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Sandia National Laboratories

Energy Resilience for Puerto Rico

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U.S. DEPARTMENT OF ENERGY NNSA

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Hurricanes Irma and Maria devastated Puerto Rico in September 2017

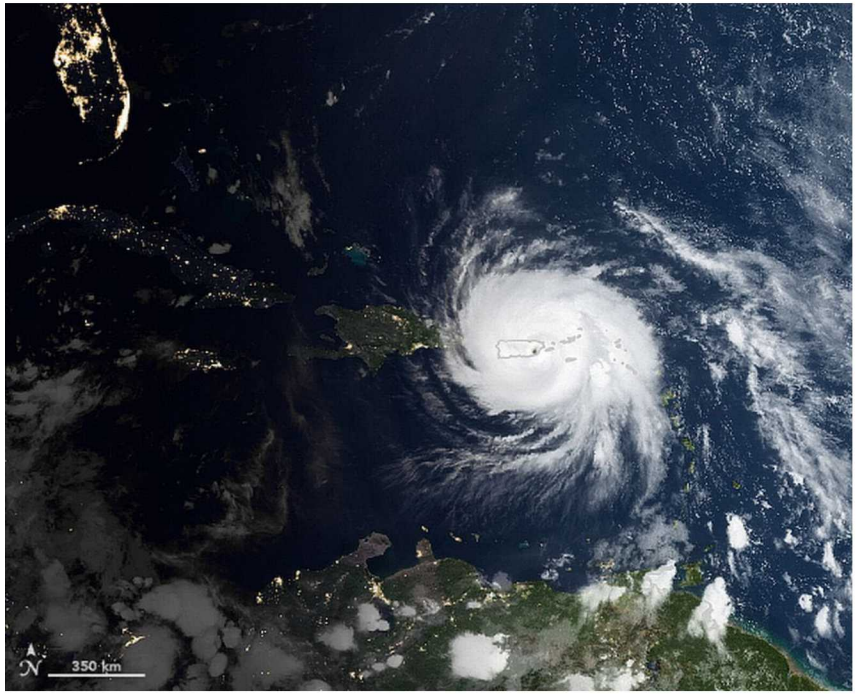
"Hurricanes Irma and Maria devastated Puerto Rico, bringing sustained winds well in excess of 150 miles per hour, heavy rains, and catastrophic flooding the likes of which the island had never seen before"

"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."

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



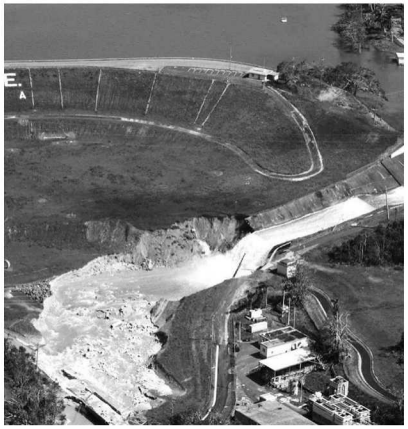
NASA Earth Observatory images by Joshua Stevens

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

Highlighted Impacts: Power System, Water, Impact on Economy

"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)

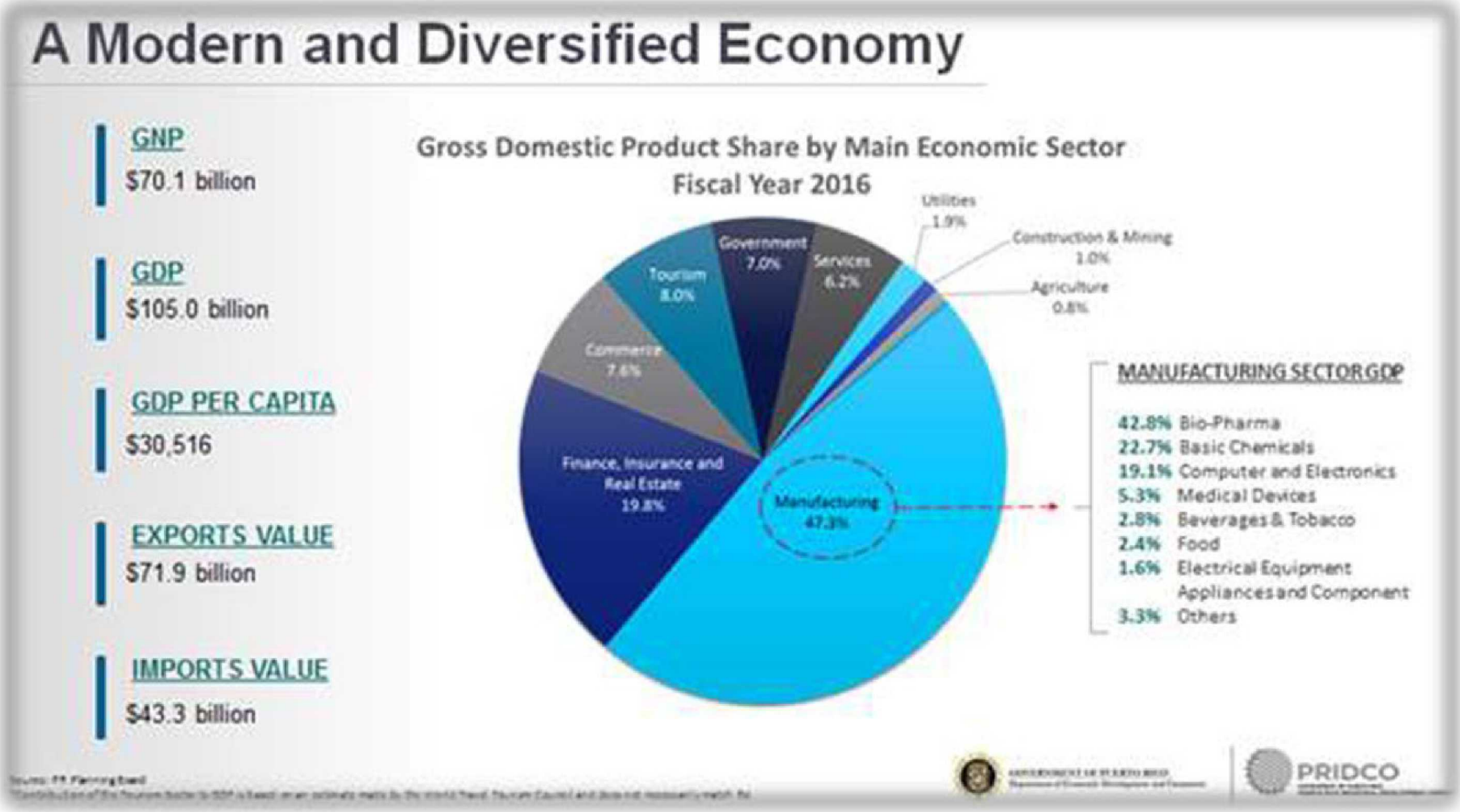
"Thousands of businesses are closed or have limited operations including the pharma manufacturing industry, which caused **serious shortages of drugs supplies in the US**. Pharmaceutical products made in Puerto Rico account for nearly 10 percent of all drugs consumed by Americans."

