Puerto Rico

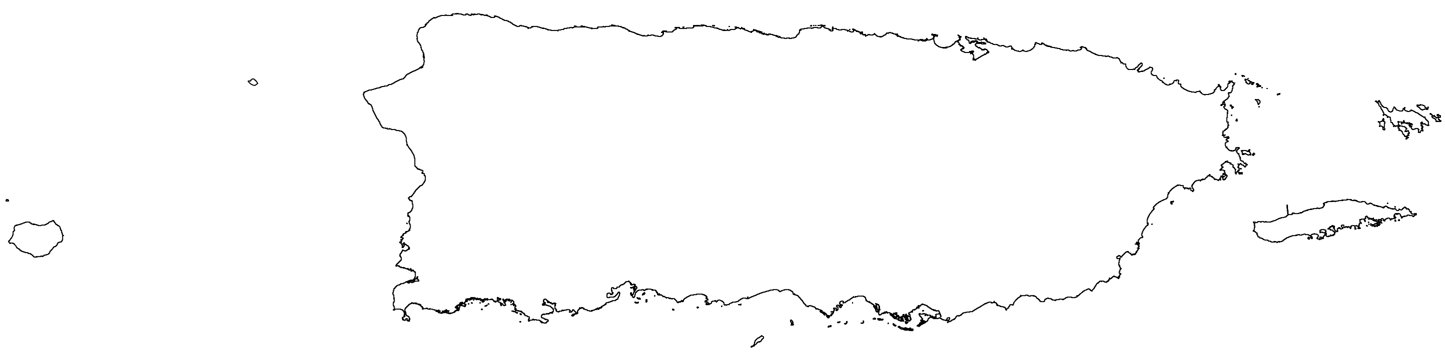
IMPLEMENTATION PLAN:

UTUADO ELECTRIC COOPERATIVE

Climate Solutions Living Lab

Harvard University

May 6, 2018



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Acronyms & Abbreviations

CO2e	**Carbon dioxide equivalent**
CFC	**National Rural Utilities Cooperative Finance Corporation (CFC)**
FERC	**Federal Energy Regulatory Commission**
GHG	**Greenhouse gas**
Kg	**Kilogram**
kWh	**Kilowatt hour**
MGD	**Millions of gallons per day**
MW	**Megawatt**
MWh	**Megawatt hour**
NRECA	**National Rural Electric Cooperative Association**
PRASA	**Puerto Rico Aqueducts and Sewers Authority**
PREC	**Puerto Rico Energy Commission**
PREPA	**Puerto Rico Electric Power Authority**
PROMESA	**Puerto Rico Oversight, Management, and Economic Stability Act**
PURPA	**Public Utility Regulatory Policies Act**
REC	**Renewable Energy Certificate / Renewable Energy Credit**
RFP	**Request for Proposals**
RUS	**Rural Utilities Service**
URE	**Unregulated Entity**
USGS	**United States Geological Survey**

1. Executive Summary

PROJECT GOALS

Goal 1: Achieve significant greenhouse gas emission reductions.
Goal 2: Generate public health benefits.
Goal 3: Produce other social and environmental benefits.

- Puerto Rico urgently needs to rebuild infrastructure destroyed by Hurricanes Irma and Maria in 2017, upgrade maintenance procedures, and establish both short and long term strategies for improving climate preparedness and recovery.
- Key principles of proposed project: transparency, partnership, local empowerment, long-term strategic planning
- Reconstruction of the power grid presents a unique opportunity to deploy greater use of renewable energy resources.
- Currently, the grid relies on imported fossil fuels for 98% of electricity production.
- This plan proposes refurbishment of legacy hydropower assets, upgraded to include a pumped solar storage system, to generate consistent, renewable power and service a population of over 33,000 residents.
- The project proposes formation of a local electric cooperative to advance implementation of a renewable enery project and ensure affordability and resilience benefits of the hydro refurbishment are recouped by the surrounding community.
- The geographic area of focus encompasses Utuado, a municipality among the hardest hit by Hurricane Maria, where approximately 30% of households remained without electricity and safe running water over seven months after the storm.
- This project centers on producing affordable, reliable, renewable power for both daily use and during or immediately following climatic or other disruptive events.
- This proposal was informed by the following drivers:
    - The 2017 hurricane season can and should serve as a game-changer for how Puerto Rico generates and delivers power across the island;
    - Refurbishment of the hydroelectric assets identified for this proposal is complex, but legally and financially feasible. Generation assets could be purchased during the upcoming privatization process of the Puerto Rico Electric Power Authority (PREPA), or alternatively, if PREPA or its successor retains the assets, the project may proceed through a public-private partnership. Current regulations allow for independent generation and wheeling service (i.e. transfer of electricity from one system to another over transmission facilities of intervening systems);
    - The distribution cooperative proposed will need to navigate several challenges. First, PREPA's distribution assets may be unavailable despite privatization and it remains unclear whether the Puerto Rico Energy Commission (PREC) would certify a competitor to PREPA. Structuring the proposal as a cooperatively-owned microgrid could address these barriers, but would likely add significant cost to the project.
- While localized solar + storage projects on critical infrastructure have been popular in the aftermath of Maria in part due to fewer corresponding legal barriers, the revitalized hydroelectric project offers substantially greater cost savings for the community on a per-kWh basis and greater co-benefits across the region.
- Based on these findings, the project team has recommended and preliminarily scoped the implementation of a 26.5 MW hydroelectric refurbishment and pumped solar installation, producing a potential offset of about 115,000 tonnes of carbon dioxide equivalents in year one, but acknowledges that the robust legal and political issues will require further investigation. The project team further recommends that interested parties continue to assess a targeted pool of solar and storage investments, to be primarily funded through philanthropic or grant mechanisms, as a possible supplement or alternative to this project given the numerous uncertainties involved.

2. Introduction

This document outlines a proposal for scoping and implementing an electric cooperative in Utuado, Puerto Rico to ensure a more stable supply of electricity and clean water for a region of the island among the hardest hit by Hurricane Maria in September 2017.

The municipality of Utuado has been identified as the pilot site for this proposal based on:

- Significant need for power and clean water systems repair and long-term strategy;
- Remote, mountainous geography presents additional challenges for disaster recovery;
- Sustained engagement from local representatives signals strong interest and capacity for project implementation.

Repairing Damage from Acute Shocks and Chronic Issues

Hurricane Maria can and should serve as a game-changer for the island. Considered an 'acute shock', the storm came just days after Hurricane Irma and highlighted the shortcomings of public agency preparedness and ability to recover from storm damage. Chronic issues including organizational inefficiencies and insolvency of public entities including the Puerto Rico Electric Power Authority (PREPA), high unemployment, and the decline of small businesses due to credit accessibility and import/export policies[1] have contributed to Puerto Rico's economic downturn over the past decade.

The devastating damage Puerto Rico experienced from Hurricanes Irma and Maria continues to impact the livelihoods of citizens and businesses across the island, diminishing quality of life and impeding economic mobility. Neglected infrastructure maintenance preceding the hurricane season contributed to Puerto Rico's vulnerability to the storms, which amplified their negative impact and the time elapsed in restoring functionality of critical infrastructure systems.

This project is positioned to seize a unique opportunity within Puerto Rico at a time when investment and strategic recovery are both urgent and critical. Despite efforts to rebuild a stronger and more reliable grid post-Maria, blackouts continue to occur, impacting the 3.3 million residents living in Puerto Rico. Failures in the power system despite recent focus on "building back better"[2] underscores the imperative for Puerto Rican residents, public officials, and other decision-makers to consider alternative means of disaster recovery and rebuilding to create a more resilient and cleaner power system for the island.

Rethinking Puerto Rico's Problematic Grid

The design of Puerto Rico's current energy system is problematic. Power is generated in areas that require transmission lines to traverse long distances, up and down mountains, and across plains before reaching consumers. Storms like Maria and

1 For more on the impact of the Jones Act and other challenges facing small business in Puerto Rico, visit https://www.cnbc.com/2015/07/07/puerto-rico-big-challenges-for-small-businesses.html.

2 For more on Puerto Rico's November 2017 "Build Back Better" report and request for federal assistance, see http://www.documentcloud.org/documents/4198852-Build-Back-Better-Puerto-Rico.html.

Irma take down power lines and require significant labor and materials to rebuild, and outages at one plant or along one line can impact millions of people as was the case with the April 18, 2018 island-wide blackout (New York Times, 2018).

The Utuado Electric Cooperative project concept is based on three key considerations:

1. Now is the time to act – it is the opportune moment to rethink ownership and management of energy infrastructure as the island's only power utility, the Puerto Rico Electric Power Authority, or PREPA, moves to privatize the system;
2. We are building off Utuado's existing assets and active grassroots approach to disaster recovery by proposing a new model for the electricity utility, which is owned and controlled by the people it serves;
3. We are turning to local power sources to produce clean energy to meet the needs of local populations.

The electric cooperative is a community-centered model for asserting local control and capturing value created by the proposed hydropower project in order to benefit the local population.

Ability to Replicate Island-Wide

This model can be replicated across the island. To formulate a proof of concept, the project team focused on the mountainous, remote municipality of Utuado to launch the project concept. The project serves to help Utuado meet urgent energy needs and can serve as a pilot for an alternative to the status quo that allows Puerto Rico to rebuild, modernize and adapt its energy infrastructure in a community-driven and community-oriented way.

The project team's engagement with local leaders in Utuado to date suggests enthusiasm for operationalizing this plan, which would entail launching a series of meetings and workshops with elected officials, municipal agencies, residents, national organizations, and other partners to move the project concept forward.

Goals for Achieving a Triple Bottom Line Project for Puertorriqueños

This project has three overarching goals to help address Puerto Rico's vulnerability to climate events while tackling underlying challenges related to system maintenance, community empowerment, and economic development:

Goal 1: Achieve significant greenhouse gas emission reductions.
Goal 2: Generate public health benefits.
Goal 3: Produce other social and environmental benefits.

The project offers a triple bottom line opportunity for investors, residents, and other stakeholders by restoring renewable energy at scale (to serve an entire municipality); improving power reliability and operational continuity for critical infrastructure (including water treatment facilities); and establishing local ownership of energy production and distribution. Cooperative management of energy production and distribution in turn can open up new avenues of financing for renewable and resilient energy infrastructure projects, create new job opportunities and positions of power for residents, and provide cost savings to an underserved and largely low-income population in Puerto Rico.

The project achieves Goal 1 by reducing Puerto Rico's dependence on imported fossil fuels by shifting Utuado's electricity supply from fossil fuels to renewable hydroelectric power, supported by solar power. The project would provide greenhouse gas emission-free electricity to all of Utuado. This is particularly significant in Puerto Rico as the island's grid is comprised of high polluting sources, including 47% petroleum (emits ~140-160 pounds of CO2 per million British thermal units), 34% natural gas (117 pounds of CO2 per million British thermal units), and 17% coal (~215-230 pounds of CO2 per million British thermal units) (U.S. EIA, 2017; U.S. EIA, 2018). Thus, any renewable energy generation added to the power system in Puerto Rico reduces dependence on high-emitting sources in favor of clean, renewable sources and can have a significant impact in reducing greenhouse gas emissions.

The project achieves Goal 2 by laying power lines from the hydroelecric generating stations directly to the wastewater treatment plant to address public health concerns related to accessibility of safe drinking water. A major consequence of the grid going down after Hurricane Maria was that water treatment plants and pumps lacked the power they needed to operate, and lacked a sufficient supply of diesel or other back-up power to restore functionality. The project team is particularly concerned with providing public health benefits by ensuring critical infrastructure like water treatment plants have a reliable energy supply in the face of storms and other disruptions to the grid.

Finally, the project achieves Goal 3 by establishing a cooperative -- a proposal centered on ensuring members are able to capture value created from this project and assume ownership of energy production and distribution for cost savings and reliability purposes. The proposal seeks to put this plan in the hands of Utuadeños instead of an outside, private company.

Puerto Rico pays the second highest price for electricity in the U.S., second only to Hawaii. The cost of electricity is linked to Goal 1 and the need to reduce dependence on imported fossil fuels. The high dependence on imported petroleum in particular adds an additional layer of vulnerability for power security and price stability as oil markets are subject to seasonal and geopolitical volatility and associated price fluctuations.

Like Hawaii and other islands, reliance on imported fuel sources is a major factor in the high cost of electricity in Puerto Rico. The project team has used the Kauai Island Utility Cooperative as a precedent for this project, which is a generation, transmission and distribution cooperative owned by the 33,000 members it serves.

By revitalizing the legacy hydro infrastructure already in place and distributing that power locally to Utuado, the project team estimates a rate of 8 cents per kWh can be achieved, reaping significant savings for the local population who currently pay closer to 20 cents per kWh. The Utuado Electric Cooperative would be the first electric cooperative for Puerto Rico and would put forward a new proposition for shaping the energy system's reconstruction and transformation.

The project will generate 26.5MW of clean energy from hydroelectric facilities, producing a potential offset of about 115,000 tonnes of carbon dioxide equivalents in year one and an average of 105,000 tonnes of offsets per year over a 20 year time period. The lower average is assuming that renewable energy evenly displaces fossil generation such that Puerto Rico meets its stated 2035 Renewable Portfolio Standard.

In short, the Utuado Electric Cooperative project offers a real financial opportunity for the community and for investors, and provides a new model for renewable energy generation and distribution at an opportune moment in Puerto Rico's energy system rebuilding process.

PROJECT DEVELOPMENT

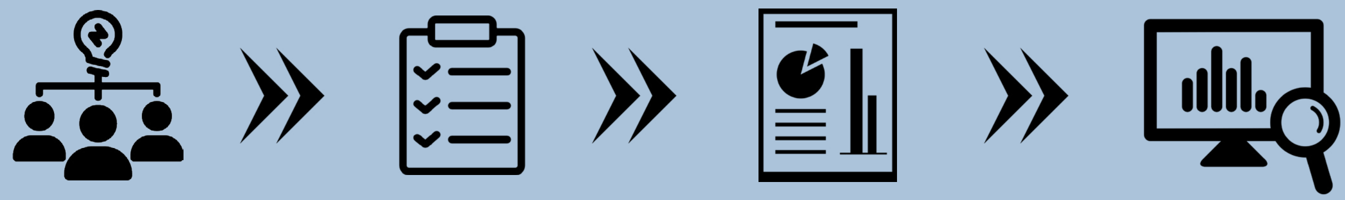
Prior to developing the implementation plan described herein, the project team examined several project ideas by first developing a universe of project ideas followed by filtering those ideas through a screening exercise that involved metrics tailored to the project goals. The results of the screening exercise brought two project ideas to the forefront for further investigation in a Feasibility Study (see full Feasibility Study in Appendix starting on page 52. The first is a solar + storage for critical infrastructure project and the second, revitalization of local hydroelectric units. The results of the Feasibility Study indicated the hydroelectric power project offers greater energy cost savings on a per-kWh basis, is able to serve a broader geographic area for meeting both daily and emergency power and clean water needs, and provides more substantial co-benefits including employment and local ownership of energy resources.

The second best project analyzed in this Feasibility Study, a solar-plus-storage project for critical infrastructure in Utuado is summarized below.

Solar-Plus-Storage Project Summary

This project would be centered at a particular center with critical loads, such as a community clinic or hospital. Utuado is home to both a regional hospital and a small VA satellite clinic. The clinic is situated in Mameyes Abajo, a town within the municipality of Utuado, and is serviced by a local nonprofit, the Corporation for Health and Scocioeconomic Development of OTOAO (PR Newswire, 2018). Given the community-oriented nature of the clinic, its connection to the federal VA system, and its relatively small size, we selected it as a potential site to examine the feasibility of a solar-plus-storage energy system.

The technology required for a solar-plus-storage system at the clinic, with the appropriate controls to run off the main electric grid, would cost around $350,000 for 10kW of rooftop solar photovoltaics and a 8kW/16kWh battery system. These estimates were informed from similar projects undertaken by Sonnen, a company that has delivered projects similar in size and style across Puerto Rico in the aftermath of Hurricane Maria, donating most of this equipment in concert with funding from other charitable sources (PR Newswire, 2017). While these systems allow the clinic to power most of its technology, lights and refrigeration to administer basic medical services, the cost of the system on a per-unit of energy basis can be quite high when compared to the retail electricity price in Puerto Rico.



Without donations and funding from other charitable organizations, it is unlikely that community centers or the local government would be able to afford a $350,000 system to power the clinic. If the community had to source funding for the project themselves or the funding was provided by an unregulated entity in exchange for carbon offsets, then a useful frame of reference for these costs would be the levelized cost of energy (LCOE) and the cost of abatement (COA). LCOE represents the net present value of the unit-cost of electricity over the lifetime of a generating asset. This calculation is key to calculating the cost of renewable energy generation assets, where the price is driven by upfront capital costs rather than operation and maintenance costs, and the COA is the average cost per ton of CO2 offset.

To estimate both the LCOE and the COA for this potential system, we used an estimated 15% capacity factor, which is an average level for residential PV systems (NREL, 2017). For a system with 10kW of solar photovoltaics, the average yearly generation would be 10kW (installed capacity) x 0.15 (capacity factor) x 8760 (hours/year) = 13,140 kWh. Over 20 years, the price of the generated electricity would be approximately $350,000 / (13,140kWh/year x 20 years) = $1.33/kWh. This represents a fairly substantial cost compared to the current price of electricity on Puerto Rico's grid at around $0.24/kWh in Puerto Rico, as well as the $0.30/kWh average from a diesel generator (Lazard, 2014).

Using a diesel generator as a comparable system for off-grid electricity generation and an emissions factor of 0.7kg of CO2e/kWh, the carbon emissions over the 20 year lifetime of the system the emissions offset would be 0.7kg CO2e/kWh x 13,140kWh/year x 20 years = 184 tons CO2e (Yun, 2016). The cost of abatement, assuming that the solar PV system is always replacing a diesel generator (and not connected to the grid), is $350,000/184 tons CO2e = $1,900/ton CO2e offset, which is a substantial unit price compared to the average range for carbon offsets in the voluntary market at approximately $3-$10 (Ecosystem Marketplace, 2017). We are not considering this project to be able to sell compliance renewable energy credits as an added revenue stream since they would be disconnected from the grid and thus not contributing to the renewable portfolio standard.

We also compared this system to a more modular system such as those sold by the company OffGridBox, including a 6x6x6 feet system that can be set up virtually anywhere to produce electricity and clean water independently from the grid. One OffGridBox system costs about $25,000 and produces around 16kWh of energy per day, for an LCOE of $2.93/kWh (OffGridBox, 2018). Using a small diesel generator to calculate the amount of emissions offset: 0.7kg CO2e/kWh x 5,840 kWh/year x 20 years = 82 tons CO2e. This translates to a cost of abatement (COA) of $25,000/82 tons CO2e = $305/ton CO2e offset. In this case, the system also includes water treatment, but the price is still comparatively high to provide a limited level of electricity.

The difference in carbon offset price per ton between both projects is likely due to the much larger size of the battery in the potential system for the clinic. The price of storage is driving the overall cost of the project. If the system is very basic and provides only enough electricity for phone charging and lighting, the storage needs similarly are very limited. In order to ensure that the clinic has enough electricity to run for at least a couple of hours if not an entire day without the sun shining,


UTUADO
CIUDAD DEL VIVÍ

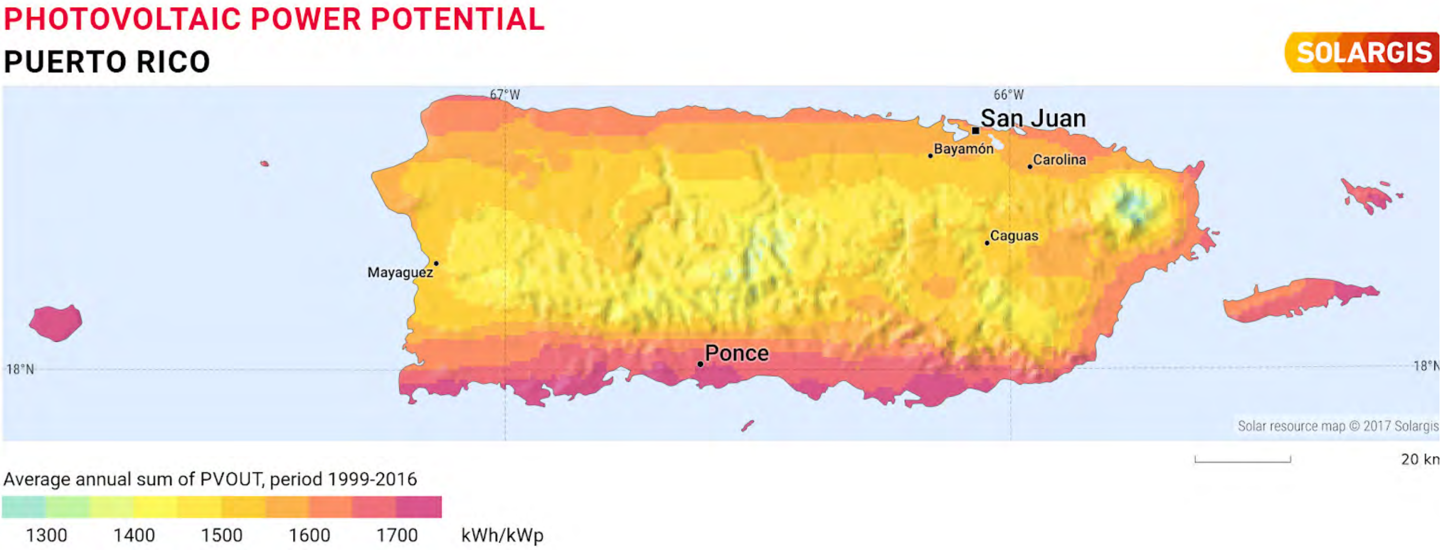
3. Project Description

This project proposes the establishment of a community-owned utility (Utuado Electric Cooperative) for the purpose of acquiring legacy hydroelectric units at Lago Dos Bocas and Lago Caonillas. Reports in recent years indicate that the Puerto Rico Electric Power Authority (PREPA) has limited capacity or interest in directly financing the refurbishment of these hydroelectric units. Our proposal involves supplementing the existing hydropower system with solar panels to create a pumped hydro project that can achieve greater resilience and efficiency performance targets. The Cooperative would be responsible for the operations, maintenance, and management of hydropower electricity generation and distribution.

3.1 VALUE PROPOSITION

In order to narrow down potential project ideas for how to deliver clean, reliable power along with resilient water infrastructure, our team studied a diversity of options for deploying Puerto Rico's renewable energy resources. Puerto Rico has over 700 MW of commercially viable wind resources left to develop. However, the majority of these resources are located offshore and relatively far from our target community of Utuado (DOE, 2007). We decided not to explore wind power as an option for this community given the poor resource availability close to the community, as well as potential disruptions to the local environment not just from the wind turbines themselves, but the necessary roads, cranes and other infrastructure required for installing a wind farm. An important component of this project involved building back in this community in a way that was climate resilient beyond restoring current infrastructure, and reports indicate that wind turbines are typically not equipped to withstand hurricane-level winds (Dengler, 2017).

There is significant potential to grow Puerto Rico's solar energy capacity, with over 1,000 MW of potential capacity on the island (NREL, 2015). Solar capacity is growing quickly in Puerto Rico as a whole, from in terms of utility-scale facilities and residential applications (EIA, 2017). However, there are certain limitations to scaling solar in Utuado, including the relatively low capacity factor due to precipitation levels in Utuado and high upfront costs of solar energy (PRAGWATER, 2018). Solar coupled with battery storage has been of particular interest in the aftermath of hurricane Maria. "Solar-plus-Storage" has often been referred to as a "microgrid" in popular media reports, most recently in the discussion of Tesla's projects related to Puerto Rico's Hurricane Maria recovery effort. These projects are usually analogous to using a generator for emergency power but with power sourced from solar photovoltaics. The addition of storage can stabilize the energy produced by intermittent solar, and provide energy when the sun isn't available for a particular home or facility, potentially making the additional cost worthwhile if a high frequency of outages is anticipated in the future. Solar+storage can be installed relatively quickly and can be connected to a larger grid as a distributed energy resource, with the standalone capability deployed in emergency situations. These systems tend to be best suited for single-facility applications and can provide a community with a sustainable supply of backup power at one central location.



Source: https://solargis.com/maps-and-gis-data/download/puerto-rico

Hydroelectric power, at both small and large scales, is one of the cheapest sources of electricity generation, with an LCOE as low as $0.02/kWh (IRENA, 2012). In places around the world where countries have exploited most of the existing hydroelectric potential refurbishment, repowering and rehabilitation of old plants can be a way of boosting output. A report by the International Renewable Energy Agency (IRENA) states that "the data available on the costs of refurbishment isn't extensive, however, studies of the costs of life extension and upgrades for existing hydropower have estimated that life extensions cost around 60 % of greenfield electro-mechanical costs and upgrades anywhere up to 90 % depending on their extent (Goldberg and Lier, 2011)." Despite these uncertainties around cost, there is evidence that refurbishment of old hydroelectric facilities is financially viable at several scales, as shown by the emergence of companies like Cube Hydro, whose entire business model is refurbishing and modernizing hydroelectric plants.

A potential problem with scaling up this approach or replicating it at other sites is that hydroelectric potential is very site-specific, so viability will depend on the characteristics of the particular reservoirs. In Puerto Rico there are 10 different hydroelectric plants representing an installed capacity of 100 MW of hydroelectric power, so it is likely that at least some of these sites have potential for refurbishment (Puerto Rico Energy Commission, 2014). Of this capacity, only 40% is operation and the annualized service factor is only 8%, so in reality this capacity is currently not providing much power to the grid (UNDIO, 2016). The oldest were built in 1915, and wear and tear has reduced their capacity over the years. Maintaining and updating these units just hasn't been a priority for Puerto Rico's electric utility, who is $9 billion dollars in debt.

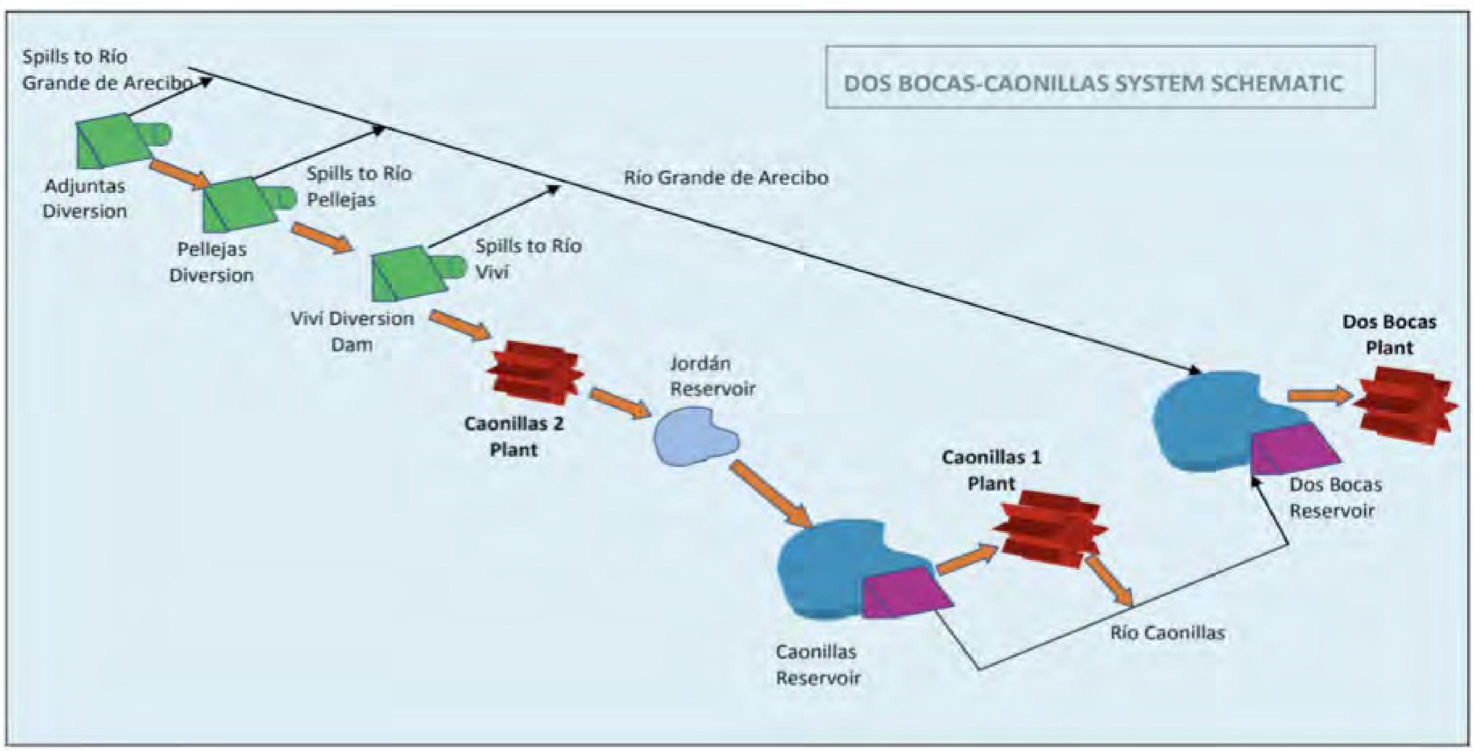
Near the municipality of Utuado there is a reservoir system built in the 1940s on the Caonillas and Dos Bocas Lakes with three hydroelectric plants with a total generating capacity of 26.5 MW. These generating assets are underutilized compared to their capacity, partly due to damage and partly to sedimentation buildup. Investing in this existing system could add a large, local resource to power the community, increasing greenhouse gas emissions offset from the project and providing power at a significantly lower cost to the community. Investing in a much larger system would increase the upfront capital cost, but it also provides revenue streams from selling electricity, renewable energy credits or carbon offsets.

The low LCOE compared to the retail electricity price as well as the fact that the dam and lakes for this system are already in place means that there is the potential for significant financial returns from this project. Looking solely at the total development cost spread out over a 25 year lifespan, the cost per kWh of the over 200,000,000 kWh generated annually is $0.03/kWh, leaving a significant margin for financial returns given the difference between this price and the average retail price of $0.24/kWh.

Our approach would be to ensure that these returns go to the community and not a private developer by creating an electric cooperative. The project is therefore able to satisfy a triple bottom line. Since the dams are already in place, the environmental impact is minimal. Financially, the cost of electricity would be substantially lower than the current retail rate, and having the community form an electric cooperative gives them control over their energy resources. We focused on this project because it provides a long-term, transformative solution for the community of Utuado that puts clean, local resources in their hands.

3.2 TECHNICAL DETAILS

The Lake Caonillas and Dos Bocas reservoir system is located in the mountainous interior municipality of Utuado. Built during the 1940s, the lakes are fed by Rio Caonillas and Rio Grande de Arecibo. The entire system is comprised of two large reservoirs (Caonillas and Dos Bocas), three hydroelectric plants, and several small diversion and holding ponds. A schematic of the system is shown in the figure below.



Although the reservoirs facilitate a wide range of economic and social activities, including hydroelectric generation, drinking water storage, and recreation, no significant maintenance has occurred at the site, resulting in the partial sedimentation of both reservoirs and the severe reduction of hydroelectric potential (PREPA, 2015).

