COMMONWEALTH OF KENTUCKY REGIONAL MICROGRIDS FOR RESILIENCE STUDY

Prepared for the Kentucky Office of Energy Policy (OEP)

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Contents

List of Figures

List of Tables

Authors

Jared Leader, Senior Manager – Research & Industry Strategy, Smart Electric Power Alliance
Harry Cutler, Senior Analyst – Research & Industry Strategy, Smart Electric Power Alliance
Carolyn Dougherty, Analyst – Research & Industry Strategy, Smart Electric Power Alliance

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 transition to a clean and modern electric future and a carbon-free energy system by 2050. We are a trusted partner providing education, research, standards, and collaboration to help utilities, electric customers, and other industry players across four pathways: Transportation Electrification, Grid Integration, Regulatory Innovation and Utility Business Models. 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.

Acknowledgements

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0.0 Executive Summary

Floods, high winds, extreme cold / winter storms, tornadoes and other uncontrollable natural disasters threaten to disrupt the electrical system in Kentucky. Therefore, it is imperative to plan and design for operational flexibility. One strategy in light of these threats is the deployment of site-specific nanogrids[1] and regional community microgrids[2] to provide electrical service to critical infrastructure and reduce the impact on the community in high-risk areas. The Kentucky Office of Energy Policy ("OEP") 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 Kentucky. It is anticipated the study results will facilitate private sector and local government with identifying resilience funding opportunities and mitigation planning purposes.

The study methodology included four steps to identify potential microgrid deployments for critical facilities to increase the state-wide resilience in Kentucky against natural hazards:

1. **Landscape Review** - Stakeholder engagement to identify prioritization around critical facility types and natural hazards.
2. **Data Collection** – Data collection to determine state-wide factors of siting and designing potential microgrids, such as load profiles, reliability hotspots, distribution of critical facilities and natural hazards, population density, and energy burden.
3. **Site Selection –** Based on selection criteria, identification of specific facilities (nanogrids) and clusters of facilities (regional community microgrids) where microgrids are suited to provide resilience.
4. **Deployment Strategy –** Sizing, cost estimates, and possible microgrid deployment strategies to increase resilience.

Possible implementation sites for deployment incorporated a preliminary prioritization that began with identifying critical infrastructure facilities and was refined by taking into consideration a number of selection criteria including:

- **Critical infrastructure facility type –** Assessment of the criticality of services each facility type provides to the public and state.
- **Geographical proximity –** Identification of critical infrastructure facilities, of the same type, within close proximity to other potential microgrid deployment sites. The relative

[1] A "nanogrid" is a small electric domain connected to the electric power grid and composed of a controller, loads (generally less than 100 kW), storage (optional), distributed generation, and gateways. Nanogrids are limited to one structure or primary load and have the ability to island from the grid and provide energy self-sufficiency. – Lawrence Berkley National Labs (LBNL), [Nanogrids: Evolving our electricity systems from the bottom up] (2010).

[2] A "microgrid" is a group of interconnected loads and distributed energy resources (DERs) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. Microgrids can connect and disconnect from the grid to enable it to operate in both grid-connected or island-modes. – U.S. Department of Energy (DOE), [The U.S. Department of Energy's Microgrid Initiative] (2012).

distance between potential sites was used to identify clusters of closely grouped facilities.

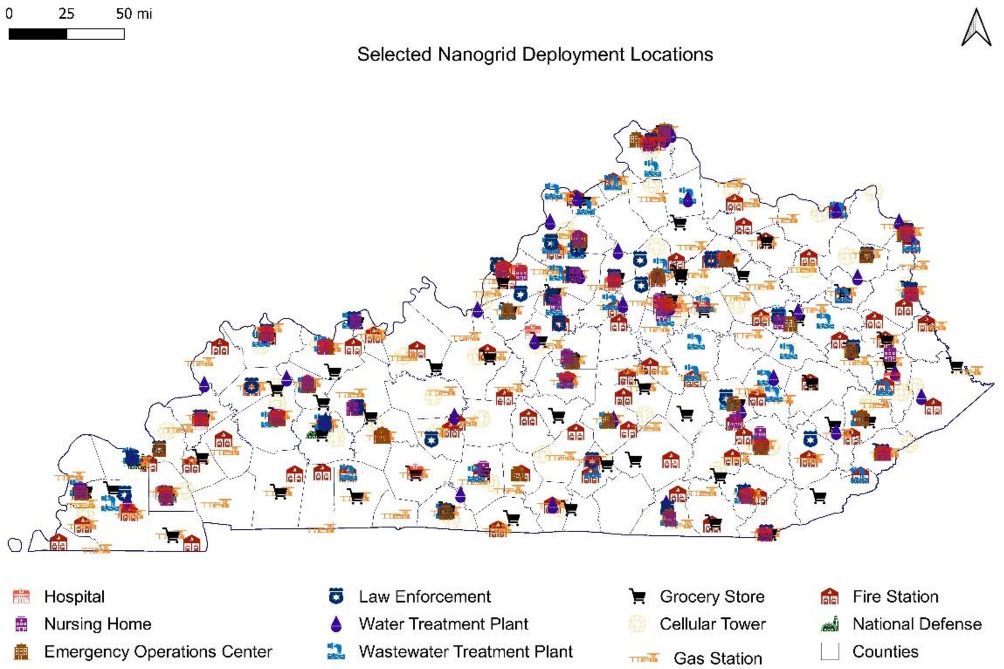
- **Areas at high risk of natural hazard –** Analysis of geographic areas at highest risk of being affected by a natural hazard. Natural hazards, which pose catastrophic threats, are grouped in Tier 1 and hazards, which pose non-catastrophic threats, are grouped in Tier 2. Priority was given to critical infrastructure facilities outside of Tier 1 and Tier 2 hazard areas.
- **Reliability hotspots –** Prioritization of potential sites located within areas identified as having reliability issues.
- **Population density –** Assessment of the population by county and urban areas to determine where grid support from a microgrid would be most impactful in the event of an outage.
- **Energy burden / underserved areas –** Consideration of the energy burden by county to determine areas that are most underserved and therefore, where a microgrid would support equity in grid reliability.

SEPA evaluated two specific deployment strategies to harden portions of Kentucky's electrical system, particularly those serving critical infrastructure and loads:

1. **Nanogrid installations** at individual critical facility infrastructure sites (e.g. healthcare facilities, water treatment plants, law enforcement facilities, grocery stores, etc.) enabling the facility to operate in isolation and provide much-needed services to Kentucky communities after a natural disaster. The installation of onsite backup generation, solar PV and battery storage at strategically located sites can create a series of self-powered centers to help the local communities recover in the immediate aftermath of a natural disaster.
2. **Regional community microgrids** serving multiple critical facility loads within a close geographic area could also operate in isolation and provide much-needed services to Kentucky communities at a large-scale after a natural disaster. The installation of onsite backup generation, solar PV and battery storage could help these communities recover quicker from natural disasters.

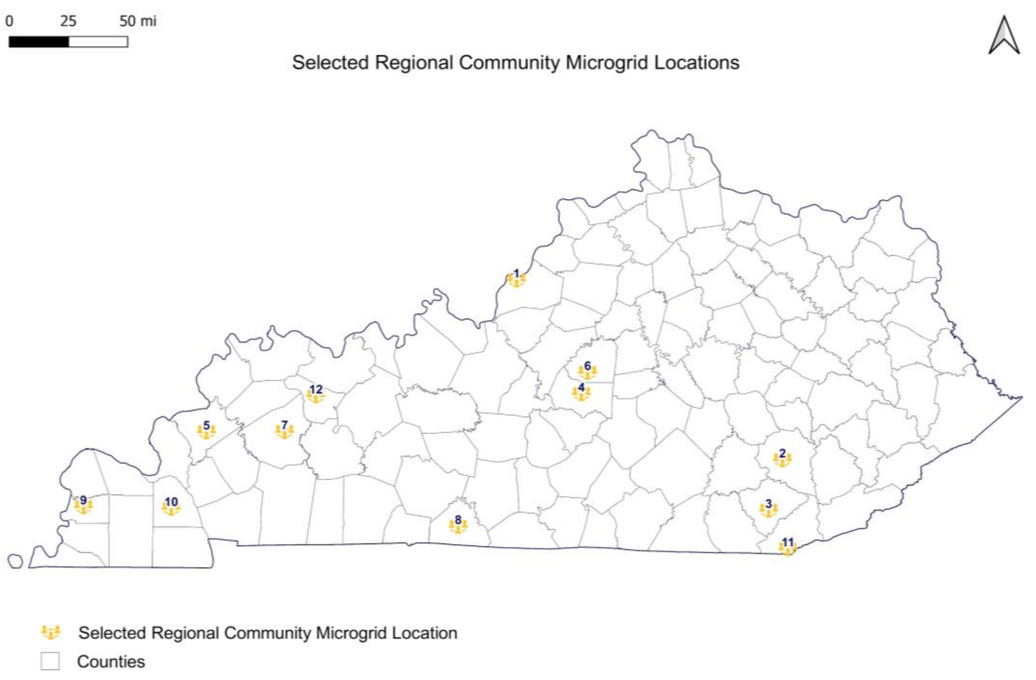
SEPA identified 558 potential nanogrid installations and 12 potential regional community microgrids. Maps of potential nanogrid and regional community microgrid deployments are included below in Figure 3.1 and Figure 3.4.

*Figure 3. 1 - **Selected Nanogrid Deployment Locations***



Source: Smart Electric Power Alliance, 2021

*Figure 3. 4 **- Selected Regional Community Microgrid Locations***

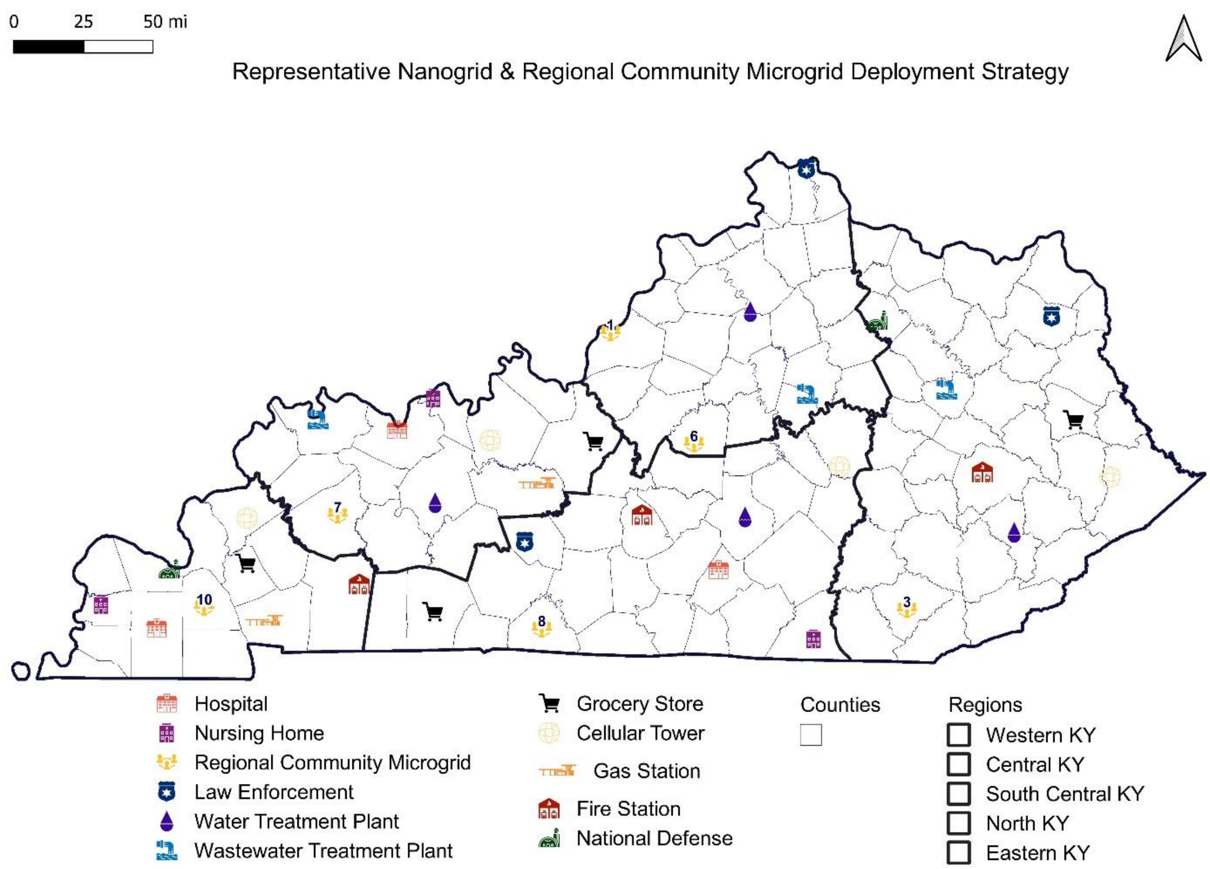


Source: Smart Electric Power Alliance, 2021

The nanogrid and regional community microgrid deployment strategies are not mutually exclusive and are encouraged to be used by stakeholders to develop a variety of deployment plans to achieve their desired objectives.

Figure 4.2 provides an illustrative example of how the two deployment strategies can be used together to achieve state-wide resilience. In this example, SEPA used a combination of site-specific nanogrids and regional community microgrids to ensure all eleven types of critical facilities are represented in each of the regions.[3]

Figure 4. 2 - ***Representative Nanogrid & Regional Community Microgrid Deployment Strategy***



Source: Smart Electric Power Alliance, 2021

[3] Note: Due to the limited number of national defense facilities, those types of facilities are not represented in each region.

The nanogrid and microgrid systems are sized for typical daily operations, leveraging standby backup generation and the dispatch of solar and battery storage. Selected sites and capital cost estimates[4] for the potential deployments are shown in Table 4.1 and 4.12 below.

*Table 4.1 - **Nanogrid Deployment Strategy Capital Cost Estimates***

Critical Infrastructure Facilities		Fossil Fuel Only Design Cost	Moderate Renewables Design Cost
Facility Type	**# Sites Selected**	**Per facility** (thousands)	**Per facility** (thousands)
Cell Towers	56	$5 - $8	$86 - $97
Hospitals	26	$861 - $1,378	$10,703 - $12,260
Nursing Homes	32	$17 - $28	$203 - $235
Water Treatment Plants	44	$10 - $17	$239 - $272
Wastewater Treatment Plants	50	$10 - $17	$239 - $272
National Defense Facilities	5	$5 - $8	$43 - $51
Law Enforcement Facilities	42	$7 - $11	$98 - $113
Fire Stations	90	$12 - $19	$166 - $192
Emergency Operations Centers	33	$7 - $11	$78 - $90
Gas Stations	110	$10 - $17	$176 - $201
Grocery Stores	70	$12 - $19	$153 - $177

Source: Smart Electric Power Alliance, 2021.

[4] Cost estimates do not include added costs associated with electrical reconfiguration as a microgrid if the clustered facilities are not all on the same electrical circuit.

*Table 4.12 - **Summary of Regional Community Microgrid Cost Estimates***

Regional Community Microgrids		Fossil Fuel Only Design Cost	Moderate Renewables Design Cost
Microgrid	**# Critical Facilities within Microgrid**	**Cost** (thousands)	**Cost** (thousands)
1 - Jefferson County Community Microgrid	5	$537 - $894	$8,798 - $9,940
2 - Clay County Community Microgrid	4	$1,141 - $1,931	$11,012 - $12,616
3 - Knox County Community Microgrid	4	$1,148 - $1,943	$11,116 - $12,732
4 - Marion County Community Microgrid	4	$43 - $72	$750 - $856
5 - Crittenden County Community Microgrid	5	$45 - $75	$667 - $766
6 - Washington County Community Microgrid	8	$63 - $106	$1,191 - $1,352
7 - Hopkins County Community Microgrid	4	$25 - $42	$367 - $420
8 - Allen County Community Microgrid	5	$38 - $64	$724 - $823
9 - Carlisle County Community Microgrid	4	$30 - $50	$548 - $622
10 - Marshall County Community Microgrid	4	$28 - $47	$614 - $693
11 - Bell County Community Microgrid	5	$42 - $69	$659 - $754
12 - McLean County Community Microgrid	4	$38 - $64	$615 - $704

Source: Smart Electric Power Alliance, 2021.

This study develops the groundwork for utilities, local and state governments, and other industry stakeholders to move from planning to the implementation phase of microgrid development. These next steps may include conducting design and engineering work of the selected sites and applying for FEMA and other funding to construct and install the microgrids. Additional potential next steps to build upon this microgrid study is to conduct further circuit, financial, and 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.

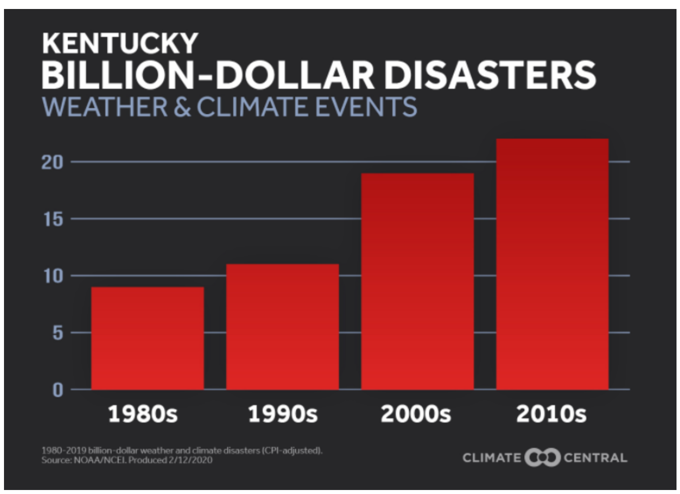
1.0 Introduction

The potential deployment of microgrids has emerged as a shared point of action for increasing the overall resilience of the electric power grid and for broader efforts of natural disaster mitigation planning.

The objective of this analysis is to outline natural disaster outage risk and the ability to strategically deploy microgrids to provide enhanced resilience to critical infrastructure across the state. This study will help local governments and the private sector to identify potential microgrid deployment strategies for local energy emergency planning and increased resilience.

Natural disaster and extreme weather events have increased in both frequency and magnitude over the past several years. In 2020, there were 22 natural disaster events in the United States each causing losses of over $1 billion dollars. This marks the sixth consecutive year with at least ten such events. These trends hold true in Kentucky as well which has been increasingly affected by natural disaster and extreme weather events. From 2000 to 2019, the state has been affected by 43 of these billion-dollar extreme weather events, spending an estimated $500 million to $1 billion per year.[5]

*Figure 1. 1 - **Kentucky Billion-Dollar Disasters***



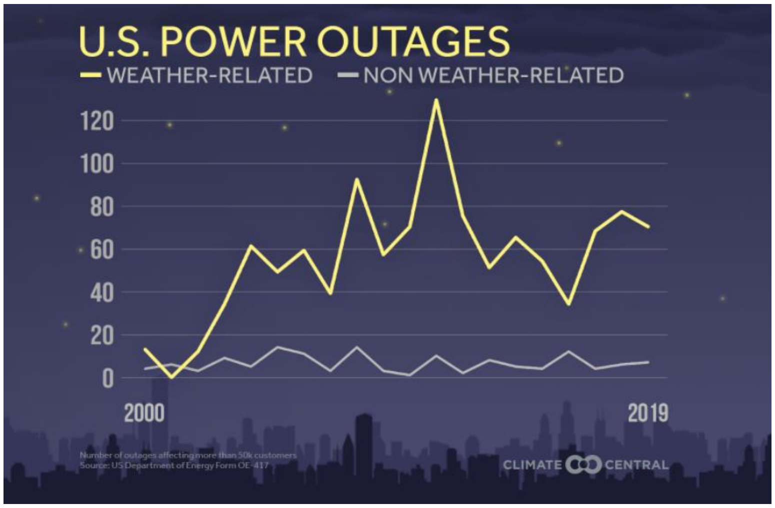
Source: Climate Central, Billion-Dollar Disasters by Decade - Kentucky (2020)

This is an increase from just 20 such events from 1980 to 1999 costing $250 million to $500 million per year.[6] A major contributor of this economic loss is power outages. National power outage data suggests a 67% increase in outages from weather-related events since 2000. Kentucky also has witnessed an increase in extreme weather-related power outages in recent years.

[5] Note this reflects the summation of billion-dollar events that affected Kentucky. It does not mean that the state suffered $1 billion in losses for each event.

[6] NOAA National Centers for Environmental Information (NCEI), U.S. Billion Dollar Weather and Climate Disasters (2021).

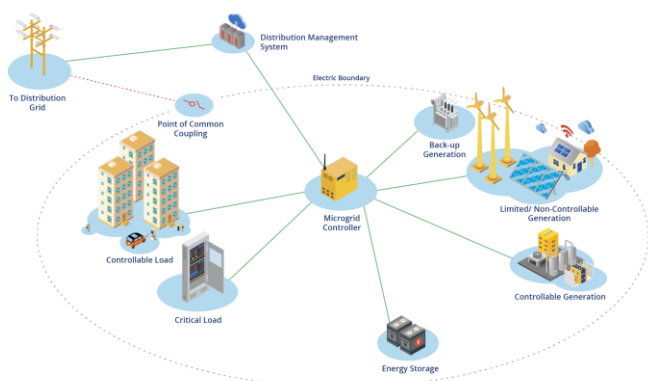
Figure 1. 2 - ***U.S. Power Outage Events***



Source: Climate Central, Power Outages (2020)

Microgrids can be a useful tool for increasing the resilience of the electric power grid in the event of power outages due from a natural disaster or extreme weather event. By definition microgrids are localized grids made up of distributed energy resources (DERs) that can connect and disconnect from the traditional power grid to serve multiple entities (or loads).[7]

Figure 1. 3 - ***Typical Microgrid Components***



Source: Smart Electric Power Alliance, 2020

The primary value of a microgrid as it relates to resilience is its ability to "island", or disconnect from the traditional power grid, and operate independently during a grid outage or disturbance.[8] When strategically located, this function enables microgrids to provide increased resilience to critical facility infrastructure in the event of a natural disaster or extreme weather event.

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[7] U.S. Department of Energy (DOE), DOE Microgrid Workshop (2011).
[8] Smart Electric Power Alliance, The Microgrid Playbook: Community Resilience for Natural Disasters, p. 5 (2020).

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.[9] The BRIC program is designed to promote a national culture of preparedness through supporting states, local governments, tribes, and territories' hazard mitigation projects.[10] FEMA has been authorized to set aside 6 percent of the aggregate post disaster federal grants provided each year to fund the program.[11] In 2020, total BRIC funding was $500 million representing a significant opportunity for Kentucky 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.

Analysis in this study includes the prioritization of several critical infrastructure facilities throughout Kentucky. Critical infrastructure facilities were prioritized based on input from multiple stakeholders (see Table 1.1 - List of Stakeholders) and coordinated with FEMA's designated Community Lifelines and Kentucky Power Company's tiered outage restoration priorities.

- Communications facilities
- Hospitals
- Nursing facilities
- Water treatment plants
- Wastewater treatment plants
- National defense facilities
- Law enforcement facilities
- Fire stations
- Emergency operations centers
- Gas stations
- Grocery stores
- Natural gas underground storage facilities
- Petroleum terminals.

The study evaluated 6,640 critical infrastructure facilities for potential microgrid sites. SEPA conducted the evaluation using a set of site-selection criteria to meet the following objectives:

1. To identify microgrid sites that can support the grid where it is needed most while protecting the technology from natural hazard-induced damage, and
2. To ensure that highly populated areas and underserved communities, the most vulnerable areas of the state, have access to essential services during power outages.

Based on this set of site-selection criteria, SEPA identified 558 potential nanogrid deployments and 12 potential regional community microgrid deployments.

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[9] Federal Emergency Management Agency (FEMA), Disaster Recovery Reform Act (DRRA) (2019) p. 6
[10] FEMA, Building Resilient Infrastructure and Communities (BRIC) (2020)
[11] FEMA, Disaster Recovery Reform Act (DRRA) (2019) p. 6

As part of the analysis, this study contains a breakdown of the economic impacts of the different approaches to strategically deploy microgrids for increased resilience against natural hazards and extreme weather events.

*Table 1. 1 - **List of Stakeholder Organizations***

Stakeholder Organizations
American Electric Power Kentucky
Duke Energy Kentucky
Kentucky Division of Water
Kentucky Emergency Management
Kentucky Environmental Response Team
Kentucky Geological Survey
Kentucky Office of Energy Policy
Kentucky Petroleum Marketers Association
Kentucky Public Service Commission
Kentucky Retail
Louisville Gas & Electric Kentucky Utilities
National Rural Electric Cooperative Association (NRECA)

Sections of this study are broken down into the following assessment components used to develop this microgrid study:

- Data Collection
- Site Selection
- Preliminary Analysis and Deployment Strategies

2.0 Data Collection

Analysis in this study was developed based on data collected by SEPA in the four following areas.

- Population / Demographics
- Critical Infrastructure Facilities
- Natural Hazards
- Utility & Electricity

Utilizing and modifying existing databases, SEPA conducted a primary geospatial assessment of the current risks to the grid and potential sites to evaluate microgrid deployment. Results of this primary assessment were presented to OEP and a group of stakeholders to prioritize critical facility infrastructure and natural hazards for the site selection process. The repeated process of criteria selection, data collection, and stakeholder review and re-prioritization effectively primed a site selection process that incorporated SEPA's 5 Step Microgrid Approach,[12] FEMA's BRIC Project guidelines,[13] and the state of Kentucky's unique needs.

The following sections provide an overview of the data collection methodology. For more information of the data collection methodology and results, see Appendix 1: Detailed Data Collection Methodology

Population / Demographics

Areas of high population density and underserved communities throughout the state were assessed in order to support grid resilience in an equitable way. To evaluate these factors, data was collected from the 2010 U.S. Census, the Kentucky Atlas and Gazetteer, and U.S. DOE Low-Income Energy Affordability Data Tool (LEAD).

Critical Infrastructure Facilities

Collaboration with stakeholders informed the selection of the types of critical facility to assess as part of the microgrid site selection process. Datasets were curated for communications facilities, hospitals, nursing homes, water treatment plants, wastewater treatment plants, national defense facilities, law enforcement facilities, fire stations, emergency operations centers, gas stations, grocery stores, natural gas underground storage facilities, and petroleum terminals. With the exception of natural gas underground storage facilities and petroleum terminals, all of the aforementioned facilities were considered for microgrid solutions.

Table 2.1 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: Detailed Data Collection Methodology.

[12] SEPA, The Microgrid Playbook: Community Resilience for Natural Disasters (2020) p. 11
[13] FEMA, When You Apply for Building Resilient Infrastructure and Communities (BRIC) Funds (2020)

*Table 2.1 - **Critical Infrastructure Facilities Data Collection Summary***

Facility	Data Source	Key Stats	Notes
Communication Facilities	HIFLD	1,234 total	Clusters of sites exist in more densely populated counties
Hospitals	OEP	137 total	More sites exist in densely populated counties.
Nursing Homes	OEP	379 total	More sites exist in densely populated counties.
Water Treatment Plants	KyGovMaps Open Data	213 total	Sites are mostly uniformly distributed across the state.
Wastewater Treatment Plants	KyGovMaps Open Data	240 total	Sites are mostly uniformly distributed across the state.
National Defense Facilities	Data Axle	46 total	Most sites are located in densely populated counties.
Law Enforcement Facilities	OEP and HIFLD	484 total	Clusters of sites exist in more densely populated counties.
Fire Stations	OEP and HIFLD	1103 total	Clusters of sites exist in more densely populated counties.
Emergency Operations Centers	HIFLD	142 total	Sites are distributed uniformly across the state.
Gas Stations	Data Axle	1973 total	Clusters of sites exist in more densely populated counties.
Grocery Stores	Data Axle	1273 total	Clusters of sites exist in more densely populated counties.
Natural Gas Underground Facilities	EIA	23 total	Most sites are located in central Kentucky.
Petroleum Terminals	HIFLD	31 total	Clusters of sites exist in more densely populated counties.

Source: Smart Electric Power Alliance, 2021

Natural Hazards

Hazards that pose significant threats to grid reliability were identified through collaboration with stakeholders. Those hazards were grouped into two categories based on the severity of their potential impact to grid infrastructure:

- **Tier 1 Hazards:** consists of hazards that, should they occur, would cause complete destruction to an area and should be avoided completely when evaluating locations for a microgrid placement. These hazards include earthquakes, landslides, karst, mine subsidence, and wildfires.
- **Tier 2 Hazards:** consists of hazards that are non-catastrophic but still pose threats to energy infrastructure. These hazards include flooding, extreme cold and winter storms, wind, and tornadoes.

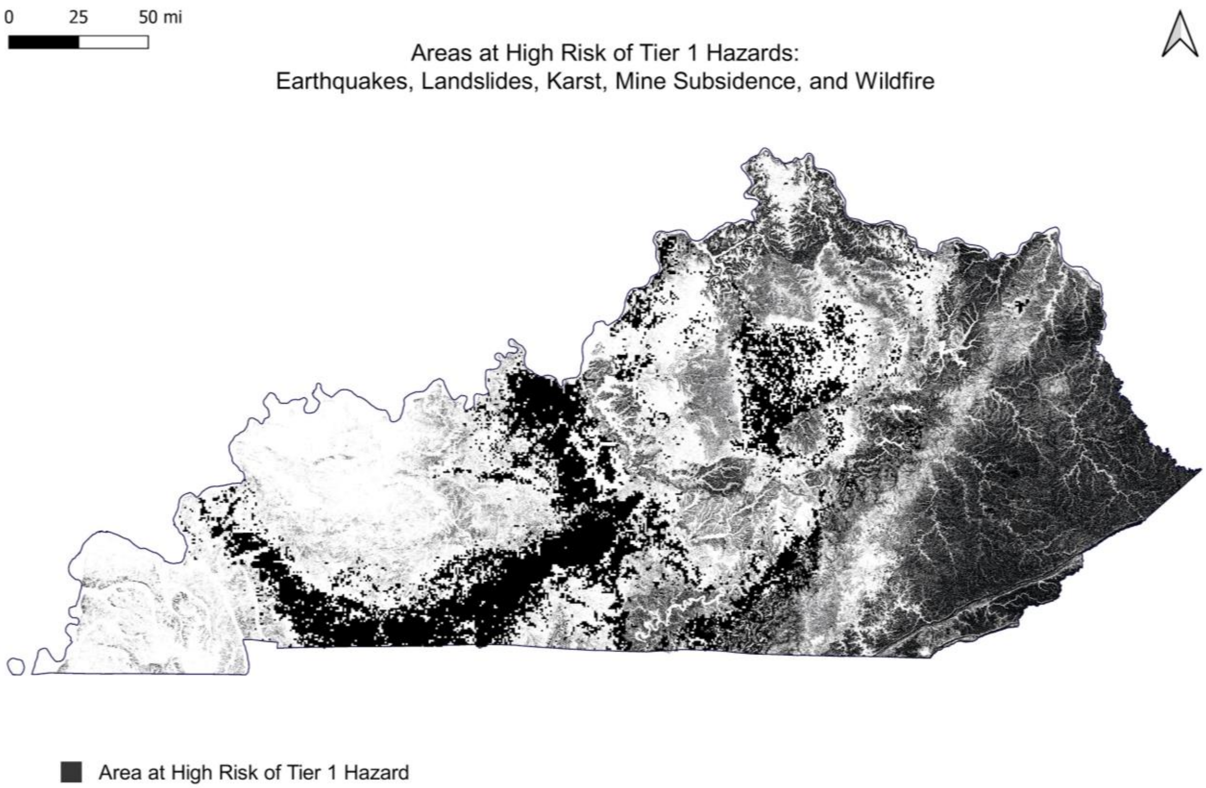
Data for these hazards was collected from sources referenced in their corresponding risk assessment, conducted as a part of the 2018 Kentucky Hazard Mitigation Plan.

The following sections provide a summary of Tier 1 and 2 natural hazards across the state. For more detailed descriptions of Tier 1 and 2 hazards, which regions of Kentucky are most susceptible to risk of these hazards, and additional guidance on siting microgrids effectively to mitigate against these hazards, see Appendix 1: Detailed Data Collection Methodology.

Tier 1 Hazards

The data collected for Tier 1 Hazards was used to evaluate areas that would pose serious threats to microgrid technology, and therefore not be suitable for siting a microgrid. The dark areas seen in Figure 2.1 below indicate areas that are highly susceptible to Tier 1 natural hazards.

*Figure 2. 1 - **Areas at High Risk of Tier 1 Hazards***

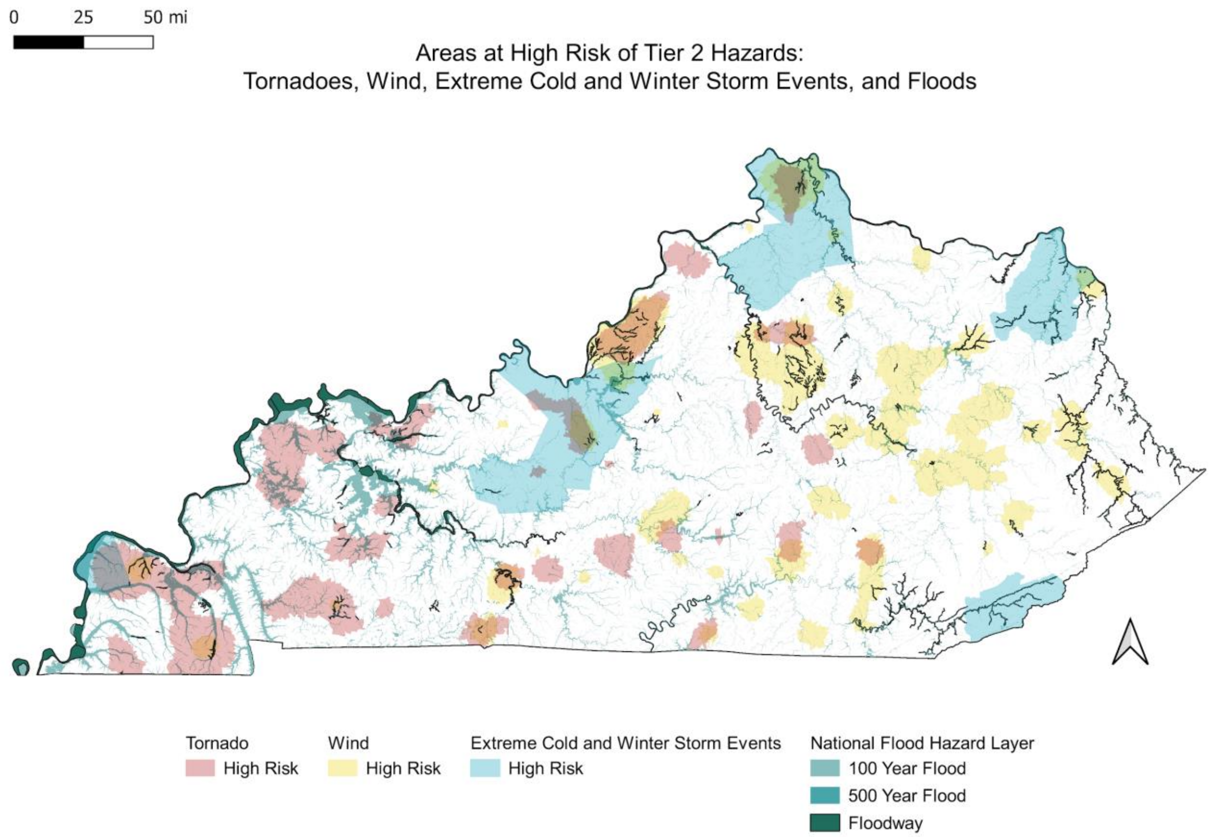


Source: Smart Electric Power Alliance (2021) based on data provided by Matt Crawford, a Kentucky Geological Survey scientist with the University of Kentucky (2020).

Tier 2 Hazards

The data collected for Tier 2 Hazards was used to evaluate disruption-prone areas that may cause damage to energy infrastructure. Figure 2.2 below shows areas that are highly susceptible to Tier 2 natural hazards.

*Figure 2. 2 - **Areas at High Risk of Tier 2 Hazards***



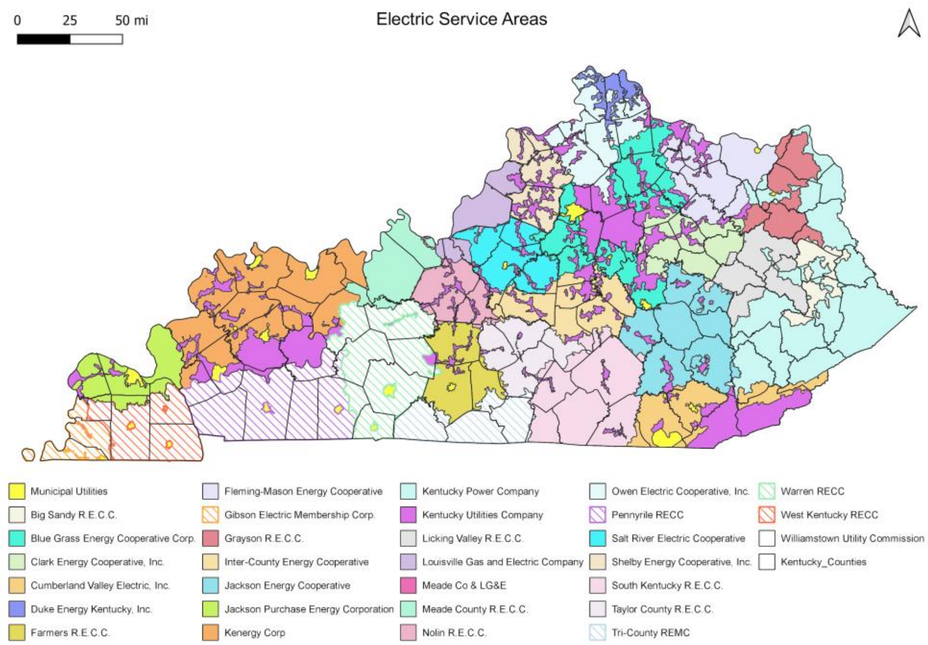
Source: Smart Electric Power Alliance (2021) based on data provided by NOAA's National Centers for Environmental Information Storm Events Database, HIFLD's Historical Tornado Tracks dataset, and FEMA's National Flood Hazard Layer (2020).

Utility and Electricity

To assess Kentucky's existing energy landscape, the following were evaluated: power plants, electric power transmission lines, electric service areas, distributed renewable generation, and reliability. Reliability data was used in the microgrid site selection process to target areas that would benefit the most from additional grid fortification. Data was collected for these factors from the U.S. Energy Information Administration, EPA, HIFLD, KyGovMaps Open Data, OEP, and the Kentucky Public Service Commission. The below sections provide an overview of the data collected on electric utilities and reliability. For additional information on utility and electricity data collection, see Appendix 1: Detailed Data Collection Methodology.

Kentucky's investor-owned utilities (IOUs) include AEP Kentucky Power, Louisville Gas and Electric Company, Kentucky Utilities Company and Duke Energy. In addition to the IOUs, there are 19 cooperatives that are powered by East Kentucky Power Cooperative and The Big Rivers Electric Corporation, and 5 local power companies powered and regulated by TVA. Figure 2.3 below shows the electric service areas and utilities in Kentucky.

*Figure 2. 3 - **Electric Service Areas in Kentucky***



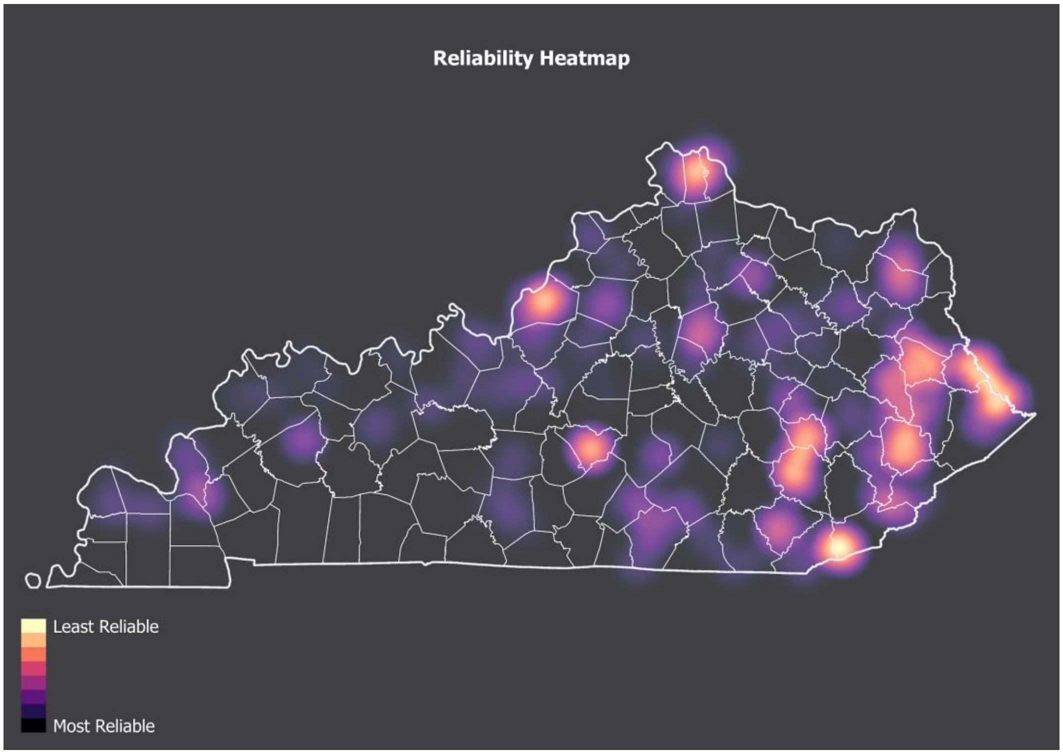
Source: Kentucky Public Service Commission. Electric Service Areas. KyGovMaps Open Data (2020).

