Splice of post-Maria damaged and repaired road and overhead lines in Toa Alta, west of San Juan. Source: Ricardo Arduengo/AFP/Getty Images[1]

Financing a More Resilient Puerto Rico

SLOAN SUSTAINABILITY LABORATORY
FINAL REPORT
MAY 17, 2018

Environmental Defense Fund	Dakota Gangi, Project Host
MIT Sloan S-Lab Team	Faina Rozental Julian Ortiz Katie Brown Lydia Li Lucy Zhang
	Jason Jay, Mentor

[1] (Arduengo, 2018)

Table of Contents

Executive Summary

In September 2017, Hurricanes Irma and Maria devastated the energy infrastructure of Puerto Rico. The damages were overwhelming and rebuild efforts have been slow to materialize. However, this unfortunate event has presented a unique opportunity to rebuild the island's infrastructure to better serve the residents of Puerto Rico with more cost-effective electricity and greater resilience against natural disasters. Given the likely increase in storm frequency and intensity, according to climate model projections, this reimagined approach is critical to the sustainability of Puerto Rico.[2]

The Environmental Defense Fund (EDF) has deep expertise in engaging private sector stakeholders to address complex environmental, social and governance (ESG) issues. Through its Sustainable Finance Team, EDF seeks to establish itself as an influential partner in mobilizing financing to rebuild Puerto Rico's energy infrastructure to higher resilience and sustainability standards. In collaboration with MIT's Sustainability Lab, EDF intends to analyze the political and financial landscape in Puerto Rico and determine high-priority initiatives to achieve its objective.

In this report, we first summarize the current state of Puerto Rico's energy infrastructure and provide an overview of stakeholders involved in the rebuild efforts. We highlight two important uncertainties that EDF will need to navigate: financial uncertainty as it relates to the privatization of the Puerto Rico Electric Power Authority (PREPA) and policy uncertainty following privatization.

Then, we introduce our research approach, including stakeholder interviews, secondary research and analytical frameworks. With respect to results and findings, we provide a financing gap analysis to illustrate the lack of sufficient resources for rebuilding the energy infrastructure. We also introduce a scenario planning tool to help EDF navigate uncertainties and evaluate potential initiatives in Puerto Rico. Lastly, we utilize an impact-feasibility matrix to highlight high-impact, high-feasibility initiatives.

Based on our analyses, we recommend that EDF focus on the following high-priority initiatives over the next 18 months, in order to effectively mobilize financing and technical support for rebuilding resilient and sustainable energy infrastructure in Puerto Rico:

- Conduct Microgrid or Storage Pilot with Influential Local Stakeholders
- Build Public Trust and Mobilize Communities
- Aggregate, Assess and Elevate Innovative Pilots

Each of these initiatives aligns with EDF's mission and capabilities and contributes toward a resilient and sustainable energy future for Puerto Rico.

[2] (Data.gov, 2018)

I. Problem Statement

EDF has deep expertise in engaging private sector stakeholders to address complex ESG issues. EDF's Sustainable Finance Team is responsible for formalizing the nature of EDF's interaction with capital market players. Through its Sustainable Finance Team, EDF seeks to establish itself as an influential partner in mobilizing financing for rebuilding energy infrastructure in Puerto Rico.

Current State

Post-hurricane rebuild efforts have been slow and unreliable. Existing financing and technical resources committed to rebuilding Puerto Rico's energy infrastructure are inadequate to meet desired resilience and sustainability standards.

Desired State

EDF hopes to achieve a desired state where Puerto Rico has access to sufficient capital and technical support to rebuild energy infrastructure with improved resilience in the event of natural disasters and significantly lower carbon intensity.

Project Approach

In collaboration with MIT's Sustainability Lab (S-Lab), EDF intends to analyze the political and financial landscape in Puerto Rico and determine high-priority initiatives to achieve its objective. Through stakeholder interviews, secondary research and scenario analyses, the MIT S-Lab team has worked to:

- Identify rebuild options that meet both resilience and sustainability standards
- Explore potential sources of capital to close the financing gap
- Propose action plans for EDF based on scenario planning around financial, political and economic uncertainty

Of note, given the expertise of S-Lab team members and EDF's core mission, damage assessment and technical evaluation of infrastructure design are outside the scope of this report.

II. Background

1. Impact of Hurricanes Irma and Maria

On September 6, 2017, Hurricane Irma, a Category 5 storm, struck Puerto Rico's northern coastline. Two weeks later, Hurricane Maria, an upper Category 4 storm, made its way up the Caribbean, bringing winds of over 150 miles per hour and dumping 25 inches of rain, resulting in catastrophic damages.[3] Puerto Rico was devastated by winds and floods. The hurricanes knocked down 80% of Puerto Rico's utility poles and transmission lines, resulting in the loss of power to essentially all of the island's 3.4 million residents. The NOAA estimate of damage in Puerto Rico and the U.S. Virgin Islands due to Hurricanes Irma and Maria is $90 billion, with a 90% confidence range of +/-$25.0 billion, or $65.0-$115.0 billion.[4]

[3] (Puerto Rico Energy Resiliency Working Group, 2017)
[4] (Berg, Penny, & Pasch, 2018)

At of the end of 2017, nearly half of Puerto Rico's residents were still without power, and by the end of January 2018, electricity had been restored to about 65% of the island.[5] The blackout is the worst in US history with more than 3.4 billion hours of electricity lost, beating out Hurricane George in 1998 and Hurricane Sandy in 2012.[6] By April 2018, Rhodium estimates power has been restored to 96% of the island, meaning that 53,000 households, between 100,000 and 200,000 people, still do not have electricity seven months after the storm.[7] Residents continue to report intermittent power, most recently experiencing a power outage that impacted over 900,000 residents due to a downed tree that triggered a series of cascading failures.[8]

2. Resilience & Sustainability Measures

In benchmarking resilience standards, our team references the definition adopted by the US Department of Homeland Security:

> Infrastructure resilience is the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.[9]

For the purposes of this project, sustainable infrastructure is scoped to include the deployment of renewable energy generation with an emphasis on distributed energy resources ("DERs"), such as microgrids.

By these measures, resilience of a solar energy system may be measured relative to its ability to survive the storm or its ability to be rebuilt quickly following a storm. Solar energy systems experienced damages during Hurricanes Irma and Maria, but the modular nature of the technology enabled fairly rapid recovery through replacement of individual panels, compared to repairs required for central generation plants. Distributed renewable assets can also reduce the risk of losing significant generation capacity in a natural disaster given broader geographic distribution, thereby increasing the overall infrastructure resilience. That said, post-Maria, the transmission and distribution system, as opposed to the generating facilities, incurred the most damage and required intensive resources to repair the miles of power lines and towers.

Post-Hurricane Maria, industry experts have pointed to poor long-term maintenance and lack of upgrades as the primary drivers for the widespread failure.[10] Given this potential root cause for the scale of the devastation, developing a utility culture focused on maintaining resilient infrastructure will require a dramatic shift in mindset and approach for the new incarnation of Puerto Rico's electricity grid.

Assessment of potential infrastructure solutions (technology selection and mix) and the associated quantitative measurements are outside the scope of this project.

---

[5] (Berg, Penny, & Pasch, 2018)
[6] (Criss, 2018)
[7] (Criss, 2018)
[8] (Robles & Wagner, 2018)
[9] (National Infrastructure Advisory Council, 2010)
[10] (Glanz & Robles, 2018)

3. Critical Areas of Uncertainty in Rebuilding Puerto Rico's Energy Infrastructure

In order to rebuild Puerto Rico's energy infrastructure to higher resilience and sustainability standards, two critical areas of uncertainty must be addressed: Financial uncertainty, which is closely tied to the proposal to privatize the decrepit Puerto Rico Electric Power Authority (PREPA), and policy uncertainty, which is further complicated by divisiveness between key Puerto Rico energy stakeholders.

PREPA Privatization and Financial Uncertainty

(See more details in Appendix II. PREPA Privatization & Debt Restructuring Overview)

Puerto Rico's energy future is inextricably linked to the fate of PREPA. As a government-owned monopoly, PREPA operates the transmission and distribution system throughout the island, while also producing the majority of its energy. Two months before Hurricanes Irma and Maria devastated Puerto Rico's antiquated energy system, PREPA filed for bankruptcy under Title III of the Puerto Rico Oversight, Management, and Economic Stability Act (PROMESA). In January 2018, Puerto Rican Governor Ricardo Rosselló announced a plan to privatize the decrepit power utility on an 18-month timeline. According to PREPA's latest fiscal plan submitted to the Financial Oversight and Management Board of Puerto Rico (FOMB), one concessionaire would be deemed responsible for transmission and distribution, while other generation assets would be privatized. Effectively, PREPA would maintain public ownership of the transmission and distribution infrastructure, which would be managed by a private third party.[11] FOMB favors privatization as a path forward for PREPA,[12] though FOMB and the Puerto Rico Energy Commission (PREC) differ in opinion as to which entity should be responsible for overseeing PREPA through the privatization process. Moody's, while generally in favor of privatization as a way to channel capital to Puerto Rico, deems the timeline "quite aggressive", citing the challenges of negotiating a price in the context of a declining population in Puerto Rico.[13]

There are two primary hurdles to achieving privatization. The first hurdle is the need to gain approval from bankruptcy court Judge Laura Taylor Swain, and the second is the need to attract serious bidders for PREPA's assets for sale.[14] Bidders will likely not want to be saddled with PREPA's debt or be forced to retire it. Currently, PREPA has $8.2 billion in public debt outstanding with $4.9 billion insured. Bondholders of the uninsured debt are seeing a decline in bond prices to as low as 35 cents on the dollar. Litigation to improve creditors' rights is also under consideration. Even if PREPA were to be privatized and its assets sold off, there remains a lack of transparency as to how the sales proceeds would be used. It is likely that a portion of the proceeds would be used to relieve the pressure on Puerto Rico's insolvent public pension system. There is also some concern that privatization would make consumers worse off. The privatization of Puerto Rico's dysfunctional water and sewage systems in the 1990's resulted in the water supply becoming even more hazardous than before.[15] Policy experts believe that an independent and well-resourced regulator will be critical to safeguarding the integrity of the privatization process.

