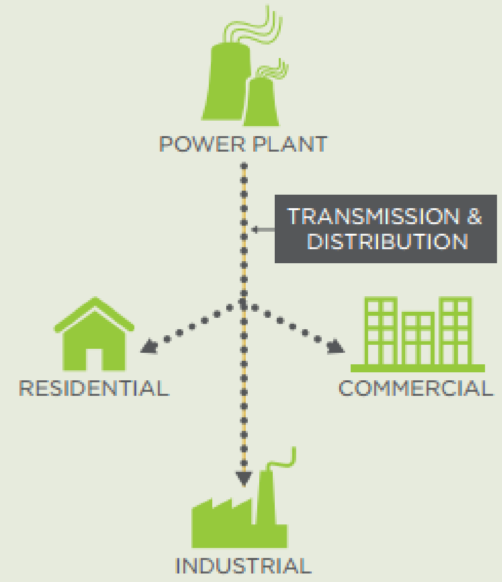
Reflections on Grids, Resiliency and Puerto Rico

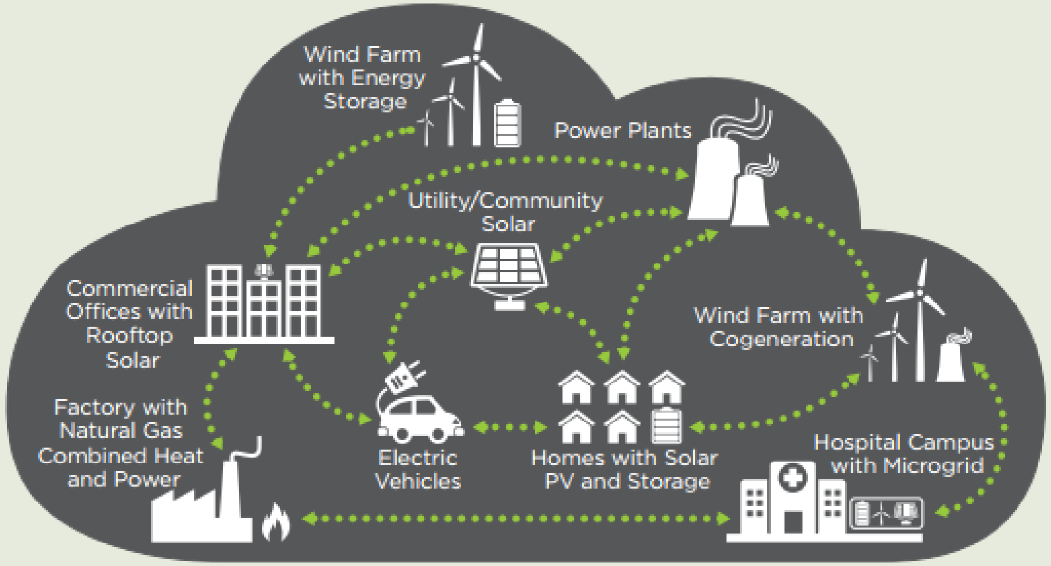
William Parks

The Nation is facing an increasingly dynamic electricity system that demands solutions to efficiently match supply and demand.

One-Way Power Flows

Two-Way Power and Information Exchange





- Large, centrally located generation facilities
- Designed for one-way energy flow
- Utility controlled
- Technologically inflexible
- Simple market structures and transactions
- Highly regulated (rate base) and pass through

- Distributed energy resources
- Multiple inputs and users, supporting two-way energy flows
- Digitalization of the electric-mechanical infrastructure: smart grid and behind the meter energy management systems
- Flexible, dynamic, and resilient
- Complex market structures and transactions
- Regulation changing rapidly around renewables, distributed generation (solar, micro-grid, storage), net metering etc.

NAVIGANT

Grid Attributes

- Reliability
- Safety
- Costs

- Utility Compact: Obligation to serve for a regulated rate of return

Grid Attributes

- Reliability
- Safety
- Affordability
- Resiliency
- Sustainability
- Flexibility

