THE ROLE OF RENEWABLE AND DISTRIBUTED ENERGY IN

A RESILIENT AND COST-EFFECTIVE ENERGY FUTURE FOR PUERTO RICO

INSIGHT BRIEF

December 2017

HIGHLIGHTS

Isaac Toussie
New York, NY
itoussie@rmi.org

Mark Dyson
Boulder, CO
mdyson@rmi.org

Ana Sophia Mifsud
Lauren Shwisberg
Roy Torbert
Stephen Doig
Rachel Gold
Mark Silberg

- Hurricanes Irma and Maria caused extraordinary damage to Puerto Rico, especially to its electrical grid. Approximately 50 percent of island households were still without power over two months after the storms, leading to the longest sustained outage in the history of the United States.
- The severe damage to the system's physical assets, coupled with pre-storm financial and operational problems, presents not only significant challenges but also a considerable opportunity to rebuild the electrical grid to be more sustainable, cost-effective, and resilient to future extreme weather events.
- The emergence of increasingly cost-effective renewable and distributed energy resources (e.g., solar photovoltaics (PV), wind turbines, batteries, and microgrids) suggests that they could play an important role in Puerto Rico's recovery and rebuild.
- However, there are many common misconceptions about the cost-effectiveness, resilience, and long-term role of these technologies that stand in the way of their broad acceptance and adoption.
- This document addresses these common misconceptions and demonstrates that these emerging technologies can play an important role in the near-term and long-term reinvestment in Puerto Rico's grid.

ABOUT THIS DOCUMENT

In October and November, 2017, Rocky Mountain Institute (RMI) engaged more than 75 stakeholders from across Puerto Rico, including the U.S. federal and Puerto Rican governments (including the Financial Oversight and Management Board), private sector (including the largest wind, solar, and coal generators in Puerto Rico), community groups, labor interests, and other entities to understand the current landscape and opportunity in Puerto Rico. On November 7th and 8th, RMI facilitated a design charrette with many of these stakeholders in order to identify cost-effective, resilient pathways forward to ensure a long-term, sustainable, financially sound rebuild of the electric power system in Puerto Rico. As an outcome of that convening, this document provides a fact-based assessment of the potential for new energy technologies to support a more robust rebuild of the island's electrical system.

This document is authored primarily by RMI, drawing upon experience working in the Caribbean supporting island governments, utilities, and regulators to assess and capture the opportunity of diversification beyond imported fossil fuels. Other organizations active in Puerto Rico contributed insights and data to this document based on their experience working on the island both pre- and post-2017 hurricanes, including ABB Group, AES Corporation, Aireko, CAMBIO Puerto Rico, GE Power, Gestamp Wind, McKinsey & Company, Natural Resources Defense Council, Pattern Energy, Puerto Rico Institute for Competitiveness and Sustainable Economy (ICSE-PR), Sonnedix, sonnen, Sunnova, Sunrun, Tesla, and numerous individual experts.

The group contributing to the body of work represented in this document continues to grow as many within and outside Puerto Rico offer their knowledge and insight to aid in the development of a more cost-effective, clean, and resilient grid.

SITUATION

Hurricanes Irma and Maria brought sustained winds above 150 miles an hour along with heavy rains causing widespread destruction throughout Puerto Rico and nearby island communities. These storms destroyed fragile transmission and distribution lines throughout the island, exacerbating the humanitarian crisis with a prolonged lack of power. Two months after the storm, the grid remained unstable, with about 50 percent of island households still without power, causing the longest sustained outage in the history of the United States. Puerto Rico Electric Power Authority (PREPA)—the island's monopoly electric utility and the largest public power agency in the United States—and the U.S. Army Corps of Engineers (USACE) estimate it may take many more months to provide power to the entire island and perhaps several years to rebuild the entire grid to pre-storm conditions.

The severe damage caused by the hurricanes opens a considerable opportunity to rebuild the electrical grid to be more sustainable, cost-effective, and resilient to future extreme weather conditions. In the last five years, the technological capability and economics of deployed new energy technologies such as utility-scale, distributed, and community-scale renewable energy; microgrids; energy storage; and demand flexibility have rapidly improved, and have been deployed and tested at scale across the world. At their current level of maturity, these technologies can play a crucial role in Puerto Rico's short- and long-term energy future, capable of supporting a better electricity system for Puerto Ricans.

