WEST VIRGINIA REGIONAL MICROGRIDS FOR RESILIENCE STUDY

Prepared for the West Virginia Office of Energy (WVOE)

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About SEPA

The Smart Electric Power Alliance (SEPA) is dedicated to helping electric power stakeholders address the most pressing issues they encounter as they pursue the transformation to a carbonfree energy system. We are a trusted partner providing education, research, standards, and collaboration to help utilities, electric customers, and other industry players across three pathways: Regulatory and Business Innovation, Grid Integration, Electrification. Through educational activities, working groups, peer-to-peer engagements and custom projects, SEPA convenes interested parties to facilitate information exchange and knowledge transfer to offer the highest value for our members and partner organizations. For more information, visit www.sepapower.org.

About WVOE

The West Virginia Office of Energy (WVOE) is one of 56 energy offices across the 50 United States, the District of Columbia, and five territories (American Samoa, Guam, Northern Mariana Islands, Puerto Rico, and the Virgin Islands). WVOE is responsible for the formulation and implementation of fossil, renewable and energy efficiency initiatives designed to advance energy resource development opportunities and provide energy services to businesses, communities and homeowners in West Virginia.

Acknowledgements

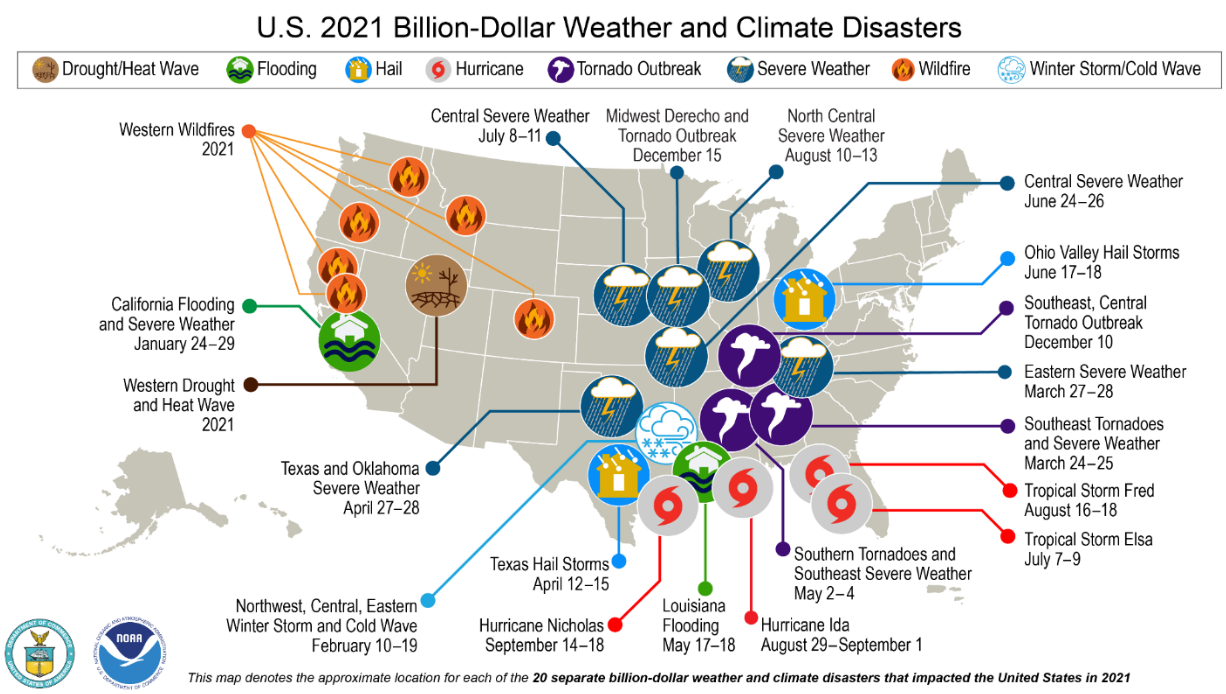
SEPA would like to thank the West Virginia Office of Energy for the opportunity to conduct this study. The development of this study was financially assisted from a grant assisted by U.S. DoE. SEPA would also like to thank our key stakeholders that provided input on our site selection criteria and played an important role in highlighting key considerations.

Disclaimer

1.0 Background

Natural disasters and extreme weather events have increased in both frequency and magnitude over the past several years. For the U.S., in 2021, US natural disasters caused $145B in economic damage and 20 weather events each had economic losses that totaled more than $1B.[1] In West Virginia, floods, derechos and ice storms prompted the Federal Emergency Management Agency (FEMA) to establish a permanent federal response team in the state.[2] In West Virginia, these extreme weather events contribute to increased and erratic rainfall and flooding and are increasing in both frequency and economic impact, causing damage to the electrical system and disruption to the power supply, and disproportionately affecting underserved communities.

Figure 1. 1 - U.S. 2021 Billion-Dollar Weather and Climate Disasters



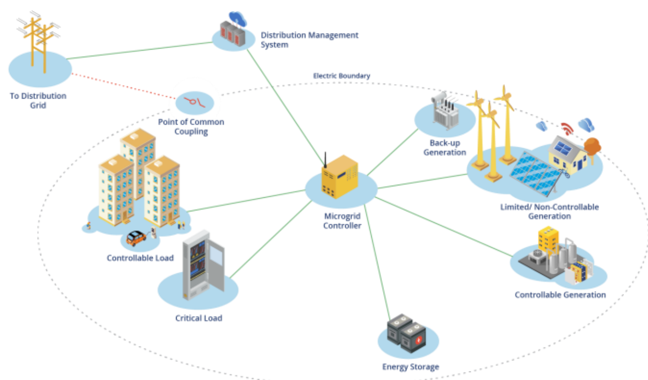
Source: U.S. National Oceanic and Atmospheric Administration, Billion-Dollar Weather and Climate Disasters (2022)

Outages are a major contributor to economic loss that can be mitigated with microgrids. The U.S. Department of Energy (DOE) defines a microgrid as ‘‘a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid

[1] U.S. National Oceanic and Atmospheric Administration (NOAA), Billion-Dollar Weather and Climate Disasters (2022).
[2] West Virginia Public Broadcasting, FEMA Makes W.Va. Disaster Response National Priority (2022).

to enable it to operate in both grid-connected or island-mode. Microgrids may be considered as an option, but not viewed as a solution in and of themselves. Microgrids represent one tool in the toolbox to help communities respond to and recover from grid outages. They can provide critical infrastructure with power in the event of a major grid outage. This can be accomplished via the strategic deployment of distributed energy resources (DERs) to provide electrical service to critical infrastructure and reduce the impact on the community. The deployment strategies contained within this study are threat specific - natural hazards - and solution specific - microgrids. Microgrids can be used to bolster resilience of communities affected by power outages due to a natural disaster or extreme weather event. They may allow communities to ride-through outages by incorporating localized generation and other DERs that can connect and disconnect from the traditional power grid to serve multiple entities (or loads).[3]

Figure 1. 2 - Typical Microgrid Components



Source: Smart Electric Power Alliance, 2020

The primary value of a microgrid for resilience is its ability to "island", or disconnect from the traditional power grid, and operate independently during a grid outage or disturbance.[4] When strategically located, this function enables microgrids to provide increased resilience to critical infrastructure.

Microgrids offer an opportunity to increase both system reliability and resilience through its ability to "island" from the traditional power grid. The North American Electric Reliability Corporation defines operating reliability as "the ability of the Bulk-Power System to withstand sudden disturbances, such as electric short circuits or the unanticipated loss of system elements from credible contingencies, while avoiding uncontrolled cascading blackouts or damage to equipment".[5]

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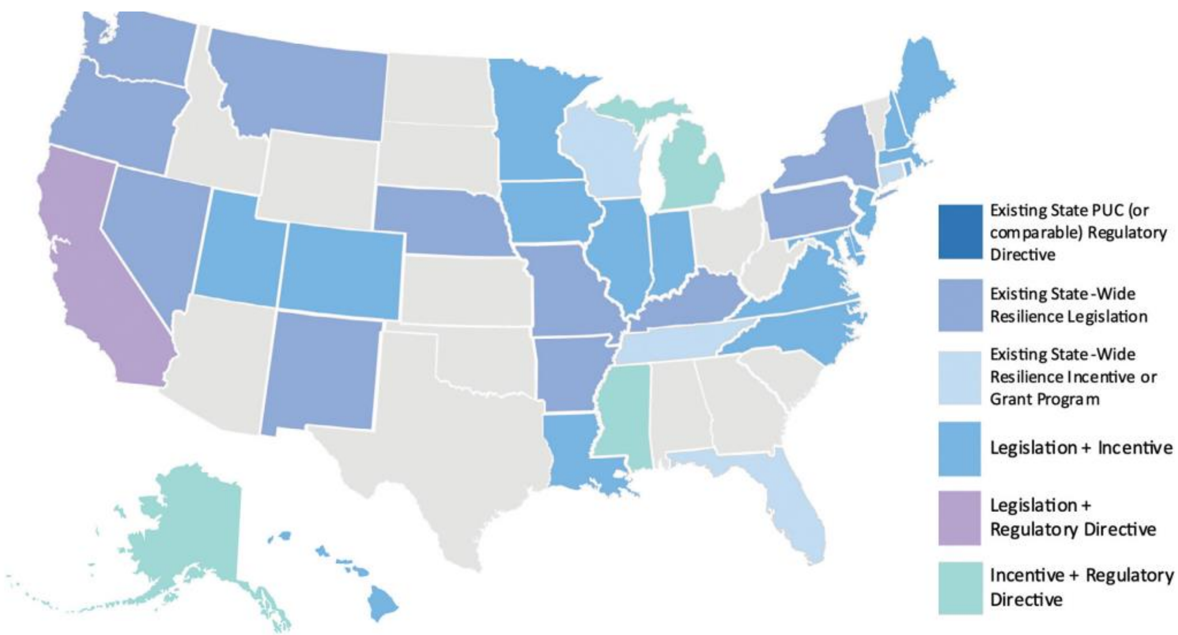
[3] U.S. Department of Energy (DOE), DOE Microgrid Workshop (2011).
[4] Smart Electric Power Alliance, The Microgrid Playbook: Community Resilience for Natural Disasters, p. 5 (2020).
[5] The North American Electric Reliability Corporation, Reliability Terminology, (2020).

There are many different definitions of resilience but Lawrence Berkeley National Labs defines resilience as "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."[6] Similar to how resilience can encompass many different definitions (e.g., events, challenges, etc.), each microgrid is unique – there is no "one-size-fits-all" approach since every scenario and site will have its own specific needs and purpose.

U.S. state-level resilience activities are on the rise (see Figure 1.3 below). State energy offices are launching programmatic initiatives for state funding opportunities for microgrid feasibility studies, microgrid financing programs, and conducting stakeholder outreach for microgrid projects. Likewise, public utility commissions are launching regulatory efforts focused on facilitating the commercialization of microgrids to forward resilience goals, such as developing tariffs, refining definitions, gaining a better understanding of the value of resilience, and convening stakeholder working groups.

Figure 1. 3 - U.S. State-Level Resilience Activities



Source: EPRI, 2021

The analysis conducted in the study is intended to support the West Virginia Office of Energy (WVOE) and key stakeholders in the state to identify state and federal funding opportunities for microgrid projects. The study analysis also provides a better understanding as to which communities within West Virginia may benefit the most from grant funding and investments into resilience projects.

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[6] Lawrence Berkeley National Labs, Quantifying grid reliability and resilience impacts of energy efficiency: Examples and opportunities, p.4 (2021)

As part of the Disaster Recovery Reform Act of 2018, the Federal Emergency Management Agency (FEMA) was authorized to develop and implement the Building Resilient Infrastructure and Communities (BRIC) grant program.[7] The BRIC program is designed to promote a national culture of preparedness through supporting states, local governments, tribes, and territories' hazard mitigation projects.[8] FEMA has been authorized to set aside 6 percent of the aggregate post disaster federal grants provided each year to fund the program.[9] In 2021, total BRIC funding was $1.16B representing a significant opportunity for West Virginia to apply for grants to implement microgrid projects from the sites identified in this study. Funding can be leveraged by state and local government entities for technical assistance such as partnership development, project scoping, and mitigation planning to progress microgrid projects from concept to implementation.

The Infrastructure Investment and Jobs Act (IIJA), signed into law in November of 2021, made $13.5B in funding available for microgrid-relevant programs that prevent outages and enhance the resilience of the grid, support electric grid reliability and resilience research, development and demonstration, and facilitate the deployment of transmission facilities that can include microgrids. This funding represents another mechanism available to West Virginians to implement microgrid projects for the sites identified in this study. [10]

The Inflation Reduction Act, which was signed into law in August 2022, adds additional funding for microgrid-relevant programs. In addition to extending the federal investment tax credit (ITC) and production tax credit (PTC) at their full credit rates for eligible facilities until 2034, the act also establishes standalone energy storage and microgrid controllers as qualifying systems eligible for the ITC. Furthermore, $3 billion in funding will be invested in community-led projects in disadvantaged communities to address environmental and public health harms related to pollution and climate change by funding climate resiliency solutions. The funding and tax credits from this law are additional financial tools that key West Virginia stakeholders can leverage to implement microgrids and prioritize disadvantaged communities. When paired with IIJA, these policies and funding can support entities, including states, cities, utilities and large energy users, who have made commitments to aggressive carbon-reduction goals and have resilience needs.

The White House's Justice40 initiative was an important consideration for how this study can target areas that have been traditionally underserved and impacted disproportionately by natural hazards and outages. The Justice40 initiative states that 40 percent of the benefits from federal clean energy and energy efficiency investments flow to disadvantaged communities. Various factors define disadvantaged communities according to the U.S. Department of Energy (DoE) and Department of Transportation (DoT) such as fossil dependence, energy burden, environmental and climate hazards, and CDC vulnerability factors as well as access to

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[7] Federal Emergency Management Agency (FEMA), Disaster Recovery Reform Act (DRRA) (2019) p. 6
[8] FEMA, Building Resilient Infrastructure and Communities (BRIC) (2021)
[9] FEMA, Disaster Recovery Reform Act (DRRA) (2019) p. 6
[10] Congress, H.R.3684 - Infrastructure Investment and Jobs Act (IIJA) (2021)

transportation, health, environmental, economic, resilience, and social factors.[11] As a part of the Justice40 initiative, the U.S. DOE/DOT developed a joint disadvantaged communities map that uses publicly available data sets[12] to display the factors they identified that define disadvantaged communities.

The objectives of this study are to:

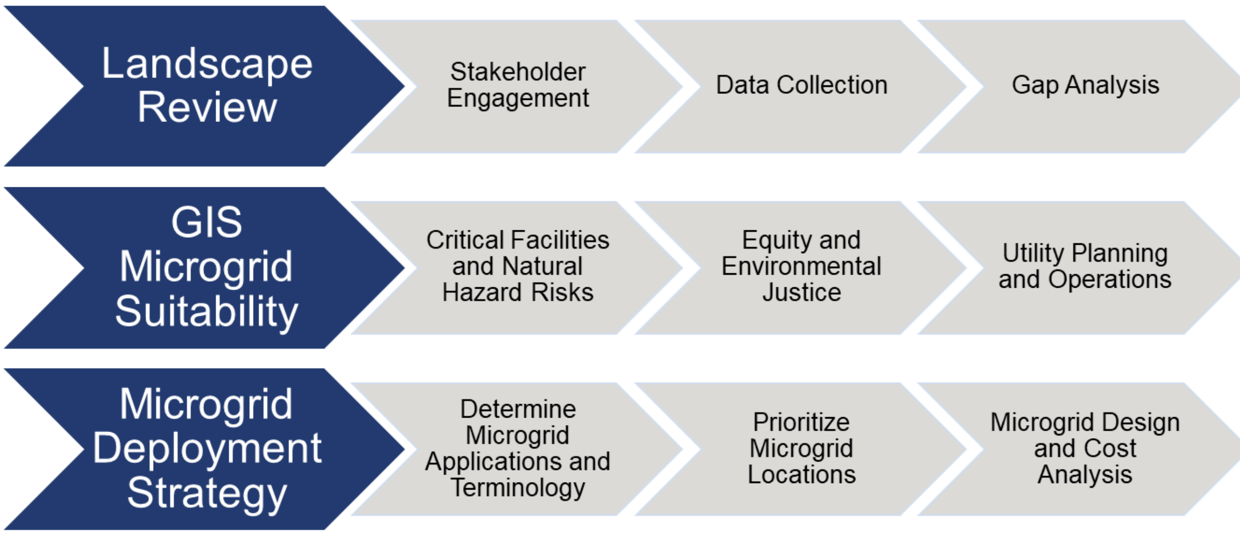
- Identify areas of the state and specific sites where WVOE can facilitate the deployment of microgrids and other solutions for resilience
- Understand how natural hazard risks, critical infrastructure, disadvantaged communities and community interest align with utility operations and planning to establish tiers of resilience need and microgrid suitability across the state
- Engage with key stakeholders to collect relevant datasets and input to conduct a comprehensive microgrid suitability and economic assessment
- Align with the White House's Justice40 Initiative, FEMA BRIC program, IIJA, and other federal and state funding opportunities for enhanced grid and community resilience

[11] The White House, Executive Order on Tackling the Climate Crisis at Home and Abroad (2021)
[12] https://anl.maps.arcgis.com/apps/webappviewer/index.html?id=33f3e1fc30bf476099923224a1c1b3ee

2.0 Executive Summary

The West Virginia Office of Energy (WVOE) contracted with the Smart Electric Power Alliance (SEPA) to conduct a microgrid study to identify opportunities for deploying microgrids to increase the overall resilience for the state of West Virginia.

SEPA takes a three-phased approach when prioritizing and evaluating potential microgrids for resilience.



Landscape Review to Collect Data and Input

The landscape review is data and stakeholder-driven. It consists of engaging a group of diverse stakeholders to enrich the microgrid deployment process by working collaboratively to socialize ideas, collect data and solicit input. For a full list of stakeholder organizations, see Table 7.1 in the Appendix.

The landscape review process includes the development of an inventory of natural hazard risks and critical infrastructure types (see Table 2.1), as well as the identification of microgrid suitability criteria and metrics to be used in the analysis (see Table 2.2).

Table 2. 1 - List of Prioritized Natural Hazard Risks and Critical Infrastructure Types

Natural Hazard Risks	
Floods	Extreme Heat
Extreme Cold & Winter Storms	Tornadoes
Wind	Wildfires
Landslides	Earthquakes

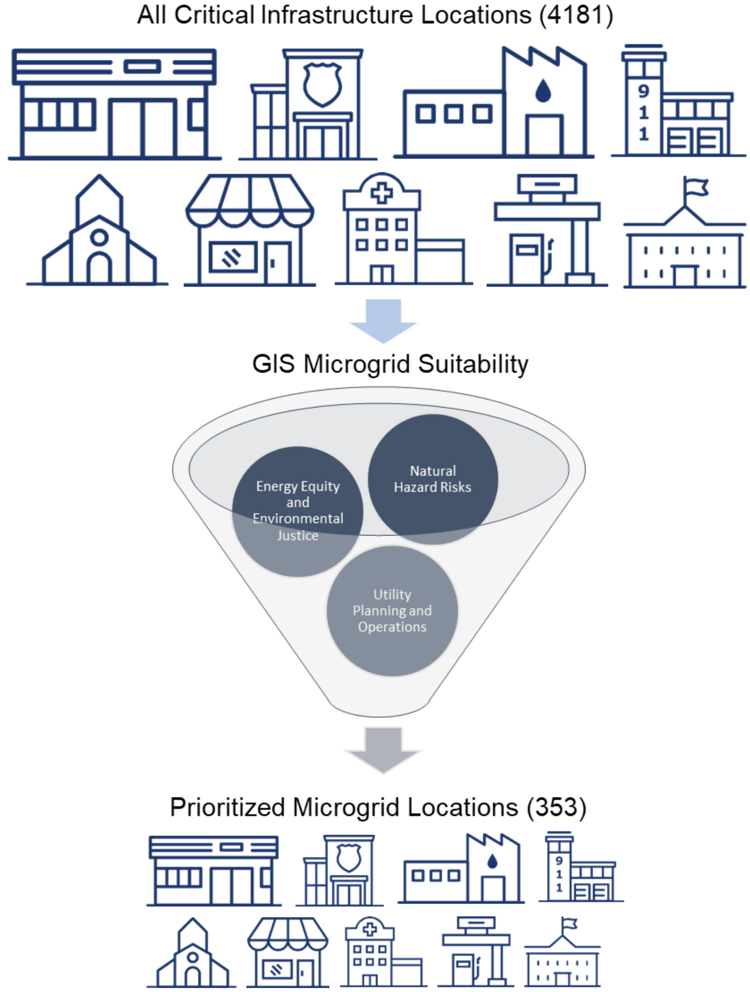
Critical Infrastructure Types	
Hospitals	Law Enforcement Facilities
Other Healthcare Facilities	Gas Stations
Water and Wastewater Treatment Facilities	Grocery Stores
Emergency Services	Convenience Stores
Community Centers	Education Facilities
	Military Installations

GIS Microgrid Suitability Analysis

The GIS microgrid suitability analysis is a geospatial analysis to prioritize potential microgrid locations and sites based on factors such as **critical infrastructure and natural hazard risks**, **energy equity and environmental justice**, and **utility planning and operations**.

The GIS microgrid suitability process selects a group of prioritized microgrid locations from a complete list of critical facilities across West Virginia (see Figure 2.1).

Figure 2. 1 - GIS Microgrid Suitability Process Overview



Source: Smart Electric Power Alliance, 2022

The GIS microgrid suitability process prioritizes these potential microgrid locations based on the suitability criteria and metrics outlined below in Table 2.2. For more detailed information regarding the suitability criteria and metrics, see section 4.0 GIS Microgrid Suitability Criteria.

Table 2. 2 GIS Microgrid Suitability Analysis

Suitability Category	Criteria and Metrics	Data Source
Pre-Screen	Already has or is required to have back-up sources of power generation	• National Fire Protection Association • American Red Cross • U.S. DoD Army Directive
Critical Infrastructure & Natural Hazard Risks	Serves critical infrastructure (see Table 2.1)	• WV Health Care Authority & Primary Care Association • Homeland Infrastructure Foundation-Level (HIFLD) • American Red Cross • The Homeland Security Infrastructure Program (HSIP) • WV Division of Emergency Management • Data Axle • Healthcare Education Foundation of West Virginia • WV Office of Emergency Services • WV Department of Education • WV Department of Environmental Protection • WV GIS Technical Center
	Serves a facility that dually functions as a designated emergency shelter	• WV Division of Emergency Management • HSIP • HIFLD • American Red Cross
	Located within a census tract with a high combined annualized frequency of the prioritized natural hazard risks (see Table 2.1)	• FEMA NRI Index
	Located near high risk flood zones (A, AE, AH, AO)	• FEMA National Flood Hazard Layer
Energy Equity & Environmental Justice	Located within a census tract with a high population density	• West Virginia Population Density by County

		• West Virginia Metropolitan Urban Areas from FEMA NRI Index
	Located within an at-risk/distressed area	• Appalachian Regional Commission County
	Located within a U.S. DOE and U.S. DOT-defined disadvantaged community	• U.S. DOE • U.S. DOT
Utility Planning & Operations	Located within an area with historically low distribution reliability statistics (e.g., SAIDI, SAIFI, CAIDI)	• West Virginia Public Service Commission Annual Reliability Reporting • WV Division of Natural Resources
	Serves a customer designated as a utility-defined essential customer	• Appalachian Power
	Located within 10-mile radius to transmission substations with frequent unscheduled emergency outages	• PJM Outage Information

Source: Smart Electric Power Alliance, 2022

Communicating Microgrid Suitability through ArcGIS StoryMaps. SEPA leveraged Esri's ArcGIS StoryMaps platform[13] to share the results of the census tract resilience needs analysis. That analysis determined tiers (Tier 1 - high potential, Tier 2 - moderate potential, and Tier 3 - low potential) of microgrids for resilience potential by census tracts. For more detailed information regarding the scoring methodology and distribution of census tract tiers, see section 4.0 GIS Microgrid Suitability Criteria.

To provide viewers with more context for the results of the analysis, the resource[14] guides viewers through each overarching criteria category used in the calculation of resilience needs scores. Furthermore, users may scroll through background information and maps displaying each data layer within a criteria category. Overall, the story was designed to empower stakeholders to understand the results of the census tract resilience analysis on a deeper level.

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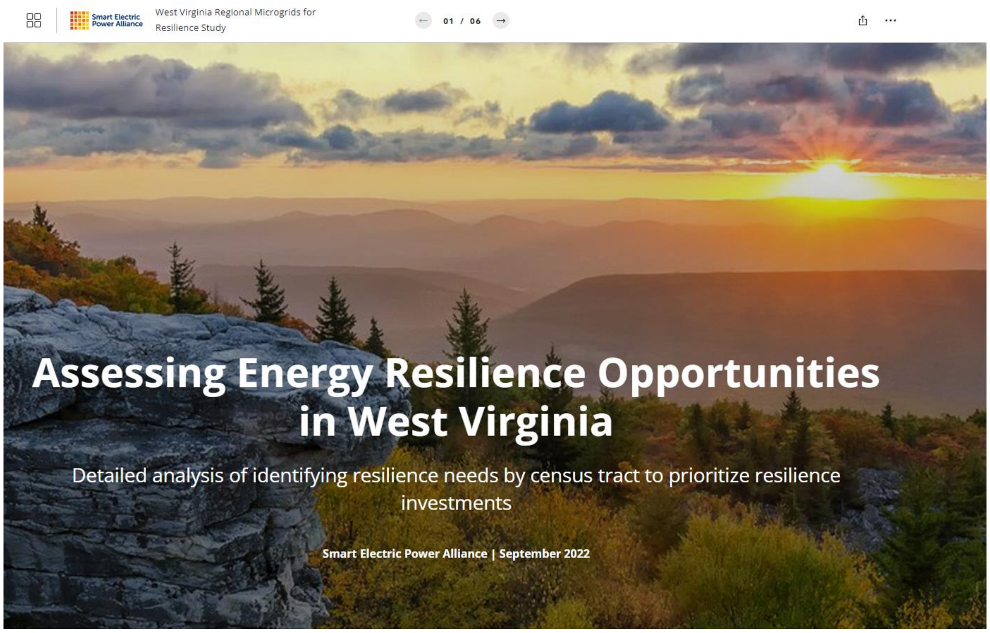
13 Esri is the company that developed the mapping software that SEPA uses in our geospatial analysis and communication of results.
14 https://arcg.is/1vi1i41

Figure 2. 2 - Snapshot of GIS Microgrid Suitability Story

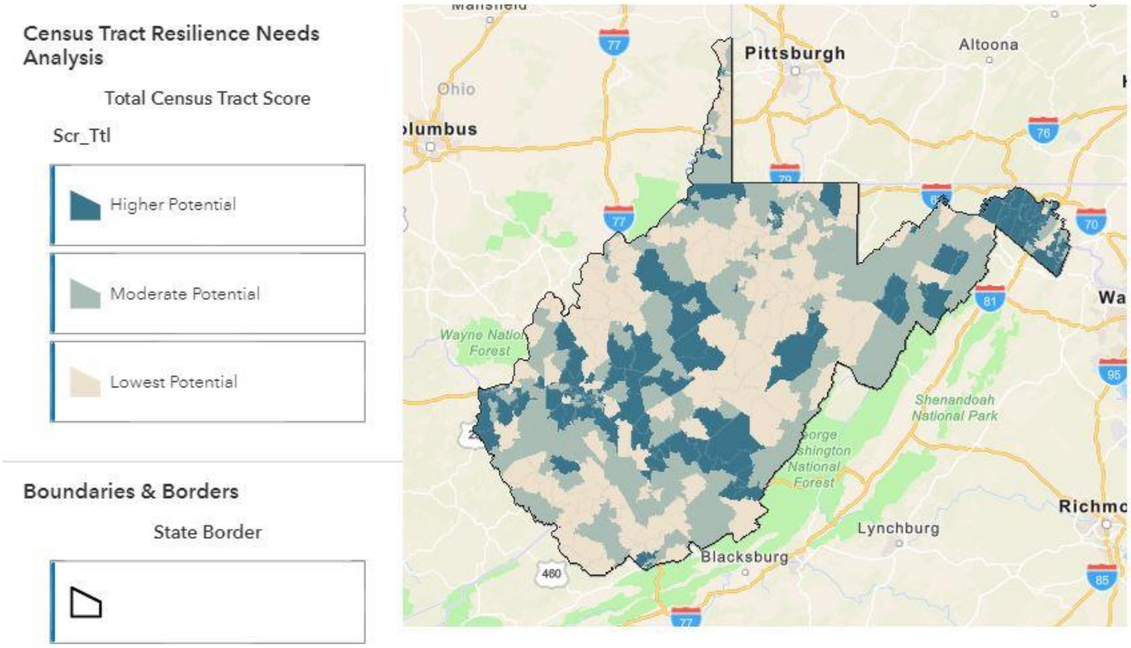


Source: Smart Electric Power Alliance, 2022

GIS Microgrid Suitability and Resilience Needs Mapping. In addition to the story, SEPA created a publicly available mapping tool[15]. Users can layer in any data that informed the microgrid suitability geospatial analysis to one singular map. This functionality was designed to empower the user to view data, identify trends, and interpret results in a more interactive way. The goal of widespread accessibility to data and study results is that varied users from different sectors are encouraged to customize the map with data that is most relevant to them, and take away key findings that advance their own work, thus increasing the value of the study.

[15] https://arcg.is/09jeGG

Figure 2. 3 - GIS Microgrid Suitability and Resilience Needs Mapping by Census Tract



Source: Smart Electric Power Alliance, 2022

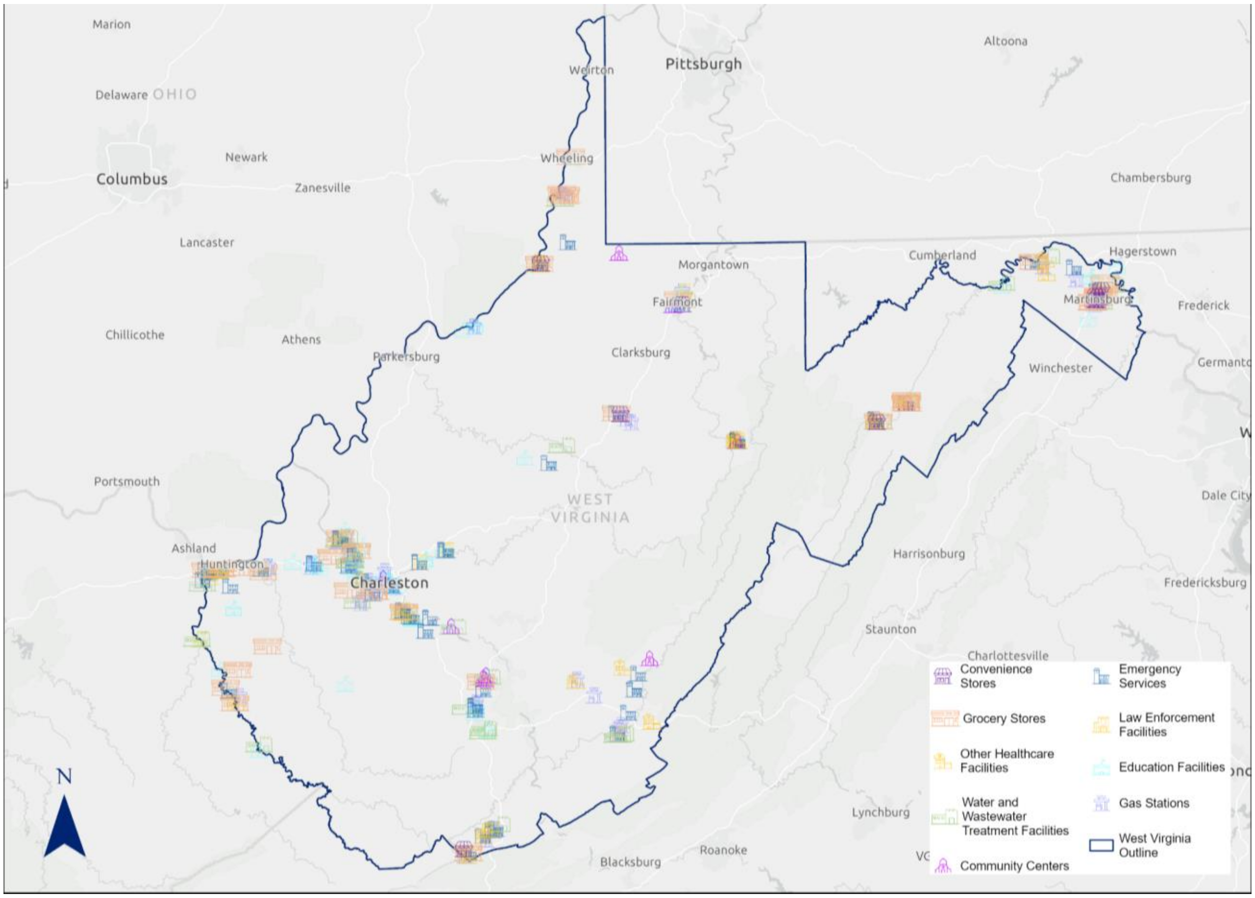
Microgrid Deployment Strategy

The goal of the microgrid deployment strategy is to prioritize and evaluate potential microgrid sites and applications that are able to island critical loads within the most vulnerable areas of the state and have access to essential services during power outages.

Determine Microgrid Applications and Terminology. SEPA evaluated two specific applications of microgrid deployment: site-specific and community microgrid projects. For more detailed information regarding the determination of microgrid applications and terminologies, see section 5.0 Microgrid Deployment Strategy.

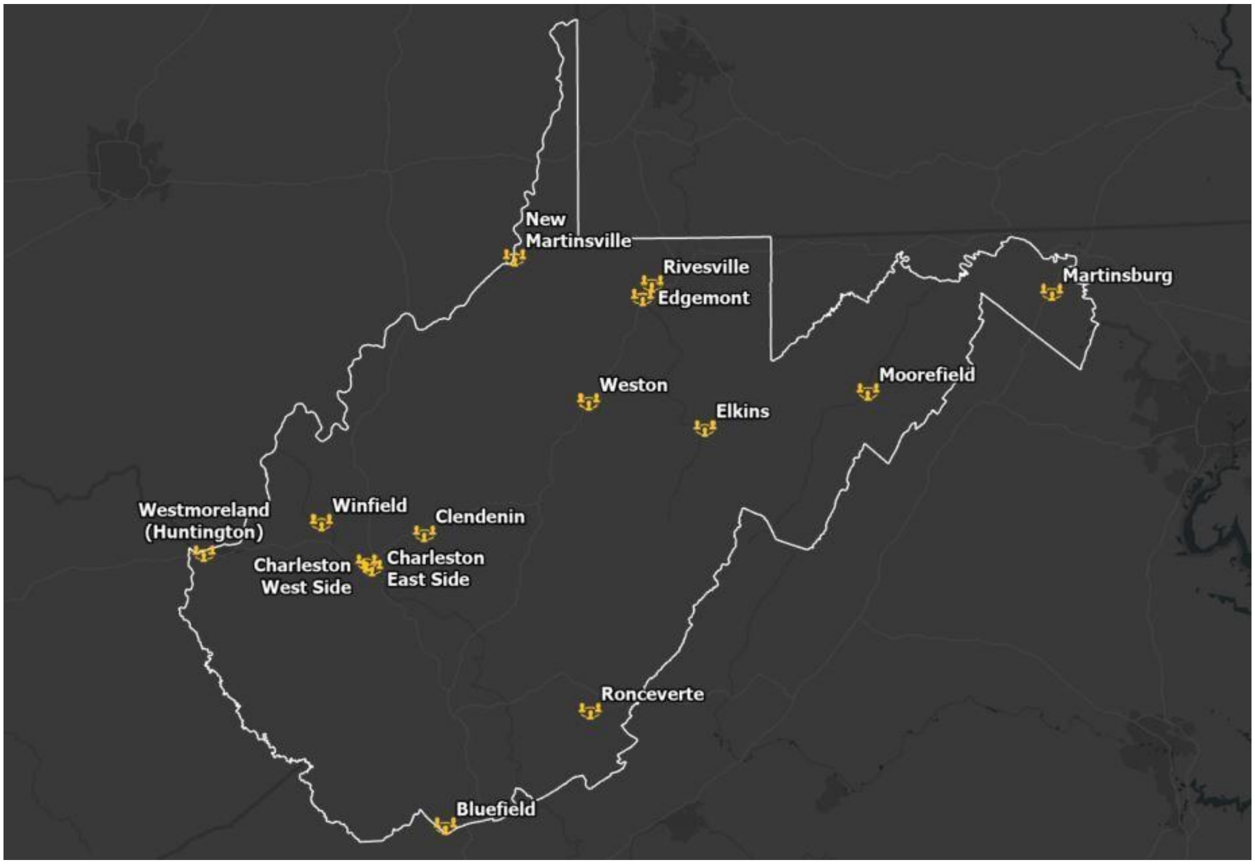
Prioritize Microgrid Locations. Based on the prioritized microgrid locations, SEPA identified 353 potential site-specific and 14 potential community microgrids. Maps of the distribution of prioritized site-specific and community microgrid deployments across the state are included below in Figure 2.4 and 2.5.

Figure 2. 4 - Prioritized Site-Specific Microgrid Locations



Source: Smart Electric Power Alliance, 2022

Figure 2. 5 - Prioritized Community Microgrid Locations

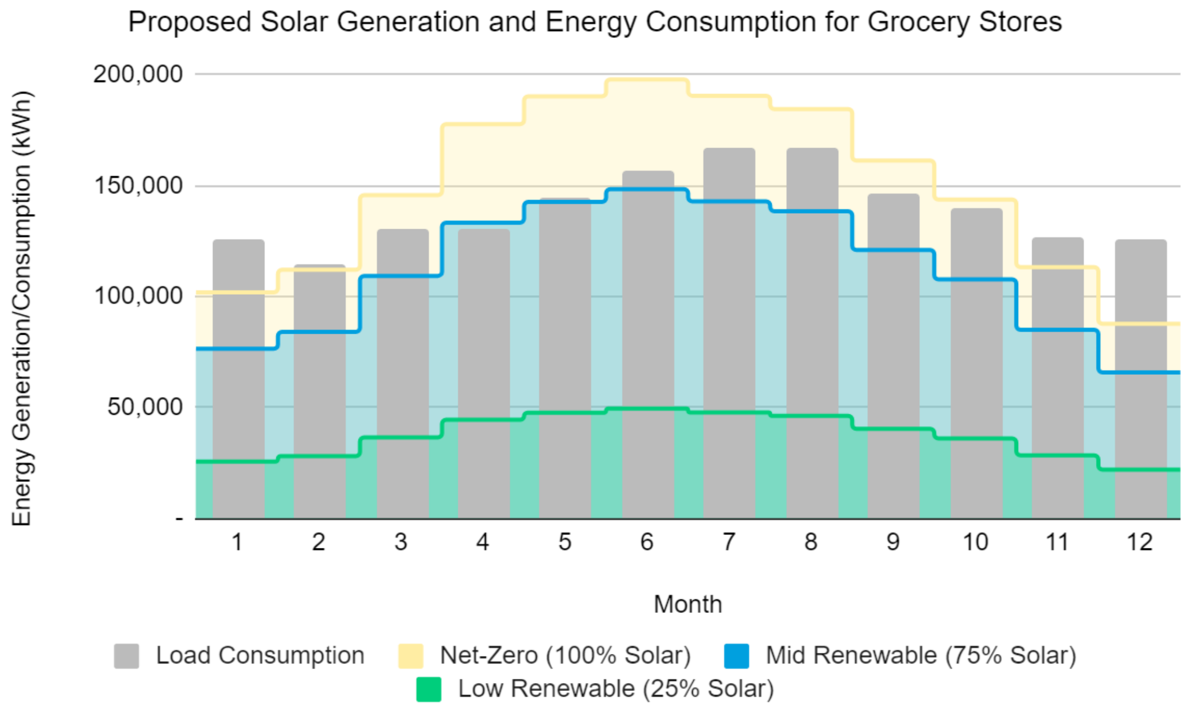


Source: Smart Electric Power Alliance, 2022

The site-specific and community microgrid deployment strategies are neither mutually exclusive nor exhaustive. Stakeholders are encouraged to utilize the GIS microgrid suitability tool and reference strategies within this study to develop a variety of deployment plans to achieve their desired objectives.

Microgrid Design and Analysis. For each critical facility type, SEPA sized and performed comparative analysis for three different microgrid scenarios accounting for high-, mid-, and low-renewable components with different cost projections and islanding capabilities. In order to size the microgrid scenarios for each critical facility type, SEPA examined the energy consumption of each facility type and proposed solar on-site generation that would offset 100% high-renewable/net-zero), 75% (mid-renewable), or 25% (low-renewable) of the facilities' consumption on an annual basis. The illustrative example in Figure 2.6 below displays the estimated monthly energy consumption and proposed solar generation for high-, mid-, and low-renewable scenarios for a Grocery Store.

Figure 2. 6 - Illustrative Energy Consumption and Solar Analysis of a Critical Facility Type (Grocery Store)

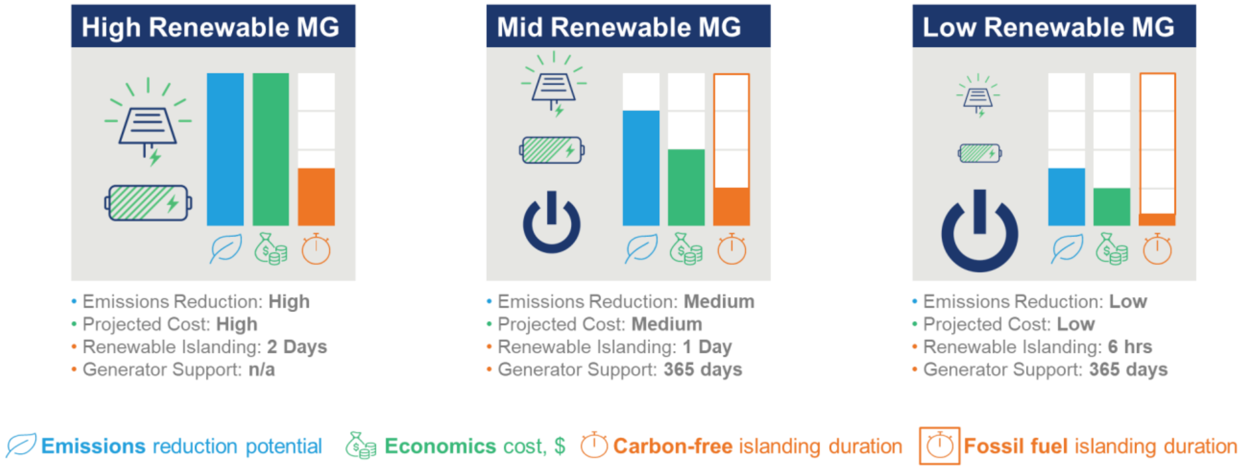


Source: Smart Electric Power Alliance, 2022

Based on load and solar analysis, microgrid scenarios of solar PV, battery energy storage, and standby generation were developed. The high renewable scenario includes only solar PV generation and a battery energy storage system (BESS), which is able to provide 48 hours of renewable islanding capability albeit at a higher cost. The mid- and low- renewable scenarios offer less costly microgrid designs that propose smaller solar PV and BESS components that are able to provide reduced renewable islanding capabilities that are offset by natural gas standby generators to provide indefinite islanding capabilities[16]. For more information on microgrid design and analysis see section 5.0 Microgrid Deployment Strategies.

[16] Indefinite islanding capabilities are reliant on natural gas supply. In the event of a loss of supply through natural gas pipelines, the system is fully dependent on its solar and storage components for islanding capabilities.

Figure 2. 7 - Illustrative Comparative Analysis of Conceptual Microgrid Scenarios



Source: Smart Electric Power Alliance, 2022

The results from this study can and should be used by utilities, local and state governments, and other industry stakeholders to move from planning to the implementation phase of microgrid development. The analysis from this study should be supplemented with design and engineering work of the selected sites and applied to construct and install the microgrids. Potential next steps to build upon this microgrid study would be to conduct further engineering, and financial benefit-cost analysis of particular sites. A key component of all microgrid development and implementation is comprehensive engagement with public and community stakeholders to facilitate the project's success.

3.0 Landscape Review

Landscape review includes stakeholder engagement and data collection to initiate the study. The prioritization and evaluation of microgrids for resilience in West Virginia is stakeholder- and data-driven.

Stakeholder Engagement

To select microgrid locations that best serve the West Virginian community, SEPA worked closely with stakeholders to understand their needs and preferences, as it relates to emergency planning and critical facilities/services. SEPA's goal was to ensure that stakeholders were engaged and educated on the analysis that could most benefit them. The main objectives when engaging our stakeholders were to:

- Provide an overview of the data inputs for the study
- Collect input on additional data sources to inform our analysis
- Garner feedback on establishing site selection suitability criteria
- Provide stakeholders with a list of suitable microgrid sites and areas in the most need for resilience investments
- Provide stakeholders with a GIS-based toolkit to identify and prioritize microgrids for resilience opportunities across the state

Summary of Stakeholder Meetings

Stakeholder Meeting #1. The first stakeholder meeting was held January 24th, 2022 to kickoff the project for our stakeholders. This meeting's objective was to create a space for stakeholders to get to know one another and provide input on the data collection phase of the study. Stakeholder organizations such as American Electric Power, Association of Counties, Chemical Alliance Zone, Consumer Advocate Division WV, Energy Efficient WV, FirstEnergy, Sierra Club WV Chapter, Solar Holler, West Virginia Office of Energy, West Virginia Public Service Commission, WV American Society of Heating and Air-Conditioning Engineers, and WV Emergency Management Agency participated in the discussion. Stakeholders provided input on prioritizing critical types of infrastructure and natural hazard risks, shown below.

Figure 3. 1 - Top Critical Types of Infrastructure

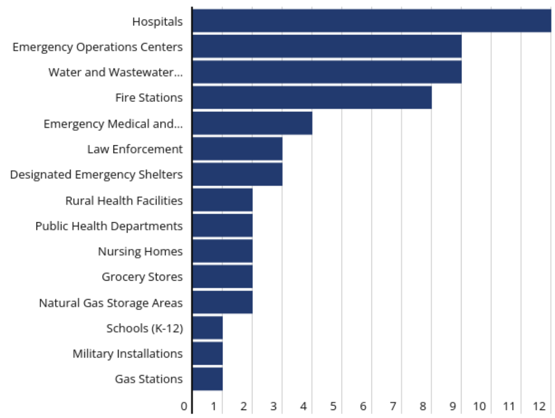
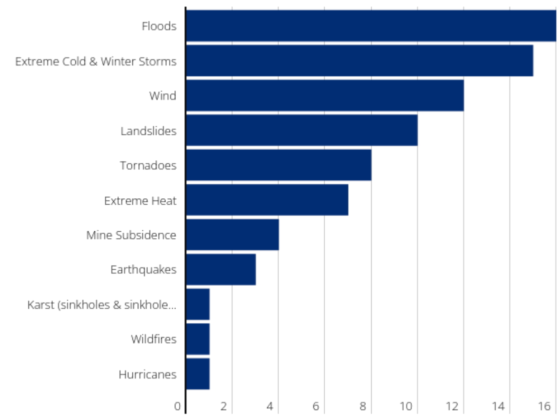


Figure 3. 2 - Top Natural Hazard Risks



Source: Smart Electric Power Alliance (2022)

Stakeholder Meeting #2. The second stakeholder meeting was held April 19th, 2022 to refine the data inputs for the study and to establish a finalized set of microgrid suitability criteria. The meeting's objective was to solicit input on the criteria for prioritizing and deploying potential microgrids. Stakeholder organizations such as American Electric Power, Association of Counties, Chemical Alliance Zone, Consumer Advocate Division WV, Energy Efficient WV, FirstEnergy, Sierra Club WV Chapter, Solar Holler, West Virginia Office of Energy, West Virginia Public Service Commission, WV American Society of Heating and Air-Conditioning Engineers, and WV Emergency Management Agency participated in the discussion. Stakeholders determined that if a critical facility has existing backup generation, it should be deprioritized in the study. It was determined that Hospitals and Military Installations were to be excluded from the analysis.

Data Collection

The following sections provide an overview of the data collection methodology.

Analysis in this study was developed based on data collected by SEPA in three areas:

- Critical Infrastructure and Natural Hazard Risks
- Energy Equity and Environmental Justice
- Utility Planning and Operations

Critical Infrastructure and Natural Hazard Risks

SEPA developed a list of 1) critical facilities as defined by FEMA, community resilience facilities, government facilities, and essential businesses, 2) natural hazard risks, as defined by FEMA's National Risk Index and National Flood Hazard Layer, and 3) facilities that dually function as designated emergency shelters to present to WVOE and key stakeholders. Following several stakeholder meetings, SEPA, WVOE and key stakeholders finalized the list and identified the relevant data necessary to conduct the study. SEPA collected, consolidated, and cleaned all publicly available datasets relevant to inform the study and to include in the GIS-based mapping toolkit to prioritize and evaluate potential microgrids for resilience projects across the state.