Utilities in Kentucky are required to file annual reliability reports with the Kentucky Public Service Commission[14]**.** 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) values. For each reporting utility, circuits with the 10 highest reporting year SAIDI values were captured within a dataset. The reporting year for each substation[15] is either 2019 or 2020. Figure 2.4 shows a heatmap to illustrate reliability issues across the state.

[14] Kentucky Public Service Commission, Electric Distribution Utility Annual Reliability Reports (2019, 2020)

[15] Coordinates for each substation were generated using the U.S. Census Bureau's Geocoder tool, Google Maps, or were sent by Big Rivers Electric Corporation and Kentucky Power Company.

*Figure 2. 4 - **Reliability Heat map***



Source: Smart Electric Power Alliance (2021) based on data from Kentucky Public Service Commission, [Electric Distribution Utility Annual Reliability Reports](#) (2019, 2020)

3.0 Site Selection

To select the most optimal microgrid locations, SEPA utilized a methodology to select microgrid locations based on critical facility type, hazard risk areas, geographical proximity, reliability hotspots, population density, and energy burden. Potential microgrid sites were categorized by facility type, and each facility type was evaluated based on a combination of the criteria listed below. The sites chosen indicate the most optimal locations for microgrid deployment across the state.

The main objectives when conducting the preliminary site selection for microgrid deployment were:

1. To identify microgrid sites that can support the grid where it is needed most while protecting the technology from natural hazard-induced damage, and
2. To ensure that highly populated areas and underserved communities, the most vulnerable areas of the state, have access to essential services during power outages.

Site Selection Criteria

The selection criteria used in selecting optimal locations for microgrid deployment included the following:

- **Critical infrastructure facility type –** Assessment of the criticality of services each facility type provides to the public and state.
- **Geographical proximity –** Identification of critical infrastructure facilities, of the same type, within close proximity to other potential microgrid deployment sites. The relative distance between potential sites was used to identify clusters of closely grouped facilities.
- **Areas at high risk of natural hazard –** Analysis of geographic areas at highest risk of being affected by a natural hazard. Natural hazards, which pose catastrophic threats, are grouped in Tier 1 and hazards, which pose non-catastrophic threats, are grouped in Tier 2. Priority was given to critical infrastructure facilities outside of Tier 1 and Tier 2 hazard areas.
- **Reliability hotspots –** Prioritization of potential sites located within areas identified as having reliability issues.
- **Population density –** Assessment of the population by county and urban areas to determine where grid support from a microgrid would be most impactful in the event of an outage.
- **Energy burden / underserved areas –** Consideration of the energy burden by county to determine areas that are most underserved and therefore, where a microgrid would support equity in grid reliability.

These criteria were used in both site specific and regional community microgrid site selection. Chosen regional community microgrid sites are shown below and indicate areas where at least 4 facilities from the primary selection are clustered within a .5 mile radius. These clustered sites are suitable for microgrid deployment at a regional level.

The site selection process was conducted for each critical facility with both objectives in mind. To meet the first objective of site selection, facilities were selected based on Tier 1 and Tier 2 hazard criteria, geographical proximity, and reliability hotspots. For nearly every critical facility type, the selection based on the aforementioned criteria yielded facilities in the western part of the state. The northern and eastern parts of the state, which are the most densely populated and underserved, were underrepresented in the selection due to Tier 1 and Tier 2 hazard impacts. To ensure the second objective of site selection was met, additional facilities were selected in highly populated areas and underserved communities with a caveat to their selection criteria: facilities in these areas were selected based on Tier 1 hazard criteria, geographical proximity, population density, and energy burden. Tier 2 hazard criteria and reliability hotspots were evaluated with leniency and the least priority in order to ensure representation in the most vulnerable areas of the state.

Microgrids deployed outside of the disruption-prone Tier 1 and Tier 2 hazard areas will avoid physical damage from the natural disaster and can still serve as a designated resilience solution for those within the disruption area. In certain cases, the high population density and energy burden criteria were prioritized over Tier 2 hazard areas to serve as an accessible and immediate resilience solution to densely populated and underserved communities. Table 3.1 below provides a summary of the site selection criteria types, data sources, and criteria descriptions.

*Table 3. 1 - **Site Selection Criteria***

Criteria Type	Data Source	Criteria Description
Located at critical facility infrastructure	-HIFLD Cellular Towers -OEP Healthcare List -KIA Water Treatment Plants -KIA Wastewater Treatment Plants -Data Axle National Defense Facilities -HIFLD Local Law Enforcement Locations -OEP Critical Facilities Master List -HIFLD Fire Stations -HIFLD Emergency Operations Centers -Data Axle Gas Stations -Data Axle Grocery Stores	Located at a critical facility site: cell tower, hospital, nursing home, emergency operations center, law enforcement, water treatment plant, wastewater treatment plant, grocery store, gas station, fire station, or national defense facility.
Not located in a Tier 1 hazard area	-KGS Earthquake Impact (Peak Ground Acceleration) -KGS Landslide Susceptibility -KGS Karst Susceptibility -KGS Mine Subsidence Susceptibility -USDA Wildfire Hazard Potential	Location not in a Tier 1 high hazard area (earthquakes, landslides, karst, mine subsidence, or wildfires)
Not located in a Tier 2 hazard area	-NOAA Wind Event Record -NOAA Tornado Event Record -NOAA Extreme Cold Event Record -NOAA Winter Storm Event Record -FEMA NFHL Flood Hazard	Location not in a Tier 2 high hazard area (wind, tornadoes, extreme cold and winter storm events, or flooding)
Located in reliability hotspot	-Kentucky Public Service Commission Annual Reliability Report Data	Located within or nearby a reliability hotspot
High population density	-Kentucky Atlas & Gazetteer -U.S. Census Bureau Data (2010)	Located in the county with the highest population density relative to the region, or within a designated urban area.
Energy burdened area	-U.S. DOE Low-Income Energy Affordability Data Tool (LEAD)	Located in the county with the highest energy burden, relative to the region.

Source: Smart Electric Power Alliance, 2021.

Each critical facility type was evaluated according to the methodology described above, and the selection of some facilities followed extra specifications. The critical facilities and their facility-specific caveats to the selection process are listed Table 3.2 below.

*Table 3. 2 - **Caveats to Selection Process***

Critical Facility	Caveat to Selection Process
Law Enforcement	Preference was given to police stations over sheriff offices.
Fire Stations	Preference was given to fire departments over fire chief offices.
Gas Stations	Preference was given to stations with closer geographic proximity to petroleum terminal facilities.
Communications Facilities	Only cellular towers were considered as potential microgrid sites.

Source: Smart Electric Power Alliance, 2021.

Selection Results

The selection process detailed above identified 558 site specific microgrid sites out of the 6,640 critical facility locations evaluated. The breakdown of the selection results for each critical facility type and potential nanogrid locations is listed in Table 3.3 below.

*Table 3. 3 – **Potential Nanogrid Locations by Critical Facility Type***

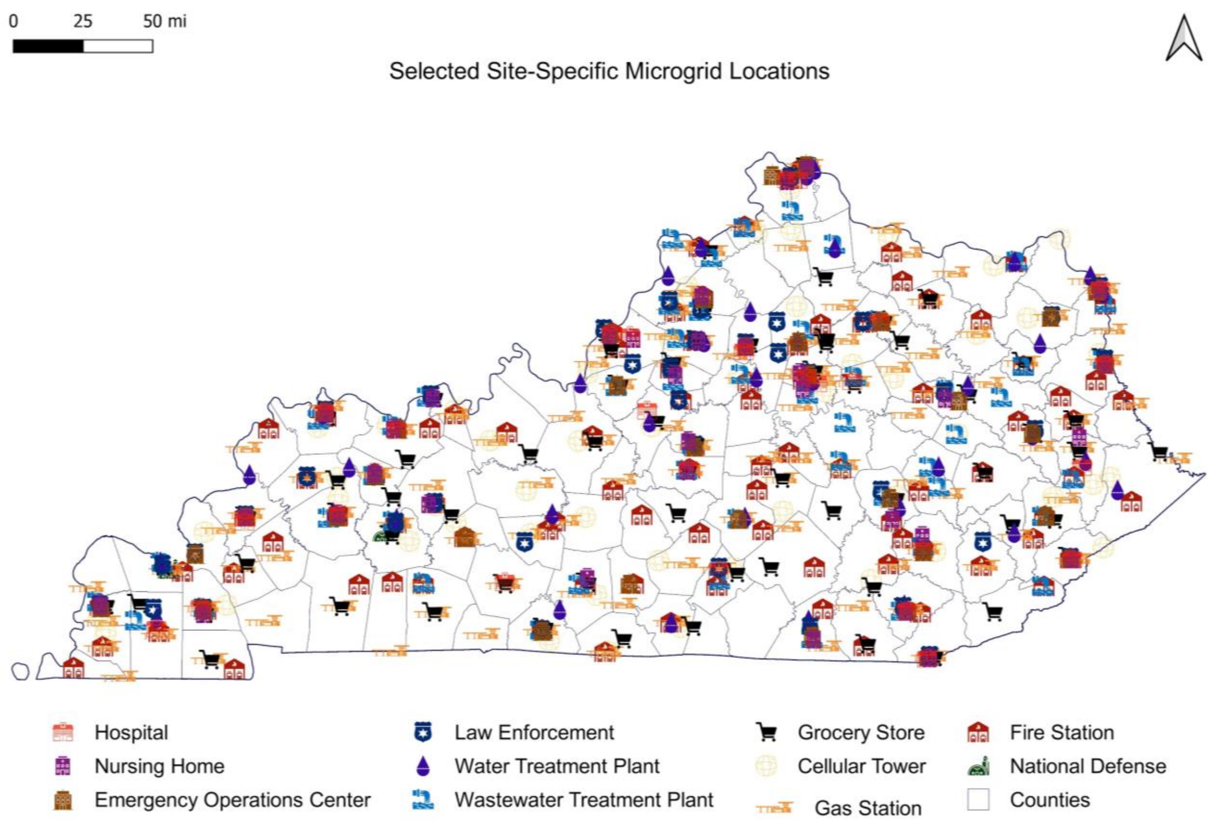
Critical Facility Type	Total # of Sites Considered	# Sites Selected	% of Total
Hospitals	137	26	19%
Nursing Homes	379	32	8%
Emergency Operations Centers	142	33	23%
Law Enforcement	484	42	9%
Water Treatment Plants	214	44	21%
Wastewater Treatment Plants	240	50	21%
Grocery Stores	1,273	70	5%
Communication	669	56	8%

Critical Facility Type	Total # of Sites Considered	# Sites Selected	% of Total
Gas Stations	1973	110	6%
Fire Stations	1,103	90	8%
National Defense	26	5	19%
Total	**6,640**	**558**	**8%**

Source: Smart Electric Power Alliance, 2021.

The spatial distribution of the 558 facilities that were selected as site specific microgrid locations is displayed in Figure 3.1 below. Each type of critical facility is represented by a different symbol, as indicated by the legend.

*Figure 3. 1 - **Selected Nanogrid Deployment Locations***



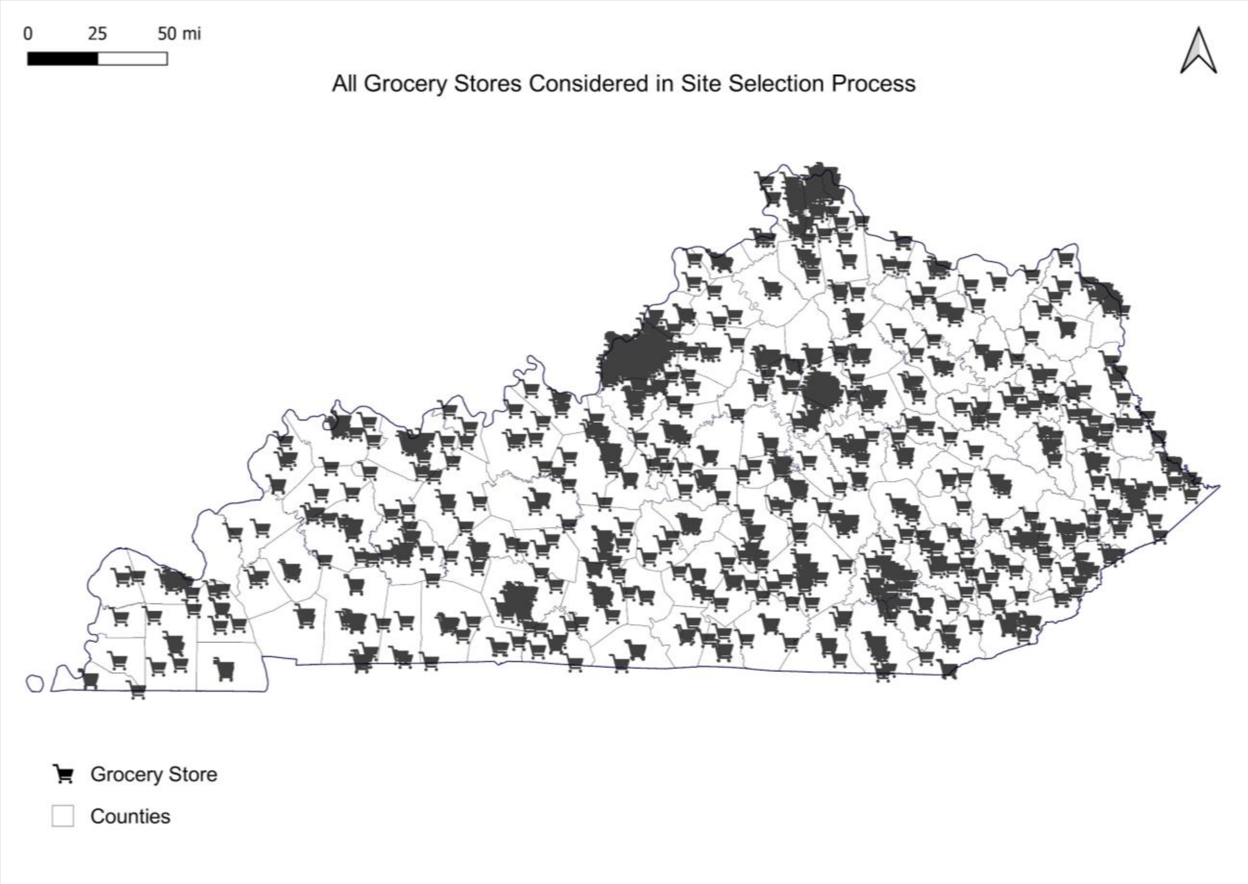
Source: Smart Electric Power Alliance, 2021

For the detailed site selection process for each critical facility type, see Appendix 2: Site Selection Parameters by Critical Facility Type

Representative Site Selection Process Example:

An example of how this selection criteria was applied to Grocery Stores is summarized below, where SEPA preliminarily identified 70 out of the 1,273 potential sites for microgrid deployment. The map below shows all grocery stores in the state that were considered in the site selection process.

*Figure 3. 2 - **All Grocery Stores Considered in Site Selection Process***



Source: Smart Electric Power Alliance, 2021.

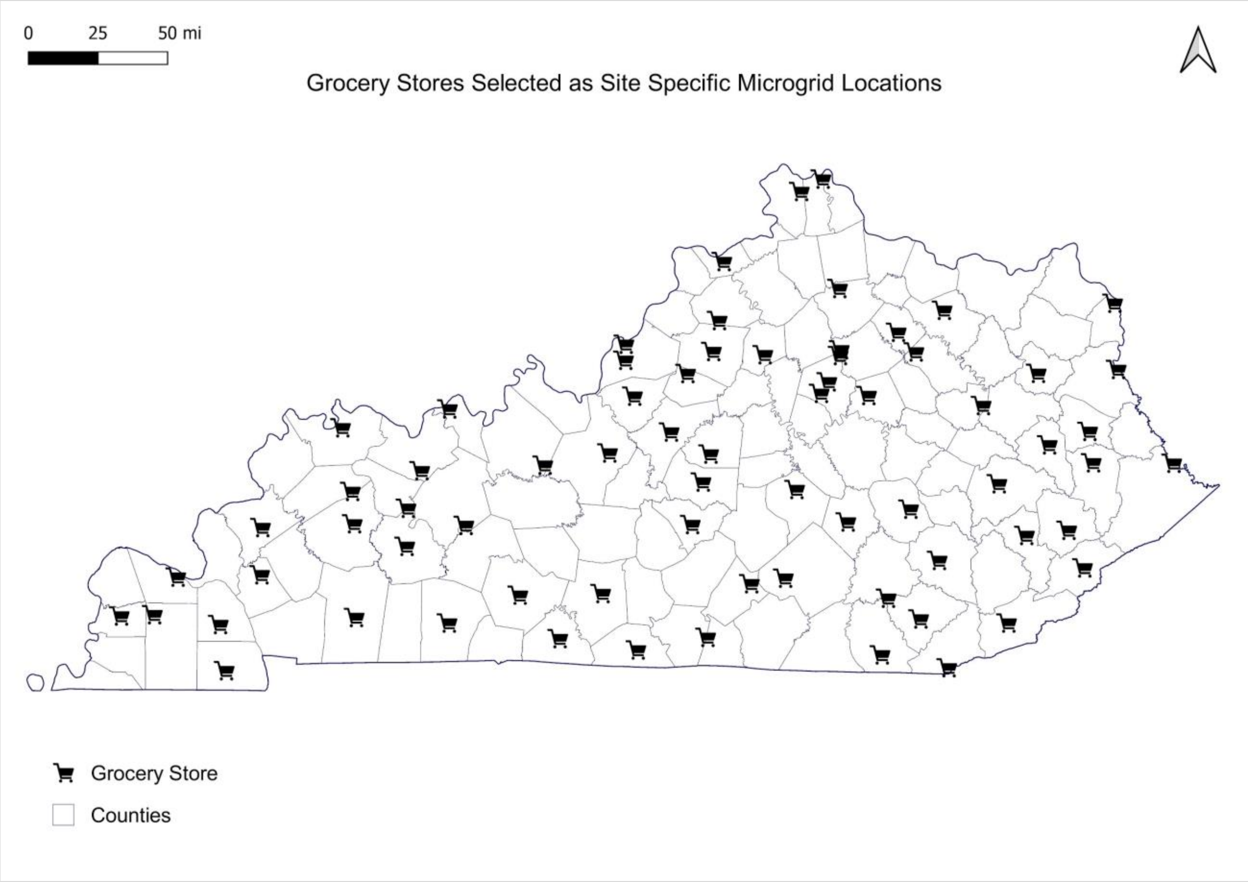
For this critical facility type, SEPA applied the selection criteria with the following prioritization:

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.

4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

The resulting preliminary recommendations for site specific microgrid deployment for grocery stores included 70 of the potential 1,273 sites as shown in the map below.

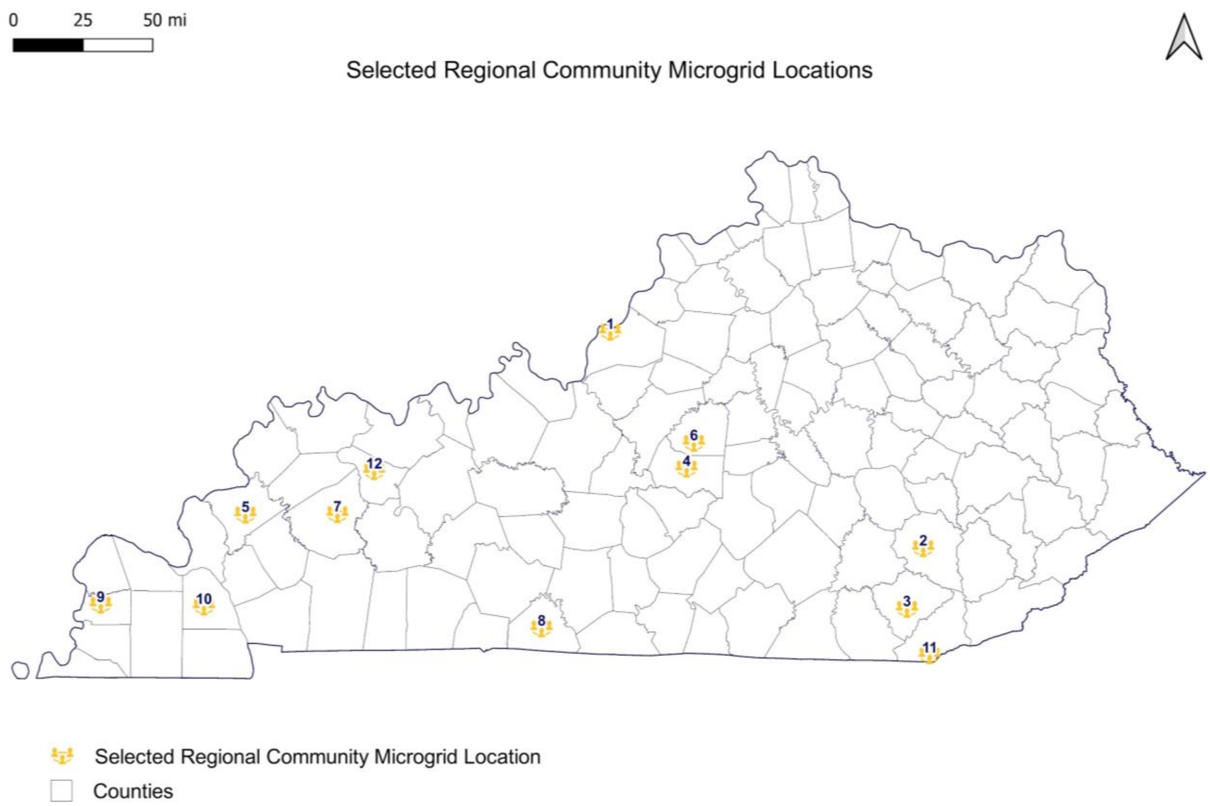
Figure 3. 3 - ***Grocery Stores Selected as Site Specific Microgrid Locations***



Source: Smart Electric Power Alliance, 2021

Where multiple of these critical facilities are located within close geographic proximity of each other, it provides an opportunity to explore resilience hubs or regional community microgrids to provide economies of scale and maximize community benefits. Clusters of at least 4 sites within 0.5 miles of each other were classified as suitable for a regional community microgrid site. Across the state, 12 total regional community microgrids sites were chosen, which are displayed in Figure 3.4 below.

Figure 3. 4 - ***Selected Regional Community Microgrid Locations***



Source: Smart Electric Power Alliance, 2021

Table 3.4 below provides a list of the selected regional community microgrids sites with the description of location and critical facilities served.

*Table 3. 4 - **Selected Regional Community Microgrid Descriptions***

Regional Community Microgrid	Description
1 - Jefferson County Community Microgrid	Microgrid to serve an emergency operations center, fire station, grocery store, hospital, and nursing home in the city of Louisville, Jefferson County.
2 - Clay County Community Microgrid	Microgrid to serve an emergency operations center, grocery store, hospital, and law enforcement facility in the city of Manchester, Clay County.
3 - Knox County Community Microgrid	Microgrid to serve an emergency operations center, gas station, hospital, and nursing home in the city of Barbourville, Knox County.
4 - Marion County Community Microgrid	Microgrid to serve a gas station, grocery store, nursing home, and wastewater treatment plant in the city of Lebanon, Marion County.
5 - Crittenden County Community Microgrid	Microgrid to serve an emergency operations center, fire station, grocery store, law enforcement facility, and nursing home in the city of Marion, Crittenden County.
6 - Washington County Community Microgrid	Microgrid to serve a cell tower, emergency operations center, fire station, gas station, grocery store, law enforcement facility, wastewater treatment plant, and water treatment plant in the city of Springfield, Washington County.
7 - Hopkins County Community Microgrid	Microgrid to serve an emergency operations center, fire station, law enforcement facility, and national defense facility in the city of Madisonville, Hopkins County.
8 - Allen County Community Microgrid	Microgrid to serve an emergency operations center, fire station, gas station, law enforcement facility, and wastewater treatment plant in the city of Scottsville, Allen County.
9 - Carlisle County Community Microgrid	Microgrid to serve an emergency operations center, fire station, law enforcement facility, and water treatment plant in the city of Bardwell, Carlisle County.
10 - Marshall County Community Microgrid	Microgrid to serve an emergency operations center, law enforcement facility, wastewater treatment plant, and water treatment plant in the city of Benton, Marshall County.
11 - Bell County Community Microgrid	Microgrid to serve a fire station, gas station, law enforcement facility, national defense facility, and nursing home in the city of Middlesboro, Bell County.
12 - McLean County Community Microgrid	Microgrid to serve a cell tower, fire station, gas station, and nursing home in the city of Calhoun, McLean County.

Source: Smart Electric Power Alliance, 2021.

4.0 Preliminary Analysis and Deployment Strategies

In addition to the site selection process, preliminary analysis was conducted on prioritized critical facilities to identify the necessary size and cost of a microgrid in order to meet its application of providing increased resilience. This included load analysis, sizing, and cost estimates to deploy microgrids at each of the prioritized critical facilities.

Load Analysis, Sizing, Cost Estimate, and Deployment Strategy Methodology

Load Analysis

As part of the system design, SEPA conducted load analysis on all of the prioritized critical facilities. To do so, real and proxy load profiles were used based on data availability for each of the critical facility types to determine typical load profile days and peak load profiles by month and load curves. For each critical facility, load factors were calculated by determining the ratio of average hourly demand to peak demand.

Sizing

Based on the load analysis, the size and asset breakdown of the microgrid systems were designed to match the load curves for each critical facility type. Sizing is based on the peak loads of a typical day for each critical facility type served by the microgrid and are capable of serving 100% of the critical facility's load for a full year (8,760 hours).[16] There are opportunities of reducing costs by building the microgrids at a reduced capacity less than 100% that are outlined in Appendix 3: Detailed Load, Sizing, and Cost Analysis.

Cost Estimates

SEPA developed capital cost estimates for two microgrid design options:

- **Moderate renewable design option** - SEPA utilized cost estimates from Lazard's Levelized Cost of Energy Analysis Version 11 and applied a 10% soft cost adder, which includes installation of a microgrid controller. The cost ranges provided in the estimates follow Lazard's low and high end estimates. This option also includes the design and cost of a fixed mount solar PV system sized to provide 50% of the site's annual energy usage. Solar PV is not subject to fuel price variability and have relatively small variable operating and maintenance (O&M) costs, which aren't included in the study.
- **Fossil fuel only design option** - SEPA referenced cost data from NREL's 2020 Annual Technology Baseline and applied a 30% soft cost adder and 7% adder for the microgrid

[16] Note standby generators should not be run unless in the event of an outage.

controller[17]. This option also includes the design and cost of a standby diesel and/or natural gas generator for resilience and reliability at the critical facilities. Fossil fuel generators are subject to fuel price variability and have relatively higher variable operating and maintenance (O&M) costs[18].

It is important to note that technologies such as solar PV and other renewable generating technologies are not subject to fuel price variability and availability and typically have small variable operating and maintenance costs (O&M), which are not taken into account in this study.

Technologies such as solar PV and other renewable generating technologies have no fuel costs and relatively small variable O&M costs. Technologies such as natural gas and other fossil fuel generating technologies have significant fuel costs and typically higher variable O&M costs than renewables. (EIA, 2021)

Deployment Strategy

Two microgrid deployment strategies were considered as part of this study. These two deployment strategies are not mutually exclusive of each other and a combination of the two strategies are encouraged to be explored by stakeholders. For the purposes of this study, they have been broken out into two distinct deployment strategies:

- **Nanogrid installation** - evaluation of nanogrid installations at individual critical facility infrastructure locations across the state based on established site selection criteria. This strategy can be used to ensure the energy needs of prioritized critical infrastructure and life-safety facilities in the event of an outage.
- **Regional community microgrid** - evaluation of potential microgrids that could increase resilience in zones across Kentucky that have several critical infrastructure facilities within close proximity to one another (0.5 miles). Critical infrastructure facilities within the zone are subject to the same site selection criteria outlined in this study. To arrive at the cost estimates for regional community microgrid deployment, representative load profiles were developed for each of the 12 regional community microgrids based on a summation of the load profiles of each critical facility type included in the microgrid. Using these load profiles, preliminary sizing and design for the regional community microgrids were determined under both fossil fuel only and moderate renewable energy design options. The following sections provide detailed information on the load profiles, system designs, and cost estimates for each of the regional community microgrids.

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[17] Assumptions for cost adders from NREL's Phase I Microgrid Cost Study: Data Collection and Analysis of Microgrid Costs in the United States: https://www.nrel.gov/docs/fy19osti/67821.pdf

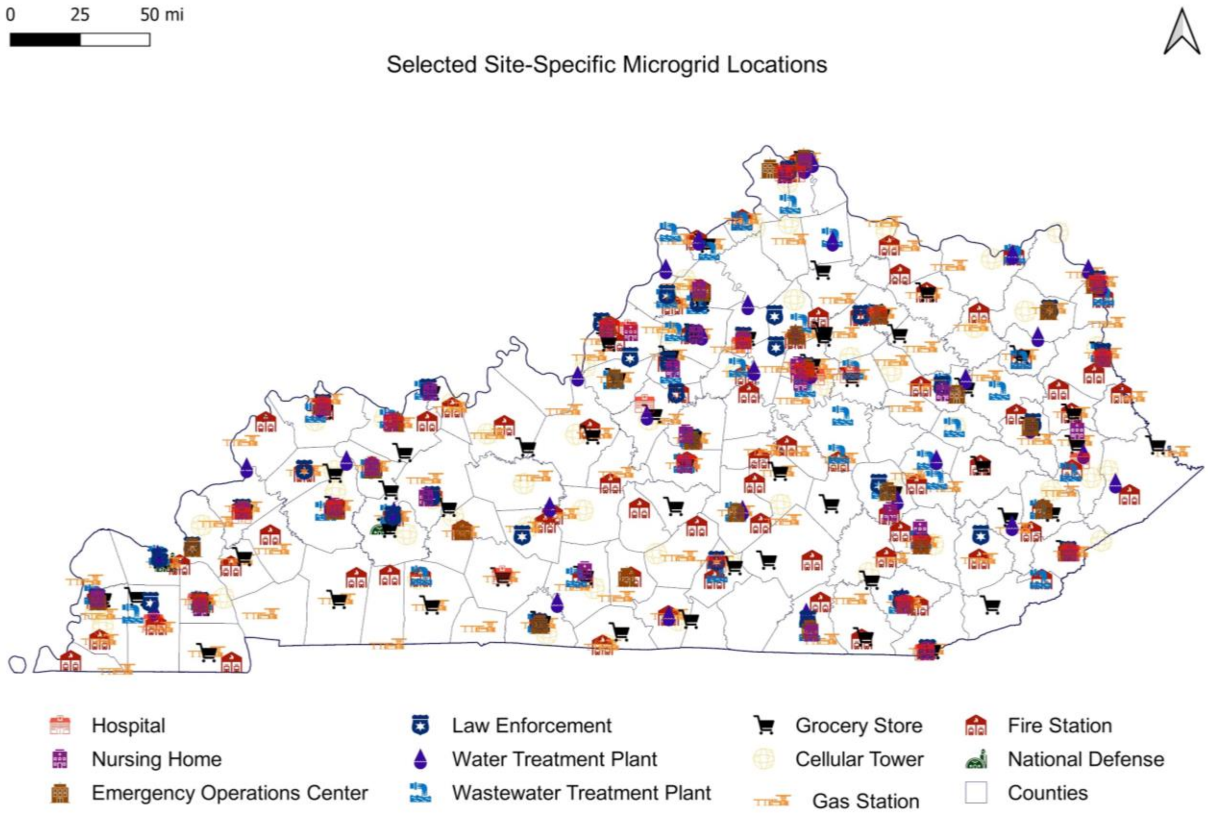
[18] U.S. Energy Information Administration (EIA), Levelized Costs of New Generation Resources in the Annual Energy Outlook (2021)

The following sections of the study provide an overview of the potential microgrid deployment strategies and estimated costs. For the detailed load analysis, sizing, and economic analysis of each of the potential microgrid deployment strategies, see Appendix 3: Detailed Load, Sizing, and Cost Analysis.

Nanogrid Deployment Strategy

This section provides an overview of the analysis conducted for the nanogrid deployment strategy. SEPA identified 558 potential sites for nanogrid deployment under this strategy based on the 11 prioritized critical facility types. The locations of these facilities are displayed in Figure 3.1 Selected Nanogrid Deployment Locations below.

*Figure 3. 1 - **Selected Nanogrid Deployment Locations***



Source: Smart Electric Power Alliance, 2021.

Table 4.1 displays cost estimates for nanogrid deployment at different critical facility locations including breakdowns for both the fossil fuel only and moderate renewable energy design options.

*Table 4. 1 - **Nanogrid Deployment Strategy Capital Cost Estimates***

Critical Infrastructure Facilities		**Fossil Fuel Only Design**	**Moderate Renewables Design**
Facility Type	**# Sites Selected**	**Per facility** (thousands)	**Per facility** (thousands)
Cell Towers	56	$5 - $8	$86 - $97
Hospitals	26	$861 - $1,378	$10,703 - $12,260
Nursing Homes	32	$17 - $28	$203 - $235
Water Treatment Plants	44	$10 - $17	$239 - $272
Wastewater Treatment Plants	50	$10 - $17	$239 - $272
National Defense Facilities	5	$5 - $8	$43 - $51
Law Enforcement Facilities	42	$7 - $11	$98 - $113
Fire Stations	90	$12 - $19	$166 - $192
Emergency Operations Centers	33	$7 - $11	$78 - $90
Gas Stations	110	$10 - $17	$176 - $201
Grocery Stores	70	$12 - $19	$153 - $177

Source: Smart Electric Power Alliance, 2021.

The following sections provide a summary analysis of nanogrid installation at each of the prioritized critical facilities. For more detailed load analysis, sizing, and cost estimates, see Appendix 3: Detailed Load, Sizing, and Cost Analysis.

Cell Towers

SEPA estimated the load profile of the 56 cell towers identified in the site selection process based on Huawei Technologies' breakdown of the power consumption for 4G and 5G mobile networks.[19] Cell towers were sized to accommodate 5G mobile networks, including anticipated data centers, to an 80% load factor. This allows the leeway for the towers to shut down 5G usage at times. A summary of the design options and costs estimates for potential cell tower nanogrid installations is below in Table 4.2.

Table 4. 2 - ***Cell Tower Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	15 kW standby generator	10 kW standby generator 2 kW battery storage 23 kW solar PV
Cost Range (per single facility)	$5,000 to $8,000	$86,000 to $97,000

Source: Smart Electric Power Alliance, 2021.

Hospitals

The load profiles for hospitals were obtained from the OpenEI[20] database based on a hospital in Lexington, Kentucky and used to evaluate the 26 locations identified in the site selection process.[21] A summary of the design options and costs estimates for potential hospital nanogrid installations is below in Table 4.3.

Table 4. 3 - ***Hospital Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	1.55 MW standby generator	1.16 MW standby generator 280 kW battery storage 2.82 MW solar PV
Cost Range (per single facility)	$861,000 to $1.38M	$10.7M to 12.3M

Source: Smart Electric Power Alliance, 2021.

Nursing Homes

The load profiles for nursing homes were obtained from the Open EI database and were based on a midrise apartment sized to 25,000 square feet. These load profiles were used to evaluate

[19] Huawei Technologies Company, 5G: Creating a green grid that slashes costs, emissions & energy use (2020)
[20] https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states
[21] Office of Energy Efficiency & Renewable Energy (EERE), Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States, OpenEI (2014)

the 32 locations identified in the site selection process. A summary of the design options and costs estimates for potential nursing home nanogrid installations is below in Table 4.4.

*Table 4. 4 - **Nursing Home Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	50 kW standby generator	35 kW standby generator 10 kW battery storage 51 kW solar PV
Cost Range (per single facility)	$17,000 to $28,000	$203,000 to 235,000

Source: Smart Electric Power Alliance, 2021.

Water & Wastewater Treatment Plants

The load profiles for water and wastewater treatment plants ("treatment plants") were obtained from American Electric Power (AEP) and used to evaluate the 94 locations identified in the site selection process. Treatment plants have a very flat load profile and do not have a seasonal peak. The load profile and seasonal makes battery storage a less valuable addition to the potential microgrid. A summary of the design options and costs estimates for potential treatment plant nanogrid installations is below in Table 4.5.

*Table 4. 5 - **Treatment Plant Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	30 kW standby generator	25 kW standby generator 10 kW battery storage 41 kW solar PV
Cost Range (per single facility)	$10,000 to $17,000	$239,000 to $272,000

Source: Smart Electric Power Alliance, 2021.

National Defense Facilities

The load profiles for national defense facilities were based on data obtained from a U.S. utility and used to evaluate the 5 locations identified in the site selection process. National defense load profile data included in this study is based on National Guard facilities and does not reflect large military installments. Potential microgrids for this critical facility type are sized to serve a National Guard facility. A summary of the design options and costs estimates for potential national defense facility nanogrid installations is below in Table 4.6. For more information about larger potential microgrids for military installments, see the case study below on the Fort Knox Military Microgrid Project

*Table 4. 6 - **National Defense Facility Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	15 kW standby generator	10 kW standby generator 2 kW battery storage 11 kW solar PV
Cost Range (per single facility)	\$5,000 to \$8,000	\$43,000 to \$51,000

Source: Smart Electric Power Alliance, 2021.

Fort Knox Military Microgrid Project:

Nolin RECC is one of the 16 cooperatives in Kentucky that receives electricity from East Kentucky Power Cooperative and distributes it to their members. One of their most essential consumers is the Fort Knox Army Base, and in 2015, Nolin RECC teamed up with the base on "Energy Security Project" to deliver emergency backup diesel and natural gas peak shaving generation for resilience and reliability at the critical base. Fort Knox Army Base, located in close proximity to Elizabethtown, is within an area designated by the reliability hotspot map within this study and puts a high value on energy independence and critical power. The microgrid project was able to demonstrate keeping the critical power on without grid support, as well as achieving energy cost savings through peak shaving and CHP services of over \$30,000 from 2015 to 2020. Utilities, local governments, and stakeholders can learn from the successes of the Fort Knox project when exploring National Guard and military base microgrid installations.

Law Enforcement Facilities

Load profiles for law enforcement facilities were obtained from AEP and used to evaluate the 42 locations identified in the site selection process. A summary of the design options and costs estimates for potential law enforcement nanogrid installations is below in Table 4.7.

*Table 4. 7 - **Law Enforcement Facility Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	20 kW standby generator	15 kW standby generator 5 kW battery storage 25 kW solar PV
Cost Range (per single facility)	\$7,000 to 11,000	\$98,000 to 113,000

Source: Smart Electric Power Alliance, 2021.

Fire Stations

The load profiles for fire stations were obtained from AEP and used to evaluate the 90 locations identified in the site selection process. A summary of the design options and costs estimates for potential fire station nanogrid installations is below in Table 4.8.

*Table 4. 8 - **Fire Station Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	35 kW standby generator	25 kW standby generator 10 kW battery storage 41 kW solar PV
Cost Range (per single facility)	$12,000 to $19,000	$166,000 to $192,000

Source: Smart Electric Power Alliance, 2021.

Emergency Operations Centers

The load profiles for emergency operations centers were obtained from the OpenEI database and used to evaluate the 33 locations identified in the site selection process. A detailed analysis of the load profile reveals the peak occurs earlier in the day during solar production, which allows for a smaller fossil fuel generator and battery storage system in the moderate renewable design scenario. A summary of the design options and costs estimates for potential emergency operation center nanogrid installations is below in Table 4.9.

*Table 4. 9 - **Emergency Operation Center Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	20 kW standby generator	10 kW standby generator 5 kW battery storage 19 kW solar PV
Cost Range (per single facility)	$7,000 to $11,000	$78,000 to $90,000

Source: Smart Electric Power Alliance, 2021.

Gas Stations

The load profiles for gas stations were obtained from AEP and used to evaluate the 110 locations identified in the site selection process. A summary of the design options and costs estimates for potential gas station nanogrid installations is below in Table 4.10.

Table 4. 10 - ***Gas Station Microgrid Design Options and Cost Estimates***

	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	30 kW standby generator	25 kW standby generator 5 kW battery storage 47 kW solar PV
Cost Range (per single facility)	$10,000 $17,000	$176,000 to $201,000

Source: Smart Electric Power Alliance, 2021.

Grocery Stores

The load profiles for grocery stores were obtained from AEP and used to evaluate the 70 locations identified in the site selection process. A summary of the design options and costs estimates for potential grocery store nanogrid installations is below in Table 4.11.

