Design of a More Reliable Power Grid for Puerto Rico

sddec18-03
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Problem Statement

Our Problem

- 80% of Puerto Rico's Power Grid destroyed
  - Hurricanes Irma and Maria paired with years with little to no maintenance
  - Lack of PREPA leadership focus on upkeep of system
  - Frequent blackouts which are difficult to resolve
  - $9 billion debt

"If you have an old grid susceptible to collapse, there is no way - until you change it completely - that it can sustain the winds of a Category 4, or even really a Category 2" - Governor Ricardo Rossello

Where We Come In

- Prepare a written proposal describing a technical and economic redesign of Puerto Rico's Utility Market

  - Technical Components
    - Natural Gas
    - Renewable Energy
    - Interconnectivity

- Implement these components into Puerto Rico's Power Grid

  - Economic Components
    - Subsidies
    - Adjusted Rates

- Provide a cost breakdown of lost income, costs of implementation, and profits

Non-functional Requirement

- Maintainability/Durability
  - The design of the power grid must be robust and at the same time efficient enough to provide constant supply of electricity to the island
  - Grid must be strong enough to handle disasters that may occur on the island
  - The design also requires a staff or a management team that can maintain the system
- Disaster Recovery
  - Full defense is unachievable, but the grid should be able to isolate outages while maintaining a consistent power supply
  - Allow for cost and time-effective replacement in case of natural disasters

Functional Requirements

Technical

- Provide safe, reliable, and efficient power generation and distribution
  - Introduction and upkeep of renewables such as solar and wind energy
  - Introduction of a natural gas deliquification port and updating of current generating systems to allow for natural gas fueling
  - Introduction of natural gas turbines

Economic

- Generate a positive revenue
  - Restructure current pricing breakdown
    - No free power to municipalities
    - Re-evaluate pricing to near the Caribbean average
    - Introduction of subsidies
  - Allow for the creation of jobs

Functional Requirement

Safety

- IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
- 2017 National Electrical Safety Code(R) (NESC(R))

Technology

- IEEE Standard Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications
- IEEE Standard for the Specification of Microgrid Controllers

IEEE

Technical Constraints

- Avoid the political aspects when designing the power grid
  - Do not include how politics may effect economics
- Unable to physically redesign the power grid
  - Utilize computer software such as PSS/E

Market Survey

- Many redesigns of Puerto Rico emphasize 100% renewable energy presence
  - This is NOT realistic
- Our model focuses on the introduction of **natural gas powered generation plants** combined with renewable energy. We also are evaluating and redesigning Puerto Rico's electric utility market.
  - Natural gas's energy density is twice that of coal (55MJ/kg vs. 29MJ/kg)
- PREPA's Proposal
  - Using pre existing hardware

Potential Risk

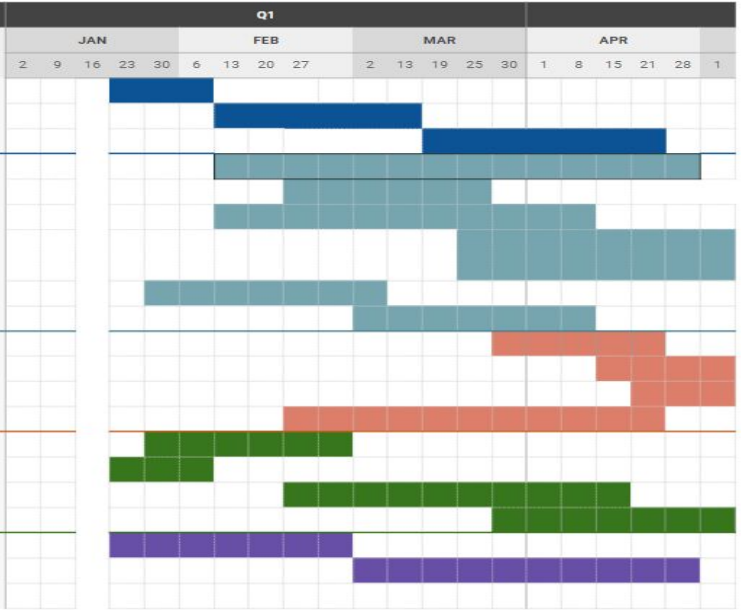
- Accuracy of Research
  - Accuracy and currentness of PREPA data
  - Accuracy of studies or quotes from other companies
    - Siemens gas turbine costs
    - Cost of renewable energy and energy storages
    - Profits associated with updates
- Weather
  - Weather, storms, and temperature swings can be unpredictable
    - If the solar panels are not able to supply energy to the island, will the energy from the cogenerator be sufficient enough to supply for the island?

