A Renewable Energy Future for Puerto Rico

Authors:
Collin Smith
Gabriel Gordon-Harper
Adela Kim
Tisura Gamage

Introduction

Puerto Rico's power system was in significant need of reform even before Hurricane Maria made landfall in September 2018. The island's electricity sector was suffering from a number of issues that had negative economic and environmental consequences on the island. Many of these problems are interconnected, and addressing them will require comprehensive changes to Puerto Rico's energy mix and power sector operations. Several of the most salient challenges Puerto Rico faces are listed below:

- *High Electricity Prices:* Puerto Rican citizens suffer from some of the highest electricity prices in the nation, with residential power prices almost twice the mainland average
- *High levels of pollution:* Electricity on the island is largely supplied by oil-fired power plants with extremely high emissions levels. These power plants are also decades old and are now largely outdated and inefficient, worsening their environmental impact while also making the power system prone to interruptions from power station outages.
- *Lack of Resilience*: Puerto Rico's transmission and distribution (T&D) infrastructure is outdated, and outages were common on the island even before last year's hurricanes. Generation on the island is located far from demand centers, increasing reliance on the vulnerable T&D system and making disruptions in supply from weather events a serious concern.
- *Falling Demand*: Puerto Rico's demand for power has been contracting due to outmigration. The island's population had decreased by 11 percent even before hurricane Maria, and depopulation is expected to continue due to economic decline (Whoriskey, 2017).
- *Financial Distress & Organizational Mismanagement:* Puerto Rico's vertically-integrated utility declared bankruptcy in July 2017 after years of financial and operational mismanagement. A few months earlier in May 2017, the government of the commonwealth of Puerto Rico, which owns the utility, also declared bankruptcy.

Hurricanes Irma and Maria have exacerbated the aforementioned problems with Puerto Rico's power grid. These natural catastrophes caused the longest blackout in US history; six months after the entire island lost power, 145,000 people still had not had their electricity restored (Chasteen, 2018). Eighty percent of the island's T&D infrastructure was destroyed. These hurricanes laid bare the significant problems that had existed in Puerto Rico's power system and showcased the need to improve the system's resiliency in the future.

From a technical, economic and policy point of view, Puerto Rico has a unique window of opportunity to not only "build back better" to higher levels of system resilience, but also to redefine the business model of its future utility. Cost reductions in renewable energy technologies like wind and solar have created an opportunity for the island to reduce operating costs by transitioning towards cleaner fuels. Meanwhile, distributed energy resources (DERs) like rooftop solar, storage, and microgrid systems can improve the resiliency of the island's power, allowing customers to maintain access to electricity during outages on the main grid. The ability for customer-sited storage and microgrids to modulate power demand can also be harnessed to reduce the cost of integrating variable renewable energy into the grid.

The benefits provided by this new structure - with utility-scale renewable energy providing clean, affordable power on the supplier side and DERs providing resiliency and flexibility on the customer side - would help address several of the current challenges to the system identified above. However, doing so would require policy initiatives and regulatory adjustments to align the incentives of all stakeholders in the system towards advancing this transition. Unfortunately, Puerto Rico's current approach to restructuring its power sector risks locking the sector into its current trajectory, one in which the challenges outlined above continue to plague Puerto Rico for years to come.

This paper will develop an alternative approach to structuring Puerto Rico's power sector, one that incorporates technical, regulatory, and policy measures to reduce costs, improve resiliency, and

drive the system towards cleaner sources of energy. It explores grid improvements that can make the system more resilient, regulatory mechanisms that can incentivize the utility to incorporate more renewable energy into the grid, and financial tools that can improve access to advanced clean energy technologies like rooftop solar and microgrids by customers across Puerto Rico. Finally, it develops a preliminary timeline for these measures and identifies the benefits they will provide to different stakeholder groups on the island to outline how this system could obtain buy-in from the island as a whole.

Background

Puerto Rico's Power Sector

Puerto Rico's energy distribution and transmission systems are owned and operated by the Puerto Rico Electric Power Authority (PREPA), a government-owned, vertically integrated power monopoly. PREPA owns six generation plants and has signed power purchase agreements (PPAs) with various independent power producers (IPPs). PREPA was self-regulated through most of its existence, but in 2014 Puerto Rico's legislature created a new regulatory body for the sector. This new regulatory body, the Puerto Rico Energy Commission (PREC), is responsible for approving wholesale and retail rates, setting efficiency and interconnection standards, and overseeing PREPA's compliance with Puerto Rico's renewable portfolio standards (RPS) that was established in 2010 to increase the levels of renewables in its energy mix (O'Neill & Borges, 2017 and Puerto Rico Energy Commission, 2017).

Puerto Rico is highly reliant on imported fossil fuels for electricity. The island's 2017 generation capacity consisted of 45% oil-fired power plants (5 of PREPA's six generators), 35.7% natural gas (burned in one of PREPA's generation facilities and by one IPP), 16.8% coal (burned by another IPP), and only 2.5% renewable energy (U.S. EIA, 2018 and Autoridad de Energia Electrica, 2017). Due to the large quantity of imported fuel in its energy mix, PREPA's retail rates are higher than every U.S. state but

Hawaii (U.S. EIA, 2017). Industrial and commercial electricity prices in Puerto Rico are 18.64 cents/kWh and 22.39 cents/kWh respectively, more than double the average U.S. price of 7.25 cents/kWh and 11.04 cents/kWh respectively. Puerto Rican residential electricity rates are similarly high, 20.47 cents/kWh in 2017 versus 13.19 cents/kWh in the mainland (U.S. EIA, 2018). Burning oil for fuel also causes significant environmental degradation; PREPA's Aguirre Power Station generated 3.5 million metric tons of CO_2 in 2015 and produces high levels of sulfuric acid (Suarrez Torres, 2017).

