Energy Resilience in Puerto Rico – Executive Summary

The role of advanced microgrids

Columbia SIPA Capstone Team | April 2019

Wood Mackenzie
POWER & RENEWABLES

Contents

Scope of this report

This Q1 2019 forecast estimates the growth of the Puerto Rico microgrid market from 2019 through 2024

Regional coverage	This report focuses on Puerto Rico; for coverage of microgrids in the continental United States, Alaska and Hawaii, please refer to US Microgrid Forecast: H1 2019 published in March 2019.
Historical context	This report covers completed and planned microgrids that have been announced through 31 March 2019.
Segments	Wood Mackenzie divides microgrids by customer type. Microgrids are classified as one of the following: city/community, commercial, island, remote, university/research, military and public institution. See the Appendix for definitions of these clusters.
Technologies	Microgrids encompass many technologies including distributed generation, energy storage and demand response; Wood Mackenzie tracks the generation mix of each microgrid resource including renewables (i.e., solar photovoltaic, wind, hydro, fuel cell), fossil (i.e., diesel and natural-gas generators) and energy storage.
Market size	Unless otherwise specified, market size is reported in megawatts of deployments (i.e., interconnected and operational) by year and segment.
Capacity metrics	Capacity reported in this report is denoted in megawatts (MW) unless otherwise noted. In keeping with industry convention, Wood Mackenzie defines capacity in terms of the interconnected power capacity, or nameplate capacity.

Source: Wood Mackenzie Power & Renewables

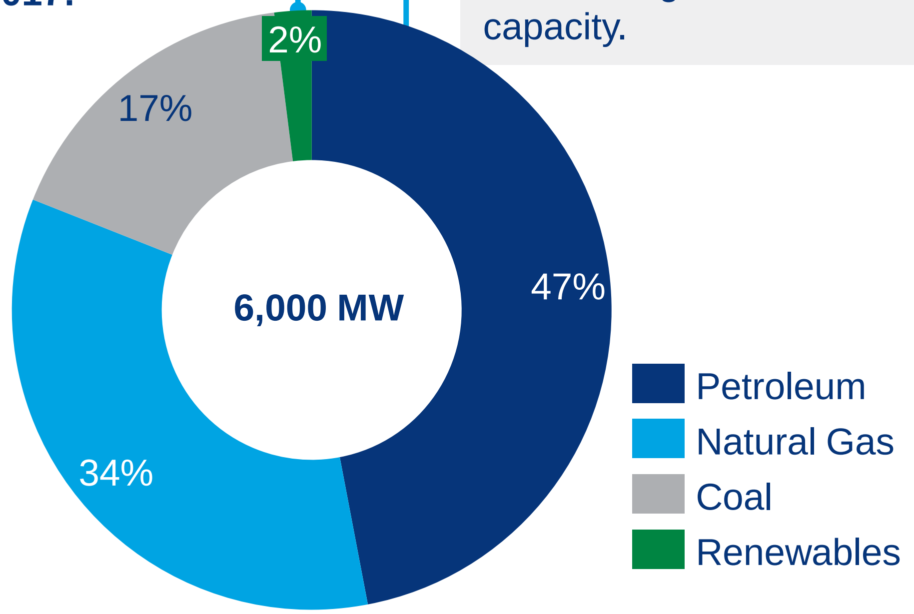
1. Introduction and key findings

As of June 2017 Puerto Rico had 6,000 MW electricity generating capacity

Prior to Hurricane Maria, resiliency for Puerto Rico's electric grid was a priority

- Prior to Hurricane Maria and Irma, PREPA suffered recurring outages which left the island of Puerto Rico without power. However, all customers were being serviced.
- These outages, often occurring several days at a time, lead nearly one-quarter of high-rise buildings and most homeowners to install and use diesel-fired generators as emergency back-ups.
- Imported petroleum projects fueled transportation, electricity generation, and industry, supplying 75% of energy consumed on the island.
- Due to maintenance and non-compliance with the Environmental Protection Agency, roughly 30% of generating plants were not operational prior to Hurricane Maria.

