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Energy Resilience for Puerto Rico

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Delivery and Energy Reliability

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Hurricanes Irma and Maria devastated Puerto Rico in September 2017

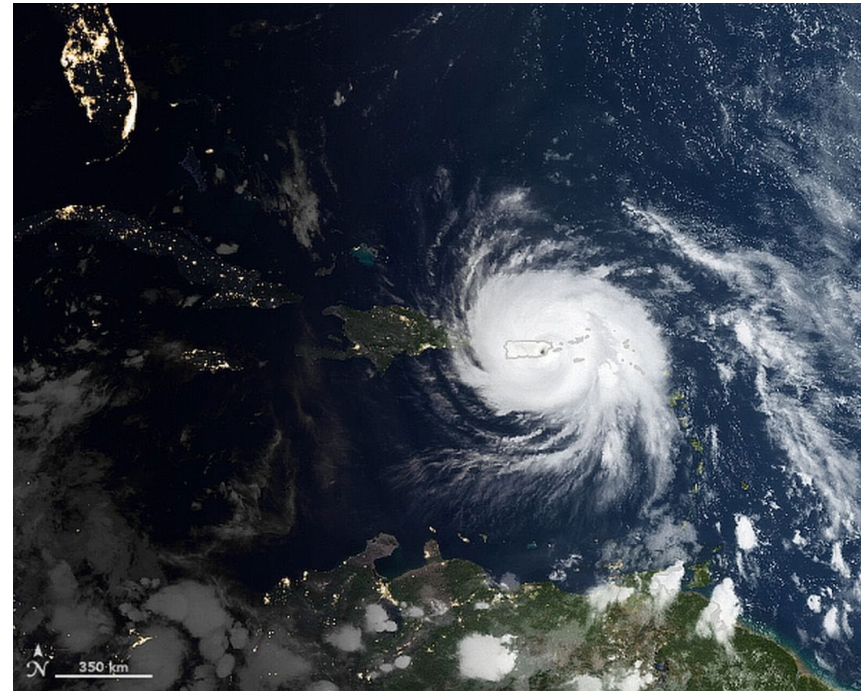
“Hurricanes Irma and Maria devastated Puerto Rico, bringing sustained winds well in excess of 150 miles per hour, heavy rains, and catastrophic flooding the likes of which the island had never seen before”

“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.

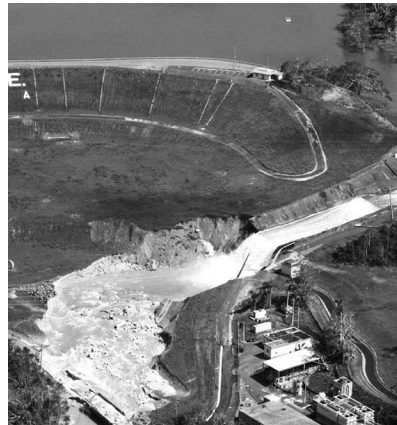
Highlighted Impacts: Power System, Water, Impact on Economy



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

"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."

- "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)



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 tenants 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?