Grid Attributes: Needs a balanced approach

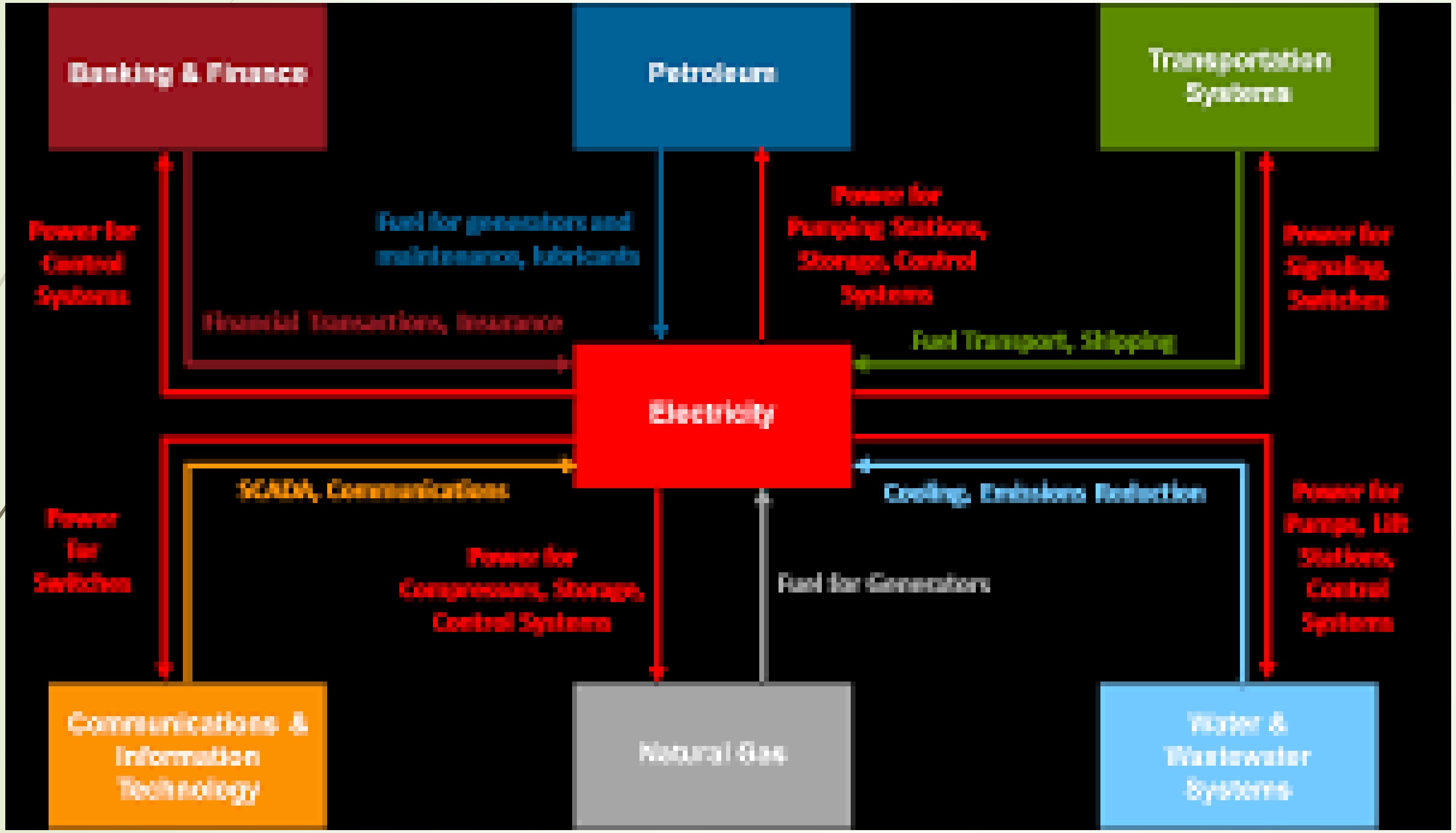
- Reliability
- Safety
- Affordability
- Resiliency
- Sustainability
- Flexibility
- Energy Efficiency/System Efficiency

- Utility Compact: Who has obligation to serve?

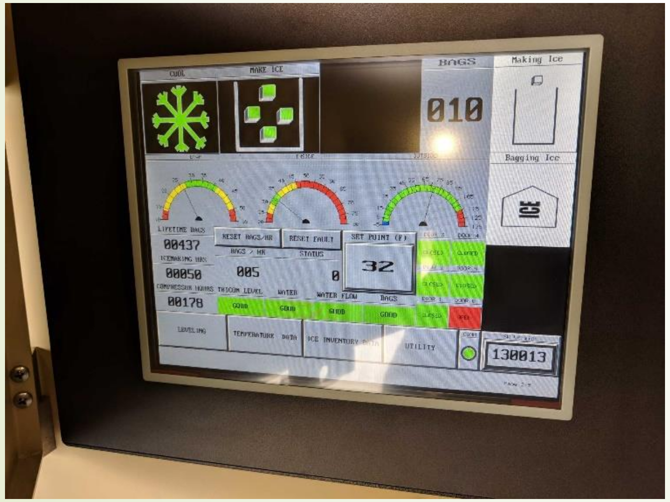
Resiliency and Reliability

- Reliability and resilience are so deeply intertwined that they are functionally inseparable.
  - **Reliability** = operational security (short term) and resource adequacy (long-term)
  - **Resilience** = "the ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to and/or rapidly recover from an event." (162 FERC 61,012) – up to and after the outage occurs
- Many resiliency measures enhance reliability (and vice versa).
- In practice, FERC, NERC and RCs have been doing BPS resilience under the reliability umbrella.

Interdependencies



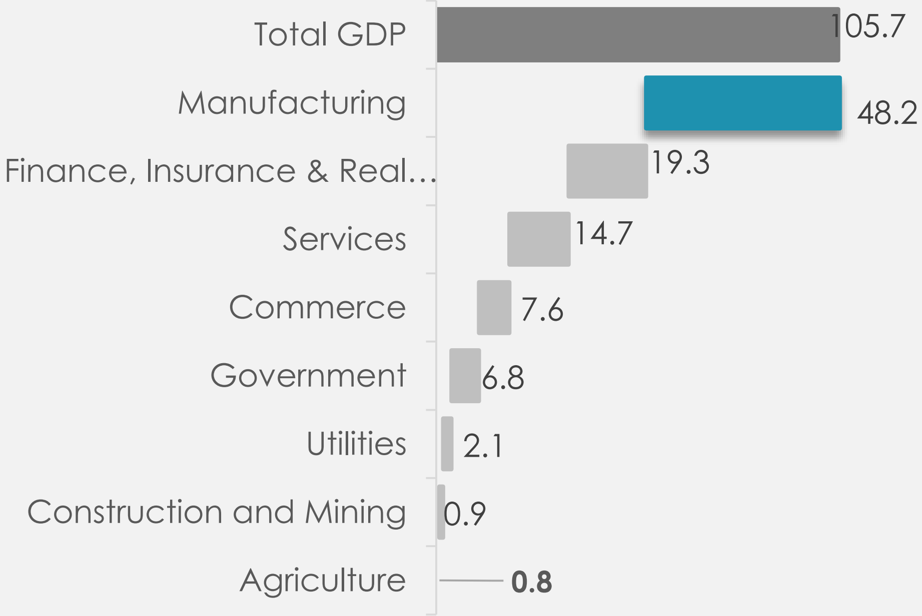
Interdependent Solutions: CIMS-Containerized Ice Maker System