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.

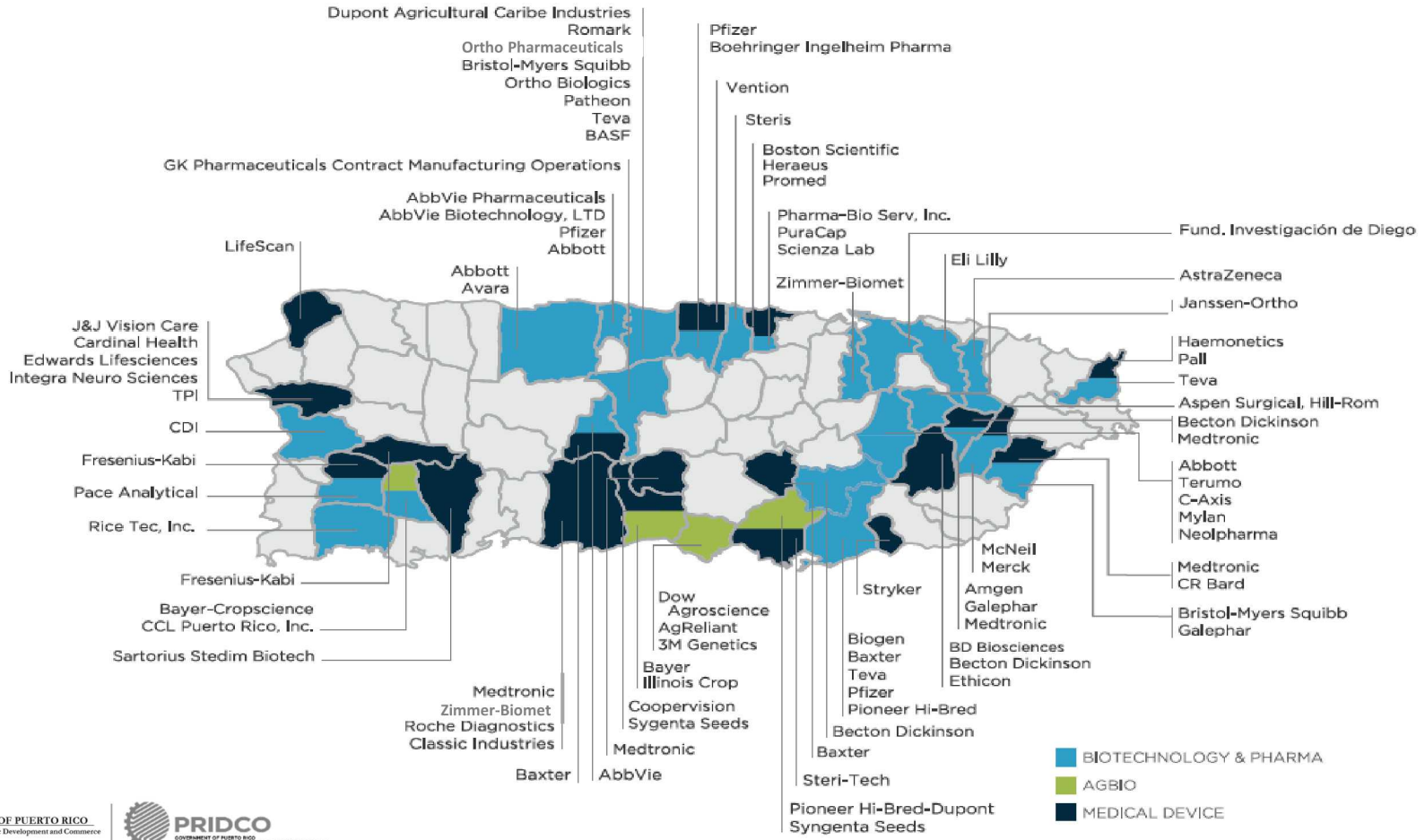
Where to focus our efforts?



DOE office of electricity asked SNL and ORNL to team up to support the rapid installation of Industrial Microgrids in Puerto Rico.

PRIDCO – Puerto Rico Industrial Development Company

PR Cluster Map: Life Sciences



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Puerto Rico – Municipalities and Proposed Microgrid Locations