Originally, Lake Caonillas held 45,124 acre-feet of water and could produce up to 21.5MW between its two plants (USGS, 2000). Due to sediment infill, which is augmented by severe weather such as hurricanes, the reservoir's size decreased from 45,000 acre-feet to 33,400 acre-feet as of 2004. Hurricane Georges (1998) resulted in the complete shutdown of Caonillas 2 Plant (5MW), which has since been inoperable. Caonillas 1 Plant (16.5MW) has reported severe mechanical issues that cause it to operate infrequently at most (PREPA, 2015). If left unmaintained, Lake Caonillas is anticipated to completely infill by 2165. Lake Dos Bocas has experienced even greater sedimentation: the storage capacity of the reservoir has decreased from 30,400 acre-feet to 13,200 acre-feet since construction (USGS, 2016). The 5MW facility operates at minimal utilization because the mechanical equipment has not been upgraded since the 1940s. If left undredged, Lake Does Bocas will infill by 2065. Despite these reservoirs vital role in providing drinking water to the capital, they are managed by PREPA not the water authority. Years of neglect by PREPA is due to the relatively small electricity generation capacity compared to the island's portfolio and the organization's mismanagement.

We propose a complete revitalization of the existing infrastructure to install a solar pumped hydroelectric system on the two reservoirs. Dredging the two reservoirs is a critical step to ensure adequate storage capacity for the pumped water system and will further improve future resiliency while benefiting the drinking water services of the system, which provides 75 MGD of freshwater to San Juan as a part of a Superaqueduct. A complete civil works and mechanical systems upgrade will be necessary for revitalization, including improving supporting infrastructure and replacing the turbines and powerhouse systems. As part of the due diligence process, we plan to assess the status of the dams but do not currently anticipate that rebuilding will be necessary.

The installation of a 20MW solar farm near Lake Dos Bocas will pump water up 530 feet to Lake Caonillas to provide pumped hydro storage. 20MW was sized by the power required to pump all inflow to Dos Bocas (325,000 acre-feet/year) up to Caonillas and is approximately the size of the generating capacity of Caonillas. To calculate the amount of power this system could store, we used the equation for theoretical maximum power:

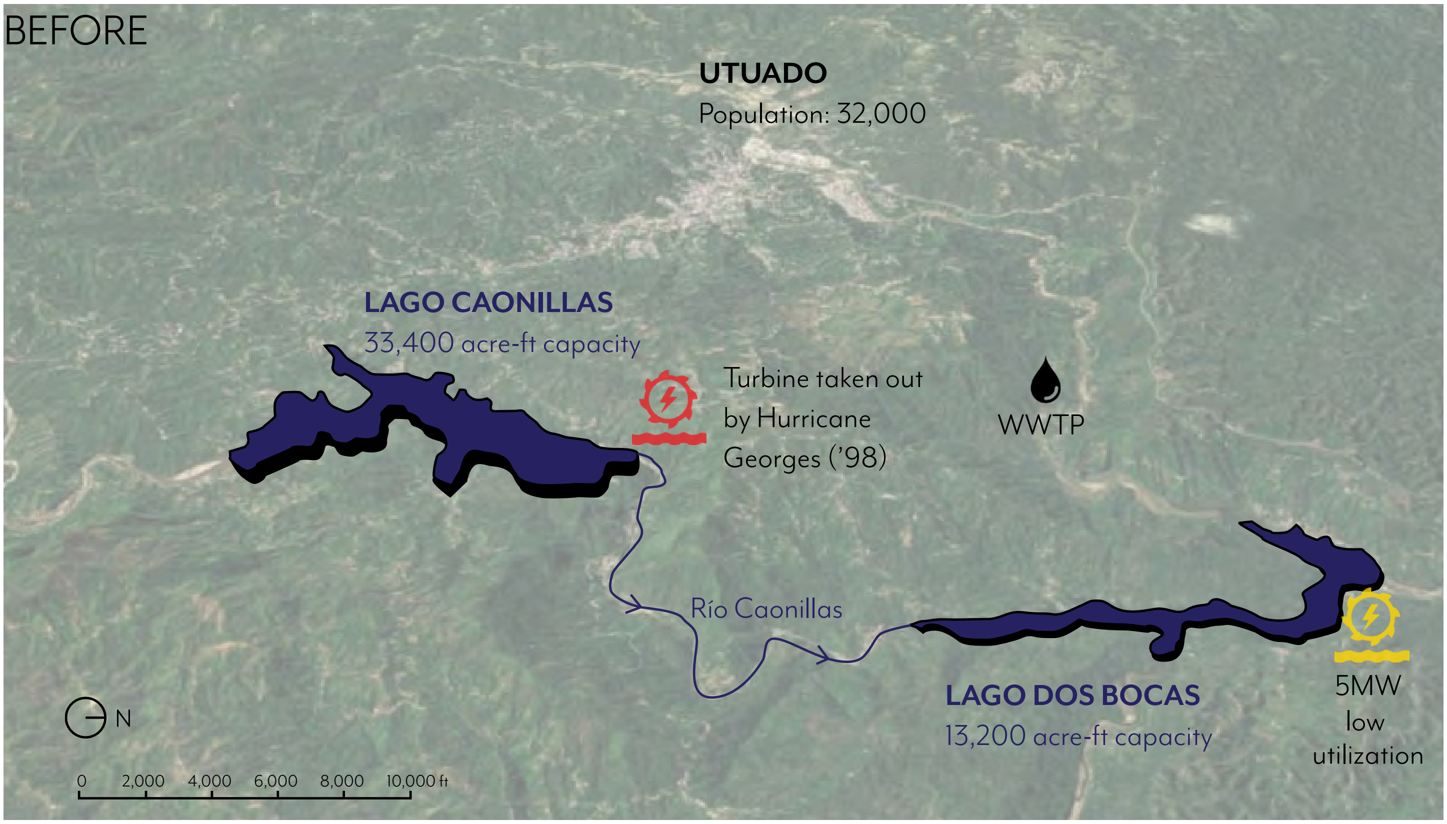
$$P = \rho q g h$$

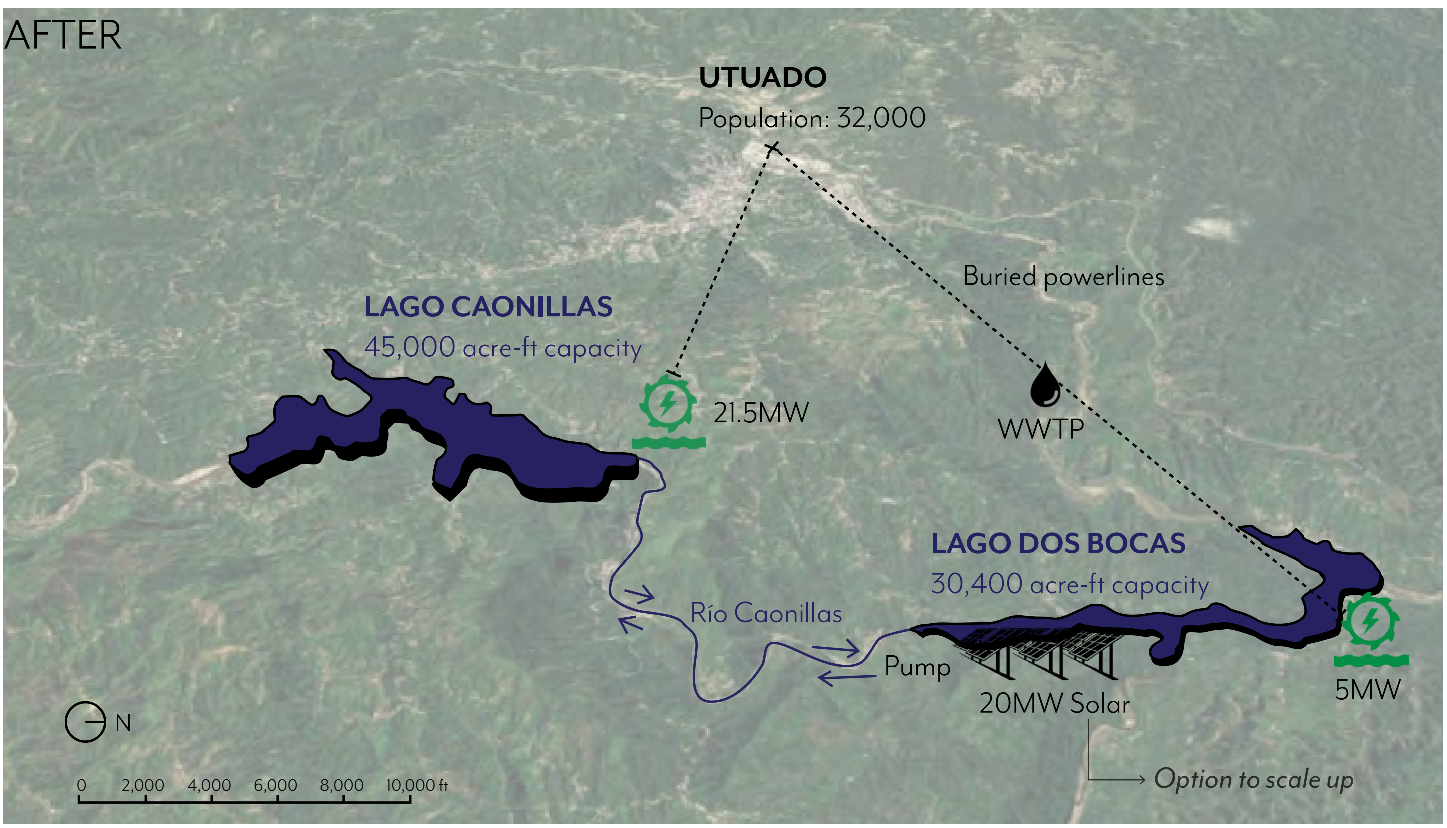
where P is power, ρ is the density of water, q is the inflow, g is the gravitational constant, and h is the height difference between the two reservoirs. Based on a survey of recent 20MW solar farms in the United States, we estimate that we will require approximately 175 acres of land and 85,000 solar panels. Installation of the pumped hydro system will also require building a network of piping to transport water from Dos Bocas to the Caonillas facilities.

Full implementation of this pumped hydroelectric storage would allow the system to produce 26.5MW and a capacity factor of 0.9 (IRENA, 2012). This corresponds to 208,926 MWh per year of electricity. Based on average Puerto Rican residential electricity consumption, we believe this system could serve around 35,000 households and meet the peak demand needs of the approximately 32,000 residents of Utuado.

After revitalization of existing infrastructure, we propose laying buried transmission lines from the two reservoirs to the town of Utuado, including direct power to the local wastewater treatment plant. Although more expensive than conventional, above-ground lines, we believe buried lines will improve the resilience of this system in the next hurricane by guaranteeing power to key community assets, including water treatment facilities and health care services.

A schematic of the current system and our proposed upgrades are shown in the figures below.





3.3 CARBON OFFSETS

We calculated the amount of CO2e offsets our project would achieve based on the current state of the electricity grid in Puerto Rico. A summary of current electricity generation on the island can be found in the table below. We estimate that producing 208,926 MWh from our hydroelectric facilities would offset approximately 115,620 metric tons of CO2eq per year based on the current make-up of Puerto Rico's electric grid.

Electricity Source	% Production (EIA, 2015)	Kg CO2eq/kWh
Oil	47	0.7
Natural gas	34	0.18
Coal	17	0.96
Renewables	2	0
Grid Average	100	0.5534

Puerto Rico has a renewable portfolio standard which specifies that 20% of electricity must come from renewable sources by 2035. If the defined standards are achieved (and fossil sources are scaled back accordingly), our project would offset 94,383 metric tons of CO2eq per year by 2035. This represents a decrease of 18% in the number of yearly carbon offsets our project would generate by 2035. However, we note that the renewable portfolio standard began in 2015 and required 12% renewable electricity generation by 2019. As of May 2018, there have been no significant increases in Puerto Rico's renewable electricity generation (remaining at 2% of total electricity) since passage of the standard. At the current rate, it is unlikely that the 2019 target will be met. Achieving 20% renewable electricity by 2035 would require substantial deviation from the current trajectory given PREPA's debt and the privatization movement that may deter progress until a path forward is settled upon.

3.4 ADDITIONALITY AND REC AND CARBON OFFSET MECHANISMS

This project is positioned to generate either carbon offsets or RECs. The proposal has been further informed by ongoing discussions with experts who have raised the question of additionality due to the financial appeal of the project. Some specialists in this arena have expressed concerns about additionality in light of the commercial viability of the project, while others have suggested that an unregulated entity could claim they expedited the process of restoring carbon power production and thus claim offsets for a certain duration of time, but should assume that these facilities would be restored in the medium to long-term, negating additionality thereafter. Other experts have asserted that additionality could apply throughout the lifespan of the project, and point to reports from PREPA stating they have no immediate plans to directly finance revitalization of these assets.

The potential barriers to financing this proposal through carbon offsets - quantifying a specific amount each year, obtaining certification, and proving additionality - are not associated with the sale of renewable energy certificates (RECs). Several factors result in RECs being an easier and potentially more desirable funding mechanism for this project. First, RECs are easier to certify than offsets. Second, Puerto Rico along with many states have compliance markets for RECs, making them legally valuable (as compared to the voluntary nature of the carbon offset market). Due to the large generating capacity of our proposed system at 26.5MW, this project can appeal to large institutions seeking to meet their compliance market standards with a single investment that will be closely monitored by the cooperative during operation. Finally, RECs can be sold throughout the operable lifetime of the system, without the limitations imposed by the additionality discussion described above.

The project team's evaluation of additionality also involved a review of redevelopment proposals from outside developers and other government agencies. A summary of those projects for revitalizing Puerto Rico's hydropower dams follows:

The Cube Hydro Proposal

In considering additionality of the hydro refurbishment project, the project team evaluated an unsolicited proposal submitted by Cube Hydro Partners to the Public Private Partnerships Authority (the "Authority") to purchase several hydroelectric plants from PREPA and put them into operation. While details are sparse, there are reasons to think the project could proceed.

First, the Authority issued a notice in October 2017 that they are considering projects aimed to "maximize" Puerto Rico's hydroelectric assets (P3 Authority, 2017) and the director of the Authority indicated that studies of the project are underway (Caribbean Business, 2017). According to the Authority's guidance on unsolicited projects (P3 Authority), these steps indicate that the project has demonstrated enough merit to pass preliminary evaluations and the Authority exercised its discretion to commission relevant studies. Second, and perhaps more significantly, the governor of Puerto Rico has touted the ability of Public-Private Partnerships and these proposals to turn around the finances of the island. (El Nueva Dia, 2017). The current administration appears interested in the potential of such projects as a proof of concept and as a signal to wary businesses that they can count on the Puerto Rican government's support.

However, it is not clear which hydro facilities will be included in Cube's project if it is selected, or over what timeframe this partnership would feasibly proceed. The Director of the Authority has stated that ongoing studies will help determine whether "it's all hydroelectric plants [or] if it's going to be [some] other hydroelectrics." (Caribbean Business, 2017). It is uncertain whether the dams at Dos Bocas and Caonillas are or will be included in the project. Furthermore, Cube Hydro would likely sell RECs into Puerto Rico's compliance market, whereas the sale of RECs by the cooperative to an external voluntary, unregulated entity would incent regulated producers in Puerto Rico to undertake additional renewable energy projects to meet the RPS standards, offering a comparative advantage on additionality from the current project team proposal.

Other Government Initiatives

Aside from the specific Cube Hydro proposal, there are some indications that hydroelectric assets may be slated to be fixed under a "baseline scenario." Francisco Rullan, the Director of the Energy Public Policy Office, has previously said that his office would like to make all 20 of Puerto Rico's hydro plants operational with an initial focus on the Dos Bocas, Caonillas 1 and 2, and Yauco 1 and 2 facilities. (Caribbean Business, 2017). To put that vision into practice, the office plans to review these proposals to determine whether they can be listed as a "critical project" under PROMESA to streamline their evaluation and permitting processes. One company—Streamflow Technology Corp.—has submitted a proposal to the Board to install an 8MW hydro project at the Carraizo Dam (Oversight Board, 2018). Additionally, PRASA's 2017 revised fiscal plan indicates that it will invest in optimization of hydro resources under its control.

However, our team finds that the present reality on the island contradicts optimistic press statements regarding movement on these projects. The particular plants in question have been offline since the early 1990s, and the current state of the Commonwealth's finances makes it unrealistic that they will be able to fund or implement these projects. The wealth of evidence regarding the government's recent and ongoing performance in relation to hydropower support a "baseline" scenario in which the dams remain under-utilized and render it unlikely that the government would proceed with hydro optimization in the near to medium term.

4. Costs & Benefits

4.1 FINANCIAL FEASIBILITY

Refurbishing existing hydroelectric facilities in concert with a pumped solar system and burying transmission lines has the potential to deliver a financially attractive, community-centered project, particularly in the context of high potential generation capacity (26.5MW capacity), high baseline retail rates of electricity, and the heavily polluting nature of the current fuel mix. Hydropower can be one of the most economical alternatives to generate renewable energy from a levelized cost perspective. The bulk of hydro capital investment is typically embedded in upfront costs for civil works like dam construction and installing mechanical equipment such as turbines and generators, and greenfield hydropower construction can pose additional social and environmental costs associated with damming the relevant water body.

While the proposed refurbishment still requires significant upfront investment, these pre-existing hydro assets present a unique opportunity to design a project with features such as buried transmission lines that in many other contexts would be cost-prohibitive. One of the primary reasons this investment has not been pursued to date is likely the significant project development cost of nearly $160M. However, an unregulated entity such as Harvard could support the project as an equity investor or by committing to a longer-term contract involving purchasing RECs generated over the project lifespan. Please see page 38 for a more detailed discussion of the proposed contract arrangements between the unregulated entity and the cooperative.

Cost Estimates and Benchmark Assumptions

<u>Hydro Refurbishment</u>

The cost of refurbishing small scale hydroelectric plants varies significantly based on the project scope and existing asset conditions, and the refurbishments are highly site and equipment-specific. The project team was unable to source specific information on the nature of existing damages or exact sedimentation levels at the plants but given the age of the plants and limited public data available, have adopted estimates that skew conservative on capital expenditures and the ensuing operating and maintenance costs (O&M) required. Due to the lifespan and known damage at the plants, we anticipate that full system upgrades will be necessary, including replacing or refurbishing all electrical generating equipment, mechanical equipment, and infrastructure (including the powerhouse, dredging the reservoir, dam, and road access). These upgrades are expected to cost approximately $500-1000/kW (IRENA, 2012). We estimate that refurbishing the entire Caonillas/Dos Bocas System (26.5MW) will therefore cost approximately $13.25 to $26.5 million. Operating and maintenance costs of refurbished hydroelectric projects are estimated to range between 1% and 6% of capital costs (IRENA, 2012), and due to the remote nature of Utuado, we have assumed 4% for the purpose of this analysis, with annual O&M expense escalation and cost contingencies at 3.5%.

While there remains substantial uncertainty around PREPA's process of selling hydroelectric assets, the project benchmarks off recent dam acquisitions across the United States to estimate $15.15-19.5M in acquisition costs for acquiring the hydroelectric assets from the electric utility. The reservoirs will require dredging assumed to be consistent with industry wide estimates of $4-8 per cubic yard and based on the surface areas of the two reservoirs, we estimate $20.7-41.5M in costs for dam dredging and related waste disposal and transport.

Pumped Solar

Installing a fixed solar PV field of 20MW is expected to cost approximately $53 million in capital and $46,800 to $84,800 in annual maintenance costs based on EIA estimates (EIA, 2016). There is limited real estate data on local land acquisition in the specific areas targeted for the solar installation but benchmarked against acreage prices for comparable listings in Corozal County, PR, we have allocated $1.8 million for relevant land acquisition. Given the remote nature of Utuado, limited current demand, and availability of vacant land in the study area, we believe this to represent a fairly inflated estimate for the 175 acres required.

While installing pumped solar does not increase the installed capacity of the hydro system, it enables a capacity factor up to 90% (IRENA, 2012), and substantially increases the total annual production of the hydro system. We expect a fully functioning pumped hydro system at Caonillas/Dos Bocas to produce:

26.5MW (installed capacity) x 0.90 (capacity factor) x 8760 (hours/year) = 208,926MWh

Buried Transmission Lines

To ensure greater resiliency in the face of future storms, the proposal design includes burying power lines between the hydroelectric plants and Utuado. A recent study estimates approximately $1.5 million per mile for new 69 kW underground lines (Electric Light and Power). The power stations are sited approximately 3, 4, and 5.25 miles from Utuado and the team therefore expects that installation of these new power lines would cost approximately $16.8 million in capital expenses. While the study also notes that O&M costs are difficult to determine, this study estimates O&M will comprise approximately 4% of capital costs per the average of available industry estimates.

A summary of key cost assumptions can be found in the appendix of this report.

Financing Alternatives

As modeled in the appendix, we project a scenario in which Harvard would provide upfront equity of $55.7M, with the remainder financed separately through a 15-year loan. Under a more conventional equity investment structure, Harvard could recoup its investment within a payback period of 11 years and participate in the proposed cooperative model under an investor class. The project as structured has an NPV of $113M and 14.4% leveraged after-tax IRR.

Alternatively, Harvard could choose to sign a multiyear agreement to purchase future renewable energy credits, or RECs, which are legally valuable commodities that represent a megawatt hour (MWh) of electricity generated by a renewable resource on the grid. Under a scenario where Harvard were to purchase ten years' worth of RECs through a ten year agreement, rather than receiving equity return, we project an average price of $26.64/MWh for the sale of these RECs, which would be sold out of Puerto Rico's existing compliance market (assumes $55.67 million for an average yearly cost of approximately $5.67 million with 208,926 MWh generated annually). This price would be comparable to previous agreements PREPA has entered with solar companies on the island; in 2014, the electric utility reached Power Purchase and Operating Agreements (PPOAs) with solar developers that priced RECs at $25-35/MWh (Sullivan and Worcester LLP, 2015). RECs are typically priced in the context of the compliance market's alternative compliance payment. Puerto Rico's alternative compliance payment is set as the equivalent or greater economic value of the purchase of RECs, multiplied by a factor of two (NC Clean Energy Technology Center, 2015). Unfortunately, a lack of transparency around PREPA's historic payments on REC prices precluded the use of alternative compliance pricing in Puerto Rico's compliance market as an additional benchmark.

While the unregulated entity adopts some risk in committing to a longer-term REC purchase agreement in exchange for providing upfront equity, the REC purchase agreement can be structured to address risks of underproduction. Furthermore, Harvard University has a precedent for entering similar long-term arrangements. In 2009, Harvard signed a power purchase agreement (PPA) for 12MW of power and RECs from a wind project in Maine, becoming one of the first universities to make such a large scale, non-mandatory Power Purchase Agreement. The PPA involves a 15-year arrangement in which Harvard will purchase half the energy and RECs that are generated (Harvard Office for Sustainability, 2017).

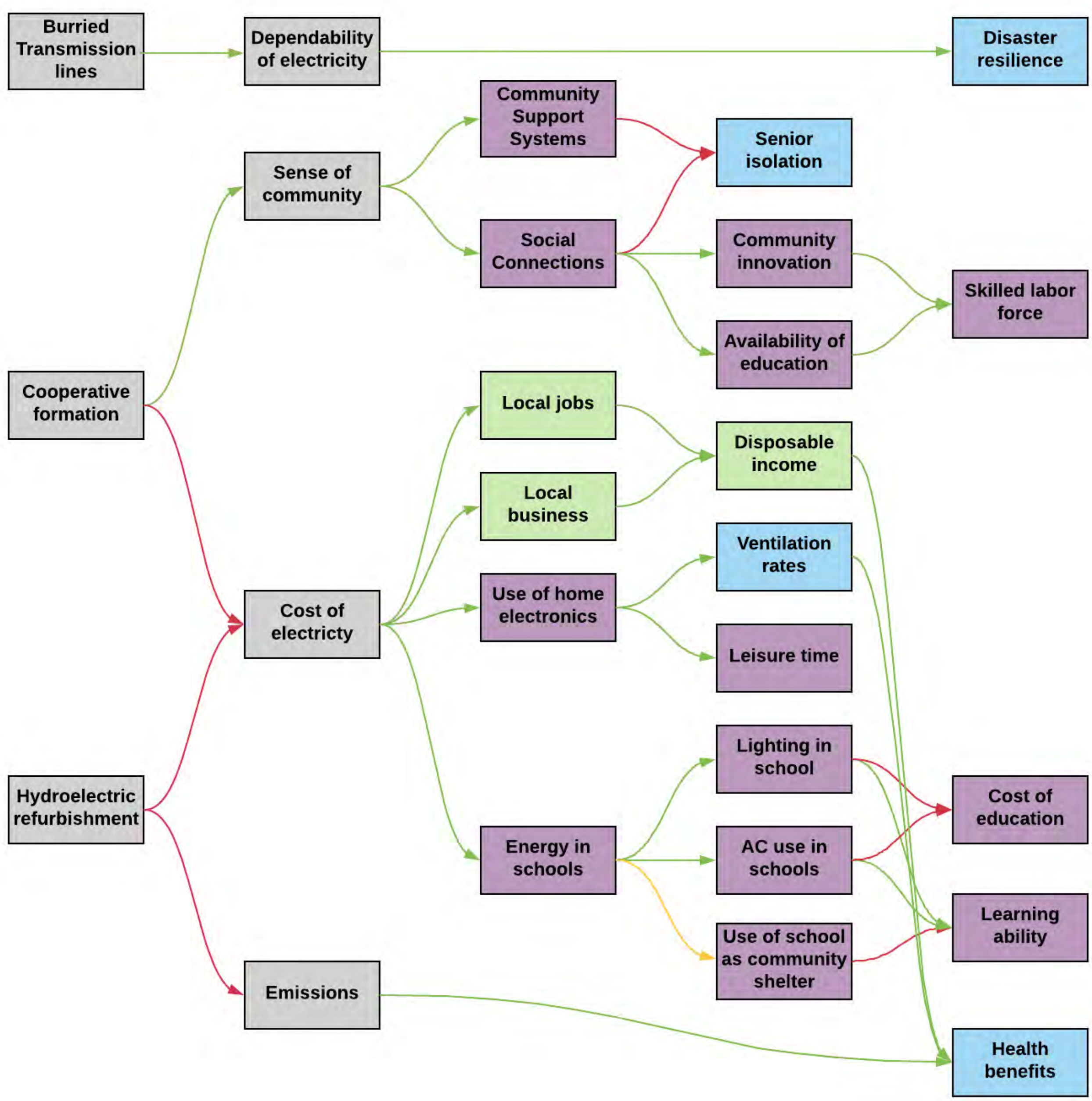
It should be noted that while LCOE for the proposed hydroelectric project would be approximately $0.03/KWh, the project team chose to set the price at $0.08/KWh to balance meeting the financing needs of the project and shaping a sufficiently attractive proposal for equity investors while providing electricity that is substantially cheaper for the residents of Utuado over the approximately $0.24/KWh retail rate. The cooperative is expected to reallocate margin or excess revenue to its members as capital credits based on their use of electricity, and could continue to evaluate alternative pricing rates closer to the baseline marginal cost of generation.

On the debt side, the cooperative could source loans from the USDA's Rural Utilities Service (RUS), which is financed through the Rural Electrification Act and authorizes direct lending as well as a loan guarantee program. RUS in 2015 committed $3.4B in loans and loan guarantees and remains a stable source of funding that has transcended changes in political administrations, with bipartisan support. The loan portfolio totals $46 billion and total investment has been $120 billion, and the program has had a delinquency rate of just 0.04% (USDA Rural Development Overview, 2017).

Unlike DOE programs that require formal solicitations, the RUS application process is highly consultative and can be tailored to the cooperative's needs. The RUS 35-year loans tend to be an attractive offer with lower than commercial 30-year fixed loan interest rates. While the program does not have a financial cap, projects generally tend to be located in low population areas of 20,000, although they are flexible on partial funding if the population exceeds those estimates (Utility Dive, 2016). The project team confirmed with the Puerto Rico office for RUS that a cooperative based in Utuado would meet geographic and population requirements for their loan funding. RUS has recently made significant loans within a comparable dollar range, including a $73M loan to finance the East Texas Electric Cooperative's hydroelectric station in Polk County, Texas (USDA RUS, 2012). Loans can cover up to 75% of project costs (as modeled, this proposal has a 65% LTV) with no origination fees and are usually confirmed or denied within three to nine months upon receiving an application. Finally, the National Rural Utilities Cooperative Finance Corporation (CFC) is another entity that could be consulted as an additional source of debt financing: the nonprofit finance cooperative provided loans totaling $24.4 billion as of 2017 (NRUCFC, Overview).

4.2 CO-BENEFITS (PUBLIC HEALTH, SOCIAL, ENVIRONMENTAL)

This project presents a unique opportunity to create tremendous impact in an underserved community through its triple bottom line approach. Not only is the project financially viable, the proposal as structured could offer numerous social, public health, and environmental benefits. Due to the cooperative aspect, benefits will accrue directly to the members of Utuado, and the impact of this project can benefit the entire community. If the project is carried out with a more developer-centric model, several co-benefits will not be realized at the residential level, as many of the co-benefits arise from reduced costs of electricity for cooperative members.



Social Co-Benefits

Social co-benefits from this project arise almost exclusively from the cooperative aspect of this project. The cooperative accomplishes two main outcomes that result in social benefits: reduced cost of electricity for Utuado and an improved sense of community.

Forming a cooperative would allow the members to purchase energy at or near the cost of generation, which initial estimates suggest could be as much as a 60% reduction in electricity costs after completion of this project. The reduced cost of electricity would be shared by both businesses and households in Utuado. Reducing overhead costs for local businesses can free funds for growth or employment, and we expect repercussions for business growth and job growth in the community.

Increased employment options and compensation, coupled with the decrease in household expenses (from reduced electricity costs) can substantially increase the disposable income for Utuado residents, which can produce personal benefits and improved quality of life (Bridge, Adhikari, & Fontenla, 2016). Increased disposable income can also increase household spending and strengthen local economic outcomes. Additionally, disposable income can be reinvested within the household through purchasing of appliances residents do not already own, particularly more energy-intensive appliances. For example, local contacts have communicated to the project team that washing machines are an appliance that would be purchased with increased disposable income. With reduced electric costs, these machines will be less costly to operate and the increase in income can lessen the hurdle of the initial purchasing cost. Washing machines can provide improved sanitation and an increase in leisure time, as residents currently wash clothes by hand.

Academic institutions within Utuado will also benefit from cheaper electricity, which can reduce functional costs for education centers and potentially allow schools to reinvest savings in direct educational services or materials (textbooks, computers, school supplies), educational staff, after-school programs, etc. The lower cost of electricity can foster improvements in lighting and indoor thermal comfort, and indoor ventilation. Improper lighting, temperature, and ventilation have been linked to decreased academic performance, reduced memory, reduced cognitive ability, and decreased attention spans. With reliable and affordable electricity, schools have a greater opportunity to improve the academic environment so that it is conducive to effective learning outcomes.

Utuado is home to the University of Puerto Rico at Utuado, which if reaping the benefits of reduced electricity costs, could potentially reinvest elsewhere in scholarships or pass benefits to students through reductions in tuition. Reinvesting savings in this manner would increase education affordability and accessibility in the community, which in turns offers potential to strengthen both the community education level and the labor force.

The formation of a cooperative also strengthens the sense of community in the region, which can result in a host of social benefits like improved support systems, increased connectivity, and improved educational outcomes (Chan, 2017).

Community support systems may be vital to Utuado given the challenges the community faces both demographically and meteorologically. Approximately, 16.7% of the population is over the age of 50 (Suburban Stats, 2018), and as the population continues to age in ensuing decades, a strong community support system can help to manage increasing demographic challenges like senior isolation (Chan, 2017). Additionally, as the climate continues to change, challenges from adverse weather events are expected to increase in Puerto Rico and community support systems often provide vital support during related natural disasters.

