EE/CprE/SE 491 WEEKLY REPORT 2

2/5/23 - 2/12/23

Group Number: **16**

Project title: **Feasibility of Solar PV Energy for Puerto Rico**

Client &/Advisor: **Vikram Dalal**

Team Members/Role: **Adam Curtis, Hannah Nelson, Isaac Buettner, Larry Trinh, Manuel Perez-Colon**

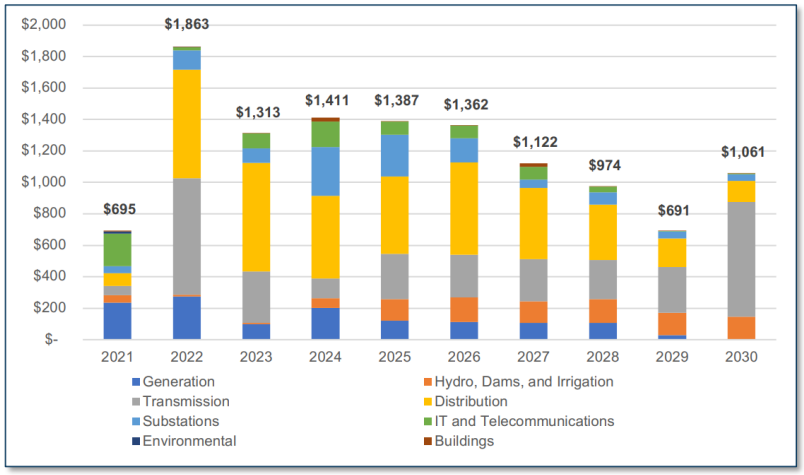
- **Weekly Summary**

Team meeting happened Monday without Dalal. We started work on the team contract and figuring out where to go in research from what we had done last week. The objectives were to determine what updates are being done/planned for the current transmission and distribution system, look into climate models for the viability of PV on certain sides of the island, energy demand, and continued storage availability and long-term needs. This project continues to be research-heavy, and there is a lot of knowledge we still need on various topics related to PV feasibility. We are slowly getting into specifics after figuring out the situation in Puerto Rico as a whole.

- **Past Week's Accomplishments**

Hannah: Read through PREPA's (government-run utility) 10-Year Infrastructure Plan, starting in 2020 and going through 2020. *Fortunately, they have plans to invest over $12 B in efforts to transform and rebuild the grid*. The budget shown below illustrates that most funds will be going to their transmission system.

Figure 1.1 – Forecast Capital Investment by Year and Asset Category ($ millions)

