



Kentucky Regional Microgrids for Resilience Study

April 7, 2021

Prepared for the NASEO-NARUC Microgrid Working Group



Acknowledgements



SEPA would like to thank the Kentucky Energy and Environment Cabinet Office of Energy Policy for the opportunity to conduct this study. The study was made possible by the U.S. Department of Energy’s State Energy Program (SEP), which provides funding and technical assistance to enhance energy security, advance state-led energy initiatives, and maximize the benefits of decreasing energy waste.



Microgrid Study Lead



Role for our project

- Stakeholder engagement
- Data collection and landscape review
- Research and industry knowledge
- Microgrid site selection and economic analysis



Profile

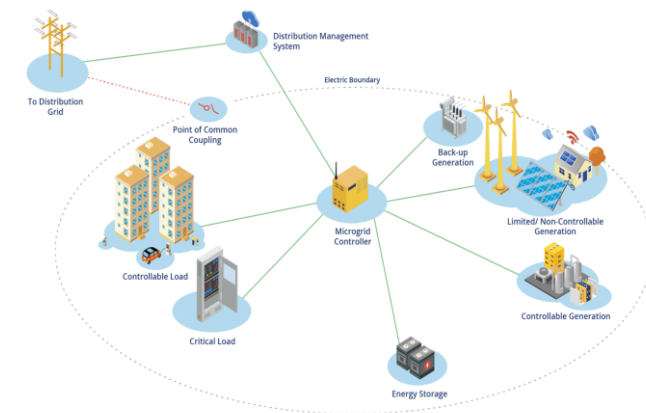
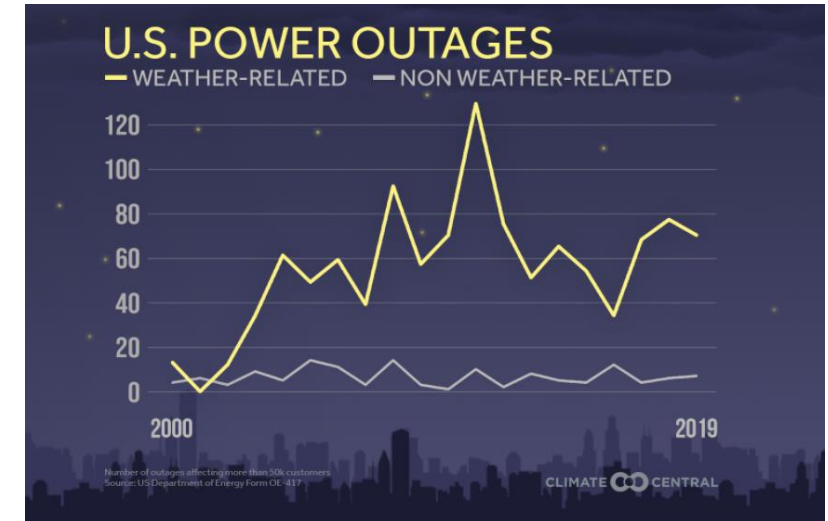
- A 501c3 membership organization founded in 1992
- Staff of ~ 50, budget of ~ \$10M
- Based in Washington, D.C.
- Advisory services, research, and industry collaboration

Microgrid Study Motivations and Goals



Microgrids as an economic solution and a BRIC funding opportunity

- Power outages are a major contributor to economic loss that can be mitigated with microgrids
- Support private and public sector opportunities for BRIC and other resiliency funding
- Select and evaluate potential sites and areas in Kentucky to achieve resilience through microgrid deployment
- Evolving hazard mitigation planning with microgrid considerations



Summary of Results

Smart Electric
Power Alliance



Smart Electric
Power Alliance

6,640

sites considered

SEPA evaluated 6,640 sites for microgrid solutions using 6 selection criteria. SEPA identified 558 potential site-specific installations and 12 potential regional community microgrids.