[11] (Merchant, 2018)
[12] (Jaresko, 2017)
[13] (Reuters, 2018)
[14] (Sherman, 2018)
[15] (Newkirk, 2018)

Puerto Rico Energy Stakeholders and Policy Uncertainty
(See more details in Appendix III. Puerto Rico Government Agencies & Stakeholders)

Given (i) the bankruptcy status of both the Commonwealth and PREPA, (ii) the push for privatization, (iii) the political dynamics among the players, and (iv) the system-wide failures and lagging recovery post-Maria, there is tremendous uncertainty about the future structure of the energy market on the island and the timescale for the full rebuild effort. In the near-term, efforts are focused on simply restoring power for residents, while long-term implementation of improved resilience and sustainability is more nebulous as the Commonwealth works through the transition away from the government-owned utility to an evolving privatization.

On the sustainability front, PREPA has been slow to integrate renewable energy and, specifically, microgrid development.[16] Only 2% of the Commonwealth's energy was generated by renewables (solar and wind) at the time of Hurricane Maria, despite passing a Renewable Portfolio Standard in 2010 to achieve 12% by 2019 and 20% by 2035, which applies to all retail electric providers of 50,000 MWh or more per year.[17] Puerto Rico lags states and other territories in offering feed-in-tariffs and other incentives that encourage renewable energy development.[18] With privatization, the role of PREC as the regulator takes on greater importance in ensuring compliance with the existing RPS goals.

Without a framework and mandate for improved resilience and sustainability, recovery efforts are primarily geared toward restoring infrastructure to pre-Maria standards. The Puerto Rico Energy Resilience Working Group, a consortium of industry and government stakeholders, released "Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico" (the "Build Back Better Report") to the Governors of Puerto Rico and New York and the Director of FEMA. This report provides recommendations to upgrade infrastructure to a minimum of Category 4 standards and deploy increased renewable energy generation. However, there appears to be little political will and associated policy change to implement these recommendations, which fall short of EDF's desired state. Additional details regarding the report can be found in Appendix IV. "Build Back Better" Report Evaluation.

While Governor Rosselló intensified advocacy for privatization of the island's electric infrastructure[19], he made several positive references to the development of microgrids on the island to improve resilience. Based on our research, the governor's interest in microgrids may provide a potential platform for collaboration between the government and private investors interested in developing microgrids on the island.

Given the uncertainties surrounding the future structure of the energy sector and regulatory policy, EDF will need to navigate these dimensions when engaging in the Puerto Rico rebuild effort. The focus of our research is to explore these uncertainties through research and application of the analytical tools, as described below.

[16] (Mercado, 2018)
[17] (NC Clean Energy Technology Center, 2015)
[18] Ibid.
[19] (Bases, 2018)

III. Research and Analytical Methods

1. Methodology

First, we completed a comprehensive literature review to collect information regarding: 1) state of Puerto Rico's energy infrastructure before and after Hurricanes Irma and Maria, 2) PREPA bankruptcy procedures and privatization plan, 3) damage assessment, estimated costs of rebuilding and potential financing sources, and 4) resilience and sustainability standards for energy infrastructure. We gathered data and information from both public and private sector sources to ensure a fair and balanced view. A list of references can be found in the Appendix of this memorandum. Key findings from these reports are summarized in the both the Background and Results sections.

Second, we identified key stakeholders and industry experts with whom to conduct interviews, which primarily covered the following areas: 1) social, political and financial considerations related to Puerto Rico's energy sector, 2) challenges of rebuilding Puerto Rico's energy infrastructure with existing resources, 3) commentary to the Building Back Better Report and current cost estimates, and 4) opportunities where private sector organizations could contribute to the process. Additionally, we conducted meetings with other Puerto Rico working groups at MIT to share information sources and key findings. Please find below a list of interviews the team have completed.

Organization	Contact Name	Contact Title	Interview Date
MIT			
MIT Sloan School of Management	Donald Lessard	Professor of Engineering Systems, Emeritus	4/6/2018
MIT Sloan School of Management	Dana Attar	MIT EMBA Go-Lab Puerto Rico Project Lead	4/12/2018
MIT Sloan School of Management	Gabriela Santiago	MBA student from Puerto Rico	4/20/2018
MIT Sloan School of Management	John Parsons	Lecturer, CoDirector of MIT's CANES Low Carbon Energy Center	5/3/2018
MIT Department of Urban Studies and Planning	Marian Swain & Adam Hasz	MIT DUSP Puerto Rico Energy Regulatory Team Lead	4/12/2018
MIT Department of Urban Studies and Planning	David Hsu	Assistant Professor of Urban and Environmental Planning	4/20/2018
MIT Department of Urban Studies and Planning	Angela Wong	MIT DUSP Puerto Rico Energy Finance Team Lead	4/20/2018
MIT Office of Sustainability	Brian Goldberg	Sustainability Project Manager	4/24/2018
MIT Energy Initiative	Harvey Michaels	Lecturer, Director of Energy Democracy Project	4/26/2018
MIT Energy Initiative	Ian Schneider	PhD Candidate, Engineering Systems	4/26/2018
EDF			
EDF	Ronny Sandoval	Director, Grid Modernization	4/20/2018
EDF	Namrita Kapur	Managing Director, EDF+Business	4/23/2018
External			
Resilient Puerto Rico Advisory Commission	Miguel A. Soto-Class	Founder and President, Center for a New Economy	4/17/2018
Coalition for Green Capital	Jeff Schub	Executive Director	4/25/2018
Mentes Puertorriqueñas en Acción	Michelle Quiles	Director	4/27/2018

Finally, we consolidated primary and secondary research findings, and utilized three analytical tools to present the results: a) financing gap analysis, b) scenario planning tool, and c) impact-feasibility matrix.

a. The financing gap analysis highlights known sources of capital available in support of the rebuilding efforts in Puerto Rico and potential gap to achieve the $17.6 billion estimated cost outlined in the Building Back Better Report. We recognize that the actual costs of rebuilding all the energy infrastructure could change significantly from current estimates due to various uncertainties, which would require the financing gap analysis to be updated as more information becomes available. Please see Section IV-1 for more details.

b. The scenario planning tool illustrates four possible outcomes given significant political and financial uncertainties. The horizontal axis highlights the variation between recovery to pre-hurricane level vs. building back to higher resilience and sustainability standards, while the

vertical axis presents the difference between completing a full privatization of PREPA vs. maintaining public ownership of privately operated assets. We analyzed key success factors, implications and potential actions from EDF under each scenario to help EDF navigate through a highly uncertain situation. We also discussed the time dimension under each scenario in order to provide better guidance for potential EDF actions. Please see Section IV-2 for more details.

c. The impact-feasibility matrix is a tool we used to facilitate discussions around EDF's priorities for potential initiatives in Puerto Rico. The Impact axis measures the potential of EDF's impact on channeling smart capital to Puerto Rico rebuild efforts or otherwise improving outcomes for Puerto Rico and its communities. The Feasibility axis measures how closely each initiative fits to EDF's core capabilities, and takes into consideration the time and resources needed to implement each initiative. Initiatives with relatively high feasibility and impact should be prioritized. Of note, we had an interactive workshop with the EDF team in order to build out the impact-feasibility matrix based on EDF's core mission and capabilities. The impact-feasibility matrix could also be updated for new initiatives that the EDF team is interested in exploring and prioritizing. Please see Section IV-3 for more details.

2. Limitations to Our Methodology

We recognize there are several limitations to our methodology. First, we initially included additional organizations we wanted to reach out to for primary research, but we were not able to gain access to any interviewees at these organizations despite multiple attempts. These organizations include FEMA, Financial Oversight & Management Board of Puerto Rico, Smart Electric Power Alliance, AECOM, CPS Energy, AES and PREPA. If possible, EDF could continue with these interviews and update the findings according.

Second, we could have benefited from more official and structured collaboration across various MIT Puerto Rico working teams. Given separate mandates, various academic departments and project leaders, and potential confidentiality issues (i.e. we are under various NDAs), we were only able to unofficially connect with them by attending their presentations or setting up separate interviews. It would potentially benefit EDF and other stakeholders if the deliverables from the first phase of these projects could be openly shared across all teams. We also recommend the S-Lab teaching team to keep in touch with EDF in order to provide updated reference materials from other working groups if available.