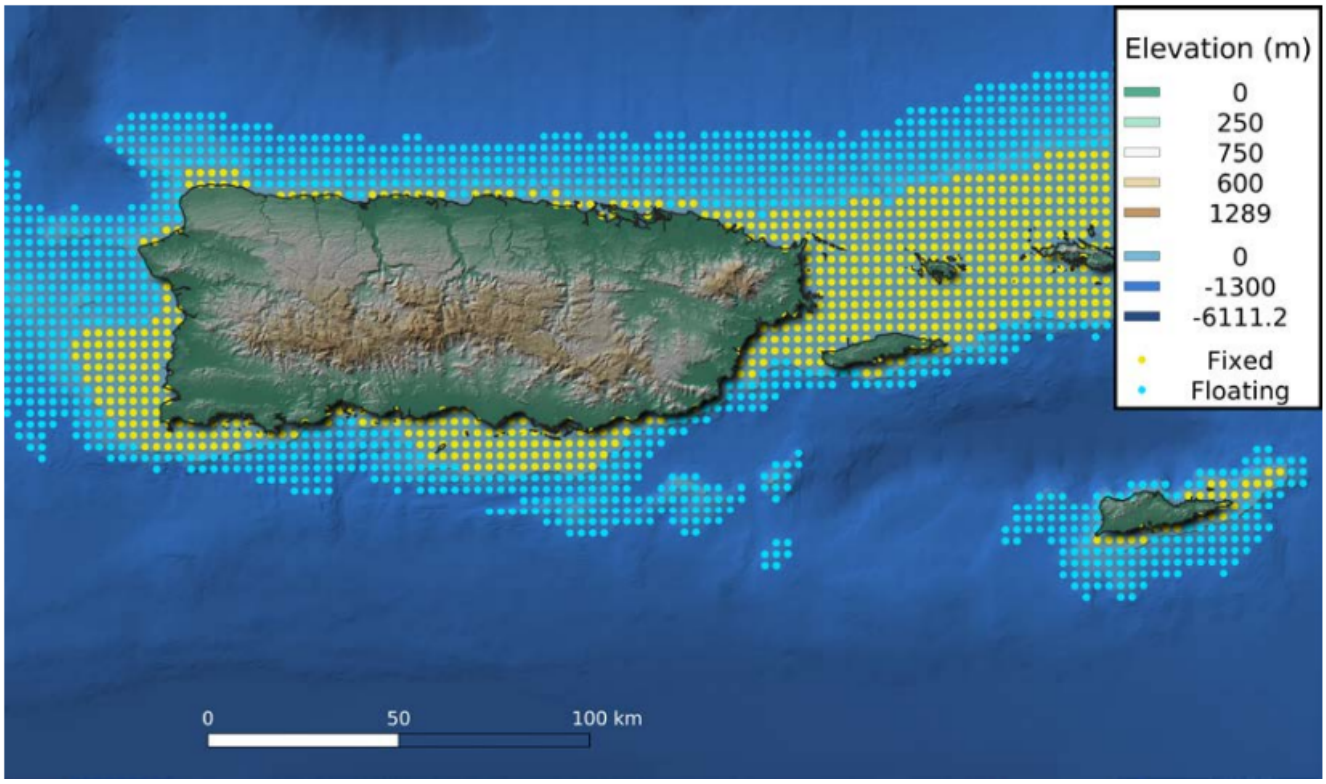


After Hurricanes Irma and Maria, almost all transmission lines had to be repaired as “temporary, emergency repairs” that were only intended to give power back to the residents for a short time. These repairs were not intended to be permanent fixes. Well, that was 5 years ago. *The current objective is to rebuild 273 miles of 115 or 230 kV lines, and 549 miles of 38 kV lines.* All remaining wood structures will be replaced with steel or concrete. These updates started in 2021. Additionally, 150 distribution feeders will be replaced and updated to the current code. They will be installing distribution automation (DA) equipment such as intelligent reclosers, fuse cutouts, and switches in hopes of maintaining reliability and resilience in natural disasters– these will be able to route electricity to critical loads such as hospitals, emergency operations, etc., and the GOAL is to keep the power on for 50% of customers.

Project Summary	Asset Category Impacted		
	Transmission	Substation	Distribution
Restore the 38-kV sub-transmission lines that have been out of service since the 2017 hurricane season	X		
Rebuild and harden the T&D systems	X		X
Deploy distribution automation technology			X
Deploy fiber optic connectivity for a robust communication network	X	X	X
Rebuild and/or relocate existing distribution substations and transmission centers		X	
Add new transmission lines and substations to mitigate the risk of widespread system failure	X	X	
Alleviate thermal constraints on the transmission system through new hazard mitigation projects	X		
Modernize the existing central dispatch center in Monacillo, add a new backup central dispatch center in Ponce, and integrate emergency remote grid control centers at Daguao and Mayagüez	X	X	X
Acquire modern equipment to support the maintenance, repair, and installation of equipment and infrastructure	X	X	X
Coordinate necessary support for retired, new, or converted thermal generation and/or new renewable generation projects, as appropriate	X	X	X

https://aeepr.com/es-pr/Documents/20201207_PREPA%2010-Year%20Infrastructure%20Plan_vF.pdf

Manuel: Analyzed the PR100 Study six month progress report by NREL. Focused on the characteristics of Weather Research and Forecasting (WRF) models and the characteristics of the Wind Resource the island has access too. These models were based on 20 years of weather, from 2001 to 2020. Based on the recent market trends offshore wind farms would be cost effective, the importance would be to have a mixture of fixed and floating. The report assumes fixed-bottom systems to be productive up until 60m of ocean depth, while floating structures have a higher cost effectiveness past that, until 1,300m.