Critical Facility Types

Table 3.1 below provides an overview of the data collected for each of these facility types. Details on the data sets for each of the above facilities is included in Appendix 1

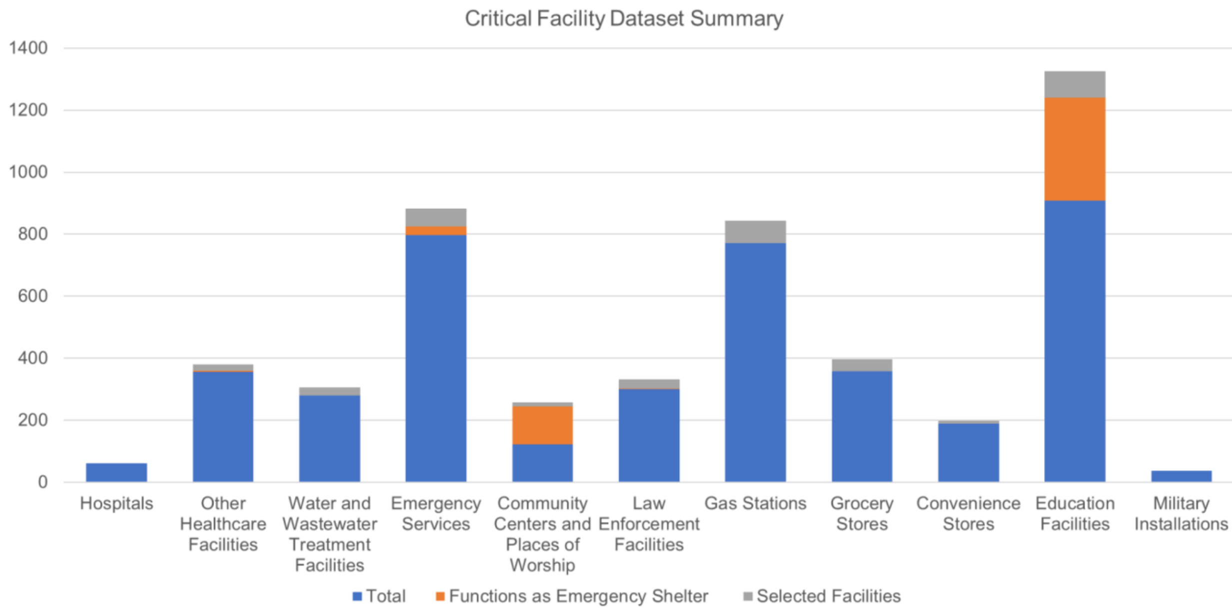
Table 3. 1 - Critical Infrastructure Data Collection Summary

Critical Infrastructure Types	Critical Infrastructure Data Source	Critical Infrastructure Types Description
Hospitals	WVGIS (WVDEM)	Institution for medical and surgical services and can be licensed by the state, free standing emergency departments, Veterans Administration, or military.
Other Healthcare Facilities	WVGIS (Nursing homes) WVGIS (Rural Health) WVGIS (Public Health)	Facilities more specialized than a hospital and provided varying health and medical services.
Water and Wastewater Treatment Facilities	WVGIS	Facilities designed to remove contaminants from wastewater and convert it into an effluent that can be returned to the water cycle
Emergency Services	WVGIS (EOCs) West Virginia State Firemen's Association WVGIS (EMS)	EMS stations consist of any location where emergency medical services personnel are stationed or based out of, or where equipment is stored for emergencies.
Community Centers	HIFLD ExpertGPS	Facility where people from a particular community can meet for social, educational, spiritual, or recreational activities.
Law Enforcement Facilities	WVGIS	A building that is a place of operation for a municipal police department, county sheriff's office or other law enforcement agency
Gas Stations	Data Axle	A retail station for fueling motor vehicles; may include vehicle servicing and repair capabilities, convenience store offerings, and/or additional fuel sales (diesel, kerosene, CNG/LNG, EV charging, etc.)
Grocery Stores	Data Axle HIFLD (pharmacies)	Community-scale market selling foods, beverages, and household goods; may include an on-site pharmacy, cafe, and/or ATM
Convenience Stores	Date Axle HIFLD (pharmacies)	Small-scale/small-footprint market with a limited selection of household goods and staple groceries; may include an on-site pharmacy

Education Facilities	WVGIS	Public and private K-12 schools and higher education facilities including universities, colleges, and career and technical centers.
Military Installations	WVGIS (National Guard Armory)	A base, camp, post, station, yard, center, or other activity under the jurisdiction of the Secretary of a military department per 10 USC § 2801(c)(4)

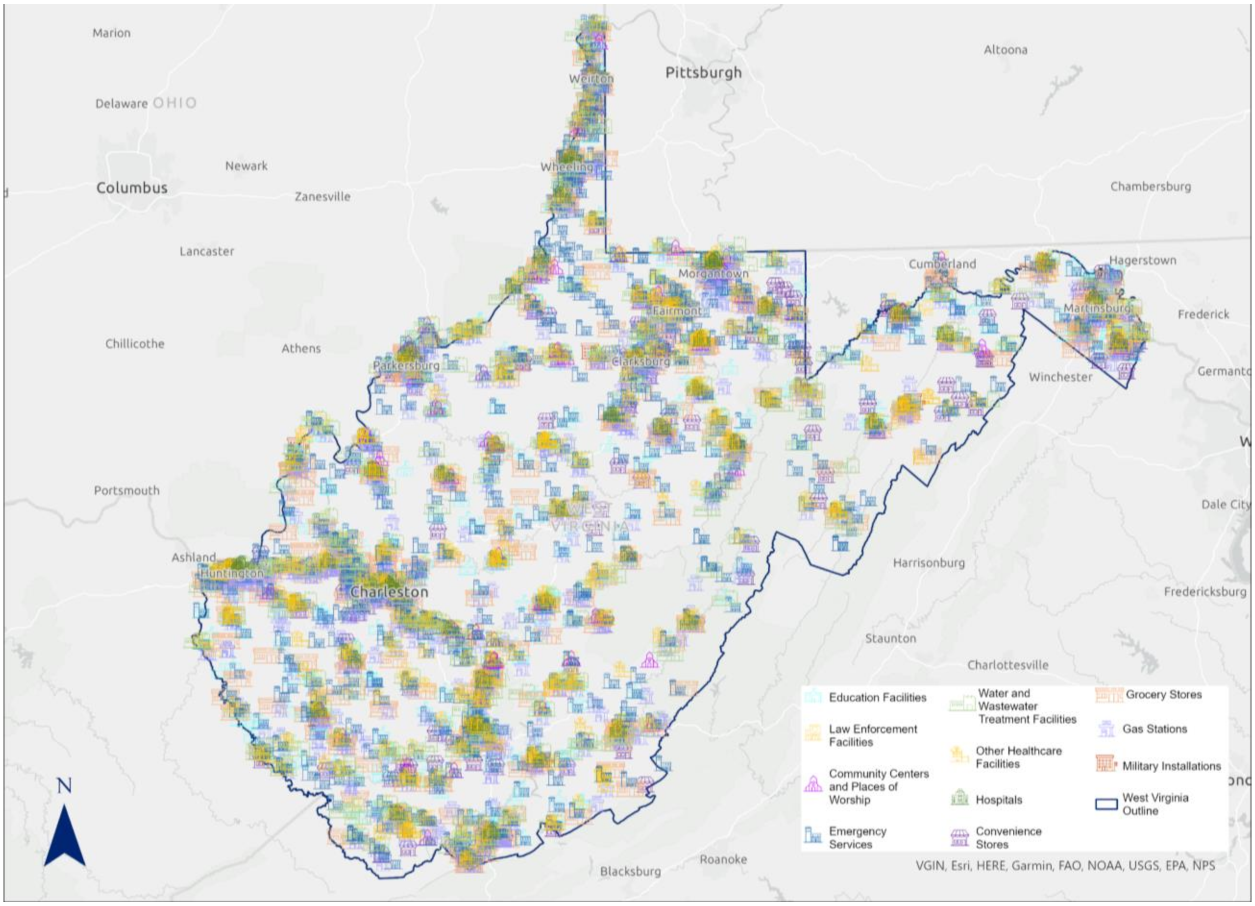
Source: Smart Electric Power Alliance, 2022

Figure 3. 3 - Critical Infrastructure Dataset Summary



Source: Smart Electric Power Alliance, 2022

Figure 3. 4 - Map of All Critical Infrastructure



Source: Smart Electric Power Alliance, 2022

Natural Hazard Risks

In addition to critical infrastructure, natural hazard risks that pose significant threats to grid reliability were identified through collaboration with stakeholders. Based on feedback from stakeholders and overlap using locational data, we focused on a list of eight natural hazard risks to evaluate (see Table 3.2). Data from the eight natural hazard risks above was converted into an annualized frequency of natural disaster (AFREQ) mapping. Data for these hazards was collected from sources referenced in their corresponding risk assessment, conducted as a part of the 2018 West Virginia Hazard Mitigation Plan.[17]

[17] Despite significant under-reporting of cases in the past, it was decided to proceed with the records available in NCEI for these events. Efforts were made to contact agencies dealing with each hazard to see if better data sources of historical accounts were available. To date, comprehensive digital databases do not exist for these hazards.

Table 3. 2 - Natural Hazard Risks Data Collection Summary

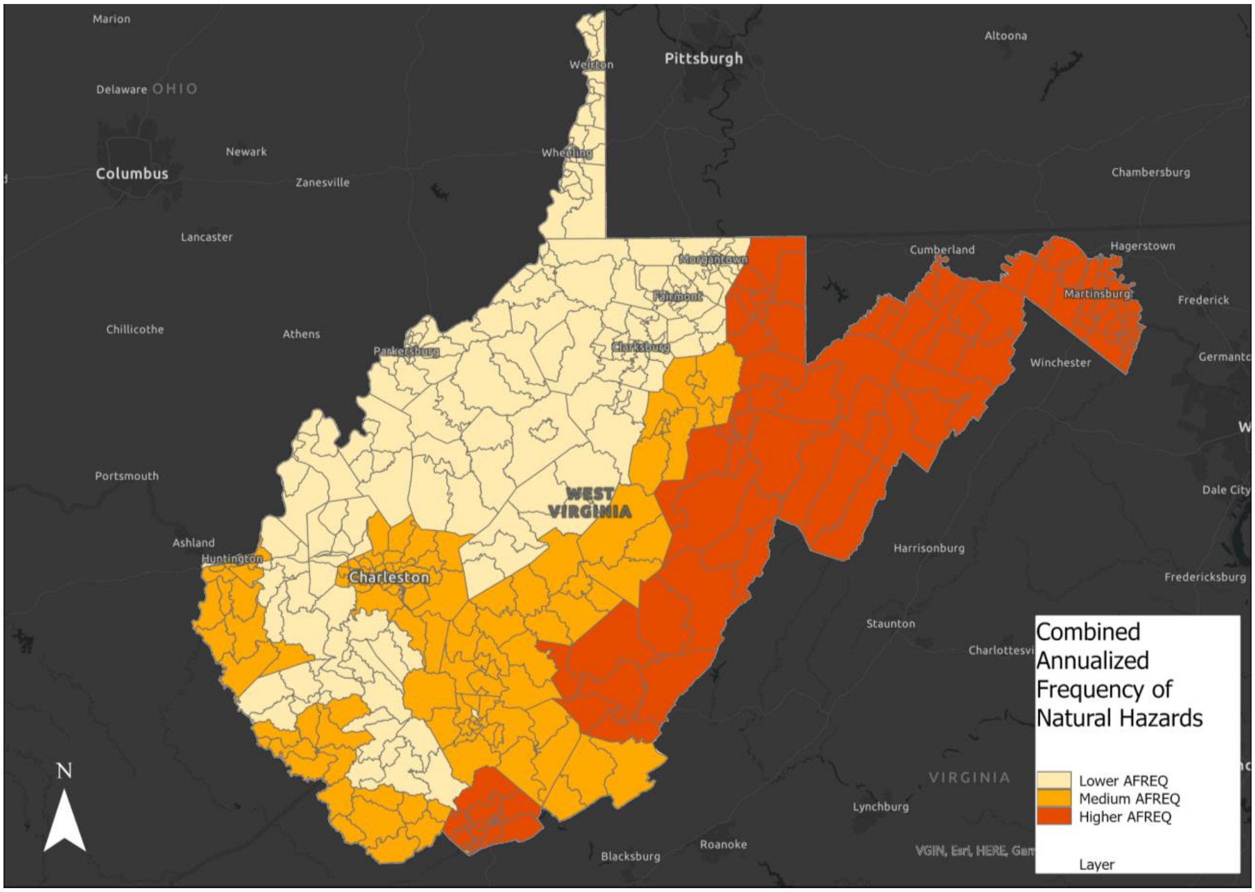
Natural Hazard Risks	Natural Hazard Risks Description
Floods	Can be characterized by either coastal flooding or riverine flooding. Coastal flooding occurs when an extreme amount of water accumulates on coastal surfaces, typically during high tides or storm surges. Riverine flooding occurs when rivers and streams surpass their capacity to contain water level and excess water overflows onto banks and low-lying surfaces. (FEMA Coastal Flooding NRI, FEMA Riverine Flooding NRI, FEMA National Flood Hazard)
Extreme Cold & Winter Storms	Consists of winter storms events containing at least one of the following: sleet, snow, or freezing rain. (FEMA Winter Weather and Ice Storm NRI)
Wind	Strong winds as a result of and result from thunderstorms Such winds can be damaging when exceeding 58 mph according to the NRI. (FEMA Strong Wind NRI)
Landslides	Characterized by the rapid movement of large masses of rock, soil, or other types of debris. (FEMA Landslide NRI)
Extreme Heat	Occurs when temperatures are abnormally high and typically corresponds to a humid environment. (FEMA Heat Waves NRI)
Tornadoes	Strong winds within a narrow rotating column, typically connected to a thunderstorm. Can be extremely damaging to infrastructure as they accumulate and disperse debris. (FEMA Tornado NRI)
Wildfires	Characterized by an unplanned burn within natural areas such as forests, grasslands, prairies, ect. (FEMA Wildfire NRI)
Earthquakes	An abnormal shaking of the Earth's surface that occurs by energy waves traveling through tectonic plates. As tectonic plates shift and overcome friction with other plates, shaking occurs throughout the surface. (FEMA Earthquake NRI)

Source: Smart Electric Power Alliance, 2022

Annualized Frequency of Natural Disaster

Pulling data from FEMA's National Hazard Index, NOAA's NCEI Storm Events Database, WV GIS Technical Center, WV Division of Forestry, and National Inventory of Dams, we identified the risk of various natural hazards to West Virginia. With input from our stakeholders, we focused on the hazards that were most relevant to our stakeholders; Floods, Extreme cold & Winter Storms, Wind, Landslides, Extreme Heat, Tornadoes, Wildfires, and Earthquakes. Once the relevant natural hazards were identified, we aggregated data from these different hazards and consolidated them into one map showing annualized frequency of natural disaster. The dark red coloring seen in Figure 3.5 below indicates areas have a higher risk due to aggregated natural hazards.

Figure 3. 5 - Combined Annualized Frequency of Natural Hazards in West Virginia

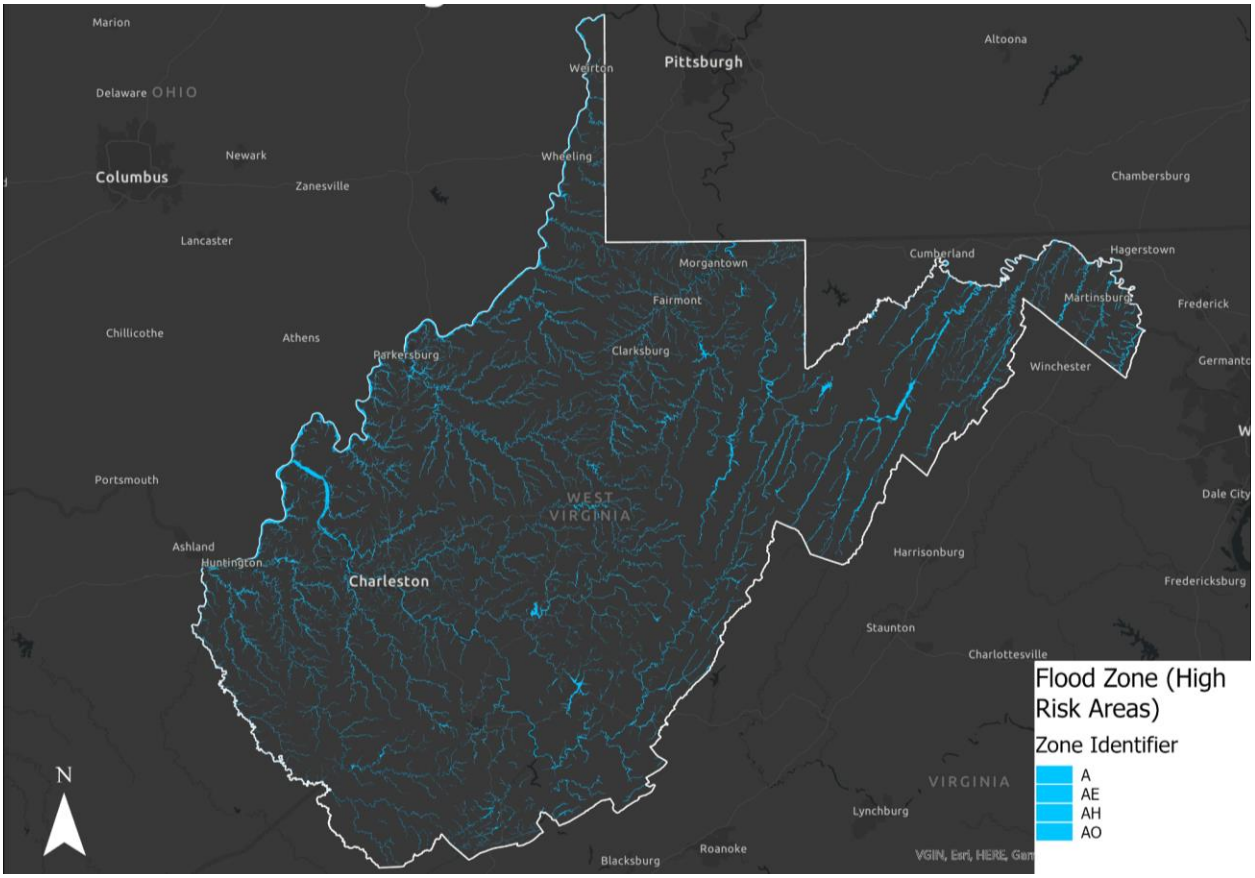


Source: Smart Electric Power Alliance (2022) based on data from FEMA's National Hazard Index, NOAA's NCEI Storm Events Database, WV GIS Technical Center, WV Division of Forestry, and National Inventory of Dams (2022).

FEMA National Flood Hazard Layer

In addition to FEMA's National Risk Index, the team utilized FEMA's National Flood Hazard Layer to identify census tracts and sites in West Virginia that are located within high risk flood zones. The blue coloring seen in Figure 3.6 below indicates areas are located within high risk flood zones.

Figure 3. 6 - High Risk Flood Zones in West Virginia



Source: Smart Electric Power Alliance (2022) based on data from FEMA's National Hazard Index (2022).

We evaluated flood zones that are designated as high risk areas by FEMA. Flood zones designated as high risk areas include the following:

- **Zone A** (Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones.)
- **Zone A1-30** (These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format).)
- **Zone A99** (Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.)
- **Zone AE** (The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones.)
- **Zone AH** (Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.)
- **Zone AO** (River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a

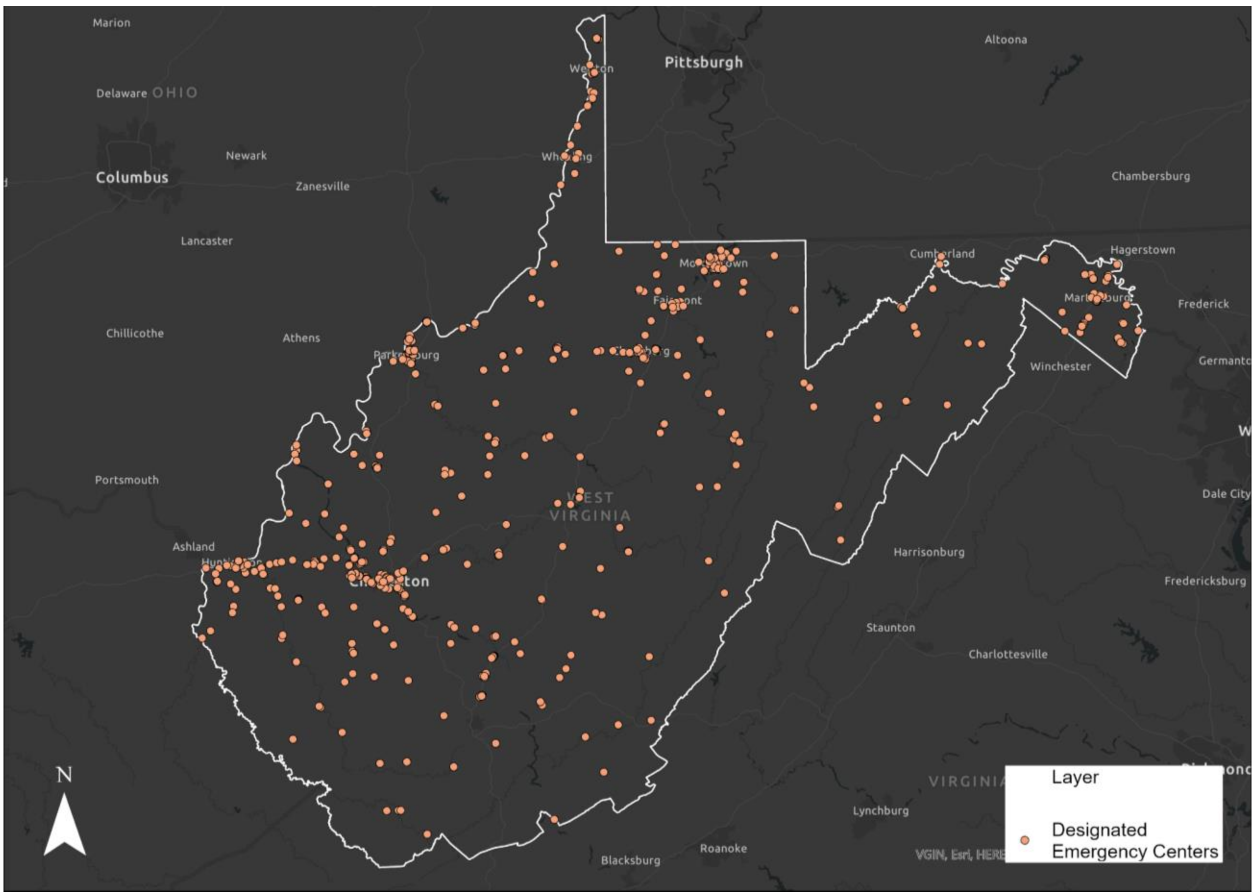
30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.)

- **Zone AR** (Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.)

Designated Emergency Shelter

To identify critical facilities that dually function as a designated emergency shelter, the team collected data from West Virginia's Division of Emergency Management, HSIP, HIFLD, and American Red Cross.

Figure 3. 7 - Designated Emergency Shelters in West Virginia



Source: Smart Electric Power Alliance (2022) based on data from West Virginia's Division of Emergency Management, HSIP, HIFLD, and American Red Cross (2022).

Out of 4,181 critical facilities evaluated in West Virginia, 486 are designated emergency shelters[18]. When critical facility types dually function as a designated emergency shelter, their

[18] WVOE analyzed the designated emergency shelters against annualized natural disasters and population density and identified potential gaps in certain regions that could benefit from more shelters.

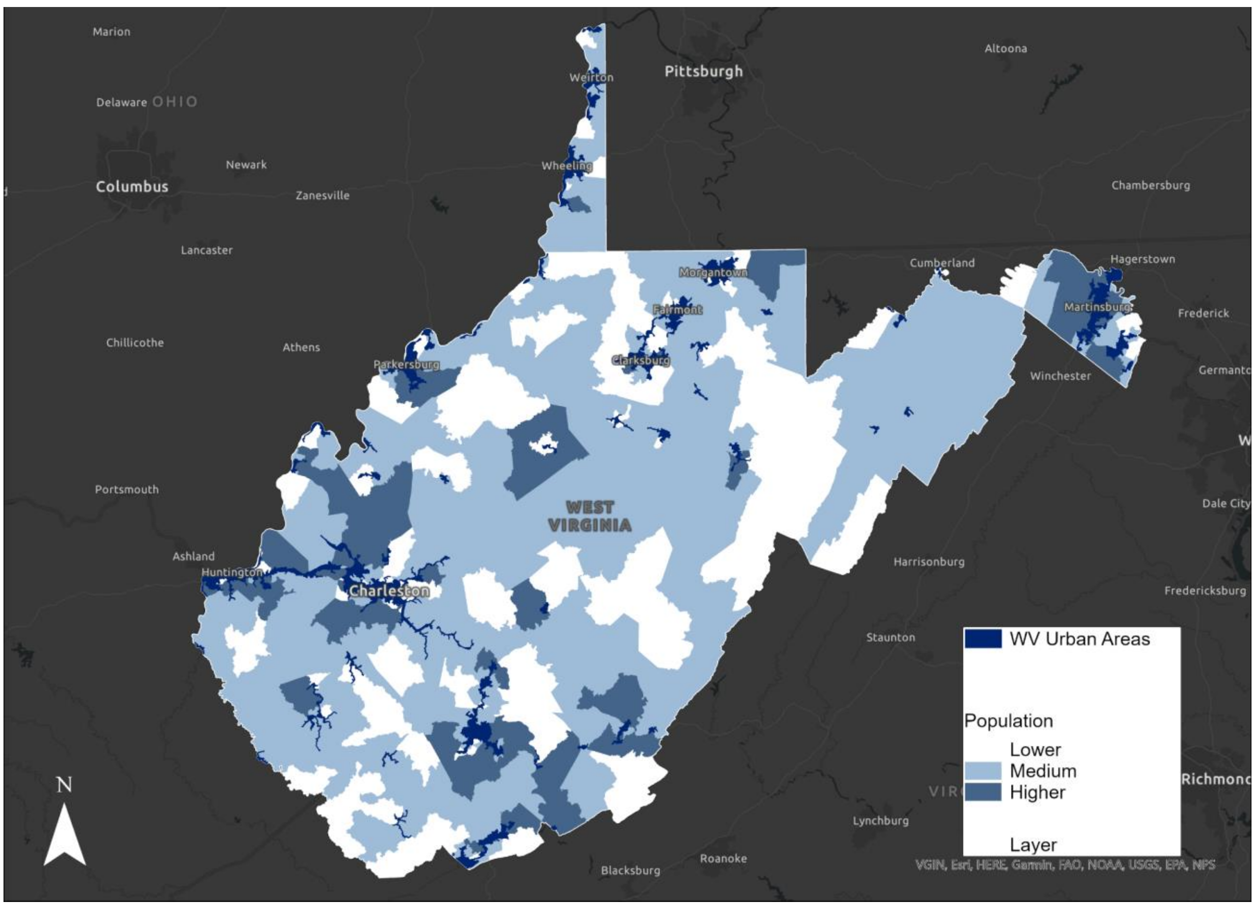
potential to increase resilience for the community as a microgrid increases and are more suitable for a potential microgrid site (see Section 4.0 for more information on suitability.

Energy Equity and Environmental Justice

Population Density & Urban Areas

Areas of high population density and underserved communities throughout the state were assessed in order to support grid resilience in an equitable way. Population density data was collected from FEMA's NRI Index, and urban areas were identified through the U.S. Census Bureau. Areas that are more densely populated are indicated by darker shades of blue in Figure 3.8 Urban areas are indicated by navy blue.

Figure 3. 8 - Population Density & Urban Areas in West Virginia



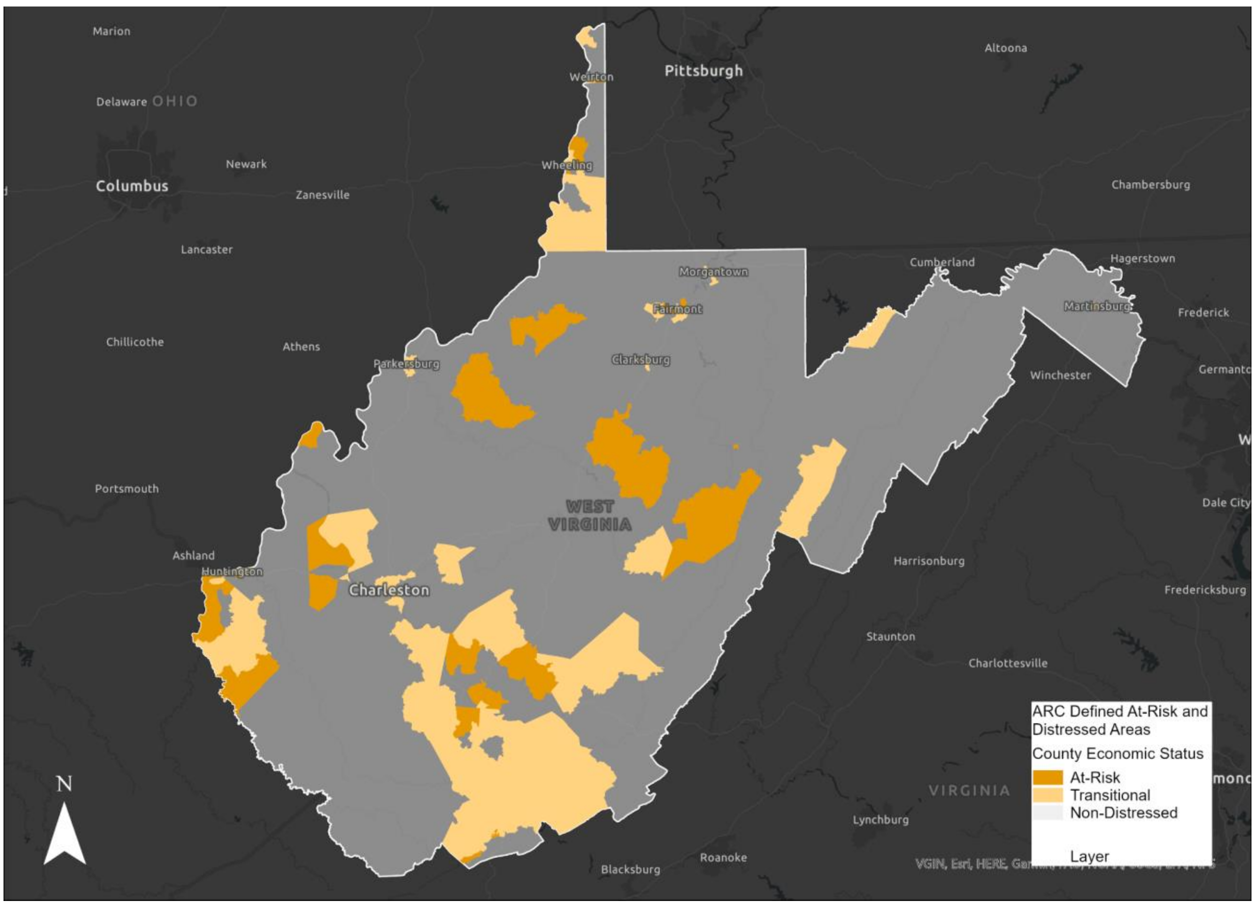
Source: Smart Electric Power Alliance (2022) based on data provided by the West Virginia Department of Economic Development (2022).

Appalachian Regional Commission County (ARC) Defined At-Risk and Distressed Areas

The team evaluated which areas across the state were economically distressed or otherwise disadvantaged. Economically distressed areas were identified using the ARC annual socioeconomic classification of counties in Appalachia. Each county is identified as distressed, at-risk, transitional, competitive, or attainment. In some instances, census tracts are identified as distressed, even if the county overall is not distressed. To classify the counties, ARC evaluates the following:

- Three-year average unemployment rates
- Per capita market income
- Poverty rates[19]

Figure 3. 9 - ARC At-Risk and Distressed Areas



Source: Smart Electric Power Alliance (2022) based on data provided by the Appalachian Regional Commission (2022).

[19] Appalachian Regional Commission, Classifying Economic Distress in Appalachian Counties (2022)

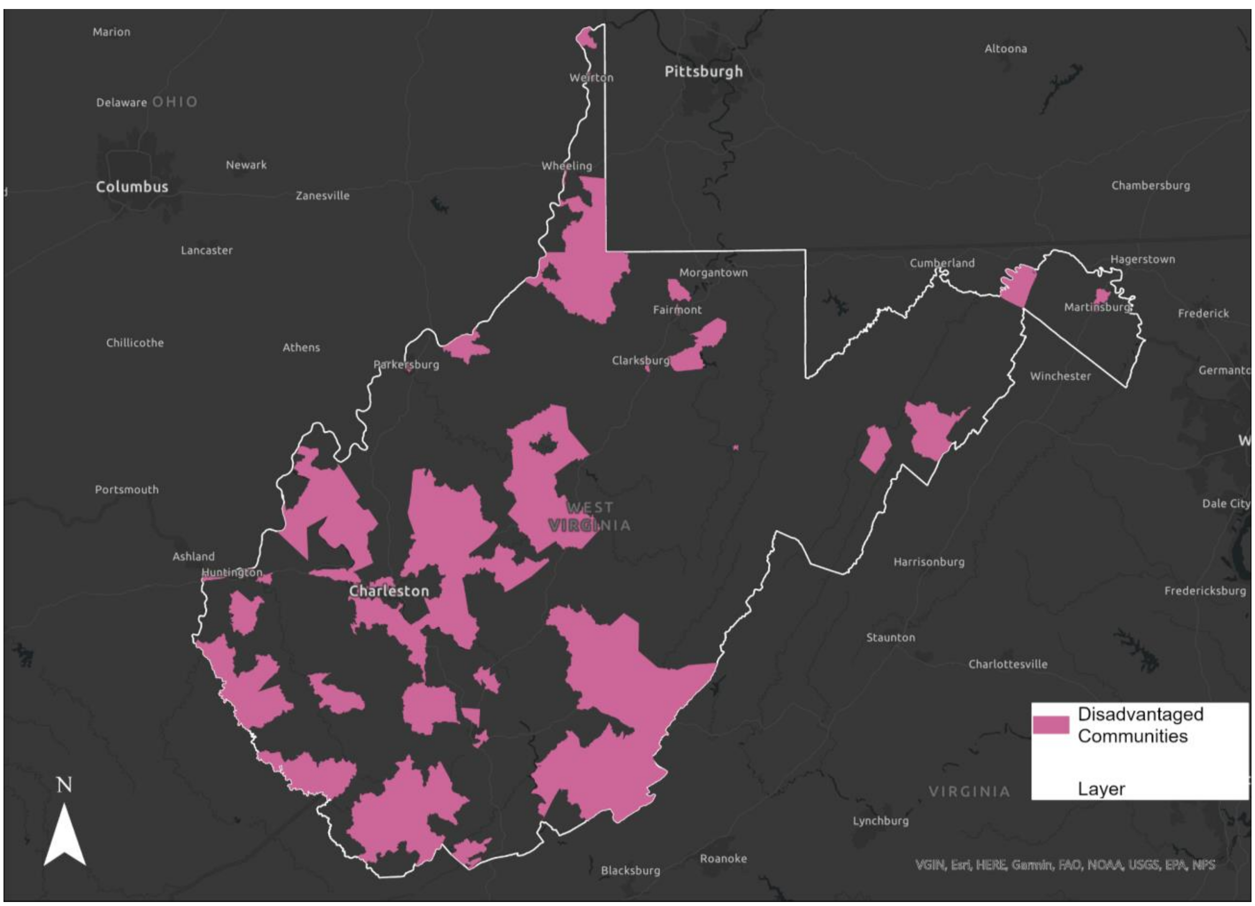
Justice40, U.S. DOE, and U.S. DOT Defined Disadvantaged Communities

In addition to ARC-defined at-risk and distressed areas, the team also included federally-defined disadvantaged communities (DACs) in the microgrid suitability criteria. SEPA leveraged a dataset of communities that fall into the joint interim definition of DACs created by the U.S. Department of Transportation (DOT) and the U.S. Department of Energy (DOE). The joint DAC definition, created for the National Electric Vehicle Infrastructure (NEVI) Formula Program, takes the following factors into consideration:

- Transportation access and energy burden
- Resilience
- Health
- Environmental pollution and climate hazards
- Fossil fuel dependence
- Social vulnerability

For more information about the DOE and DOT methodologies of defining disadvantaged communities, see Argonne National Laboratory's Electric Vehicle Charging Equity Considerations.

Figure 3. 10 - Justice40, U.S. DOE, and U.S. DOT Defined Disadvantaged Communities



Source: Smart Electric Power Alliance (2022) based on data provided by Justice40 (2022).

Utility Planning and Operations

Utility planning and operations is an important component of the study to evaluate how microgrids can be sited and utilized to provide utility operations and planning services to the utilities in West Virginia. A list of electric utilities in West Virginia is in Table 3.3.

Table 3. 3 - Electric Utilities in West Virginia

West Virginia Electric Utilities	Utility Type
Appalachian Power Company and Wheeling Power Company	Investor Owned
The Potomac Edison Company	Investor Owned
Monongahela Power Company (Mon Power)	Investor Owned
Black Diamond Power Company	Investor Owned
Craig-Botetourt Electric Cooperative	Cooperative
New Martinsville Electric Utility	Municipality
Harrison Rural Electric Association	Cooperative
Philippi Municipal Electric	Municipality

Utility-Defined Essential Customers

Appalachian Power is an investor-owned electric utility company and subsidiary of AEP that serves much of southern West Virginia. Monongahela Power and the Potomac Edison Company are subsidiaries of FirstEnergy and serve the northern portion of West Virginia. As the distribution electric utilities, Appalachian Power, MonPower and Potomac Edison are responsible for providing safe, affordable, and reliable electricity to its customers. Certain customers are defined by the utilities as essential customers who receive priority during power outage restoration based on the nature of their criticality. Per stakeholder input and guidance from the WVOE team, it was determined that sites with this designation should be prioritized above those without, and it should be included as a suitability criteria. Based on Appalachian Power's definition, customer sites with the following characteristics were elevated in the scoring:

- Facilities that through the loss of electric service could pose an immediate threat to life, such as hospitals and critical care nursing homes (those licensed for ventilators).
- Facilities that through the loss of electrical service could pose a hazard to public safety or a threat to the environment. This includes water treatment, wastewater plants, and airports.
- Local and state government agencies which would act as First Responders to an emergency or who direct that response.

- Other facilities that would respond to an emergency. These are not critical to protect life or property, but would help in the overall recovery. This would include shelters (Red Cross), medical clinics, physician's offices, communication centers, FAA navigational facilities, military base, AEP facility and other facilities important to the maintenance of public safety or well-being.

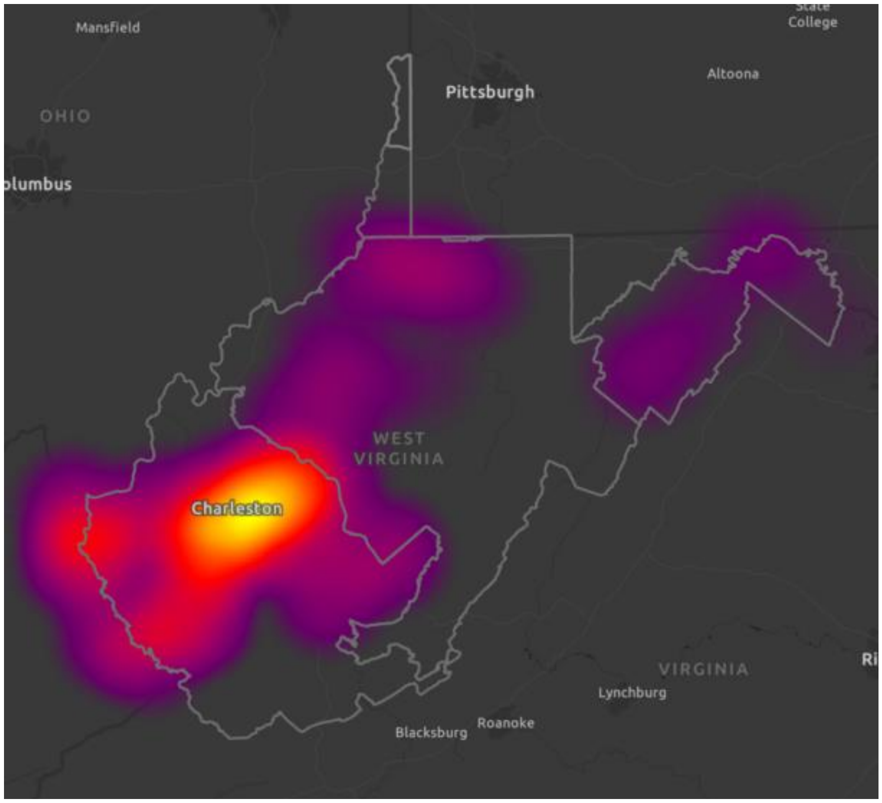
Distribution System Reliability

Investor-owned utilities in West Virginia are required to file annual reliability reports with the West Virginia Public Service Commission[20]**.** SEPA compiled the dataset containing the top ten worst performing circuits for each utility. The worst performing circuits for each utility were based on the reporting-year System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) values. The methodology used to identify worst performing circuits is based on both SAIFI and SAIDI. The feeders were ranked excluding major storms using the January 1 - December 31 timeframe and consisted of:

1. For each circuit calculate a circuit SAIFI using only distribution-caused outages
2. Select the worst 20% of circuits based on the highest circuit SAIFI
3. Rank the selected circuits based on SAIDI using only distribution-caused customer minutes
4. Select the required number of circuits based on the highest customer minutes. These circuits are then identified as the worst performing.

[20] West Virginia Public Service Commission, Electric Distribution Utility Annual Reliability Reports (2019, 2020)

Figure 3. 11 - Reliability Heat Map



Source: Smart Electric Power Alliance (2022) based on data from West Virginia Public Service Commission, [Electric Distribution Utility Annual Reliability Reports] (2019, 2020)

Figure 3.11 above is a heatmap of the worst performing circuits across the state. We plot all of the worst performing circuits on the map, and then we generate a heatmap which allows us to see where the highest concentration of worst performing circuits lie within the state. A purple color indicates that there is a worst performing circuit in the area, and the more brightly colored orange, red, and bright yellow indicate where there are several worst performing circuits in a close proximity. Reading the map, we can see that there are some worst performing circuits located in the northeast corner and western side of West Virginia. There are several worst performing circuits located in the Charleston area.

Historical Transmission System Outages

In addition to distribution system failures, power outages can often result from transmission system vulnerabilities. SEPA worked with PJM to collect outage information for all transmission substations in West Virginia and identified all transmission substations that have experienced an unscheduled emergency outage in the past year. When critical facility types are located within a 10-mile radius to these transmission substations, their potential to increase resilience for the community as a microgrid increases and are more suitable for a potential microgrid site (see Section 4.0 GIS Microgrid Suitability Criteria). Figure 3.12 below shows the distribution of these substations across the state.

Figure 3. 112 - Historical Transmission System Outages

Source: Smart Electric Power Alliance (2022) based on data from PJM

4.0 GIS Microgrid Suitability Criteria

This study establishes criteria and metrics to determine suitable sites and communities that have the highest risk and could benefit from a potential microgrids for resilience project. Per stakeholder input, SEPA conducted microgrid suitability across the state based on the following methodology:

1. Conduct Pre-Screening
2. Assign Critical Infrastructure and Hazard Risks Scoring
3. Assign Energy Equity and Environmental Justice Scoring
4. Assign Utility Planning and Operations Scoring
5. Assign Aggregate GIS Microgrid Suitability Scoring (for each critical facility)
6. Select Highest Scoring Critical Facilities
7. Conduct Cluster Analysis
8. Assign Aggregate GIS Microgrid Suitability Scoring (for each census tract)

GIS Microgrid Suitability Methodology

The methodology below was utilized to develop microgrid prioritization. Highest-scoring critical facilities and census tracts were prioritized and can be used to examine where to prioritize resilience investments in the future, including site-specific and community microgrids for resilience.

1. Conduct pre-screening for all critical facility types

All critical facility types that have existing back-up power and/or require back-up power were deprioritized and excluded from the study. Hospitals[21], military installations[22], and emergency shelters[23] known to have existing back-up power capabilities and requirements were deprioritized.

2. Assign critical Infrastructure and natural hazard risks scoring for each critical facility

Each critical facility and census tract was allotted a total maximum potential score of 1 for this category based on equal weighting of the following criteria:

- Serves critical infrastructure (0.25)
- Serves a facility that dually functions as a designated emergency shelter (0.25)
- Located within a census tract with a high combined annualized frequency of the prioritized natural hazard risks (0.25)

[21] The National Fire Protection Association: identified the need for Hospital backup requirements to keep generators running for 96 hours.
[22] U.S. DoD Army Directive requires all mission-critical bases to be equipped with 14 days of energy and water security to power and sustain critical missions.
[23] The American Red Cross (ARC) identified 417 ARC designated shelters in West Virginia. 22 of which (5%) have back-up power. For lower scale shelters serving 1-5000 disaster affected population should have 2-3 days of dedicated power and larger scale disasters 5000+ population should have 2-3 weeks of dedicated power.

- Located within high risk flood zones (0.25)

3. Assign energy equity and environmental justice scoring for each critical facility

Each critical facility and census tract was allotted a total maximum potential score of 1 for this category based on equal weighting of the following criteria:

- Located within a census tract with a high population density (0.33)
- Located within an at-risk/distressed area (0.33)
- Located within a U.S. DOE and U.S. DOT-defined disadvantaged community (0.33)

4. Assign utility planning and operations scoring for each critical facility

Each critical facility and census tract was allotted a total maximum potential score of 1 for this category based on equal weighting of the following criteria:

- Located within an area with historically low distribution reliability statistics (0.33)
- Serves a customer designated as a utility-defined essential customer (0.33)
- Located within 10-mile radius to transmission substations with unscheduled emergency outages (0.33)

5. Aggregate GIS microgrid suitability scores for each critical facility

Each critical facility and census tract had a maximum total score of 3. The combined scores for each critical facility were evaluated and ranked within each critical facility type. Hospitals and military installations were scored, but ultimately not chosen as potential sites for microgrid prioritization due to not passing the pre-screening criteria. The top-ten percent of scores[24] for each facility type were identified as the highest potential sites for microgrid prioritization. The figures below show the distribution of scores for each facility type.

6. Select the highest scoring critical facilities based on GIS suitability criteria and metrics

The GIS microgrid suitability process prioritizes potential microgrid locations based on the criteria and metrics outlined above. Figure 4.1 below illustrates the process identifying prioritized microgrid locations based on the highest scoring sites.

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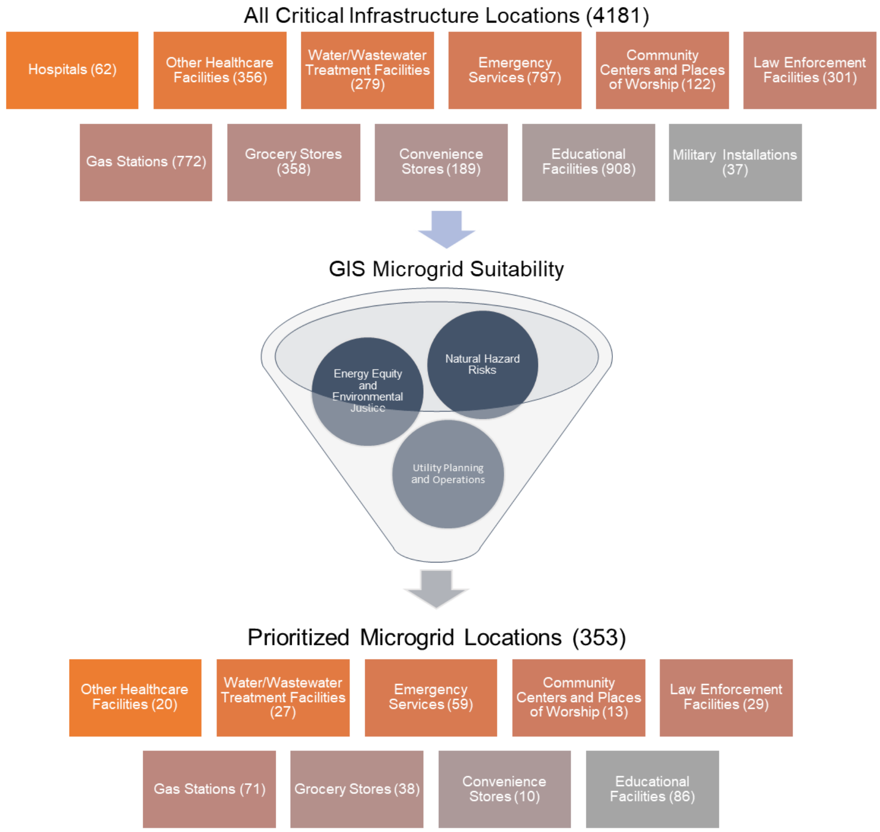
[24] For example, if we are looking at the scores of 200 fire stations, we want to select those that score the highest. If want to select the top-ten percent of those 200 fire stations in terms of their score, we will calculate 10% of 200, which is 20, and then select the top 20 highest scoring facilities. We will be left with 20 fire stations that scored the highest within the fire stations dataset. Out of all of the fire stations we scored (200), those 20 fire stations we selected are the sites that are prioritized for microgrid deployment.