The connectivity of the community can increase as the cooperative demands and fosters increase community interactions (Chan, 2017). Strengthening this community network holds the potential to allow individuals to discover different opportunities and utilize local networks for employment and educational opportunities. The improved sense of community can also foster substantial improvements in community education, consequently improving the skilled labor pool and resulting in economic outcomes that incent further innovation, creating a positive feedback loop.

Public Health Co-Benefits

The public health co-benefits of the project are linked to all stages of the project, but the largest impacts are derived from emission-free electricity production that improves local air quality by offsetting current generation sources that are not emission-free. Burning fossil fuels produces a wide range of hazardous air pollutants like nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons, and particulate matter (PM). These pollutants manifest in a variety of reduced health outcomes (Clark, Millet, & Marshall, 2014; Colborn, Kwiatkowski, Schultz, & Bachran, 2011; Perera, 2016): most cause inflammation of airways, decrease lung function, increase respiratory sensitivity, aggravate serious lung conditions, increase the risk of respiratory infection and increase the risk of developing respiratory conditions like asthma and chronic obstructive pulmonary disease (COPD). Repeated inflammation can easily compound into serious cardiovascular outcomes like ischemic heart disease, and myocardial infarction (heart attack).

Some pollutants, such as PM, can also penetrate the alveolar membrane and enter the bloodstream, where they produce changes in blood chemistry and further propagate cardiovascular outcomes (Meng et al., 2013). This project is expected to offset the emissions of many harmful pollutants (see Table 4.2.1). Quantifying the health benefits associated with reducing these harmful pollutants, the project could save approximately $32.77 million in social damages related to healthcare every year (see Appendix page 112 for emissions calculation). However, this number is likely an underestimate in that it does not incorporate reductions in harmful heavy metal emissions nor does it consider that emissions occur in close proximity to Utuado residents' living quarters.

Table 4.2.1

Pollutant	Tons of Pollutant Emissions Averted Per Year
Sulfur dioxide	280
Nitrous oxides	270
Carbon monoxide	35
Ammonia	2
Black Carbon	1
Organic carbon	0.5

In addition to reducing outdoor exposures, the project offsets exposure to harmful indoor air pollutants indoors. Utuado is particularly vulnerable to air pollution because most homes are built with natural ventilation, i.e. the quality of indoor air is directly proportional to the quality of the outdoor air. The hydroelectric cooperative could improve indoor air by providing energy at a lower cost, increasing use of electric fans and air conditioning (AC) units that improve indoor air quality by increasing ventilation rates and humidity levels, and offering filtration in the case of AC units. The use of fans and AC units also improves thermal comfort within the home, which reduces the risk of heat stress and heat stroke (Mayo Clinic, 2018). Another local risk factor for health includes the use of liquid propane (LP) and biomass burning cookstoves. Both LP and wood/biomass burning cookstoves produce hazardous air pollutants like NOx and PM. Biomass burning stoves produce black carbon, a type of PM that has been repeatedly linked to cancer development (Valavanidis, Vlachogianni, Fiotakis, & Loridas, 2013). Both types of cookstoves can harm human health because the emissions remain mostly contained within the room and the user is exposed to much higher pollutant concentrations. By reducing the cost of electricity, electric cookstoves may become a more affordable option and reduce the burden of disease caused by the reliance on LP and biomass cooking.

Another set of public health benefits are achieved through improved grid resilience linked to burying transmission lines. Lack of power post-disaster can result in substantial health repercussions, both from exacerbation of heatwave like conditions and from the lack of potable water from treatment plant failure. After Hurricane Maria, high temperatures and high humidity placed a large degree of thermal stress on the population (Campbell, 2017). While residents can typically adapt to these conditions with the use of fans or air conditioners, absent those alternatives for air conditioning, similar situations create the equivalent of an inescapable heatwave. Reliable power post-hurricanes allows the community to maintain thermal cooling mechanisms and reduce extended exposure to high temperatures.

The project can also help provide clean drinking water by ensuring that treatment plants remain functional following a natural disaster. Post-Maria, treatment plants could not generate enough electricity to operate the large pumps used to move water through the treatment plant. As a result, people resorted to sourcing drinking water directly from surface water bodies. Simultaneously, wastewater treatment plants could not treat the wastewater, which was discharged untreated into local water bodies. As a result, cases of waterborne infectious diseases increased immediately after Maria. Leptospirosis is a bacterial infection caused by the genus Leptospira and can occur in both humans and animals. It spreads to humans via contact with urine of other infected humans or mammals, most typically rats. While leptospirosis is easily treated with a regimen of antibiotics, infections are often misdiagnosed as other diseases and have a range of symptoms including fever, headache, chills, muscle aches, vomiting, jaundice, abdominal pain, and or diarrhea. If the infection is not treated, it can result in severe kidney damage, meningitis, liver failure, respiratory distress, and death. 74 cases of Leptospirosis were reported in Puerto Rico in the three months following Maria (Curtis, 2017) compared to an average of 100 to 150 cases of Leptospirosis reported annually throughout the entire United States. The CDC estimates that every year at least 50% of Leptospirosis cases across the United States are in Puerto Rico ("Leptospirosis," 2017).

Utuado has many characteristics of a high-risk community for Leptospirosis and other water borne diseases, as the municipality is poor and has an urban rodent population. Typically, treatment methods at the water treatment plant remove pathogens that cause waterborne infections like Leptospira, but because the plant did not have electricity during and after Maria, it was unable to sufficiently treat the water supply (Campbell, 2017). If transmission lines to the water treatment plant are buried, then the plants will be able to function after a disaster and their ability to provide clean drinking water will not be impeded.

Environmental Co-Benefits

By reducing harmful emissions, this project will produce environmental benefits, as improvements in air quality can benefit local ecosystems. Quantifying the reduction in pollutant emissions from Table 4.2.1, the project is estimated to save between $10.5-22.1 million in environmental damages. Air pollutants can damage ecosystems through pathways like acid rain, eutrophication, direct exposures for wildlife and vegetation, haze, ozone depletion, and climate change. As one example, air pollutants can damage trees and other plants (Union of Concerned Scientists, n.d.) and offsetting these emissions and improving air quality can manifest in increased resiliency of local vegetation. This will benefit the community by improving disaster resilience for the local environment. One way adequate vegetation improves disaster resilience is by reducing the risk of landslides (Cazzuffi & Crippa, 2005). As climate change is expected to usher in periods of extreme drought followed by extreme rain, the risk of landslides in mountainous areas will increase. The improvements made to local forests by improved air quality may counteract some effects of climate change and reduce landslide risks under future scenarios with extreme weather. Additionally, improvements in vegetation robustness will improve crop yields and may yield economic benefits for local farmers, as well as nutritional benefits for the local community.

4.3 UNINTENDED CONSEQUENCES

While the project does achieve a triple bottom line, there is the possibility that it could produce unintended consequences. Both reservoirs are used as drinking water supplies for San Juan and potential issues of water availability or contamination could create adverse impacts.

Currently, both reservoirs are dependent on precipitation for recharge. If rainfall levels are insufficient to maintain these reservoirs, both Utuado's electricity and San Juan's water would be adversely impacted. Initial water budget calculations suggest that the area can absorb a 30% reduction in annual precipitation (see Appendix page 114 for water budget calculation). The most extreme climate projections indicate that precipitation in the area will decrease by 15-25% by 2080 ("Climate Prediction," 2018), which may render the system unsustainable in that extended timeframe. Additionally, since the area is projected to undergo periods of extreme drought and extreme rain, the integrity of the dams will need to be adequately maintained to reduce flood risk.

Hydroelectric facilities can cause environmental damages ("Environmental Impacts of Hydroelectric Power," n.d.), typically from leaching toxicants in the soil into water (Dai, Zheng, & Liu, 2010), where they enter the food-web. Through bioaccumulation, these toxicants can present severe effects on humans and wildlife (Hylander et al., 2006). While this scenario cannot be entirely negated, evidence suggests it is not a concern for this project. Through bioaccumulation, toxicants eventually leave the local environment and concentrations return to a safe level, typically between 30-40 years after the impoundment of the reservoir (Linkov, von Stackelberg, Burmistrov, & Bridges, 2001). Both Lago Dos Bocas, and Lago Caonillas were impounded in the 1940's ("Lago Dos Bocas at Damsite," 2018). As almost 80 years has passed since their construction, we do not anticipate related environmental consequences. Since the project does not require flooding additional areas, equilibrium is expected to be maintained. While it is possible that dredging might expose soil that has not interacted with the water and thus release toxicants, those substances would be reflective of local industrial activity prior to impoundment. While data on historical industry is not publicly available, research to date has not indicated any local industrial activity close enough to result in significant environmental impacts. Concerns from local stakeholders could be mitigated by taking fish samples to validate these assumptions, and soil samples could be taken from the lakebed prior to dredging.

In addition to the potential for unintended water quality and availability impacts, the project may also adversely affect the community of Utuado. The formation of the cooperative carries the potential to create an additional level of stratification within the population, based on those included and excluded within the community. As it will be more difficult to include people who are homeless or do not have formal property rights, it is unlikely that a cooperative would automatically include the full set of residents within Utuado. The cooperative could be potentially exploitative or reap co-benefits that are not shared among those excluded from the member-owner structure, thereby potentially furthering inequity within the community.

5. Implementation Plan

At its core, an electric cooperative holds three key principles:

1. The utility company is owned by the members it serves;

2. Each member-owner is entitled to a vote in company decision-making;

3. Surplus revenue at the end of each year is redistributed to member-owners according to pre-agreed upon terms.

PROJECT STRUCTURE AND IMPLEMENTATION OVERVIEW

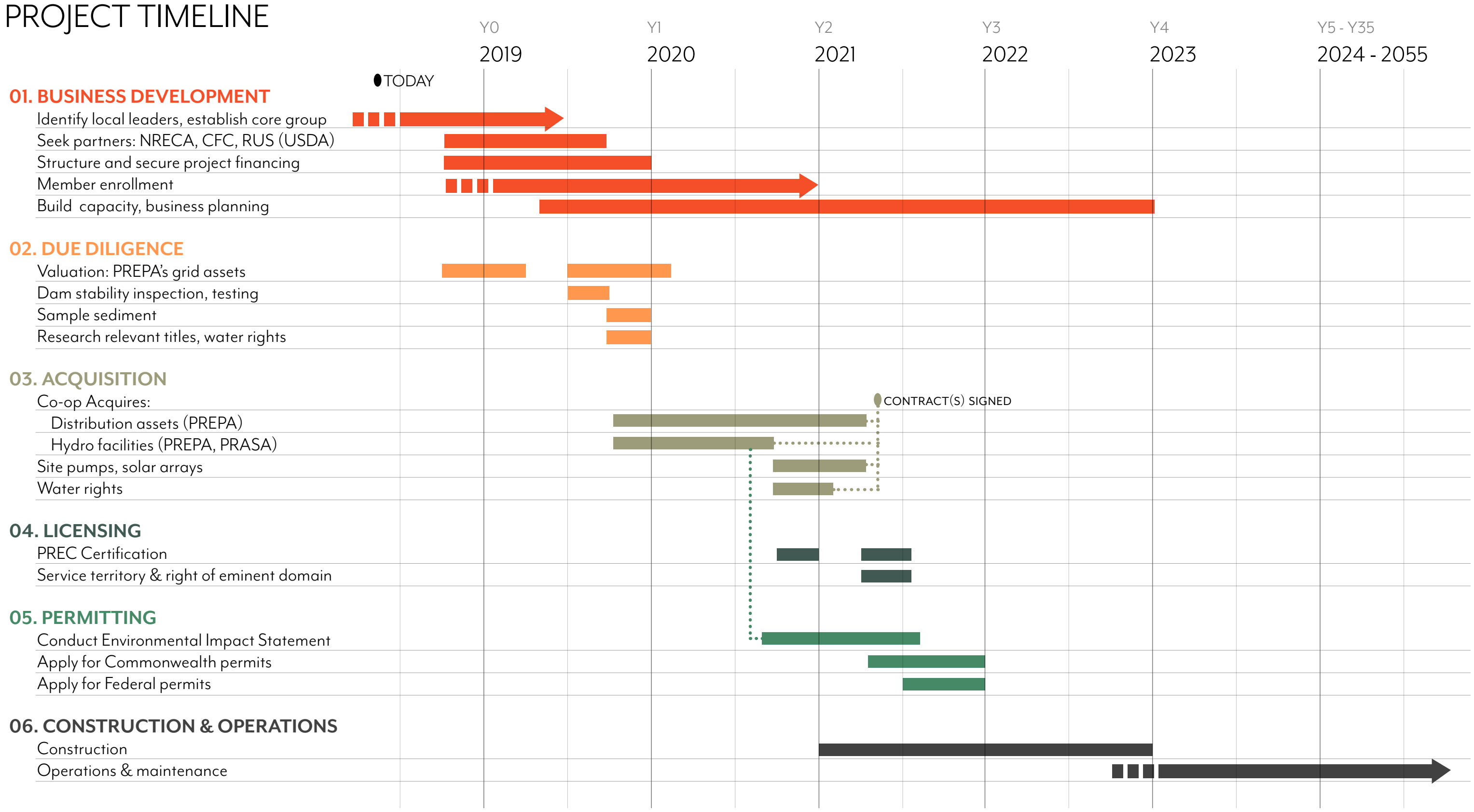
The foundation of this project is the Utuado Electric Cooperative -- a model for power authority and ownership new to Puerto Rico, but well-established in other parts of the United States. Partnerships with national cooperative support groups like the National Rural Electric Cooperatives Association (NRECA), the National Rural Electric Finance Corporation (CFC), and USDA's Rural Utility Service (RUS) underpin the cooperative's development and success.

To implement the project, local leaders will establish a planning group that will form the cooperative and begin enrolling members. The cooperative will then seek to partner with the national cooperative support groups. These groups have expertise in building capacity and serve as the main sources of financing for electric cooperatives. Because these groups view buy-in from the local community as the foundation of a cooperative's success, it is imperative that the planning group engage the community in ways that demonstrate their commitment prior to partnering with the national groups.

Once established, the cooperative will work to perform due diligence, acquire assets and rights of use, obtain the necessary licenses and permits, and complete construction so that the cooperative is operational by 2023.

Because the cooperative and its partners are the hub of the project, the role of the unregulated entity (URE) is limited to an agreement to purchase RECs. However, if it were so inclined, an entity like Harvard might also make its expertise available to the cooperative throughout the implementation of the project to lower costs and facilitate capacity building.[3]

PROJECT TIMELINE



3 Additional ways Harvard might be involved include the engineering of the hydro retrofit, the due diligence process for testing of sediment, and through additional legal support for the cooperative through the Environmental Law and Policy Clinic.

01. BUSINESS DEVELOPMENT

Key Steps: Local leaders establish planning group that forms the cooperative and enrolls members; cooperative partners with support groups; cooperative obtains financing and builds operational capacity.

A fundamental aspect of this project includes partnering with national support groups who provide financing for electric cooperatives and have expertise in building the capacity to operate electric utilities. These entities include the National Rural Electric Cooperative Association (NRECA), the National Rural Utilities Cooperative Finance Corporation (CFC), and the USDA's Rural Utility Service (RUS). In conversations with these groups, they have stressed that a cooperative's strength and success stems from the commitment of its members and leaders, and they view concerted community engagement as a prerequisite for involvement. This engagement and preliminary capacity building may include surveys, informational meetings, workshops, meeting with public officials, and relationship building with Puerto Rican cooperatives and other local partners.

To establish community support, local leaders should consider establishing a planning group that forms the cooperative[4] and begins to enroll members. If it desires, the URE may provide its support to the cooperative at this stage financially or through its expertise. For example, members of the Emmett Environmental Law and Policy Clinic could assist with the formation of the electric cooperative although involvement from the URE is not strictly necessary at this early stage.

The planning group will shape its own development strategy based on guidelines, mentorship and guidance from other cooperative associations. A key starting point may include using a survey and/or information sessions to gauge residents' interest, support, and willingness to pay tariffs necessary to maintain the cooperative's financial viability.

The scope of organizing an electric cooperative is outlined in NRECA's Guide for the Creation of Electric Cooperatives.[5]

The 18 steps articulated in the guide, shown on the opposite page, can serve as a framework for the planning group in Utuado that can be tailor to specific needs as the organization evolves.

Once the local community is sufficiently engaged, the cooperative should reach out to national electric cooperative support groups to form supporting partnerships. As modeled by the Kauai Island Utility Cooperative, these groups can help the cooperative cover startup costs, finance asset purchases, and provide operating capital. Additionally, the cooperative should work with these groups to build its operational capacity.

4 Note that there may need to be two cooperatives because it is unclear whether a distribution utility will be permitted to own generation under the next regulatory regime in Puerto Rico. As it now stands, there is no such prohibition on a distributor owning generation assets and this section proceeds under the assumption that a generation and distribution cooperative is formed.

5 To download the guide, visit http://www.nrecainternational.coop/wp-content/uploads/2016/11/Module2GuidefortheCreationofElectricCooperatives.pdf

These 18 steps articulated in the NRECA guide can serve as a framework for the planning group in Utuado that can be tailor to specific needs as the organization evolves.

1. Conduct a leadership meeting to discuss the need for a cooperative.
2. Meet with people who have expressed interest in forming an electric cooperative. Vote to determine if process should continue. If affirmative, select a Provisional Committee.
3. Survey potential members to determine interest in the creation of an electric cooperative.
4. Conduct a General Meeting to discuss the results of the survey. Vote to decide whether or not to proceed.
5. If the decision is to proceed, select a Steering Committee.
6. Contact the appropriate government and regulatory organizations, such as the Ministry of Energy.
7. Conduct a feasibility study.
8. Hold a General Meeting to discuss the results of the feasibility study, and conduct a confidential/secret vote on whether to proceed.
9. Develop a business plan and further financial analyses.
10. Hold a General Meeting to discuss the results of the financial analyses and the business plan. Vote on whether to proceed.
11. Prepare the necessary legal documentation and initiate the incorporation process.
12. Carry out a member registration campaign.
13. Conduct a Founding Assembly with all the potential charter members to approve the Bylaws and choose a Board of Directors.
14. Conduct Board Meetings to elect officers and assign responsibilities to implement the business plan.
15. Implement the necessary legal steps, e.g. incorporation, service territory concession, construction authorizations or transfer of existing electrical infrastructure, and tariff approval.
16. Prepare a capitalization plan and loan applications.
17. Prepare to start operations by hiring a General Manager and acquiring the necessary infrastructure, tools, and equipment.
18. Commence operations.

02. DUE DILIGENCE

Key Steps: Determine the value of PREPA's assets; study electricity use in the community; test dam stability; sample sediment; and research relevant titles and water rights.

Before acquiring assets, the cooperative should study the value and condition of the distribution and generation assets.

The value of PREPA's distribution assets may be impaired due to Hurricane Maria or historic mismanagement. The cooperative will need to carefully assess the value of these assets before contracting for their purchase or use. Additionally, the cooperative should acquire load data for the community to model potential revenues and savings for community members.

The cooperative should also evaluate several aspects of the hydro generation project before investing. First, PREPA's dam stability testing program has lagged due to underfunding. The cooperative should test dam stability prior to investment to assess safety and the likelihood of obtaining a dam construction permit. Second, dredging the reservoirs will increase generation capacity and extend the lifetime of the project. As such, the cooperative should test sediment in the reservoir to determine the environmental repercussions and approach to dredging the reservoirs, and whether it is likely a dredging permit will issue. Third, the cooperative should research water rights, managed by the Department of Natural and Environmental Resources, in the reservoir and downstream to ensure the project will not impair pre-existing interests. Fourth, the cooperative should research titles to potential sites for the solar generation.

03 & 04. ASSET ACQUISITION AND LICENSING

Key Steps: Acquire ownership or use of PREPA's distribution assets, the hydroelectric generation facilities, water rights, and rights for siting of pumps and solar arrays; obtain regulatory approval to generate and distribute electricity, including, if possible, an exclusive service territory and right of eminent domain.

The current regulatory structure is a potential barrier to the project because PREPA owns the generation assets and currently serves as the monopoly electricity service provider on the island. However, there are strong indications that PREPA will be privatized in a way that will enable the project to move forward.

In January, Governor Rosselló announced that "[PREPA] will cease to exist as it deficiently operates today." He supports "a model of privatization of power generation and a concession, term-defined, for energy distribution and transmission." Further, proposed legislation authorizes PREPA "[t]o carry out competitive requests for proposals or public private partnership contracts . . . to sell or dispose of any PREPA asset and/or to transfer or permanently delegate (for a fixed or temporary time period) any operation, function or service to a Proponent."

While uncertain, this planned privatization presents a unique opportunity for the cooperative to enter the generation and distribution markets. It seems most likely that PREPA will sell its distribution assets under an RFP process and will retain ownership of the distribution system while entering public private partnerships (PPP) for its operation. If PREPA indeed follows this course, then the cooperative should submit a bid to purchase the hydro assets and enter a proposal for a PPP. If PREPA does not initiate a formal partnership process, then the cooperative may submit an unsolicited proposal to the Public Private Partnership Authority,[6] which will study the desirability of the project and determine whether to move forward in consultation with PREPA.[7] If the cooperative is unable to enter a PPP with PREPA, then it can seek certification as a cooperatively owned microgrid under the Puerto Rico Energy Commission's draft microgrid regulations.[8] Similarly, if PREPA does not begin a sale of the hydro generators, then the cooperative can approach PREPA about a sale or submit an unsolicited proposal to the PPP Authority.

After acquiring the hydro generation, the cooperative should seek certification to generate electricity from the Puerto Rico energy commission. Additionally, it should seek to obtain water rights and rights (likely easements or leases) in the sites used for pumps and solar arrays.

As the privatization effort is developing, the cooperative should remain attentive and respond to developments as needed.

05. PERMITTING

Key Steps: Conduct environmental assessments; apply for Commonwealth permits; seek determinations on whether federal permits are necessary and apply as needed.

The hydro retrofit requires Puerto Rican permits and may need federal permits. The cooperative should conduct the necessary environmental assessments, including an environmental impact statement for dredging in a drinking water supply, apply to the Puerto Rican authorities for permits, and seek determinations from federal agencies regarding whether permits are needed.

6 Unsolicited projects must be for less than $55,000,000. ***See*** L.P.R.A §2601(t); §2608.

7 Two important issues to address in the PPP agreement are the authority to distribute electricity and the right of eminent domain. PREPA is currently the only entity with approval to distribute electricity in the Commonwealth, so the PPP should provide the cooperative with the exclusive right to distribute electricity in the service territory. Additionally, the PPP should deal with rights and duties regarding maintenance and improvement of the distribution facilities, including the right of eminent domain. Specifically, if the eventual legislation doesn't allow PREPA to delegate its power of eminent domain then the cooperative should insist on a procedure that requires PREPA to exercise its eminent domain authority on its behalf.

8 In this case, the cooperative should redesign the project to serve critical assets in the community, such as schools and hospitals, and slowly include residential customers because a microgrid serving a community of around 30,000 people is substantially larger than typical microgrid projects. Because this eventuality seems like a remote possibility, further discussion is left out of this implementation plan.

While there are no indications that the project will struggle to obtain permits from the Puerto Rican authorities, federal permitting may present a hurdle for the project given the current listings of the relevant water bodies as impaired.

Commonwealth Permitting

First, PROMESA Title V offers an opportunity to qualify a project as related to "critical infrastructure" where expedited permitting processes are utilized. The cooperative should apply through the FOMB and go through the notice and comment period required under the statute. If selected, the expedited permitting process may significantly decrease both the time and costs associated with obtaining Puerto Rican permits.

Second, under the Commonwealth's Public Policy Environmental Act, actions by Puerto Rican agencies that "significantly affect the environmental quality" require assessments of their environmental impact, and, because the dredging will occur in a drinking water supply, an environmental impact statement is necessary. It is likely least burdensome to conduct all required analyses at once. The presence of endangered species should be included in each analysis.

If the project is not selected by the FOMB, then the cooperative should apply for the following permits: a dam construction permit from the Puerto Rico Dam Safety Program run by PREPA; a general construction permit from both the Environmental Quality Board and the Puerto Rico Planning Board; and for a dredging permit and water use permit[9] from the Department of Natural and Environmental Resources. Puerto Rico is in the process of streamlining its permitting processes and while the cooperative should first apply through the Permits Management Office, it may need to apply separately to the other relevant agencies if these processes are not yet integrated.

Federal Permitting

Federal permitting may present a barrier to the project because the reservoirs were listed as impaired on Puerto Rico's 2016 §303(d) list.[10] As such, there will be a higher burden to obtain certification from the Puerto Rico Environmental Quality Board that the project meets the state's water quality standards.[11] However, there is a chance that the project will not require federal permits because the particular waters may fall outside the jurisdiction of those agencies.

These relevant agencies are the Federal Energy Regulatory Commission (FERC), the Environmental Protection Agency (EPA), and the Army Corps of Engineers (ACE). This section discusses each in turn.

FERC

Under section 23(b)(1) of the Federal Power Act, hydropower projects must be licensed or granted an exemption from licensing by FERC if the project falls under FERC's jurisdiction. In the relevant part, FERC has jurisdiction when a project is located on navigable waters of the United States.[12] FERC, however, does not currently license the generator at Dos Bocas

9 Water use permits and fees are governed by DNER's Regulation for the Utilization, Use, Conservation and Management of the Waters of Puerto Rico (Regulation No. 6213 of Oct. 9, 2000).

10 *See* EPA, ***Puerto Rico 2016 305(b) and 303(d) Integrated Report*** at 273 (2016).

11 The EQB promulgated Water Quality Standards Regulations in 2003, available in Spanish, that govern its review of certification requests.

12 Navigable waters are defined as

> those parts of streams or other bodies of water over which Congress has jurisdiction under its authority to regulate commerce with foreign nations and among the several States, and which either in their natural or improved condition notwithstanding interruptions between the navigable parts of such streams or waters by falls, shallows, or rapids compelling land carriage, are used or suitable for use for the transportation of persons or property in interstate or foreign commerce, including therein all such interrupting falls, shallows, or rapids, together with such other parts of streams as shall have been authorized by Congress for improvement by the U.S. or shall have been recommended to Congress for such improvement after investigation under its authority

> 16 USC §796 (8).

nor at Caonillas.[13] As the project at Dos Bocas is currently operating at a diminished capacity and does not meet the automatic licensing exemption[14] nor maintain a case-specific license exemption,[15] it appears FERC disclaimed jurisdiction over these particular waters. Therefore, the cooperative likely does not need a license from FERC.

The cooperative is nonetheless required to seek a determination from FERC regarding whether a license is needed. To do so, it should file a Notice of Intention and a Petition for Declaratory Order with FERC.[16] If FERC asserts jurisdiction, then the cooperative must obtain a license.

To obtain a license, the cooperative must receive a certification from the Puerto Rico Environmental Quality Board (EQB) that the project meets the Commonwealth's water quality standards.[17] Certification may be hard to obtain because the two reservoirs are currently impaired for dissolved oxygen, and hydroelectric projects can exacerbate this issue.[18] However, the EQB may certify the project with conditions or exempt the project from certification. It is not unprecedented for the EQB to issue exemptions where a project may not meet water quality standards but offers significant benefits. ***See Surf and Env't Conservation Coalition v. Dep't of the Army United States***, 322 F. Supp. 2d 126 (D.C.P.R. 2004) (holding that the Army Corps violated the certification requirement when it discharged dredged material into a water body adjacent to the one for which it received a certification exemption from EQB). This project presents a compelling case for an exemption for two reasons: first, it delivers significant economic, environmental, and public health benefits, as previously outlined, and second, it will dredge reservoirs that supply San Juan's drinking water and which are experiencing significant rates of sedimentation. The certification requirement may present a hurdle for the project, but it is not an absolute barrier if EQB is convinced to support the project given the significant benefits.

EPA

While there will be several point sources involved in the project—at each generator and for the pumped storage—an NPDES permit is not necessary because the water will be released into the same water body from which it was taken. Both the EPA's Water Transfer Rule and Second Circuit precedent hold that water released into Waters of the United States that was originally taken from the same surrounding water body does not constitute a "discharge" such that an NPDES permit is required. While the cooperative may still work with the EPA for a determination that no permit is needed, it is unlikely that it will have to apply for an NPDES permit.

Army Corps

The Army Corps of Engineers (ACE or Army Corps) regulates "works" in the "navigable waters" of the United States under the Rivers and Harbors Act (RHA). As such, if these are jurisdictional waters, both the dam construction and the dredging of the reservoirs would be subject to the ACE's jurisdiction and require permits. In addition to tide-influenced waters, navigable waters include those that "have been used in the past, or may be susceptible for use to transport interstate or foreign commerce."[19] As this jurisdictional hook tracks that of FERC and FERC appears to have determined that its jurisdiction does not reach these projects (see above), it appears the cooperative will not need a permit from the Army

13 To download a list of active FERC licenses, visit https://www.ferc.gov/industries/hydropower/gen-info/licensing.asp

14 The relevant projects are not conduits (a "tunnel, canal, pipeline, aqueduct, flume, ditch, or similar man-made water conveyance") and thus fail the conduit exemption of §4.90.

15 To download a list of active FERC exemptions, visit https://www.ferc.gov/industries/hydropower/gen-info/licensing.asp

16 18 CFR Part 24 governs the substance of these filings. In general, the petitioner is responsible for offering details on the project such as location, the project's sponsor, plans for the project, a history of the project, and a preliminary jurisdictional analysis of the area's navigability.

17 A certification is needed under §401 of the Clean Water Act. While a permit will not be needed under §402 of the CWA (discussed below), the Supreme Court determined that the relevant "discharge" in §401 is distinct from that in §402, making certification under §401 necessary for hydroelectric generators. ***See S. D. Warren Co. v. Me. Bd. of Envtl. Prot.***, 126 S. Ct. 1843, 1850 (2006).

18 EQB's Water Quality Standards Regulations of 2003 will govern their certification analysis. Because the EQB regulations are not available in English, this implementation plan does not provide analysis of whether the project will be able to receive a certification.

19 33 USC §403.

Corps under its RHA authority.

In addition to its authority under the RHA, the Army Corps regulates discharges of dredged or fill material into the Waters of the United States under the Clean Water Act. Because this authority extends to Waters of the United States rather than to navigable waters, the Army Corps will likely have jurisdiction over any discharges associated with the dredging of the reservoirs. The cooperative may still avoid the Army Corps' permitting requirements, however, by designing its dredging project so as not to constitute a "discharge" under the ACE's regulations.

The corps exempts "incidental fallback" of dredged material from its definition of "discharge".[20] However, the regulations do not define what constitutes incidental fallback and the subject has been the focus of extensive litigation. Guidance from 1999 stated that incidental fallback included:

> dredged material that falls from a dredge bucket as it is raised up through the water column; dredged material that falls from a dredge cutterhead or clamshell bucket as it is moved through the sediment to pick up and remove soil; and the movement of dredged material around a backhoe bucket as it is moved through the soil in its normal, routine use in lifting the sediment.
>
> EPA, ***Memorandum: Regulation of Certain Activities in Light of American Mining Congress v. Corps of Engineers***, April 11, 1997, incorporated into ***Memorandum U.S. Environmental Protection Agency Regional Offices U.S. Army Corps of Engineers Divisions and Districts***, May 10, 1999.

In practice, the Army Corps considers the question on a case-by-case basis, and the cooperative should work with the Corps for a factual determination on whether there will be a discharge that requires a permit or whether there will merely be incidental fallback that is exempt from the permitting requirement.