Seasonal winds speeds show similar outputs, with a common increase at noon due to the ocean breeze. Nevertheless, wind speeds are higher in summer/winter than in spring/fall.

There is recorded data for the island divided into four sites: northwest, northeast, southwest, and southeast. The northwest location shows the highest winds in the afternoon, but other sites are outputting more wind during nighttime. This could show promise in a complementary solar and wind grid. Another important factor is that the southwest location has the lowest winds on average, possibly indicating that there shouldn't be wind investments in that are.

Adam: Performed some data analysis on the demand and price data found from the EIA website, comparing demand per residential customer in PR to demand per residential customer in IA. Demand in PR was almost half of the demand in IA, yet the price per kWh in PR was over two times the price in IA [1]. All of this comes with the unreliability of the grid in Puerto Rico, bringing us to the conclusion that the average Puerto Rican residential customer uses less power than the average Iowan residential customers, yet has to put up with frequent outages and much higher prices. I then started looking at estimates for the cost of installing photovoltaics on an average home, and found data on the amount of time it would take for a customer to recoup their investment in PV via sending their excess generated power into the grid for a credit from the company operating the grid. More research will need to be done to determine whether an average Puerto Rican family can afford an investment in PV and battery backup. In IA, the average cost to install a 6kW PV system is $10,478 [2], but that is accounting for a 26% tax credit, which may not be feasible for the Puerto Rican Government to match.

			RESIDENTIAL				COMMERCIAL				INDUSTRIAL			
			Revenue	Sales	Customers	Price	Revenue	Sales	Customers	Price	Revenue	Sales	Customers	Price
Year	State	Data Status	Thousand Dollars	Megawatthou	Count	Cents/kWh	Thousand Dollars	Megawatthou	Count	Cents/kWh	Thousand Dollars	Megawatthou	Count	Cents/kWh
2022	PR	Preliminary	1,726,121	6,036,860	1,370,491	28.59	2,157,850	6,857,224	127,695	31.47	467,103	1,624,857	589	28.75
2021	PR	Final	1,506,288	7,119,383	1,358,513	21.16	1,799,862	7,484,529	126,159	24.05	380,303	1,853,200	591	20.52
2020	PR	Final	1,329,048	6,908,138	1,351,190	19.24	1,568,470	7,320,018	125,391	21.43	360,707	1,909,660	587	18.89
2019	PR	Final	1,329,706	6,205,152	1,341,424	21.43	1,810,611	7,905,084	124,912	22.90	420,178	2,048,192	588	20.51
2018	PR	Final	1,265,179	6,102,980	1,346,102	20.73	1,893,330	8,202,893	126,527	23.08	405,173	2,128,354	602	19.04
2017	PR	Final	1,123,005	5,045,346	1,337,756	22.26	1,549,337	6,819,591	127,065	22.72	344,034	1,746,554	618	19.70
2016	PR	Final	1,169,715	6,524,294	1,332,152	17.93	1,677,137	8,568,776	127,180	19.57	356,154	2,249,787	632	15.83

Larry: Work on comparing the prices of electricity between Puerto Rico and other states in the US. I found out that there are a couple of reasons behind the increase of electricity prices: First, Puerto Rico Electric Power Authority (PREPA) has a big amount of debt, so it has to increase the price to have enough money to pay stockholders. Second, Puerto Rico's population has decreased for the last 20 years up to 16 percent, so each person has to pay more for electricity. Last but not least, transmission lines are not stable, and relying on an expensive fossil fuel pushes the price up. I am also doing some research about solar grid integration to get a better understanding about solar energy in order to support and help other team members.

