NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Evaluating Utility Costs Savings and Resilience: A Case Study in Port Arthur, Texas

Byron Pullutasig, Scott Belding
November 2024

NREL/PR-7A40-87735

Disclaimer

– This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

– This analysis was conducted as a part of the Solar Energy Innovation Network (SEIN) and relies on site information provided to NREL by GTEC/HARC that has not been independently validated by NREL. See https://www.nrel.gov/solar/market-research-analysis/solar-energy-innovation-network.html for more information about SEIN.

– The analysis results are not intended to be the sole basis of investment, policy, or regulatory decisions. Since the original study was conducted in June 2023, the results have changed slightly due to evolving technology economics and updates in rate tariffs.

– This analysis was conducted using the NREL REopt Model (http://www.reopt.nrel.gov). REopt is a techno-economic decision support model that identifies the cost-optimal set of energy technologies and dispatch strategy to meet site energy requirements at minimum lifecycle cost, based on physical characteristics of the site and assumptions about energy technology costs and electricity and fuel prices.

– The data, results, conclusions, and interpretations presented in this document have not been reviewed by technical experts outside NREL.

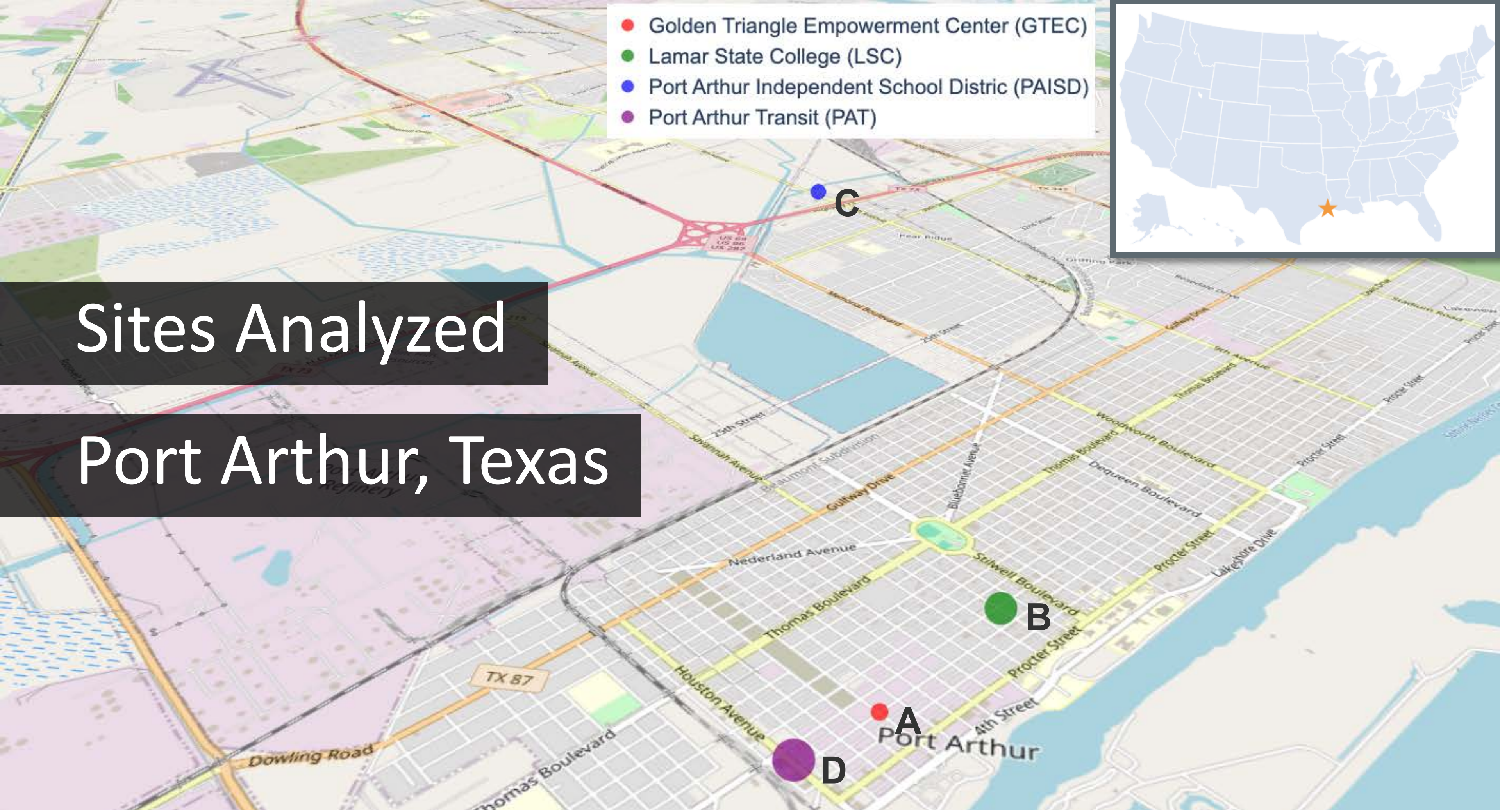
Analysis Overview

- Engineers from the National Renewable Energy Laboratory (NREL) used the REopt[1] platform to support the Solar for Safety and Success (3S) project in Port Arthur, Texas, through the Solar Energy Innovation Network (SEIN)[2].
- Led by the Houston Advanced Research Center (HARC), the 3S project developed pathways for commercial-scale resilient clean energy projects benefiting underserved communities in Port Arthur.
- The analysis focused on specific Port Arthur community facilities (Golden Triangle Empowerment Center (GTEC), Port Arthur Independent Schools District (PAISD), Lamar State College (LSC), and Port Arthur Transit (PAT)). It evaluated the techno-economic potential of **solar photovoltaics (PV) + battery energy storage system (BESS) + generators** at these sites.
- The analysis includes **cost-optimal technology sizing** to minimize lifecycle energy costs and a **resilience** evaluation to quantify how solar, storage, and generators can increase the probability of surviving a simulated grid outage.
- The analysis incorporates the **Value of Lost Load (VoLL) and Microgrid Upgrade Cost** to estimate the value and costs of sustaining operations during outages at these critical facilities. Two VoLL values were considered based on the facility need: 1) general resilience VoLL to support continued operations, and 2) specific VoLL for sites serving as emergency shelters.

[1] https://reopt.nrel.gov/
[2] https://www.energy.gov/eere/solar/solar-energy-innovation-network

Sites Analyzed

Port Arthur, Texas



Note: Each site location marker represents a specific site (e.g., PAT, GTEC, LSC, or PAISD), and the size of the marker corresponds to the number of buildings or facilities within that site. The marker may not be placed exactly where each analysis site is located.

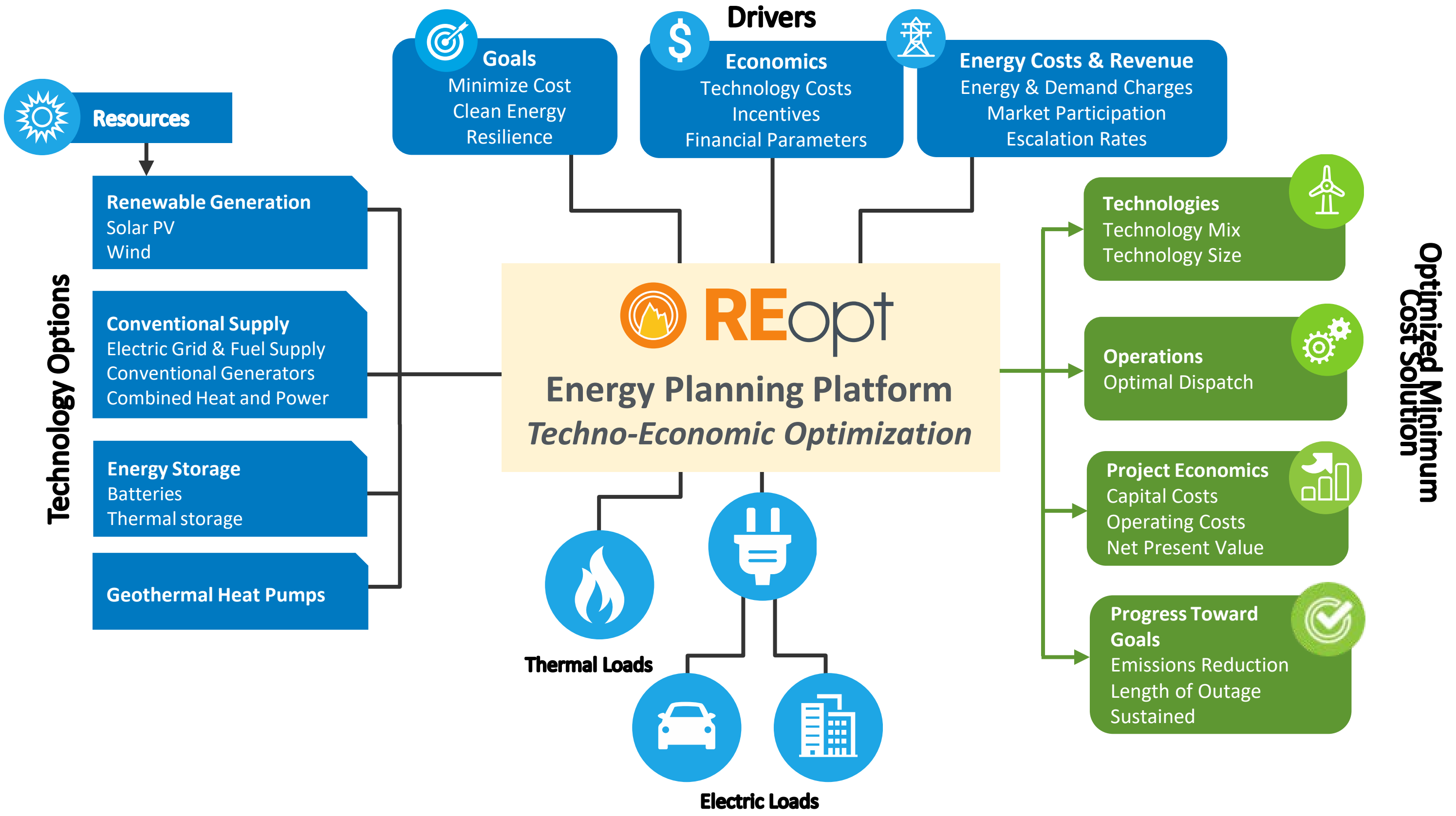
Analysis Scenarios

NREL evaluated the following scenarios for each Port Arthur site, assuming direct purchase of the system in all cases.

A0 Business-as-Usual	A1 Standalone PV	A2 PV and Storage	B1 PV, Storage, and Generator	B2 PV, Storage, and Generator
No Change	**Cost-Savings**	**Cost-Savings**	**Resilience**	**Resilience**
Assumes the site continues to purchase all their energy from their utility	Assumes the site can purchase utility electricity and install **only** PV to lower the cost of utility purchases	Assumes the site can purchase utility electricity and install PV and/or battery storage to lower the cost of utility purchases	**Without** considering the **VoLL** and **microgrid upgrade costs** **Assumes the systems must be sized to meet all electric loads through a 3-day outage*	**With** the **VoLL** and **microgrid upgrade costs** **Assumes the systems must be sized to meet all electric loads through a 3-day outage* ***VoLL Values*** **General VoLL = $3.0/kWh* **Emergency Shelter VoLL = $9.67/kWh*

REopt Energy Planning Platform

Formulated as a mixed integer linear program, REopt provides an integrated, cost-optimal energy solution.



Executive Summary (1/2)

Objective: Assess the integration of PV, Storage, and Emergency Generators to enhance energy resilience and economic efficiency for Port Arthur's community facilities.

Key Takeaways

PV + BESS Cost-Effectiveness

- For most sites PV combined with BESS was found to have economic benefits .

Battery Energy Storage Systems (BESS)

- Although a small BESS is included in the configuration of GTEC and PAT-Fuel Station, inclusion is impractical at these sizes. It is recommended that BESS not be included at these facilities. However, as prices continue to fall for energy storage, it can be reevaluated in the next couple of years.

Value of Lost Load (VoLL)

- VoLL is a highly subjective estimate that significantly influences economic outcomes of scenarios B2. The results highlight the high economic value of resilience in preventing costly power outages.
- Assumed a 3-day outage occurring annually over 25 years, collaboratively determined with HARC and facility stakeholders.

High-Level Implications for Port Arthur

- Integration of PV and BESS supports sustainability goals with reductions in CO_2 emissions and utility costs.
- Incorporating VoLL and microgrid costs leads to substantial financial savings and improved operational reliability.

Executive Summary (2/2)

Objective: Assess the integration of PV, Storage, and Emergency Generators to enhance energy resilience and economic efficiency for Port Arthur's community facilities.

Caveats & Assumptions

VoLL Estimation
- VoLL values were established in collaboration with HARC and the through scoping conversations with community stakeholders.
- Although derived from real operational financial data, VoLL estimates are highly subjective due to the assumption of annual outages duration and energy consumption during the outage.
- The methodology that was used to derive VoLL is outlined for transparency; however, these estimates remain imperfect and should be interpreted with caution.

System Integration
- References to generators specifically pertain to emergency generators.
- BESS sizes below 1 kW may add unnecessary complexity for large facilities and are not recommended for practical implementation.