Figure 4. 1 - Detailed GIS Microgrid Suitability Process



Source: Smart Electric Power Alliance (2022)

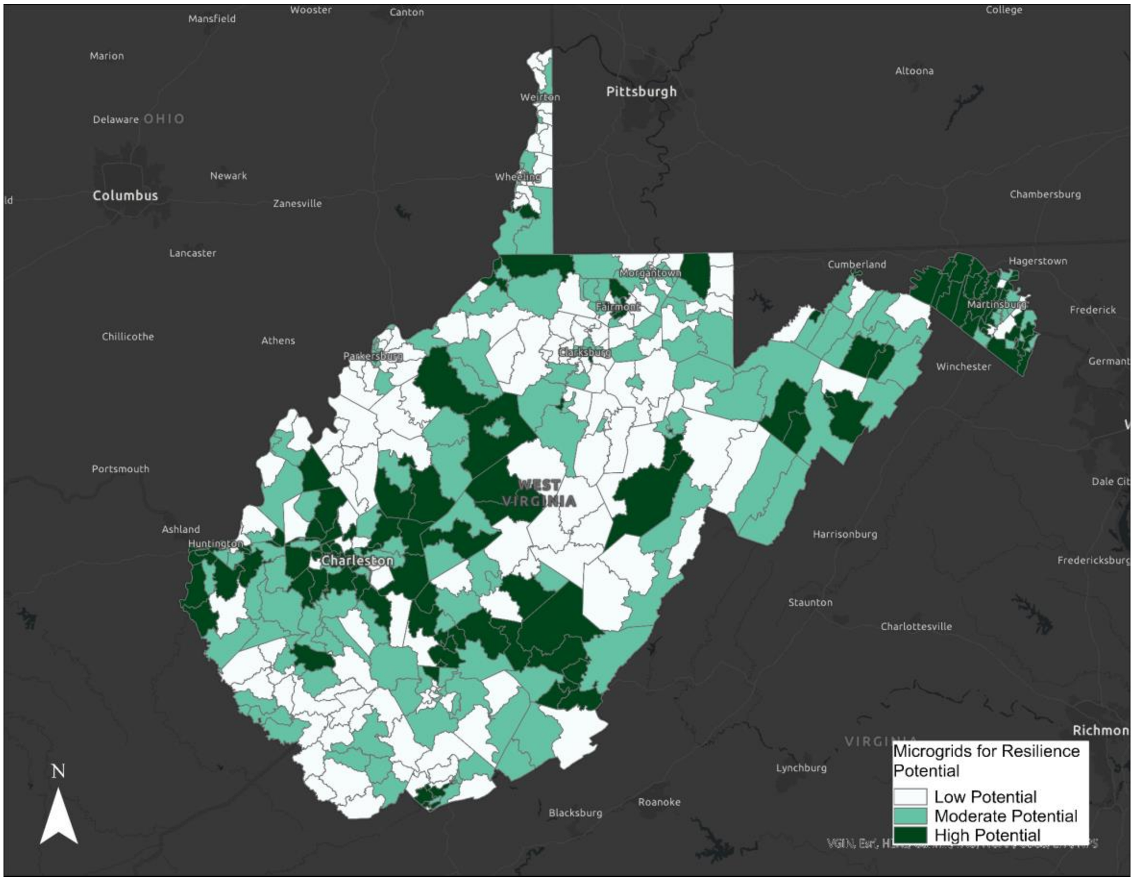
7. Conduct cluster analysis of top scoring facilities

The team performed a point cluster analysis to determine clusters of at least two prioritized critical facilities (from steps 1 to 7) within a 0.5 mile radius that could serve as a potential community microgrid.

8. Assign an aggregate GIS microgrid suitability score to each census tract to determine resilience needs

Based on the GIS microgrid suitability criteria and metrics, SEPA assigned each census tract with either a Tier 1 (high), Tier 2 (moderate), or Tier 3 (low) for resilience needs. Figure 4.2 below illustrates the distribution of census tracts in West Virginia by their microgrids for resilience potential. There are 546 census tracts in West Virginia - 177 are identified as Tier 1, 189 are identified as Tier 2, and 180 are identified as Tier 3. 32.4% of the census tracts in West Virginia fall within Tier 1 areas.

Figure 4. 2 - Microgrids for Resilience Potential by Census Tract



Source: Smart Electric Power Alliance, 2022

Communicating Microgrid Suitability through ArcGIS StoryMaps. SEPA leveraged Esri's ArcGIS StoryMaps platform to share the results of the census tract resilience needs analysis. That analysis determined tiers (Tier 1 - high potential, Tier 2 - moderate potential, and Tier 3 - low potential) of microgrids for resilience potential by census tracts.

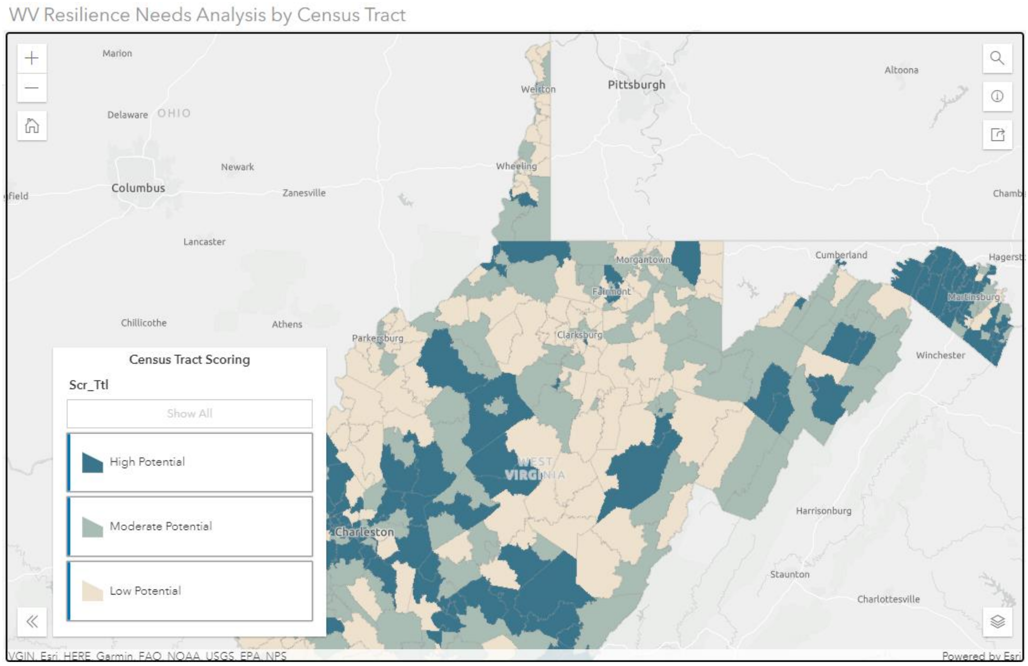
To provide viewers with more context for the results of the analysis, the resource guides viewers through each overarching criteria category used in the calculation of resilience needs scores. Furthermore, users may scroll through background information and maps displaying each data layer within a criteria category. Overall, the story was designed to empower stakeholders to understand the results of the census tract resilience analysis on a deeper level.

Figure 4. 3 - Snapshot of GIS Microgrid Suitability Story

Source: Smart Electric Power Alliance, 2022

GIS Microgrid Suitability and Resilience Needs Mapping. In addition to the story, SEPA created a publicly available mapping tool. Users can layer in any data that informed the microgrid suitability geospatial analysis to one singular map. This functionality was designed to empower the user to view data, identify trends, and interpret results in a more interactive way. The goal of widespread accessibility to data and study results is that varied users from different sectors will encourage stakeholders to customize the map with data that is most relevant to them, and take away key findings that advance their own work, thus increasing the value of the study.

Figure 4. 4 - GIS Microgrid Suitability and Resilience Needs Mapping by Census Tract



Source: Smart Electric Power Alliance, 2022

5.0 Microgrid Deployment Strategies

Through a statewide landscape review and a GIS microgrid suitability analysis, SEPA identified critical facility and community microgrid sites and developed a microgrid deployment strategy for West Virginia. This process included the determination of microgrid applications and technologies, prioritization of microgrid locations, and completion of a design and cost analysis for site-specific and community microgrid locations. The microgrid deployment strategy synthesized information, input, and data from WVOE, local utilities, and other project stakeholders to guide the development of microgrids and improve critical facility resilience in West Virginia.

Microgrid Applications and Terminology

SEPA evaluated two specific applications of microgrid deployment: site-specific and community microgrid projects.

Site-specific microgrids are set up as a single customer microgrid serving FEMA lifelines (e.g., healthcare, water treatment, emergency services, and law enforcement facilities), resilience hubs (e.g., community centers and places of worship) and essential business (e.g., gas stations and grocery stores).

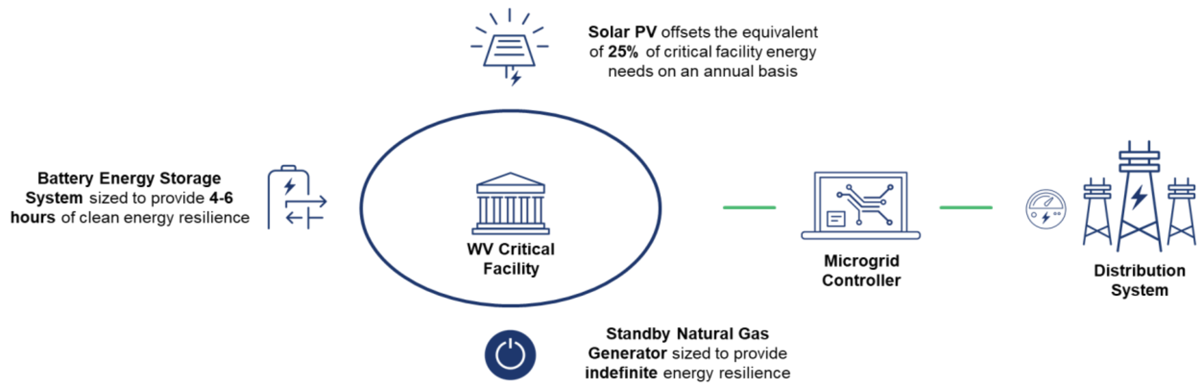
Community microgrids are set up as a multiple customer microgrids serving multiple critical sites within a 0.5 mile radius of each other. Load served may include facilities and businesses that provide "6F" services, i.e. food, fuel, finance, pharma, first responders, or phones. A community microgrid often serves a combination of the facilities mentioned in the microgrid types above.

Conceptual Low-, Mid-, High-Renewable Microgrid Design Scenarios[25]

The graphics below describe the conceptual designs for low- mid- and high-renewable (net-zero) microgrids addressed through the economic analysis in this report. For each critical facility or critical facility cluster, the project team sized microgrid components and estimated potential costs for low-, mid-, and high-renewable microgrid scenarios based on the estimated load and energy resilience needs of each facility type.

[25] Conceptual designs for community microgrids will mirror the site-specific WV critical facility microgrids presented in this section, with the exception that they will serve multiple loads and customers within the electrical boundary (represented by the circle). This study assumes that all community microgrid loads are on the same electrical feeder. Future analysis may need to consider associated electrical and interconnection / utility costs for reconfiguration if the loads are not on the same feeder.

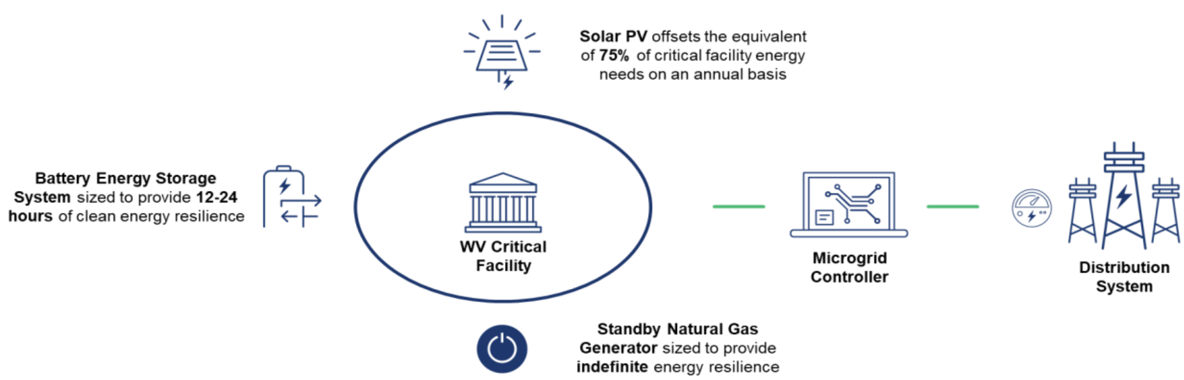
Figure 5. 1 - Low-Renewable Microgrid Conceptual Design



Source: Smart Electric Power Alliance, 2022

The low-renewable microgrid is capable of providing a critical facility with 4-6 hours of clean energy resilience using only a battery energy storage system and on-site solar PV generation. Additionally, this microgrid design is capable of providing indefinite energy resilience with a standby generator. The solar PV is sized to generate 25% of each critical facility's estimated load on an annual basis. The BESS is sized to provide a critical facility with 4-6 hours of continuous energy resilience during the month of the year with the highest recorded peak load.

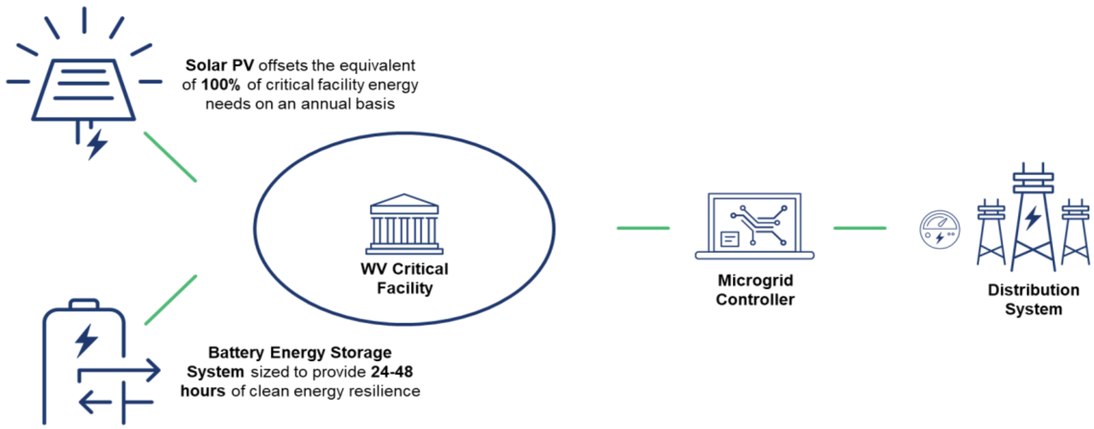
Figure 5. 2 - Mid-Renewable Microgrid Conceptual Design



Source: Smart Electric Power Alliance, 2022

The mid-renewable microgrid is capable of providing a critical facility with 12-24 hours of clean energy resilience using only a battery energy storage system and on-site solar PV generation. Additionally, this microgrid design is capable of providing indefinite energy resilience with a standby generator. The solar PV is sized to generate 75% of each critical facility's estimated load on an annual basis. The BESS is sized to provide a critical facility with 12-24 hours of continuous energy resilience during the month of the year with the highest recorded peak load.

Figure 5. 3 - High-Renewable (Net-Zero) Microgrid Conceptual Design



Source: Smart Electric Power Alliance, 2022

The high-renewable microgrid is capable of providing a critical facility with 24-48 hours of clean energy resilience using only a battery energy storage system and on-site solar PV generation. The solar PV is sized to generate 100% of each critical facility's estimated load on an annual basis, making this a net-zero scenario. The BESS is sized to provide a critical facility with 24-48 hours of continuous energy resilience during the month of the year with the highest recorded peak load. The BESS would be charged primarily by the on-site solar PV.

Site-Specific Microgrid Deployment Strategy

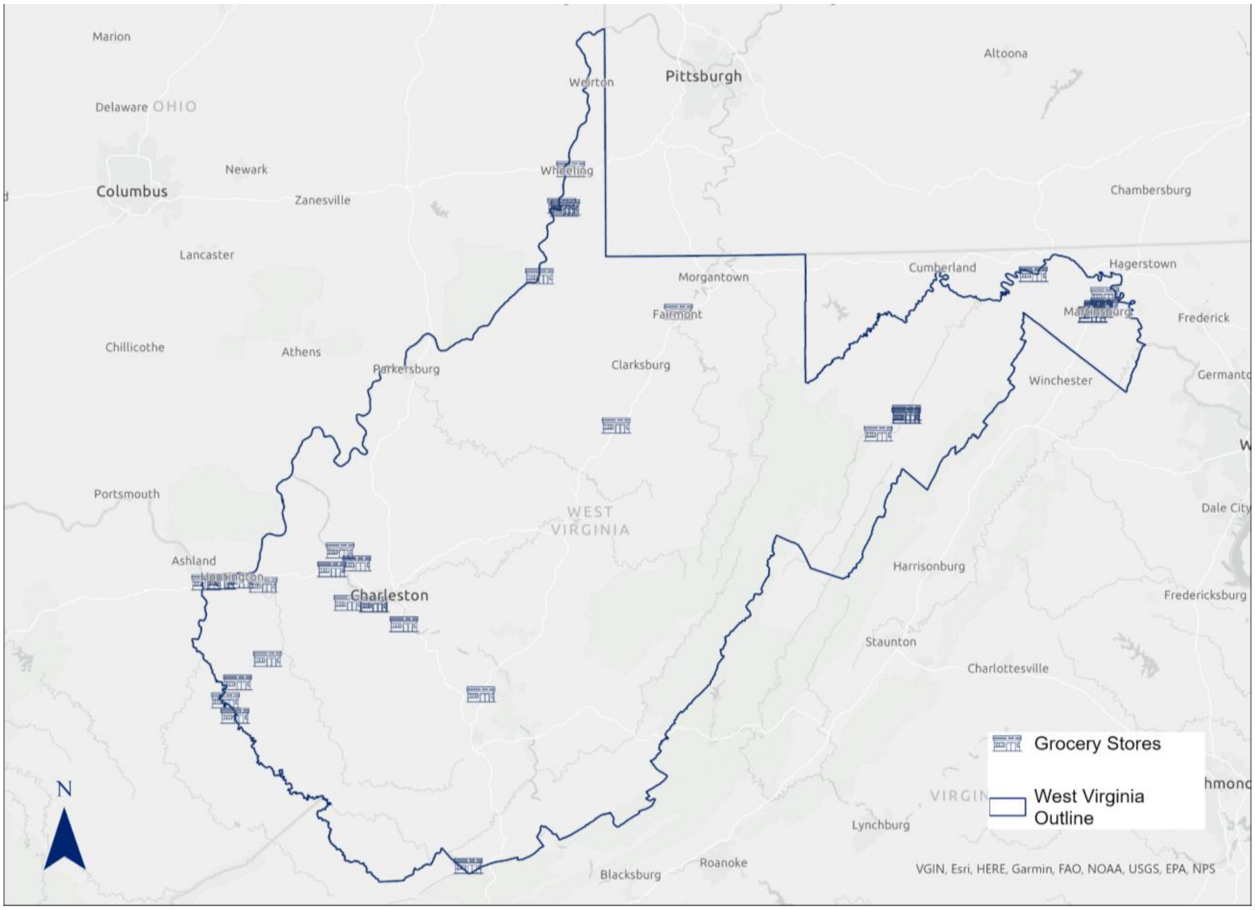
SEPA identified 353 sites that provide critical functions and services as prioritized site-specific microgrid locations. SEPA sized and carried out comparative analysis for three different microgrid scenarios for each critical facility business case accounting for low-, mid-, and high-renewable components with different cost projections and islanding capabilities. For details on load, sizing, design and economic analysis for each site-specific microgrid, see Appendix 1

Grocery Store

Grocery stores are community lifelines that provide food, beverages, and household goods to community members. Grocery store locations may also support other vital related services with on-site pharmacies, cafes, and/or ATMs. These services remain critical during outages, and some grocery stores may not have the resilience capabilities to continue operations.

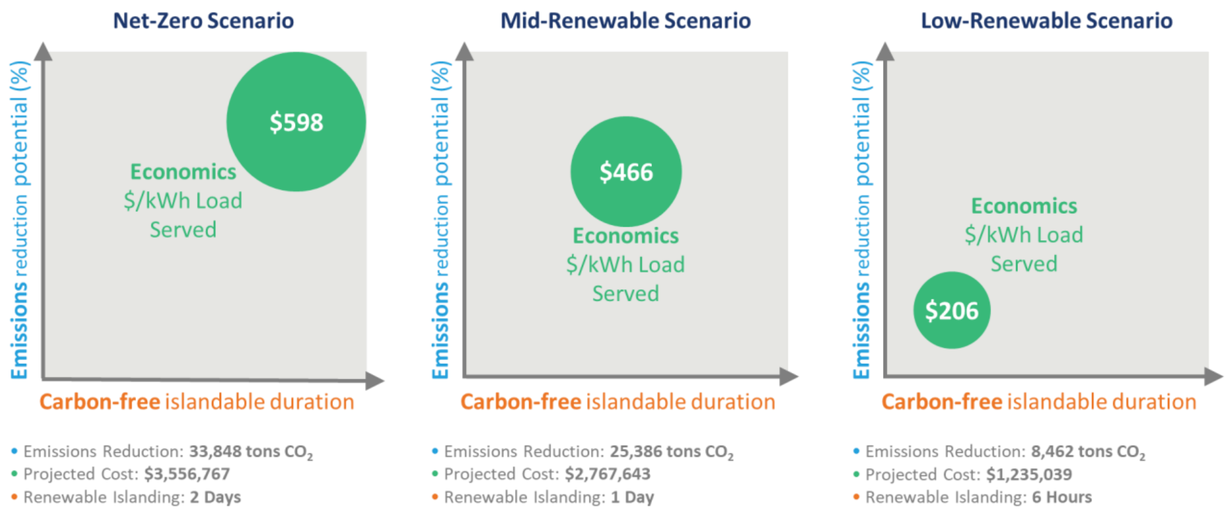
SEPA identified 38 potential site-specific grocery store microgrids. Maps of the distribution of prioritized site-specific grocery store microgrid deployments across the state are included below in Figure 5.4.

Figure 5. 4 - Prioritized Site-Specific Grocery Store Microgrid Locations



Source: Smart Electric Power Alliance, 2022

Figure 5. 5 - Comparative Analysis of Conceptual Microgrid Scenarios for Grocery Stores



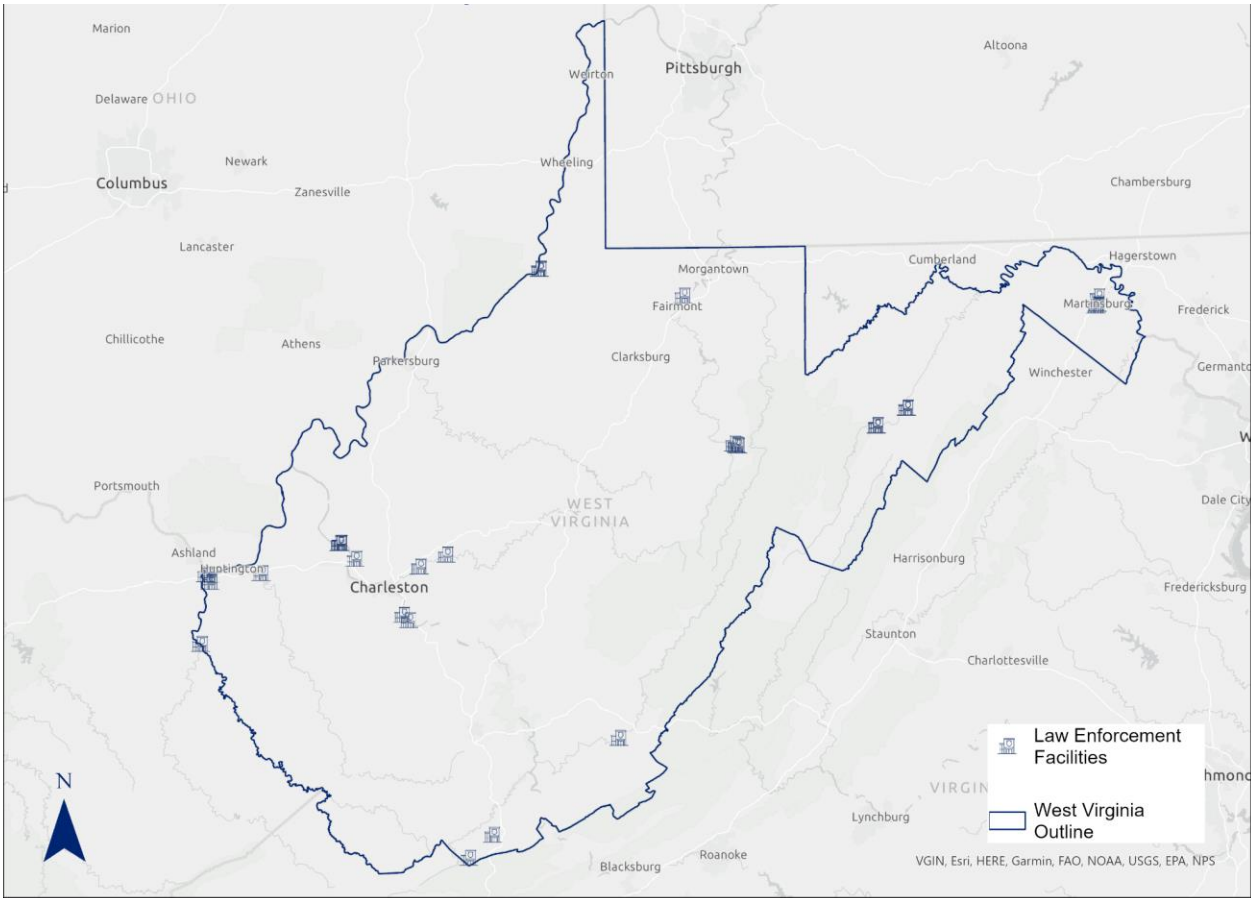
Source: Smart Electric Power Alliance, 2022

Law Enforcement Facility

Law enforcement facilities are places of operation for municipal police departments, county sheriff's offices or other law enforcement agencies. Law enforcement facilities provide critical services to communities, including a range of prevention, preparedness, response, and recovery services during both blue sky operations and emergency incident response. Law enforcement's emergency incident response services are critical during outages, and some facilities may not have the resilience capabilities to continue operations.

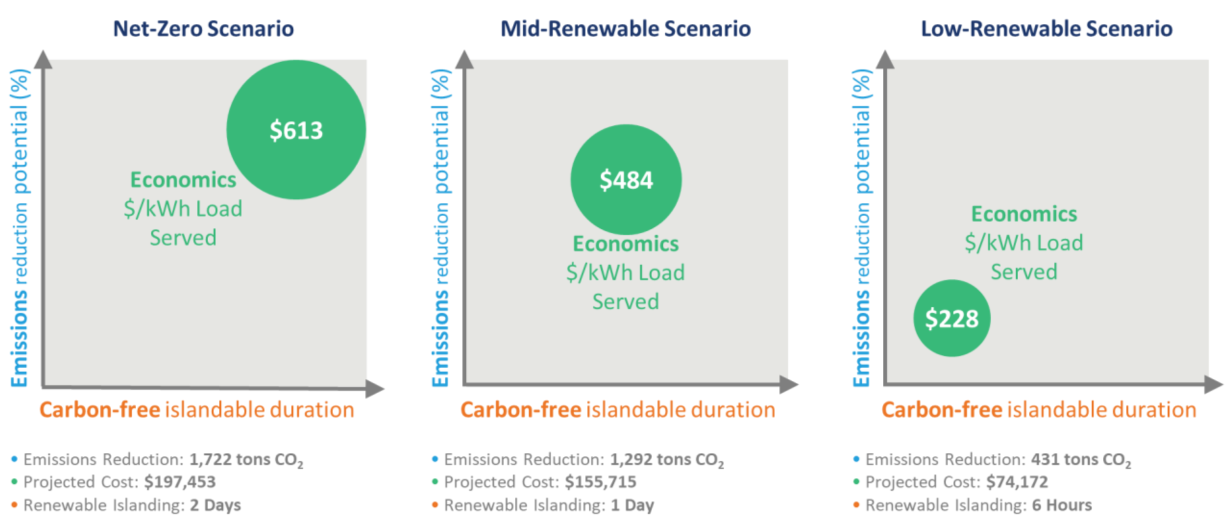
SEPA identified 29 potential site-specific law enforcement facility microgrids. Maps of the distribution of prioritized site-specific law enforcement facility microgrid deployments across the state are included below in Figure 5.6.

Figure 5. 6 - Prioritized Site-Specific Law Enforcement Facility Microgrid Locations



Source: Smart Electric Power Alliance, 2022

Figure 5. 7 - Comparative Analysis of Conceptual Microgrid Scenarios for Law Enforcement Facilities



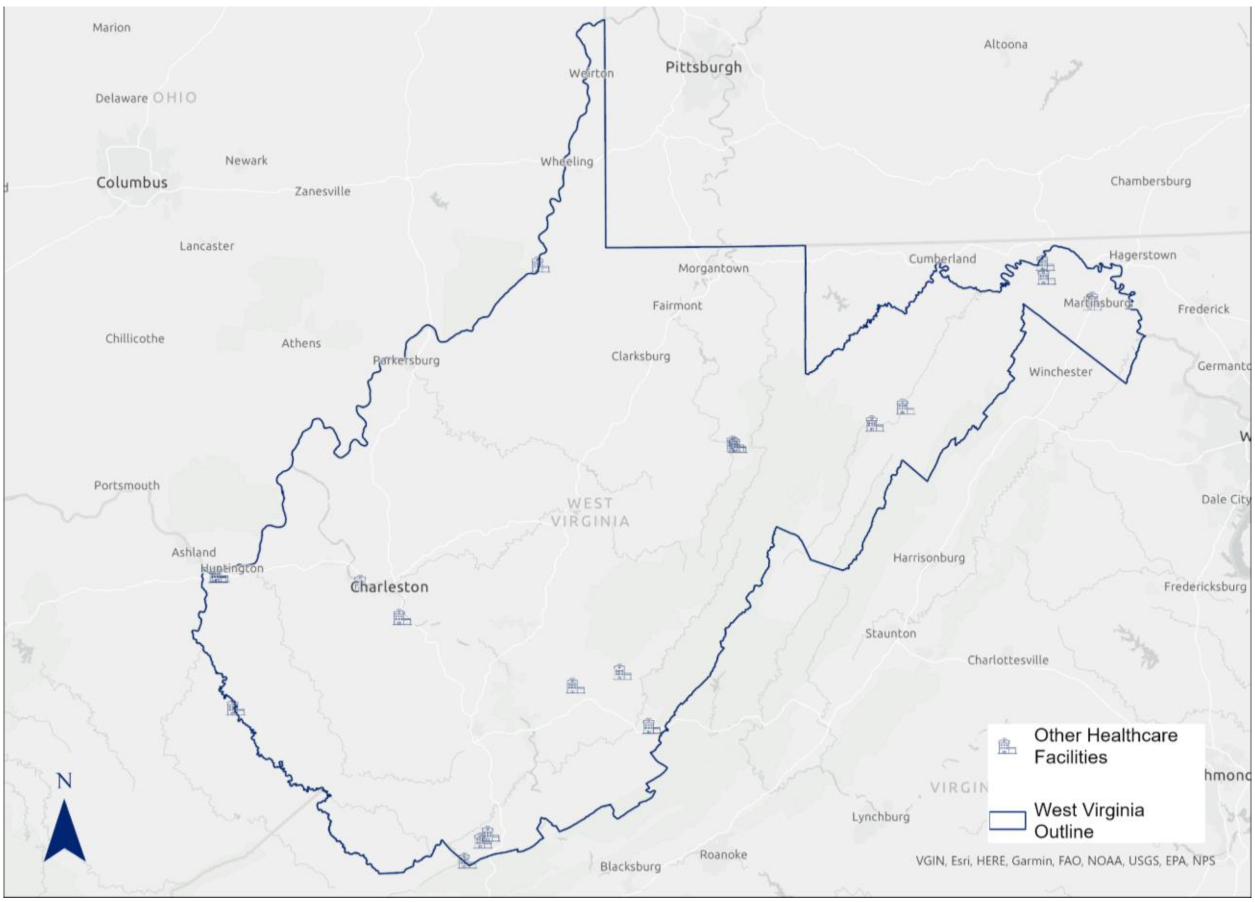
Source: Smart Electric Power Alliance, 2022

Other Healthcare

Other healthcare facilities are more specialized than hospitals and include varying health and medical facilities, such as rural health clinics, outpatient clinics and medical offices, long-term care facilities, urgent care facilities, clinical labs, and other relevant healthcare facilities. These facilities may not have the same backup generation or resilience capabilities as hospital facilities, but their ability to serve patients may remain critical during an outage, depending on the facility type and the community it serves.

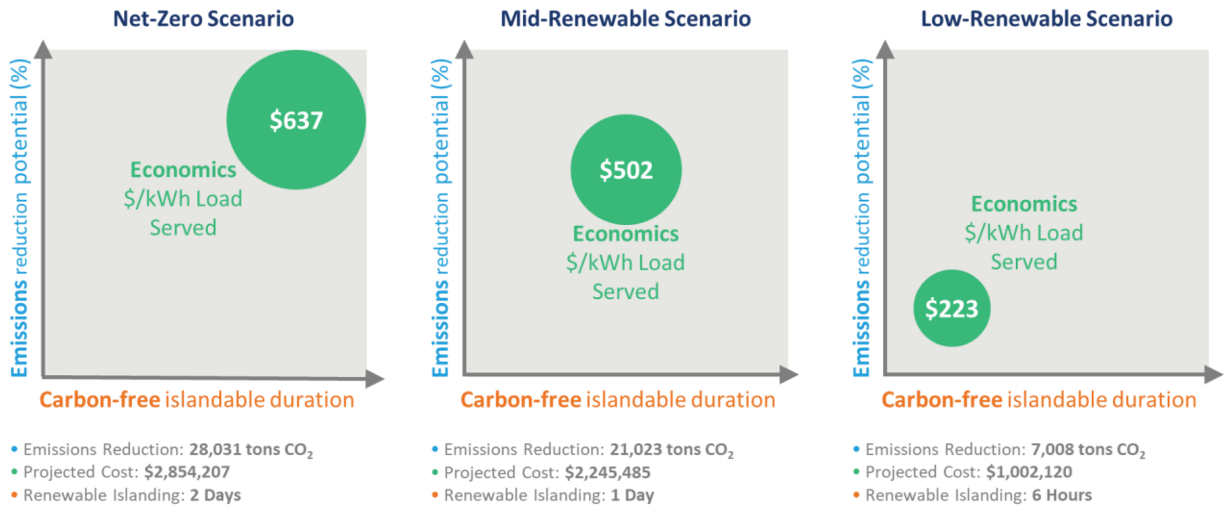
SEPA identified 20 potential site-specific other healthcare facility microgrids. Maps of the distribution of prioritized site-specific other healthcare facility microgrid deployments across the state are included below in Figure 5.8.

Figure 5. 8 - Prioritized Site-Specific Other Healthcare Facility Microgrid Locations



Source: Smart Electric Power Alliance, 2022

Figure 5. 9 - Comparative Analysis of Conceptual Microgrid Scenarios for Other Healthcare Facilities



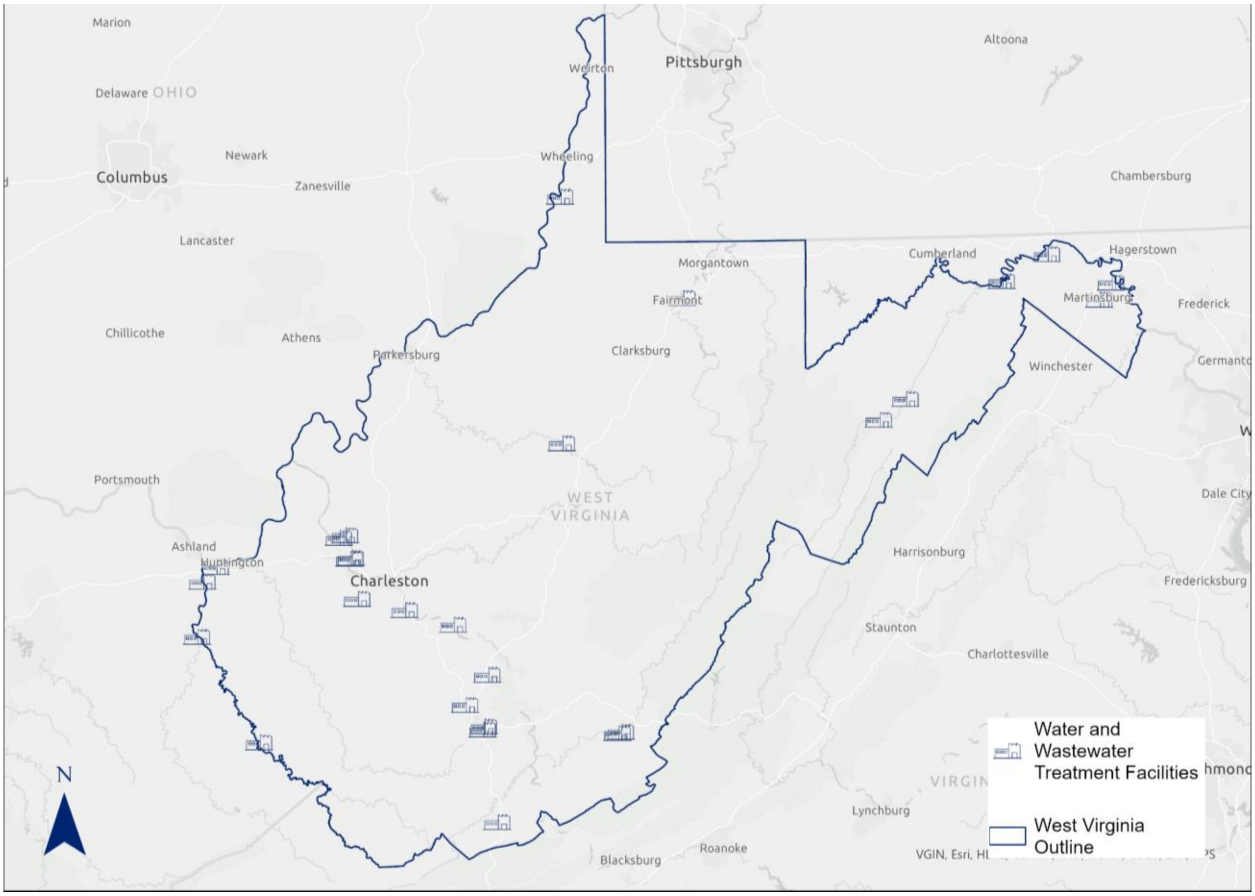
Source: Smart Electric Power Alliance, 2022

Water Treatment

Water and wastewater treatment facilities are designed to remove contaminants from wastewater and convert it into an effluent that can be returned to the water cycle. Many communities rely on water treatment facilities for their clean water supply. Outages at a facility can cause overflows that can create a public health risk and harm the local environment, but can be mitigated by developing on-site resilience capabilities to continue operations.

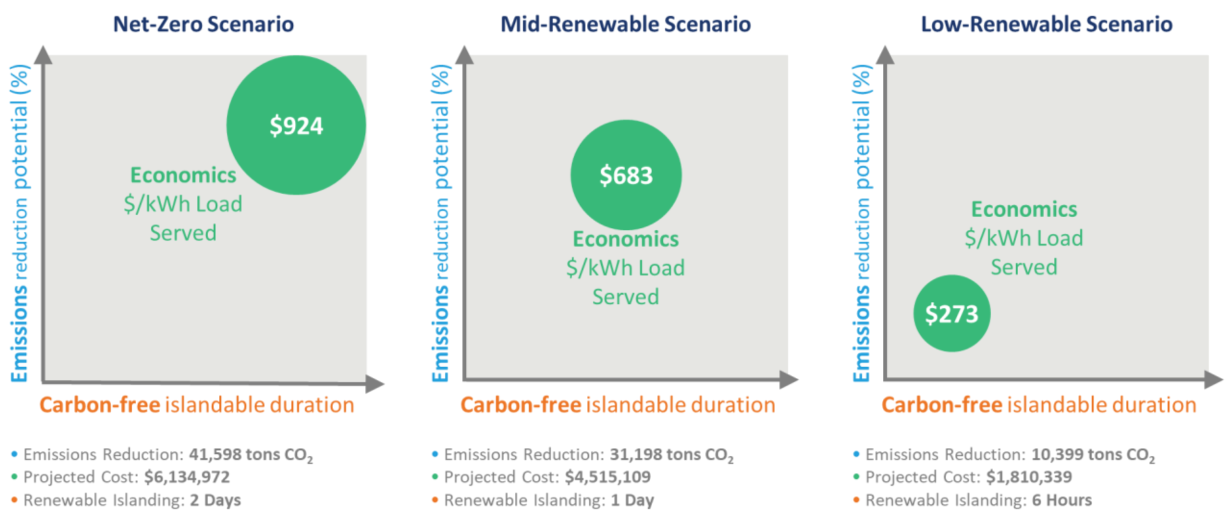
SEPA identified 27 potential site-specific water treatment facility microgrids. Maps of the distribution of prioritized site-specific water treatment facility microgrid deployments across the state are included below in Figure 5.10.

Figure 5. 10 - Prioritized Site-Specific Water Treatment Facility Microgrid Locations



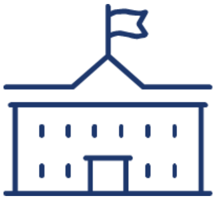
Source: Smart Electric Power Alliance, 2022

Figure 5. 11 - Comparative Analysis of Conceptual Microgrid Scenarios for Water Treatment Facilities



Source: Smart Electric Power Alliance, 2022

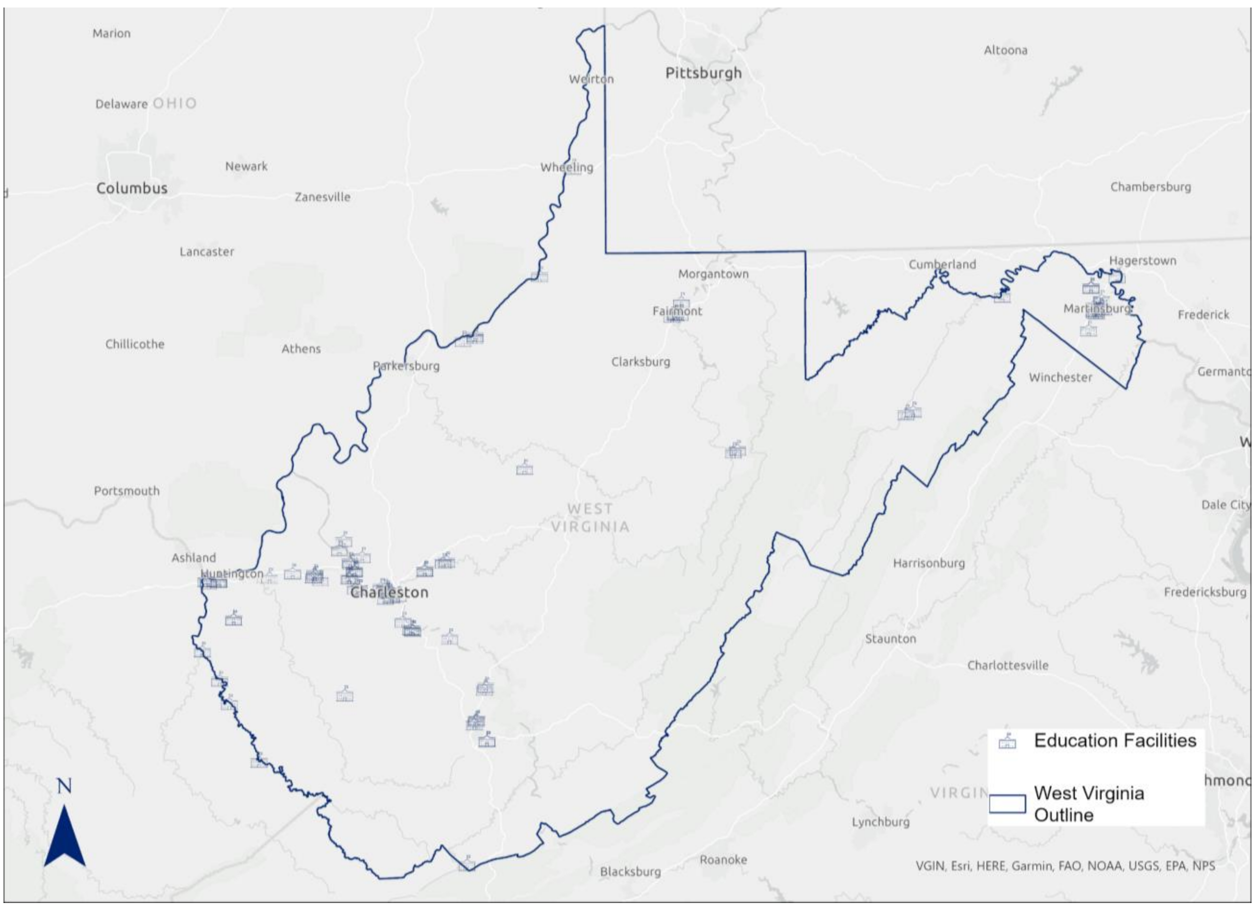
Education Facilities



Educational facilities include career and technical centers, stand-alone higher education facilities, and public K-12 schools. Educational facilities often serve their communities through after-school activities (e.g. cultural and social events, youth activities, resource use and information dissemination, health, leisure, and recreation activities, and adult learning[26]), and sometimes serve as community shelters or other emergency facilities. Many of these community services remain critical during outages, and some educational facilities may not have the resilience capabilities to continue operations during an outage.

SEPA identified 86 potential site-specific education facility microgrids. Maps of the distribution of prioritized site-specific educational facility microgrid deployments across the state are included below in Figure 5.12.

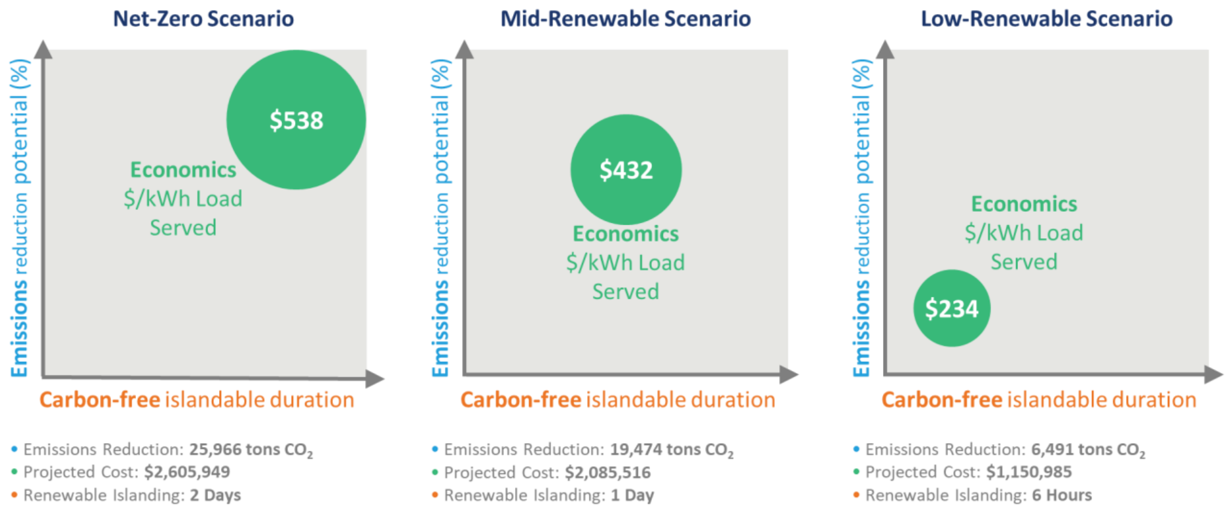
Figure 5. 12 - Prioritized Site-Specific Educational Facility Microgrid Locations



Source: Smart Electric Power Alliance, 2022

[26] https://www.oecd.org/education/innovation-education/2033741.pdf

Figure 5. 13 - Comparative Analysis of Conceptual Microgrid Scenarios for Education Facilities



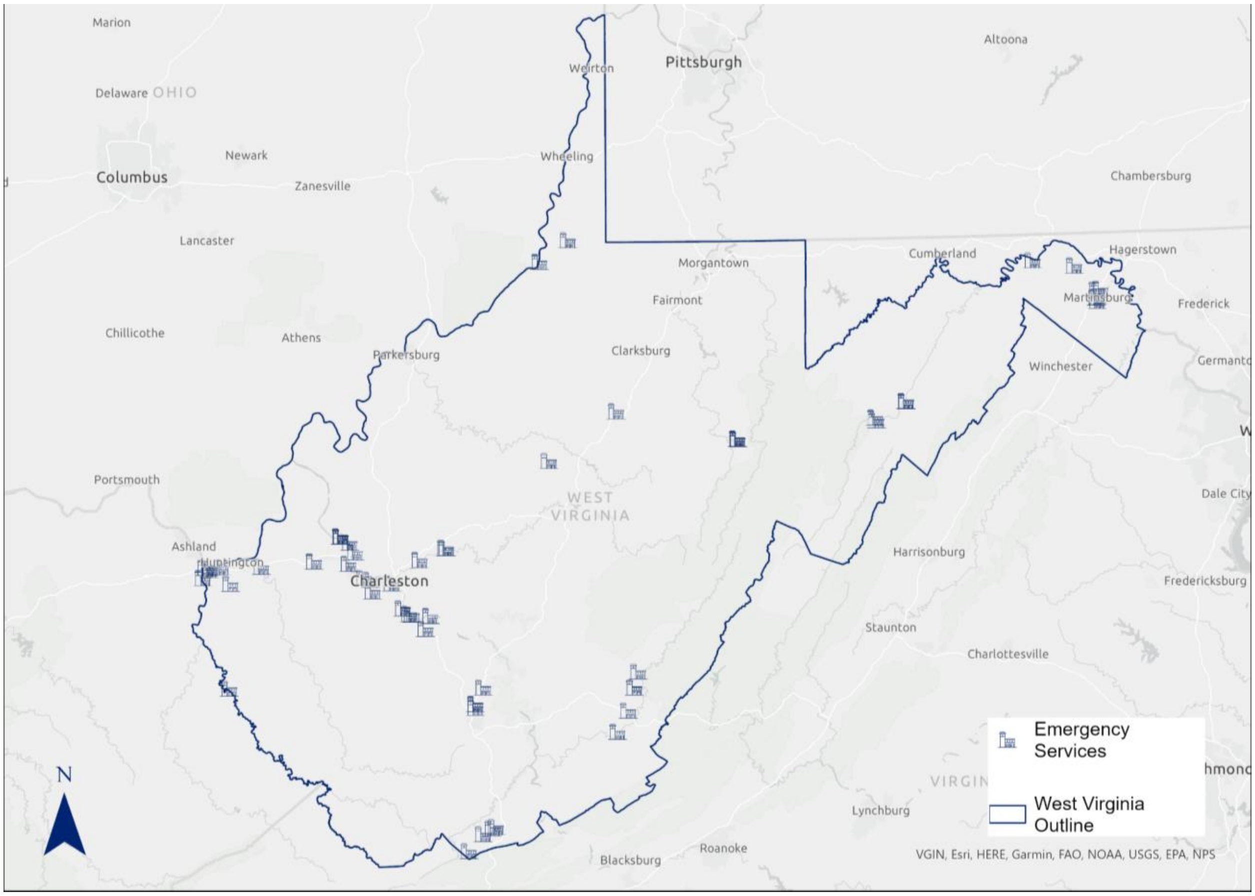
Source: Smart Electric Power Alliance, 2022

Emergency Services

Emergency services include any location where emergency services personnel (e.g. such as fire protection, ambulance, or rescue) are stationed or where equipment is stored for emergencies. These facilities provide emergency services to communities or administrative and support services essential to the operation of such emergency facilities. Ensuring that these facilities have backup generation or resilience capabilities is key to emergency incident response during an outage.

