Designing a Model for Puerto Rico: A Micro-Grid Case Study of Transmission following Hurricane Maria

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MOTIVATION

- This project aims to explore "how micro-grid infrastructure can relieve energy demand in disaster zones" by observing behavior of grids when certain transmission conditions are available."
- On September 6-7, 2017 category 5 Hurricane Maria hit in Puerto Rico. wind speed was 240+ kmh and badly damaged the national grid.
- Power lines between cities were knocked down, and 80% of the national grid was destroyed

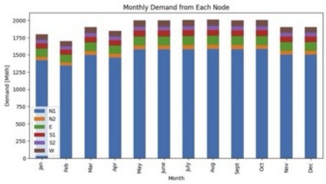
This project aims to understand what capacity of microgrids (solar + battery) could be installed to provide energy to the people of Puerto Rico when national grid connection is not possible.

Puerto Rico Hurricanes Map

Source: https://www.usgs.gov/media/images/puerto-rico-hurricanes-map

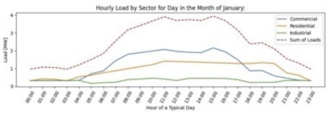
PROJECT BACKGROUND

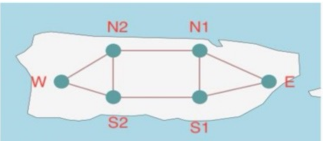
- In 2016, Puerto Rico had a national consumption of 23 TWh
- Three sectors make up Puerto Rico's consumption: Residential (39%), Industrial (14%) and Commercial (47%) . An hourly consumption profiles for each sector was also created.
- In 2016, the Electricity generation had 71.82% coming from Petroleum, 17.85% from Natural Gas, 8.47% from Coal and 1.86% from Renewable Energy

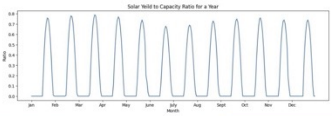


The figure below illustrates the nodes utilized in the model. Each node is coded with the data (demand, generation, storage) of the region. The node is representative of all systems in the region.

- Northeast most populated and most commercial and industrial buildings are located, correlating to the high demand for N1 in the Monthly Demand.
- Hourly load variation is considered as the variation load of that particular whole month and Maximum Peak demand is 138 MW, which is visualised from May to October in the year.

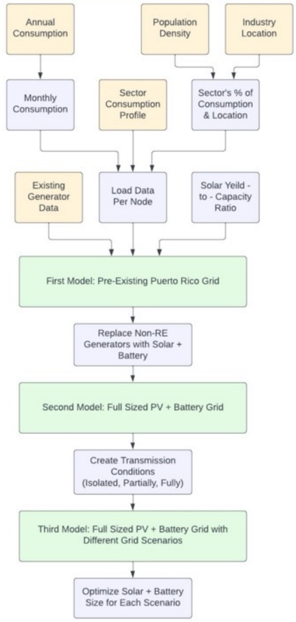






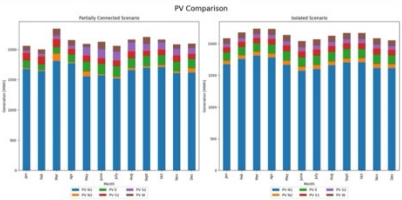
- Solar in the North, East, South, and West is all similar, so one profile for Solar Yield-to-Capacity Ratio was utilized for the entirety of Puerto Rico
- The Yeild to Capacity Ratio was calculated off of data from the Solar Global Atlas

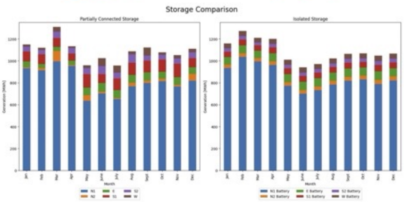
METHODS FLOWCHART



TRANSMISSION SCENARIOS: PV & STORAGE COMPARISON

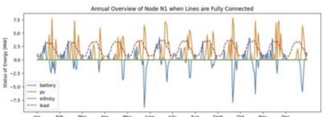
- During Partial Connection: The PV Generation may increase or decrease as exchange across transmission lines and storage in batteries occur losses not experience in the Isolated Scenario.
- During Isolation: PV Generation is subject only to the local load with demand being satisfied by the system at each node. The size of the nodes here are entirely self-sufficient
- During the Summer PV performance is low as the irradiation is low.
- Oversizing PV Capacity due to optimization creates the opportunity for this behaviour when lines are connected, the difference comes from behavior in the battery and lines.

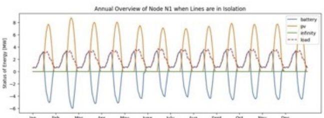


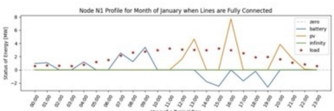


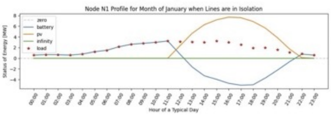
- The maximum discharging hours of Battery is nine hours. The battery efficiency is set to 90%.
- The cumulative sum of each node's battery is utilized to find the capacity at each node. The difference between maximum charging and maximum discharging values for a cycle is the required size.
- In the partially connected scenario, capacity of the battery storages have been increased due to sharing with other nodes and the line losses.

- When observing behavior at each individual node, a fully connected grid transfers energy between nodes even though each node is self-sufficient in an isolated case. This has been discovered to be due to the optimizer – when there is no difference in cost nor CO2 emissions the model randomly delegates load, even though there are line and battery losses associated with the randomization.
- Most of the power flow is from S1 and N2 to N1 when lines are fully connected. In the current scenario, S1 and N2 are oversized PV capacities.



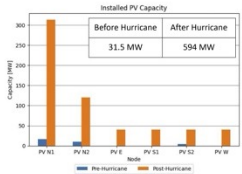


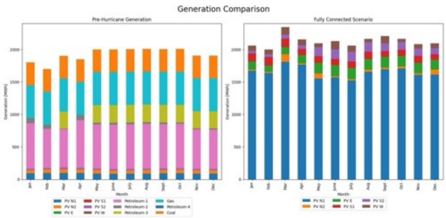




CONCLUSIONS

- After Hurricane Maria the model is designed to utilize only the renewable energy system: PV and Battery.
- At each node the total sum of all micro-grid capacities will equal that of the total PV installed capacity.
- Battery of each micro-grid will also be calculated and represented with this method.





In the Post-Hurricane Scenarios (Fully Connected, Partially Connected, and Isolated) the overall electricity generation is much higher than before.

- This is due to the inclusion of batteries in the grid model.
- Line efficiencies impact the delivered power in both pre and post hurricane models.

This model specifically aimed to understand what capacity of solar and battery would be needed to provide a micro-grid to each region in Puerto Rico, following the conditions of Hurricane Maria, where transmission was completely isolated or partially connected.

We are hopeful that the study and creation of similar models will help communities globally pursue renewable energy as a resilient energy source.

ACKNOWLEDGEMENTS

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