A Modern and Diversified Economy

GNP

\$70.1 billion

GDP

\$105.0 billion

GDP PER CAPITA

\$30,516

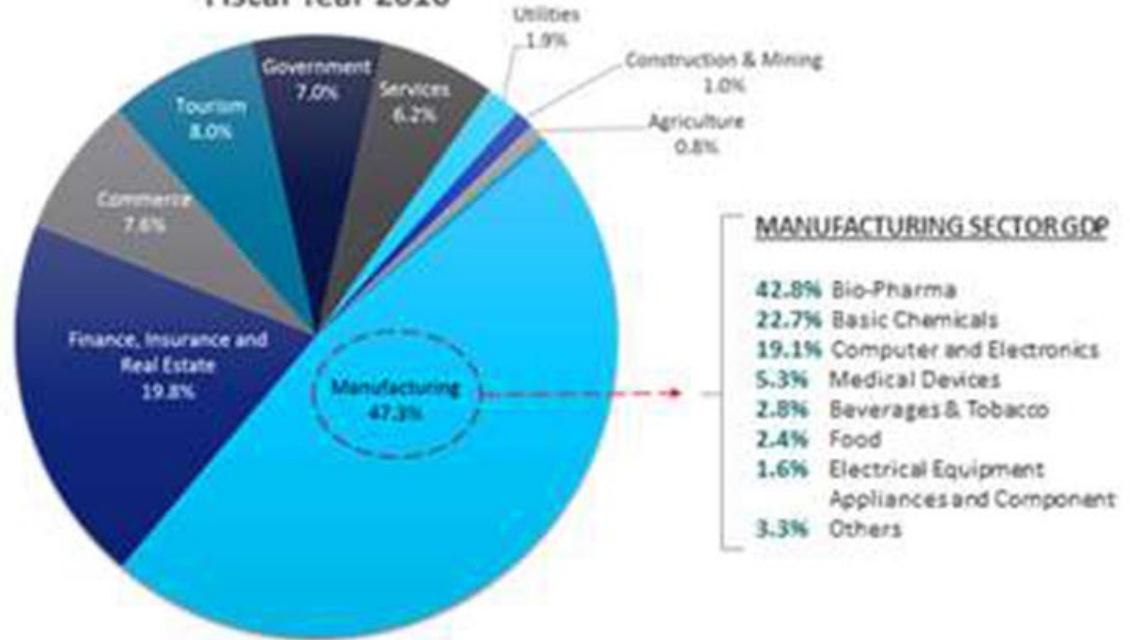
EXPORTS VALUE

\$71.9 billion

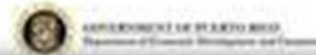
IMPORTS VALUE

\$43.3 billion

Gross Domestic Product Share by Main Economic Sector
Fiscal Year 2016



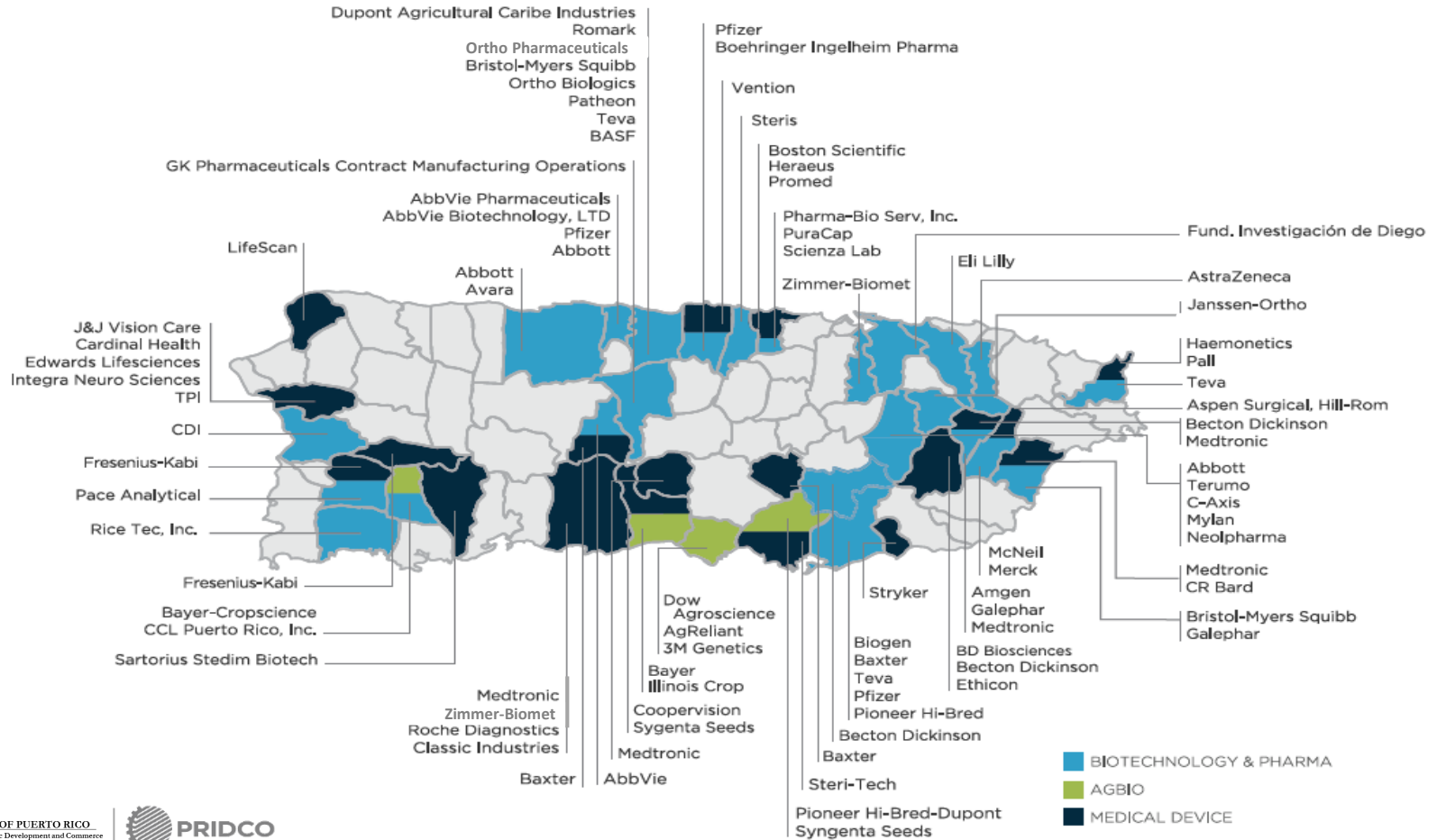
Source: PR Planning Board
Contribution of the Tourism Sector to GDP is based on estimates made by the World Travel Tourism Council and does not necessarily match the