Optimization Constraints
- Technology sizes for scenario B2 were fixed to the sizes found in Scenario B1 to ensure consistent comparisons

Conclusion & Strategic Implications

Balanced Investment Approach
- While PV and BESS provide economic and environmental advantages, incorporating VoLL and microgrid costs results in noticeable increases in financial and operational benefits.

Strategic Focus Areas:
- Track advancements and cost reductions in battery technology to reassess feasibility for system sizes below 1 kW.
- Engage with stakeholders to validate and adjust VoLL assumptions, ensuring accurate economic assessments.
- Address practical challenges of integrating emergency generators with BESS to streamline implementation and maximize benefits.

The Golden Triangle Empowerment Center (GTEC)

Exploring Resilience for a Site Serving Critical Community Services

Site Overview GTEC

Location: Golden Triangle Empowerment Center (GTEC)
617 Procter St, Port Arthur, TX 77642

Photo/Image Credit: Google Earth Satellite

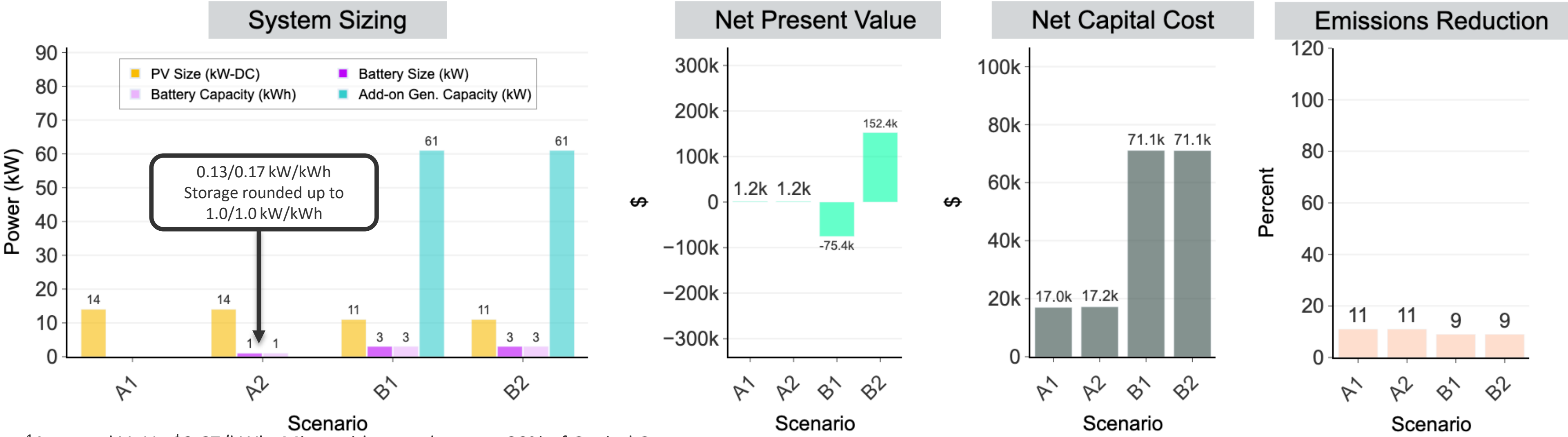
GTEC provides free job training and certifications to underserved communities, focusing on industrial, electrical, and digital sectors. The center also serves a crucial role in workforce reintegration for justice-impacted individuals. Due to its significant impact on local economic stability and community support, GTEC was selected as a critical site for resilience analysis.

	Available Space	Estimated area (sq. ft.)
Space Constraints for PV Installations	Roof	30,540
	Carport	0
	Land	0
	Total:	30,540

Key Takeaways: GTEC

Scenarios	
Cost-Savings	**Resilience**
A1. Standalone PV	**B1.** PV + Storage + Gen without Microgrid cost and VoLL
A2. PV + Storage	**B2.** PV + Storage + Gen with Microgrid cost and VoLL

Scenarios A1-A2: PV and PV with storage yield moderate benefits, with a 15% renewable energy penetration, 11% CO_2 reduction, and 10% utility savings, resulting in a small positive NPV of $1.2k. **Scenario B1:** Introducing resilience through additional storage and a generator increases costs, leading to a negative NPV . **Scenario B2:** However, when considering microgrid costs and the VoLL, the system achieves a 34% savings compared to business as usual, with a significant positive NPV of **$152.4k**, despite higher total lifecycle costs. Although shown here for Scenario A2, BESS is found to not be cost effective due to its small size (0.13/0.17 kW/kWh).



[1]Assumed VoLL: $9.67/kWh; Microgrid upgrade costs: 20% of Capital Cost

GTEC Summary – Key Takeaways

#	Scenario	PV Sizing (kW DC)	Battery Sizing (kW)	Battery Sizing (kWh)	Generator Sizing (kW)	VoLL ($/kWh)	NPV	% Savings Compared to BAU
A1	Cost-optimal Standalone PV– *No outage consideration*	14	-	-	-	-	$1.2k	1%
A2	Cost-optimal PV + Battery – *No outage consideration*	14	1	1	-	-	$1.2k	1%
B1	Resilience PV + Battery (**without** VoLL and Microgrid Costs) – *72-hour outage, 100% Critical Load*	11	3	3	0 (Existing)+ 61 (New)	$0.0/kWh	-$75.4k[1]	-38%
B2	Resilience PV + Battery (**with** VoLL and Microgrid Costs[2]) – *72-hour outage, 100% Critical Load*	11	3	3	0 (Existing)+ 61 (New)	$9.67/kWh	$152.4k[1]	44%

[1]B1 includes outage costs (e.g., fuel) in the NPV and LCC calculations but excludes the VoLL and microgrid upgrade costs. B2 includes outage costs along with VoLL and microgrid upgrades in the NPV and LCC calculations.

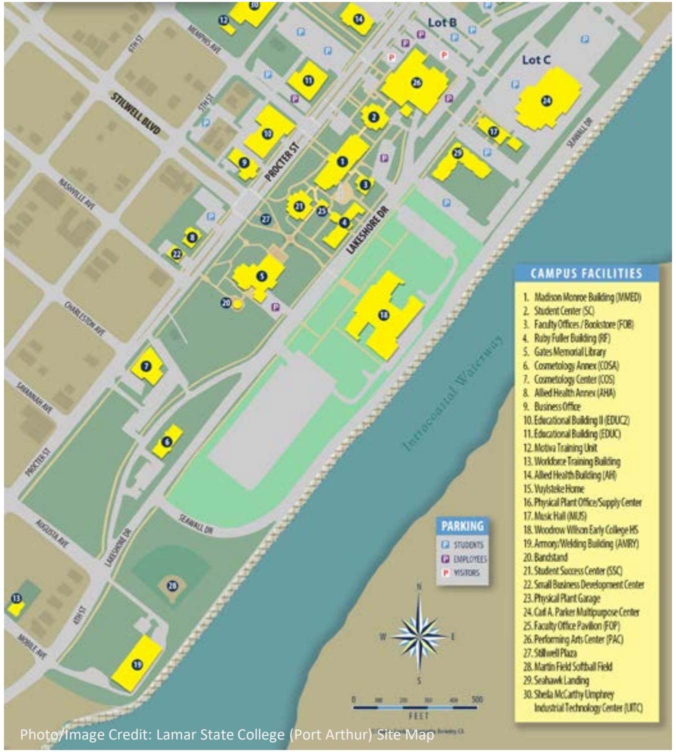
[2] Assumes a microgrid upgrade cost equivalent to 20% of the total capital cost of the system

Lamar State College (LSC)

Evaluating Energy Resilience for College Campus Infrastructure

Site Overview LSC

Category	Category Avg. Annual Energy Usage (kWh)	Representative Building[1]
Low Energy Usage	~40,000	Physical Plant Building
Medium Energy Usage	~210,000	Cosmetology Center
High Energy Usage	~560,000	Madison Monroe Educational Building
Emergency Shelter	-	Carl A. Parker Multipurpose Center



Photo/Image Credit: Lamar State College (Port Arthur) Site Map

[Lamar State College](LSC) in Port Arthur, Texas, consists of thirty buildings with diverse energy consumption profiles. For this analysis, these buildings were categorized into three groups—low, medium, and high energy consumption—with one representative building selected from each category based on the average annual energy consumption. These selected buildings serve as models for similar structures with comparable energy usage. The Physical Plant Building, Cosmetology Center, and Madison Monroe Educational Building were chosen for this purpose. Additionally, the Carl A. Parker Multipurpose Center was identified as an emergency shelter during outages. Due to its significance, a higher VoLL and microgrid upgrade costs were evaluated to ensure a more comprehensive resilience analysis.

[1]These buildings were used to be representative of the other buildings in the categories outlined above. See appendix for mode detail.

LSC Summary – Key Takeaways

This slide summarizes system sizing, annual % RE, and NPV for all nine sites. Additional details about project economics (specific costs and savings) for each of these sites and scenarios are provided in the appendix.

Category	Low Energy Usage	Medium Energy Usage	High Energy Usage	Shelter
Scenario A1: Standalone PV				
PV Capacity (kW-DC)	6	25	61	145
Annual % RE Electricity (%)	16%	14%	17%	18%
Net Present Value ($)	$519.1	$2.77k	$5.85k	$13.96k
Scenario A2: PV + Storage				
PV Capacity (kW-DC)	6	25	61	145
Battery Capacity (kW / kWh)	1/1	2/2	3/4	7/9
Annual % RE Electricity (%)	16%	14%	17%	18%
Net Present Value ($)	$546.0	$2.91k	$6.0k	$14.39k
Scenario B1[1]: PV + Storage + Generator (*without VoLL and microgrid costs[2]*)				
PV Capacity (kW-DC)	5	78	61	123
Battery Capacity (kW / kWh)	1/2	19/21	3/4	20/36
Generator Capacity (kW)	100 (Existing) + 0 (New)	0 (Existing)+102 (New)	250 (Existing) + 0 (New)	(250) Existing + 1149 (New)
Annual % RE Electricity (%)	15%	44%	17%	15%
Net Present Value ($)	-$124.77	-$145.8k	$4.46k	-$182.04
Scenario B2[1]: PV + Storage + Generator (*with VoLL and microgrid costs[2]*)				
PV Capacity (kW-DC)	5	78	61	123
Battery Capacity (kW / kWh)	1/2	19/21	3/4	20/36
Generator Capacity (kW)	100 (Existing) + 0 (New)	0 (Existing)+102 (New)	250 (Existing) + 0 (New)	(250) Existing + 1149 (New)
Annual % RE Electricity (%)	15%	44%	17%	15%
Value of Lost Load ($/kWh)	3.0	3.0	3.0	9.67
Net Present Value ($)	$118.9	$49.6k	$6.0k	$297.23k

[1] B1 includes outage costs (e.g., fuel) in the NPV and LCC calculations but excludes the VoLL and microgrid upgrade costs. B2 includes outage costs along with VoLL and microgrid upgrades in the NPV and LCC calculations.

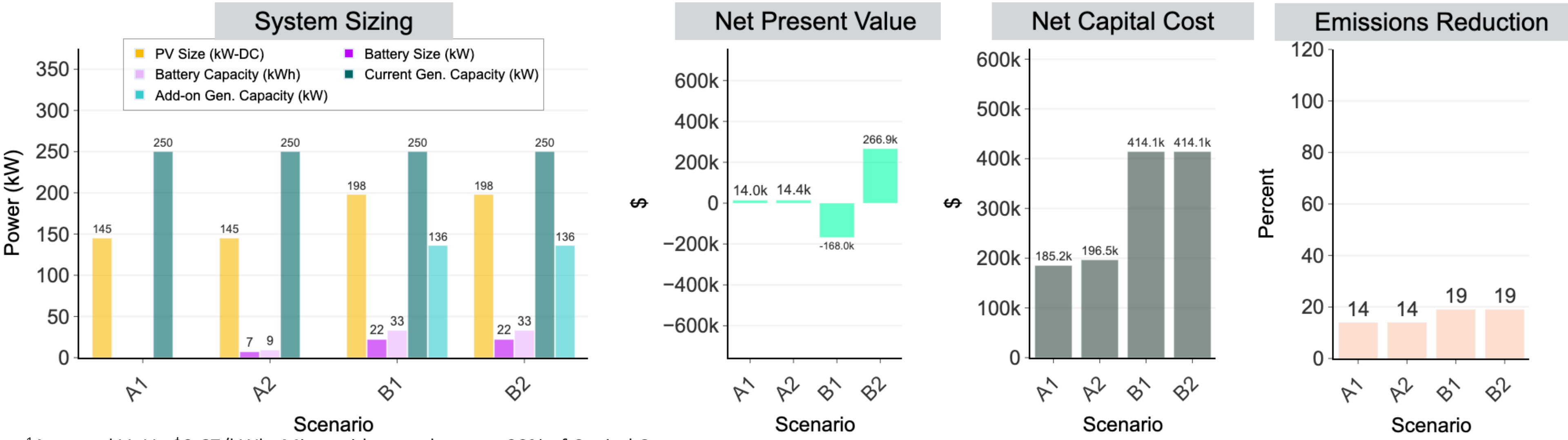
[2] Assumes a microgrid upgrade cost equivalent to 20% of the total capital cost of the system; For scenarios with existing back up generator, we exclude the 20% microgrid costs

