Jan 2019 - March 2020) (McArdle, 2020).

This high fossil fuel dependency has significant consequences for electricity ratepayers. The average price of electricity in Puerto Rico in 2020 was higher than all but two US states, and per-capita electricity use was around one-third of average consumption across the 50 states (EIA, 2021b). Heavy reliance on petroleum for electricity generation is a contributing factor to the disproportionately high electricity rates on the island (EIA, 2021b). According to PREPA, the purchase of fossil fuels makes up approximately 65% of the cost of electricity to consumers and, as a result, fluctuating prices associated with buying these fuels are reflected in the consumers' energy bills (PREB, 2022) (Figure 2).

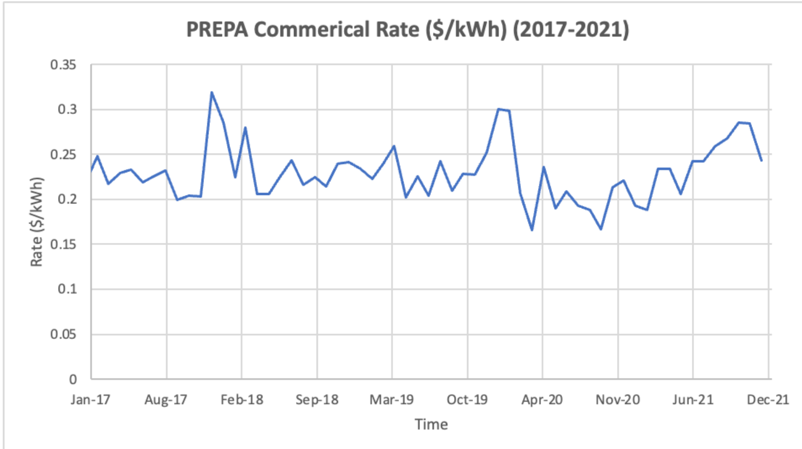

Figure 2. PREPA rate charged to commercial enterprises between 2017-2021.

Every three months, the Puerto Rico Energy Bureau (PREB) evaluates and approves quarterly reviews of rate adjustments (LUMA, 2021). The most recent rate increase was approved in March 2022 and set the residential electricity rate at $0.29/kWh for April-June 2022 (PREB, 2022) (Appendix 3). This is an increase of 13%, up from $0.26/kWh in the previous quarter (PREB, 2022). This rate increase reflects a general trend upward over the past five years, with the cost of electricity being $0.20/kWh in 2017 (Hoff, 2018; Lu & Alcantara, 2018).

Natural Disasters and the Grid

Puerto Rico is particularly vulnerable to natural disasters such as hurricanes and earthquakes and these events can have drastic consequences on the island's electric grid. Following the landfall of Hurricane Maria, net electricity generation on the island collapsed from 1.57 million MWh in August 2017 to 0.27 million MWh in September 2017 (Figure 3). For four months after the hurricane, coal and renewable units were completely offline as the grid relied on natural gas and petroleum power (McArdle, 2019). It took six months after Hurricane Maria for power to be restored to over 90% of consumers across Puerto Rico, with some municipalities in remote regions remaining at less than 80% (Chasteen, 2018).

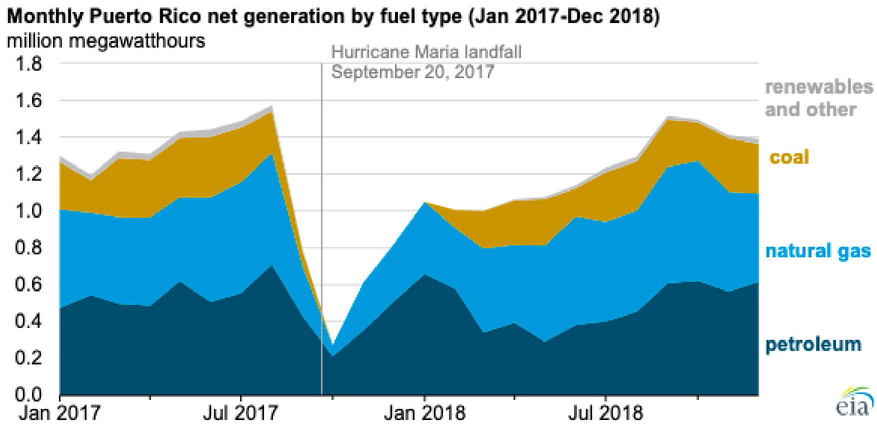

Figure 3. Monthly Puerto Rico net generation by fuel type (Jan 2017 - Dec 2018) (McArdle, 2019).

In addition to causing widespread outages, natural disasters can have bounce back effects on efforts to move away from petroleum dependence. For instance, at the turn of 2020, Puerto Rico was hit with a 6.5 magnitude earthquake. This caused damage to the Costa Sur and EcoEléctrica natural gas-based power plants—the island's two largest power plants (EIA, 2021b). This event caused a spike in petroleum-based electricity generation, jumping from around 0.4 million MWh in early December 2019 to around 0.8 million MWh in January 2020 (Figure 1). As the intensity and frequency of storms has increased in recent decades and is expected to continue increasing due to climate change-related effects, adding grid resilience is essential (EPA, 2016).

Increasing Momentum for Clean Energy

Measures to increase clean energy on the island are helping to reduce dependence on fossil fuels and alleviate pressure for increasing rates. A transition to a cleaner future was outlined in the Puerto Rico Energy Public Policy Act ("Act") (2019). This document charts a path for Puerto Rico to realize 100% renewable energy by 2050. Interim goals include meeting 40% renewable energy generation by 2025, the phaseout of coal-fired generation by 2028, a 30% improvement in energy efficiency by 2040, and 60% renewable energy generation by 2040 (DOE, n.d.) (Figure 4). Notably, the Act has provisions that specifically aim to facilitate the development of renewable energy projects (Puerto Rico Energy Public Policy Act, 2019).

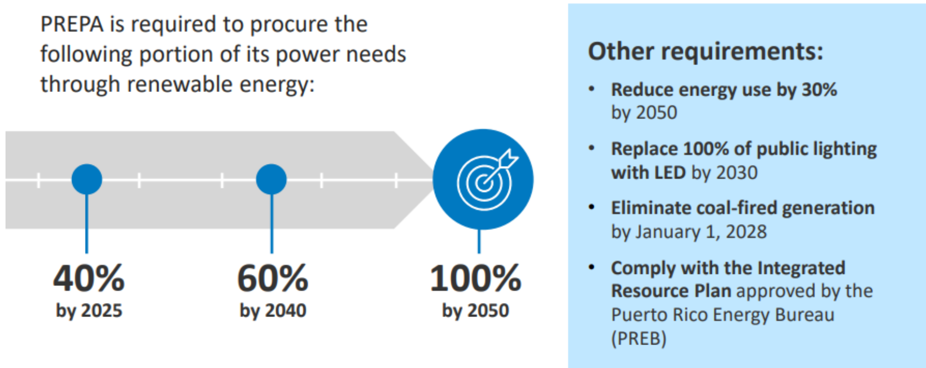

Figure 4: Puerto Rico's Grid Decarbonization Goals (PR100: Puerto Rico Grid Resilience and Transition to 100% Renewable Energy, 2022).

This momentum involves off-grid developments as well. An estimated $400 million is being invested in solar energy by businesses, individuals, and communities to develop grid alternatives (Peñaloza & Allen, 2019). Projects such as FCPR's establishment of a solar utility on Culebra, increase clean energy consumption in addition to meeting overarching reliability and resilience goals.

Culebra, Puerto Rico

Culebra is a small island municipality with a land area 28 km^2, located 27 km east of the Puerto Rico mainland. With a population of 1,792 as per the 2020 census, Culebra is Puerto Rico's least populated municipality (U.S. Census Bureau, n.d.). Median income on Culebra is $25,658 (U.S. Census Bureau, n.d.). There are just over 60 businesses total on the island (FCPR, n.d.-b). The small island is accessible to the mainland via a 45-minute ferry ride from the town of Ceiba and by flights from Ceiba and San Juan, the capital of Puerto Rico. With its many beaches and nature reserves, Culebra is a largely tourism dependent economy.

Figure 5. A map of the undersea transmission line connecting the main island of Puerto Rico to the island of Vieques, followed by the island of Culebra (in red). ("Culebra, Puerto Rico," 2022).

The island receives most of its electricity via an undersea transmission line from the main island. This 38 kV line connects the main island first to Vieques and then goes on to Culebra (Figure 5) (Campbell et al., 2017).

Hurricane Impacts on Culebra

When Hurricane Maria struck in September 2017, it de-energized the transmission line from the mainland to Vieques by damaging the connections and towers on either side of the line (Sotomayor, 2020). This separated both the islands of Vieques and Culebra from the mainland grid, leaving the island municipalities without power and communication for weeks before regular ferry transport resumed (Sotomayor, 2020).