This document addresses frequently cited concerns about new technologies and their costs, reliability, and resilience benefits, and describes the role these technologies can play in both the short- and long-term rebuilding of Puerto Rico's electrical system.

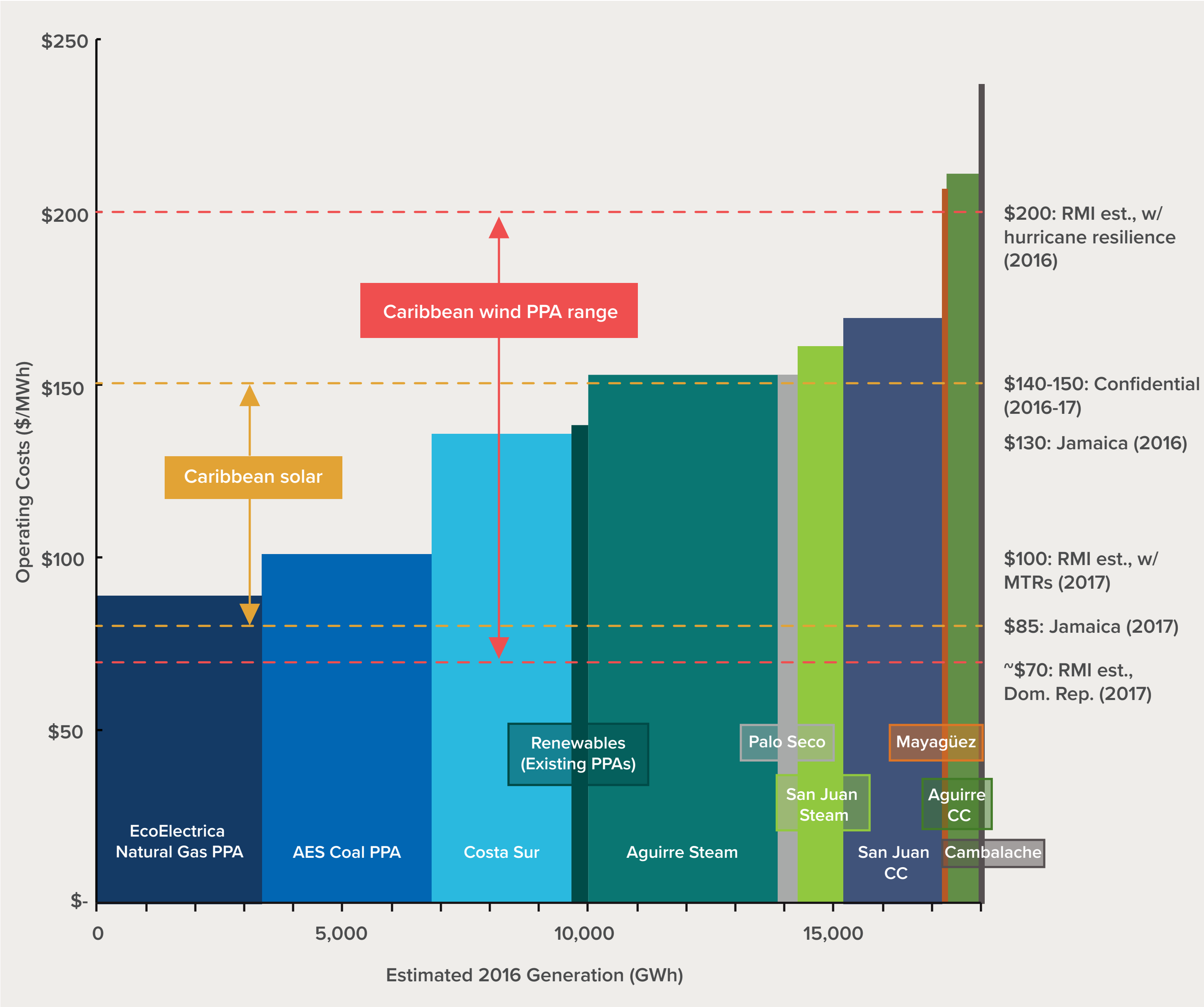
CONCERN: NEW ENERGY TECHNOLOGIES ARE NOT COST-EFFECTIVE