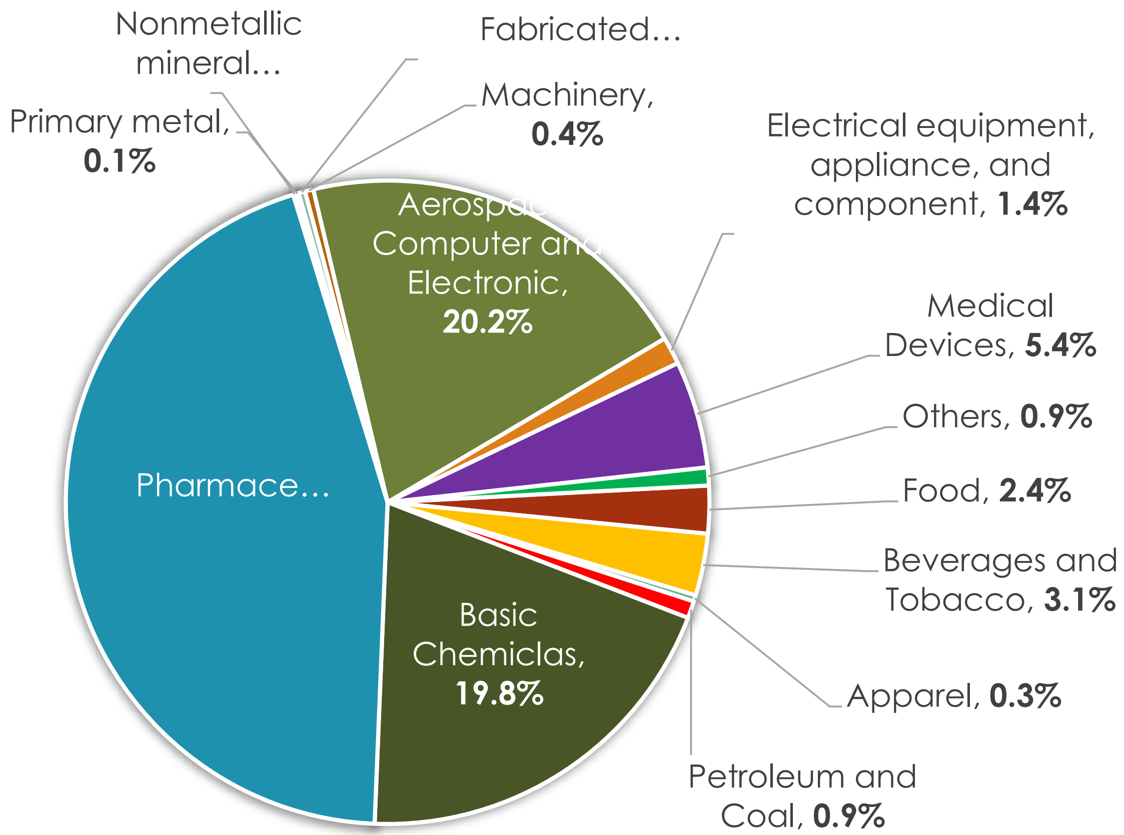
Puerto Rico Economy

GNP $70.1 billion
GDP $105.7 billion
GDP PER CAPITA $30,516
EXPORTS VALUE $71.9 billion
IMPORTS VALUE $43.3 billion