Puerto Rico's T&D lines were in poor condition prior to last year's hurricanes. In a PREPA assessment five months before Hurricane Maria struck, PREPA reported that deferred upkeep had resulted in a "degraded and unsafe" grid, which needed an estimated $4 billion of investment (Brown, 2017). Outages where common on the island even before the hurricanes, and the situation worsened when hurricane Maria and Irma hit the island, destroying roughly 80% of its fragile T&D networks (Tolson, 2018). The cost to restore Puerto Rico's transmission and distribution system is estimated to exceed $17 billion (New York Power Authority, 2017.)

This issue is compounded by the fact that 70% of Puerto Rico's centralized generation facilities are in the south of the island, while 70% of electricity demand is located in the more populated north (Gallucci, 2018). These power plants are connected to demand centers via long distance transmission lines over mountainous rugged terrain. The vulnerability of these lines to severe weather events, and the expense and challenge associated with their repair and maintenance were major contributing factors to the wide-range and long-term nature of Puerto Rico's post-hurricane blackout. In addition, these plants themselves are becoming increasingly expensive to maintain. The median age of a PREPA power plant is 44 years old, over two and a half times the US industry standard of 18 years. Underinvestment in PREPA's aging infrastructure also resulted in a 15.9% forced outage rate, one and a half times the industry standard for US oil-based power plants (Puerto Rico Electric Power Authority, 2015).

Policy Support for Renewable Energy

Despite the low contribution of renewable energy to Puerto Rico's current energy mix, the government has passed measures to support the development of wind and solar energy on the island. In 2010, the government passed new legislation that established a Renewable Portfolio Standard (RPS), setting renewable energy targets at 12% in 2015, 15% in 2020, and 20% in 2035. A Green Energy Fund was also created in 2010 to provide additional financial support to the industry; among other things, this fund provides direct rebates of up to 60% for small systems and 50% for larger systems (Puerto Rico Department of Economic Development and Commerce, 2018). Puerto Rico also established a net metering policy in 2007 to support the growth of rooftop solar (U.S. DOE, 2018).

With renewable energy penetration currently at 2%, Puerto Rico missed its 2015 RPS target of 12% by a large margin. This is partially due to instability in Puerto Rico's support of renewable energy. Stakeholders we spoke with informed us that when the RPS was passed in 2010, PREPA signed over 60 new contracts for utility-scale renewable energy in Puerto Rico. However, after an administration shift in Puerto Rico's government only 11 of these contracts were ever developed. The stakeholders noted that this damaged investor confidence in the Puerto Rico renewable energy market; since PREPA is the sole off-taker for utility-scale renewable energy in Puerto Rico, investors have little ability to hedge the risk that projects on the island will be delayed or canceled.

In terms of distributed renewable energy, the net metering system in Puerto Rico has been generally successfully, with developers on the island stating that it significantly improves the economics of distributed solar systems on the island. However, the rebates disbursed by the Green Energy Fund have been less effective. According to one developer, since rebates for smaller systems (100 kW) were disbursed on a first-come, first-serve basis, the funds were often exhausted within hours of becoming available. Developers thus could not guarantee customers that they would be able to receive them.

Rebates for larger systems (1 MW) were dispersed through a competitive tendering process and so may have avoided this problem, but this component of the program was discontinued in 2017. The fund also has administrative problems, including unexpected delays in project evaluation and a long reimbursement process (Renewable energy execs…, 2017), which has reduced its usefulness.

Privatization Plans:

Puerto Rico's governor Ricardo Roselló announced in January 2018 that his government intended to privatize PREPA. Although details of the sector's new structure are still being finalized, Governor Roselló has revealed that he intends to sell PREPA's generation assets to private investors and then offer operation of PREPA's T&D infrastructure to an outside company under a long-term concession agreement. Governor Roselló stated that he proposed privatization as a way to improve efficiency in Puerto Rico's power sector, believing that a private company could tighten operations at the island's electric utility (Bade, 2018). He also called for increasing Puerto Rico's renewables portfolio to 30% (Roselló, 2018). Around the same time, PREPA's governing board in February formally adopted a new vision for Puerto Rico's power sector that highlighted the importance of customer relations, financial viability, reliability and resilience, sustainability, and economic growth opportunities (Puerto Rico Electric Power Authority, February 2018).

However, not all of the government's decisions have been in step with this progressive vision. Shortly before he announced the decision to privatize PREPA, Governor Roselló proposed consolidating the sector's regulatory commission, PREC, into a larger government body that also includes regulatory agencies for consumer protection and telecommunications (Bade and Walton, 2018). Many independent analysts saw this move as a step backward, effectively watering down PREC's ability to effectively regulate the island's utility. Although this proposal was ultimately withdrawn, it created concern that

the Puerto Rican government did not intend to include a strong independent regulator in the new energy system it is creating.

Analysis of Current Approach

Risks of the Current Approach

Some stakeholders have expressed concern that privatization's ability to assist the government in raising funds is being prioritized over the transition's potential to create a lower-cost, cleaner, more resilient energy system. According to Governor Roselló, privatizing PREPA's assets could raise $2-4 billion in funds (Kaske and Rivera, 2018). However, given uncertainties regarding the future of the island's electricity market, declining electricity demand in Puerto Rico, and the age of the utility's power generation assets, investors would likely be unwilling to purchase PREPA's oil-fired power plants without assurances that the new T&D utility planned to purchase their power at a cost-recoverable rate for a period long enough to make the purchase worthwhile. This would likely result in a multi-year or multi-decade power purchase agreement, locking in both Puerto Rico's dependence on imported oil, and prices for the high cost of generation using that resource for years to come.

