Energy Resilience for Puerto Rico

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SAND2019-7036 C
Hurricanes Irma and Maria devastated Puerto Rico in September 2017

“Hurricanes Irma and Maria devastated Puerto Rico, bringing sustained winds well in excess of 150 miles per hour, heavy rains, and catastrophic flooding the likes of which the island had never seen before”

“The storms caused nearly complete devastation, including the catastrophic failure of the Island’s power grid, water and wastewater infrastructure, and communications networks”

“The economy of the island ground to a halt in the face of physical damages, loss of supporting infrastructure, and the absence of power and water.”

“Roads and bridges failed or were blocked by debris across the island, leaving communities stranded and unable to obtain life-saving aid, food, water and medicine for a period of weeks. **More than 472,000 housing units were destroyed** or experienced major damages.”

Early on September 20, Hurricane Maria a powerful Category 4 hurricane directly hit Puerto Rico crossing the entire island and dumping feet of rain.

“Build Back Better- Puerto Rico”, Request for Federal Disaster Assistance
November, 2017

➤ “Months after the storm hit (November 2017) approximately 60% of the island was still without power”

➤ “Since Maria made landfall seven months ago, more than 100,000 Americans are still without power on the island” (May 2018)

➤ “Caused the longest sustained power outage in U.S. history”

“70 % of the potable water is either unavailable or has yet to be certified as safe to drink “ (November 2017)

“Thousands of businesses are closed or have limited operations including the pharma manufacturing industry, which caused serious shortages of drugs supplies in the US. Pharmaceutical products made in Puerto Rico account for nearly 10 percent of all drugs consumed by Americans.”
Project 1: Industrial Microgrids

SNL and ORNL have partnered with the Puerto Rico Industrial Development Company (PRIDCO) to investigate the potential of industrial-scale microgrids in strategic locations on the island to bolster the resiliency of these and (potentially) surrounding locations.

Many industrial sites on the island experienced weeks to months running on backup diesel generators in an attempt to continue operations while also providing a place for employees and their families to gather where they could have lights and showers. In order to keep and attract new tenets to Puerto Rico in the wake of Hurricane Maria, PRIDCO is investing in 4 industrial-scale sites as a pilot project.
Where to focus our efforts?

DOE office of electricity asked SNL and ORNL to team up to support the rapid installation of Industrial Microgrids in Puerto Rico.
Puerto Rico – Municipalities and Proposed Microgrid Locations
Añasco Site – Aerial View
Añasco

EDWARD LIFESCIENCES

Sole supplier to the whole world of the Swann-Ganz hemodynamic monitoring catheter. Catheter used to monitor oxygenation, blood pressure and temperature for people in critical care of the hospitals, i.e. after an open-heart surgery.

J & J VISION CARE (AMO MANUFACTURING)

Manufactures intraocular contact lenses cataracts and myopia correction. This division of J&J is the largest supplier in USA and in the world of “Lasik” surgery and the intra-ocular contact lenses is the consumable.

INTEGRA

Critical supplier of J&J in collagen products, including a wound healing wrap used after surgeries and accidental wounds. Also, they provide different devices for the treatment of hydrocephaly.

GENERAL ELECTRIC (GE)

In the Añasco facility, they manufacture, power line monitoring systems.

AMPHENOL

Critical supplier to Edwards, they provide temperature sensors that are installed in the Swann-Ganz catheter that Edwards manufactures. Also, they supply the automotive and heavy equipment (Caterpillar) with the pressure sensors and differential pressure sensors that are used in the engines of the equipment.

CARDINAL HEALTH

In the Añasco facility, Cardinal manufactures all of the nylon tubing and IV sets for Cardinal Health which is one of the major healthcare providers of the US.

TECHNO PLASTICS (Small Business)

Critical supplier of the injection molded and subassemblies for the medical device industry, including the ones located in the Añasco Industrial Park.

EMPLOYEES 3,000
Aguadilla Site – Aerial View

HONEYWELL
Services supplier to the commercial and defense aerospace.

PRATT & WHITNEY
Services provider to defense aerospace sector.

HEWLETT PACKARD ENTERPRISE
One of the cloud servers’ data center for Hewlett Packard. Provides cloud services to the whole world.

Total Employees
1,900
Jayuya Site – Aerial View

**BAXTER HEALTHCARE**

Major supplier of Saline solution to the hospitals in mainland US.

**ABBVIE**

Manufactures Levothyroxine under the Synthroid brand which is the preferred by the Physicians, and the Americas supply is manufactured in this facility.

**Total Employees**

600
United Technologies - Aerospace parts manufacturer for defense and commercial aircraft.

Ag Reliant - Agricultural Biotechnology lab in corn, soybean, sorghum, cottonseed and sunflower.