Power was eventually restored in December 2017 with the installation of two large diesel generators by the Federal Emergency Management Authority and the U.S. Army Corp of Engineers. These generators were used intermittently to provide baseload power, primarily during the evening hours for lighting and cooling, along with powering telecom infrastructure for communication (Lloréns Vélez, 2019; Sotomayor, 2020). It took until March 2019 (over 15 months), for undersea transmission to be restored by PREPA (Lloréns Vélez, 2019). PREPA also approved the construction of a 6 MW diesel generation project in Culebra, consisting of three, 2 MW high-speed diesel generators (PREPA, 2017). These are intended to provide backup power in the event of supply disruptions from the transmission line. Culebra has a peak load of approximately 2.4 MW and the excess capacity of this 6 MW project has the additional benefit of providing backup capacity to Vieques (PREPA, 2017).

FCPR's Solar Utility in Culebra

FCPR Renewable Energy Projects

Increasing Renewable Energy adoption became one of FCPR's main priorities following Hurricane Maria (FCPR, 2021). As such, FCPR created a strategic plan to encourage community energy independence through electricity production, beginning with projects that connect local homes to grids, followed by projects that create energy independence for businesses, and finally by a project to create a corridor of renewable energy access in the central zone of Puerto Rico. More information on some of FCPR's renewable energy projects follows:

1. **Toro Nego Microgrid (2018):** A microgrid serving 28 homes with off-grid solar energy in Toro Negro, Ciales became Puerto Rico's first community-owned solar system, an effort spearheaded through a partnership between FCPR and Somos Solar, a solar PV focused NGO (FCPR, n.d.-c).
2. **Esperanza Village Microgrid (2019):** A microgrid connecting 9 low-income rental homes Puerto Rico's first certified microgrid system was established through a partnership between FCPR and the San Salvador Energy Cooperative Pirucho Co-op in Esperanza Village, Caguas (NimB, 2021).
3. **Culebra Solar Utility (2022):** A solar utility that will serve an initial 50 businesses and nonprofits on the island of Culebra is currently in the construction phase of the project. This project has received a contribution from the Economic Development Administration and other philanthropic investors (FCPR, 2021).
4. **Green Energy Corridor (Study in progress):** A viability study is currently being done to assess the potential to have a Green Energy Corridor to connect communities in the central part of Puerto Rico with access to renewable energy resources (FCPR, n.d.-c).

This master's project assists FCPR with the establishment of the Culebra Solar Utility. Building off previous successes, this project will provide additional learning opportunities for FCPR's future renewable energy projects.

Solar Utility: Basics

The idea behind the solar utility is simple: Businesses will pay for the energy service provided by the utility through rooftop solar and battery systems that have been fitted to meet the individual facility energy needs. These businesses that purchase this utility electricity become subscribers to the service (Figure 6).

This solar utility differs from previous projects in that it is not a microgrid system that distributes energy to customers but rather a network of rooftop solar and battery storage system that are located at individual businesses. Rooftop solar was seen as a more viable option for this solar utility as compared to developing a centralized microgrid, at least in part due to space restrictions on the island (FCPR, personal communication, December 1, 2021). Rooftop solar allows for power to be drawn directly from the system to meet the energy needs of that facility.

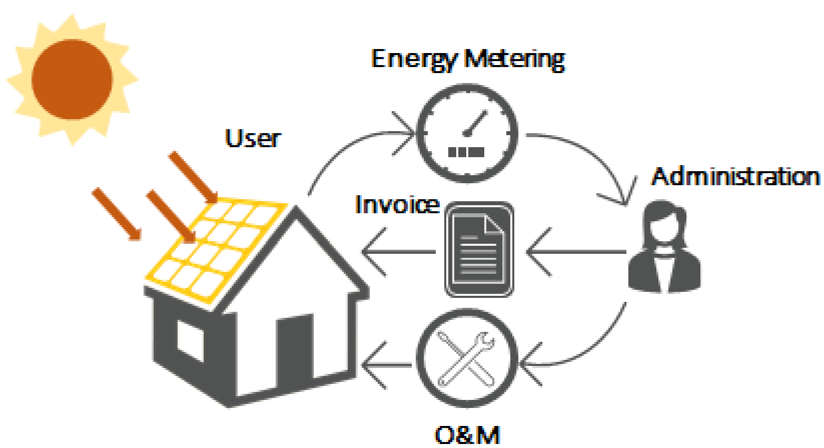

Figure 6. Subscriber-Utility Relationship (FCPR, n.d.-b).

While renewable energy is often thought of as "free" electricity since there are no fuel costs associated with PV solar electricity production, the subscribers of this utility will pay for the electricity consumed from their systems. From the utility standpoint, these payments are critical to the long-term success of the project because it allows the utility to address system operation and maintenance (O&M), equipment replacement, expansion, and other operational costs to ensure continued service. Subscribers will purchase electricity at a $0.21/kWh rate that has already been submitted to PREB. This rate is lower than the approximate $0.28/kWh rate businesses were paying the PREPA utility between January-March 2022, making it a more cost-effective option (LUMA, 2022b).

Under the solar utility model proposed by FCPR, initial capital costs and installation are covered through the project grant, while the utility covers any maintenance needs. In 2019, the Economic Development Administration (EDA) granted $4.1 million to FCPR as part of the Tax Cuts and Jobs Act Opportunity Zone program and was matched with $1 million in local funds to be directed toward capital costs (EDA, 2019). All operational and maintenance needs of the panels and systems will be the responsibility of the solar utility.

Solar Utility: Infrastructure

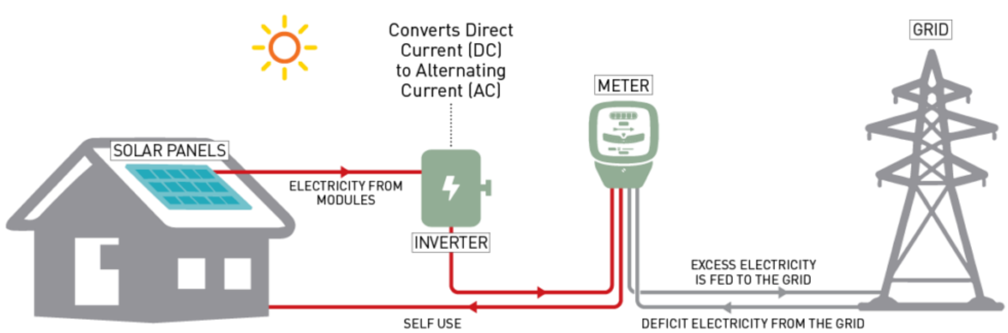

Figure 7. Grid Connection and Net Metering (Patel, 2019).

This project is anticipated to have an initial cumulative generating capacity of 950 kW to meet the energy needs of 50 businesses (PREB, 2021). These numbers are expected to grow as more businesses subscribe to the utility and new systems are installed. The solar panels to be used for this project have a power output of 440-450 W and the average DC system size for a subscriber is 17.7 kW. Hurricane resistant racking is used to safeguard the solar systems during any extreme weather events. More information about the solar systems can be referred to in Appendix 1.

The subscribers enrolled in this program will continue to be connected to the grid infrastructure. This means that subscribers can access PREPA's default utility electricity if the solar system production is not sufficient to meet demand. Further, systems will have net metering option, meaning that they will have the ability to sell energy that is generated in excess back to the broader electric grid (Figure 7). This provides both a financial benefit to the subscriber, and an ancillary benefit of providing the local grid with clean energy.

Though the subscribers remain connected to the grid, the systems also have islanding capabilities. Islanding refers to the ability of a solar panel system to isolate from the grid and continue generating electricity even when there is a power outage on the main grid. Solar islanding for grid-connected systems is made possible when an inverter is able to disconnect the system from a grid (Palmetto, n.d.). Combined with battery storage, the systems can provide a critical source of electricity during a grid disruption.

Electric Service Company

A subsidiary of FCPR, *Comunitaria de Puerto Rico Servicios, Inc.* (FCPRS), will be in charge of day-to-day management of the solar utility. Currently, FCPRS is not a recognized as an Electric Service Company by PREB. PREB requires an organization to register as an Electric Service Company when the total generating capacity reaches an aggregate 1 MW or more (PREB, 2021). FCPRS's anticipates an initial generating capacity of 950 kW and must apply to be an Electric Service Company once reaching 1 MW.

While FCPR has a critical role in establishing the project and accompanying managing subsidiary, the solar utility is not meant to live indefinitely with FCPR. The utility will be owned and operated by FCPR for the first 10 years of the project, after which the assets will be transferred to a community board in Culebra (FCPR, n.d.-a).

SWOT Analysis

A SWOT analysis is provided to identity the different for the project. A SWOT analysis is a way to identify and categorize the Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T) that affect the project. These are grouped into internal factors (strengths and weaknesses) and external factors (opportunities and threats) (Figure 8). This framework is a useful tool in guiding the strategic plan by providing useful insights on the functionality of different components of the project.