[1] https://www.eia.gov/state/data.php?sid=RQ#Prices

[2] https://www.forbes.com/home-improvement/solar/cost-of-solar-panels/

Isaac: Looked into alternative energy storage solutions that could fit the industry and economy of Puerto Rico. One alternative that was researched was thermal battery technology. The operating principle is the same with normal battery storage technology, except with a few key differences. Thermal energy storage operates at a much higher efficiency as input electricity is converted to heat. One drawback is that the system itself does not have a direct output which converts the thermal energy back into electricity, however, researching into Puerto Rico's economy, it was found that, at the very least, the industrial sector could benefit from this technology. New thermal energy storage solution companies are offering technologies that boast this high efficiency energy transfer all at a low price as they are built from much more common resources than the precious metals in batteries. This heat could be used to reduce CO2 emissions in the industrial sector, while saving money. Additionally, under the right conditions when powered by renewable energy, these thermal stations can provide around the clock heat at up to 1500℃. This would be useful for industries in Puerto Rico such as Chemical processing plants, alcohol distilleries, pharmaceutical manufacturers, and more. Alternatively, it could be used to replace or lower usage of coal or natural gas in power plants by supplying excess heat which could produce supercritical steam.

Individual contributions

NAME	**Individual Contributions** *(Quick list of contributions. This should be short.)*	**Hours this week**	**HOURS cumulative**
Adam Curtis	Research, Google Slides	5	14
Hannah Nelson	Research	6	13
Isaac Buettner	Research	4	10
Larry Trinh	Research, power points	4	12.5
Manuel Perez	Research	4	8

- **Plans for the upcoming week** *(Please describe duties for the upcoming week for each member. What is(are) the task(s)?, Who will contribute to it? Be as concise as possible.)*

Team meeting Monday at 3:15 PM

Hannah **-** I briefly saw an article saying the privatization of PR's grid was finalized 2 weeks ago. This could be very problematic for PR's grid if the new company decides not to follow what is highlighted in PREPA's guide. I want to research what Genera's plan is…they are not owners of generation, transmission, or distribution; they are simply contracted to operate and maintain it. So, this could only mean that they are the ones to carry out the updates. Since this is still new, it may take a while for Genera to announce what they are doing. In addition to this, MIT published a framework for evaluating PR's grid– they ran many simulations and came up with multiple recommendations for how to improve the reliability of their grid. I plan to read this and see what is possible for us to do with our skillset.

Manuel - I plan to gain a complete picture for the government's plan and commitment to the PR energy crisis. Also trying to help others on the team by connecting them with resources I might have from my prior work experience or known businesses on the island. Trying to find resources that might only be in Spanish to see if there is anything different that we can ascertain.

Adam - I plan to dig deeper into the cost of purchasing and installing microgrids and photovoltaics into an average home in Puerto Rico. I have contacts in the electrical contracting company I used to work for which I plan to ask some general questions about installing PV on homes to gain more background knowledge, and potentially an itemized estimate. I would also like to spend time digging into the economic situation of the average family in Puerto Rico, to find what kind of investment in PV could be affordable for them if there is no federal tax credit from the Puerto Rican government.

Larry: I plan to finish up my part, work together with Adam to discuss our works because for the first two or three weeks we were working on similar tasks. I am also doing some more research about solar energy grid integration to gain better understanding. I also check with my coworkers who have backgrounds in power systems and solar energy about any documentation that we can use for our project.

Isaac: I want to be able to draw my first phase research to a close this week in terms of gaining final solid numbers for storage to build up now, and what to gain for the future. I want to see if I can get feedback from teammates and the project advisor, but also be able to provide final feedback myself. I want to start looking towards the next phase and compiling all of our data and sorting it together to look and make sure we hit everything we wanted to for the first phase of research. I also want to make sure I'm just on the right track and to see if thermal energy is even viable as an energy storage solution or if I should reconsider and go back to standard battery energy storage solutions.