This is an especially large problem because demand for electricity in Puerto Rico has been on a negative trajectory for over a decade, and it is projected to continue declining primarily due to outmigration (see Figure 1 in Appendix). According to PREPA's 2017 Fiscal Plan, between 2006-2016 PREPA's energy sales fell by 16%, and sales were projected to decline by an additional 23% by 2026 (Puerto Rico Electric Power Authority 2017). After Hurricane Maria, electricity demand from a centralized utility is predicted to further decline by 20-35%, and overall electric system demand is projected to fall 5-20% both by 2028 (Torres and Kunkel, 2018).

Electricity demand reduction in Puerto Rico has been caused in large part due to emigration from the island. New population statistics published after Hurricane Maria have increased Puerto Rican

outmigration projections to 470,000 residents between 2017-2019 as a result of the hurricane, a number equivalent to Puerto Rico's total population loss over the entire previous decade of economic stagnation (Meléndez and Hinojosa, 2017). This reduction in demand is exacerbated by increasing energy efficiency and the increasing adoption of distributed energy resources like rooftop solar and CHP on the island. If long-term PPA's for oil-fired electricity are indeed established, then the utility operating in Puerto Rico will be forced to increase electricity rates over time because the high cost of producing oil-based electricity would be distributed amongst fewer and fewer ratepayers.

Rising electricity rates would result in an increasing number of ratepayers seeking refuge from increasing electricity bills by investing in relatively lower cost distributed energy systems, resulting in further reductions in demand, and further rate hikes. Furthermore, continued reliance on generation far from demand, would necessitate the continued use of an unstable transmission grid that is expensive to maintain and upgrade thus leading to further degradation of the quality of Puerto Rico's electricity system, resulting in further grid defection, further rate hikes, and thus further grid defection. This vicious cycle, a well-studied phenomenon in mainland United States and elsewhere, is known as the utility death spiral (Felder, 2014). Long-term PPA contracts which lock in an over-capacity of high cost oil-fired electricity generation for years to come would likely condemn Puerto Rico's electricity system to this phenomenon, regardless of whether the sector is publicly or privately run.

Importance of regulation in privatization process

Moves by Puerto Rico's government to weaken the regulatory agency's role in the sector are also problematic, as a strong regulatory body and framework is essential for any electricity sector undergoing privatization. Privatization in and of itself will not result in increased efficiency and modernization. In practice, privatization typically results in improved outcomes only under certain conditions, one of which is a strong regulatory framework. In most cases where privatization has been successful, the

public utility in question was already well-operated with strong oversight from government officials (Baer, 2014). Rather than weakening PREC's oversight of the power sector (as Governor Roselló has proposed in the past), Puerto Rico should move to bolster the strength of the sector's regulatory agency to ensure privatization results in a low-cost, clean, resilient energy system.

Strong regulation is especially important for Puerto Rico given the island's strong need to attract investment in its cash-strapped electricity sector. A number of stakeholders we spoke with echoed this sentiment, maintaining that investors welcome strong regulatory framework, because standardized and clear rules create the certainty that investors need to ensure profitability. A strong regulator will be especially important to the implementation of regulatory mechanisms to incentivize the development of clean energy sources (discussed further in Recommendations). If potential T&D concessionaires perceive Puerto Rico's regulator as weak or unstable, they might not have faith that regulatory incentives will stay in place for the long term, creating a disincentive to move toward clean energy or even bid for the concession rights in the first place.

Puerto Rico's regulator could also play a more direct role in supporting community-owned and privately-owned distributed energy and microgrids by developing rules that encourage development of renewable resources and integrate them with the main grid. PREC has already taken steps towards doing this by developing preliminary regulations for microgrids that clarified how different types of microgrids would be defined and operated. However, DER providers that we spoke with emphasized that in order to develop the type of stable regulatory environment that will drive investment in the sector, Puerto Rico will need clear rules on how microgrids will be regulated and how the power and other grid services they provide will be valued by the utility.

Recommendations

1. Grid hardening measures to improve resilience

The island of Puerto Rico experienced multiple severe weather events in 2017 that destroyed most of the existing T&D infrastructure, leaving the island and its people vulnerable. The damage from these events was extensive, and the island's power are not fully restored even at the time of writing this report. To prevent such massive disruptions in the future, it is also important that the island rebuild its power grid to be both functional and capable of withstanding future weather-related shocks.

A resilient power grid should be capable of executing preventive measures, mitigating the impact of extreme events, and reducing the time needed to restore service to consumers. In addition to securing customers against disruption in power service from weather events, these measures can also lead to significant economic savings (Wang & Gharavi, 2017). This is especially true in Puerto Rico because of the island's exposure to extreme weather events. A failure to invest in grid resilience measures now means that damage from future weather events will be higher, increasing costs in the long term. A brief survey of best practices and examples of other regions that have experienced analogous events reveals a handful of short- and long-term measures that could help Puerto Rico avoid this issue.

In addition, the resilience of the electricity grid is a crucial element for all future investments in Puerto Rico's power sector. If utility customers feel the grid cannot be relied on, they will look for alternatives to utility-provided power. This is an especially acute problem with large industrial customers, who may leave the island if disruptions to the utility's power supply become too frequent. Building back customer confidence in the resiliency of the electricity system will ensure a stable revenue flow to the utility, which in turn would improve the utility's credit rating. This would also boost investor confidence in the utility, making it easier for developers (including renewable energy developers) that have signed PPAs with the utility to receive financing from 3rd party lenders.