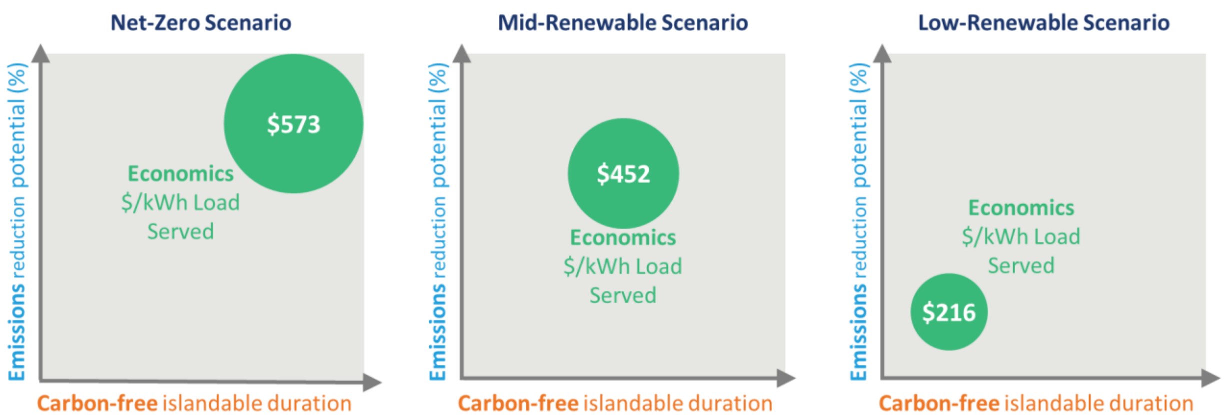
SEPA identified 59 potential site-specific emergency services facility microgrids. Maps of the distribution of prioritized site-specific emergency services facility microgrid deployments across the state are included below in Figure 5.14.

Figure 5. 14 - Prioritized Site-Specific Emergency Services Microgrid Locations



Source: Smart Electric Power Alliance, 2022

Figure 5. 15 - Comparative Analysis of Conceptual Microgrid Scenarios for Emergency Services Facilities



Net-Zero Scenario	Mid-Renewable Scenario	Low-Renewable Scenario
Emissions Reduction: **2,863 tons CO_2**	Emissions Reduction: **2,147 tons CO_2**	Emissions Reduction: **716 tons CO_2**
Projected Cost: **$336,089**	Projected Cost: **$264,455**	Projected Cost: **$127,430**
Renewable Islanding: **2 Days**	Renewable Islanding: **1 Day**	Renewable Islanding: **6 Hours**

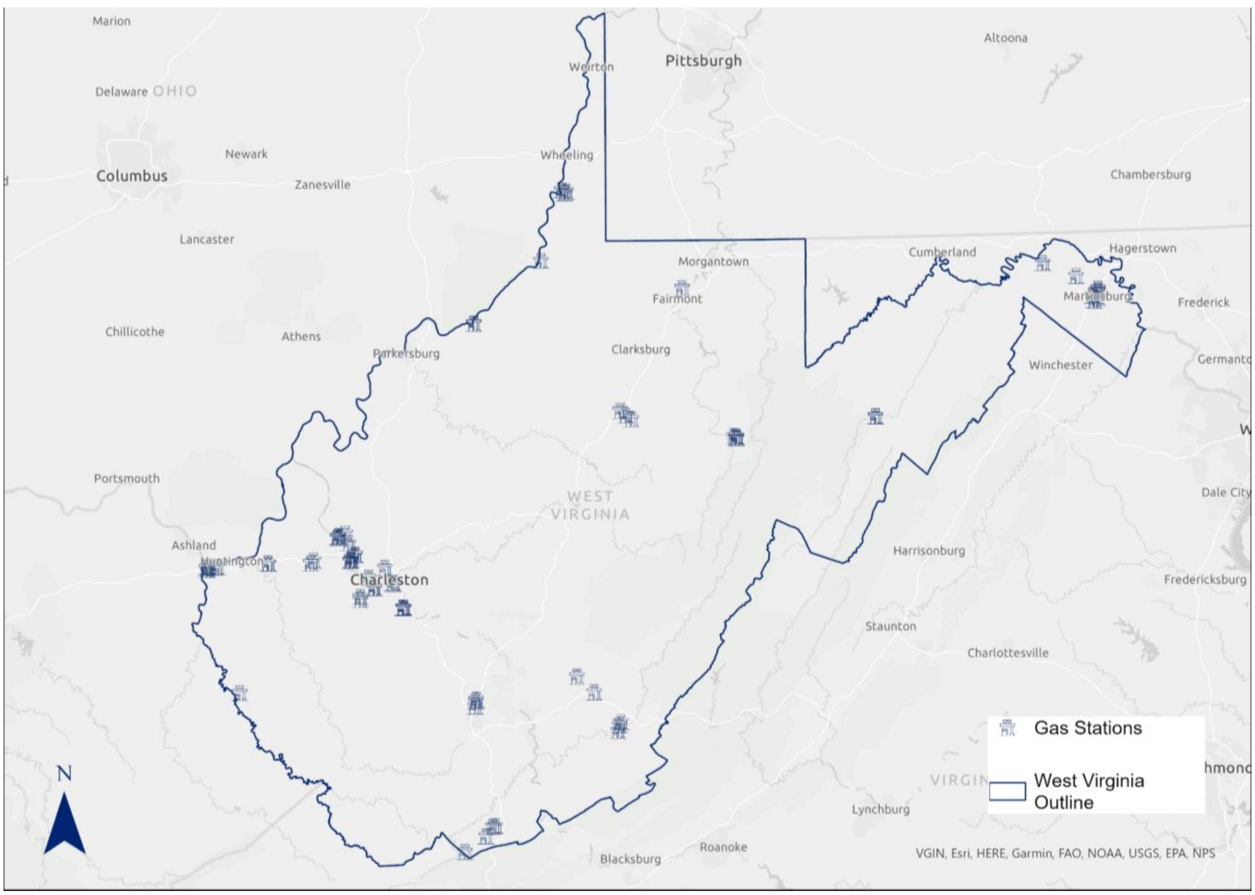
Source: Smart Electric Power Alliance, 2022

Gas Station

Gas Stations include retail stations for fueling motor vehicles that may provide vehicle servicing and repair capabilities, convenience store offerings, and/or additional fuel sales (e.g. diesel, kerosene, CNG/LNG, EV charging, etc.). During an outage, these facilities may be critical to providing continuity of operations for emergency services, public or private vehicle fleets, and personal transportation. Ensuring that these facilities have backup generation or resilience capabilities is key to supporting vehicle fleets involved in emergency incident response and ensuring that individuals have the means to evacuate.

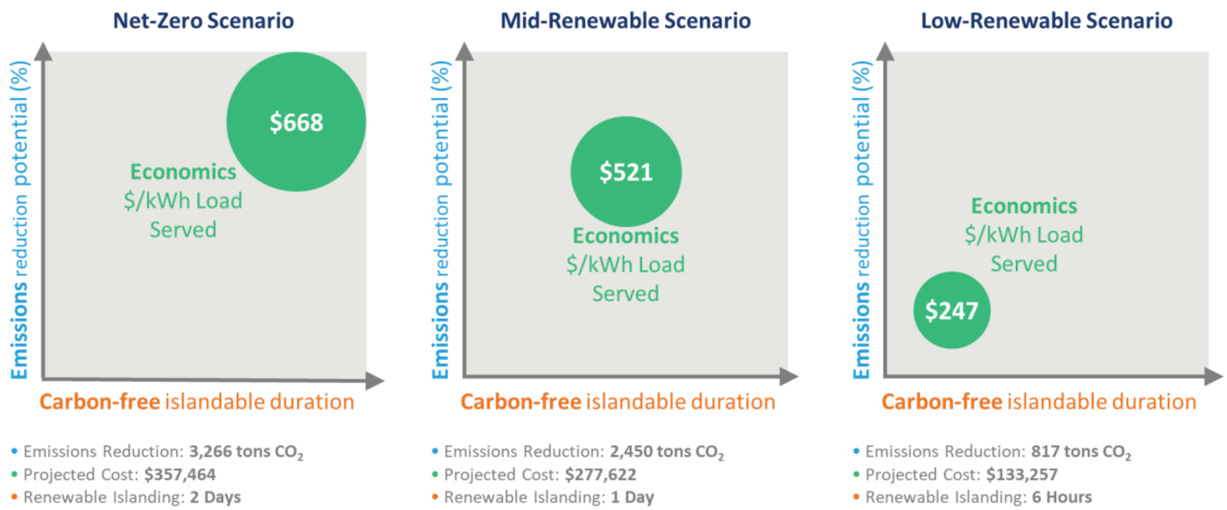
SEPA identified 71 potential site-specific gas station facility microgrids. Maps of the distribution of prioritized site-specific gas station microgrid deployments across the state are included below in Figure 5.16.

Figure 5. 16 - Prioritized Site-Specific Gas Station Microgrid Locations



Source: Smart Electric Power Alliance, 2022

Figure 5. 17 - Comparative Analysis of Conceptual Microgrid Scenarios for Gas Stations



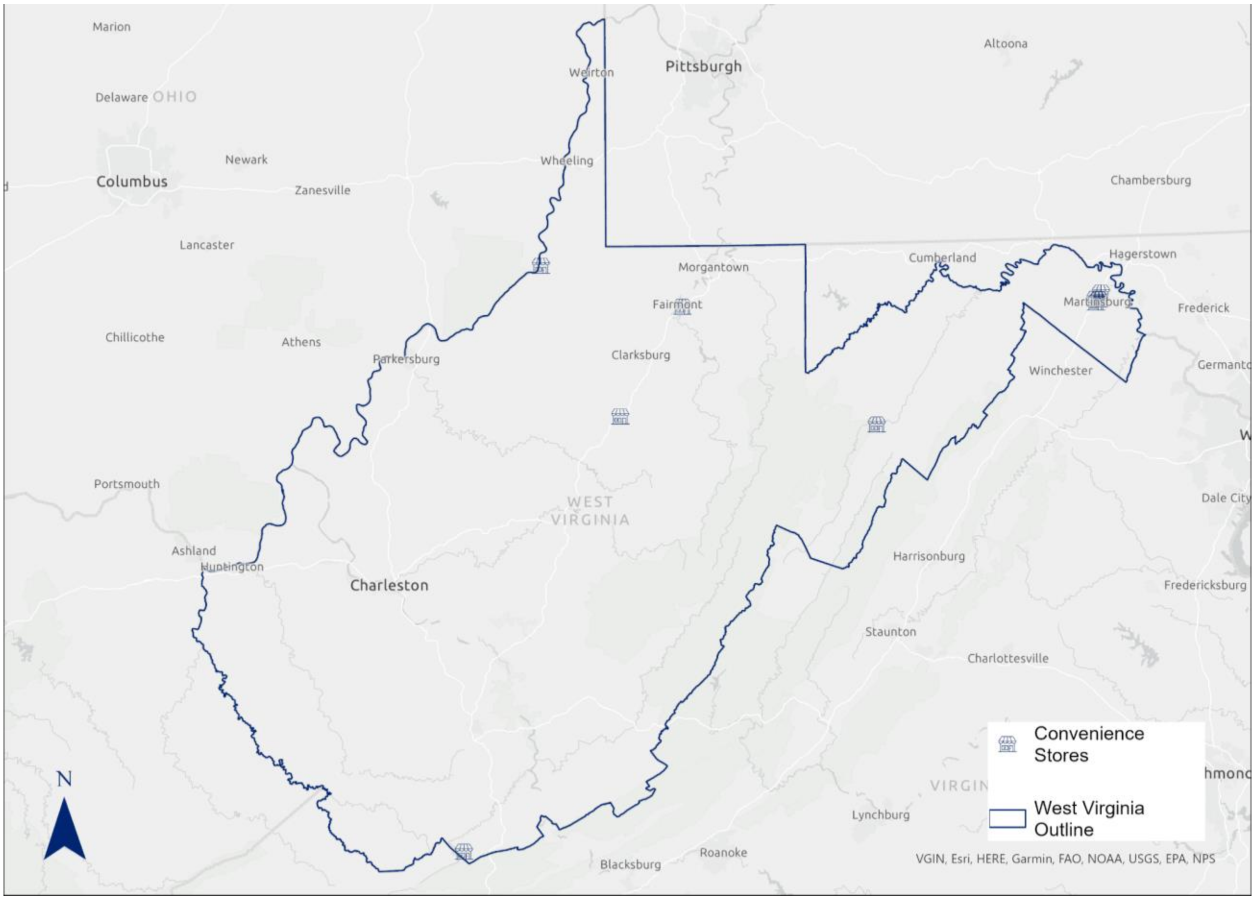
Source: Smart Electric Power Alliance, 2022

Convenience Store

Convenience stores are small-scale/small-footprint markets that stock a limited selection of household goods and staple groceries. Some convenience stores may include an on-site pharmacy or serve as a grocery store to small communities. Convenience stores, especially those that serve as community grocers, are a community lifeline that provides food, beverages, household goods, and/or support services to community members. These services remain critical during outages, and many convenience stores may not have the resilience capabilities to continue operations during an outage.

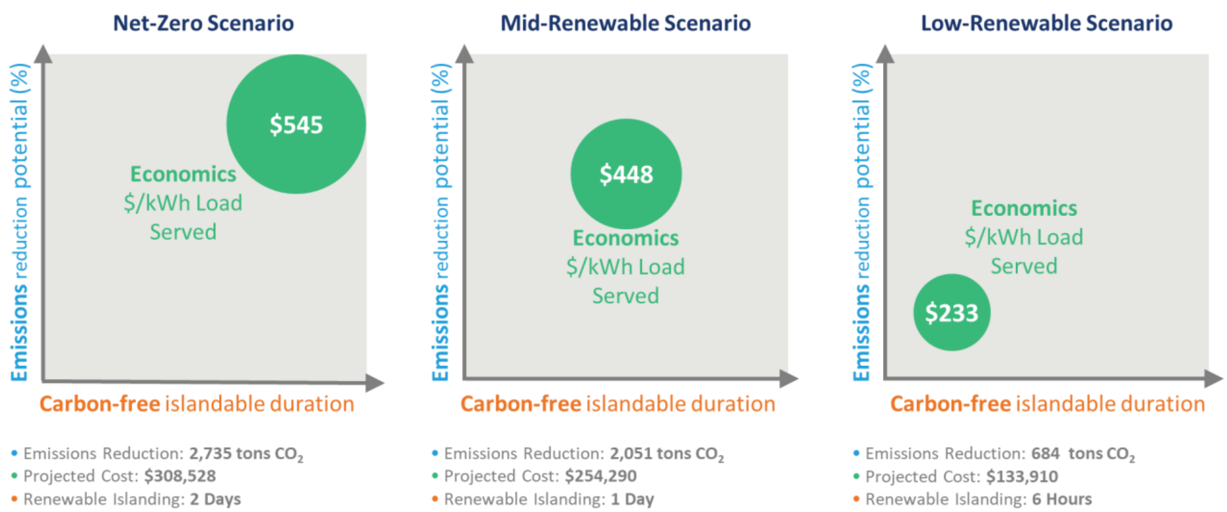
SEPA identified 10 potential site-specific convenience store facility microgrids. Maps of the distribution of prioritized site-specific convenience store microgrid deployments across the state are included below in Figure 5.18.

Figure 5. 18 - Prioritized Site-Specific Convenience Store Microgrid Locations



Source: Smart Electric Power Alliance, 2022

Figure 5. 19 - Comparative Analysis of Conceptual Microgrid Scenarios for Convenience Stores



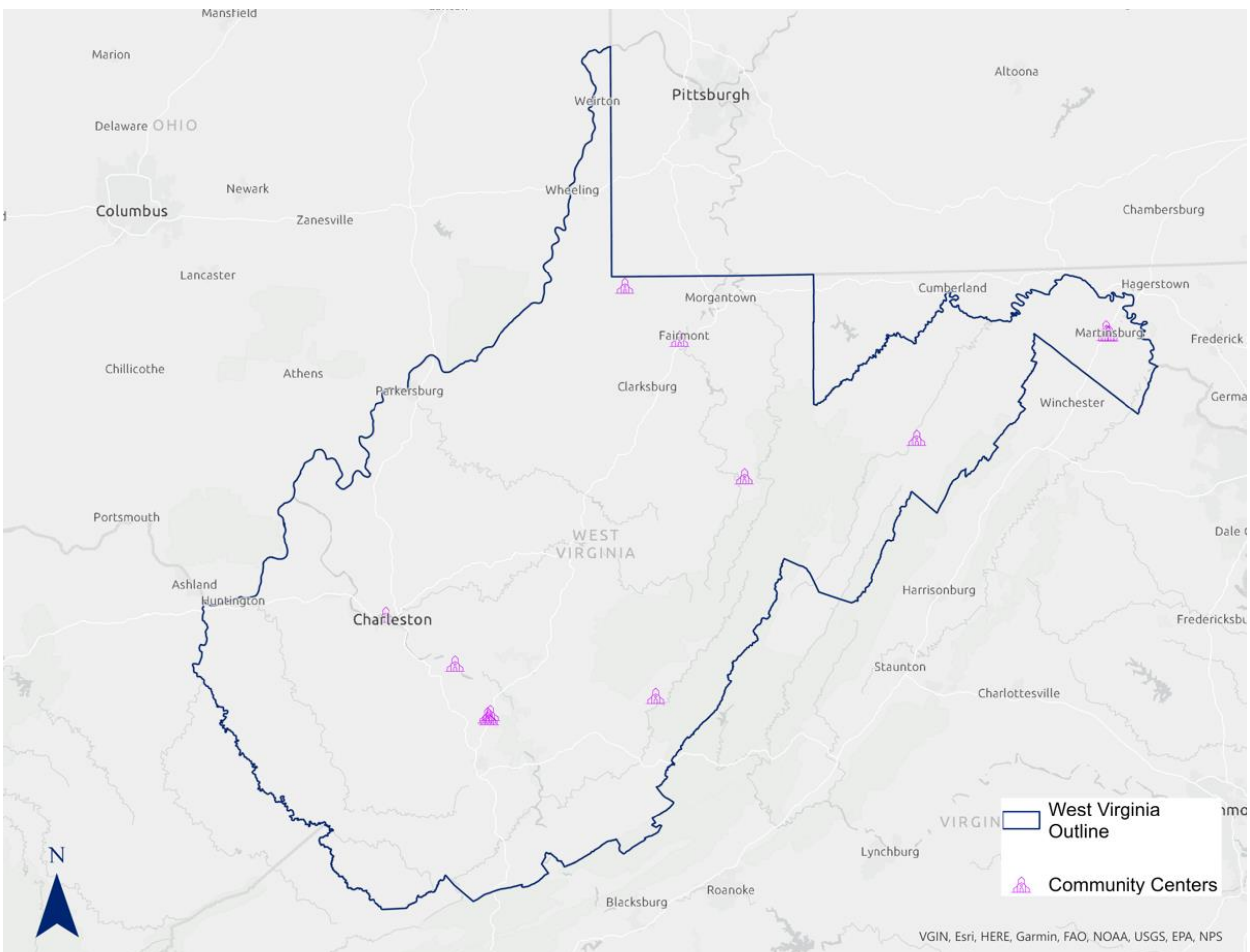
Source: Smart Electric Power Alliance, 2022

Community Centers

Community Centers include recreation centers, senior centers, places of worship, and other facilities where people from a particular community can meet for social, educational, spiritual, or recreational activities. Many of these facilities also serve as community emergency shelters, or provide other emergency services during a major outage. Many of these community services remain critical during outages, and some community centers may not have the resilience capabilities to continue operations during an outage.

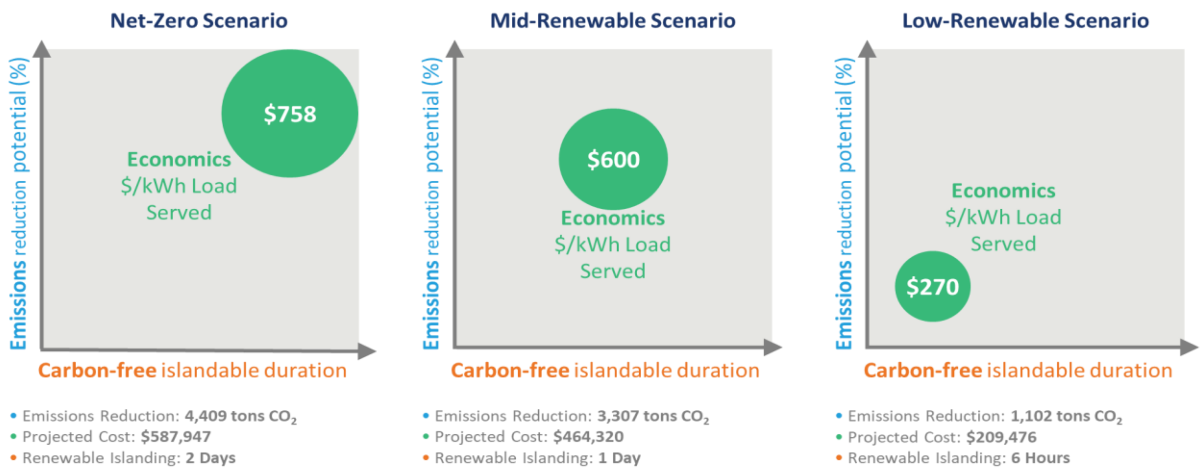
SEPA identified 13 potential site-specific community facility microgrids. Maps of the distribution of prioritized site-specific law enforcement community center microgrid deployments across the state are included below in Figure 5.20.

Figure 5. 20 - Prioritized Site-Specific Community Center Microgrid Locations



Source: Smart Electric Power Alliance, 2022

Figure 5. 21 - Comparative Analysis of Conceptual Microgrid Scenarios for Community Centers



Source: Smart Electric Power Alliance, 2022

Table 5. 1 - Site-Specific Microgrid Deployment Strategy Capital and O&M Cost Estimates

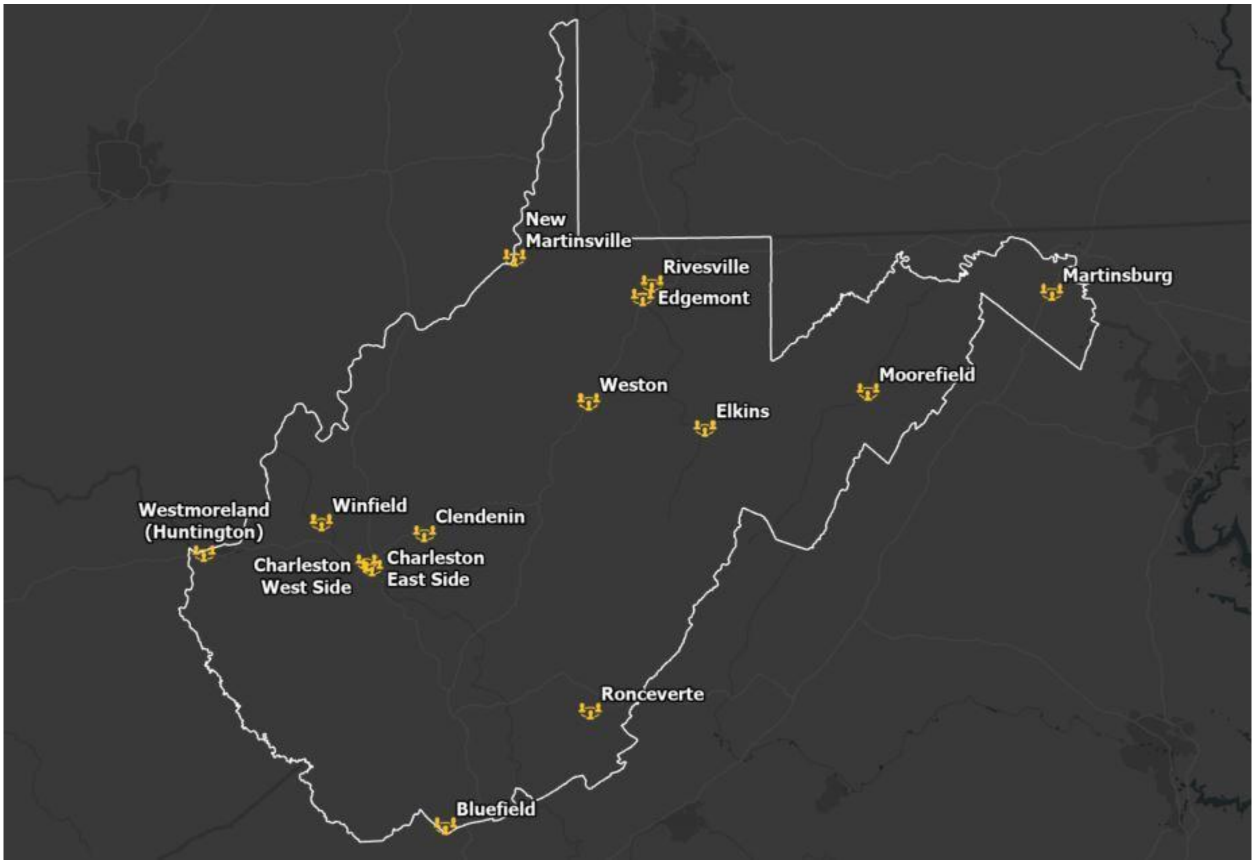
Critical Infrastructure Facilities		Low-Renewable Design Cost, $ ($/kWh served)	Mid-Renewable Design Cost, $ ($/kWh served)	High-Renewable Design Cost, $ ($/kWh served)
Facility Type	**# Sites Selected**	**Per facility**	**Per facility**	**Per facility**
Other Healthcare Facilities	20	1,002,120 (223)	2,245,485 (502)	2,854,207 (637)
Water and Wastewater Treatment Facilities	27	1,810,339 (273)	4,515,109 (683)	6,134,972 (924)
Emergency Services	59	127,430 (216)	264,455 (452)	336,089 (573)
Community Centers	13	209,476 (270)	464,320 (600)	587,947 (758)
Law Enforcement Facilities	29	74,172 (228)	155,715 (484)	197,453 (613)
Gas Stations	84	133,257 (247)	277,622 (521)	357,464 (668)
Grocery Stores	38	1,235,039 (206)	2,767,643 (466)	3,556,767 (598)
Convenience Store	12	133,910 (233)	254,290 (448)	308,528 (545)
Education Facilities	86	1,150,985 (234)	2,085,516 (432)	2,605,949 (538)

Source: Smart Electric Power Alliance, 2022.

Community Microgrid Deployment Strategy

SEPA identified 14 clusters of critical facilities that each had 2+ critical facilities within a 0.5 mile radius of one another as potential community microgrid deployments[27]. SEPA sized and carried out comparative analysis for three different microgrid scenarios for each community microgrid accounting for high-, mid-, and low-renewable components with different cost projections and islanding capabilities. For details on load, sizing, design and economic analysis for each community microgrid, see Appendix 4.

Figure 5. 22 - Potential Community Microgrid Deployments



Source: Smart Electric Power Alliance, 2022

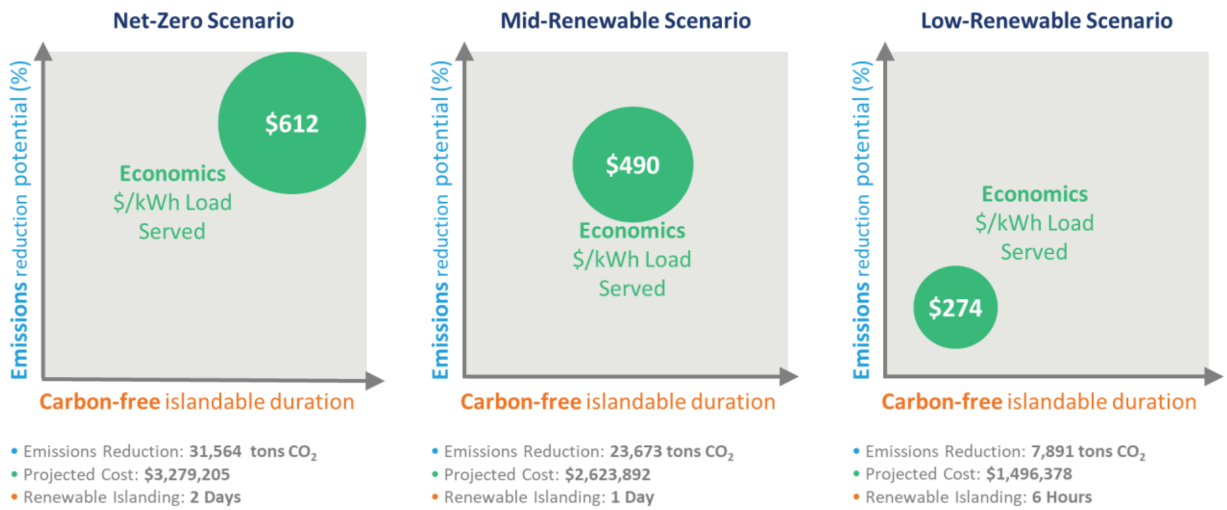
Charleston East Side

The Charleston East Side community microgrid includes three critical facilities within its electrical boundary:

- Piedmont Year-Round Education Center (Educational Facility)
- Charleston Fire Department Station 1 (Emergency Services)
- Par Mor (Convenience Store)

[27] Additional costs for reconfiguring the local distribution system for potential community microgrid deployments would need to be accounted for on a case specific basis.

Figure 5. 23 - Comparative Analysis of Conceptual Microgrid Scenarios for the Charleston East Side Site



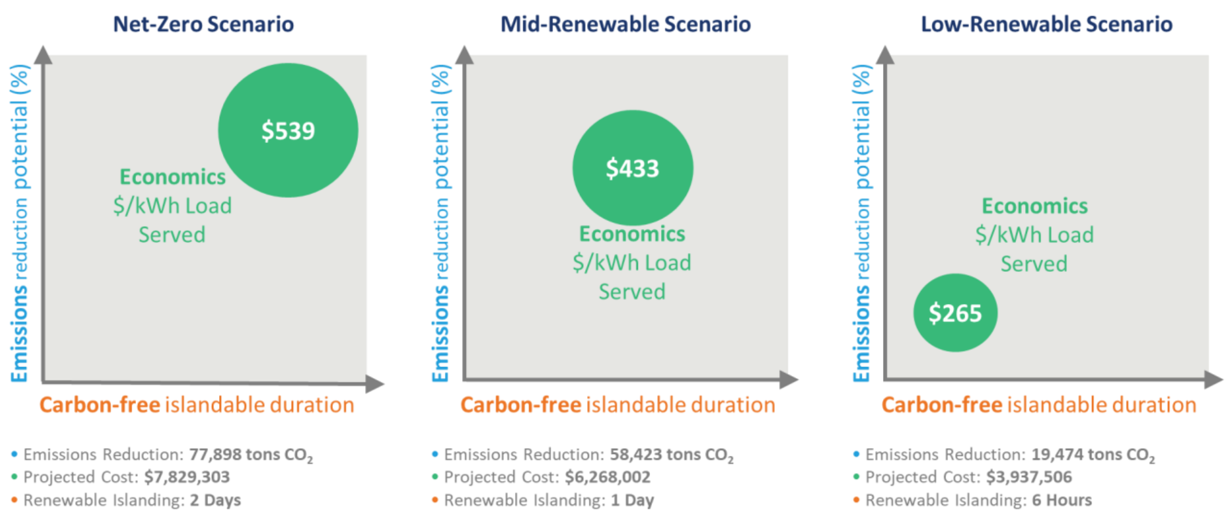
Source: Smart Electric Power Alliance, 2022

Charleston West Side

The Charleston West Side community microgrid includes three critical facilities within its electrical boundary:

- Educational Facility (J.E. Robins Elementary School / Designated Shelter)
- Educational Facility (Stonewall Jackson Middle School / Designated Shelter)
- Educational Facility (Glenwood Elementary School / Designated Shelter)

Figure 5. 24 - Comparative Analysis of Conceptual Microgrid Scenarios for the Charleston West Side Site



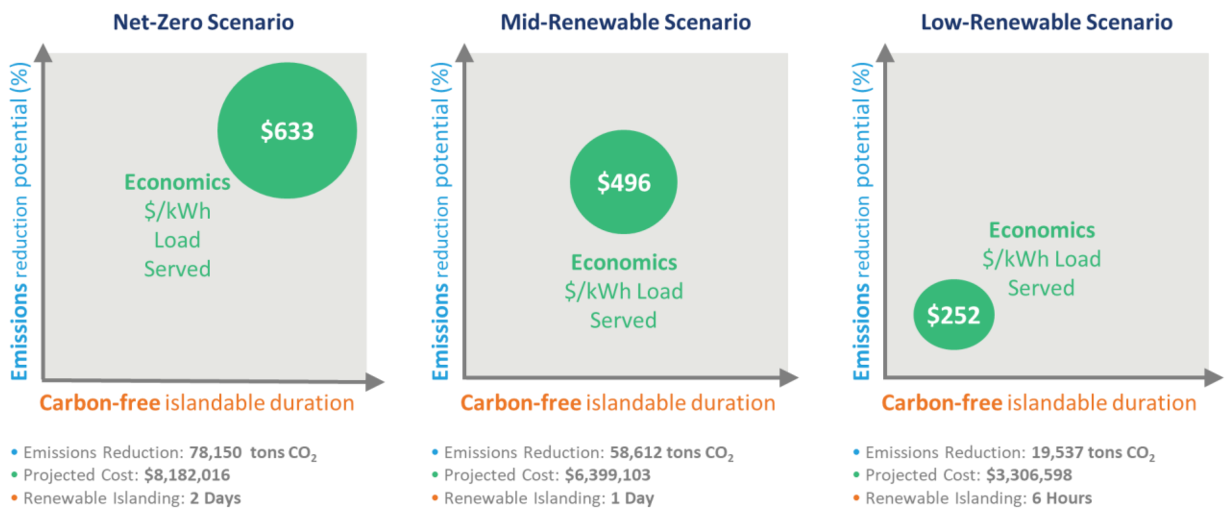
Source: Smart Electric Power Alliance, 2022

Winfield

The Winfield community microgrid includes six critical facilities within its electrical boundary:

- Gas Station (Town of Winfield Speedway)
- Law Enforcement Facility (Winfield Police Department)
- Educational Facility (Winfield Elementary School / Designated Shelter)
- Emergency Services (Putnam County 9-1-1 Center)
- Convenience Store (Farmers Meat Deli)
- Water Treatment Facility (Town of Winfield)

Figure 5. 25 - Comparative Analysis of Conceptual Microgrid Scenarios for the Winfield Site



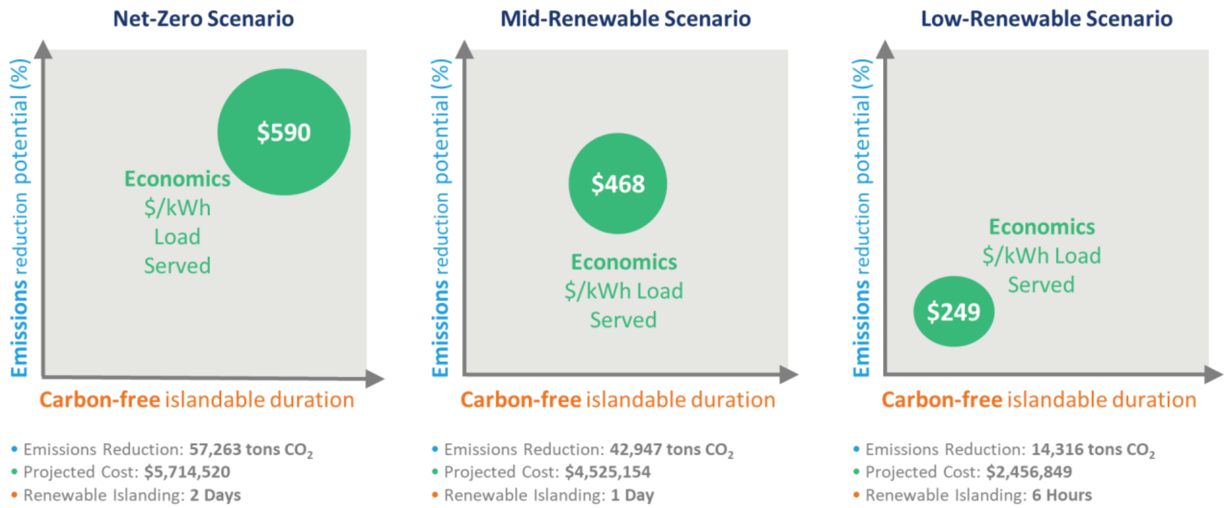
Source: Smart Electric Power Alliance, 2022

Westmoreland (Huntington)

The Westmoreland (Huntington) community microgrid includes three critical facilities within its electrical boundary:

- Gas Station (Clark’s Pump-N-Shop)
- Educational Facility (Kellogg Elementary School / Designated Shelter)
- Other Healthcare Facility (Spring Valley High Health Center)

Figure 5. 26 - Comparative Analysis of Conceptual Microgrid Scenarios for the Westmoreland (Huntington) Site



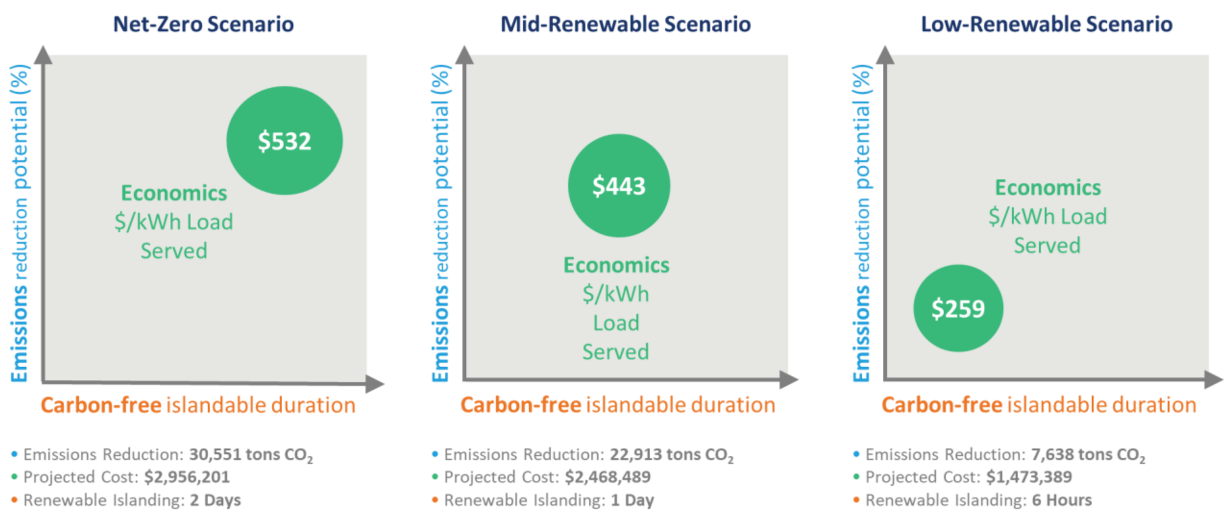
Source: Smart Electric Power Alliance, 2022

Clendenin

The Clendenin community microgrid includes three critical facilities within its electrical boundary:

- Educational Facility (Clendenin Elementary School)
- Law Enforcement Facility (Clendenin Police Department)
- Emergency Services (Clendenin Volunteer Fire Department)

Figure 5. 27 - Comparative Analysis of Conceptual Microgrid Scenarios for the Clendenin Site



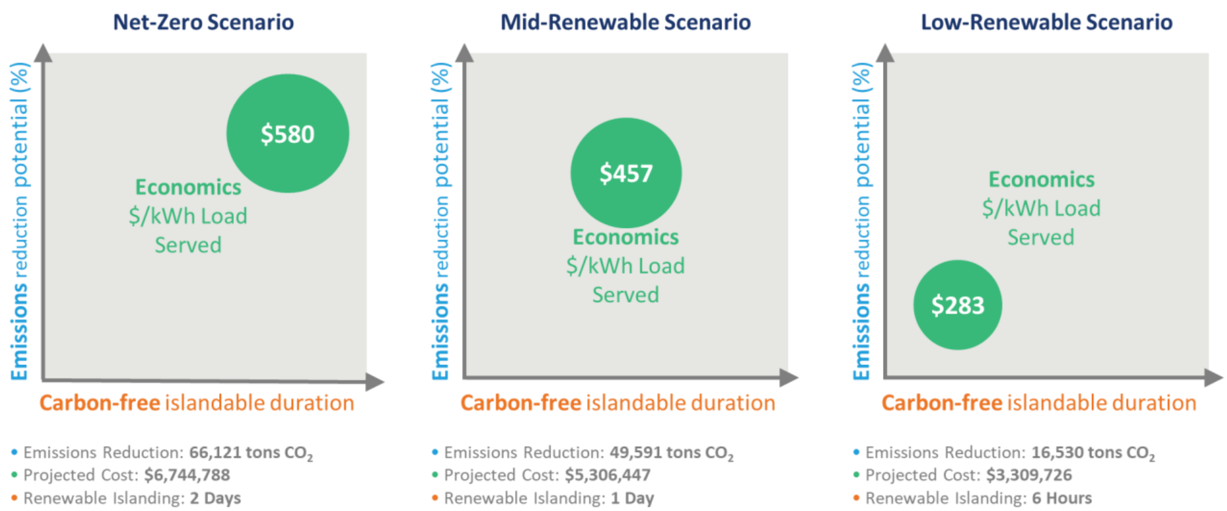
Source: Smart Electric Power Alliance, 2022

New Martinsville

The New Martinsville community microgrid includes five critical facilities within its electrical boundary:

- Law Enforcement Facility (Wetzel County Sheriff)
- Law Enforcement Facility (New Martinsville Police Department)
- Educational Facility (WVNCC - New Martinsville Campus)
- Emergency Service (New Martinsville Fire Department Station 218)
- Grocery Store (Witschey's Market)

Figure 5. 28 - Comparative Analysis of Conceptual Microgrid Scenarios for the New Martinsville Site



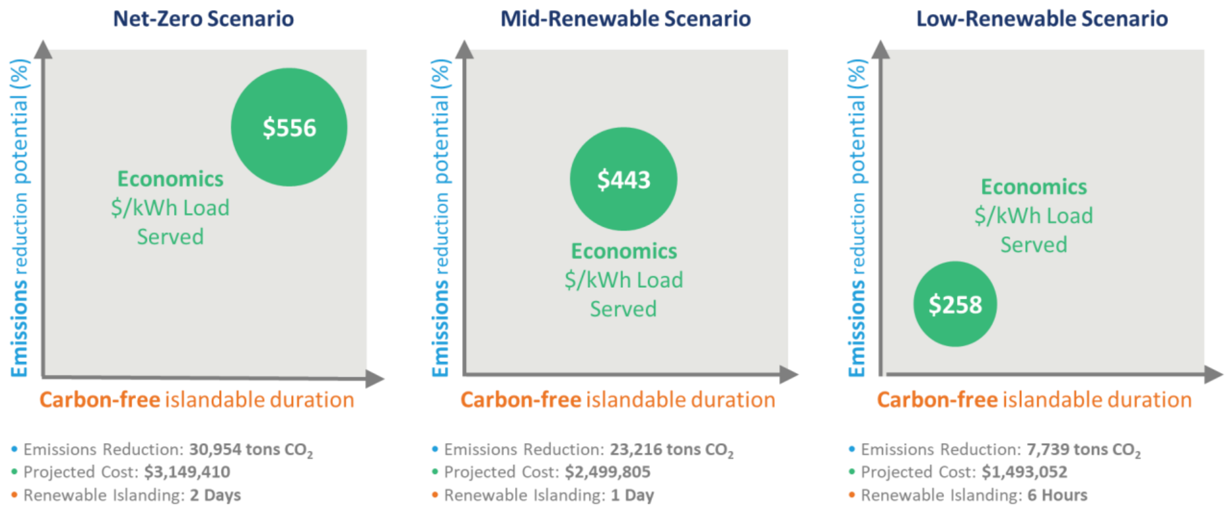
Source: Smart Electric Power Alliance, 2022

Rivesville

The Rivesville community microgrid includes three critical facilities within its electrical boundary:

- Educational Facility (Rivesville Elementary School / Designated Shelter)
- Gas Station (7-11)
- Law Enforcement Facility (Rivesville Police Department)

Figure 5. 29 - Comparative Analysis of Conceptual Microgrid Scenarios for the Rivesville Site



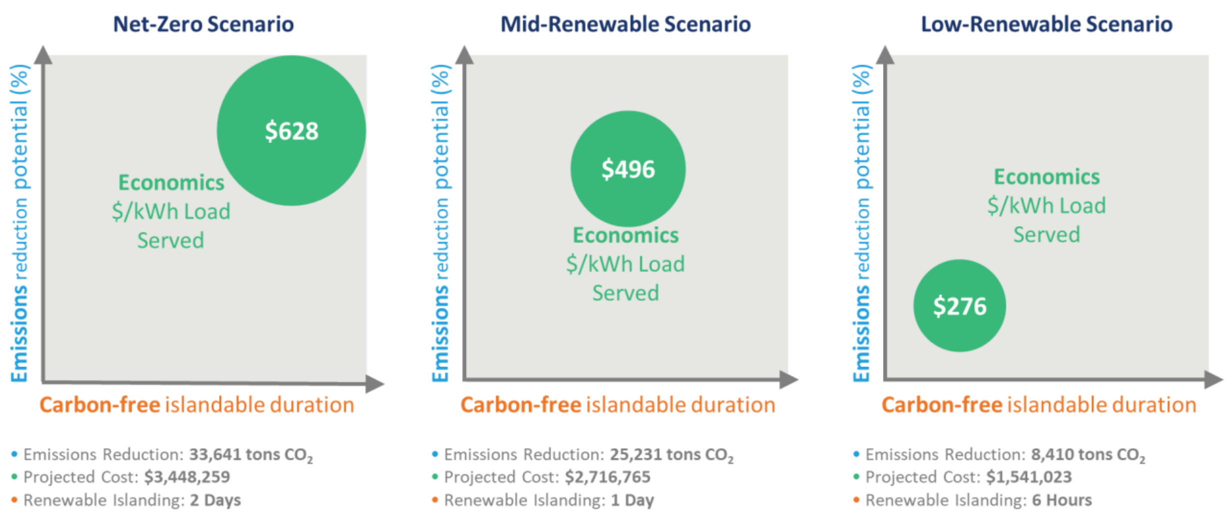
Source: Smart Electric Power Alliance, 2022