STRENGTHS	WEAKNESSES
·Financial support for initial capex ·Rooftop solar and battery storage ·Continued access to the main grid ·Net metering capabilities ·Abundant solar resources ·Ability to expand subscriber base ·Inventory availability	·Unavailability of skilled workforce ·Low granularity of data ·Inability to meet full demand
OPPORTUNITIES	**THREATS**
·Grid decarbonization goals ·Development of REC market ·Increases in cost of grid electricity ·Decreasing equipment costs ·Allowable rate adjustments	·Natural disasters ·Equipment shipping delays ·Material concerns ·Inflation rates

Figure 8. SWOT Analysis Overview.

Strengths

Financial Support for Initial Capital Expenditures

In 2019, FCPR was awarded a $4.1 million grant from the Economic Development Administration matched with $1 million in local funds (EDA, 2019). This funding is being directed toward the initial cost of the solar energy systems and installation. Covering the project's initial capital expenditures allows the electricity rate to be significantly lower than it would otherwise, and therefore allows the price to be competitive from the initiation of the project.

Rooftop Solar and Battery Storage

Energy will be produced from solar rooftop systems located on-site with the clients as opposed to centralized solar generation at a single site. This allows each solar and battery storage system to be sized to meet the needs of an individual business. Rooftop solar systems, unlike mini grids will be placed on the businesses themselves and hence not require additional land. Such systems will also allow the utility to obtain data on solar consumption on a per subscriber basis and allow the subscribers to better visualize the benefits of transitioning to solar.

Further, rooftop solar systems and battery storage are considered to be well-established technologies, reducing uncertainties that can be associated with newer renewable energy technologies.

Continued Access to Main Grid

Maintaining continued access to the main grid provides an added layer of energy reliability to subscribers and therefore incentivizes subscribers to maintain enrollment in the utility. The solar utility provides a win-win scenario where the subscriber will pay PREPA only for electricity that it consumes in excess of the solar utility production.

Net Metering Capabilities

The rooftop solar systems will have net metering capabilities which means that any energy that is produced in excess may be sold back to the grid. If net metering is utilized, then the subscriber can see potentially lower electricity bills which can add to the attractiveness of the solar utility.

Abundant Solar Resources

Culebra lies at the latitude of 18 degrees North and its proximity to the equator leads to high, year-round solar energy potential (Appendix 2) (Salasovich & Mosey, 2019). Solar production varies throughout the year, with the lowest production in November and highest production being in March, but the variation is relatively minimal. Consistent solar resources allow for predictable and reliable energy generation across the year.

Ability to Expand Subscriber Base

Fifty businesses, NGOs, and critical facilities are currently enrolled to be subscribers in the Solar Utility with the option to expand the subscriber base in the future. There are just over 60 businesses on Culebra (FCPR, n.d.-b). Subscriber base expansion is beneficial for two reasons. First, it allows subscribers that may have been unsure or uninformed about the project to have an opportunity to join the utility at a later date. Secondly, this supports the long-term viability of the project as it allows for additional revenue.

Inventory Availability

FCPR will maintain an inventory of equipment on Culebra which will allow for any maintenance needs, such as parts replacement, to be resolved with a short turnaround. This ensures that the systems will be online for greater periods, boosting solar generation. It also helps to reduce the costs of bringing supplies and equipment from the main island as the only ways to access Culebra are through a 45-minute ferry ride or via plane.

Weaknesses

Unavailability of Skilled Workforce

This project will require an electrician to perform O&M of the solar, storage, and grid assets. It is expected that someone on Culebra should be trained or have prior training to be able to fill this role part-time. A potential weakness of not having a skilled on-site workforce is the dependency to outsource tasks to skilled workers on the main island of Puerto Rico. This would add both delays to getting the systems fixed along with additional labor and transportation costs.

Low Granularity of Data

The project is constrained by lack of hourly demand data. Access to time-of-day demand-side information could be beneficial toward decision-making and improving processes in the future such as charging and discharging decisions for batteries and allow the subscribers to maximize net-metering, and therefore subscriber savings.

Inability to Meet Full Demand

The rooftop solar systems are not sized to meet 100% of the subscriber demand. It is expected that energy consumption beyond storage capacity during evening and night hours will come from the PREPA grid infrastructure and be charged at the higher PREPA rate. Subscribers will still have to pull from the main grid and hence will still be exposed to high and fluctuating electricity prices.

Opportunities

Grid Decarbonization Goals

Puerto Rico has a goal to have 100% renewable energy generation by 2050. This will be accomplished by means of increasing the territory's Renewable Portfolio Standard (RPS) to meet outlined interim and final targets (*S.B. 1121 No. 17-2019*, 2019). These grid decarbonization goals point to the shift toward renewable energy sources on the island, meaning there is public and political backbone to support the long-term sustainability of the project.

Development of REC market

Renewable Energy Certificates are tied to the production of one-megawatt-hour of renewable energy and is a method of tracking clean energy production. Typically, RECs can be retired or sold for offsets and therefore could be a source of additional revenue for the Solar

Utility. While the solar utility could potentially generate RECs, such a market to monetize the RECs does not yet exist (Star, 2021). There is currently a proposed rulemaking on the “Renewable Energy Certificates Regulation and Compliance with the Renewable Portfolio Standard of Puerto Rico” to create a RECs market (PREB, n.d.). If approved, RECs monetization could be a source of additional revenue.

Increases in Cost of Grid Electricity

The average electricity rate paid by Culebra businesses in 2019 was around $0.26/kWh. Given the steady increase in electricity prices in Puerto Rico over the years, it is expected that these rates will continue to increase. Price hikes are driven in part due to fossil fuel dependence and the volatility of the global petroleum market (LUMA, 2021). Additionally, an agreement to cancel PREPA’s $9 billion in outstanding debt would have caused an increase in rates from $0.027-0.046/kWh, but was canceled in March due to concerns about rising fuel costs and inflation (Kunkel & Sanzillo, 2019). Combined, the impending electricity rate increases and the possible future debt-restructuring related increases, could favor strengthen the case for grid-alternatives.

Decreasing Equipment Costs

The solar utility uses a range of equipment, but the two biggest cost factors are the solar panels and the batteries. Prices for the solar systems have decreased rapidly over the past decade while efficiency has increased (NREL, 2021b). Solar batteries are costly, but prices are expected to see a significant decrease in prices over the next 10 years, which is the anticipated battery replacement period for this project (NREL, 2021a). Not accounting for inflation, this movement suggests that the solar utility may be able to see lower replacement costs for equipment.

Allowable Rate Adjustments

While an electricity rate has already been submitted to the PREB to cover 10 years of operating the solar utility, this rate is able to be adjusted. If an unforeseen event creates unanticipated costs for the utility, a revised rate may be used for cost recovery. By allowing for such adjustments, it ensures that charges associated with cost recovery do not get pancaked together, causing a dramatic increase in costs after the 10-year fixed period expires.

Threats

Natural Disasters

Due to its geographic location, Puerto Rico is prone to natural disasters such hurricanes and earthquakes (USDA, n.d.). While the rooftop panels will have de-mounting capabilities, these threats can still damage equipment that is left exposed. Any natural disaster could lead to loss of service due to equipment damage.

Supply Chain Concerns

The solar and battery storage industries have recently seen delays in shipping. The primary cause has been supply-chain constraints exacerbated during the pandemic (Balaraman, 2022). As a result of a demand-supply imbalance, increasing inflation, and increasing demand for solar technology, there is upward pressure on solar panel prices (Balaraman, 2022). Further, solar panel deliveries are also seeing delays attributed to an anti-dumping investigation by the Department of Commerce (Gheorghiu, 2022). While these threats appear not to immediately affect the solar utility, they are important to keep in mind as equipment begins to need replacement.

Price Volatility for Equipment Raw Materials

Shortages caused due to reduced supply of critical raw materials for equipment such as lithium is also a cause for concern. Without financially viable alternatives to lithium, increased demand for a range of technology products may put pressure on battery production and even drive-up storage equipment costs. While the initial capital expenditures are covered for this project, it is expected that the inflated lithium market will be long lasting, and this could affect costs as we seek to replace battery storage equipment for this project (Benchmark Mineral Intelligence, n.d.).

Inflation Rates

Another external threat to the project is the possibility of high inflation rates. With inflation rates currently at a 40-year high, this raises the possibility that high inflation rates can significantly lower the net income of the project (Rushe, 2022). This could potentially lead FCPR to raise their electricity rate for the solar utility to make up for these losses and ensure the financial sustainability of the project.

Rate-Design Model

A factor that is critical to the success of the solar utility is the establishment of an electricity rate that is financially sustainable given a range of different inputs to the business model. To assess the feasibility of different rates for the solar utility, a rate-design model has been created. This rate-design model has three main sections: Revenue, Costs, and Financial Statements. The revenue calculation considers electricity consumption from the solar utility per subscriber and the selected utility electricity rate. The cost estimation covers the range of costs the utility will see on an annual basis and throughout the project lifespan. The results from the revenue and costs section serve as inputs to the Financial Statements generated for the utility. Lastly, the benefits to subscribers for enrolling in this project are calculated as the difference between what they would pay without the utility and with the utility, along with emissions abatement benefits.