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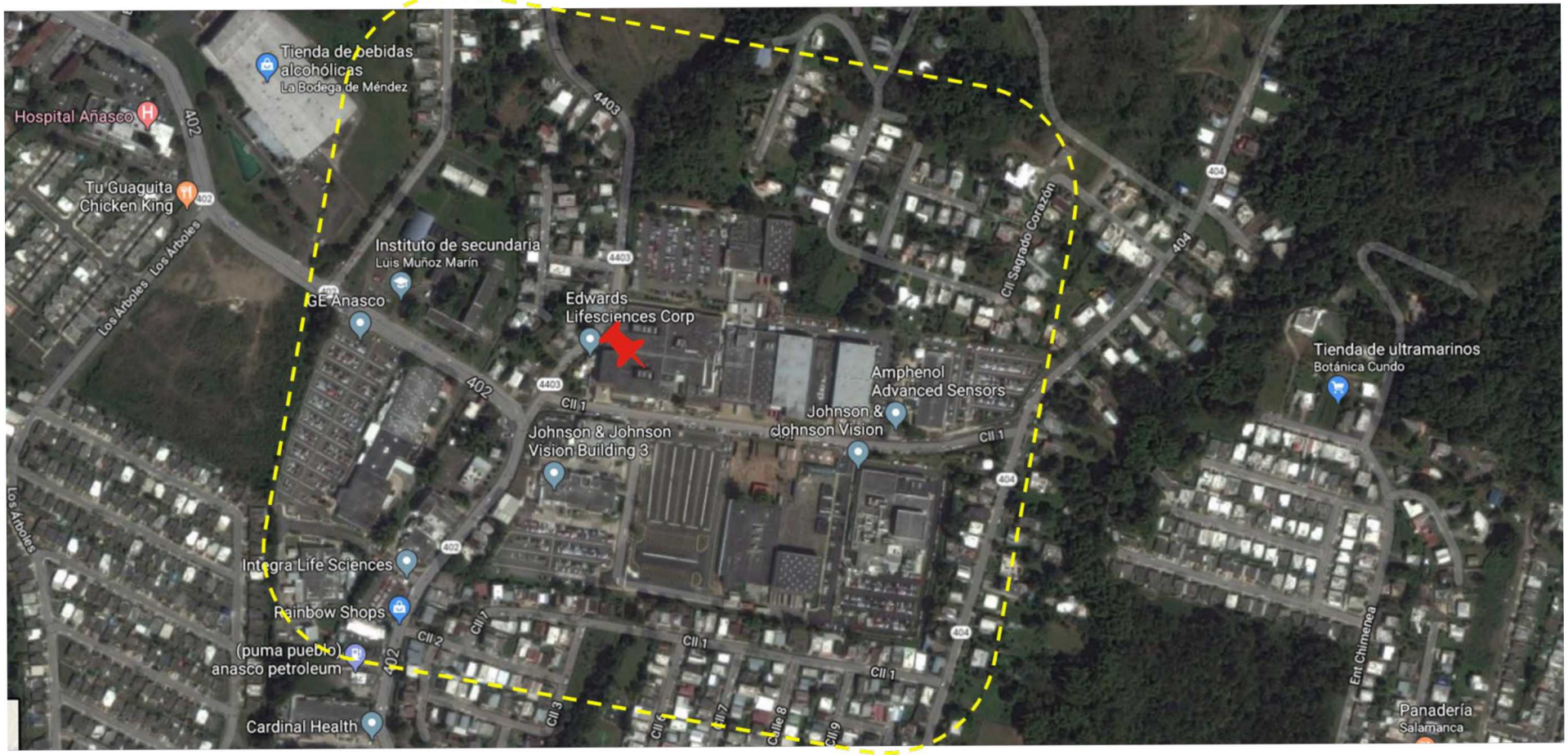
1 Añasco Site – Aerial View



1 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 *(G E)*	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.

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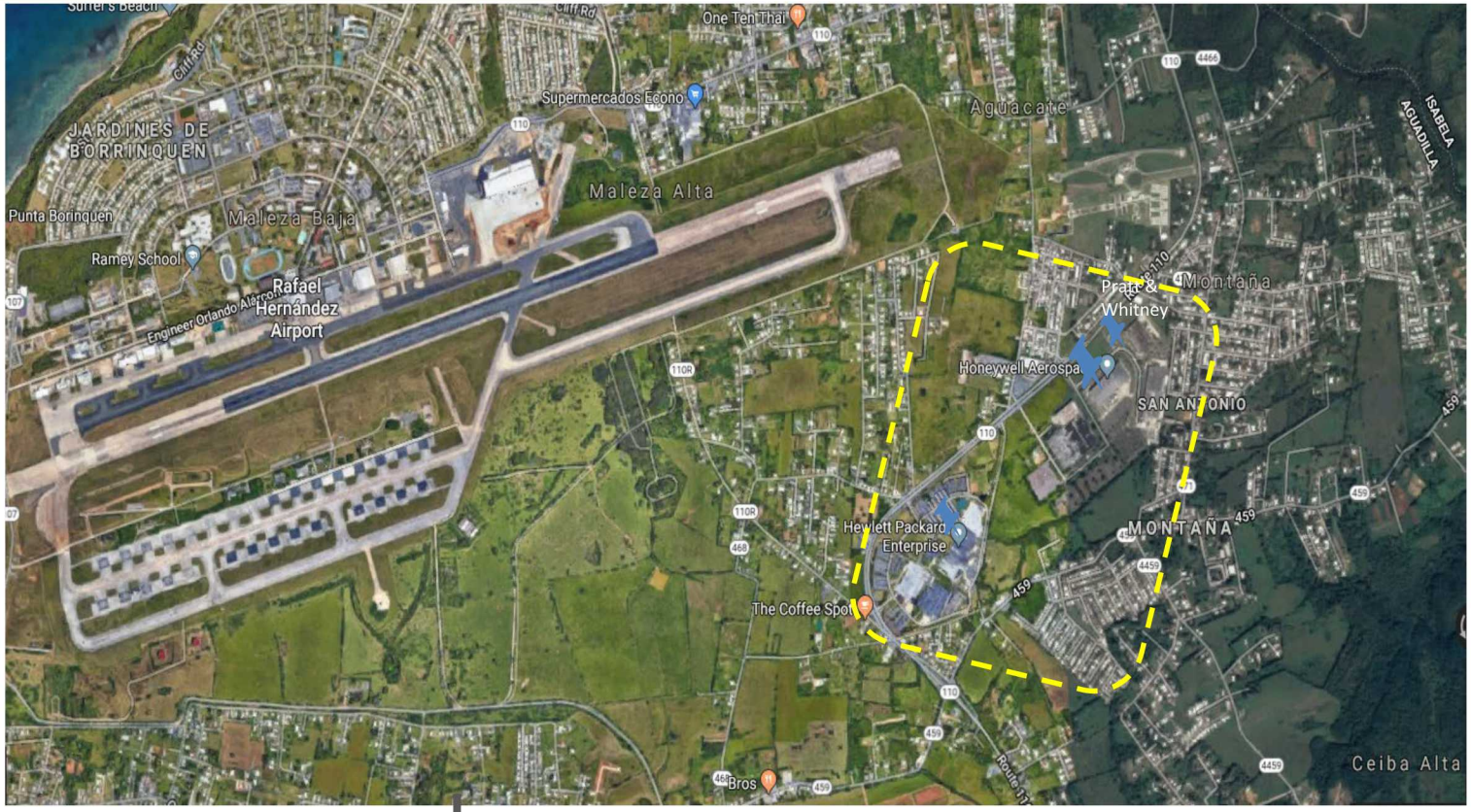
EMPLOYEES **3,000**

