University of Puerto Rico at Mayagüez: 2022 US Solar District Cup Design of a Resilient Microgrid for PNNL

U.S. DEPARTMENT OF ENERGY SOLAR DISTRICT CUP COLLEGIATE DESIGN COMPETITION

Introduction

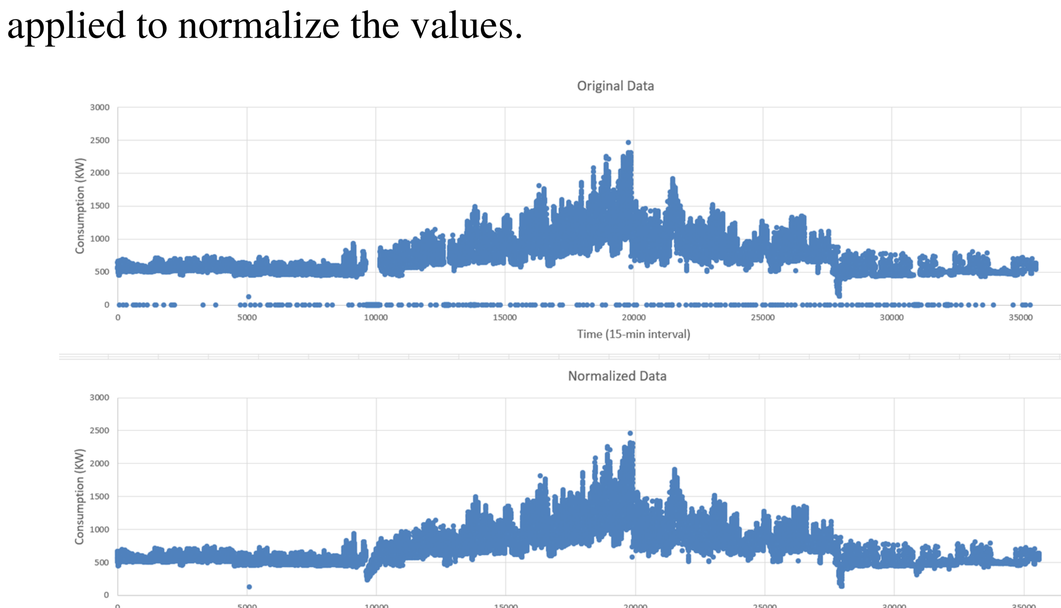
The Solar District Cup (SDC) challenges multidisciplinary collegiate student teams to develop forward-thinking designs for optimized distributed energy systems; therefore, teams must assume the role of a solar-plus-storage developer and present a proposal of the most reliable, resilient, and cost-effective system possible for the district use case assigned by the competition organizers. District use cases are entities (e.g. urban districts, universities campuses, and more.) interested in pursuing distributed renewable energy solutions who are willing to collaborate with National Renewable Energy Lab (NREL) by providing energy use data for multiple buildings, electrical infrastructure, and master plans to serve as the basis for the solutions of the teams participating in the competition. The University of Puerto Rico at Mayaguez Campus team was assigned to the Pacific Northwest National Laboratory use case, for which the main goal was to design a resilient microgrid system using photovoltaic and energy storage systems. To achieve the final design proposed, a lot of details were considered such as PNNL's future development plans, flooding areas, weather patterns, and types of terrains. Additionally, several energy storage technologies such as vanadium flow batteries, iron flow batteries, zinc-bromine flow batteries, and li-ion batteries were examined. Along with the technical aspect of the design an economic analysis was done to support the decisions that lead to the final proposed design composed of three microgrids and a diversified portfolio of PV and energy storage systems.