Creating a resilient grid is thus a foundational component of Puerto Rico's clean energy transition, so investing in a more resilient grid will be a first step in this transition. In the short term, physical asset "hardening" is needed to create a more resilient grid. This refers to generally hardening the vulnerable physical infrastructure to prevent damage in the event of extreme weather. It usually requires changes in design standards, such as for electrical poles, construction guidelines, maintenance routines, inspection procedures and recovery practices (Edison Electric Institute, 2014). Efforts to "harden" the electricity grid must focus on three elements: prevention, recovery and survivability.

An example of grid hardening projects necessary in Puerto Rico is the need to change transmission line design on the island. Transmission lines consist of a set of anchor towers held up by tension between the wires. If a disruption occurs, a domino effect can cause many towers to break together. This domino effect was part of the reason the damage from Hurricane Maria was so extensive, ultimately bringing down four-fifths of the island's T&D infrastructure (Tolson, 2018), which will cost $4.9 billion to rebuild. (New York Power Authority, 2017) Adopting stronger conductors and more robust towers to withstand natural hazards is a very basic resilience measure that can be implemented. Minimum physical dimensions, innovative designs and strong materials for poles and towers, as well as concrete reinforcing for vulnerable poles and towers, are essential.

Design and construction standards that support damage prevention recovery, and survivability have an important role to play in other areas as well. In addition to requiring more resilient pole design to withstand high winds, standards should require that substations and other vulnerable facilities be elevated if they are located in coastal areas susceptible to flooding and storm surge. The Puerto Rico Resiliency Working Group, a collection of experts providing recommendations for rebuilding Puerto Rico's electricity grid estimates that it will cost $1.7 billion to rebuild PREPA's substations, a cost which these standards could have helped to avoid. (New York Power Authority, 2017) Hardening the physical facilities by adopting higher wind-resistant construction standards for power plants, as well as using

water proof sealants and flood walls for flooding or storm surge situations, can help improve a system's resilience in the face of natural disaster. The Puerto Rico Resiliency Working Group considered wind damage and flooding resistance to be two of the primary areas for improvement, estimating that hardening upgrades would cost $5.3 and $1.2 billion for these issues respectively (New York Power Authority, 2017.)

The undergrounding of transmission and distribution lines is another possible measure that can improve grid infrastructure's resistance to weather events, but only if implemented prudently. The costs associated can be extremely high, and some studies suggest that undergrounding lines actually increases restoration times because of the complicated nature of the system for restoration crews and the inability of the restoration crew to visually pinpoint the cause of the disruption. The possibility of flooded substations and damaged underground facilities have historically highlighted vulnerabilities in this approach. As such, fool-proofing the system requires the use of anti-corrosive materials and thicker outer protection for cables, which can often make these projects financially untenable. The common approach recommended by experts is hardening infrastructure through selective or targeted undergrounding of worst-performing feeders or feeder portions, and through undergrounding substation feeders that affect the most customers (Pasqualini, 2016). Targeted undergrounding is also recommended for important facilities such as hospitals, police, and pharmacies.

Unfortunately, the aforementioned recommendations for improved resilience measures are costlier to implement than traditional grid investments. The Puerto Rico Resiliency Working Group estimates that total grid hardening costs in Puerto Rico would amount to roughly $17.6 billion, almost twice PREPA's current unpaid debt. (New York Power Authority, 2017) Given PREPA's current financial situation, designating up-front capital and long-term revenue stream needed to make these investments will present a challenge for the utility. Some possible solutions to this funding challenge include:

- **Federal Funds:** PREPA may be able to tap into federal sources of funds to cover the up-front

costs of these investments. One source of funding that could be used is the Federal Emergency Management Agency (FEMA). Almost $ 2.2 billion in federal aid was approved for Puerto in March 2018, a portion of which could be allocated for grid improvements (FEMA, 2018). The Robert T. Stafford Disaster Relief and Emergency Assistance Act (the Stafford Act) authorizes the FEMA funding in a disaster situation and funding is available for municipal, state, and rural electric cooperatives (Edison Electric Institute, 2014). In addition, Governor Roselló recently announced that PREPA would receive an additional $2 billion in funding for post-hurricane investments in energy infrastructure; investments in the sorts of grid hardening measures outlined above should be prioritized when this federal funding is allocated (Kaske, 2018).

- **Rate Recovery:** Because grid hardening measures can reduce costs in the long term, it's possible for the utility to recover the costs over time through their rates. Usually, an electric utility can recover the costs of system hardening by rate-basing the costs and requesting cost recovery in a general rate case. However, immediate cost recovery of the system hardening costs can be a burden for an already over-burdened customer base, especially in Puerto Rico. In practice, the regulatory commission typically requires that these costs be accounted as either an asset or a liability, allowing utilities to recover the costs over a long period of time by spreading their costs across future rate periods (Edison Electric Institute, 2014).

2. Regulatory mechanisms to drive transition towards clean energy sources

Rather than focus on raising money by privatizing PREPA's generation assets, the government of Puerto Rico should focus on the value of PREPA's T&D assets. It can do this by developing a regulatory framework that allows a T&D concessionaire to grow its profits while investing in the clean, low-cost, resilient electricity infrastructure needed on the island. Although falling demand for electricity makes it challenging for a utility in Puerto Rico to grow profits by increasing revenue, significant opportunities

exist to reduce costs by taking advantage of clean energy technologies like renewable energy and DERs. The problem is that Puerto Rico's regulatory framework is not designed for the utility to capture the benefits of these cost reductions. Puerto Rico's rate design is relatively typical of traditional 20th century electricity regulation. Rates are set as a function of the utility's investment and operating cost, which means that the utility's profits will be the same regardless of how much it actually costs to operate the system. The following section introduces opportunities for the Puerto Rican utility to reduce costs and suggests regulatory mechanisms that would incentivize the utility to pursue these opportunities.