2 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

3 Jayuya Site – Aerial View

BAXTER HEALTHCARE

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

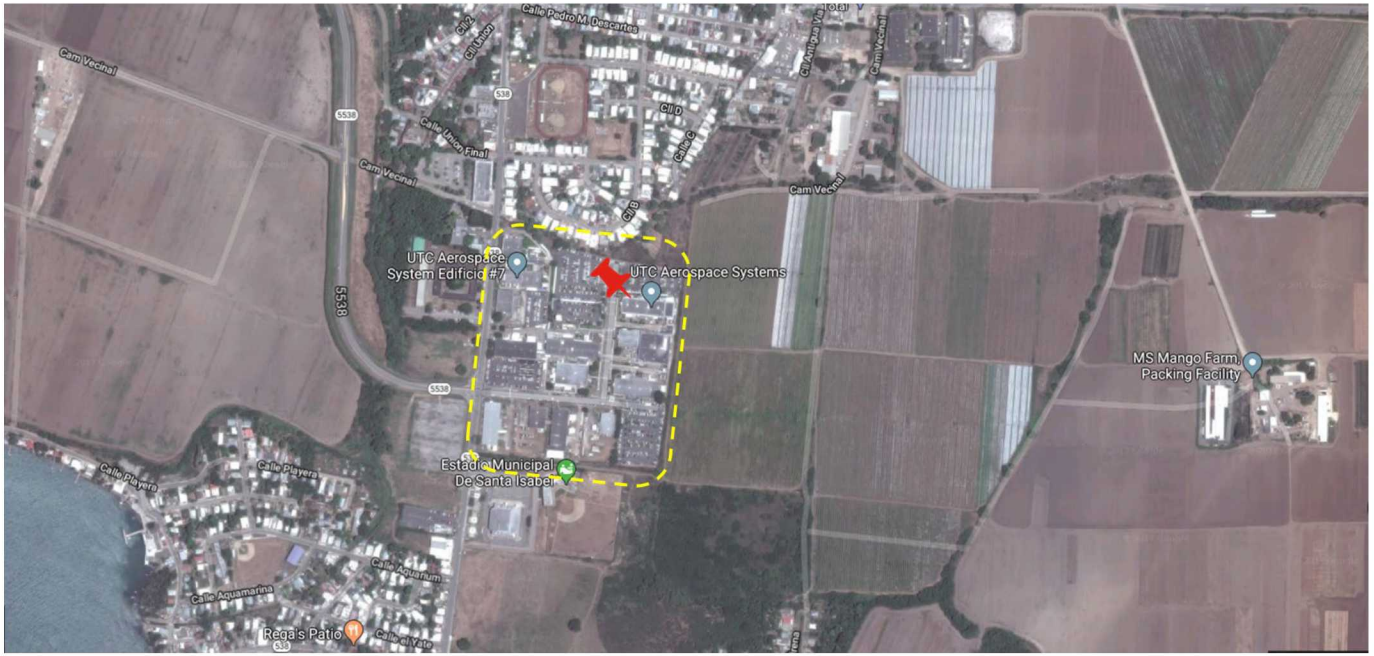
ABBVIE

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

6 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

Total EMPLOYEES

2,400 *

**includes seasonal employees*

Implementation Summary

	Microgrid Development Potential		Industries Supported				Econ. Impact
Site	Immediate Action	Longer Term Action	Pharma./ Medical	Defense/ Technology	Agriculture	Other	Direct Jobs
Añasco	●		●	●			3,000
Aguadilla	●			●			1,900
Jayuya	●		●				600
Barceloneta/ Manati		●	●	●	●	●	4,660
Juana Diaz	●		●		●		3,050
Santa Isabel	●			●	●	●	2,400
Canovanas		●	●				175
Humacao		●	●				1,155

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.

1 Añasco Site – Location Map

AREA AVAILABLE	
Roofing *(sf)*	256,114
Empty Lots *(quantity)*	1
Empty Lots *(acres)*	2.63
Parking Lots *(quantity)*	5
Parking Lots *(acres)*	6.88

Tenants:

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

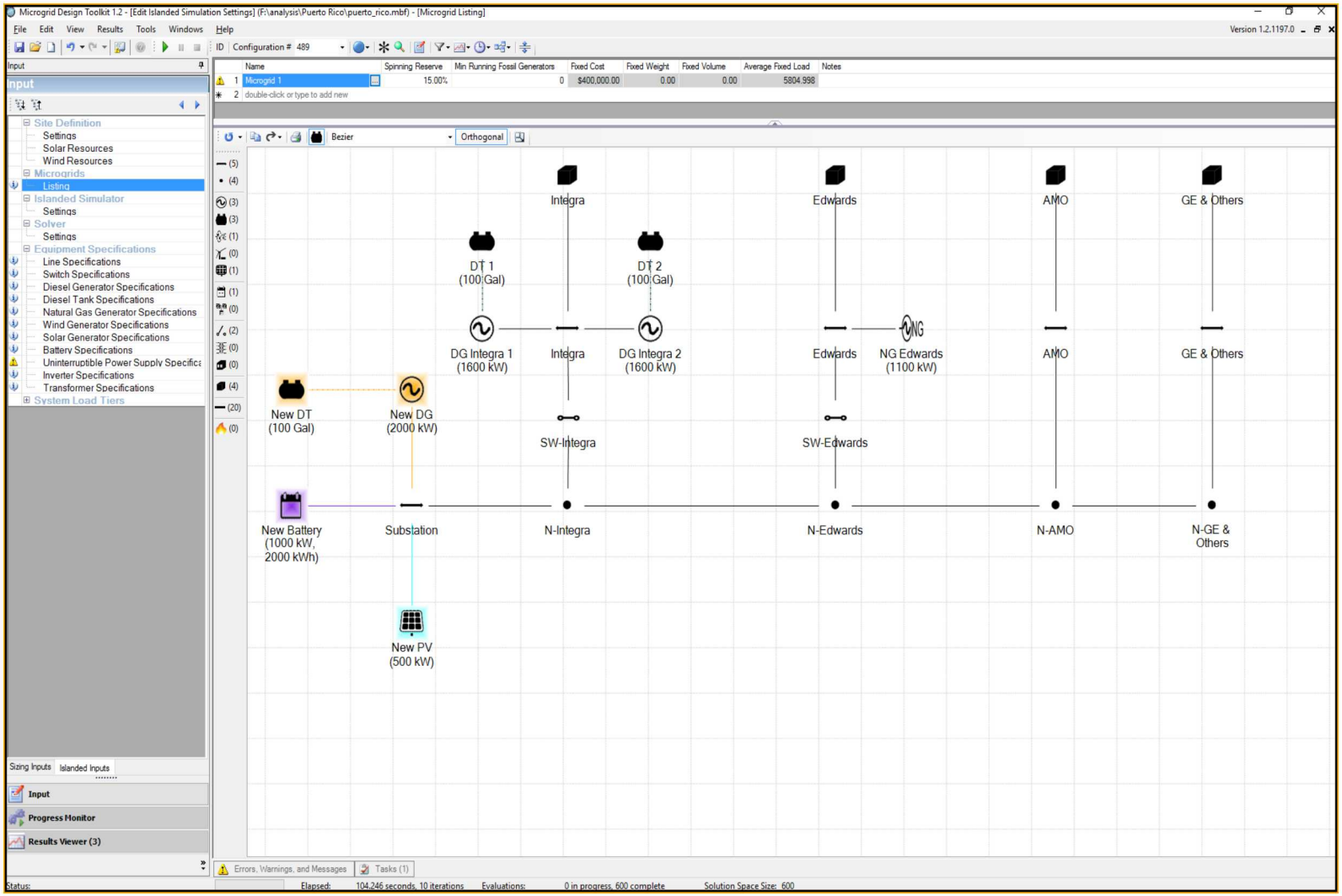
Additional Tenants that do not appear in the map:

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

Undeveloped Land

Parking Lot

Añasco Sandia Microgrid Model



1 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

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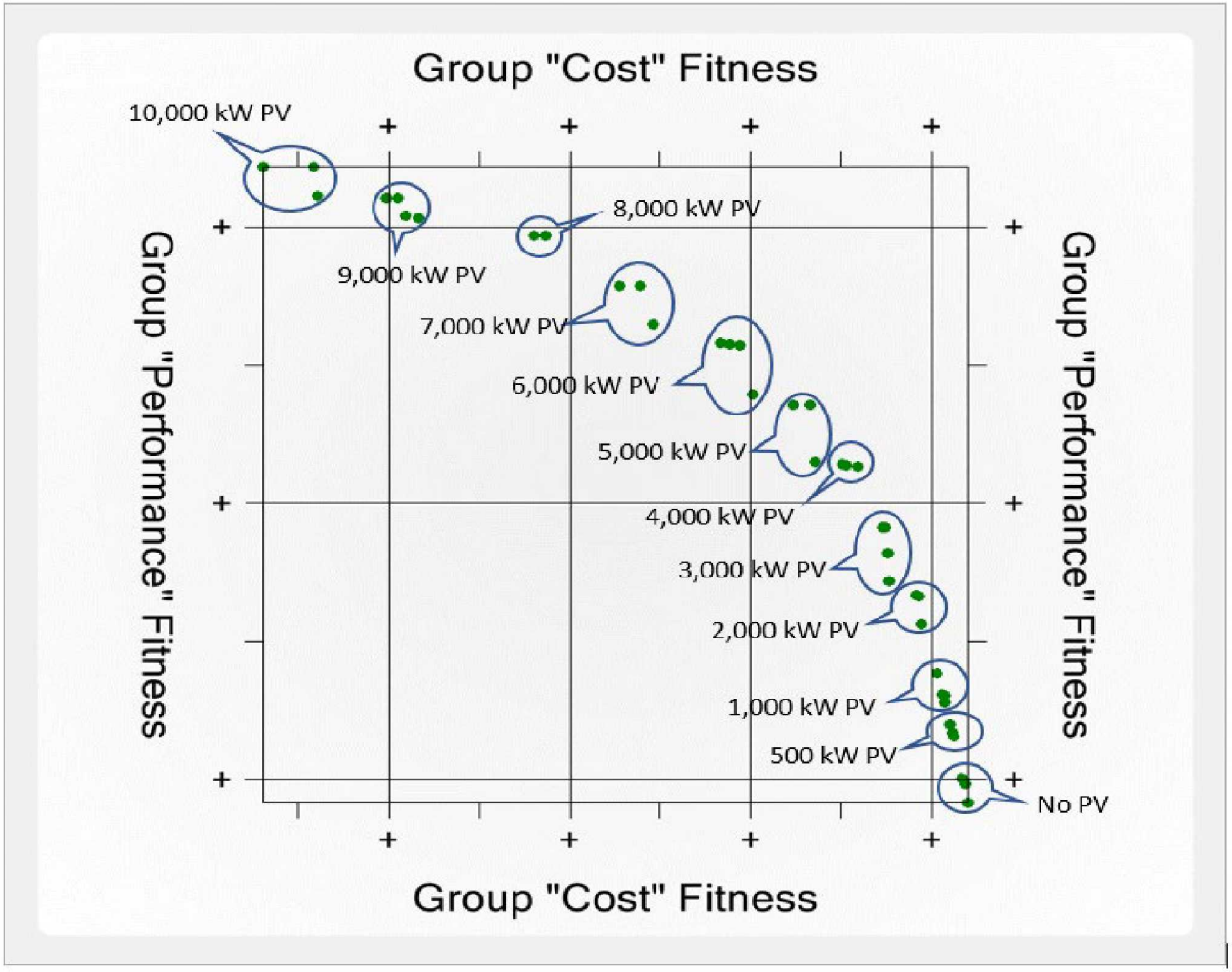
Añasco Industrial Park