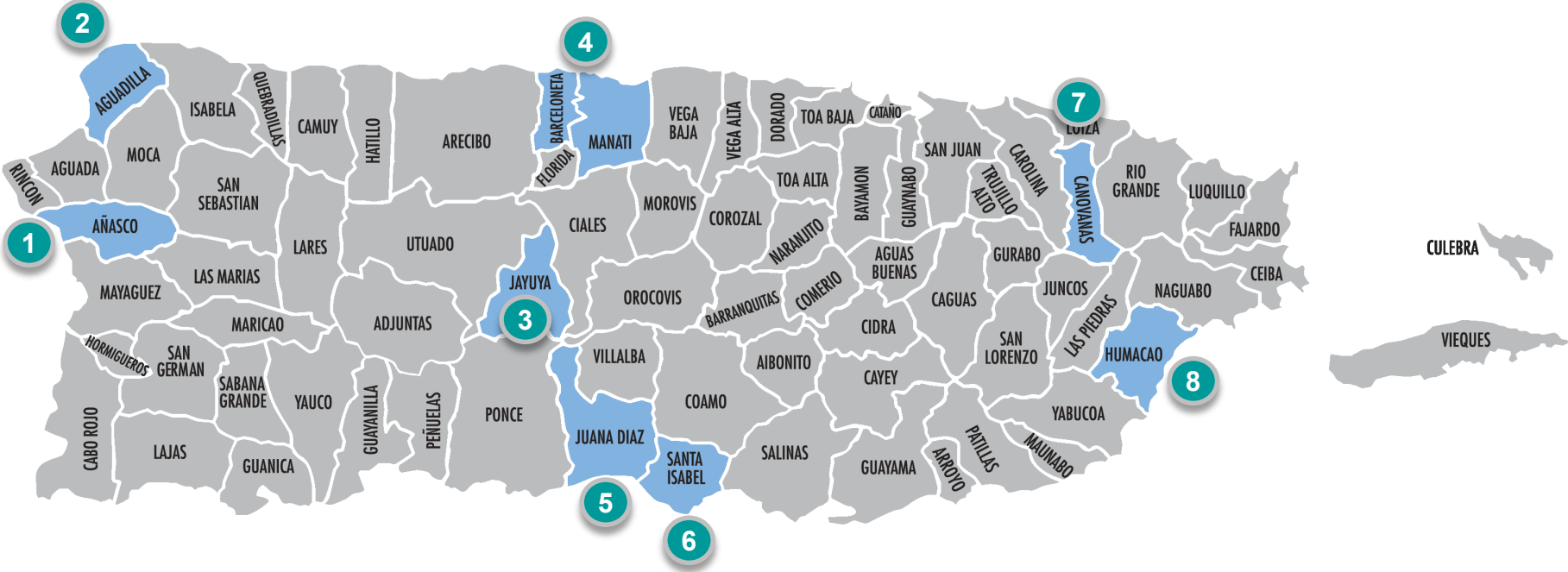
DOE office of electricity asked SNL and ORNL to team up to support the rapid installation of Industrial Microgrids in Puerto Rico.

PRIDCO – Puerto Rico Industrial Development Company

PR Cluster Map: Life Sciences



Puerto Rico – Municipalities and Proposed Microgrid Locations



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 (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.