Project Milestones & Schedule

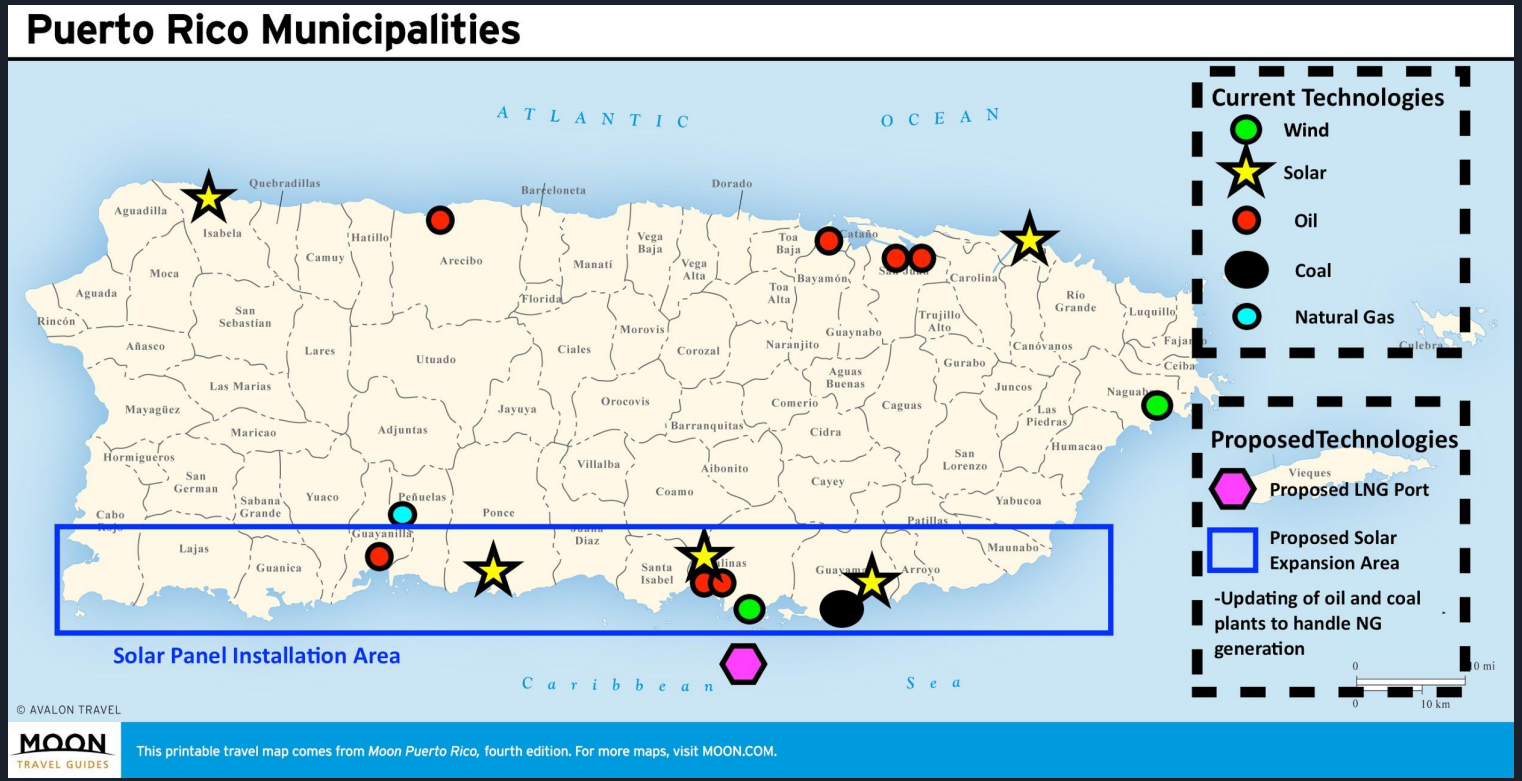
PROJECT TIMELINE

PROJECT TITLE	Puerto Rico's new power grid	COMPANY NAME	Iowa State University
PROJECT MANAGER	Logan Lillis	DATE	4/18/18