6

site selection criteria



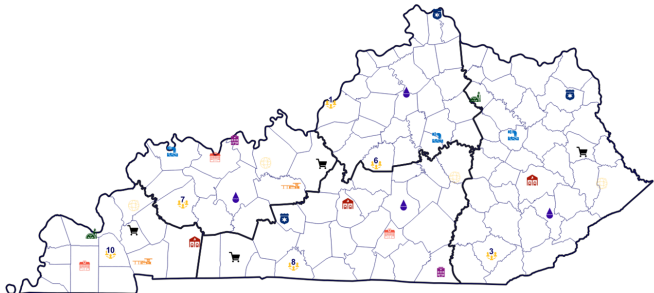
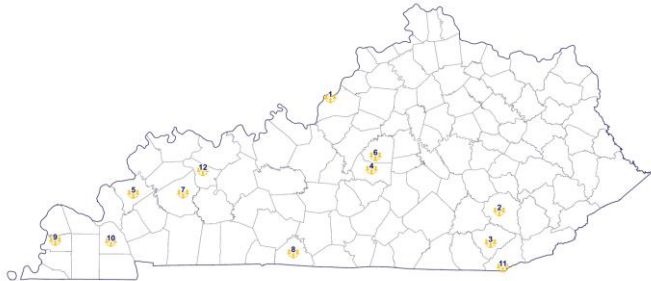
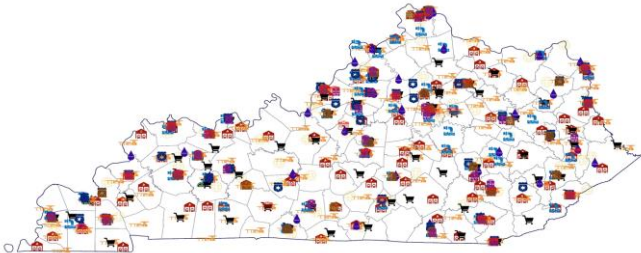
558

potential site-specific
installations



12

potential regional
community microgrids



Study Methodology

Identifying potential microgrid deployments for critical facilities to increase the state-wide resilience in Kentucky against natural hazards

Landscape Review

- Stakeholder engagement
- Prioritizing critical facilities and natural hazards

Data Collection

- Critical facilities
- Load profiles
- Reliability hostpots
- Natural hazards
- Population density
- Urban areas
- Energy Burden

Site Selection

- Nanogrids (specific facilities)
- Regional community microgrids (clusters)

Deployment Strategy

- Sizing
- Cost estimates
- Deployment options



Landscape Review – Critical Facilities and Natural Hazards

Natural Hazard Prioritized List:

- ✓ Extreme Cold & Winter Storms
- ✓ Floods
- ✓ Wind
- ✓ Tornadoes

Avoiding Microgrid Deployment in High-Risk Areas of:

- ✓ Earthquakes, landslide, karst, mine subsidence and wildfires

Natural Hazards for Future Consideration

- ✓ Extreme heat














Critical Facility Prioritized List:

- Water Treatment Facilities - Wastewater/Water Treatment Plants
- Emergency Operations Centers - Temporary or Permanent Emergency Preparedness Command Centers
- Health Care Facilities - Hospitals and Nurseries
- Fire Stations
- National Defense - Military & National Guard Bases
- Law Enforcement - Police, Sheriff and Park Police Stations
- Gas Stations & Petroleum Terminals
- Grocery Stores
- Communications Facilities - Radio, TV and Cell Tower Transmission



Data Collection - Critical Facilities



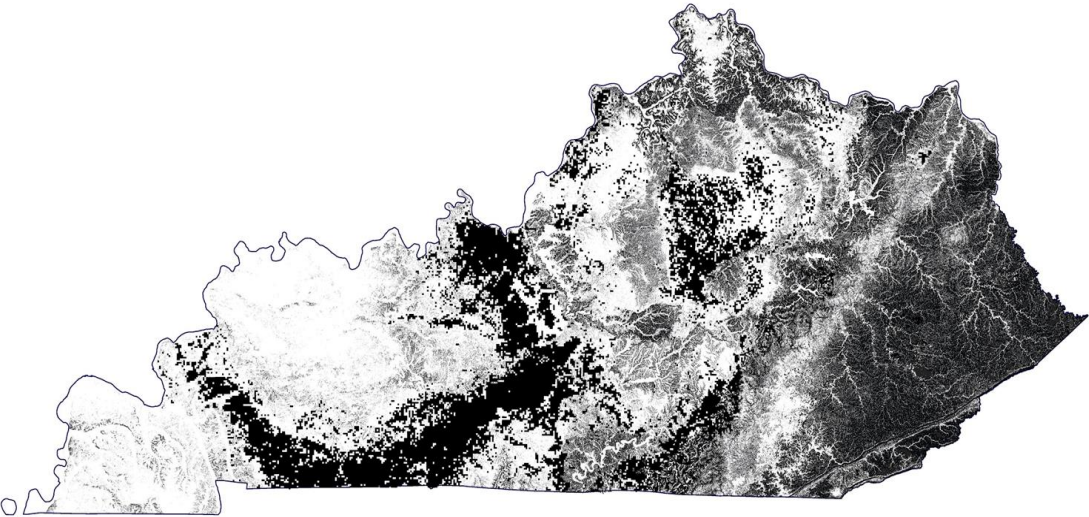
	Facility	Data Source	Key Stats	Notes
	Communication Facilities	HIFLD	1,234 total	Clusters of sites exist in more densely populated counties
	Hospitals	OEP	137 total	More sites exist in densely populated counties.
	Nursing Homes	OEP	379 total	More sites exist in densely populated counties.
	Water Treatment 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.