Table 4. 11 - ***Grocery Store Microgrid Design Options and Cost Estimates***

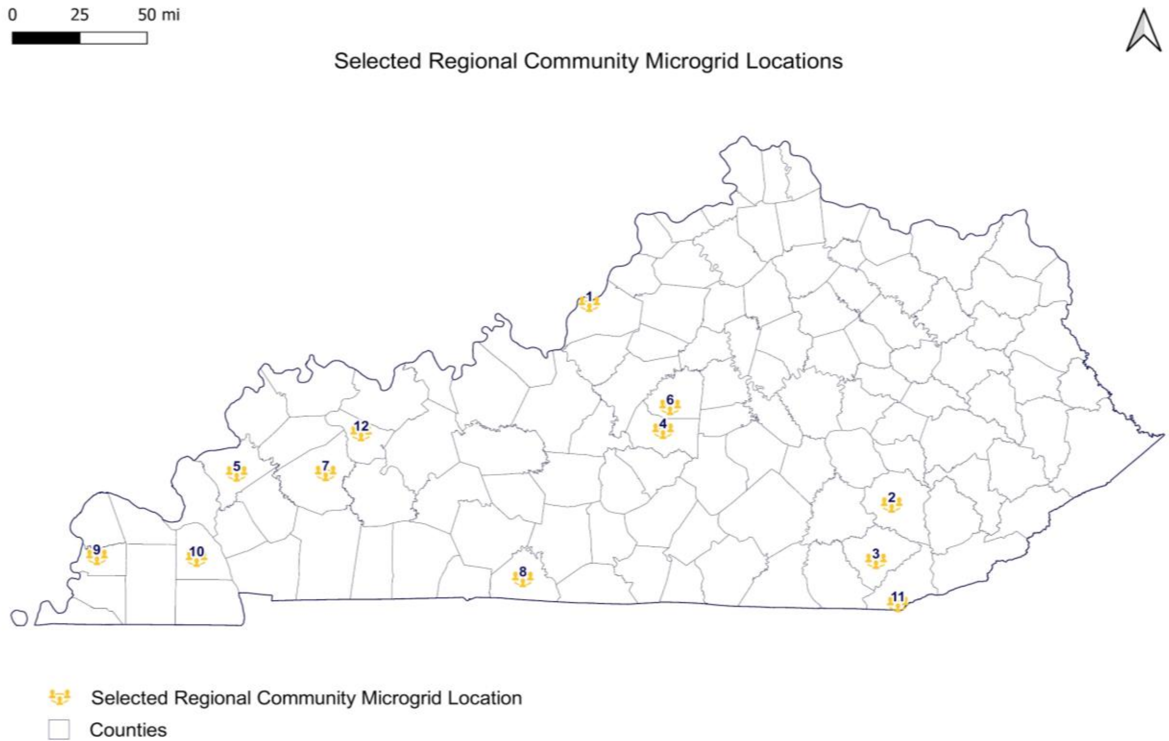
	Fossil Fuel Only	Moderate Renewable
Design (per single facility)	35 kW standby generator	30 kW standby generator 5 kW battery storage 39 kW solar PV
Cost Range (per single facility)	$12,000 to $19,000	$153,000 to $177,000

Source: Smart Electric Power Alliance, 2021.

Regional Community Microgrids Deployment Strategy

This section provides an overview of the analysis conducted for the potential regional community microgrid deployment strategy. SEPA identified 12 microgrid sites, which include 56 different critical facilities. These 12 community microgrids contain 4 to 8 critical facilities within 0.5 miles from one another. Each type of critical facility is included in at least one of the community microgrids. The locations of these regional community microgrids are displayed in Figure 3.4 below.

*Figure 3. 4 - **Selected Regional Community Microgrid Locations***



Source: Smart Electric Power Alliance, 2021.

Table 4.12 below provides a breakdown of the facilities included and costs associated with each regional community microgrid under both the fossil fuel only and moderate renewable energy design options. The following key identifies the icons used to represent the different critical facilities:

Emergency Operations Centers	**Hospitals**
Cell Towers	**Nursing Homes**
Fire Stations	**Water Treatment Plants**
Gas Stations	**Wastewater Treatment Plants**
Grocery Stores	**National Defense**
Law Enforcement Facilities	

*Table 4. 12 - **Regional Community Microgrid Strategy Cost Estimates***[22]

Regional Community Microgrid	Critical Facilities	Estimated Costs for Fossil Fuel Only Design (thousands)	Estimated Costs for Moderate Renewable Design (thousands)
1 - Jefferson County Community Microgrid		$537 - $894	$8,798 - $9,940
2 - Clay County Community Microgrid		$1,141 - $1,931	$11,012 - $12,616
3 - Knox County Community Microgrid		$1,148 - $1,943	$11,116 - $12,732
4 - Marion County Community Microgrid		$43 - $72	$750 - $856
5 - Crittenden County Community Microgrid		$45 - $75	$667 - $766
6 - Washington County Community Microgrid		$63 - $106	$1,191 - $1,352

[22] Cost estimates do not include added costs associated with electrical reconfiguration as a microgrid if the clustered facilities are not all on the same electrical circuit.

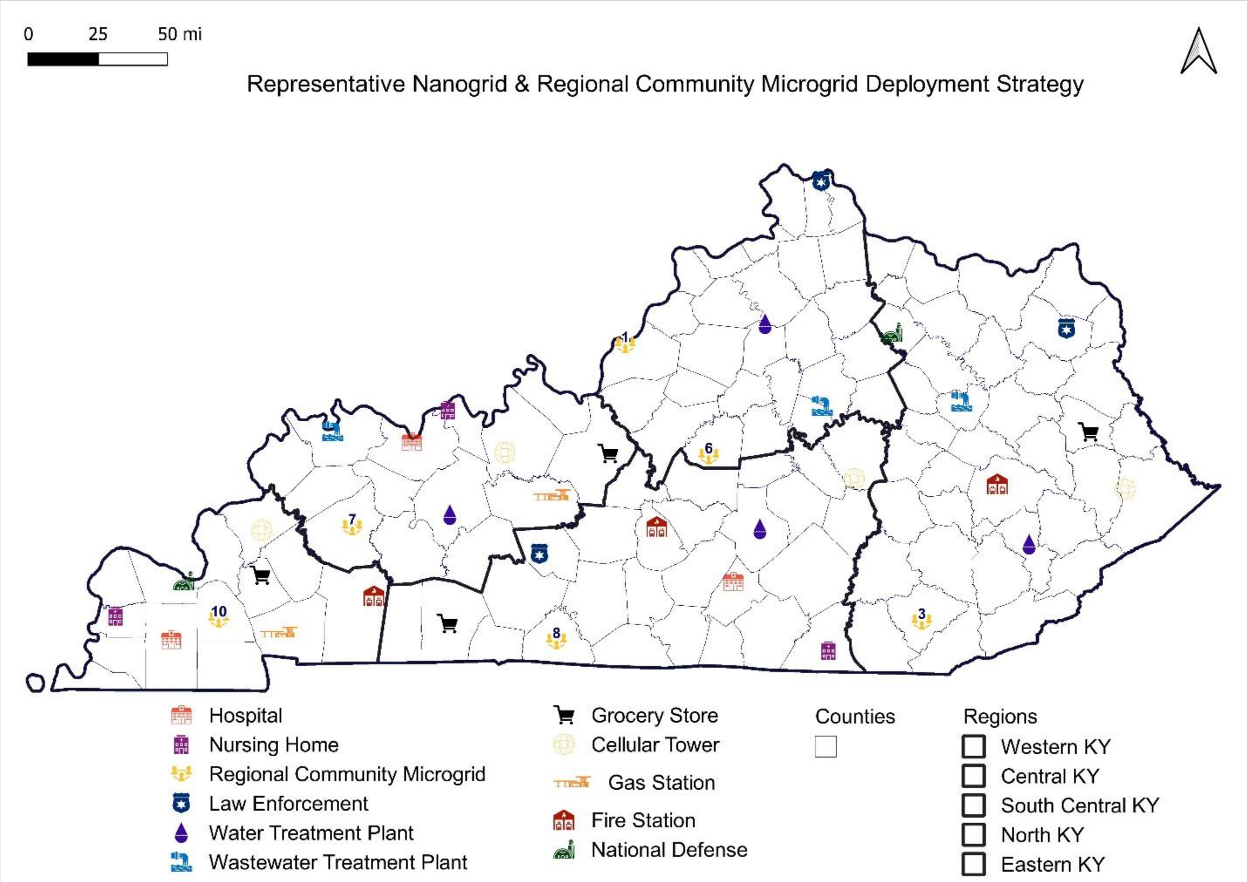
7 - Hopkins County Community Microgrid		$25 - $42	$367 - $420
8 - Allen County Community Microgrid		$38 - $64	$724 - $823
9 - Carlisle County Community Microgrid		$30 - $50	$548 - $622
10 - Marshall County Community Microgrid		$28 - $47	$614 - $693
11 - Bell County Community Microgrid		$42 - $69	$659 - $754
12 - McLean County Community Microgrid		$38 - $64	$615 - $704

Source: Smart Electric Power Alliance, 2021.

For more detailed load analysis, sizing, and cost estimates for the potential regional community microgrid deployment strategies, see Appendix 3: Detailed Load, Sizing, and Cost Analysis.

Representative Combined Deployment Strategy:

*Figure 4. 1 – **Representative Nanogrid & Regional Community Microgrid Deployment Strategy***



The nanogrid and regional community microgrid deployment strategies are not mutually exclusive to one another. In fact, in order to achieve state-wide resilience it will be necessary to employ a combination of the two strategies.

Figure 4.1 illustrates one way these two strategies can be used together to achieve state-wide resilience. In developing this example, SEPA strategically selected six regional community microgrids across the state (1, 3, 6, 7, 8, and 10) and took inventory of the critical facilities included at each location. SEPA then identified several nanogrid locations to (1) ensure all 11 types of critical facilities were represented in each region and (2) ensure microgrid and nanogrid representation across the entire state.[23]

[23] Note: Due to the limited number of national defense facilities, those types of facilities are not represented in each region.

5.0 Conclusion

When strategically located, microgrids' ability to island from the traditional power grid enables them to provide increased resilience to critical facilities. The analysis included in this study provides a blueprint for Kentucky utilities, local and state governments, and other stakeholders to develop microgrid deployment strategies to achieve desired outcomes and increase the resilience of the electric power grid. When developing these strategies, it is important to take a holistic approach that involves the consideration of both nanogrids 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.

Key takeaways from the microgrid deployment approaches outlined within this study are:

- Evaluating microgrids by looking at the problems they are trying to solve and the services they are providing is a key step to build an understanding of where microgrids can provide the most resilience value in Kentucky.
- Utilizing this study to facilitate early and often coordination between utilities, local and state governments, and other stakeholders in Kentucky, who each have specific roles and responsibilities as it relates to the operation and planning of the electric system as well as the development of emergency preparedness plans.
- Increasing community resilience in Kentucky not only involves a holistic approach to microgrid planning and emergency preparedness, but also involves siting and constructing microgrids that can withstand natural disaster threats.
- Identifying potential microgrid sites for community resilience in Kentucky requires a combination of determining critical infrastructure facilities, defining areas of vulnerability, and evaluating load profiles and microgrid scenarios.

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 on future plans.

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

6.0 Appendices

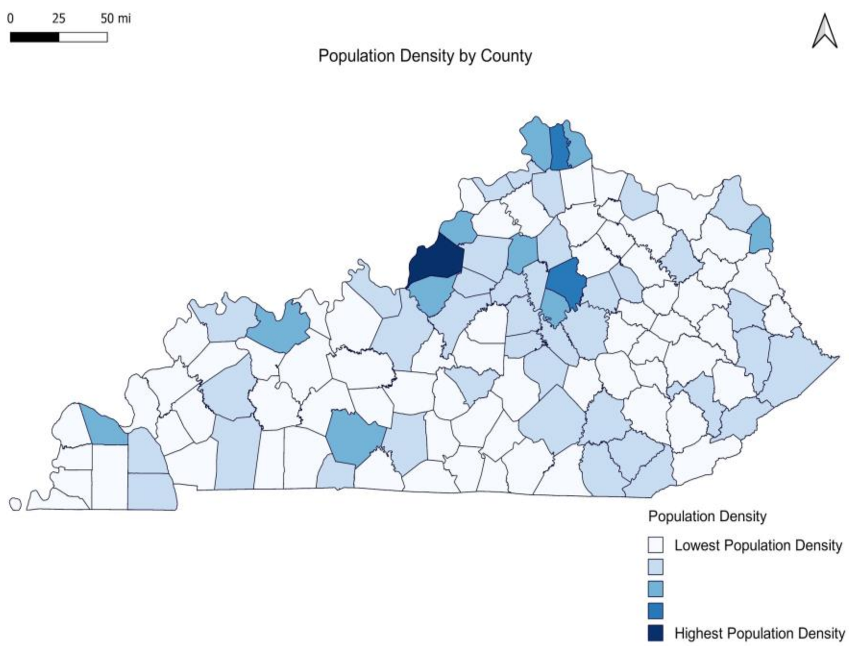
Appendix 1: Detailed Data Collection Methodology

This appendix includes a detailed summary of the methodology used for collecting the following datasets used in this study: population / demographics, critical infrastructure facilities, natural hazards, and utility and electricity.

Population / Demographics

An important step in the data collection process was to identify areas of high population density as well as underserved communities throughout the state. A population density dataset was developed from the 2010 U.S. Census population density values by county, hosted within the Kentucky Atlas and Gazetteer.[24] Additionally, a dataset of designated urban areas was procured from the 2010 U.S. Census.[25] To identify underserved communities, an energy burden dataset was created from county energy burden values sourced from the U.S. DOE Low-Income Energy Affordability Data Tool (LEAD).[26] This dataset identifies the percentage of a resident's income that is spent on energy; those with the highest energy burden are classified as underserved.

*Figure 6.1. 1 - **Population Density by County***



Source: Kentucky Atlas and Gazetteer. Commonwealth of Kentucky (2020).

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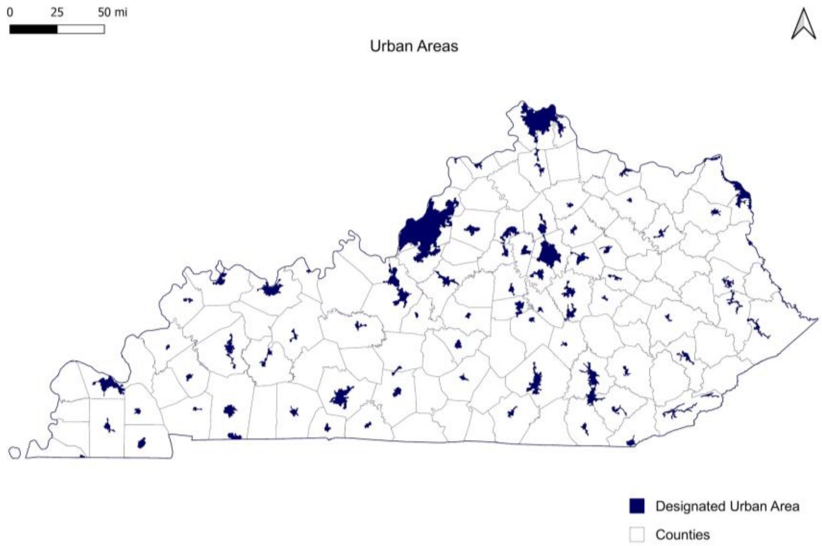
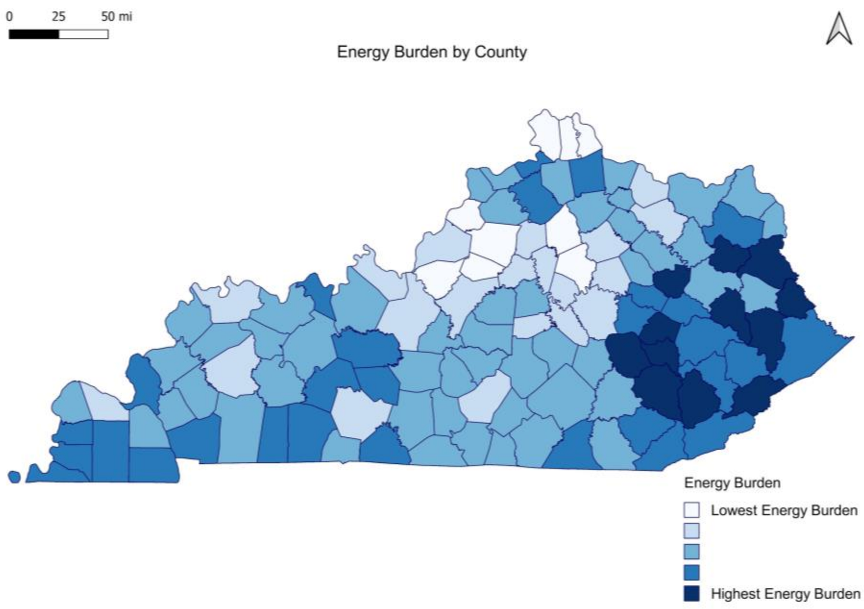
[24] Kentucky Atlas and Gazetteer. Commonwealth of Kentucky (2020)
[25] United States Census Bureau. Urban Areas, TIGER/Line Shapefiles (2010)
[26] United States Department of Energy. Avg. Energy Burden (% income) for Counties in Kentucky. Low-Income Energy Affordability Data (LEAD) Tool (2020)

*Figure 6.1. 2 - **Urban Areas***



Source: United States Census Bureau. [Urban Areas.](#) TIGER/Line Shapefiles (2010).

*Figure 6.1. 3 - **Energy Burden by County***



Source: United States Department of Energy. [Avg. Energy Burden (% income) for Counties in Kentucky](#). Low-Income Energy Affordability Data (LEAD) Tool (2020).

Critical Infrastructure Facilities

Critical facilities throughout Kentucky were identified as potential microgrid host sites. These sites were identified to ensure the energy needs of critical infrastructure and life-safety facilities were met in the event of a power outage due to a natural hazard or extreme weather event. Certain types of critical facilities were prioritized for evaluation in the microgrid site selection process. The prioritization of critical facilities was strategic, based on local utility practices, FEMA's Community Lifelines, and stakeholder input.

It was important in identifying critical facility infrastructure, to include a utility perspective in the decision making process. Kentucky Power Company's tiered outage restoration priorities were used as a starting point to prioritize critical facility infrastructure. When responding to an outage, Kentucky Power Company prioritizes five groups of customers in the following order: (1) hospitals and nursing facilities, (2) water and wastewater facilities, (3) local government, police, fire stations, and EMS, (4) shelters, military facilities, FAA navigational facilities, and communication facilities, and (5) schools.[27] This ranking was considered in determining which critical facilities would be evaluated as microgrid host sites.

Facilities designated as Community Lifelines by FEMA, including energy infrastructure and food distributors, were also included in the prioritized list at the recommendation of OEP, the Kentucky Retail Association, and Duke Energy. After evaluating the input from several stakeholders, data sets were curated for the following facilities:

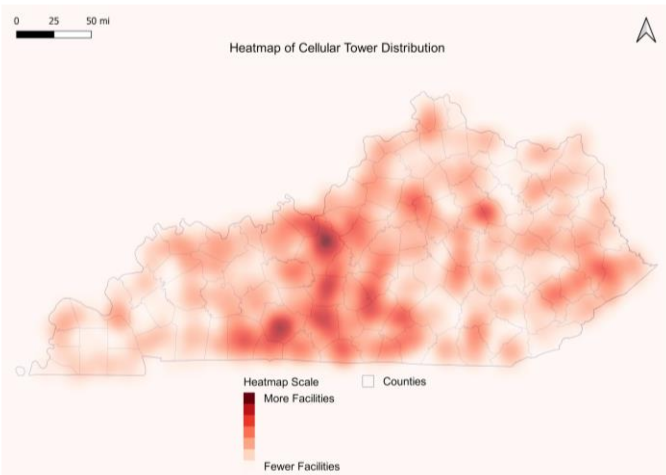
- Communications Facilities
- Hospitals
- Nursing Homes
- Water Treatment Plants
- Wastewater Treatment Plants
- National Defense Facilities
- Law Enforcement Facilities
- Fire Stations
- Emergency Operations Centers
- Gas Stations
- Grocery Stores
- Natural Gas Underground Storage Facilities[28]
- Petroleum Terminals[29]

[27] Tiered customer response list was conveyed to SEPA in an email from Kentucky Power Company.
[28] Microgrid solutions were not considered natural gas storage facilities.
[29] Microgrid solutions were not considered petroleum terminals.

Communications Facilities

Communications facilities are defined as Community Lifelines by FEMA and include cellular towers, radio transmission towers, and TV station transmitters. However, due to the increasing role cellular communication has in emergency preparedness and safety, cellular towers were prioritized in the microgrid site selection. The communications facilities dataset was downloaded from HIFLD and includes 1,234 total data entries, including 669 cellular towers, 141 AM radio transmission towers, 348 FM radio transmission towers, 37 TV analog station transmitters, and 39 TV digital station transmitters.

*Figure 6.1. 4 - **Heatmap of Cell Tower Distribution***



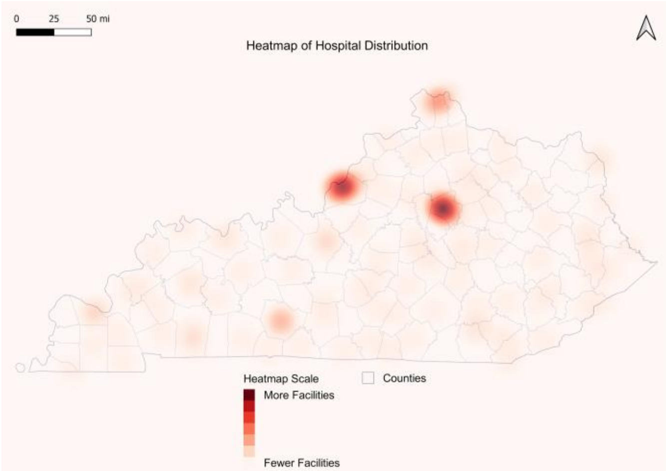
Source: Smart Electric Power Alliance (2021) based on data from Department of Homeland Security, Cellular Towers, Homeland Infrastructure Foundation Level Data (HIFLD) (2020).

Communications facilities are not uniformly distributed throughout the state of Kentucky; clusters of facilities, indicated by a darker shade of red, occur in densely populated counties.

Hospitals

Hospitals are defined as Community Lifelines by FEMA and provide a variety of medical services to patients and must be equipped with standby emergency power. From the list of healthcare facilities provided by OEP, 137 hospitals were included in the analysis.

*Figure 6.1. 5 - **Heatmap of Hospital Distribution***



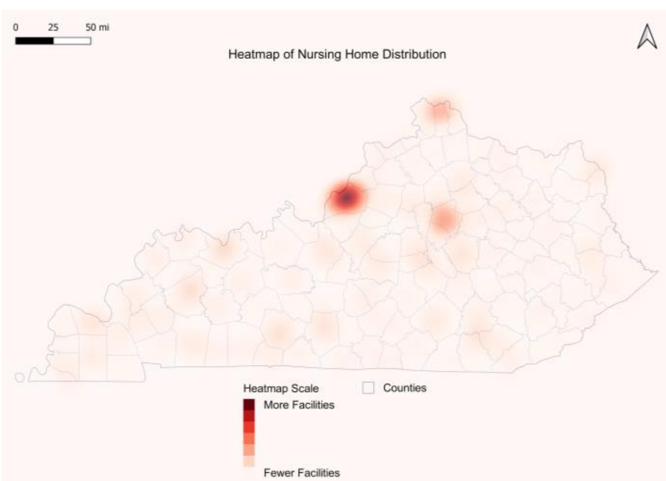
Source: Smart Electric Power Alliance (2021) based on data from list of healthcare facilities provided by OEP (2020).

Hospitals are mostly uniformly distributed throughout the state, but some densely populated counties (like Jefferson County and Fayette County) have several hospitals, while other counties do not have any hospitals.

Nursing Homes

Nursing Homes that provide long-term care to elderly patients are defined as Community Lifelines by FEMA and are required to have an emergency generator. The nursing home data within this data set was derived from the list of healthcare facilities provided by OEP, and includes 379 listed nursing homes.

*Figure 6.1. 6 - **Heatmap of Nursing Home Distribution***



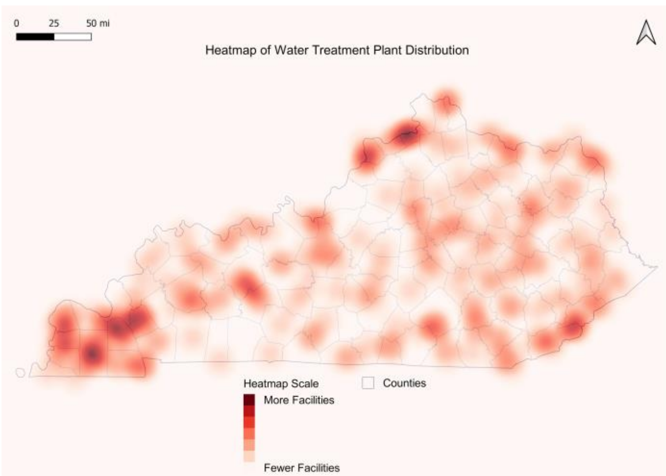
Source: Smart Electric Power Alliance (2021) based on data from list of healthcare facilities provided by OEP (2020).

Nursing homes are generally distributed evenly throughout the state, but some densely populated counties (like Jefferson County and Fayette County) have more nursing homes than less densely populated counties. Each county, however, has at least one nursing home.

Water Treatment Plants

Water Treatment Plants are designated as a FEMA Community Lifeline and are critical to the community in cleaning and distributing potable water across the state. . The data set for these facilities was downloaded from the KyGovMaps geospatial database and contains data entries for each of the 213 water treatment plants across the state.

*Figure 6.1. 7 - **Heatmap of Water Treatment Plant Distribution***



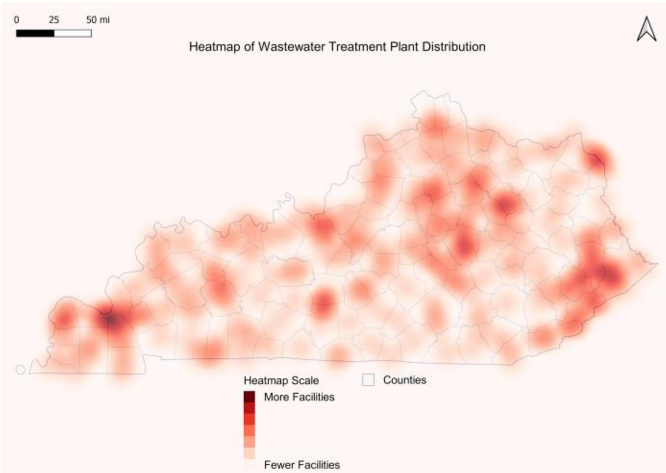
Source: Smart Electric Power Alliance (2021) based on data from Kentucky Infrastructure Authority. Ky Water Treatment Plants. KyGovMaps Open Data (2020).

The distribution of water treatment plants is mostly uniform, but some counties do not have a treatment plant while other counties have several treatment plants.

Wastewater Treatment Plants

Similar to water treatment plants, Wastewater Treatment Plants are designated as a Community Lifeline by FEMA and are critical to the community in cleaning sewage and water for it to be returned to the environment. The data set for these facilities was also downloaded from the KyGovMaps geospatial database and contains data entries for each of the 240 wastewater treatment plants across the state.

*Figure 6.1. 8 - **Heatmap of Wastewater Treatment Plant Distribution***



Source: Smart Electric Power Alliance (2021) based on data from Kentucky Infrastructure Authority. Wastewater Treatment Plants. KyGovMaps Open Data (2020).

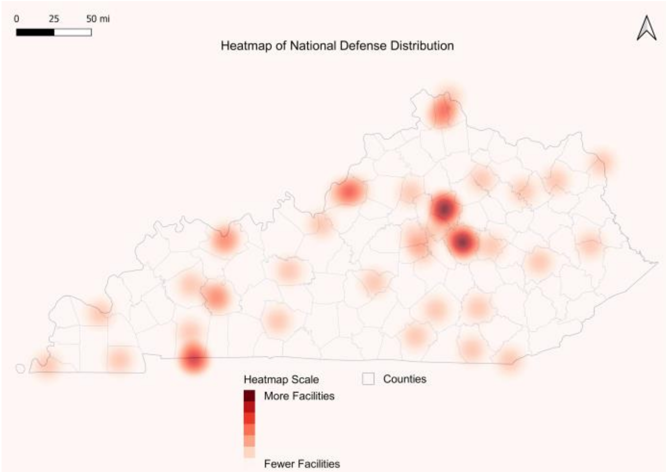
The distribution of wastewater treatment plants is mostly uniform, but some counties do not have a treatment plant while other counties have several treatment plants.

National Defense Facilities

National Defense falls under the Safety and Security category of FEMA Community Lifelines and refers to military installations and facilities designated as integral to national security. Data Axle, a business data provider, was utilized to create this data set. Facilities with North American Industry Classification System[30] (NAICS) codes associated with military bases, National Guard facilities, and national security were downloaded and merged into a single data set. Following a meeting with OEP, the Wendell H. Ford Regional Training Center was added to the data set. There are 46 total national defense facilities throughout the state, including 29 National Guard facilities, 3 military bases, and 14 additional facilities related to national security (e.g. Army Reserve, Coast Guard, Department of Homeland Security Offices, etc.).

[30] https://www.naics.com/

Figure 6.1. 9 - ***Heatmap of National Defense Distribution***



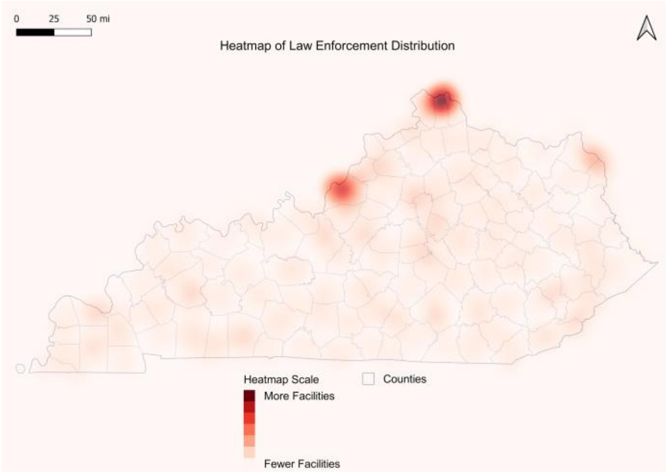
Source: Smart Electric Power Alliance (2021) based on data from combined dataset of facilities with national security-related NAICS codes from Data Axle (2020).

Distribution of national defense facilities throughout the state is not uniform; more facilities are located within densely populated counties.

Law Enforcement Facilities

Law Enforcement, a Community Lifeline designated by FEMA, refers to emergency response and crime control services distributed throughout the state. Law Enforcement data was collected through both the Critical Facilities Master List maintained by the OEP and HIFLD. The law enforcement dataset from the Master List and HIFLD were merged, and duplicate entries were removed. From this merged list, only data entries classified as police departments, sheriff offices, and park police were kept; data entries with any other designation were removed. This process resulted in a data set with a total of 484 total law enforcement facilities to be analyzed in the site selection process.

*Figure 6.1. 10 - **Heatmap of Law Enforcement Distribution***



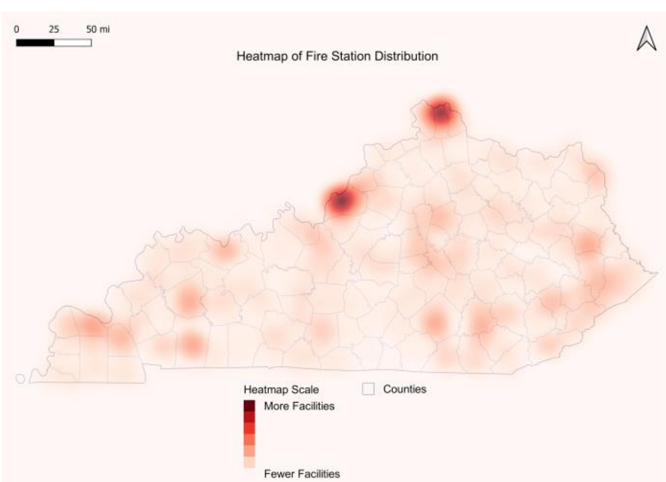
Source: Smart Electric Power Alliance (2021) based on data from the merged OEP Critical Facilities Master List and HIFLD's Local Law Enforcement Locations dataset (2020).

Law enforcement facilities are clustered throughout the state, especially in metropolitan and densely populated areas. The counties, which contain the most law enforcement facilities, include Jefferson County, Boone County, Kenton County, and Campbell County.

Fire Stations

Fire Stations are categorized as a FEMA Community Lifeline and are critical to the community in responding to health and safety emergencies. The fire stations in this dataset were sourced from a Critical Facilities Master List maintained by the OEP and HIFLD. The fire stations dataset from the Master List and HIFLD were merged, and duplicate entries were removed. This process resulted in 1,103 total fire stations to be analyzed in the site selection process.

*Figure 6.1. 11 - **Heatmap of Fire Station Distribution***



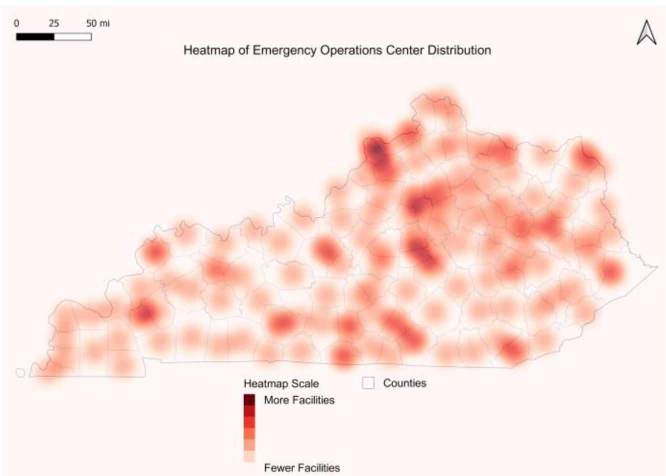
Source: Smart Electric Power Alliance (2021) based on data from the merged OEP Critical Facilities Master List and HIFLD's Fire Stations dataset (2020).

In terms of spatial distribution of these facilities, fire stations are more concentrated in counties with higher population densities, especially in North Kentucky.

Emergency Operations Centers

Emergency Operations Centers serve as emergency management command centers, where information is shared and response efforts are coordinated. These centers may have permanent locations, or they might be set up on a provisional basis to mitigate an incident. The data for emergency operations centers was sourced from HIFLD. There are a total of 142 emergency operations centers included in the data set and analyzed in the site selection process.

*Figure 6.1. 12 - **Heatmap of Emergency Operations Center Distribution***



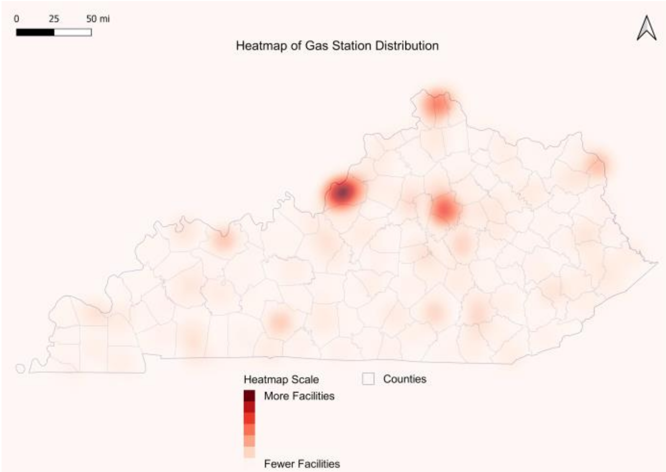
Source: Smart Electric Power Alliance (2021) based on data from Department of Homeland Security. Merged dataset of Local Emergency Operations Centers (EOC) and State Emergency Operations Centers (EOC). Homeland Infrastructure Foundation Level Data (HIFLD) (2020).

There is at least one emergency operations center per county, making the spatial distribution of these facilities mostly uniform across the state.

Gas Stations

Gas Stations fall within the Energy category of FEMA Community Lifelines. The gas stations in this dataset were sourced through a NAICS code query from Data Axle. The NAICS code query returned 1,973 gas stations within Kentucky, which were analyzed in the site selection process.

*Figure 6.1. 13 - **Heatmap of Gas Station Distribution***



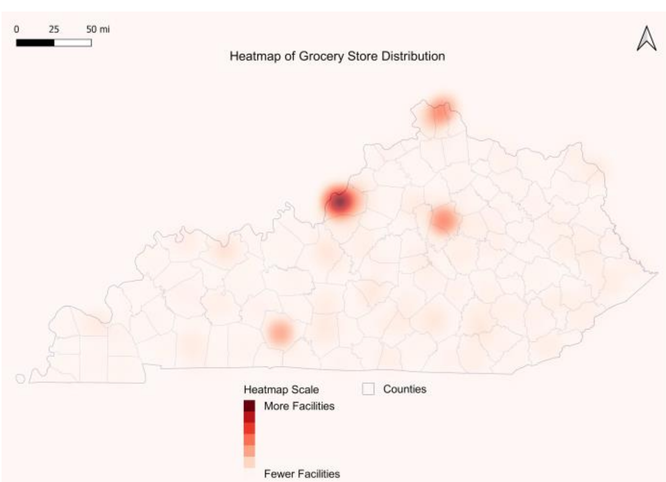
Source: Smart Electric Power Alliance (2021) based on data from combined dataset of facilities with gas station-related NAICS codes from Data Axle (2020).

The locations of gas stations are concentrated in urban areas and counties with higher population densities, especially in Northern Kentucky.

Grocery Stores

Grocery stores are included in this study as a FEMA Community Lifeline and are critical to the community in providing access to essential food and pharmaceutical services. Using Data Axle, this dataset was extrapolated by querying businesses with NAICS codes that designated them as retail grocery stores. In the edited and final dataset, 1,273 grocery stores remain to be analyzed in the site selection process.

*Figure 6.1. 14 - **Heatmap of Grocery Store Distribution***



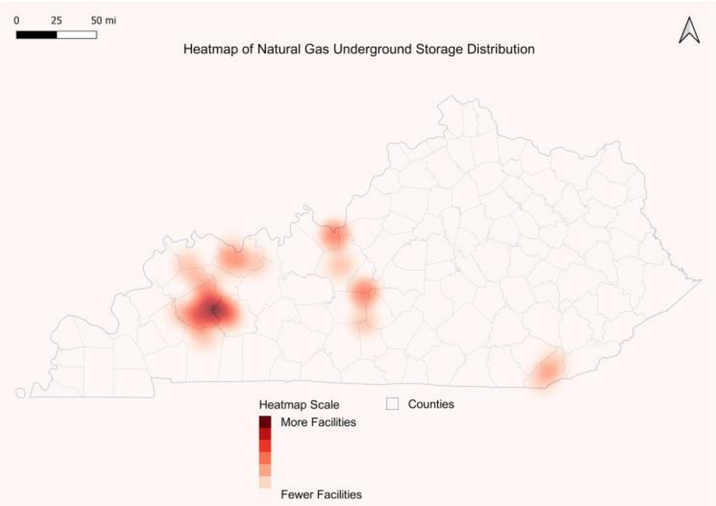
Source: Smart Electric Power Alliance (2021) based on data from combined dataset of facilities with food retail-related NAICS codes from Data Axle (2020).

Grocery stores are clustered within counties with high population densities.

Natural Gas Underground Storage

Natural Gas Storage facilities fall within the Energy category of FEMA Community Lifelines but will not be considered as microgrid hosts due to the general back-up power capabilities at the facilities. It is important to note that they effectively contribute to the resilience of Kentucky's natural gas infrastructure in maintaining reliable and responsive natural gas delivery. Underground storage facilities vary in their storage methods, capacity, and deliverability rate, and this data for these facilities was derived from the Energy Information Association (EIA).

Figure 6.1. 15 - ***Heatmap of Natural Gas Underground Storage Distribution***



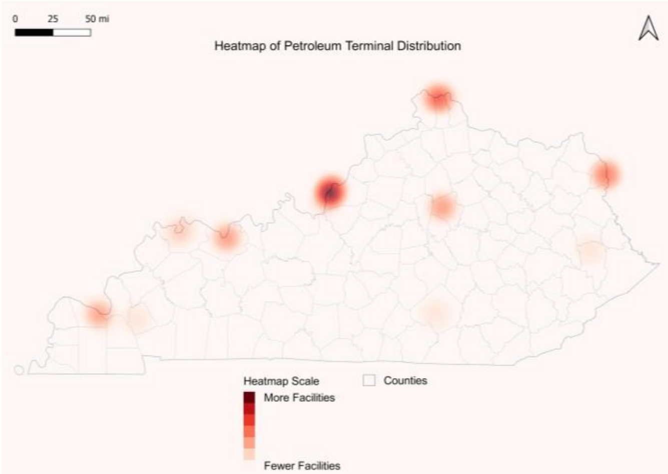
Source: Smart Electric Power Alliance (2021) based on data from U.S. Energy Information Administration. Natural Gas Underground Storage. Layer Information for Interactive State Maps (2019).

All of these facilities fall within Bell, Daviess, Hancock, Hardin, Hart, Henderson, Hopkins, Meade, Metcalfe, and Muhlenberg counties. A majority of these counties are located in the central Kentucky region.

Petroleum Terminals

Petroleum Terminals fall within the Energy category of FEMA Community Lifelines. These facilities were emphasized as highly critical by the OEP, and will be referenced as criteria in selecting gas station microgrid sites. Petroleum terminals themselves, however, will not be selected as potential microgrid sites. Petroleum terminals serve as storage facilities for crude oil and refined petroleum products. Data for petroleum facilities was collected from HIFLD, which identified 31 total terminals.

Figure 6.1. 16 - ***Heatmap of Petroleum Terminal Distribution***



Source: Smart Electric Power Alliance (2021) based on data from Department of Homeland Security, Petroleum Terminals, Homeland Infrastructure Foundation Level Data (HIFLD) (2020).

Petroleum terminals are not uniformly distributed throughout the state. Counties that have terminals include McCracken County, Lyon County, Henderson County, Daviess County, Jefferson County, Pulaski County, Fayette County, Boone County, Kenton County, Campbell County, Floyd County, and Boyd County.