PHASE		DETAILS
	Phase timeline:	
1	Project Plan	Version 1
		Version 2
		Final version
2	Research	Power Grids
		Natural Gas
		Energy Storage
		Micro grids
		Renweables Resources
		Prices and demand
3	Proposal	Company selection
		Cost and rates for new grid
		Grid map
		Technical proposal
4	Other Deliverables	Contact PREPA
		Team website
		Standards
		Test plan
5	Design Document	Version 1
		Version 2



Conceptual Sketch



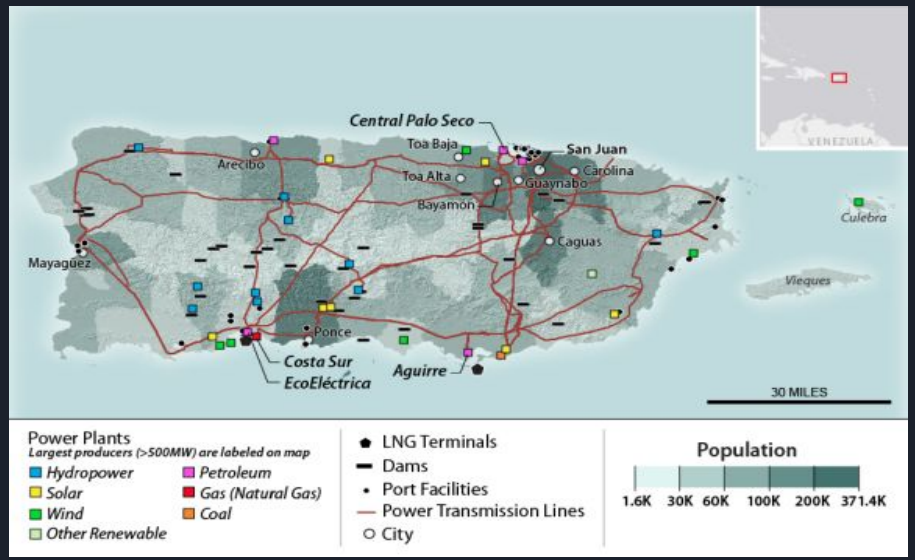
Functional Decomposition: Generation

Publicly Owned:

- PREPA (aka AEE): 7 Oil Generation Plants , 1 Oil/Natural Gas Plant
- 2 Private Cogeneratoes (Natural gas and Coal)
- 6023 MW

Privately Owned:

- AES: 1 Solar, 1 Coal (478MW)
- Gas Natural Fenosa: 1 Natural Gas (510 MW)
- Sonnedix: 2 Solar(61MW)
- Sovereign Bank(Gestamp Wind): 1 Wind (26MW)
- Uriel Renewables and Coqui Power: 1 solar (27MW)
- Pattern Energy: 1 Wind (75MW)
- Windmar Renewable Energy: 1 Solar(4.5MW)
- 21 Hydroelectric Plants (156MW)

