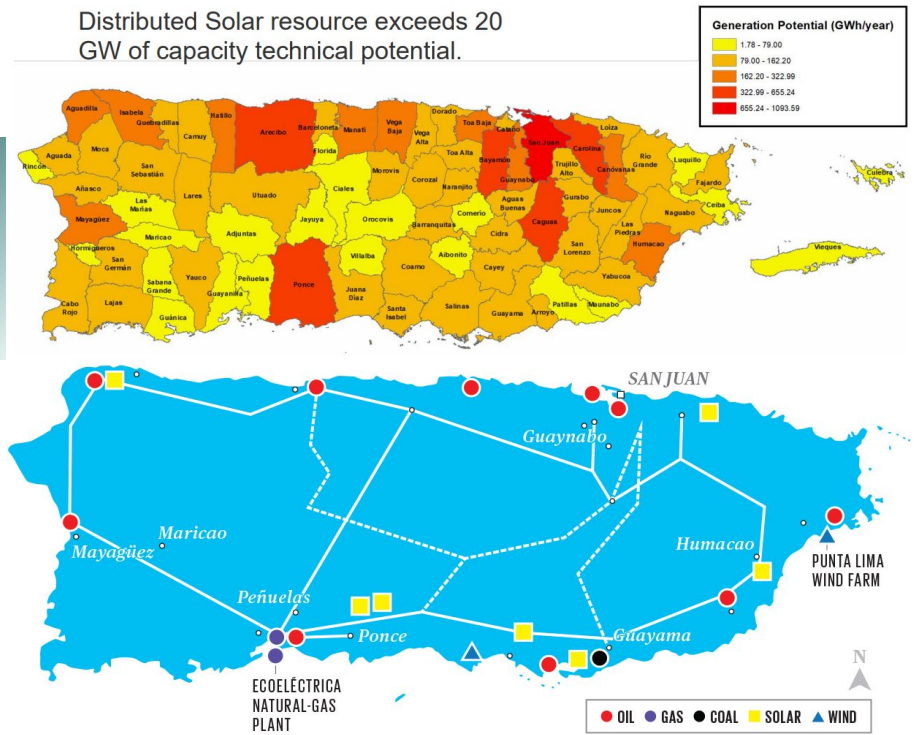
PHOTOVOLTAIC FEASIBILITY IN PUERTO RICO

SDDEC23-16: Isaac Buettner, Adam Curtis, Hannah Nelson, Manuel Perez-Colon, & Larry Trinh
Advised by Prof. Vikram Dalal



Problem Statement

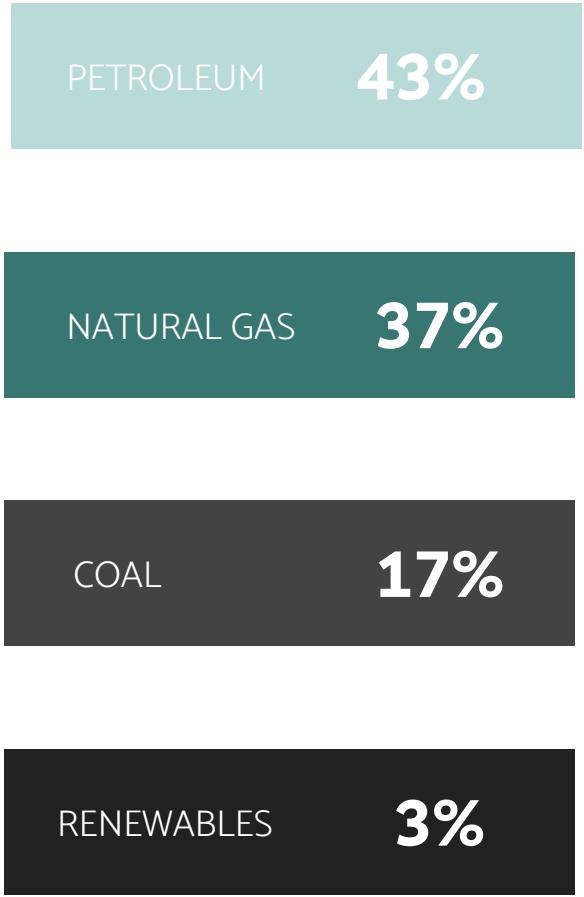
Our project aims to provide a plan for ensuring reliable and affordable power to all Puerto Rico using photovoltaics combined with battery storage units.

- Puerto Rico's grid is very unstable as a result of frequent hurricanes, outdated power plants, and poor management.
- Renovation and modernization of the transmission, distribution, and generation systems.