In the fiscal year ending June 30, 2017:



41% comes from two wind farms: one of them, the 95-megawatt Santa Isabel facility, is the largest wind farm in the Caribbean.

127-megawatts utility-scale solar photovoltaic generating capacity and 88 megawatts of distributed capacity.

Source: Wood Mackenzie Power & Renewables, Puerto Rico Energy Commission, Solar Magazine, US Energy Information Administration

The aftermath of Hurricane Maria rippled through Puerto Rico's electric grid

Sep 2017

September 6, Hurricane Irma cuts off power to two-thirds of Puerto Rico's electricity customers.
On September 20, Hurricane Maria hit Puerto Rico, destroyed most of the island's electric grid, including 80% of the transmission and distribution system.

Intact generators could not supply power due to the lack of functioning transmission infrastructure, leaving most of the island without power.

Oct 2017

By October 3, Power had been restored to approximately 10% of customers. Full restoration was expected to take months, and many Puerto Rican homeowners and businesses bought gas and diesel-fired generators.

Nov 2017

Six weeks after Hurricane Maria, 30% of customers had been restored.

By mid-November 50% of Puerto Ricans were still without power.

Aug 2018

Nearly a year after Maria, PREPA reported that power had been restored to all homes that lost electricity from the storm.

Source: Wood Mackenzie Power & Renewables, Puerto Rico Energy Commission, Solar Magazine, US Energy Information Administration

Basic microgrids lead the operational capacity

However, the majority of planned projects are advanced microgrids

Microgrids in the Wood Mackenzie context

WoodMac defines microgrids as an independently operable part of the distribution network that has the following features:

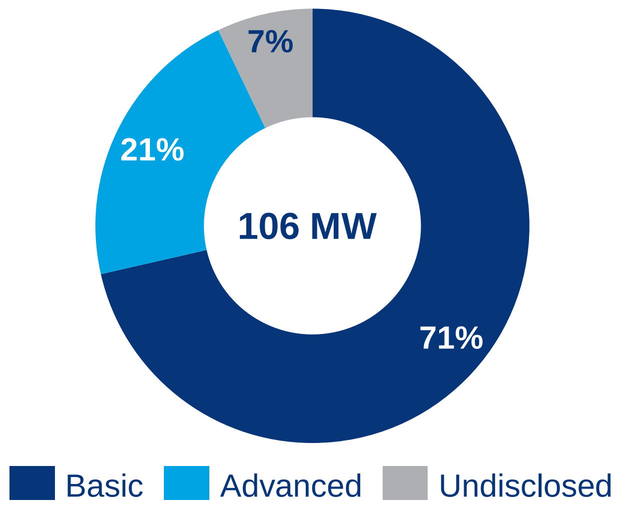
1. Ability to provide power and energy services in both grid-connected and island mode
2. Single building (> 100 kW) or multiple buildings
3. Local electric and/or heat generation and load
4. Advanced distributed energy resources (DERs) and grid asset control, monitoring and dispatch

WoodMac further delineates microgrids into basic and advanced systems:

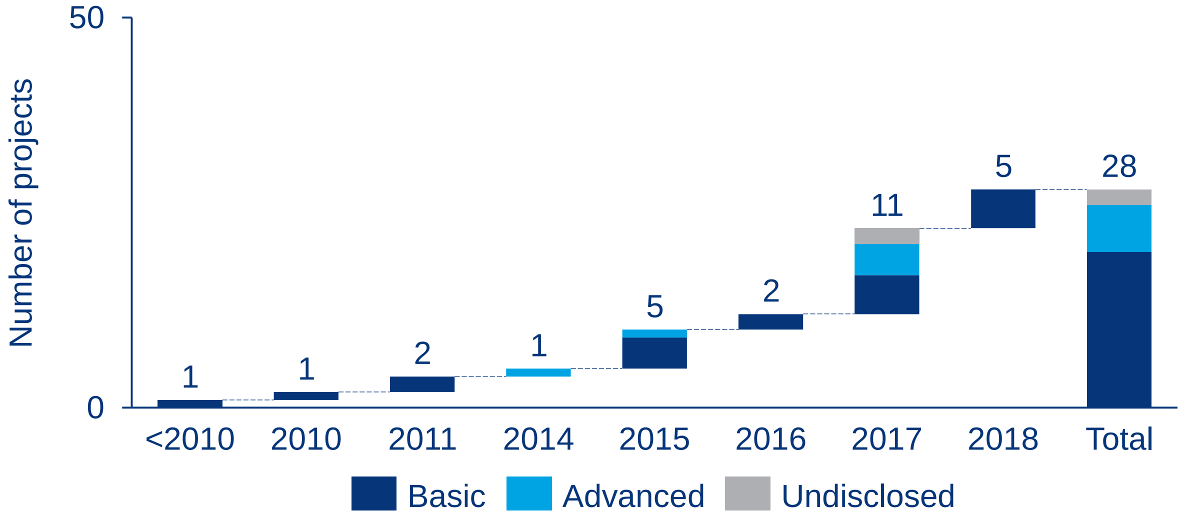
1. Advanced microgrids have multiple DERs and complex controls
2. Basic microgrids have one deployed DER technology, with the ability to island for at least 24 hours, that can provide power and energy services both in grid-connected or islanded modes

DERs that cannot run in parallel with the grid do not qualify as microgrids under our definition.

Operational microgrid capacity by complexity, Q1 2019



Operational and planned microgrids by complexity



Note: There are 13 planned projects, 38% basic and 62% advanced

Source: Wood Mackenzie Power & Renewables

The microgrid market in Puerto Rico has faced challenges for growth

The barriers to developing microgrids in Puerto Rico include policy delays, investment uncertainties and lack of financing

Puerto Rico is a relatively small market for microgrids, in which few large projects account for the majority of installed capacity

60% of the microgrid capacity addition between 1989 and 2018 came from three large scale projects of around 20 MW each. 85% of installed capacity added in the East and South can be explained by a single large project respectively. In the North of Puerto Rico, 27% of installed capacity comes from one project. This demonstrates both how small Puerto Rico's microgrid current systems are, and that the market is in fact determined by three large projects.

Grid resiliency, access to clean energy and reliable supply of electricity are the primary drivers for microgrids. CHP and Solar dominate the market

The driving factors for the large projects are enhancing resiliency and providing access to clean energy, whereas the driving factors for smaller projects are enhancing grid resiliency and reliability of supply, lower upfront cost of smaller systems and the ability to quickly install them. Solar PV and CHP account for 44% and 35% of the total capacity of 106.2 MW installed in 2018. Solar PV capacity is primarily driven by two large projects coming online in 2015, whereas CHP plants primarily based on diesel are deployed in pharmaceutical companies, commercial sector like hospitals, sports complex and manufacturing facilities. Large commercial customers will continue to rely on CHP/diesel generators. A lot of small solar projects are coming online on the island, however, as they are lower than 100 kW, are not considered in this report.

Once finalized, microgrid interconnection regulations will contribute to vendor, developer, and investor confidence

Before Hurricane Maria, Puerto Rico had interconnection regulations for distributed energy resources (DERs) but did not have regulatory framework for larger microgrid systems. After Hurricane Maria, Puerto Rico Energy Commission (PREC) approved microgrid regulations, but Puerto Rico Electric Power Authority (PREPA) continues to delay regulations for microgrid interconnection, so PREC is now in the process of developing the microgrid interconnection regulations. The lack of enforcement and the privatization of PREPA contribute to uncertainties in the near future, but when PREC finishes developing microgrid interconnection regulations, vendors, developers, and investors will have more confidence in entering Puerto Rico's microgrid market.