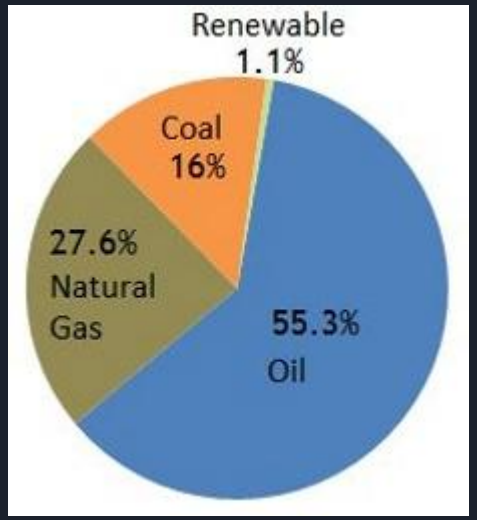


Functional Decomposition: Generation

Electric System

Generating Capacity: 6,023MW

Peak Demand (in 9/05): 3,685MW



U.S. electricity generation by source, amount, and share of total in 2017[1]		
Energy source	**Billion kWh**	**Share of total**
Total - all sources	4,015	
Fossil fuels (total)	2,495	62.7%
Natural gas	1,273	31.7%
Coal	1,208	30.1%
Petroleum (total)	21	0.5%
Petroleum liquids	13	0.3%
Petroleum coke	9	0.2%
Other gases	14	0.4%
Nuclear	805	20.0%
Renewables (total)	687	17.1%
Hydropower	300	7.5%
Wind	254	6.3%
Biomass (total)	64	1.6%
Wood	43	1.1%
Landfill gas	11	0.3%
Municipal solid waste (biogenic)	7	0.2%
Other biomass waste	3	0.1%
Solar (total)	53	1.3%
Photovoltaic	50	1.2%
Solar thermal	3	0.1%
Geothermal	16	0.4%
Pumped storage hydropower[3]	-6	-0.2%
Other sources	13	0.3%

Functional Decomposition: Natural Gas in Puerto Rico

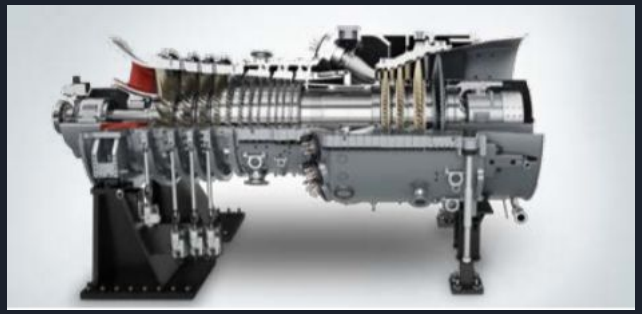
Natural Gas Deliquification Port

- Currently, import 55 billion cubic feet of LNG each year
  - Main imports from Trinidad and Tobago
  - Some industrial customers receive LNG from the US
- Floating deliquification port proposed and approved by FERC in 2015
  - Off coast of Aguirre, where current LNG imports come through.
- Originally planned a pipeline from south coast to north, but nixed due to environmental and load concerns
  - North coast has 2 natural gas-fired generation plants. Currently use trucks to transport LNG
- PREPA reportedly has run feasibility reports on if a northern deliquification port is possible

Functional Decomposition: Natural Gas Turbines

Gas Turbines from Siemens

- Focus on combined cycle power generator
  - Uses both gas and heat energy to supply energy
  - Heavy-duty gas turbines are primary focus
    - Robust and flexible
    - Functions as a cogenerator
    - Designed for large combined cycle power generator
- Work as a cogenerator to the renewable energy
  - Supply power without solar or wind supply
  - Cost of solar energy storages are expensive
- Implemented throughout the world

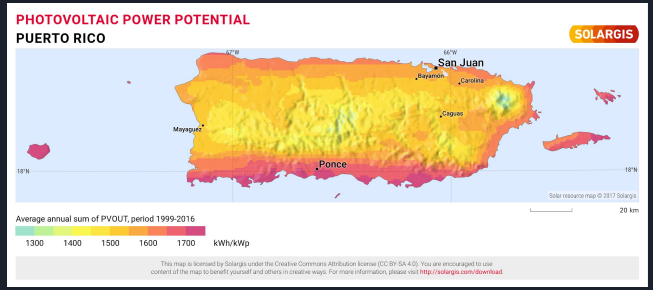


Functional Decomposition: Renewable Energy - Solar

- South coast has most potential
- Contact with AES, who owns the 23.7MW Ilumina Solar Farm
  - Fixed axis
  - Power increases w/ solar irradiance up to 20MW per PREPA contract
  - Provided irradiance data for lowest solar irradiance reading for “worst case” comparison
- Generally 14 hours of sunlight per day

Our Proposal:

- South coast, fixed-axis solar farm(s)
  - Based on communications with AES and NREL research on axis effectiveness
  - Specific locations TBD
  - Area conservation with sheep or livestock