PUERTO RICO'S GENERATION

PR's government set a goal to be 100% reliant on renewable energy by 2050.

- Action is not being taken at the level it needs to be in order to achieve this goal
- Price of electricity is incredibly high: 23 cents/kWh in residential sector
- Necessary to bring communities together under goals of reliability and sustainability



USERS

Puerto Rican Residents

Deserve reliable and affordable power, and to not be worried about when next outage will occur. Price hikes cause tension in families and unnecessary financial burdens.

Essential Services

Services like hospitals, restaurants and emergency responders need to have a stable grid to provide the highest quality of amenities possible.

Utilities

Concerned about their safety trying to repair downed power lines and other grid connections. Deserve to have a job where they feel comfortable and can provide for themselves & families.

FUNCTIONAL REQUIREMENTS

1. Offset Puerto Rico's current total energy consumption, which currently sits at approx. 16 TWh
2. Decrease the price per kWh for the people to make it more affordable while still profitable for the utility company (Genera PR)
3. Final plan must be economically feasible given the approx. $3B USD allocated from US Government for improving the grid.
4. The grid has to be stable under several weather conditions.
5. Must be easy to maintain and operate.

STANDARDS

1. Final Design must follow all applicable IEEE and NECA/NFPA standards, including but not limited to:
    a. IEEE Recommended Practice for Utility Interface of Photovoltaic Systems (929-2000)
    b. IEEE 1547: "IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces"
    c. NECA 417-19: Designing, Installing, Operating, & Maintaining Microgrids
    d. NFPA 70 (NEC): National Electrical Code
    e. NFPA 855: Standard for Installation of Energy Storage Systems

POTENTIAL RISKS & MITIGATION

Failure to Meet PR's 2025 Goal

Risk Factor: 0.2
Mitigation: Spend significant time on research to make sure our plan is credible and feasible.

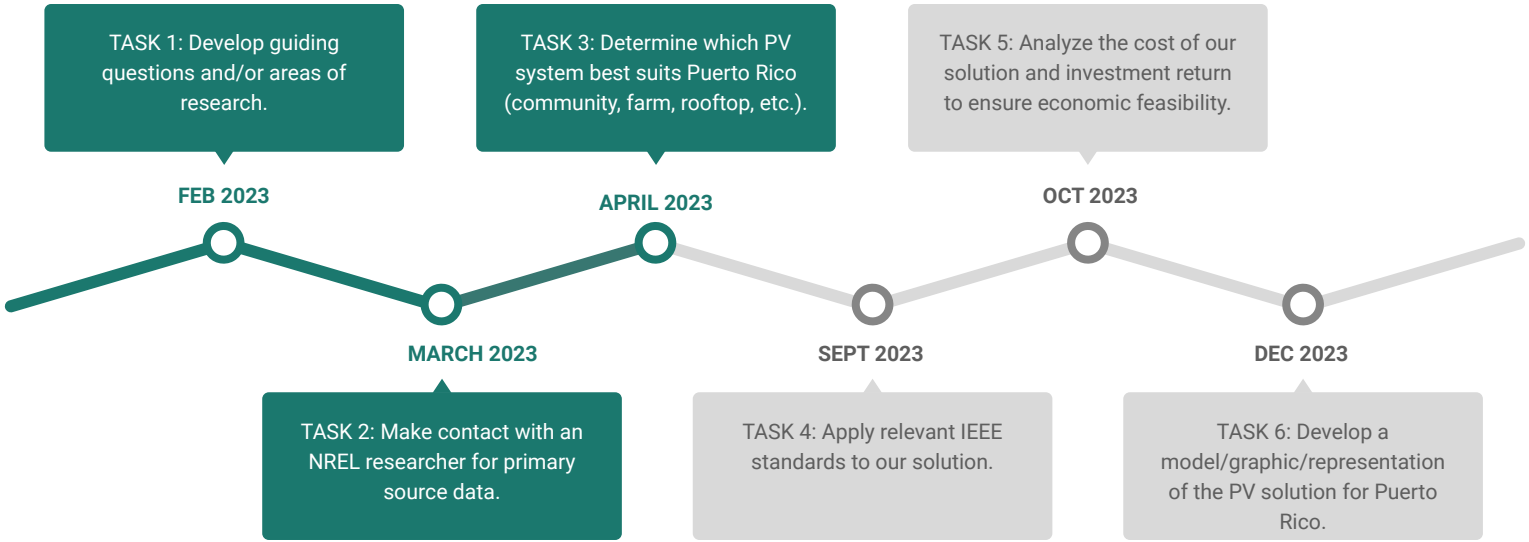
Cybersecurity Threats

Risk Factor: 0.3
Mitigation: Stay updated with NERC guidelines and aware of physical threats to the grid.