Over the course of this 12-week project, the S-Lab team evaluated the project and stakeholder landscape, developed a project work plan, conducted primary and secondary research, and completed the final report. Given the ever-changing situation in Puerto Rico, we were not able to fully analyze all the complexity around the rebuilding plan to develop a comprehensive set of solutions for EDF. As a mitigant, we prioritized our efforts to provide the EDF team with analytical frameworks necessary to continue with this research and update actionable items based on new findings.

Additional details regarding the research methodology and interactions with the EDF team can be found in Appendix I. Reflection on Analytical Tools and EDF-MIT Interactive Workshop.

IV. Findings and Results

1. Financing Gap Analysis

Rebuild Cost

Released in December 2017, the Build Back Better Report outlines a $17.6 billion recovery plan to restore and improve Puerto Rico's electric infrastructure.[20] The cost of each rebuilding recommendation is summarized below. As reflected in the cost estimate below, the majority of the funds are associated with the transmission and distribution systems, which sustained significant damage in the storm and required the most time to repair, extending the recovery period to greater than six months.

"Build Back Better" Cost Summary	
Rebuild Recommendations	**Total ($ Millions)**
Overhead Distribution (includes 38 kV)	$5,268
Underground Distribution	$35
Transmission - Overhead	$4,299
Transmission - Underground	$601
Substations - 38 kV	$856
Substations -115 kV & 230 kV	$812
System Operations	$482
Distributed Energy Resources	$1,455
Generation	$3,115
Fuel Infrastructure	$683
Total Estimated Cost	**$17,606**

Note: each line item estimate includes a 30% scope confidence escalator; final cost estimates requrie multiple engineering studies and an updated IRP.

Since damage assessment and technical evaluation of infrastructure design is outside the scope of this report, we use this rebuild cost of $17.6 billion provided in the Build Back Better Report as a baseline. We recognize that there are certain limitations to this rebuilding plan in terms of cost assessment, primarily its failure to 1) incorporate higher resilience and sustainability standards, and 2) include capital needed to cover any potential liabilities from the PREPA bankruptcy proceedings. Additional details regarding the Build Back Better Report can be found in Appendix IV. "Build Back Better" Report Evaluation.

Financing Sources

Financing sources that are currently available to Puerto Rico for the purposes of grid rebuilding are a combination of federal grant funding and private or public private partnership investments.

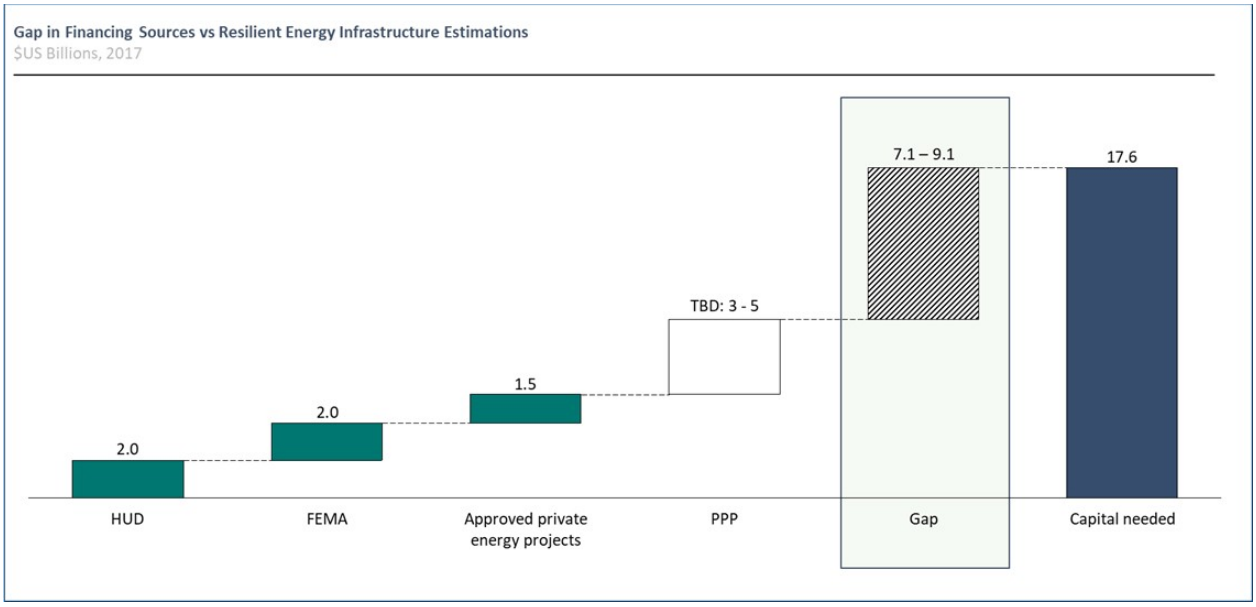
Currently allocated grant funding totals approximately $4 billion from a number of federal agencies. Puerto Rico has received $11 billion under the US Department of Housing and Urban Development's Community Development Block Grant program to support housing, local businesses, and rebuilding of infrastructure, of which $2 billion has been designated for energy grid repairs.[21] The appropriation bill does not currently specify whether the $2 billion would be allocated for direct use by the government or the utility. FEMA has also allocated $2 billion to the US Army Corps of Engineers to execute the mission agreement for power restoration.

[20] (Puerto Rico Energy Resiliency Working Group, 2017)
[21] (Kerchof, 2018)

In addition to the already allocated grants, there is a goal to invest $5 billion over the next 10 years through Public Private Partnerships to rebuild services and infrastructure. There have already been several unsolicited bids for private investment, which are being considered under the energy-focused fast-track program called PROMESA Title V Critical Projects Process. These capital investments total $1.5 billion.[22] The four projects are New Era Eolic LLC's Parque Eólico del Norte, Energy Answers International Inc.'s Arecibo Resource Recovery Facility, NORELCO's Energy Optimization at the Ponce and Bayamón Correctional Institutional Complexes, and ARG Precision Corp.'s dual fuel energy generation backup and reserves for PREPA.[23]

Financing Gap

Based on the approved funding from HUD and FEMA of $2 billion each, $1.5 billion of greenlighted private projects and a projected total of $3-5 billion in Public Private Partnership investments, there remains a substantial financing gap of $7-$9 billion.



This gap is subject to change should additional aid funding be allocated to Puerto Rico for the purposes of rebuilding the grid. There is potential for the Coalition for Green Capital to assist the NY Green Bank with setting up a satellite office in Puerto Rico to support green bank financing; however, there is no current active discussion with Puerto Rico given the high degree of uncertainty in the energy infrastructure regulatory environment.[24] Therefore, there is no green bank financing included in the gap analysis.

Currently, there are no insurance claims included in available funds for rebuilding Puerto Rico's energy infrastructure. However, according to the Stafford Act Emergency Funding guidelines included in PREPA's fiscal plan updated in April 2018, "the cost to restore and repair the damaged infrastructure not

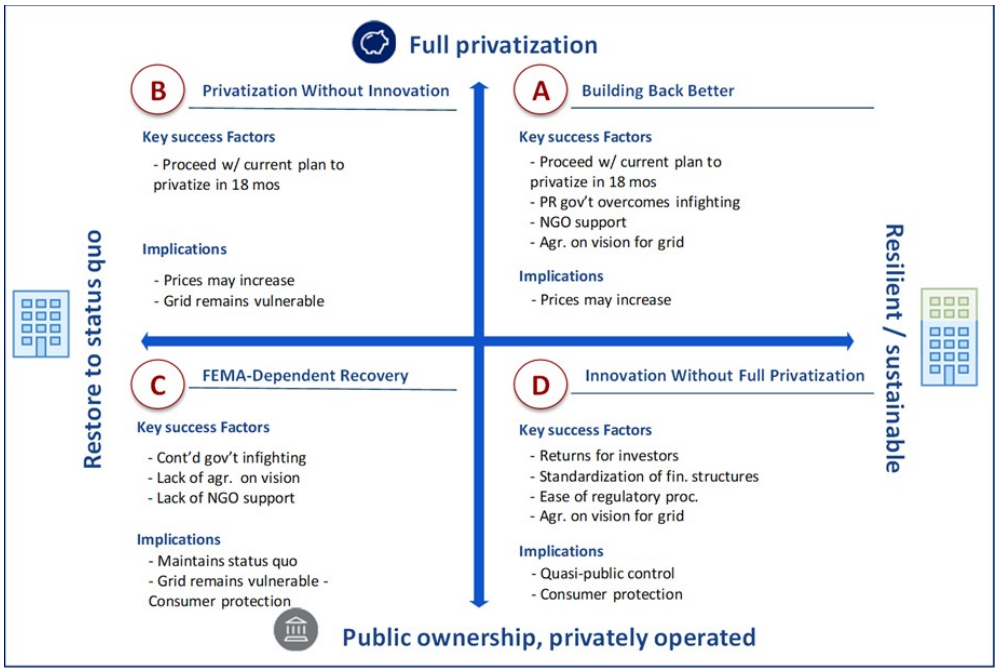
[22] (Financial Oversight and Management Board for Puerto Rico, 2018)
[23] Ibid.
[24] (Schub, 2018)

covered by insurance proceeds is expected to be covered by FEMA Public Assistance Funds."[25] By June, PREPA may have a better estimate of insurance claims for storm-related damage.