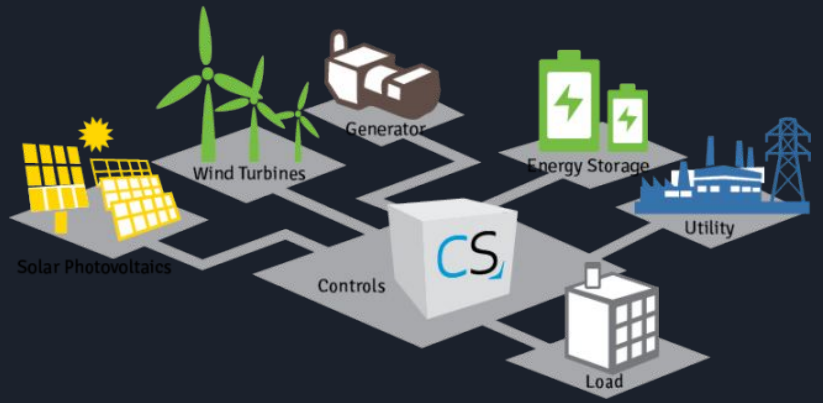
Functional Decomposition: Interconnectivity

Microgrids

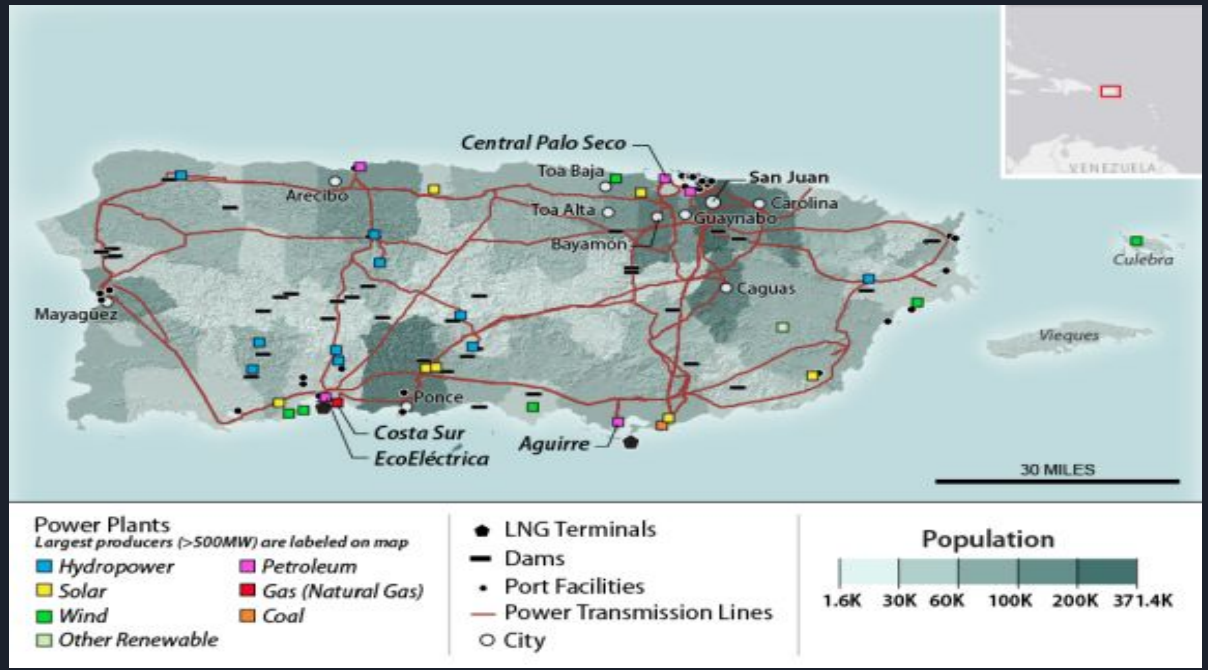
- Island mode
- Autonomous microgrid with energy storage system
- Overcome natural disasters

Interconnectivity

- Contingency plans



Functional Decomposition: Interconnectivity - Transmission and distribution



Functional Decomposition: Energy Storage

Background of energy storage on the island

- Previous Company supplying the island was ABB.
- Majority of current energy storage components supplied by AES
  - 6MW batteries donated
  - Suggested installation of solar panels and microgrids
- Other companies working to introduce energy storage include Tesla, Sonnen and Tabushi America
- 300 million awarded in a contract to the Company Whitefish Energy