1. Reality: Renewable energy is cost-effective due to steep price declines in recent years

Historically, the claim that renewable energy is not cost-effective when compared with incumbent options has been true. But over the past decade, policies driven by industrialized nations have been successful in building a robust global competitive business environment that has both stimulated demand and significantly augmented learning and downward price pressure for renewables. This has made the manufacturing, distribution, sale, installation, and operation of new energy technologies competitive, and in many cases cheaper and more readily available than incumbent options for power generation.

As a result, global utility-scale solar and wind prices have decreased by 86 percent and 67 percent respectively, from 2009–2017, and regional solar and wind prices are now cost-competitive with the existing fossil fuel-based generation in Puerto Rico. Based on RMI analysis of PREPA operational data and multiple quotes and bids from project developers across the Caribbean, prices for recent solar and wind projects in the region have ranged from $0.08/kWh to $0.15/kWh and $0.07/kWh to $0.20/kWh, respectively, while operating costs from existing fossil fuel generation in Puerto Rico range from $0.09/kWh to $0.28/kWh. (Note that these numbers should not be compared to retail rates in Puerto Rico, as utility retail rates also include delivery costs.)

Figure 1: Cost of existing Puerto Rico generation compared to new renewable energy projects



Source: RMI analysis of PREPA data and benchmark PPA prices across Caribbean region.

Going forward, renewables will almost certainly be more cost-effective as the trend of decreasing renewable prices continues, while imported fossil fuel prices remain relatively high and volatile. Project developers estimate that new, large-scale solar PV generation facilities in Puerto Rico could be delivered at $0.05/kWh to $0.06/kWh in 2018–2019 (exclusive of transmission). Recognizing, harnessing, and furthering these cost trends, for example through competitive procurement processes, can ensure least-cost energy resources contribute significantly to Puerto Rico's energy future.

2. Reality: Energy storage is already cost-effective for many applications, and is trending downward in price

While the cost of dedicated energy storage (e.g., batteries including lithium-ion, lead acid, and vanadium flow) has historically been a barrier, globally, costs have come down 70 percent from 2010 to 2016, and the trend is expected to continue with costs likely to come down another 50 percent by 2020. As a result, even at today's prices, combining a renewable energy system with batteries can be less expensive than the fossil fuel alternative, while providing numerous other benefits including reduced carbon emissions, resilience to fuel supply or grid disruptions, and reduction in exposure to fuel price risk.

Two recent examples in the U.S. demonstrate the emerging competitiveness of storage and its growing role on the grid. In Arizona, NextEra Energy Resources recently signed an agreement with Tucson Electric Power for a solar and storage facility for less than $0.045/kWh. In Hawaii, AES Corporation will deliver 28 MW of PV combined with a 20 MW, 100 MWh battery system, providing Kauai Island Electric Cooperative with dispatchable renewable energy at a contracted price of $0.11/kWh. Such storage systems can also provide other benefits, for example by allowing thermal power plants to operate at optimal efficiency levels.

In Puerto Rico, project developers estimate that a long-duration battery-based energy storage system (e.g., 10-hour duration) integrated with solar PV could provide energy for approximately $0.095–$0.115/kWh.[1] Energy storage thus represents a cost-effective method for moving solar energy into nighttime hours and directly reducing the costs of imported fossil fuels.

3. Reality: Microgrids can cost-effectively improve resilience

Large-scale renewable energy and battery storage projects can be achieved at very low cost, due in part to economies of scale in project size. However, smaller-scale community systems, distributed nearer to customers, even if somewhat more expensive, can often provide significant additional value. One increasingly common model is a microgrid: a collection of loads, generators, and/or storage, ranging in scale from a single building to an entire city, that is typically grid-connected but can disconnect safely ("island") and continue operating in cases where the main grid goes down.