Additionally, under the recent tax reform from the Tax Cuts and Jobs Act, Puerto Rico has been designated an Opportunity Zone which allows private investors to make tax-free gains by investing in the designated zone, but the exact amount of tax savings is unclear.[26]

2. Scenario Planning Framework and Analysis

EDF recognizes that Puerto Rico is currently a crowded space and that a variety of factors will determine how the energy system will evolve. In addition, EDF does not have first-hand experience working in Puerto Rico. However, the organization can leverage its reform expertise, technical expertise (i.e. grid interconnectivity), and sustainable finance expertise (leveraging public/philanthropic capital to bring in investments and to reduce the cost of capital) to relieve some of the immediate pressures and to set up a dedicated, open forum in which long-term energy solutions can be discussed openly among diverse stakeholders.



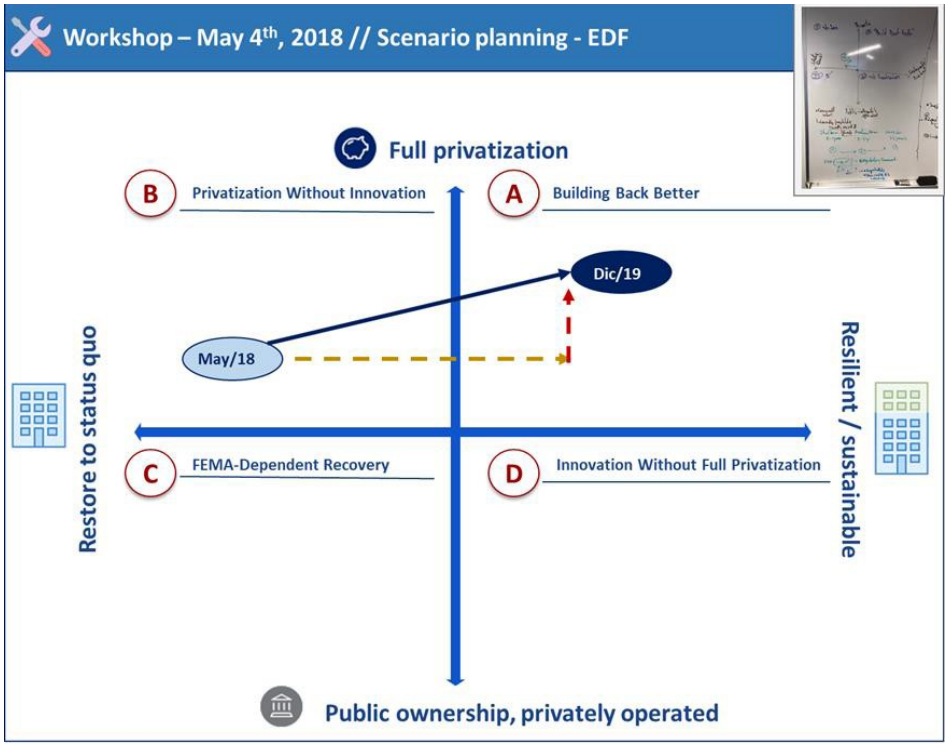
EDF acknowledges that there is still uncertainty about who the key decision makers will be in shaping Puerto Rico's energy future. The scenario planning workshop with the S-Lab team on May 4, 2018 provided EDF with an opportunity to explore initiatives in the context of this uncertainty. The workshop yielded three directional guidelines for EDF's strategy in Puerto Rico to mobilize innovation and capital markets to rebuild the energy infrastructure:

[25] (Puerto Rico Electric Power Authority, 2018)
[26] (Weller, 2018)

- *EDF should act on an 18-month timeline to make progress on its objectives in Puerto Rico:* From May 2018 to December 2019, EDF should define its roadmap of (i) planning its strategy, prioritizing initiatives under the strategy, and defining the feasibility of those initiatives (6 months); and (ii) implementing the prioritized initiatives to position the energy infrastructure rebuild to meet higher resilience and sustainability standards (12 months).

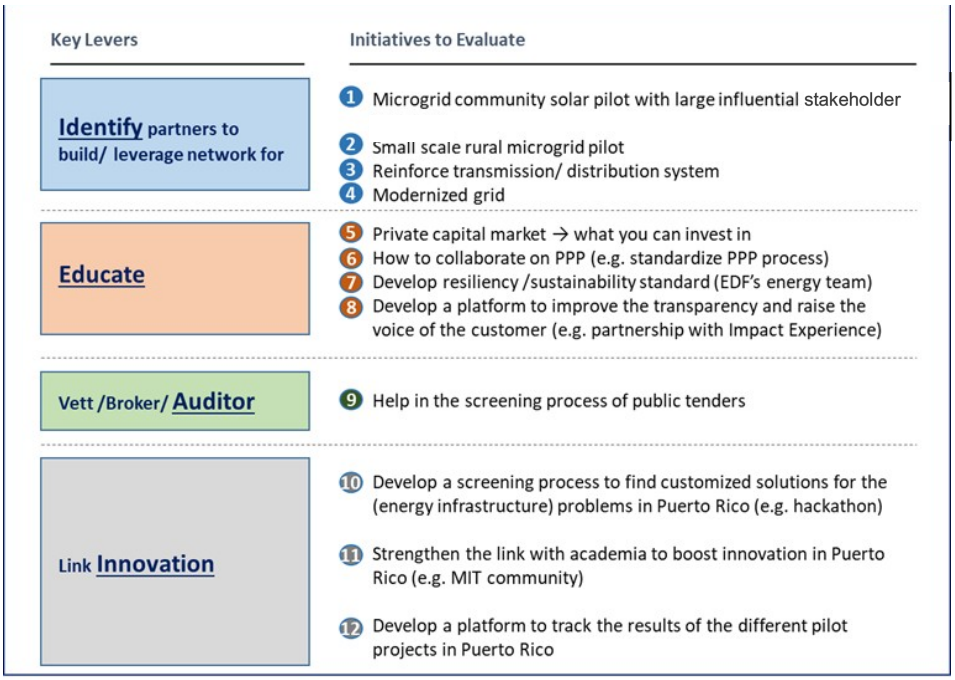
- *EDF should influence the regulatory framework to rebuild more resilient and sustainable energy infrastructure:* EDF should play a role in educating stakeholders and in helping to establish a regulatory environment that supports more sustainable and resilient energy infrastructure.

- *EDF should help to heal the divide between Puerto Rico's diverse stakeholders by bringing capital to the table:* By providing a credible path for capital to be deployed, EDF can bring people to the table to bridge the partisan divide.

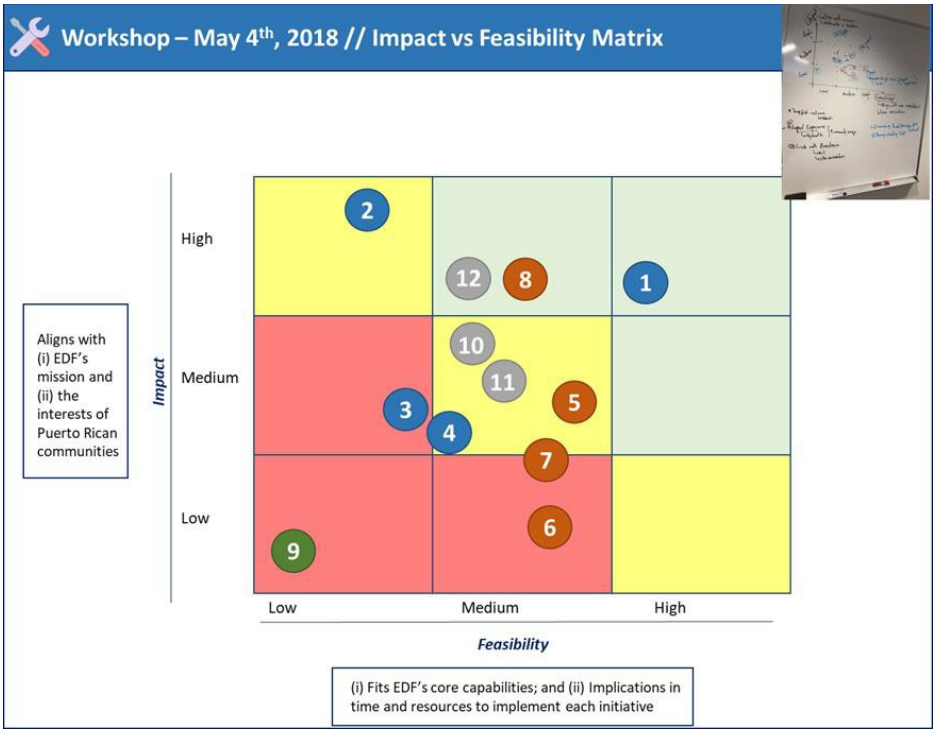


3. Impact vs. Feasibility Matrix

In the workshop, we identified a list of 12 initiatives around 4 levers of action that EDF can pull:



By evaluating each initiative in the Impact vs. Feasibility matrix, we were able to prioritize the key initiatives to focus in the short term and medium term:



As a result of the workshop on May 4th, we identified three levels of priorities for EDF to consider:

- ***Focus - High Priority:*** Dedicate time and resources to doing a deep dive (i.e. understand the stakeholder map and context of each initiative, define the resources needed, align an action plan with key players, and execute and evaluate with Key Performance Indicators) on the following 3 initiatives:

    - **[Initiative 1] Conduct Microgrid or Storage Pilot with Influential Local Stakeholders**: This initiative has medium-high impact because it could have a high community impact and EDF could demonstrate the need for and benefits of more resilient and sustainable energy infrastructure. The demonstration impact can be scaled by partnering with influential stakeholders on the Island, and then used to inform policy decisions on the use of microgrids.