Natural Hazards

Natural hazards threaten grid reliability by damaging electricity infrastructure, which puts customers within those hazard areas at risk of losing power and access to critical services. The analysis in this study identifies natural hazard and extreme weather threats as well as areas most vulnerable and at high-risk to power outage caused by these threats. To determine which natural hazard risks to evaluate as a part of this study, SEPA utilized the 2018 Kentucky Hazard Mitigation Plan published by Kentucky Emergency Management (KYEM). This Mitigation Plan contains reports detailing the impact of and risk associated with several natural hazards affecting the state, including: flooding, dam collapse, drought, earthquakes, landslides, karst, mine subsidence, winter storms, wind, extreme temperatures, and wildfires. This list of natural hazards was revised and prioritized based on the threat they pose to grid resilience and input from key Kentucky stakeholders.

Natural hazards analyzed in this study vary in terms of their impact across the state. Additionally, some of these natural hazards are inherently more threatening to grid resilience than others. Hazards, which currently present the lowest risk to grid resilience, such as extreme heat, were not considered in this study due to their relative impact. However, the occurrence and magnitude of extreme heat is projected to increase substantially in the future, and the inclusion of this hazard in future grid resilience measures will likely be necessary.

For the purposes of this study, natural hazards, which currently pose significant disruptions to the grid, were evaluated. Through several meetings with various stakeholders, two groups of natural hazards were generated:

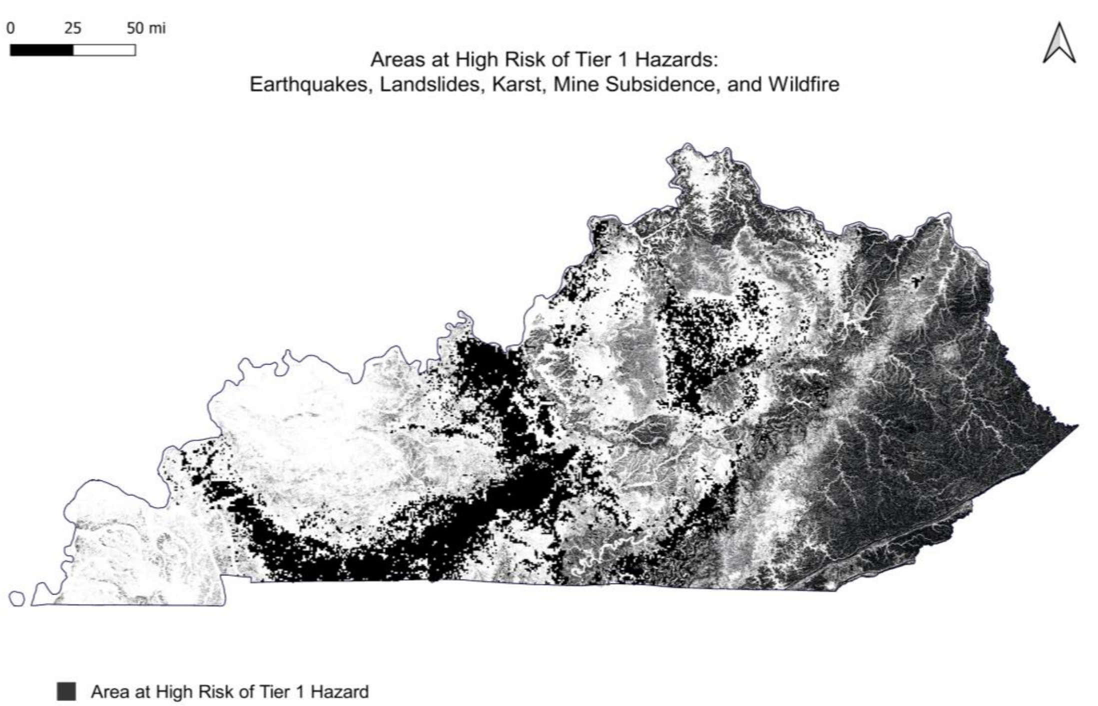
- **Tier 1 Hazards:** consists of hazards that, should they occur, would cause complete destruction to an area and should be avoided completely when evaluating locations for a microgrid placement. These hazards include earthquakes, landslides, karst, mine subsidence, and wildfires.
- **Tier 2 Hazards:** consists of hazards that are non-catastrophic but still pose threats to energy infrastructure. These hazards include flooding, extreme cold and winter storms, wind, and tornadoes.

Datasets of each natural hazard were created according to the methodology outlined in the 2018 Kentucky Hazard Mitigation Plan. To ensure accuracy in the identification of high hazard risk areas across the state, SEPA prioritized data procurement from the same data sources that were referenced in each KYEM risk assessment and other Kentucky entities.

Tier 1 Hazards

The data collected for Tier 1 Hazards was used to evaluate areas that would pose serious threats to microgrid technology, and therefore not be suitable for siting a microgrid. The dark areas seen in Figure 2.1 below indicate areas that are highly susceptible to Tier 1 natural hazards.

Figure 2.1 - ***Areas at High Risk of Tier 1 Hazards***



Source: Smart Electric Power Alliance (2021) based on data provided by Matt Crawford, a Kentucky Geological Survey scientist with the University of Kentucky (2020).

The following sections include descriptions of the Tier 1 natural hazards, which regions of Kentucky are most susceptible to risk of these hazards, and guidance on siting microgrids effectively to mitigate against these hazards.

Earthquakes

Several seismic zones affect Kentucky: the New Madrid, Wabash Valley, and Eastern Tennessee. Historically, the most severe earthquakes occur in the New Madrid seismic zone, which is located at the western tip of the state. Earthquakes can cause damage to infrastructure, with the severity of that damage dependent on ground motion. KYEM's Earthquakes risk assessment included several maps, one of which evaluated the potential ground-motion amplification hazard.[31] Areas that have the highest potential ground-motion amplification hazard can expect the most infrastructure damage in the event of an earthquake. Therefore, SEPA obtained the GIS data used in the creation of this amplification potential map in order to identify areas where infrastructure is at higher risk of earthquakes throughout the state.[32]

According to the National Earthquake Hazards Reduction Program (NEHRP) hazard level classes, western Kentucky has a moderate amplification hazard risk, while other areas of the state have a low or no amplification hazard risk. This study concerns areas of high hazard risk and therefore all areas of moderate, low, or no risk are still suitable for microgrid deployment.

Landslides

Landslides can cause catastrophic damage and severely impact transportation and utilities. While landslides and their impacts are generally underreported, the Kentucky Geological Survey (KGS) has determined areas within the state that are most susceptible to future landslide occurrence. Within the Landslides risk assessment, several maps were included: one map displayed locations of landslide occurrence, another map displayed three classes of landslide susceptibility, and another map displayed four classes of landslide vulnerability, which is calculated from weighing landslide susceptibility by population distribution.[33] SEPA worked with KGS to obtain the GIS data used in the landslide susceptibility map to identify areas at higher risk of landslides.[34]

The same ranges of landslide susceptibility values which were used to classify areas of low, moderate, and high risk in the assessment map were applied to the raw GIS data used in SEPA's reproduced map to ensure consistency.

The reproduced map reflects KGS's assertion that landslide susceptibility is high in eastern Kentucky, moderate in western Kentucky, and low in central Kentucky. When determining

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[31] Kentucky Office of Emergency Management (KYEM), Earthquakes (2018) p. 7

[32] Data used in this analysis was provided by Matt Crawford, a Kentucky Geological Survey geologist with the University of Kentucky

[33] KYEM, Landslides (2018)

[34] Data used in this analysis was provided by Matt Crawford, a Kentucky Geological Survey geologist with the University of Kentucky

potential sites for microgrid deployment, locations near, but not within areas of high susceptibility should be considered due to the destructive nature of this particular hazard.

Karst

Karst refers to terrain that is composed of soluble rock below the land's surface. Due to the soluble characteristic of the rock, it can begin to dissolve, and eventually cause sinkholes. In addition to sinkhole creation, karst less frequently facilitates flooding and water contamination. It is estimated that 19,981 square kilometers of Kentucky has high karst potential, according to KYEM's Karst and Sinkhole Hazards risk assessment.[35] The assessment also includes several maps that classify different parts of the state according to a karst/sinkhole hazard score. According to the report, risk is best reflected when the hazard score is calculated from both karst potential area and sinkhole density.[36] To maintain accuracy, SEPA utilized the final hazard score map when assessing the risk of karst and obtained the GIS data used in that map to conduct analysis on areas at high risk to karst.[37]

The same ranges of karst/sinkhole hazard score values which were used to classify areas of low, moderate, high, and severe risk in the selected assessment map were applied to the raw GIS data used in SEPA's reproduced map to ensure consistency.

This reproduced map reflects the assessment's conclusion that karst and sinkhole hazard is high in western, south central, and central Kentucky. Microgrids should be placed near, but not within areas with high and severe hazard scores because a sinkhole event would destroy any infrastructure on top of it.

Mine Subsidence

Mine subsidence is the settling of land due to underground mine collapse, which can affect utility infrastructure. The severity of mine subsidence events, and the amount of consequential damage, is dependent on the age, type, and number of mines, among several other factors. KYEM's Mine Subsidence risk assessment identified the areas within Kentucky that were the most susceptible to the hazard.[38] A map of underground mine distribution is included in this assessment, which can be used to determine the areas with the most mines and in turn indicate areas with highest risk of subsidence. SEPA worked with KGS to obtain the GIS data on underground mine distribution in order to identify areas of high risk to mine subsidence.[39]

SEPA reproduced the assessment map to reflect the following findings of the risk assessment: 1) mine subsidence is only a hazard in eastern and western Kentucky, 2) historically, more mine subsidence events occur in western Kentucky. Areas affected by 1-2, 3, and 4-5 mines were

[35] KYEM, Karst and Sinkhole Hazards (2018) p. 47
[36] KYEM, Karst and Sinkhole Hazards (2018) p. 53
[37] Data used in this analysis was provided by Matt Crawford, a Kentucky Geological Survey geologist with the University of Kentucky
[38] KYEM, Mine Subsidence (2018)
[39] Data used in this analysis was provided by Matt Crawford, a Kentucky Geological Survey geologist with the University of Kentucky

categorized as low, moderate, and high risk, respectively. As this hazard has the potential to damage utility infrastructure, microgrids should be placed near, but not within, areas with high risk.

Wildfires

On average, 2 to 3 wildfires occur in Kentucky each day of the year.[40] Wildfires typically ignite from human activities or lightning strikes. When these fires occur, their severity and duration depends on the amount of available fuel, the topography of the area, and weather conditions.[41] KYEM's wildfire risk assessment, written in collaboration with the Kentucky Division of Forestry, evaluated the spatial distribution of wildfire occurrences and consequential economic losses.[42] This risk assessment provided a map of wildfire occurrences as well as a table with the number of fire events in each county.

SEPA reviewed the risk of wildfire occurrence by evaluating data from the USDA's Forest Service, which is referenced on Kentucky.gov. Wildfire Hazard Potential data was downloaded from USDA's site, which classifies areas at varying levels of risk of wildfire occurrence, including none, very low, low, moderate, high, and very high. During SEPA's geospatial evaluation, these classes were simplified into low, moderate, and high risk.

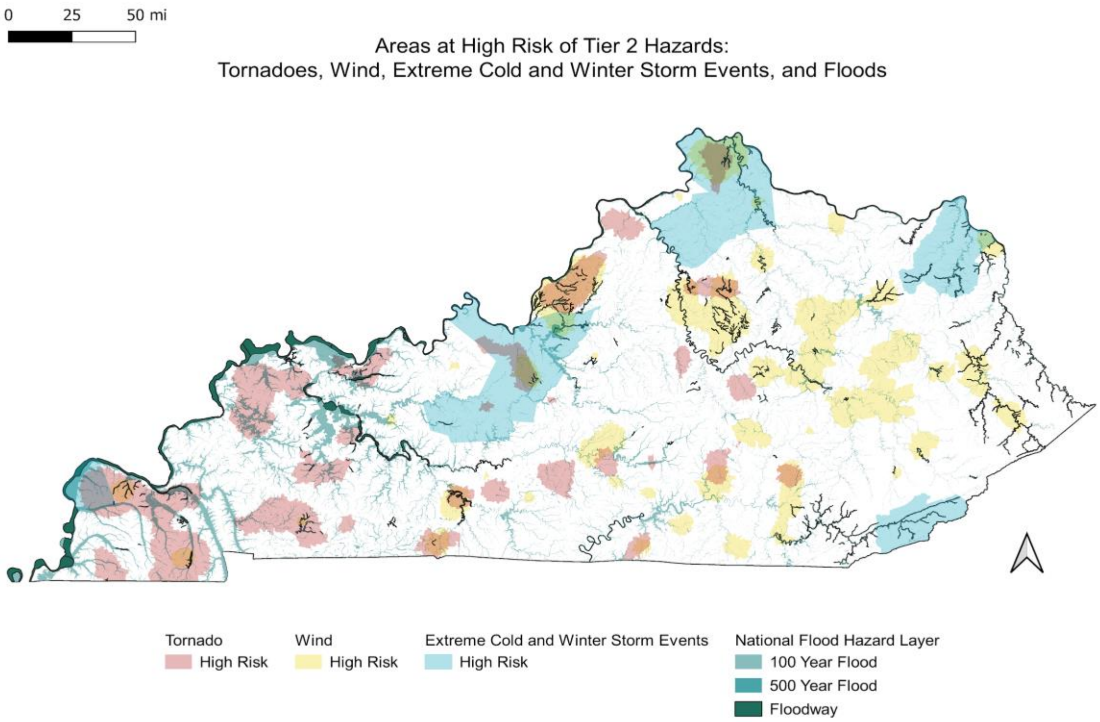
KYEM's wildfire risk assessment found that eastern Kentucky experiences the most frequent and most severe wildfires compared to the rest of the state.[43] The U.S. Forest Service's Wildfire Hazard Potential (WHP) map reflects KYEM's findings that most of Kentucky has a very low WHP with the exception of eastern Kentucky having relatively higher WHP.[44] A microgrid placed near, but not within, areas of high WHP would support the grid in the event of wildfire ignition.

Tier 2 Hazards

The data collected for Tier 2 Hazards was used to evaluate disruption-prone areas that may cause damage to energy infrastructure. The map below shows areas that are highly susceptible to Tier 2 natural hazards.

[40] KYEM, Risk Assessment: Wildfire (2018) p. 18
[41] KYEM, Risk Assessment: Wildfire (2018) p. 1
[42] KYEM, Risk Assessment: Wildfire (2018)
[43] KYEM, Risk Assessment: Wildfire (2018) p. 24
[44] U.S. Forest Service, Wildfire Risk to Communities: Spatial datasets of landscape-wide wildfire risk components for the United States (2020)

*Figure 2.2 - **Areas at High Risk of Tier 2 Hazards***



Source: Smart Electric Power Alliance (2021) based on data provided by NOAA's National Centers for Environmental Information Storm Events Database, HIFLD's Historical Tornado Tracks dataset, and FEMA's National Flood Hazard Layer (2020).

The following sections include descriptions of the Tier 2 natural hazards, which regions of Kentucky are most susceptible to risk of these hazards, and guidance on siting microgrids effectively to mitigate against these hazards.

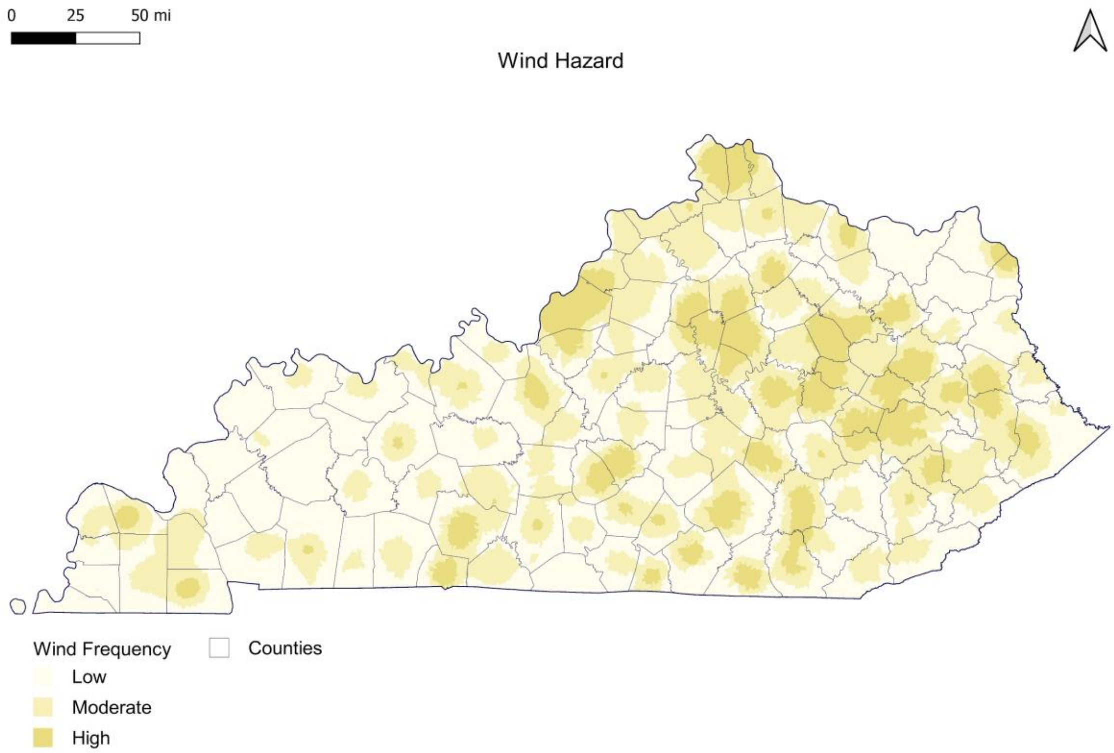
Winds

Wind poses threats to aboveground energy infrastructure, which can subsequently cause power outages. Straight-line winds cause more damage than tornadoes, according to the Wind: Tornadoes and Severe Thunderstorm risk assessment published by KYEM.[45] Within this risk assessment, wind hazard was assessed for the state of Kentucky. The data used to evaluate wind hazard was derived from The National Centers for Environmental Information (NCEI) Storm Events database, which was created and hosted by The National Oceanic and Atmospheric Administration (NOAA). The wind dataset used in the KYEM assessment included all reported wind occurrences with recorded gusts of at least 50 knots dating back to 2013. To evaluate wind risk in the same way, SEPA's data collection process treated KYEM's methodology outlined in the risk assessment as a best practice. For this microgrid study, wind records of at least 50 knots beginning in 2013 were extrapolated from NOAA's NCEI database and compiled into a singular wind hazard dataset. This dataset contains records of wind occurrences, the county in which the wind was observed and recorded, the time and date that

[45] KYEM, Risk Assessment: Wind: Tornadoes and Severe Thunderstorm (2018) p. 72

the wind began, the source of the hazard report, and the coordinates of the location where the wind event was initially observed.

*Figure 6.1. 17 - **Wind Hazard***



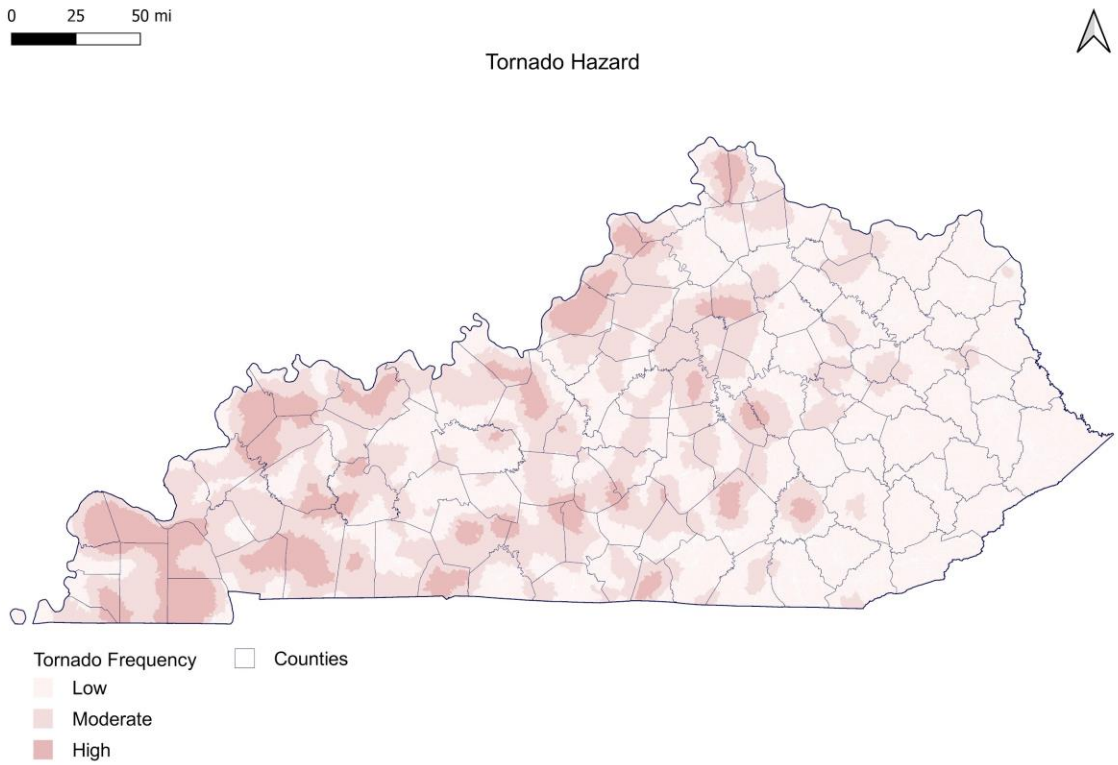
Source: Smart Electric Power Alliance (2021) based on data provided by NOAA's National Centers for Environmental Information [Storm Events Database](#) (2020).

Using those coordinates, SEPA generated a heatmap to evaluate historical wind occurrence across the state. This heatmap can be used to effectively assess areas in which wind hazard is the highest. Areas with the highest occurrences of wind include the counties of Boone, Kenton, Campbell, Jefferson, Franklin, Fayette, Greenup, Boyd, Taylor, Green, Pulaski, Lee, Owsley, Breathitt, and Morgan. These counties are generally located in the northern and central parts of the state of Kentucky.

Tornadoes

Tornadoes, while less damaging than straight-line winds, still pose a significant risk to aboveground utility infrastructure. Tornado risk was evaluated within the KYEM Wind: Tornadoes and Severe Thunderstorm risk assessment by evaluating historical tornado occurrences and tornado track maps. Within the KYEM assessment, tornadic activity was collected from the Louisville, Paducah, and Jackson National Weather Service field offices. As tornadic data from these sources varied in time and public availability, SEPA collected tornado track GIS data with records starting in 1950 from the National Weather Service, hosted within the Homeland Infrastructure Foundation-Level Data site.[46]

*Figure 6.1. 18 - **Tornado Hazard***



Source: Smart Electric Power Alliance (2021) based on data provided by HIFLD, Historical Tornado Tracks (2020).

Using that historical data, SEPA generated a heatmap highlighting areas with the highest historical tornadic activity, which serves as an indication of hazard risk across the state. KYEM's assessment concluded that regions most susceptible to tornadoes include western, northwestern, and central Kentucky, which is reflected in SEPA's heatmap.

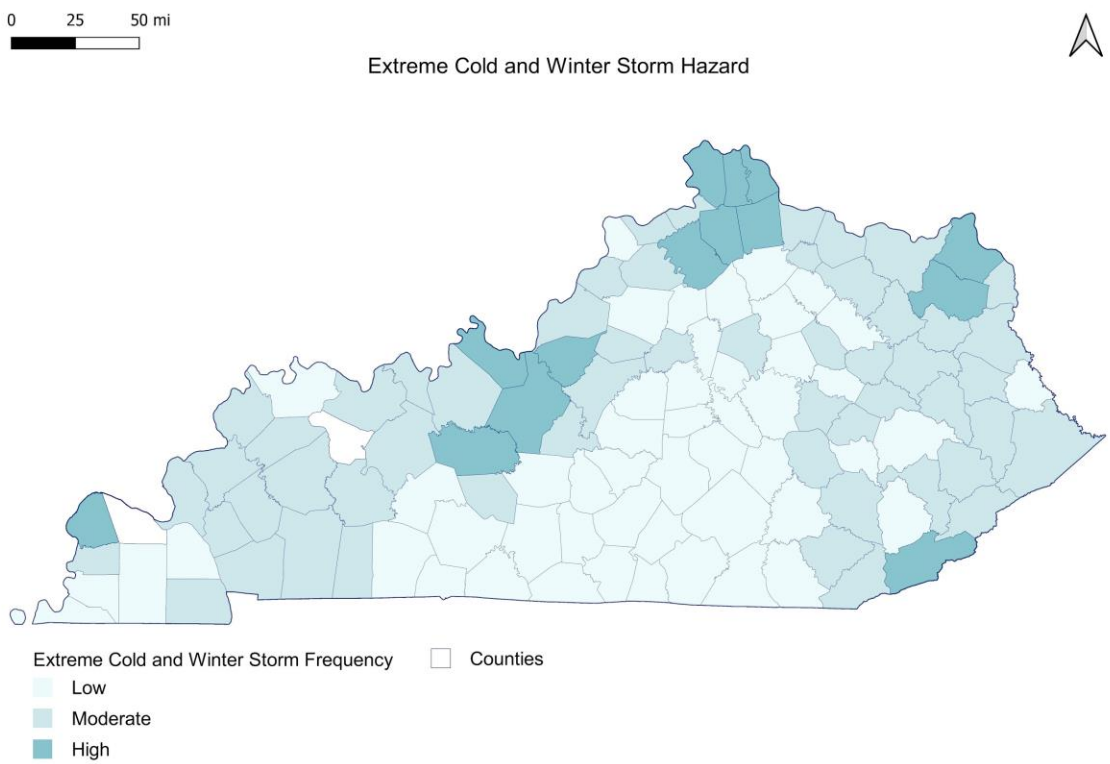
Extreme Cold and Winter Storm Events

Winter hazards are multi-faceted in terms of types of events and their effects. The types of hazards, which significantly affect Kentucky during the winter, include extreme cold and wind chill, ice storms, heavy snow, and winter storms. Each of these hazards can cause water system bursts, leakages, and power outages, which create life-threatening conditions exacerbated by the cold. KYEM evaluated the risk of extreme cold and winter storm events in their Extreme Temperatures and Severe Winter Storms risk assessments. To assess hazard risk, KYEM pulled records of hazard occurrence, beginning in 2013, from NOAA's NCEI Storm Events database. These records include the county in which the hazard occurred, which enabled KYEM to draw conclusions regarding which regions are most at risk. SEPA adapted

[46] Department of Homeland Security, Historical Tornado Tracks, HIFLD (2020)

this approach using NOAA's NCEI Storm Events database to create a dataset from all recorded extreme cold and wind chill, ice storm, heavy snow, and winter storm events beginning in 2013.

*Figure 6.1. 19 - **Extreme Cold and Winter Storm Hazard***



Source: Smart Electric Power Alliance (2021) based on data provided by NOAA's National Centers for Environmental Information Storm Events Database (2020).

Using this dataset, the risk of winter hazard occurrence by county was visualized through a choropleth map. This choropleth map confirmed KYEM's conclusions regarding regional impact of these hazards; eastern and southeastern Kentucky are especially susceptible. Counties which are at the highest risk of experiencing extreme cold and winter storms include Ballard, Grayson, Meade Hardin, Bullitt, Boone, Kenton, Grant, Owen, Pendleton, Greenup, Carter, and Harlan counties.

Flood Risk

Floods incur more damage and occur more frequently than every other natural hazard in Kentucky. Different flood types, which typically occur in the state, include riverine, urban, and flash floods. These floods are known to cause fatalities and significant economic loss. KYEM's Flood Risk Assessment analyzed risk across the state and evaluated vulnerability to 100 year floods, flood losses, and economic effects through FEMA's HAZUS tool.[47]

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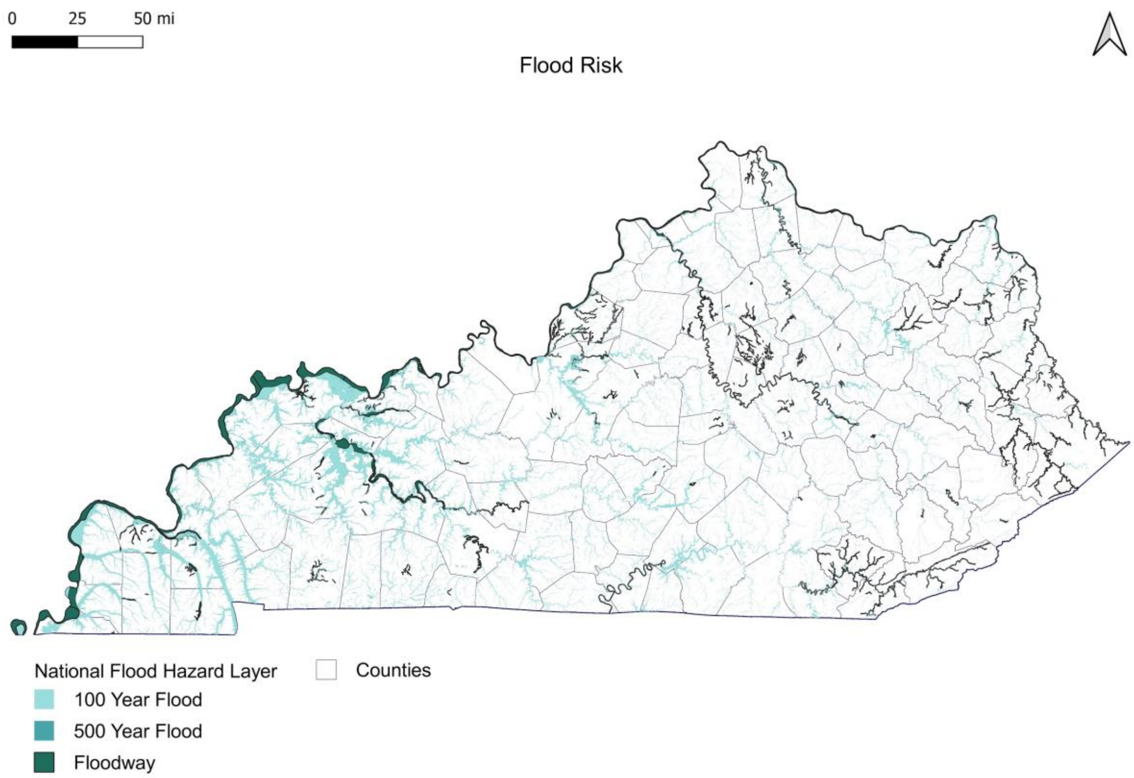
[47] KYEM, Flood Risk Assessment (2018)

In KYEM's study, susceptibility to 100-year floods was assessed using FEMA's National Flood Hazard Layer, which contains Flood Insurance Rate Map panels and GIS data. SEPA used this layer and conducted flood risk analysis through the download of GIS data for each of Kentucky's 120 counties. Each county GIS download includes vector data of areas impacted by 100 year floods, 500 year floods, floodways, minimal flood hazard, and levee reduced flood risk. These impacted areas are clearly outlined, facilitating a qualitative decision-making process, which involves considering microgrid sites nearby, but not within, areas at risk of flooding.

*Figure 6.1. 20 - **Flood Risk***



Source: Smart Electric Power Alliance (2021) based on data provided by FEMA, National Flood Hazard Layer (2020).

KYEM's Flood Risk Assessment concluded that eastern Kentucky is the most susceptible to flash floods, central Kentucky experiences flood events with more warning time than those in eastern Kentucky, and northern & western Kentucky floods have the most warning time and the highest risk of economic loss. The Assessment also determined that the counties with the highest flood risk include Jefferson, Franklin, Pike, Daviess, and Floyd Counties. Looking at the National Flood Hazard Layer data, these conclusions are validated; the areas designated as 100 and 500 year floodplains are larger in northern and western Kentucky, where the terrain is more gently sloping.

Utility and Electricity

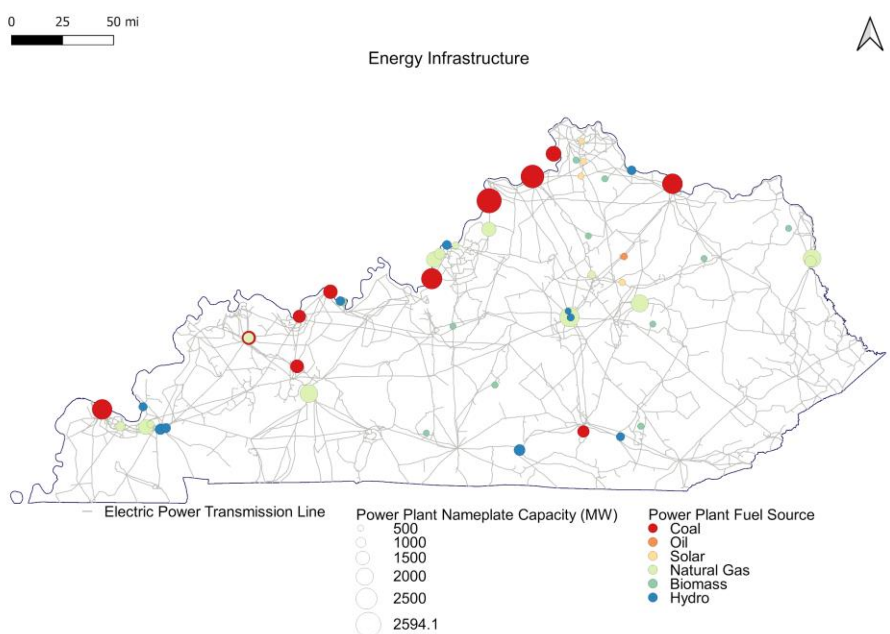
An understanding of existing generation and distribution resources and areas with grid reliability issues informs both microgrid site selection and individual microgrid system specifications. To evaluate the energy landscape, datasets were generated for energy infrastructure, electric service areas, distributed renewable generation, and grid reliability.

Energy Infrastructure

Power plant information was gathered from the Kentucky Energy Dashboard[48] and the U.S. Energy Information Administration (EIA).[49] The list of power plants and their characteristics from the EIA was compared against the list from the Kentucky Energy Dashboard to ensure accuracy, and a power plant dataset was created. Operational landfill gas project data from the EPA was merged with this power plant dataset.[50] This dataset contains the name of the power plant, nameplate capacity, and type of fuel produced, technology used, energy source, and coordinates.

Electric power transmission line data was collected from HIFLD, and includes voltage information.[51]

*Figure 6.1. 21 - **Energy Infrastructure***



Source: Smart Electric Power Alliance (2021) based on data provided by EIA and HIFLD (2020).

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[48] Kentucky Energy Dashboard, Kentucky Power Plants (2020)
[49] Shapefile created by U.S. Energy Information Administration containing power plant information provided by OEP.
[50] United States Environmental Protection Agency, Project and Landfill Data by State, Landfill Methane Outreach Program (LMOP) (2020)
[51] Department of Homeland Security, Electric Power Transmission Lines, HIFLD (2020)

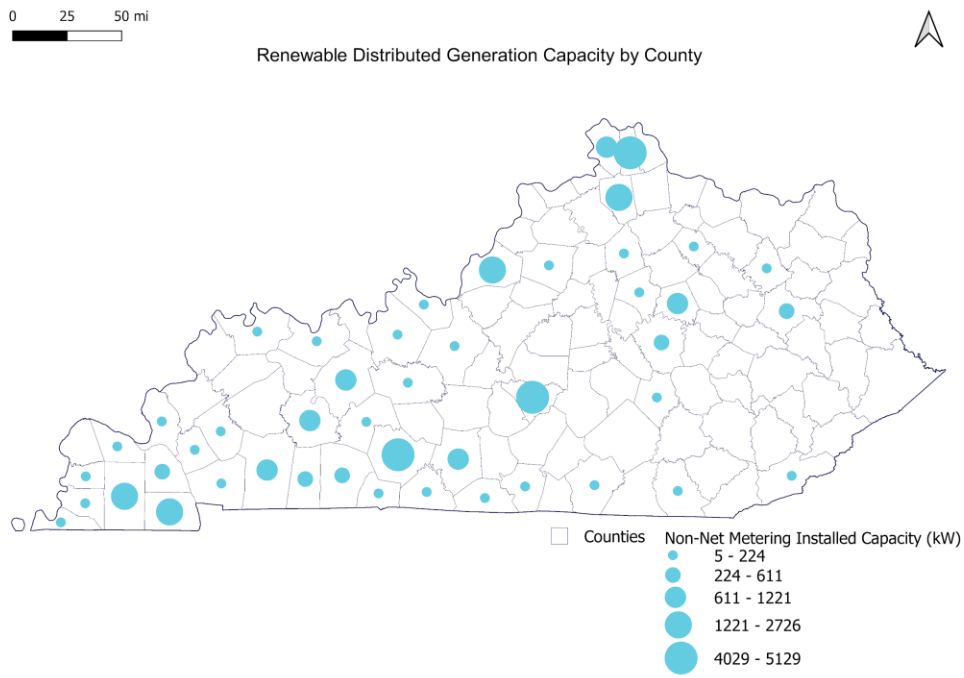
Electric Service Areas

A dataset of electric service areas across the state is displayed in the Kentucky Energy Dashboard and was downloaded from KyGovMaps Open Data.[52] This dataset contains the areas serviced by each utility, utility name, type, and class.

Distributed Renewable Generation

Displayed in the Kentucky Energy Dashboard, datasets of net and non-net metering installed renewable capacity by county were provided by OEP.

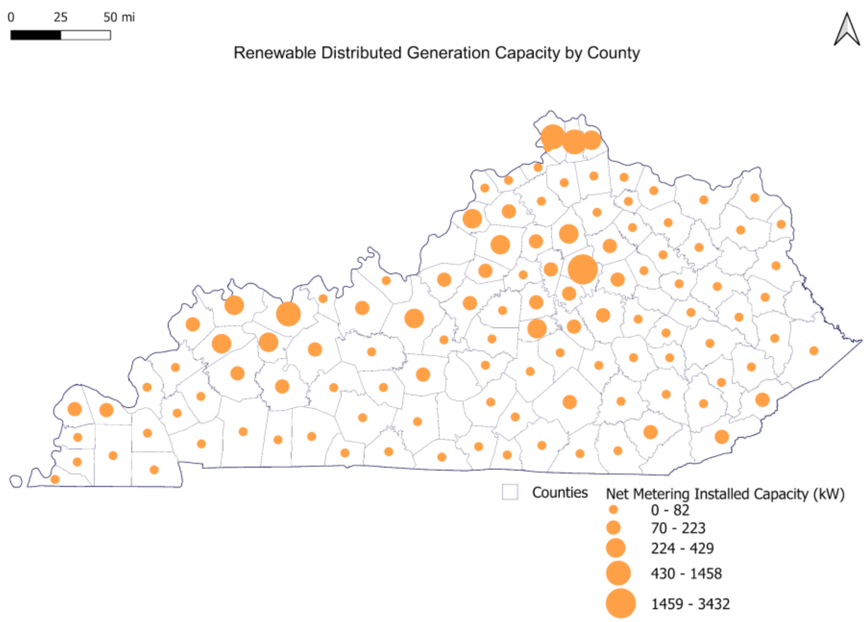
Figure 6.1. 22 - ***Renewable Distributed Generation: Non-Net Metering Installed Capacity***



Source: Kentucky Office of Energy Policy. Non-Net Metering Installed Capacity (2020).

[52] Kentucky Energy Dashboard, Electric Service Areas, KyGovMaps Open Data (2020)

*Figure 6.1. 23 - **Renewable Distributed Generation: Net Metering Installed Capacity***



Source: Kentucky Office of Energy Policy. Net Metering Installed Capacity (2020).

Reliability

A dataset containing the top ten worst performing circuits for each utility was collected from annual reliability reports filed with the Kentucky Public Service Commission.[53] SEPA identified the worst performing circuits for each utility based on the reporting year System Average Interruption Duration Index (SAIDI) values. For each reporting utility, circuits with the 10 highest reporting year SAIDI values were captured within a dataset. Information within the dataset includes the utility to which each circuit belongs, locational information, areas served, 5 year average SAIDI and System Average Interruption Frequency Index (SAIFI) values, and reporting year SAIDI and SAIFI values. The reporting year for each substation is either 2019 or 2020. Coordinates for each substation were generated using the U.S. Census Bureau's Geocoder tool, Google Maps, or were sent by Big Rivers Electric Corporation and Kentucky Power Company. The reporting year SAIDI values were used to generate a heatmap, shown below, and evaluate reliability issues across the state.

[53] Kentucky Public Service Commission, Electric Distribution Utility Annual Reliability Reports (2019, 2020)

Appendix 2: Site Selection Parameters by Critical Facility Type

This appendix includes a detailed summary of the site selection parameters applied to each of the critical facility types for the site specific and regional community microgrid deployments evaluated in this analysis.

Hospitals

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Nursing Homes

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per

county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.

4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Emergency Operations Centers

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Law Enforcement

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected. Police stations were prioritized over sheriff offices.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Water Treatment Plants

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and

Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.

6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Wastewater Treatment Plants

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Grocery Stores

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.

2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Communication

1. Critical Facility Structure – only cellular towers were evaluated as potential microgrid sites.
2. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
3. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
4. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.
5. Reliability – for remaining sites, those near reliability hotspots were prioritized.
6. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites

that did not meet those two criteria were still considered if necessary for representation in densely populated areas.

7. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Gas Stations

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected. Preference was given to stations with closer geographic proximity to petroleum terminal facilities.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

Fire Stations

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized.
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.