[1] Comments provided by AES Corporation to PREC, November 20, 2017, Case No. CEPR-IN-2017-0002.

Microgrid projects typically come at a cost premium compared to the average cost of service of large-scale grids, but offer an opportunity to avoid incurring resilience-related costs in other areas of the grid. The median price of microgrids in the U.S. is $2,971/kW, or between two and three times higher than large-scale generating resources, but these can also offset grid-related investments otherwise necessary to provide reliability and resilience. For example, microgrids in Borrego Springs, CA; Houston, TX; and the Bronx, NY have demonstrated resilience through natural disasters, powering thousands of customer homes and businesses without the expense of storm-hardening all components of the grids that serve them (e.g., underground distribution networks, concrete towers). Such microgrids also minimize lost economic productivity during a wider grid disruption, minimize land use and transmission requirements for central generation, and minimize the portion of electricity bills used to buy imported fossil fuels.

In Puerto Rico, RMI interviews with project developers suggest that it is possible to deploy solar and battery-based microgrids, with optional diesel backup, for between $0.18–$0.24/kWh for remote communities and/or small-scale (<1 MW) systems sited at large businesses. These anticipated costs are higher than energy production at many of Puerto Rico's existing generating stations and higher than average rates, but could prove more cost-effective than storm-hardening difficult and remote parts of the grid against another category 4 or 5 hurricane that could occur in future years.

4. Reality: End-use efficiency is a large and cost-effective energy resource

Utilities in the United States have decades of experience in investing in energy efficiency programs and technologies that avoid the need to build conventional, supply-side alternatives to generate and deliver power. Leading U.S. utilities have saved 3 percent per year on retail sales through energy efficiency investments, and average total resource costs for energy efficiency programs across the country are less than $0.05/kWh, significantly lower than Puerto Rico's existing marginal generation costs.

A study by University of Puerto Rico Mayagüez researchers in 2013 found a potential for 26 percent energy savings from energy efficiency in Puerto Rico over a 10-year period. Regional experience in the Caribbean suggests that this resource can be cost-effective; energy-efficiency lighting programs cost ~$0.02/kWh, while island-wide efficiency portfolios of different technologies range from $0.05-$0.07/kWh.[2] Given the damage to Puerto Rican homes as a result of the 2017 hurricanes, some efficiency measures may be more cost-effective than they are in other contexts; for example, rooftop solar hot water systems—which are already in Puerto Rican building codes—can be procured at scale and installed at lower cost when combined with recovery efforts targeted at repairing residential roofs.

[2] Based on RMI analysis of nearby Caribbean island nations' energy efficiency potential and cost curves.

CONCERN: NEW ENERGY TECHNOLOGIES ARE NEITHER RESILIENT NOR RELIABLE

1. Reality: Renewable energy can support a reliable grid, especially with storage

Grid reliability refers to the ability of generators and the grid to meet power requirements on demand, at all times. While it is true that solar and wind do not generate power constantly, when viewed as part of a broader resource portfolio, renewable electricity generation can be a critical component of a reliable grid. The U.S. Department of Energy (DOE) 2012 Renewables Electricity Future Study found that up to 80 percent of U.S. electricity could be provided by renewable energy resources with no impact on reliability, and other more recent and detailed DOE studies have similarly shown high reliability with high levels of renewable energy. In island contexts, with smaller grids more difficult to balance in real time, high penetrations are still possible. This has been practically demonstrated in Hawaii: the islands of Oahu, Maui, and Hawaii currently achieve 11 percent, 25 percent, and 40 percent renewable energy respectively, with reliability much higher than Puerto Rico's primarily oil-based grid.

To support high-renewable grids, a growing number of demonstration projects have shown that renewables can provide advanced grid reliability services. The August 2017 Staff Report on Electricity Markets by the U.S. DOE found that "there is a growing understanding of the abilities of variable renewable energy (VRE) to economically contribute to grid flexibility and reliability." Demonstration projects co-led by grid operators and a U.S. national lab have shown that a 300 MW solar power plant project can sustain system reliability as effectively and more efficiently than a natural gas plant, and its ability to provide a range of grid reliability services is "comparable to, or better than, conventional resources."