GOVERNMENT OF PUERTO RICO
Department of Economic Development and Commerce



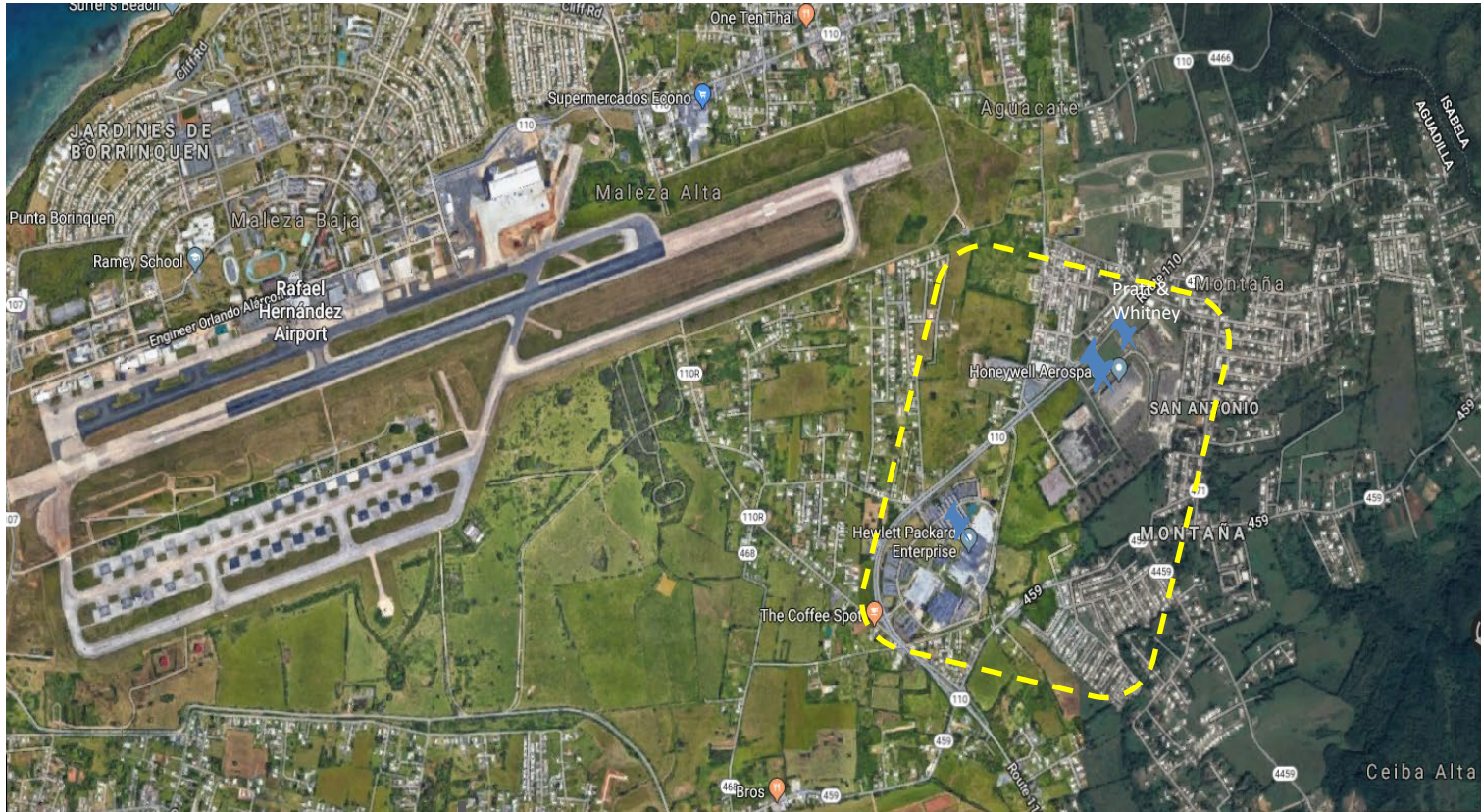
PRIDCO
GOVERNMENT OF PUERTO RICO
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY

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

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

Undeveloped Land

Tenants:

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

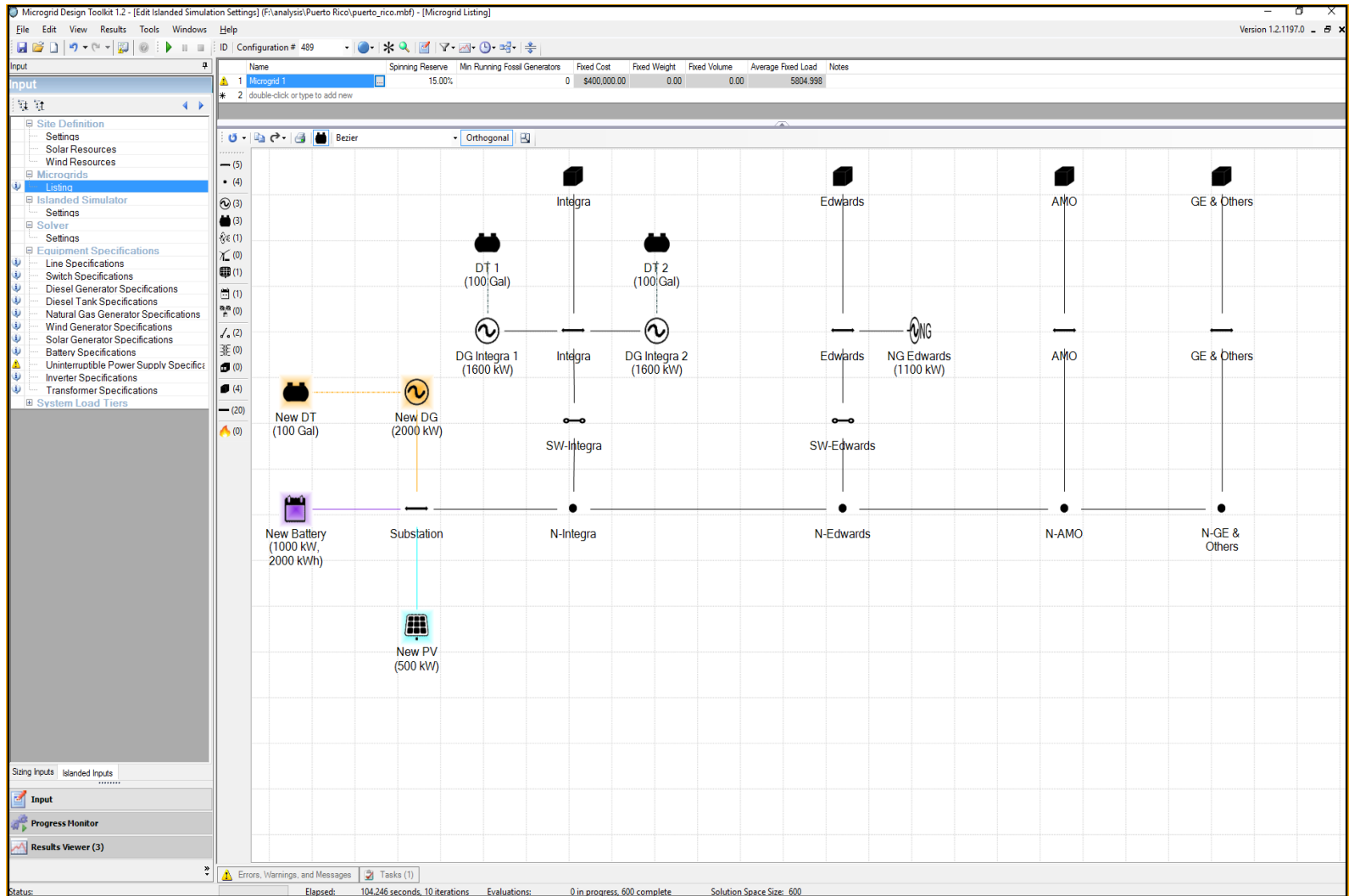
Additional Tenants that do not appear in the map:

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

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

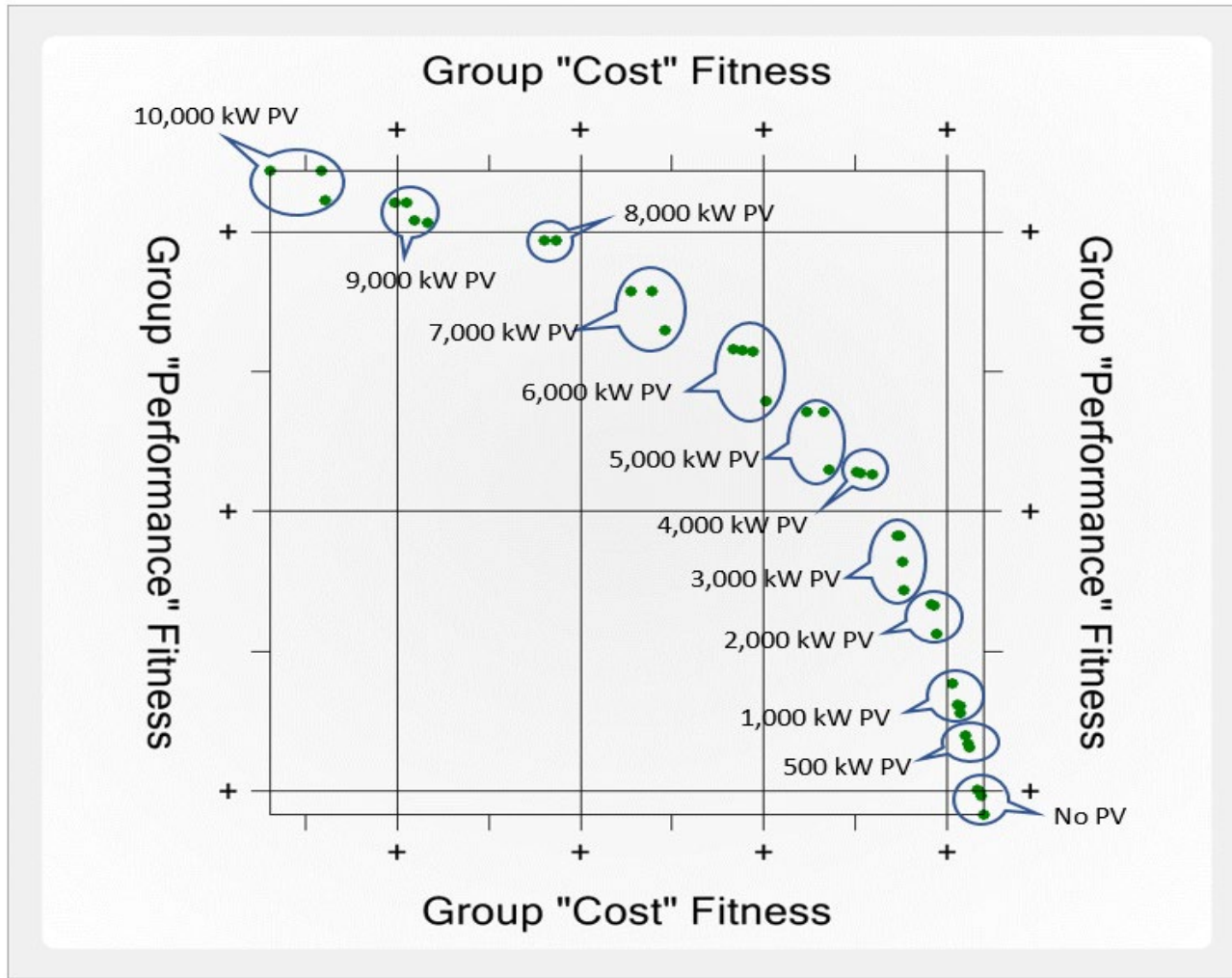
Total ~2MW



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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%