Participant Hesitancy

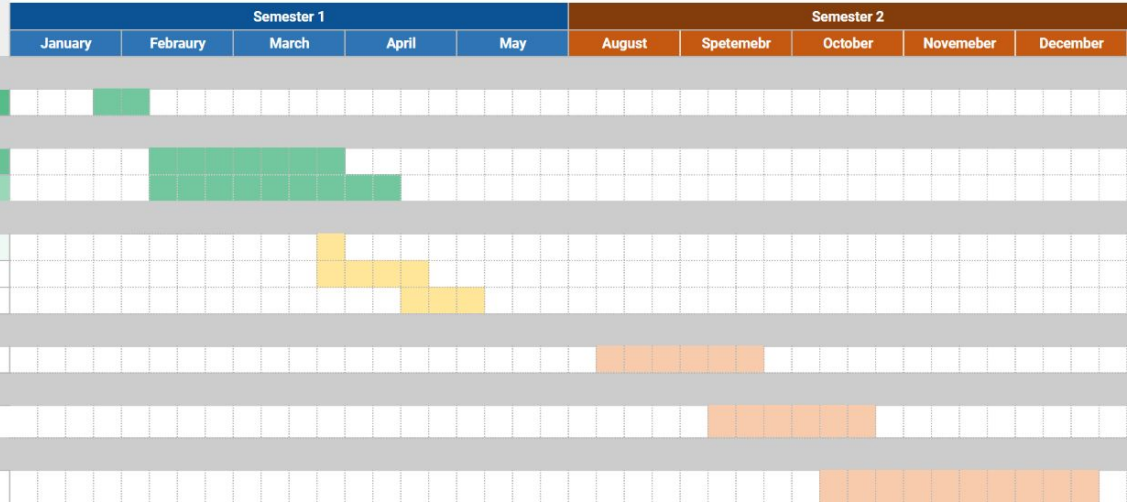
Risk Factor: 0.3
Mitigation: Include the long term benefits and investment returns of installing rooftop PV.

TIMELINE


TASK 1: Develop guiding questions and/or areas of research.
FEB 2023
TASK 2: Make contact with an NREL researcher for primary source data.
MARCH 2023
TASK 3: Determine which PV system best suits Puerto Rico (community, farm, rooftop, etc.).
APRIL 2023
TASK 4: Apply relevant IEEE standards to our solution.
SEPT 2023
TASK 5: Analyze the cost of our solution and investment return to ensure economic feasibility.
OCT 2023
TASK 6: Develop a model/graphic/representation of the PV solution for Puerto Rico.
DEC 2023

PROJECT TIMELINE

WBS NUMBER	TASK TITLE	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Developing Key Areas of Research**				
1.1	Introductorty Research	1/30/23	2/13/23	13	100%
2	**Primary Research**				
2.1	Scope and Goal Setting	2/13/23	3/27/23	4	90%
2.2	Research	2/13/23	4/14/23	60	60%
3	**Determine the Correct PV System**				
3.1	Indetifying Alternatives	3/30/23	4/3/23	4	10%
3.2	Comparing Options	3/30/23	4/17/23	18	0%
3.3	Assessing Viability	4/17/23	5/1/23	14	0%
4	**Apply relevant IEEE standards**				
4.1	IEEE Standards	8/18/23	9/18/23	31	0%
5	**Analyze Cost and Detremine Feasability**				
5.1	Cost Analysis	9/15/23	10/23/23	38	0%
6	**Develop Model**				
6.1	Model Creation	10/9/23	12/4/23	56	0%



Major Aspects Of Proposed Design

- PV Generation Method
    - Community Scale Photovoltaic Installations (Roofs of Basketball Courts, Commercial/Public Buildings).
    - Residential Rooftop Solar Installations

- Energy Storage Method
    - High Capacity Battery packs located near new Community Scale PV installations
    - Battery Size will vary depending on number of customers/load serviced by each installation.
- Maintenance Plan
    - Scheduled maintenance plan for new PV installations and battery backups