3 solutions with different cost/performance trade offs

1: Most Expensive, Highest Performing	
New PV	10,000 kW
New Diesel	1,600 kW
New Storage	None
Purchase Cost	$32,314,000
Energy Availability	100%
Diesel Fuel Used (Gal. per Day)	5487
Natural Gas Used (MBTU per Day)	201
Total Diesel Generation	5,900 kW
Total Natural Gas Generation	1,100 kW
Total Solar Generation	10,000 kW
Overall Diesel Efficiency	28.05%
Overall Diesel Utilization	53.04%
Overall Natural Gas Efficiency	18.56%
Overall Natural Gas Utilization	53.04%

2: Middle Expense, Middle Performance	
New PV	5,000 kW
New Diesel	1,600 kW
New Storage	1000 kW / 2000 kWh
Purchase Cost	$18,529,000
Energy Availability	99.999609%
Diesel Fuel Used (Gal. per Day)	6,538
Natural Gas Used (MBTU per Day)	271
Total Diesel Generation	5,900 kW
Total Natural Gas Generation	1,100 kW
Total Solar Generation	5,000 kW
Overall Diesel Efficiency	36.45%
Overall Diesel Utilization	78.71%
Overall Natural Gas Efficiency	24.66%
Overall Natural Gas Utilization	79.72%

3: Lowest Expense, Lowest Performance	
New PV	None
New Diesel	1,600 kW
New Storage	250 kW / 500 kWh
Purchase Cost	$1,655,000
Energy Availability	99.873061%
Diesel Fuel Used (Gal. per Day)	8316.96
Natural Gas Used (MBTU per Day)	296
Total Diesel Generation	5,900 kW
Total Natural Gas Generation	1,100 kW
Overall Diesel Efficiency	36.78%
Overall Diesel Utilization	83.05%
Overall Natural Gas Efficiency	24.93%
Overall Natural Gas Utilization	83.05%

LCOE and Budget Estimates

	Añasco		Aguadilla		Jayuya	
	Gen+PV+Battery costs	LCOE	Gen+PV+Battery costs	LCOE	Gen+PV+Battery costs	LCOE
1: Most Expensive, Highest Performing	$32,314,000	$0.230	$61,457,500	$0.222	$20,800,000	TBD
2: Middle Expense, Middle Performance	$18,529,000	$0.184	$35,232,500	$0.179	$12,200,000	TBD
3: Lowest Expense, Lowest Performance	$1,655,000	$0.128	$11,257,500	$0.146	$200,000	TBD

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

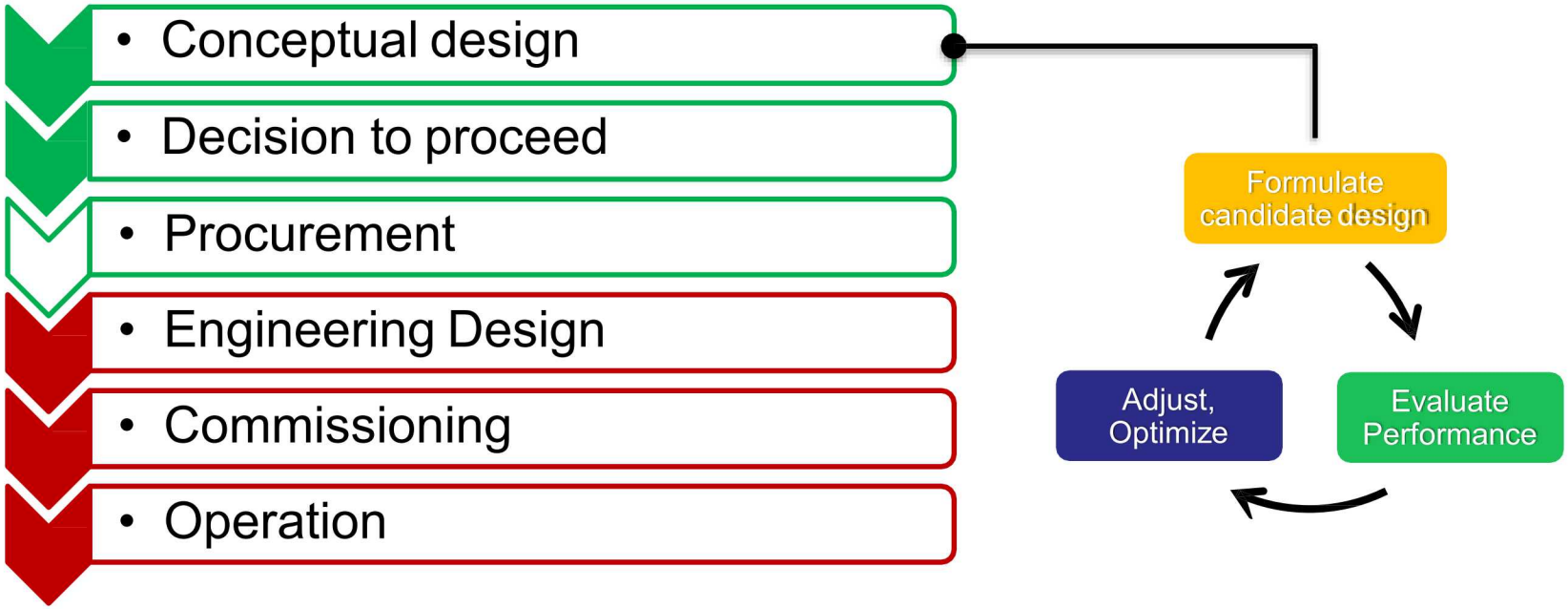
	Aguadilla	Añasco	Jayuya	Santa Isabel	Juana Diaz
Solar Potential	High	Medium	Low	High	High
Load (MVA/MW Peak)	18.75/15*	9.4/7.5*	6.25/5*	4.7/4.2	9.7/8.7
Industries Served	Aerospace, Defense, Cloud Computing, Bio-technology	Bio-pharma, technology	Bio-pharma	Aerospace, agricultural research, logistics	Manufacture of medical devices.
PQ/Outage Issues	Several per month	Several per month	Several per month	Several per month	Several per month
Critical Supplier?	No	Yes	Yes	Yes	No (in top 3)
Off-Grid Motivation	High	High	Medium	Medium	High
Cost Estimate (Middle Case for Performance)**	$35,000,000 w/ 9 MW of PV	$18,500,000 w/ 5 MW of PV	$12,000,000 w/ 4 MW of PV	TBD	TBD
Employees	1900	3000	600	1500+	1500

