PHOTOVOLTAIC FEASIBILITY IN PUERTO RICO

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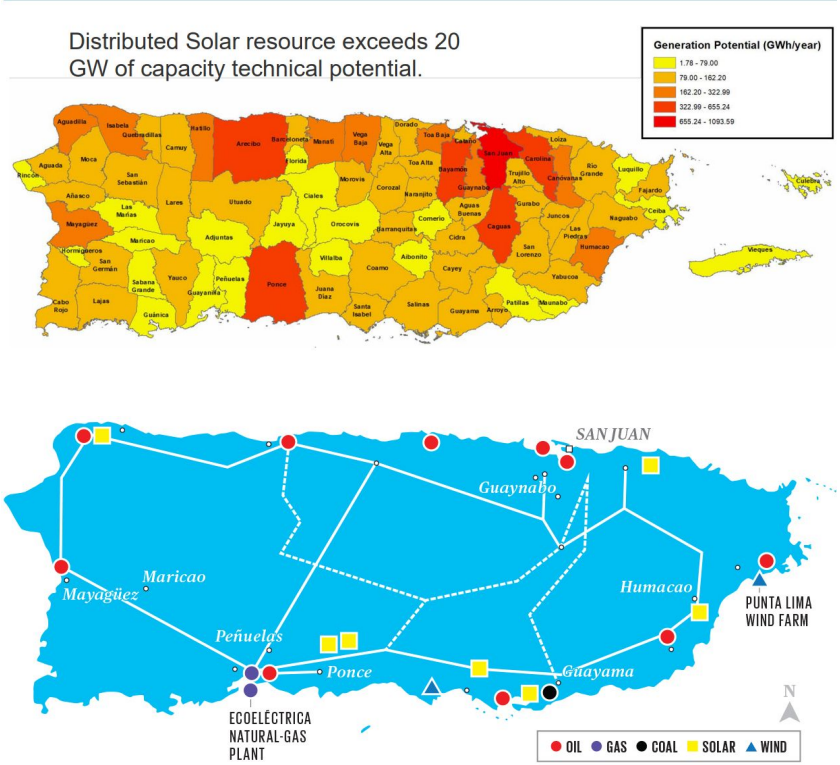


Problem Statement

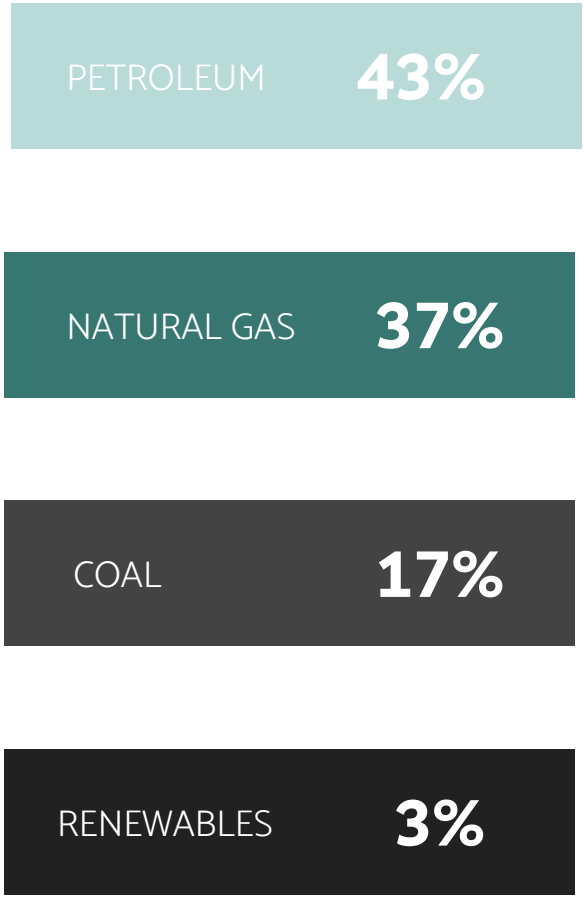
Puerto Rico's grid is very unstable as a result of frequent hurricanes, outdated power plants, and poor management.

Our project provides a plan for ensuring reliable and affordable power to Puerto Ricans using photovoltaics combined with battery storage units.