Accenture - Administrative services for UTC

DHL - Logistics services for UTC

Total Employees: 2,400 *

*includes seasonal employees
## Implementation Summary

<table>
<thead>
<tr>
<th>Site</th>
<th>Microgrid Development Potential</th>
<th>Industries Supported</th>
<th>Econ. Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediate Action</td>
<td>Longer Term Action</td>
<td>Direct Jobs</td>
</tr>
<tr>
<td>Añasco</td>
<td>●</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>Aguadilla</td>
<td>●</td>
<td></td>
<td>1,900</td>
</tr>
<tr>
<td>Jayuya</td>
<td>●</td>
<td></td>
<td>600</td>
</tr>
<tr>
<td>Barceloneta/Manati</td>
<td>●</td>
<td>●</td>
<td>4,660</td>
</tr>
<tr>
<td>Juana Diaz</td>
<td>●</td>
<td></td>
<td>3,050</td>
</tr>
<tr>
<td>Santa Isabel</td>
<td>●</td>
<td></td>
<td>2,400</td>
</tr>
<tr>
<td>Canovanas</td>
<td>●</td>
<td></td>
<td>175</td>
</tr>
<tr>
<td>Humacao</td>
<td>●</td>
<td></td>
<td>1,155</td>
</tr>
</tbody>
</table>
Goals for Conceptual Resilient Microgrid Design

Focus on resilient microgrids that maximize the amount of renewable energy while using conventional gensets and storage to meet LCOE targets of less than $0.20 per kWh.

- Minimize the use of diesel fuel to reduce supply line risk.
- Standalone microgrid mode to supply 100% of power needs in industrial park without the need to connect to local utility. Avoid interconnection delays.
- Renewable Energy to reduce environmental impact and increase resiliency.
- Meet a cost target below current utility rates to make microgrid projects attractive to tenant businesses.
- Challenge to address multi tenant microgrids.
# Añasco Site – Location Map

## AREA AVAILABLE

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofing (sf)</td>
<td>256,114</td>
</tr>
<tr>
<td>Empty Lots (quantity)</td>
<td>1</td>
</tr>
<tr>
<td>Empty Lots (acres)</td>
<td>2.63</td>
</tr>
<tr>
<td>Parking Lots (quantity)</td>
<td>5</td>
</tr>
<tr>
<td>Parking Lots (acres)</td>
<td>6.88</td>
</tr>
</tbody>
</table>

### Undeveloped Land

### Tenants:

- **A** Edwards Lifesciences
- **B** J&J Vision Care (AMO)
- **C** Amphenol

### Additional Tenants that do not appear in the map:

- Cardinal Health PR
- Techno-Plastics Industries
- Integra Neurosciences PR
- GE Industrial of PR

![Diagram of the Añasco Site with labels for Undeveloped Land, Empty Lots, Parking Lots, and Tenants](image-url)
Añasco Sandia Microgrid Model
Rooftop PV: 1.0MW,
Empty Parking Lot PV (repurpose for PV only): 0.5MW,
Active Parking Lot PV (canopy style): 0.5MW
Total ~2MW
Añasco Industrial Park
### 3 solutions with different cost/performance trade-offs

<table>
<thead>
<tr>
<th>1: Most Expensive, Highest Performing</th>
<th>2: Middle Expense, Middle Performance</th>
<th>3: Lowest Expense, Lowest Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New PV</strong></td>
<td>5,000 kW</td>
<td>None</td>
</tr>
<tr>
<td><strong>New Diesel</strong></td>
<td>1,600 kW</td>
<td>1,600 kW</td>
</tr>
<tr>
<td><strong>New Storage</strong></td>
<td>1000 kW / 2000 kWh</td>
<td>250 kW / 500 kWh</td>
</tr>
<tr>
<td><strong>Purchase Cost</strong></td>
<td>$18,529,000</td>
<td>$1,655,000</td>
</tr>
<tr>
<td><strong>Energy Availability</strong></td>
<td>99.999609%</td>
<td>99.873061%</td>
</tr>
<tr>
<td><strong>Diesel Fuel Used (Gal. per Day)</strong></td>
<td>8316.96</td>
<td>6,538</td>
</tr>
<tr>
<td><strong>Natural Gas Used (MBTU per Day)</strong></td>
<td>296</td>
<td>271</td>
</tr>
<tr>
<td><strong>Total Diesel Generation</strong></td>
<td>5,900 kW</td>
<td>5,900 kW</td>
</tr>
<tr>
<td><strong>Total Natural Gas Generation</strong></td>
<td>1,100 kW</td>
<td>1,100 kW</td>
</tr>
<tr>
<td><strong>Total Solar Generation</strong></td>
<td>5,000 kW</td>
<td>5,000 kW</td>
</tr>
<tr>
<td><strong>Overall Diesel Efficiency</strong></td>
<td>36.78%</td>
<td>36.45%</td>
</tr>
<tr>
<td><strong>Overall Diesel Utilization</strong></td>
<td>83.05%</td>
<td>78.71%</td>
</tr>
<tr>
<td><strong>Overall Natural Gas Efficiency</strong></td>
<td>24.93%</td>
<td>24.66%</td>
</tr>
<tr>
<td><strong>Overall Natural Gas Utilization</strong></td>
<td>83.05%</td>
<td>79.72%</td>
</tr>
</tbody>
</table>
LCOE and Budget Estimates