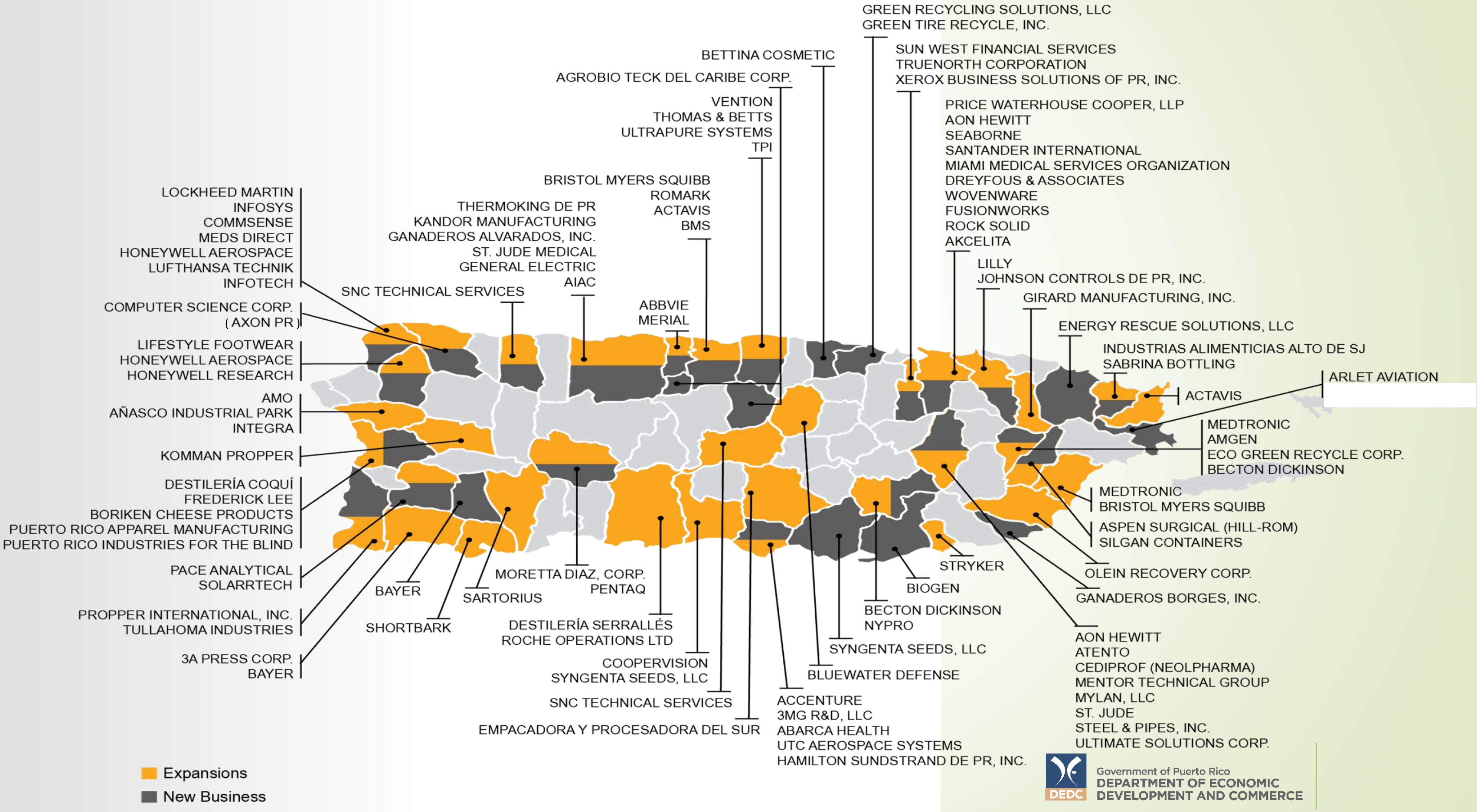
GROSS DOMESTIC PRODUCT SHARE BY MAIN ECONOMIC SECTOR
FISCAL YEAR 2017



MANUFACTURING GROSS DOMESTIC PRODUCT BY INDUSTRY
FISCAL YEAR 2017



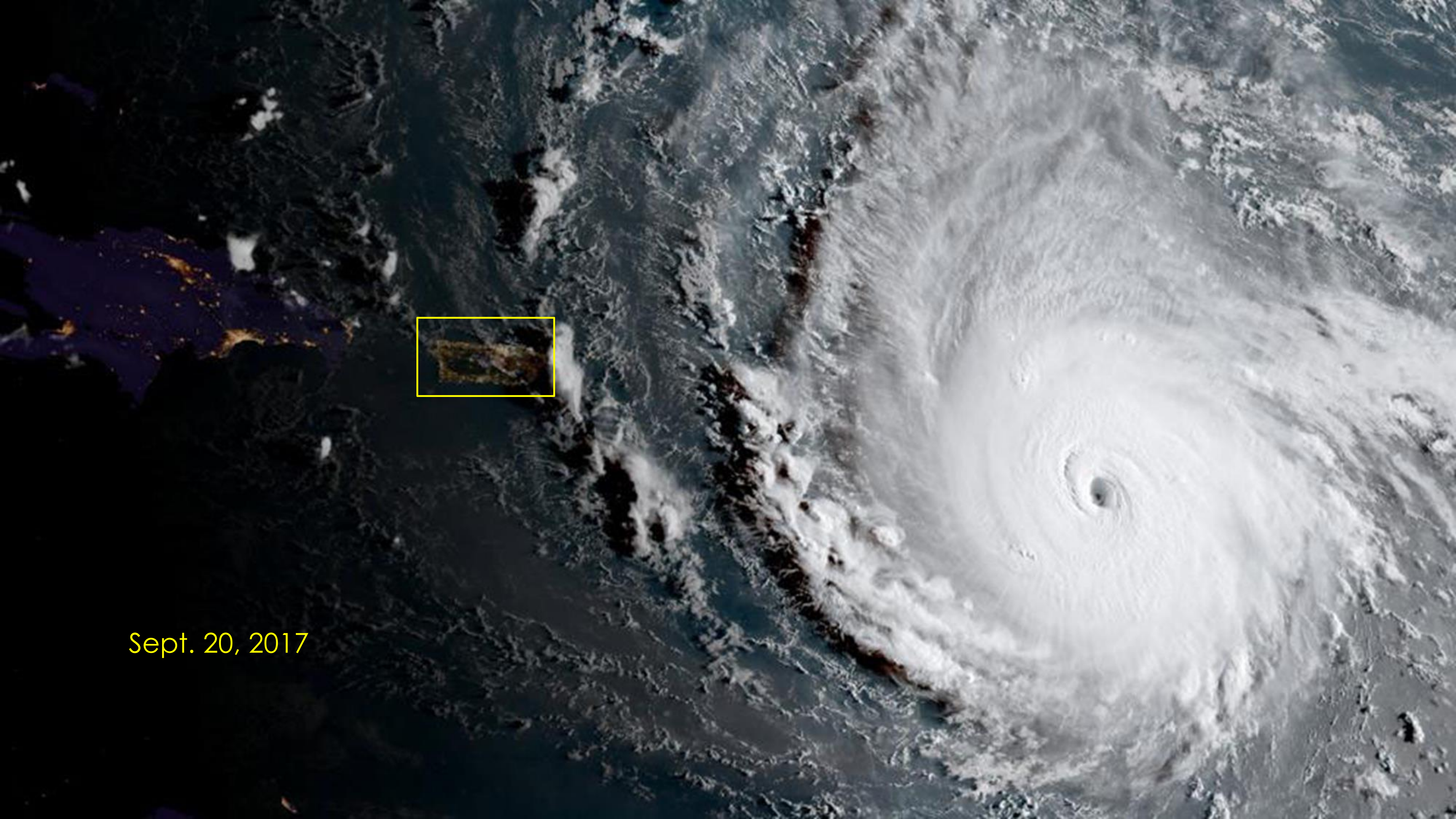
Puerto Rico Clusters Map – Industries



Government of Puerto Rico
DEPARTMENT OF ECONOMIC DEVELOPMENT AND COMMERCE
DEDC

Generation, Transmission & Distribution

$4Bn needed PRIOR to the storm to update grid infrastructure to "stabilize and improve operational efficiency, safety, reliability, environmental compliance, and conversion to clean energy" - PREPA