Data Collection - Tier 1 and 2 Hazards



0 25 50 mi

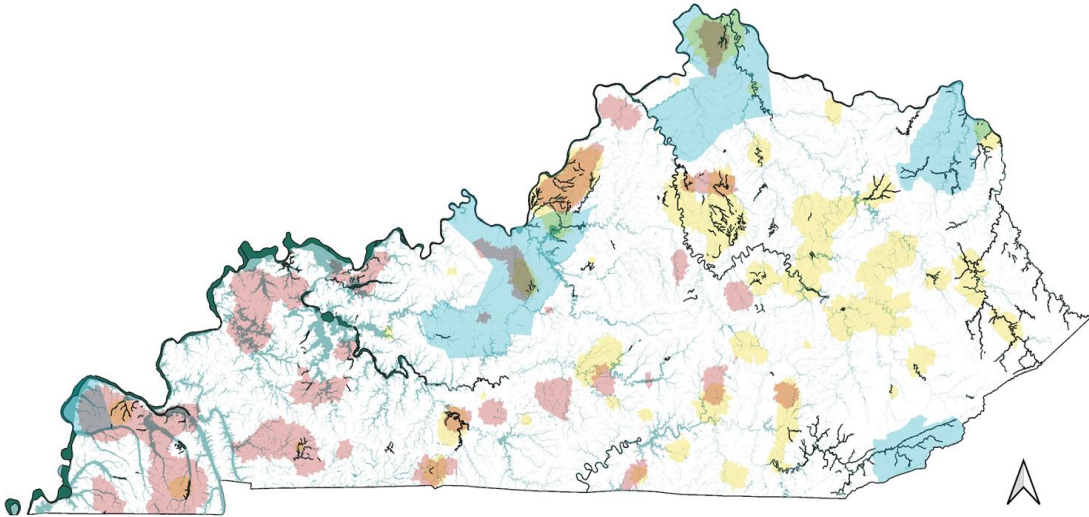
Areas at High Risk of Tier 1 Hazards:
Earthquakes, Landslides, Karst, Mine Subsidence, and Wildfire



■ Area at High Risk of Tier 1 Hazard

0 25 50 mi

Areas at High Risk of Tier 2 Hazards:
Tornadoes, Wind, Extreme Cold and Winter Storm Events, and Floods

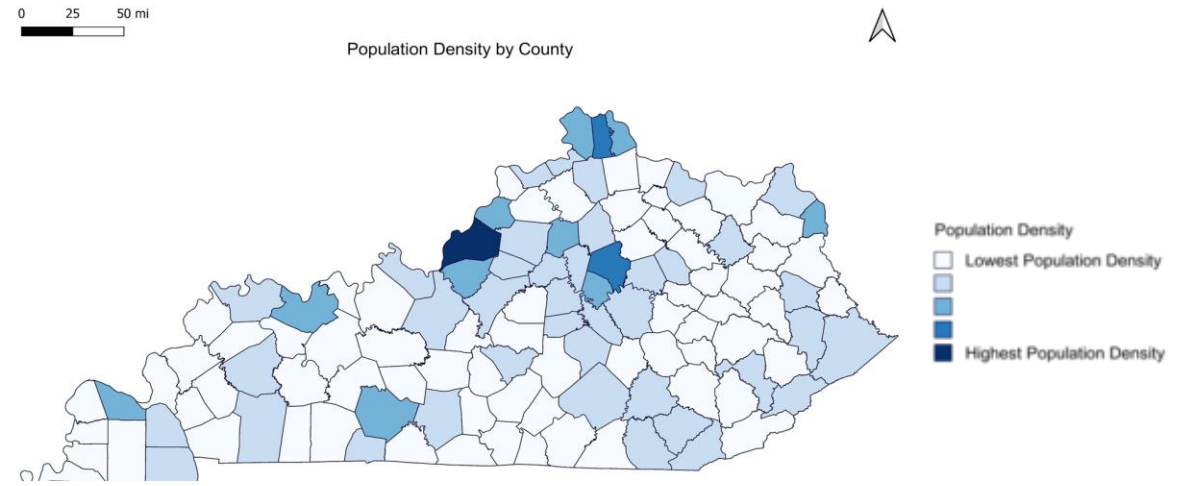


Tornado High Risk	Wind High Risk	Extreme Cold and Winter Storm Events High Risk	National Flood Hazard Layer
100 Year Flood	500 Year Flood	Floodway	