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%

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%

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

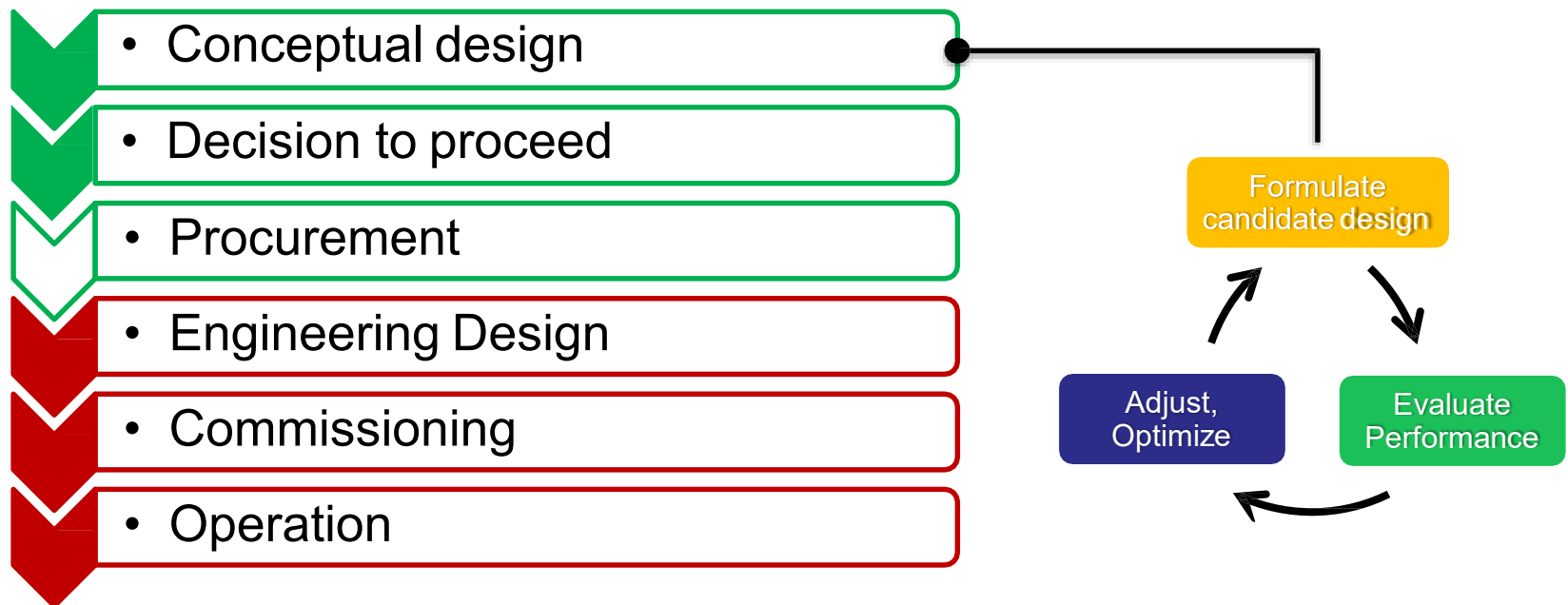
	Aguadilla	Añasco	Jayuya	Santa Isabel	Juana Diaz
Solar Potential	High	Medium	Low	High	High
Load (MVA/MW Peak)	18.75/15*	9.4/7.5*	6.25/5*	4.7/4.2	9.7/8.7
Industries Served	Aerospace, Defense, Cloud Computing, Bio-technology	Bio-pharma, technology	Bio-pharma	Aerospace, agricultural research, logistics	Manufacture 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