Revenue Calculation

Load Curve Estimation

Using PREPA receipts, historical electricity consumption figures from January 2019 to December 2021 for 11 different businesses in Culebra were obtained (Example receipt with historical data given in Appendix 4 and 5). Data starting from March 2020 was considered to be non-representative of a normal business-as-usual scenario, and hence excluded, as the COVID-19 pandemic affected electricity demand across the island (newenergy, 2020). The subset of data from January 2019 to February 2020 was then used to compute the average electricity consumption for a business in Culebra. This was then fitted into a polynomial function to yield the load curve for an average business in Culebra, indexed by month (Figure 9). The U.S. electricity demand is forecasted to grow at a rate of 1% annually between 2020 to 2050 and this has been used as an input to account for increase in subscriber electricity demand over the project life-cycle (EIA, 2021a).

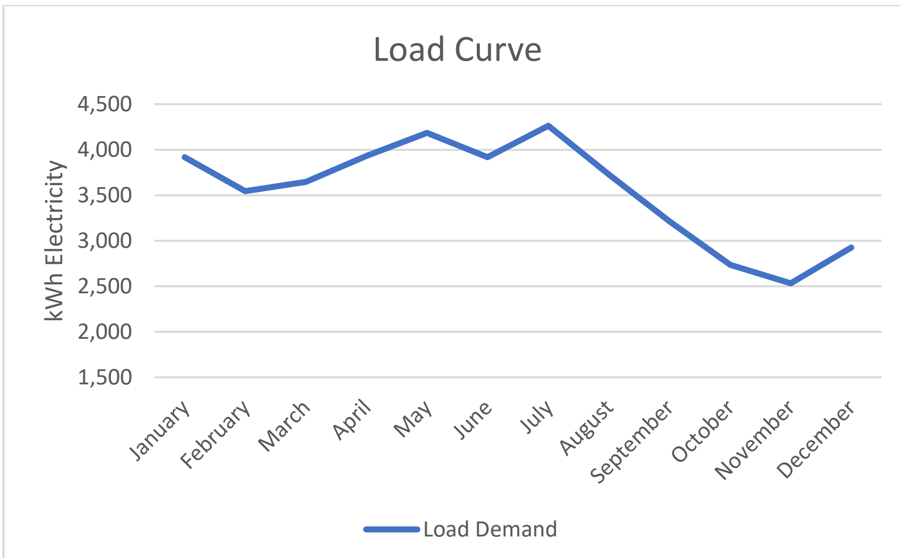

Figure 9. Culebra Load Curve Estimation.

As shown in Figure 9, peak electricity consumption takes place in the hot summer months of May-June-July due to the use of cooling devices such as air-conditioners. Consumption declines over the following months as temperatures cool down before increasing again in December-January in-line with the peak Caribbean tourist season (Frommers, n.d.).

Solar Production Forecast

PVWatts – an open-access tool developed by National Renewable Energy Laboratory (NREL) – was used to generate solar production forecasts for a solar system for an average business client in Culebra. Monthly level data was chosen for further analysis in line with the granularity of the load curve. The solar production curve can be seen in Figure 10.

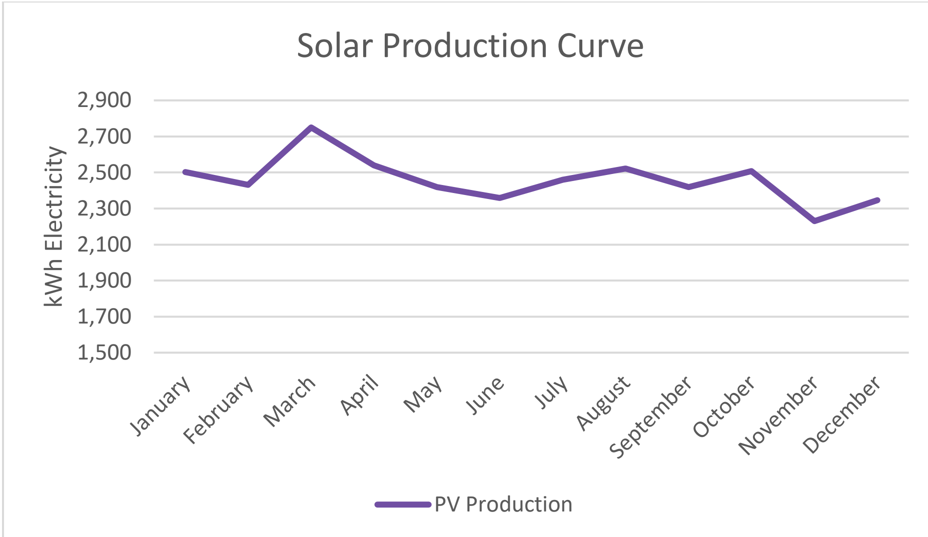

Figure 10: Solar Production Curve of Solar Utility Project.

Given Culebra's proximity to the equator (Latitude: 18°N), the incident solar resource is largely constant across the year. This is reflected in the low seasonal variation of solar production from the rooftop solar systems (Figure 10). A degradation factor of - 0.5% per year was included to account for reduced solar panel performance over time (Mow, 2018).

Figure 11 shows the load curve and the PV supply curve for year 1 on the same chart. It illustrates that the solar production is not sufficient to meet 100% of the demand for an average business in Culebra. Here, it is important to note that the businesses will remain connected to the main PREPA grid, and any unmet demand can be fulfilled from the main grid.

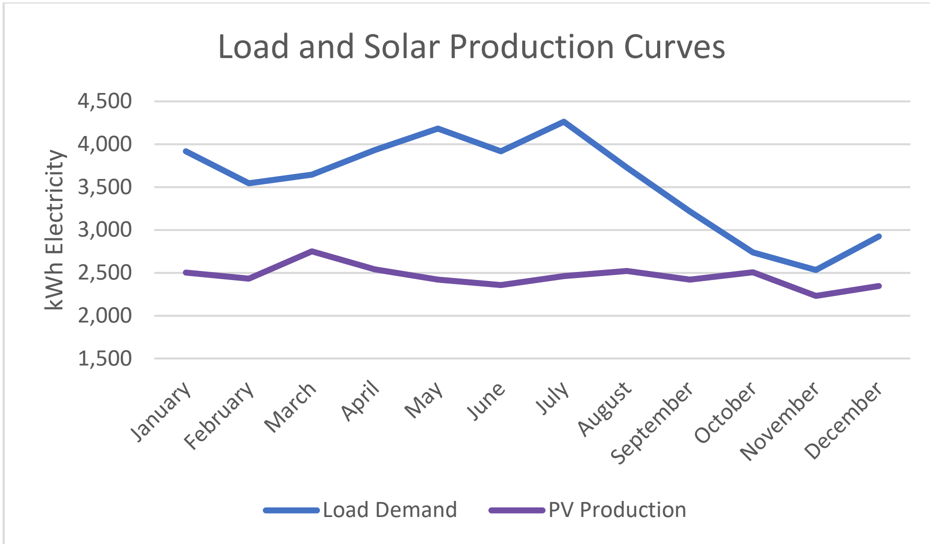

Figure 11: Electricity Load Demand and Solar Production Curve for utility subscribers.

Monte Carlo Simulations

The Monte Carlo simulation method is used to model the probability of different process outcomes in scenarios which cannot easily be predicted due to the influence of random variables (Kenton et al., 2021). For this analysis, solar production can be fairly assumed to be constant for a given month of a year. However, the consumption is difficult to predict due to a multitude of factors which could influence demand across subscribers and time. Therefore, in this analysis, the monthly demand from the load curve (Load Curve Value; LCV) was scaled to account for 5 scenarios corresponding to very low, low, medium, high, and very high demand. Each of these scenarios were assigned a probability value corresponding to the likelihood of the scenario taking place (Table 1).

Demand Scenario	Value	Probability	Cumulative Probability
Very Low	LCV*0.8	0.05	0.05
Low	LCV*0.9	0.15	0.20
Medium	LCV	0.60	0.80
High	LCV*1.1	0.15	0.95
Very High	LCV*1.2	0.05	1

Table 1. Monte Carlo Demand Scenarios.

Next, the model ran 10,000 Monte Carlo simulations per month to simulate demand variation across the 5 scenarios. A random number generator giving values between 0 and 1 was used for this purpose, and this generated value was then compared with the cumulative probability table to determine which demand scenario will be applicable for the given simulation. For example, a generated number of 0.17 would align with the Low Demand Scenario. This would occur for each month, across all 10 years of the project, in each of the 10,000 simulations, thus giving estimates for total electricity demand for utility subscribers.

Multiplying Solar Consumption with Utility Rate

Lastly, the simulated demand value was compared with the solar production for the particular month. The lower value between demand and solar production gives us the actual solar consumption for a client in that month. The solar consumption was then multiplied by the inputted utility rate to obtain monthly client revenue which was then aggregated and then multiplied by the number of clients in that year to give the annual revenue for a given year for one simulation. Averaging the results of the 10,000 simulations, we were able to obtain the average simulated yearly revenue for the utility.

The revenue calculation process is summarized in Figure 12.