PUERTO RICO'S FLEET

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: $0.25/kWh in residential sector
- Necessary to bring communities together under goals of reliability and sustainability



FUNCTIONAL REQUIREMENTS

1. Offset a portion of Puerto Rico's energy generation, which currently sits at approx. 18B kWh
2. Lower the levelized cost of electricity (LCOE) to improve affordability for PR residents from 25c/kWh to a price similar to that found in California (15c/kWh)
3. Final plan must be economically feasible given the $1.3B allocated from US Government for improving the grid
4. Technology must be stable under severe weather events
5. Must be easy to maintain and operate

DESIGN DESCRIPTION

Covered, open-air basketball courts are extremely common throughout the island of Puerto Rico:

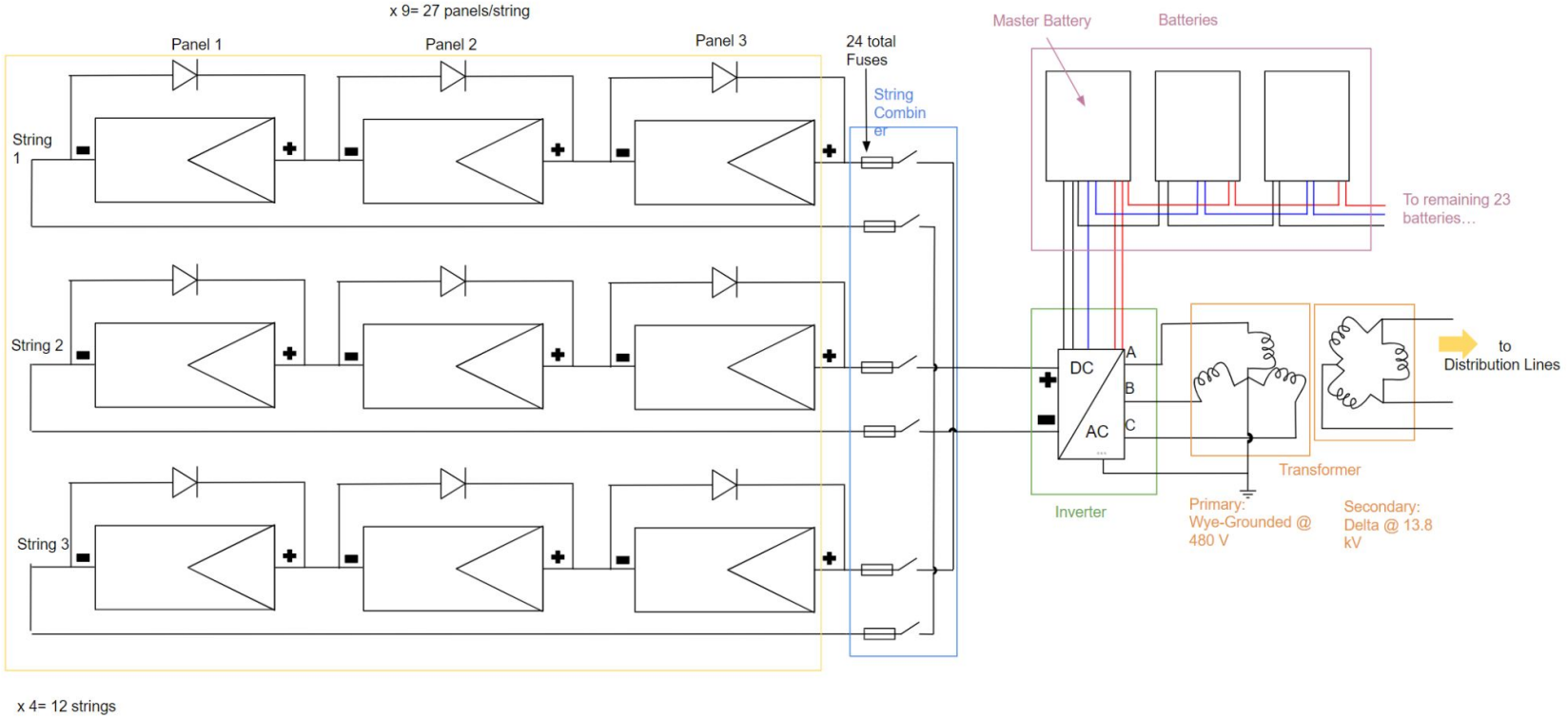
- ***Utilizing untapped*** rooftop potential with plentiful sunlight
- Located within a community, owned by the grid operator (LUMA), this is an economically feasible, easily installed, widely applicable system.
- Battery to be installed in secure location near system to power approximately 50 homes with battery backup that can support these homes for 14 hours