Edgemont

The Edgemont community microgrid includes three critical facilities within its electrical boundary:

- Place of Worship / Designated Shelter (Fleming Memorial Presbyterian Church)
- Educational Facility (Jayenne K-12 Schools / Designated Shelter)
- Gas Station (Sunoco)

Figure 5. 30 - Comparative Analysis of Conceptual Microgrid Scenarios for the Edgemont Site



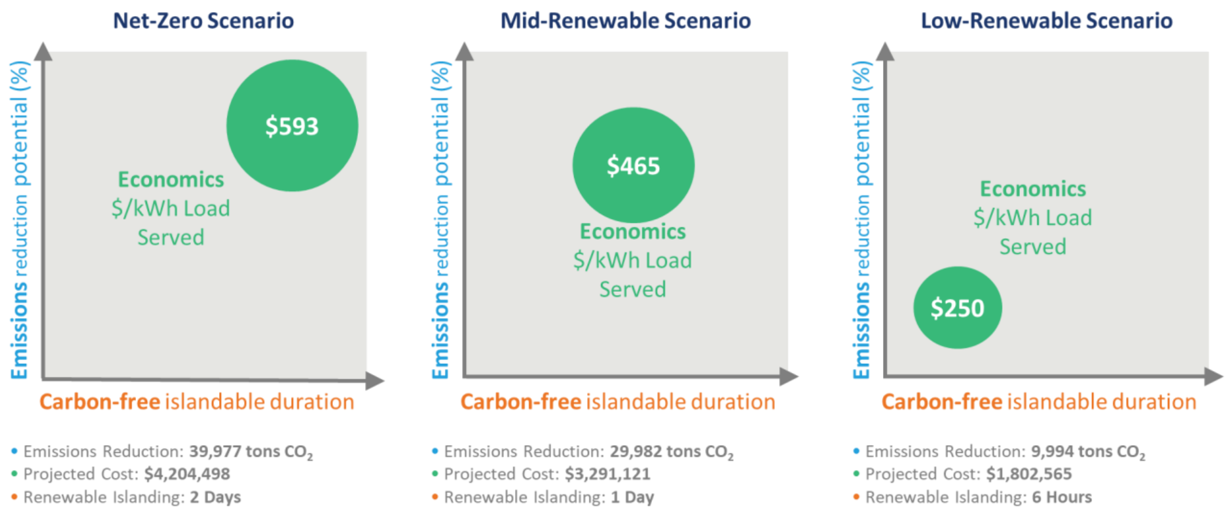
Source: Smart Electric Power Alliance, 2022

Weston

The Weston community microgrid includes three critical facilities within its electrical boundary:

- Emergency Services (Lewis County Emergency Ambulance Service Authority Company 8)
- Gas Station (Burton's Service Station)
- Grocery Store (Shop 'n Save)

Figure 5. 31 - Comparative Analysis of Conceptual Microgrid Scenarios for the Weston Site



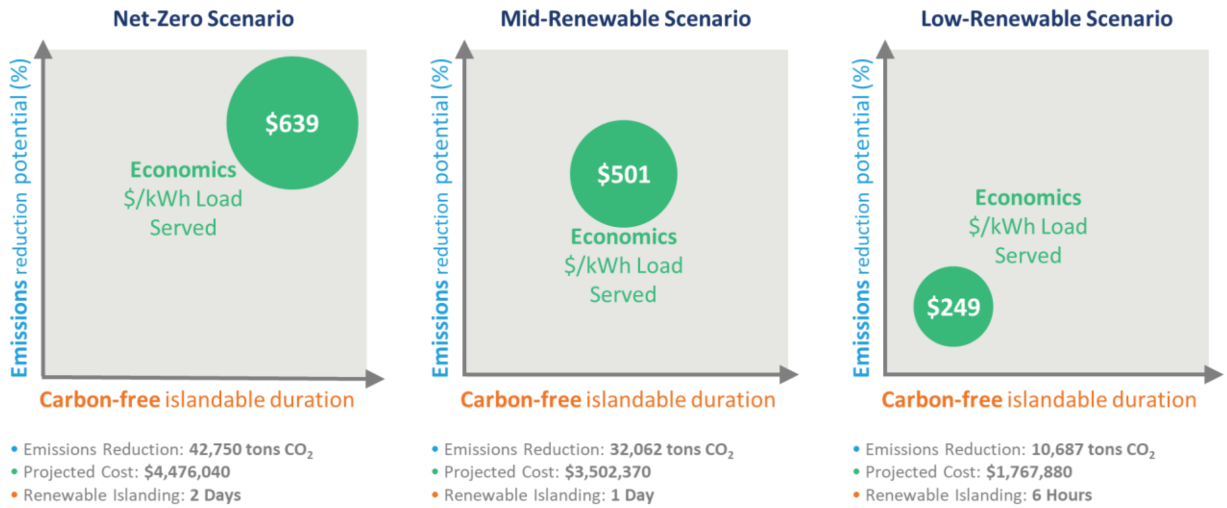
Source: Smart Electric Power Alliance, 2022

Elkins

The Elkins community microgrid includes six critical facilities within its electrical boundary:

- Emergency Services (Elkins Fire Department)
- Place of Worship (Woodford Memorial United Methodist Church / Designated Shelter)
- Other Healthcare Facility (Randolph County Health Department)
- Emergency Services (Randolph County 9-1-1)
- Emergency Services (Randolph County Emergency Squad 1)
- Law Enforcement Facility (Randolph County Sheriff's Office)

Figure 5. 32 - Comparative Analysis of Conceptual Microgrid Scenarios for the Elkins Site



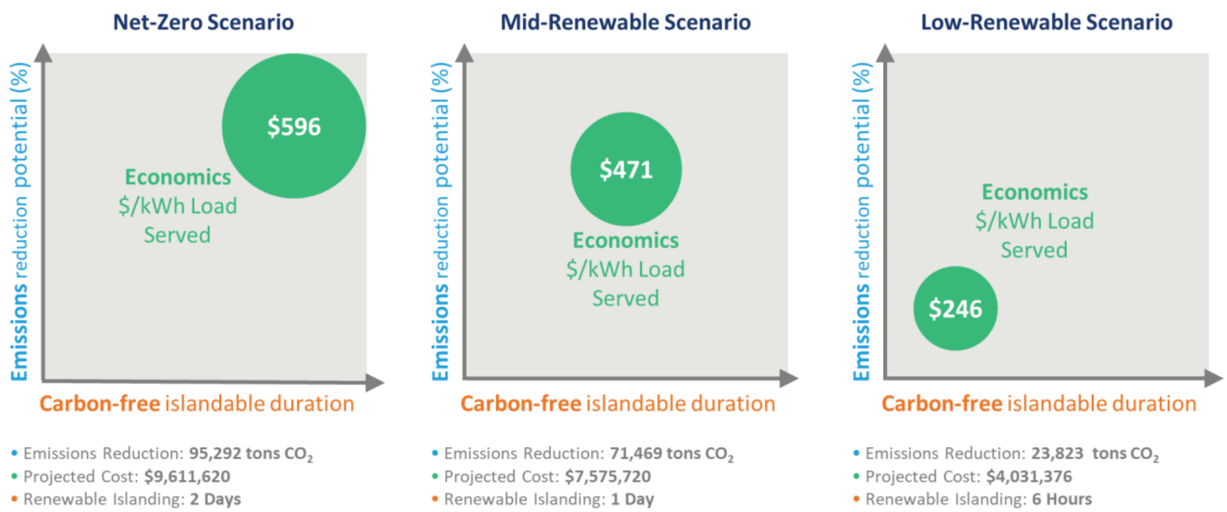
Source: Smart Electric Power Alliance, 2022

Moorefield

The Moorefield community microgrid includes six critical facilities within its electrical boundary:

- Other Healthcare Facility (Love Memorial Clinic)
- Emergency Services (Moorefield Volunteer Fire Department)
- Grocery Store (Shop ‘n Save)
- Educational Facility (Moorefield Elementary School / Designated Shelter)
- Emergency Services (Fraley Ambulance Service)
- Law Enforcement Facility (Hardy County Sheriff's Office)

Figure 5. 33 - Comparative Analysis of Conceptual Microgrid Scenarios for the Moorefield Site



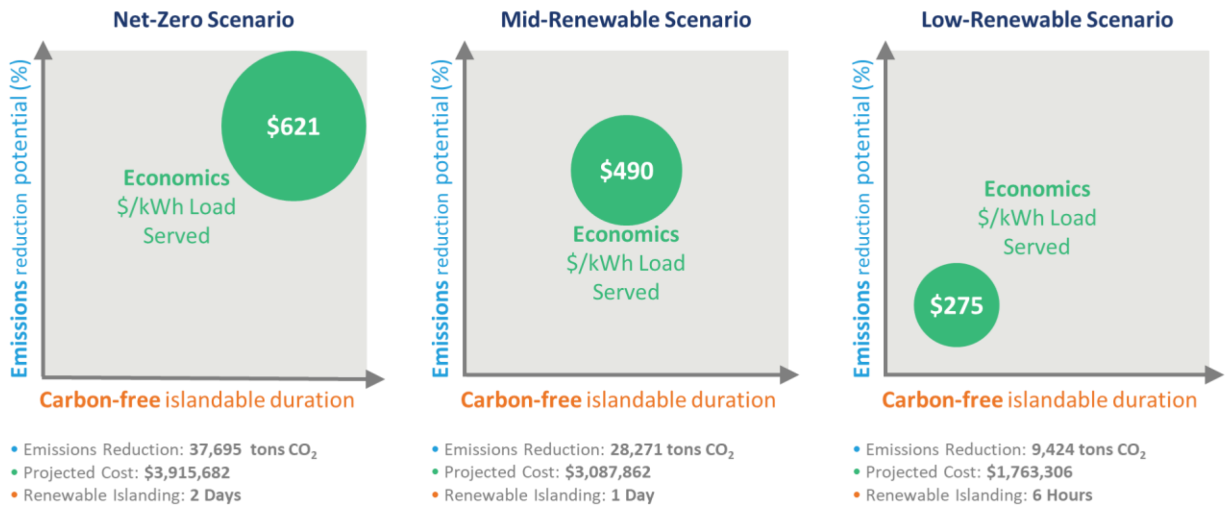
Source: Smart Electric Power Alliance, 2022

Martinsburg

The Martinsburg community microgrid includes five critical facilities within its electrical boundary:

- Convenience Store (7-Eleven)
- Emergency Services (Martinsburg Fire Department)
- Educational Facility (Burke Street Elementary School / Designated Shelter)
- Place of Worship (Calvary United Methodist Church / Designated Shelter)
- Law Enforcement Facility (Martinsburg Police Department)

Figure 5. 34 - Comparative Analysis of Conceptual Microgrid Scenarios for the Martinsburg Site



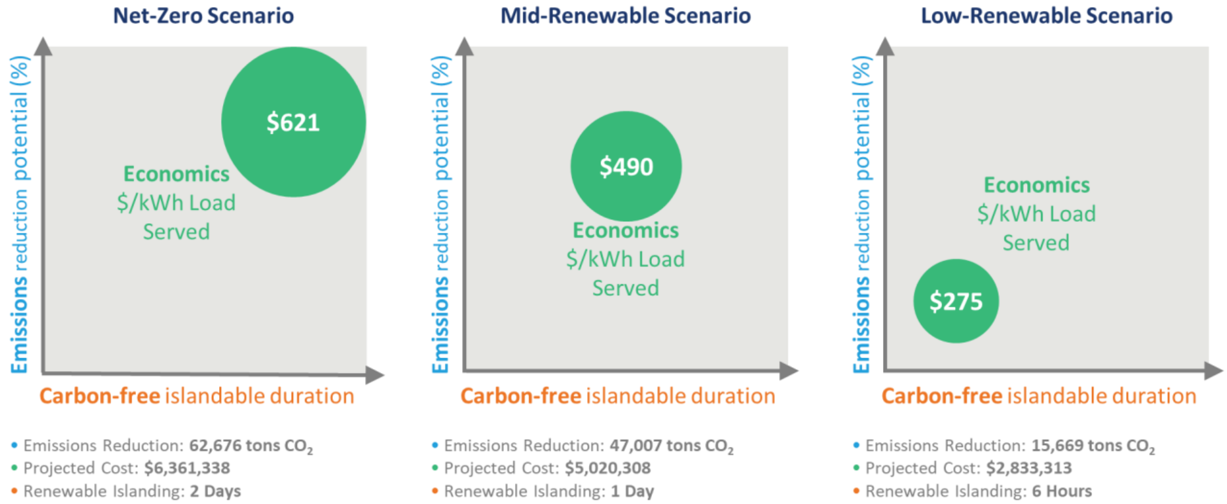
Source: Smart Electric Power Alliance, 2022

Bluefield

The Bluefield community microgrid includes three critical facilities within its electrical boundary:

- Educational Facility (Bluefield State College)
- Grocery Store (Grant's SuperMarket)
- Emergency Services (Bluefield Fire Department Station 1)

Figure 5. 35 - Comparative Analysis of Conceptual Microgrid Scenarios for the Bluefield Site



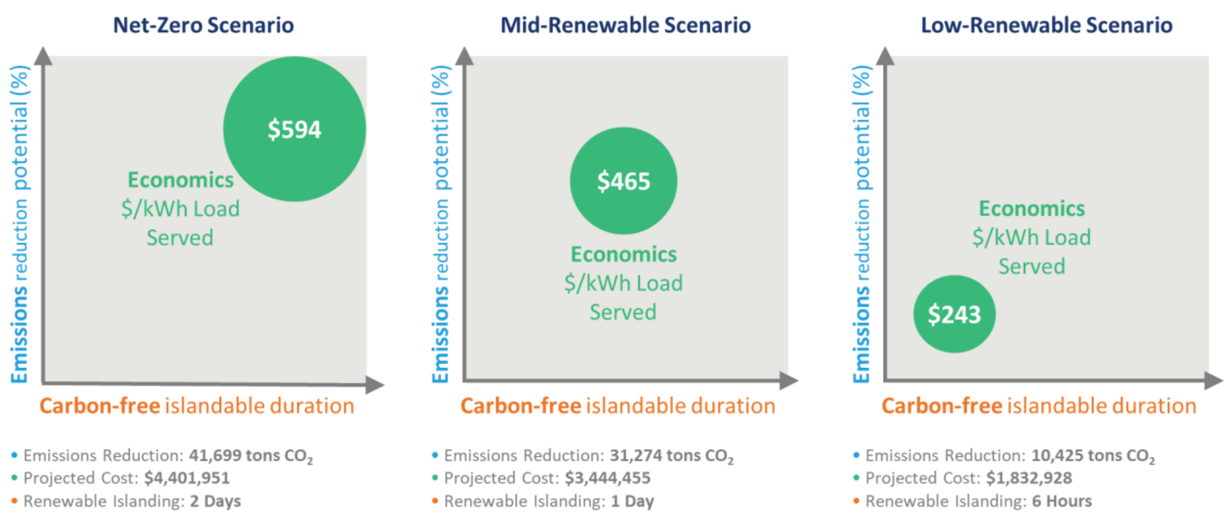
Source: Smart Electric Power Alliance, 2022

Ronceverte

The Ronceverte community microgrid includes four critical facilities within its electrical boundary:

- Law Enforcement Facility (Ronceverte Police Department)
- Gas Station (Ronceverte Service Station)
- Grocery Store (Kroger)
- Emergency Services (Ronceverte Volunteer Fire Department)

Figure 5. 36 - Comparative Analysis of Conceptual Microgrid Scenarios for the Ronceverte Site



Source: Smart Electric Power Alliance, 2022

Table 5. 2 - Community Microgrid Deployment Strategy Capital and O&M Cost Estimates

Community Microgrids	Low-Renewable Design Cost, $ ($/kWh served)	Mid-Renewable Design Cost, $ ($/kWh served)	High-Renewable Design Cost, $ ($/kWh served)
Microgrid	**Per facility**	**Per facility**	**Per facility**
Charleston East Side	1,496,378 (274)	2,623,892 (490)	3,279,205 (612)
Charleston West Side	3,937,506 (265)	6,268,002 (433)	7,829,303 (539)
Winfield	3,306,598 (252)	6,399,103 (496)	8,182,016 (633)
Westmoreland (Huntington)	2,456,849 (249)	4,525,154 (468)	5,714,520 (590)
Clendenin	1,473,389 (259)	2,468,489 (443)	2,956,201 (532)
New Martinsville	3,309,726 (283)	5,306,447 (457)	6,744,788 (580)
Rivesville	1,493,052 (258)	2,499,805 (443)	3,149,410 (556)
Edgemont	1,541,023 (276)	2,716,765 (496)	3,448,259 (628)
Weston	1,802,565 (250)	3,291,121 (465)	4,204,498 (593)
Elkins	1,767,880 (249)	3,502,370 (501)	4,476,040 (639)
Moorefield	4,031,376 (246)	7,575,720 (471)	9,611,620 (596)
Martinsburg	1,763,306 (275)	3,087,862 (490)	3,915,682 (621)
Bluefield	2,833,313 (251)	5,020,308 (455)	6,361,338 (575)
Ronceverte	1,832,928 (243)	3,444,455 (465)	4,401,951 (594)

Source: Smart Electric Power Alliance, 2022.

6.0 Conclusion

When strategically located, a microgrid's ability to island from the traditional power grid enables it to provide increased resilience to a critical facility. The analysis included in this study provides a blueprint for West Virginia utilities, local and state governments and other stakeholders to develop microgrid deployment strategies that help critical facilities achieve desired resilience outcomes and improve the electric power grid as a whole. When developing these strategies, it is important to take a holistic approach that involves the consideration of both site-specific and regional community microgrids. Based on the objectives and constraints, utilizing one or both approaches may make the most sense and provide the most value.

SEPA identified several key takeaways from the microgrid deployment approaches outlined within this study, including:

- Customers need to first understand resilience is a grid issue that can be solved in many different types of ways. It is important to consider microgrids as one solution of many to be explored.
- Evaluating microgrids by looking at the problems they are trying to solve and the services they can provide is a key step to build an understanding of where microgrids can provide the most resilience value in West Virginia
- Utilizing this study to facilitate early and often coordination between utilities, local and state governments and other stakeholders in West Virginia, who each have specific roles and responsibilities can support utility operations and planning of the electric system and emergency preparedness planning
- Identifying potential microgrid sites for community resilience in West Virginia requires a combination of inventorying critical infrastructure facilities, defining areas of natural hazard, system and social vulnerabilities, and evaluating load profiles and microgrid scenarios
- While this study focuses on microgrids as a community resilience solution, the mapping tools and datasets compiled as a part of this project can be leveraged for energy and community resilience planning across the state

In addition to outlining the role microgrids can play in enhancing community resilience, this study also highlights the importance of conducting a highly-coordinated planning effort across relevant stakeholder organizations and entities. This approach to coordination should be replicated in future plans.

SEPA is confident that the results of this study will support the future deployment of microgrids in West Virginia and contribute to increasing the resilience of the electric power grid against natural disasters and severe weather events.

There are several next steps for WVOE to put these microgrid deployment strategies into action across the state of West Virginia:

- Update state energy assurance and hazard mitigation planning with microgrids for resilience strategies outlined in this study
- Build partnerships between utilities, local and state governments, and other stakeholders at identified microgrid locations and census tracts with resilience needs
- Pursue FEMA BRIC applications to conduct site-specific feasibility studies and build microgrids prioritized in this study with key stakeholders from West Virginia Emergency Management Division and FEMA
- Pursue potential microgrid projects and associated funding applied towards projects located on or near-by mine lands
- Pursue IIJA state formula funding to conduct additional technical assistance and stakeholder engagement at specific sites or within specific communities
- Coordinate with utilities on integrating results and analysis in this study with utility distribution and integrated resource planning

7.0 Appendices

Table 7. 0 - List of Stakeholder Organizations

Stakeholder Organizations	
American Federation of Labor and Congress of Industrial Organizations	Pickering Energy Solutions
Allegheny Science & Technology	PJM Interconnection LLC
Appalachian Mountain Advocates	Polymer Alliance Zone
Appalachian Power Company	The Potomac Edison Company
Association of Counties	Power In My Back Yard
Black Diamond Power Company	Region Planning & Development Councils
Camp Dawson	Revolt Energy
Chemical Alliance Zone	Sierra Club WV Chapter
Citizen Action Group	Solar Holler
City of Smithers	Solar United Neighbors
Clone Capital, LLC	West Virginia Community Development Hub
Consumer Advocate Division WV	Tri-State/Service Roofing & Sheet Metal Group
Contractors Association of West Virginia	West Virginia Energy Users Group
Craig-Botetourt Electric Cooperative	West Virginia GIS Technical Center
Energy Efficient WV	West Virginia Office of Energy
Gas and Oil Association of WV	West Virginia Oil Marketers and Grocers Association
Geostellar	West Virginia Public Service Commission
Harrison Rural Electric Association	Wheeling City Council
Healthcare Education Foundation of West Virginia Emergency Preparedness	Wheeling Power Company
Home Builders Association of WV	WV American Society of Heating and Air-Conditioning Engineers
Interfaith Power and Light	WV Association of Counties
Leafkey	WV Center on Budget & Policy
Philippi Municipal Electric	WV Chapter of American Institute of Architects
Marshall University	WV Municipal League
Milestone Solar Consultants	WV Society of Professional Engineers
Monongahela Power Company (Mon Power)	WV Voluntary Organizations Active in Disaster

Mountain View Solar & Wind	West Virginia Department of Environmental Protection
Municipal League	WVU College of Law Center for Energy
New Martinsville Municipal Electric	WVU Energy Institute
New Vision Renewable Energy	Green Shepherd, LLC
Philippi Municipal Electric	West Virginia Emergency Management Division

Appendix 1: Detailed Load, Sizing and Cost Analysis for Site-Specific Microgrids

This appendix includes the detailed load analysis, sizing, and economic analysis for site-specific microgrids.

Grocery Stores

Load and Solar Analysis

The grocery store load profile used in this study is an average of hourly load values from the Open Energy Data Initiative (OEDI)[28] for "Supermarkets" in Climate Zones 4A and 5A, to align to the IECC climate zones that fall within West Virginia. The load profile represents average hourly facility load for a 45,000 sqft., 1 floor supermarket.

[28] Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States

Figure 7. 1 - Grocery Store Load and Solar Analysis

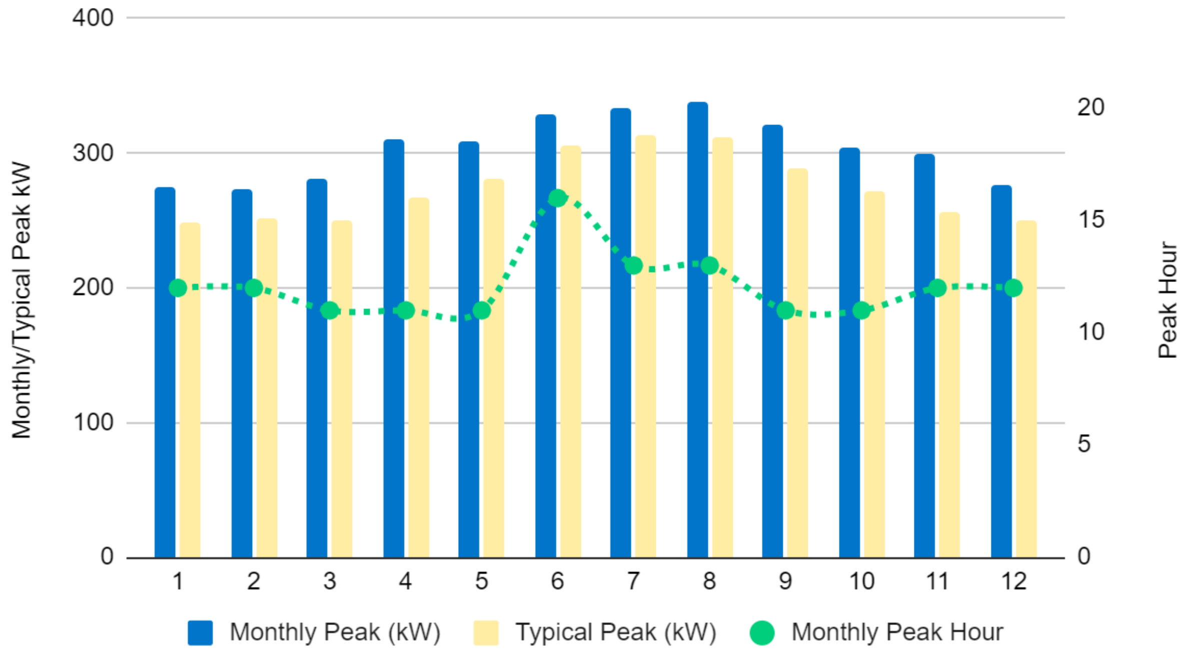


Figure 7. 2 - Proposed Solar Generation and Energy Consumption (Grocery Stores)

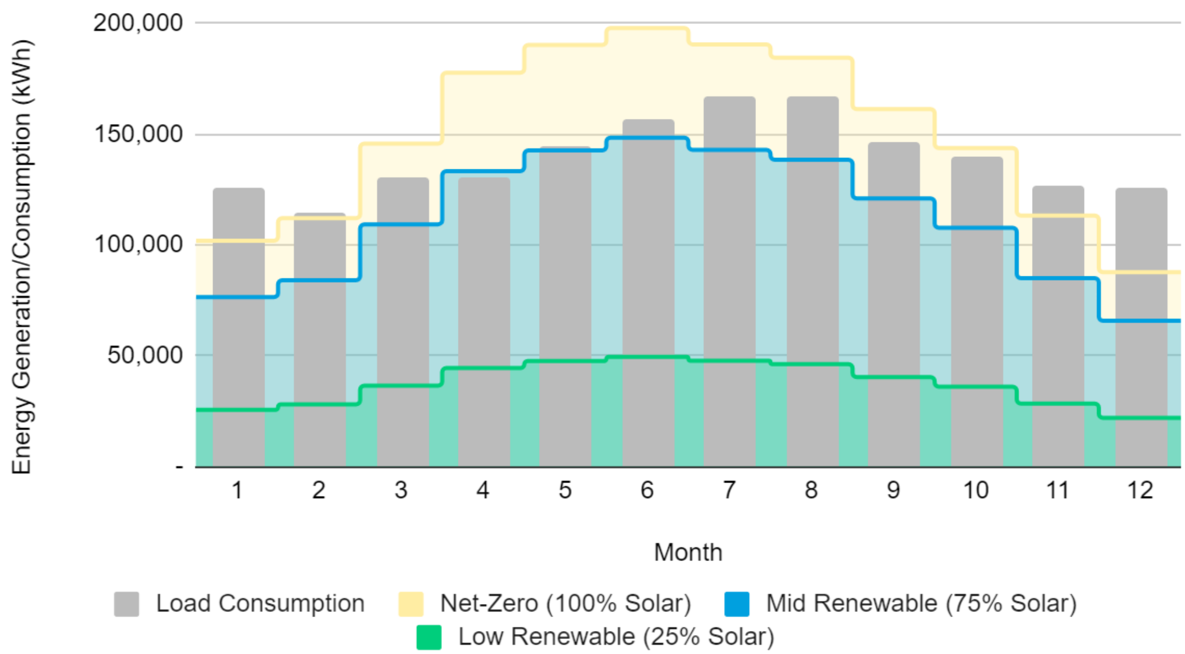


Table 7. 1 – Grocery Stores Microgrid Sizing

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1371	1029	343
Battery Capacity (kW)	350	275	200
Battery Capacity (kWh, 4-hour)	1400	1100	800
Standby Generation (kW)	0	150	185

Table 7. 2 –Microgrid Scenarios Economic Analysis (Grocery Store)

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,281,158	2,131,750	2,075,011	1,710,868	1,598,813	1,556,258	570,289	532,938	518,753
Battery ($)	636,756	567,078	462,487	500,308	445,561	363,383	363,861	324,045	264,278
Standby Generator ($)	-	-	-	75,000	60,000	45,000	92,500	74,000	55,500
Design, IT, Operational ($)	555,793	514,063	483,333	435,462	400,833	374,217	195,552	177,330	159,720
Component Costs ($)	3,473,707	3,212,891	3,020,831	2,721,639	2,505,207	2,338,858	1,222,202	1,108,312	998,251
Solar NPV O&M ($)	273,009	217,075	193,839	204,757	162,806	145,380	68,252	54,269	48,460
Battery NPV O&M ($)	163,586	126,801	87,527	128,532	99,629	68,771	93,478	72,458	50,015
Total O&M ($)	436,595	343,876	281,366	333,289	262,436	214,151	161,730	126,726	98,475
Total Project Costs ($)	3,910,302	3,556,767	3,302,197	3,054,928	2,767,643	2,553,009	1,383,932	1,235,039	1,096,726

Law Enforcement Facilities

Load and Solar Analysis

The law enforcement facility load profile used in this study was provided to SEPA by American Electric Power (AEP) from a law enforcement facility located in climate zone 4A. The sample facility had a similar footprint and functionality of buildings taken from a representative sample of identified critical facilities.

Figure 7. 3 - Law Enforcement Load and Solar Analysis

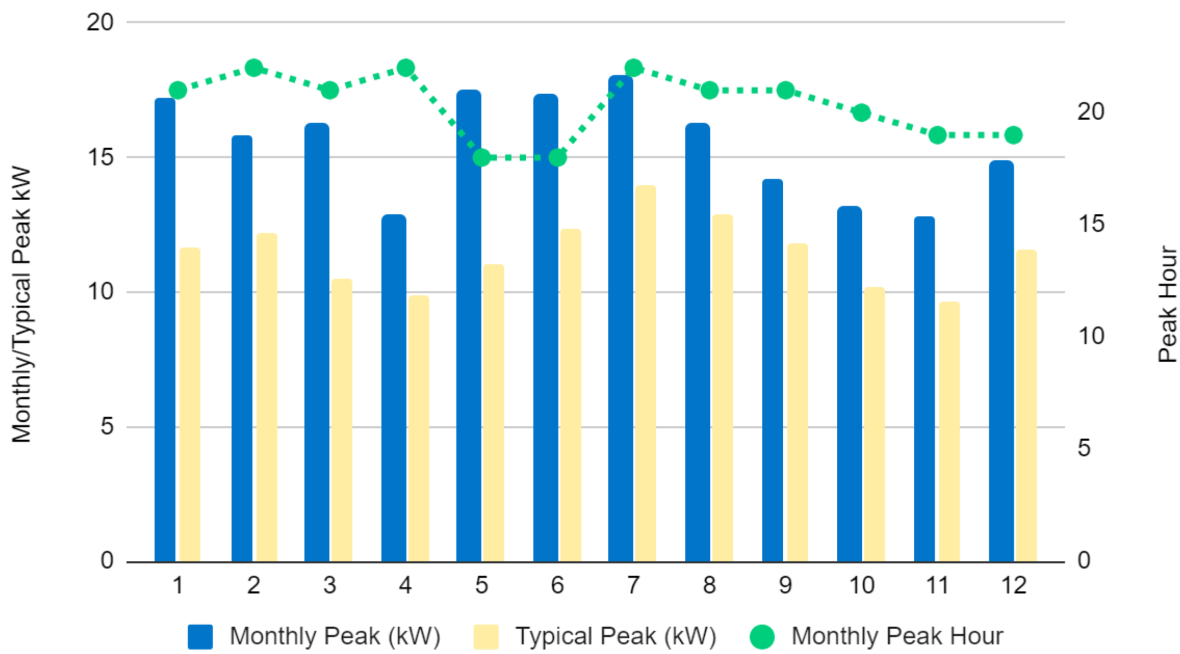


Figure 7. 4 - Proposed Solar Generation and Energy Consumption (Law Enforcement)

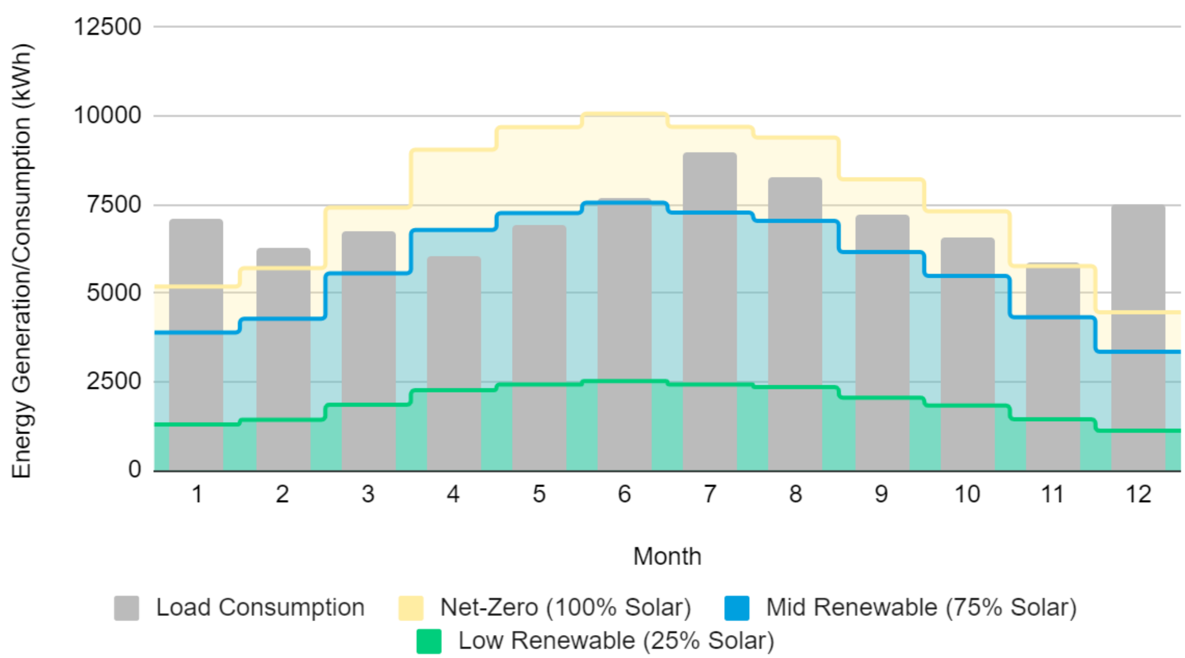


Table 7. 3 - Law Enforcement Microgrid Sizing

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	70	52	17
Battery Capacity (kW)	25	20	15
Battery Capacity (kWh, 4-hour)	100	80	60
Standby Generation (kW)	0	10	10

Table 7. 4 - Microgrid Scenarios Economic Analysis for Law Enforcement

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	116,071	108,469	105,582	87,053	81,352	79,186	29,018	27,117	26,395
Battery ($)	45,483	40,506	33,035	36,386	32,404	26,428	27,290	24,303	19,821
Standby Generator ($)	-	-	-	5,000	4,000	3,000	5,000	4,000	3,000
Design, IT, Operational ($)	30,772	28,376	26,403	24,465	22,430	20,688	11,678	10,556	9,375
Component Costs ($)	192,326	177,350	165,020	152,904	140,186	129,302	72,985	65,977	58,591
Solar NPV O&M ($)	13,891	11,045	9,863	10,419	8,284	7,397	3,473	2,761	2,466
Battery NPV O&M ($)	11,685	9,057	6,252	9,348	7,246	5,002	7,011	5,434	3,751
Total O&M ($)	25,576	20,103	16,115	19,766	15,530	12,399	10,484	8,196	6,217
Total Project Costs ($)	217,902	197,453	181,135	172,670	155,715	141,701	83,469	74,172	64,808

Other Healthcare Facilities

Load and Solar Analysis

The other healthcare facility load profile used in this study is an average of hourly load values from OEDI for "Outpatient Health Care" in Climate Zones 4A and 5A, to align to the IECC climate zones that fall within West Virginia. The load profile represents average hourly facility load for a 40,946 sqft., 3 floor facility.

Figure 7. 5 - Other Healthcare Facilities Load Analysis

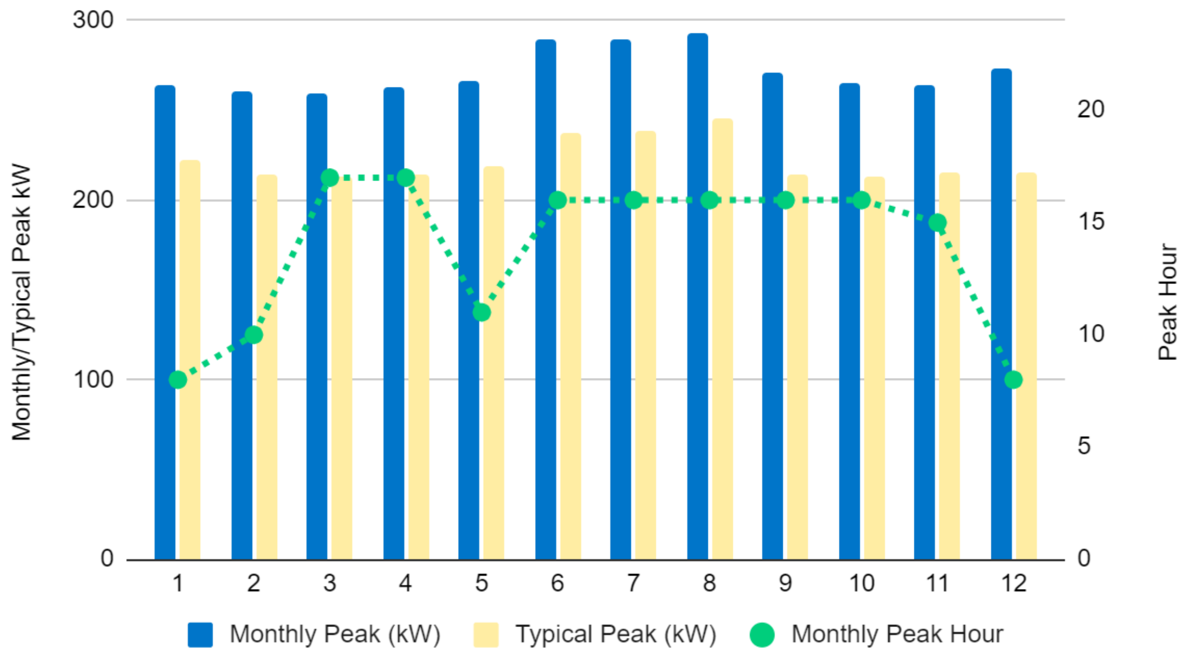


Figure 7. 6 - Proposed Solar Generation and Energy Consumption (Other Healthcare Facilities)

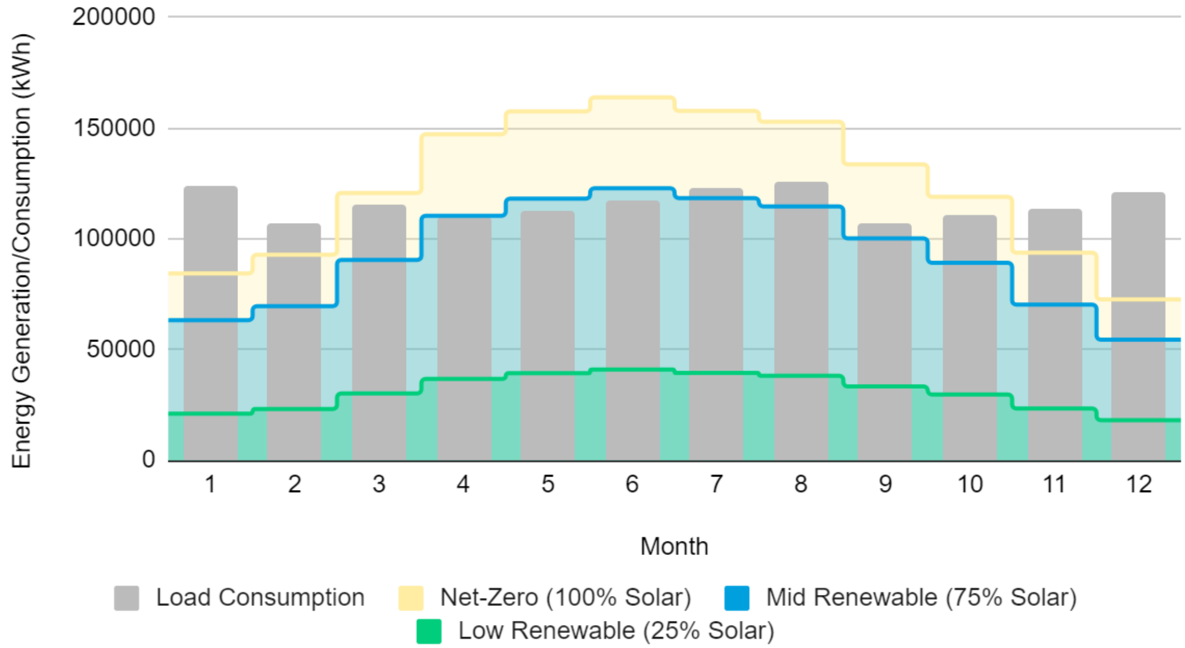


Table 7. 5 - Microgrid Sizing for Other Healthcare Facilities

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1136	852	284
Battery Capacity (kW)	250	200	150
Battery Capacity (kWh, 4-hour)	1000	800	600
Standby Generation (kW)	0	160	185

Table 7. 6 - Microgrid Scenarios Economic Analysis for Healthcare Facilities

	High Renewable			**Mid Renewable**			**Low Renewable**		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	1,889,122	1,765,392	1,718,404	1,416,842	1,324,044	1,288,803	472,281	441,348	429,601
Battery ($)	454,826	405,056	330,348	363,861	324,045	264,278	272,895	243,033	198,209

Standby Generator ($)	-	-	-	80,000	64,000	48,000	92,500	74,000	55,500
Design, IT, Operational ($)	446,466	413,419	390,238	354,420	326,112	304,968	159,557	144,454	130,154
Component Costs ($)	2,790,415	2,583,866	2,438,990	2,215,122	2,038,201	1,906,049	997,233	902,835	813,464
Solar NPV O&M ($)	226,090	179,769	160,527	169,568	134,827	120,395	56,523	44,942	40,132
Battery NPV O&M ($)	116,847	90,572	62,519	93,478	72,458	50,015	70,108	54,343	37,511
Total O&M ($)	342,937	270,341	223,046	263,045	207,284	170,410	126,631	99,286	77,643
Total Project Costs ($)	3,133,352	2,854,207	2,662,036	2,478,167	2,245,485	2,076,459	1,123,864	1,002,120	891,107

Water Treatment Facilities

Load and Solar Analysis

The water treatment facility load profile used in this study was provided to SEPA by AEP from a water treatment facility located in climate zone 4A. The sample facility had a much smaller footprint than facilities taken from a representative sample of identified critical facilities. SEPA adjusted hourly loads evenly based on the comparative annual consumption of a more representative facility that serves 55,000 customers, processes an average of 5.5 million gallons per day (MGD) and can handle flows of up to 26 MGD. The sample facility had a similar footprint and functionality of buildings taken from a representative sample of identified critical facilities.

Figure 7. 7 - Water Treatment Plant Load and Solar Analysis

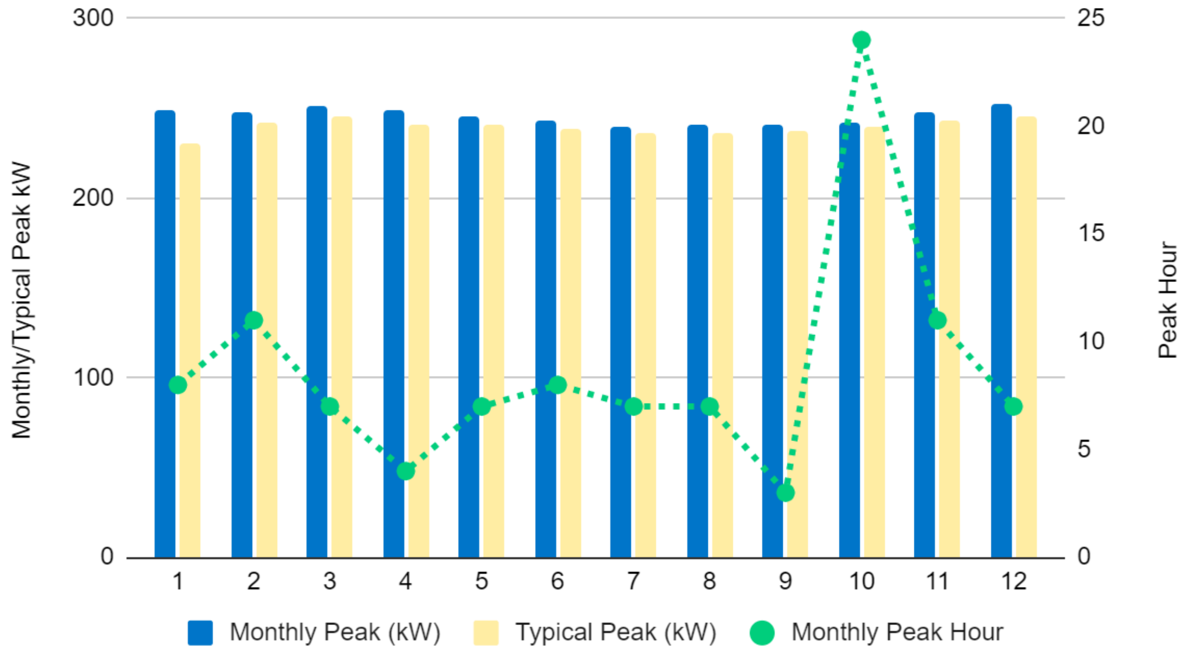


Figure 7. 8 - Proposed Solar Generation and Energy Consumption (Water Treatment Plants)

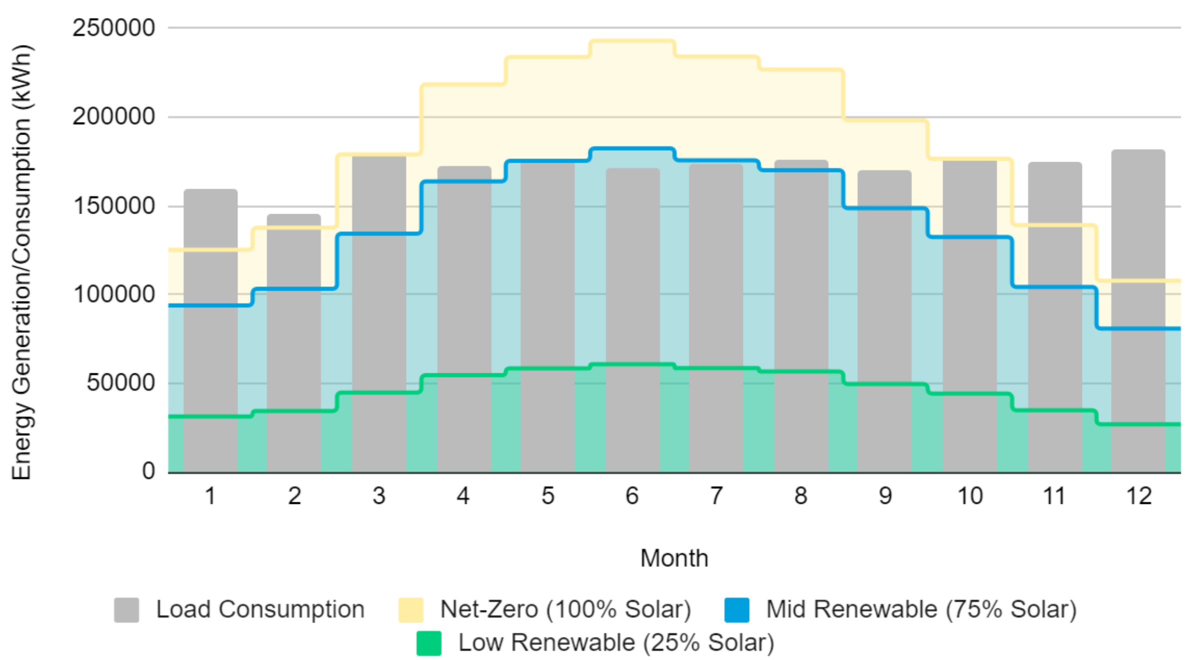


Table 7. 7 - Microgrid Sizing for Water Treatment Plants

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1685	1264	421
Battery Capacity (kW)	1200	825	375
Battery Capacity (kWh, 4-hour)	4800	3300	1500
Standby Generation (kW)	0	180	220

Table 7. 8 - - Microgrid Scenarios Economic Analysis for Water Treatment Plant

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,803,446	2,619,830	2,550,100	2,102,584	1,964,873	1,912,575	700,861	654,958	637,525
Battery ($)	2,183,164	1,944,267	1,585,670	1,500,925	1,336,684	1,090,148	682,239	607,583	495,522
Standby Generator ($)	-	-	-	90,000	72,000	54,000	110,000	88,000	66,000
Design, IT, Operational ($)	949,830	869,352	787,766	703,526	642,582	582,233	284,400	257,246	228,390
Component Costs ($)	5,936,440	5,433,449	4,923,536	4,397,035	4,016,139	3,638,956	1,777,500	1,607,787	1,427,437
Solar NPV O&M ($)	335,516	266,776	238,220	251,637	200,082	178,665	83,879	66,694	59,555
Battery NPV O&M ($)	560,866	434,746	300,092	385,595	298,888	206,313	175,271	135,858	93,779
Total O&M ($)	896,382	701,522	538,312	637,233	498,970	384,979	259,150	202,552	153,334
Total Project Costs ($)	6,832,822	6,134,972	5,461,848	5,034,268	4,515,109	4,023,935	2,036,650	1,810,339	1,580,771

Education Facilities

Load and Solar Analysis

The education facility load profile used in this study is an average of hourly load values from a sample K-12 facility provided by FirstEnergy, and OEDI load profiles for "Primary School" and “Secondary School” in Climate Zones 4A and 5A, to align to the IECC climate zones that fall within West Virginia. The load profile represents the average footprint and functionality of buildings taken from a representative sample of identified critical facilities.