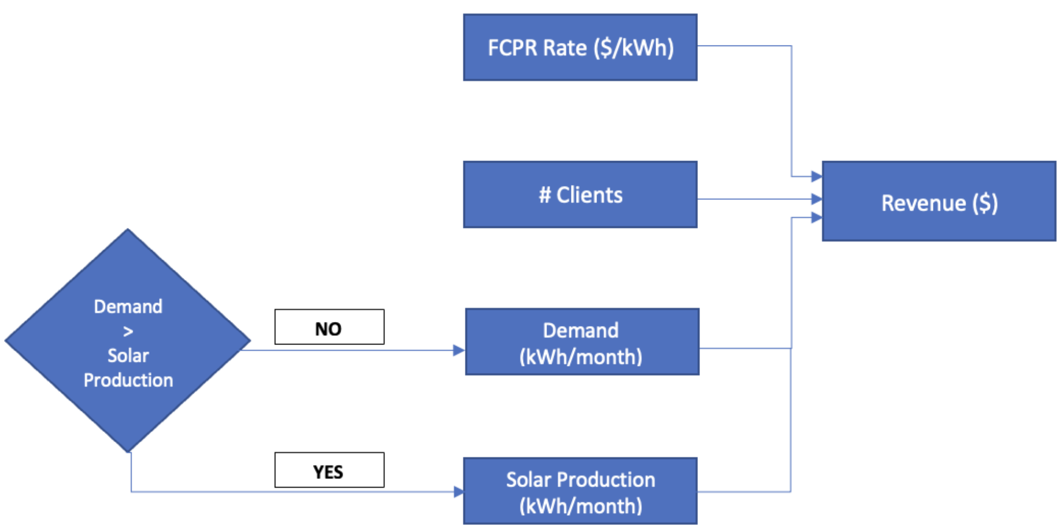

Figure 12. Revenue Calculation Process

Cost Estimation

Operations and Maintenance

This includes any costs which go towards the regular operations and maintenance of the solar and storage assets, along with the structural and electrical Balance of Systems (BOS). These costs were calculated based on NREL estimates for residential rooftop solar PV + storage systems which were then scaled by a Cost Escalation Factor to account for the higher costs seen on the island as opposed to the 50 U.S. states. A Cost Escalation Factor of 1.5 was used as a result of cost estimations in previous projects done by FCPR.

Administrative

This header includes all costs which go into running an office. FCPR has been allotted a permanent office location in Culebra to serve as an office and inventory storage. Administrative cost includes the rent to be paid for this site, staff salaries, office supplies, billing software, transportation costs along with training for employees and local residents.

FCPR envisions two types of staff for this project. First, a permanent office staff who shall be responsible for the day-to-day activities of the utility, along with client engagement, billing, and payments. Second, the project will have an electrician hired on a part-time (10 hours/week) basis to ensure smooth operation and repairs of the solar systems on the island. Their wages were estimated based on the Occupational Employment and Wage Statistics database available with the US Bureau of Labor Statistics (Table 2).

Occupation	Mean Hourly Wage
Electrician	14.33
Office and Administrative Support Workers, All Other	12.59

Table 2. FCPR Employee Wage Estimation (BLS, 2022).

Insurance

Puerto Rico is at high risk of natural disasters such as hurricanes. It is important to ensure that the equipment is insured in the event of any calamity. Insurance costs for this project were estimated based on NREL estimates for residential rooftop PV plus storage systems which were then scaled-up with the Cost Escalation Factor.

Correction

FCPR seeks to reserve a fixed amount of money per client per month which will be set aside and used to cover any repairs and equipment replacement during and beyond the initial 10-year project period. This is essential to ensure financial sustainability for the project and to provide a corpus for project expansion as the utility enrolls more subscribers over time.

All costs were increased annually in line with an annual inflation rate of 2.5% as has been used for similar studies performed by NREL. A flow chart explaining the breakdown of the different cost components can be seen in Figure 13.

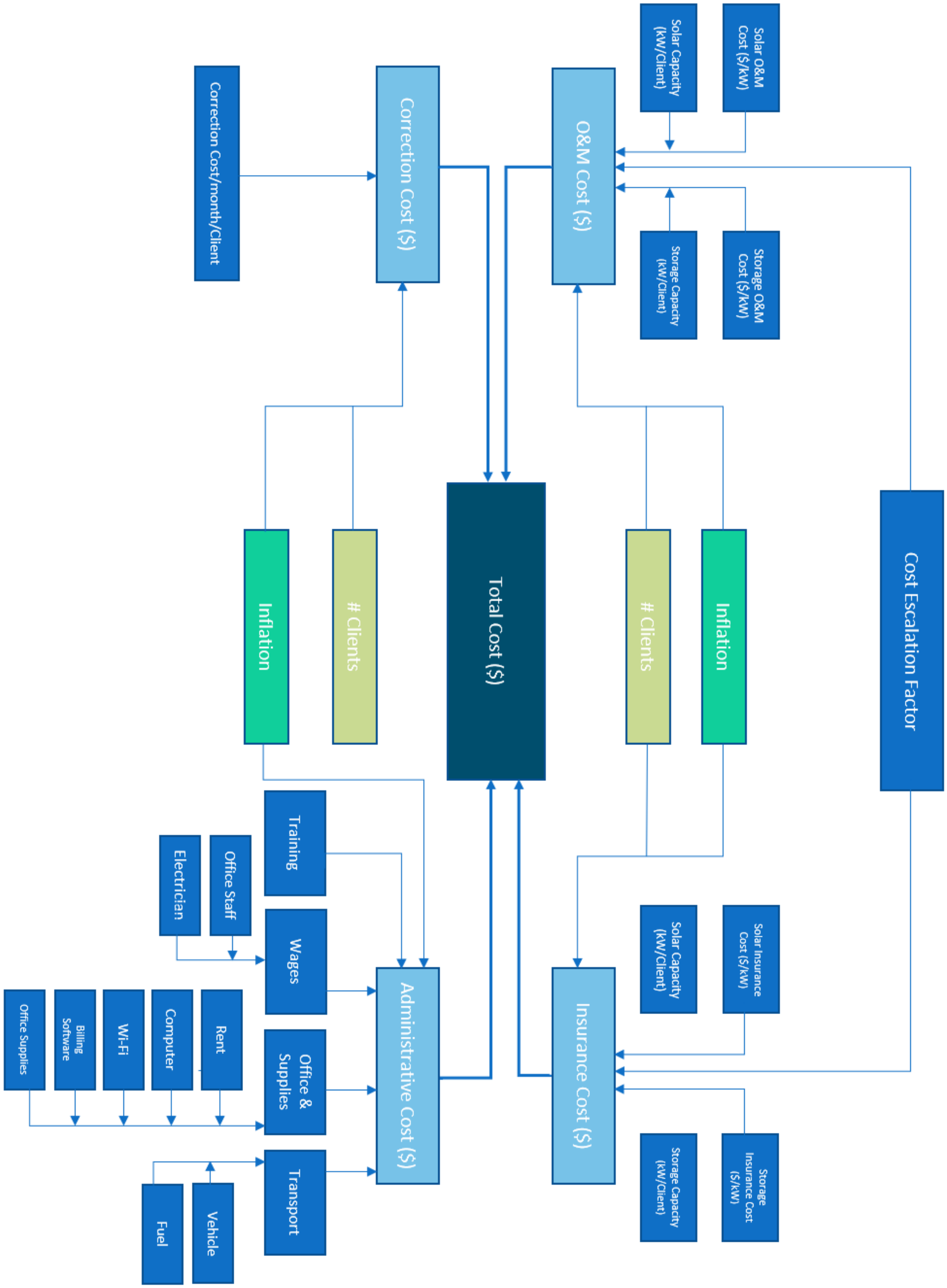

Figure 13. Cost Calculation Process.

Cost Breakdown

Projecting these costs across the 10-year project cycle, a percentage breakdown of the total cost across O&M, administrative, insurance and correction costs was obtained. This cost breakdown changes over time (Figure 14).

Figure 14. Cost Breakdown Over Time.

Correction costs make up the largest share of costs across the 10 years and this share grows over time. O&M cost is the second-largest cost header, reaching 24% in 10 years. Administrative costs peak in the first year of operation due to higher costs of setting up the office and associated one-time costs before stabilizing around 13%. Lastly, insurance costs make up the smallest cost header by value, rising from 6.6% of the total cost in the first year of operation to 7.4% in 10 years.

Benefits

Transitioning Culebra's businesses to decentralized generation with rooftop solar not only boosts grid resiliency and reliability, but also realizes additional consumer and environmental benefits over and beyond the project life cycle. Two key and tangible benefits of FCPR's solar utility project are Culebra subscriber savings and total emissions abated by the project.

Subscriber Savings

The rate offered by the solar utility ($0.21/kWh) is lower than the rate paid by the businesses to PREPA in 2019 ($0.24-0.26/kWh). Electricity consumed from the solar systems will displace the existing consumption from PREPA. Paying a lower rate for this electricity will enable the subscribers to realize significant cost savings. The rate-design model estimates annual savings of $2,600 per subscriber, which amounts to 23.9% of their total electricity bill in a business-as-usual case.