Sept. 20, 2017

EMERGENCY RESPONSE – PROGRESS REPORT

Notwithstanding the precautionary measures taken prior to the Hurricanes, Puerto Rico's infrastructure was significantly damaged by Hurricanes Irma and Maria

	1 Day After	30 Days	45 Days	110 Days
Cell Service	5%	61%	92%	92%
Potable Water	44%	69%	83%	96%
Electricity Restored Based on Generation	0%	21%	41%	82%[1]
ATMs	114	1,047	1,160	1,586
Gas Stations	40%	78%	84%	88%

As of January 10, 2018

- Priorities
  - Hospitals
  - Water Supply
  - Industrial Base

Recovery Planning

Engaged experts from DOE, Power Marketing Administrations, USDA, USACE, FEMA, Puerto Rico, and DOE National Laboratories working with industry to develop a strategy for catalyzing an innovative, secure and resilient electricity system for Puerto Rico

Sandia National Laboratories

FEMA

Oak Ridge National Laboratory

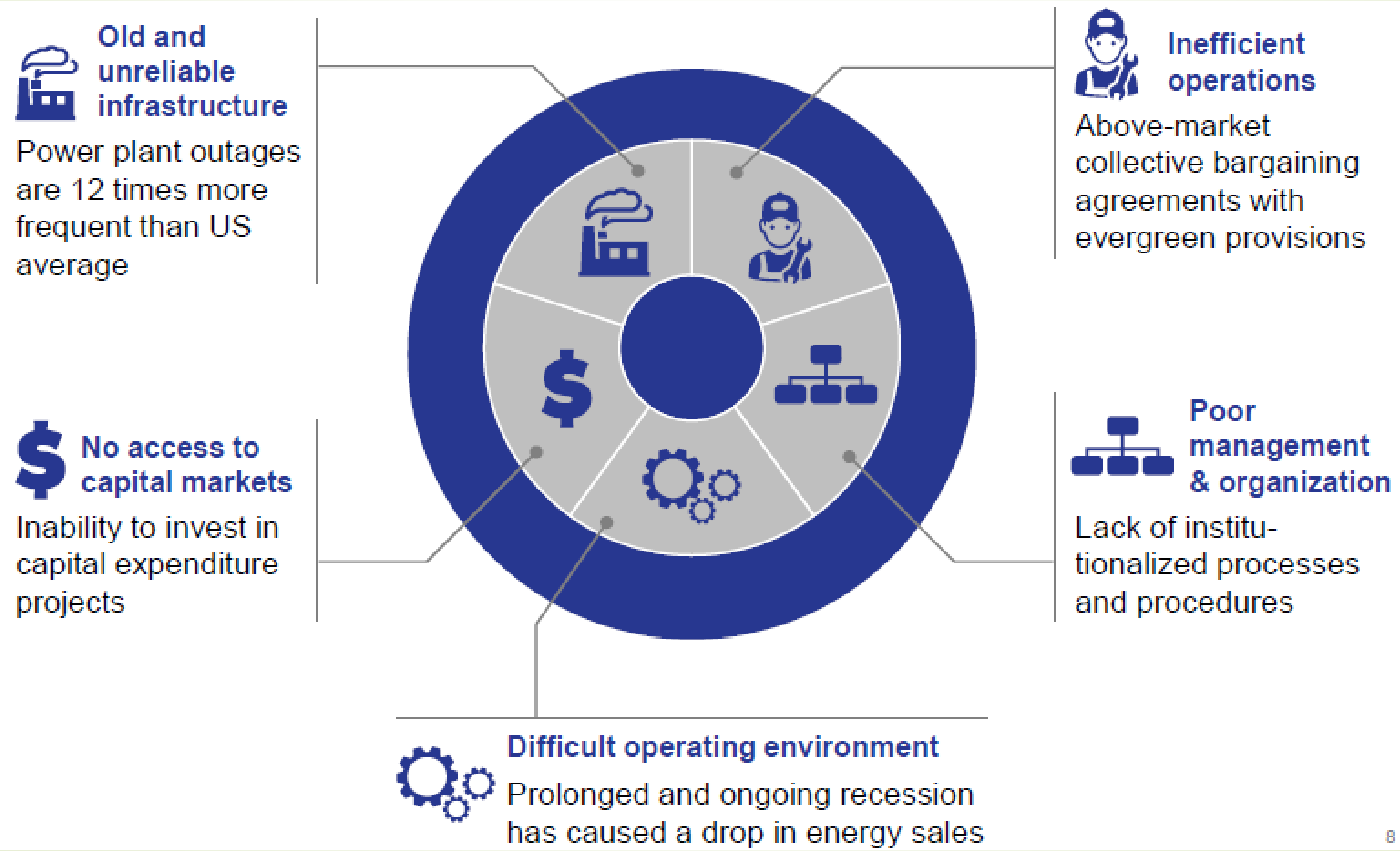
PRIDCO
GOVERNMENT OF PUERTO RICO
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY

US Army Corps of Engineers

GOVERNMENT OF PUERTO RICO
Department of Economic Development and Commerce

Pacific Northwest NATIONAL LABORATORY

Longer Term Recovery for Puerto Rico



Grid Modernization Elements

Resilience Enhancement Options	Definition	Example
Hardening	Physical changes that improve the durability and stability of specific pieces of infrastructure	Raising and sealing water-sensitive equipment
Security measures	Measures that detect and deter intrusions, attacks, and/or the effects of manmade disasters	In-depth security checks on all employees, badged entry and limited access areas, and surveillance and monitoring
Maintenance and general readiness	Routine efforts to minimize or prevent outages	Vegetation management and regular inspection and replacement of worn-out components
Modernization, control enhancements, and smart-grid technology	Technology and materials enhancements to create a more flexible and efficient grid	Integration of smart-grid technologies, such as smart meters and phasor measurement units
Diversified and integrated grid	Transitioning of the grid from a centralized system to a decentralized generation and distribution system	Integration of distributed generation sources, such as renewable energy sources and establishment of microgrids
Redundancy, backup equipment, and inventory management	Measures to prepare for potential disruptions to service	Maintenance of spare equipment inventory, priority agreements with suppliers, and maintenance of a supply of backup generators
Mutual aid programs	Agreements that encourage entities to plan ahead and put in place mechanisms to acquire emergency assistance during or after a disaster	Agreements between utilities to send aid or support after a disaster
Succession training, knowledge transfer, and workforce development	Planning for transfer of knowledge and skills from a large retiring workforce, to a smaller, younger workforce	Proactive efforts to create training and cross-training programs and succession plans
Business continuity and emergency action planning	A formal plan that addresses actions and procedures to maintain operations preceding an event	Components including employee awareness, training, and exercising
Models	Mathematical constructs that provide information on performance and/or disruptions to aide in decision making	Probabilistic risk models to assist in predicting outage impacts after an event

Energy Resilience Solutions for the Puerto Rico Grid

- Update mutual aid agreements and prime incident command systems
- Review requirements for distribution poles carrying telecommunications and electricity
- Replace temporary transmission towers with monopoles, a design that withstood the hurricane force winds
  - Establish microgrid regulations
  - Update Energy Assurance Plans
  - Analyze
    - Power flow
    - Production cost and capacity expansion
    - Microgrid, storage and system segmentation
    - Infrastructure independencies (water, waste water, wastes, telecommunications, transportation and buildings)

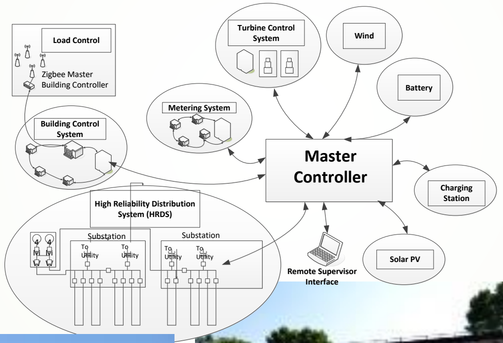
Resilient Distribution and Microgrids

Intelligent switches

Energy storage

Wind turbine

PMU



Rooftop solar

Charging stations

Solar canopy at charging station

Grid Modernization Initiative: Resilient Distribution Systems

Grid Resilience and Intelligence Platform (GRIP)	Predictive analytics, machine learning, and AI will help anticipate and recover from grid events quicker.
Resilient Alaskan Distribution System Improvements using Automation, Network Analysis, Control, and Energy Storage (RADIANCE)	Enhance the resilience methods for distribution grids under harsh weather, cyber-threats, and dynamic grid conditions using multiple networked microgrids, energy storage, and early-stage grid technologies.
Increasing Distribution Resiliency using Flexible DER and Microgrid Assets Enabled by OpenFMB	Accelerate the deployment of resilient and secure distribution concepts through the flexible operation of traditional assets, DERs, and microgrids using OpenFMB.
Integration of Responsive Residential Loads into Distribution Management Systems	Validate open-source home energy management systems (HEMS) to support distribution resiliency use cases and end-to-end interoperability.
CleanStart-DERMS	Demonstrate DER-driven mitigation, blackstart and restoration strategy for distribution feeders with integration of applied robust control, communications and analytics layer, and coordinated hierarchical solution.
Resilient Distribution Systems	focus on effective integrated resource planning and metrics, control systems, inverter-dominated islanding with storage and regional consortia

Campus Microgrid at IIT

IIT is working with the local electric utility, ComEd in the development of the Bronzeville Community microgrid that would interconnect with the IIT microgrid creating the first-ever cluster of a private microgrid and a utility microgrid in a metropolitan region of the U.S.

Peak load at IIT has consistently decreased approximately 20% from 2007 levels.

Objective	Results
Reduce Peak Load	60% of peak load
Improve Reliability	✓
Enable Integration of Renewables	✓
Enhance Security and Resiliency	✓
Increase Consumer Engagement	✓
Improve System Efficiencies	6.6%
Create Economic Value (net present value [NPV])	+4.6 Million BCR 1.38