3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected. Fire departments were prioritized over fire chief offices.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized.
5. Population Density – sites that were located in highly populated areas and urban areas were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within densely populated areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in densely populated areas.
6. Energy Burden – sites that were located in counties of high energy burden were selected according to all previous criteria except for Tier 2 Hazard Areas and Reliability. Sites within underserved areas that did not fall within high risk areas of Tier 2 hazards and were located near reliability hotspots were prioritized, but the sites that did not meet those two criteria were still considered if necessary for representation in lower income areas.

National Defense

1. Tier 1 Hazard Areas – SEPA evaluated the areas at the highest risk of Tier 1 hazards across the state. Sites that were not located within those high risk areas were prioritized
2. Tier 2 Hazard Areas – for sites not within Tier 1 hazard areas, sites located in areas with the lowest risk of Tier 2 hazards were prioritized.
3. Geographical Proximity – for sites not within high risk areas of Tier 1 and Tier 2 hazards, SEPA estimated the geographical proximity sensitivity as approximately to a 10 to 15-mile radius range, meaning that if multiple sites were within this distance of each other one would be selected. For each type of critical facility, one facility was selected per county, but in the densely populated urban areas of Louisville, Lexington, and Covington, two facilities were selected.
4. Reliability – for remaining sites, those near reliability hotspots were prioritized.

Appendix 3: Detailed Load, Sizing and Cost Analysis

This appendix includes the detailed load analysis, sizing, and economic analysis for the nanogrid and regional community microgrid deployment strategies.

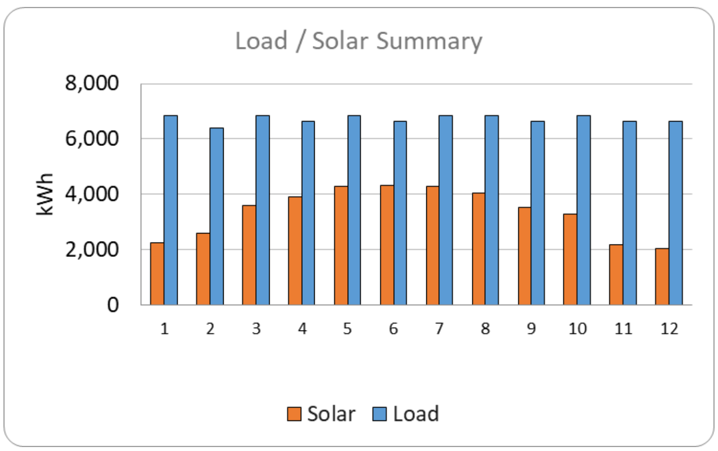
Nanogrid Deployment Strategy

Cell Towers

SEPA estimated the load profile of the 56 cell towers identified in the site selection process based on Huawei Technologies' breakdown of the power consumption for 4G and 5G mobile networks.[54] Cell towers were sized to accommodate 5G mobile networks, including anticipated data centers, to an 80% load factor. This allows the leeway for the towers to shut down 5G usage at times. Using these assumptions, average monthly demand is 9 kW with peak demand set at 12 kW.

Figure 6.3.1 displays the solar energy production (kWh) compared to the estimated cell tower load over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 4,328 kWh and lowest in December at 2,031 kWh.

*Figure 6.3. 1 - **Load & Solar Output Summary - Cell Towers***

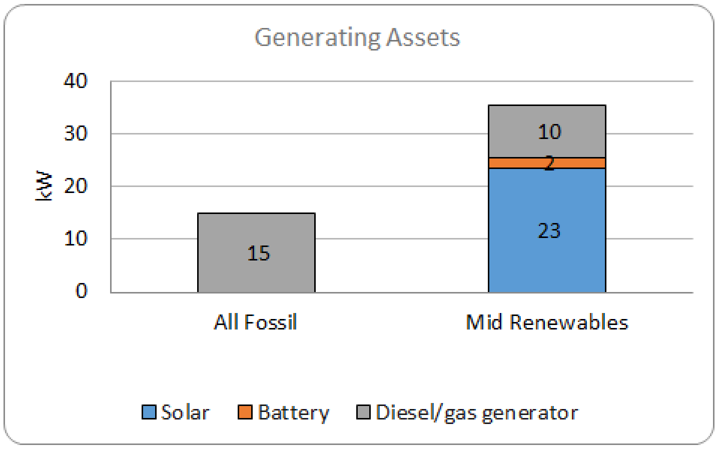


Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 15 kW standby generator is required to provide backup power capability for the cell tower for a full year. Alternatively, the moderate renewable design option requires a 10 kW standby generator, 2 kW battery storage system, and 23 kW solar system.

[54] Huawei Technologies Company, 5G: Creating a green grid that slashes costs, emissions & energy use (2020)

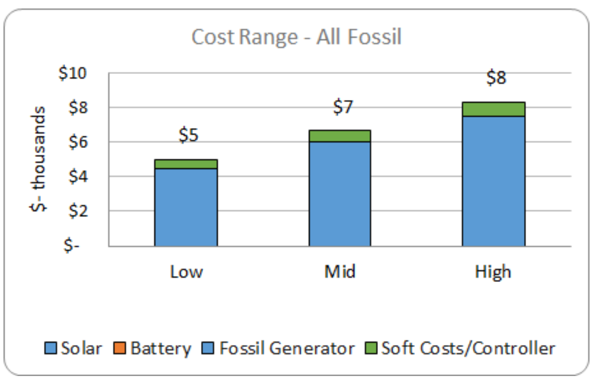
Figure 6.3. 2 - ***Nanogrid Generation Assets - Cell Towers***

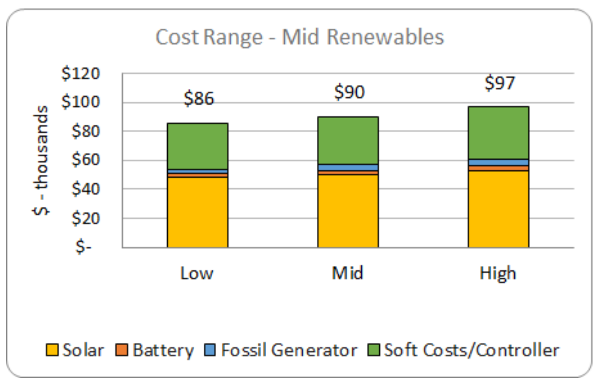


Source: Smart Electric Power Alliance, 2021.

Figure 6.3.3 below represents the cost range for the fossil fuel only and moderate renewables design options at 5G cell towers. Nanogrids under both design options are sized to provide backup power capability at cell towers 100% of the time. Costs for nanogrids sized to accommodate a 4G cell tower are approximately half those for a 5G cell tower under both design options.

Figure 6.3. 3 - ***Nanogrid Cost Estimates - Cell Towers***





Source: Smart Electric Power Alliance, 2021.

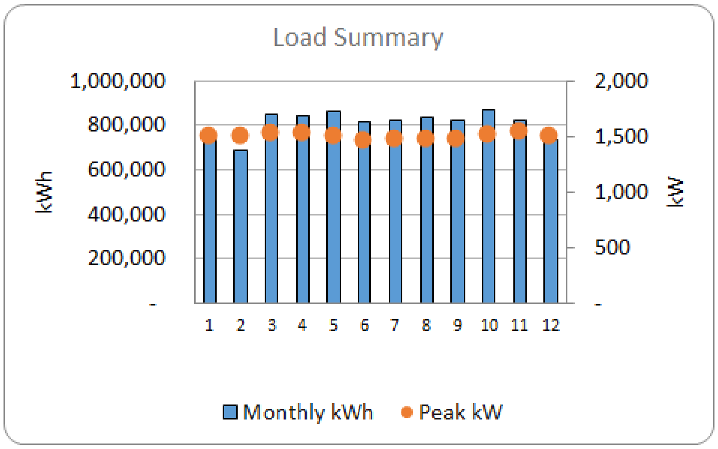
Hospitals

The load profiles for hospitals were obtained from the OpenEI[55] database based on a hospital in Lexington, Kentucky and used to evaluate the 26 locations identified in the site selection process.[56] As seen in Figure 6.3.4, hospitals are winter peaking with the highest demand and usage occurring in November and have a high load factor of 72% based on a 1,109 kW average monthly demand and a 1,533 kW peak demand.

55 https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states

56 Office of Energy Efficiency & Renewable Energy (EERE), Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States, OpenEI (2014)

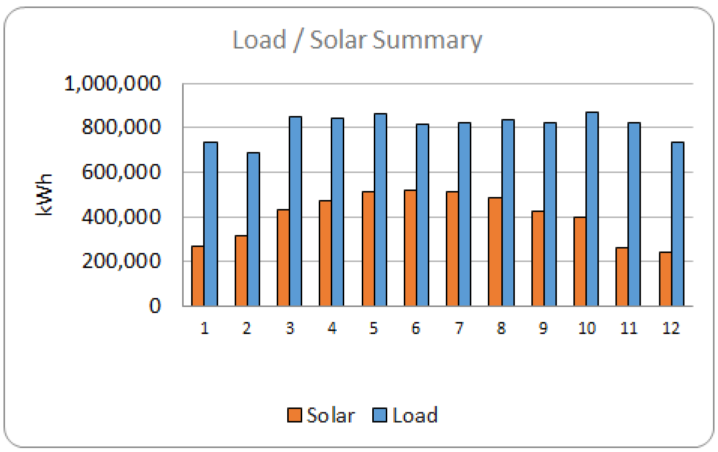
*Figure 6.3. 4 - **Load Summary - Hospitals***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.5 displays the solar energy production (kWh) compared to the load at a typical hospital over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 520,002 kWh and lowest in December at 244,029 kWh.

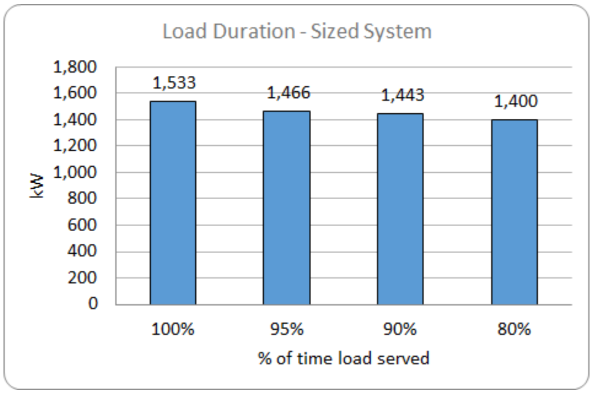
*Figure 6.3. 5 - **Load & Solar Output Summary - Hospitals***

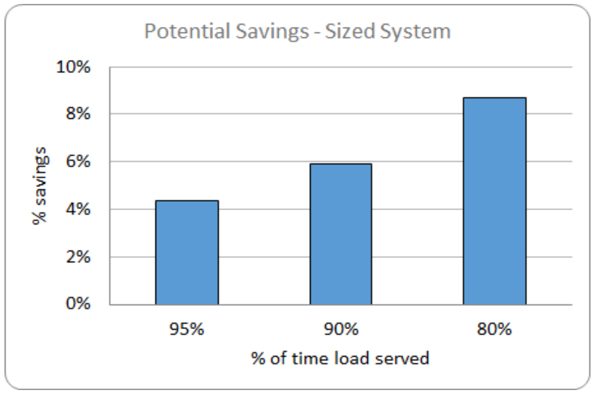


Source: Smart Electric Power Alliance, 2021.

Figure 6.3.6 below displays the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at hospitals 100% of the time for the full year, the nanogrid must be sized to accommodate 1,533 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (1,466 kW) there is potential for 4% savings on the overall price of the nanogrid.

*Figure 6.3. 6 - **Nanogrid Load Duration & Potential Cost Savings - Hospitals***

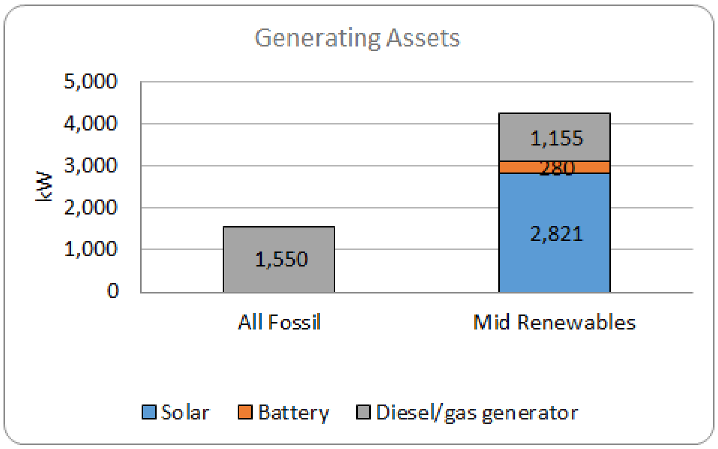




Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 1,550 kW standby generator is required to provide backup power capability for a full year. Alternatively, the moderate renewable design option requires a 1,155 kW standby generator, 280 kW battery storage system, and 2,821 kW solar system.

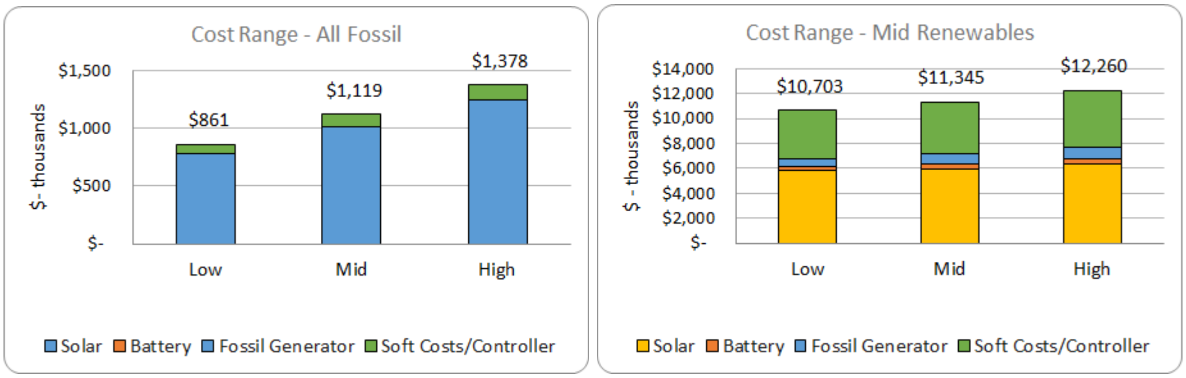
*Figure 6.3. 7 - **Nanogrid Generation Assets - Hospitals***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup power capability at hospitals 100% of the time.

*Figure 6.3. 8 - **Nanogrid Cost Estimates - Hospitals***

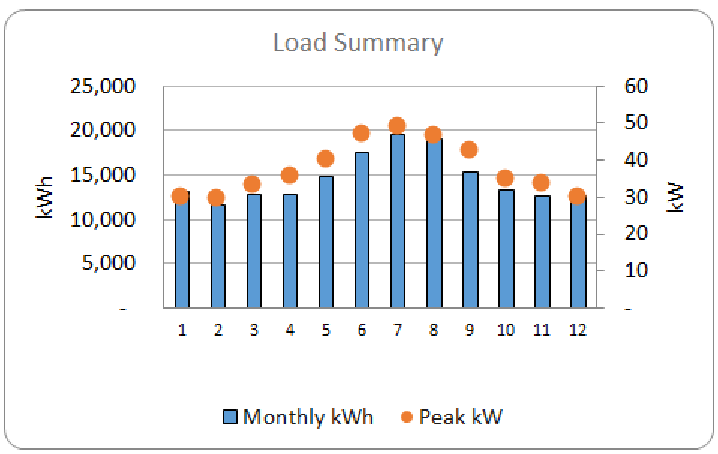


Source: Smart Electric Power Alliance, 2021.

Nursing Homes

The load profiles for nursing homes were obtained from the Open EI database and were based on a midrise apartment sized to 25,000 square feet. These load profiles were used to evaluate the 32 locations identified in the site selection process. As seen in Figure 6.3.9, nursing homes are summer peaking with the highest demand and usage occurring in July and have a medium load factor of 41% based on 20 kW average monthly demand and 49 kW peak demand.

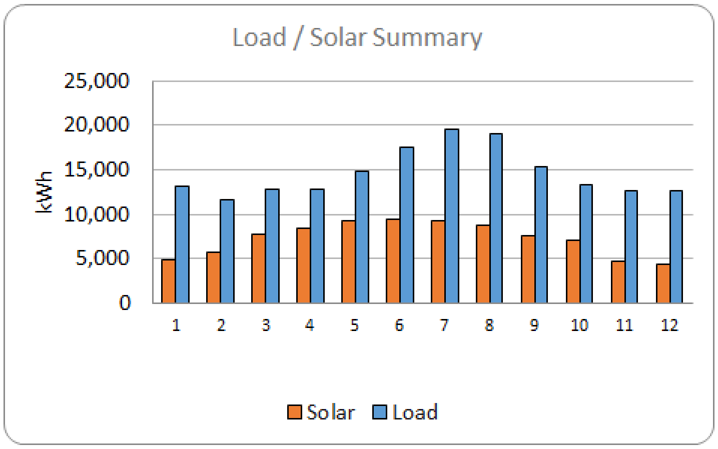
*Figure 6.3. 9 - **Load Summary - Nursing Homes***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.10 displays the solar energy production (kWh) compared to the load at a typical nursing home over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 9,403 kWh and lowest in December at 4,413 kWh.

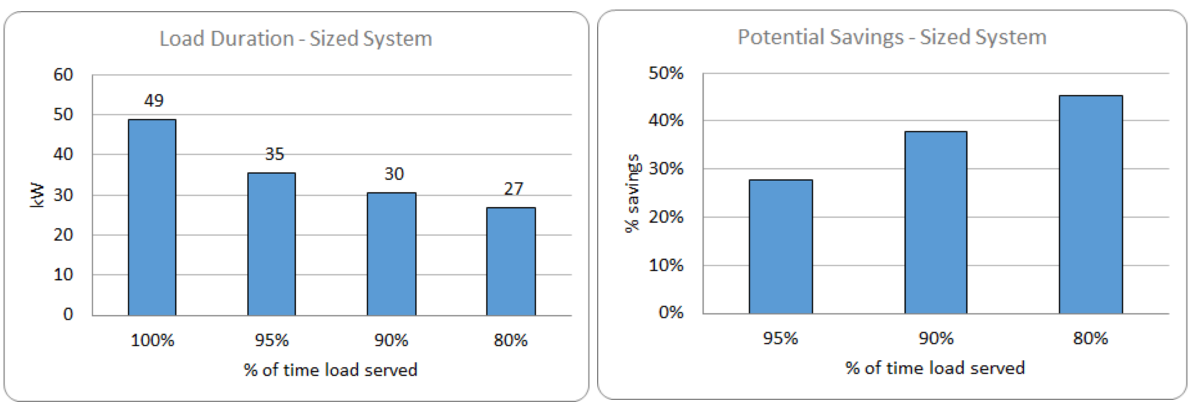
*Figure 6.3. 10 - **Load & Solar Output Summary - Nursing Homes***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.11 below display the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at nursing homes 100% of the time for the full year, the nanogrid must be sized to accommodate 49 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (35 kW) there is potential for 28% savings on the overall price of the nanogrid.

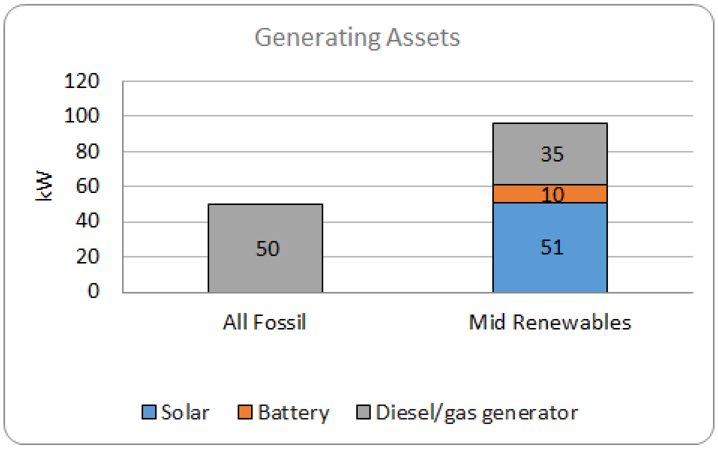
*Figure 6.3. 11 - **Nanogrid Load Duration & Potential Cost Savings - Nursing Homes***



Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 50 kW standby generator is required to provide backup outage capability for a full year. Alternatively, the moderate renewable design option requires a 35 kW standby generator, 10 kW battery storage system, and 51 kW solar system.

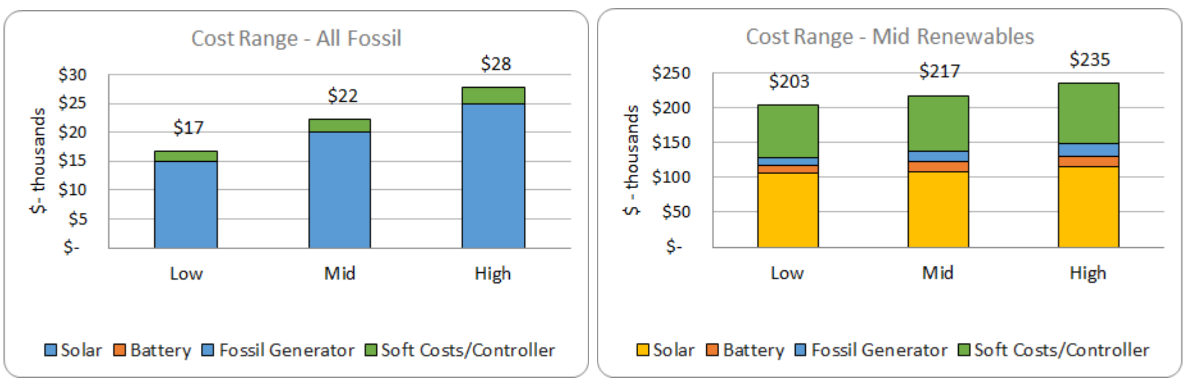
*Figure 6.3. 12 - **Nanogrid Generation Assets - Nursing Homes***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup outage capability at nursing homes 100% of the time.

*Figure 6.3. 13 - **Nanogrid Cost Estimates - Nursing Homes***

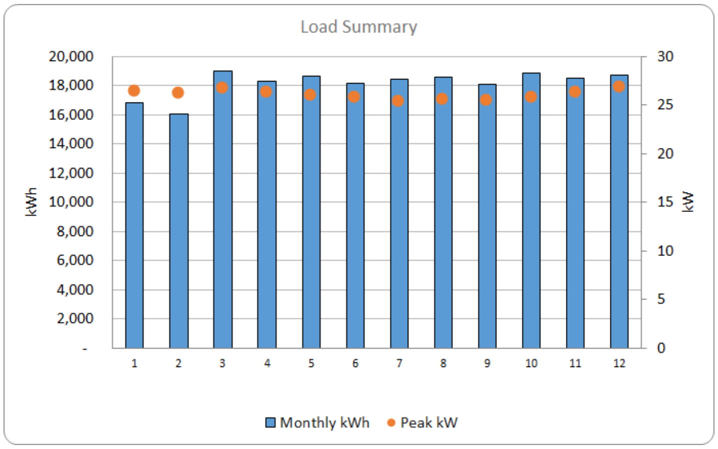


Source: Smart Electric Power Alliance, 2021.

Water & Wastewater Treatment Plants

The load profiles for water and wastewater treatment plants ("treatment plants") were obtained from American Electric Power (AEP) and used to evaluate the 94 locations identified in the site selection process. As seen in Figure 6.3.14, treatment plants have a very flat load profile and do not have a seasonal peak: they have an average monthly demand of 25 kW and peak demand of 27 kWh. Treatment plants have a very high load factor of 93%. This high load factor makes battery storage a less valuable addition to the potential microgrid.

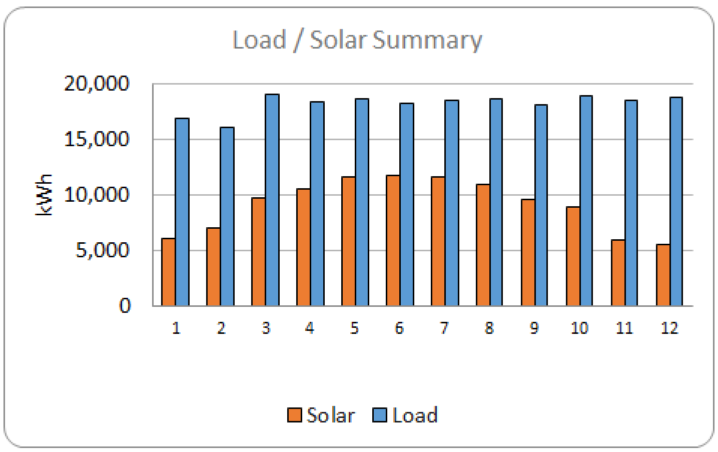
Figure 6.3. 14 - **Load Summary - Water & Wastewater Treatment Plants**



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.15 displays the solar energy production (kWh) compared to the load at a typical treatment plant over the course of a year in a moderate renewable energy deployment option. For this critical facility type, solar energy production is highest in June at 11,707 kWh and lowest in December at 5,494 kWh.

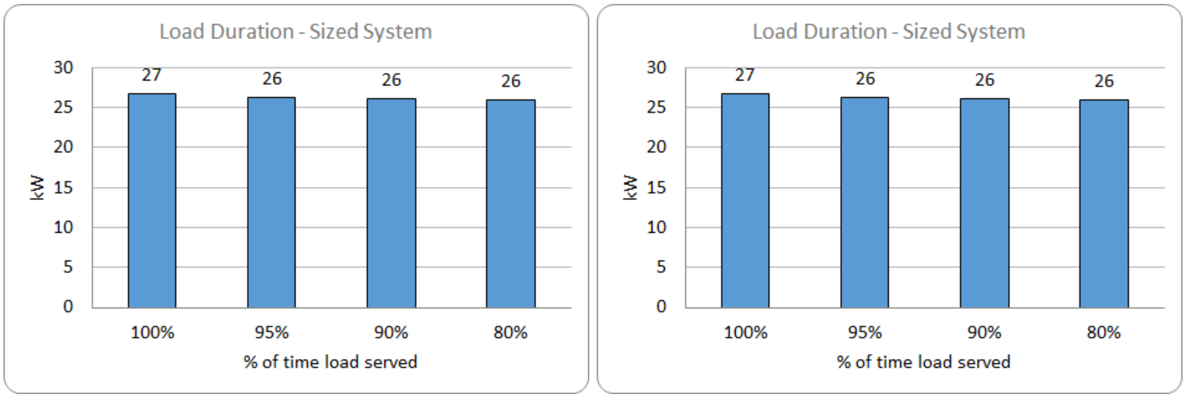
Figure 6.3. 15 - **Load & Solar Output Summary - Water & Wastewater Treatment Plants**



Source: Smart Electric Power Alliance, 2021.

The figure below displays the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at treatment plants 100% of the time for the full year, the nanogrid must be sized to accommodate 27 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (26 kW) there is potential for 2% savings on the overall price of the nanogrid.

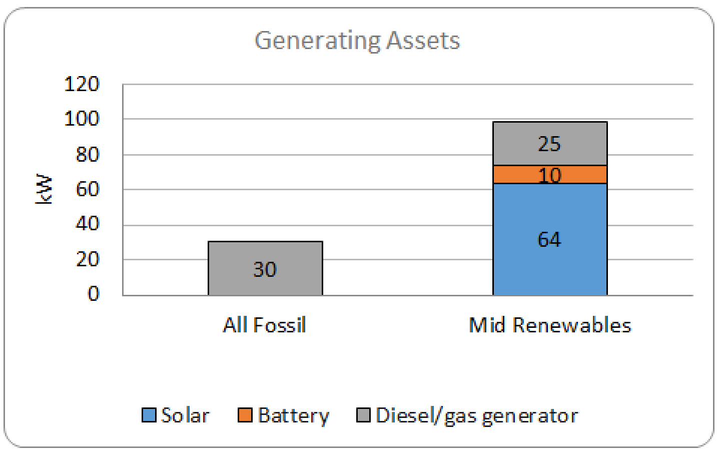
Figure 6.3. 16 - ***Nanogrid Load Duration & Potential Cost Savings - Water & Wastewater Treatment Plants***



Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 30 kW standby generator is required to provide backup outage capability for a full year. Alternatively, the moderate renewable design option requires a 25 kW standby generator, 10 kW battery storage system, and 41 kW solar system.

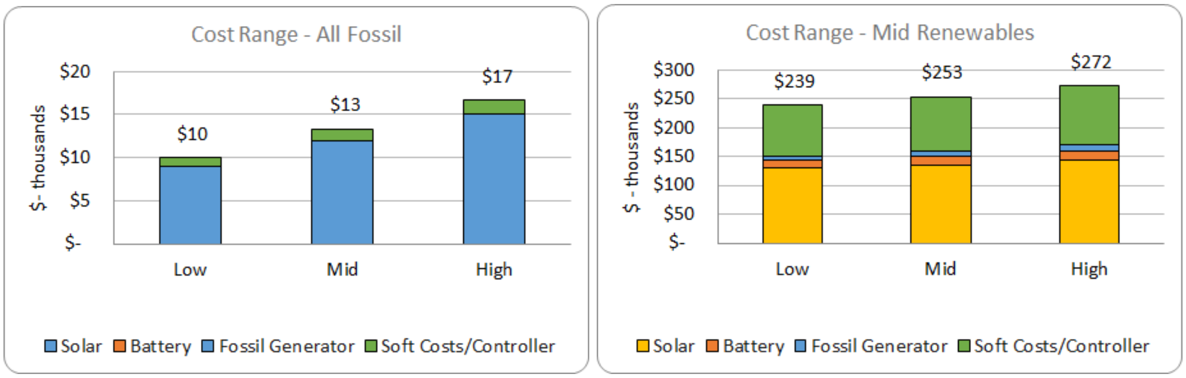
Figure 6.3. 17 - ***Nanogrid Generation Assets - Water & Wastewater Treatment Plants***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup outage capability at treatment plants 100% of the time.

*Figure 6.3. 18 - **Nanogrid Cost Estimates - Water & Wastewater Treatment Plants***

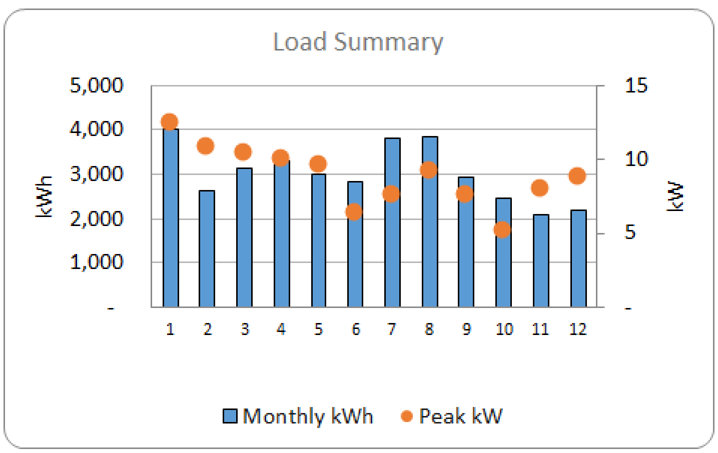


Source: Smart Electric Power Alliance, 2021.

National Defense Facilities

The load profiles for national defense facilities were based on data obtained from a U.S. utility and used to evaluate the 5 locations identified in the site selection process. As seen in Figure 6.3.19, national defense facilities are winter peaking with the highest demand and usage occurring in the month of January. National defense facilities have a medium load factor of 38% based on a 5 kW average monthly demand and a 12 kW peak demand.

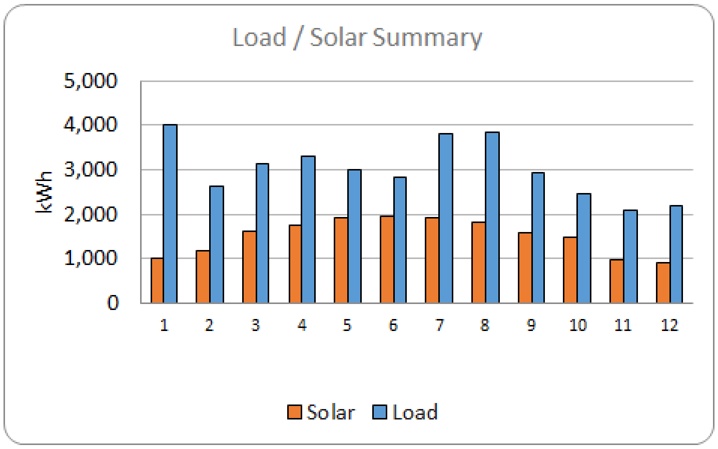
*Figure 6.3. 19 - **Load Summary - National Defense Facilities***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.20 displays the solar energy production (kWh) compared to the load at a typical national defense facility over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 1,945 kWh and lowest in December at 913 kWh.

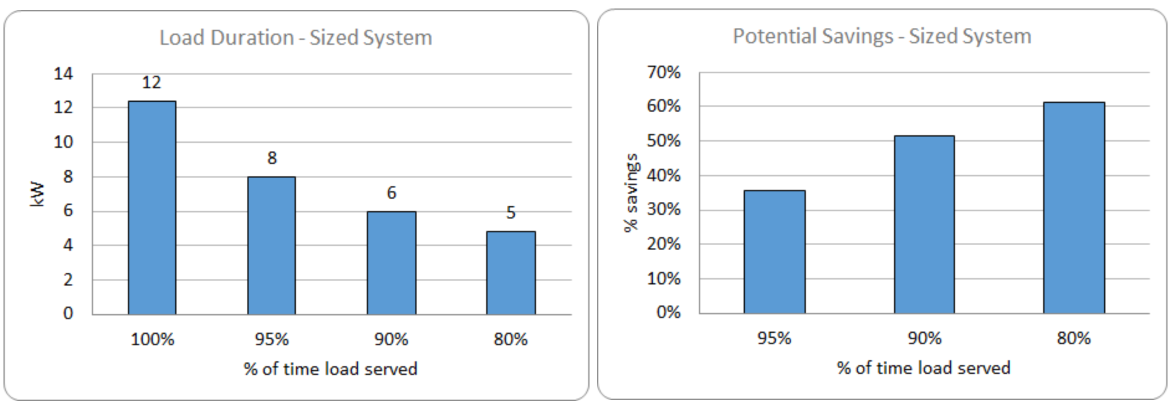
*Figure 6.3. 20 - **Load & Solar Output Summary - National Defense Facilities***



Source: Smart Electric Power Alliance, 2021.

The figure below displays the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at national defense facilities 100% of the time for the full year, the nanogrid must be sized to accommodate 12 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (8 kW) there is potential for 35% savings on the overall price of the nanogrid.

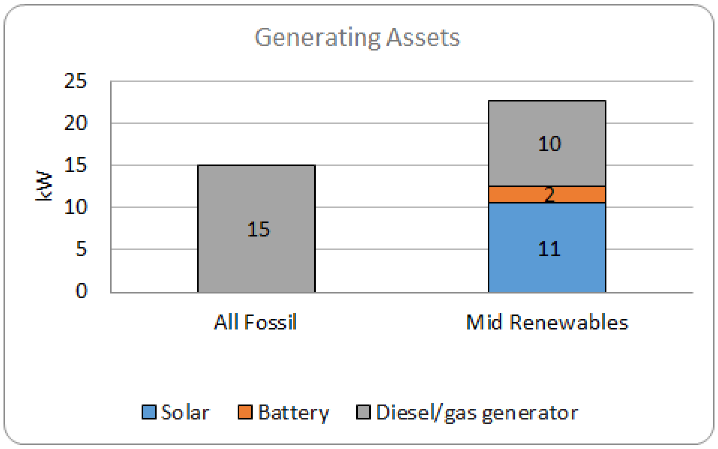
*Figure 6.3. 21 - **Nanogrid Load Duration & Potential Cost Savings - National Defense Facilities***



Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 15 kW standby generator is required to provide backup outage capability for a full year. Alternatively, the moderate renewable design option requires a 10 kW standby generator, 2 kW battery storage system, and 11 kW solar system.

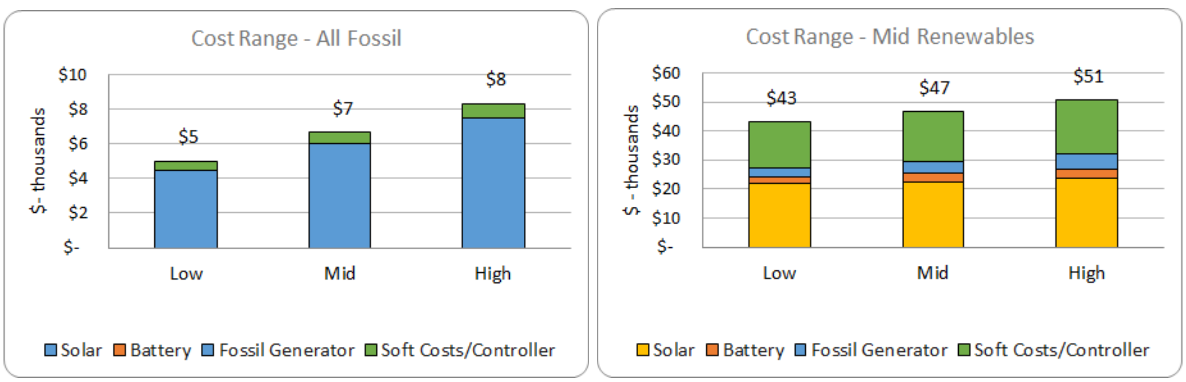
Figure 6.3. 22 - ***Nanogrid Generation Assets - National Defense Facilities***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup outage capability at national defense facilities 100% of the time.

Figure 6.3. 23 - ***Nanogrid Cost Estimates - National Defense Facilities***

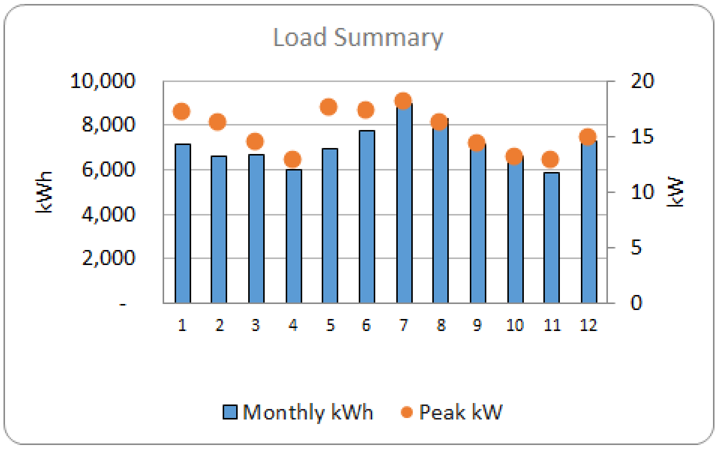


Source: Smart Electric Power Alliance, 2021.

Law Enforcement Facilities

Load profiles for law enforcement facilities were obtained from AEP and used to evaluate the 42 locations identified in the site selection process. As seen in Figure 6.3.24, law enforcement facilities are summer peaking with the highest demand and usage occurring in July and have a medium load factor of 54% based on a 10 kW monthly average demand and 18 kW peak demand.

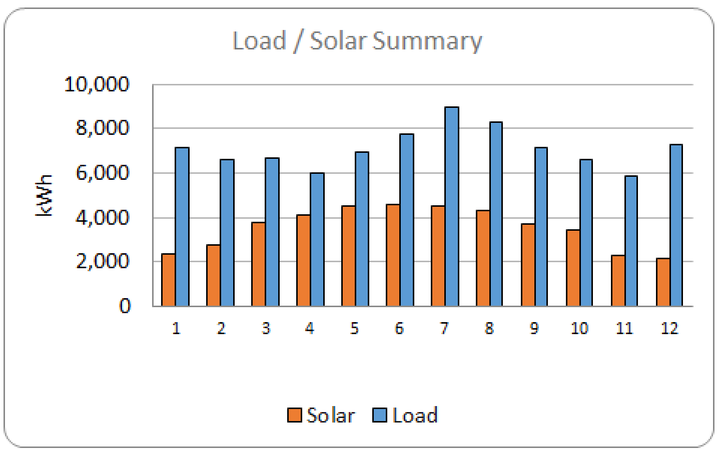
*Figure 6.3. 24 - **Load Summary - Law Enforcement Facilities***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.25 displays the solar energy production (kWh) compared to the load at a typical law enforcement facility over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 4,573 kWh and lowest in December at 2,146 kWh.

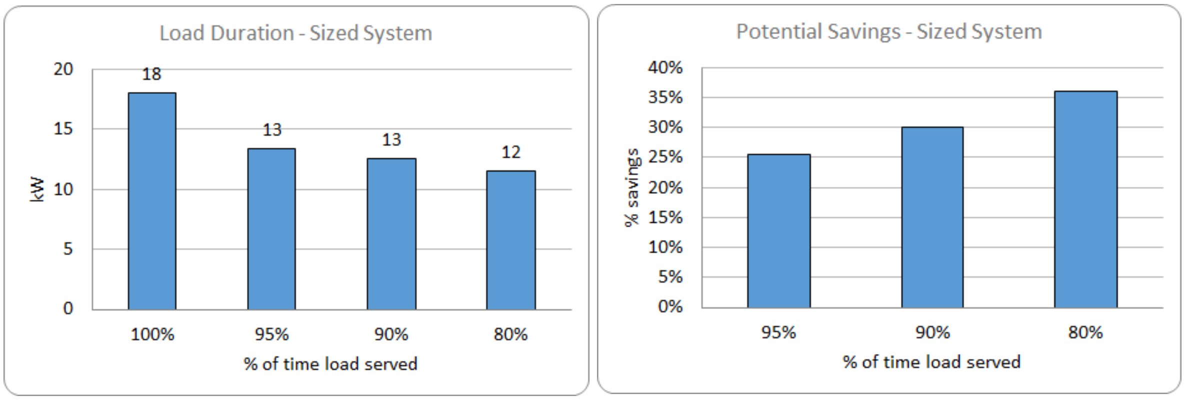
*Figure 6.3. 25 - **Load & Solar Output Summary - Law Enforcement Facilities***



Source: Smart Electric Power Alliance, 2021.