Clear up the microgrid cost

Key Takeaways: LSC Shelter

Scenarios	
Cost-Savings	**Resilience**
A1. Standalone PV	**B1.** PV + Storage + Gen without Microgrid cost and VoLL
A2. PV + Storage	**B2.** PV + Storage + Gen with Microgrid cost and VoLL

Standalone PV and PV with storage offer modest reductions in a slight utility cost savings (1%). Adding resilience with storage and a generator increases costs significantly and results in a negative NPV, but integrating microgrid costs and VoLL improves financial outcomes, 11% savings compared to business as usual, and a significant positive NPV of **$266.9k**



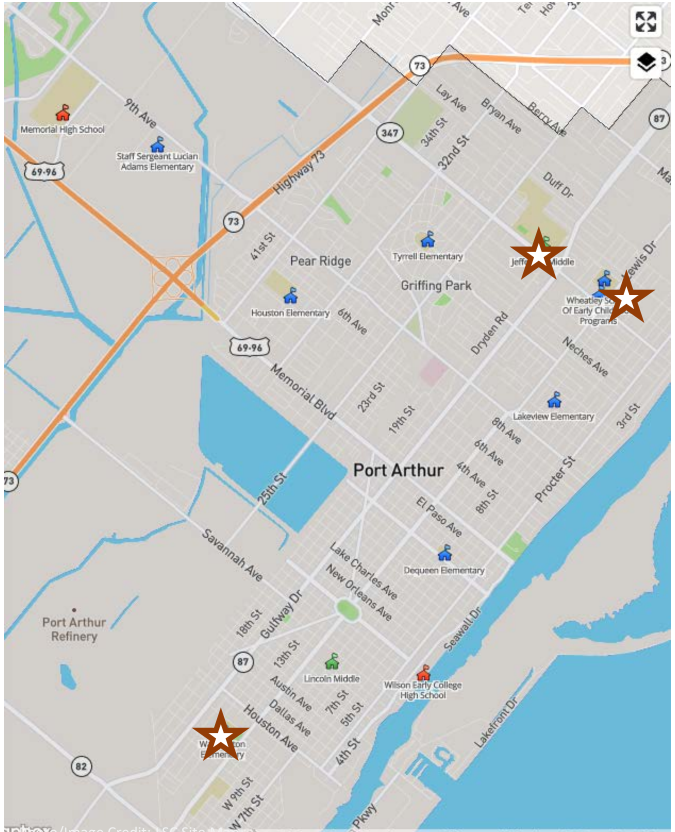
[1]Assumed VoLL: $9.67/kWh; Microgrid upgrade costs: 20% of Capital Cost

Port Arthur Independent School District (PAISD)

Assessing Energy Needs in Educational Facilities

Site Overview
PAISD

Category	Selected Building[1]
Low Energy Usage	Wheatley School Of Early Childhood
Medium Energy Usage	Booker T. Washington Elementary
High Energy Usage	Thomas Jefferson Middle School



Photo/Image Credit:

Using a similar approach for LSC, **PAISD** buildings in Port Arthur, Texas were analyzed by categorizing them into three groups based on energy consumption—low, medium, and high. From each category, a representative school was selected according to its average energy usage, serving as a model for other schools with similar energy profiles. The selected schools—Wheatley School of Early Childhood Programs, Booker T. Washington Elementary School, and Thomas Jefferson Middle School—illustrate the district's diverse energy demands. Additionally, Thomas Jefferson Middle School, recognized for its critical role as a shelter, has the highest energy consumption. To ensure a comprehensive resilience analysis, the Value of Lost Load (VoLL) for this facility was adjusted.

[1]These buildings were used to be representative of the other buildings in the categories outlined above. See appendix for mode detail.

PAISD Summary – Key Takeaways

This slide summarizes system sizing, annual % RE, and NPV for all three sites. Additional details about project economics (specific costs and savings) for each of these sites and scenarios are provided in the appendix.

Category	Low Energy Consumption	Medium Energy Consumption	High Energy Consumption/Shelter
Scenario A1: Standalone PV			
PV Capacity (kW-DC)	90	149	378
Annual % RE Electricity (%)	14%	14%	14%
Net Present Value ($)	$16.5k	$18.6k	$71.1k
Payback Period (Years)	12.12	12.6	12.1
Scenario A2: PV + Storage			
PV Capacity (kW-DC)	85	144	365
Battery Capacity (kW / kWh)	4/5	5/7	12/16
Annual % RE Electricity (%)	14	13	11%
Net Present Value ($)	$16.8k	$19.1k	$72.3k
Payback Period (Years)	12.25	12.7	12.2
Scenario B1: PV + Storage + Generator (*without* VLL and microgrid costs)			
PV Capacity (kW-DC)	91	638	672
Battery Capacity (kW / kWh)	4/5	42/59	94 /166
Generator Capacity (kW)	178 (New)	197 (New)	798 (New)
Annual % RE Electricity (%)	15%	58%	25%
Net Present Value ($)	-$205.9k	-$328.3k	-$980.0k
Payback Period (Years)	-	19.2	-
Scenario B2: PV + Storage + Generator (*with* VLL and microgrid costs)			
PV Capacity (kW-DC)	91	638	672
Battery Capacity (kW / kWh)	4/5	42/59	94 /166
Generator Capacity (kW)	178 (New)	197 (New)	798 (New)
Annual % RE Electricity (%)	15%	58%	25%
VoLL ($/kWh)	3.00	3.00	9.67
Net Present Value ($)	$116.02k	$236.2k	$4.7M
Payback Period (Years)	-	19.2	-

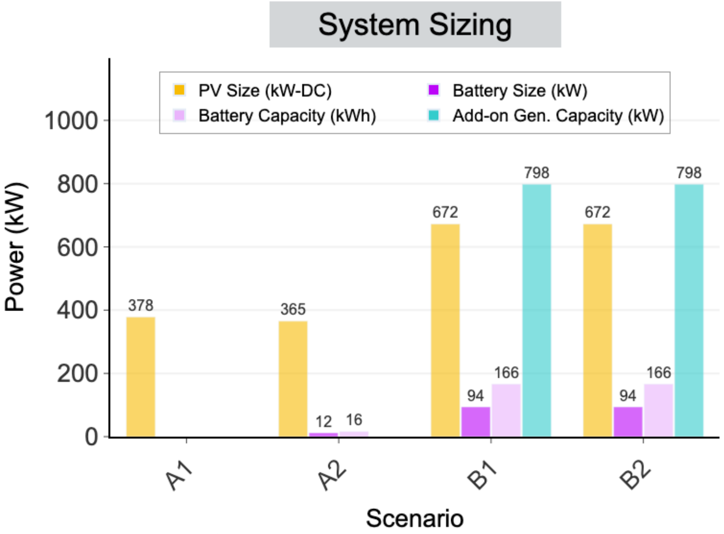
[2]B1 includes outage costs (e.g., fuel) in the NPV and LCC calculations but excludes the VoLL and microgrid upgrade costs. B2 includes outage costs along with VoLL and microgrid upgrades in the NPV and LCC calculations.

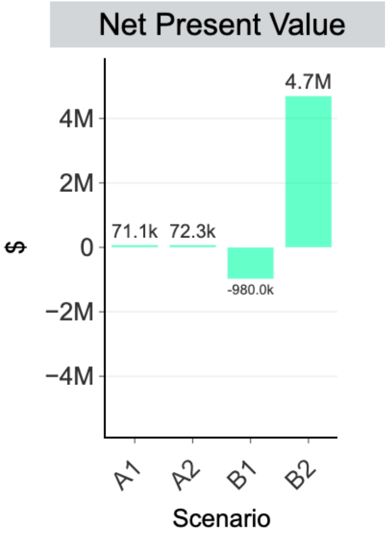
Note: These technology sizes are small because scaling them up increases costs without increasing the energy savings benefit, this making the systems less cost-effective within these scenarios.

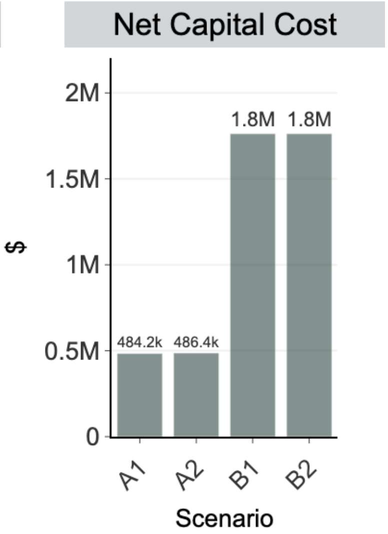
Key Takeaways: PAISD Shelter

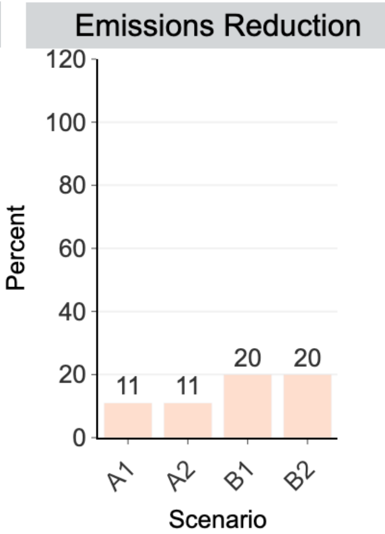
Scenarios	
Cost-Savings	Resilience
A1. Standalone PV	**B1.** PV + Storage + Gen without Microgrid cost and VoLL
A2. PV + Storage	**B2.** PV + Storage + Gen with Microgrid cost and VoLL

Thomas Jefferson Middle School, PAISD's highest energy consumer and a potential emergency community shelter, sees modest benefits from standalone PV and PV with storage, achieving 11% CO2 reductions and 1% utility savings with a 12-year payback and slightly positive NPVs. Adding resilience with more storage and a generator increases costs and results in a negative NPV. However, when factoring in microgrid costs and the value of lost load (VLL), the system becomes highly advantageous, 20% utility savings, and 40% overall savings compared to business as usual and the largest NPV of **$4.7M**









[1]Assumed VoLL: $9.67/kWh; Microgrid upgrade costs: 20% of Capital Cost

Port Arthur Transit (PAT)

Analyzing Energy Stability for Public Transit Operations

Site Overview – Port Arthur Transit

Building:
Fuel Station
Terminal
Administration
Maintenance
H.O Mills Facilities


Photo/Image Credit: Kim Brent / The Enterprise

Port Arthur Transit (PAT) in Port Arthur, Texas, consists of several buildings, each analyzed individually for its specific energy usage. This approach provided a detailed understanding of the energy demands across the transit authority's operations, reflecting the diversity in energy consumption and service needs among PAT facilities. None of these buildings were designated as emergency shelters.

Note: Port Arthur Transit used a 5-day outage duration threshold for their site analysis, which is higher than the other sites analyzed.

Cost-Optimal Results Summary, by Category

This slide summarizes system sizing, annual % RE, and NPV for all five sites. Additional details about project economics (specific costs and savings) for each of these sites and scenarios are provided in the following slides.

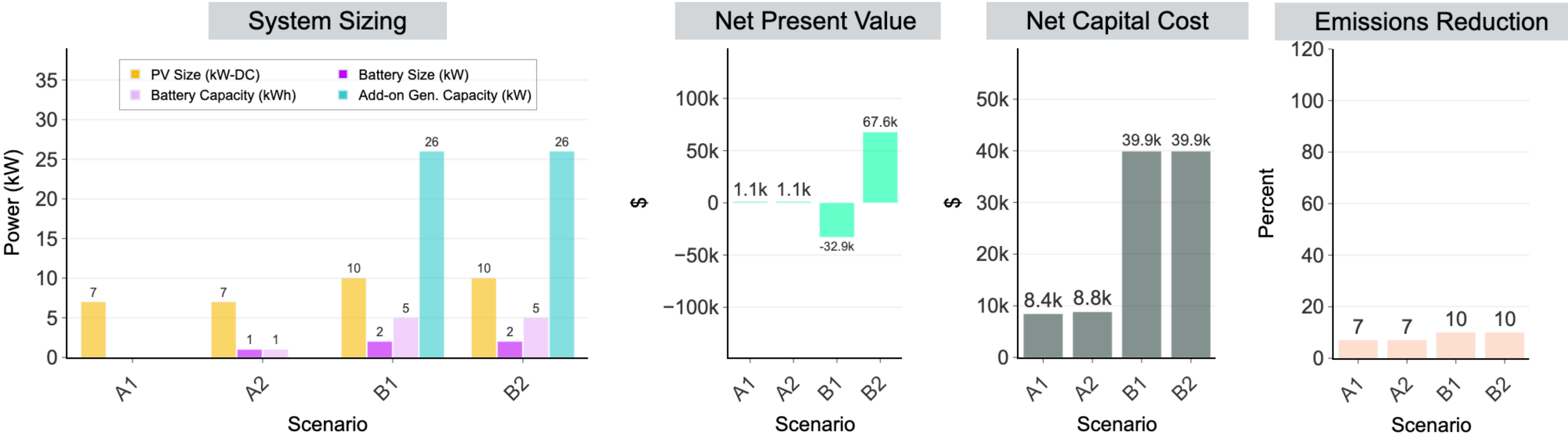
Building	Fuel Station	Terminal	Admin	H.O Mills	Maintenance
Scenario A1: Standalone PV					
PV Capacity (kW-DC)	3	22	7	9	42
Annual % RE Electricity (%)	62%	66%	9%	11%	7%
Net Present Value ($)	$1.13k	$10.6k	$1.12k	$976.7	$5.98k
Scenario A2: PV + Storage					
PV Capacity (kW-DC)	3	22	7	9	42
Battery Capacity (kW / kWh)	0 / 0	0 / 0	1 / 1	1 / 1	2 / 2
Annual % RE Electricity (%)	62%	66%	9%	11%	7%
Net Present Value ($)	$1.13k	$10.6k	$1.14k	$982.79	$6.1k
Scenario B1: PV + Storage + Generator (*<u>without</u> VLL and microgrid costs*)					
PV Capacity (kW-DC)	4	22	10	47	42
Battery Capacity (kW / kWh)	0 / 0	0 / 0	2 / 5	4 / 5	16 / 30
Generator Capacity (kW)	2 (New) + 0 (Existing)	45 (Existing)+0(New)	0 (Existing)+26 (New)	28(Existing)+0(New)	250 (Existing) + 31 (New)
Annual % RE Electricity (%)	82%	34%	14%	55%	7%
Net Present Value ($)	-2.26k	$10.5k	-$32.9k	-$7.28k	-$49.77k
Scenario B2: PV + Storage + Generator (*<u>with</u> VLL and microgrid costs*)					
PV Capacity (kW-DC)	4	22	10	47	42
Battery Capacity (kW / kWh)	0 / 0	0 / 0	2 / 5	4 / 5	16 / 30
Generator Capacity (kW)	2 (New) + 0 (Existing)	45 (Existing))+0(New)	0 (Existing)+26 (New)	28(Existing) +0(New)	250 (Existing) + 31 (New)
Annual % RE Electricity (%)	82%	66%	14%	55%	7%
VoLL ($/kWh)	$3.0/kWh	$3.0/kWh	$3.0/kWh	$3.0/kWh	$3.0/kWh
Net Present Value ($)	$5.18k	$10.78k	$67.61k	$11.58k	-$6.31k