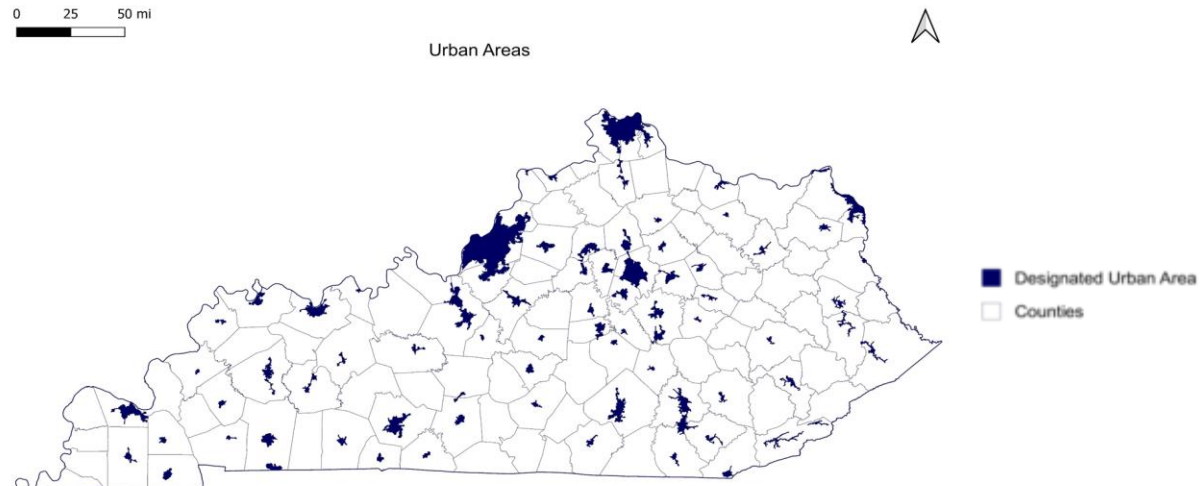
Source: Smart Electric Power Alliance (2021) based on data provided by Matt Crawford, a Kentucky Geological Survey scientist with the University of Kentucky (2020).

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).

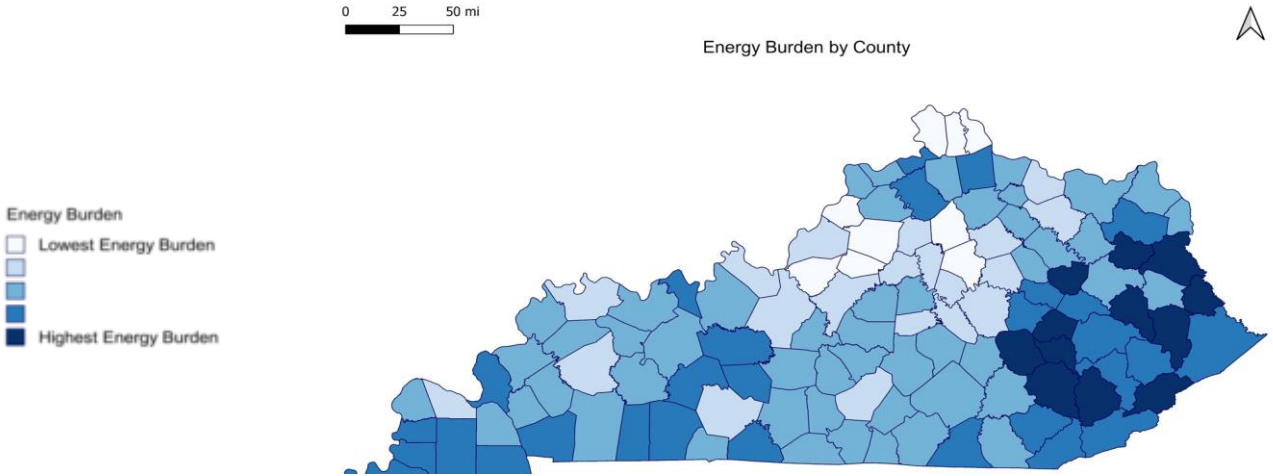
Data Collection - Population Density, Urban Areas, and Energy Burden