Methodology/Solution Approach

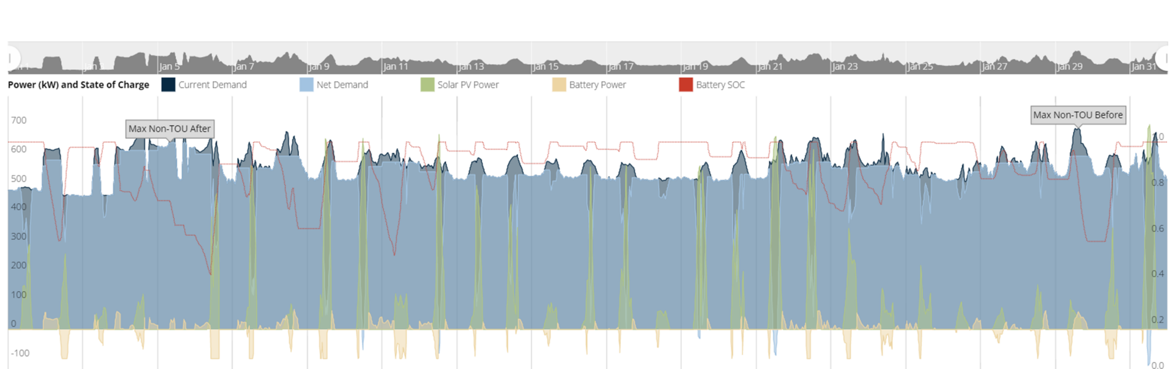
- Identify the characteristics, restrictions, future plans, and goals of the buildings and ground areas that could be used for the system and select the best candidates.
- Design and simulate the photovoltaic systems using Aurora Solar software.
- Identify the power and energy capacity of the battery system to comply with the competition requirements.
- Assess the different energy storage technologies and select the optimal mix of technologies to align with PNNL's goals.
- Make a financial analysis of the proposed system using Energy Toolbase and the System Advisory Model (SAM) software.
- Calculate the time of work to develop a construction timeline.
- Plan strategies to engage community members.

Distribution System Impact Analysis

Before designing the systems, the given load profiles of the buildings had to be analyzed due to some discrepancies. At random intervals the building's consumption suddenly went to 0 kW or the data available was not reliable. To solve this different statistical methods such as rolling average, variance comparison, and pattern recognition were applied to normalize the values.



The microgrid management system controls the dispatch strategy of the PV and ES systems. These strategies are peak shaving, load shifting, and demand charge management. This said, the strategy used in this project was peak shaving; therefore, an example can be seen applied to the microgrid of the building 331 in the image below.



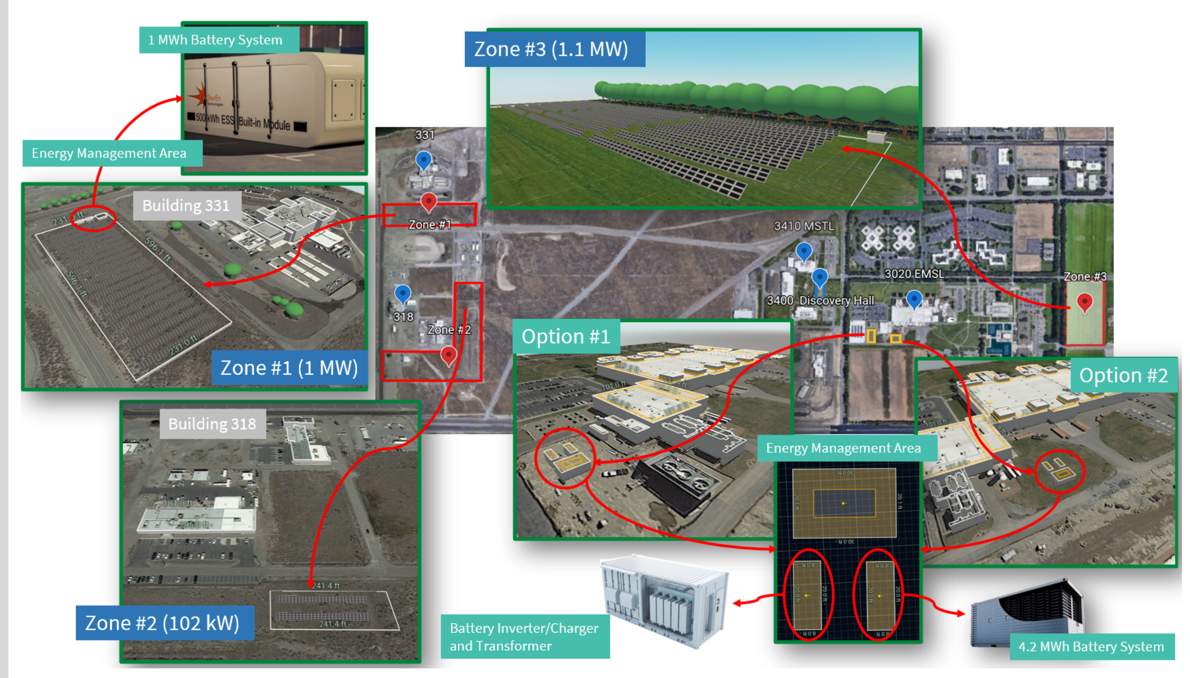
PV System Design and Operation

Design Restrictions

- PV Systems can only be installed withing the red lines.
- No exports to the electrical grid are allowed.
- The energy storage system designed must be able to sustain 25 % of the peak load of certain buildings as shown in the table.
- The energy storage system can only be charged by the PV System.

