EE/CprE/SE 491 WEEKLY REPORT 5

2/26/23 - 3/5/23

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**

- ***o*** **Weekly Summary**

Team meeting without Prof. Dalal– we met on Discord. Went over what we had researched in the last week and realized there was a bit of overlap in certain areas like economics and pricing of PV. This is expected for the project. We created a shared doc to organize "by topic" instead of "by person." However, in lieu of finding more information for Dalal, we have not yet organized our research in that way. This week, we aimed our research at quantitative data like what percent of PR can accommodate rooftop PV systems, what those costs are, climate data, etc. Moving into next week (with many exams for us all), we will focus on combining the research we have done in the past month into a topic-by-topic document.

- ***o*** **Past Week's Accomplishments**

Hannah: Changed the plan slightly from what I thought I would work on. After the team meeting, decided to compare and contrast utility-scale scale solar farms with residential microgrids. Research from MIT, Princeton, and NREL indicated that microgrids (rooftop solar) will be more efficient, reliable, and sustainable. To support this, NREL used light detection and ranging technology to scan 96% of PR's buildings. From this and the criteria for suitability (shading, tilt, min. area, etc.), they found that there are 24.6 TWh of solar potential in PR. This accounts for 4x of their current consumption. Theoretically, Puerto Rico has the potential to offset all their electric needs.

Assumptions for Building Suitability

Rooftop Suitability Assumptions

Roof Physical Characteristics	Description
Shading	Measured shading for four seasons and required an average of 80% unshaded surface
Azimuth	All possible azimuths
Tilt	Average surface tilt <= 60 degrees
Minimum Area	>= 1.62 m^2 (area required for a single solar panel)

PV Performance Assumptions

PV System Characteristics	Value for Flat Roofs	Value for Tilted Roofs
Tilt	15 degrees	Tilt of plane
Ratio of module area to suitable roof area	0.70	0.98
Azimuth	180 degrees (south facing)	Midpoint of azimuth class
Module Power Density	183 W/m^2	
Total system losses	Varies (SAM defaults + individual surface % shading)	
Inverter efficiency	96%	
DC-to-AC ratio	1.2	

Manuel: Researched the cost of offshore wind power installation and cost per kW. In 2021 US offshore wind had a cost of approximately $1.3 million per MW. While the installation cost of these units seems to be at 2-4 million dollars and an additional yearly maintenance cost of $42,000-48,000. This makes it seem like a less viable option that solar panels, since the economice invest required is far too great even for the production granted. Another advantage of the current solar power resource is the benefits that it gives Puerto Ricans homeowners of being able to sell back the energy they generate from theri rooftops.

https://weatherguardwind.com/how-much-does-wind-turbine-cost-worth-it/#:~:text=What's%20the%20cost%20of%20a,on%20wind%20turbine%20operational%20cost.

Adam: Found a source itemizing the percentages of generation from each source in Puerto Rico. “For fiscal year 2022 (July 2021 to June 2022), natural gas-fired power plants generated 43% of Puerto Rico’s total electricity. Petroleum generated an additional 37% of total electricity, coal generated 17%, and renewables generated 3%”[1]. I also found a source stating a company named Crowley opened a new Liquid Natural Gas facility in Peñuelas, that can deliver 94 million gallons on Liquid Natural Gas per year and help supply at least 120 MW of power generation [2].
I compiled a list of existing power plants in PR, which can be seen below. I believe there are a few more that I haven't been able to find information on yet, but will look for more in the coming week.

Plant Name	Fuel	Capacity (MW)	Location	Construction Date	Notes
Palo Seco Power Plant	Residual #6 Oil	602	Cataño	Between 1960-1970	
Aguirre Thermoelectic Power Plant	Residual #6 Oil	900	Salinas	1975	
Aguirre Combined Cycle Power Plant	Distilled #2 Diesel	592	Salinas	1977	
Costa Sur Power Plant	Residual #6 Oil	990	Guayanilla	Between 1962-1973	Heavily Damaged by Earthquake in 2020
San Juan Thermoelectric Power Plant	Residual #6 Oil	400	San Juan	Between 1965-1969	
San Juan Combined Cycle Power Plant	Distilled #2 Diesel	464	San Juan	Between 2008-2009	
Cambalanche Power Plant	Distlled #2 Diesel	165	San Juan	1996-1997	Turbine 1 Irreparable after Maria
AES Puerto Rico Power Station	Coal	510	Guayama	1998-2002	Consumed almost 1.4 million tons of coal in 2021

Finally, I did some searching for standards that we should keep in mind as we continue working on this project, one from IEEE [3] and one from NECA [4].