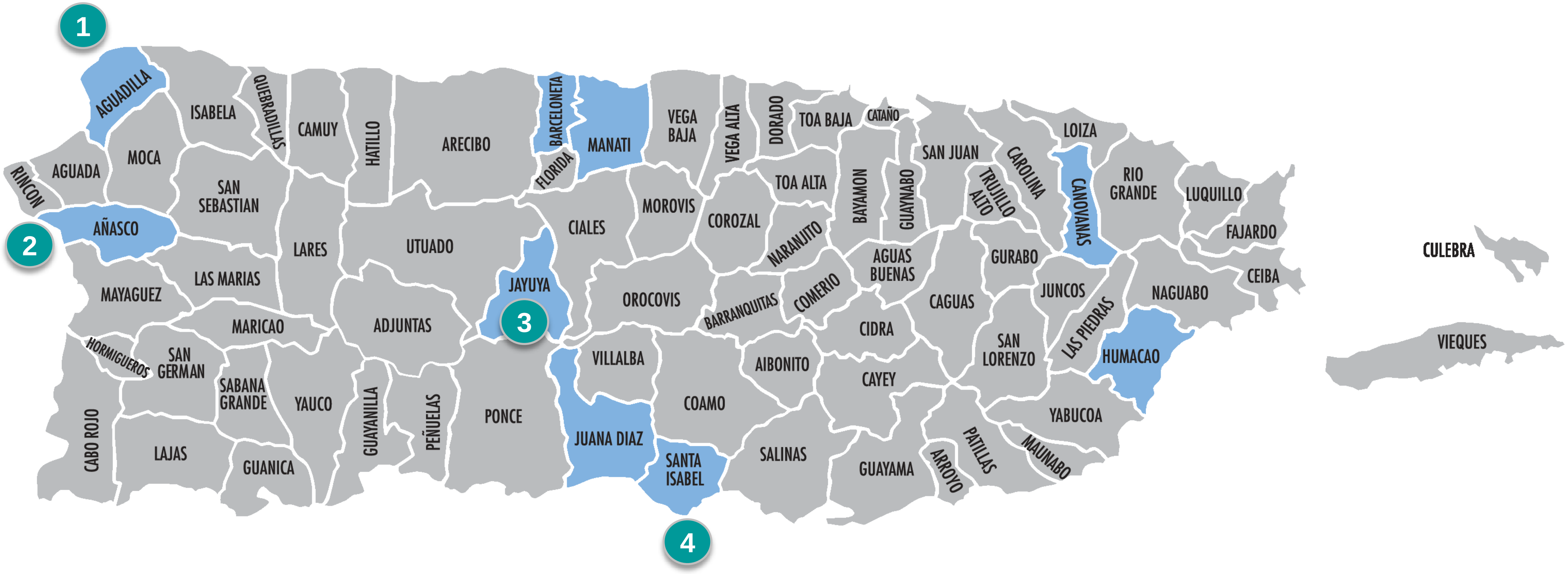
Year	2007	2008	2009	2010	2011	2012	2013
Peak Load (kW)	12,921	10,638	10,475	10,125	10,342	10,263	10,619
Reduction	NA	17.7%	18.9%	21.6%	20%	20.6%	17.8%

PRIDCO Request for Proposals

PRIDCO decided to conduct a Pilot Project to demonstrate that Microgrids can be a solution for power generation and delivery in Puerto Rico with the following elements:

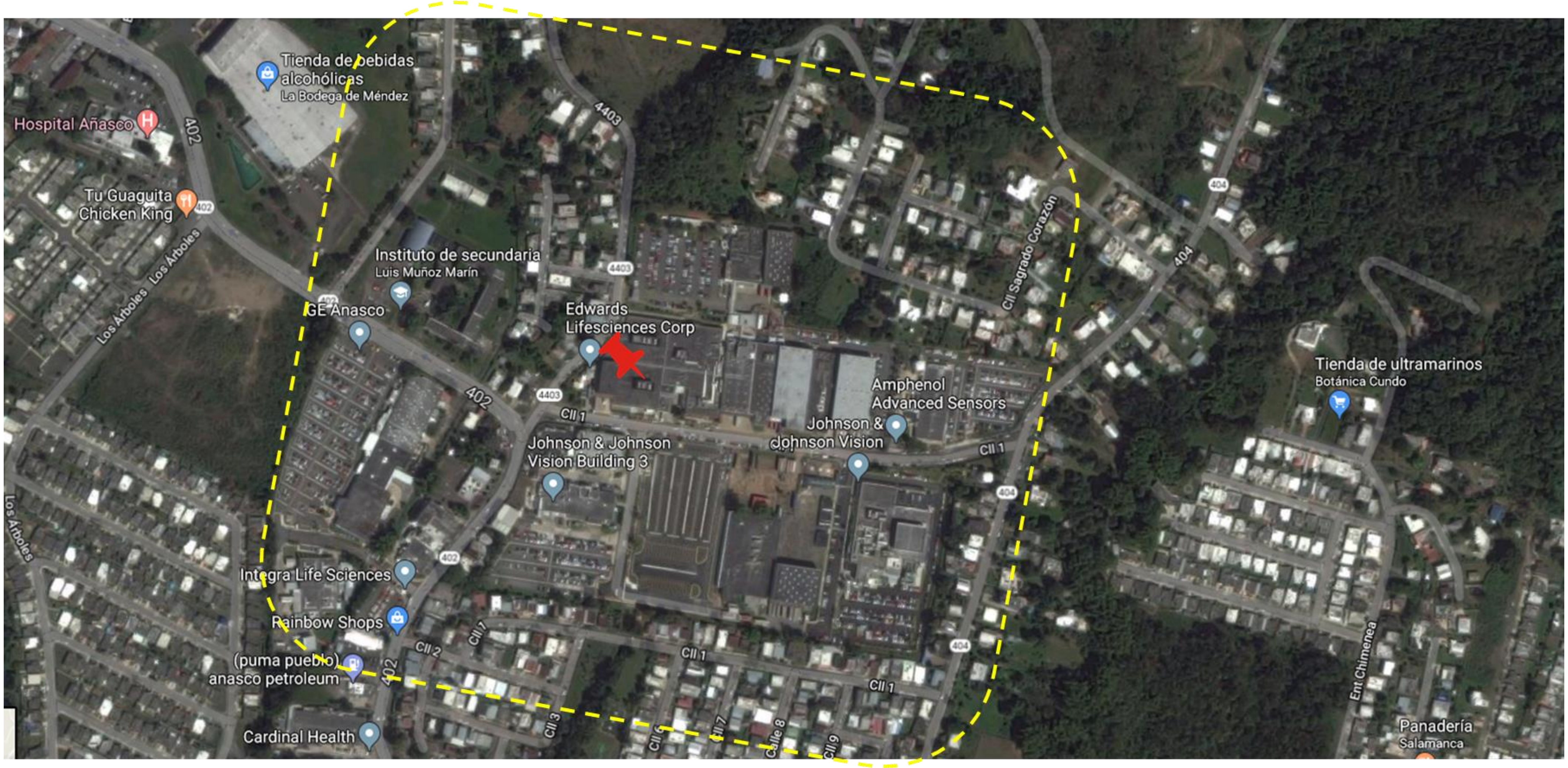
- reasonable cost per kilowatt
- resiliency
- sustainability
- reliability
- customer engagement and empowerment