Note: PAT used a 5-day outage duration threshold for their site analysis, which is higher than the other sites analyzed.

Key Takeaways: PAT Admin Building

Scenarios	
Cost-Savings	Resilience[1]
A1. Standalone PV	**B1.** PV + Storage + Gen without Microgrid cost and VoLL
A2. PV + Storage	**B2.** PV + Storage + Gen with Microgrid cost and VoLL

Standalone PV and PV with storage offer a reduction in utility savings, with similar payback periods of about 12 years and a slight positive NPV. Introducing resilience through added storage and a generator increases initial costs and leads to a negative NPV. However, when including microgrid costs and the value of lost load (VLL), the scenario shows a significant improvement with a 12% utility savings, and a 26% overall savings compared to business as usual, resulting in a strong positive NPV of **$67.6k.**

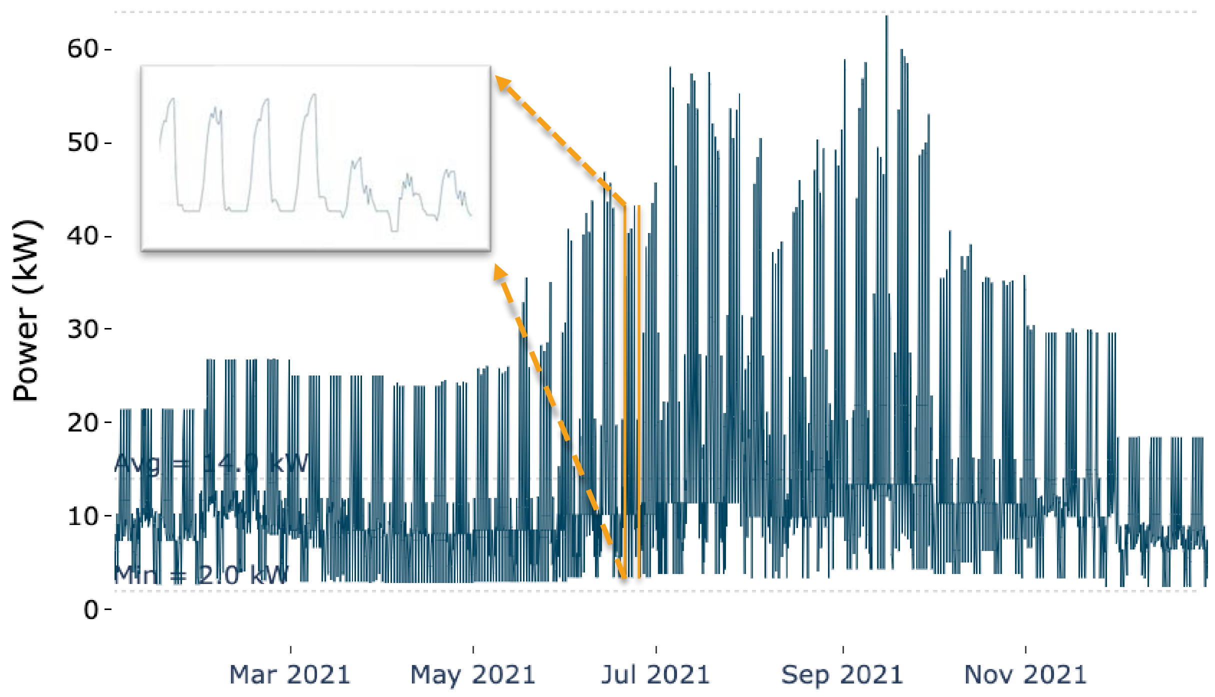


[1]Assumed VoLL: $3.0/kWh; Microgrid upgrade costs: 20% of Capital Cost; PAT used a 5-day outage duration threshold for their site analysis, which is higher than usual.

Inputs and Assumptions

Note: The following slides present assumptions specific to GTEC, but many assumptions remain consistent across all sites. The utility rate, for instance, is uniform across sites, with variations only in energy consumption. The key site-specific variables are energy consumption, existing generation capacity, and the timing of outages. Aside from these factors, most other assumptions apply uniformly to all sites. For a comprehensive list of detailed site-specific assumptions, please refer to the appendix.

Load Data for GTEC



- Monthly **load** data was provided for the **2022** calendar year
- Load profile was based on a small-sized office and secondary school (based on DOE Commercial Reference Building database) scaled using the sites annual consumption and modified to ensure that the consumption matches operating hours
  - GTEC Operating Hours: Monday through Thursday: 10 AM to 2 PM, Friday-Sunday: Closed

Note: See appendix for other sites' load data

Utility Rate

NET MONTHLY BILL	Effective 6-2-23
A. Customer Charge	$52.59 per month
B. Billing Load Charge	$9.50 per kW
C. Energy Charge* *Plus the Fixed Fuel Factor per Schedule FF and all applicable riders.	$ 0.02840 per kWh
D. The Texas retail fixed fuel factor	
**Delivery Voltage*	**Fixed Fuel Factor*
*Secondary	*$0.0284888 per kWh
E. Riders	$0.0056838 per kWh
F. Net Metering	Buy Back Rates: -Summer Rate $0.05322/kWh -Winter Rate $0.050725/kWh

- Golden Triangle Empowerment Center (GTEC) is serviced by Entergy Texas, INC. These charges reflect a recently updated rate tariff effective 6-2-23.
- This rate is classified as General Service – Secondary (TX-GS1)[1].

For more information visit:

https://cdn.entergy-texas.com/userfiles/content/price/tariffs/eti_gs.pdf

[1]All sites share the same rate tariff class

Estimating the Value of Lost Load (VoLL) for Emergency Shelter

This analysis provides a baseline VoLL from directly estimated impacts but does not attempt to describe a full and total quantification of VoLL. Estimating VoLL is complex and requires extensive analysis, as shown by K. Anderson et al. (2018).

Information to Potentially Consider in VoLL for GTEC

- **Staff Affected by Power Outage**
- **Daily Operational Costs**
- **Childcare Needs:** Students acquire childcare but do not take off work to attend courses.
- **Equipment Rental:** No rental equipment lost during outages.
- **Food Storage:** No food stored onsite that might spoil.
- **Additional Operational Costs:** Replacement of technology equipment during power surges.
- **Manual Equipment Restart Needs:** Triple phase power causes delays up to 4 days post-outage. Phone lines, routers, servers, security systems, access control require service technicians.

Actual Metrics Used in This Analysis for GTEC[1]

Daily Operational Loss:

- **Human Resources:** 3 Instructors, 1 Admin, 1 Program Director, 1 Job Developer left idle.
- **Operational Cost:** $5,000/day. Potential loss with extended outages.
- **Operational Hours:** Daily (9 AM - 5 PM) & Evening (6:30 PM - 9:30 PM).

Energy Consumption:

- **Peak Month:** September 2021
- **Daily Consumption:** Not publicly disclosed

[1] Derived from GTEC Property Use Information

References: Anderson, K.; Laws, N.D.; Marr, S.; Lisell, L.; Jimenez, T.; Case, T.; Li, X.; Lohmann, D.; Cutler, D. Quantifying and Monetizing Renewable Energy Resiliency. Sustainability 2018, 10, 933. https://doi.org/10.3390/su10040933

Resilience Costs and Benefits

- The **Value of Lost Load (VoLL)**[1] is factored into the optimization. This is the value that the user places on the unmet site load during grid outages, or the losses that the site would experience if the load were not met.

Value of Lost Load (VoLL) - Emergency Shelter: $9.67/kWh
Value of Lost Load (VoLL) - General: $3.00/kWh[3]

- The **Microgrid Upgrade Cost** is factored into the optimization. To gain resiliency, the PV/battery/generator must be installed as an island-able system. This requires additional equipment.

Microgrid Upgrade Costs:
20% of system capital cost

$$^{1}VoLL_{shelter} = \frac{Operation\ Cost\ (\$) + Infrastructure\ Vulnerabilities(\$) + Student\ Impact\ \&\ Indirect\ Costs\ (\$) + Equipment\ Vulnerabilities\ (\$) + Stakeholders\ Affected\ (\$)}{Total\ Estimated\ Energy\ Consumption\ During\ Outage\ (kWh)}$$

$$^{2}VoLL_{baseline} = \frac{\$5{,}000\ per\ day}{517.2\ kWh\ per\ day} = \$\ 9.67\ per\ kWh$$

[1]This full VoLL includes difficult-to-quantify elements that are therefore excluded from the following analysis. They are enumerated here to show that the true experienced VoLL for GTEC is likely greater than the conservative baseline VoLL used in this analysis.
[2]The $9.67/kWh baseline VoLL used in this analysis includes quantified metrics like operational cost and human resource idle time. Indirect costs such as student impact and equipment vulnerabilities are acknowledged but not quantified in this analysis (see above and see previous slide).
[3] Assumed one-third of the VoLL from the emergency shelters. This is a conservative estimate based on U.S. studies, which report VoLL values ranging from $3 to $12/kWh.

References: Van der Welle, A.; van der Zwaan, B. An Overview of Selected Studies on the Value of Lost Load (VoLL); Energy Research Centre of the Netherlands (ECN), Policy Studies Department.

Economic Parameters and Cost Assumptions

Key assumptions	
Analysis period	25 years
Ownership model	Direct Purchase
Technologies considered	PV, Battery storage, Generator
PV & Battery incentives	30% ITC (IRA[1])
Discount rate	5.64% for site
Inflation	2.5% per EIA[2]
Electricity cost escalation rate	2%/year per EIA utility cost escalation rates[2]
PV cost	$1,592/kW per NREL Annual Technology Baseline (ATB[3])
PV O&M cost	$17/kW-year per NREL (ATB[3])
Battery cost	$388/kWh + $775/kW based on Wood Mackenzie US Energy Storage Monitor
Battery replacement costs (year 10)	$220/kWh + $440/kW based on Wood Mackenzie US Energy Storage Monitor