<table>
<thead>
<tr>
<th></th>
<th>Añasco</th>
<th>Aguadilla</th>
<th>Jayuya</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gen+PV+Battery costs</td>
<td>LCOE</td>
<td>Gen+PV+Battery costs</td>
</tr>
<tr>
<td>1: Most Expensive, Highest Performing</td>
<td>$32,314,000</td>
<td>$0.230</td>
<td>$61,457,500</td>
</tr>
<tr>
<td>2: Middle Expense, Middle Performance</td>
<td>$18,529,000</td>
<td>$0.184</td>
<td>$35,232,500</td>
</tr>
<tr>
<td>3: Lowest Expense, Lowest Performance</td>
<td>$1,655,000</td>
<td>$0.128</td>
<td>$11,257,500</td>
</tr>
</tbody>
</table>

Microgrid performance was measured by energy availability and fuel consumption.
Assumptions and caveats for LCOE analysis:
- Simulation period is for 1 year of continuous standalone microgrid operation based on an estimated load profile- 8760 hours.
- Capital cost to be financed at 6.5%. 100% financed assumed.
- Asset life time 25 years
- No PV degradation.
- Existing generation can be run continuously for no additional cost assumed for Añasco case. All new generation assumed for Aguadilla Case.
- The “Puerto Rico adder” over mainland estimated cost per KW of generation asset not yet estimated.
- T&D costs to build the connectivity of the microgrid not yet estimated and BOS not yet estimated.
- Battery utilization is small with current dispatch scheme in MDT that prioritizes energy availability. We are working on alternative formulations.
### PRIDCO Sites Table Summary

<table>
<thead>
<tr>
<th></th>
<th>Aguadilla</th>
<th>Añasco</th>
<th>Jayuya</th>
<th>Santa Isabel</th>
<th>Juana Diaz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solar Potential</strong></td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Load (MVA/MW Peak)</strong></td>
<td>18.75/15*</td>
<td>9.4/7.5*</td>
<td>6.25/5*</td>
<td>4.7/4.2</td>
<td>9.7/8.7</td>
</tr>
<tr>
<td><strong>PQ/Outage Issues</strong></td>
<td>Several per month</td>
<td>Several per month</td>
<td>Several per month</td>
<td>Several per month</td>
<td>Several per month</td>
</tr>
<tr>
<td><strong>Critical Supplier?</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No (in top 3)</td>
</tr>
<tr>
<td><strong>Off-Grid Motivation</strong></td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Cost Estimate (Middle Case for Performance)</strong>*</td>
<td><strong>$35,000,000 w/ 9 MW of PV</strong></td>
<td><strong>$18,500,000 w/ 5 MW of PV</strong></td>
<td><strong>$12,000,000 w/ 4 MW of PV</strong></td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td><strong>Employees</strong></td>
<td>1900</td>
<td>3000</td>
<td>600</td>
<td>1500+</td>
<td>1500</td>
</tr>
</tbody>
</table>

* Estimated value
** See LCOE slide for list of assumptions. Cost estimate is for generation assets only.
Status of Project

- PRIDCO and SNL and ORNL provided detailed technical and regulatory feedback and suggested changes to the new Puerto Rico microgrid rule proposed by the Puerto Rico regulatory commission.
- A Request for Proposals on four industrial microgrid solutions was issued in Fall 2018 and the response was excellent with industry estimated solutions right in the target LCOE range.
- PRIDCO has selected two vendors to provide CHP/Solar/Storage and NG generators for 4 sites.

- Conceptual design
- Decision to proceed
- Procurement
- Engineering Design
- Commissioning
- Operation
“Since Maria made landfall seven months ago, more than 100,000 Americans are still without power on the island” (May 2018). 5% left unserved
Advanced DER Integration Analysis and Methodology
Partner: University of Puerto Rico

- Identify loss of service areas by comparing pre hurricane and after 4-6 months nighttime images
- Overlay population density map and estimate amount of customers affected
- Locate critical infrastructure in previously identified areas
- Evaluate impact of new distributed generation assets
NASA nighttime light images

Baseline (Pre-Hurricane)

3-4 Months After Hurricane

Reference: https://svs.gsfc.nasa.gov/4658
Key water and telecommunications infrastructure

Pumping Stations

Population Density Color Mapped

Radio/Cellphone Towers
Current Work

- **Census Population Data Processing**
  - Import Census Shapefile into Google Earth

- **Extreme Blackout are identification**
  - Import NASA nighttime images
  - Identity extreme blackout areas of interest.

- **Resource Clustering of Identified Areas**
  - Import infrastructure datasets
  - Identify key areas for test cases.

Future Work

- Select test cases from identified areas
- Run power flow simulations to determine impact of DER and microgrid at selected areas.
Questions?

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