Emissions Abatement

Puerto Rico's energy grid generates almost twice as much CO_2e as compared to the US average. Other emissions like NO_x and SO_2 are 6 and 8.6 times the US average respectively (Table 3). This can be attributed to the island's heavy reliance on fossil fuels to meet its electricity requirements.

Region	Total output emission rates (kg/MWh)		
	CO_2e	**Annual NO_X**	**SO_2**
U.S. Average	372.6	0.2	0.2
Puerto Rico	728.6	1.7	1.9

Table 3. Emissions Output (kg/MWh) from Mainland U.S. Grid and Puerto Rico Grid.

Increased solar generation will displace the existing fossil-fuel generation mix and hence lead to a decrease in emissions. This project will abate 1076 MT CO_2e in the first year of its operation. Reduced emissions of NO_x and SO_2 will also contribute to improved air pollution outcomes, especially for communities residing close to fossil-fuel generation plants on the main island.

Sensitivity Analyses

A series of sensitivity analyses were performed to better account for future changes in Puerto Rico and Culebra's energy landscape, and to provide more accurate recommendations to FCPR. In each of these analyses, the inputs of the model were adjusted to find their effects on subscriber savings, project operations, and project finance. Specifically, the adjusted inputs are PREPA and FCPR electricity rates, annual inflation, and the potential of FCPR needing to pay taxes on project revenue.

PREPA Electricity Rates

The first analysis looked at the effect of changing PREPA electricity rates on subscriber savings. Subscriber savings is the difference between what Culebra subscribers would pay for their electricity demand over the project lifespan of 10 years with and without the operation of this solar utility. The different PREPA electricity rates considered ranged from a lower value of $0.24/kWh, which is a conservative estimate of the rate being paid by commercial entities in Culebra in recent years, to $0.30/kWh**,** which reflects a general upward movement in PREPA electricity rates in recent years (Acevedo, 2021).

To perform the sensitivity analysis, all the inputs to the model were fixed expect for the PREPA electricity rates. At each step in changing the rate, two outputs were recorded: subscriber savings and percentage of total payment (Figure 15, Table 4). This percentage of total payment was calculated by dividing a subscriber's savings over the 10-year period by the total amount of money they would pay to PREPA for 10 years without the solar utility.

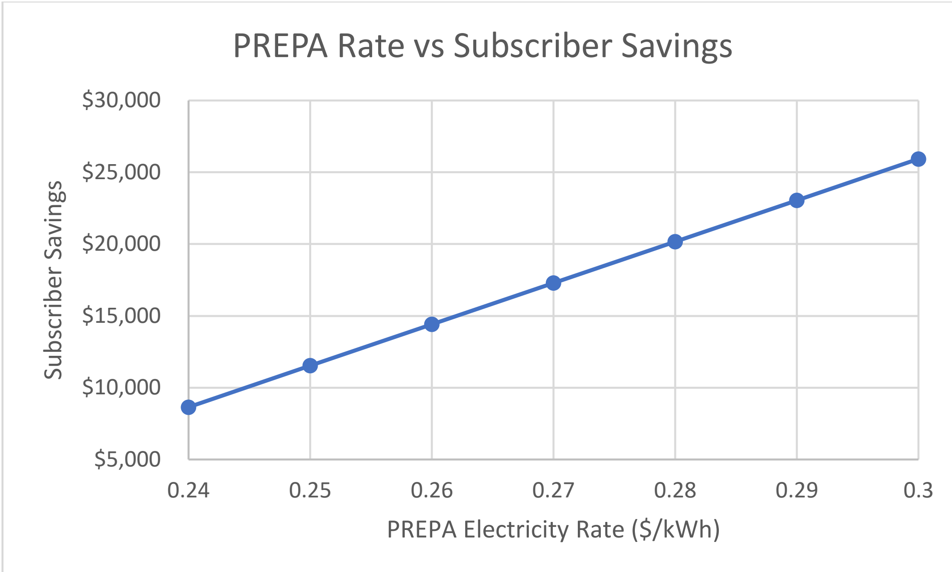

Figure 15. Effect of PREPA Rate on Subscriber Savings.

PREPA Rate	Subscriber Savings	% of Total Payment
$0.24/kWh	$8,600	14%
$0.26/kWh	$14,400	24%
$0.28/kWh	$20,200	33%
$0.30/kWh	$26,000	43%
$0.32/kWh	$31,800	52%

Table 4. Sensitivity Analysis for PREPA Rate on Subscriber Savings and % of Total Payment.

This sensitivity analyses finds that, as long as PREPA electricity rates are higher than FCPR rates this solar utility project will be a net benefit to subscribers in Culebra. As PREPA rates increase, the project becomes beneficial to these Culebra subscribers.

FCPR Electricity Rates

This analysis provides insight on the effect of changing FCPR electricity rates on project finances and subscriber savings. These FCPR rates refer to the amount charged by the solar utility to Culebra subscribers for solar electricity through this project. FCPR has already submitted an electricity rate of $0.21/kWh to the PREB for (PREB, 2021). The different FCPR electricity rates considered ranged from a lower value of $0.17/kWh, which was considered due to low capital expenditures and zero fuel costs in this project, to $0.23/kWh**,** which could be used if FCPR needed to adjust the rate due to an unexpected event.

To perform the sensitivity analysis, all the inputs to the model were fixed expect for the FCPR electricity rates. At each step in changing the rate, four outputs were recorded: subscriber savings, average annual revenue gained by FCPR, project net income, and a corresponding profit margin (Table 5). This net income is calculated by subtracting total costs incurred by FCPR over the project of lifespan of 10 years from the total revenue gained. The corresponding profit margin is a metric to assess the relative profitability of a business.

FCPR Rate	Subscriber Savings	Annual Revenue	Net Income	Profit Margin
$0.17/kWh	$26,000	$256,000	- $6,700	0%
$0.19/kWh	$20,200	$286,000	$294,000	10%
$0.21/kWh	$14,400	$316,000	$595,000	19%
$0.23/kWh	$8,600	$346,000	$896,000	26%

Table 5. Sensitivity Analysis for FCPR Rate on Subscriber Savings, Annual Revenue, Net Income, and Profit Margin.

This sensitivity analysis finds that the relationship between subscriber savings and profit margin is inversely related. As the FCPR rate increases, there is greater annual revenue going to FCPR, but less subscriber savings staying directly on the island. For example, an FCPR electricity rate of $0.21/kWh yields a profit margin almost twice as much as that of a $0.19/kWh rate, but with around 25% less subscriber savings.

Inflation Rates

Next, the relationship between changing annual inflation rates and costs was examined. This rate-design model uses a baseline inflation rate of 2.5%, which is the standard used by NREL in projections and forecasts for similar projects (Feldman et al., 2021). However, to understand how different inflation rates would affect project finances, the input is varied between 1% and 7% to reflect the variation that is seen with inflation rates over time (Figure 16, Table 6).

For the sensitivity analysis, all inputs remained at the baseline scenario except the inflation rate. The outputs analyzed were the total costs, net income, and profit margin of the project.

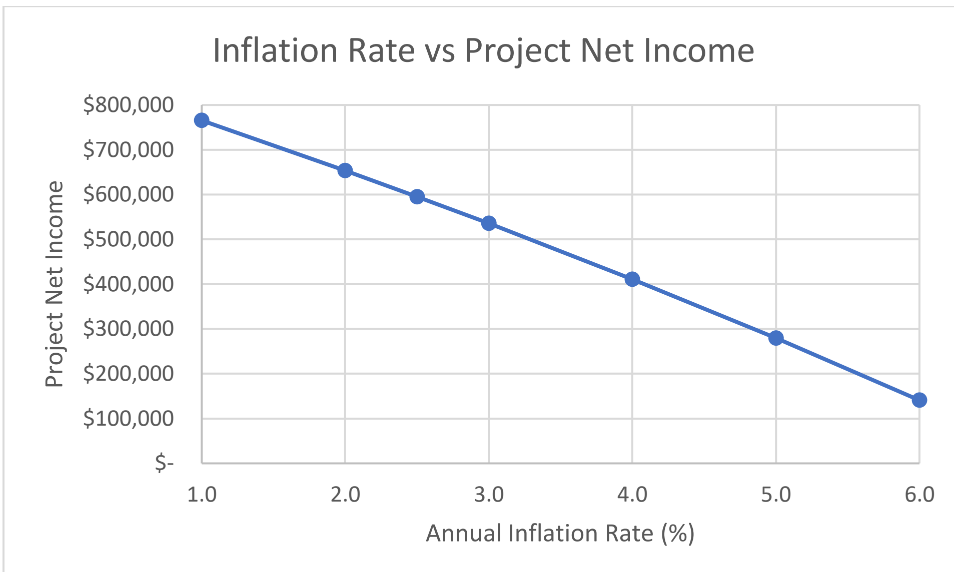

Figure 16. Effect of Inflation Rate on Project Net Income.