The figure below displays the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at law enforcement facilities 100% of the time for the full year, the nanogrid must be sized to accommodate 18 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (13 kW) there is potential for 26% savings on the overall price of the nanogrid.

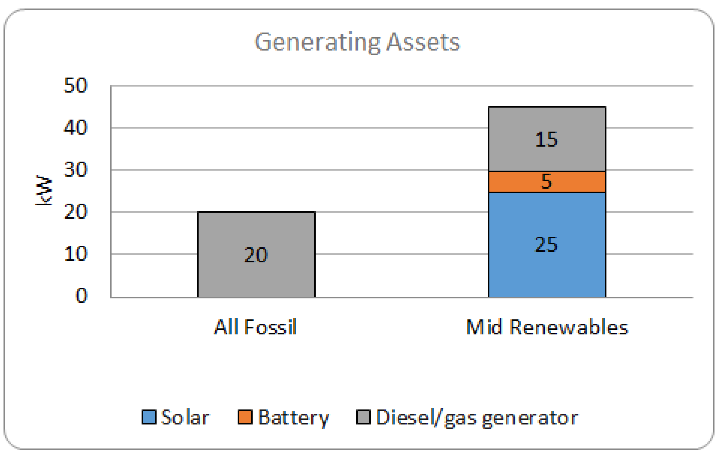
*Figure 6.3. 26 - **Nanogrid Load Duration & Potential Cost Savings - Law Enforcement Facilities***



Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 20 kW standby generator is required to provide backup outage capability for a full year. Alternatively, the moderate renewable design option requires a 15 kW standby generator, 5 kW battery storage system, and 25 kW solar system.

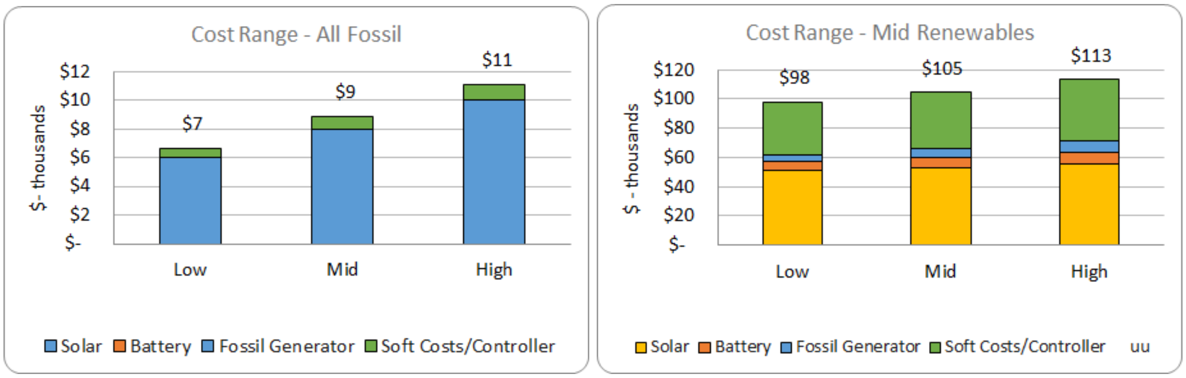
*Figure 6.3. 27 - **Nanogrid Generation Assets - Law Enforcement Facilities***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup outage capability at law enforcement facilities 100% of the time.

*Figure 6.3. 28 - **Nanogrid Cost Estimates - Law Enforcement Facilities***

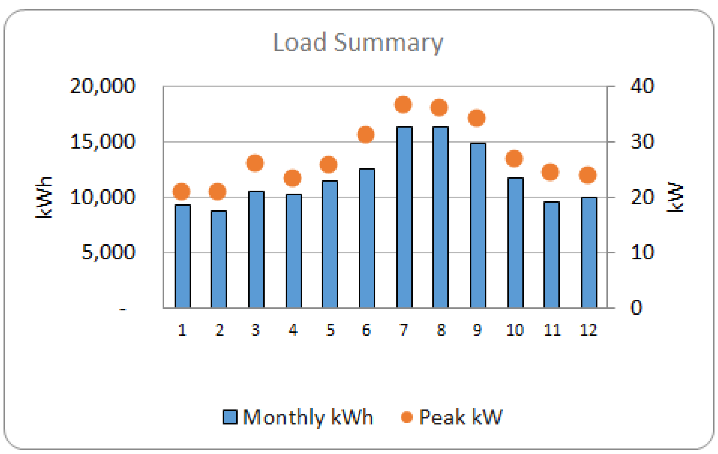


Source: Smart Electric Power Alliance, 2021.

Fire Stations

The load profiles for fire stations were obtained from AEP and used to evaluate the 90 locations identified in the site selection process. As seen in Figure 6.3.29, fire stations are summer peaking with the highest demand and usage occurring in the months of July and August and have a medium load factor of 45% based on a 16 kW average monthly demand and 36 kW peak demand.

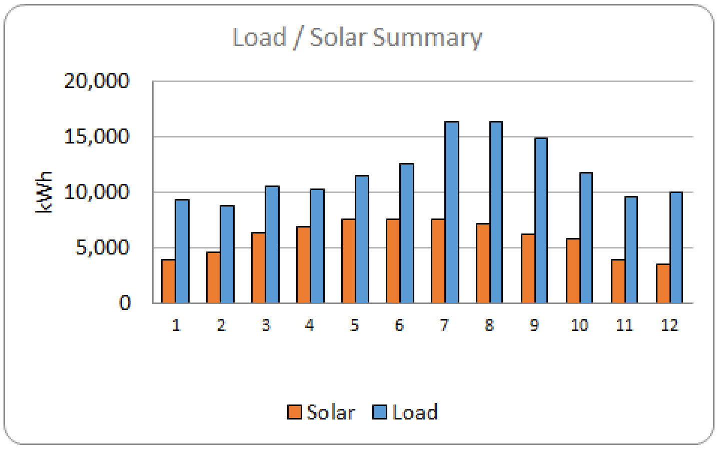
*Figure 6.3. 29 - **Load Summary - Fire Stations***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.30 displays the solar energy production (kWh) compared to the load at a typical fire station over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 7,600 kWh and lowest in December at 3,567 kWh.

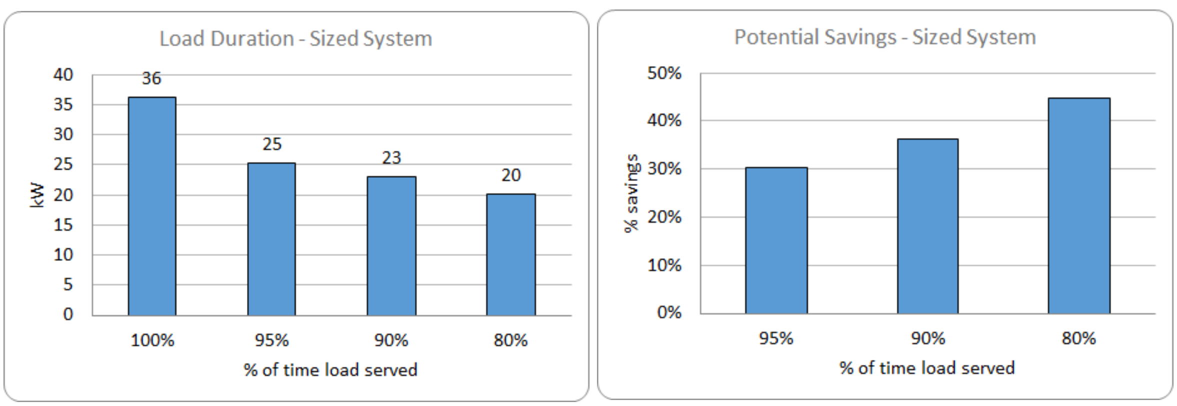
*Figure 6.3. 30 - **Load & Solar Output Summary - Fire Stations***



Source: Smart Electric Power Alliance, 2021.

The figure below displays the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at fire stations 100% of the time for the full year, the nanogrid must be sized to accommodate 36 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (25 kW) there is potential for 30% savings on the overall price of the nanogrid.

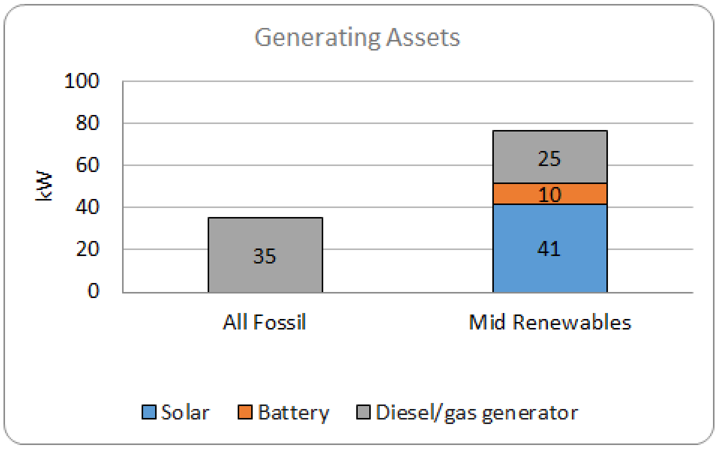
*Figure 6.3. 31 - **Nanogrid Load Duration & Potential Cost Savings - Fire Stations***



Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 35 kW standby generator is required to provide backup outage capability for a full year. Alternatively, the moderate renewable design option requires a 25 kW standby generator, 10 kW battery storage system, and 41 kW solar system.

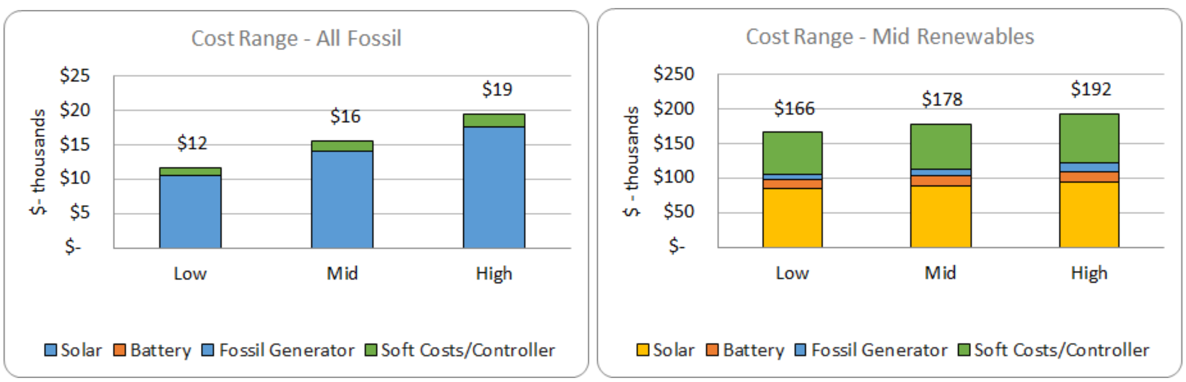
Figure 6.3. 32 - ***Nanogrid Generation Assets - Fire Stations***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup outage capability at fire stations 100% of the time.

Figure 6.3. 33 - ***Nanogrid Cost Estimates - Fire Stations***

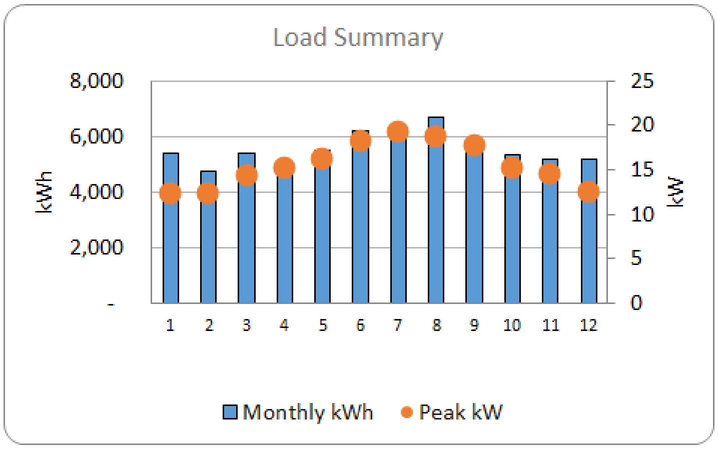


Source: Smart Electric Power Alliance, 2021.

Emergency Operations Centers

The load profiles for emergency operations centers were obtained from the OpenEI database and used to evaluate the 33 locations identified in the site selection process. As seen in Figure 6.3.34, emergency operations centers are summer peaking with the highest demand and usage occurring in the months of July and August. A detailed analysis of the load profile reveals the peak occurs earlier in the day during solar production, which allows for a smaller fossil fuel generator and battery storage system in the moderate renewable design scenario. Emergency operations centers have a medium load factor of 39% based on an 8 kW average monthly demand and 19 kW peak demand.

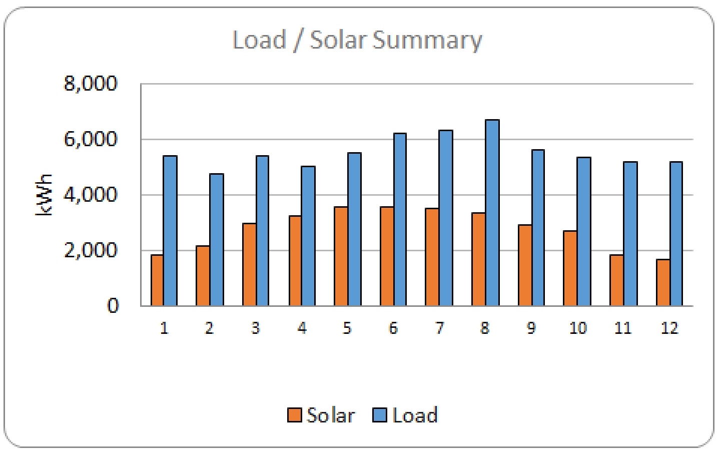
*Figure 6.3. 34 - **Load Summary - Emergency Operations Centers***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.35 displays the solar energy production (kWh) compared to the load at a typical emergency operations center over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 3,567 kWh and lowest in December at 1,674 kWh.

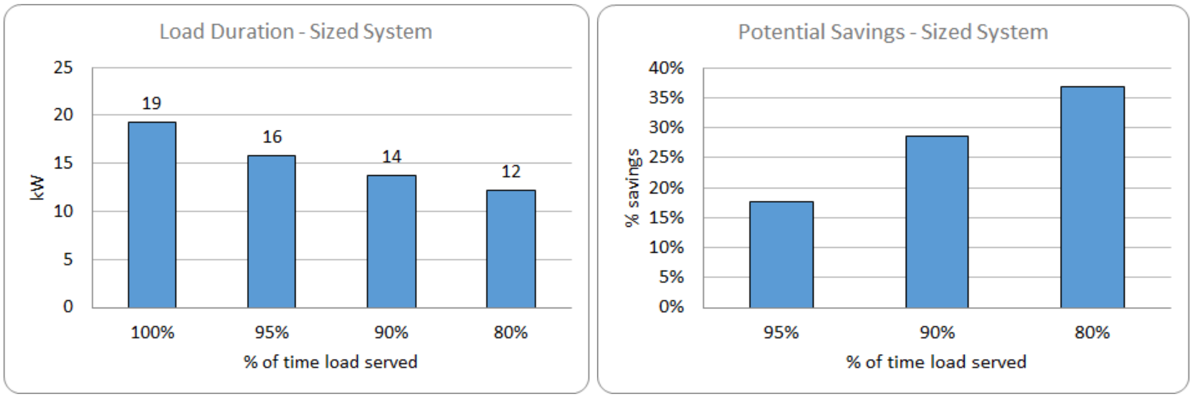
*Figure 6.3. 35 - **Load & Solar Output Summary - Emergency Operations Centers***



Source: Smart Electric Power Alliance, 2021.

The figure below displays the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at emergency operations centers 100% of the time for the full year, the nanogrid must be sized to accommodate 19 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (16 kW) there is potential for 18% savings on the overall price of the nanogrid.

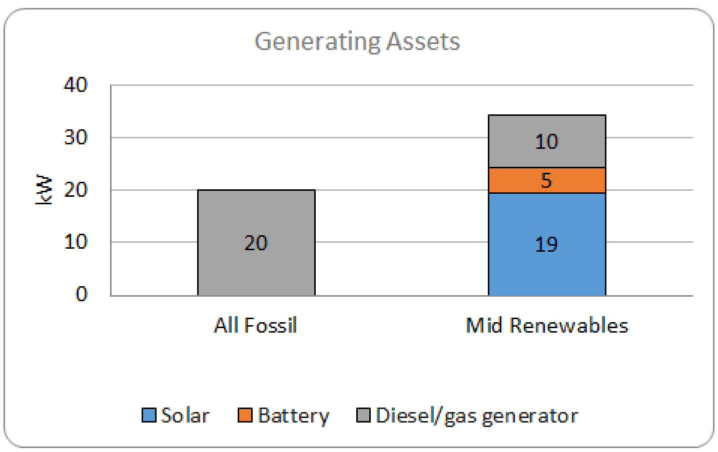
*Figure 6.3. 36 - **Nanogrid Load Duration & Potential Cost Savings - Emergency Operations Centers***



Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 20 kW standby generator is required to provide backup outage capability for a full year. Alternatively, the moderate renewable design option requires a 10 kW standby generator, 5 kW battery storage system, and 19 kW solar system.

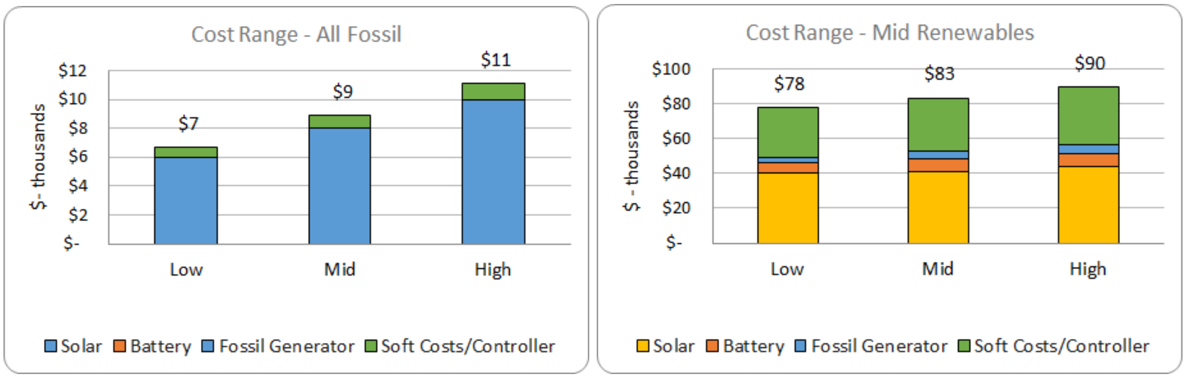
*Figure 6.3. 37 - **Nanogrid Generation Assets - Emergency Operations Centers***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup outage capability at emergency operations centers 100% of the time.

Figure 6.3. 38 - ***Nanogrid Cost Estimates - Emergency Operations Centers***

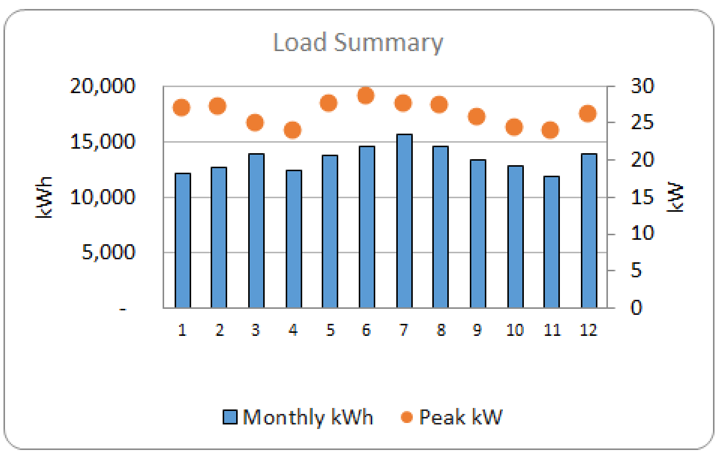


Source: Smart Electric Power Alliance, 2021.

Gas Stations

The load profiles for gas stations were obtained from AEP and used to evaluate the 110 locations identified in the site selection process. As seen in Figure 6.3.39, gas stations are summer peaking with the highest demand and usage occurring in the month of June. Gas stations have a high load factor of 65% based on an 18 kW average monthly demand and 29 kW peak demand.

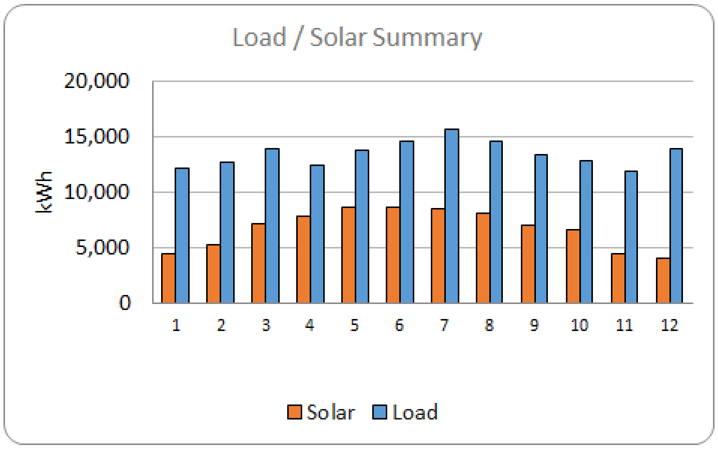
Figure 6.3. 39 - ***Load Summary - Gas Stations***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.40 displays the solar energy production (kWh) compared to the load at a typical gas station over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 8,672 kWh and lowest in December at 4,069 kWh.

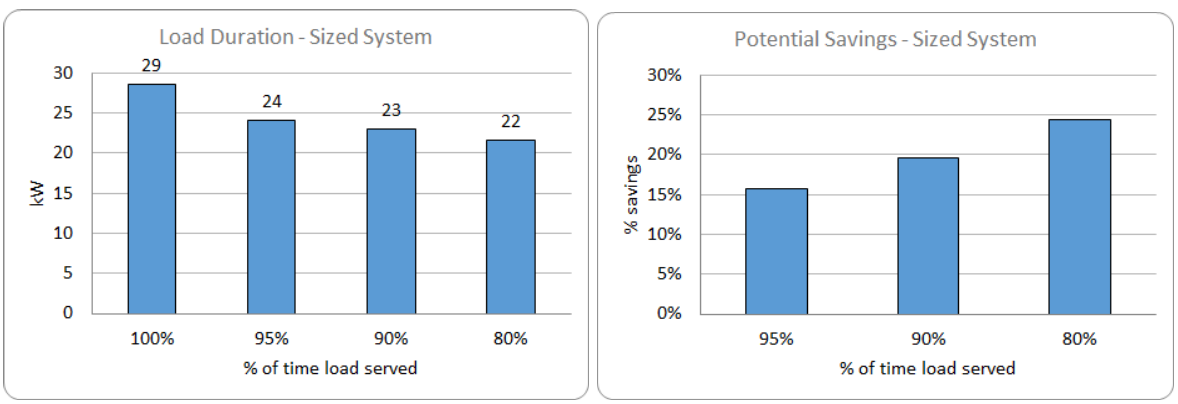
Figure 6.3. 40 - ***Load & Solar Output Summary - Gas Stations***



Source: Smart Electric Power Alliance, 2021.

The figure below displays the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at gas stations 100% of the time for the full year, the nanogrid must be sized to accommodate 29 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (24 kW) there is potential for 16% savings on the overall price of the nanogrid.

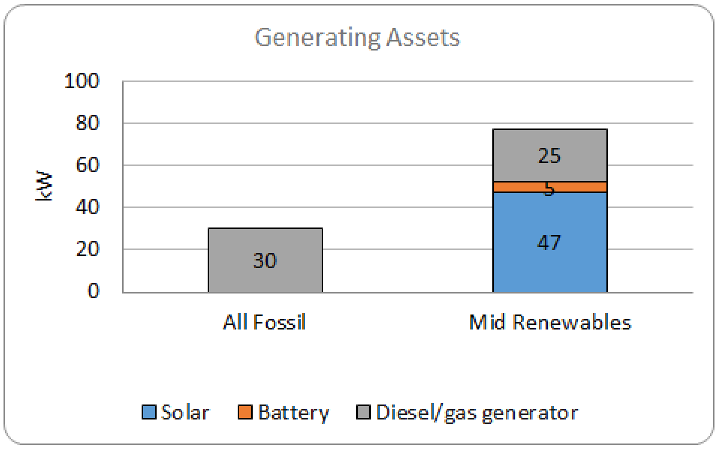
Figure 6.3. 41 - ***Nanogrid Load Duration & Potential Cost Savings - Gas Stations***



Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 30 kW standby generator is required to provide backup outage capability for a full year. Alternatively, the moderate renewable design option requires a 25 kW standby generator, 5 kW battery storage system, and 47 kW solar system.

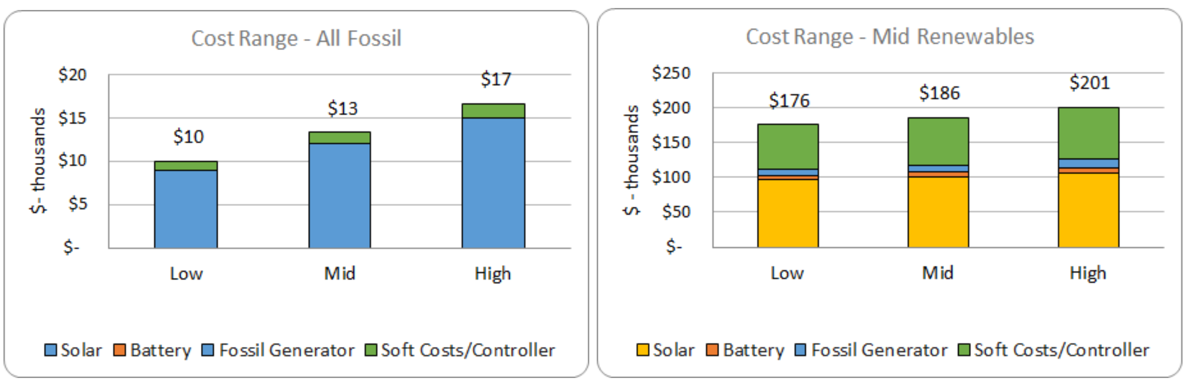
Figure 6.3. 42 - ***Nanogrid Generation Assets - Gas Stations***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup outage capability at gas stations 100% of the time.

Figure 6.3. 43 - ***Nanogrid Cost Estimates - Gas Stations***

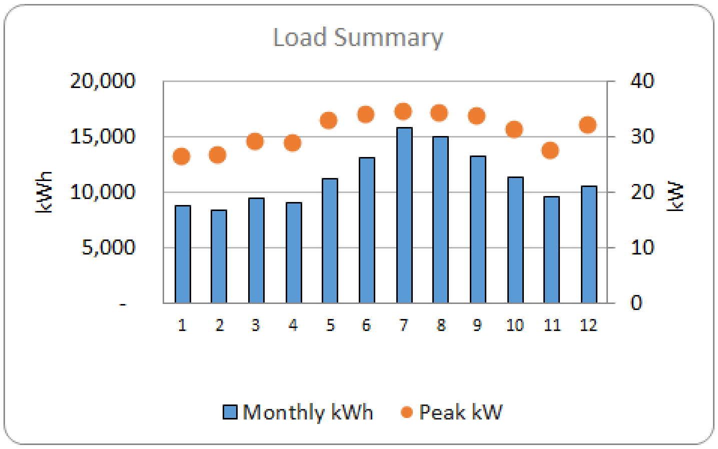


Source: Smart Electric Power Alliance, 2021.

Grocery Stores

The load profiles for grocery stores were obtained from AEP and used to evaluate the 70 locations identified in the site selection process. As seen in Figure 6.3.44, grocery stores are summer peaking with the highest demand and usage occurring in the months of June, July, and August. Grocery stores have a medium load factor of 45% based on a 15 kW average monthly demand and a 34 kW peak demand.

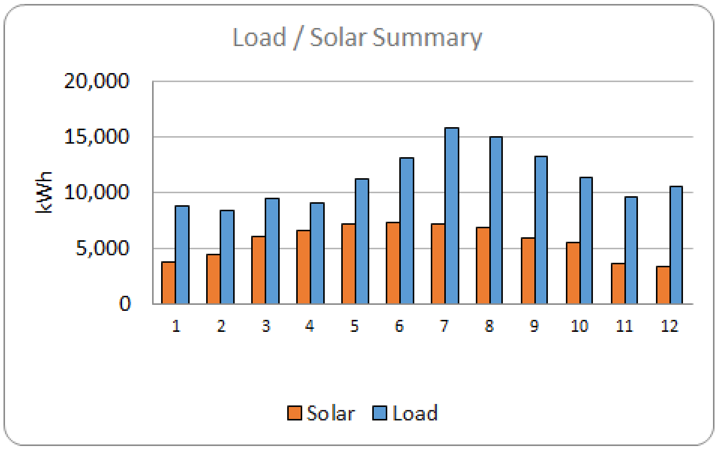
*Figure 6.3. 44 - **Load Summary - Grocery Stores***



Source: Smart Electric Power Alliance, 2021.

Figure 6.3.45 displays the solar energy production (kWh) compared to the load at a typical grocery store over the course of a year in a moderate renewable energy deployment option. For this critical facility, solar energy production is highest in June at 7,262 kWh and lowest in December at 3,408 kWh. Energy export of solar to the grid at grocery stores is highest in April at 2,427 kWh and lowest in December at 567 kWh.

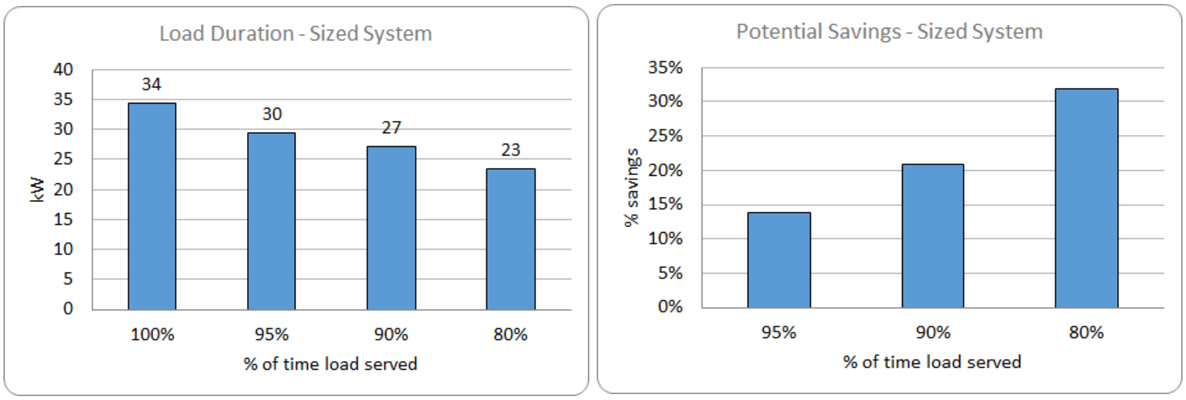
*Figure 6.3. 45 - **Load & Solar Output Summary - Grocery Stores***



Source: Smart Electric Power Alliance, 2021.

The figure below displays the relationship between the critical facility's load, percentage of time load is served, and potential savings. From the *Load Duration* chart, in order to serve the load at grocery stores 100% of the time for the full year, the nanogrid must be sized to accommodate 34 kW. The *Potential Savings* chart displays the potential cost savings for a nanogrid sized to serve a lesser percentage of time. For example, if the nanogrid is sized to 95% (27 kW) there is potential for 14% savings on the overall price of the nanogrid.

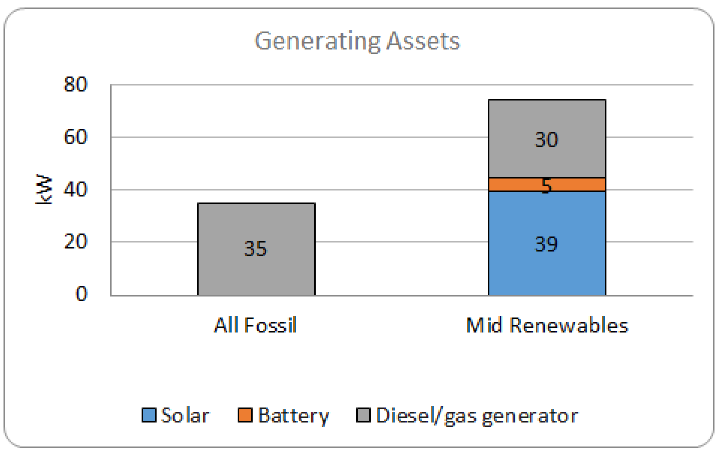
Figure 6.3. 46 - ***Nanogrid Load Duration & Potential Cost Savings - Grocery Stores***



Source: Smart Electric Power Alliance, 2021.

In the fossil fuel only design option, a 35 kW standby generator is required to provide backup outage capability for a full year. Alternatively, the moderate renewable design option requires a 30 kW standby generator, 5 kW battery storage system, and 39 kW solar system.

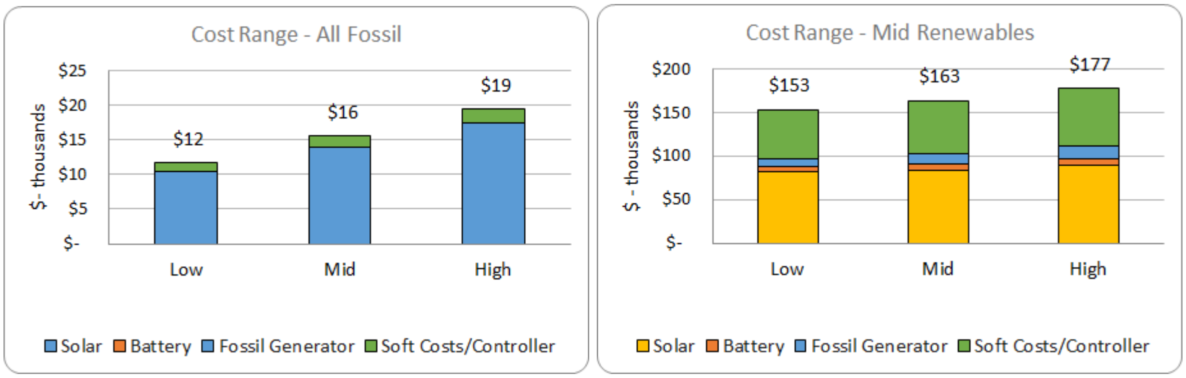
Figure 6.3. 47 - ***Nanogrid Generation Assets - Grocery Stores***



Source: Smart Electric Power Alliance, 2021.

The following figure represents the cost range for the fossil fuel only and moderate renewables design options. Nanogrids under both design options are sized to provide backup outage capability at grocery stores 100% of the time.

*Figure 6.3. 48 - **Nanogrid Cost Estimates - Grocery Stores***



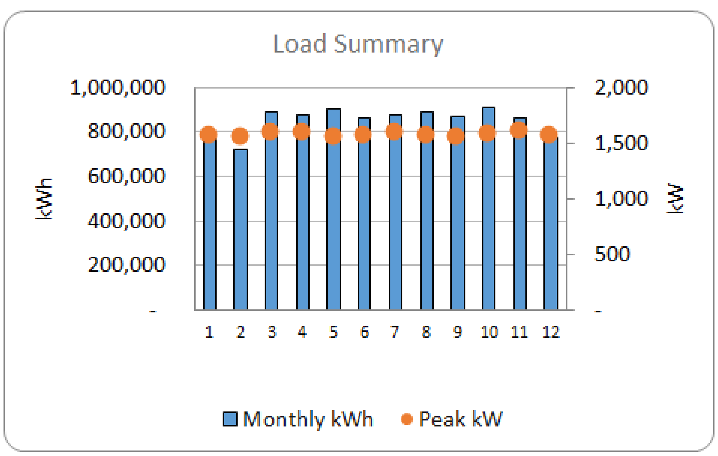
Source: Smart Electric Power Alliance, 2021.

Regional Community Microgrid Deployment Strategy

1 - Jefferson County Community Microgrid

The Jefferson County Community Microgrid is designed to serve an emergency operations center, fire station, grocery store, hospital, and nursing home in the city of Louisville. From the aggregated loads, this cluster of facilities has a flat load profile with a slight peak in November. This combination of facilities has a high load factor of 72% based on 1,165 kW average monthly demand and 1,610 kW peak demand.

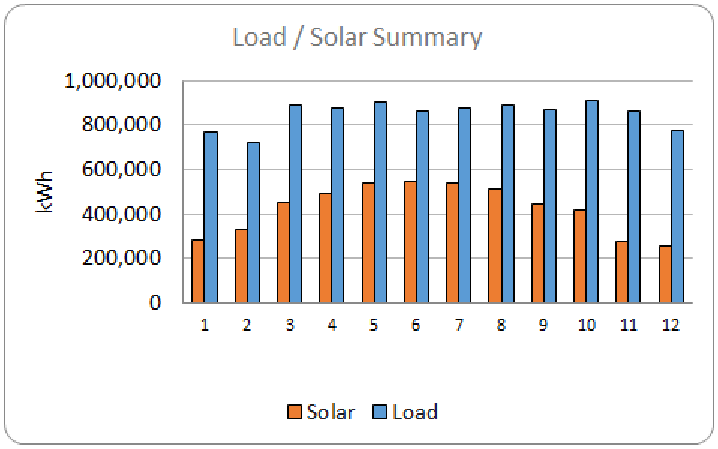
*Figure 6.3. 49 - **Load Summary - Jefferson County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 547,834 kWh and lowest in December at 257,090 kWh.

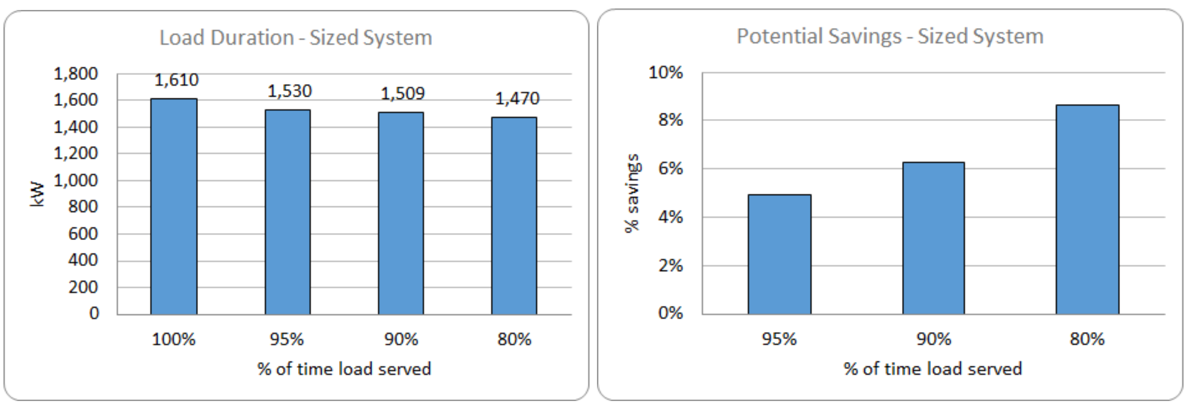
*Figure 6.3. 50 - **Load & Solar Output Summary - Jefferson County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 1,610 kW. As seen in Figure 6.3.51, there are some limited potential savings when reducing the system size. For example, if the system is sized to 95% (1,530 kW) there is potential for 5% savings on the overall price of the microgrid.

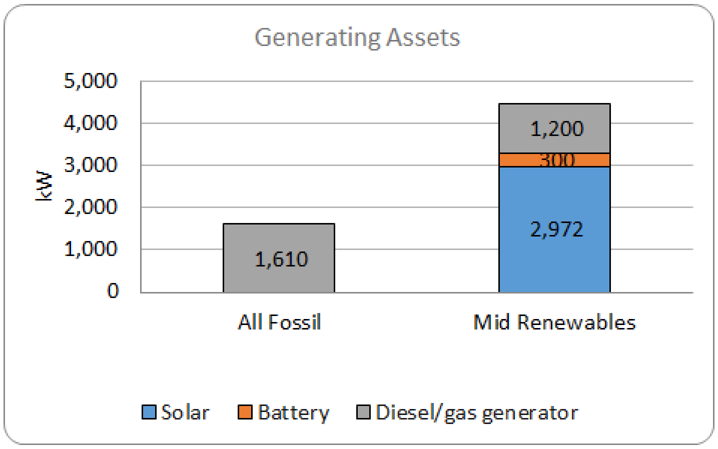
*Figure 6.3. 51 - **Microgrid Load Duration & Potential Cost Savings - Jefferson County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 1,610 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 1,200 kW standby generator, 300 kW battery storage system, and 2,972 kW solar system.