If the Army Corps takes the position that a Department of the Army permit is needed either under its RHA or CWA authority, then the project will once again require certification that it meets the Commonwealth's water quality standards.[21] As discussed above, this presents a hurdle given the current condition of the reservoirs, but the project may still receive a conditional certification or an exemption from EQB. If it survives certification requirements, the project should pass the ACE's broad public interest review as outlined in 33 CFR 320.4(a) due to its significant public benefits.

In summary, the ACE regulates work in navigable waters and discharges of dredged material into the Waters of the United States. It is unlikely that the project ultimately requires a permit from the Army Corps because the Corps likely lacks jurisdiction over the affected areas under the RHA and because the dredging will not result in a regulated discharge under the CWA. If a permit is needed, the requisite water quality certification presents a hurdle for the project, but a conditional certification or an exemption from certification may offer a way around this requirement. The Army Corps works with individual project proponents by giving jurisdictional determinations and rulings on whether a project will result in a discharge. The cooperative should therefore work with the Army Corps to receive jurisdictional and factual determinations to determine whether a DA permit is needed and apply for permits if necessary.

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20 33 C.F.R. § 323.2(d)(2)(3).

21 The ACE's regulations require that the project comply "with applicable effluent limitations and water quality standards[...] during the construction and subsequent operation of the proposed activity." 33 CFR 320.4(d).

PERMITTING SUMMARY

AUTHORITY	PERMITS	PROCESS
Puerto Rico	Required Permits: • a dam construction permit from the Puerto Rico Dam Safety Program run by PREPA; • a general construction permit from both the Environmental Quality Board and the Puerto Rico Planning Board; • a dredging permit from the Department of Natural and Environmental Resources; • a water use permit from the Department of Natural and Environmental Resources.	(1)(a): Apply for "critical infrastructure" status with FOMB under Title V of PROMESA. (1)(b)If cannot obtain critical infrastructure status, file with the Permits Management Office and other authorities as needed. (2) Conduct Environmental Assessments and (at least for dredging) Environmental Impact Statement.
Federal	Potential Permits: · Operating License from FERC; · NPDES permit from EPA (likely not needed); · Dam construction and dredging permits from the Army Corps of Engineers.	(1) File Notice of Intention with FERC; apply for license if FERC asserts jurisdiction. (2) (if desired) Contact EPA for determination on NPDES permit requirement. (3)(a) Ask Army Corps for jurisdiction determination; (3)(b) Work with Corps for factual determination of whether there will be a "discharge" of dredged material or merely "incidental fallback." Apply for a dredging permit if Corps determines there will be a discharge. (4) If federal permits are needed, work with EQB to receive a certification or a conditional certification that the project meets the Commonwealth's water quality standards. If a certification will not issue, ask for an exemption from certification due to the project's significant benefits.

06. CONSTRUCTION AND OPERATION

Throughout the stages discussed above, the cooperative should continue to build its operational capacity under the guidance of NRECA and CFC. As part of this capacity-building process, the cooperative will enter employment contracts that will serve as a foundation for the future operation of the distribution and generation assets.

Additionally, it should seek to enter contracts with service providers who will be able to complete construction of the hydro retrofit and pumped solar project, including dredging of the affected reservoir. Working with these contractors early in the process may provide an opportunity for their expertise to aid in the relevant permitting processes.

Contract with the Unregulated Entity

The fundamental document governing the URE's involvement with the cooperative project will be the REC purchase agreement. The basic purpose of the document is to guarantee the cooperative some revenue that it may be able to use as collateral for financing. For the URE, the purchase agreement will lay out the terms governing the exchange of RECs and provide assurances regarding additionality.

Key terms in the agreement include the price of RECs, the number of RECs that will be purchased each year, and the term of the agreement. There should also be robust representations, covenants and warranties ensuring additionality of the RECs. Fundamental to additionality will be a covenant that the cooperative will avoid double counting by refraining from retiring any of the RECs Harvard claims or by selling offsets to a third party. The contract should provide for monitoring of double counting using one of the standard REC tracking protocols. To be particularly strict on additionality, Harvard could include a clause detailing the types of claims the cooperative can make about the carbon profile of the electricity it sells.

The parties should also engage in frank discussions about who will bear the risk that the project will not produce the contemplated number of RECs, and the contract should include detailed terms outlining what happens when the number of RECs falls short. For example, it is foreseeable that there may be an interruption in service in the event of the next hurricane, so the parties should detail whether the parties will be excused from performance or whether there will be a breach that entitles a party to damages in that event. In addition, the parties should discuss a liquidated damages clause that will help to provide certainty around the consequences for a breach of contract.

The Role of an Unregulated Entity

There are several points along the implementation plan where Harvard could leverage its institutional capacity as a leader in clean energy deployment, as well as an institution that seeks to achieve fossil-fuel free status by 2050 in part through clean energy procurement. Harvard could support the project development through initiatives across different centers and campuses. This could include legal assistance in the set-up of an electric cooperative for the community from the Emmett Environmental Law and Policy Clinic at Harvard Law School, as well as policy analysis support from the Harvard Kennedy School's Energy Policy group in structuring a system that can incorporate electric cooperatives into Puerto Rico's evolving energy regulatory landscape, among other options. This project could also benefit from technical assistance from Harvard's experts in energy and environmental science, who could help fill information gaps and conduct additional in-depth studies to scope the technical aspects of the project, which would represent a significant cost-savings for the project up-front. These services could be provided on a voluntary basis by Harvard faculty, staff, researchers and students interested in clean energy development and who have an opportunity within the project scope to contribute their knowledge and skills to Puerto Rico's recovery.

Further along in the project, as an unregulated entity, Harvard could purchase Renewable Energy Credits generated by this project possibly on a year-by-year basis or by arranging a multi-year contract at a fixed price in exchange for providing upfront equity. The purchase of RECs from this project would directly contribute to the development of clean energy in Puerto Rico. This is a compliance market where the Renewable Portfolio Standard has not been met in any year since it was set. Removing these RECs from this compliance market as a way for local producers to meet the RPS standards will further incentivize the construction of additional renewable electricity projects on the island.

Additionally, this stream of revenue could further improve the financial viability of the project. As we have seen, adding resiliency measures significantly increases the overall costs of the proposal, and Harvard's contribution could make the difference in enabling buried transmission lines that ensure that this community has power and clean water during future blackouts. Harvard would be directly contributing to building back better in Puerto Rico, working at the forefront of not just climate mitigation, but resiliency and improved adaptation.

6. Conclusions

The Utuado Electric Cooperative proposed in this document seeks to reduce Puerto Rico's vulnerability to climate events while tackling underlying challenges related to system maintenance, community empowerment, and economic development.

During our final presentation, we received suggestions that a larger energy system at the reservoirs should be explored. Specifically, experts suggested installing even more solar power (up to 100MW) than what we called for in the implementation plan. Rather than deploying solar to power the pumped hydroelectric system, it could be used under this expanded scope to provide additional electricity to cooperative members or sold to other customers beyond Utuado. The hydroelectric power would be used to stabilize the load and provide power during night hours and cloudy days. This expanded system could generate additional RECs or offsets, take advantage of tax incentives specifically targeting solar power, and provide additional revenue to the cooperative without significantly affecting operation and maintenance.

However, this system requires more analysis before gaining our endorsement. First, the project would call for substantially more capital investment, necessitating rethinking of financial models along the lines of engaging other private developers or tax equity investors. Second, the scale of the project adds legal complexity. For example, the cooperative would need to sign a power purchase agreement for the sale of the excess electricity, and it is unclear whether PREPA will remain the sole purchaser of electricity or if its privatization will result in other offtakers taking its place. Further, the project will need to be interconnected to the grid, and it remains unclear who will serve that role in the wake of PREPA's privatization. Perhaps more obviously, a greater amount of land will need to be leased for use in the project and associated environmental impacts may make it more difficult to be permitted. Although we do not attempt to address this additional design proposal given the substantial divergence in scope and structure, the project team considers it an alternative worth future consideration for interested parties involved in this project implementation.

The major question for the project moving forward surrounds the privatization effort and the future of Puerto Rico's electricity market and associated regulatory environment. While the cooperative is dependent on the outcome of these developments, it should seek to position itself to engage in the ongoing political dialogue.

The due diligence process will address questions about water rights, the current value and state of PREPA's assets, and the composition of sediment in the reservoir. Beyond the due diligence process, the co-operative can work with regulators for determinations on permitting that will answer remaining questions on the steps needed for project implementation.

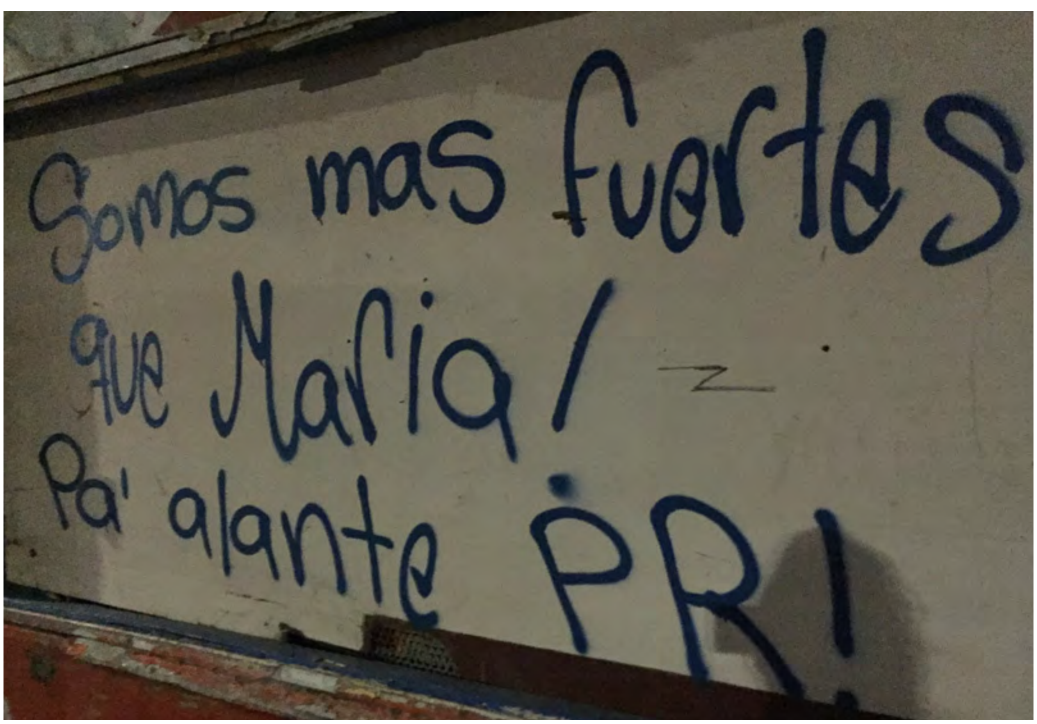
In conclusion, the proposed Utuado Electric Cooperative described in this document seeks to reduce Puerto Rico's vulnerability to climate events while tackling underlying challenges related to system maintenance, community empowerment, and economic development.

Offering a triple bottom line investment opportunity for investors, residents, and other stakeholders, the project can achieve:

- renewable energy production at scale (to serve an entire municipality);
- improved power reliability and operational continuity for critical infrastructure; and
- local ownership of energy production and distribution.

This project concept of local cooperative management for renewable energy generation and distribution across the island in turn can open up new avenues of financing for renewable energy projects and resilient energy infrastructure, create new job opportunities and positions of power for residents, and provide cost savings to an underserved and largely low-income population in Puerto Rico.

Learning from past mistakes and relying on research and analysis of climate change impacts and social vulnerabilities, this project seeks to propose a new mechanism for power security and island resilience for both short-term and long-term objectives.



Utuado, 2018.

Appendix

Project Screening

The screening exercise formed the foundation for our project development, and identified two priority alternatives, a cooperative hydroelectric project and a solar + storage project, to carry forward into the feasibility study.

Our team considered a number of screening criteria, including:

- **Adverse impacts**: foreseeable adverse impacts and risks of unforeseen impacts
- **GHG emissions reduction** potential
- **Financial feasibility**: total returns, policy levers, and expected costs of potential projects
- **Political** and **community buy-in**
- **Public health benefits**: includes access to services and overall health outcomes
- **"Sellability"**: likelihood that a third party would undertake the project or buy credits to offset their emissions
- **Social benefits**: community benefits beyond GHG reductions or public health benefits such as financial benefits due to job creation, lower electricity costs, increased access to electricity, and higher resiliency of the electric grid
- **Technical feasibility** and potential **replicability** across other communities

Screening criteria considerations were scored on a 0 (low) - 10 (high) scale, based on group consensus, to reflect our group's project priorities. Please see page 48 for matrices.

Screening Criteria	Weighted Results
Adverse impacts/unintended consequences	0.051
GHG emissions reduction potential	0.136
Financial feasibility	0.169
Political and community	0.119
Public health benefits	0.102
Sellable	0.136
Social benefits	0.068
Technical feasibility	0.136
Time-frame	0.085
Total	1

Lago Caonillas, 2018.

The team explored two realms of solutions: restoration of power and restoration of drinking water supply. During this exercise, we evaluated natural water sanitation facilities, greywater water recirculation, and rainwater harvesting, but determined that a substantial number of water quality and access issues have been primarily linked to the absence of power affecting treatment facilities. Given the potential for greater project impact and the ability to simultaneously address power issues in the water sector, we narrowed the focus to projects that prioritize power restoration and energy system transformation.

Projects considered in this screening exercise:

PROJECT 01: Hydro Retrofit
Upgrade existing hydropower infrastructure for local reliability.

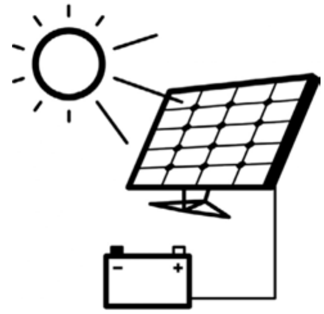
PROJECTS 02 – 04: Community Solar + Storage
Provide alternative renewable energy source through solar power with a backup storage option that ensures resiliency in light of storm events. Variations:
02 Residential
03 Community Buildings
04 Emergency Services

PROJECT 05: Microgrid
Locally-produced power and distribution able to “island” or operate independently from the grid.

PROJECT 06: Virtual Power Plant
Cloud-based, aggregated power from heterogeneous Distributed Energy Resources (DERs) for power generation, sale, and distribution.

SCREENING RESULTS

PROJECT 01: Hydro Retrofit



PROJECT 03: Community Solar + Storage

Team members individually ranked projects based on our respective areas of expertise, and in light of preliminary research into the aforementioned criteria. Information for this assessment included but was not limited to: analysis of Puerto Rico's Electricity Commission's Renewable Portfolio Standard targets from 2015; proposed Puerto Rico Electric Power Authority (PREPA) reform and privatization schemes; revised microgrid draft regulations; recently proposed projects from electricity providers like AES; hospital and social service recovery reports post-Maria; specific reports and research gathered from local contacts in Utuado; available energy data on the island collected by various private and public entities; high-profile energy proposals from companies like Tesla; and research into existing energy infrastructure across the island, such as the status of hydroelectric plants sited in Utuado.

This research was supplemented by direct communications with over 15 Puerto-Rico based stakeholders across energy, water, education, business, communications, urban planning, government, and nonprofit sectors. We have been in touch with contacts at the Puerto Rico Energy Center to determine which projects will require more fine-grained data, whether that data would be accessible or could be substituted with reasonable proxies, and what community partners have expressed as their greatest needs.

Scoring matrices and the aggregate results of the screening are provided in the appendix. The screening exercise formed the foundation for our project development, and identified two priority projects to carry forward into the feasibility study.

SCREENED OUT: RESIDENTIAL SCALE

Given limited financial incentives, median household income, and lack of economies of scale, the team did not find a residential solar proposal to offer sufficient benefits competitive with the alternatives discussed in this report.

While many Puerto Ricans have expressed interest in individual power alternatives, residential-scale projects were not deemed economically feasible in the specific context of the team's mandate and course objectives. The viability of solar home systems depends largely on the retail price of electricity and financial subsidies available for these systems. Puerto Rico does not offer a state income tax credit, but the federal Investment Tax Credit (ITC) allows homeowners to deduct some solar system costs and could potentially provide some assistance for systems that can total upwards of $15,000. Despite statements from proponents such as Elon Musk that there is "no scalability limit" to solar home systems, such systems are often cost prohibitive (Clean Air Watch, 2017), are not readily feasible for a population whose median household income averages $15,875 (American Community Survey, 2016).

Beyond the upfront costs, residential solar is significantly less attractive when compared to the cost effectiveness of utility-scale solar systems. Utility-scale PV solar is roughly half the cost per kWh of electricity compared to a residential-scale system (Forbes, 2015). In the context of this study, the greenhouse gas emissions potential of projects is another important criteria, and utility-scale systems have been found to avoid approximately 50% more carbon emissions when compared to residential PV systems.

Though utility-scale solar systems are more economically attractive, the benefits provided by residential solar systems include making use of underutilized space such as rooftops and allowing for on-site generation independent of distribution lines. The cost and logistics of installing solar + storage systems on a household-by-household basis make the residential-scale proposition impractical. However, the benefits of off-grid, localized power generation are attractive, which led the team to consider scaling up the size of a residential project to larger buildings such as a hospital, school, or water treatment plant. By focusing on community-scale solar + storage, the project team is afforded improved economies of scale and perhaps more importantly, emergency preparedness benefits designed with the whole community in mind in the event of the next power outage.

SCREENING CRITERIA MATRICES

Screening Outcome: Aggregated Decision Matrix.

	Hydro		Solar + storage (residential)		Solar + storage (centers)		Solar + storage (emergency services)		Microgrid		VPP	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Alyssa	3.508	4.831	3.542	5.441	3.898	5.746	4.288	5.983	4.034	5.525	3.136	4.475
Bridger	5.068	6.847	4.407	6.373	5.068	6.712	5.339	6.949	3.678	5.458	2.254	4.305
Ethan	3.22	6.034	3.441	5.983	4.254	6.559	3.831	5.797	3.034	5.407	2.627	4.898
Isabella	3.712	5.898	3.424	5.831	3.678	5.958	3.678	6.059	2.712	4.898	2.356	4.237
Let	4.186	6.814	4.949	6.356	5.576	7.153	5.153	6.881	3.729	5.441	3.153	5.458
Max	3.831	7.22	4.627	7.576	4.627	7.407	4.458	6.983	2.458	6.458	2.695	5.983
Average	3.920833333	6.274	4.065	6.26	4.516833333	6.589166667	4.457833333	6.442	3.274166667	5.531166667	2.7035	4.892666667
Standard deviation	0.648010005	0.87132887	0.676468772	0.732853601	0.720198977	0.649932125	0.676700057	0.550608028	0.630419041	0.507712287	0.378903022	0.701163794
Comments					#1 highest low mean	# 1 highest high mean	#2 highest low mean	#2 highest high mean	#1 lowest low mean	#2 lowest high mean	#2 lowest low mean	#1 lowest high mean

Screening Outcome: Averaged Results - Summary.

Project	Average of all results	Standard deviation of all results	Comments
Hydro	5.10	1.37	
Residential	5.16	1.14	
Centers	**5.55**	1.28	#1 highest mean considering all results
Emergency	5.45	1.75	#2 highest mean considering all results
Microgrid	4.40	1.54	
VPP	3.80	0.64	

Alyssa: Decision Matrix.

add your scores [1 is lowest, 10 is highest] to each yellow box

		Repairing hydroelectric plant				Solar + storage (residential)				Solar + storage (key community centers)				Solar + storage for emergency services				Full microgrid				Virtual power plant			
Screening criteria	Weight	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS
GHG emissions potentia	0.136	7	9	0.949	1.220	2	4	0.271	0.542	4	6	0.542	0.814	5	7	0.678	0.949	6	8	0.814	1.085	6	8	0.814	1.085
Social benefits	0.068	2	3	0.136	0.203	4	6	0.271	0.407	6	8	0.407	0.542	4	7	0.271	0.475	5	7	0.339	0.475	5	6	0.339	0.407
Public health benefits	0.102	2	3	0.203	0.305	5	8	0.508	0.814	5	7	0.508	0.712	5	7	0.508	0.712	6	7	0.610	0.712	5	6	0.508	0.610
Technical feasibility	0.136	5	6	0.678	0.814	6	8	0.814	1.085	4	7	0.542	0.949	5	7	0.678	0.949	3	5	0.407	0.678	2	4	0.271	0.542
Political & community	0.119	3	5	0.356	0.593	7	9	0.831	1.068	6	8	0.712	0.949	6	8	0.712	0.949	5	6	0.593	0.712	3	4	0.356	0.475
Time-frame	0.085	4	6	0.339	0.508	4	8	0.339	0.678	4	7	0.339	0.593	5	7	0.424	0.593	5	8	0.424	0.678	2	4	0.169	0.339
Financial (policy levers)	0.169	5	7	0.847	1.186	3	5	0.508	0.847	5	7	0.847	1.186	6	8	1.017	1.356	5	7	0.847	1.186	4	6	0.678	1.017
Sellable	0.136	3	6	0.407	0.814	6	8	0.814	1.085	6	8	0.814	1.085	7	9	0.949	1.220	5	6	0.678	0.814	3	4	0.407	0.542
mpacts/unintended cons	0.051	3	5	0.153	0.254	4	5	0.203	0.254	3	5	0.153	0.254	2	4	0.102	0.203	3	4	0.153	0.203	1	3	0.051	0.153
Total	1			3.508	4.831			3.542	5.441			3.898	5.746			4.288	5.983			4.034	5.525			3.136	4.475

Bridger: Decision Matrix.

add your scores [1 is lowest, 10 is highest] to each yellow box

		Repairing hydroelectric plant				Solar + storage (residential)				Solar + storage (key community centers)				Solar + storage for emergency services				Full microgrid				Virtual power plant			
Screening criteria	Weight	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS
GHG emiissions potential	0.136	6	9	0.814	1.220	6	8	0.814	1.085	7	8	0.949	1.085	4	7	0.542	0.949	7	10	0.949	1.356	6	8	0.814	1.085
Social benefits	0.068	3	6	0.203	0.407	7	9	0.475	0.610	8	10	0.542	0.678	8	10	0.542	0.678	7	10	0.475	0.678	4	6	0.271	0.407
Publuc health benefits	0.102	5	7	0.508	0.712	7	9	0.712	0.915	8	10	0.814	1.017	9	10	0.915	1.017	7	9	0.712	0.915	2	8	0.203	0.814
Technical feasibility	0.136	8	10	1.085	1.356	5	7	0.678	0.949	6	7	0.814	0.949	7	8	0.949	1.085	1	2	0.136	0.271	1	1	0.136	0.136
Political & community	0.119	5	8	0.593	0.949	6	8	0.712	0.949	5	8	0.593	0.949	8	10	0.949	1.186	4	6	0.475	0.712	2	5	0.237	0.593
Time-frame	0.085	8	10	0.678	0.847	4	8	0.339	0.678	4	8	0.339	0.678	5	8	0.424	0.678	1	2	0.085	0.169	1	1	0.085	0.085
Financial (policy levers)	0.169	7	8	1.186	1.356	4	7	0.678	1.186	6	8	1.017	1.356	6	8	1.017	1.356	5	8	0.847	1.356	3	7	0.508	1.186
Sellable	0.136	7	9	0.949	1.220	3	7	0.407	0.949	5	8	0.678	1.085	8	10	1.085	1.356	7	9	0.949	1.220	4	7	0.542	0.949
Adverse impacts/unintended consequences	0.051	4	5	0.203	0.254	4	8	0.203	0.407	7	8	0.356	0.407	7	8	0.356	0.407	4	8	0.203	0.407	4	7	0.203	0.356
Total	1			5.068	6.847			4.407	6.373			5.068	6.712			5.339	6.949			3.678	5.458			2.254	4.305

Ethan: Decision Matrix.

add your scores [1 is lowest, 10 is highest] to each yellow box

		Repairing hydroelectric plant				Solar + storage (residential)				Solar + storage (key community centers)				Solar + storage for emergency services				Full microgrid				Virtual power plant			
Screening criteria	Weight	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS	Low Score	High Score	Weight LS	Weight HS
GHG emiissions potential	0.136	7	9	0.949	1.220	6	8	0.814	1.085	5	8	0.678	1.085	5	8	0.678	1.085	6	8	0.814	1.085	2	6	0.271	0.814
Social benefits	0.068	4	6	0.271	0.407	6	9	0.407	0.610	6	8	0.407	0.542	6	7	0.407	0.475	6	8	0.407	0.542	4	6	0.271	0.407
Publuc health benefits	0.102	1	7	0.102	0.712	4	7	0.407	0.712	7	9	0.712	0.915	4	7	0.407	0.712	4	7	0.407	0.712	4	5	0.407	0.508
Technical feasibility	0.136	3	8	0.407	1.085	3	6	0.407	0.814	5	8	0.678	1.085	5	8	0.678	1.085	1	4	0.136	0.542	2	5	0.271	0.678
Political & community	0.119	4	7	0.475	0.831	4	9	0.475	1.068	5	9	0.593	1.068	4	7	0.475	0.831	5	7	0.593	0.831	4	6	0.475	0.712
Time-frame	0.085	4	7	0.339	0.593	5	8	0.424	0.678	6	8	0.508	0.678	6	7	0.508	0.593	2	6	0.169	0.508	3	7	0.254	0.593
Financial (policy levers)	0.169	4	7	0.678	1.186	3	6	0.508	1.017	4	7	0.678	1.186	4	6	0.678	1.017	3	7	0.508	1.186	4	7	0.678	1.186
Sellable	0.136	5	7	0.678	0.949	5	8	0.678	1.085	6	8	0.814	1.085	4	7	0.542	0.949	3	8	0.407	1.085	3	5	0.407	0.678
Adverse impacts/unintended consequences	0.051	1	4	0.051	0.203	7	9	0.356	0.458	8	9	0.407	0.458	5	8	0.254	0.407	6	8	0.305	0.407	4	7	0.203	0.356
Total	1			3.220	6.034			3.441	5.983			4.254	6.559			3.831	5.797			3.034	5.407			2.627	4.898

Isabella: Decision Matrix.

add your scores [1 is lowest, 10 is highest] to each yellow box

		Repairing hydroelectric plant				Solar + storage (residential)				Solar + storage (key community centers)				Solar + storage for emergency services				Full microgrid				Virtual power plant			
Screening criteria	**Weight**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**
GHG emiissions potential	0.136	5	8	0.678	1.085	3.5	7	0.475	0.949	4	7.5	0.542	1.017	4	7.5	0.542	1.017	5	8	0.678	1.085	4	8.5	0.542	1.153
Social benefits	0.068	4	8	0.271	0.542			0.000	0.000			0.000	0.000			0.000	0.000			0.000	0.000			0.000	0.000
Public health benefits	0.102	4	6	0.407	0.610	5	8.5	0.508	0.864	5	8	0.508	0.814	5	9	0.508	0.915	5.5	8	0.559	0.814	5.5	8	0.559	0.814
Technical feasibility	0.136	7	9	0.949	1.220	4	8	0.542	1.085	5	8	0.678	1.085	5	8	0.678	1.085	3	6	0.407	0.814	2	4	0.271	0.542
Political & community	0.119	4	7	0.475	0.831	6	9	0.712	1.068	5	8.5	0.593	1.008	5	8.5	0.593	1.008	4	7	0.475	0.831	4	6	0.475	0.712
Time-frame	0.085	5	7	0.424	0.593	6	8	0.508	0.678	6	8	0.508	0.678	6	8	0.508	0.678	3	6	0.254	0.508	2	4	0.169	0.339
Financial (policy levers)	0.169	3	6	0.508	1.017	4	7	0.678	1.186	5	8	0.847	1.356	5	8	0.847	1.356	2	5	0.339	0.847	2	4	0.339	0.678
Sellable	0.136	4	8	0.542	1.085	6	8	0.814	1.085	6	9	0.814	1.220	6	9	0.814	1.220	4	8	0.542	1.085	3	6	0.407	0.814
Adverse impacts/unintended consequences	0.051	4	7	0.203	0.356	6	8	0.305	0.407	6	9	0.305	0.458	6	9	0.305	0.458	4	8	0.203	0.407	3	6	0.153	0.305
Total	1			3.712	5.898			3.424	5.831			3.678	5.958			3.678	6.059			2.712	4.898			2.356	4.237

Leticia: Decision Matrix.

add your scores [1 is lowest, 10 is highest] to each yellow box

		Repairing hydroelectric plant				Solar + storage (residential)				Solar + storage (key community centers)				Solar + storage for emergency services				Full microgrid				Virtual power plant			
Screening criteria	**Weight**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**
GHG emiissions potential	0.136	8	10	1.085	1.356	4	6	0.542	0.814	4	6	0.542	0.814	3	5	0.407	0.678	6	8	0.814	1.085	4	8	0.542	1.085
Social benefits	0.068	4	8	0.271	0.542	4	7	0.271	0.475	6	9	0.407	0.610	6	9	0.407	0.610	6	9	0.407	0.610	6	8	0.407	0.542
Public health benefits	0.102	2	6	0.203	0.610	3	6	0.305	0.610	5	8	0.508	0.814	6	9	0.610	0.915	3	6	0.305	0.610	3	6	0.305	0.610
Technical feasibility	0.136	7	10	0.949	1.356	9	10	1.220	1.356	9	10	1.220	1.356	7	10	0.949	1.356	2	4	0.271	0.542	1	4	0.136	0.542
Political & community	0.119	2	7	0.237	0.831	7	9	0.831	1.068	8	10	0.949	1.186	7	8	0.831	0.949	7	9	0.831	1.068	7	9	0.831	1.068
Time-frame	0.085	3	7	0.254	0.593	9	10	0.763	0.847	9	10	0.763	0.847	9	10	0.763	0.847	1	2	0.085	0.169	1	3	0.085	0.254
Financial (policy levers)	0.169	7	9	1.186	1.525	6	7	1.017	1.186	7	9	1.186	1.525	7	9	1.186	1.525	6	8	1.017	1.356	5	8	0.847	1.356
Sellable	0.136	5	7	0.678	0.949	6	7	0.814	0.949	7	10	0.949	1.356	7	10	0.949	1.356	9	10	1.220	1.356	8	9	1.085	1.220
Adverse impacts/unintended consequences	0.051	2	5	0.102	0.254	8	10	0.407	0.508	8	10	0.407	0.508	8	10	0.407	0.508	3	7	0.153	0.356	6	9	0.305	0.458
Total	1			4.186	6.814			4.949	6.356			5.576	7.153			5.153	6.881			3.729	5.441			3.153	5.458

Max: Decision Matrix.

add your scores [1 is lowest, 10 is highest] to each yellow box

		Repairing hydroelectric plant				Solar + storage (residential)				Solar + storage (key community centers)				Solar + storage for emergency services				Full microgrid				Virtual power plant			
Screening criteria	**Weight**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**	**Low Score**	**High Score**	**Weight LS**	**Weight HS**
GHG emiissions potential	0.136	6	10	0.814	1.356	3	8	0.407	1.085	3	8	0.407	1.085	3	7	0.407	0.949	3	9	0.407	1.220	2	8	0.271	1.085
Social benefits	0.068	4	8	0.271	0.542	5	9	0.339	0.610	5	9	0.339	0.610	4	8	0.271	0.542	5	9	0.339	0.610	3	6	0.203	0.407
Publuc health benefits	0.102	4	8	0.407	0.814	5	9	0.508	0.915	5	9	0.508	0.915	4	8	0.407	0.814	5	9	0.508	0.915	4	7	0.407	0.712
Technical feasibility	0.136	6	10	0.814	1.356	9	10	1.220	1.356	9	10	1.220	1.356	9	10	1.220	1.356	1	7	0.136	0.949	3	8	0.407	1.085
Political & community	0.119	5	8	0.593	0.949	6	9	0.712	1.068	6	9	0.712	1.068	6	8	0.712	0.949	4	9	0.475	1.068	4	7	0.475	0.831
Time-frame	0.085	3	6	0.254	0.508	5	10	0.424	0.847	5	8	0.424	0.678	5	8	0.424	0.678	1	6	0.085	0.508	3	6	0.254	0.508
Financial (policy levers)	0.169	4	10	0.678	1.695	6	10	1.017	1.695	6	10	1.017	1.695	6	10	1.017	1.695	3	7	0.508	1.186	4	8	0.678	1.356
Sellable	0.136	5	9	0.678	1.220	5	8	0.678	1.085	6	9	0.814	1.220	6	9	0.814	1.220	3	6	0.407	0.814	3	6	0.407	0.814
dverse impacts/unintended consequence	0.051	7	10	0.356	0.508	9	10	0.458	0.508	7	10	0.356	0.508	7	10	0.356	0.508	4	9	0.203	0.458	7	10	0.356	0.508

Feasibility Study

PROJECT DEVELOPMENT

Produced March 9, 2018

This study was produced to examine project options that ranked highest against screening criteria developed by the project team in the screening exercise phase of project development.