Inflation Rate	Total Project Costs	Net Income	Profit Margin
1.0%	$2,395,000	$765,000	24%
3.0%	$2,625,000	$535,000	17%
5.0%	$2,881,000	$279,000	9%
7.0%	$3,166,000	-$5,400	0%

Table 6. Sensitivity Analysis for Inflation Rate on Total Project Costs, Net Income, and Profit Margin.

The analysis reveals that a marginal increase in annual inflation rate can significantly increase the project costs incurred by FCPR, thus reducing net income by a significant margin over the 10-year lifespan of the project. For instance, a 1% increase in annual inflation rate leads to a 3.5% reduction in the project's profit margin value, although project costs rise at a faster rate at higher inflation rates. If inflation rates are lower than expected, FCPR can afford to charge a lower $/kWh electricity rate, leading to more subscriber savings on the island.

Tax Rates

The last sensitivity analyses explored how changing tax rates on FCPR revenue would affect project costs and financial operations for the solar utility project. Currently, FCPR does not pay taxes on the revenue gained from the project, but that might change in the future. The different tax rates considered ranged from a lower of 0%, the baseline scenario that FCPR is currently experiencing, to 20%, a high estimate of potential tax on FCPR revenue.

For this analysis, all inputs remained at the baseline scenario, except the changing tax rate. The outputs calculated include total taxes paid by FCPR over the 10-year lifespan of the project, a net income of the project over the same 10 years, and a corresponding profit margin (Table 7).

Tax Rate	Total Taxes Paid	Net Income	Profit Margin
0%	$0	$595,000	19%
5%	$158,000	$437,000	14%
10%	$316,000	$279,000	9%
15%	$474,000	$121,000	4%
20%	$632,000	($36,800)	-1%

Table 7. Sensitivity Analysis for Tax Rate on Total Taxes Paid, Net Income, and Profit Margin.

This analysis shows that FCPR's electricity rate strategy may have to change if taxes were introduced into the project. FCPR currently will not have to pay taxes on the revenue gained from the solar utility project, but a 1% increase in tax rate leads to around a $31,600 reduction in net income over the project lifespan. If the tax rate was increased to 20%, holding all other inputs constant, the solar utility project would have a negative profit margin.

Model Limitations

The rate-design model has inputs that can be adjusted to assess different outcomes. These can be changed both individually and simultaneously, creating a powerful tool in strategy planning for the utility as various factors change in coming years. However, the outcomes are dependent on the input parameters being up-to-date, accurate, and reflective of the conditions that can expect to be seen in Culebra. With these factors in mind, we assess two major limitations of the rate-design model:

First, the model could be improved through the use of a more robust set of monthly data on energy consumption from participating businesses in Culebra. The sample size for the revenue calculation was limited to monthly data covering only 11 businesses from January 2019-March 2020, and a load curve was fitted using this data. To have a more accurate understanding of energy usage trends it would be helpful to obtain data from a larger set of businesses as well as for longer timeframes.

The model could also be further improved with more granular data on electricity consumption. The current iteration of the model uses monthly demand and PV generation data to maintain consistency even though hourly information on PV generation is available. Having hourly consumption data would provide more accurate insight into subscriber savings and net metering benefits. Currently, there is no information available on how much energy is used in the night, past the battery storage limits, when the businesses would need to pull energy from the grid and therefore pay higher electricity prices. With more granular data, this model would be able to adjust the expected subscriber savings accordingly. Time-of-day consumption data would also help us to estimate net-metering benefits for the subscribers with greater accuracy.

Discussion

This model suggests that FCPR charge an electricity rate of $0.19/kWh as the solar utility's ongoing rate. This rate would lead to savings of $26,000 per subscriber over 10 years, in addition to other ancillary benefits such as increasing electricity resilience on the island, abating 1,076 metric tons of CO_2e emissions per year, and providing avenues for community energy independence with the eventual transfer of solar assets to a community-owned NGO on the island. According to this model, an FCPR electricity rate of around $0.17/kWh would correspond with a project profit margin close to 0%. However, to guard against any project costs that are currently unknown, unaccounted for, or potentially miscalculated this analysis, this analysis suggests using an FCPR rate that would yield a higher net income over the 10 years.

Furthermore, while the electricity rate charged by FCPR is meant to be static for the project lifespan of 10 years, FCPR retains the opportunity to modify it in extreme cases. The sensitivity analyses can help with these decisions by exploring general trends and relationships between the inputs to the rate-design model such as inflation, PREPA electricity rate, solar utility electricity rate, and taxes and key outputs of the model, such as the project's financial characteristics and subscriber savings.

A key finding from these sensitivity analyses is that inflation rates have the largest impact on project finances for the solar utility, as even a marginal increase in inflation rate can lead to significant increases in project costs over the 10 years. If inflation rates are lower than expected, FCPR may be able to charge a lower price for their electricity, which would bring more savings to subscribers. In the scenario that inflation rates are significantly higher than expected, FCPR may have to pivot and charge a higher rate to ensure the financial sustainability of the project.

FCPR has already submitted an electricity rate of $0.21/kWh to PREB to charge for their solar utility project, which yields a profit margin of 19% over the 10 years. At this rate, subscribers will see a savings of $14,400 per subscriber over the project lifespan. This $0.21/kWh rate will provide less immediate subscriber savings than the recommended $0.19/kWh rate, but all assets of the solar utility project will be transferred over to a Culebra-owned community board after 10 years. This transfer includes both the solar infrastructure and any net income gained by FCPR, meaning these missing benefits remain within the community.

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Appendix

Location	Culebra, Puerto Rico
Latitude	18.29° N
Longitude	65.30° W
DC System Size	17.7 kW
Module Type	Premium
Array Type	Fixed (roof mount)
Array Tilt	18°
Array Azimuth	180°
System Losses	14.08%
Invertor Efficiency	96%
DC to AC Size Ratio	1.2
Capacity Factor	19.1%

Appendix 1. NREL PVWatts inputs for average solar rooftop system in this project.

Appendix 2. Photovoltaic Power Potential for Puerto Rico (ESMAP, 2020).

		January 2022 – March 2022		April 2022 – June 2022		Difference		
Tariff	Consumption (kWh)	Bill ($)	$/kWh	Bill ($)	$/kWh	Bill ($)	$/kWh	%
GRS Residential	800	$204.02	0.2550	$232.57	0.2882	$26.57	0.0332	13.0%

Appendix 3. Impact of the April-June 2022 Rate Increase on Residential Customers (PREB, 2022).

LUMA | Total amount due by March 1, 2022: **$156.19** | PAGE 3 OF 4

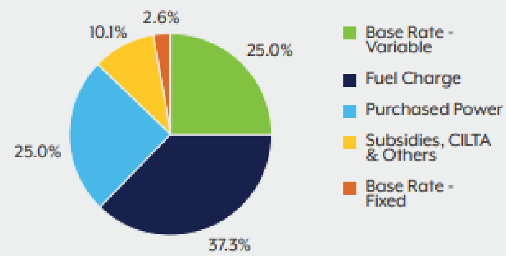
The installation of equipment to generate energy from renewable sources may help to reduce your electricity bill and LUMA, through its commercial office or the Internet, shall provide you with information on how you may qualify to enroll in the net metering program. Furthermore, tax benefits are available to incentivize the purchase of this equipment. Additional information about these benefits is available at the Energy Public Policy Program.

ACCOUNT DETAIL

Balance *Pay immediately*		**$0.00**
Amount Due Previous Period	*$0.00*	
Payments Credited	*- $75.00*	
Current Charges		**$156.19**
Total Amount Due		**$156.19**