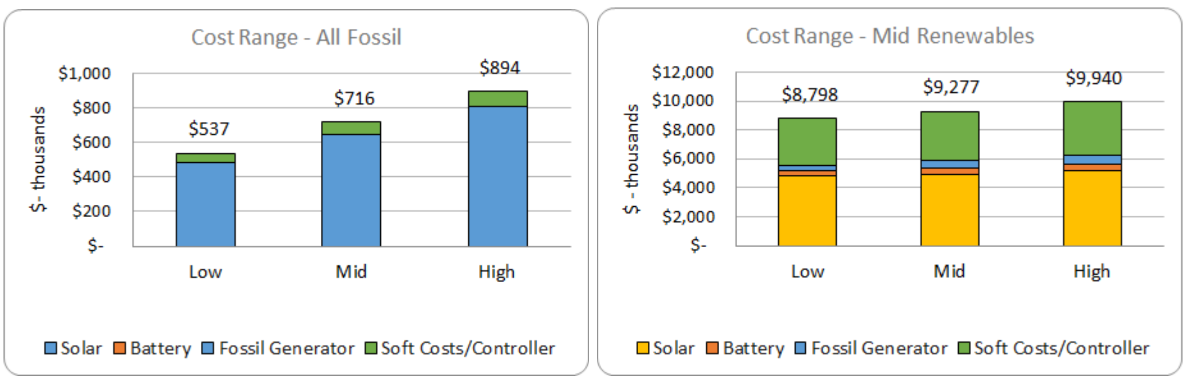
*Figure 6.3. 52 - **Microgrid Generation Assets - Jefferson County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Jefferson County Community Microgrid under fossil fuel only and moderate renewable energy design options.

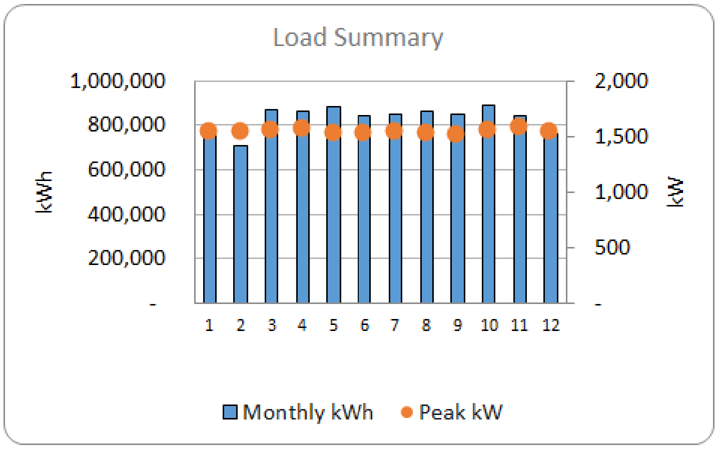
*Figure 6.3. 53 - **Microgrid Cost Estimates - Jefferson County Community Microgrid***



2 - Clay County Community Microgrid

The Clay County Community Microgrid is designed to serve an emergency operations center, grocery store, law enforcement facility, and hospital in the city of Manchester. From the aggregated loads, this cluster of facilities has a flat load profile with a slight peak in November. This combination of facilities has a high load factor of 72% based on 1,139 kW average monthly demand and 1,578 kW peak demand.

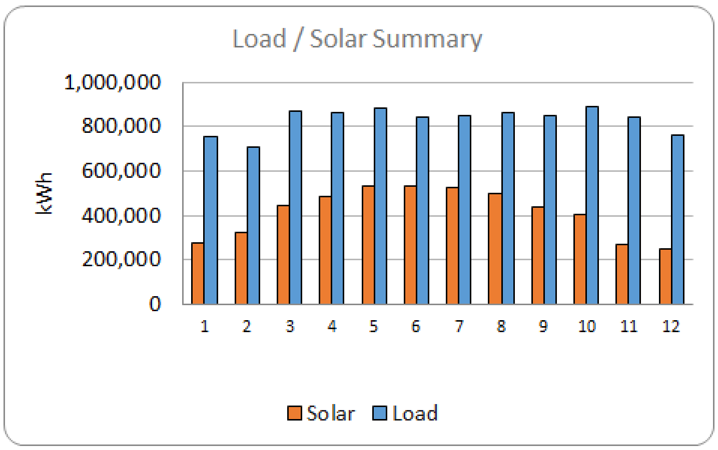
*Figure 6.3. 54 - **Load Summary - Clay County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 535,403 kWh and lowest in December at 251,257 kWh.

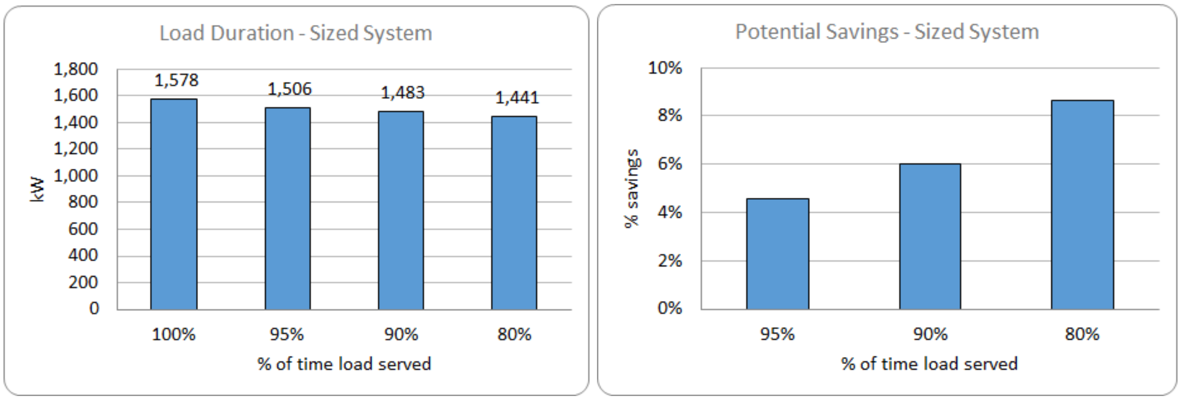
*Figure 6.3. 55 - **Load & Solar Output Summary - Clay County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 1,578 kW. As seen in Figure 6.3.56, there are some limited potential savings when reducing the system size. For example, if the system is sized to 95% (1,506 kW) there is potential for 5% savings on the overall price of the microgrid.

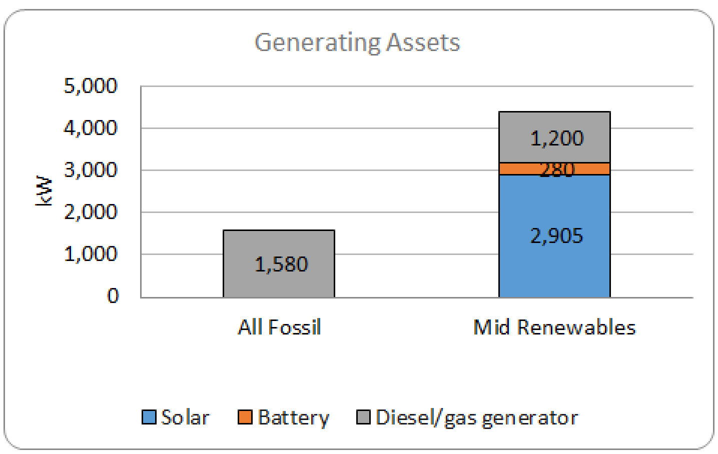
Figure 6.3. 56 - ***Microgrid Load Duration & Potential Cost Savings - Clay County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 1,580 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 1,200 kW standby generator, 280 kW battery storage system, and 2,905 kW solar system.

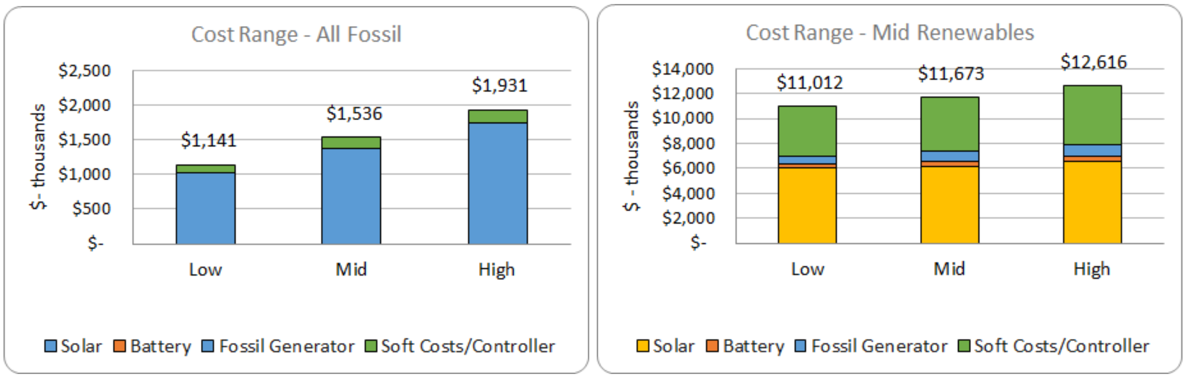
Figure 6.3. 57 - ***Microgrid Generation Assets - Clay County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Clay County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 58 - **Microgrid Cost Estimates - Clay County Community Microgrid***

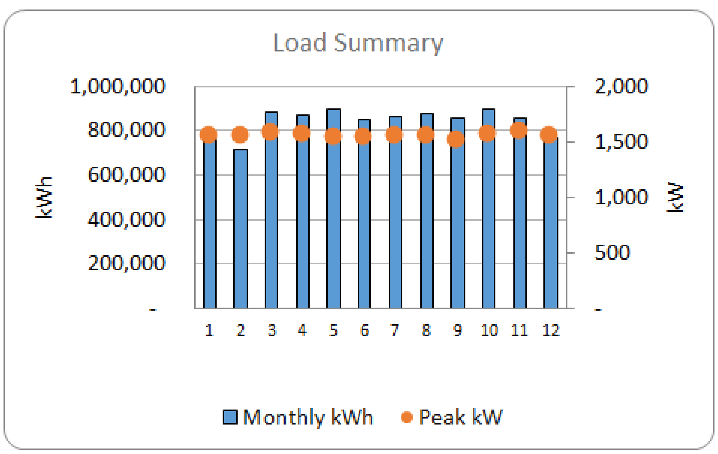


Source: Smart Electric Power Alliance, 2021.

3 - Knox County Community Microgrid 

The Knox County Community Microgrid is designed to serve an emergency operations center, gas station, hospital, and nursing home in the city of Barbourville. From the aggregated loads, this cluster of facilities has a flat load profile with a slight peak in November. This combination of facilities has a high load factor of 73% based on 1,152 kW average monthly demand and 1,588 kW peak demand.

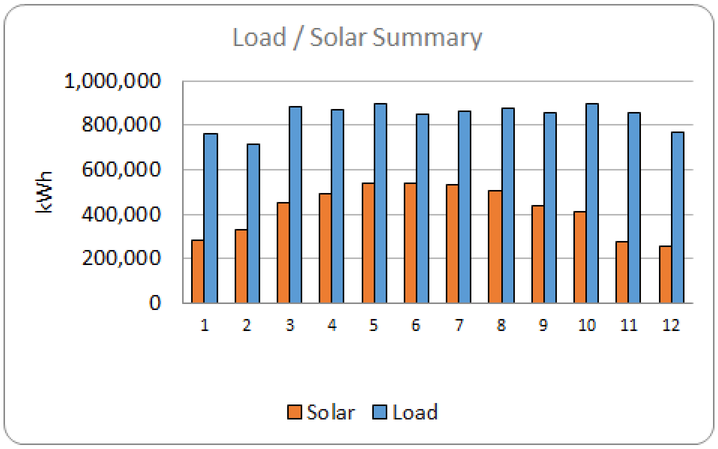
*Figure 6.3. 59 - **Load Summary - Knox County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 541,643 kWh and lowest in December at 254,185 kWh.

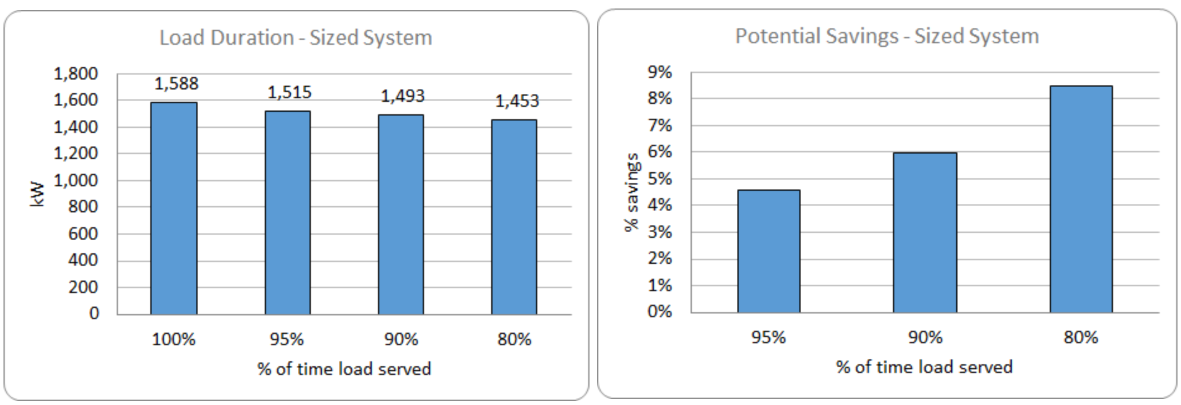
Figure 6.3. 60 - ***Load & Solar Output Summary - Knox County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 1,578 kW. As seen in Figure 6.3.61, there are some limited potential savings when reducing the system size. For example, if the system is sized to 95% (1,506 kW) there is potential for 5% savings on the overall price of the microgrid.

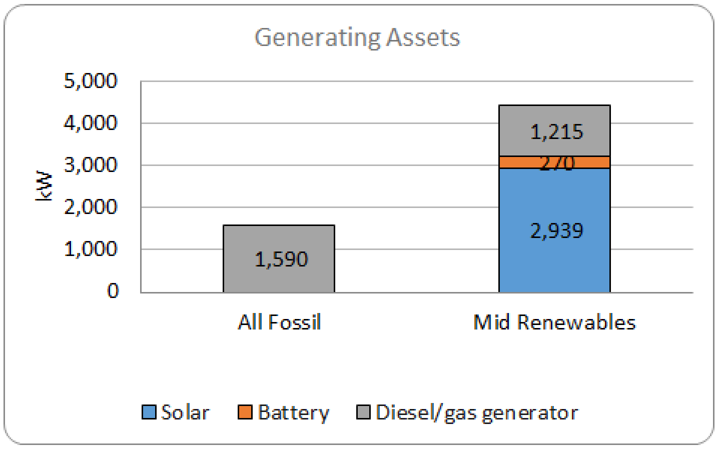
Figure 6.3. 61 - ***Microgrid Load Duration & Potential Cost Savings - Knox County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 1,580 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 1,200 kW standby generator, 270 kW battery storage system, and 2,939 kW solar system.

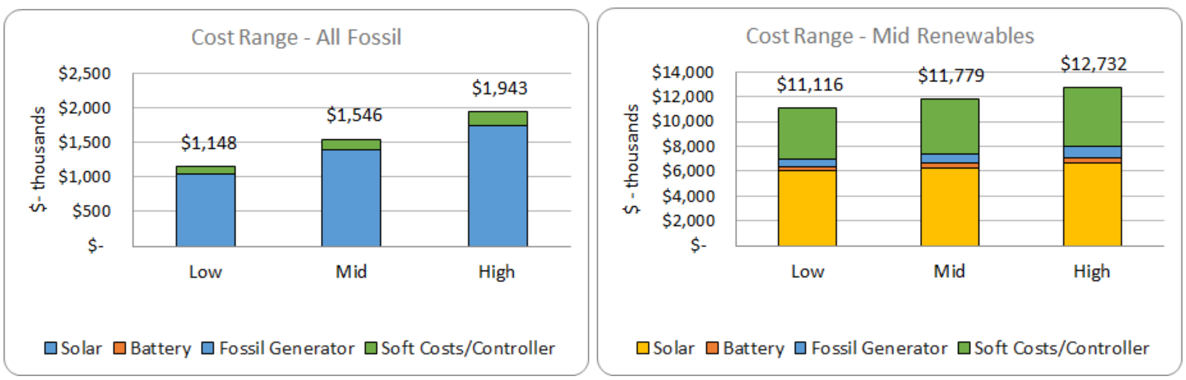
*Figure 6.3. 62 - **Microgrid Generation Assets - Knox County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Knox County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 63 - **Microgrid Cost Estimates - Knox County Community Microgrid***

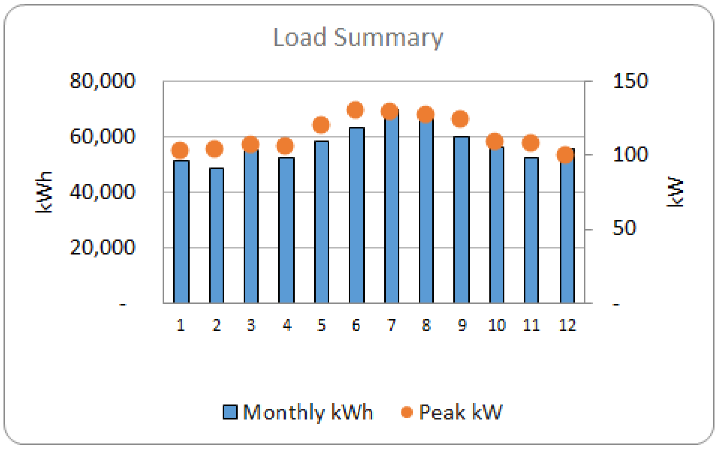


Source: Smart Electric Power Alliance, 2021.

4 - Marion County Community Microgrid

The Marion County Community Microgrid is designed to serve a gas station, grocery store, nursing home, and wastewater treatment plant in the city of Lebanon. From the aggregated loads, this cluster of facilities is summer peaking with the highest demand and usage occurring in June and July. These facilities have a high load factor of 61% based on 79 kW average monthly demand and 129 kW peak demand.

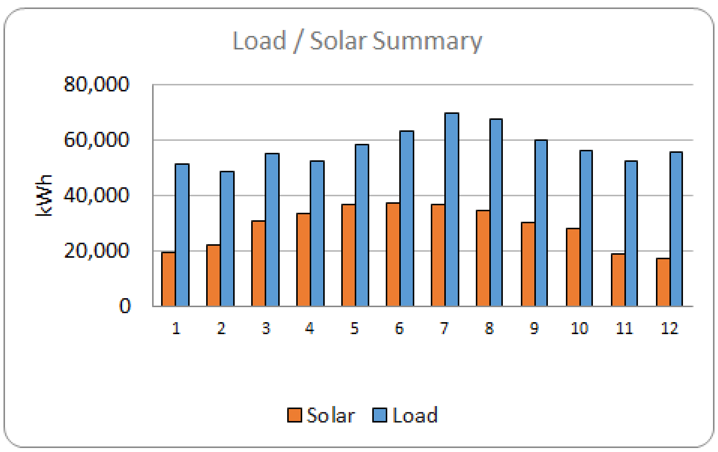
Figure 6.3. 64 - ***Load Summary - Marion County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 37,044 kWh and lowest in December at 17,384 kWh.

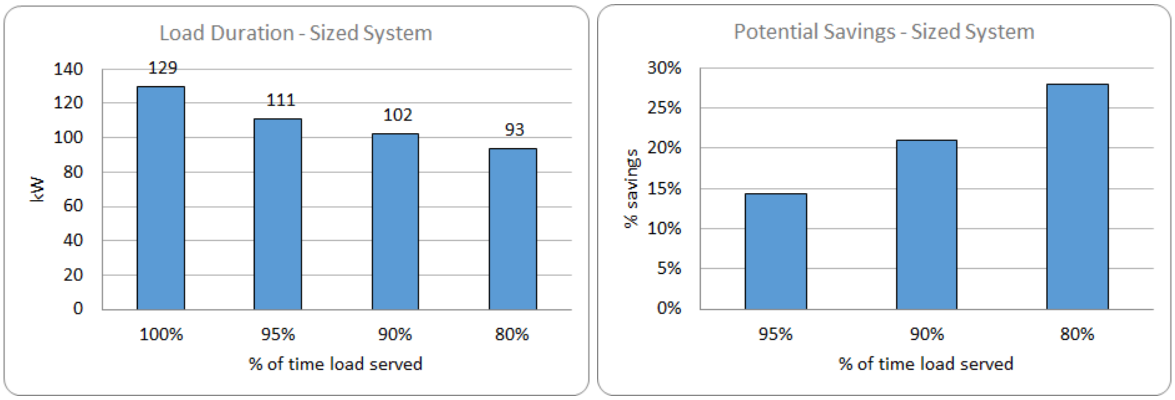
Figure 6.3. 65 - ***Load & Solar Output Summary - Marion County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 129 kW. As seen in Figure 6.3.66, there are some potential savings when reducing the system size. For example, if the system is sized to 95% (111 kW) there is potential for 14% savings on the overall price of the microgrid.

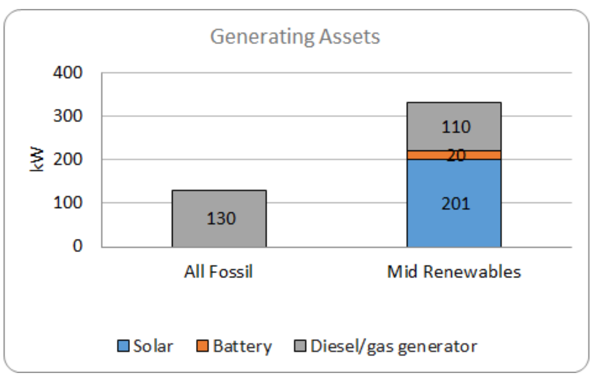
Figure 6.3. 66 - ***Microgrid Load Duration & Potential Cost Savings - Marion County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 130 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 110 kW standby generator, 20 kW battery storage system, and 201 kW solar system.

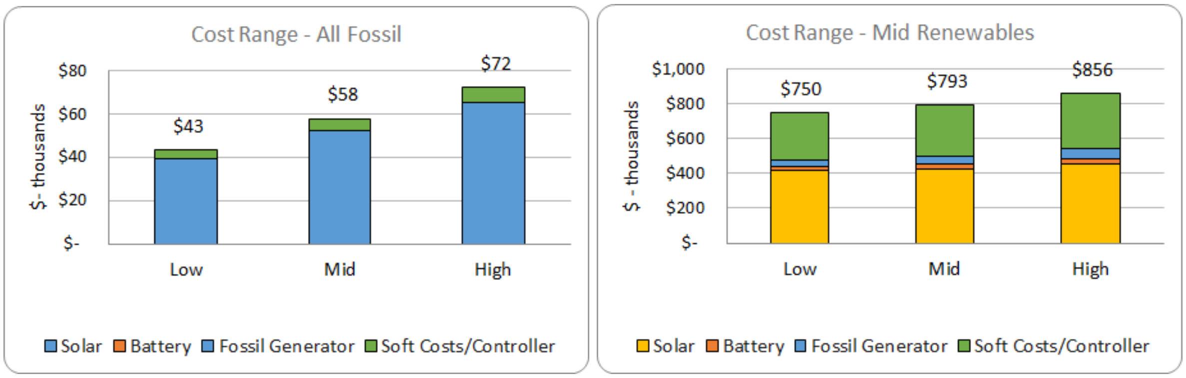
Figure 6.3. 67 - ***Microgrid Generation Assets - Marion County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Marion County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 68 - **Microgrid Cost Estimates - Marion County Community Microgrid***

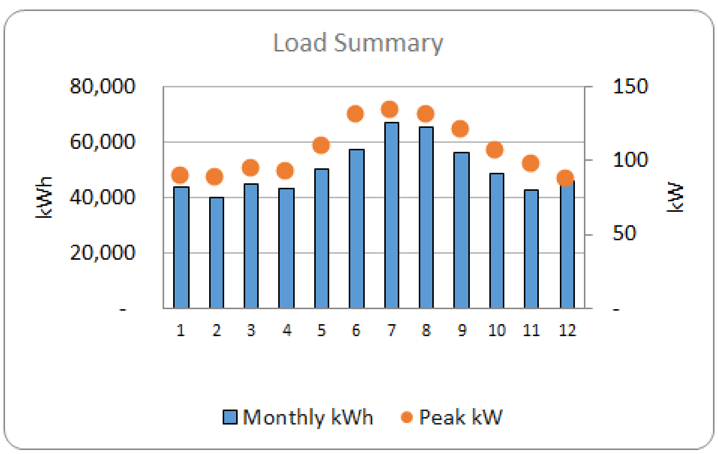


Source: Smart Electric Power Alliance, 2021.

5 - Crittenden County Community Microgrid

The Crittenden County Community Microgrid is designed to serve an emergency operations center, fire station, grocery store, law enforcement facility, and nursing home in the city of Marion. From the aggregated loads, this cluster of facilities is summer peaking with the highest demand and usage occurring in July. This combination of facilities has a medium load factor of 52% based on 69 kW average monthly demand and 133 kW peak demand.

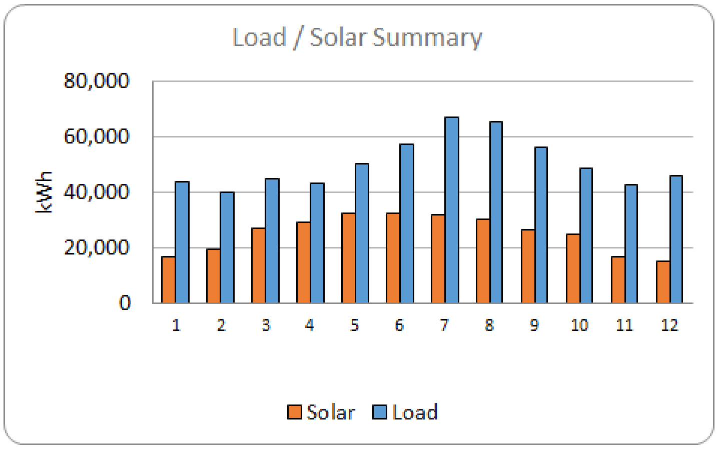
*Figure 6.3. 69 - **Load Summary - Crittenden County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 32,405 kWh and lowest in December at 15,207 kWh.

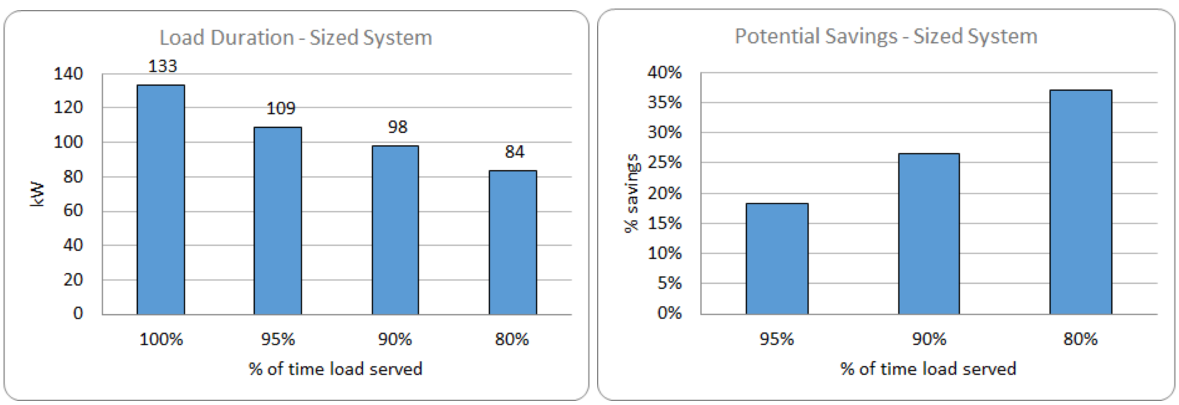
*Figure 6.3. 70 - **Load & Solar Output Summary - Crittenden County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 133 kW. As seen in Figure 6.3.71, there are some significant potential savings when reducing the system size. For example, if the system is sized to 95% (109 kW) there is potential for 18% savings on the overall price of the microgrid.

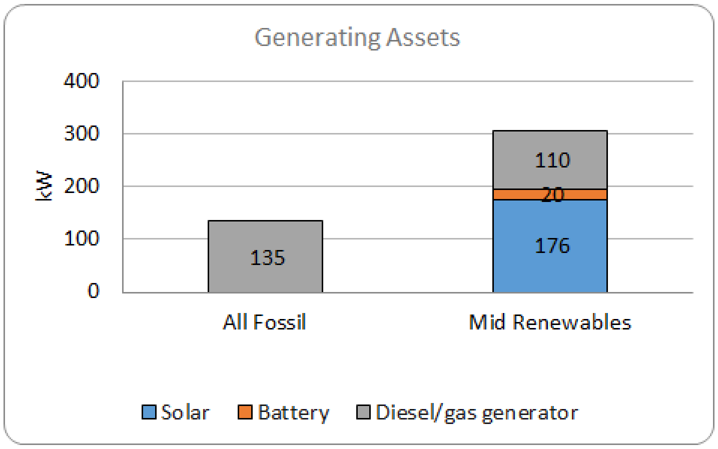
*Figure 6.3. 71 - **Microgrid Load Duration & Potential Cost Savings - Crittenden County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 135 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 110 kW standby generator, 20 kW battery storage system, and 176 kW solar system.

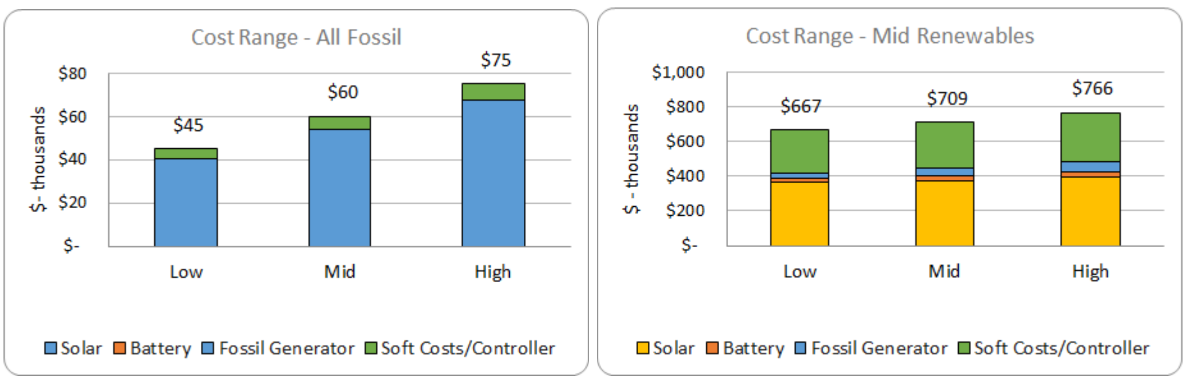
*Figure 6.3. 72 - **Microgrid Generation Assets - Crittenden County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Crittenden County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 73 - **Microgrid Cost Estimates - Crittenden County Community Microgrid***

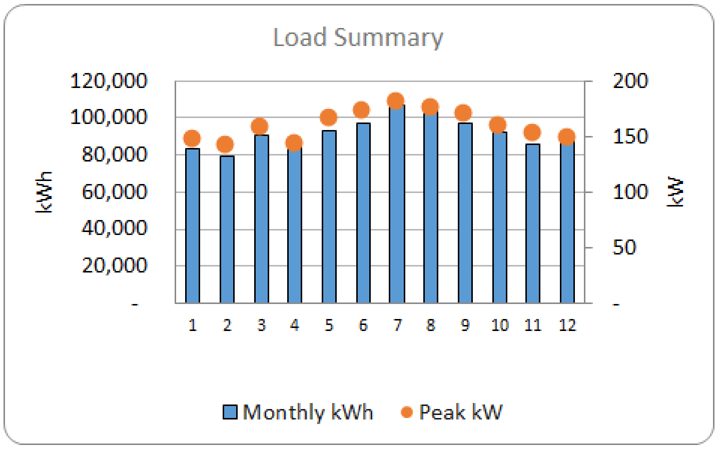


Source: Smart Electric Power Alliance, 2021.

6 - Washington County Community Microgrid

The Washington County Community Microgrid is designed to serve an emergency operations center, cell tower, fire station, gas station, grocery store, law enforcement facility, water treatment plant and wastewater treatment plant in the city of Springfield. From the aggregated loads, this cluster of facilities is summer peaking with the highest demand and usage occurring in July. This combination of facilities has a high load factor of 70% based on 126 kW average monthly demand and 181 kW peak demand.

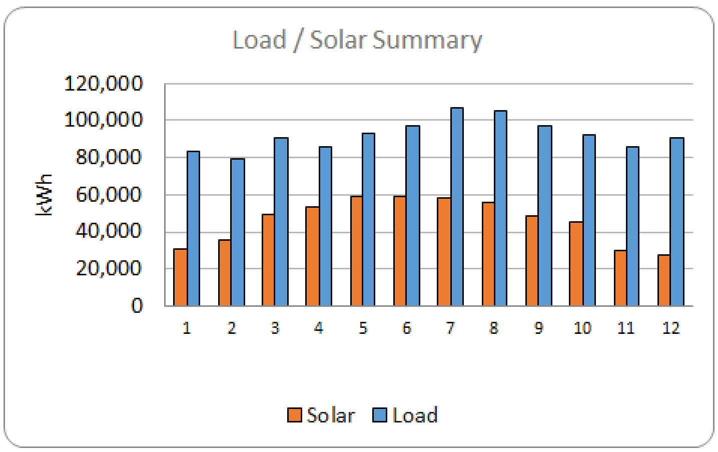
*Figure 6.3. 74 - **Load Summary - Washington County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 59,416 kWh and lowest in December at 27,883 kWh.

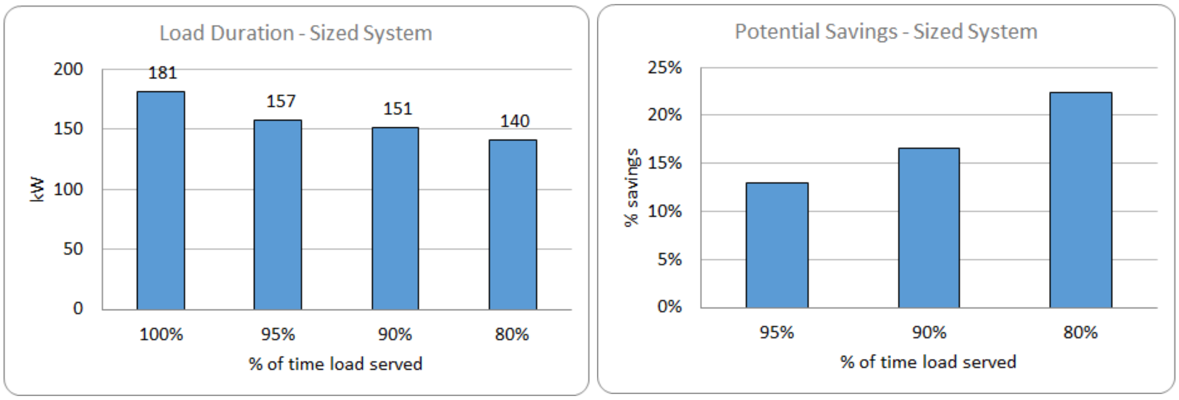
*Figure 6.3. 75 - **Load & Solar Output Summary - Washington County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 181 kW. As seen in Figure 6.3.76, there are some potential savings when reducing the system size. For example, if the system is sized to 95% (157 kW) there is potential for 13% savings on the overall price of the microgrid.

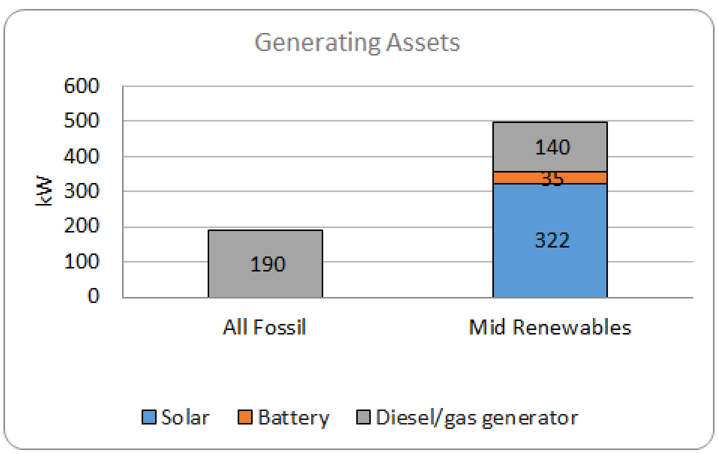
Figure 6.3. 76 - ***Microgrid Load Duration & Potential Cost Savings - Washington County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 190 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 140 kW standby generator, 35 kW battery storage system, and 322 kW solar system.

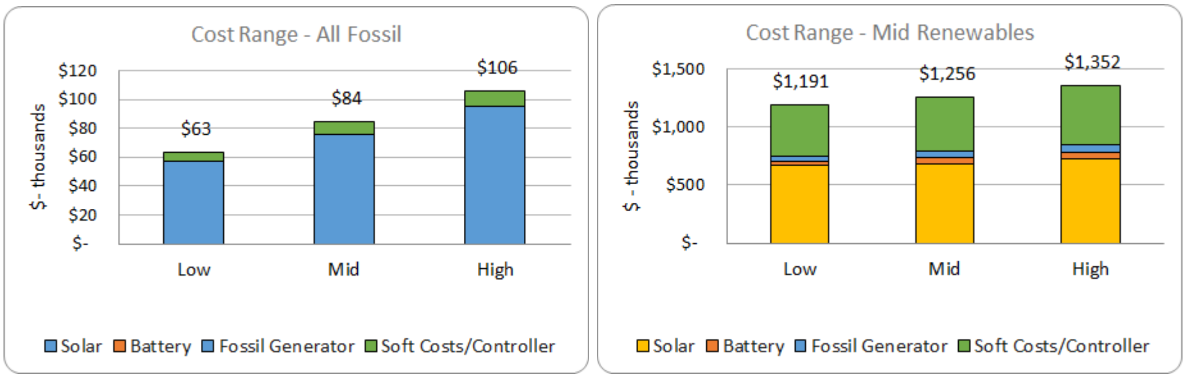
Figure 6.3. 77 - ***Microgrid Generation Assets - Washington County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Washington County Community Microgrid under fossil fuel only and moderate renewable energy design options.

Figure 6.3. 78 - ***Microgrid Cost Estimates - Washington County Community Microgrid***

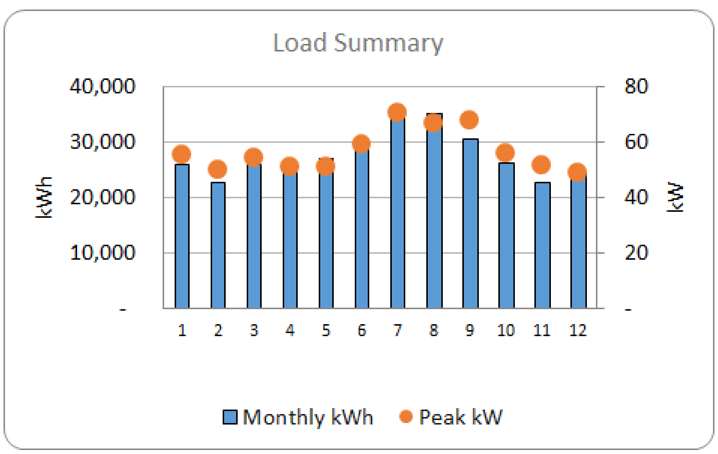


Source: Smart Electric Power Alliance, 2021.

7 - Hopkins County Community Microgrid

The Hopkins County Community Microgrid is designed to serve an emergency operations center, fire station, law enforcement facility, and national defense facility in the city of Madisonville. From the aggregated loads, this cluster of facilities is summer peaking with the highest demand occurring in July. This combination of facilities has a medium load factor of 54% based on 38 kW average monthly demand and 70 kW peak demand.

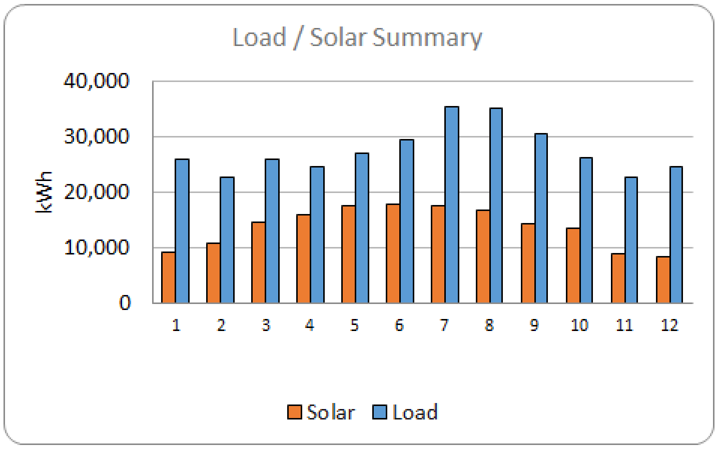
Figure 6.3. 79 - ***Load Summary - Hopkins County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 17,686 kWh and lowest in December at 8,300 kWh.