    - **[Initiative 8] Build a platform to improve the transparency of the energy infrastructure rebuild process and elevate the voice and concerns of end users:** This initiative ranks medium on Feasibility because EDF is in the process of building experience in the difficult work of engaging communities in policy development. EDF should leverage this evolving experience to design a solution to elevate the voice of Puerto Rican communities. The missing voice of the energy customer in Puerto Rico is a critical concern; by elevating it, EDF can have medium-high impact as a trusted messenger of the people's voice to the government and private sector.

    - **[Initiative 12] Build a system (i.e. platform) to assess the impact of pilot projects in paving the way for more resilient and sustainable energy infrastructure in Puerto Rico:** By aggregating and assessing different energy pilots being carried out on the Island, EDF can have medium-high impact in that it can help to close the information gap faced by governmental, private and social organizations looking to promote the implementation of best practices or innovations. EDF should invest in defining processes to track and influence conversations around key pilots. This initiative ranks as medium feasibility.

- ***Keep An Eye On - Medium Priority****:*

    - **[Initiative 2] Small-scale rural microgrid pilot in the island:** A pilot in a remote, rural area would rank high on community impact, but low on proving that the regulatory environment needs to change to accommodate microgrids. The higher and broader impact would be to mobilize powerful actors and rigorously prove the impact potential for widespread microgrid usage.

- **[Initiative 3] Reinforced/upgraded transmission & distribution system; and [Initiative 4] Modernized grid:** EDF's focus is on a comprehensive resilience plan, rather than building back to status quo as prescribed in the Build Back Better Plan. EDF advocating for why the status quo plan will not improve Puerto Rico's energy future will have a high impact. On Feasibility, the Department of Energy (DOE) is working closely with PREPA to map its assets and run scenarios to model the system in order to see how much investment will be needed to supply the minimum load. The feasibility of these EDF initiatives is hampered slightly by the delay in the completion of the DOE/PREPA analysis, which will ultimately help EDF identify new potential best practices to promote.

- **[Initiative 5] Educate the private capital market:** This initiative is highly feasible because it is aligned with EDF core capabilities of accessing and educating diverse audiences. However, there is still a lack of clarity on how private investors could play a role in rebuilding the energy infrastructure in Puerto Rico. EDF should carefully evaluate what deals they advocate for (i.e. medium impact until the PREPA/DOE plan materializes so that EDF can analyze the revised context).

- **[Initiative 6 and 7] Develop PPP and resilience/sustainability standards:** These initiatives are medium-low impact and medium feasibility. EDF has the capabilities to help define the standards around PPP and energy infrastructure resilience and sustainability, but other entities have done substantial work on these issues. Subsequently, EDF's role could be to curate the work that others have done so that more energy can be spent on implementing PPPs instead of navigating disparate resources on PPP standards.

- **[Initiative 10] Develop a screening process to find customized solutions**; **[Initiative 11] Engage with academia (e.g. MIT) to boost innovation in the region:** EDF could bridge the innovation from academia and startups to meet Puerto Rico's energy needs (e.g. MIT Climate Co-Lab). The feasibility of these initiatives is medium-low as this is not part of EDF's core competencies and it could also generate the misconception that EDF is using Puerto Rico as a testing ground, putting Puerto Rican citizens at risk if solutions fail. On the other hand, those initiatives could have medium-high impact as Puerto Rico's energy future requires innovative solutions beyond what is proposed in the Build Back Better Report.

- ***Deprioritize - Low Priority:***

  - **[Initiative 9] Help with screening public tenders:** This initiative is low feasibility and low impact because EDF does not have experience screening public tenders and does not consider this activity part its core capabilities.

4. The Potential for Microgrid Developments in Puerto Rico

We would like to discuss the potential to develop microgrids in Puerto Rico given EDF's existing energy sector expertise and initiatives focused on grid modernization. The potential role microgrids could play in a comprehensive power sector transformation plan is recognized by PREPA. In The New Fiscal Plan (April 2018 version), PREPA stated that "Puerto Rico needs an upgraded grid to increase reliability and resilience, reduce cost, facilitate distributed generation and microgrids, and allow for better monitoring and control."[27] PREPA indicated that the addition of microgids does not imply independent operation; rather, microgrids are largely components of a centralized grid infrastructure, unless installed in certain remote areas.[28]

Microgrids could provide power to both critical facilities and residential communities, creating decentralized energy generation hubs throughout the island. Key locations for potential microgrids include but are not limited to hospitals, police and fire stations, shelters, and critical commercial and industrial ("C&I") facilities. Potential benefits of building microgrids in Puerto Rico include improved energy resilience with a diversified portfolio of distributed assets, shortened repair time compared to centralized generation, and reduced cost of operating backup capacity and peaker plants.

There are also significant challenges to integrating microgrids as part of Puerto Rico's energy infrastructure. First, existing PREPA infrastructure is fragile, antiquated, and lacks the ability to incorporate sophisticated microgrid systems.[29] Second, there are significant risks for developers and investors to commit to long-term capital projects given political and financial uncertainties in Puerto Rico. Last, the overall impact of microgrids on electricity costs is unclear. For more detailed analysis of the benefits and challenges of developing microgrids in Puerto Rico, please refer to Appendix V. Microgrid Benefits and Challenges.

V. Recommendations

Our team believes that EDF's Sustainable Finance Team, which is responsible for formalizing the nature of EDF's interaction with capital markets, can take on several high impact, high feasibility initiatives in the short term to help Puerto Rico begin to rebuild its energy infrastructure to higher sustainability and resilience standards. These initiatives fall squarely within the three-pronged strategy of EDF's Sustainable Finance Team: getting the rules right, making engagement and investment easier, and demonstrating returns.

Overall, we believe that the success of EDF's engagement in Puerto Rico will hinge on strong, trusted partnerships with influential local stakeholders. The Puerto Rican context is fraught with uncertainty about PREPA's future and public distrust in both the public utility and the government. Currently, EDF does not have a first-hand understanding of the social and political context. Having a nuanced understanding of the political and socioeconomic dynamics will give EDF an advantage in navigating a shifting landscape.

---

[27] (Puerto Rico Electric Power Authority, 2018)
[28] Ibid.
[29] (Attar, Beckwith, Chandra, Neuhoff, & Wiltberger, 2018)

Recommendation 1: Conduct Microgrid or Storage Pilot with Influential Local Stakeholder(s) (Initiative 1 in the Impact-Feasibility Matrix)

We recommend that EDF consider collaborating with local stakeholders on a microgrid or community storage pilot. However, the discussion between the S-Lab team and the EDF team on May 4, 2018, yielded a shift in focus from piloting in a remote, rural setting to piloting in a higher visibility setting with an established commercial stakeholder. Per our discussion, we agreed that a pilot in a remote, rural area would likely rank high on community impact, but low on providing a platform to facilitate the necessary changes to the regulatory environment to accommodate and accelerate the deployment of microgrids. A broader impact could be brought about by mobilizing powerful actors and rigorously proving the impact potential for widespread microgrid usage. EDF may leverage its existing partnerships and technical expertise to conduct high visibility pilots and document rigorous pre- and post-assessments in a case study.

Recommendation 2: Build Public Trust and Mobilize Communities (Initiative 8 in the Impact-Feasibility Matrix)

Public trust in PREPA and government agencies in Puerto Rico is at a low point. EDF can leverage its position as a neutral party to take the temperature on public sentiment and share those findings to help heal the divide. Our initial desk research and interviews reveal that the lack of action and transparency on the part of the public energy utility and the government has left the communities of Puerto Rico skeptical about being able to play a meaningful role in deciding Puerto Rico's energy future. EDF could engage in a public relations campaign to move the needle on clean energy. Conducting a poll that asks citizens who they trust most to enact change could elevate the most important issues for communities to both PREPA and the government, which have both committed to rebuilding the energy infrastructure to be more consumer-centric.

As part of this work stream, EDF would benefit from learning about community-driven energy infrastructure initiatives that helped to mobilize marginalized communities after Hurricane Maria. Some examples it could learn from include Casa Pueblo, a local non-profit organization, raised enough donations to purchase and install solar powered bulbs to power the entire town and then other neighboring towns. Another example is the town of San Sebastian, which organized a makeshift electric power brigade of retired electricians to fix the power cables that had fallen.

Recommendation 3: Aggregate, Assess and Elevate Innovative Pilots (Initiative 12 in the Impact-Feasibility Matrix)

We recommend that EDF take on the initiative of aggregating and assessing innovative pilots, microgrid or otherwise, that have been implemented on the Island since Hurricane Maria. By analyzing these projects on the dimensions of community engagement, scalability, affordability, among others, EDF will be able to shine light on potential investment opportunities for private investors should the regulatory environment become more accommodating to new entrants. Glorimar Ripoll, the Puerto Rico

government's chief innovation officer and MIT alumna, may be open to receiving assistance on this very task as she strives to bring forth the most innovative solutions. A critical piece of this work will be to define the key metrics EDF would use to assess individual projects, which would be aggregated for comparison. EDF is uniquely positioned to take on this role because of its technical and community- engaging expertise. Some post-hurricane pilot projects included Tesla sending Powerwall 2 battery packs to bring individual rooftop solar installations back online (and potentially be used to support microgrids in the future), and Sonnen installing 10 microgrid systems in community facilities in remote areas.