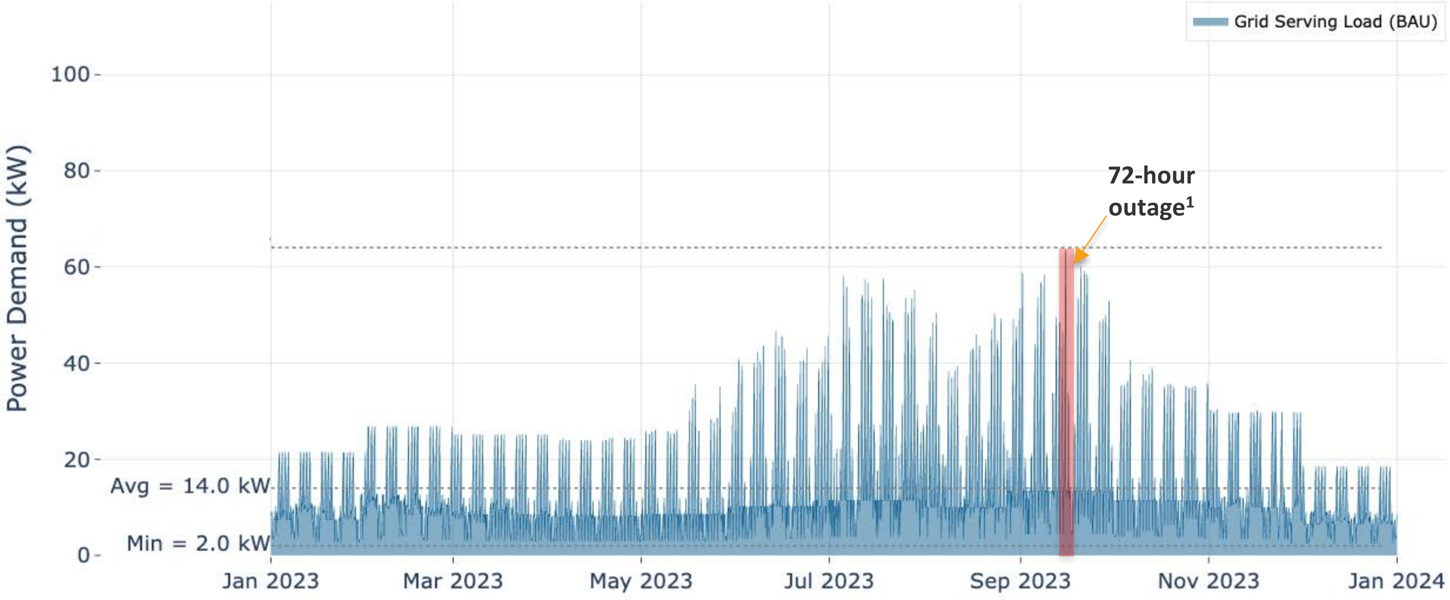
[1] IRA - https://www.irs.gov/inflation-reduction-act-of-2022
[2] EIA - https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2023&region=1-0&cases=ref2023&start=2023&end=2048&f=A&linechart=ref2023-d020623a.3-3-AEO2023.1-0&map=ref2023-d020623a.4-3-AEO2023.1-0&sourcekey=0
[3] ATB - https://atb.nrel.gov/

Outage Modeling GTEC

For resilience scenarios, PV + battery + generator were evaluated to support a **critical load** equal to **100%** of the site's typical load for a **72-hour outage duration**. The timing of this simulated outage was selected based on the site's annual peak demand.

- 72-hour outage: **9/20 1 PM – 9/23 1 PM**

Generator Inputs	Assumptions
Fuel Cost	$3.00/gal (diesel)
Fuel Cost Escalation Rate	2.7% (EIA)
Fuel Availability	300 gallons
Generator Capital Cost ($/kW)	650



[1] REopt modeled four distinct outages, one for each season of the year occurring at the peak demand periods. The 72-hour outage represents a severe disaster coinciding with peak demand for the year and is not based on local utility reliability data.

Questions:

Byron Pullutasig Byron.Pullutasig@nrel.gov

Scott Belding Scott.Belding@nrel.gov

www.nrel.gov

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Appendix

General Analysis Scenarios Evaluated Per Site

NREL evaluated the following scenarios for the site locations in this analysis. All scenarios assume that the system is purchased directly via appropriations.

- **A0. Base case:** The business-as-usual case, assuming the site purchases all energy from the utility.
- **A1. Economic size of standalone PV:** The minimum lifecycle cost case, assuming the site can purchase utility electricity and install **only** PV to lower the cost of utility purchases (no outage survivability requirements).
- **A2. Economic size of PV and battery storage:** The minimum lifecycle cost case, assuming the site can purchase utility electricity and install PV and/or battery storage to lower the cost of utility purchases (no outage survivability requirements).
- **B1. Resilience:** A cost-optimal system that provides both grid-connected value during normal operations and can continue operating at 100% of the typical critical load during a **72-hour (3-day)** outage for most sites, and a **120-hour (5-day)** outage for PAT. Expected outage costs (**excluding VoLL and microgrid upgrade costs**) are included in the net present value (NPV) and lifecycle cost (LCC) calculations.
- **B2. Resilience:** Beyond the considerations in B1, also accounts for additional expected outage costs, **including VoLL and microgrid upgrade costs**, to further refine the NPV and LCC analysis.

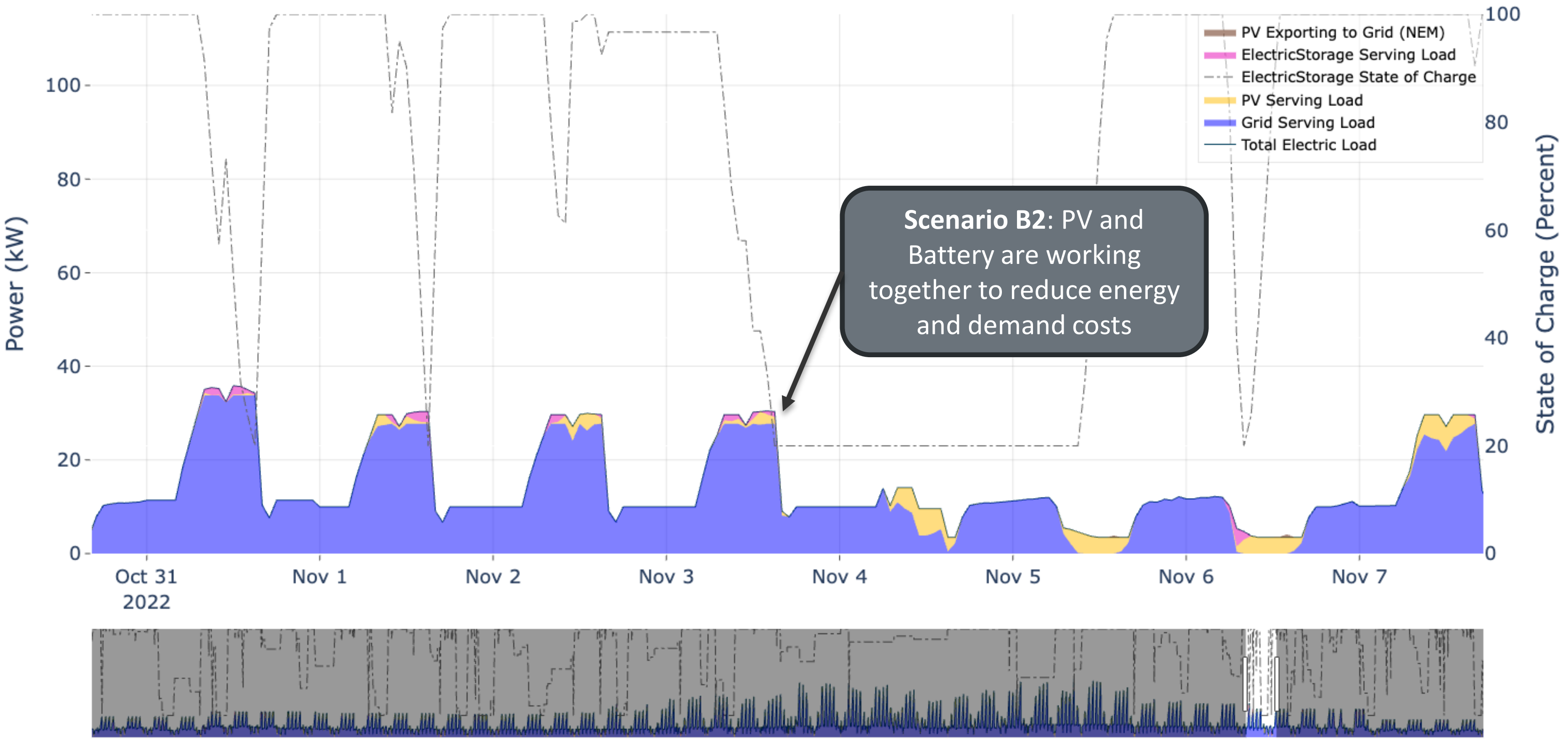
Definitions:

- **Lifecycle cost (LCC):** calculated as the present value of the sum of all capital costs (less any incentives considered), operations & maintenance (O&M) costs, battery replacement costs, and grid purchases throughout the 25-year analysis period.
- **Net present value (NPV):** calculated as the LCC savings for the investment case relative to the business-as-usual (BAU) case. A positive NPV indicates a cost-effective project; a negative NPV indicates the investment case is more expensive than the BAU case.

Detailed Results: GTEC

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience
PV Size (kW-DC)	-	13.25	13.22	10.34	10.34
Battery Size (kW)	-	-	0.13	2.18	2.18
Battery Capacity (kWh)	-	-	0.17	2.94	2.87
Add-on Gen. Capacity (kW)	-	-	-	60.03	60.03
Net Capital Cost ($)	-	$16.98k	$17.17k	$71.09k	$71.06k
Initial Capital Cost without Incentives ($)	-	$23.71k	$23.86k	$75.85k	$75.83k
Initial Capital Cost with Incentives ($)	-	$16.98k	$17.09k	$69.66k	$69.64k
Annual OM Cost ($)	-	$238.47	$238.01	$1.39k	$1.39k
RE Penetration (%)	-	15	15	11	11
Annual CO2 Emissions (Tons)	40.82	36.25	36.26	37.26	37.26
Lifecycle CO2 Emissions (Tons)	1020.54	906.26	906.49	931.44	931.4
Lifecycle CO2 Reduction (%)	-	11	11	9	9
Year 1 Energy Charges ($)	$7.91k	$6.83k	$6.83k	$7.04k	$7.04k
Year 1 Demand Charges ($)	$4.21k	$3.96k	$3.95k	$3.86k	$3.86k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$12.74k	$11.42k	$11.4k	$11.52k	$11.52k
Year 1 Energy Charge Savings ($)	-	$1.08k	$1.08k	$869.67	$869.87
Year 1 Demand Charge Savings ($)	-	$241.86	$255.90	$345.22	$342.91
Year 1 Total Electric Bill Savings ($)	-	$1.32k	$1.33k	$1.21k	$1.21k
Year 1 Utility Savings (%)	-	10	10	10	10
Avg. Outage Duration Survived (Hours)	-	-	-	3122	3122
Lifecycle Utility Electricity Cost ($)	$206.1k	$184.75k	$184.53k	$186.44k	$186.47k
Payback Period (Years)	-	12.86	12.91	-	-
Total Lifecycle Cost ($)	$206.1k	$204.89k	$204.88k	$281.53k	$295.76k
Net Present Value ($)	-	$1.2k	$1.22k	-$75.44k	$152.4k
Savings Compared to BAU (%)	-	1	1	-37	34
Annual PV Production (kWh)	-	18371.17	18335.98	14338.03	14344.69
PV Levelized Cost of Energy ($/kWh)	-	0.09	0.09	0.09	0.09

Example Optimal Dispatch for GTEC

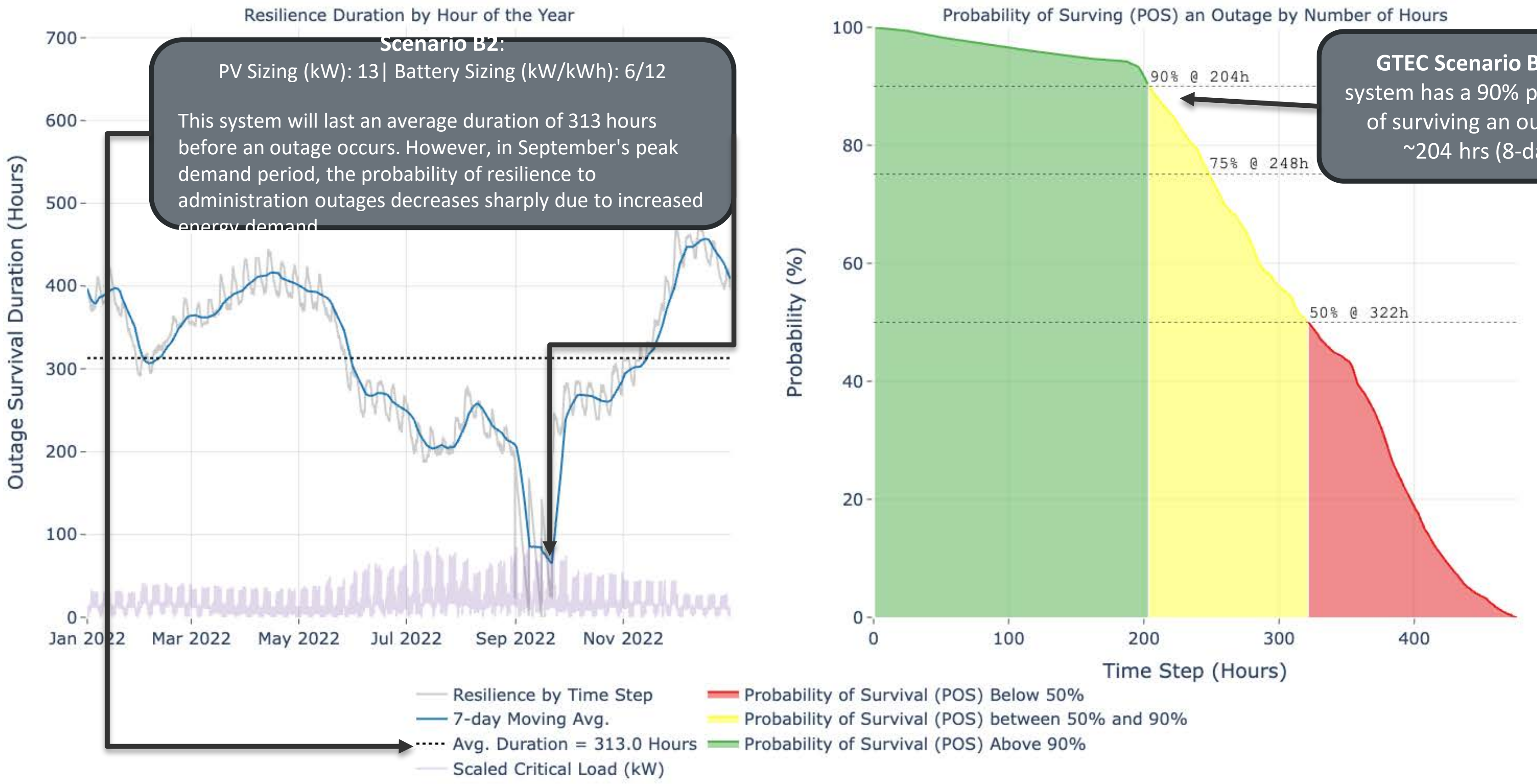


GTEC Resilience Metrics for Scenario B2

Scenario B2:
PV Sizing (kW): 13| Battery Sizing (kW/kWh): 6/12

This system will last an average duration of 313 hours before an outage occurs. However, in September's peak demand period, the probability of resilience to administration outages decreases sharply due to increased energy demand