Why we need energy storage

- Assist in supplying renewable energy

Functional Decomposition: Economics and PREPA

Background info:

- Puerto Rico's utility rates are at or above $0.10/kilowatt-hour below the Caribbean regional average
  - $0.24/kWh commercial
  - $0.20/kWh residential
  - $0.18/kWh industrial
- PREPA provides all 78 municipalities, many government owned, enterprises, and some for profit businesses free power
  - Set in place in 1958

Functional Decomposition: Economics and PREPA (continued)

Our plan:

- Introduce a subsidy system
  - PREPA will fund a set dollar value of electricity. Any amount over this subsidy is funded by the company
    - Encourages cognizant energy use
- Encourage PREPA leadership to prioritize grid maintenance
  - Provide a cost breakdown outlining money lost due to the constant blackouts
  - Provide a maintenance plan and guide for government-run upkeep efforts
  - Educate on how the lack of maintenance led to 80% grid failure post-natural disaster

Hardware and Software used

Project Hardware

- Solar panels
- Microgrids
- Energy storage
- Gas turbines

Project Software

- PSS/E Online Software

Test Plan

Compliance Test

- A compliance test will be facilitated to check whether the implemented hardware produces desirable results as specified in the data sheet.
  - Example: Gas turbines energy supply based on the Siemens datasheet

Simulation Test

- We will be conducting a simulation test of the prepared design using a software
  - Current plan: PSS/E
- Many other options of simulation still being investigated
  - Algorithms
  - Assistance by area industry professionals

Current Status and Milestones

- Have all the “pieces of the puzzle”
  - Natural Gas: Generation and Port
  - Solar Energy / Renewable Energy Storage / Gas Turbines
  - Interconnectivity
  - Economic proposal

Member Contributions

Logan Lillis - Communications and Reports Lead

- Renewable Energy (Solar and Wind)
- Natural Gas
  - Deliquification Port and Imports
- Economic Analysis
- Generation
- Weekly Reports, Weekly Meeting Logs

Ricardo Rodriguez-Menas - Webmaster and Project Plan Lead

- Energy Storage
- Website Upkeep
- Project Timeline

Heiqal Zamri -Test Engineer Nead

- Natural Gas
  - Imports
- Energy Storage
- Test Plan

Plan for Next Semester

- Design the specific routes of added interconnectivity both in terms of microgrids and connecting generation plants
  - Meet with area industry professionals
- Possibly add new/more hardware to the grid
  - Wind, solar, amount of natural gas-fired power generation facilities
- Use computer softwares to mimic the grid and test for natural disasters and various contingencies
- Calculate short and long-term total costs and profits associated with the redesign
- Create and present a technical and economic proposal document for the redesign of Puerto Rico’s electric system

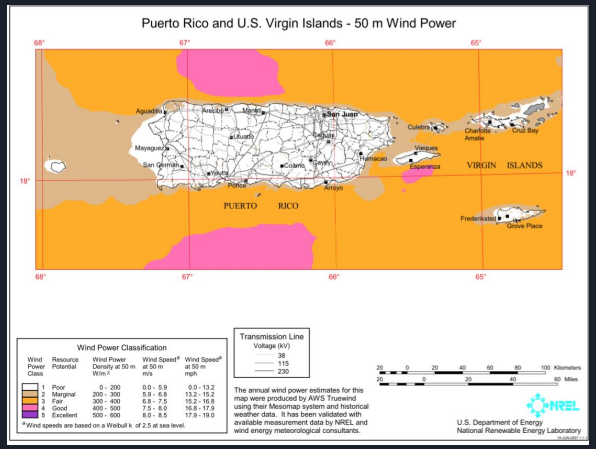
Questions?

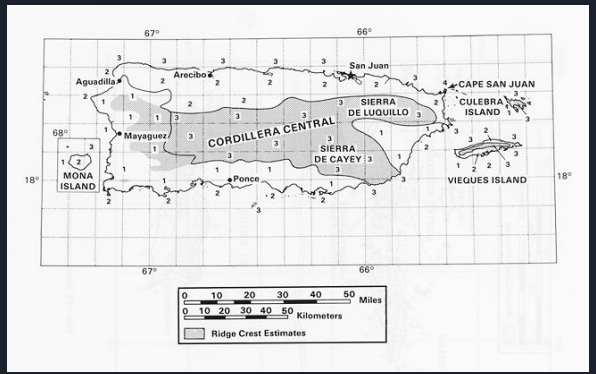
Thank you for your time!