* Estimated value

** See LCOE slide for list of assumptions. Cost estimate is for generation assets only.

Status of Project

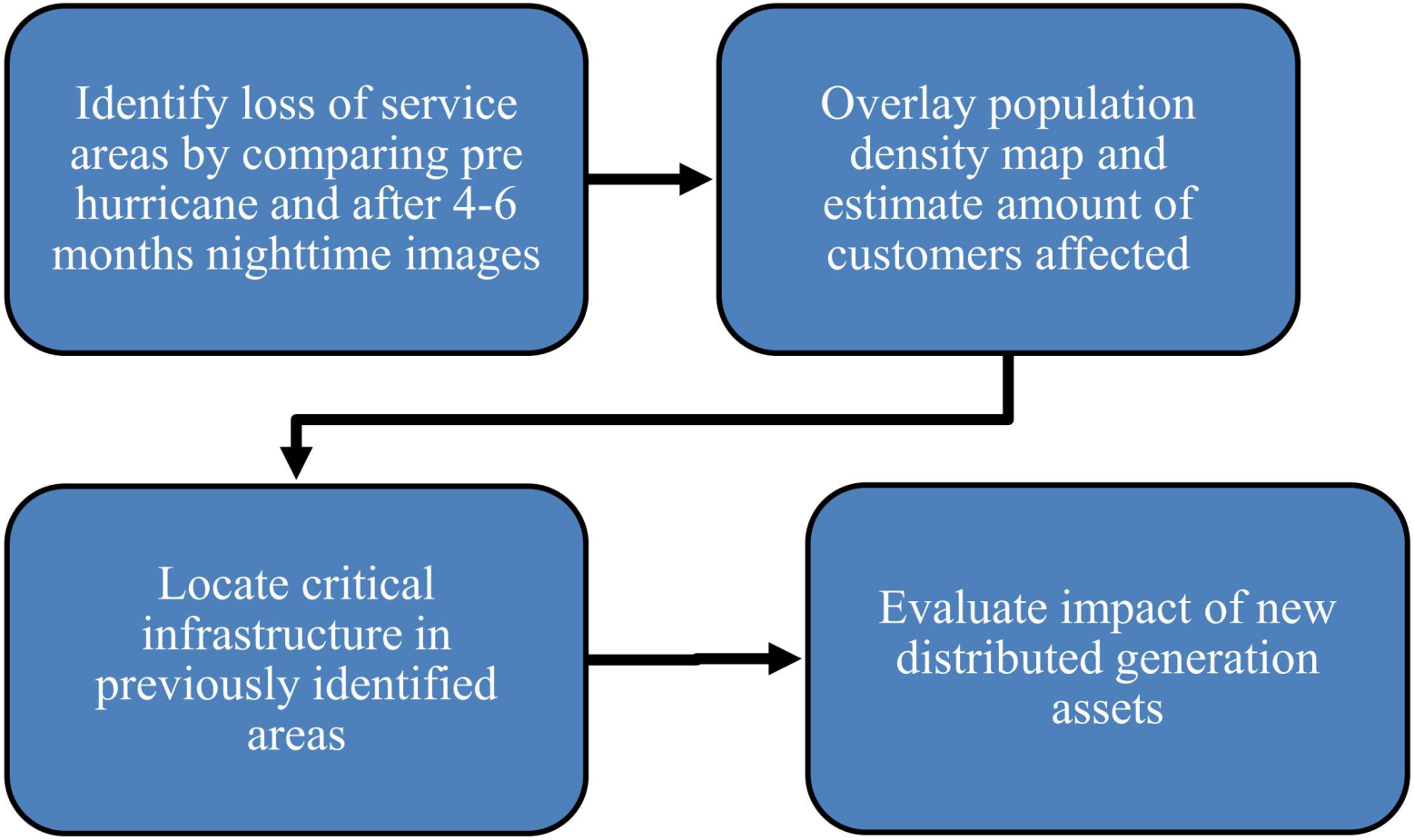
- PRIDCO and SNL and ORNL provided detailed technical and regulatory feedback and suggested changes to the new Puerto Rico microgrid rule proposed by the Puerto Rico regulatory commission.
- A Request for Proposals on four industrial microgrid solutions was issued in Fall 2018 and the response was excellent 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



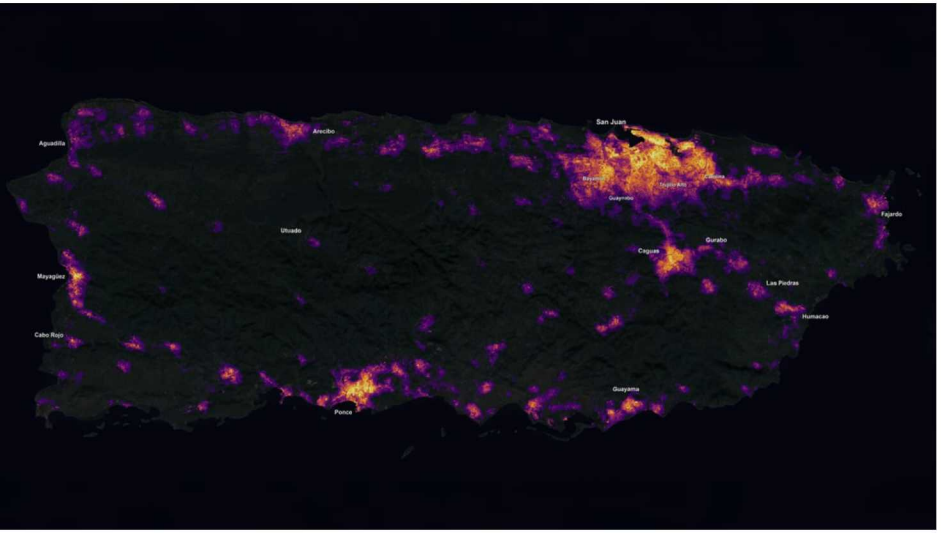
Project 2: Last Mile Project: 5% left unserved