GTEC Scenario B2: The system has a 90% probability of surviving an outage of ~204 hrs (8-days)



Note: See appendix for a complete summary of these and other metrics per site

Site Overview: LSC

PV, battery, and generator systems were evaluated at Lamar State College building sites, summarized below:

LSC Buildings	Ground Square Footage (GSF)
EDUCATIONAL BUILDING II	5,410
MADISON MONROE EDUCATIONAL BUILDING	35,942
FACULTY OFFICE BUILDING	3,181
RUBY RUTH FULLER EDUCATIONAL BUILDING	13,945
GATES MEMORIAL LIBRARY	19,799
COSMETOLOGY CENTER	9,372
MUSIC HALL	8,169
EDUCATIONAL BUILDING	12,226
FINANCE OFFICE	7,637
PHYSICAL PLANT BUILDING	5,377
COSMETOLOGY ANNEX	7,522
STUDENT CENTER	3,6448
ARMORY BUILDING	23,520
ALLIED HEALTH ANNEX	3,777
ALLIED HEALTH BUILDING	8,333
RECORDS STORAGE BUILDING	1,891
PERFORMING ARTS CENTER	38,582
SMALL BUSINESS DEVELOPMENT CENTER	1,894
STUDENT SUCCESS CENTER	6,679
SHEILA M UMPHREY INDUSTRIAL TECHNOLOGY CENTER	31,074

Categorized by Energy Consumption Range:	
Low Energy Consumption (< 100,000 kWh)	
PHYSICAL PLANT BUILDING[1]	
COSMETOLOGY ANNEX	**Average kWh**
ALLIED HEALTH ANNEX	**~40,000**
RECORDS STORAGE BUILDING	
SMALL BUSINESS DEVELOPMENT CENTER	
Medium Energy Consumption (100,000 - 500,000 kWh)	
ALLIED HEALTH BUILDING[1]	**Average kWh**
STUDENT SUCCESS CENTER	**~210,000**
RUBY RUTH FULLER EDUCATIONAL BUILDING	
COSMETOLOGY CENTER	
High Energy Consumption (> 500,000 kWh)	
GATES MEMORIAL LIBRARY	
MADISON MONROE EDUCATIONAL BUILDING[1]	**Average kWh**
STUDENT CENTER	**~560,000**
CARL A PARKER MULTIPURPOSE CENTER[1]	

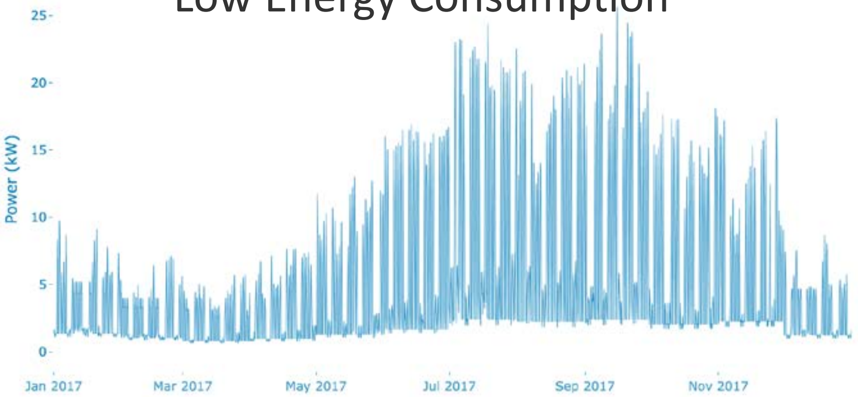
Category	Category Avg. Energy Usage (kWh)	Representative Building
Low Energy Usage	~40,000	Physical Plant Building[1]
Medium Energy Usage	~210,000	Cosmetology Center[1]
High Energy Usage	~560,000	Madison Monroe Educational Building[1]
Shelter	-	Carl A. Parker Multipurpose Center[1]

[1]These buildings were used to be representative of the other buildings in the categories outlined above.
Category 1: Low Energy Consumption - **PHYSICAL PLANT BUILDING;** Category 2: Medium Energy Consumption - **ALLIED HEALTH BUILDING;** Category 3: High Energy Consumption - **MADISON MONROE EDUCATIONAL BUILDING;** Category 4: Shelter - **CARL A PARKER MULTIPURPOSE CENTER**

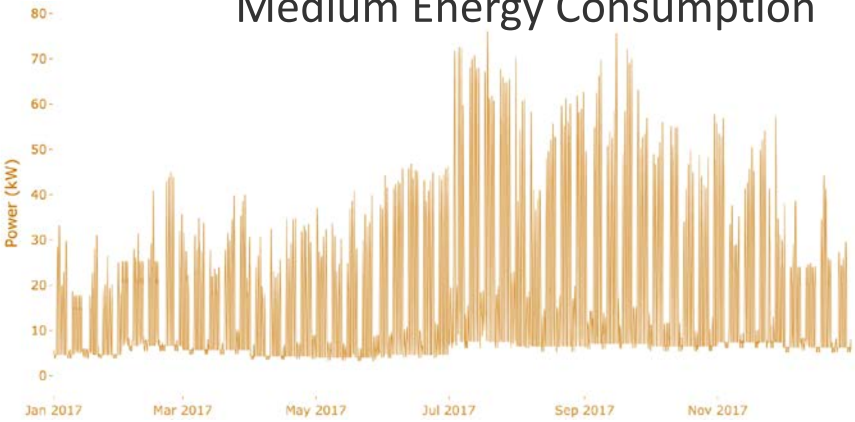
Loads: LSC

Category	Avg. Energy Usage (kWh)	Representative Building
Low Energy Usage	~40,000	Physical Plant Building[1]
Medium Energy Usage	~210,000	Cosmetology Center[1]
High Energy Usage	~560,000	Madison Monroe Educational Building[1]
Shelter	-	Carl A. Parker Multipurpose Center[1]

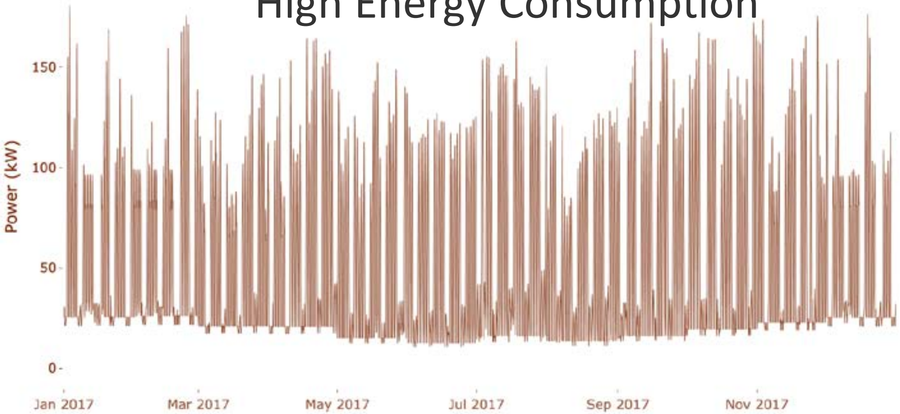
Low Energy Consumption



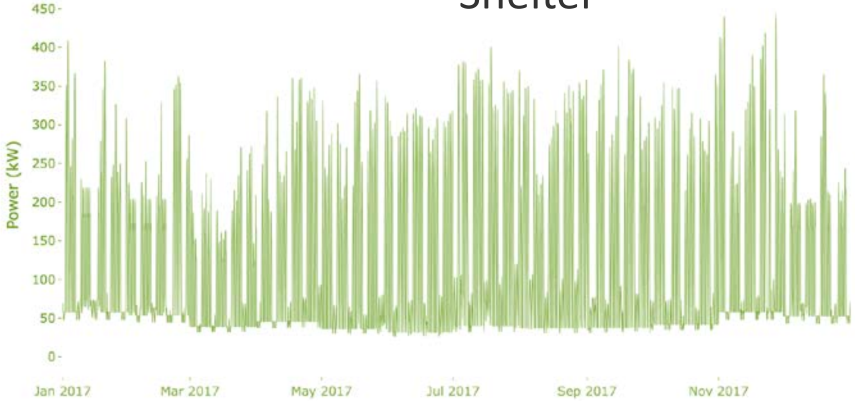
Medium Energy Consumption



High Energy Consumption



Shelter



Detailed Results: Low Energy User

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	5.14	5.14	5.06	5.06
Battery Size (kW)	-	-	0.25	1	1
Battery Capacity (kWh)	-	-	0.33	1.32	1.32
Current Gen. Capacity (kW)	100	100	100	100	100
Net Capital Cost ($)	-	$6.59k	$7.02k	$8.22k	$8.23k
Initial Capital Cost without Incentives ($)	-	$9.2k	$9.58k	$10.57k	$10.57k
Initial Capital Cost with Incentives ($)	-	$6.59k	$6.86k	$7.57k	$7.57k
Annual OM Cost ($)	$2.0k	$2.09k	$2.09k	$2.09k	$2.09k
RE Penetration (%)	-	16	16	15	15
Annual CO2 Emissions (Tons)	15	13.22	13.22	13.25	13.25
Lifecycle CO2 Emissions (Tons)	374.9	330.54	330.55	331.23	331.19
Lifecycle CO2 Reduction (%)	-	12	12	12	12
Year 1 Energy Charges ($)	$2.87k	$2.46k	$2.46k	$2.46k	$2.46k
Year 1 Demand Charges ($)	$1.67k	$1.57k	$1.54k	$1.49k	$1.49k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$5.16k	$4.65k	$4.62k	$4.57k	$4.57k
Year 1 Energy Charge Savings ($)	-	$409.46	$410.82	$408.44	$408.73
Year 1 Demand Charge Savings ($)	-	$98.82	$127.00	$178.98	$179.04
Year 1 Total Electric Bill Savings ($)	-	$508.28	$537.82	$587.42	$587.77
Year 1 Utility Savings (%)	-	10	10	11	11
Lifecycle Utility Electricity Cost ($)	$83.53k	$75.31k	$74.83k	$74.03k	$74.02k
Payback Period (Years)	-	12.78	12.99	14.28	14.25
Total Lifecycle Cost ($)	$118.11k	$117.59k	$117.57k	$118.24k	$118.24k
Net Present Value ($)	-	$519.13	$545.95	($124.77)	$118.88
Annual PV Production (kWh)	-	7128.6	7128.6	7016.38	7022.09

Detailed Results: Medium Energy User

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	24.46	24.37	77.74	77.74
Battery Size (kW)	-	-	1.25	18.92	18.92
Battery Capacity (kWh)	-	-	1.65	20.93	19.96
Current Gen. Capacity (kW)	-	-	-	101.52	101.52
Net Capital Cost ($)	-	$31.34k	$33.4k	$221.81k	$221.32k
Initial Capital Cost without Incentives ($)	-	$43.77k	$45.5k	$257.26k	$256.82k
Initial Capital Cost with Incentives ($)	-	$31.34k	$32.58k	$210.15k	$209.84k
Annual OM Cost ($)	-	$440.20	$438.63	$3.43k	$3.43k
RE Penetration (%)	-	14	14	44	44
Annual CO2 Emissions (Tons)	79.32	70.88	70.91	52.36	52.37
Lifecycle CO2 Emissions (Tons)	1983.12	1772.1	1772.85	1309.07	1309.34
Lifecycle CO2 Reduction (%)	-	11	11	34	34
Year 1 Energy Charges ($)	$15.3k	$13.28k	$13.28k	$9.86k	$9.87k
Year 1 Demand Charges ($)	$9.03k	$8.56k	$8.42k	$7.1k	$7.13k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$24.95k	$22.46k	$22.32k	$17.58k	$17.62k
Year 1 Energy Charge Savings ($)	-	$2.01k	$2.01k	$5.44k	$5.43k
Year 1 Demand Charge Savings ($)	-	$476.72	$617.65	$1.93k	$1.9k
Year 1 Total Electric Bill Savings ($)	-	$2.49k	$2.63k	$7.37k	$7.33k
Year 1 Utility Savings (%)	-	10	11	30	29
Lifecycle Utility Electricity Cost ($)	$403.7k	$363.44k	$361.18k	$284.48k	$285.1k
Payback Period (Years)	-	12.68	12.91	-	-
Total Lifecycle Cost ($)	$403.7k	$400.93k	$400.79k	$549.46k	$573.81k
Net Present Value ($)	-	$2.77k	$2.91k	-$145.75k	$49.6k
Annual PV Production (kWh)	-	33912.2	33791.42	107801.98	107804.84