EDF may also consider partnering with organizations such as Impact Experience, which elevates the community voice through curated capital experiences that bring communities, investors and entrepreneurs to the table, as a way to deploy capital for the most innovative solutions to Puerto Rico's technological and community needs.

Appendix

Appendix I. Reflection on Our Analytical Approach and the EDF-MIT Interactive Workshop

We acknowledge that there are multiple benefits and limitations to the tools and methodologies that we used in this project. To guide future efforts, we consolidate the key benefits, limitations, learnings and potential uses of each tool that we implemented.

- Financial Gap Analysis

    - *Key benefits*: The financial gap analysis tool helped us to understand the diverse stakeholders in an ecosystem. In addition, it provided us with a sense of the scale of the problem and the need for action.
    - *Main limitations and challenges:* The lack of structural data is a challenge to painting a complete picture of what sources of capital could be made available for rebuilding Puerto Rico's energy infrastructure. In addition, in the context of high financial and regulatory uncertainty in Puerto Rico, we see a challenge in defining the goal or end state of the energy system.
    - *Learnings on how to mitigate the limitations and overcome the challenges?* In order to have a more accurate estimate of the financing gap, it is important to iterate on the analysis with different stakeholders and to validate the basic assumptions and sources of data with the client. Using rough ranges as opposed to exact figures, as we did in our estimate, was useful in focusing the discussion on the magnitude of the problem rather than the details of what the exact financing gap is.
    - *Where could this tool be useful?* This tool could be implemented in different strategic projects in which the organization is trying to define a main financial goal, or in projects in which there are multiple stakeholders collaborating to achieve a common objective and there is a lack of understanding on the combined impact of their individual contributions or actions.

- Scenario Planning

    - *Key benefits:* It was useful to frame our discussion on how to make impactful decisions in a highly uncertain environment. It was easy to interpret and communicate.
    - *Main limitations and challenges:* One of the challenges was narrowing our selection and definition of the two or three key elements of uncertainty. In addition, the likelihood of each scenario will change over time, so the organization should re-evaluate its position and its potential levers of influence as it gains a better understanding of the environment.
    - *Learnings on how to mitigate the limitations and overcome the challenges?* It is key to develop a root cause analysis in order to define the two or three most important exogenous variables that create the environment of uncertainty. Also, the organization should develop a workshop and invite different internal and external stakeholders with diverse perspectives in order to have a richer discussion about the organization's role.

- *Where could this tool be useful?* This tool could used to facilitate initial conversations around an uncertain scenario for the organization. It helps to drive discussions around potential levers of influence and control.

- Impact vs Feasibility Matrix

  - *Key benefits*: This tool was key to identifying initiatives to explore, and to discussing the biggest implementation challenges given the organization's capabilities and constraints.
  - *Main limitations and challenges:* There could be a selection bias in the discussion of the initiatives (i.e. the EDF employees in the workshop were already working on or planning projects for Puerto Rico). Also, the matrix is a snapshot of the current understanding of the initiatives, their impact and feasibility. Thus, the matrix should be revisited as the organization continues to explore its alternatives in Puerto Rico.
  - *Learnings on how to mitigate the limitations and overcome the challenges?* The organization should invite people from different backgrounds to participate in a workshop to build and reflect on the matrix. Also, the organization should share sufficient but not overly detailed information about each potential initiative in advance so that the participants can actively contribute their experience and perspectives to discussion. Lastly, the organization should organize a strategic workshop every quarter or six month to review the status of the prioritized initiatives and potential changes of the matrix.
  - *Where could this tool be useful?* This tool could be useful in an organization with a lack of clarity on how to prioritize a set of potential strategic initiatives, especially if resources are limited. The tool is useful for both assessments that have both qualitative and quantitative measures of success. In other words, even if an initiative does not have a quantitative valuation assigned to it, the tool can still help the organization set a direction for resource allocation and further analysis on specific initiatives as needed.

Appendix II. PREPA Privatization & Debt Restructuring Overview

Puerto Rico's energy future is inextricably linked to the future of PREPA. Two months before Hurricanes Maria and Irma devastated Puerto Rico's antiquated energy system, PREPA filed for bankruptcy in the United States District Court of Puerto Rico under Title III of the Puerto Rico Oversight, Management, and Economic Stability Act (PROMESA). In the aftermath of the hurricanes, PREPA has struggled to restore power to Puerto Rico's citizens. In January 2018, Puerto Rican Governor Ricardo Rosselló announced a plan to privatize the decrepit power utility on an 18-month timeline. The privatization proposal is comprised of three stages: Legislation through the Legislative Assembly of Puerto Rico to establish a legal framework for the sale of PREPA, followed by acceptance, and then approval of purchase proposals.[30] According to PREPA's latest fiscal plan submitted to the Financial Oversight and Management Board of Puerto Rico (FOMB), funds for PREPA's operations would come from the concessionaire as well as the federal government. One concessionaire would be deemed responsible for transmission and distribution, while other generation assets would be privatized. PREPA would maintain public ownership of the transmission and distribution infrastructure, which would be managed by a private third party.[31]

FOMB favors privatization as a path forward for PREPA,[32] though FOMB and the Puerto Rico Energy Commission (PREC) have differing opinions -- which have sparked litigation -- as to which entity is responsible for overseeing PREPA through the privatization process. Moody's, while generally in favor of privatization as a way to channel capital to the Island, deems the timeline "quite aggressive", citing the challenges of negotiating a price in the context of a declining population in Puerto Rico.[33]

There are two primary hurdles to achieving privatization. The first hurdle is the need to gain approval from bankruptcy court Judge Laura Taylor Swain, and the second is the need to attract serious bidders for PREPA's assets for sale.[34] Bidders will likely not want to be saddled with PREPA's debt or be forced to retire it. Currently, PREPA has $8.2 billion USD in public debt outstanding with $4.9 billion insured. Bondholders of the uninsured debt are seeing a decline in bond prices to as low as 35 cents on the dollar. Bond insurer Assured Guaranty, which guarantees payment on $4.9 billion of the PREPA bonds, has stated that PREPA must find a way to settle with creditors. Litigation to improve creditors' rights is also under consideration.

Even if PREPA were to be privatized and its assets sold off, there remains a lack of transparency as to how the sales proceeds would be used. It is likely that a portion of the proceeds would be used to relieve the pressure on Puerto Rico's insolvent public pension system. There is also some concern that privatization would make consumers worse off. The privatization of Puerto Rico's dysfunctional water and sewage systems in the 1990's resulted in the water supply becoming even more hazardous than before.[35]

---

[30] (Balmaceda, 2018)
[31] (Merchant, 2018)
[32] (Jaresko, 2017)
[33] (Reuters, 2018)
[34] (Sherman, 2018)
[35] (Newkirk, 2018)

Should the PREPA privatization process move forward, there is a growing voice among policy experts and the Puerto Rican people advocating for the transition to be managed by an independent and well-resourced regulator. José Román, the interim president of the PREC, who is often found to be at odds with the opinion of Governor Rosselló, is a strong proponent of an independent energy regulator. PREPA's recently-established Transformation Advisory Council (TAC) consisting of senior executive leaders from the power sector convened to advise PREPA's management and board, will be privatization-agnostic, but committed to working with both the regulator and customers to create a more customer-centric energy system.

Appendix III. Puerto Rico Government Agencies & Stakeholders

GOVERNMENT	
Puerto Rico Electric Power Authority (PREPA)	● With over 70 years in operation, the government-owned, monopoly-provider PREPA served 1.5 million customers prior to Hurricane Maria. Following the storm and delay in power restoration, the customer base is now estimated at 1.4 million customers due to an exodus from the island. ● In May 2017, the Financial Oversight & Management Board placed the Commonwealth of Puerto Rico into federal bankruptcy.[36] In July 2017, PREPA entered bankruptcy proceedings. ● Following Hurricane Maria, PREPA's response has largely been deemed inadequate due to slow mobilization and incomplete restoration of power more than 6 months later. ● PREPA's recovery response post-Maria has been hampered by the uncertainty around the bankruptcy and subsequent privatization effort. ● PREPA lacks sufficient financial resources to repair existing infrastructure, which is estimated at $17 billion dollars. Additionally, PREPA bondholders are exercising influence in financial decisions in an attempt to safeguard their investments during the liquidation process.[37]
Puerto Rico Energy Commission (PREC)	● Founded in 2014, the PR Energy Commission is chartered to provide regulatory oversight for PREPA.[38] Prior to its establishment, PREPA was self-regulated. ● The stated mission of the commission is "to achieve a reliable, efficient and transparent electric system, which provides power services at reasonable prices." Puerto Rico grid prices are nearly two times higher than the US mainland due to reliance on imported fossil fuels.[39] ● Commissioners are appointed by the governor with the advice and consent of Puerto Rico's Senate.
Financial Oversight & Management Board of Puerto Rico	● Founded in 2016, the Financial Oversight and Management Board for Puerto Rico is tasked with creating "the necessary foundation for economic growth and to restore opportunity to the people of Puerto Rico." FOMB is asserting budgetary authority over PREPA. ● The extent of this authority was challenged in court by PREC, which asserted the FOMB overstepped by circumventing PREC's regulatory oversight of PREPA's actions when not seeking PREC's review and approval of investments to be made by PREPA.[40] Additionally, the Governor of Puerto Rico is challenging FOMB's