1. Replacement of oil-fired generation with wind and solar power

Timeframe: Short/Medium Term

Key Mechanism: Multi-Year Rate Plans, Performance-Based Regulation

Currently, almost two-thirds of PREPA's expenditures come from fuel and power purchases (Puerto Rico Electric Power Authority, January 2018), and it expects fuel costs to increase by 64% over the next decade (Puerto Rico Electric Power Authority, 2017). Electricity from utility-scale wind and solar energy can cost less than half the price of PREPA's oil-fired power plants (see Figure 2 in Appendix), and solar energy developers quoted prices as low as .05 $/kWh for to be systems installed in 2019 (Toussie, 2017). If the distribution utility was able to keep a portion of these savings as profit, this would be a powerful incentive for the company running Puerto Rico's electricity grid to transition towards these technologies. This can be done through the use of **Multi-year Rate Plans (MRPs)**, a regulatory mechanism that has already been developed and adopted by a number of utility regulators in the mainland U.S. to incentivize utilities to reduce costs.

MRPs extend the time between rate case for utilities. Typically, regulators hold rate cases annually to recalibrate a utility's electricity prices to its cost of operations. Under an MRP system, regulators set the utility's rates at the beginning of a longer-term rate period, and then continue using

those rates for multiple years, regardless of the utility's actual operating costs during that period. This creates an incentive for the utilities to reduce system costs over the course of the rate period, since any reduction in costs will translate into increased profit for them over the length of the rate period. When combined with performance standards to ensure that utilities are not cutting costs simply by neglecting investments in the system, this mechanism aligns utilities' interest in increased profits with customers' interest in a low-cost and efficient system (Lowry, 2016).

This is a particularly suitable approach for Puerto Rico given the substantial opportunities for cost reductions in Puerto Rico's generation mix. Puerto Rico could offer a 25-year concession for a company to run its T&D infrastructure and then break that 25-year period into five distinct five-year rate periods. If the concessionaire is able to reduce costs by signing PPAs with lower-cost generation (much of which could be built out in two to three years) it could keep those savings as profits over the course of the first rate period. Rates would then be reduced to recover the utility's new lower operating costs at the beginning of the second rate period. A portion of the savings the utility retains from this rate structure could then provide additional capital for to invest in grid improvements to drive further cost reductions. This process would continue every five years for the length of the 25-year concession (see Figure 3 in Appendix).

However, it is important to note that simply incentivizing cost reductions does not guarantee that the concessionaire will switch to cleaner energy sources. Ensuring that the system also includes the deployment of renewable energy (instead of gas turbines or other relatively low-cost generation sources) requires the incorporation of specific performance metrics. Under this approach, known as **Performance-Based Regulation (PBR)**, the utility is typically rewarded for achieving certain target metrics, or penalized for failing to achieve them. The exact targets would be up to the discretion of the regulator but should touch on issues important for societal welfare. Potential areas with possible performance-based metrics have been included below:

- *Reliability:* The utility would be required to keep outages below a certain level over the course of the rate period.
- *Grid Modernization:* The utility could be required to make certain investments in modern grid equipment. For example, the utility might be required to install smart meters at 90% of Puerto Rican households by the end of the first rate period, which would help it to incorporate DERs and regulate energy efficiency.
- *Renewable Energy Deployment:* A certain percentage of Puerto Rico's power should be required to come from renewable sources. These targets could be set up to track Puerto Rico's current renewable energy targets, and then adjusted at the beginning of each new rate plan to more ambitious targets if necessary.
- *Resiliency*: The utility could be required to maintain a certain number of island-able facilities in each of Puerto Rico's population centers.

These performance incentives can be structured to integrate with an MRP system as well. For example, the Puerto Rican utility might only be allowed to retain excess profits from reducing costs within a rate period if it meets the objectives set out by the regulator. The regulator could add further incentives by allowing the utility to retain a portion of the savings it produced in one rate period into the next period if it meets certain targets. Figure 4 in the Appendix illustrates how such a system could be structured with two performance incentives, one for renewable energy deployment and one for grid modernization.

Many of these targets would likely require up-front investments, which could present a challenge for the utility. Some of the funding could come from federal sources, as described in the grid hardening section. In addition, as Puerto Rico's power generation is currently 200% over peak capacity, the utility could consider retiring one or two of its most expensive to operate oil fired generation facilities, thus reducing the overall cost of producing electricity (Torres and Kunkel, 2018). Premium rate plans and

differentiated services, further discussed below, could also provide the utility with extra revenue generation. Finally, the utility could consider renegotiating current PPA's to reduce the cost of non-oil fired power it purchases. However, this is a controversial option as it could negatively impact on the investor climate in Puerto Rico, and thus would need to be approached prudently.

2. Integration of customer-sited DERs with the larger power system

Timeframe: Medium/long term

Key Mechanisms: Integrated Resource Plans, Specialized Rate Plans

One of the most unique aspects of Puerto Rico's power system is the substantial customer interest in battery storage systems to provide back-up power in the case of grid outages. Puerto Ricans' experience in the wake of Hurricane Maria, coupled with frequent power outages that occurred before the hurricane, have convinced many that storage systems – usually coupled with rooftop solar – are worthwhile investments to ride out grid outages and provide a resilient power supply during future extreme weather events. Several stakeholders we spoke on the island, including developers and academics, predicted that in ten years, as solar + storage system costs decreased and more financing mechanisms became available, the majority of households in Puerto Rico could have some sort of energy storage system installed.

This is a faster uptake of "behind-the-meter" battery storage than is happening in most other parts of the world, and it creates significant new opportunities to reduce the cost of operating Puerto Rico's power system. Behind-the-meter battery systems can help shift electricity demand away from peak periods, reducing the utility's need to procure power from expensive peaker power plants. They can also provide ancillary services like frequency regulation and spinning reserves, critical grid services that will become more important as the amount of variable renewable energy on the grid increases.