We expect limited capacity growth in 2019 and 2020, with a significant rise in 2021 and 2022, and steady growth afterwards

Uncertainty surrounding policy enforcements has driven down the pipeline capacity in 2019 and 2020, which explains the limited capacity growth during these two years. The capacity additions will experience significant growth in 2021 and 2022 due to the pipeline of four large projects. CHP projects will continue dominating the market as commercial users choose to install CHP units to replace diesel backup generators for resiliency and reliability, with an increased integration of renewables.

Source: Wood Mackenzie Power & Renewables

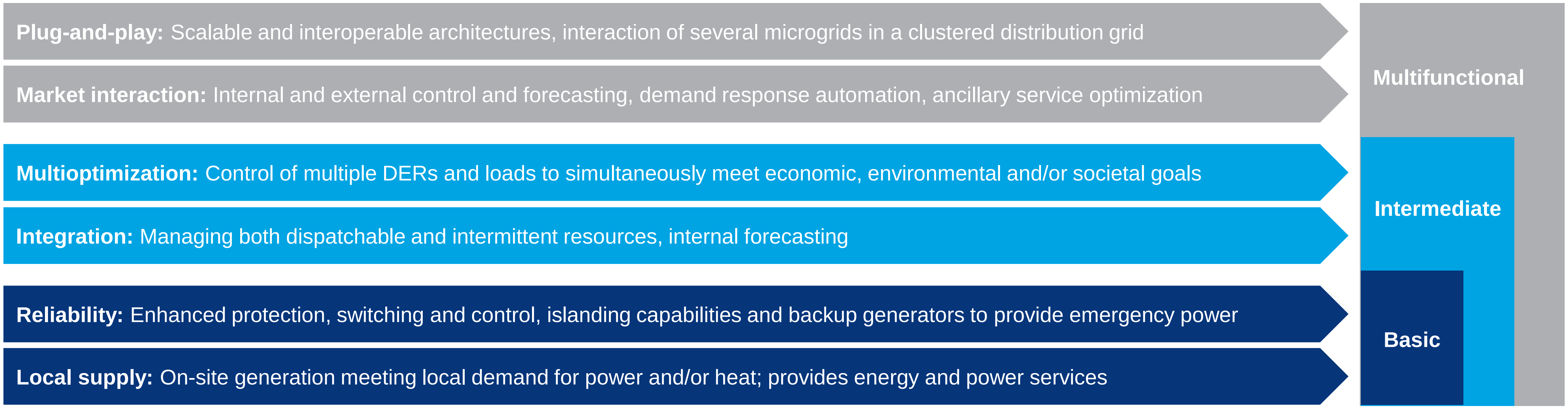
5 Appendix

Advanced vs. basic microgrids

Segmentation

Microgrids vary in complexity ranging from a basic microgrid – a backup generator that is capable of running in parallel with the grid and has the ability to automatically island and resynchronize to the grid after an outage – to a multifunctional microgrid with increased capabilities providing more flexible generation and enhanced reliability to both the local community and the bulk power grid. For the purpose of our research, intermediate and multifunctional microgrids will both be referred to as advanced microgrids.

Basic power management and supply technologies for remote or island communities continue to be deployed, and wider-ranging behind-the-meter, utility and wholesale market applications have rapidly developed within recent years, allowing organizations to re-examine their applicability to broader use cases that can apply to multiple stakeholders. Notable ongoing research initiatives and technology commercialization-oriented programs indicate that microgrids may become the building blocks of an increasingly diffuse yet interconnected distribution network of the future. The figure below describes key characteristics that we have found to be common across microgrids of the same level of complexity.



Source: Wood Mackenzie Power & Renewables

Definition of microgrid ownership models

End user: The majority of end-user-owned microgrids are driven by stacking value propositions, almost always inclusive of added onsite reliability. Large customers, such as the military, university campuses or data centers, are increasingly willing to pay for a higher degree of energy security. This ownership class is simply defined to be a behind-the-meter project (often interconnected to the low-voltage grid) that is entirely owned and operated by the end customer. Examples include many universities (e.g., the 26 MW Princeton University Microgrid), military bases (e.g., Fort Hood’s 30 MW deployment), and commercial properties (e.g., Stone Edge Farm Estate Vineyards’ Sonoma Microgrid).