A Feasibility Study was used to select one project to carry forward to the implementation planning phase. Thus, the information presented in the following pages was produced prior to subsequent research conducted in the development of the implementation plan for the hydropower electric cooperative project described at the outset of this report. As a result, details described in the Feasibility Study may have been substantively revised during the implementation plan phase. In addition, this study covers information that, where relevant, was carried over into the implementation plan of this document.

CONTENTS

The project alternatives were assessed compared to the expected baseline conditions for each criteria, and rated along the system defined below.

Red: Indicates significant barriers, challenges, or risks to implementation. Low impact.

Yellow: Indicates unknowns, concerns, or substantial variables that would need to be addressed during or after implementation.

Green: Indicates a high feasibility for implementation, with probable level of certainty. High impact.

FEASIBILITY STUDY OVERVIEW

CRITERIA	HYDRO COOPERATIVE	SOLAR + STORAGE
Greenhouse Gas Reductions		
Additionality		
Costs		
Financial Viability		
Legal Considerations		
Governance + Stakeholder Complexity		
Economic Development Potential		
Technical Feasibility		
Scalability / Replicability		
Co-Benefits + Climate Preparedness		
Unintended Consequences		

1. Executive Summary

• Hurricane Maria demonstrated how extreme weather has and will continue to affect communities across Puerto Rico, while aging infrastructure challenges on the island underscore the need for investment in greater climate preparedness.

• The hurricane season of 2017 highlighted the necessity for transparency, partnership, and long-term strategy -- principles that underpin our project development.

• The current grid rehabilitation and reconstruction presents an opportunity to transition to renewable energy resources. The projects outlined in this feasibility study provide a population of approximately 32,000 residents with a new source of local renewable energy for both daily use and greater resiliency during emergency events.

• The study finds:

  • Refurbishment of the hydro assets is complex but legally feasible. The generation assets would be purchased in PREPA's upcoming privatization, or alternatively, if PREPA or its successor retains the assets, the project might proceed through a public-private partnership. Additionally, the current regulatory structure allows for independent generation and there exists a wheeling service mandate.

  • Significant legal barriers exist for a distribution cooperative. First, PREPA's distribution assets may be unavailable and secondly, it is unclear that the Energy Commission would certify a competitor to PREPA. Structuring as a cooperatively owned microgrid could address these barriers but likely adds significant costs to the project.

  • Solar + storage projects on critical infrastructure do not face significant legal barriers, but the legal thresholds for certification and interconnection may inform project size.

• Based on these findings, the Puerto Rico team has estimated a higher overall benefit to conducting the hydroelectric project, but acknowledges the robust legal and political issues that require further investigation. Continuing to evaluate a limited pool of solar and storage investments, primarily funded through philanthropic or grant mechanisms, may be a useful supplement or alternative given the risks presented through our hydroelectric alternative.

2. Introduction

The aftermath of Hurricane Maria, which hit Puerto Rico in September 2017, largely decimated the island's energy grid while wreaking similarly devastating impacts to water and housing infrastructure. The Department of Housing estimates that more than 75,000 homes were destroyed during Hurricane Maria, and at least 335,000 suffered some level of damage.

Recovery is far from complete. More than five months after the hurricane, hundreds of thousands of residents across the island lack reliable electricity and "last-mile" customers in more remote regions of the island are unlikely to have power restored until the summer of 2018 at the earliest. Nearly a fifth of the island's small businesses have not reopened, slackening economic growth in a region already grappling with fiscal and infrastructure challenges prior to the storm.

Hurricane Maria has prompted a re-envisioning of how the island can rebuild its electric grid quickly and sustainably in light of a historic reliance on oil and coal. A number of companies including Tesla and Sonnen have introduced solar and associated battery storage projects in recent months to allow for greater flexibility in the face of grid outages, and have provoked discussions about how to rebuild transmission on the island, where overhead lines suffered significant damage during the storm. Even prior to Hurricane Maria, Puerto Ricans faced four to five times the number of outages compared to the continental United States and have paid among the highest electricity rates in the nation at more than 20 cents per kilowatt hour (GTM, 2017). PREPA, one of the largest public power authorities in the United States, has accumulated over $4 billion in maintenance needs and generates nearly half its power from expensive oil-fired plants (The Conversation, 2017, EIA, 2017).

Governor Ricardo Rosselló has announced a privatization plan for PREPA and its latest fiscal plan assumes the authority will cease to operate in current form within 18 months, with a process that has yet to be detailed but will likely involve selling existing generation assets, and potentially transfer management of the transmission and distribution system (GTM, 2018).

The Climate Living Lab's Puerto Rico team has been assessing solutions that address the historic opportunity presented by this restructuring of the island's electricity management and infrastructure. The team was tasked with considering projects that a voluntary third-party could undertake to meet their climate goals, and selected options based on potential scalability, replicability, financial feasibility and applicability for renewable energy credit markets, as well as ability to deliver community and public health benefits. These projects included a co-op model for electricity generation at legacy hydroelectric facilities located in the central mountainous region of Utuado, as well as a number of solar projects, including solar and storage solutions, a community microgrid, and a virtual power plant that could integrate other heterogeneous renewable sources. Based on the final screening process, we proceeded with two alternatives for this feasibility assessment: first, a retrofit of hydroelectric facilities at the Dos Bocas and Caonillas reservoirs in Utuado, and second, the installation of solar power, combined with associated storage capacity, to provide renewable electricity to the local VA satellite clinic in Mameyes Abajo.

Judith A. Vivas School, Utuado, 2018.

3. Site Selection

Utuado, a municipality of approximately 32,000, provides a representative case study of common economic and infrastructure challenges faced by other towns across Puerto Rico, particularly outside the more developed San Juan metropolitan area.

Utuado is located in the mountainous region of Puerto Rico, over an hour and a half drive from the capital of San Juan. It has a population of over 33,000, and a median household income of $14,852. Utuado is also home to over 20 public schools and 2 college campuses. As of February 2018, parts of Utuado remain without power and it is expected to be among the last places to reconnect to the grid, as the Army Corps has estimated power may be restored by the end of May 2018. Utuado's remote location and vulnerability to future hurricanes make it critical to rebuild in a way that can sustainably and reliably supply the municipality's energy needs going forward.

While we considered several municipalities during initial project scoping, Utuado was ultimately selected as a target area of interest due to the severity of impacts sustained from Hurricanes Irma and Maria; its remote geography; the proximity to existing hydroelectric assets with high potential; and the on-the-ground contacts we have established there. Utuado's assets, including a University of Puerto Rico campus, small businesses, and a water treatment plant make the municipality particularly compelling for our project site. The economic decline Utuado has experienced in recent years along with the significant challenges it has faced related to recovery from the 2017 hurricanes, including its remote, mountainous geography and it distance from ports and warehouses, represents challenges faced by many other municipalities across the island, further contributing to its strong candidacy as a case study for this project.

4. Criteria Descriptions

GREENHOUSE GAS OFFSET POTENTIAL

The Puerto Rico Electric Power Authority currently generates approximately 47% of the island's electricity from oil, 34% from natural gas, 17% from coal and 2% from renewables (EIA). Meanwhile, the fuel oil burned at PREPA's older power plants, which have a median age of 44 years compared to an industry average of about 18, has been noncompliant with clean air standards under the Mercury and Air Toxics Standards. PREPA has indicated its intention to rely on a greater share of natural gas rather than repairing the older generators and installing scrubbers, but the delay of the Aguirre Offshore gasport project has presented challenges to implementing this transition. PREPA's latest fiscal plan estimated an increase in island-wide use of renewables to 18 percent of generation by 2026. However in 2010, the Puerto Rican legislature established an RPS requiring PREPA to source 12% of electricity from renewables in 2015 and scaling up to 20% by 2035, although that 2015 goal has not been met (EIA).

ADDITIONALITY

Recent proposals to refurbish PREPA's hydro facilities cut against the additionality of the hydro project. The Solar + Storage project is additional as long as optimal project partners are chosen.

COST

Puerto Rico has one of the highest retail electricity prices in the United States. One of our project goals was to reduce this financial burden on consumers. We analyzed our two projects based on available data and case studies to roughly estimate the price of electricity on a $/kWh basis.

FINANCIAL VIABILITY

While both the community solar and the hydro co-op alternatives are eligible for a number of financial incentive programs, many of these benefits are related to taxable income benefits and debt financing advantages. As such, these are unlikely to be of interest to a 501(c)(3) tax-exempt non-profit organization or an unregulated entity who would be evaluating these investments to meet voluntary offset goals, and an interested entity such as Harvard University would likely partner with a for-profit partner such as a corporation or tax equity investor on these initiatives.

LEGAL AND POLICY CONSIDERATIONS

Puerto Rico's Electricity Sector and Regulatory Structure

PREPA is the sole distributor of electricity on Puerto Rico and generates about 66% of the island's power. (EIA, 2018). Puerto Rico is dependent on imported fossil fuels as the island's generation mix is about 47% oil, 34% natural gas, 17% coal, and 2% renewable. It has the second highest retail electricity rates in the country at about $0.24/kWh.

Puerto Rico undertook several efforts to increase use of renewable resources in recent years. Of note are an RPS with a 20% by 2035 target, a net metering program that offers compensation at the greater of $.10/kWh or avoided cost, programs for energy efficiency, and a green energy fund.

Until recently, PREPA operated as a monopoly free from standard rate regulation. While PREPA still maintains a monopoly on distribution, a 2014 law—the Transformation and Energy RELIEF Act—established the Puerto Rico Energy Commission (PREC) to regulate electric companies, including PREPA, and their rates.

PROMESA AND THE OVERSIGHT BOARD

PROMESA was enacted on June 30, 2016 to address the fiscal emergency in Puerto Rico. 48 U.S.C. § 2121 et. seq. established a seven-member, independent Financial Oversight and Management Board that operates as an entity within the Puerto Rico government. "The purpose of the Oversight Board is to provide a method for [Puerto Rico] to achieve fiscal responsibility and access to the capital markets." § 2121(a).

The Oversight Board maintains broad powers over Puerto Rico's elected representatives and official operations. In general, the Oversight Board certifies agreements between government entities and their creditors, approves fiscal plans submitted by covered entities, confirms budgets, and monitors performance for consistency with those budgets. The Oversight Board may designate any instrumentality, in its sole discretion and including municipalities, as covered by its supervision.

Importantly, the Oversight Board is empowered to prevent the enforcement and application of laws, contracts, regulations, and executive orders that it finds are inconsistent with existing fiscal plans and budgets.

RECENT LEGAL, POLICY AND REGULATORY DEVELOPMENTS

PREPA Privatization Efforts

Joining other voices, including the Oversight Board's, Governor Rosselló recently called for PREPA's privatization. The governor stated that he supports "a model of privatization of power generation and a concession, term-defined, for energy distribution and transmission." (Caribbean Business, 2018). He expects that the effort will take 18 months to complete and will proceed in three phases. First, the legal framework will be developed through legislation, and the government will issue a request for proposals. Second, the relevant parties will evaluate the "technical, economic, and financial" merits of projects. Third, the government will negotiate terms and conditions for the selected proposals.

While this model embraces the privatization of generation assets, it is unclear what "concession, term-defined" means with respect to distribution and transmission and at least some analysts suggest that it may mean PREPA retains ownership over the distribution infrastructure. (Greentech Media, 2018).

PREC Reform Proposals

In January 2018, Governor Rosselló released plans to overhaul the PREC by combining it with Puerto Rico's consumer advocate and the telecommunication and transportation regulators. (E&E News, 2018). The new entity would be led by a single department leader appointed by the governor. Following the announcement, a bill was introduced in the legislature to carry out the governor's vision.

Critics, however, fear that the plan would result in less stringent oversight of PREPA. Indeed, the Oversight Board objected to the planned overhaul and gave the government 30 days to reform the plan to ensure PREC remains a separate agency with robust regulatory powers. Additionally, US Congressional members Nydia Velázquez, Raúl Grijalva and José Serrano expressed concerns in a letter to the governor. Governor Rosselló has yet to respond to these objections.

Opportunities Due to Recent Changes in Law

Three recent changes of law may provide opportunities for increased financial returns for renewable energy projects in Puerto Rico.

The 2018 tax reform creates a tax-deferral mechanism designed to spur investment in qualified "opportunity zones." While the final bill stripped language that would have designated all of Puerto Rico as a qualifying opportunity zone, it allows the governor to designate 25% of qualifying low-income areas in Puerto Rico as opportunity zones. Once designated, investors who sell appreciated investment assets defer taxes on gains by investing proceeds in an "opportunity zone fund." The basis of the original investment will be stepped up over time, thereby shielding gains from taxation. While details on the program are forthcoming—including which areas in Puerto Rico will qualify and what it will take to be certified as an opportunity zone fund—the program may offer value for project partners. While the particular assets in the projects would not be appreciated assets, hypothetically, project partners may sell their personal appreciated assets and invest the proceeds in the project because it would offer a way to defer taxes. This tax mechanism may therefore be a way to attract outside capital.

The Bipartisan Budget Act of 2018 allocated $2 billion to Puerto Rico for "enhanced or improved electrical power systems." However, FEMA allocates funds based on what it would take to rebuild infrastructure and makes owners responsible for the costs of improvements.[22] While §20601 provides that FEMA may give assistance for replacement or restoration of power systems to industry standards "without regard to the pre-disaster condition of the facility or system," this expansion relates to the operating condition of the system prior to the disaster and not, as some have suggested, to whether the infrastructure's nature may be adapted in order to increase resiliency. Despite restrictions on disaster relief funds, there are programs for hazard mitigation under §404 and §406 of the Stafford Act that may be utilized by Puerto Rico. (FEMA, 2018 Public Assistance Guidance at 98-99).

While PROMESA generally adds another layer of oversight that contributes to project uncertainty, it also provides for the listing of "critical infrastructure" projects. A critical project must address critical infrastructure needs, create jobs, have low environmental impacts, and be executed without public funds. If selected, projects receive expedited permitting, which would likely reduce transaction costs.

22 It may therefore be a worthwhile endeavor for an interested party to file a petition for rulemaking with FEMA asking for it to change its practices in recognition of the "enhanced or improved" language in the 2018 legislation. This change might make federal recovery funds available for improvements; however, as it now stands, FEMA's regulations do not allow it to allocate funds for costs of improvements.

GOVERNANCE AND STAKEHOLDER CONSIDERATIONS

Local Control + Citizen Participation
Driven by the urgency to accelerate power recovery after a storm and the need to reduce high costs of electricity on the island, the two projects considered in this study propose governance structures centered on our primary stakeholder group: resident and community-based consumers. Each project proposes a variation on two core project components: (1) a new or improved source of renewable energy; and (2) participation from electricity consumers in the management of the local power system.

ECONOMIC DEVELOPMENT POTENTIAL

Home to approximately 32,000 people, Utuado – like many municipalities on the island of Puerto Rico – has been experiencing the consequences of economic downturn for over a decade. From 2014 to 2015, total employment has decreased by nearly 5% and as of 2016, 52% of the population is in poverty (American Community Survey, 2016).

Significantly impacted by both Federal and Commonwealth economic policies that govern taxes, trade, and employment, the local economy in Utuado is currently in a state of decline. Preferential incentives for large corporations have made it difficult for small businesses to compete, resulting in empty storefronts in Utuado Pueblo (central Utuado), the erosion of traditional business practices (ex. business operations schedule), and a stifled environment for entrepreneurship. Costly damages from Hurricane Maria have further impacted businesses already facing financial instability and insecurity, and have left many businesses unable to reopen after the storm.

Agriculture has historically been a key economic driver for Utuado, which was once the largest coffee producer in Puerto Rico (now the third). Utuado's rainy mountainous climate supports the production of a variety of crops, including corn, rice, cotton, tobacco, plantains, bananas and oranges. The largest industries in Utuado are retail trade, health care and social assistance, educational services, and public administration. The Dos Bocas and Caonillas reservoirs support the tourism, entertainment and recreation industry in Utuado as the sites for sport fishing, guest houses, and restaurants.

TECHNICAL FEASIBILITY

Technical feasibility of the projects was evaluated on three criteria: (1) whether the system could be implemented and operated using currently available technology; (2) whether it was appropriate in context of Utuado's climate and geography; and (3) whether it could provide resiliency to the energy system during a future hurricane. Due to these criteria, we ruled out electricity generation from wind, biomass, and tides. Community solar PV and hydroelectric power generation scored highly in this category.

ADVERSE IMPACTS & UNINTENDED CONSEQUENCES

Downstream consequences of the project need to be considered in order to understand how to reduce negative impacts. Impacts and consequences were hypothesized through a synthesis of possible environmental impacts, community structures, and anticipated future disasters. Possible consequences were anticipated for both projects. In determining project feasibility, the magnitude of these impacts were compared to the benefits of the project.

CO-BENEFITS

In addition to the core benefits of these projects - resilient electricity - each project will produce other benefits downstream. Similar to how impacts and consequences were hypothesized, environmental conditions, community structures, and anticipated future disasters were considered to determine possible other positive impacts related to these projects. The benefits were grouped into three sections: social benefits, educational benefits, and health benefits. In determining project feasibility, the magnitude of these benefits were considered to ensure the projects produce ample improvements within the community.

5. Analysis: Hydro Coop

This report examines the feasibility of repairing and retrofitting existing hydroelectric facilities located along Lago Dos Bocas and Lago Caonillas near Utuado, and installing pump storage technology with solar to enhance the resilience and storage capacity of the hydroelectric stations. The ongoing developments of PREPA's privatization process present a unique opportunity for local residents to participate in the formation of a consumer-owned electric cooperative to own these assets and the generation of hydroelectric power at these facilities.

BACKGROUND ON ELECTRIC COOPERATIVES

In the United States, more than 800 distribution cooperatives provide electricity to over 40 million people in 47 states, in service territories that cover more than half of the nation. (NRECA). These coops generate nearly 5 percent of the electricity produced across the United States and retire over $800 million in capital credits annually (NRECA). Often based in rural locations, this model of private, consumer-owned electric utilities emerged after the Rural Electrification Administration (now the Rural Utilities Service under the U.S. Department of Agriculture) was created in 1935, and offered an opportunity to electrify rural areas of the United States that had been difficult to finance through traditional investor-owned utilities (MNCEE).

At a broad level, electric cooperatives are nonprofit corporations, incorporated under state statutes and granted federal tax-exempt status if at least 85% of annual income is derived from members (Coop Law). The National Rural Electric Cooperative estimates that approximately 726 cooperatives across the country in 43 states use hydropower, with a combined capacity across generation, transmission, and distribution of 692 MW (NRECA). Under this model, members of the cooperative are customers with a one-member-one-vote system, and these private, independent businesses provide at-cost service. Generation and Transmission, or G&T cooperatives, provide wholesale power to distribution cooperatives that are the direct providers of electricity to their member-owners (NRECA). Profit margins produced under these cooperative models are typically reinvested into the electrical system and each member is entitled to patronage or capital credits. Cooperatives tend to access upfront capital and occasionally service operations and maintenance needs through a combination of loans, grants, and private financing. The Rural Utility Service under the USDA has been a traditional source of low-cost capital, offering interest at approximately the Treasury bill rate plus one-eighth percent (Utility Dive, 2016).

EXISTING FACILITIES AT LAGO DOS BOCAS AND LAGO CAONILLAS

Lago Dos Bocas was constructed in 1942 by the Puerto Rico Electric Power Authority to generate hydroelectricity, and has also served as a source of potable water within a system that connects the Dos Bocas and Caonillas reservoirs and transports water northward.

At Lago Caonillas Reservoir, 3 hydroelectric generators at 2 stations provide a capacity of 21.5 MW, although the stations were built in 1948 and one of the stations, with a capacity of 3.5 MW, has been inoperable due to damage from Hurricane George in 1998. The second station, with total capacity of 18 MW, has experienced operational challenges since 2013 due to excessive shaking of a turbine that has rendered a second turbine inoperable. The technical component of this proposal would involve retrofitting the existing infrastructure with climate resilient hydroelectric generators, but should not require building a new reservoir.

At Lago Dos Bocas Reservoir, at the confluence of Rio Caonillas and Rio Grande de Arecibo, 2 hydroelectric generators exist at a station built in 1942, with a total capacity of 5MW. While the operating status of these generators remains unclear from publicly accessible information, if in need of repair, these stations would similarly require retrofits with climate resilient hydroelectric generators but not a new reservoir structure.

The USGS has noted that there has been significant sediment infilling that has compromised storage capacity at Lago Caonillas and Lago Dos Bocas, and this project will require dredging for adequate hydroelectric power generation. While these assets currently remain under PREPA's management, there has been recent speculation about revamping hydroelectric facilities in Puerto Rico through public-private partnerships, with some interest expressed in early 2017 by the Energy Public Policy Office Director Francisco Rullán about renewing and operating the plants at Dos Bocas and Caonillas, although there have been no announcements to date on this front (Caribbean Business, 2017).

GREENHOUSE GAS REDUCTIONS

HYDRO COOPERATIVE

Potential to generate 190,000 tons of CO2 offsets per year.

The technical analysis for hydroelectricity generated at the Dos Bocas and Caonillas reservoirs assumes the system can generate 208,926 MWh of electricity per year based on the following estimate (as further described in the technical component of this report):

26.5MW(installed capacity) x 0.90 (capacity factor) x 8760 (hours/year) = 208,926 MWh

To calculate potential annual offsets, we assume that this generation will offset the average carbon intensity of Puerto Rico's grid, which is comprised of 47% oil (0.27857 kgCO2e per kWh), 34% natural gas (0.18 kgCO2e per kWh), 17% coal (0.3 kgCO2e per kWh), and 2% renewables (Carbon Trust, Engineering Toolbox). At a broad level, a weighted mean carbon intensity would suggest an average 0.243 kgC02e per kWh for Puerto Rico's grid, in which case the hydroelectric project would create approximately

208,926,000 kWh * 0.243 kgCO2e/kWh, or 189,994.03 tons of CO2 offsets per year.

ADDITIONALITY

HYDRO COOPERATIVE

The additionality of carbon reductions created by refurbishing hydroelectric facilities on Puerto Rico may be called into question in light of recent proposals to fix these assets and place them in use. Other co-benefits of the project, however, should make the proposal attractive to an unregulated entity.

1. THE CUBE HYDRO PROPOSAL

In considering additionality of the hydro refurbishment project, the project team evaluated an unsolicited proposal submitted by Cube Hydro Partners to the Public Private Partnerships Authority (the "Authority") to purchase several hydroelectric plants from PREPA and put them into operation. While details are sparse, there are reasons to think the project could proceed.

First, the Authority issued a notice in October 2017 that they are considering projects aimed to "maximize" Puerto Rico's hydroelectric assets (P3 Authority, 2017) and the director of the Authority indicated that studies of the project are underway (Caribbean Business, 2017). According to the Authority's guidance on unsolicited projects (P3 Authority), these steps indicate that the project has demonstrated enough merit to pass preliminary evaluations and the Authority exercised its discretion to commission relevant studies. Second, and perhaps more significantly, the governor of Puerto Rico has touted the ability of Public-Private Partnerships and these proposals to turn around the finances of the island. (El Nueva Dia, 2017). The current administration appears interested in the potential of such projects as a proof of concept and as a signal to wary businesses that they can count on the Puerto Rican government's support.

However, it is not clear which hydro facilities will be included in Cube's project if it is selected, or over what timeframe this partnership would feasibly proceed. The Director of the Authority has stated that ongoing studies will help determine whether "it's all hydroelectric plants [or] if it's going to be [some] other hydroelectrics." (Caribbean Business, 2017). It is uncertain whether the dams at Dos Bocas and Caonillas are or will be included in the project. Furthermore, Cube Hydro would likely sell RECs into Puerto Rico's compliance market, whereas the sale of RECs by the cooperative to an external voluntary, unregulated entity would incent regulated producers in Puerto Rico to undertake additional renewable energy projects to meet the RPS standards, offering a comparative advantage on additionality from the current project team proposal.

2. OTHER GOVERNMENT INITIATIVES

Aside from the specific Cube Hydro proposal, there are some indications that hydroelectric assets may be slated to be fixed under a "baseline scenario." Francisco Rullan, the Director of the Energy Public Policy Office, has previously said that his office would like to make all 20 of Puerto Rico's hydro plants operational with an initial focus on the Dos Bocas, Caonillas 1 and 2, and Yauco 1 and 2 facilities. (Caribbean Business, 2017). To put that vision into practice, the office plans to review these proposals to determine whether they can be listed as a "critical project" under PROMESA to streamline their evaluation and permitting processes. One company—Streamflow Technology Corp.—has submitted a proposal to the Board to install an 8MW hydro project at the Carraizo Dam (Oversight Board, 2018). Additionally, PRASA's 2017 revised fiscal plan indicates that it will invest in optimization of hydro resources under its control.

However, our team finds that the present reality on the island contradicts optimistic press statements regarding movement on these projects. The particular plants in question have been offline since the early 1990s, and the current state of the Commonwealth's finances makes it unrealistic that they will be able to fund or implement these projects. The wealth of evidence regarding the government's recent and ongoing performance in relation to hydropower support a "baseline" scenario in which the dams remain under-utilized and render it unlikely that the government would proceed with hydro optimization in the near to medium term.

3. POTENTIAL PROJECT DESIGN OPPORTUNITIES

While refurbishment projects appear docketed for completion and therefore are likely not additional, we may be able to modify our project to bolster our claims of additionality.

First, even if Cube Hydro's project is selected, it may not include all of the non- or low-functioning hydro assets on the island. In that case, our project could move forward with respect to an asset excluded from Cube's project and thereby make a better claim to additionality. Of course, this approach does present risks given the uncertainty and dependence on the outcome of the Cube project.

Second, there may be ways to install new hydro facilities at preexisting dams/reservoirs (similar to the Streamflow Technology proposal mentioned above). While this would likely increase the difficulty of the design process and increase associated costs, it would significantly differentiate the project from the baseline case.

Lastly, our project proposal involves the establishment of an electric cooperative. This would not add to the project's total carbon offsets but would ensure that the financial returns of the project go directly to this underserved community rather than a private investor. The community currently does not have access to the capital needed to acquire these hydroelectric assets and would require philanthropic funding, loan guarantees, or other financial contributions in order to do so, and therefore an unregulated entity could claim responsibility for co-benefits to the community resulting from the project.

COSTS

HYDRO COOPERATIVE

A hydroelectric cooperative could substantially reduce electricity bills in Utuado.

The cost of refurbishing small scale hydroelectric plants varies depending on the extent of the project (life extension versus upgrades). Due to the age and damage to the three plants, we plan to perform full systems upgrades including replacing or refurbishing all electrical generating equipment, mechanical equipment, and infrastructure (including the powerhouse, dredging the reservoir, dam, and road access).

THESE UPGRADES ARE EXPECTED TO BE $500-1000/KW (IRENA).

Therefore, we estimate that refurbishing the entire Caonillas/Dos Bocas System (26.5MW) will cost between $13.25 and $26.5 million in capital expenses. The O&M costs of refurbished hydroelectric projects are estimated to be between 1% and 6% of capital costs (IRENA). Due to the remote nature of Utuado, we assume 5% for this analysis.

To build resilience, we propose burying power lines between the hydroelectric plants and Utuado. A recent study estimates that it costs $1.5 million per mile for new 69 kW underground lines (Electric Light and Power). The power stations are approximately 3, 4, and 5.25 miles from Utuado. Therefore, we estimate that installing these power lines will cost $16.8 million in capital expenses. The study also notes that O&M costs are difficult to determine. Therefore in this analysis, we use the same percentages used for the refurbished hydroelectric portion of 1% of capital costs.

Finally, we estimate that a fixed solar PV field of 20MW costs $53 million in overnight capital and $46,800/yr (EIA).

While installing pumped solar does not increase the installed capacity of the system, it enables a capacity factor up to 90% (IRENA).

In total, we expect a fully functioning pumped hydro system at Caonillas/Dos Bocas to produce:

26.5MW(INSTALLED CAPACITY) X 0.90 (CAPACITY FACTOR) X 8760 (HOURS/YEAR) = 208,926MWH

For estimating the cost per kWh, we consider two lifetime scenarios of the project, 20 years and 40 years. The table below demonstrates the range of cost/kWh of the system we expect at this level of analysis. In all scenarios, the cost per kWh is much lower than the retail market on the island, but corresponds to costs common for hydroelectric power across this country, lending greater confidence to this broad analysis.

	Low ($/kWh)	High ($/kWh)
20 year life	0.03	0.03
40 year life	0.02	0.02

FINANCIAL VIABILITY

HYDRO COOPERATIVE

Tax credits, cooperative bank grants & loans, and renewable energy credits generated by this project make it attractive financially.

TAX CREDITS

Hydroelectric projects in Puerto Rico are eligible for property tax exemption, which could represent a significant savings given the amount of space the hydroelectric plants require.

LOW INTEREST BONDS

The Clean Renewable Energy Bonds (CREBs) also provide electric coops with the opportunity to issue zero-interest bonds for renewable energy projects, and since its inception, co-ops have applied for more than $500 million in renewable project bonds (NRECA).

GRANTS + LOAN GUARANTEES

The Rural Utilities Service (RUS), National Rural Utilities Cooperative Finance Corporation, and CoBank ACB provide loans for hydroelectric co-ops across the United States. Under the USDA's Rural Energy for America Program, hydroelectric technologies are eligible for loans for systems up to 30 MW. Cooperatives can access relatively cost-effective financing through loans and grants from RUS and CFC, as well as FEMA funds for electricity repairs (Utility Dive, 2016).

RUS in 2015 committed $3.4B in loans and loan guarantees, and remains a stable source of funding that has transcended changes in political administrations, with bipartisan support. The loan portfolio totals $46 billion and total investment has been $120 billion, and the program has had a delinquency rate of just 0.04%. The RUS 35-year loans tend to be an attractive offer with lower than commercial 30-year fixed loan interest rates. The program does not have a financial cap, although projects generally tend to be located in low population areas of 20,000, though they are flexible on partial funding if the population exceeds those estimates (Utility Dive, 2016).