Figure 7. 9 - Education Facilities Load and Solar Analysis

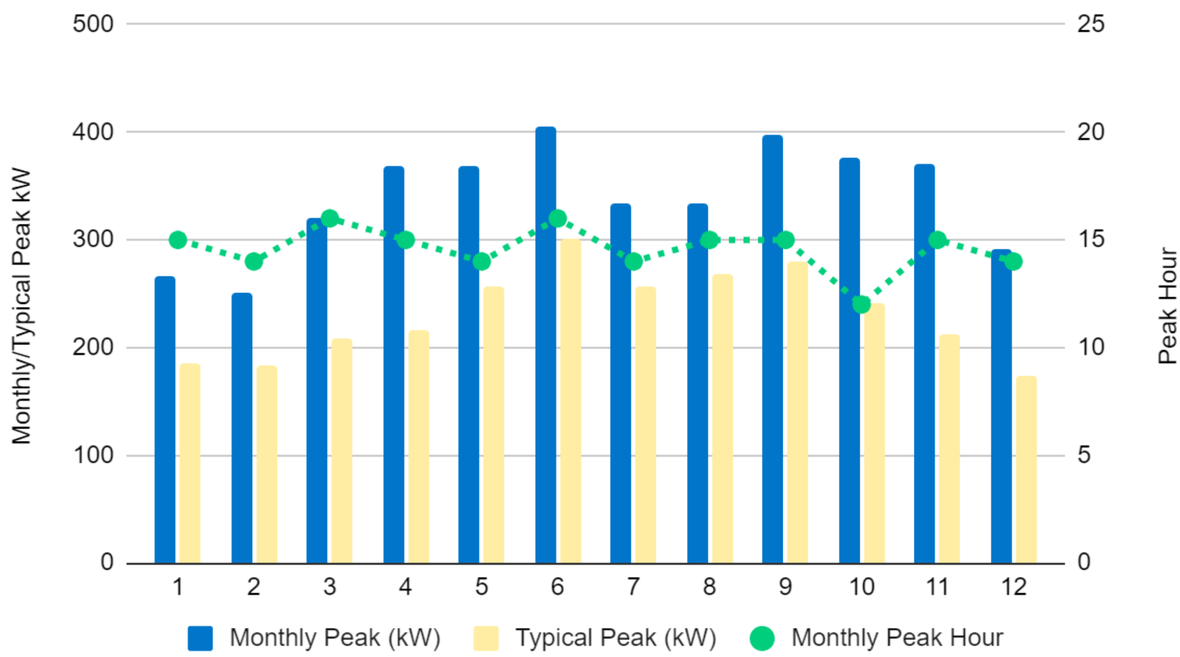


Figure 7. 10 - Proposed Solar Generation and Energy Consumption (Education Facilities)

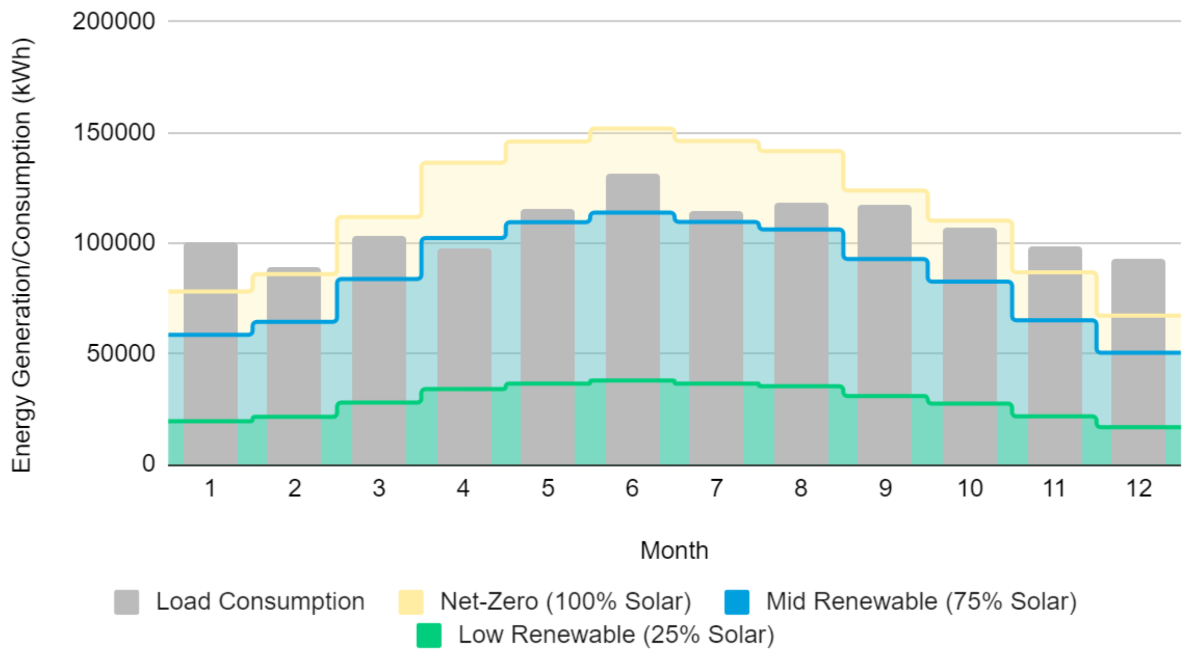


Table 7. 9 - Microgrid Sizing for Education Facilities

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1052	789	263
Battery Capacity (kW)	215	180	225
Battery Capacity (kWh, 4-hour)	860	720	900
Standby Generation (kW)	0	185	225

Table 7. 10 - Microgrid Scenarios Economic Analysis (Education Faciltiies)

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	1,749,954	1,635,338	1,591,812	1,312,465	1,226,504	1,193,859	437,488	408,835	397,953
Battery ($)	391,150	348,348	284,099	327,475	291,640	237,851	409,343	364,550	297,313

Standby Generator ($)	-	-	-	92,500	74,000	55,500	112,500	90,000	67,500
Design, IT, Operational ($)	407,829	377,845	357,316	329,989	303,265	283,278	182,730	164,454	145,289
Component Costs ($)	2,548,933	2,361,531	2,233,227	2,062,429	1,895,409	1,770,487	1,142,062	1,027,839	908,055
Solar NPV O&M ($)	209,435	166,526	148,701	157,076	124,894	111,526	52,359	41,631	37,175
Battery NPV O&M ($)	100,488	77,892	53,766	84,130	65,212	45,014	105,162	81,515	56,267
Total O&M ($)	309,923	244,418	202,467	241,206	190,106	156,539	157,521	123,146	93,442
Total Project Costs ($)	2,858,856	2,605,949	2,435,694	2,303,634	2,085,516	1,927,027	1,299,583	1,150,985	1,001,497

Emergency Services

Load and Solar Analysis

The emergency services load profile used in this study was provided to SEPA by AEP from a fire station located in climate zone 4A. The sample facility had a similar footprint and functionality to buildings taken from a representative sample of identified critical facilities.

Figure 7. 11 - Emergency Services Load and Solar Analysis

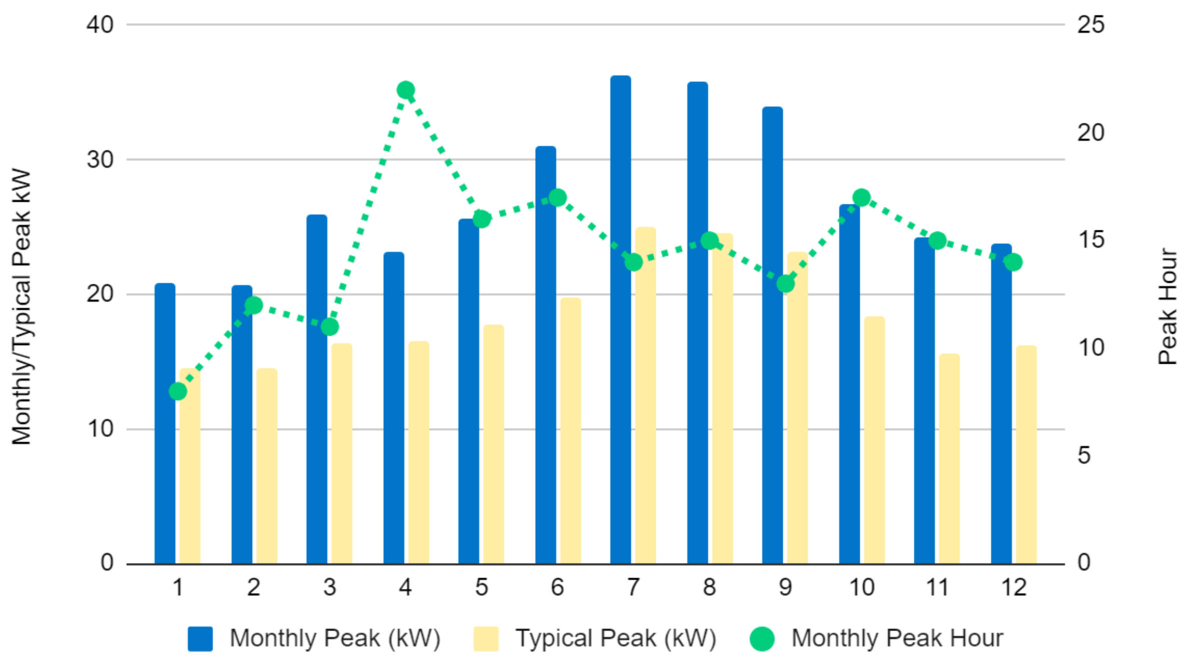


Figure 7. 12 - Proposed Solar Generation and Energy Consumption (Emergency Services)

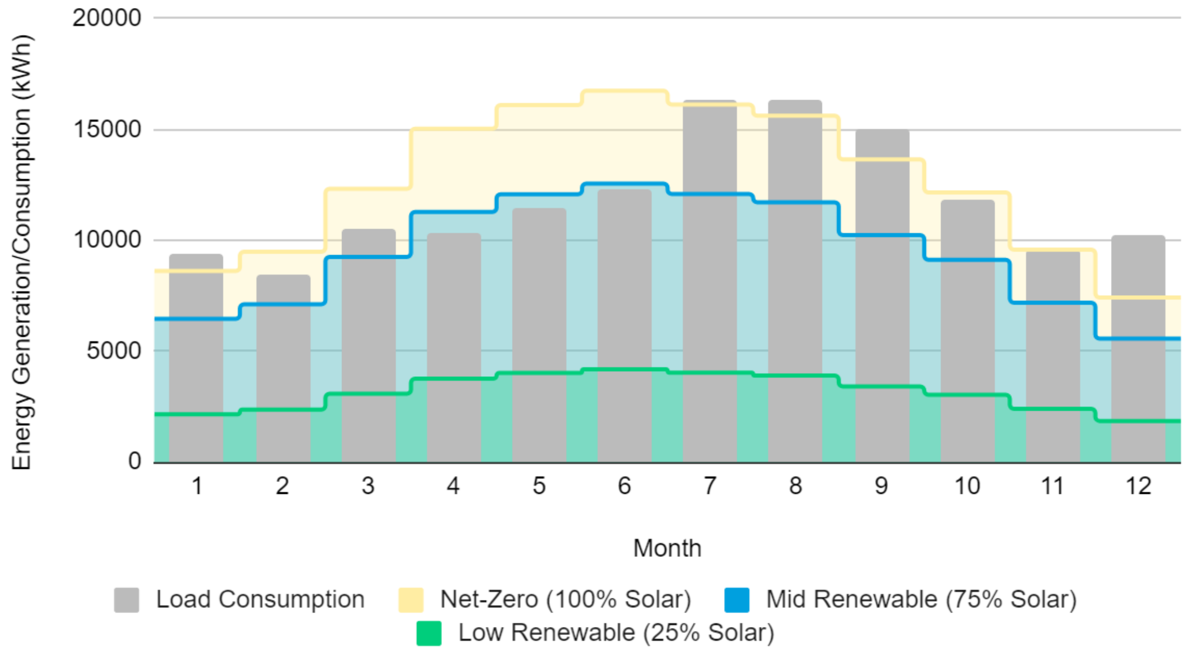


Table 7. 11 - Microgrid Sizing for Emergency Services

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	116	87	29
Battery Capacity (kW)	45	35	25
Battery Capacity (kWh, 4-hour)	180	140	100
Standby Generation (kW)	0	20	25

Table 7. 12 - Microgrid Scenarios Economic Analysis for Emergency Services

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	192,925	180,289	175,490	144,694	135,217	131,618	48,231	45,072	43,873
Battery ($)	81,869	72,910	59,463	63,676	56,708	46,249	45,483	40,506	33,035

Standby Generator ($)	-	-	-	10,000	8,000	6,000	12,500	10,000	7,500
Design, IT, Operational ($)	52,342	48,228	44,753	41,594	38,081	35,022	20,231	18,205	16,078
Component Costs ($)	327,135	301,428	279,706	259,964	238,006	218,889	126,445	113,783	100,485
Solar NPV O&M ($)	23,089	18,359	16,394	17,317	13,769	12,295	5,772	4,590	4,098
Battery NPV O&M ($)	21,032	16,303	11,253	16,359	12,680	8,753	11,685	9,057	6,252
Total O&M ($)	44,122	34,662	27,647	33,676	26,449	21,048	17,457	13,647	10,350
Total Project Costs ($)	371,257	336,089	307,353	293,639	264,455	239,937	143,902	127,430	110,835

Gas Stations

Load and Solar Analysis

The gas station load profile used in this study was provided to SEPA by AEP from a gas station located in climate zone 4A. The sample facility had a similar footprint and functionality to buildings taken from a representative sample of identified critical facilities.

Figure 7. 13 - Gas Station Load and Solar Analysis

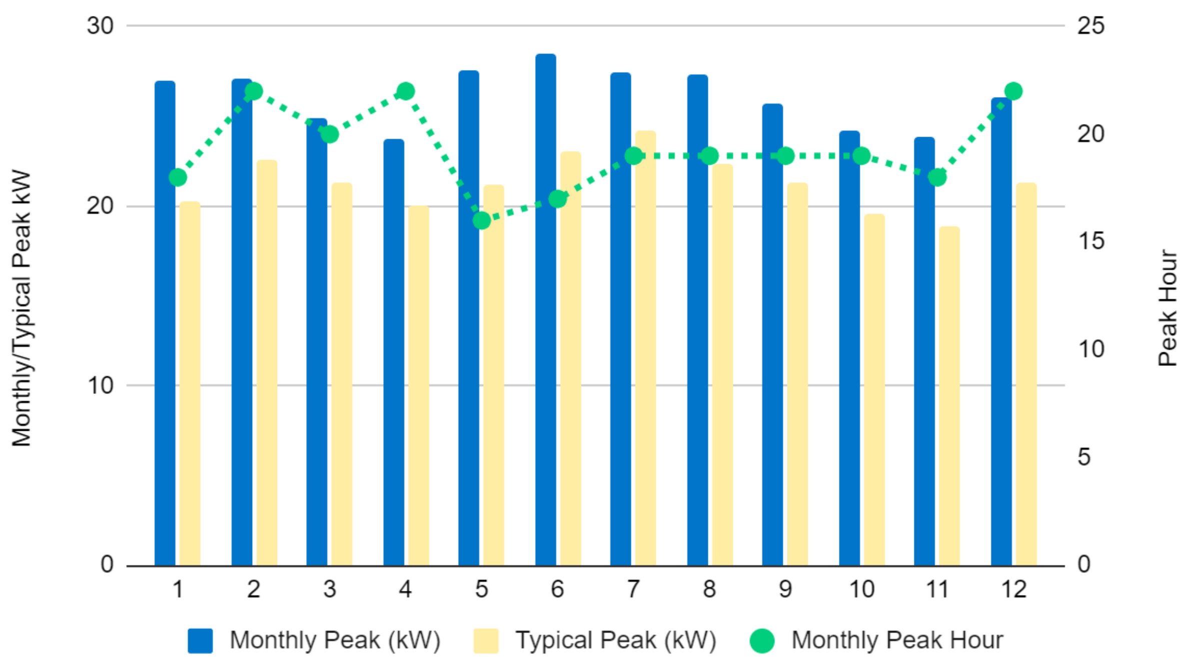


Figure 7. 14 - Proposed Solar Generation and Energy Consumption (Gas Stations)

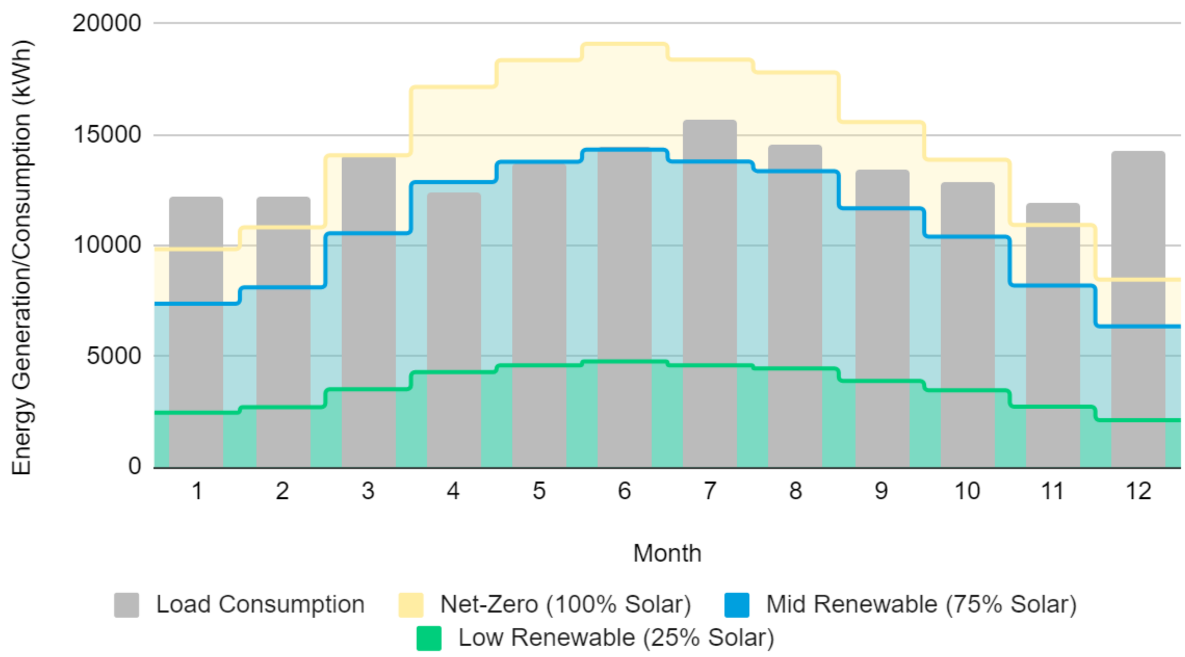


Table 7. 13 - Microgrid Sizing for Gas Stations

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	132	99	33
Battery Capacity (kW)	40	30	25
Battery Capacity (kWh, 4-hour)	160	120	100
Standby Generation (kW)	0	20	20

Table 7. 14 - Microgrid Scenarios Economic Analysis (Gas Stations)

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	220,110	205,694	200,219	165,083	154,270	150,164	55,028	51,423	50,055
Battery ($)	72,772	64,809	52,856	54,579	48,607	39,642	45,483	40,506	33,035

Standby Generator ($)	-	-	-	10,000	8,000	6,000	10,000	8,000	6,000
Design, IT, Operational ($)	55,787	51,524	48,205	43,745	40,167	37,296	21,050	19,034	16,969
Component Costs ($)	348,669	322,027	301,279	273,407	251,044	233,102	131,560	118,963	106,059
Solar NPV O&M ($)	26,343	20,946	18,704	19,757	15,709	14,028	6,586	5,236	4,676
Battery NPV O&M ($)	18,696	14,492	10,003	14,022	10,869	7,502	11,685	9,057	6,252
Total O&M ($)	45,038	35,437	28,707	33,779	26,578	21,530	18,270	14,294	10,928
Total Project Costs ($)	393,708	357,464	329,986	307,185	277,622	254,632	149,830	133,257	116,987

Convenience Stores

Load and Solar Analysis

The convenience store load profile used in this study was provided to SEPA by AEP from a convenience store located in climate zone 4A. The sample facility had a similar footprint and functionality to buildings taken from a representative sample of identified critical facilities.

Figure 7. 15 - Convenience Store Load and Solar Analysis

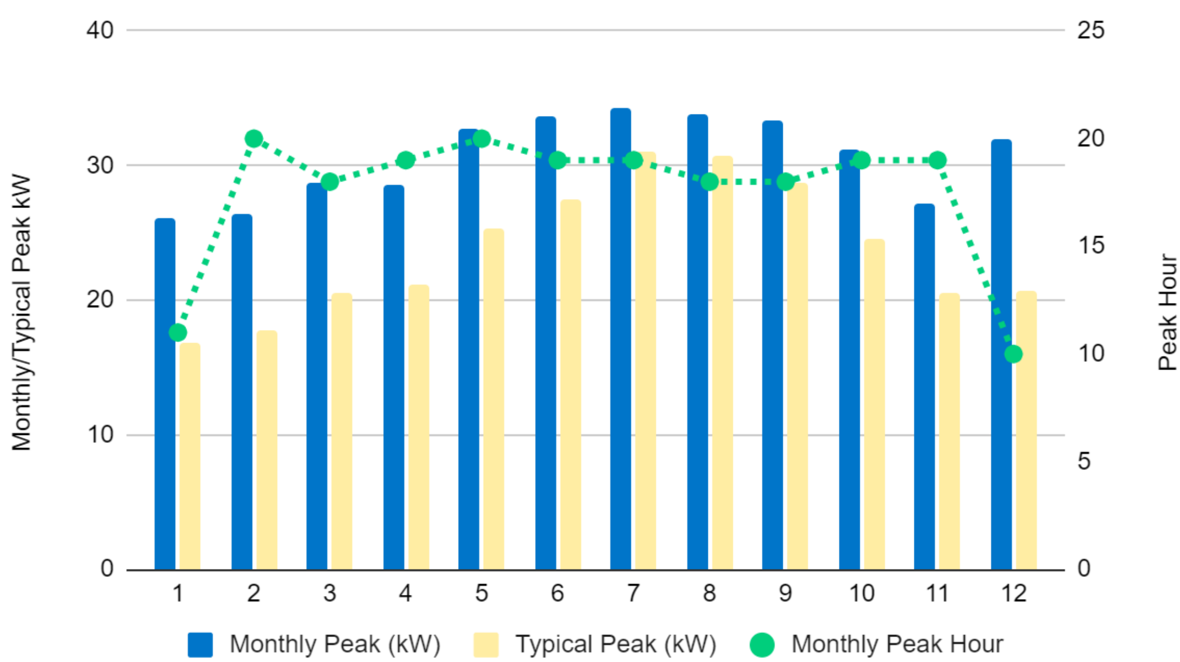


Figure 7. 16 - Proposed Solar Generation and Energy Consumption (Convenience Stores)

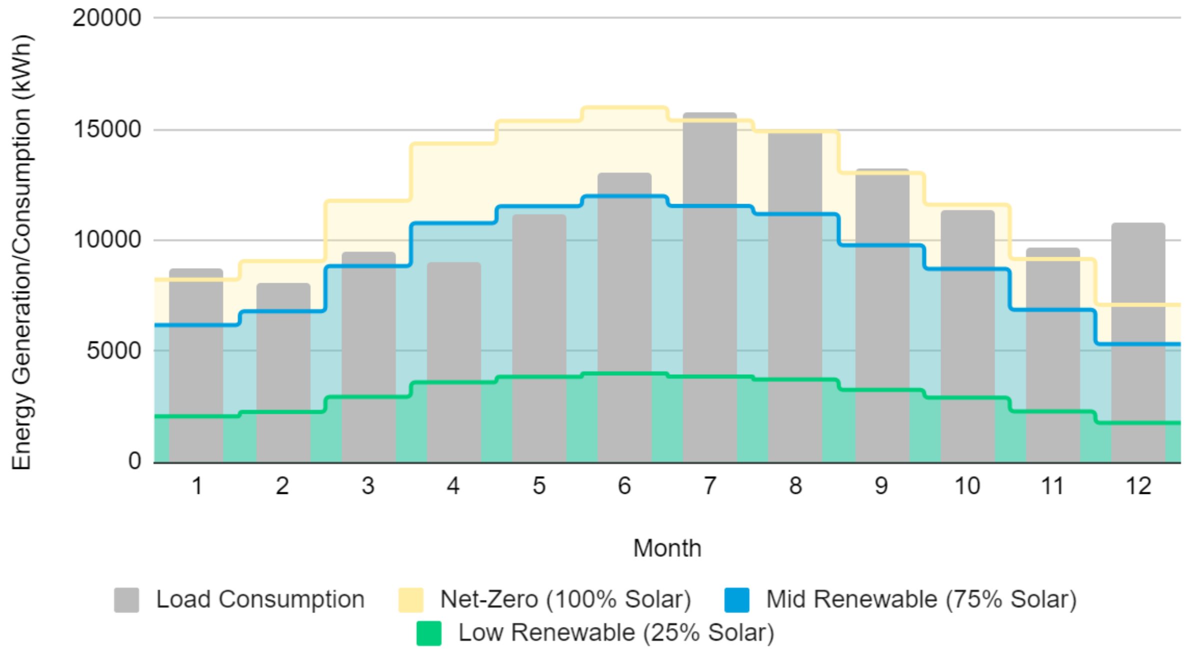


Table 7. 15 - Microgrid Sizing for Convenience Stores

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	111	83	28
Battery Capacity (kW)	38	35	30
Battery Capacity (kWh, 4-hour)	150	140	120
Standby Generation (kW)	0	15	20

Table 7. 16 - Microgrid Scenarios Economic Analysis for Convenience Stores

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	184,332	172,258	167,674	138,249	129,194	125,755	46,083	43,065	41,918
Battery ($)	68,224	60,758	49,552	63,676	56,708	46,249	54,579	48,607	39,642

Standby Generator ($)	-	-	-	7,500	6,000	4,500	10,000	8,000	6,000
Design, IT, Operational ($)	48,106	44,384	41,376	39,890	36,553	33,620	21,078	18,985	16,678
Component Costs ($)	300,661	277,401	258,602	249,315	228,454	210,124	131,740	118,656	104,238
Solar NPV O&M ($)	22,061	17,541	15,663	16,546	13,156	11,748	5,515	4,385	3,916
Battery NPV O&M ($)	17,527	13,586	9,378	16,359	12,680	8,753	14,022	10,869	7,502
Total O&M ($)	39,588	31,127	25,041	32,904	25,836	20,500	19,537	15,254	11,418
Total Project Costs ($)	340,249	308,528	283,643	282,219	254,290	230,624	151,277	133,910	115,656

Community Centers

Load and Solar Analysis

The community center load profile used in this study is an average of hourly load values from three sample facilities provided by FirstEnergy, a newer place of worship, an older place of worship, and a K-12 education facility. The load profile represents the average footprint and functionality of buildings taken from a representative sample of identified critical facilities.

Figure 7. 17 - Community Center Load and Solar Analysis

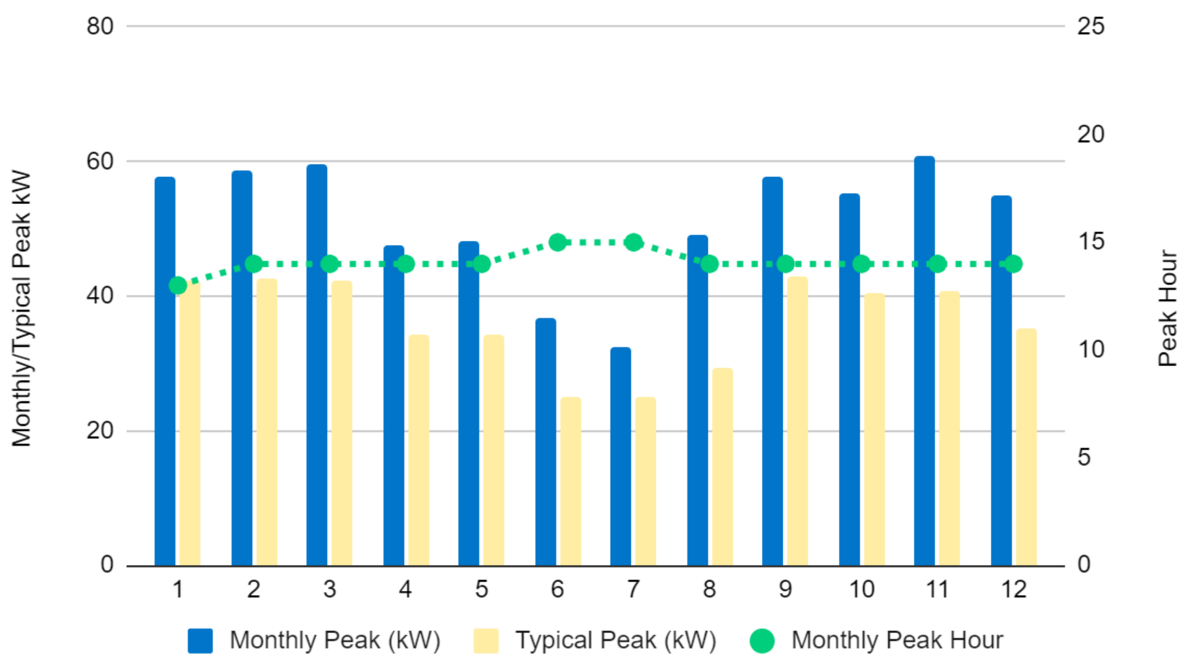


Figure 7. 18 - Proposed Solar Generation and Energy Consumption (Community Centers)

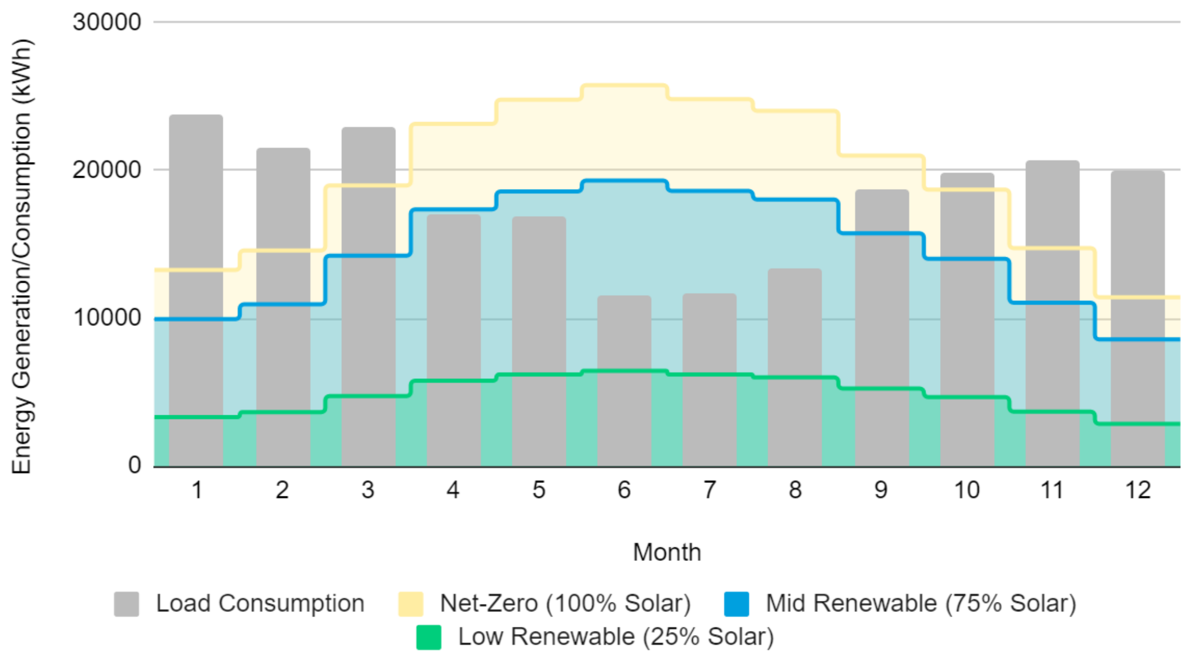


Table 7. 17 - Microgrid Sizing for Community Centers

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	179	134	45
Battery Capacity (kW)	100	80	45
Battery Capacity (kWh, 4-hour)	400	320	180
Standby Generation (kW)	0	25	35

Table 7. 18 - Microgrid Scenarios Economic Analysis for Community Centers

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	297,131	277,670	270,279	222,848	208,252	202,709	74,283	69,417	67,570
Battery ($)	181,930	162,022	132,139	145,544	129,618	105,711	81,869	72,910	59,463

Standby Generator ($)	-	-	-	12,500	10,000	7,500	17,500	14,000	10,500
Design, IT, Operational ($)	91,250	83,751	76,651	72,551	66,261	60,175	33,076	29,777	26,197
Component Costs ($)	570,311	523,443	479,070	453,443	414,131	376,096	206,728	186,104	163,729
Solar NPV O&M ($)	35,561	28,275	25,248	26,670	21,206	18,936	8,890	7,069	6,312
Battery NPV O&M ($)	46,739	36,229	25,008	37,391	28,983	20,006	21,032	16,303	11,253
Total O&M ($)	82,299	64,504	50,256	64,062	50,189	38,942	29,923	23,372	17,566
Total Project Costs ($)	652,610	587,947	529,326	517,505	464,320	415,039	236,650	209,476	181,295

Appendix 2: Detailed Load, Sizing and Cost Analysis for Community Microgrids

This appendix includes the detailed load analysis, sizing, and economic analysis for community microgrids.

Charleston East Side

Figure 7. 19 - Charleston East Side Load and Solar Analysis

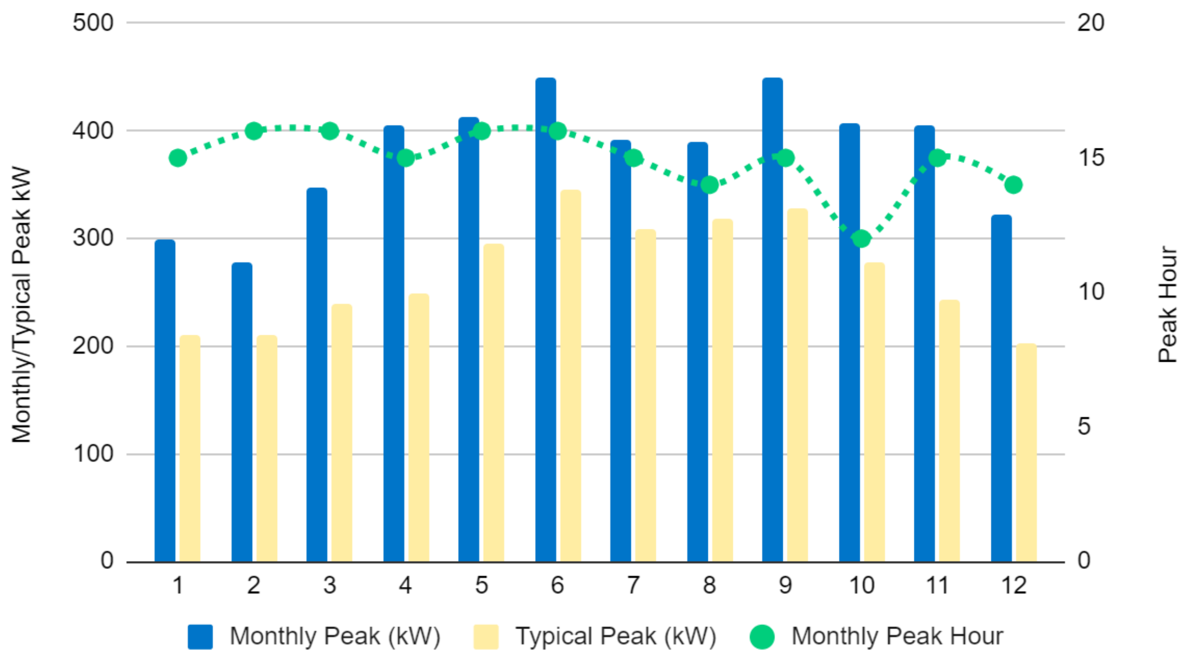


Figure 7. 20 - Proposed Solar Generation and Energy Consumption for Charleston East Side

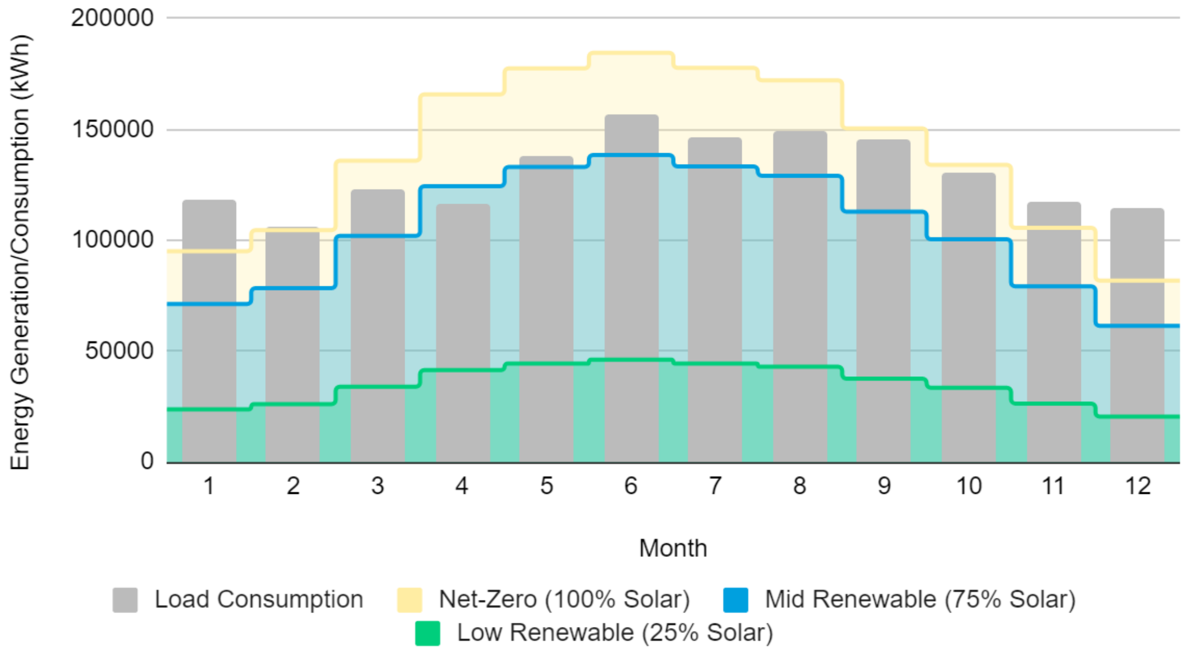


Table 7. 19 - Microgrid Sizing for Charleston East Side

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1279	959	320
Battery Capacity (kW)	310	270	325
Battery Capacity (kWh, 4-hour)	1240	1080	1300
Standby Generation (kW)	0	165	230

Table 7. 20 - Microgrid Scenarios Economic Analysis for Charleston East Side

	High Renewable			**Mid Renewable**			**Low Renewable**		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,127,210	1,987,886	1,934,976	1,595,408	1,490,914	1,451,232	531,803	496,971	483,744
Battery ($)	563,984	502,269	409,631	491,212	437,460	356,776	591,274	526,572	429,452

Standby Generator ($)	-	-	-	82,500	66,000	49,500	115,000	92,000	69,000
Design, IT, Operational ($)	512,608	474,315	446,592	413,166	379,881	353,811	235,824	212,485	187,085
Component Costs ($)	3,203,803	2,964,470	2,791,199	2,582,285	2,374,255	2,211,318	1,473,900	1,328,028	1,169,281
Solar NPV O&M ($)	254,585	202,425	180,758	190,938	151,819	135,568	63,646	50,606	45,189
Battery NPV O&M ($)	144,890	112,309	77,524	126,195	97,818	67,521	151,901	117,744	81,275
Total O&M ($)	399,475	314,735	258,282	317,133	249,637	203,089	215,547	168,350	126,464
Total Project Costs ($)	3,603,278	3,279,205	3,049,481	2,899,419	2,623,892	2,414,408	1,689,448	1,496,378	1,295,746

Charleston West Side

Figure 7. 21 - Charleston West Side Load Analysis

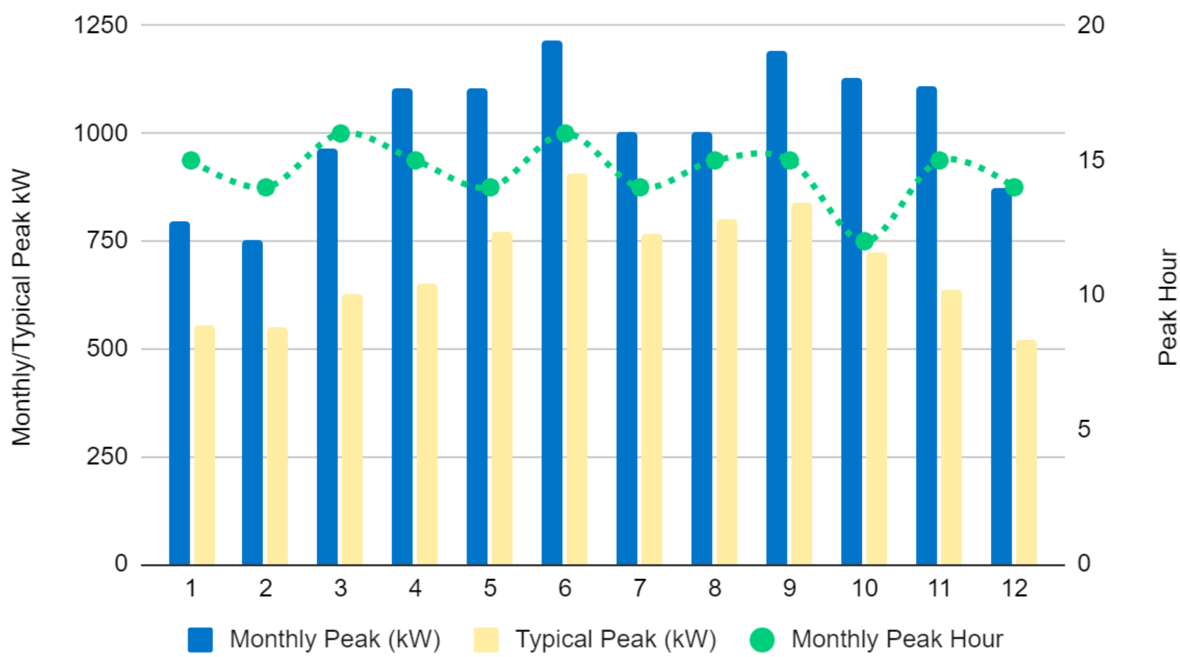


Figure 7. 22 Proposed Solar Generation and Energy Consumption for Charleston West Side

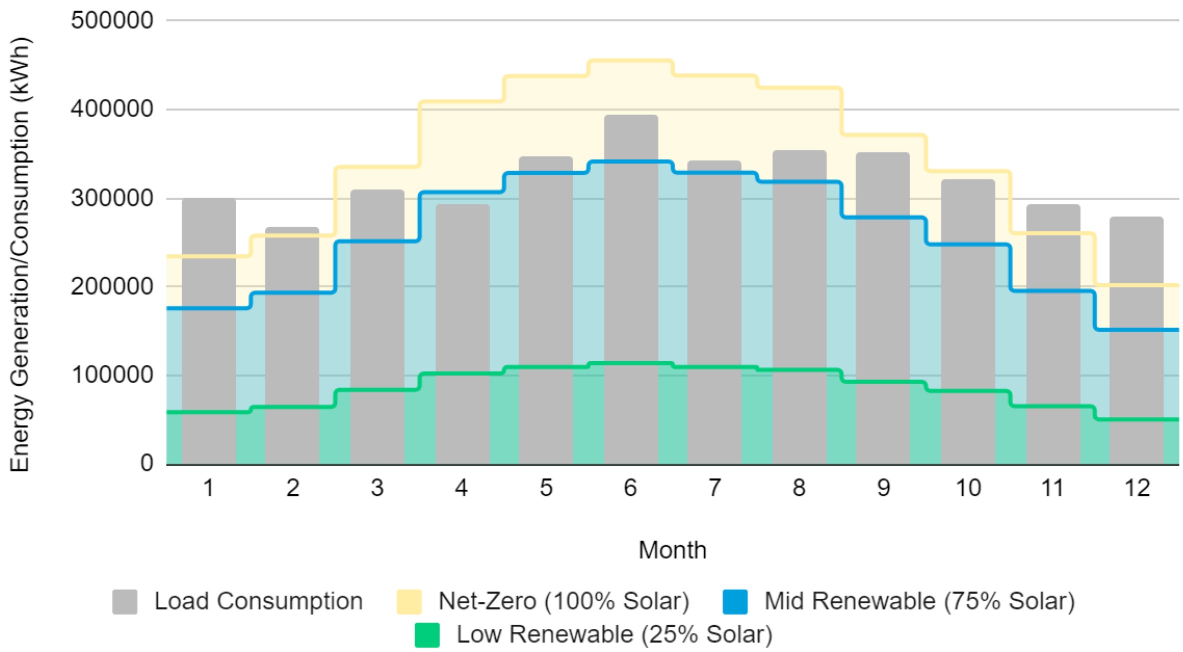


Table 7. 21 - Microgrid Sizing for Charleston West Side

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	3156	2367	789
Battery Capacity (kW)	650	545	900
Battery Capacity (kWh, 4-hour)	2600	2180	3600
Standby Generation (kW)	0	555	610

Table 7. 22 - Microgrid Scenarios Economic Analysis for Charleston West Side

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	5,249,862	4,906,015	4,775,435	3,937,396	3,679,511	3,581,576	1,312,465	1,226,504	1,193,859
Battery ($)	1,182,547	1,053,145	858,905	991,520	883,021	720,158	1,637,373	1,458,200	1,189,253

Standby Generator ($)	-	-	-	277,500	222,000	166,500	305,000	244,000	183,000
Design, IT, Operational ($)	1,225,221	1,135,078	1,073,208	991,698	911,340	851,092	619,969	557,848	488,783
Component Costs ($)	7,657,629	7,094,238	6,707,547	6,198,115	5,695,872	5,319,327	3,874,808	3,486,552	3,054,894
Solar NPV O&M ($)	628,304	499,577	446,103	471,228	374,683	334,577	157,076	124,894	111,526
Battery NPV O&M ($)	303,802	235,488	162,550	254,727	197,447	136,292	420,649	326,060	225,069
Total O&M ($)	932,106	735,065	608,652	725,954	572,130	470,869	577,725	450,954	336,595
Total Project Costs ($)	8,589,735	7,829,303	7,316,199	6,924,069	6,268,002	5,790,196	4,452,533	3,937,506	3,391,489

Winfield

Figure 7. 23 - Winfield Load and Solar Analysis

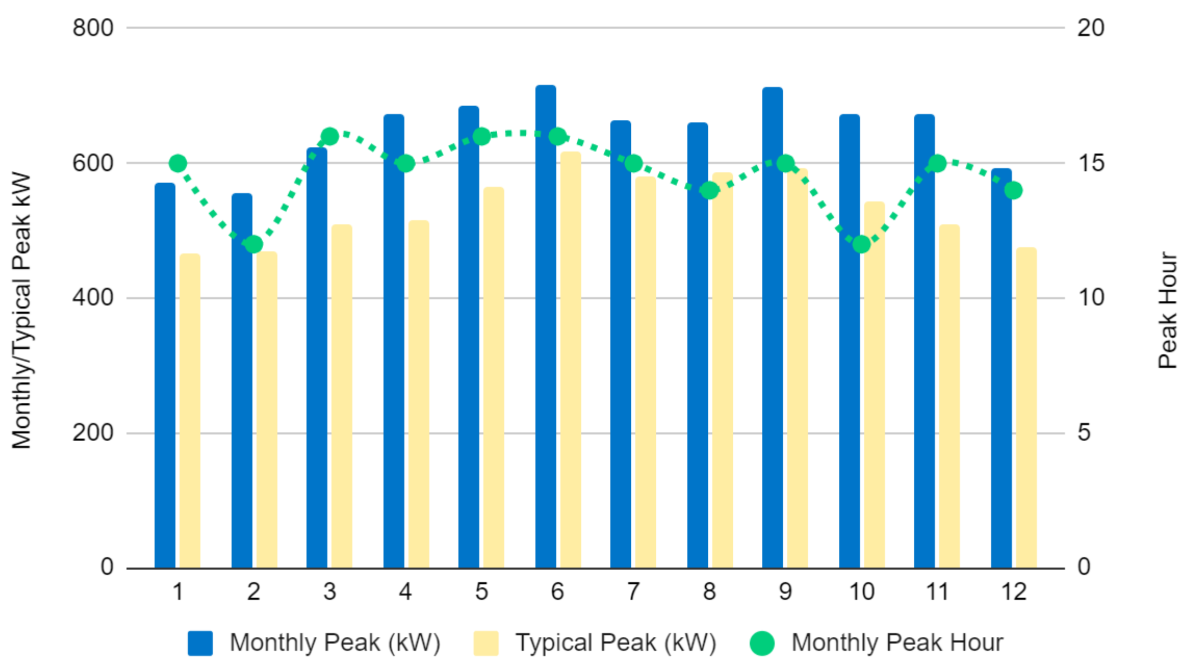


Figure 7. 24 Proposed Solar Generation and Energy Consumption (Winfield)