Additional Information

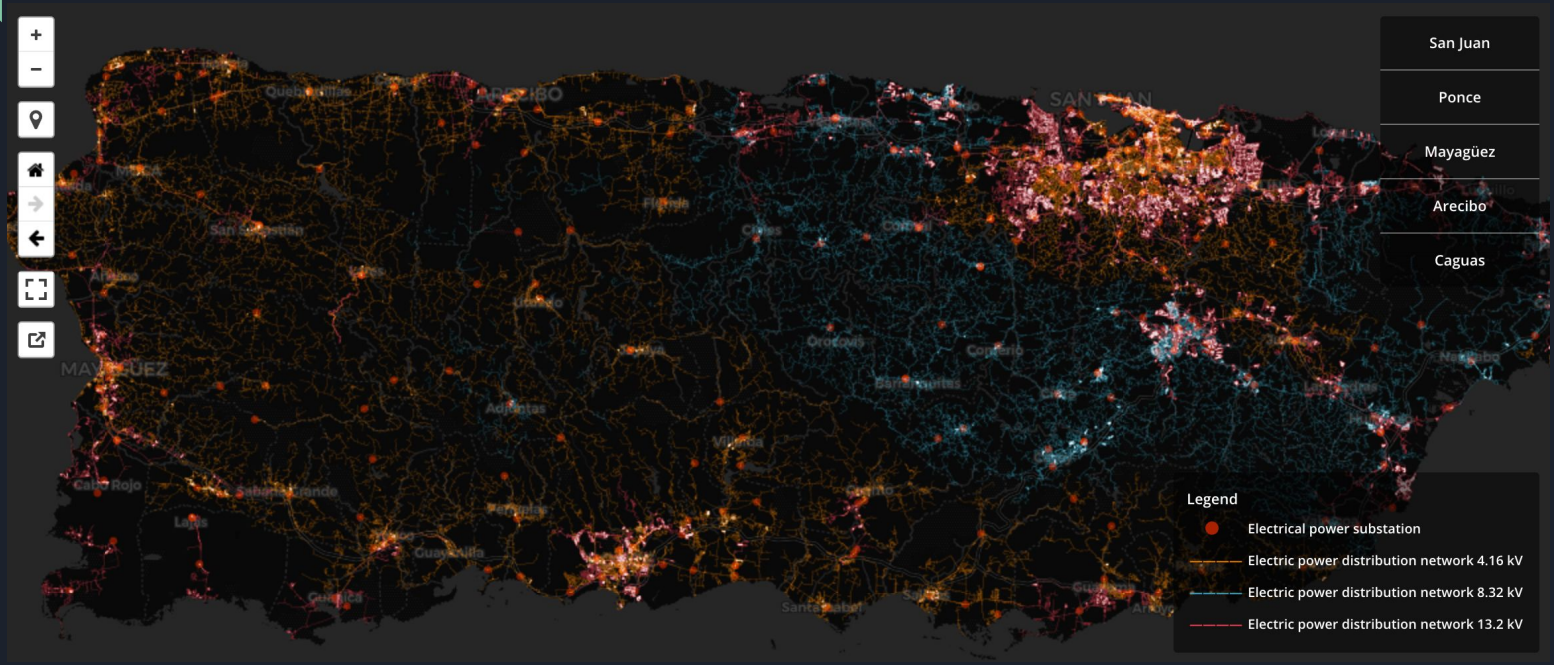
Functional Decomposition: Renewable Energy - Wind

- Puerto Rico is home to the Santa Isabel Facility
  - Largest wind farm in the Caribbean
  - This combined with one other wind farm generated half of Puerto Rico's renewable energy
- Some conflicting data on where wind is "viable"
  - 22mph trade winds year-round
  - For now, opted to focus on energy storage for these farms vs proposing new plants (will be added in future)





Current Grid



Demand & Distribution