Detailed Results: High Energy User

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	60.23	60.23	60.23	60.23
Battery Size (kW)	-	-	2.44	2.44	2.44
Battery Capacity (kWh)	-	-	3.22	3.22	3.22
Current Gen. Capacity (kW)	250	250	250	250	250
Net Capital Cost ($)	-	$77.19k	$81.42k	$81.43k	$81.42k
Initial Capital Cost without Incentives ($)	-	$107.8k	$111.49k	$111.5k	$111.49k
Initial Capital Cost with Incentives ($)	-	$77.19k	$79.83k	$79.83k	$79.83k
Annual OM Cost ($)	$5.0k	$6.08k	$6.08k	$6.08k	$6.08k
RE Penetration (%)	-	17	17	17	17
Annual CO2 Emissions (Tons)	159.74	138.95	138.95	138.95	138.95
Lifecycle CO2 Emissions (Tons)	3993.41	3473.73	3473.75	3473.72	3473.75
Lifecycle CO2 Reduction (%)	-	13	13	13	13
Year 1 Energy Charges ($)	$30.8k	$25.93k	$25.92k	$25.92k	$25.92k
Year 1 Demand Charges ($)	$18.39k	$17.27k	$17.0k	$17.0k	$17.0k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$49.82k	$43.82k	$43.54k	$43.54k	$43.54k
Year 1 Energy Charge Savings ($)	-	$4.87k	$4.89k	$4.89k	$4.89k
Year 1 Demand Charge Savings ($)	-	$1.13k	$1.4k	$1.4k	$1.4k
Year 1 Total Electric Bill Savings ($)	-	$6.0k	$6.28k	$6.28k	$6.28k
Year 1 Utility Savings (%)	-	12	13	13	13
Lifecycle Utility Electricity Cost ($)	$806.12k	$709.07k	$704.45k	$704.45k	$704.45k
Payback Period (Years)	-	12.81	13.01	13.01	13.01
Total Lifecycle Cost ($)	$892.57k	$886.72k	$886.57k	$888.11k	$888.31k
Net Present Value ($)	-	$5.85k	$6.0k	$4.46k	$6.0k
Annual PV Production (kWh)	-	83514.73	83514.73	83521.38	83514.73

Detailed Results: Shelter

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	144.48	144.48	122.93	122.93
Battery Size (kW)	-	-	6.52	19.61	19.61
Battery Capacity (kWh)	-	-	8.6	35.53	46.05
Current Gen. Capacity (kW)	250	250	250	250	250
Add-on Gen. Capacity (kW)	-	-	-	148.67	172.15
Net Capital Cost ($)	-	$185.18k	$196.51k	$330.34k	$356.82k
Initial Capital Cost without Incentives ($)	-	$258.62k	$268.47k	$387.86k	$413.77k
Initial Capital Cost with Incentives ($)	-	$185.18k	$192.23k	$315.71k	$340.27k
Annual OM Cost ($)	$5.0k	$7.6k	$7.6k	$10.19k	$10.66k
RE Penetration (%)	-	18	18	15	15
Annual CO2 Emissions (Tons)	368.07	318.2	318.21	325.63	325.6
Lifecycle CO2 Emissions (Tons)	9201.78	7955.06	7955.15	8140.68	8140.06
Lifecycle CO2 Reduction (%)	-	14	14	12	12
Year 1 Energy Charges ($)	$70.77k	$59.16k	$59.12k	$60.56k	$60.53k
Year 1 Demand Charges ($)	$42.06k	$39.35k	$38.62k	$37.69k	$37.56k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$113.45k	$99.13k	$98.37k	$98.87k	$98.71k
Year 1 Energy Charge Savings ($)	-	$11.61k	$11.65k	$10.21k	$10.24k
Year 1 Demand Charge Savings ($)	-	$2.72k	$3.44k	$4.37k	$4.5k
Year 1 Total Electric Bill Savings ($)	-	$14.32k	$15.08k	$14.58k	$14.74k
Year 1 Utility Savings (%)	-	13	13	13	13
Lifecycle Utility Electricity Cost ($)	$1.84M	$1.6M	$1.59M	$1.6M	$1.6M
Payback Period (Years)	-	12.82	13.03	-	-
Total Lifecycle Cost ($)	$1.92M	$1.91M	$1.91M	$2.1M	$2.14M
Net Present Value ($)	-	$13.96k	$14.39k	-$182.04k	$297.23k
Annual PV Production (kWh)	-	200352.04	200352.04	170467.27	170465.37

Site Overview: PAISD

PV, battery, Generators were evaluated at Port Arthur Independent School District Buildings sites, summarized below:

School	Address	Total kWh	Cost
MEMORIAL HIGH SCHOOL	3501 Sgt. Lucian Adams Dr. Port Arthur, TX 77642	HIGH	$396,969
THOMAS JEFFERSON MIDDLE SCHOOL*	2200 Jefferson Dr. Port Arthur, TX 77642	HIGH	$383530
ABRAHAM LINCOLN MIDDLE SCHOOL	1023 Abe Lincoln Ave. Port Arthur, TX 77640	HIGH	$365,988
BOOKER T. WASHINGTON ELEMENTARY SCHOOL*	1300 Freeman Ave. Port Arthur, TX 77640	MEDIUM	$213,625
WOODROW WILSON EARLY COLLEGE HIGH SCHOOL	1500 Lakeshore Dr. Port Arthur, TX 77642	MEDIUM	$170,148
TYRRELL ELEMENTARY SCHOOL	4401 Ferndale Port Arthur, TX 77642	LOW	$ 93,130
WHEATLEY SCHOOL OF EARLY CHILDHOOD PROGRAMS*	1100 Jefferson Dr. Port Arthur, TX 77642	LOW	$ 94,415

These buildings were used to be representative of the other buildings in the categories outlined above.

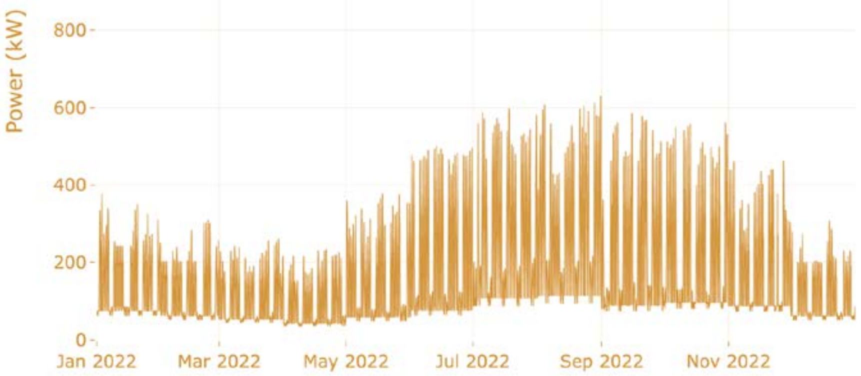
Category 1: Low Energy Consumption - WHEATLEY SCHOOL OF EARLY CHILDHOOD PROGRAMS
Category 2: Medium Energy Consumption - BOOKER T. WASHINGTON ELEMENTARY SCHOOL
Category 3: High Energy Consumption - THOMAS JEFFERSON MIDDLE SCHOOL

Loads: PAISD

Category	School
High	THOMAS JEFFERSON MIDDLE SCHOOL
Medium	BOOKER T. WASHINGTON ELEMENTARY SCHOOL
Low	WHEATLEY SCHOOL OF EARLY CHILDHOOD PROGRAMS

Low Energy Consumption

Medium Energy Consumption



High Energy Consumption

Detailed Results: Low Energy User

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	90	85	91	91
Battery Size (kW)	-	-	4	5	5
Battery Capacity (kWh)	-	-	5	7	7
Add-on Gen. Capacity (kW)	-	-	-	178	178
Net Capital Cost ($)	-	$114.25k	$114.06k	$283.85k	$283.85k
Initial Capital Cost without Incentives ($)	-	$159.56k	$156.49k	$328.94k	$328.94k
Initial Capital Cost with Incentives ($)	-	$114.25k	$112.05k	$280.79k	$280.79k
Annual OM Cost ($)	-	$1.6k	$1.53k	$5.18k	$5.18k
RE Penetration (%)	-	14	14	15	15
Annual CO2 Emissions (Tons)	277.16	246.33	247.82	245.77	245.77
Lifecycle CO2 Emissions (Tons)	6928.99	6158.2	6195.51	6144.17	6144.15
Lifecycle CO2 Reduction (%)	-	11	11	11	11
Year 1 Energy Charges ($)	$53.56k	$46.18k	$46.49k	$46.04k	$46.04k
Year 1 Demand Charges ($)	$31.69k	$29.58k	$29.29k	$29.05k	$29.05k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$85.87k	$76.38k	$76.4k	$75.71k	$75.71k
Year 1 Energy Charge Savings ($)	-	$7.38k	$7.08k	$7.53k	$7.53k
Year 1 Demand Charge Savings ($)	-	$2.11k	$2.39k	$2.63k	$2.63k
Year 1 Total Electric Bill Savings ($)	-	$9.49k	$9.47k	$10.16k	$10.16k
Year 1 Utility Savings (%)	-	11	11	12	12
Lifecycle Utility Electricity Cost ($)	$1.39M	$1.24M	$1.24M	$1.23M	$1.23M
Payback Period (Years)	-	12.12	12.25	-	-
Total Lifecycle Cost ($)	$1.39M	$1.37M	$1.37M	$1.6M	$1.65M
Net Present Value ($)	-	$16.51k	$16.77k	-$205.87k	$116.02k

Detailed Results: Medium Energy User

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	149	144	638	638
Battery Size (kW)	-	-	5	42	42
Battery Capacity (kWh)	-	-	7	59	59
Add-on Gen. Capacity (kW)	-	-	-	197	197
Net Capital Cost ($)	-	$190.9k	$192.69k	$1.07M	$1.07M
Initial Capital Cost without Incentives ($)	-	$266.62k	$264.81k	$1.38M	$1.38M
Initial Capital Cost with Incentives ($)	-	$190.9k	$189.61k	$1.04M	$1.04M
Annual OM Cost ($)	-	$2.68k	$2.59k	$15.41k	$15.41k
RE Penetration (%)	-	14	13	58	58
Annual CO2 Emissions (Tons)	503.14	451.73	453.45	282.89	282.93
Lifecycle CO2 Emissions (Tons)	12578.49	11293.22	11336.31	7072.29	7073.25
Lifecycle CO2 Reduction (%)	-	10	10	44	44
Year 1 Energy Charges ($)	$95.43k	$83.07k	$83.43k	$55.84k	$55.87k
Year 1 Demand Charges ($)	$49.53k	$46.54k	$46.08k	$39.73k	$39.85k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$145.58k	$130.23k	$130.13k	$96.19k	$96.34k
Year 1 Energy Charge Savings ($)	-	$12.36k	$12.0k	$39.59k	$39.56k
Year 1 Demand Charge Savings ($)	-	$2.99k	$3.46k	$9.8k	$9.68k
Year 1 Total Electric Bill Savings ($)	-	$15.35k	$15.46k	$49.39k	$49.24k
Year 1 Utility Savings (%)	-	11	11	34	34
Lifecycle Utility Electricity Cost ($)	$2.36M	$2.11M	$2.11M	$1.56M	$1.56M
Payback Period (Years)	-	12.58	12.71	19.18	19.18
Total Lifecycle Cost ($)	$2.36M	$2.34M	$2.34M	$2.68M	$2.73M
Net Present Value ($)	-	$18.59k	$19.05k	-$328.33k	$236.23k

Detailed Results: High Energy User

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	378	365	672	672
Battery Size (kW)	-	-	12	94	94
Battery Capacity (kWh)	-	-	16	166	166
Add-on Gen. Capacity (kW)	-	-	-	798	798
Net Capital Cost ($)	-	$484.18k	$486.36k	$1.76M	$1.76M
Initial Capital Cost without Incentives ($)	-	$676.22k	$668.82k	$2.08M	$2.08M
Initial Capital Cost with Incentives ($)	-	$484.18k	$478.89k	$1.69M	$1.69M
Annual OM Cost ($)	-	$6.8k	$6.55k	$28.04k	$28.04k
RE Penetration (%)	-	14	14	25	25
Annual CO2 Emissions (Tons)	1184.48	1053.81	1058.58	951.81	951.81
Lifecycle CO2 Emissions (Tons)	29611.89	26345.34	26464.45	23795.34	23795.31
Lifecycle CO2 Reduction (%)	-	11	11	20	20
Year 1 Energy Charges ($)	$229.13k	$197.88k	$198.85k	$176.81k	$176.81k
Year 1 Demand Charges ($)	$135.34k	$126.34k	$125.23k	$113.81k	$113.81k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$365.09k	$324.84k	$324.7k	$291.24k	$291.24k
Year 1 Energy Charge Savings ($)	-	$31.25k	$30.28k	$52.32k	$52.32k
Year 1 Demand Charge Savings ($)	-	$9.0k	$10.11k	$21.53k	$21.53k
Year 1 Total Electric Bill Savings ($)	-	$40.25k	$40.39k	$73.85k	$73.85k
Year 1 Utility Savings (%)	-	11	11	20	20
Lifecycle Utility Electricity Cost ($)	$5.91M	$5.26M	$5.25M	$4.71M	$4.71M
Payback Period (Years)	-	12.1	12.21	-	-
Total Lifecycle Cost ($)	$5.91M	$5.84M	$5.84M	$6.89M	$7.07M
Net Present Value ($)	-	$71.1k	$72.33k	-$979.95k	$4.7M