Model based on court located at Calle Azucena, Dorado, 00646, Puerto Rico

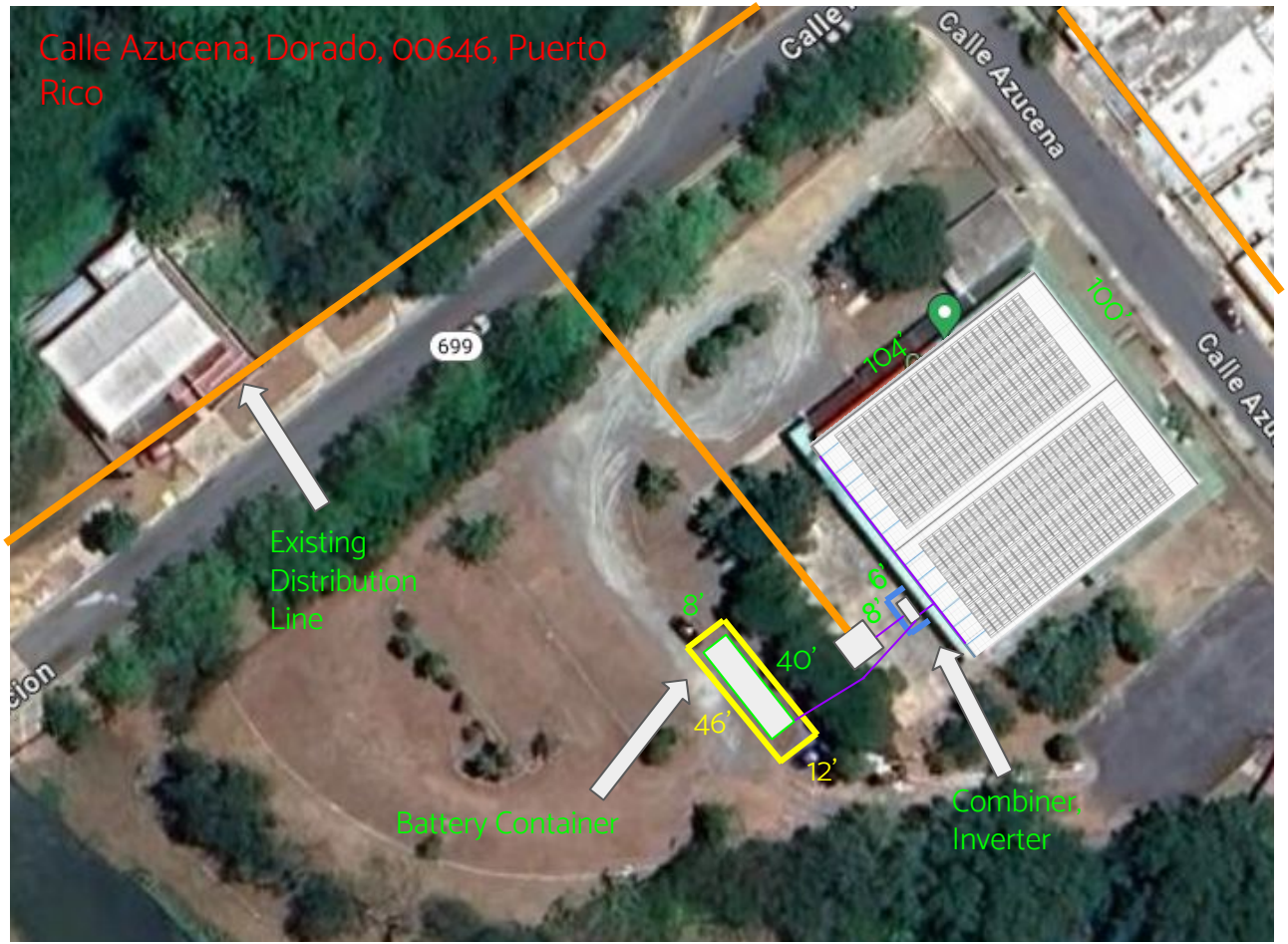
PRODUCT SPECIFICATIONS

- Trina Solar TALLMAX 490W DE15V(II) Panels
  - 324 panels = 158.76 kW
  - 20.8% max. efficiency
- Solectria XGI 1500 175-480 Inverter
  - 175 kW power rating
  - Output: 480 VAC, 3-Phase
- Solectria XGI 1500 20A String Combiner
  - 20 A with 24 fuses
- Envirotran 3-Phase Pad Mounted Transformer
  - 480 V Wye-Grounded : 13.8 kV Delta
  - 175 kVA
  - FR3 dielectric fluid: non-toxic, higher performance