Puerto Rico – Municipalities and Proposed Microgrid Locations (subject to modification)



2 Añasco Site – Aerial View

Geographic Coordinates 18.29N, 67.14W



Microgrid Design Toolkit (MDT)

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

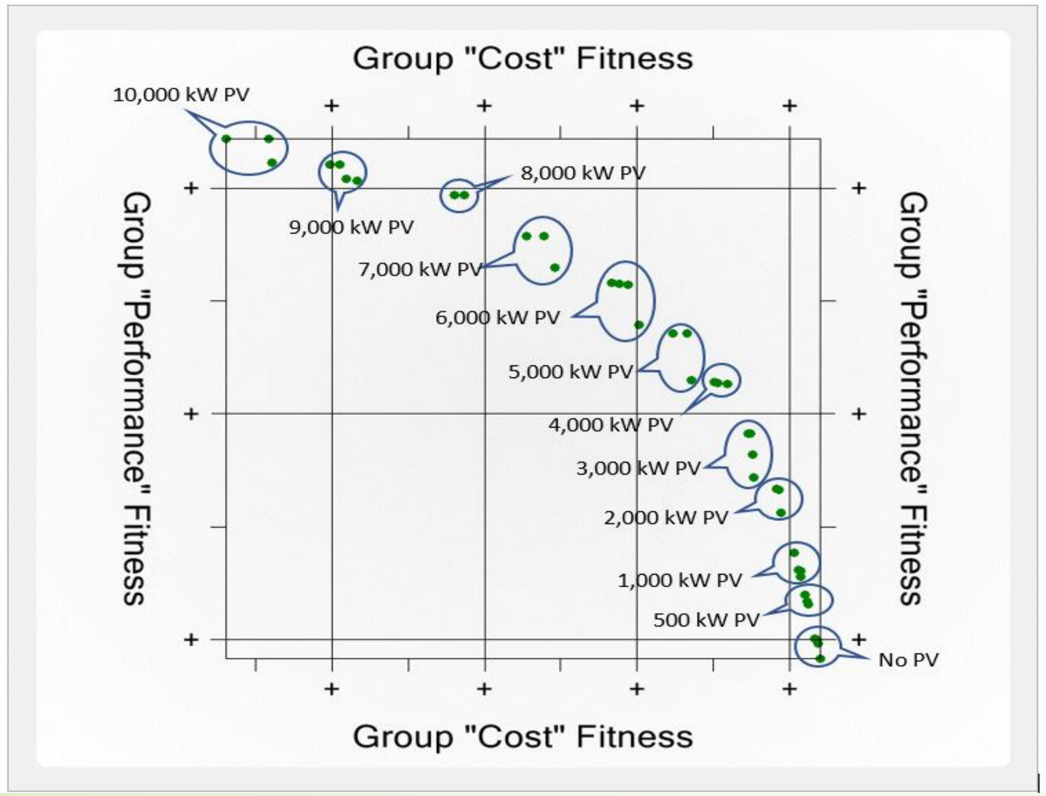
ITERATIONS to Refine Results

Facility Analysis

Microgrid Area Only

Rooftop PV: 1.0MW, Empty Parking Lot PV (repurpose for PV only): 0.5MW, Active Parking Lot PV (canopy style): 0.5MW

Total ~2MW



PRIDCO Request for Proposals

- The microgrid shall be capable of supporting indefinite “island-mode” operation, meeting base load energy demand at all points of the year.
- The systems solution shall combine:
  - Renewable sources
  - Storage systems/technology
  - Backup generation source.
- Proponents shall provide two solutions:
  - Solution No. 1, connection with the proposed generation mix shall comply with Regulation on Microgrid Development Num. 9028, of May 18, 2018
  - Solution No. 2 proposed generation mix not limited by the Microgrid Regulation, using the best and most efficient scenario with renewables in the combination. The system shall include a minimum of 15% of renewable sources.

Rules of Engagement for Microgrids are unclear

There is a strong move towards microgrids as a "solution" to resiliency.

-for connected (to the utility) MGs, do we need to change our thinking about "obligation to serve"?

-when an event such as a hurricane destroys both industrial microgrids as well as utility lines, how long will it take for the MG to get up and running again? Especially if local generation (e.g., solar panels) are destroyed? During this time will MG owners compete with utility for skilled technicians to restore power? Could MG owners develop private agreements for "mutual aid"?

-If MGs only use utility-connected power during emergency situations, then they are using the utility as insurance. How is this priced? Are PUCs onboard with this type of pricing? During a lengthy time for restoration, are MGs for industrial parks given priority? How is prioritization priced? Does this cause confusion between private and public goods?

Other Considerations

- Cybersecurity and communications networks
- Critical infrastructure interdependencies
- Rate and market structure
- Operations and maintenance
- Governance
- Labor union, consumer and regulatory issues
- Human resource challenges

Summary

- Identify those grid attributes desired and their interdependencies: establish your priorities
- Study and implement appropriate standards and procedures before an event
  - Energy Assurance and mutual assistance Plans
  - Know federal, state or local counterparts
  - Practice
- Utilize emerging best practices, tools and technologies
  - Resilient recovery mindset
- Assess your goals, roles of participants and costs: develop a comprehensive plan instead of piecemeal legislation and regulation for a balanced solution