Building	Peak Load	25% of Peak Load	Minimum Duration	Min. Energy Capacity Needed
3020	2080 kW	520 kW	6 hrs.	3120 kWh
318	14 kW	3.5 kW	5 min.	0.292 kWh
331	895 kW	223.75 kW	4 hrs.	895 kWh
3400	6.5 kW	1.625 kW	1 hr.	1.625 kWh
3410	390 kW	97.5 kW	30 min.	48.75 kWh

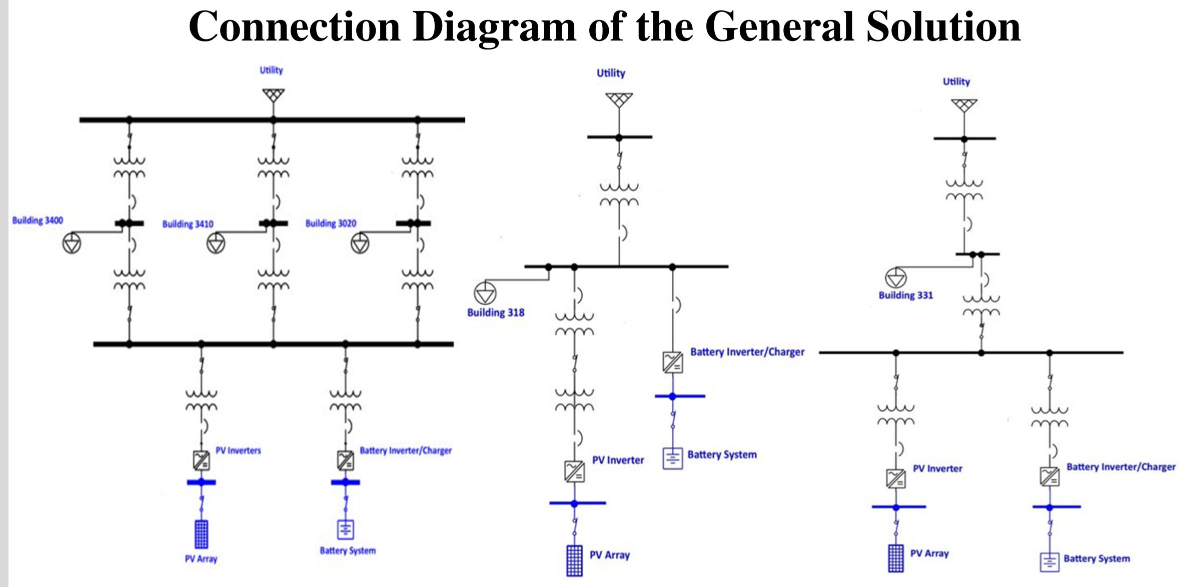
General Solution



General Solution Specifications

Microgrid Details		Photovoltaic System Information					Energy Storage System General Information						
Microgrid or System	Buildings Connected	Location	Mount Type	Tilt	Size	Annual Output	Chemistry	Size	Power	Critical Load	Time Sustained Scenarios (hrs.)		
#1	3020	Zone #3	Ground Mount	35°	1.1 MW	1.6 GWh	Li-Ion Battery	4.2 MWh	1.3 MW	520 kW	7.9	6	6
	3400									1.63 kW	6.8	6.8	6.8
	3410									97.5 kW	0.5	0.5	11
#2	318	Zone #2			102 kW	0.3 GWh	Zinc-Bromine Flow Battery	30 kWh	15 kW	3.5 kW	8.6		
#3	331	Zone #1			1 MW	1.5 GWh	Vanadium Flow Battery	1 MWh	100 kW	224 kW	4.47		
Totals					2.2 MW	3.4 GWh		5.23 MWh					

Connection Diagram of the General Solution



Summary of Results

Strategy to Engage Community Members

- PNNL Official website
- Sustainable energy
- Research experience
- Reuse existing wiring lines in buildings to develop future projects.
- Hiring a specialized external company
- Workshops or talks as a teaching tool