SCHEMATIC

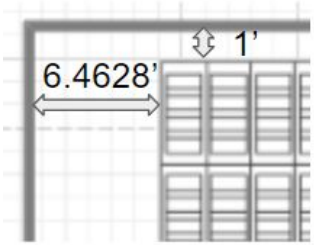

x 9= 27 panels/string
Panel 1
Panel 2
Panel 3
24 total Fuses
String Combiner
String 1
String 2
String 3
Master Battery
Batteries
To remaining 23 batteries…
DC
AC
A
B
C
Inverter
Transformer
Primary: Wye-Grounded @ 480 V
Secondary: Delta @ 13.8 kV
to Distribution Lines
x 4= 12 strings

AERIAL VIEW

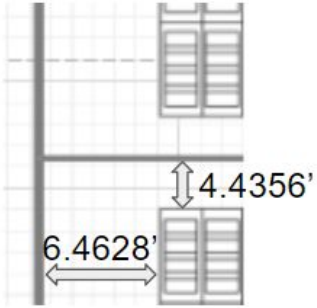


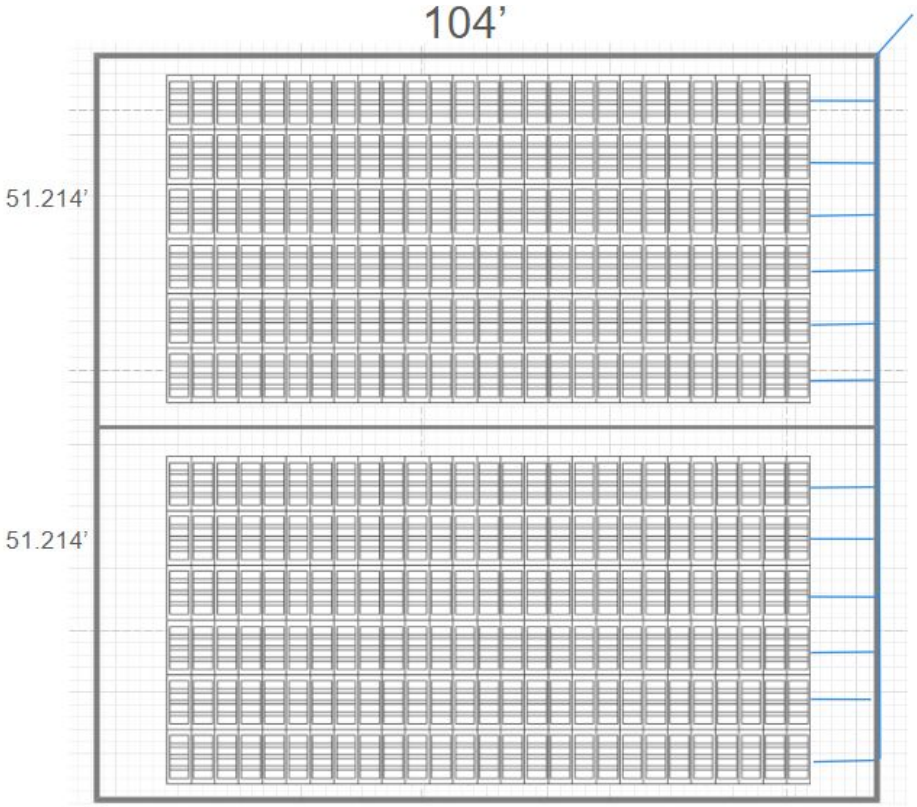
(324) 490W Panels:
158.76kW Peak Output

ROOFTOP CLOSE-UP



Mirrored on both sides





12.5 degree roof pitch

1 row = 27 panels wired in series.
12 rows wired in parallel using string combiner.