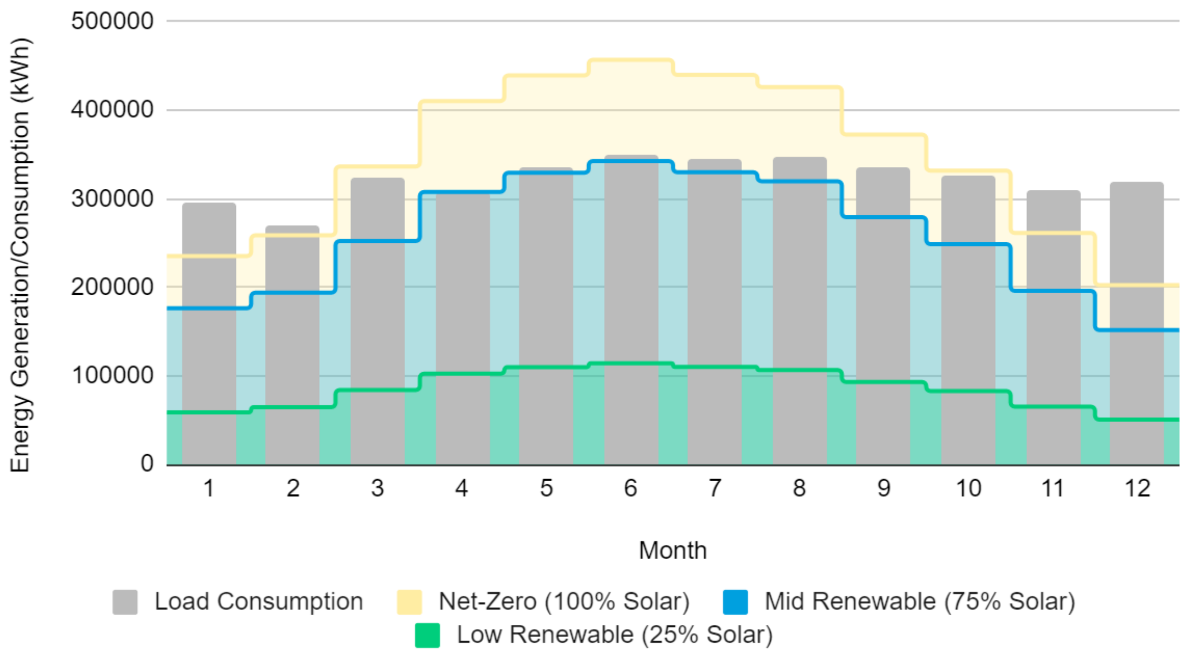


Table 7. 23 - Microgrid Sizing for Winfield

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	3166	2375	792
Battery Capacity (kW)	795	635	665
Battery Capacity (kWh, 4-hour)	3180	2540	2660
Standby Generation (kW)	0	365	405

Table 7. 24 - Microgrid Scenarios Economic Analysis for Winfield

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	5,266,837	4,921,879	4,790,876	3,950,128	3,691,409	3,593,157	1,316,709	1,230,470	1,197,719
Battery ($)	1,446,346	1,288,077	1,050,506	1,155,258	1,028,841	839,084	1,209,837	1,077,448	878,725

Standby Generator ($)	-	-	-	182,500	146,000	109,500	202,500	162,000	121,500
Design, IT, Operational ($)	1,278,702	1,182,849	1,112,644	1,007,216	926,905	865,093	519,818	470,461	418,656
Component Costs ($)	7,991,885	7,392,804	6,954,027	6,295,102	5,793,155	5,406,834	3,248,864	2,940,378	2,616,601
Solar NPV O&M ($)	630,335	501,192	447,545	472,751	375,894	335,659	157,584	125,298	111,886
Battery NPV O&M ($)	371,574	288,019	198,811	296,792	230,053	158,799	310,813	240,922	166,301
Total O&M ($)	1,001,909	789,212	646,356	769,543	605,948	494,457	468,397	366,220	278,187
Total Project Costs ($)	8,993,794	8,182,016	7,600,383	7,064,645	6,399,103	5,901,292	3,717,261	3,306,598	2,894,788

Westmoreland (Huntington)

Figure 7. 25 - Westmoreland (Huntington) Load and Solar Analysis

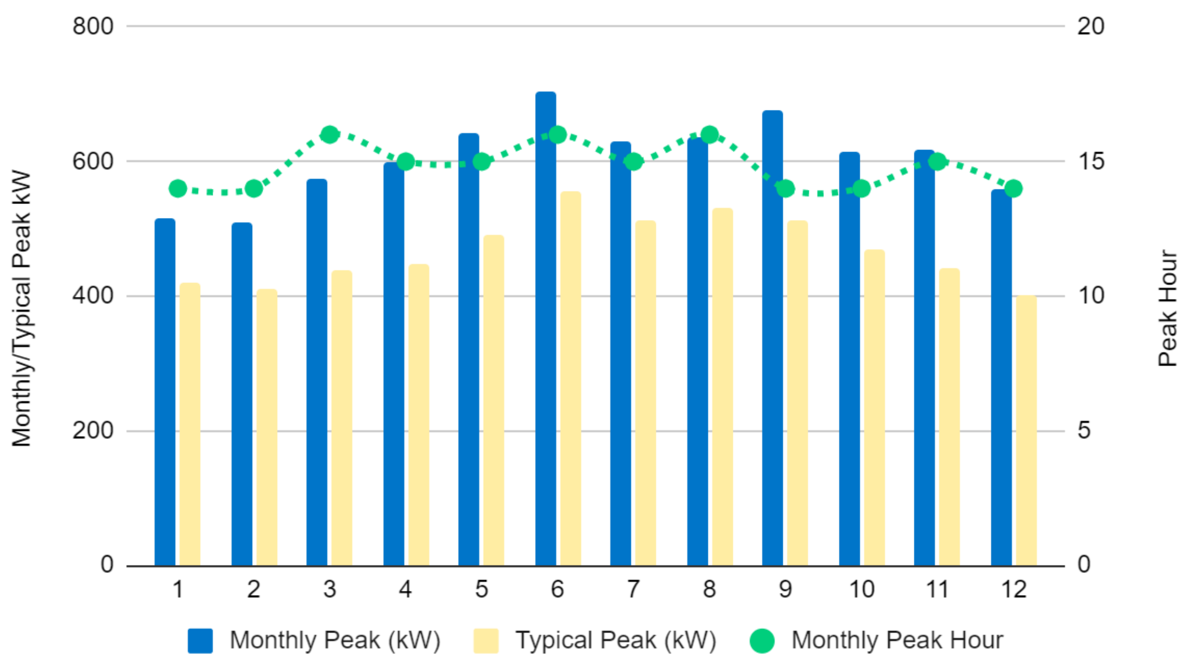


Figure 7. 26 - Proposed Solar Generation and Energy Consumption for Westmoreland (Huntington)

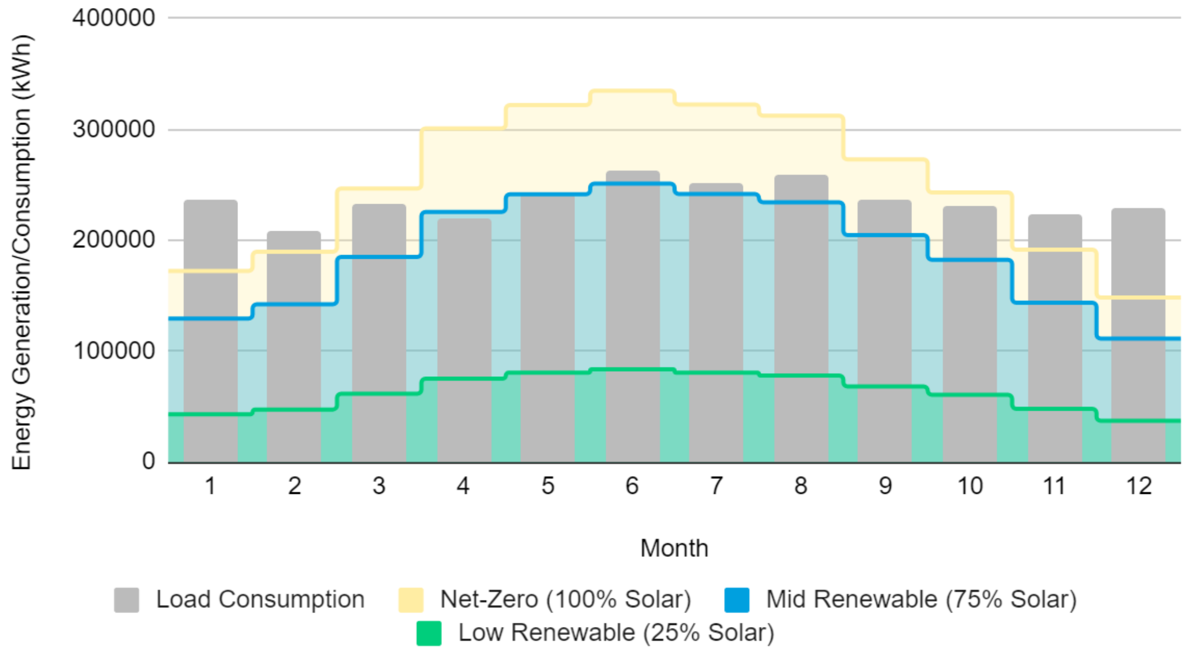


Table 7. 25 - Microgrid Sizing for Westmoreland (Huntington)

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	2320	1740	580
Battery Capacity (kW)	460	385	490
Battery Capacity (kWh, 4-hour)	1840	1540	1960
Standby Generation (kW)	0	310	355

Economic Analysis

Table 7. 26 - Microgrid Scenarios Economic Analysis for Westmoreland (Huntington)

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**

Solar ($)	3,606,424	3,510,434	2,894,390	2,704,818	2,632,826	964,797	901,606	877,609	3,606,424
Battery ($)	745,302	607,840	700,432	623,786	508,736	891,459	793,909	647,482	745,302
Standby Generator ($)	-	-	155,000	124,000	93,000	177,500	142,000	106,500	-
Design, IT, Operational ($)	828,900	784,433	714,252	657,639	616,107	387,382	350,003	310,779	828,900
Component Costs ($)	5,180,627	4,902,707	4,464,073	4,110,242	3,850,668	2,421,137	2,187,518	1,942,370	5,180,627
Solar NPV O&M ($)	367,240	327,931	346,401	275,430	245,948	115,467	91,810	81,983	367,240
Battery NPV O&M ($)	166,653	115,035	179,944	139,481	96,280	229,020	177,521	122,538	166,653
Total O&M ($)	533,893	442,966	526,345	414,911	342,228	344,487	269,331	204,520	533,893
Total Project Costs ($)	5,714,520	5,345,674	4,990,418	4,525,154	4,192,896	2,765,624	2,456,849	2,146,890	5,714,520

Clendenin

Figure 7. 27 - Clendenin Load and Solar Analysis

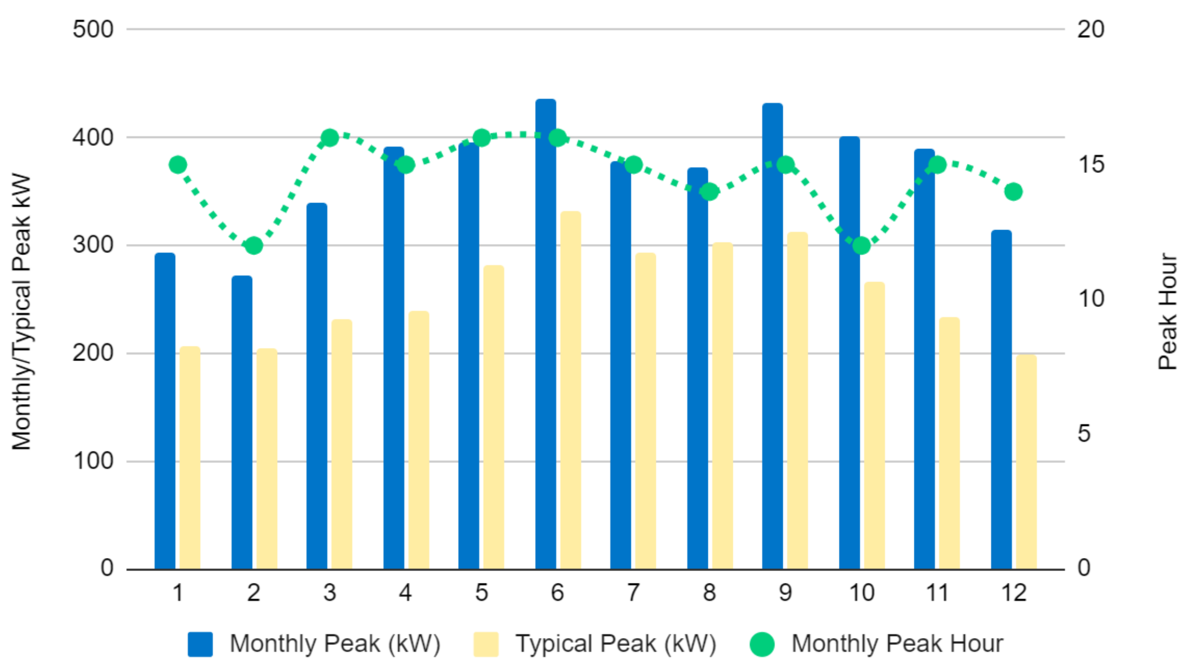


Figure 7. 28 Proposed Solar Generation and Energy Consumption for Clendenin

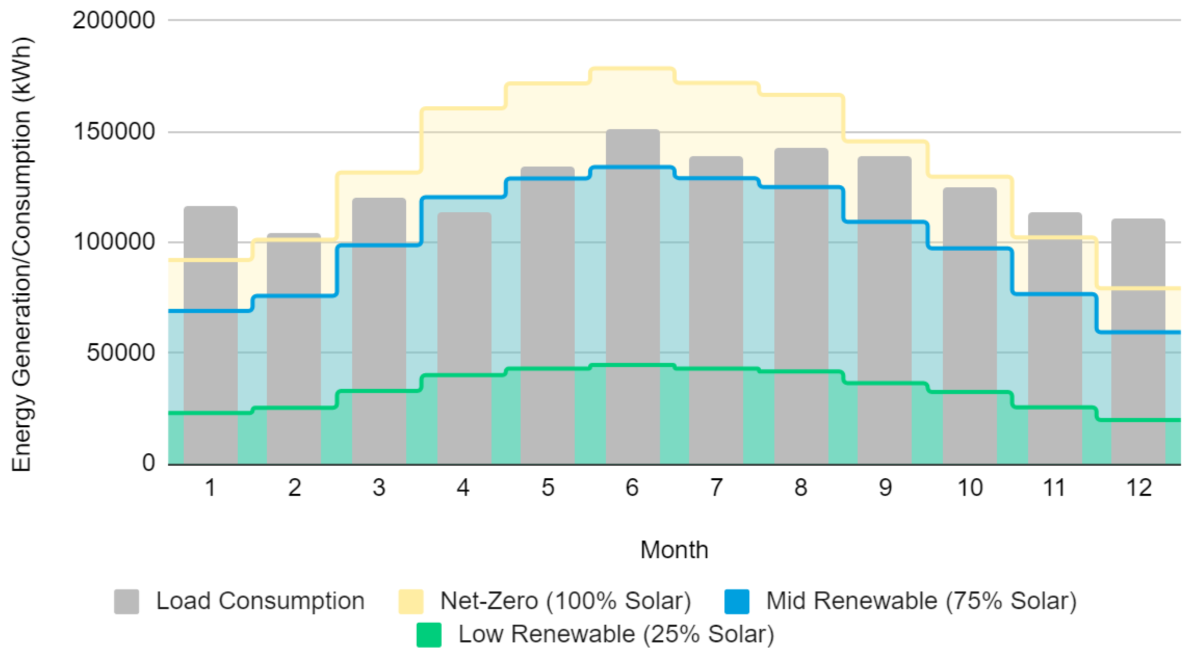


Table 7. 27 - Microgrid Sizing for Clendenin

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1238	928	309
Battery Capacity (kW)	205	225	325
Battery Capacity (kWh, 4-hour)	820	900	1300
Standby Generation (kW)	0	185	225

Table 7. 28 - Microgrid Scenarios Economic Analysis for Clendenin

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,058,950	1,924,096	1,872,884	1,544,212	1,443,072	1,404,663	514,737	481,024	468,221
Battery ($)	372,957	332,146	270,885	409,343	364,550	297,313	591,274	526,572	429,452

Standby Generator ($)	-	-	-	92,500	74,000	55,500	112,500	90,000	67,500
Design, IT, Operational ($)	463,220	429,760	408,337	389,725	358,404	334,757	232,097	209,066	183,843
Component Costs ($)	2,895,127	2,686,002	2,552,106	2,435,780	2,240,026	2,092,233	1,450,608	1,306,662	1,149,016
Solar NPV O&M ($)	246,415	195,930	174,957	184,811	146,947	131,218	61,604	48,982	43,739
Battery NPV O&M ($)	95,815	74,269	51,266	105,162	81,515	56,267	151,901	117,744	81,275
Total O&M ($)	342,230	270,199	226,223	289,974	228,462	187,485	213,505	166,726	125,014
Total Project Costs ($)	3,237,357	2,956,201	2,778,329	2,725,754	2,468,489	2,279,719	1,664,113	1,473,389	1,274,030

New Martinsville

Figure 7. 29 - New Martinsville Load and Solar Analysis

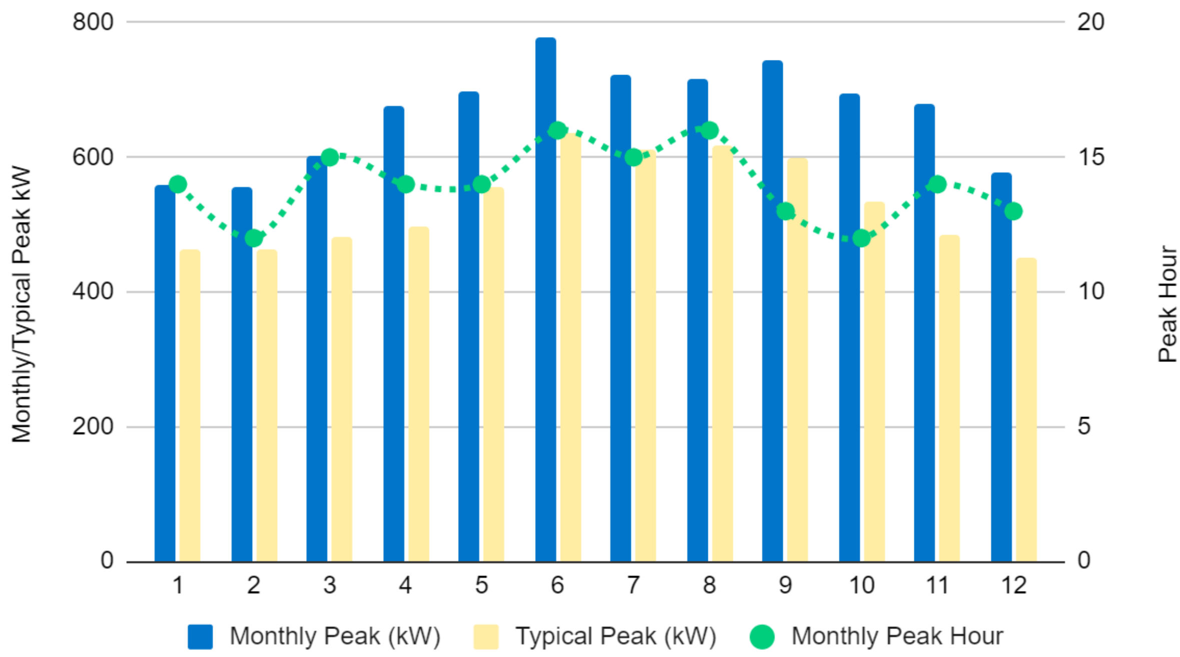


Figure 7. 30 Proposed Solar Generation and Energy Consumption for New Martinsville

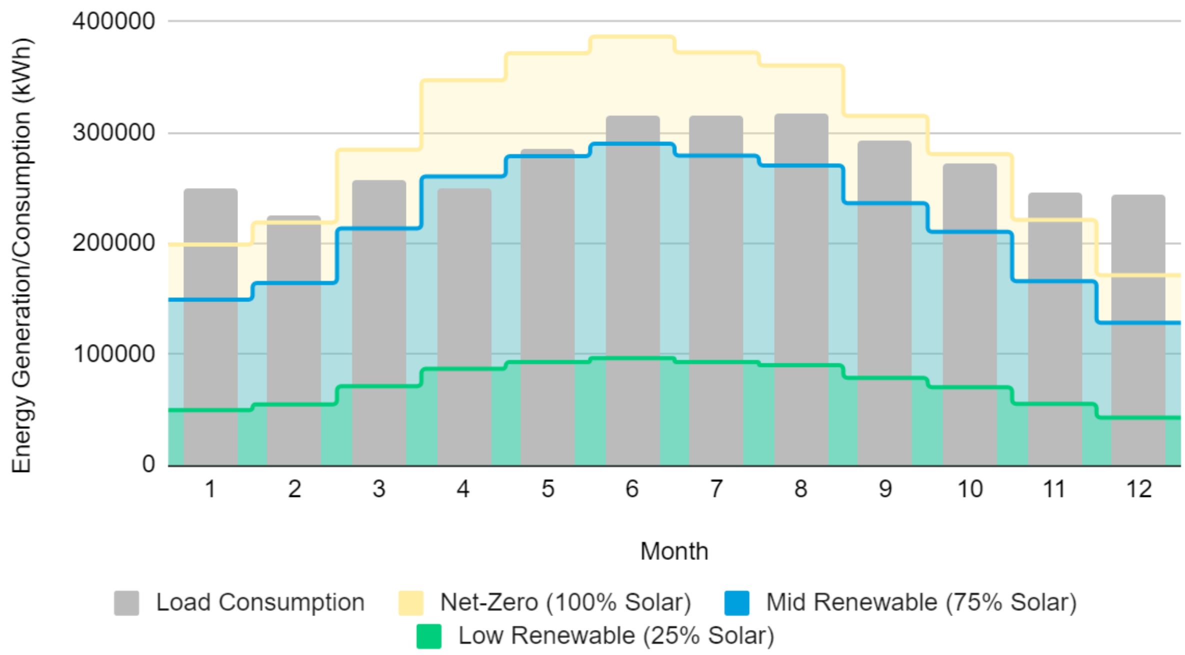


Table 7. 29 - Microgrid Sizing for New Martinsville

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	2679	2009	670
Battery Capacity (kW)	595	490	625
Battery Capacity (kWh, 4-hour)	2380	1960	2500
Standby Generation (kW)	0	310	1118

Table 7. 30 - Microgrid Scenarios Economic Analysis for New Martinsville

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	4,456,178	4,164,315	4,053,476	3,342,134	3,123,237	3,040,107	1,114,045	1,041,079	1,013,369
Battery ($)	1,082,485	964,032	786,228	891,459	793,909	647,482	1,137,065	1,012,639	825,870

Standby Generator ($)	-	-	-	155,000	124,000	93,000	559,000	447,200	335,400
Design, IT, Operational ($)	1,054,984	976,828	921,848	835,922	769,742	720,112	535,259	476,365	414,217
Component Costs ($)	6,593,647	6,105,176	5,761,553	5,224,515	4,810,888	4,500,701	3,345,368	2,977,283	2,588,856
Solar NPV O&M ($)	533,316	424,050	378,660	399,987	318,038	283,995	133,329	106,013	94,665
Battery NPV O&M ($)	278,096	215,562	148,796	229,020	177,521	122,538	292,118	226,430	156,298
Total O&M ($)	811,412	639,612	527,456	629,007	495,559	406,533	425,447	332,443	250,963
Total Project Costs ($)	7,405,059	6,744,788	6,289,008	5,853,522	5,306,447	4,907,234	3,770,815	3,309,726	2,839,819

Rivesville

Figure 7. 31 - Rivesville Load and Solar Analysis

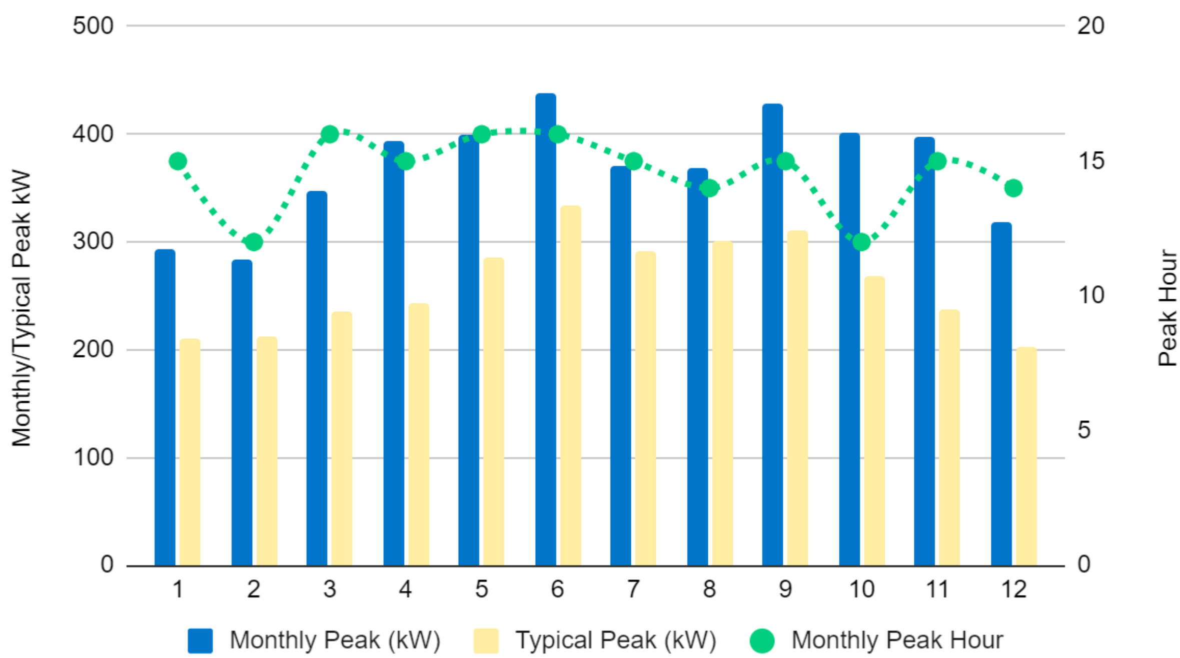


Figure 7. 32 - Proposed Solar Generation and Energy Consumption for Rivesville

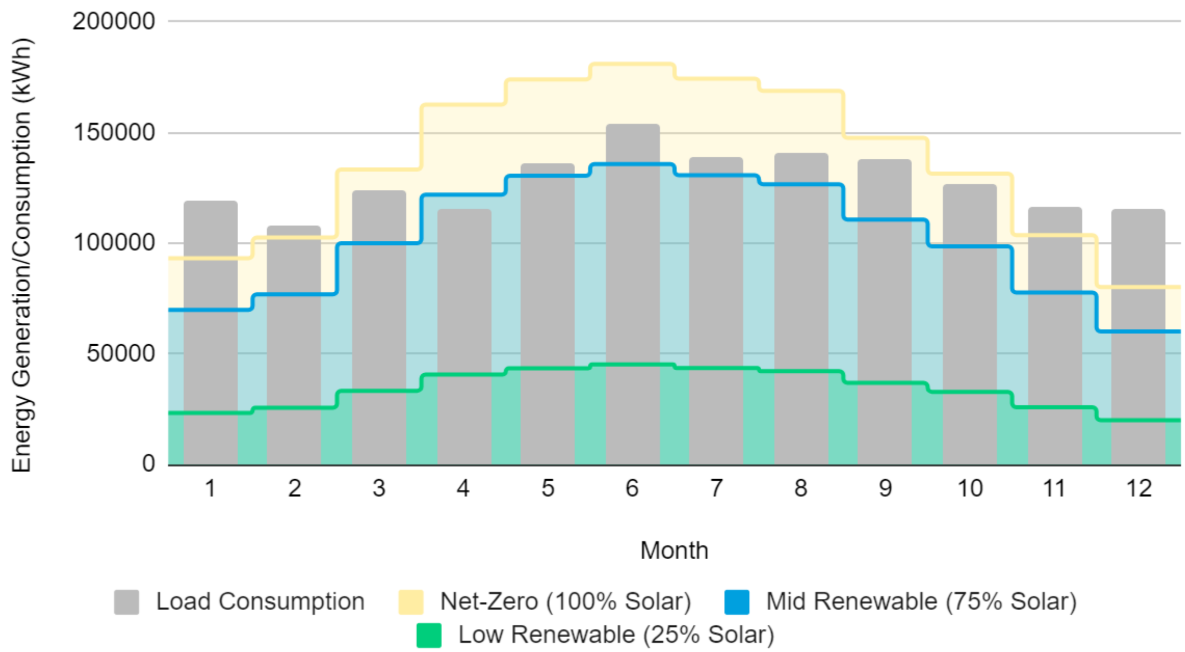


Table 7. 31 - Microgrid Sizing for Rivesville

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1254	941	314
Battery Capacity (kW)	275	230	330
Battery Capacity (kWh, 4-hour)	1100	920	1320
Standby Generation (kW)	0	175	225

Table 7. 32 - Microgrid Scenarios Economic Analysis for Rivesville

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,086,135	1,949,501	1,897,612	1,564,601	1,462,126	1,423,209	521,534	487,375	474,403
Battery ($)	500,308	445,561	363,383	418,440	372,651	303,920	600,370	534,673	436,059

Standby Generator ($)	-	-	-	87,500	70,000	52,500	112,500	90,000	67,500
Design, IT, Operational ($)	492,656	456,202	430,666	394,389	362,815	338,977	235,125	211,819	186,279
Component Costs ($)	3,079,099	2,851,264	2,691,660	2,464,930	2,267,591	2,118,606	1,469,528	1,323,867	1,164,241
Solar NPV O&M ($)	249,669	198,517	177,268	187,252	148,888	132,951	62,417	49,629	44,317
Battery NPV O&M ($)	128,532	99,629	68,771	107,499	83,326	57,518	154,238	119,555	82,525
Total O&M ($)	378,200	298,146	246,039	294,751	232,214	190,468	216,655	169,184	126,842
Total Project Costs ($)	3,457,299	3,149,410	2,937,699	2,759,680	2,499,805	2,309,074	1,686,184	1,493,052	1,291,083

Edgemont

Figure 7. 33 - Edgemont Load and Solar Analysis

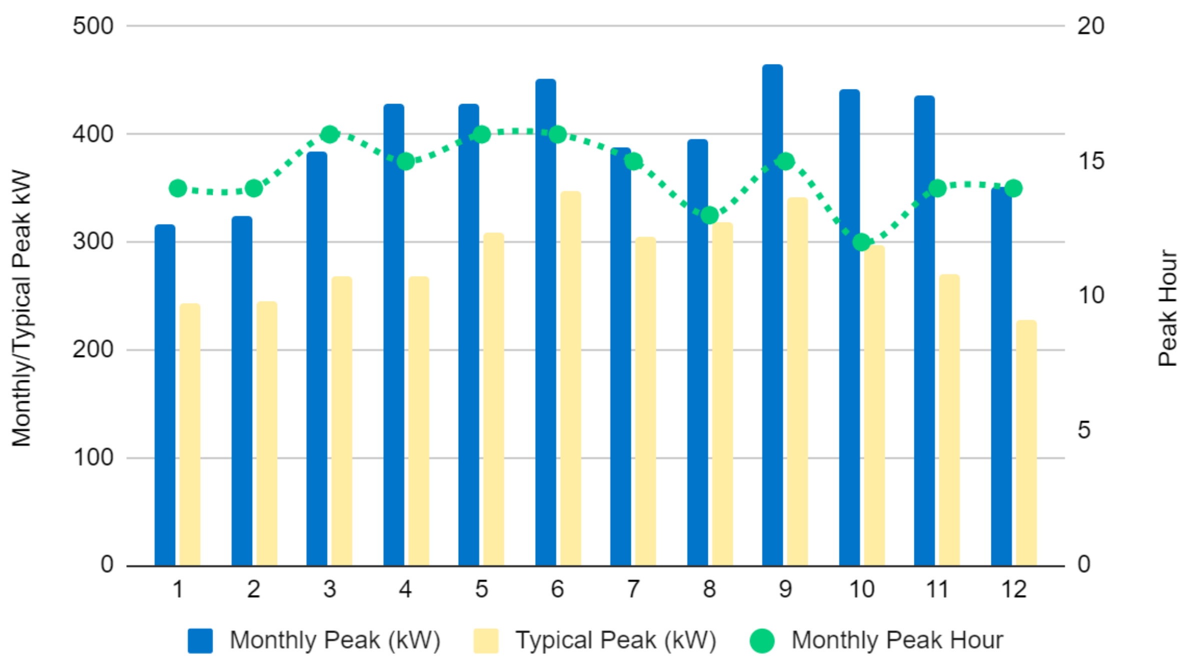


Figure 7. 34 - Proposed Solar Generation and Energy Consumption for Edgemont

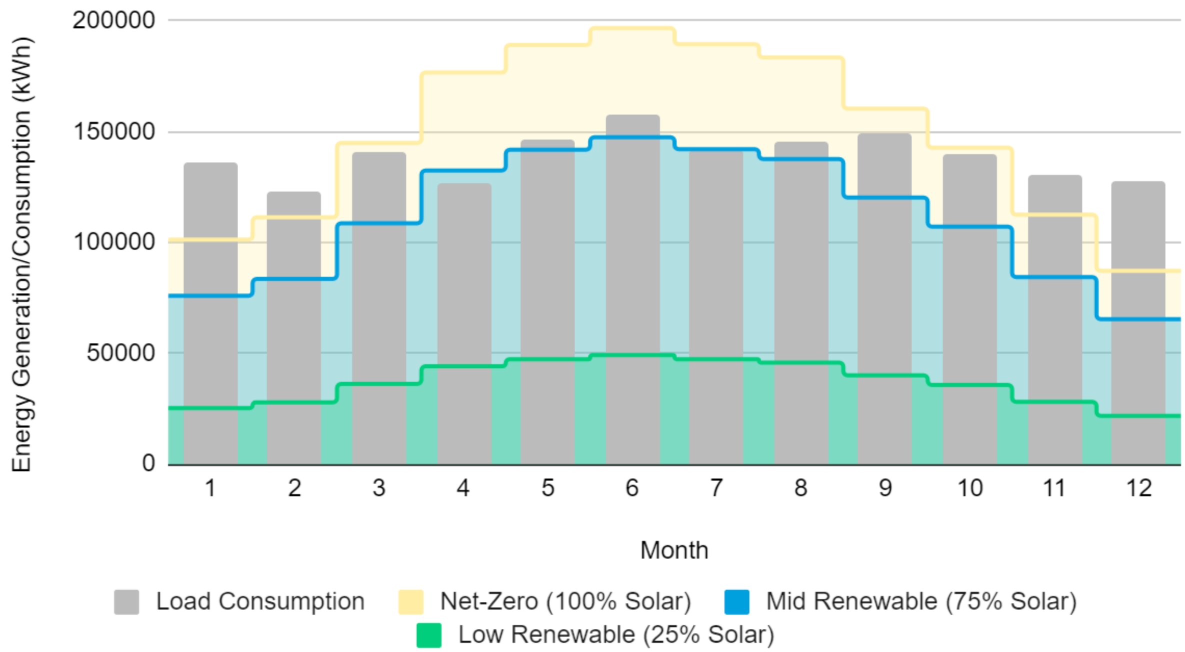


Table 7. 33 - Microgrid Sizing for Edgemont

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1363	1022	341
Battery Capacity (kW)	310	250	325
Battery Capacity (kWh, 4-hour)	1240	1000	1300
Standby Generation (kW)	0	190	235

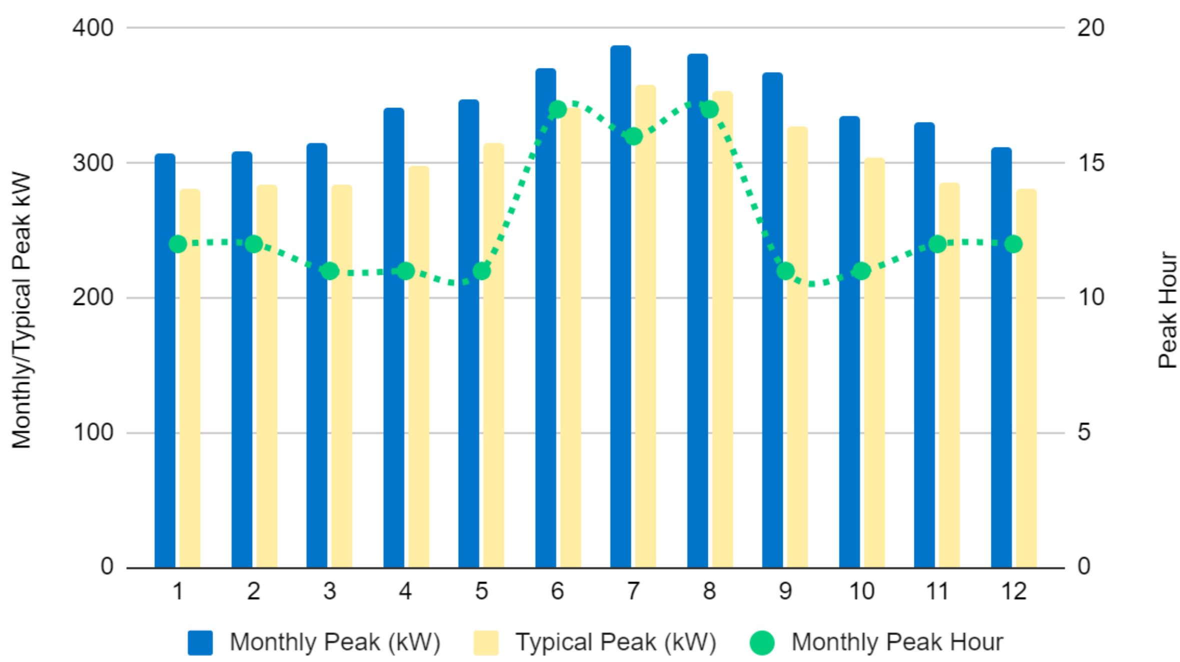
Table 7. 34 - Microgrid Scenarios Economic Analysis for Edgemont

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,267,195	2,118,702	2,062,310	1,700,396	1,589,026	1,546,732	566,799	529,675	515,577

Battery ($)	563,984	502,269	409,631	454,826	405,056	330,348	591,274	526,572	429,452
Standby Generator ($)	-	-	-	95,000	76,000	57,000	117,500	94,000	70,500
Design, IT, Operational ($)	539,272	499,233	470,846	428,614	394,301	368,396	242,966	219,095	193,434
Component Costs ($)	3,370,451	3,120,203	2,942,787	2,678,835	2,464,383	2,302,476	1,518,538	1,369,343	1,208,964
Solar NPV O&M ($)	271,338	215,746	192,653	203,503	161,810	144,490	67,834	53,937	48,163
Battery NPV O&M ($)	144,890	112,309	77,524	116,847	90,572	62,519	151,901	117,744	81,275
Total O&M ($)	416,228	328,056	270,177	320,351	252,382	207,009	219,736	171,680	129,438
Total Project Costs ($)	3,786,679	3,448,259	3,212,964	2,999,186	2,716,765	2,509,485	1,738,274	1,541,023	1,338,402

Weston

Figure 7. 35 - Weston Load and Solar Analysis



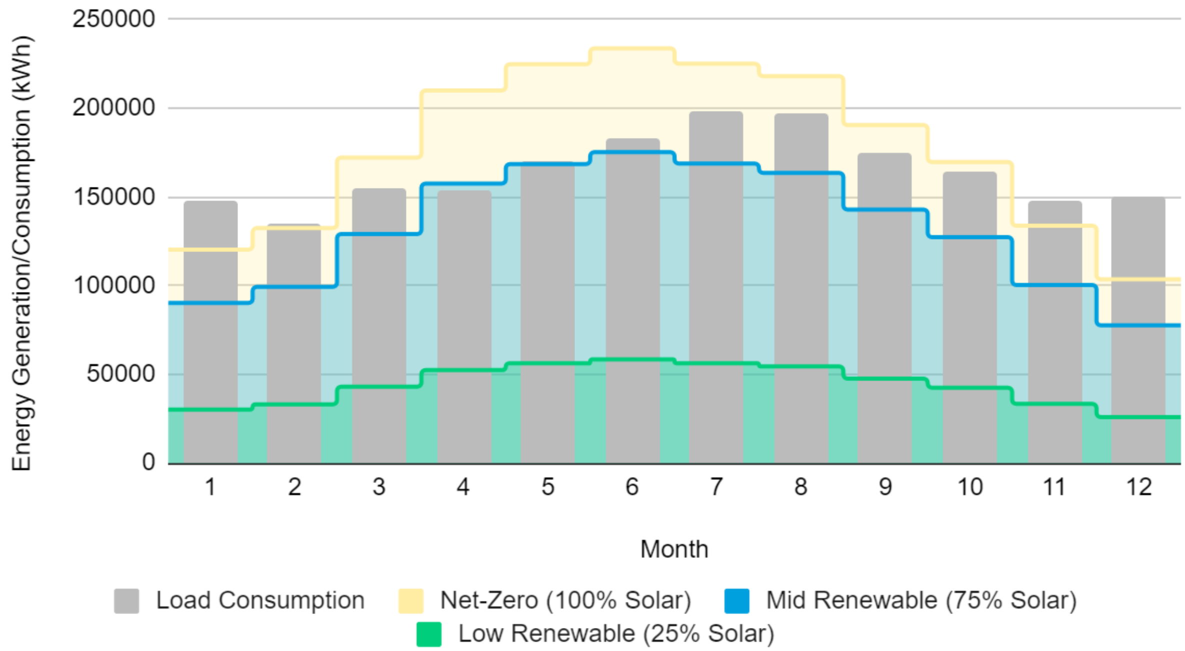


Figure 7. 36 - Proposed Solar Generation and Energy Consumption for Weston

Table 7. 35 - Microgrid Sizing for Weston

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1620	1215	405
Battery Capacity (kW)	415	335	370
Battery Capacity (kWh, 4-hour)	1660	1340	1480
Standby Generation (kW)	0	175	297

Table 7. 36 - Microgrid Scenarios Economic Analysis for Weston

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,694,193	2,517,733	2,450,720	2,020,645	1,888,300	1,838,040	673,548	629,433	612,680
Battery ($)	755,011	672,392	548,378	609,467	542,775	442,666	673,142	599,482	488,915

Standby Generator ($)	-	-	-	87,500	70,000	52,500	148,500	118,800	89,100
Design, IT, Operational ($)	656,991	607,643	571,257	517,640	476,395	444,420	284,798	256,708	226,799
Component Costs ($)	4,106,195	3,797,768	3,570,355	3,235,251	2,977,470	2,777,627	1,779,989	1,604,423	1,417,494
Solar NPV O&M ($)	322,441	256,380	228,937	241,831	192,285	171,703	80,610	64,095	57,234
Battery NPV O&M ($)	193,966	150,350	103,782	156,575	121,367	83,776	172,934	134,047	92,528
Total O&M ($)	516,407	406,729	332,719	398,406	313,651	255,478	253,544	198,142	149,763
Total Project Costs ($)	4,622,602	4,204,498	3,903,073	3,633,657	3,291,121	3,033,105	2,033,533	1,802,565	1,567,257

Elkins

Figure 7. 37 - Elkins Load and Solar Analysis

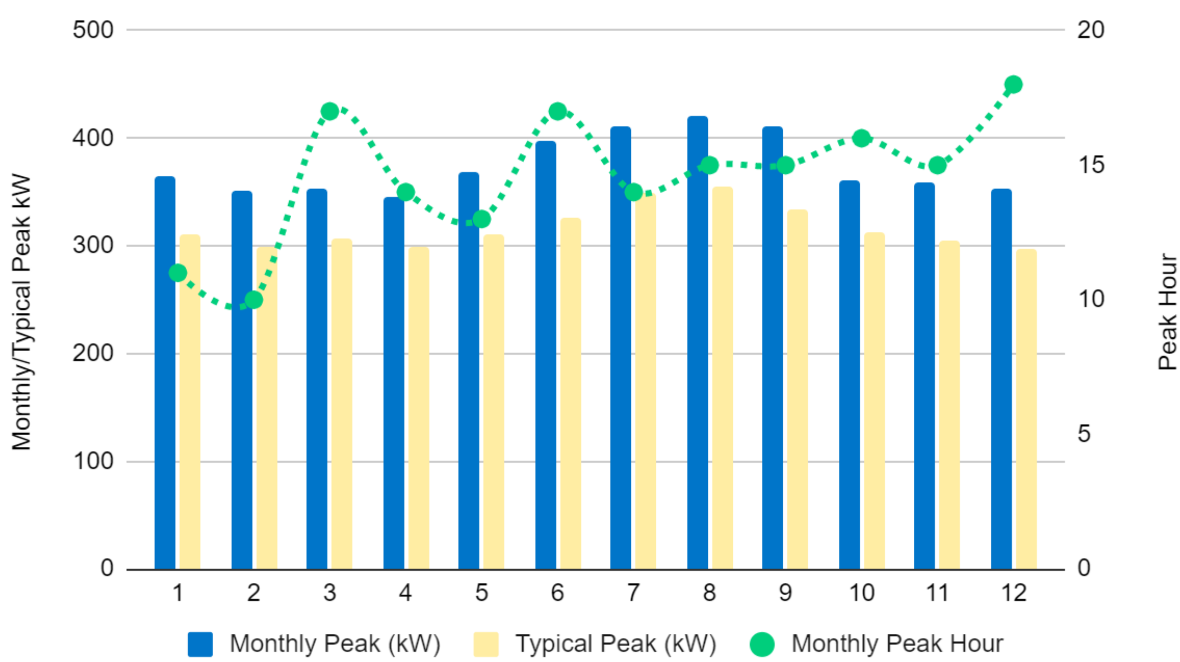


Figure 7. 38 - Proposed Solar Generation and Energy Consumption for Elkins

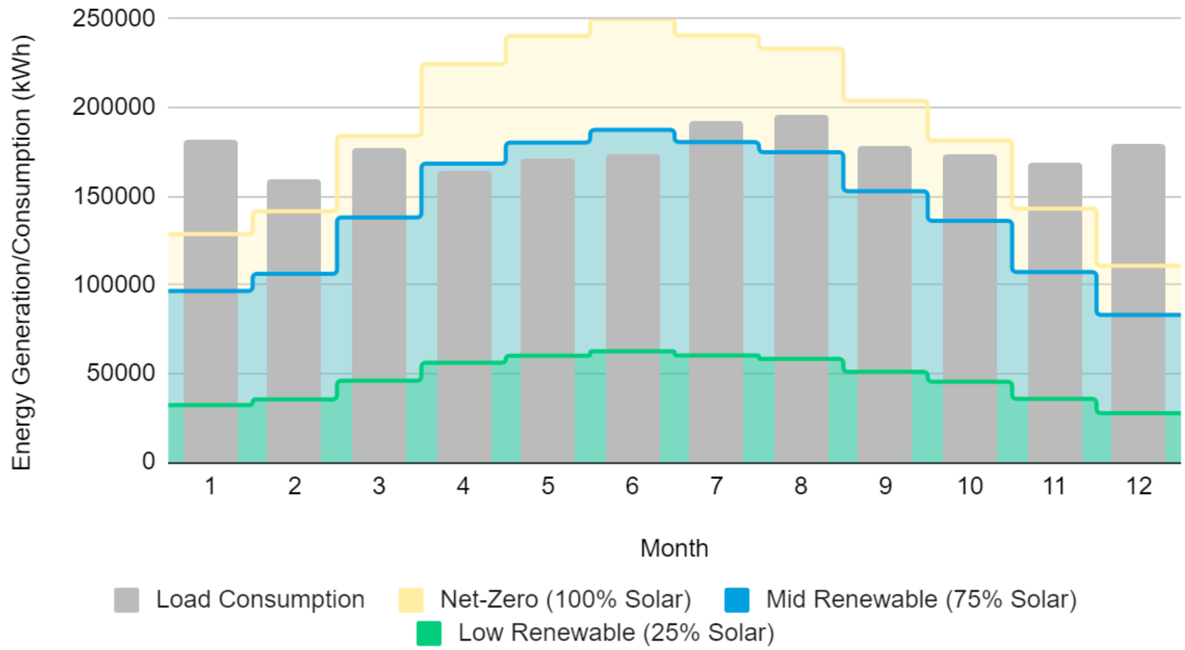


Table 7. 37 - Microgrid Sizing for Elkins

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1732	1299	433
Battery Capacity (kW)	435	345	340
Battery Capacity (kWh, 4-hour)	1740	1380	1360
Standby Generation (kW)	0	215	250