Utility: Owned by the regulated utility, microgrids that employ this ownership structure are generally operated as 1) a “non-wires alternative” solution to defer transmission and/or distribution investment (e.g., substation or line capacity upgrades) by addressing congestion, capacity constraints and/or reliability on a feeder; 2) a “public-purpose” solution to modernize existing assets and better serve underlying customers; or 3) a customer-sited solution that is partially leased to a tenant for added reliability while also providing the utility with a source of local generation and grid support. In recently deployed and prospective customer-sited utility-owned projects, the utility has generally covered project costs including design, permitting, finance, construction and operations and maintenance, while leasing the facility to the end customer at a significantly reduced price. Each contract agreement would further define resource-dispatch rights and obligations. In regulatory regimes that permit utility-controlled DERs, the utility often holds the right to dispatch onsite generation to target local congestion and provide grid services while the end customer benefits from guaranteed onsite backup generation.

Utility-owned microgrid examples includes Duke’s McAlpine Creek Circuit and Mount Holly microgrids, PGE’s Salem Power Center and Oncor’s Lancaster Microgrid, as well as the military’s Fort Huachuca Direct Coupling Microgrid (owned and operated by Tucson Electric Power).

Source: Wood Mackenzie Power & Renewables

Definition of microgrid ownership models (continued)

Third party: Traditionally provided through a long-term agreement (e.g., custom-designed lease or PPA), third-party energy service companies (including deregulated utility branches) like Duke Energy Renewables, Hitachi, Enchanted Rock (through its joint venture Texas Microgrids), Ameresco and NRG are increasingly providing “microgrids-as-a-service.” Such an offering can significantly reduce end-customer liabilities including capital investments and O&M costs.

Examples include the Duke Energy- and REC-owned and -operated microgrid at Schneider Electric’s Boston One Campus; Cogen Power Technologies’ Burrstone Energy Center (between Faxton-St. Luke’s Healthcare, St. Luke’s Nursing Home and Utica College); and Gen-X Energy Development’s SkyGrid Microgrid in Hawaii. Several other microgrids employ third-party ownership models but have been categorized under “mixed,” as other stakeholders also hold ownership rights to the microgrid and underlying assets.

Municipality/community: The recent wave of state-level resilience programs has spurred the development of community-type microgrids for outage and storage resilience. While projects are still competitively solicited, incentives often play a major part in the decision-making process. Municipality/community projects can range from single-site wastewater plants to multi-site critical infrastructure deployments that include several stakeholders (e.g., municipalities, regulated utilities, behind-the-meter customers, etc.). Distinguished from the “mixed” category, these projects focus on community- and/or municipality-owned critical infrastructure. Though these projects have not yet resulted in significant capacity deployment due to the relatively small size of their critical load, the next stage of state-driven programs (e.g., NYSERDA’s NY Prize) are moving beyond feasibility studies toward actual project development.

Examples include many several Alaskan remote communities (e.g., Kodiak Island), municipal projects under Connecticut’s DEEP program (e.g., Town of Windham), and others.

Mixed: Microgrids that host multiple owners and operators of the system and underlying assets. Mixed co-ownership examples include Bridgeport University (NRG owns fuel cell), Aligned Data Center Microgrid (with Arizona Public Service), MCAS-Yuma (also with APS), Woodbridge (United Illuminating owns the fuel cell), the proposed New Jersey TransitGrid microgrid, and SDG&E’s Borrego Springs microgrid expansion (to include NRG’s 26 MW solar generation facility and expanded to incorporate all 2,800 metered customers in Borrego Springs).

Source: Wood Mackenzie Power & Renewables

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