2 x (27 x 6) = 324 Panels @ 490W = 158.76 kW

985.5 DC Volts input to inverter
161.16 A input to inverter

BATTERY STORAGE

EG4 14.3 kWh PowerPro WallMount All Weather Battery

- 14.3 kWh x 26 units = 371.8 kWh
- Made of $LiFePO_4$
- $279.65/kWh!
- Must be wall-mounted

BATTERY STORAGE CONTAINER

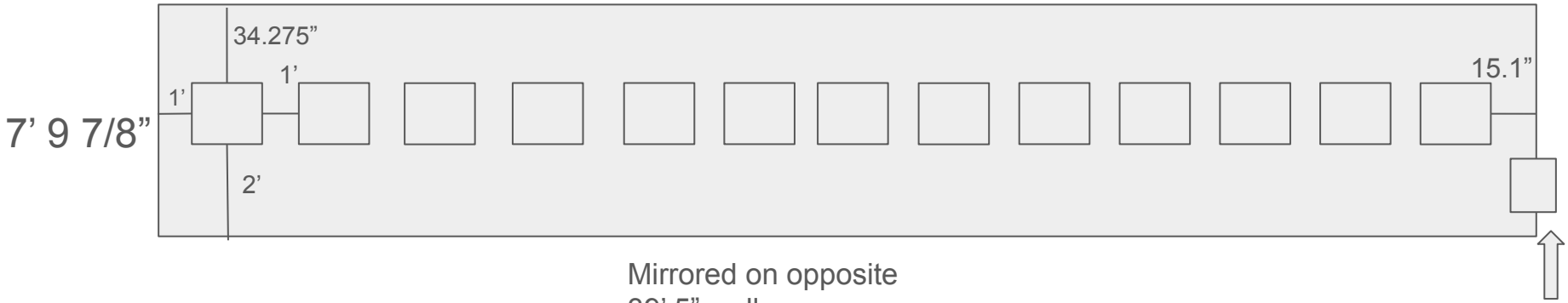
1. Standard 40’ storage container
2. Batteries in parallel with kits from same supplier
3. 450 sq. ft. AC unit to keep batteries cool
4. Each comes with a wall mount bracket

1 battery

22.3”

35.6”

13 batteries on each 39’ 5”’ wall = 26 batteries = 371.8 kWh of storage



LOCATIONS

We located 168 potential locations for our design. These location were decided on a variety of factors:

- Flat roofs
- Structural stability
- Available Sunlight
- Access to Grid
- Proximity to communities

POTENTIAL RISKS & TESTING

Failure to Meet PR's 2025 Goal

PR's goal is to be at 40% renewable energy by 2025. Our project cannot singlehandedly achieve that goal, but can provide an example of PV installations in communities and help make steps toward that goal.

Cybersecurity Threats

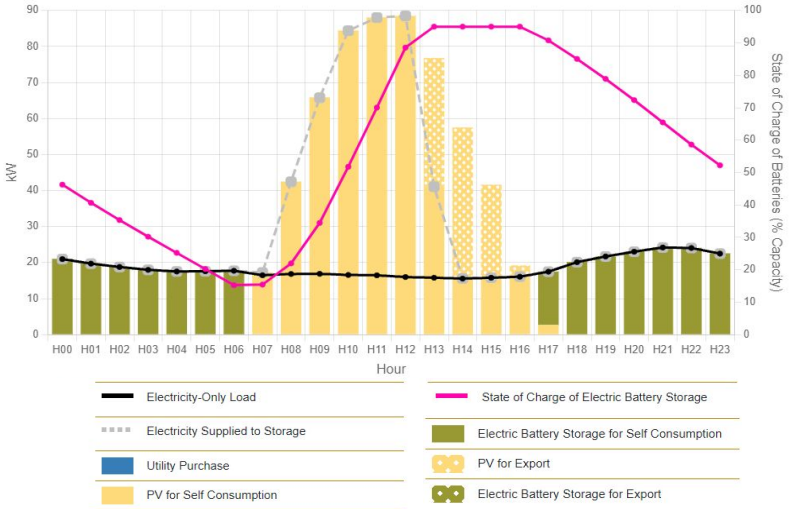
Any IoT device can become an entry point a hacker uses to pivot into a larger system.

Testing:

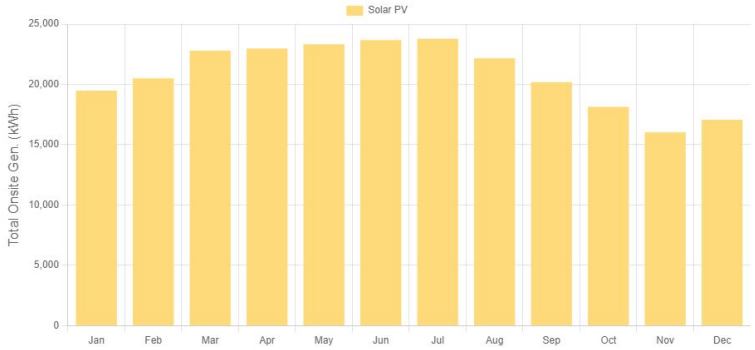
- 5G cellular hotspot → wired ethernet cable
- Testing implementation (5G hotspot and inverter) through Pratum, and asking Solectria to verify their web-based monitoring
  - Inverter includes firewall
  - Principle of Least Privilege: only allowing required traffic inbound AND outbound
- Limits (outside) access to inverter, software, controls by physical connection through ethernet cable, secured by fencing & camera
- $5000 penetration testing conducted by Pratum, 1 time charge

