

The U.S. Department of Energy (DOE) has provided subject matter expertise, technical assistance, training, and analysis to Puerto Rico and federal agencies in support of long term power system recovery following Hurricane Maria. Below are several discrete analysis-based reports developed by DOE over the course of this effort. In addition to these reports a delegation of the National Laboratories provided PREPA employees training and technical assistance during a series of multi-day working sessions in June and October of 2018.

1. DOE, "Energy Resilience Solutions for the Puerto Rico Grid," June 2018.

DOE's Office of Electricity (OE) published the *Energy Resilience Solutions for the Puerto Rico Grid* report on June 20, 2018.^a The report contained recommendations for the Government of Puerto Rico to consider for incorporation into its recovery plans including the plan that Congress required from the Federal Emergency Management Agency (FEMA) to support the Commonwealth in developing through Section 21210 of P.L. 115-123 (2018). The recommendations reflected principles of resilience, and were intended to inform investments that used federal appropriations in the energy infrastructure in the Commonwealth of Puerto Rico.

2. DOE, "Current/Proposed Communications Plan for Puerto Rico," August 14, 2018.

OE has evaluated PREPA's communications system and provided recommendations on network configurations to improve day-to-day as well as emergency communications, building upon existing equipment and protocols. Enhanced communications capabilities will support system reliability and resilience, as well as provide a means of emergency communications for FEMA and the Puerto Rico Emergency Management Agency. This analysis was provided directly to PREPA.

3. Pacific Northwest National Laboratory (PNNL), "Improving Resilience of Puerto Rico Electric Infrastructure (Transmission)," Official Use Only, October 2018.

In this report, PNNL provides preliminary recommendations for improving grid resiliency based on power flow contingency analysis, voltage stability analysis, and dynamic contingency analysis, utilizing system models and data from PREPA. PNNL's Dynamic Contingency Analysis Tool (DCAT) was used to analyze dynamic behavior and cascading sequences resulting from major generation and transmission outages that could arise from extreme hurricane-related events. Trusted commercial tools, PSS[®]E and PowerWorld, were also used. More than 50,000 contingencies were studied, including a hurricane contingency scenario comprised of six stages of line outages. This analysis was provided directly to PREPA.

4. ANL & PNNL, "Multi-Lab Modeling Support for Critical Loads in Puerto Rico," Official Use Only, October 18, 2018.

ANL and PNNL identified the location and interconnected infrastructure of several classes of critical loads in Puerto Rico and used modeling, analysis, and industry expert consultation to prioritize resilience enhancing investments that support continuity of electricity supply to those facilities. This analysis was provided directly to PREPA.

5. SNL, "Using Energy Storage to Support Puerto Rico's Transmission System," September 2018.

This report examined the most critical near-term issues with the transmission system: frequency regulation and response, and analyzed the impacts of incorporating energy storage systems of varying sizes with the goal of immediately minimizing load shedding while laying the foundation for future renewable energy integration. The analysis concluded that 240 MW/60 MWh of energy storage would stabilize system frequency sufficiently to avoid loss of load for rapid load changes or generation outages up to and including loss of the largest generation unit on

^a https://www.energy.gov/sites/prod/files/2018/06/f53/DOE%20Report_Energy%20Resilience%20Solutions%20for%20the%20PR%20Grid%20Final%20June%202018.pdf

the island. Based on current industry average storage costs the initial power-focused energy storage capacity would be \$100-125 million. This analysis was provided directly to PREPA.

6. SNL, "Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico," September 2018.

An analysis of microgrids to increase resilience was conducted for the island of Puerto Rico. Critical infrastructure throughout the island was mapped to the key services provided by those sectors to help inform primary and secondary service sources during a major disruption to the electrical grid. Additionally, a resilience metric of burden was developed to quantify community resilience, and a related baseline resilience figure was calculated for the area. To improve resilience, SNL performed an analysis of where clusters of critical infrastructure are located and used these suggested resilience node locations to create a portfolio of 159 microgrid options throughout Puerto Rico. The team then calculated the impact of these microgrids on the region's ability to provide critical services during an outage, and compared this impact to high-level estimates of cost for each microgrid to generate a set of efficient microgrid portfolios. This analysis was provided directly to PREPA.

7. DOE, "Investment Considerations for Puerto Rico's Power System Recovery," March 2019.

Based on analysis performed by the National Labs and through extensive industry expert consultation, OE has developed a set of investment considerations for Puerto Rico's power system that could provide immediate improvements in Puerto Rico's energy system and lay the foundations of further investments in furtherance of improved resilience, renewable energy investments, and lower costs. These investment considerations have been developed in coordination with the federal interagency and shared with PREPA.