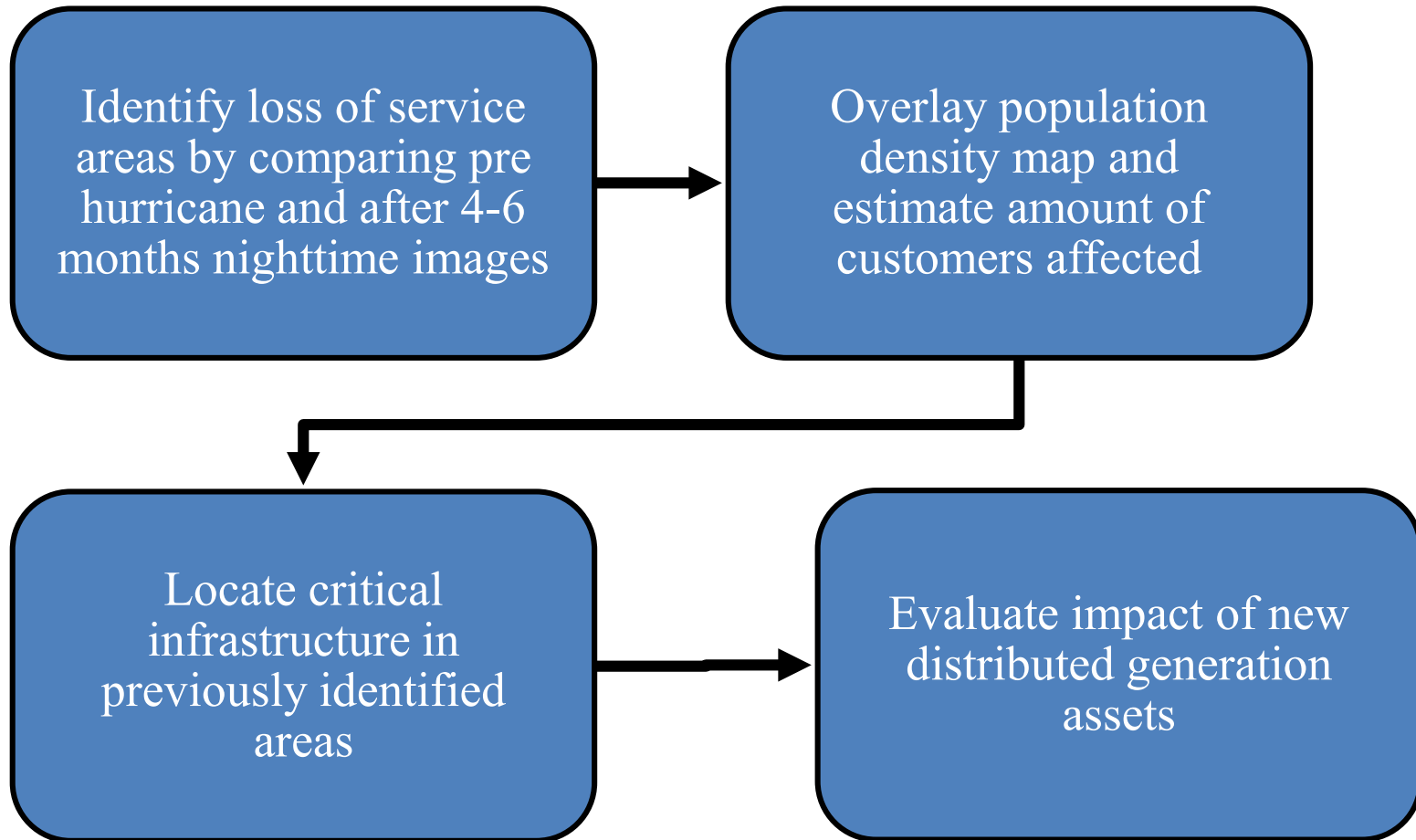


Project 2: Last Mile Project: 5% left unserved

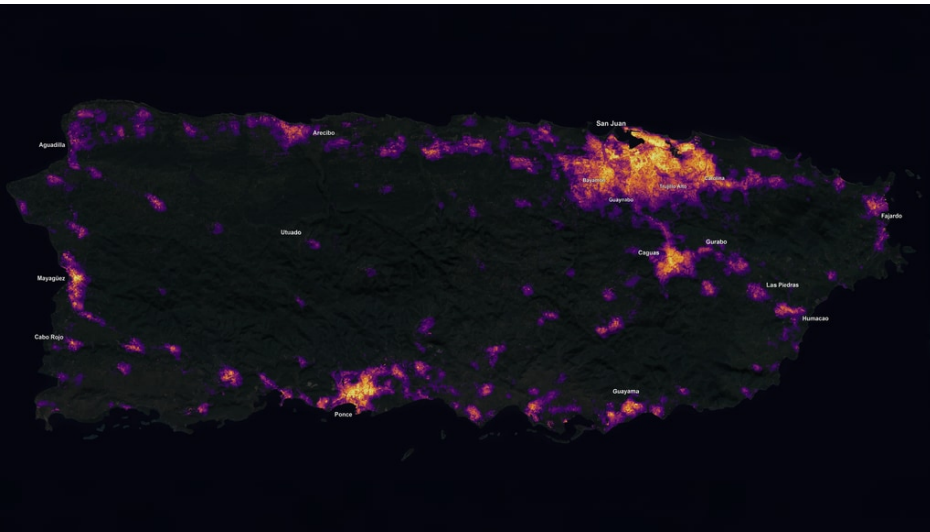
“Since Maria made landfall seven months ago, more than 100,000 Americans are still without power on the island” (May 2018). 5% left unserved