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

[2]https://www.crowley.com/news-and-media/press-releases/puerto-rico-lng-facility/

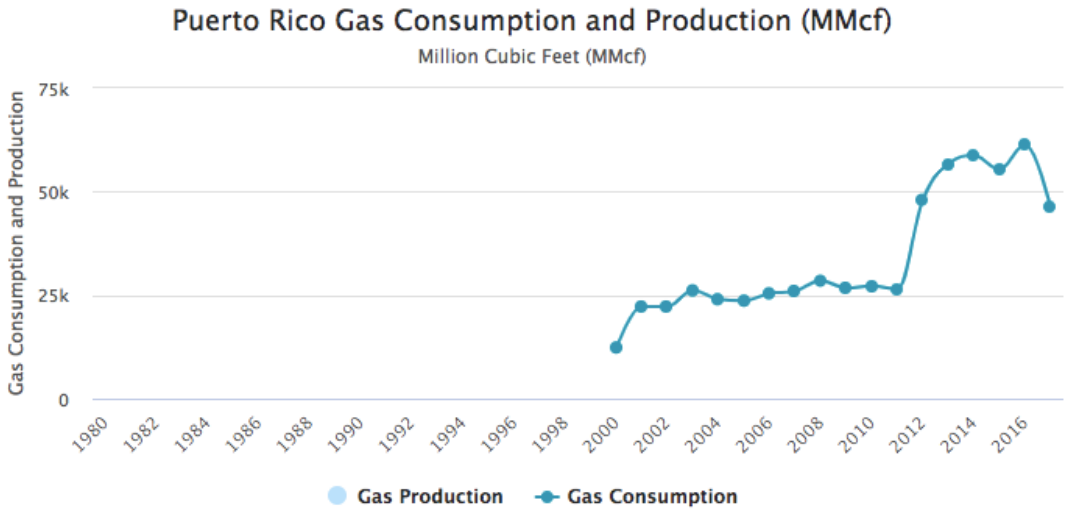
[3]**https://standards.ieee.org/ieee/1547.1/6039/**

[4]https://portal.necanet.org/s/product-details?id=a1B1U00000QReHDUA1

Larry: Worked on comparing the electricity price with some other states in the US. Basically, the electricity price in Puerto Rico is ranked in the third place behind Hawaii and New Hampshire. At the same time, I was working on researching the potential of natural gas in Puerto Rico.

"Puerto Rico does not produce natural gas and has no proved reserves. However, the 2013 U.S. Geological Survey assessment also identified possible undiscovered natural gas resources in a subsea formation south of the island. Natural gas arrives in Puerto Rico at two liquefied natural gas (LNG) import terminals, one located near Ponce at Guayanilla Bay in the southwest and one at the Port of San Juan in the north. The regasified LNG is used to fuel electricity generation at the 766-megawatt Costa Sur power plant and the 580-megawatt EcoEléctrica power plant. There are also several small natural gas-fired generating units at industrial sites. The imported LNG mostly comes from Trinidad and Tobago, with smaller shipments from Nigeria, Oman, and Spain. Minor amounts of LNG from the U.S. mainland are also shipped to Puerto Rico to supply fuel to industrial customers and container ships"

Basically, Since 2012 natural gas has recently increased significantly because they are trying to replace natural gas with petroleum because natural gas is better for the environment and cheaper than petroleum.



https://www.worldometers.info/gas/puerto-rico-natural-gas/
https://www.eia.gov/state/analysis.php?sid=RQ

Isaac:

Battery Storage:

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Natural Gas:

- New Fortress Energy secured a 5 year contract in San Juan back in 2019, supplying LNG to the north of Puerto Rico. The contract is handled in terms of BTU rather than kw/h. Additionally allowing the conversion of San Juan units 5 and 6 to combined cycle natural gas generation. They secured this on the basis of experience and capcity, approach and methodology, and price. They believe natural gas is complimentary to renewable energy and state that over the 5-year period PREPA will be saving $150 million a year for a total of $750 million. Additionally, they have the ability to renew this contract for 3 more terms at present at the end of this term. [1]
- At present the northern natural gas plant, Costa Sur, accounts for 766MW of the 1346MW provided by natural gas. [2]
- Pricing for first 5 year term [3]:

  Delivered price: 115% Henry Hub + $8.50/MMBtu (Months 1-12)

  Delivered price: 115% Henry Hub + $7.50/MMBtu (Months 13-24)

  Delivered price: 115% Henry Hub + $6.50/MMBtu (Months 25-60)

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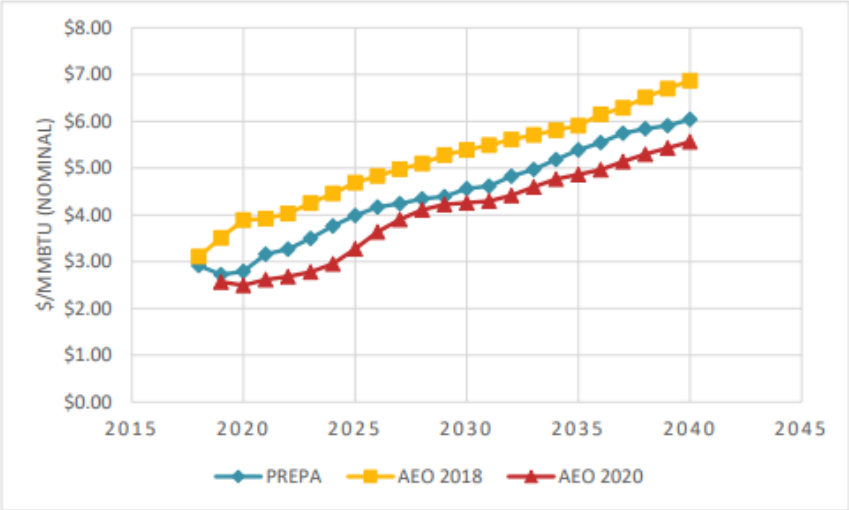
Figure 6. Henry Hub Forecast: PREPA, AEO 2018, and AEO 2020 ($/MMBtu nominal)



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- New Fortress contract additionally includes monthly capacity charge of $833,333.33 for the whole five year contract, this is provided in ROI 1-38, Attachment C. [2] (pg. 145)

- [1] https://www.businesswire.com/news/home/20190305005983/en/New-Fortress-Energy-Signs-Contract-Supply-Natural
- [2] https://www.eia.gov/state/print.php?sid=RQ#111
- [3] https://energia.pr.gov/wp-content/uploads/sites/7/2020/08/AP20180001-IRP-Final-Resolution-and-Order.pdf

Individual contributions

NAME	**Individual Contributions** *(Quick list of contributions. This should be short.)*	**Hours this week**	**HOURS cumulative**
Adam Curtis	Research, Requirements, Powerpoint	5	24
Hannah Nelson	Research, Power-Point	4	23
Isaac Buettner	Research, power point	4	19
Larry Trinh	Research, power points	5	22.5
Manuel Perez	Research, Power Point	5	12

- **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 -
Manuel - Identify current plans for solar power and assess their viability. Contact companies in Puerto Rico that are currently working on rooftop PV installations adn assess the market rate and possibilities for contracting these companies to wokr for the government.

Adam - Verify the list of power plants I found and add to it as necessary. Work to secure access to the IEEE and NECA standards if deemed necessary from meeting with advisor. Work to nail down requirements that we must meet in order to be successful (Budget, Cost per customer), and look for a price/location for a new Natural Gas plant that could supplement our PV solution.
Larry - Making powerpoint file and having a meeting with Dr Dalal. Continue researching some more precise information. Doing some more research about the potential of natural gas in Puerto Rico because there is not too much data about natural gas on the internet. Preparing some questions for the team meeting tomorrow.
Isaac - For this upcoming week, I'd like to go back to focusing on energy storage and securing accurate pricing for Puerto Rico, especially by looking at pricing relative to the United States and what impacts price shifts. Although I started looking at natural gas, I think that we only need one person working on it so I'll leave my notes and resources with Larry after this week.