ELECTRICITY SALES

A project of this size would likely over-generate and under-generate electricity for this town at different times of the day. Even with built-in pumped storage, there would be periods during which it would be profitable to sell into the wholesale electricity market. The cooperative electric utility could sell energy directly into the grid, but to calculate potential yearly revenue streams, information on hourly, daily, and seasonal price fluctuations is required, which has not been publicly available.

RENEWABLE ENERGY CREDITS

A 26.5MW hydroelectric project could generate a significant number of renewable energy credits in the Puerto Rico compliance market. According to one source, PREPA had been purchasing RECs for a price of about $35/MWh (EIA), which if true would provide up to $0.035/kWh, a significant revenue stream for the project. Of course, this would remain a stable source given annual fluctuations in the price of RECs. As the island approaches reaching its Renewable Portfolio Standard, an argument could be made to sell these RECs to an unregulated entity to drive the development of additional renewable energy projects in Puerto Rico.

LEGAL CONSIDERATIONS

HYDRO COOPERATIVE

Overall, refurbishment and ongoing management of the hydroelectric generation facilities is legally feasible; however, there are significant legal barriers with respect to the ownership and operation of electric distribution facilities.

Two legal issues present potential barriers to the hydroelectric project's feasibility: (1) ownership or use of PREPA's assets; and (2) regulatory uncertainty. Because the generation and distribution sides of the project receive divergent treatment with respect to both asset ownership and regulatory oversight, each is discussed in turn.

REFURBISHMENT OF THE HYDROELECTRIC GENERATION IS LEGALLY COMPLEX BUT FEASIBLE

While there are legal hurdles, there are not strict legal barriers associated with the refurbishment of the hydroelectric generation facilities, as the assets will likely be available due to PREPA's privatization, and the regulatory structure allows independent electricity generation.

PREPA currently owns the generation facilities at Dos Bocas and Caonillas, and there are several ways the transaction might be structured to allow for ownership or use of the assets. First, if the PREPA privatization effort moves forward, the project would likely need to participate in whatever RFP structure is designed. Otherwise, a negotiated sale of the assets would be feasible, or if that fails, then a joint venture or public-private partnership between PREPA and the project partners could be designed. One complication in this area is the overlapping jurisdiction of the Oversight Board and PREC—both have authority to prevent the enforcement of PREPA's contracts for sale or use of the generation assets. However as long as a fair price is offered, it seems unlikely that either regulator would block the transaction. Additionally, there is currently no legal barrier for a cooperative to be the entity that enters such an arrangement with PREPA as Puerto Rico has a general cooperatives statute that provides cooperatives with a similar legal status as that of corporations. See General Cooperative Associations Act (2004), 5 L.P.R.A. Ch. 102 §4391 (providing that every cooperative is a juridicial person on par with others).

Once the hydroelectric assets are purchased or a partnership for their restoration is formed, then regulatory approval to operate the assets should be forthcoming, as certification of generators falls squarely within PREC's authority and there are several independent generators already located on the island. Additionally, PREPA's statute contains a wheeling mandate under which transmission must be provided, and the projects are "qualified facilities" under PURPA due to their size and renewable source of generation. See 18 C.F.R. §292.204.

Three legal issues complicate the refurbishment and operation of the hydroelectric assets. First, sedimentation is an ongoing problem in the reservoirs, and dredging, if necessary, can run into environmental problems. See Implementation Plan, section 5, above, for analysis of permitting. Second, PRASA and agricultural interests may have priority rights over the reservoir's water, which may cause issues with power generation. Third, the dams may not meet current USGS earthquake stability requirements, and coming into compliance would likely be costly. Altogether, these risks are not absolute barriers to implementation, but they do increase risk and may significantly decrease project returns.

Despite these issues, the refurbishment of the hydro generation remains legally feasible, as contracting for the sale or use of the hydro facilities is possible, and the regulatory structure provides some certainty for independent generators. On the other hand, significant barriers appear with respect to taking over electric distribution service.

CREATION OF AN ELECTRIC DISTRIBUTION COOPERATIVE FACES SIGNIFICANT LEGAL HURDLES & LIKELY REQUIRES LEGISLATIVE ACTION

Unlike the generation side of the project, distribution presents significant legal barriers in regard to both authority to operate as a distributor of energy and ownership of the distribution assets.[23] While cooperatives are specifically provided for under Puerto Rican law, there is no electric cooperative statute as there are in other jurisdictions. Additionally, PREPA currently maintains a monopoly over electric distribution and it is unclear whether PREC has the authority to certify an electric service company that proposes to distribute electricity outside of the microgrid context.[24] There are several potential solutions to these problems. First, the legislature might be convinced to pass legislation specifically providing for electric cooperatives or amending PREC's regulatory authority. Second, the project might be structured as a microgrid that falls under PREC's newly-released regulations (however, it appears this would significantly increase project costs given increased technological requirements). Analysis of the potential microgrid redesign is left as outside the scope of this report. Third, it seems most likely that PREPA will retain ownership of the distribution assets while entering public-private partnerships(PPP) for the operation of those facilities. In that scenario, the cooperative would participate in whatever process PREPA puts forward for entering a PPP.[25]

In addition to barriers presented by the current regulatory structure, the distribution aspect of the project may face asset ownership concerns as it is unclear whether PREPA's distribution assets will be available under privatization efforts.[26] In the best case scenario, PREPA's distribution assets would be sold off during the privatization effort and the cooperative would be able to bid in the RFP process. As discussed above, it now appears likely that PREPA will retain the assets but enter a PPP for their use. This structure would work well for the cooperative. On the other hand, if the assets are not available, then it seems that the legislature would have made a conscious decision to preserve PREPA's role as monopoly electricity distribution service provider on the island.

If PREPA were unwilling to sell these assets or negotiate a concession for their use, then it seems unlikely the legislature would step in to force a sale to a newly-formed cooperative. This analysis suggests that the ability to procure PREPA's distribution assets would be heavily dependent on the outcome of the current political process surrounding privatization, which falls largely outside the scope of this project's control. Additionally, as mentioned above, both the Oversight Board and PREC retain veto power over any transaction to sell off or lease PREPA's distribution assets.

Because of the above concerns, enabling legislation may be needed. The legislation should transfer ownership of PREPA's distribution assets to the cooperative or, at a minimum, provide for their use. It should also specify a defined service territory inside which the cooperative will have exclusive right to distribute electricity. Granting the cooperative condemnation power would help keep costs of new construction low. Finally, the legislation should define how the cooperative will be regulated.[27]

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23 Please note: legislation was proposed subsequent to the creation of this feasibility study. As discussed in the implementation plan, it now appears most likely that PREPA will retain ownership of the distribution assets but enter into Public-Private Partnerships for their use. The cooperative therefore has a feasible path towards gaining use of PREPA's assets and regulatory approval to serve as a distributor of electricity if the privatization legislation passes. However, because it is still uncertain whether that bill will become law and whether PREPA will dutifully implement it even if it does pass, this section ignores the proposed legislation and takes a broader view of the potential paths to implementation.

24 The definition of "Electric Power Company or Electric Power Service Company" in the Commission's statute is "any natural or juridical person or entity engaged in the generation, billing, or resale of electric power. In the case of PREPA, it shall also include transmission and distribution." 22 L.P.R.A. §1051a(k). This definition implies PREPA exclusivity with respect to transmission and distribution.

25 Analysis is included in the Implementation Plan, section 5, above.

26 While our project contemplates burying critical transmission lines in order to enhance reliability, the project would utilize much of PREPA's existing distribution infrastructure.

27 Many cooperatives receive light or no rate regulation from state regulators because they do not have incentives to overcharge customers as do for-profit utilities. However, due to PREPA's performance prior to state oversight being introduced in 2014, it may be politically insensitive to push for regulatory exemptions for cooperatives.

HYDRO COOPERATIVE

Forming an electric cooperative to own and operate the legacy hydropower units requires significant local organization and poses challenges related to the complexity of governing bodies involved.

REGAINING BENEFITS FROM LEGACY SYSTEM FOR LOCAL PRIMARY STAKEHOLDERS

The rivers and reservoirs encompassed in the hydroelectric power project are shared resources that local populations depend on. As such, the tourism and hospitality industry around the reservoirs, agriculture sector, and 30,000+ people who live in proximity to these water bodies are key stakeholders. From the outset, this project would require extensive community outreach to this stakeholder group to clearly communicate project requirements, expectations, and timeline, and to provide information to develop organizing capacity for establishing an electric cooperative. Anecdotal evidence suggests a stigma around hydroelectric generation across the island related to the abandonment of hydropower in favor of large capacity oil and gas-fired power plants, which underscores the importance of educational outreach and marketing for this project to generate local interest.

This project proposes to recondition an existing system, as opposed to building anew. Thus, any environmental hazards related to constructing a hydroelectric power project, including flooding and ecosystem disruption, are pre-existing. This project would infuse capital to modernize and strengthen this legacy infrastructure, and provide benefits that have been lost over the years due to lack of maintenance and low utilization, and introduce new storm preparedness features such as remote monitoring equipment. While community members represent a wide range of interests that may present conflicts and challenges, the overarching benefits of reviving this system are likely to be positively received by the resident and local population stakeholder group.

Residents of Puerto Rico currently rely on an energy system that heavily dependent on imported fossil fuels. Geopolitical, macroeconomic, and global environmental concerns highlight the unstable and unsustainable nature of this model. Reinvesting in hydroelectric power captures the benefits of locally produced power that is greenhouse gas emission free. This project would not only work toward diversifying power generation to hedge against fuel availability risks and decarbonizing the grid for public and environmental health reasons, but also produces power at a lower cost than fossil fuel-based combustion. This competition with the fossil fuel industry may present challenges related to existing contracts PREPA has made with fossil fuel providers.

A NEW BUSINESS MODEL FOR THE ISLAND: ELECTRIC COOPERATIVE

No utility cooperatives currently exist on the island, but cooperative movements in general have been growing in recent years in Puerto Rico, in large part due to the advocacy and organization of the Puerto Rican Cooperative League. In 2008 Act No. 247, known as the "Puerto Rico Cooperative Development Commission Organic Act," was enacted to enable the growth of the cooperative model in Puerto Rico. The Act established the Cooperative Development Commission to support the cooperative movement, recognizing it as "one of the main tools for the integral development of society" (Government of Puerto Rico, 2008). As of 2012, 196 cooperatives were active on the island – mainly falling into housing, savings and credit, consumption, health and commercial, and associated work categories.

A cooperative governing structure makes decisions more democratic and transparent by establishing bylaws for compensation and procedures for voting on policies and other important business decisions. As a critical preliminary step, this project must verify local Utuadeños are interested in democratic governance and desire the associated responsibilities. In addition, cooperatives generally require initial investment from members (ex. registration fees), and then rely on the continuous cash flow generated by the consumption and payment for electricity. It is possible that encouraging all residents to become cooperative member-owners may be met with resistance due to the extent to which residents live in informal housing and tap into electricity without paying PREPA as formal customers as is. The lower cost per-kWh and additional benefits provided by membership may help shift residents out of the informal economy to the formal pay-for-energy system.

PREPA UNCERTAINTIES: TRANSFER OF ASSET OWNERSHIP, RIGHTS TO TRANSMISSION AND DISTRIBUTION

The hydroelectric units of interest are currently owned by PREPA, as is the transmission and distribution of energy (overhead lines). PREPA's privitization has led to a handful of companies expressing interest in PREPA's assets, so this project raises uncertainty related to the market competition for these hydroelectric units (Mercado, 2018). In addition, Cube Hydro Partners, an investment and acquisition firm focused on modernizing hydroelectric facilities, is also a stakeholder and potential competitor for this project as the company is currently conducting a "technical viability and economic feasibility study" for Puerto Rico's hydroelectric system (Caribbean Business, 2017). If purchased by a private company, such as Cube Hydro Partners, the hydro project would still be feasible if run as a distribution co-op that formed a Power Purchase Agreement (PPA) with the private power generation company.

If PREPA retains ownership of transmission and distribution and the hydro units are purchased by another party, the project partners may decide to proceed with the 175-acre solar development that is included in the hydropower project design and pursue the solar development as a standalone generation project. The strength of this project would be compromised if both assets and distribution are inaccessible.

A positive development in the island's recovery that could be beneficial for this project is a Memorandum of Understanding (MOU) PREPA recently entered with the National Rural Electric Cooperative Association (NRECA), the American Public Power Association (APPA), and the Edison Electric Institute (EEI). The MOU allows investor-owned electric companies, public power utilities, and electric co-ops to provide emergency services in coordination with PREPA, USACE, FEMA in the recovery effort (Hadfield, 2017; Rocha, 2017). Experts from electric co-ops are expected during a second wave of assistance, which may benefit this project as the presence of cooperative partners can spread awareness of how electric cooperatives form and operate. Contractors currently assisting in recovery efforts have often been paid significantly more than local PREPA employees and are often not assigned the riskiest work (ex. lineman that do not operate on live wires). An electric cooperative structure may serve to promote a framework that reduces the occurrence of pay inequality.

LOCAL, STATE, AND FEDERAL LEVEL AGENCY INVOLVEMENT CREATES PROJECT COMPLEXITY

In addition to residents, this project involves multiple branches of government at various levels. The Municipality of Utuado would be an important project partner given the value of engaging with local authorities on the significant economic, environmental, and social impacts involved.

At the state level, the State Office of Public Energy Policy, PREPA, Puerto Rico Energy Commission, Puerto Rico Aqueduct and Sewer Authority (PRASA), the Governing Board of the Cooperative Development Commission, and the Financial Oversight and Management Board all have a stake and oversight authority in the project. If successful, the project may contribute to policy-making that supports similar projects and encourages greater allocation of funds for such proposals.

At the national level, the Federal Energy Regulatory Commission regulates hydropower operations and inspects both project construction and operations. However, FERC currently licenses only one hydro facility on Puerto Rico, and the project may fall outside FERC's regulatory authority. The existing engagement of the National Rural Electric Cooperative Association (NRECA) in Puerto Rico energy system rebuilding is a benefit to this project as the organization provides "legislative, legal

ECONOMIC DEVELOPMENT POTENTIAL

HYDRO COOPERATIVE

Harnessing hydropower through a locally owned and operated electric cooperative provides economic development opportunities at multiple levels.

A MUCH-NEEDED BOOST FOR THE LOCAL ECONOMY

As a new industry in Utuado's economy, an electric cooperative would require a significant investment in vocational training for utility operations and business management. As a self-governing enterprise, the members of the utility would benefit from any margin the utility might generate, thereby capturing value created by the project and keeping it within the local economy. This profit-sharing financial benefit is open to all customers who wish to join as member-owners, while electricity cost savings provided by the new power source would benefit all electricity customers in Utuado. Upfront costs and annual dues for participating in the cooperative as a member-owner may deter or exclude low income residents from joining. Project financing may allow for member payment waivers, should the cooperative governing board vote to approve such a policy. With community at the center of cooperative values, additional economic benefits may be generated from this business model, including revitalization projects, job creation, and increased reliability of electricity service.

MODEL FOR ISLAND-WIDE HYDROPOWER REVIVAL

The proposal to purchase and recondition the hydroelectric generating units at the Dos Bocas and Caonillas reservoirs may serve as a model for encouraging a renewed interest in hydro power across the island. In recent years, hydropower has counted for approximately 0.5% of Puerto Rico's electricity (EIA, 2017). With the potential to generate up to 26.5MW of electricity, this project could significantly contribute to achieving Puerto Rico's Renewable Portfolio Standard.

Increasing the reliability of electricity across the island is a priority at both local and state levels of government and thus may be an attractive project for the public sector. In addition, the cooperative model is regarded in state policy as "an

HYDRO COOPERATIVE

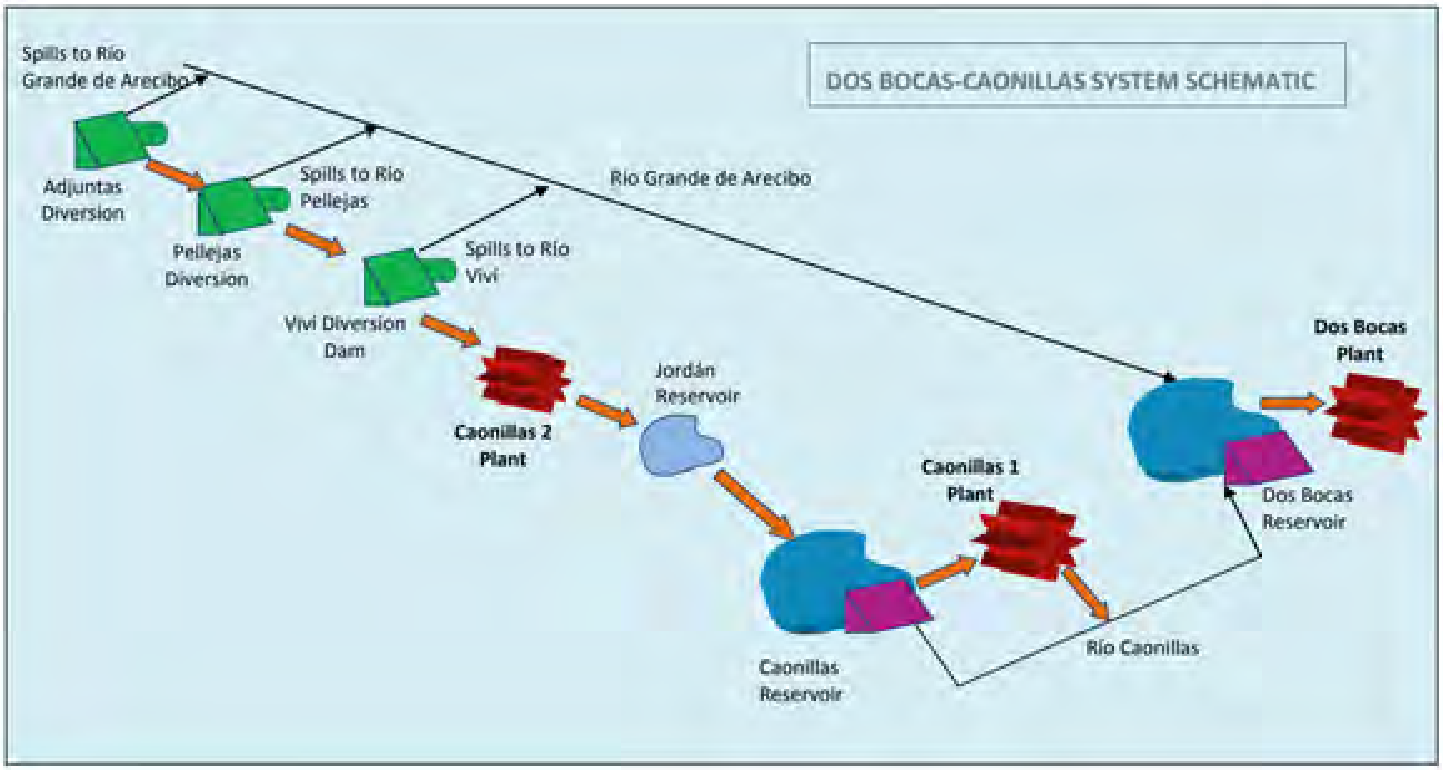
Solar with pumped hydro storage provides a unique opportunity to revitalize aging infrastructure.

HYDRO WITH PUMPED STORAGE: A UNIQUE OPPORTUNITY TO REVITALIZE AGING INFRASTRUCTURE

Hydroelectric power, at both small and large scales, is one of the cheapest sources of electricity generation (IRENA, 2012). In many places around the world where countries have exploited existing hydroelectric potential, refurbishment, repowering and rehabilitation of old plants can be an effective means of boosting output. A report by the International Renewable Energy Agency (IRENA) states that "the data available on the costs of refurbishment isn't extensive, however, studies of the costs of life extension and upgrades for existing hydropower have estimated that life extensions cost around 60 % of greenfield electro-mechanical costs and upgrades anywhere up to 90 % depending on their extent (Goldberg and Lier, 2011)." Despite these uncertainties around cost, there is evidence that refurbishment of old hydroelectric facilities is financially viable at several scales, as seen in the emergence of companies like Cube Hydro (http://www.cubehydropartners.com/about), whose business model primarily involves refurbishing and modernizing hydroelectric plants.

A potential problem with scaling up this approach or replicating it at other sites is that hydroelectric potential remains highly site-specific, and viability will depend on the characteristics of the relevant reservoirs. In Puerto Rico, there are 10 different hydroelectric plants that represent an installed capacity of 100 MW of hydroelectric power (CEPR, 2015), and at least some of these sites have potential for refurbishment. This capacity provides less than half a percent of Puerto Rico's energy generation, and refurbishment at different sites could substantially increase clean energy generation and offset petroleum thermoelectric plants on the island (CEPR, 2016).

The Lake Caonillas/Dos Bocas reservoir system is built on the Rio Caonillas and Rio Grande de Arecibo. The system is located in the municipalities of Arecibo and Utuado. The system is comprised of two large reservoirs (Caonillas and Dos Bocas), three hydroelectric plants, and several small diversions and holding ponds. A schematic of the system is shown in the figure below.



The system was constructed in the 1940s. Originally, Lake Coanillas held 45,124 acre-feet of water and could produce up to 21.5MW between its two plants. The reservoir receives approximately 200,900 acre-feet/year of inflow from its drainage basin. Due to natural sediment infill (which is augmented by severe weather such as hurricanes), the reservoir had a capacity of 33,433 acre-feet in 2004. Sediment infill and Hurricane George (1998) resulted in the complete shutdown of Caonillas 2 Plant, which has not been operable since. Caonillas 1 Plant has severe operational issues that causes it to operate at a minimal utilization rate.

At construction, Lake Dos Bocas held 30,420 acre-feet of water and could produce up to 5MW of power. The reservoir receives approximately 325,000 acre-feet/year of inflow from its drainage basin. Due to natural sediment infill, the reservoir had a capacity of 13,241 acre-feet of water in 2004. Dos Bocas Plant is still operational, but the turbine, penstocks, and powerhouse have not had major upgrades since construction.

We propose installing a solar plus pumped hydroelectric storage system on the two reservoirs. Water would be pumped up approximately 530 feet from Lake Dos Bocas to Lake Caonillas. We propose that all inflow to Lake Dos Bocas is pumped to Lake Caonillas. To calculate how much power this system could store, we used the equation for theoretical maximum power:

$$P=\rho qgh$$

where P is power, ρ is the density of water, q is the inflow, g is the gravitational constant, and h is the height difference between the two reservoirs. We calculate that in an average year, the pumped hydro storage system would operate at 20MW (approximately the size of Caonillas 1 Plant if it was operating at capacity).

The proposal would require renovations to legacy infrastructure and the installation of new piping, power lines, and a 20MW solar farm. Dredging the two reservoirs is recommended to ensure adequate storage capacity for the pumped water and to improve future resiliency. Replacing the turbines at the three plants will be needed to operate the turbines at a high utilization rate. We believe that we can utilize most of the existing pipelines in the system. However, a more detailed investigation into the existing infrastructure is required to determine its extent and condition. We also propose installing new underground powerlines that connect to Utuado and the island-wide grid. Burying power lines, while more expensive than installing them above ground, will help maintain power in the event of future hurricanes or other natural disasters. Finally, we propose installing a 20MW solar farm that will operate during the day to pump water from Dos Bocas to Caonillas. **Based on a survey of other recent 20MW solar farms in the United States, we estimate that we will need approximately 175 acres of land and 85,000 solar panels.**

Overall, we do not believe there are significant barriers to the technical feasibility of this project, as dredging reservoirs and retrofitting old/defunct hydroelectric facilities are common practice. Moving forward, a active and well-funded maintenance plan should be adopted so that the system operates at capacity and is prepared for future natural disasters. A drought adaptation plan should also be considered for different climate scenarios; however, the dredging of the reservoirs and installation of a pumping system may provide additional water security to the region.

We plan to explore the feasibility of installing these solar panels on the dam or floating them to avoid additional real estate costs; however, given the rural nature of the municipalities of Arecibo and Utuado, purchasing additional land should not present a substantial constraint to the feasibility of this project.

SCALABILITY / REPLICABILITY

HYDRO COOPERATIVE

Hydrodelectric power is one of the cheapest sources of electricity; however, it is site-specific and therefore not replicable everywhere.

REHABILITATION OF OLD UNITS CAN BE AN EFFECTIVE MEANS OF BOOSTING OUTPUT.

Hydroelectric power, at both small and large scales, is one of the cheapest sources of electricity generation (IRENA). In many places around the world where countries have exploited existing hydroelectric potential, refurbishment, re-powering and rehabilitation of old plants can be an effective means of boosting output. A report by the International Renewable Energy Agency (IRENA) states that “the data available on the costs of refurbishment isn’t extensive, however, studies of the costs of life extension and upgrades for existing hydropower have estimated that life extensions cost around 60 % of greenfield electro-mechanical costs and upgrades anywhere up to 90 % depending on their extent (Goldberg and Lier, 2011). Despite these uncertainties around cost, there is evidence that refurbishment of old hydroelectric facilities is financially viable at several scales, as seen in the emergence of companies like Cube Hydro (CubeHydro.com), whose business model primarily involves refurbishing and modernizing hydroelectric plants.

A potential problem with scaling up this approach or replicating it at other sites is that hydroelectric potential remains highly site-specific, and viability will depend on the characteristics of the relevant reservoirs. In Puerto Rico, there are 10 different hydroelectric plants that represent an installed capacity of 100 MW of hydroelectric power (Puerto Rico Energy Commission), and at least some of these sites have potential for refurbishment. This capacity provides less than half a percent of Puerto Rico's energy generation, and refurbishment at different sites could substantially increase clean energy generation and offset petroleum thermoelectric plants on the island.

CO-BENEFITS

HYDRO COOPERATIVE

Key benefits include an increase in disposable income, multiple educational opportunities, and a reduction in local health hazards.

COOPERATIVE COULD INCREASE DISPOSABLE INCOME, AND STRENGTHEN COMMUNITY BONDS

Forming a cooperative with the residents of Utuado to manage the refurbished hydroelectric facilities can produce social benefits that include: a substantial decrease in the cost of electricity, an improved sense of community, and an improved economy. Forming a cooperative would allow the members to purchase energy at essentially the cost of generation, and initial estimates suggest as much as a 60% reduction in electricity costs after completion of this project (please refer to the cost discussion on page 69). In addition to stimulating the local economy, the increase in household income of co-op members corresponds with improvements in personal benefits and quality of life (Bridge et al., 2016).

For example, one expected result of this project is an increase in the number of washing machines. With reduced electric costs, these machines will be less costly to operate, and the increase in income will lessen the hurdle of the initial purchasing cost. Washing machines provide improved sanitation and an increase in leisure time.

The formation of a cooperative also strengthens the sense of community in the region, which can result in a host of social benefits like improved support systems, increased connectivity, and improved educational outcomes (Chan, 2017). Community support systems may be vital to Utuado given the challenges the community faces both demographically and meteorologically. A substantial portion of the community is over the age of 40 (Suburban Stats, 2018), and as the population continues to age in ensuing decades, a strong community support system can help to manage increasing demographic challenges like senior isolation. Additionally, as the climate continues to shift, challenges from adverse weather events are expected to increase in Puerto Rico, and community support systems are often vital to determining local resilience to natural disasters.

The connectivity of the community will likely increase as the cooperative demands and fosters increase community interactions. Strengthening the community network allows an individual to discover different opportunities and utilize local networks for employment and educational opportunities (Chan, 2017). Coupled with the project's ability to affect education (discussed below), the improved sense of community can potentially produce substantial improvements in community education, consequently improving the skilled labor pool. A larger skilled labor pool can improve economic outcomes and foster further innovation, thus creating a positive feedback loop.

COOPERATIVE AND ITS RELIABLE ENERGY INCREASE EDUCATIONAL PROSPECTS

The proposed hydroelectric cooperative can increase the reliability of energy for local schools, allowing them to maintain an environment more conducive to learning. Currently, some schools within Utuado have been unable to operate on a regular schedule as they have been used as shelters throughout the day (Jervis, 2018). By increasing the dependability of electricity services throughout the area, schools can return to normal operations and reduce their functionality as emergency sites. Additionally, the burden of disasters will be lessened on each family, reducing the risk of absenteeism from children who might otherwise be required to attend to support at home post-disaster.

Cheaper electricity can reduce functional costs for education centers and potentially allow schools to reinvest savings in direct educational services or materials (textbooks, computers, school supplies), educational staff, after-school programs, etc. The lower cost of electricity can foster improvements in lighting and indoor thermal comfort, and indoor ventilation; improper lighting, temperature, and ventilation have been linked to decreased academic performance, reduced memory, reduced cognitive ability, and decreased attention spans (Hathaway, 1995; Stafford, 2015). With reliable and affordable electricity, schools have a greater opportunity to improve the academic environment so that it is conducive to effective learning outcomes.

Utuado is home to the University of Puerto Rico at Utuado, which if reaping the benefits of reduced electricity costs, could potentially reinvest elsewhere in scholarships or pass benefits to students through reductions in tuition. Reinvesting savings in this manner would increase education affordability and accessibility in the community, which in turns offers potential to strengthen both the community education level and the labor force.

OFFSETTING COMBUSTION CAN REDUCE EXPOSURES TO HARMFUL AIR POLLUTANTS

This project has the potential to produce robust health benefits because replacing current electricity generation mechanisms (mostly diesel generation) with an emission free source of electricity can lead to significant improvements in air quality. Burning fossil fuels produces a wide range of hazardous air pollutants like nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons, and particulate matter (PM). These pollutants manifest in a variety of reduced health outcomes(Clark et al., 2014; Colborn et al., 2011; Perera, 2016): most cause inflammation of airways, decrease lung function, increase respiratory sensitivity, aggravate serious lung conditions, increase the risk of respiratory infection and increase the risk of developing respiratory conditions like asthma and chronic obstructive pulmonary disease (COPD). Repeated inflammation can easily compound into serious cardiovascular outcomes like ischemic heart disease, and myocardial infarction (heart attack). Some pollutants, such as PM, can also penetrate the alveolar membrane and enter the bloodstream where they produce changes in blood chemistry and further propagate cardiovascular outcomes (Meng et al., 2013). Replacing diesel generators with renewable energy reduces the emission of and subsequent exposure to the aforementioned hazardous air pollutants.
It is worth mentioning that improvements in air quality will also affect local vegetation. Air pollutants can damage trees and other plants (Union of Concerned Scientists, n.d.), and as air quality improves, increased robustness of local vegetation can further reduce the risk of landslides (Cazzuffi & Crippa, 2005). As climate change is expected to usher in periods of extreme drought followed by extreme rain, the risk of landslides in mountainous areas will increase. The improvements made to local forests by improved air quality may counteract some effects of climate change and reduce landslide risks in future scenarios with extreme weather.

CHEAPER ENERGY CAN REDUCE HEALTH HAZARDS

Utuado is particularly vulnerable to air pollution because most homes are built with natural ventilation, i.e. the quality of indoor air is directly proportional to the quality of the outdoor air. The hydroelectric cooperative has the ability to improve indoor air by providing energy at a lower cost, which can increase use of electric fans and air conditioning (AC) units that improve indoor air quality by increasing ventilation rates and humidity levels, and offering filtration in the case of AC units. The use of fans and AC units also improves thermal comfort within the home, which reduces the risk of heat stress and heat stroke (Mayo Clinic, 2018).