Advanced DER Integration Analysis and Methodology

Partner: University of Puerto Rico



NASA nighttime light images



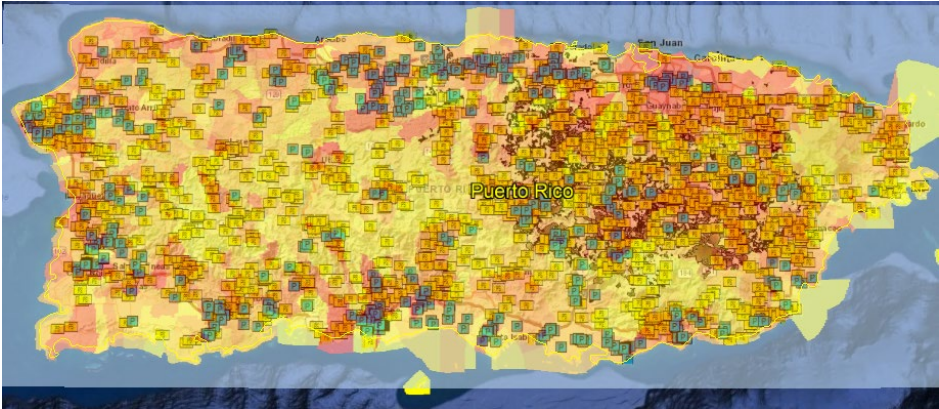
Baseline (Pre-Hurricane)



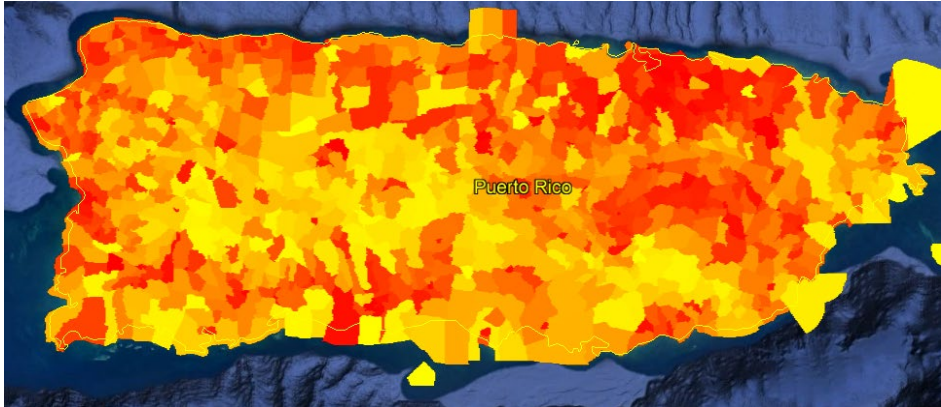
3-4 Months After Hurricane

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

Key water and telecommunications infrastructure



Pumping Stations

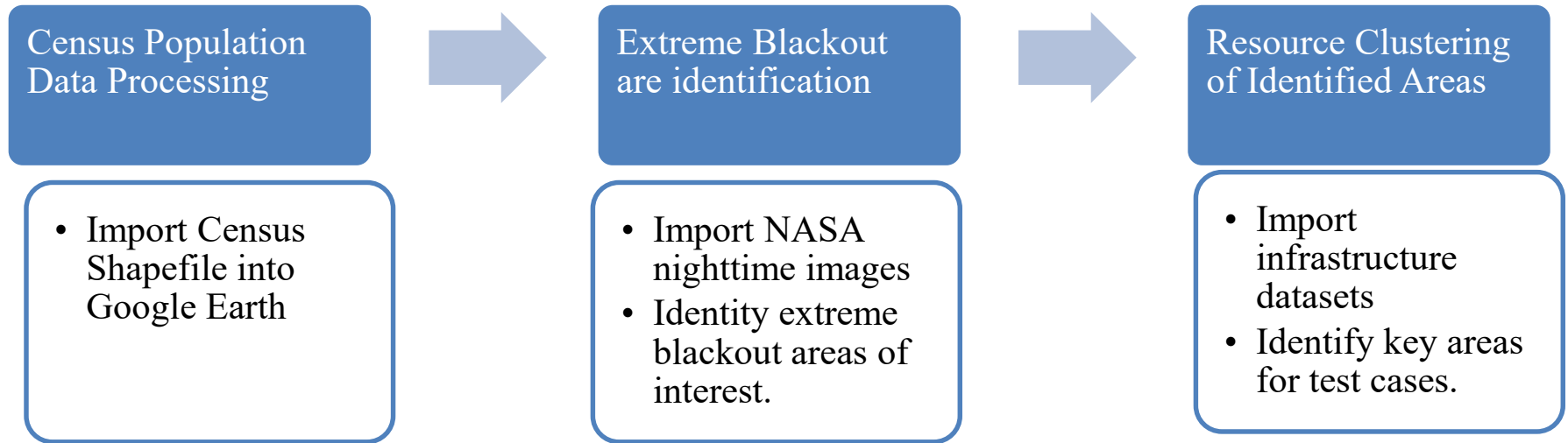


Population Density Color Mapped



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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