Renewables in Puerto Rico have historically made up only a small fraction (less than 3 percent) of the generation mix. With reliability in Puerto Rico a persistent concern before the hurricanes, any integration of renewables must consider the current grid fragility and the relative inflexibility of existing generators. However, leading U.S. states, including the islanded systems in Hawaii, have already demonstrated the capability to integrate 10–40 percent solar and wind generation into their systems, with no impact on reliability. With these lessons in mind, there is significant room for growth in renewable generation in Puerto Rico before the island reaches technical or economic limits, especially given the increasingly cost-effective trend of integrating storage with renewables to provide firm power when weather-driven generators are not available.

2. Reality: Renewable energy and energy storage can improve grid resilience

The resilience of an electric system refers to how quickly and how well it can recover from a widespread outage. A system's resilience is dictated by the resilience of each component of the grid (e.g., whether individual generators fail during disruptions) as well as on the overall design of the system which can provide multiple paths to deliver electricity. Both renewable energy projects and conventional power plants tend to be very resilient to physical damage, but are only as resilient as the transmission and distribution system to which they are connected.

Hurricanes in 2017 demonstrated the lack of resilience of transmission and distribution networks in Puerto Rico and other Caribbean islands, but confirmed that renewable energy generators are, in fact, very resilient. In Puerto Rico, 90 percent of utility-scale solar PV and wind capacity on the island is operating or ready to operate, while only two renewable energy generation sites were damaged.[3] Similarly, approximately 75–95 percent of residential solar systems remained physically intact.[4] These statistics are likely to improve in the future as engineering, design, and installation lessons from 2017's hurricanes are applied to new projects, at moderate costs ranging from $0.05 to $0.15 per watt of installed capacity (e.g., a 3–15 percent capital cost increase).

The experience of Puerto Rico in 2017 demonstrates that the resilience of the power system has less to do with the resilience of generators, especially renewable facilities, and more to do with substations and transmission lines which were damaged and unable to allow intact renewable projects to feed power into the grid. While renewables proved themselves resilient to disruption, the grid itself kept them from serving customers' needs. A grid designed with renewable generators and energy storage nearer to customers, with modern interconnection standards, could mitigate this issue in the future.

CONCERN: NEW ENERGY TECHNOLOGIES DO NOT HAVE A ROLE IN THE SHORT- OR LONG-TERM REBUILDING EFFORT

1. Reality: Renewable energy and storage can be installed and commissioned quickly

While renewable energy and battery storage projects were, until recently, generally time-consuming to site and design, in the past two years developers have completed a number of projects in record time. Tesla, Greensmith Energy, and AES Energy Storage collectively deployed more than 70 MW of large-scale lithium-ion storage in six months in the first half of 2016 in response to a grid emergency. In just five months in late 2016, AES built what was at the time the world's largest lithium-ion battery to service a utility grid (120 MWh) for San Diego Gas & Electric. Similarly, Southern California Edison and Tesla completed a 30 MW/80 MWh battery storage project from contracting to completion in the four months from September–December 2016. Finally, in 2017, Tesla completed installation of the world's largest lithium-ion battery farm (100 MW/129 MWh) in under 100 days in South Australia.

The same haste has also recently been achieved in Puerto Rico. In the aftermath of the hurricanes, companies have already restored power to several businesses and communities on the island with combined solar and storage projects, completed in a matter of days or weeks.[5] These projects range from "centers of refuge" that provide basic services like Wi-Fi and phone charging, to larger-scale projects that meet nearly the full needs of large facilities. Approximately five percent of Puerto Rico's population lives in remote, mountainous regions, and official estimates suggest those communities could require up to a year to get reconnected to the grid. Depending on available land, parking, or rooftop structures, these sites could be ideal candidates for microgrid solar and

[3] Based on Pattern Energy's direct communications with individual plant owners as of 11/15/17.
[4] Based on RMI's direct communication with local project developers as of 11/28/17.
[5] Based on RMI's direct communication with project developers (e.g., Tesla, Sunrun, sonnen).

storage systems, which could bring power back to these communities faster than a traditional rebuild in addition to providing numerous other longer-term benefits such as resilience, reliability, and lower cost.