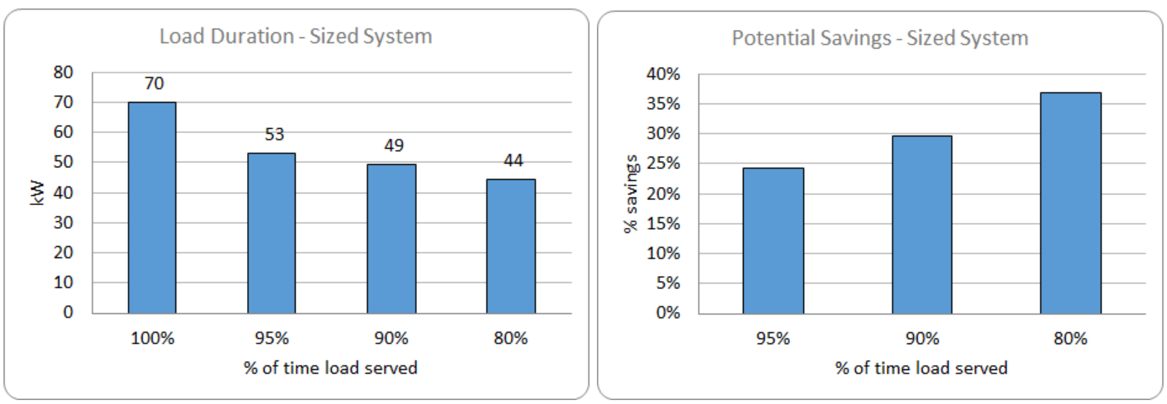
Figure 6.3. 80 - ***Load & Solar Output Summary - Hopkins County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 70 kW. As seen in Figure 6.3.81, there are significant potential savings when reducing the system size. For example, if the system is sized to 95% (53 kW) there is potential for 24% savings on the overall price of the microgrid.

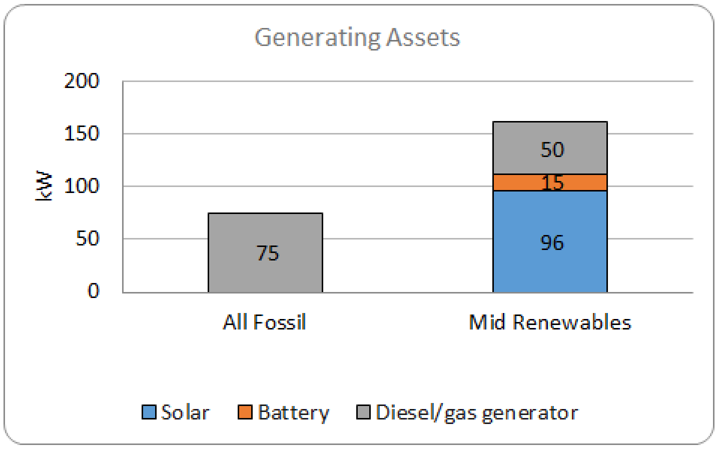
Figure 6.3. 81 - ***Microgrid Load Duration & Potential Cost Savings - Hopkins County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 75 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 50 kW standby generator, 15 kW battery storage system, and 96 kW solar system.

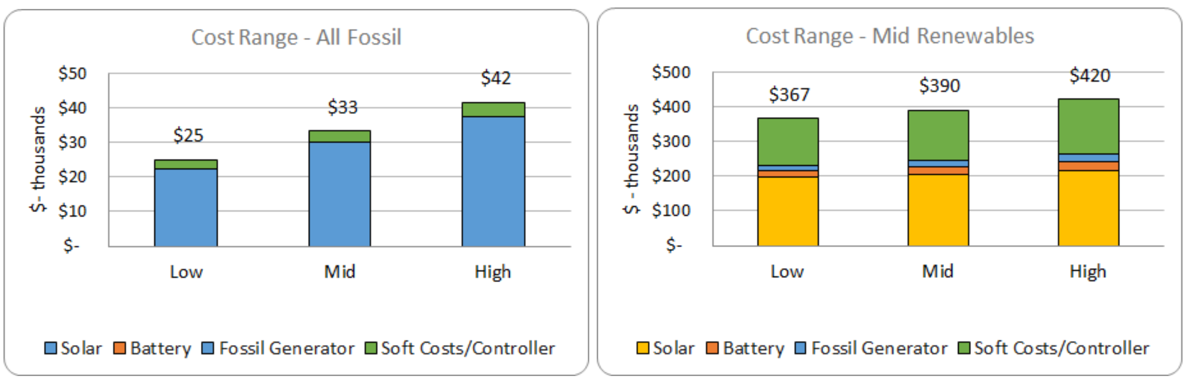
Figure 6.3. 82 - ***Microgrid Generation Assets - Hopkins County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Hopkins County Community Microgrid under fossil fuel only and moderate renewable energy design options.

Figure 6.3. 83 - ***Microgrid Cost Estimates - Hopkins County Community Microgrid***

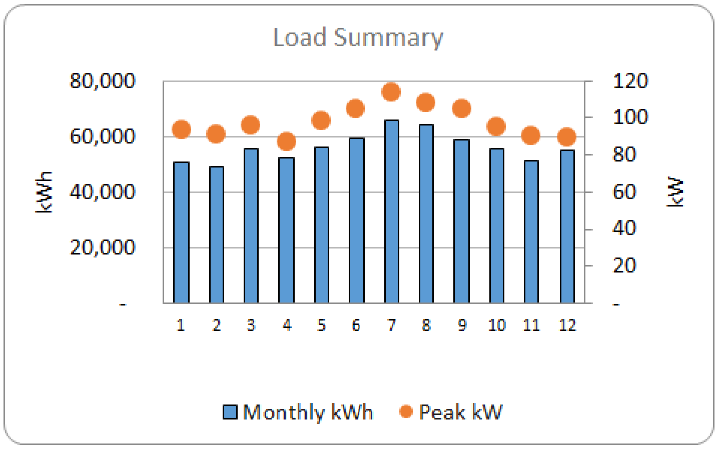


Source: Smart Electric Power Alliance, 2021.

8 - Allen County Community Microgrid

The Allen County Community Microgrid is designed to serve an emergency operations center, fire station, gas station, law enforcement facility and wastewater treatment plant in the city of Scottsville. From the aggregated loads, this cluster of facilities is summer peaking with the highest demand and usage occurring in July. This combination of facilities has a high load factor of 68% based on 77 kW average hourly demand and 113 kW peak demand.

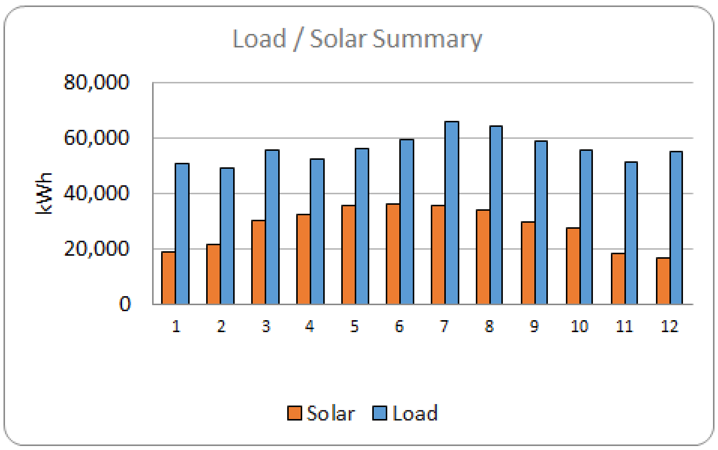
Figure 6.3. 84 - ***Load Summary - Allen County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 36,119 kWh and lowest in December at 16,950 kWh.

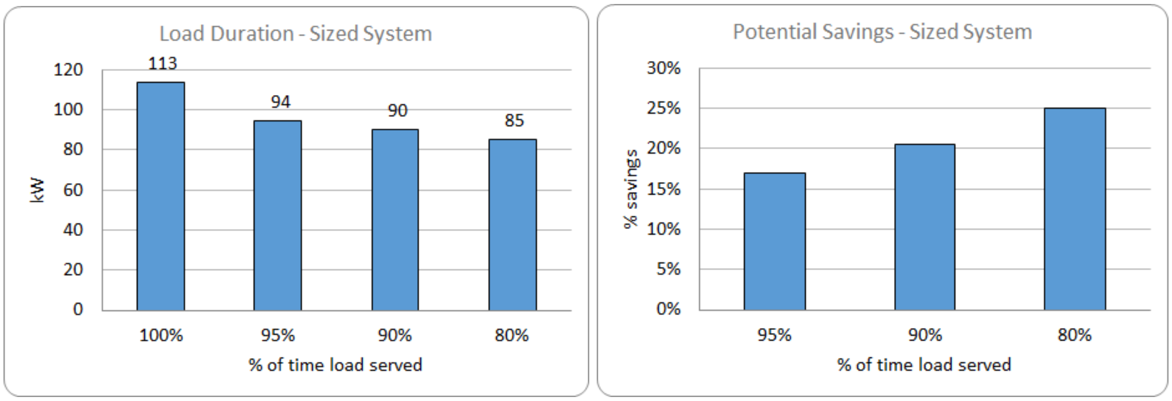
Figure 6.3. 85 - ***Load & Solar Output Summary - Allen County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 113 kW. As seen in Figure 6.3.86, there are significant potential savings when reducing the system size. For example, if the system is sized to 95% (94 kW) there is potential for 17% savings on the overall price of the microgrid.

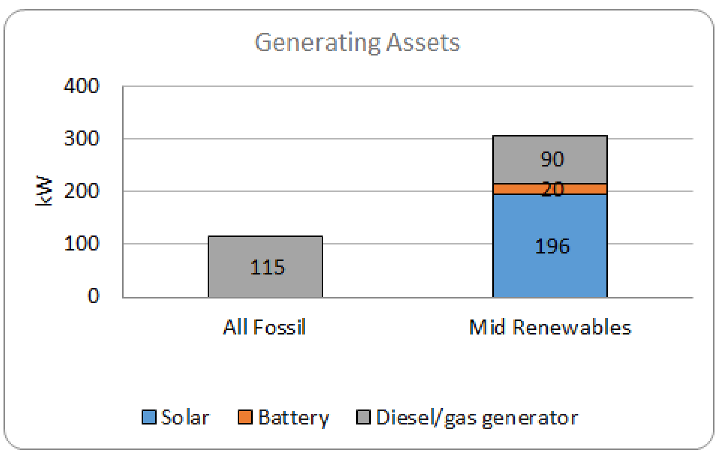
*Figure 6.3. 86 - **Microgrid Load Duration & Potential Cost Savings - Allen County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 115 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 90 kW standby generator, 20 kW battery storage system, and 196 kW solar system.

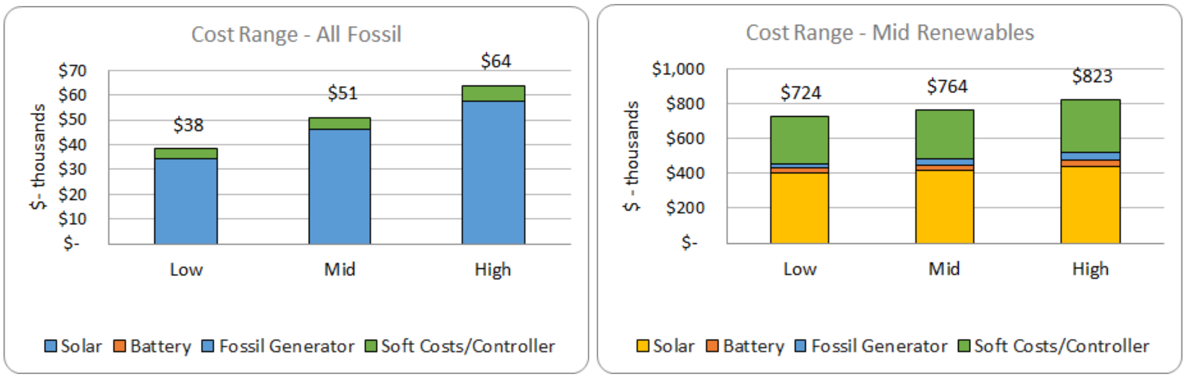
*Figure 6.3. 87 - **Microgrid Generation Assets - Allen County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Allen County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 88 - **Microgrid Cost Estimates - Allen County Community Microgrid***

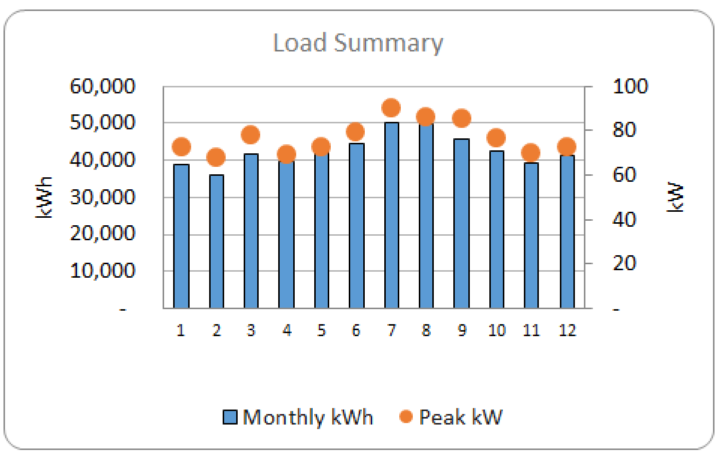


Source: Smart Electric Power Alliance, 2021.

9 - Carlisle County Community Microgrid

The Carlisle County Community Microgrid is designed to serve an emergency operations center, fire station, law enforcement facility, and water treatment facility in the city of Bardwell. From the aggregated loads, this cluster of facilities is summer peaking with the highest demand and usage occurring in July. This combination of facilities has a high load factor of 65% based on 58 kW average monthly demand and 90 kW peak demand.

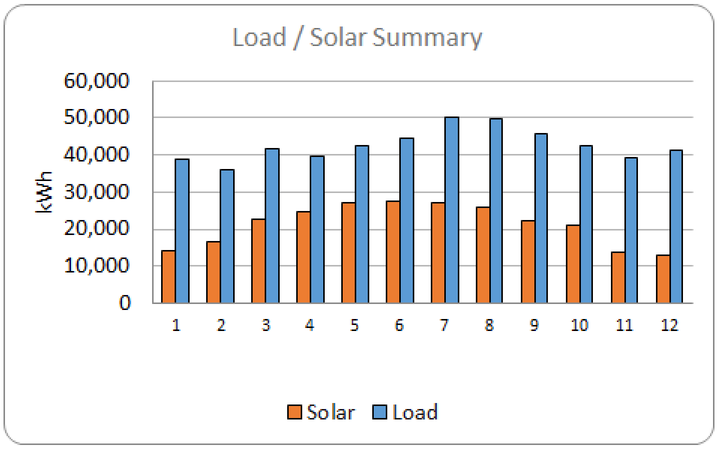
*Figure 6.3. 89 - **Load Summary - Carlisle County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 27,448 kWh and lowest in December at 12,881 kWh.

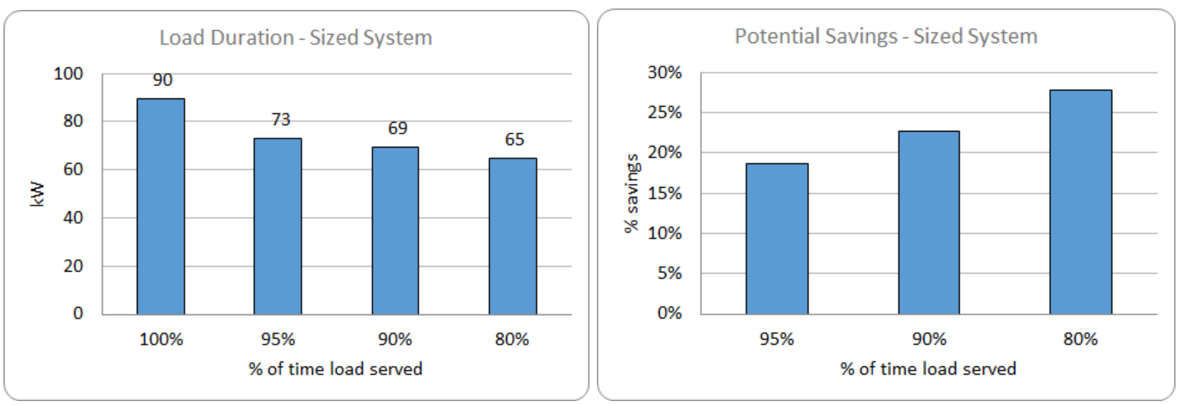
*Figure 6.3. 90 - **Load & Solar Output Summary - Carlisle County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 90 kW. As seen in Figure 6.3.91, there are significant potential savings when reducing the system size. For example, if the system is sized to 95% (73 kW) there is potential for 19% savings on the overall price of the microgrid.

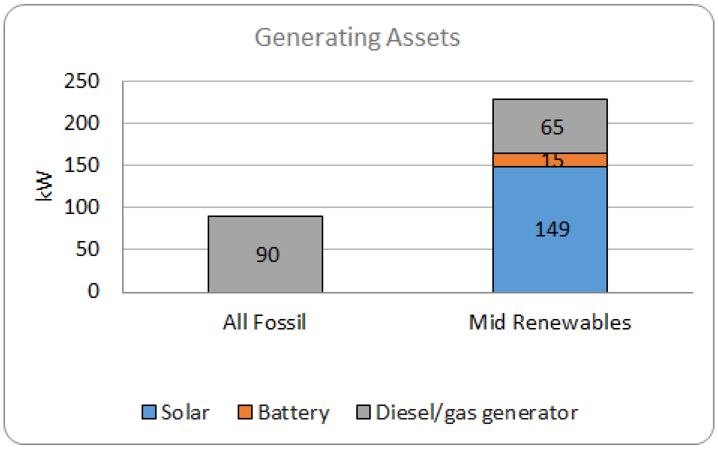
*Figure 6.3. 91 - **Microgrid Load Duration & Potential Cost Savings - Carlisle County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 90 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 65 kW standby generator, 15 kW battery storage system, and 149 kW solar system.

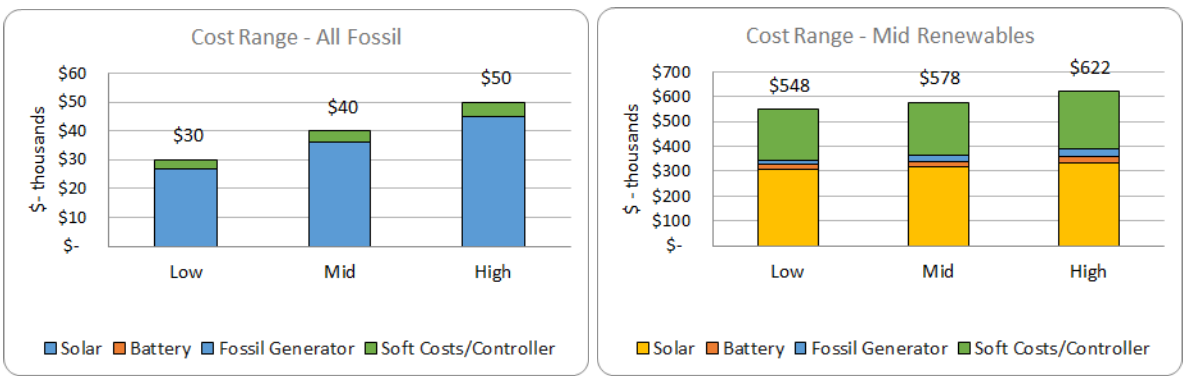
*Figure 6.3. 92 - **Microgrid Generation Assets - Carlisle County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Carlisle County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 93 - **Microgrid Cost Estimates - Carlisle County Community Microgrid***

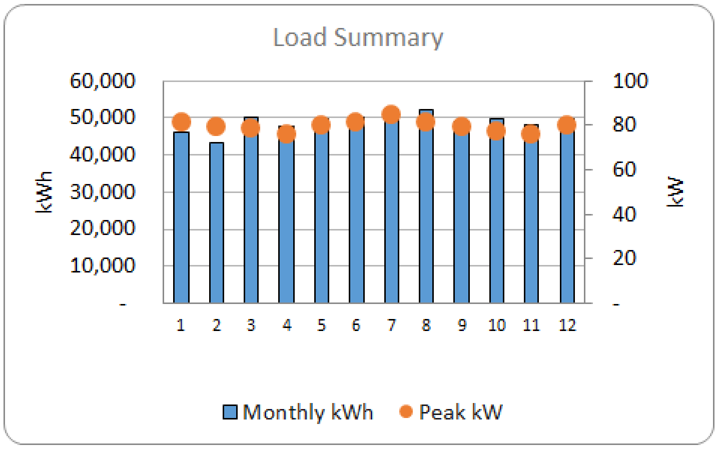


Source: Smart Electric Power Alliance, 2021.

10 - Marshall County Community Microgrid

The Marshall County Community Microgrid is designed to serve an emergency operations center, law enforcement facility, water treatment facility and wastewater treatment facility in the city of Benton. From the aggregated loads, this cluster of facilities has a flat load profile with a slight peak in July. This combination of facilities has a high load factor of 79% based on 67 kW average monthly demand and 85 kW peak demand.

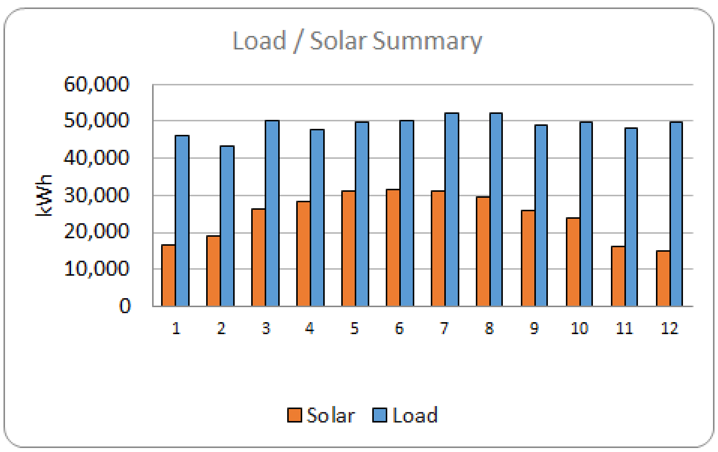
*Figure 6.3. 94 - **Load Summary - Marshall County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 31,555 kWh and lowest in December at 14,808 kWh.

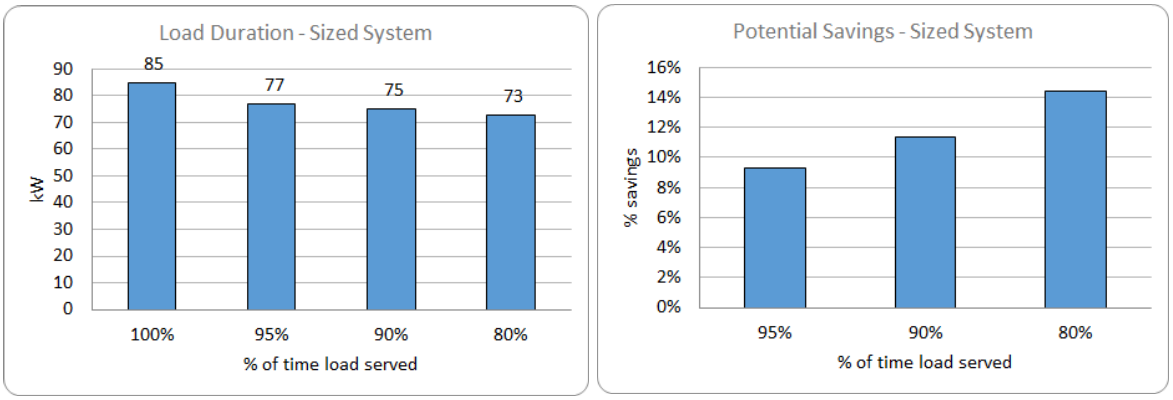
*Figure 6.3. 95 - **Load & Solar Output Summary - Marshall County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 85 kW. As seen in Figure 6.3.96, there are some potential savings when reducing the system size. For example, if the system is sized to 95% (77 kW) there is potential for 9% savings on the overall price of the microgrid.

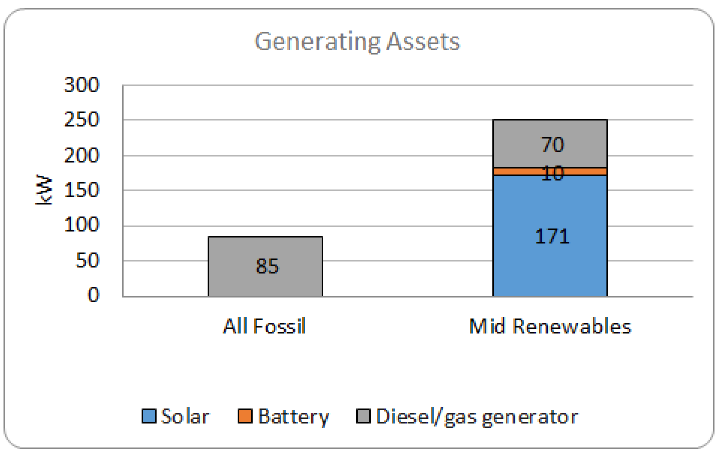
Figure 6.3. 96 - ***Microgrid Load Duration & Potential Cost Savings - Marshall County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires an 85 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 70 kW standby generator, 10 kW battery storage system, and 171 kW solar system.

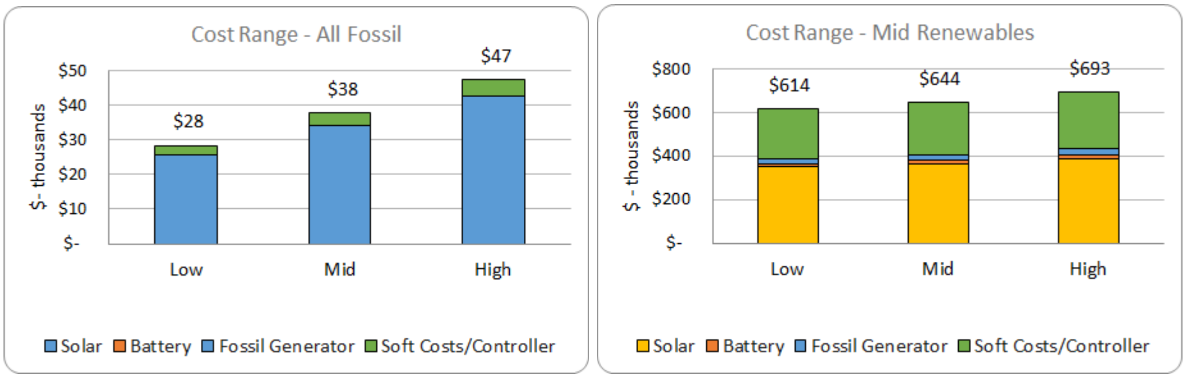
Figure 6.3. 97 - ***Microgrid Generation Assets - Marshall County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Marshall County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 98 - **Microgrid Cost Estimates - Marshall County Community Microgrid***

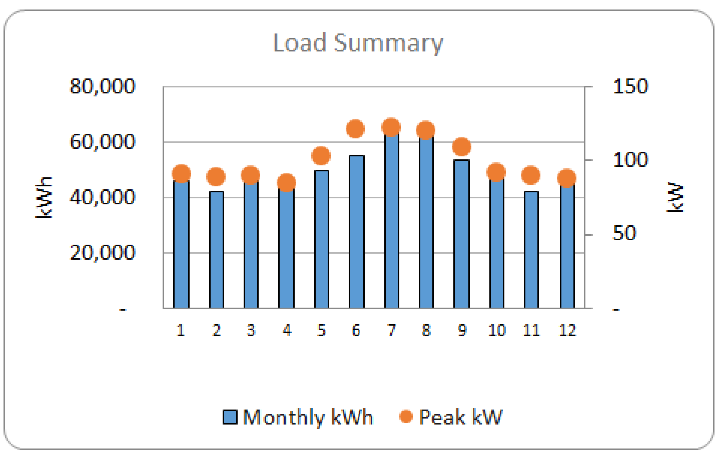


Source: Smart Electric Power Alliance, 2021.

11 - Bell County Community Microgrid

The Bell County Community Microgrid is designed to serve a fire station, gas station, law enforcement facility, nursing home, and national defense facility in the city of Middlesboro. From the aggregated loads, this cluster of facilities is summer peaking with the highest demand and usage occurring in July. This combination of facilities has a medium load factor of 56% based on 68 kW average monthly demand and 122 kW peak demand.

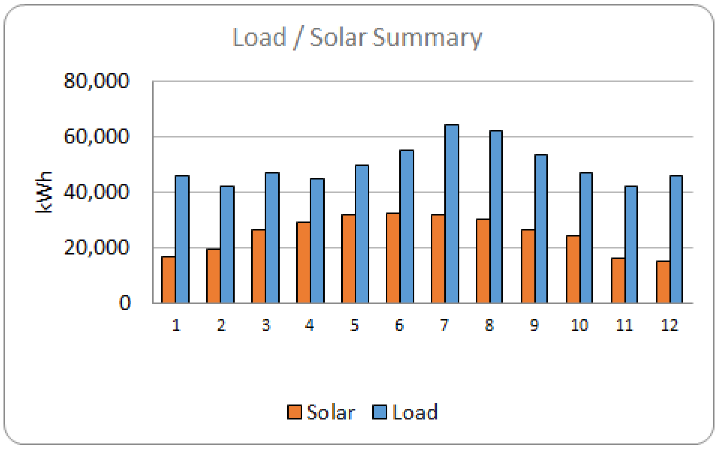
*Figure 6.3. 99 - **Load Summary - Bell County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 32,193 kWh and lowest in December at 15,108 kWh.

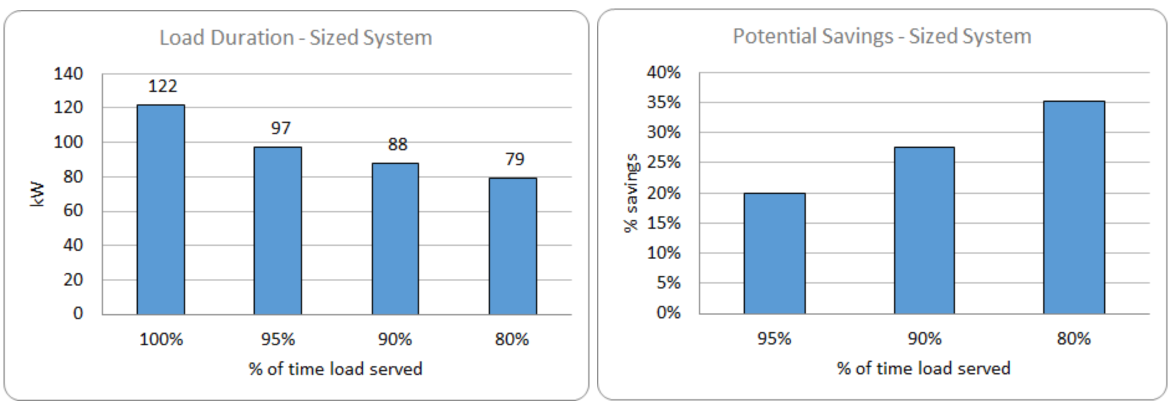
Figure 6.3. 100 - ***Load & Solar Output Summary - Bell County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 122 kW. As seen in Figure 6.3.101, there are significant potential savings when reducing the system size. For example, if the system is sized to 95% (97 kW) there is potential for 20% savings on the overall price of the microgrid.

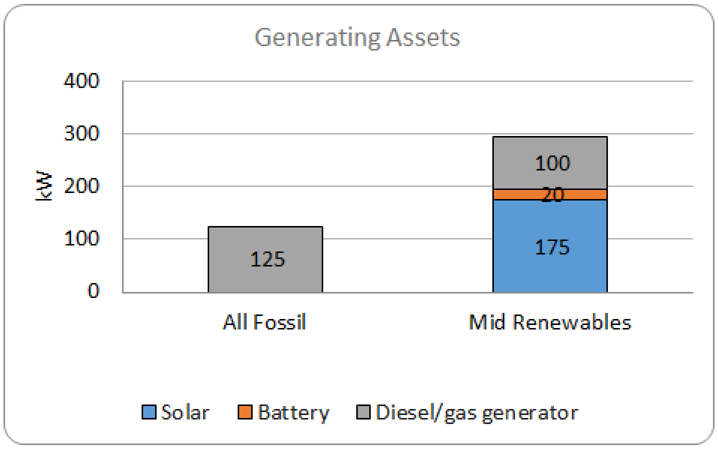
Figure 6.3. 101 - ***Microgrid Load Duration & Potential Cost Savings - Bell County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 125 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 100 kW standby generator, 20 kW battery storage system, and 175 kW solar system.

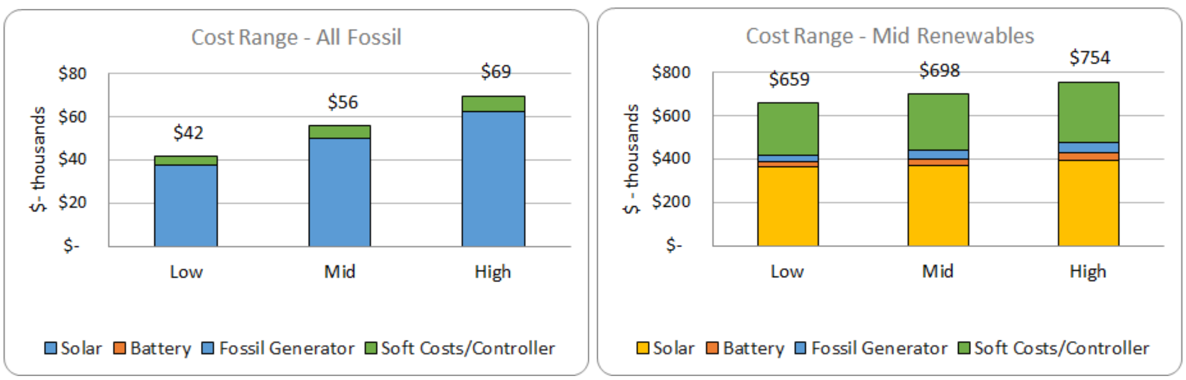
*Figure 6.3. 102 - **Microgrid Generation Assets - Bell County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the Bell County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 103 - **Microgrid Cost Estimates - Bell County Community Microgrid***

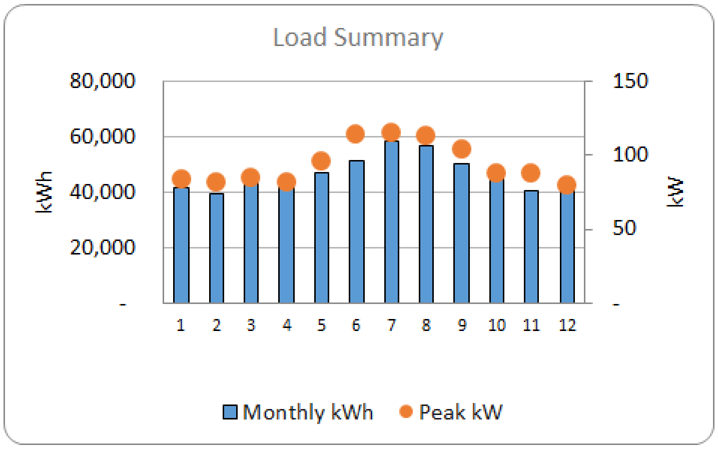


Source: Smart Electric Power Alliance, 2021.

12 - McLean County Community Microgrid

The McLean County Community Microgrid is designed to serve a cell tower, fire station, gas station, and nursing home in the city of Calhoun. From the aggregated loads, this cluster of facilities is summer peaking with the highest demand and usage occurring in June and July. This combination of facilities has a medium load factor of 56% based on 64 kW average monthly demand and 114 kW peak demand.

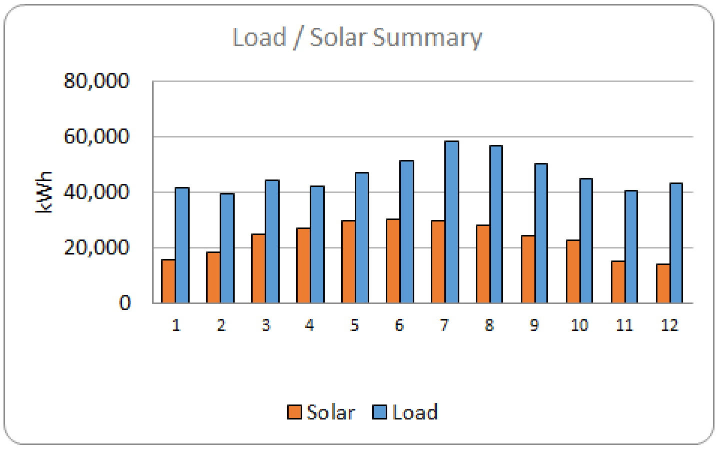
*Figure 6.3. 104 - **Load Summary - McLean County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

For this microgrid, solar energy production is highest in June at 30,003 kWh and lowest in December at 14,080 kWh.

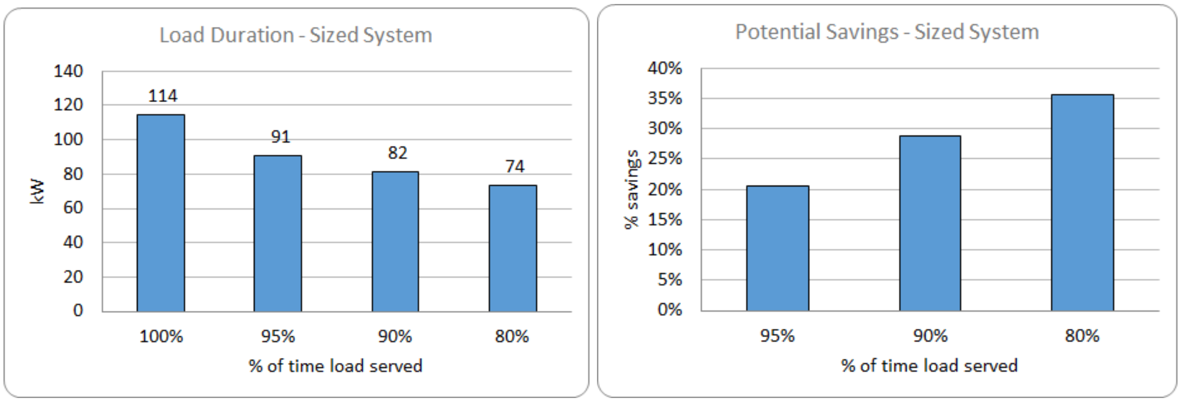
*Figure 6.3. 105 - **Load & Solar Output Summary - McLean County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

In order to serve the load at these facilities 100% of the time for the full year, the community microgrid must be sized to 114 kW. As seen in Figure 6.3.106, there are significant potential savings when reducing the system size. For example, if the system is sized to 95% (91 kW) there is potential for 21% savings on the overall price of the microgrid.

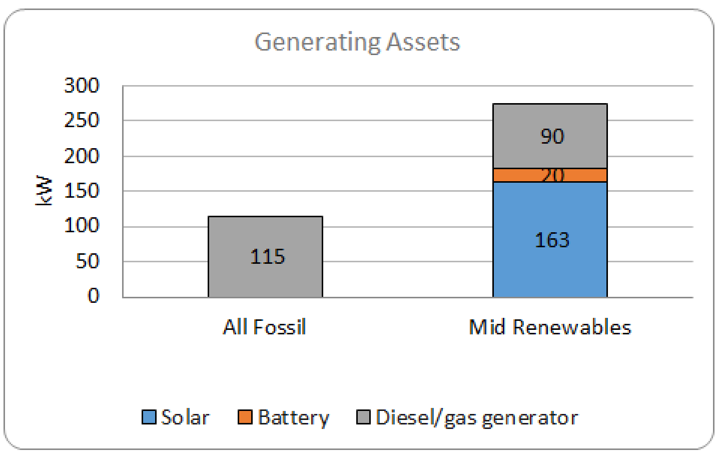
*Figure 6.3. 106 - **Microgrid Load Duration & Potential Cost Savings - McLean County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

This community microgrid requires a 115 kW standby generator under the fossil fuel only design scenario in order to provide backup power capability to this cluster of facilities for a full year. The moderate renewable design option requires a 90 kW standby generator, 20 kW battery storage system, and 163 kW solar system.

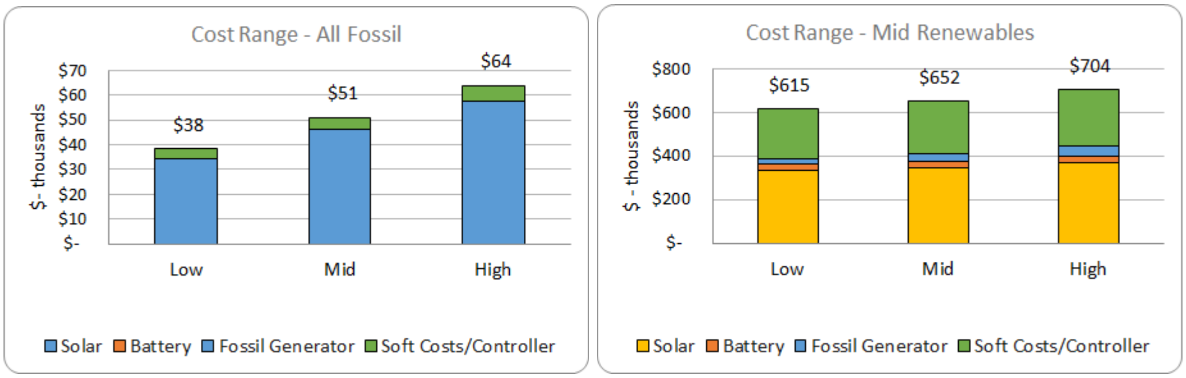
*Figure 6.3. 107 - **Microgrid Generation Assets - McLean County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.

The figure below represents the cost range for the McLean County Community Microgrid under fossil fuel only and moderate renewable energy design options.

*Figure 6.3. 108 - **Microgrid Cost Estimates - McLean County Community Microgrid***



Source: Smart Electric Power Alliance, 2021.