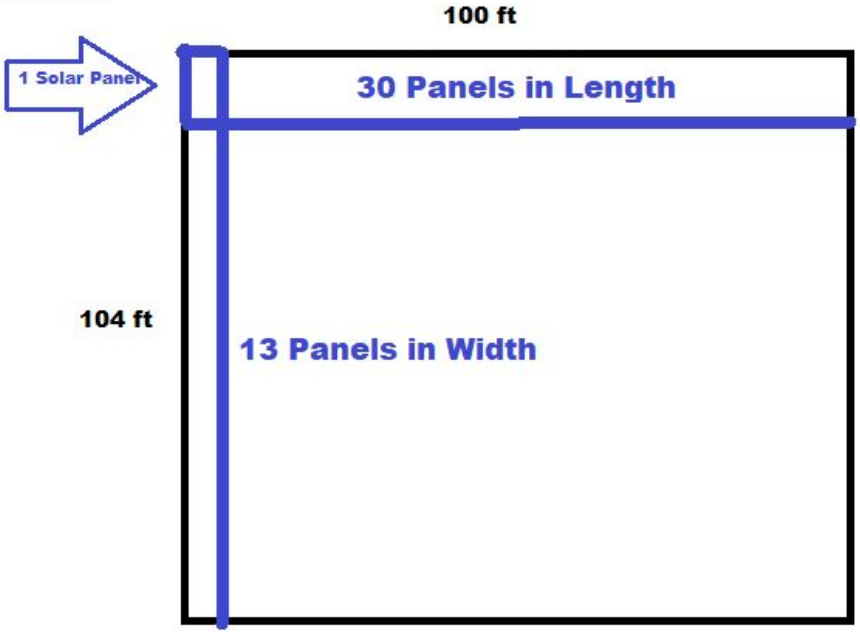
Covered Basketball Court PV Installation

- Covered, Open-Air Basketball Courts-Common in Puerto Rico near residential areas
- We chose one example with typical dimensions of 100' x 104' x 31' to design a Community Solar Installation
- Battery Backup will be installed in secure location near solar panels/inverters.

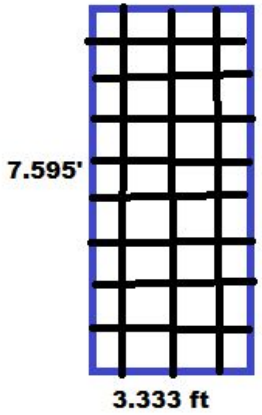
LR 100x104x31

Covered Basketball Court PV Installation

Dean Steel Buildings Inc.
LR 100 x 104 x 31 Covered Basketball Court



Trina Solar
TALLMAX
490W
DE15V(II)
7.595' x 3.333'



390 Total Panels, Each generating 490W, overall 191100W, or .1911 MW

$9,920 per pallet of 31 Panels, 320$ per panel = $124,800

Rough Estimate of $100,000 for labor, inverters, mounting, wire = $225,000 total investment

Note: Numbers are not finalized

Residential PV

DEMAND

- Exponential increase in the last 8 years = 5.5% of PR demand
- From June 2014 - January 2025:

$$6.822e^{.0397(127)} = 1.055 \text{ GW by 2025}$$

.

- Can work backwards to determine the amount of rooftop PV using the capacity of panels we want to use and the predicted number of customers.

COST

- Average cost of a residential rooftop PV system is $8000 for 1.68 kW system including battery storage
- Return investment in 8.3 years!

COST ESTIMATE

- Very few real costs, monetary or otherwise, in completing our design other than time
- Access to PSS/E should be granted through the University
- Approximately $3 Billion of investment from U.S. Government to work with for final design
    - Maintenance plan
    - Replace the panels after X years for more efficient and cost-effective ones

HARDWARE & SOFTWARE

- Hardware:
  - Trina Solar Panels
  - We are waiting for them to return contact about specifics on their work on the Puerto Rico Convention Center
- Software:
  - PSS/E
  - Excel

TESTING

Unit Testing

Simulation of our designs in PSS/E Software Ensuring our final estimates for costs of installation are 100% correct given market conditions at time of completion

Security Testing

Use North American Electric Reliability Corporation (NERC) regulations to ensure that our system is secure physically and safe from any threats that may come through the smart grid.

Integration Testing

PSS/E Can also be used to determine how the Solar generation, battery storage, and distribution work together.

Acceptance Testing

We plan to conduct a survey to gauge the interest of the Puerto Rican people in investing their time and resources in our proposed plan, as well as in Photovoltaics in general.

CURRENT STATUS & RECENT MILESTONES

- Tasks 1, 2, and 3 (research, contact, and choosing the solution) have been completed
- Have completed extensive research to determine the best methods and practices
- Have a firm grip on economic undertaking and the resources Puerto Rico has

PLAN FOR FUTURE

PRIMARY GOALS FOR NEXT SEMESTER

- Design detailed models for:
  - Residential rooftops
  - Basketball courts
  - Large commercial buildings
- Installation costs and investment return
- PSS/E
- Involvement of Puerto Rican residents
- PV costs are coming down very rapidly– continue to investigate

Thank you for listening!

Questions?