Energy Resilience for Puerto Rico

Industrial Microgrid Project

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Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525.
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.”
Where to focus our efforts?

A Modern and Diversified Economy

Gross Domestic Product Share by Main Economic Sector
Fiscal Year 2016

GNP
$70.1 billion

GDP
$105.0 billion

GDP PER CAPITA
$30,516

EXPORTS VALUE
$71.9 billion

IMPORTS VALUE
$43.3 billion

DOE office of electricity asked SNL and ORNL to team up to support the rapid installation of Industrial Microgrids in Puerto Rico.
PRIDCO – Puerto Rico Industrial Development Company
PR Cluster Map: Life Sciences
Puerto Rico – Municipalities and Proposed Microgrid Locations
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 for 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
Juana Diaz Site – Aerial View

80% of the manufacturing capacity of the company in the world and is the #2 global supplier of the daily use contact lenses.

**COOPERVISION**

Is one of the supplier of cotton seeds and corn seeds to the USA farmers. Plus has an Agriculture Biotechnology laboratory in corn, soybean, sorghum, cottonseed and sunflower.

**MONSANTO (BAYER)**

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

**SYNGENTA**

**Total Employees**

3,050 *

*includes seasonal employees
## Santa Isabel Site – Aerial View

### 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

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**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>Pharma./Medical</td>
</tr>
<tr>
<td>Añasco</td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Aguadilla</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jayuya</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barceloneta/Manati</td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Juana Diaz</td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Santa Isabel</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canovanas</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humacao</td>
<td>●</td>
<td></td>
<td></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.
Investment Options: Conceptual Design

- A resilience framework compares conceptual designs options
  - Technical description of candidate resilience improvements and their respective cost estimates
  - Could involve optimization and analysis of trade-offs among options
- Useful engage stakeholders and drive decision-making

- Conceptual design
- Decision to proceed
- Procurement
- Engineering Design
- Commissioning
- Operation
Design Optimization Tools

Sandia Microgrid Design Toolkit (MDT)

- A decision support tool for early-stage resilience design involving microgrids.
- Has functions to identify and compare microgrid design options in terms of user defined objectives such as cost, performance, and reliability.
- Provides many views and features to help explore that trade space and extract information.
- Publically available
Mission Requirements and Baseline Models
- Equipment deployed creates demand
- Or demand (load) models
- Or custom load models

Equipment Data Base
- Energy demand/production
- Usage specification
- Reliability information

Technology Options and User Inputs
- Identify energy producers and technology options
- Select location & season (solar and/or wind profile)
- Reliability and maintenance cost data
- Select user mode
  - Performance analysis
  - Parametric study
  - Optimization

MDT Results
- Energy performance
  - Energy availability, cost, fuel used, volume, silent watch, gen utilization
- Parametric sweep results
- Optimal & feasible solutions
  - Generator types/counts
  - PV type/amount
  - Battery type/quantity

ITERATIONS to Refine Results
Microgrid Design Toolkit (MDT)

- MDT calculates a Pareto Frontier, a set of solutions that represent efficient trade-offs among the design objectives.

Each point represents a complete, unique microgrid design.

Point “A” is the highest cost, highest performing solution. Point “B” is the lowest cost, lowest performing solution. There are many options in between representing different trade-offs.

Given any point on the chart, no improvement in cost can be made without corresponding decrease in performance and visa versa.

This chart shows 2 objective dimensions, cost and performance. The MDT supports up to 5 dimensions.
### Añasco Site – Location Map

#### AREA AVAILABLE

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></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>

#### 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
Añasco Sandia Microgrid Model
Añasco Sandia Microgrid Model

PV potential initial assessment

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><strong>1: Most Expensive, Highest Performing</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New PV</td>
<td>10,000 kW</td>
</tr>
<tr>
<td>New Diesel</td>
<td>1,600 kW</td>
</tr>
<tr>
<td>New Storage</td>
<td>None</td>
</tr>
<tr>
<td>Purchase Cost</td>
<td>$32,314,000</td>
</tr>
<tr>
<td>Energy Availability</td>
<td>100%</td>
</tr>
<tr>
<td>Diesel Fuel Used (Gal. per Day)</td>
<td>5487</td>
</tr>
<tr>
<td>Natural Gas Used (MBTU per Day)</td>
<td>201</td>
</tr>
<tr>
<td>Total Diesel Generation</td>
<td>5,900 kW</td>
</tr>
<tr>
<td>Total Solar Generation</td>
<td>10,000 kW</td>
</tr>
<tr>
<td>Diesel Fuel Used (Gal. per Day)</td>
<td>8316.96</td>
</tr>
<tr>
<td>Natural Gas Used (MBTU per Day)</td>
<td>296</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>2: Middle Expense, Middle Performance</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New PV</td>
<td>None</td>
</tr>
<tr>
<td>New Diesel</td>
<td>1,600 kW</td>
</tr>
<tr>
<td>New Storage</td>
<td>1000 kW / 2000 kWh</td>
</tr>
<tr>
<td>Purchase Cost</td>
<td>$18,529,000</td>
</tr>
<tr>
<td>Energy Availability</td>
<td>99.999609%</td>
</tr>
<tr>
<td>Diesel Fuel Used (Gal. per Day)</td>
<td>6,538</td>
</tr>
<tr>
<td>Natural Gas Used (MBTU per Day)</td>
<td>271</td>
</tr>
<tr>
<td>Total Diesel Generation</td>
<td>5,900 kW</td>
</tr>
<tr>
<td>Total Solar Generation</td>
<td>5,000 kW</td>
</tr>
<tr>
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<td>8316.96</td>
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<tr>
<td>Natural Gas Used (MBTU per Day)</td>
<td>296</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>3: Lowest Expense, Lowest Performance</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New PV</td>
<td>None</td>
</tr>
<tr>
<td>New Diesel</td>
<td>1,600 kW</td>
</tr>
<tr>
<td>New Storage</td>
<td>250 kW / 500 kWh</td>
</tr>
<tr>
<td>Purchase Cost</td>
<td>$1,655,000</td>
</tr>
<tr>
<td>Energy Availability</td>
<td>99.873061%</td>
</tr>
<tr>
<td>Diesel Fuel Used (Gal. per Day)</td>
<td>5487</td>
</tr>
<tr>
<td>Natural Gas Used (MBTU per Day)</td>
<td>201</td>
</tr>
<tr>
<td>Total Diesel Generation</td>
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<td>8316.96</td>
</tr>
<tr>
<td>Natural Gas Used (MBTU per Day)</td>
<td>296</td>
</tr>
</tbody>
</table>

Overall Diesel Efficiency
- **1**: 28.05%
- **2**: 36.45%
- **3**: 36.78%

Overall Diesel Utilization
- **1**: 53.04%
- **2**: 78.71%
- **3**: 83.05%

Overall Natural Gas Efficiency
- **1**: 18.56%
- **2**: 24.66%
- **3**: 24.93%

Overall Natural Gas Utilization
- **1**: 53.04%
- **2**: 79.72%
- **3**: 83.05%
## 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>$35,000,000 w/ 9 MW of PV</td>
<td>$18,500,000 w/ 5 MW of PV</td>
<td>$12,000,000 w/ 4 MW of PV</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.
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 Information on potential industrial microgrid solutions was issued in April 2018 and the response was excellent with industry estimated solutions right in the target LCOE range.

Supporting PRIDCO with the development of an RFP for the 5 sites.

Formulate candidate design
Adjust, Optimize
Evaluate Performance

- Conceptual design
- Decision to proceed
- Procurement
- Engineering Design
- Commissioning
- Operation
Questions?

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