Another local risk factor for health includes the use of liquid propane (LP) and biomass burning cookstoves. Both LP and wood/biomass burning cookstoves produce hazardous air pollutants like NOx and PM. Biomass burning stoves produce black carbon, a type of PM that has been repeatedly linked to cancer development (Valavanidis et al., 2013). Both types of cookstoves can harm human health because the emissions remain mostly contained within the room, and thus the user is exposed to much higher concentrations. By reducing the cost of electricity, electric cookstoves may become a more affordable option and reduce the burden of disease caused by the reliance on LP and biomass cooking.

As referenced through several potential pathways above, the project stands to produce health impacts from the improvements to individual income and educational levels, which tend to be positively correlated with improved access to health care, quality of care, and overall health outcomes.

HYDRO COOPERATIVE

Water budget, toxins, and community stratification are key concerns.

REDUCTIONS IN RAINFALL COULD JEOPARDIZE THE WATER BUDGET

The hydroelectric cooperative project presents caveats that could counteract the co-benefits associated with the project. Given the range of models around climate projections, and with the completion of this project, Utuado will rely on these reservoirs for both water and electricity. Unfortunately, both reservoirs are dependent on precipitation for recharge. If rainfall levels are insufficient to maintain these reservoirs, both Utuado's water supply and electricity would be in jeopardy. Initial water budget calculations suggest that the area can absorb a 30% reduction in annual precipitation. The most extreme climate projections indicate that the precipitation in the area will decrease by 15-25% by 2080 ("Climate Prediction," 2018), which may render the system unsustainable over that timeframe. Additionally, since the area is projected to undergo periods of extreme drought and extreme rain, the integrity of the dams would need to be adequately maintained to reduce flood risk.

WHILE THE POTENTIAL LEACH OF TOXICANTS COULD BE A PROBLEM, EVIDENCE SUGGESTS THIS IS UNLIKELY GIVEN CHARACTERISTICS OF THE RESERVOIRS

Hydroelectric facilities can cause environmental damages ("Environmental Impacts of Hydroelectric Power," n.d.), typically from leaching toxicants in the soil into water(Dai et al., 2010), where they enter the food-web. Through bioaccumulation, these toxicants can present severe effects on humans and wildlife (Hylander et al., 2006). While this scenario cannot be entirely negated, evidence suggests it is not a concern for this project. Through bioaccumulation, these toxicants eventually leave the local environment, and concentrations return to a safe level, typically between 30-40 years after the impoundment of the reservoir (Linkov et al., 2001). Both Lago Dos Bocas, and Lago Caonillas were impounded in the 1940's ("Lago Dos Bocas at Damsite," 2018). As almost 80 years has passed since their construction, we do not anticipate related environmental consequences.

While it is possible that dredging might expose soil that has not interacted with the water and release toxicants, those toxicants would be reflective of local industrial activity prior to impoundment. While data on historical industry has not been publicly available, we do not anticipate industrial activity close enough to result in significant environmental impacts. Concerns from local stakeholders could be mitigated through fish samples to validate these assumptions, and soil samples could be taken from the lakebed prior to dredging. However, we have no evidence to suggest the lakes are at risk, and given the cost of lakebed soil samples, did not incorporate this process into current budget estimates.

COOPERATIVE COULD CREATE ANOTHER LAYER OF STRATIFICATION IN THE COMMUNITY

The formation of the cooperative carries the potential to create an additional level of stratification within the population, based on those included and excluded within the community. As it will be more difficult to include people who are homeless or do not have formal property rights, it is unlikely that a cooperative would automatically include the full set of residents within Utuado. The cooperative could be potentially exploitative or reap co-benefits that are not shared among those excluded from the member-owner structure, thereby potentially furthering inequity within the community.

AS CLIMATE CHANGE CONTINUES, NEW CHALLENGES WILL ARISE IN ISLAND COMMUNITIES LIKE PUERTO RICO.

Changes in rainfall, ocean acidification, increased extreme weather events, sea-level rise, and warmer temperatures are expected to change island ecosystems and destabilize local economies. Therefore, it is worth contemplating how best to reach the ultimate goal of climate adaptation for island communities. Scientists have created models aiming to predict future climate scenarios, but many variables remain that are difficult to speculate and integrate into models.

The most extreme model (RCP 8.5) suggests anywhere between 0.5 to 1.5 meters of sea-level rise by 2100 (Mercado-Irizarry, 2017). While sea-level rise of this amount will not directly affect the mountainous community of Utuado, it has the potential to devastate coastal communities in Puerto Rico like San Juan and Ponce. Utuado is dependent on these economic hubs and would be significantly affected by severe damages to those areas.

Additionally, climate models suggest longer periods of extreme drought followed by extreme rains. Drastic shifts in precipitation extremes can cause landslides in mountainous areas. The extended period of drought damages vegetation, weakens roots, and dries out soil, which becomes more compact and impermeable to water. When heavy rain returns to dry areas, it can trigger flash flooding that can rip vegetation and trees from the ground, as their weakened roots are not sufficiently strong to anchor them, and lead to landslides. Utuado is a mountainous community that has already experienced landslides from events like Hurricane Maria, and faces the risk of additional landslides from similar events in the future.

While modeling presents a wide range of scenarios, it is clear that island communities will be among those most impacted by climate change effects. The severe scenarios raise the question of how and over what timeframe true adaptation is possible, and whether, if Utuado faces risks that render it later uninhabitable, there should be greater discussion about longer term relocations.

Utility Solar, Aguirre, 2018.

6. Analysis: Solar+Storage

The second option evaluated by our team involves installing a series of solar and storage systems to sustain electrical systems both during normal operations and in the wake of grid outages. Prior to Hurricane Maria, Puerto Rico had approximately 215MW of solar installed on the island, but the prolonged absence of grid power has triggered a rise in microgrid installations and solar and storage solutions that can reduce supply chain issues with diesel generators, provide power after a storm, and allow critical facilities to extend their fuel supply (GTM1, GTM2, 2017).

AES, a local electricity provider on the island, has also argued that a network of solar + storage grids may be the most effective and resilient solution. In November 2017, AES submitted comments regarding a network of "mini-grids" that would include utility-scale solar of up to 10,000MW and 2500MW of 10-hour duration battery based energy storage, at an estimated price point of $0.11 per Kwh (The Hill, 2017).

Meanwhile, residential scale providers have been donating systems for smaller projects since September, including an ongoing initiative by companies Sonnen and Pura Energia to donate Energy Oasis microgrids to community sites across the island. Sonnen has created the Foundation for Energy Security to bring additional community solar and storage models to Puerto Rico; recent examples included solar systems to power community washing machines and village community and food shelters in La Perla, Loiza, and Morovis, and a local school in Aguadilla (PR NewsWire, 2017). These systems tend to range from 4-8kW. Tesla has installed larger systems elsewhere, including a 13MW solar and 52MWh battery system on Kauai, where they are selling power through a 20 year power purchase agreement to the local utility for 13.9 cents per KWh, which is competitive with diesel prices on the island (GTM, 2017). Meanwhile, AES has also installed a 28MW solar and 20MW 5 hour duration storage system on Kauai for 11 cents per KWh (GTM, 2017).

In Utuado, the local hospital, about a dozen local schools, and the Santa Isabel Water Treatment Plant are community sites that offer opportunities for solar and storage systems to replace existing generators that rely on diesel fuel. In addition to assessing these locations on size, nature of social services provided, and legal considerations for their use during emergencies, potential shading and irradiance factors could rule out several of these sites.

For the purposes of this analysis, the project team chose to focus on a solar plus storage system at a local VA satellite clinic. The clinic is in Mameyes Abajo, a town within the municipality of Utuado and is serviced by a local nonprofit, the Corporation for Health and Scocioeconomic Development of OTOAO (El Perico, 2018). Given the community-oriented nature of the clinic, its connection to the federal VA system, and its relatively small size, we selected it as a potential site to examine the feasibility of a solar-plus-storage energy system.

The technology required for a solar-plus-storage system with the appropriate controls to run off the main electric grid would cost around $350,000 for 10kW of rooftop solar photovoltaics and a 8kW/16kWh battery system. These estimates were taken from Sonnen, a company that has delivered several similar-size and style projects across Puerto Rico in the aftermath of Hurricane Maria, donating most of the equipment as well as using funding from other charitable sources (PR Newswire, 2017). The benefits of these systems is that the clinic could power most of its technology, lights and refrigeration to administer basic medical services, however, the cost of the system on a per-unit of energy basis is quite high when compared to the retail electricity price in Puerto Rico.

Without donations and funding from other charitable organizations, it is unlikely that community centers or the local government would be able to afford a $350,000 system that can only power a small building. If the community had to find funding for the project themselves, or the funding was provided by an unregulated entity in exchange for carbon offsets, then a useful frame of reference for these costs would be the levelized cost of energy (LCOE) and the cost of abatement (COA). LCOE is the net present value of the unit-cost of electricity over the lifetime of a generating asset. This calculation is key to calculating the cost of renewable energy generation assets, where the price is driven by upfront capital costs rather than operation and maintenance costs, and the COA is the average cost per ton of CO2 offset.

To estimate both the LCOE and the COA for this potential system, we will use an estimated 15% capacity factor, which is average for residential PV systems (NREL, 2017). For a system with 10kW of solar photovoltaics, the average yearly generation would be 10kW (installed capacity) x 0.15 (capacity factor) x 8760 (hours/year) = 13,140 kWh. Over 20 years, the price of the generated electricity would be $350,000 / (13,140kWh/year x 20 years) = **$1.33/kWh,** which is quite expensive compared to both the price of electricity on the grid, which is around $0.24/kWh in Puerto Rico as well as the $0.30/kWh average from a diesel generator (Lazard, 2014).

Using a diesel generator as a comparable system for off-grid electricity generation and an emissions factor of 1.27kg of CO2e/kWh, the carbon emissions over the 20 year lifetime of the system the emissions offset would be 1.27kg CO2e/kWh x 13,140kWh/year x 20 years = 70 tons CO2e (University of Michigan). The cost of abatement, assuming that the solar PV system is always replacing a diesel generator (and not connected to the grid), the COA is $350,000/333.8 tons CO2e **= $1,048/ton CO2e offset,** which is quite high compared to the average price range for carbon offsets in the voluntary market, which is $3-$10 (Ecosystem Marketplace, 2017).

We can also compare this system to a more modular system such as OffGridBox, which is a 6x6x6 feet system that can be set up virtually anywhere to produce electricity and clean water independently from the grid. One OffGridBox system costs about $25,000 and produces around 16kWh of energy per day, for LCOE gives a cost of **$2.93/kWh** (OffGridBox). OffGridBox calculates that their system offsets 1.9 tons of CO2e per year from not burning diesel oil, also using a small diesel generator for comparison, giving a COA of $25,000/39 tons CO2e = $658/ton CO2e offset. In this case, the system also includes water treatment, but the price is still quite high for a basic level of electricity.

GREENHOUSE GAS REDUCTIONS

SOLAR + STORAGE

Limited potential for offset sales from solar + storage.

The solar and storage systems that would be installed at the local community sites evaluated in Utuado will be replacing on-site diesel generation, which the Carbon Trust Estimates produces around 0.2674 $kgCO_2e$ per kWh.

Given an installed capacity of approximately 15kW per site, for approximately 6 selected sites:

15kW (installed) x .2 (capacity factor) x 8760 hours/year = 26,280 kWh * 6 sites = 157,680 kWh

If we assume this project will include installation of solar and storage systems that generate approximately 157,680 kWh, using a diesel conversion factor of 0.2674 $kgCO_2e$ per kWh, then this represents 46.48 tons of CO_2 offsets, with 1 kg = 0.0011 tons (Carbon Conversion Factors). The average price for voluntary offsets is around \$3/tCO_2e (CBD Carbon Markets). This represents an annual return of \$139.43, which is unlikely to represent a sufficiently attractive revenue stream. Based on the average intensity of the grid, we note that this results in a relatively insignificant level of savings even at a high range estimate of \$10/tCO_2e.

0.243 $kgCO_2e$/kWh (average carbon intensity for Puerto Rico's grid) x 0.0011 tons/kg = 0.002673 tCO_2e "offset" per kWh of Puerto Rico grid generation displaced

Low range estimate, at \$3/tCO_2e: \$0.0008/kWh displaced

High range estimate, at \$10/tCO_2e: \$0.027/kWh displaced

The limited potential for offset sales from solar + storage points to the need for alternative financing mechanisms outside the carbon credits markets, as discussed further in the financial opportunities section of this report.

Current systems in Puerto Rico have primarily been funded through donations, often from the technology companies themselves, such as Tesla. Although the levelized cost of energy provided by these systems is still high compared to the traditional electricity grid, these systems have been small enough that philanthropic sources have been sufficient to cover the upfront costs.

In Orocovis, a municipality in central Puerto Rico with a population of over 20,000, Sonnen and Pura Energía donated two solar and storage systems to power a local school, replacing diesel generation. This back-up is capable of powering computers, lighting, and refrigerators for the school and enabled the community to rely on an off-grid center for emergency power (GTM, 2018). The total cost of these donated systems, which include a 15kW rooftop solar system and two batteries storing a combined 22kWh was $350,000 (GTM, 2018).

Notably, the equipment in Orocovis was donated and this project did not involve GHG emissions offsets, sale of RECs, or net metering to generate revenue streams. If the community had to fund the project themselves, levelized cost of energy per kWh would serve as a useful frame of reference for this system.

The generating capacity of the system is 15kW. The amount of electricity generated depends on solar insolation at that particular location, but a high estimate for the capacity factor – i.e. percentage of time the generating source is actually producing electricity – would be around 20% (NREL, 2017). A rough estimate of the system's total yearly output would therefore be:

15kW (installed capacity) x 0.2 (capacity factor) x 8760 (hours/year)
= 26,280 kWh

Assuming a 20 year project lifetime, we can divide the total cost of the system to calculate $350,000/20 = $17,500/year over that lifespan.

The cost per kWh of the system in place in Orocovis would then be:

$17,500 (average yearly cost) = $0.67/kWh
26,280 kWh (average yearly output)

This is far above the average retail electricity rate of $0.24/kWh for Puerto Rico, which indicates that grants and philanthropic sources are likely to serve as important funding sources for this type of project.

Financing based on GHG emissions offsets is not likely to be feasible for this project. These solar and storage systems are displacing diesel generation, which the Carbon Trust estimates produces around 0.2674 kgCO2e per kWh (Carbon Trust, 2017). If this project offset 26,280 kWh of diesel generation per year, this would represent 7,027kg of CO2 per year, or around 7 tons of CO2 offsets. The average price per for voluntary offsets is around $3/tCO2e (Carbon Trust, 2017). That represents around $21 per year in project returns, which is not a sufficient revenue stream to make this particular project feasible through offset sales.

In the capital of San Juan, Tesla donated 700 solar panels generating 200kW and one 500kW Powerpack to repower the Children's Hospital (Inside Climate News, 2017). The hospital serves 25 children full-time and provides other services to 3,000 more. Although the price of the donation has not been publicly disclosed, Tesla Powerpacks cost approximately $1,680/kW and we estimate that the cost of installing solar panels in Puerto Rico is $4.50/W. Therefore, we estimate the total cost of the donation to be $1.74 million. The generating capacity of the system is 200kW. Using a similar capacity factor estimate, we calculate:

200kW (installed capacity) x 0.2 (capacity factor) x 8760 (hours/year) = 350,400 kWh generated

If we assume that the lifetime of the project is 20 years, then we can divide the total cost of the system over those 20 years which would be $1.1 million/20 = $87,000year.

The cost per kWh of the system in place in at the Children's Hospital would then be:

$87,000 (average yearly cost) = $0.25/kWh
350,400 kWh (average yearly output)

This price is below the retail electricity rate of $0.24/kWh, so this project would provide electricity at a roughly competitive price over its lifetime. It should be noted that Tesla's donation is only temporary, as the company is actively exploring contract opportunities and has suggested it would dissemble the system if no buyers are identified.

If this project offset 350,400kWh of diesel generation per year, then this would represent 93,700 kgCO2 per year, or around 47 tons. Therefore, the project could sell offsets on the voluntary market for $141/year. This is not a sufficient revenue stream to finance this project long-term through offset sales.

ADDITIONALITY

SOLAR + STORAGE

The additionality of offsets produced by installing solar + storage on critical infrastructure will largely depend on whether the owners or operators of the particular site had plans to undertake similar investments absent the unregulated entity's involvement.

While Puerto Rico does have a Renewable Portfolio Standard that aims to deliver 20% renewable energy by 2035, this program will not affect the additionality of offsets as long as the associated project RECs are not sold into Puerto Rico's REC market. Furthermore, Puerto Rico does not have binding policies, such as a cap and trade program, that would call the additionality of offsets into question. Therefore, these offsets would be additional from a broad regulatory perspective.

On a project-specific level, the additionality of offsets produced by installing solar + storage on critical infrastructure will largely depend on whether the owners or operators of the particular site had plans to undertake similar investments absent the unregulated entity's involvement. Therefore, adequate due diligence and contractual provisions can help ensure that the specific offsets each project produces are additional.

While it does not strictly speak to additionality, an unregulated entity based in the United States may prefer offsets from projects in Puerto Rico given the concept of "matching" their own reductions. For example, if a university were the intended client, the university may prefer offsets from a hospital in Puerto Rico that it could then use to match its own emissions at an associated hospital. One drawback of the Puerto Rico projects is that the higher price of power might indicate that a market participant would eventually have funded the project; however, this seems overly attenuated and remote of a possibility to seriously undercut claims of additionality.

COSTS

SOLAR + STORAGE

Solar + battery storage, without significant philanthropy, would not provide cheap electricity to the people of Utuado.

Based on our case studies of similar projects built in the wake of Hurricane Maria, the cost of installing a solar+storage system on a community asset may be prohibitive. Despite the media narrative about the success of these projects in restoring power to Puerto Rico, these systems do not provide cheaper electricity than the existing expensive retail market on the island.

Additionally, due to their small size, these systems are not candidates for voluntary offset markets. Instead, their success is heavily reliant on philanthropy. While likely not replicable or sustainable on a large scale, companies looking to demonstrate new technologies could be targeted to implement these kinds of systems on the island. A large factor in the high cost involves the battery storage component. Reducing the storage component of a particular installation or exploring newer, unproven technologies that need deployment opportunities (with research institutions or technology companies willing to finance this themselves) could be a potential strategy for reducing the cost per kWh for these systems.

FINANCIAL VIABILITY

SOLAR + STORAGE

Equipment donation, grants, and other layers of financing are required for financial viability.

TAX CREDITS

A solar project would be eligible for a variety of tax incentives for an involved private entity, including a sales tax exemption on the purchase of solar technologies (DSIRE) as well as the Business Energy Investment Tax Credit, which can credit up to 30% of the total cost of the system (DSIRE).

GRANTS

A solar+storage project would also be eligible for grants from the United States Department of Agriculture's Rural Energy for America Program, which provides funding for the purchase and installation of solar energy systems of varying sizes. Grants can cover up to 25% of total eligible project costs, which can be combined with loan guarantee funding for up to 75% of eligible project costs (REAP Fact Sheet). The loan has a maximum term of 15 years for machinery and equipment. Green Energy Fund Grants may also be possible through the Puerto Rico Green Energy Fund, which covers up to 40% of the total cost for Tier 1 projects that are 100kW or smaller (PR Green Energy Fund). However, it is unclear at this time whether the Green Energy Fund currently has funding to provide grants.

NET METERING

When connected to the grid, a solar+storage project could sell excess energy into the electric grid for a guaranteed price of $0.10/kWh for up to 75% of the excess energy, with a system capacity limit of 25 kW for residential (DSIRE, AEEPR, NREL).

VOLUNTARY CARBON OFFSETS

A project of this scale would generate a limited number of offsets as discussed in the Greenhouse Gas section above. With the average price for voluntary offsets around \$3/tCO2e, carbon offsets will not be considered a significant funding source for this project, as even at a high range estimate of \$10/tCO2e the aggregate installation of these solar and storage projects would involve a comparable cost of \$0.027 per kWh displaced from Puerto Rico's electric grid (CBD).

EQUIPMENT DONATION

Companies like Tesla have generated a great deal of media attention during the Hurricane Maria relief effort in Puerto Rico by donating their technology to power hospitals and other community centers. In the small town of Orocovis, Sonnen, a German technology company partnered with a local installer, Pura Energía to provide solar+storage to a school free of charge (GTM). There may be other technology companies looking to compete in a domestic market with solar tariffs who may be interested in similar projects to raise their profile and enhance visibility.

Plaza de Utuado, 2018.

LEGAL CONSIDERATIONS

SOLAR + STORAGE

Investing in Solar + Storage on critical infrastructure is legally feasible, however, there are important legal and regulatory considerations when structuring the transaction.

TRANSACTION STRUCTURE

The relevant parties in the Solar + Storage option are the URE (Harvard), the site host, and, potentially, the service provider. Several potential structures for the project are analyzed below, and, despite some drawbacks, the project team finds the upfront financing model to be the most viable alternative.

1) Upfront financing
The upfront financing model would likely be structured as a tripartite contract between Harvard, the site host and the service provider. Harvard would pledge to put up the capital in exchange for RECs from the project or repayment over time from the site host, and the service provider would agree to install and maintain the project.

This model is advantageous because it gives the site host certainty about the project and likely lowers barriers for their participation. Harvard could benefit from greater control over project implementation given a tripartite contract structure. Another benefit to this model is that the service provider will be a for-profit corporation that may pay federal income taxes and ownership of the project can be assigned to the service provider so that it can take advantage of available tax savings.

This model does present risks in that Harvard is committing money upfront and if the project is unsuccessful or if the site host runs into financial difficulties, Harvard could incur a loss on its capital investment. While this risk might be mitigated through contractual terms or insurance, it is unlikely to be completely neutralized.

However, Harvard or a similar unregulated entity could consider initial pilots that provide the upfront capital financing as a philanthropic effort to build momentum for solar and storage projects across the island. Virtually all of the recent profiles of solar and storage projects installed on the island have been donations or philanthropic efforts, and an unregulated entity could consider similar initiatives along the lines of a social responsibility investment. Providing the capital for such a project could be exchanged for valuable data collection or an opportunity to pilot or test new solar and storage technologies, such as the organic solar cell development being studied under Harvard's Clean Energy Project or flow batteries under development by researchers from Harvard's John A Paulson School of Engineering and Applied Sciences (The Harvard Gazette, 2013; SEAS Press Release, 2017) .

2) REC purchase agreement

Under this arrangement, Harvard would sign a purchase agreement with the site host for a certain number of RECs each year for a set number of years. As the system generates energy and RECs are created, Harvard would pay the site host an agreed amount in exchange for the RECs.

In contrast to the upfront financing model, the REC purchase agreement is a minimal commitment from Harvard on the front end. However, this minimal investment comes at the cost of less project control and the associated risk that the project is not realized given the barriers the site host would need to surmount in finding a service provider and acquiring initial financing.

Given that this project is unlikely to produce many RECs over its lifetime, the additional revenue stream does not provide much benefit to the site host or give a service provider or financier much additional assurance that they will be repaid. Therefore, the project team recommends pursuing this option under some variation of the above upfront financing model.

3) Service provider partnership or loan guarantee

A third approach could involve partnering with an active service provider in the area, who could provide some or all of the initial capital given some ongoing commitment from an unregulated entity such as Harvard to REC purchases, providing financial assurance that the ite host will be able to repay the initial loan amount.

This approach represents a hybrid arrangement in which Harvard would agree to purchase RECs but receives more certainty that projects would be implemented as the service provider also agrees to contribute capital for the system. However, this seems less likely to be a viable option in this particular instance because there are so few RECs created by the projects that Harvard's commitment to purchase RECs provides minimal additional certainty to the service provider that loans will be repaid.

A loan guarantee does not seem like an advantageous structure given that it carries the same risks as the upfront financing model—that the site host will not be able to repay and Harvard will be on the hook for the full cost of the system—with less control over the project. We therefore do not recommend a loan guarantee structure in this instance.

REGULATORY ISSUES: CERTIFICATION, NET METERING, INTERCONNECTION, AND MICROGRIDS

Distributed generators below 1 MW and energy storage below 1 MW do not need to be certified by PREC. However, if the aggregate system size is larger than 1 MW, then the project owner will need to obtain certification. At six potential sites, all requiring a maximum of 15kW system, our project is well below these thresholds and will not require certification.

Puerto Rico's net metering law provides expedited processes for interconnection where capacity is less than 1 MW and interconnection is guaranteed where systems are less than 500kW. Interconnection standards for projects larger than 1 MW are set by PREPA with direction from the legislature that the final standards be consistent with industry best practices. The project is comfortably below these thresholds and will qualify for expedited interconnection.

Under the proposed regulations, a "microgrid" is "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to PREPA's grid." Further, "a microgrid can connect and disconnect from PREPA's grid to enable it to operate in both grid-connected or off the grid." As the Solar + Storage concept is designed to be able to operate in an islanded mode, it would likely qualify as a microgrid.

If the microgrid is owned by the electricity's user, then it qualifies as self-supply and has no requirements under the regulation. However, if it is third-party owned, as is likely the case, then it must register with the commission. Systems larger than 250kW must demonstrate compliance with technological requirements to register and they have ongoing reporting responsibilities whereas smaller systems are exempt from this oversight. The contemplated systems are well below this threshold and therefore will have a lower regulatory burden.

EMERGENCY SERVICE CONTRACTS AND RESTRICTIONS

Because the project envisions utilizing the selected sites for emergency services, it will be necessary to include contractual provisions outlining the site hosts' ongoing commitments and specific responsibilities during an emergency. These contracts must necessarily respond to the specific constraints on each organization regarding space availability and usage. However, system-wide restrictions on the use of school property are relevant to project design.

Puerto Rican law forbids the use of school buildings as emergency hospitals without express consent of the Education Secretary or his designee and then only in extreme emergencies. Additionally, permission to use school buildings may be granted but the activities must be outside of regular school hours, not for-profit and cannot be continuous. Therefore, the project and its associated contracts must be designed around these constraints.[28]

28 While school buildings were utilized for emergency services during Hurricane Maria, likely in violation of these laws, a URE would likely hesitate to sign a contract that calls for knowing violations of Puerto Rican law. Additionally, a contract calling for violations of the law might be unenforceable and therefore introduces unnecessary uncertainty.

SOLAR + STORAGE

The stand-alone and site-specific nature of this project allows for ease of implementation, though it requires a transparent process for determining the buildings selected for installation.

ON OR OFF-GRID DISTRIBUTED GENERATION AND STORAGE FOR DISASTER PREPAREDNESS

This project entails solar PV arrays plus battery storage for priority community sites that provide key services in times of emergency. These sites include: hospitals, clinics, schools, and water treatment facilities. Due to the decentralized nature of this project, various stakeholders are involved – each with their own forms of governance. As a result, the policies governing a specific site's ability to implement such a system will vary depending on the property owner (for instance, a district school compared to a clinic or a PRASA water treatment facility)

This project proposes to address the poor state of infrastructure and hurricane recovery delays by creating a system that can operate independently from the grid during the event of an outage. The system would be sized according to the desired output during an emergency-scenario, which may be limited to lights, outlets, communications, and micro-water filtration units at a minimum or extend to energy supply for emergency medical services and refrigeration for a hospital system.

HOW TO DECIDE WHERE TO INSTALL? SITE SELECTION: UNDERSTANDING LOCAL NEEDS

Considering our key stakeholder group of local residents and business owners, an assessment would be required to solicit input on which community assets are critical to maintain operations during storm events. From there, the project would need to determine technical feasibility of each specific site proposed. Interest in installing these systems may come from various property owners (that may or may not implement solar systems otherwise) including the municipality, the Utuado

School District, PRASA for the water treatment facility, and corporations including Walgreens or Selectos (supermarket) seeking to replace diesel generators used during the aftermath of Maria.

During normal operations, the systems would be connected to the grid with the ability to sell energy after meeting on-site demand. This excess energy could provide financial benefits to the property manager and thus should be considered when determining priority sites for implementation.

Stakeholders may opt to create a local "Storm Preparedness Program" to establish a formal application and review process for site selection. Considering vulnerable populations within the community, including children and the elderly, as well as specific instances of emergency management challenges in the recovery stage of Hurricane Maria such as the inability to communicate, sites may be identified and prioritized by public officials as a matter of public safety.

GOVERNING THE AGGREGATED SYSTEM - CITIZEN PARTICIPATION

Increasing citizen participation in the energy system is an important component of climate adaptation. The more people who can build, operate and manage local energy systems, the less pressure exists on a single entity to restore power as in the aftermath of Hurricane Maria. Resiliency involves returning to the status-quo of energy operations, but adaptation involves learning from the challenges and failure of the preexisting system and generating a new paradigm that can address problems previously confronted.

Partnering with the National Institute of Island Energy and Sustainability (INESI, Instituto Nacional de Energía y Sostenibilidad Isleña) could be an option in establishing a governance structure for this localized system. An entity within the University of Puerto Rico, INESI is an interdisciplinary coalition of community groups, government agencies, private companies, the press, and other sectors of Puerto Rican society. With a university campus in Utuado, INESI could provide support for creating a framework to oversee the solar systems in a coordinated, holistic manner. In addition, INESI has relationships with the State Public Energy Policy Office of Puerto Rico and the Office of the General Coordinator for Socioeconoimc Finance and Self Management (OFSA) for advancing research and recommendations on public energy policy. INESI has entered a Memorandum of Understanding with each state-level body to carry out implementation and sustainability projects, which could in turn support the efforts of this district-scale solar project.

As demonstrated by various solar + storage projects recently developed on the island, a site-by-site implementation approach is feasible for this proposition – for example, the solar + storage project at a school in Orionis, supplied by Sonnen GmbH and Pura Energía, has been designed and built to run completely off-grid on a 15-kW solar array with two battery systems of combined 22 kWh and is the tenth of its kind that Sonnen and Pura Energía have installed since Hurricane Maria hit 5 months ago (Renewable Energy World, 2018).

However, an oversight committee or governing board for the local solar + storage projects could provide additional project benefits, including transparency and accountability in how sites are selected, how infrastructure is maintained, and how value is captured from access power sold. This type of committee or governing board would place the ownership and decision-making into the hands of local participants, in a way that is similar to the cooperative model.

ECONOMIC DEVELOPMENT POTENTIAL

SOLAR + STORAGE

On-site power generation and storage allows property owners to achieve long-term cost savings while launching building-scale energy data collection, monitoring, and management.

SOLAR + STORAGE SYSTEMS NOT YET ECONOMICALLY VIABLE

While the falling cost of solar PV has been recognized over the past five years – decreasing by almost 20% over that time period – the cost of storage has also been showing declines in recent years, but is still too expensive to be economically viable as a primary mechanism for energy delivery (NY Solar Smart, 2017).

Batteries are particularly important in this project, as they are also critical as a source of back-up power during and after extreme weather events. However, this essential component of the project option is not yet available at competitive prices.

ENCOURAGING THE DIRTY DIESEL TO CLEAN RENEWABLE SHIFT

Hurricane Maria forced many local goods and service providers to rely on diesel generators for limited power access. Not only do diesel generators produce exhaust that contain more than 40 toxic air contaminants, including nitrogen oxide, they are also costly and dependent on the availability of fuel, which can result in long lines for purchasing diesel as seen in the aftermath of Hurricane Maria (American Journal of Respiratory and Critical Care Medicine, 2011). Solar + storage systems are designed to operate in isolation from the grid, to provide an emergency supply of power during the event of an outage. For this project, critical community infrastructure including hospitals, the water treatment plant, and schools identified as shelters are prioritized in site selection for these facilities. Thus, these site would be the beneficiaries of cost savings both in times of power outage and in normal operating scenarios.