In order to fully take advantage of these resources, the utility must include a detailed plan for their integration in their **Integrated Resource Plan (IRP).** The use of IRPs has already been adopted by Puerto Rico, and PREPA is currently in the midst of developing a new draft of its first IRP for review by PREC (Roura, 2018). Whichever company takes over operation of PREPA's infrastructure after restructuring should be required to include the current and expected level of uptake in DERs like solar + storage and microgrids so that it can determine whether any investments in new peaking generation or other infrastructure can be avoided.

Next, the concessionaire should be empowered to design **specialized rate plans** that allow customers with these types of DERs to provide services to the grid. This can be as simple as "time of use" (ToU) rate plans that have higher rates during times of peak demand, incentivizing customers to shift their electricity use away from these periods when electricity costs the most to produce. However, the utility could also experiment with more complex rate designs, such as plans that give customers credits on the electricity bills in exchange for allowing the utility to charge/discharge their batteries to balance conditions on the grid. The utility could even offer plans with value-added services the utility themselves could install a microgrid system on a customers' premise to provide additional resiliency if extreme weather events damage the main grid. Customers could pay for this value-added service either by paying a premium on their electricity bill, or by allowing the utility to use the microgrid for grid balancing (or through a mixture of both).

This approach would provide the utility with additional profit opportunities while also allowing customers to receive compensation for using their DERs to support the grid. Although DER deployment in Puerto Rico may not be high enough at the moment for them to offer significant benefits to the system, the utility should still begin implementing pilot rate programs for DER owners to gauge customer interest and fine-tune rate structures so that when uptake of DERs reaches the expected levels, the foundation will already be in place to optimize their use.

3. Financial tools to support distributed solar and other DERs

Although adoption of distributed solar, storage, and microgrids has been growing in Puerto Rico, these technologies also tend to have high up-front cost. Forty-five percent of Puerto Ricans live below the federal poverty line and would have difficulty investing in these technologies (Government Development Bank of Puerto Rico). Deploying DERs to the broader population will be key to ensuring that any rate adjustments necessary to allow the utility to maintain a constant revenue do not disproportionately fall on the poor. However, one distributed solar developer we spoke with noted that many of the loan products that allow Puerto Ricans to bypass these technologies' upfront costs are not available to low-income communities because of prohibitively high credit requirements. He also mentioned that banks in Puerto Rico are also generally unfamiliar with solar energy products and are thus reluctant to finance them.

One of the major concerns many lending institutions have for solar loans is the risk of customer default. The government can alleviate this issue by providing loan guarantees to safeguard lenders' revenue from solar loans up to a certain amount. This would attract investors to the solar space and empower them to make loans to customer groups they otherwise might not have worked with. In a similar vein, microgrids become more marketable when government intervention funds, credits, or sovereign guarantees are available. For example, the World Bank's Multilateral Investment Guarantee Agency (MIGA) provides investment guarantee including coverage for currency and country related risks in microgrid projects (Kirchhoff et al.). This approach contributes to up-scaling investment in microgrid projects.

Loan guarantees could also make DER investments more accessible to low-income communities, which often cannot meet the high 650 FICA threshold required by most loan providers for DER projects on the island. Loan guarantees would make lenders more comfortable lending to customers with lower

credit scores by alleviating lenders' concerns regarding the losses associated with default. The Puerto Rican government should make equitable deployment of solar a major part of its loan guarantee program, perhaps by providing higher loan guarantees to lenders that maintain portfolios that include a proportion of customers with lower credit scores.

One developer we spoke with on the island suggested loan guarantees could offer a far more effective use of government funds to incentivize renewables than cash hand-outs like those provided by the Green Energy Fund. Puerto Rico would thus be better served if the commonwealth government redirected the resources it currently devotes to the Green Energy Fund, rather making funds available as loan guarantees to finance for green technology projects . This would help create a sustainable investment climate for distributed solar on the island, allowing the marketplace to find the most effective loan products for customers on the island. As solar loans become more common and the risks associated with lending to different customer classes becomes better understood, the funds available for loan guarantees could be gradually reduced.

Timeline:

Puerto Rico's energy transition is unlikely to happen overnight. Even with strong political will, support from the Federal Government and outside investments, Puerto Rico still lacks a mature regulatory structure, financially sustainable electricity utility and accountable and transparent legal institutions. This energy transition is likely to be a continuing process as opposed to a one-size-fits-all silver bullet. As such, it is helpful to breakdown this process into achievable objectives short term (1-2 years), medium term (3-5 years) and long term (5-25 years).

<u>Next 1-2 years: Short term targets</u>

- Make investments in grid hardening

- Decommission inefficient generation assets
- Introduce Multi-Year Rate Plans and Performance Based Regulation into the regulatory framework

Next 3-5 Years: Medium term targets:

- Develop new investments in grid scale renewable energy
- Advance grid modernization measures to support energy "prosumers" (eg. deployment of smart meters)
- Include DER deployment in utility IRPs
- Pilot specialized rate plans and other programs to allow the utility to monetize behind the meter assets
- Introduce loan guarantees for customer-sited solar and storage systems

Next 20 years: Long term objectives

- Achieve Puerto Rico's RPS targets
- Lower rates to half their current level, to reflect lower costs from investments in renewable energy
- Achieve broad deployment of DERs and microgrids to improve customers' ability to ride through grid outages
- Establish a system for behind-the-meter energy services to be compensated, either through specialized rate plans or the development of a wholesale energy market that can price these services
- Develop rate plans that allow utilities to be compensated for differentiated services, such as high levels of resilience and power quality based on specialized customer demands

Benefits for different stakeholders:

- *Concessionaire:* The alternative approach to an energy transition in Puerto Rico offered by this paper creates new revenue streams for the company running Puerto Rico's T&D infrastructure, reducing the impact of falling electricity sales and making Puerto Rico's T&D concession more attractive to potential bidders. In addition to cost savings, the concessionaire would benefit from the positive public relations it would receive as a result of introducing greener energy resources to the Puerto Rican grid, reducing greenhouse gas emissions and local air pollutants, while also increasing energy security and extreme weather resilience to the island's electricity system.
- *Customers:* By incentivizing a switch to lower-cost, more resilient generation and creating a systematic process by which the savings from this switch would be shared with ratepayers, electricity customers in Puerto Rico could expect long-term price reductions and improvements to grid resilience and reliability over the length of the concession. These price reductions and improvements in reliability would be beneficial to both residential and industrial customers, ideally incentivizing more companies to set up or expand operations in Puerto Rico.
- *Developers:* The alternative approach presented in this paper incentivizes the utility to invest in new clean energy resources and more secure transmission infrastructure in order to reduce costs below energy prices before their scheduled step down. This would create business opportunities for competitive third-party companies, which would also create new jobs in Puerto Rico. The provision of loan guarantees would also expand opportunities for third parties providing distributed solar and other DERs by improving their access to financing.

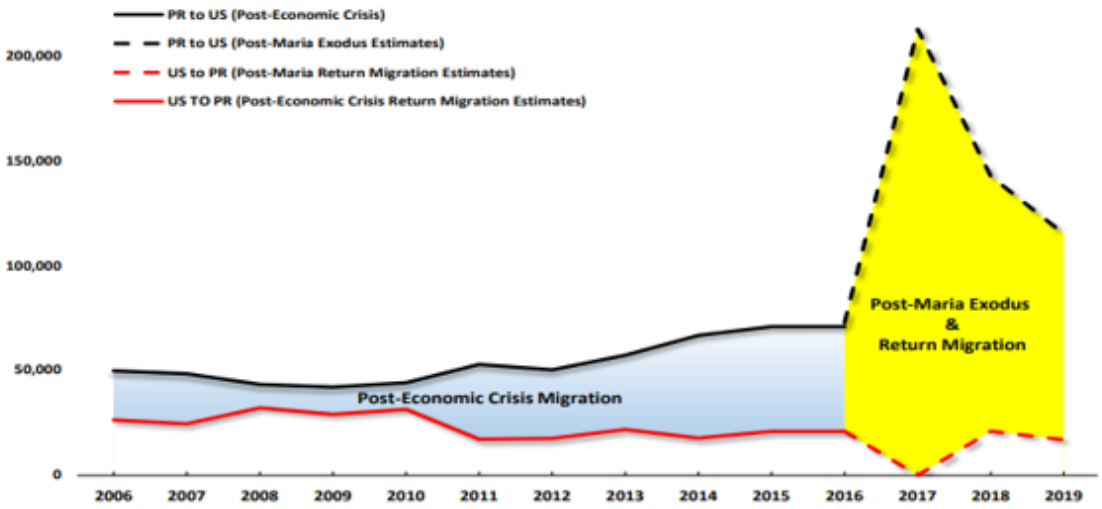
- *Government:* By creating new opportunities for Puerto Rico's electric utility to increase profits over the long-term, the alternative approach should increase the value of the concession for PREPA's T&D infrastructure. This in turn will help the Puerto Rican government to raise funds through the concession to improve PREPA's financial situation. The increased value of the concession agreement would offset the reduction in value of PREPA's generation assets, much of which should be retired over the next half-decade to make way for cheaper and cleaner energy resources.

Conclusion

The challenges that Puerto Rico faces are multi-faceted, and the task ahead of it is a daunting one. However, these challenges also present an opportunity for Puerto Rico to move its power sector out of 20th-century paradigms and into one where customers are able to receive electricity that is clean, resilient, and affordable. The route towards this new power system are also multi-faceted and will require technical, regulatory, and financial measures to achieve. The measures outlined in this paper – investments in grid hardening, regulatory mechanisms to align utility incentives with societal goals, and financial tools that expand access to clean energy technologies – will assist Puerto Rico's transition towards this new system. By adopting this alternative approach, Puerto Rico will be investing in the long-term health of a power sector that will serve customers, businesses and other stakeholders with affordable, clean, and resilient power.