Table 7. 38 - Microgrid Scenarios Economic Analysis for Elkins

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,881,099	2,692,398	2,620,736	2,160,824	2,019,298	1,965,552	720,275	673,099	655,184

Battery ($)	791,397	704,797	574,805	627,660	558,977	455,880	618,563	550,876	449,273
Standby Generator ($)	-	-	-	107,500	86,000	64,500	125,000	100,000	75,000
Design, IT, Operational ($)	699,523	647,085	608,675	551,616	507,481	473,511	278,826	252,186	224,659
Component Costs ($)	4,372,019	4,044,279	3,804,216	3,447,600	3,171,756	2,959,443	1,742,664	1,576,161	1,404,116
Solar NPV O&M ($)	344,810	274,166	244,819	258,608	205,624	183,614	86,203	68,541	61,205
Battery NPV O&M ($)	203,314	157,596	108,783	161,249	124,990	86,276	158,912	123,178	85,026
Total O&M ($)	548,124	431,761	353,602	419,856	330,614	269,891	245,115	191,719	146,231
Total Project Costs ($)	4,920,143	4,476,040	4,157,818	3,867,456	3,502,370	3,229,334	1,987,779	1,767,880	1,550,346

Moorefield

Figure 7. 39 - Moorefield Load and Solar Analysis

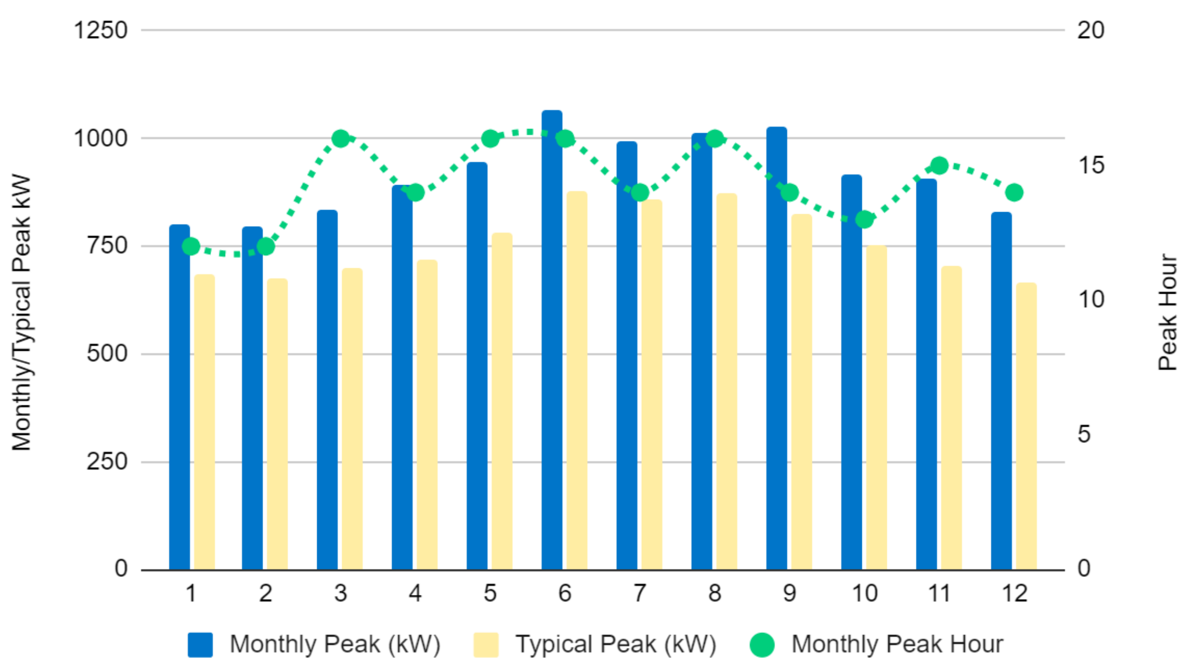


Figure 7. 40 - Proposed Solar Generation and Energy Consumption for Moorefield

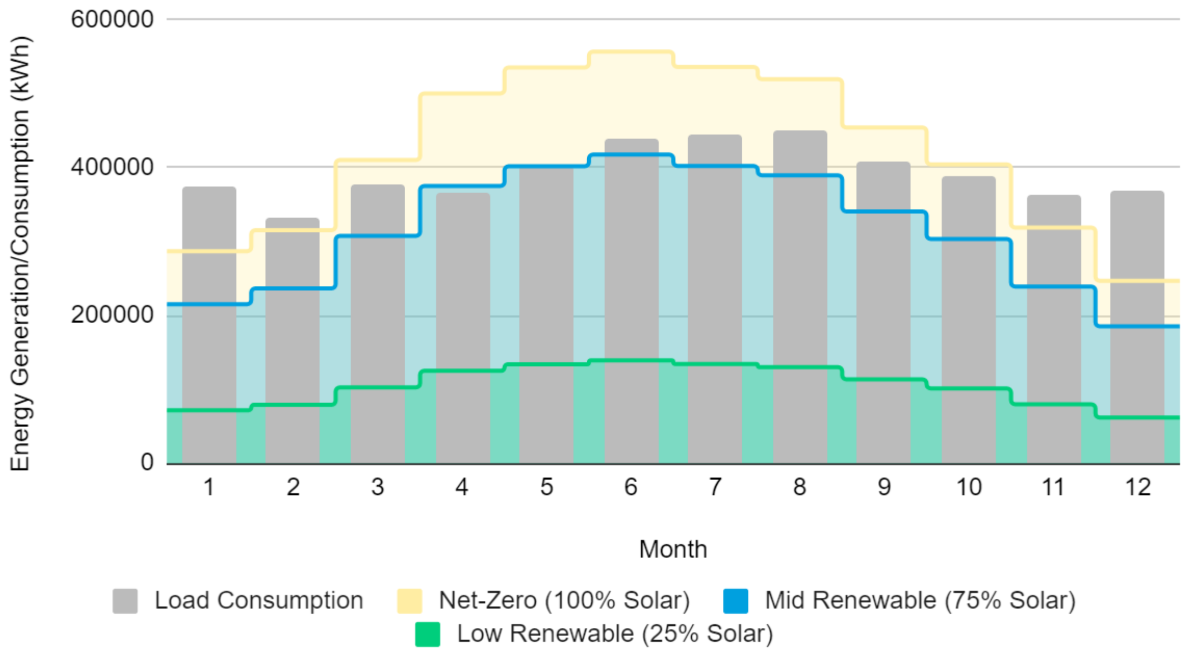


Table 7. 39 - Microgrid Sizing for Moorefield

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	3861	2896	965
Battery Capacity (kW)	810	670	800
Battery Capacity (kWh, 4-hour)	3240	2680	3200
Standby Generation (kW)	0	470	545

Table 7. 40 - Microgrid Scenarios Economic Analysis for Moorefield

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	6,422,155	6,001,528	5,841,789	4,816,616	4,501,146	4,381,342	1,605,539	1,500,382	1,460,447

Battery ($)	1,473,636	1,312,380	1,070,327	1,218,933	1,085,549	885,332	1,455,443	1,296,178	1,057,113
Standby Generator ($)	-	-	-	235,000	188,000	141,000	272,500	218,000	163,500
Design, IT, Operational ($)	1,503,960	1,393,125	1,316,594	1,194,390	1,099,942	1,030,033	634,949	574,202	510,678
Component Costs ($)	9,399,751	8,707,033	8,228,710	7,464,940	6,874,637	6,437,707	3,968,430	3,588,762	3,191,739
Solar NPV O&M ($)	768,604	611,133	545,717	576,453	458,349	409,288	192,151	152,783	136,429
Battery NPV O&M ($)	378,585	293,454	202,562	313,150	242,733	167,551	373,911	289,831	200,061
Total O&M ($)	1,147,188	904,586	748,279	889,603	701,083	576,839	566,062	442,614	336,491
Total Project Costs ($)	10,546,939	9,611,620	8,976,989	8,354,543	7,575,720	7,014,546	4,534,492	4,031,376	3,528,229

Martinsburg

Figure 7. 41 - Martinsburg Load and Solar Analysis

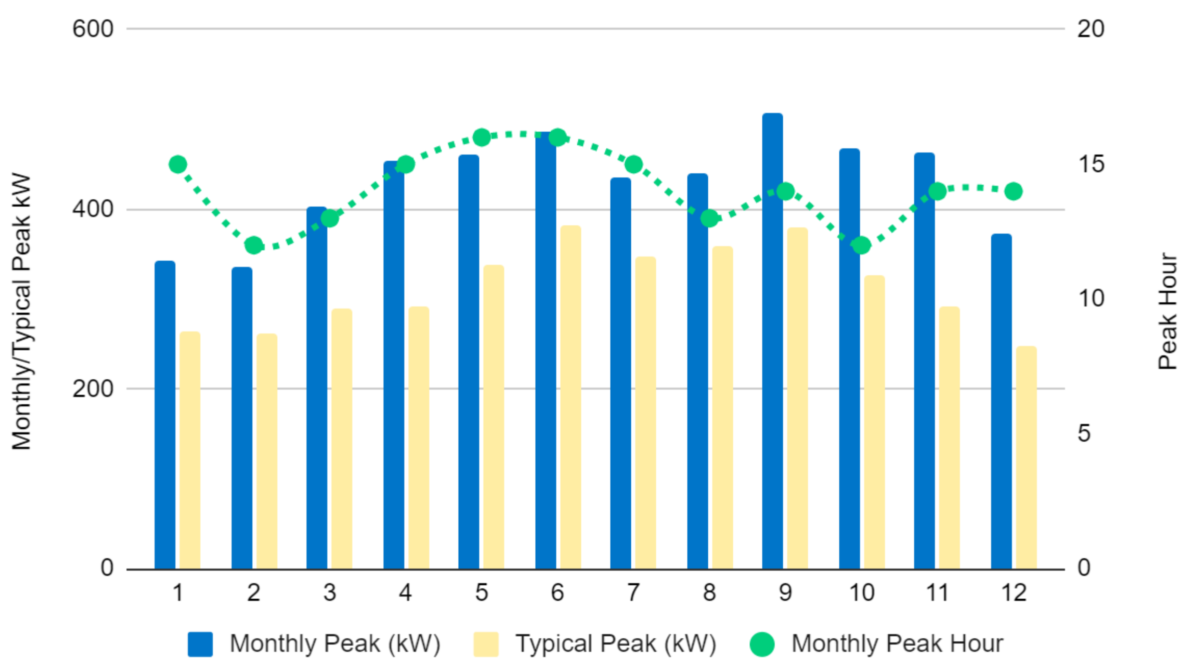


Figure 7. 42 - Proposed Solar Generation and Energy Consumption for Martinsburg

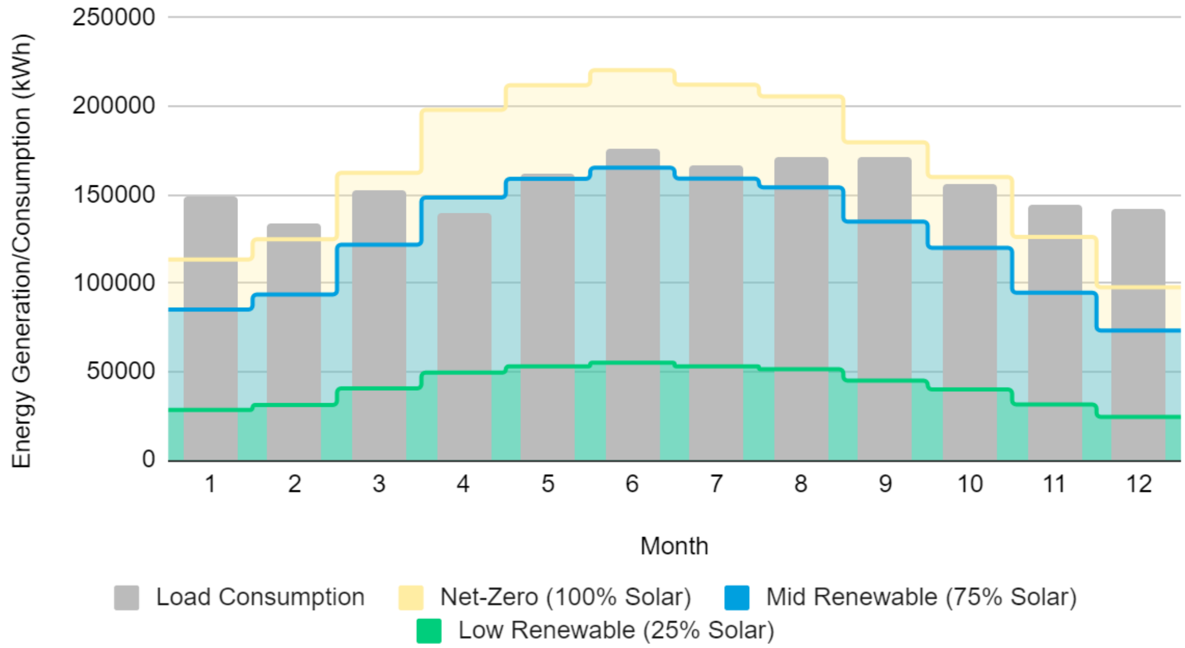


Table 7. 41 - Microgrid Sizing for Martinsburg

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1527	1145	382
Battery Capacity (kW)	370	305	375
Battery Capacity (kWh, 4-hour)	1480	1220	1500
Standby Generation (kW)	0	185	288

Table 7. 42 - Microgrid Scenarios Economic Analysis for Martinsburg

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,540,412	2,374,024	2,310,837	1,905,309	1,780,518	1,733,127	635,103	593,506	577,709

Battery ($)	673,142	599,482	488,915	554,887	494,168	403,024	682,239	607,583	495,522
Standby Generator ($)	-	-	-	92,500	74,000	55,500	144,000	115,200	86,400
Design, IT, Operational ($)	612,106	566,382	533,286	486,228	447,369	417,457	278,351	250,722	220,882
Component Costs ($)	3,825,660	3,539,889	3,333,037	3,038,924	2,796,055	2,609,109	1,739,693	1,567,011	1,380,513
Solar NPV O&M ($)	304,037	241,746	215,869	228,027	181,309	161,902	76,009	60,436	53,967
Battery NPV O&M ($)	172,934	134,047	92,528	142,553	110,498	76,273	175,271	135,858	93,779
Total O&M ($)	476,970	375,793	308,398	370,581	291,807	238,175	251,280	196,295	147,746
Total Project Costs ($)	4,302,630	3,915,682	3,641,435	3,409,505	3,087,862	2,847,285	1,990,972	1,763,306	1,528,259

Bluefield

Figure 7. 43 - Bluefield Load and Solar Analysis

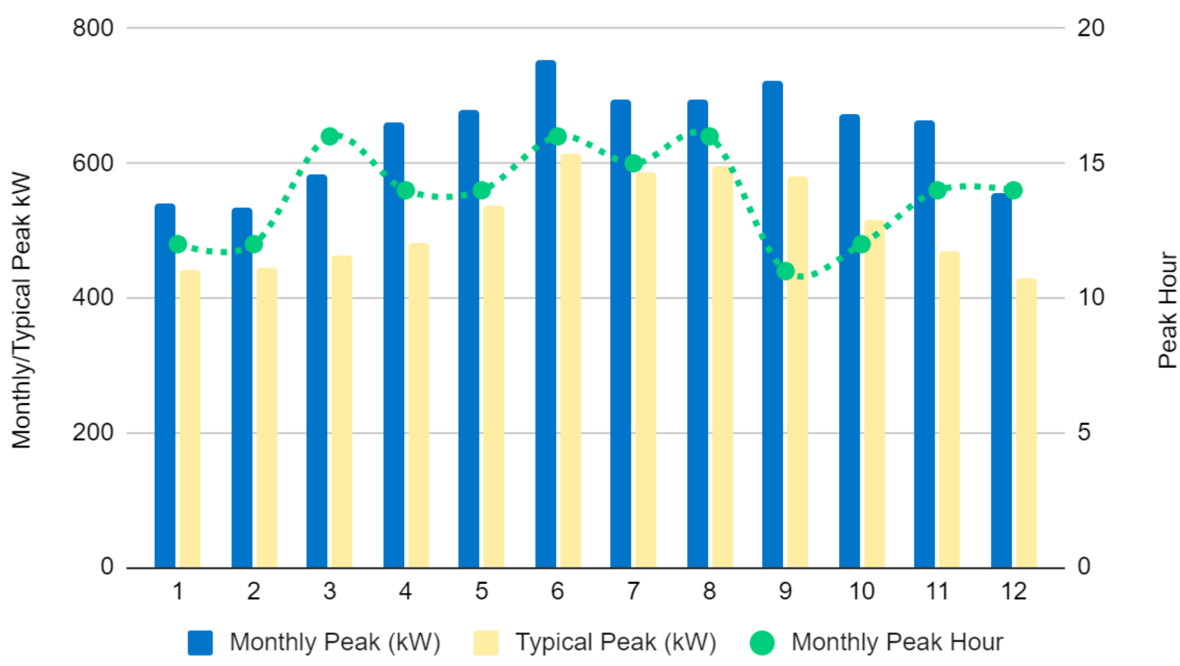


Figure 7. 44 - Proposed Solar Generation and Energy Consumption for Bluefield

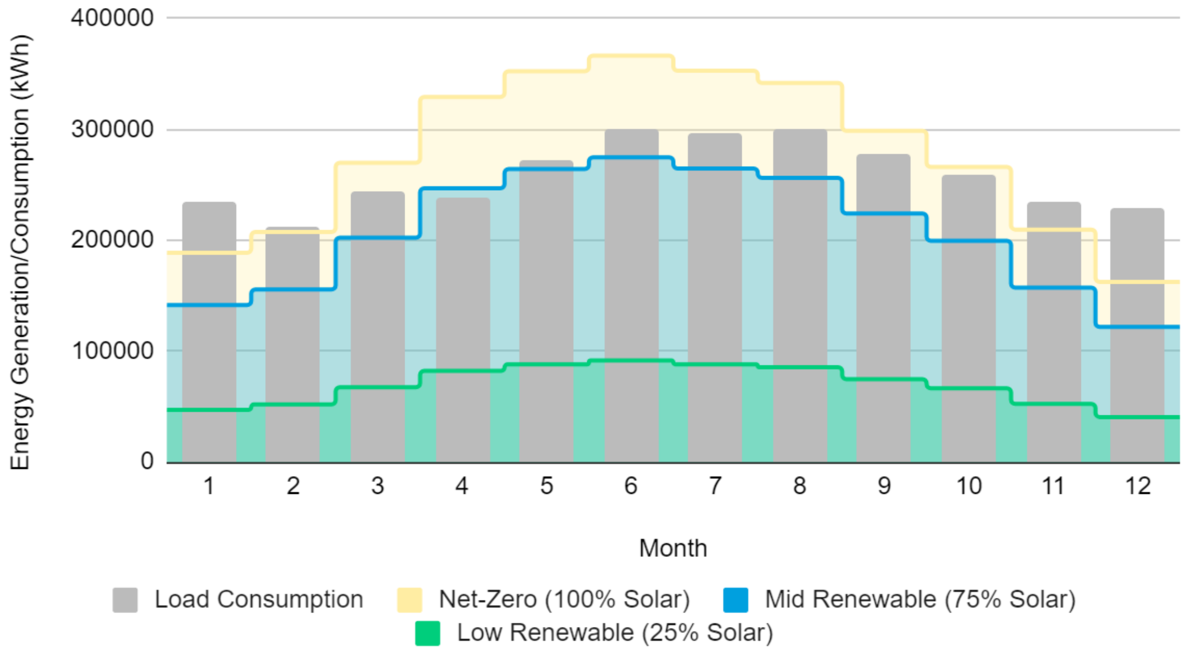


Table 7. 43 - Microgrid Sizing for Bluefield

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	2539	1905	635
Battery Capacity (kW)	550	460	600
Battery Capacity (kWh, 4-hour)	2200	1840	2400
Standby Generation (kW)	0	295	385

Table 7. 44 - Microgrid Scenarios Economic Analysis for Bluefield

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**

Solar ($)	4,224,037	3,947,378	3,842,313	3,168,027	2,960,533	2,881,735	1,056,009	986,844	960,578
Battery ($)	1,000,617	891,122	726,765	836,879	745,302	607,840	1,091,582	972,134	792,835
Standby Generator ($)	-	-	-	147,500	118,000	88,500	192,500	154,000	115,500
Design, IT, Operational ($)	995,172	921,619	870,301	790,935	728,350	681,538	445,732	402,472	355,983
Component Costs ($)	6,219,825	5,760,119	5,439,379	4,943,342	4,552,185	4,259,613	2,785,823	2,515,450	2,224,897
Solar NPV O&M ($)	505,533	401,960	358,934	379,150	301,470	269,200	126,383	100,490	89,733
Battery NPV O&M ($)	257,064	199,259	137,542	214,999	166,653	115,035	280,433	217,373	150,046
Total O&M ($)	762,596	601,218	496,476	594,148	468,122	384,236	406,816	317,863	239,779
Total Project Costs ($)	6,982,422	6,361,338	5,935,855	5,537,490	5,020,308	4,643,849	3,192,639	2,833,313	2,464,676

Ronceverte

Figure 7. 45 - Ronceverte Load and Solar Analysis

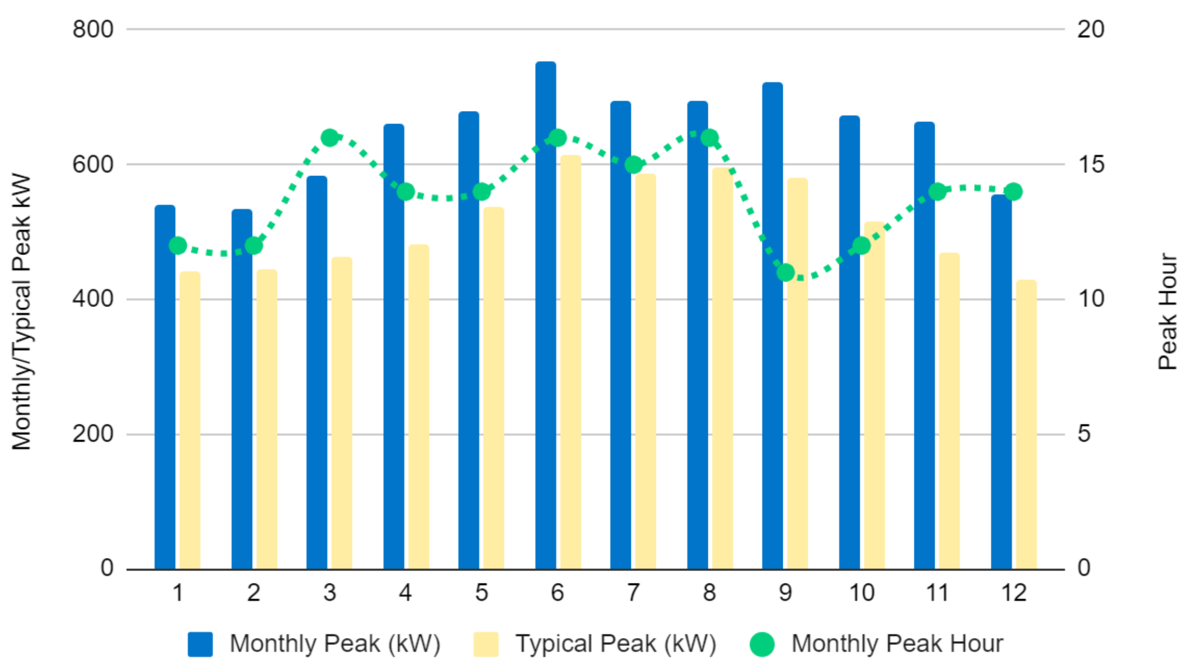


Figure 7. 46 - Proposed Solar Generation and Energy Consumption for Ronceverte

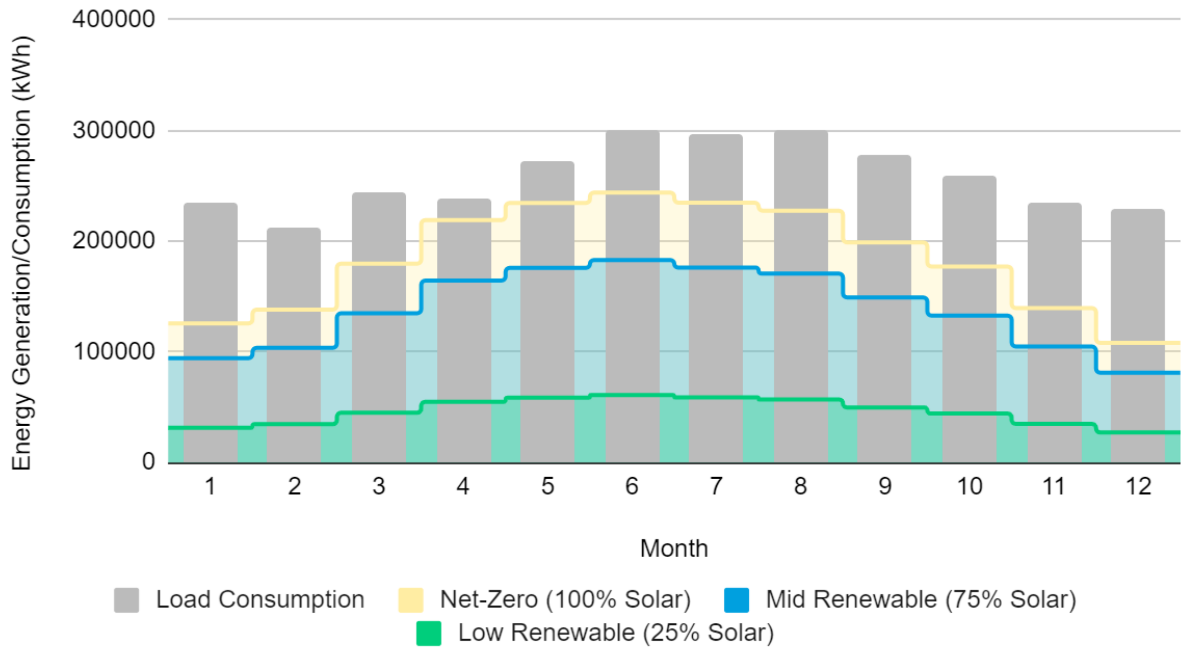


Table 7. 45 - Microgrid Sizing for Ronceverte

	High Renewable	Mid Renewable	Low Renewable
Solar (kWDC)	1689	1267	422
Battery Capacity (kW)	440	355	385
Battery Capacity (kWh, 4-hour)	1760	1420	1540
Standby Generation (kW)	0	180	215

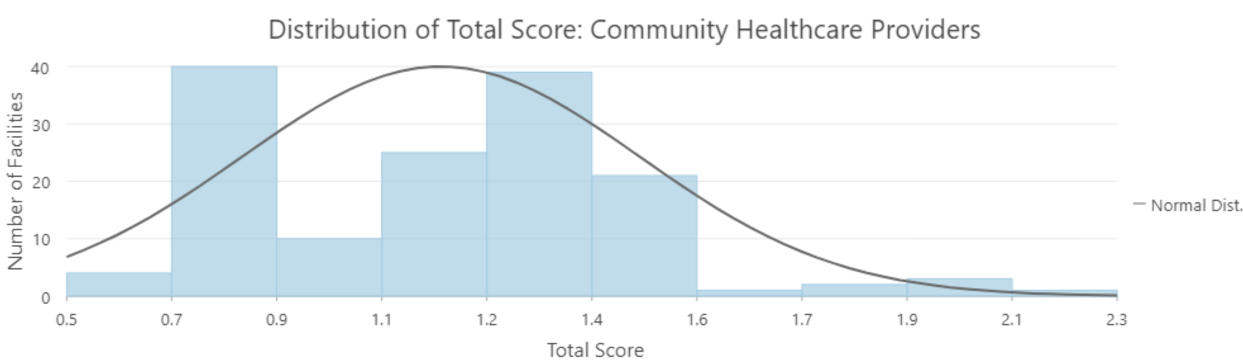
Table 7. 46 - Microgrid Scenarios Economic Analysis for Ronceverte

	High Renewable			Mid Renewable			Low Renewable		
Project Costs	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**	**High Cost**	**Mid Cost**	**Low Cost**
Solar ($)	2,810,264	2,626,202	2,556,302	2,107,698	1,969,651	1,917,226	702,566	656,550	639,075

Battery ($)	800,493	712,898	581,412	645,853	575,179	469,094	700,432	623,786	508,736
Standby Generator ($)	-	-	-	90,000	72,000	54,000	107,500	86,000	64,500
Design, IT, Operational ($)	687,763	636,019	597,660	541,629	498,444	464,823	287,714	260,255	230,916
Component Costs ($)	4,298,520	3,975,119	3,735,374	3,385,179	3,115,274	2,905,143	1,798,212	1,626,591	1,443,228
Solar NPV O&M ($)	336,332	267,425	238,800	252,249	200,569	179,100	84,083	66,856	59,700
Battery NPV O&M ($)	205,651	159,407	110,034	165,923	128,612	88,777	179,944	139,481	96,280
Total O&M ($)	541,983	426,832	348,833	418,172	329,181	267,877	264,028	206,337	155,979
Total Project Costs ($)	4,840,504	4,401,951	4,084,208	3,803,351	3,444,455	3,173,020	2,062,239	1,832,928	1,599,207

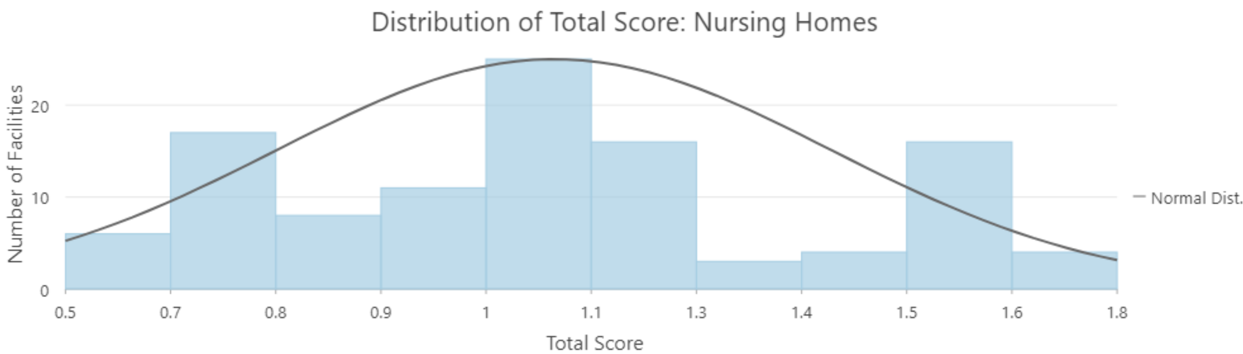
Appendix 3: Detailed Distribution of Scores by Critical Facility Type

Figure 7. 47 - Community Healthcare Providers



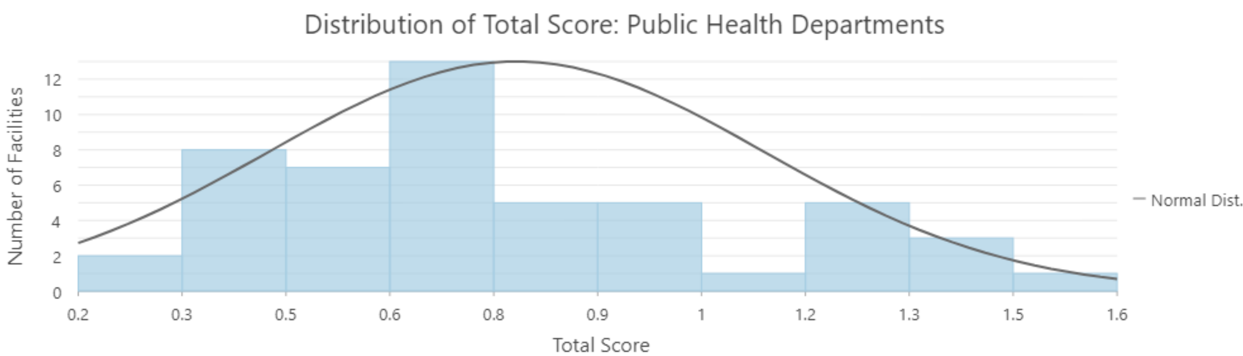
Source: Smart Electric Power Alliance (2022)

Figure 7. 48 - Nursing Homes



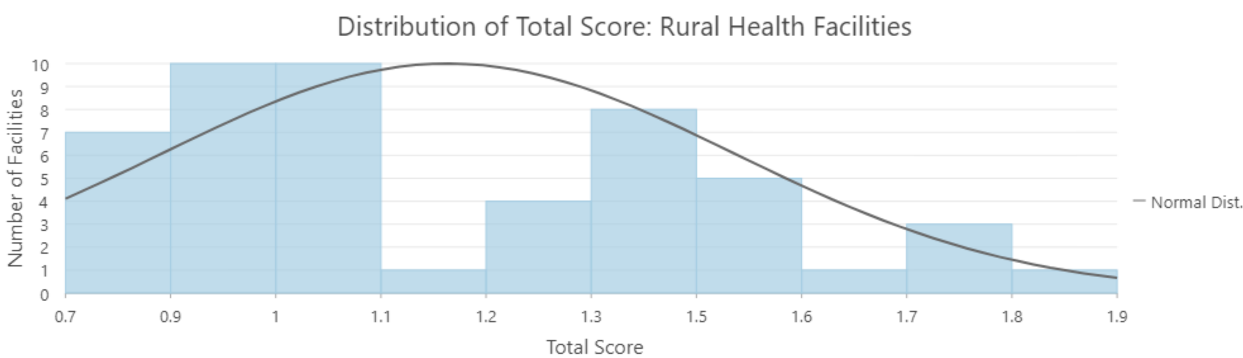
Source: Smart Electric Power Alliance (2022)

Figure 7. 49 - Public Health Departments



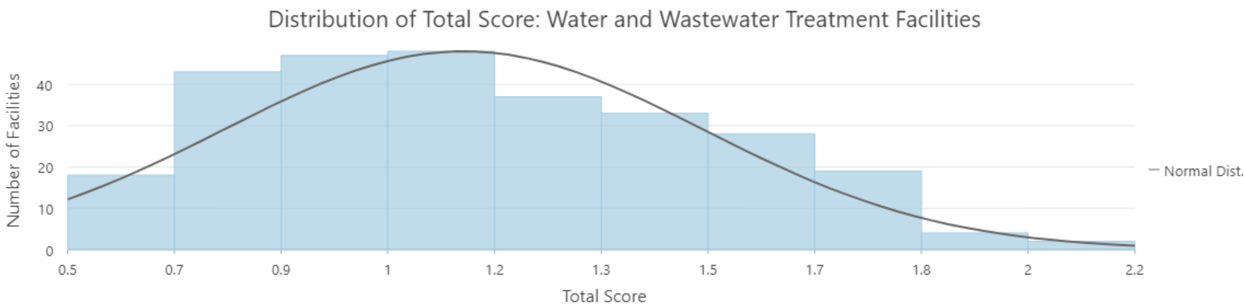
Source: Smart Electric Power Alliance (2022)

Figure 7. 50 - Rural Health Facilities



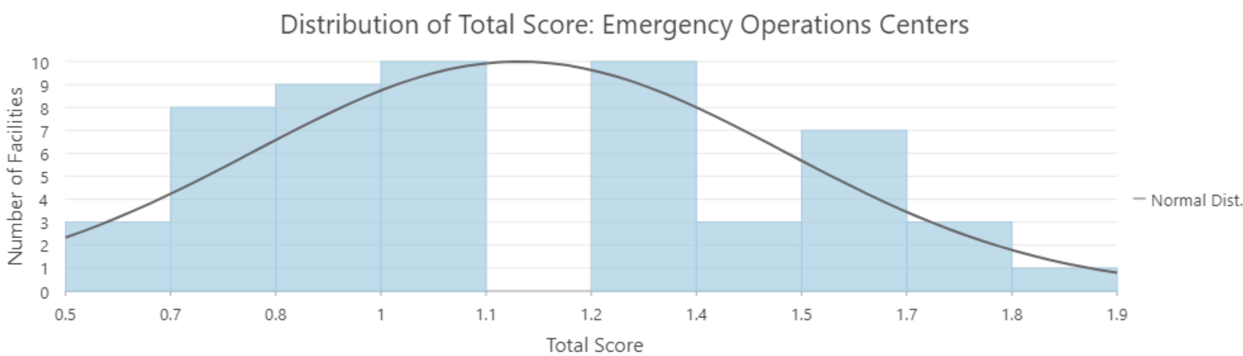
Source: Smart Electric Power Alliance (2022)

Figure 7. 51 - Water and Wastewater Treatment Facilities



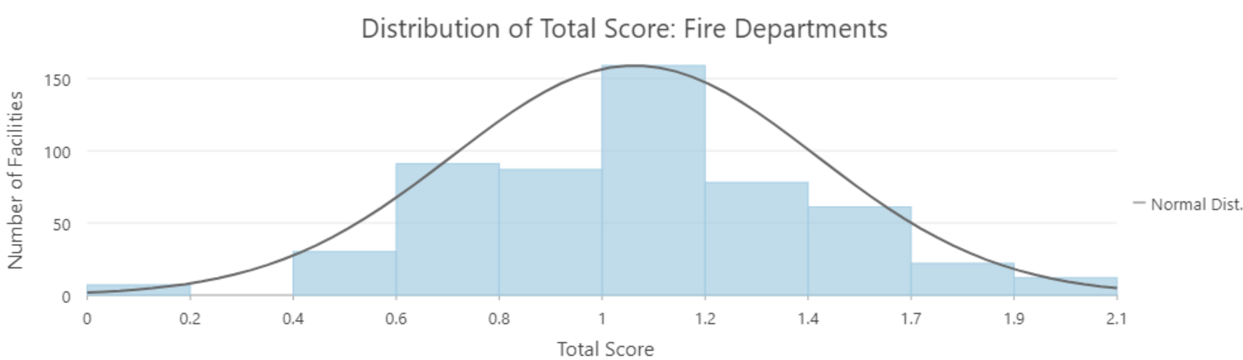
Source: Smart Electric Power Alliance (2022)

Figure 7. 52 - Emergency Operations Centers



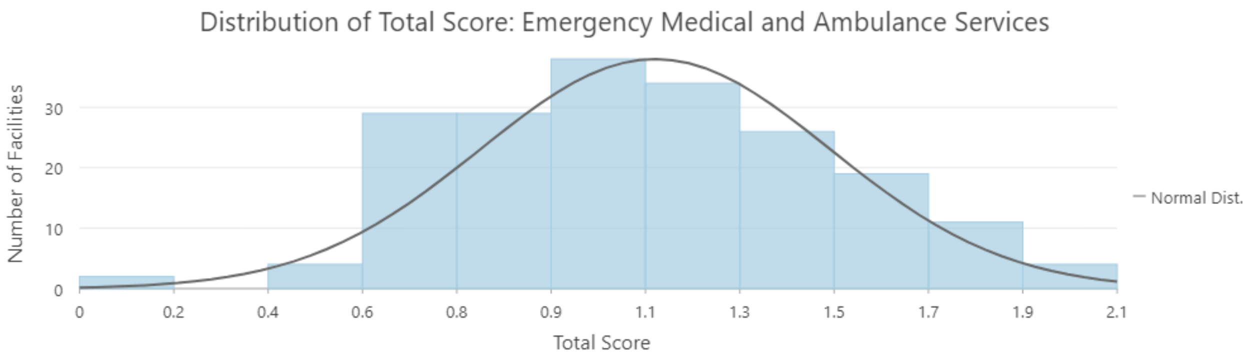
Source: Smart Electric Power Alliance (2022)

Figure 7. 53 - Fire Departments



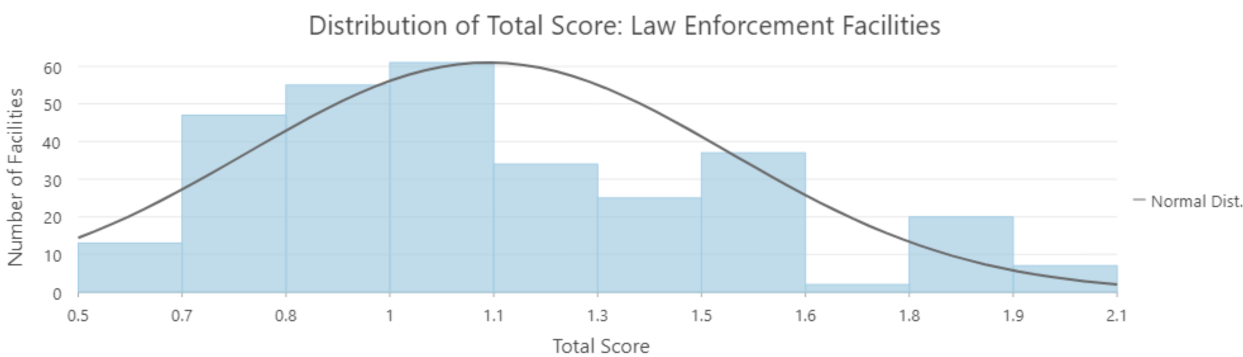
Source: Smart Electric Power Alliance (2022)

Figure 7. 54 - Emergency Medical and Ambulance Services



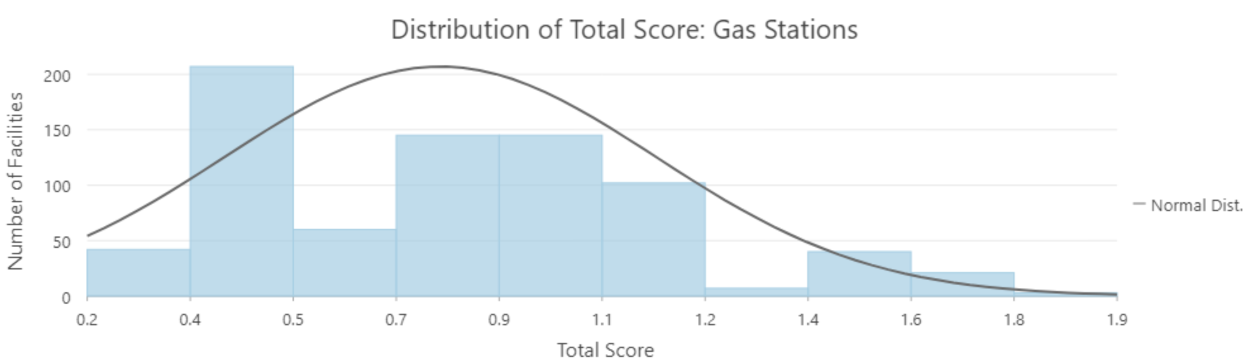
Source: Smart Electric Power Alliance (2022)

Figure 7. 55 - Law Enforcement



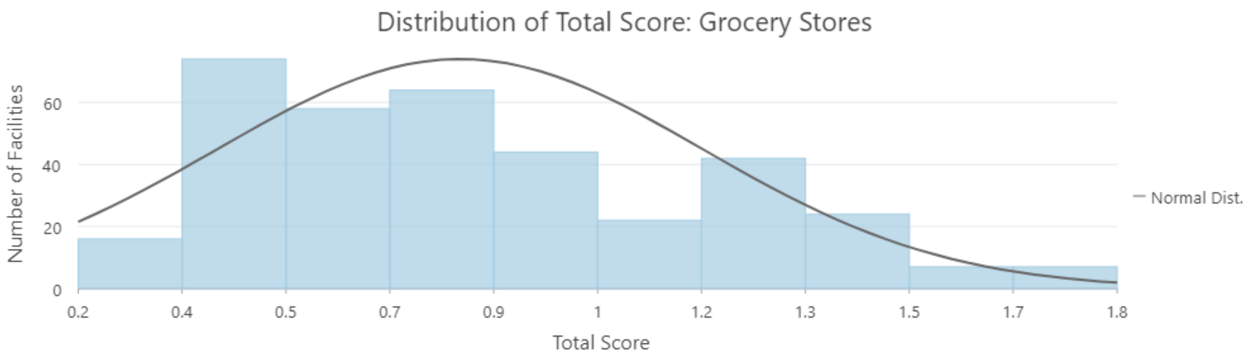
Source: Smart Electric Power Alliance (2022)

Figure 7. 56 - Gas Stations



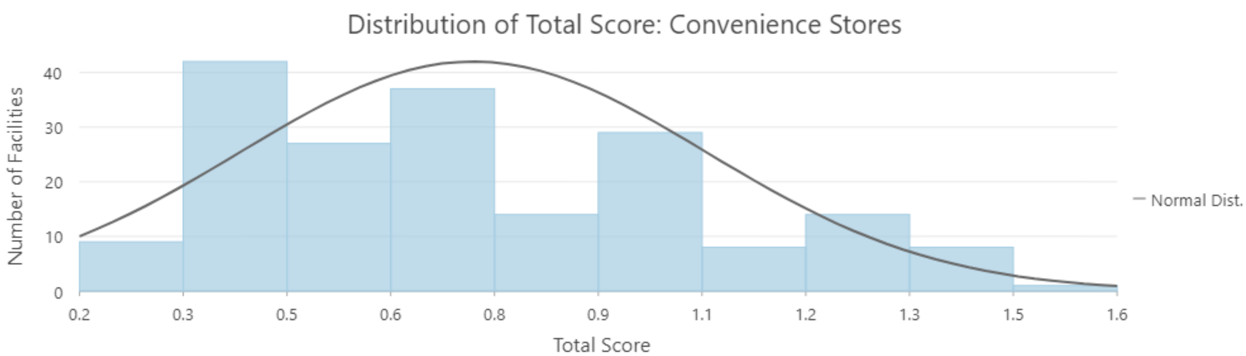
Source: Smart Electric Power Alliance (2022)

Figure 7. 57 - Grocery Stores



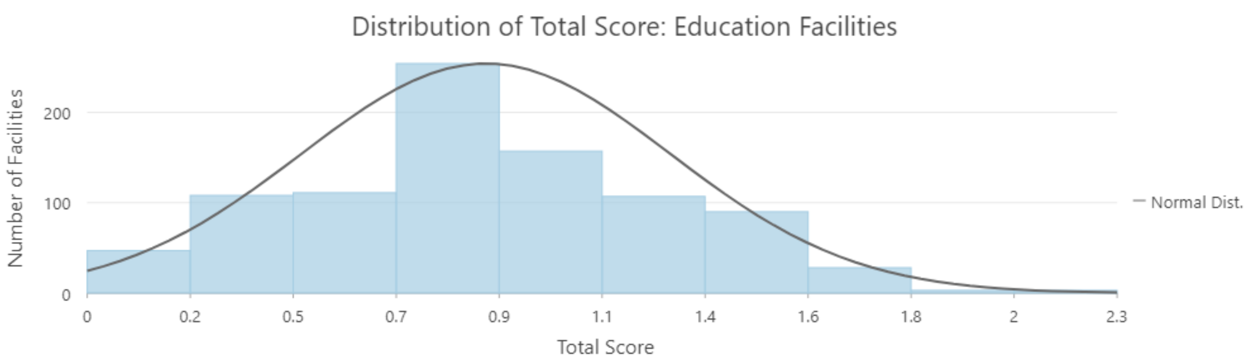
Source: Smart Electric Power Alliance (2022)

Figure 7. 58 - Convenience Stores



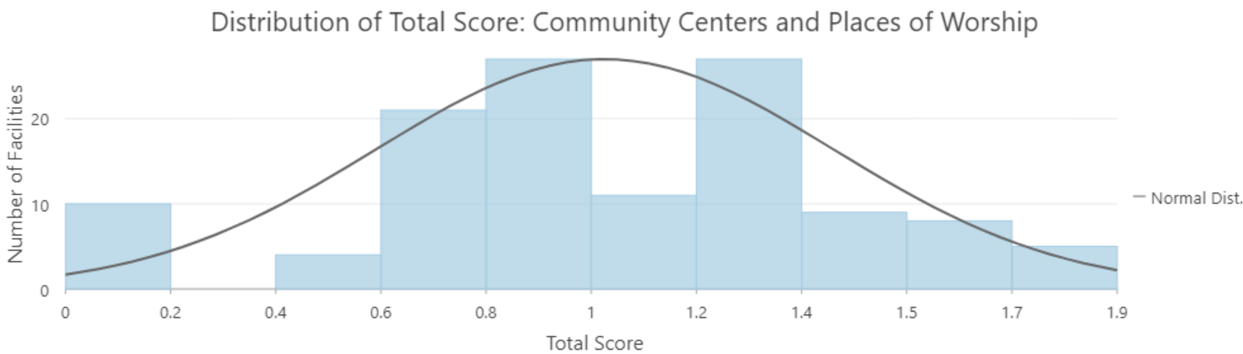
Source: Smart Electric Power Alliance (2022)

Figure 7. 59 - Education Facilities



Source: Smart Electric Power Alliance (2022)

Figure 7. 60 – Community Centers and Places of Worship Facilities



Source: Smart Electric Power Alliance (2022)