“Since Maria made landfall seven months ago, more than 100,000 Americans are still without power on the island” (May 2018). 5% left unserved

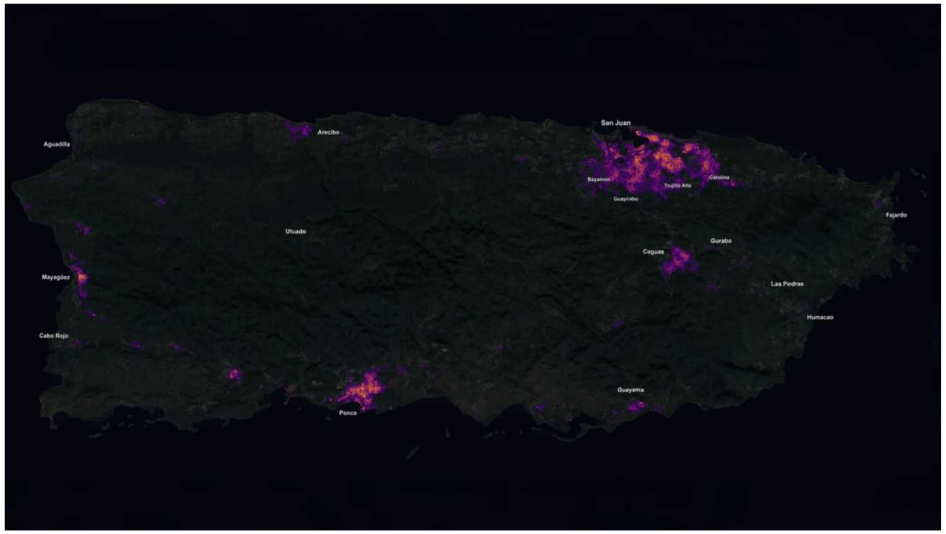
Advanced DER Integration Analysis and Methodology
Partner: University of Puerto Rico



NASA nighttime light images



Baseline (Pre-Hurricane)

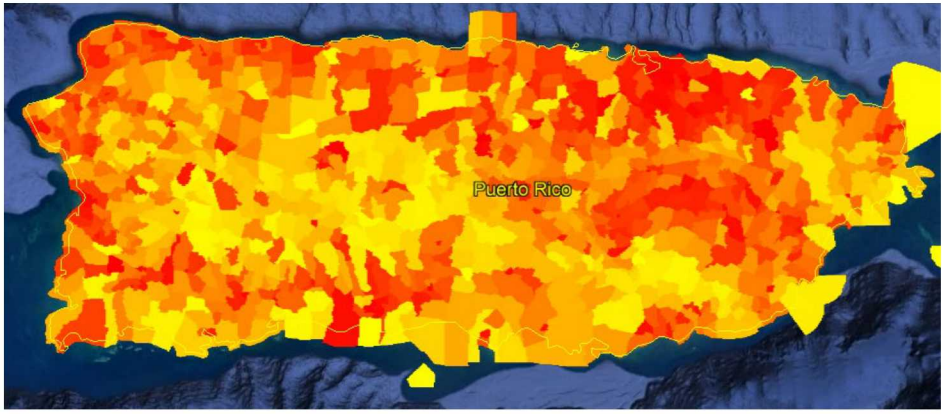


3-4 Months After Hurricane

Reference: https://svs.gsfc.nasa.gov/4658

Key water and telecommunications infrastructure

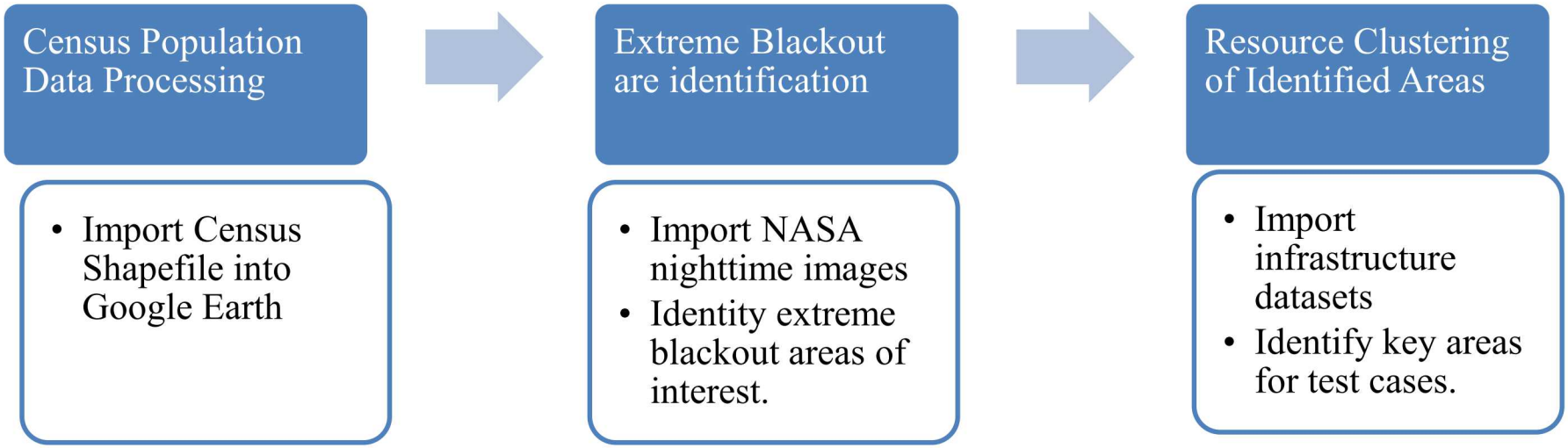
Pumping Stations



Population Density Color Mapped

Radio/Cellphone Towers

Current Work



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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