Site Overview: PAT

PV, battery, and generator systems were evaluated at Port Arthur Transit building sites, summarized below:

Entergy Accounts		
Building:	**Address:**	**Rate Class:**
Terminal	300 Procter St	TX-GS: General Service
Administration	344 Procter St	TX-GS: General Service
Fuel Station	325 Dallas	TX-GS: General Service
Maintenance	347 4th St	TX-GS: General Service
H.O Mills Facilities	Collective	TX-GS: General Service

Detailed Results: Fuel Station

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	2.88	2.88	3.81	3.81
Battery Size (kW)	-	-	-	1	-
Add-on Gen. Capacity (kW)	-	-	-	1.78	1.78
Net Capital Cost ($)	-	$3.7k	$3.7k	$7.55k	$6.48k
Initial Capital Cost without Incentives ($)	-	$5.16k	$5.16k	$9.33k	$8.42k
Initial Capital Cost with Incentives ($)	-	$3.7k	$3.7k	$7.14k	$6.48k
Annual OM Cost ($)	-	$51.92	$51.92	$104.18	$104.17
RE Penetration (%)	-	62	62	82	82
Annual CO2 Emissions (Tons)	1.99	1.02	1.02	0.7	0.7
Lifecycle CO2 Emissions (Tons)	49.73	25.39	25.39	17.57	17.61
Lifecycle CO2 Reduction (%)	-	49	49	65	65
Year 1 Energy Charges ($)	$671.87	$376.57	$376.57	$335.70	$335.90
Year 1 Fixed Cost Charges ($)	$259.00	$259.00	$259.00	$259.00	$259.00
Year 1 Total Electric Bill Costs ($)	$930.87	$635.57	$635.57	$594.70	$594.90
Year 1 Energy Charge Savings ($)	-	$295.30	$295.30	$336.17	$335.97
Year 1 Total Electric Bill Savings ($)	-	$295.30	$295.30	$336.17	$335.97
Year 1 Utility Savings (%)	-	32	32	36	36
Lifecycle Utility Electricity Cost ($)	$15.07k	$10.29k	$10.29k	$9.63k	$9.63k
Payback Period (Years)	-	10.78	10.78	19.36	16.4
Total Lifecycle Cost ($)	$15.07k	$13.94k	$13.94k	$17.33k	$17.56k
Net Present Value ($)	-	$1.13k	$1.13k	-$2.26k	$5.18k

Detailed Results: Terminal

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	21.54	21.54	21.78	21.79
Current Gen. Capacity (kW)	45	45	45	45	45
Net Capital Cost ($)	-	$27.61k	$27.61k	$27.91k	$27.93k
Initial Capital Cost without Incentives ($)	-	$38.56k	$38.56k	$38.99k	$39.0k
Initial Capital Cost with Incentives ($)	-	$27.61k	$27.61k	$27.91k	$27.93k
Annual OM Cost ($)	$900.00	$1.29k	$1.29k	$1.29k	$1.29k
RE Penetration (%)	-	66	66	66	66
Annual CO2 Emissions (Tons)	14.18	6.91	6.91	6.83	6.82
Lifecycle CO2 Emissions (Tons)	354.51	172.7	172.7	170.69	170.6
Lifecycle CO2 Reduction (%)	-	51	51	52	52
Year 1 Energy Charges ($)	$4.74k	$2.27k	$2.27k	$2.25k	$2.25k
Year 1 Fixed Cost Charges ($)	$259.00	$259.00	$259.00	$259.00	$259.00
Year 1 Total Electric Bill Costs ($)	$5.0k	$2.53k	$2.53k	$2.51k	$2.51k
Year 1 Energy Charge Savings ($)	-	$2.47k	$2.47k	$2.48k	$2.49k
Year 1 Total Electric Bill Savings ($)	-	$2.47k	$2.47k	$2.48k	$2.49k
Year 1 Utility Savings (%)	-	49	49	50	50
Lifecycle Utility Electricity Cost ($)	$80.86k	$40.87k	$40.87k	$40.66k	$40.65k
Payback Period (Years)	-	10.2	10.2	10.23	10.23
Total Lifecycle Cost ($)	$96.42k	$85.8k	$85.8k	$85.93k	$85.93k
Net Present Value ($)	-	$10.63k	$10.63k	$10.49k	$10.78k

Detailed Results: Administration Building

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	6.59	6.59	9.9	9.9
Battery Size (kW)	-	-	0.21	1.67	1.67
Battery Capacity (kWh)	-	-	0.28	4.06	4.06
Add-on Gen. Capacity (kW)	-	-	-	25.97	25.97
Net Capital Cost ($)	-	$8.45k	$8.82k	$39.91k	$39.91k
Initial Capital Cost without Incentives ($)	-	$11.8k	$12.12k	$44.46k	$44.46k
Initial Capital Cost with Incentives ($)	-	$8.45k	$8.68k	$38.47k	$38.47k
Annual OM Cost ($)	-	$118.67	$118.67	$697.49	$697.49
RE Penetration (%)	-	9	9	14	14
Annual CO2 Emissions (Tons)	32.15	29.92	29.92	28.8	28.8
Lifecycle CO2 Emissions (Tons)	803.63	747.99	747.99	720.04	720.04
Lifecycle CO2 Reduction (%)	-	7	7	10	10
Year 1 Energy Charges ($)	$6.16k	$5.62k	$5.62k	$5.36k	$5.36k
Year 1 Demand Charges ($)	$2.93k	$2.77k	$2.75k	$2.56k	$2.56k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$9.72k	$9.01k	$8.99k	$8.54k	$8.54k
Year 1 Energy Charge Savings ($)	-	$541.97	$542.55	$804.12	$804.12
Year 1 Demand Charge Savings ($)	-	$162.55	$186.15	$379.08	$379.08
Year 1 Total Electric Bill Savings ($)	-	$704.52	$728.70	$1.18k	$1.18k
Year 1 Utility Savings (%)	-	7	7	12	12
Lifecycle Utility Electricity Cost ($)	$157.26k	$145.86k	$145.47k	$138.12k	$138.12k
Payback Period (Years)	-	12.23	12.41	-	-
Total Lifecycle Cost ($)	$157.26k	$156.14k	$156.13k	$190.15k	$190.16k
Net Present Value ($)	-	$1.12k	$1.14k	-$32.89k	$67.61k

Detailed Results: HO Mills

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	8.9	8.9	46.6	46.6
Battery Size (kW)	-	-	0.16	3.26	3.26
Battery Capacity (kWh)	-	-	0.21	4.67	4.67
Current Gen. Capacity (kW)	28	28	28	28	28
Net Capital Cost ($)	-	$11.41k	$11.69k	$65.57k	$65.57k
Initial Capital Cost without Incentives ($)	-	$15.93k	$16.17k	$88.5k	$88.5k
Initial Capital Cost with Incentives ($)	-	$11.41k	$11.58k	$63.37k	$63.37k
Annual OM Cost ($)	$560.00	$720.18	$720.18	$1.4k	$1.4k
RE Penetration (%)	-	11	11	55	55
Annual CO2 Emissions (Tons)	36.38	33.38	33.38	20.68	20.68
Lifecycle CO2 Emissions (Tons)	909.55	834.44	834.45	516.92	516.92
Lifecycle CO2 Reduction (%)	-	8	8	43	43
Year 1 Energy Charges ($)	$7.17k	$6.46k	$6.45k	$4.15k	$4.15k
Year 1 Demand Charges ($)	$3.68k	$3.49k	$3.47k	$2.94k	$2.94k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$11.47k	$10.57k	$10.55k	$7.71k	$7.71k
Year 1 Energy Charge Savings ($)	-	$712.62	$713.39	$3.02k	$3.02k
Year 1 Demand Charge Savings ($)	-	$189.39	$207.03	$743.61	$743.61
Year 1 Total Electric Bill Savings ($)	-	$902.01	$920.42	$3.76k	$3.76k
Year 1 Utility Savings (%)	-	8	8	33	33
Lifecycle Utility Electricity Cost ($)	$185.6k	$171.01k	$170.71k	$124.77k	$124.77k
Payback Period (Years)	-	12.71	12.8	15.42	15.42
Total Lifecycle Cost ($)	$195.29k	$194.31k	$194.3k	$202.57k	$202.58k
Net Present Value ($)	-	$976.70	$982.79	-$7.28k	$11.58k

Detailed Results: Maintenance Building

Scenario	A0. Business as Usual (BAU)	A1. Standalone PV	A2. PV and Storage	B1. PV and Storage - Resilience	B2. PV and Storage - Resilience with Microgrid Cost and VLL
PV Size (kW-DC)	-	42	42	42	42
Battery Size (kW)	-	-	1.36	15.84	15.84
Battery Capacity (kWh)	-	-	1.8	29.9	29.9
Current Gen. Capacity (kW)	250	250	250	250	250
Add-on Gen. Capacity (kW)	-	-	-	31.1	31.1
Net Capital Cost ($)	-	$53.83k	$56.2k	$113.92k	$113.92k
Initial Capital Cost without Incentives ($)	-	$75.18k	$77.24k	$131.19k	$131.19k
Initial Capital Cost with Incentives ($)	-	$53.83k	$55.3k	$101.88k	$101.88k
Annual OM Cost ($)	$5.0k	$5.76k	$5.76k	$6.38k	$6.38k
RE Penetration (%)	-	7	7	7	7
Annual CO2 Emissions (Tons)	257.48	243.3	243.31	243.35	243.35
Lifecycle CO2 Emissions (Tons)	6437.09	6082.61	6082.64	6083.82	6083.82
Lifecycle CO2 Reduction (%)	-	6	6	5	5
Year 1 Energy Charges ($)	$50.73k	$47.27k	$47.27k	$47.22k	$47.22k
Year 1 Demand Charges ($)	$25.73k	$24.77k	$24.62k	$23.57k	$23.57k
Year 1 Fixed Cost Charges ($)	$621.00	$621.00	$621.00	$621.00	$621.00
Year 1 Total Electric Bill Costs ($)	$77.09k	$72.67k	$72.51k	$71.42k	$71.42k
Year 1 Energy Charge Savings ($)	-	$3.46k	$3.47k	$3.51k	$3.51k
Year 1 Demand Charge Savings ($)	-	$960.75	$1.11k	$2.16k	$2.16k
Year 1 Total Electric Bill Savings ($)	-	$4.42k	$4.58k	$5.67k	$5.67k
Year 1 Utility Savings (%)	-	6	6	7	7
Lifecycle Utility Electricity Cost ($)	$1.25M	$1.18M	$1.17M	$1.16M	$1.16M
Payback Period (Years)	-	12.45	12.61	22.76	22.76
Total Lifecycle Cost ($)	$1.33M	$1.33M	$1.33M	$1.38M	$1.38M
Net Present Value ($)	-	$5.98k	$6.1k	-$49.77k	-$6.31k

Financial, Economic, & Grid Assumptions

Economic Inputs	Assumptions
Technologies	Solar PV + Lithium-ion battery energy storage
Analysis period	25 years
Ownership models	Direct purchase
Discount rate (nominal)	5.64% owner discount rate
Inflation rate	2.5% rate
Electricity cost escalation rate (nominal)	1.9%/year
Host effective tax rate	0%/year

Technology Assumptions

Solar PV Inputs	Assumptions
System type	Rooftop PV
Technology resource	PV production factors obtained for this location using REopt
Area available for PV	System sizing not constrained by area available
DC-to-AC ratio	1.2
Tilt	35°
Azimuth	180° (south-facing)
Capital costs	$1592/kW-DC per NREL ATB
O&M costs	$17/kW/yr per NREL ATB
Incentives	The passage of the Inflation Reduction Act of 2022 impacts the value of the U.S. Investment Tax Credit available for many of the technologies modeled by REopt. As such, this analysis uses the REopt default Federal incentive based on percentage of capital cost of 30% for PV and Battery systems (updated from previous assumptions from 26% for both PV and Battery systems). This value assumes the project meets prevailing wage and registered apprenticeship requirements. See the White House Guidebook for more details.
Net metering limit	100 kW per Entergy https://www.entergy-texas.com/net-metering/

Battery Energy Storage Inputs	Assumptions
Battery type	Lithium-ion
AC-AC round trip efficiency	89.9% (includes inverter and rectifier efficiencies of 96%)
Initial state of charge	50%
Minimum state of charge	20%
Capital costs	$388/kWh + $775/kW based on Wood Mackenzie Energy Storage Monitor December 2021
Replacement costs (year 10)	$220/kWh + $440/kW based on Wood Mackenzie Energy Storage Monitor December 2021