[36] (Peluso, 2017)
[37] (Sanzillo, 2017)
[38] (Puerto Rico Energy Commission, 2016)
[39] (U.S. Energy Information Administration, 2018)
[40] (Walton, 2018)

	budgetary authority through refusal to implement benefit cuts in the Commonwealth's general budget, which would in turn impact PREPA.[41] ● The Board includes seven members appointed by the President of the United States and one ex officio member designated by the Governor of Puerto Rico.[42] Members are not elected by the public. ● The Board has not provided comment on specific infrastructure rebuild plans or efforts.
Governor of Puerto Rico, Ricardo Rosselló	● As a member of the New Progressive party in Puerto Rico, Governor Rosselló developed and promotes the plan to privatize PREPA with the stated goal of achieving lower energy prices.[43] ● Shortly after the storm, the governor exchanged tweets with Tesla's Elon Musk seeking help in the recovery efforts.[44] This exchange signaled Governor Rosselló's openness to adopting microgrid technology to improve energy resilience. However, uncertainty remains as the regulatory environment is considered in flux given PREPA's bankruptcy and planned privatization.
US Federal Emergency Management Agency (FEMA)	● Mission: Helping people before, during, and after disasters.[45] FEMA's efforts post-Maria have drawn criticism due to the relative level of resources and speed of response when compared to the agency's response in Houston following Hurricane Harvey.
LOCAL	
Resilient Puerto Rico Advisory Commission	● Community engagement and visibility into potential options for building and financing improved infrastructure. ● The Commission is in favor of microgrid deployment.
Resilient Power Puerto Rico	● A non-profit that launched a $2.5M solar energy initiative focused on microgrids may be a interesting partner for pilot projects in underserved communities.

[41] (Florido, 2018)
[42] (The Financial Oversight and Management Board for Puerto Rico, 2018)
[43] (Kask, Rivera, & Levin, 2018)
[44] (Kusnetz, 2017)
[45] (Federal Emergency Management Agency, 2018)

Appendix IV. "Build Back Better" Report Evaluation

In reviewing the Build Back Better Report, the recommendation to build Puerto Rico's energy infrastructure to withstand Category 4 storms seems to lack long-term vision. Prior to the hurricanes, PREPA reported that only 15% of the transmission lines were built to mid-Category 4 criteria and the remaining 85% were built to lesser standards. While the recommendation may be pragmatic in terms of near-term execution, the Build Back Better consortium appears to discount the potential frequency of Category 5 storms.

The proposed budget reflects a rebuild of pre-Maria infrastructure with a subset of the budget directly linked to incorporating more resilient infrastructure design:

- 3.6% for underground transmission and distribution lines (less susceptible to damage that overhead lines);
- 8.2% for distributed energy generation (e.g. energy storage and microgrids)

Build Back Better highlights the geographical, climate, and population distribution as challenges in redesigning and rebuilding this infrastructure. Use of underground lines is relatively low due to Puerto Rico's mountainous terrain, which would require extensive tunnelling or boring to service all populations. In its place, Build Back Better highly recommended use of monopoles vs. open-truss towers to carry electrical lines, as these structures fair better in higher winds.

Additionally, Build Back Better mentions but does not prioritize the role that renewable energy and, most notably, microgrids can play in improving the energy security, resilience, and sustainability of Puerto Rico. As a net importer of energy (primarily petroleum oil and liquid natural gas[46]), Puerto Rico could benefit greatly from the expanded deployment of renewable energy resources. At the time of Maria, just 2% of Puerto Rico's energy came from renewables.

With significant energy generation capacity and infrastructure to restore, many in the energy sector noted the lack of interest in solar and wind resources.[47] In 2015, PREPA released new renewable energy targets of 20% by 2035. The Build Back Better report recommends increasing this target and designing transmission infrastructure for renewable interconnection, but does not provide an explicit recommendation on the revised target.

The "Generation" budget is associated with inspection and near-term rebuild of existing generation facilities. Of the $3.1 million budgeted, 91% is associated with two plants (Aguirre oil-fired plant and Palo Seco combination gas plant), while 2% is dedicated to restoring the renewable energy facilities on the island. That said, the "Operations" proposal is primarily linked to grid modernization that would enable increased penetration for renewable energy generation, which will be critical to achieving even the model 20% goal currently published by PREPA. Under a privatization scenario, achieving these targets is uncertain, given existing regulatory hurdles.

As a whole, the Build Back Better report provides fairly modest recommendations on the resilience side by anchoring design to Category 4 storm standards. With respect to sustainability, it gives voice to the

[46] (U.S. Energy Information Administration, 2018)
[47] (Bhave, 2017)

potential benefits of renewables, but does not quantify the benefits or provide specific targets of recommendations that could be leveraged as the foundation for a rebuild action plan.

The “Build Back Better” Report pragmatically distinguishes between immediate needs for emergency power, mid-term goals of returning to pre-hurricane standards, and long-term goals of grid hardening. In our research, we have found that many stakeholders are struggling with compromises between speedy recovery and long-term grid modernization efforts.

Appendix V. Microgrid Benefits and Challenges

In December 2017, 53 groups and companies, including Sunnova, AES, the Puerto Rico Solar Energy Industries Association (PR-SEIA), the Advanced Energy Management Alliance (AEMA), and the New York Smart Grid Consortium, submitted their thoughts about microgrids or, in many cases, broader goals for the island's future energy system.[48] In January 2018, the Puerto Rico Energy Commission unveiled proposed regulations for future microgrid installations on the island. According to the commission's regulation, "a microgrid shall consist, at a minimum, of generation assets, loads and distribution infrastructure to serve load under normal operating and usage conditions."[49]

Benefits

Incorporating microgrids could improve resilience of Puerto Rico's energy infrastructure, primarily because it enables localized generation during grid outages through independent operation. In other words, microgrids would be able to mitigate the risk of losing concentrated energy generation capacity since it is much less likely a diversified portfolio of microgrid assets would be damaged at the same time. This risk-management potential is particularly important in island nations like Puerto Rico, given the pathway of hurricanes is extremely unpredictable.

Resilience, in this case, could also be interpreted as how fast backup generating capacity could come online or how long damaged assets would be repaired. Localized maintenance and services would allow for accelerated repairs when microgrid assets are damaged; while traditional, large-scale generation assets require much longer repair processes managed by the central operator. Of course, localized maintenance would require more skilled workers to conduct basic repairs, but these distributed assets will likely require less sophisticated services compared to utility-scale power plants. It could also create more local job opportunities with necessary training.

Additionally, Puerto Rico's existing energy islanding capability is mainly provided by diesel backup generators, which have been widely relied upon post Hurricanes Irma and Maria. However, the cost of maintaining and operating emergency generators is quite high given difficulty in transporting fuel to island nations. Furthermore, backup generators usually sit idle until an emergency happens, while microgrids would be utilized much more frequently as an integrated part of the centralized grid. Microgrids with storage capacity could be used to shave peak demand, and thus further reduce the cost of operating peaker plants.

Challenges

There are also significant challenges to integrating microgrids as part of Puerto Rico's energy infrastructure. First of all, the centralized grid managed by PREPA today is fragile, antiquated, and lacks the ability to incorporate sophisticated microgrid systems that can switch back and forth between grid connected and local operation without any interruption in power. The governor has called for grid modernization, but there is no detailed implementation plan or assessment of overall cost. As the MIT EMBA Go-Lab Team points out, microgrid pilots are possible, but a robust system of microgrids and DERs is not feasible until the grid is sufficiently modernized.[50]

---

[48] (Merchant, Puerto Rico Energy Commission Lays Out Rules for a Future Microgrid Landscape, 2018)
[49] (Puerto Rico Energy Commission, 2018)
[50] (Attar, Beckwith, Chandra, Neuhoff, & Wiltberger, 2018)

Secondly, there are significant risks for developers and investors to commit to long-term capital projects given political and financial uncertainties in Puerto Rico. There is currently no incentive program or accelerated approval process to facilitate microgrid developments. According to Chris Shelton, the chief technology officer at AES, microgrid developments would require either FEMA to participate directly, or the federal government set up a more viable long-term structure to incentivize investments.[51] Given uncertainties around the privatization of PREPA and new appointments for PREC, we foresee additional difficulty in long-term planning for Puerto Rico's energy sector.

Finally, power generation is a game of scale in most cases, which means microgrids could cause electricity to be more expensive in Puerto Rico as overall demand for centralized generation capacity decreases. There are some existing cost-benefit analyses for microgrids, such as the New York State Energy Research and Development Authority (NYSERDA) model, but nothing in the context of an island nation where centralized generation is significantly more expensive and less reliable than mainland.[52] Many uncertainties remain, for example, how much distributed capacity would be built and whether Puerto Rico would design a new pricing system (combination of fixed and volumetric charges). Thus, it is almost impossible to estimate the overall impact on electricity costs with the interaction of microgrids going forward.