LOCAL SYSTEM, LOCAL TRAINING

The decentralized site-by-site approach can offer Utuado the opportunity to incorporate solar system vocational training into its economic development program. While several sites may be privately owned, municipal buildings and schools can serve as sites for educational programs and job training. Solar + storage systems designed for disaster preparedness at schools in Florida provide an example of a partnership between the local university and the government, which could serve as a model for Utuado to follow (e.g. tapping into the University of Puerto Rico campus located in Utuado).

Hurricane Maria Damage, Utuado, 2018.

TECHNICAL FEASIBILITY

SOLAR + STORAGE

Preparing for the next Maria with solar + battery storage.

In the wake of Hurricane Maria, disaster relief efforts have focused on restoring power to critical load centers on Puerto Rico. The most common technology used for these efforts has been solar photovoltaic panels coupled with battery storage to replace backup diesel generators. The coupling of battery storage with solar helps stabilize energy generation from intermittent solar to provide electricity in the absence of sunlight. Solar plus storage offers several benefits: it can be installed relatively quickly, connected to the larger grid, and has standalone capability for emergency situations.

From a technical perspective, there are no significant barriers to the feasibility of these projects. The technologies are mature and can be rapidly deployed after natural disasters. Solar systems typically have a lifetime of 20 years and capable of surviving hurricanes with negligible damage (Jordan, D.C. & Kurtz, S.R., 2014).

In Utuado, we are constrained by the lack of data regarding electricity consumption at local schools, community centers, and hospitals. Therefore, we have analyzed similar projects built on the island in the wake of Hurricane Maria to demonstrate comparable costs and what our system could achieve.

SOLAR + STORAGE

Solar+storage projects can use proven, off-the-shelf technologies that easily scale up or down depending on the application.

SCALING SOLAR + STORAGE DEPENDS ON FINANCING OPTIONS.

Based on the technology alone, it is feasible to think that several communities in Puerto Rico, particularly those in remote areas, could benefit from having one or more community buildings equipped with solar generation and battery storage. The difficulty in scaling this approach to the entire island or to other remote areas that are vulnerable to long-term electricity outages primarily lies in the financing. Adding battery storage increases the cost of solar photovoltaic generation substantially, and despite adding an important layer of resiliency, makes projects too costly for vulnerable populations to bear. Scaling this approach will require identifying companies willing to donate or offer a significant discount on their technology, or identifying philanthropic sources willing to shoulder the cost burden based on the social benefits to communities without stable power sources.

The project team also assessed the possibility of packaging several solar plus battery storage projects to create a portfolio that provided substantial greenhouse gas emissions reductions. The core idea behind this modular approach was that while no individual project could generate significant offsets, a package of many projects could. However, we were unable to identify specific economies of scale that would make these expensive systems attractive on the voluntary offsets market from a price perspective.

Two factors present barriers to this approach at this time. First, the high cost of batteries that operate off-grid, which are needed to guarantee power during the night and cloudy days, make microgrids uncompetitive relative to the current cost of generating electricity on the island. Second, since the costs of installing these systems are largely driven by the equipment themselves, there are limited marginal benefits to install twenty systems in different locations across the island as opposed to one. While microgrids offer unique solutions to some of the energy challenges on the island, the price of battery storage must drastically fall before they can be readily financially attractive beyond philanthropic efforts.

The Fox Islands are two sparsely populated islands in Maine. The islands' electricity is provided by an electric cooperative of about 1,950 members (Fox Island Wind). Until 2009, electricity was provided exclusively through a submarine cable, which resulted in electricity prices that were about three times the price of electricity on the mainland (Harvard Gazette).

In 2008, the electric cooperative voted to fund a 4.5 MW wind project in order to control the costs of electricity for the island ratepayers (Fox Island Wind). This project cost between $12-14 million dollars, which was funded through a $9.5 million loan at 4% interest from the United States Department of Agriculture's Rural Utilities Service and a $5 million investment from a private communications company who could take advantage of the tax credits from the project including the business investment tax credit and wind production tax credit (Maine Biz).

The revenue streams for the project involve the sale of electricity to the mainland in the wholesale market as well as the sale of renewable energy credits. The price of RECs fluctuate widely, and has varied from $20/MWh to less than $1/MWh in recent years (NREL).

Despite fluctuations in electricity and REC prices, however, the project has been financially sustainable and all of the benefits are enjoyed by community members directly through their electricity bills (Harvard Gazette).

This model allows the community itself to have ownership and self-determination over its energy and would give a community with unreliable and costly power sources a different option that they have more control over. If the project produces financial returns, this project would provide more benefits to the locals in the hands of the community rather than in the hands of developers. In the case of Fox Islands, their electricity rate which could go as high as $0.25/kWh is now around $0.05/kWh (Maine Biz).

CO-BENEFITS

SOLAR + STORAGE

Key benefits include reliability of public services during a major storm event and the opportunity for educational programming.

SOLAR CAN PRODUCE BENEFITS BY ELECTRIFYING COMMUNITY SHELTERS.

The addition of solar + storage to key healthcare locations will increase these centers' resilience by allowing them to operate in some capacity even when the grid cannot be relied on for electricity. In addition to allowing the site to function during intermittent power fluctuations of the grid, the local community site can serve as a shelter or emergency center during and after a natural disaster. A shelter with electricity during a severe weather event can provide beneficial services by acting as a hub to distribute supplies, food, and water. Additionally, electricity can be used by residents for personal needs like charging phones and other battery devices. Finally, in worst-case scenarios, the shelter can serve as a host facility for displaced victims who may have lost their homes during a storm or disaster.

CENTERS CAN PROVIDE EDUCATIONAL BENEFITS TO DURING DISASTERS

Regardless of the facility selected, the shelter can disseminate educational information during natural disasters, including critical topics such as rationing supplies, scenario planning, and other survival information. During the most recent storm, some residents sought water from unsanitary locations, as discussed below. Had accurate information been provided to these individuals, unintended health consequences could have been avoided.

SOLAR CAN REDUCE HEALTH OUTCOMES

Installing solar + storage on key healthcare infrastructure in Utuado presents numerous health co-benefits given the site's capacity as an emergency shelter, reduction in pollutant emissions, and its ability to remain operational during power outages.

Emergency shelters provide health benefits during natural disasters that include serving as a hub for distributing food and water, which ensures proper nutrition and prevents infection from consuming spoiled food or drinking contaminated water. Following Hurricane Maria, many Puerto Ricans did not have access to clean drinking water, or clean water for sanitation (Campbell, 2017), and cases of leptospirosis were reported. Leptospirosis is a bacterial infection caused by Leptospira and can occur in both humans and animals ("Leptospirosis," 2017). Leptospirosis is spread to humans via contact with urine of other infected humans or mammals – typically rats. While leptospirosis is easily treated with a regimen of antibiotics, infections are often misdiagnosed as other diseases and have a range of symptoms that include fever, headache, chills, muscle aches, vomiting, jaundice, abdominal pain, or diarrhea. If the infection is untreated, it can lead to severe kidney damage, meningitis, liver failure, respiratory distress, and death. Utuado has many characteristics of a high-risk community for leptospirosis and other water borne diseases, as the municipality is poor and has an urban rodent population. While Utuado normally receives treated water, the facility needs electricity to cycle water through the treatment plant – and without power, the facility is unable to provide treated water. This meant that people were drinking directly from surface waters, which had been contaminated. Basic information provided by the healthcare system about how to reduce exposure to contaminants could have reduced the number of cases.

Shelters also provide thermal comfort, a sanitary environment, and security. Providing a space where people can find reprieve from heat and humidity can reduce the risk of heat stress and heat stroke, and as the climate continues to warm, ensuring a thermally controlled space will become critical to preventing additional heat-related deaths. Sanitation also applies to storage of food, water, and medical supplies, and application of medical treatments in a manner that reduces infection. In addition to providing sanitation, shelters with reliable electricity can provide a sense of security, mitigating a range of health impacts from the mental distress or insecurity that arises post-disasters ("Emergency and humanitarian action," 2010). These can include anxiety and elevated cortisol levels, which contribute to cardiovascular disease incidence (namely hypertension), suppressed immunity, onset of diabetes type 2, and bone loss.

Like the hydro-coop project, this project will also offset some emissions from electrical generation. As discussed in the hydro-coop co-benefits section (bullet 3),burning fossil fuels produces a wide range of hazardous air pollutants which manifest in a variety of health outcomes. Offsetting this harmful emissions can reduce healthcare outcomes. However, due to the small amount of energy generated by this project, it is worth noting that these emissions reductions are expected to be significantly less than those offset by the hydro project.

The solar + storage project has the potential to greatly improve health by allowing the healthcare center to function post-disasters. Post-Maria, the absence of electricity devastated local health care services and infrastructure. Communication between hospitals was negligible, so specialists could not be reached and patients were transferred to trauma centers or other hospitals with no knowledge of the facility or the availability of beds, number of supplies, number of physicians, or functionality of systems. Vaccines and other supplies that require cold-storage spoiled in the absence of refrigeration. Emergency procedures – including surgeries – were performed via flashlights by physicians on their second or third consecutive shift (Newkirk II, 2018). Patients who need regular treatments like dialysis were unable to receive treatment because the required machines rely on a consistent power source. These challenges were compounded by the volume of patients arriving with injuries from the storm, leaving the health care system largely immobilized. Months after the disaster, patients report health repercussions from Hurricane Maria, including respiratory issues caused from exposure to mold in damaged homes with poor ventilation. The recent hurricanes have highlighted the critical link between power and medical infrastructure, and by providing a source of reliable energy, this proposal can enhance key functionality at chosen healthcare sites.

UNINTENDED CONSEQUENCES

SOLAR + STORAGE

Potential drawbacks and adverse impacts are highly site-specific.

FUNCTION AS A SHELTER MAY NOT BE FEASIBLE DUE TO LIMITED SPACE IN UNDERSERVED AREAS

A healthcare center may have limited ability to function as a community shelter, as medical care will take priority. Both clinics and hospitals have limited space, and these centers may not have sufficient space to perform additional duties.
For example, the number of hospital beds are not distributed evenly throughout the island and most areas have far fewer hospital beds than needed. Areas like San Juan, have approximately 4.2 beds per 1000 residents, far above the national average of 2.9; meanwhile, poorer areas have far fewer. The average in underserved communities is 2.1 beds per 1000 residents, which is below the national average, and in some areas it averages 1.3 beds per 1000 residents (Perreira, Lallemand, Napoles, & Zuckerman, 2017). In areas like San Juan, where hospital beds are plentiful, healthcare centers may have additional space allowing them to host displaced residents in the case of an emergency. However, in underserved areas, the limited number of beds at hospitals reduces the viability of a model using hospitals for emergency shelters, as the center will likely not have enough room for patients let alone others.

FUNCTION AS A SHELTER MAY IMPAIR THE HOSPITALS' ABILITY TO PERFORM HEALTHCARE FUNCTIONS

In addition to limited space, these centers have limited capacity from a staffing perspective, and serving as a centralized hub for emergency functions other than healthcare services may impair the ability of the staff to perform their primary duties in providing health care services.

While the island has enough healthcare workers (dentists, nurses, pharmacists, and physicians), they are not distributed evenly throughout the island, and are concentrated in wealthier areas, like San Juan. In underserved areas, access to physicians is the largest concern. The US Health Resources and Services Administration (HRSA) has deemed 72 of the island's 78 municipalities to be medically underserved. Many of these municipalities are considered health professional shortage areas (HPSAs), meaning the population-to-provider ratio is 3,500:1 or higher (Perreira, Peters, Lallemand, & Zuckerman, 2017).

HPSAs are assessed on a scale of 1 to 26,where higher scores indicate higher needs. Utuado, is considered a HPSAs for both primary care and mental health, with a HPSA score of 17 and 21 respectively. In 2017, the number of practitioners providing primary care was estimated to be 1 full-time equivalent (FTE), and zero FTE for mental health providers (U.S. Department of Health & Human Services, 2017) Utuado is already in need of healthcare professionals and adding extra duties for healthcare professionals (i.e. educational campaigns, resource management, and other proposed shelter duties) can exacerbate their stretched schedules. The healthcare infrastructure in Utuado does not have enough trained health workers to perform healthcare services and shelter services during a disaster.

Furthermore, it is unclear if enough healthcare workers are in place to sustain additional functions even in areas with high numbers of healthcare practitioners, like San Juan. After Hurricane Maria, reports of physicians working double and triple shifts were common (Newkirk II, 2018). Physicians were working longer hours because many could not be reached or make it to the hospitals; while providing power to the hospital may help physicians perform functions within the facility, it does not enable physicians to reach the center and physicians may still be expected to work longer hours to meet demand. Healthcare workers who work substantial consecutive hours have been shown to make additional mistakes including more serious medical errors, serious diagnostic errors, on-the-job attention failures, and more needlestick and other sharp injuries (Lockley et al., 2007).

HEALTHCARE CENTERS ACROSS THE ISLAND ARE NOT EQUAL

The majority of the healthcare infrastructure in Puerto Rico is already in need of drastic improvements, and adding additional functionality on an already stressed system could cause severe damage. The healthcare infrastructure is disproportionately distributed, as mentioned, and while a hospital/emergency shelter model may work in areas with sufficient capacity like San Juan, the model is unlikely to translate to most regions across the island. Considering primary care HPSAs alone, 39 of the 78 municipalities are drastically underserved. Of the approximately 1,690,470 people living in these 39 primary care HPSAs, only 1.92% report having their primary care needs met (U.S. Department of Health & Human Services, 2017). The Henry J Kaiser Family Foundation estimates that at least 554 additional practitioners are needed to fully meet existing demands (Kaiser Family Foundation, 2017). While providing reliable power will allow these centers to function after disasters, it will not substitute for a dearth of practitioners.

7. Feasibility Study Results

Based on these findings, the Puerto Rico team has estimated a higher net benefit to implementing the **hydroelectric cooperative project**, as demonstrated through a weighting of project criteria.

Our results indicate the hydro cooperative presents the most compelling project alternative in light of team discussions, research, and the aforementioned criteria matrix. In a simplified scoring system, assuming a standardized weighting system: Red = 1, Yellow = 2, Green = 3) hydro scores 27.5, solar + storage scores 25.5.

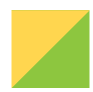
We acknowledge the robust legal and political issues that require further investigation. As stated in the legal component of this analysis, if the hydroelectric assets are sold during PREPA's privatization process, the community co-operative would participate in the RFP process, and if they are retained by PREPA or its successor, would aim to participate in a public-private partnership. If a competitive proposal like that proposed by Cube Hydro is accepted, our proposal would aim to add capacity to another existing facility and we would submit the process to expedite under the "critical infrastructure" procedures specified in PROMESA Title V.

If PREPA retains control over distribution assets, we would intend to qualify as a cooperatively owned microgrid and construct separate distribution infrastructure, although this may entail purchasing rights of way from individual property owners, and substantially raise project costs. Continuing to evaluate a limited pool of solar and storage investments, primarily funded through philanthropic or grant mechanisms, may be a useful supplement or alternative given the risks presented through our hydroelectric alternative.

The major differences between the two projects include: solar + storage is not financially viable, doesn't provide (much needed) economic development benefits, and does not provide as many co- or climate-benefits. The hydro-coop project is more complex legally and stakeholder-wise and not as satisfying on the additionality piece. While the project may have more significant unintended consequences given its broader scope of impact, it also has the potential for much greater co- and climate-benefits.

Moving into the implementation planning phase, we will further consider the opportunity to integrate distributed solar into the overall project package and will work to address key outstanding questions related to additionality, legal considerations, governance and stakeholder complexity, and unintended consequences.

FEASIBILITY STUDY OVERVIEW

CRITERIA	HYDRO COOPERATIVE	SOLAR + STORAGE
Greenhouse Gas Reductions		
Additionality		
Costs		
Financial Viability		
Legal Considerations		
Governance + Stakeholder Complexity		
Economic Development Potential		
Technical Feasibility		
Scalability / Replicability		
Co-Benefits + Climate Preparedness		
Unintended Consequences		

Health & Environmental Averted Damages Calculations

METHOD:

1. Pull recent emissions information from National Emissions Inventory (NEI)
2. Isolate emissions from electricity generation
3. Find emissions per unit of generated electricity (ton/MWh)
4. Calculate emissions reduced based on expected project generation
5. Use current literature to assign dollar amounts to each ton of emission
6. Convert dollars to current dollar values

RESULTS:

Dollar evaluations for damages associated with certain pollutants are listed in the table below (Shindell, 2015).

	5%			**3%**			**1.40%**		
Pollutant	*Median*	*Comp Health*	*Regional Climate*	*Median*	*Comp Health*	*Regional Climate*	*Median*	*Comp Health*	*Regional Climate*
Carbon Dioxide	27	0	0	84	0	0	150	0	0
BC	210000	62000	19000	270000	62000	26000	310000	62000	34000
Sulfur Dioxide	40000	33000	3000	42000	33000	4400	43000	33000	5900
Carbon Monoxide	410	200	0	630	240	0	820	250	0
OC	64000	51000	6100	68000	51000	8700	71000	51000	12000
Nitrogen oxides	67000	67000	90	67000	67000	350	67000	67000	600
Ammonia	24000	22000	820	25000	22000	1200	25000	22000	1600

Aguirre Station (oil-fueled), Salinas, 2018.

Emissions numbers taken from the 2014 National Emissions Inventory were used to derive the following averted social costs. These calculations were done in 2007 dollars; thus they were adjusted for inflation and converted to 2018 dollars.

		5%			3%			1.40%		
Pollutant	**Emissions Reduction**	*Median*	*Comp Health*	*Regional Climate*	*Median*	*Comp Health*	*Regional Climate*	*Median*	*Comp Health*	*Regional Climate*
BC	0.980973559	206004.447	60820.36066	18638.49762	264863	60820.36066	25505.31253	304101.8	60820.36066	33353.10101
Sulfur Dioxide	277.8435056	11113740.2	9168835.685	833530.5168	1.2E+07	9168835.685	1222511.425	11947271	9168835.685	1639276.683
Carbon Monoxide	35.46399658	14540.2386	7092.799316	0	22342.3	8511.359179	0	29080.48	8865.999145	0
OC	0.353217135	22605.8966	18014.07389	2154.624524	24018.8	18014.07389	3072.989075	25078.42	18014.07389	4238.60562
Nitrogen oxides	268.473608	17987731.7	17987731.74	24162.62472	1.8E+07	17987731.74	93965.7628	17987732	17987731.74	161084.1648
Ammonia	1.998257058	47958.1694	43961.65528	1638.570788	49956.4	43961.65528	2397.90847	49956.43	43961.65528	3197.211293
	Total Costs Averted	29392580.7	27286456.31	880124.8345	3E+07	27287874.87	1347453.398	30343220	27288229.51	1841149.766

Water Budget Calculation

METHOD:

1. Find recharge area for both reservoirs
2. Find average annual precipitation for recharge areas
3. Estimate annual water usage from both reservoirs
4. Determine rate of recharge compared to rate of consumption
5. Use ICP models to anticipate future climate effects on annual precipitation
6. Compare anticipated changes in future recharge rate changes to current water budget

Recharge areas for reservoirs (“Lago Caonillas at Damsite,” 2008; “Lago Dos Bocas at Damsite: Drainage Area,” n.d.)

RESERVOIR	RECHARGE AREA
Lago Caonillas	50.4 square miles
Lago Dos Bocas	162.2 square miles

Average annual precipitation =
1.915 m (“Climate Utuado: Temperature, Climograph, Climate table for Utuado,” n.d.)

Annual Recharge =
(50.4+162.2 sqmi)*(27800000 sqft/sqmi) * (1.915 m)*(3.28 ft/m) * 7.48 gal/cuft = 278 billion gallons per year

Daily recharge average = 761 Mgal/day

Consumption rates for reservoirs (Molina-Rivera, 2014)

RESERVOIR	DAILY CONSUMPTION IN MILLION GALLONS PER DAY
Lago Caonillas	104.93
Lago Dos Bocas	340.33

Consumption rate for San Juan public-supply water = 83.8 Mgal/day (Molina-Rivera, 2014)

Daily consumption total = 529 Mgal/day

Percent of maximal use based on recharge = 70%

The most extreme climate models suggest up to 25% decrease in precipitation for Puerto Rico by 2080 ("Climate Prediction," 2018). With a 25% reduction in rainfall, the percent of maximal use based on recharge will be approximately 92%.

Financials

Cost Assumptions (high end of range)	Range/Estimate
Hydro Refurbishment	
Capital*	26,500,000
Acquisition Costs**	19,500,000
Dam Dredging, Disposal, Transport***	41,472,000
*Estimated $500-1000/kW in capital costs for refurbishing 26.5 MW plant per IRENA (2012): https://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-hydropower.pdf	
** Based on review of recent acquisitions of functioning dams in the 20-40MW range in the contiguous U.S., less cost estimates of capital refurbishment	
*** Incorporates industry estimates of $4-8 per cubic yard for dredging costs	
Pumped Solar System	
Solar and storage installation (20MW)*	53,000,000
Solar land acquisition**	1,796,808
Total Capital, Solar	54,796,808
*Installation costs sourced from EIA (2016): https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capcost_assumption.pdf	
**Land acquisition informed by acreage prices publicly available for farmland in Corozal County, PR.	
Buried Transmission Lines	
Burying Lines*	16,800,000
*Estimated $1.5 million per mile for new 69 kW underground lines per Electric Light and Power (2016): https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capcost_assumption.pdf	
Scenario Cost Summary	
Total Capital	**159,068,808**
Total O&M*	6,362,752
*Estimated mid-range of industry estimates for O&M as percent of capital costs (4%), per IRENA (2012): https://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-hydropower.pdf; Electric Light and Power (2016): http://www.elp.com/articles/powergrid_international/print/volume-18/issue-2/features/underground-vs-overhead-power-line-installation-cost-comparison-.html; and IRENA (2012): https://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-solar_pv.pdf. O&M assumptions for buried transmission includes estimates for base transmission cost, conductor multiplier, stucture multiplier, re-conductor multiplier, terrain multiplier, row acres/mile, land cost/acre, number of miles).	
Additional Notes	
Total kWh generated per annum (26.5MW*90% cap factor*8760 hours/year)	208,926,000
Income escalation - annual inflation rate %	2.5
Income escalation - annual electricity price increase (% in addition to inflation rate)*	3.5
Discount rate %**	6.5
25 year project lifespan***	
*Annual inflation rate informed by historic trends 1914-2018 (https://tradingeconomics.com/united-states/inflation-cpi). While electricity price assumptions fall within a higher end of estimates within the contiguous United States, electricity prices have been rising steeply in Puerto Rico over the past decade and on average, retail electricity rates have risen at a mean rate of 4% from 2007-2017 nation-wide (https://news.energysage.com/residential-electricity-prices-going-up-or-down/). As of spring 2018, PREPA would require a more than 30 cent per KWh rate to meet debt obligations and cover operational costs and pensions, and rates in Puerto Rico continue to be higher than 49 of 50 states (http://caribbeanbusiness.com/prepa-must-increase-rates-to-meet-debt-payment/; https://www.eia.gov/state/print.php?sid=RQ#91).	
** Discount rate informed by range assessed from similar projects per IRENA (2012): https://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-hydropower.pdf	
*** Project lifespan primarily informed by depreciation in solar assets and useful life of the PV system (refurbished hydro assets conventionally last beyond this timeframe)	

Hydropower Refurbishment Summary

DEVELOPMENT COSTS	
Total Development Cost {see cost assumptions}	$159,068,808
KWH generated per year	208,926,000
Price set per KWH	$0.080

CAPITAL STRUCTURE	
LTV	65%
Equity {Unregulated Entity}	$55,674,083
Debt	$103,394,725
Debt Term*	15
Debt Interest Rate*	5.00%
Annual Debt Payment (15 years)	($9,961,284)
Market Discount Rate	6.5%

EXPENSES	
Income Escalation**	6.00%
O&M Expense Escalation and Cost Contingencies***	3.50%
O&M Expenses (% of Capital)***	4%
Energy Sales Taxes {exempted}†	0%
Income Taxes {exempted}†	0.00%

DEPRECIATION (SLM Method)	
Depreciation Basis (Year)	25

Notes

*Debt term and interest rate informed by similar range loans for hydroelectric projects funded by the USDA Rural Utilities Service (https://www.rd.usda.gov/programs-services/electric-infrastructure-loan-loan-guarantee-program).

**Income escalation includes 2.5% inflation and 3.5% electricity rate increase (see cost assumptions).

*** O&M expense escalation and cost contingencies informed by the following standards/guidelines for small hydro development and pumped storage hydroelectric power plants: https://jrenewables.springeropen.com/track/pdf/10.1186/s40807-018-0048-1; http://sos.ri.gov/documents/publicinfo/omdocs/minutes/6154/2015/42539.pdf

† Assumes project will claim tax exemptions afforded to hydro and solar projects within Puerto Rico (eligible tax exemptions for personal property taxes, state excise tax, and sales and use taxes on equipment, associated accessories, and components): https://www.energy.gov/savings/puerto-rico-sales-and-use-tax-exemption-green-energy; https://www.pf-cpa.com/tax_exemption_for_green_energy.html

†† Includes infrastructure maintenance, other equipment, and facility and staffing costs (site maintenance, plant equipment maintenance, operations and administration, other equipment and supplies).

PRO FORMA	0	1	2	3	4	5	6	7	8	9	10
INCOME											
Value of electricity generated (nominal)		$16,714,080	$17,716,925	$18,779,940	$19,906,737	$21,101,141	$22,367,209	$23,709,242	$25,131,796	$26,639,704	$28,238,086
EXPENSES											
(Operating Expenses)††		($6,362,752)	($6,585,449)	($6,815,939)	($7,054,497)	($7,301,405)	($7,556,954)	($7,821,447)	($8,095,198)	($8,378,530)	($8,671,778)
NET OPERATING INCOME	($159,068,808)	$10,351,328	$11,131,476	$11,964,001	$12,852,239	$13,799,736	$14,810,256	$15,887,795	$17,036,599	$18,261,174	$19,566,308
Debt Service		($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)
CASH FLOW AFTER FINANCING	($55,674,083)	$390,043	$1,170,192	$2,002,717	$2,890,955	$3,838,452	$4,848,971	$5,926,510	$7,075,314	$8,299,890	$9,605,024
Energy Sales, Income Tax Exemption											
CASH FLOW AFTER TAXES	($55,674,083)	$390,043	$1,170,192	$2,002,717	$2,890,955	$3,838,452	$4,848,971	$5,926,510	$7,075,314	$8,299,890	$9,605,024

UNLEVERAGED IRR	10.97%
LEVERAGED BEFORE-TAX IRR	14.42%
LEVERAGED AFTER-TAX IRR	14.42%
NPV	$113,414,792

OFF-SHEET CALCULATIONS										
AMORTIZATION	1	2	3	4	5	6	7	8	9	10
Beginning of Year Outstanding Principal	$103,394,725	$98,491,831	$93,338,096	$87,920,686	$82,226,111	$76,240,190	$69,948,019	$63,333,928	$56,381,448	$49,073,265
End of Year Outstanding Principal	($98,491,831)	($93,338,096)	($87,920,686)	($82,226,111)	($76,240,190)	($69,948,019)	($63,333,928)	($56,381,448)	($49,073,265)	($41,391,183)
Amortization	$4,902,894	$5,153,735	$5,417,410	$5,694,575	$5,985,920	$6,292,171	$6,614,091	$6,952,480	$7,308,182	$7,682,083
TAXABLE INCOME										
Cash Flow After Financing	($390,043)	($1,170,192)	($2,002,717)	($2,890,955)	($3,838,452)	($4,848,971)	($5,926,510)	($7,075,314)	($8,299,890)	($9,605,024)
Amortization	$4,902,894	$5,153,735	$5,417,410	$5,694,575	$5,985,920	$6,292,171	$6,614,091	$6,952,480	$7,308,182	$7,682,083
Depreciation	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)
Taxable Income	**($1,849,902)**	**($2,379,209)**	**($2,948,059)**	**($3,559,132)**	**($4,215,284)**	**($4,919,552)**	**($5,675,172)**	**($6,485,586)**	**($7,354,460)**	**($8,285,693)**

Average Annual Payment to Harvard/Unregulated Entity	$9,297,913	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
PV of Cash Flow After Financing		$390,043	$1,098,772	$1,880,485	$2,714,512	$3,604,180	$4,553,025	$5,564,799	$6,643,488	$7,793,324	$9,018,802
Year of Equity Payback to Harvard		$55,284,039	$54,185,268	$52,304,783	$49,590,271	$45,986,090	$41,433,066	$35,868,267	$29,224,780	$21,431,455	$12,412,654
{11 Year Payback Period}											

FINANCIAL SUMMARY CONTINUED ON NEXT PAGE (YEARS 11-25)

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
$29,932,372	$31,728,314	$33,632,013	$35,649,934	$37,788,930	$40,056,265	$42,459,641	$45,007,220	$47,707,653	$50,570,112	$53,604,319	$56,820,578	$60,229,813	$63,843,601	$67,674,218
($8,975,291)	($9,289,426)	($9,614,556)	($9,951,065)	($10,299,352)	($10,659,830)	($11,032,924)	($11,419,076)	($11,818,744)	($12,232,400)	($12,660,534)	($13,103,652)	($13,562,280)	($14,036,960)	($14,528,254)
$20,957,081	**$22,438,888**	**$24,017,457**	**$25,698,869**	**$27,489,577**	**$29,396,436**	**$31,426,718**	**$33,588,144**	**$35,888,909**	**$38,337,712**	**$40,943,785**	**$43,716,926**	**$46,667,532**	**$49,806,641**	**$53,145,964**
($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)	($9,961,284)										
$10,995,797	**$12,477,604**	**$14,056,173**	**$15,737,584**	**$17,528,293**	**$29,396,436**	**$31,426,718**	**$33,588,144**	**$35,888,909**	**$38,337,712**	**$40,943,785**	**$43,716,926**	**$46,667,532**	**$49,806,641**	**$53,145,964**
$10,995,797	$12,477,604	$14,056,173	$15,737,584	$17,528,293	$29,396,436	$31,426,718	$33,588,144	$35,888,909	$38,337,712	$40,943,785	$43,716,926	$46,667,532	$49,806,641	$53,145,964

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
$41,391,183	$33,316,070	$24,827,819	$15,905,293	$6,526,274										
($33,316,070)	($24,827,819)	($15,905,293)	($6,526,274)	$3,332,594										
$8,075,113	$8,488,251	$8,922,526	$9,379,019	$9,858,868										
($10,995,797)	($12,477,604)	($14,056,173)	($15,737,584)	($17,528,293)	($29,396,436)	($31,426,718)	($33,588,144)	($35,888,909)	($38,337,712)	($40,943,785)	($43,716,926)	($46,667,532)	($49,806,641)	($53,145,964)
$8,075,113	$8,488,251	$8,922,526	$9,379,019	$9,858,868										
($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)	($6,362,752)
($9,283,436)	**($10,352,105)**	**($11,496,399)**	**($12,721,317)**	**($14,032,178)**	**($35,759,188)**	**($37,789,470)**	**($39,950,896)**	**($42,251,662)**	**($44,700,465)**	**($47,306,537)**	**($50,079,678)**	**($53,030,285)**	**($56,169,394)**	**($59,508,716)**

Year 11	**Year 12**													
$10,324,692	$11,716,060	$13,198,284	$14,777,074	$16,458,491	$27,602,287	$29,508,655	$31,538,163	$33,698,506	$35,997,852	$38,444,869	$41,048,756	$43,819,279	$46,766,799	$49,902,314
$2,087,962	($9,628,098)													

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