Deposit(s) or Bond(s) Received: $100

ELECTRICITY CHARGE BREAKDOWN



SERVICE AND METER INFORMATION

Service Address: 7746 Ave. Ponce De León

Premises ID: 9999999999

Rate: 112 – General Residential Service

Period: 01-Jan-2022 to 01-Feb-2022

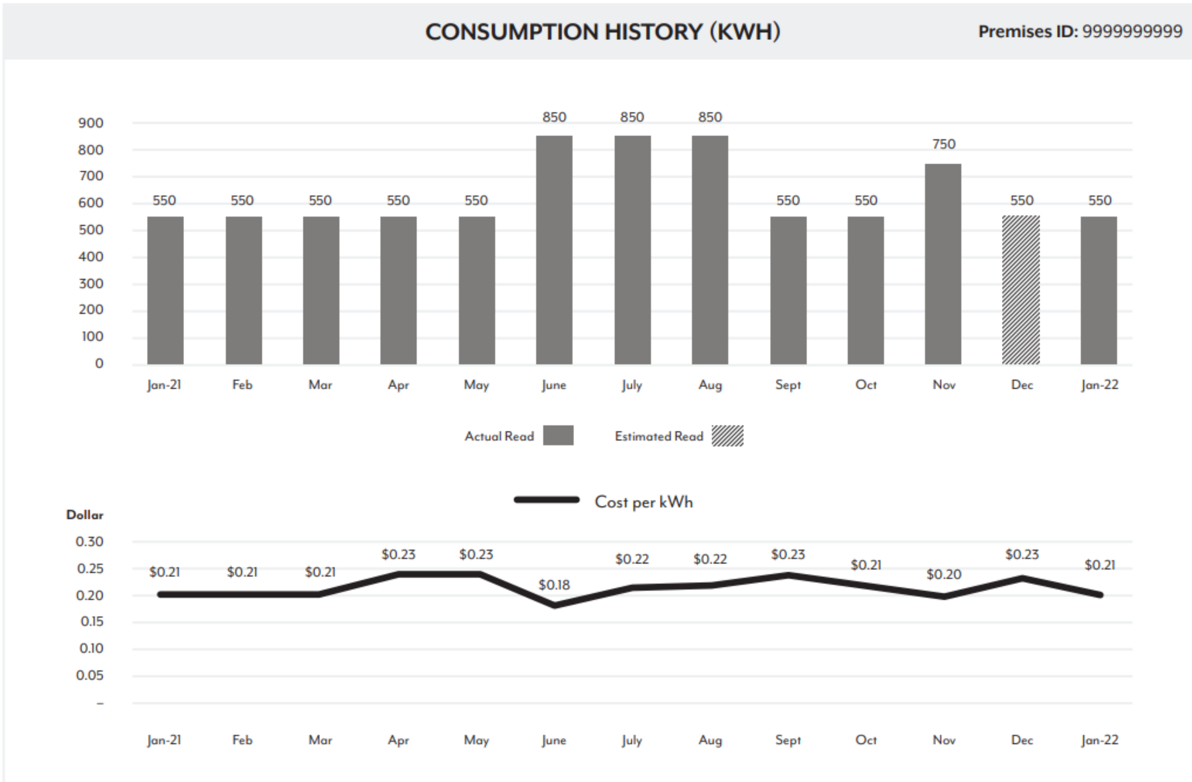
Next Read: 01-Mar

Meter Number	Read Date	Current Read	Previous Read Date	Previous Read	Consumption kWh	Consumption Days	Constant
AB0000000	01-Feb	1000000.99 E	01-Jan	1000000.99	100,000,000.99	31	1

CURRENT CHARGES DETAIL

DESCRIPTION	TARIFF	CHARGE
Service Charges		
Customer Charge		$4.00
Consumption Charge	425 kWh x $.04944	$21.01
Additional Consumption Charge	325 kWh x $.05564	$18.08
Sub Total		**$43.09**
Reconciliation Clauses		
Rider FCA-Fuel Charge Adj	750 kWh x $.077633	$58.22
Rider PPCA-Purchased Power Charge Adj	750 kWh x $.052081	$39.06
Rider CILTA-Municipalities Adj	750 kWh x $.007246	$5.43
Rider SUBA-Subsidies, Public Light & other Subv HH	750 kWh x $.012414	$9.31
Rider SUBA-Subsidies, Public Light & other Subv NHH	750 kWh x $.009210	$6.91
Provisional Rate Adjustment	750 kWh x -$.007771	- $5.83
Sub Total		**$113.10**
Total		**$156.19**

Appendix 4. Sample Electricity Bill for Residential Customers (LUMA, 2022a).



Appendix 5. Sample Historical Consumption Data Included in Electricity Bill

		Year 1	Year 2	Year 3	Year 4	
Revenue						
	Electricity Units Sold	1,472,518	1,480,311	1,487,695	1,494,950	
	Average Electricity Price ($/kWh)	0.19	0.19	0.19	0.19	
	Total Electricity Revenue	$ 279,778.48	$ 281,259.11	$ 282,662.09	$ 284,040.41	$
	Other Revenue	$ -	$ -	$ -	$ -	$
	Total Revenue	$ 279,778.48	$ 281,259.11	$ 282,662.09	$ 284,040.41	$
Operating Expenses						
Cost of Sales						
	Correction Cost	$ (120,000.00)	$ (124,230.00)	$ (128,596.50)	$ (133,103.68)	$
	O&M Cost	$ (51,509.25)	$ (53,324.95)	$ (55,199.24)	$ (57,133.92)	$
	Insurance Cost	$ (15,888.62)	$ (16,448.70)	$ (17,026.84)	$ (17,623.62)	$
	Total COGS	$ (187,397.87)	$ (194,003.65)	$ (200,822.59)	$ (207,861.22)	$
	Gross Profit	$ 92,380.61	$ 87,255.46	$ 81,839.50	$ 76,179.19	$
	Gross Profit Margin %	33%	31%	29%	27%	
Sales, General and Administrative (SG&A)						
	Rent	$ (500.00)	$ (512.50)	$ (525.31)	$ (538.45)	$
	Electrician Salary	$ (1,719.60)	$ (1,762.59)	$ (1,806.65)	$ (1,851.82)	$
	Office Staff Salary	$ (26,187.20)	$ (26,841.88)	$ (27,512.93)	$ (28,200.75)	$
	Administrative Costs	$ (54,561.23)	$ (31,337.85)	$ (32,108.26)	$ (32,897.93)	$
	Total SG&A Costs	$ (54,561.23)	$ (31,337.85)	$ (32,108.26)	$ (32,897.93)	$
	SG&A %	20%	11%	11%	12%	
Earnings Before Interest and Tax / Operating Income						
	EBIT	$ 37,819.38	$ 55,917.61	$ 49,731.24	$ 43,281.26	$
	Operating Margin	14%	20%	18%	15%	
Tax						
	Taxes	$ -	$ -	$ -	$ -	$
Net Income						
	Net Income	$ 37,819.38	$ 55,917.61	$ 49,731.24	$ 43,281.26	$
	Profit Margin	14%	20%	18%	15%	

	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Totals
	1,502,073	1,509,151	1,516,082	1,522,856	1,529,498	1,536,041	
	0.19	0.19	0.19	0.19	0.19	0.19	
	285,393.89	$ 286,738.68	$ 288,055.55	$ 289,342.72	$ 290,604.71	$ 291,847.71	
	-	$ -	$ -	$ -	$ -	$ -	
	285,393.89	$ 286,738.68	$ 288,055.55	$ 289,342.72	$ 290,604.71	$ 291,847.71	$ 2,859,723.35
	(137,755.85)	$ (142,557.43)	$ (147,513.00)	$ (152,627.25)	$ (157,905.02)	$ (163,351.28)	
	(59,130.84)	$ (61,191.89)	$ (63,319.03)	$ (65,514.29)	$ (67,779.74)	$ (70,117.51)	
	(18,239.59)	$ (18,875.34)	$ (19,531.49)	$ (20,208.64)	$ (20,907.44)	$ (21,628.56)	
	(215,126.27)	$ (222,624.67)	$ (230,363.52)	$ (238,350.18)	$ (246,592.20)	$ (255,097.35)	$ (2,198,239.53)
	70,267.62	$ 64,114.01	$ 57,692.02	$ 50,992.54	$ 44,012.51	$ 36,750.36	
	25%	22%	20%	18%	15%	13%	
	(551.91)	$ (565.70)	$ (579.85)	$ (594.34)	$ (609.20)	$ (624.43)	
	(1,898.12)	$ (1,945.57)	$ (1,994.21)	$ (2,044.06)	$ (2,095.17)	$ (2,147.54)	
	(28,905.77)	$ (29,628.41)	$ (30,369.12)	$ (31,128.35)	$ (31,906.56)	$ (32,704.22)	
	(33,707.34)	$ (35,696.68)	$ (35,387.38)	$ (36,259.03)	$ (37,152.47)	$ (38,068.24)	
	(33,707.34)	$ (35,696.68)	$ (35,387.38)	$ (36,259.03)	$ (37,152.47)	$ (38,068.24)	$ (367,176.41)
	12%	12%	12%	13%	13%	13%	
	36,560.28	$ 28,417.33	$ 22,304.64	$ 14,733.51	$ 6,860.04	$ (1,317.88)	$ 294,307.41
	13%	10%	8%	5%	2%	0%	
	-	$ -	$ -	$ -	$ -	$ -	$ -
	36,560.28	$ 28,417.33	$ 22,304.64	$ 14,733.51	$ 6,860.04	$ (1,317.88)	$ 294,307.41
	13%	10%	8%	5%	2%	0%	10%

Appendix 6. Income Statement for solar utility under recommended rate of $0.19/kWh.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Net Income	$37,819.38	$55,917.61	$49,731.24	$43,281.26	$36,560.28	$28,417.33	$22,304.64	$14,733.51	$6,860.04	$(1,317.88)
Adding back Depreciation and Amortization										
Cash from Operations	$37,819.38	$55,917.61	$49,731.24	$43,281.26	$36,560.28	$28,417.33	$22,304.64	$14,733.51	$6,860.04	$(1,317.88)
Investment										
Subtracting Capital Investments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Adding back Salvage Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	$37,819.38	$55,917.61	$49,731.24	$43,281.26	$36,560.28	$28,417.33	$22,304.64	$14,733.51	$6,860.04	$(1,317.88)
Cash Balance	$37,819.38	$93,736.99	$143,468.23	$186,749.49	$223,309.77	$251,727.10	$274,031.74	$288,765.25	$295,625.29	$294,307.41

Appendix 7. Statement of Cash Flows for solar utility under recommended rate of $0.19/kWh.