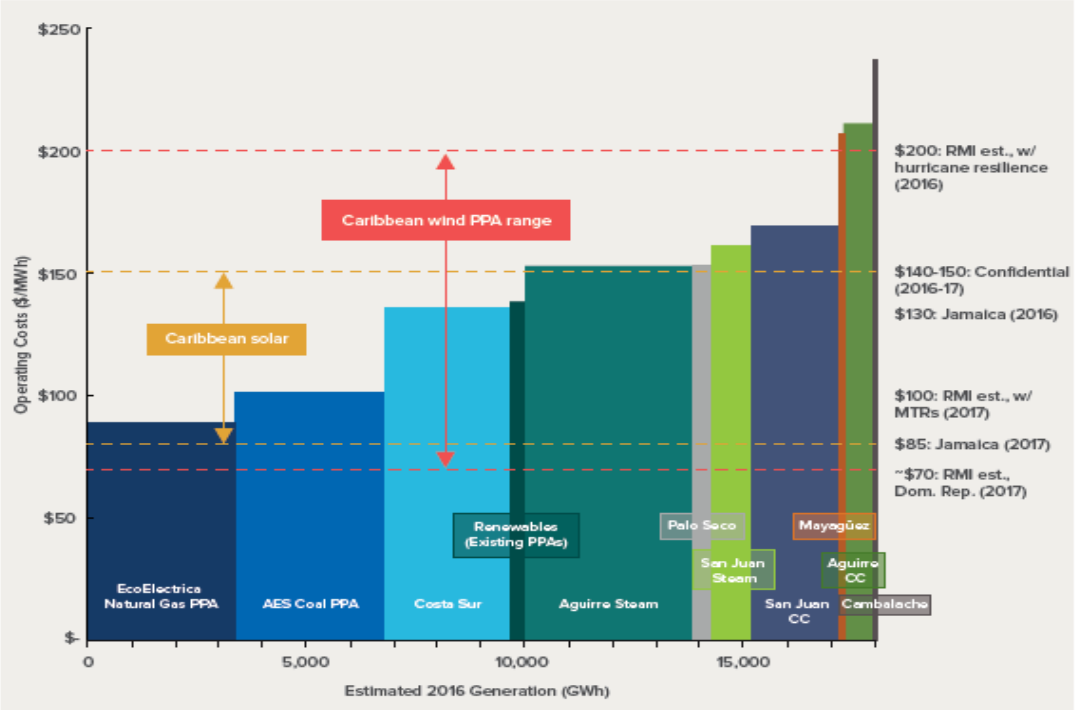
Appendix

Figure 1: Past and Projected Migration from Puerto Rico to the US



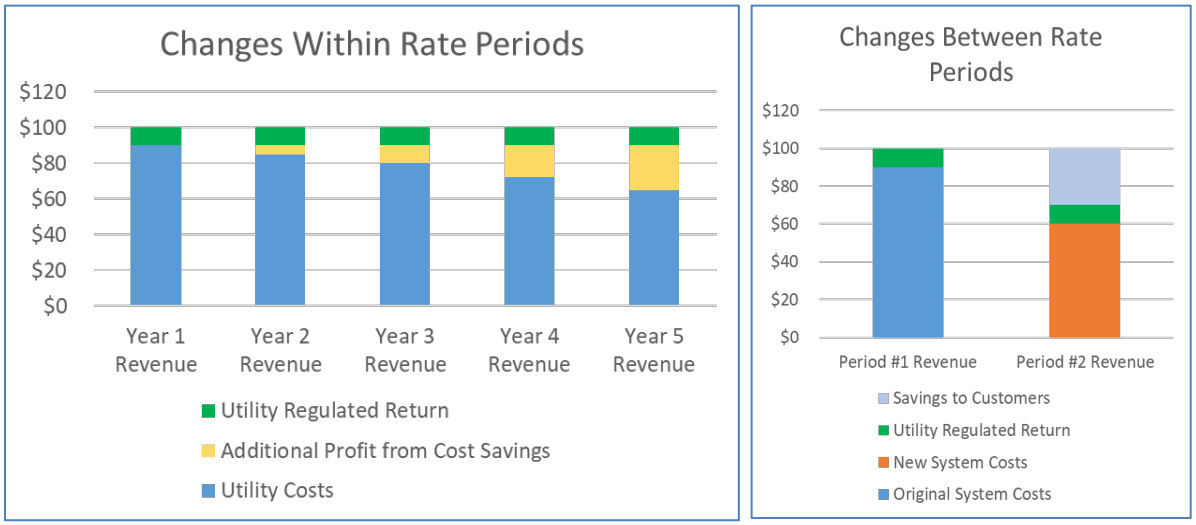
Source: Meléndez and Hinojosa 2017

Figure 2: Comparison Between Renewable Energy and PREPA's Current Generation Mix



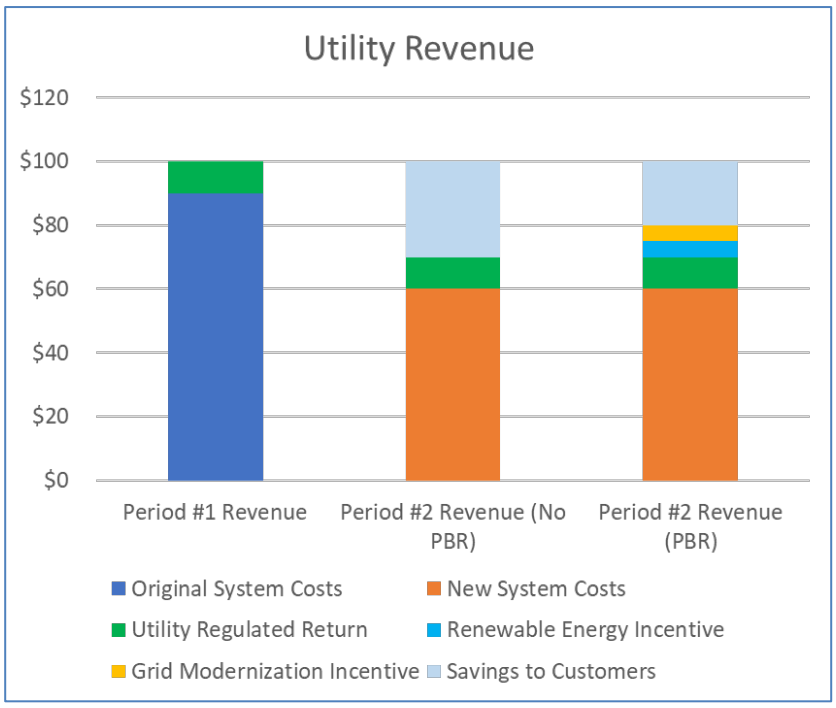
Source: Toussie et al. 2017

Figure 3: Changes in utility revenue within and between rate plans in MRP system[1]



Source: Original Content

Figure 4: Illustration of performance-based incentives in Puerto Rico



Source: Original Content

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[1] Monetary values in these charts are for illustrative purposes only and do not correspond with actual utility revenue in Puerto Rico

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