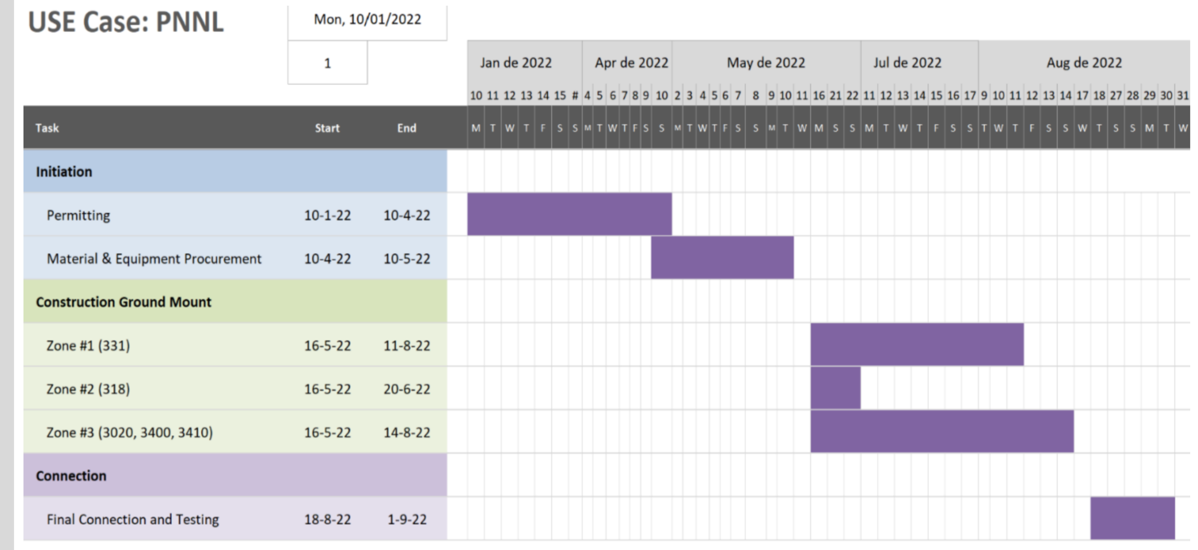
Goals Achieve

Resiliency	3 different Microgrids to help them achieve their resiliency goals
Diversified Battery Portfolio	3 different battery chemistries for them to use as testbeds
Secure and Efficient Energy Management	Microgrid management system that allows to secure their systems; Microgrid that efficiently controls the energy
Master Plan	Our designs meet all the requirements established in the PNNL Master Plan provided
Financial Analysis	The models account for additional capabilities intended
Risk Analysis	Each of our designs took into consideration topographic, drought, and flood risk analysis

PNNL USE CASE
THIRD PLACE

Development Construction Plan

Permitting Construction and Interconnection Timeline



Calculations for Estimated Time of Work

Ground Mount Systems	System Size (kW)	Solar Panels Quantity	Workers	Person Hours	Estimated Time to Complete (weeks)
Zone #1 (331)	1,000	2160	16	8,000	12.50
Zone #2 (318)	101.5	216	4	812	5.07
Zone #3 (3020, 3400, 3410)	1,100	2,376	17	8,800	12.94
Total	2,201.5	4,752	37	30,703	12.94

Construction Analysis

To achieve the Development Construction Plan, several analyses were carried out to guarantee the safety and development of the project in five different stages.

- Local Construction Permitting and Codes
- Timeline for Permitting, Construction, and Interconnection
- Construction Staging Approach
- Risks to Successful Project
- Strategy to Engage Community