[51] (Behr & Ferris, 2017)
[52] (New York State Energy Research and Development Authority, 2015)

Appendix VI. Twitter Exchange between Governor Rossello and Elon Musk, Tesla CEO

References

Arduengo, R. (2018). *Before and after: See how Puerto Rico is recovering from Hurricane Maria.* The Washington Post. From https://www.washingtonpost.com/world/before-and-after-see-how-puerto-rico-is-recovering-from-hurricane-maria/2018/03/19/2d07ea3a-2bc3-11e8-b0b0-f706877db618_gallery.html?utm_term=.cf528792f705

Attar, D., Beckwith, G., Chandra, N., Neuhoff, C., & Wiltberger, C. (2018, May 7). Organizational and Policy Needs for Microgrid Development in Puerto Rico. (F. Rozental, Interviewer) Cambridge, MA. From https://drive.google.com/open?id=1EuiKCCIrYXJVPCBMdSfgHTUJEpCGp0ld

Balmaceda, J. (2018, April 3). *Puerto Rico's PREPA Privatization: A Sale Too Private*. From Forbes DebtBusters: https://www.forbes.com/sites/debtwire/2018/04/03/puerto-ricos-prepa-privatization-a-sale-too-private/#6585d8097490

Bases, D. (2018, January 22). *Puerto Rico to sell off crippled power utility PREPA*. From Reuters Business News: https://www.reuters.com/article/us-puertorico-power-prepa/puerto-rico-to-sell-off-crippled-power-utility-prepa-idUSKBN1FB31M

Behr, P., & Ferris, D. (2017, December 8). *Microgrids could save Puerto Rico. But first, a fight*. From E&E News reporters: https://www.eenews.net/stories/1060068479

Berg, R., Penny, A. B., & Pasch, R. J. (2018). *Tropical Cyclone Report - Hurricane Maria (AL 152017).* National Hurricane Center. Silver Spring, Maryland: National Hurricane Center. From https://www.nhc.noaa.gov/data/tcr/AL152017_Maria.pdf

Bhave, M. (2017, December 28). *Build Back Better' in Puerto Rico — Microgrids Treated Shoddily*. From Renewable Energy World: https://www.renewableenergyworld.com/articles/2017/12/build-back-better-in-puerto-rico-microgrids-treated-shoddily.html

Criss, D. (2018, April 16). *Puerto Rico's power outage is now the second-largest blackout on record*. From CNN U.S.: https://www.cnn.com/2018/04/16/us/puerto-rico-blackout-second-largest-globally-trnd/index.html

Data.gov. (2018). *Climate Model Projections*. From Data.gov Climate: https://www.data.gov/climate/portals/

Federal Emergency Management Agency. (2018, March 26). *About the Agency*. From Federal Emergency Management Agency: https://www.fema.gov/about-agency

Financial Oversight and Management Board for Puerto Rico. (2018). *Oversight Board Opens 30-Day Public Comment Period for Projects Being Considered Under PROMESA's Title V Critical Projects Process.* San Juan, PR: Financial Oversight and Management Board for Puerto Rico. From https://juntasupervision.pr.gov/wp-content/uploads/wpfd/49/5a539b3136233.pdf

Florido, A. (2018, April 21). *Puerto Rico Board, Governor Clash Over Finances*. From npr National : https://www.npr.org/2018/04/21/604638980/puerto-rico-board-governor-clash-over-finances

Glanz, J., & Robles, F. (2018, May 6). *How Storms, Missteps and an Ailing Grid Left Puerto Rico in the Dark*. From The New York Times U.S.: https://www.nytimes.com/interactive/2018/05/06/us/puerto-rico-power-grid-hurricanes.html

Jaresko, N. (2017, November 7). Examining Challenges in Puerto Rico's Recovery and the Role of the Financial Oversight and Management Board. (H. C. Resources, Interviewer) From http://democrats-naturalresources.house.gov/imo/media/doc/testimony_jaresko.pdf

Kask, M., Rivera, Y., & Levin, J. (2018, January 22). *Puerto Rico to Start Privatizing Embattled Energy Company*. From Bloomberg Markets: https://www.bloomberg.com/news/articles/2018-01-22/puerto-rico-to-start-process-of-privatizing-energy-company-prepa

Kerchof, C. (2018, April 10). *HUD Announces CDBG-DR Awards, Provides Massive Amounts for Puerto Rico and Mitigation*. From Enterprise: https://www.enterprisecommunity.org/blog/2018/04/hud-announces-cdbg-dr-awards

Kusnetz, N. (2017, October 6). *Elon Musk: Tesla Could Help Puerto Rico Power Up Again with Solar Microgrids*. From Inside Climate News: https://insideclimatenews.org/news/06102017/elon-musk-puerto-rico-solar-microgrids-rossello-rebuild-power-grid

Mercado, E. M. (2018, March 21). *Privatization Fever with Renewable Energy Fails in Puerto Rico*. From Centro de Periodismo Investigativo: http://periodismoinvestigativo.com/2018/03/privatization-fever-with-renewable-energy-fails-in-puerto-rico/

Merchant, E. F. (2018, January 8). *Puerto Rico Energy Commission Lays Out Rules for a Future Microgrid Landscape*. From Greentech Media Microgrids: https://www.greentechmedia.com/articles/read/puerto-rico-energy-commission-island-microgrid#gs.SGG8ZBQ

Merchant, E. F. (2018, February 5). *Puerto Rico's Utility Moves Toward Privatization, With Strained Cooperation*. From Greentech Media: https://www.greentechmedia.com/articles/read/puerto-ricos-utility-moves-towards-privatization-but-struggles-persist-in-b#gs.1PMOtuU

National Infrastructure Advisory Council. (2010). *A Framework for Establishing Critical Infrastructure Resilience Goals.* Washington D.C.: National Infrastructure Advisory Council. From https://www.dhs.gov/xlibrary/assets/niac/niac-a-framework-for-establishing-critical-infrastructure-resilience-goals-2010-10-19.pdf

NC Clean Energy Technology Center. (2015, May 6). *Puerto Rico - Renewable Energy Portfolio Standard*. From Database of State Incentives for Renewables & Efficiency: http://programs.dsireusa.org/system/program/detail/4267

New York State Energy Research and Development Authority. (2015). *Assessing the Benefits and Costs of Developing a Microgrid: Model User's Guide.* New York, NY: New York State Energy Research and Development Authority.

Newkirk, V. R. (2018, January 24). *The Peril of Privatizing PREPA*. From The Atlantic: https://www.theatlantic.com/politics/archive/2018/01/puerto-rico-will-privatize-prepa/551342/

Peluso, R. I. (2017, May 8). *Puerto Rico Files For Bankruptcy Protection*. From Corporate Trust Insider: https://www.corporatetrustinsider.com/2017/05/puerto-rico-files-for-bankruptcy-protection/

Puerto Rico Electric Power Authority. (2018). *New Fiscal Plan for PREPA.* Puerto Rico Electric Power Authority. San Juan, PR: The Financial Oversight and Management Board for Puerto Rico. From https://juntasupervision.pr.gov/wp-content/uploads/wpfd/50/5ad90880bf3a7.pdf

Puerto Rico Energy Commission. (2016, January 15). *About the Puerto Rico Energy Commission*. From Puerto Rico Energy Commission: http://energia.pr.gov/en/about-the-commission/

Puerto Rico Energy Commission. (2018). *Regulation on Microgrid Development.* San Juan, PR: Puerto Rico Energy Commission.

Puerto Rico Energy Resiliency Working Group. (2017). *Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico.* New York: Governer of New York. From

https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/PRERWG_Report_PR_Grid_Resiliency_Report.pdf

Reuters. (2018, January 23). *Moody's Issues Statement Regarding Puerto Rico's Move To Privatize PREPA*. From Reuters Market News: https://www.reuters.com/article/brief-moodys-issues-statement-regarding/brief-moodys-issues-statement-regarding-puerto-ricos-move-to-privatize-prepa-idUSFWN1PI177

Robles, F., & Wagner, J. (2018, April 18). *Puerto Rico Is Once Again Hit by an Islandwide Blackout*. From The New York Times U.S.: https://www.nytimes.com/2018/04/18/us/puerto-rico-power-outage.html

Sanzillo, T. (2017, April 27). *5 reasons Puerto Rico's electric debt deal is a rip-off*. From The Hill: http://thehill.com/blogs/pundits-blog/economy-budget/330732-5-reasons-puerto-ricos-electric-debt-deal-is-a-rip-off

Schub, J. (2018, April 25). (M. S.-L. Team, Interviewer)

Sherman, B. (2018, February 2). *Bondholders need to face reality in Puerto Rico power authority privatization plan*. From CNBC Bonds: https://www.cnbc.com/2018/02/02/in-puerto-ricos-prepa-privatization-bondholders-need-to-face-reality-commentary.html

The Financial Oversight and Management Board for Puerto Rico. (2018, April 5). *Announcement*. From https://juntasupervision.pr.gov/index.php/en/home/

U.S. Energy Information Administration. (2018, April 19). *Puerto Rico Territory Energy Profile*. From https://www.eia.gov/state/print.php?sid=RQ

Walton, R. (2018, March 6). *Puerto Rico regulators, federal oversight board wrestle for control of PREPA*. From Utility Dive: https://www.utilitydive.com/news/puerto-rico-regulators-federal-oversight-board-wrestle-for-control-of-prep/518542/

Weller, J. (2018, February 9). *Puerto Rico is primed to get tens of millions in stateside investments*. From The Hill: http://thehill.com/opinion/finance/373149-puerto-rico-is-primed-to-get-tens-of-millions-in-statewide-investments