2. Reality: There are net benefits to deploying new technologies both while the system is being restored and after restoration is complete

In addition to their speed of deployment, renewable energy, energy storage, and microgrids offer numerous long-term benefits compared to rebuilding Puerto Rico's electric power system back to its expensive, vulnerable, and unreliable pre-hurricane state. Along with being resilient to disruption of the island-wide grid, distributed energy resources can have long-term value including low cost (e.g., the long-term price of new renewable projects is less than the operating cost of existing generation assets) and reliability (e.g., microgrids and energy storage can provide firm capacity and/or peak-shaving services to the island's main grid).

Distributed energy deployments around the U.S. and the world have demonstrated these long-term benefits in many instances. For example, renewable energy deployed in the U.S. over the last decade is causing a significant downward pressure on wholesale market prices, offsetting the use of higher-cost, fossil fuel-fired generators. A microgrid in San Diego, CA offers the local utility peak capacity services to improve reliability during constrained periods on the grid, and other distributed energy resources (including energy storage) in California have been aggregated to mitigate price spikes and avoid scarcity in the regional grid.

The scale of these benefits in Puerto Rico is likely even greater than on the mainland U.S. Oil-fired power plants in Puerto Rico alone account for more than 55 percent of the total operating cost of generation. New energy technologies would take away the need to run such expensive generation and mitigate the macroeconomic impacts of fuel price volatility on the island's economy. They also could reduce system rebuild costs by flattening load curves and thus minimizing the need to build for higher peak loads, and potentially even enabling earlier decommissioning of Puerto Rico's aging generator fleet. These long-term cost savings should be carefully considered alongside the upfront capital costs required to add new technologies to the system.

IMPLICATIONS OF EMERGING OPPORTUNITIES

The improving economics and emerging capabilities of renewable energy, energy storage, and microgrids create an opportunity to set aside the grid design paradigms of the past and reinvest in Puerto Rico's grid in a way that allows for a resilient, cost-effective, and clean energy future for the island while making it a beacon for twenty-first-century power systems.

In the near term, there are no-regrets solutions that are cost-effective to implement as soon as possible, even as the island-wide grid itself is rebuilt. Solar PV and storage systems, in particular, can be deployed quickly and provide value in the short and long term. Investments in energy efficiency and other large-scale renewable energy projects, as well as improvements to existing thermal assets, can provide long-term cost savings and reliability benefits.

To successfully capture value from these opportunities, there are several key implications for near-term action:

- **Coordinate new technology deployment with grid rebuild efforts.** Project developers should site new projects to meet both near-term repowering needs (e.g., remote communities, major commercial facilities) as well as provide long-term value, and ensure that they are built with the proper hardware (e.g., inverters, durable equipment) to allow seamless interconnection with the grid when it is fully online. Working closely with central grid planners can guarantee that investment in distributed energy is complementary to, not duplicative with, rebuilding the central grid.
- **Combine financing solutions to fund deployment of new technologies that complement existing grid rebuild efforts.** The utility should prioritize project deployments based on their near-term and long-term value to the Puerto Rico grid and the island's economy, not based solely on their financeability under current rules and regulations. By leveraging federal, philanthropic, and private funds, it will be possible to quickly deploy the full suite of resources necessary to restore power fully to the island.
- **Invest in a system that is equitable to all customers.** Investors, regulators, and government agencies should prioritize investment in distributed energy resources toward projects that provide at least as much value to the system as they extract in savings from PREPA rates, while carefully screening investment in central grid assets to avoid stranding those costs in a future with a growing share of distributed energy resources. Failing to consider the long-term cost and value of both distributed and central grid investments could increase tariffs for PREPA customers.

A coordinated effort by the Puerto Rico government, regulatory commission, and utility to catalogue, prioritize, and competitively procure potential renewable and distributed energy projects can serve to ensure that the best opportunities can be fast-tracked, while supporting the least cost and highest value in the long run.