Financial Analysis

Finance Parameters, PPA & Cash Purchase for each System

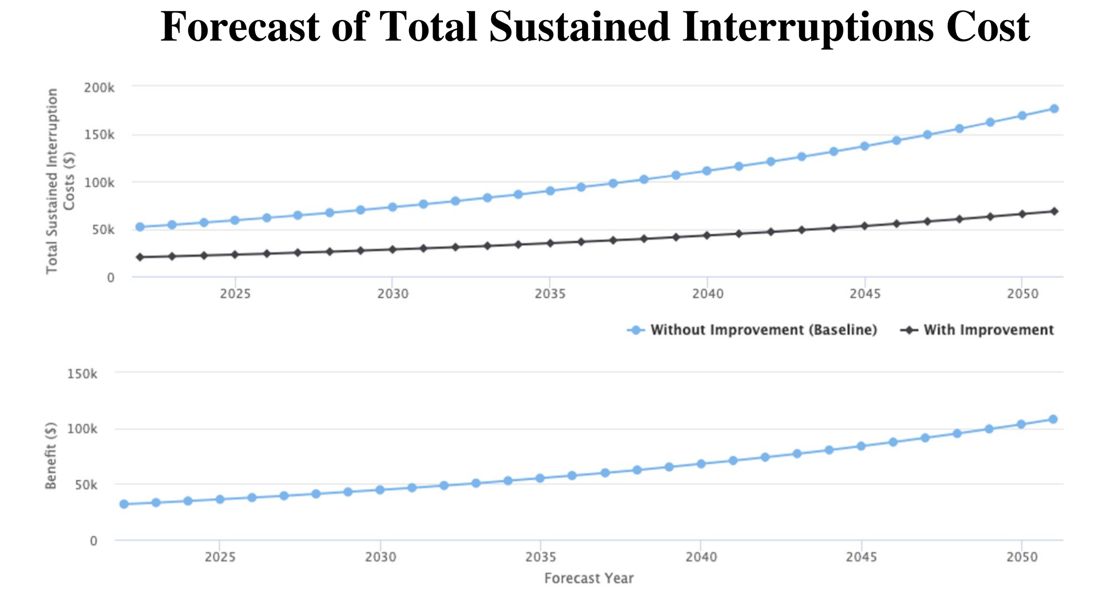
Finance Parameters	PPA	Cash Purchase
LCOE PV Generation	$0.093 /kWh	$0.031 /kWh
Net Present Value	($46,039)	($42,680)
Total Payments	$366,418	$216,600
Electric Bill Savings - 20 years	$200,930	
PPA Escalation Rate	3.19%	-
Starting PPA Rate	$0.08	-
Upfront Payment	$0	$216,600
IRR (20 years)	10.42%	10.5%
Total Incentives	$95,889	
Net Payments	$270,529	$120,711

Finance Parameters	PPA	Cash Purchase
LCOE PV Generation	$0.085 /kWh	$0.036 /kWh
Net Present Value	($396,941)	($653,672)
Total Payments	$3,321,657	$2,485,001
Electric Bill Savings - 20 years	$1,922,763	
PPA Escalation Rate	4.37%	-
Starting PPA Rate	$0.08	-
Upfront Payment	$0	$2,485,001
IRR (20 years)	10.57%	10.6%
Total Incentives	$1,100,110	
Net Payments	$2,221,547	$1,384,891

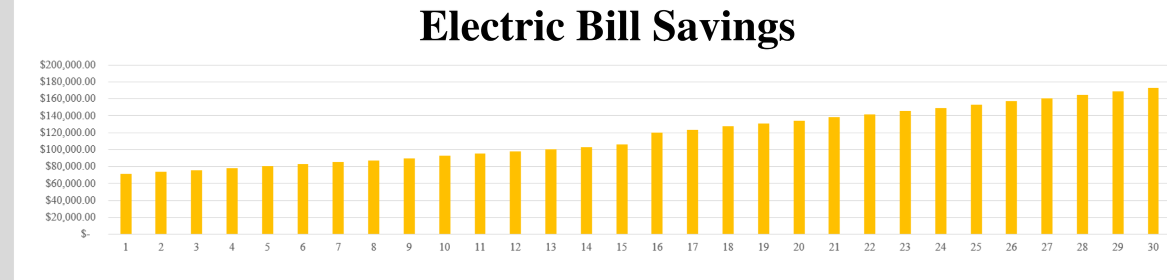
Initial Year	2022	
Lifetime	30 years	
Inflation Rate	4.3%	
Discount Rate	10%	
Status	Without System	With System
SAIFI	25	10
SAIDI	125	10
CAIDI	5	1

Finance Parameters	PPA	Cash Purchase
LCOE PV Generation	$0.083 /kWh	$0.062 /kWh
Net Present Value	($339,114)	($2,253,153)
Total Payments	$3,181,758	$4,261,600
Utility Savings - 20 years	$1,954,092	
PPA Escalation Rate	4.18%	-
Starting PPA Rate	$0.08	-
Upfront Payment	$0	$4,261,600
IRR (20 years)	10.13%	10.80%
Total Incentives	$1,886,610	
Net Payments	$1,295,148	$2,374,990

Forecast of Total Sustained Interruptions Cost



Electric Bill Savings



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