- Total annual energy production is 250,096 kWh per site
- 22.3% of energy is exported as excess from the site to the grid
- Net Zero solution enables 99.2% of utility balance to be energy exports (0.8% energy imports)

Electricity Dispatch for October, Peak, Aggregate

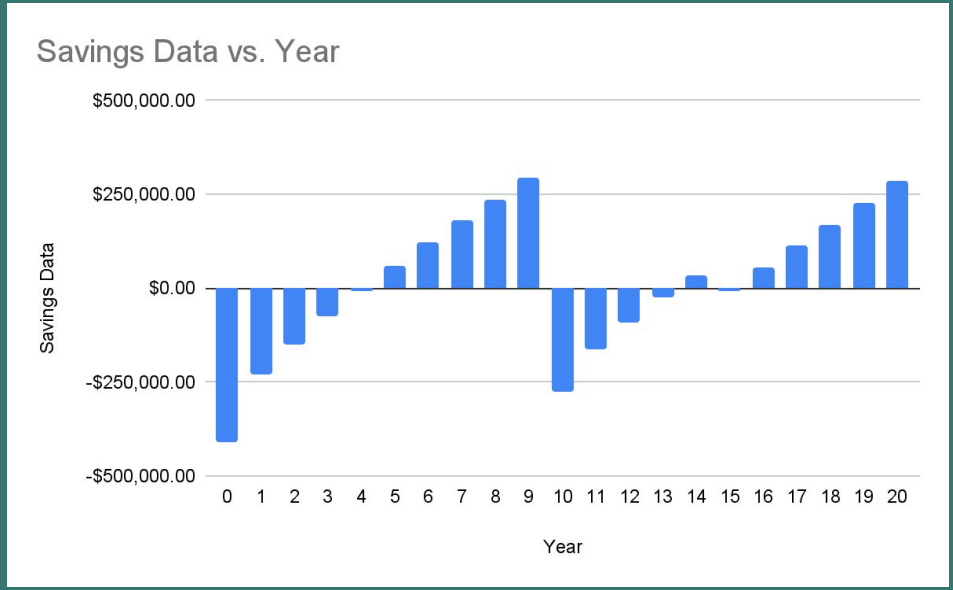


Monthly On-Site Generation (kWh)



COSTS & ECONOMIC ANALYSIS

- Total cost of the system is $409,935, funded by the $1.3 Billion Federal Grant, this includes installation, maintenance, and federal incentives
- Levelized cost of electricity (LCOE) is $0.1318/kWh
  - $33,000/year per site in revenue
  - Comparable to what we pay in Iowa
- Internal rate of return of 10%
- Break-even in year 5
- Payback period ends in year 14



CHALLENGES

- XENDEE software
  - Learning new software
  - Multiple optimization reruns
  - Software glitches
- Communication with outside organizations and resources
- Scope
  - Started with a very broad problem-statement, took a lot of time to narrow it down to a feasible system that is easily expandable to all of Puerto Rico

FUTURE WORK

IF project were to be undertaken by Puerto Rican government and installations were constructed at all 168 potential locations we found:

- We could generate 26,671,680 kW, or 0.148% of total current generation in PR.
- These 168 locations would use only 5.29% of the $1.3 billion already allocated by the U.S. government for PV projects in PR.

Current Generation in PR (All Sources)	18000000000	kW
Generation of 1 site	158760	kW
Cost of 1 site	409935	$
# of sites	168	
Total cost	68869080	$
Total Generation	26671680	kW
% Offset (of 18000000000)	0.148176	%

CLOSING STATEMENTS

Our teams design is a unique and feasible system that could be implemented with the current technology commercially available to Puerto Rico and the US government. It utilizes the existing infrastructure to create real estate for photovoltaics, one of Puerto Rico's largest issues when it comes to renewable energy.

This module could also apply other flat and open spaces with no shade near communities like parking lots, grocery stores, etc.

Most importantly it is an economically viable option than serves communities in need.

QUESTIONS?

Thank you!!