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



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



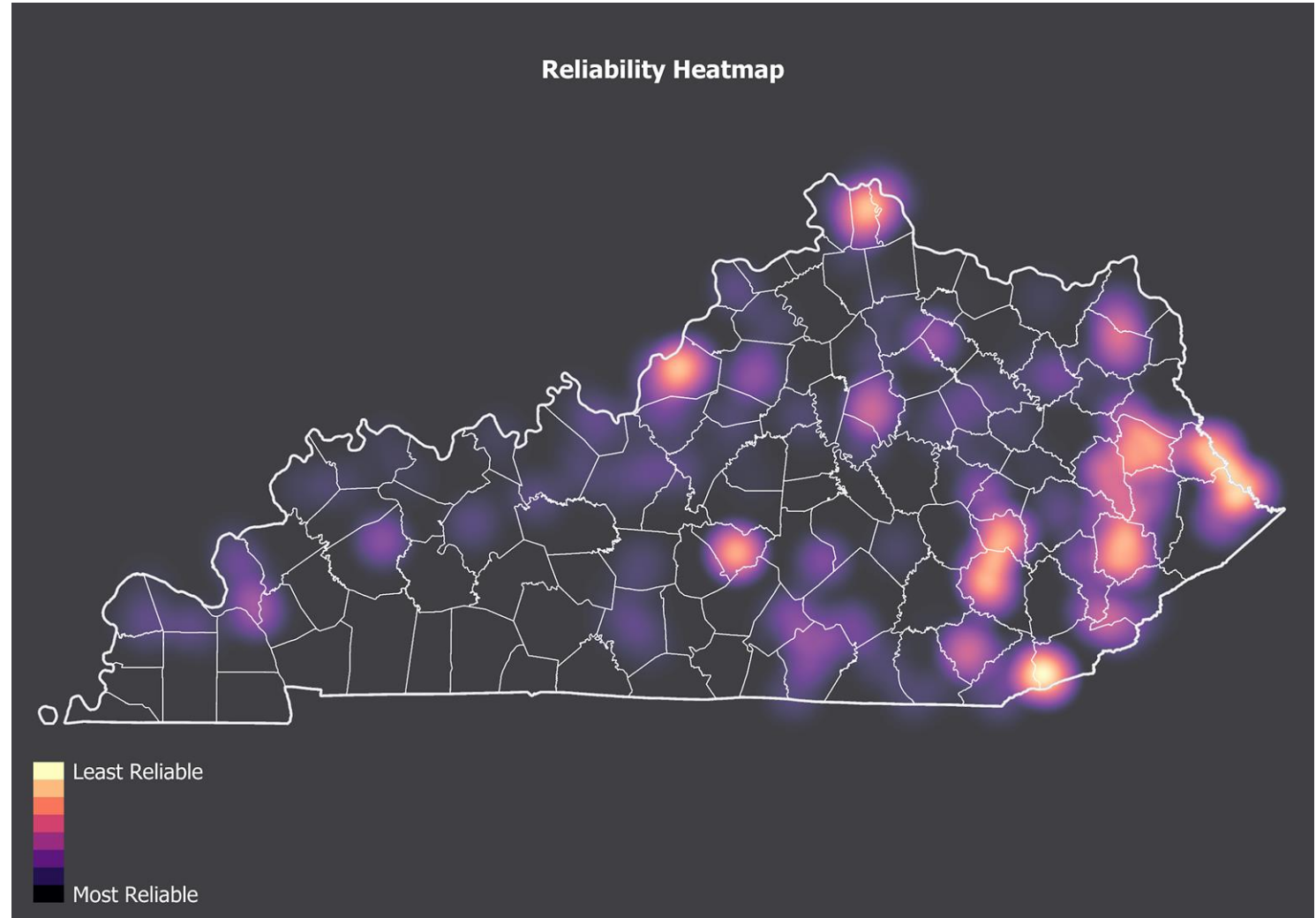
Source: United States Department of Energy. [Avg. Energy Burden \(% income\) for Counties in Kentucky](#). Low-Income Energy Affordability Data (LEAD) Tool (2020).

Data Collection – Reliability Hotspots



Map Development Methodology

- Data collected from annual reliability reports filed by utilities with the Kentucky Public Service Commission.
- Locational data for the top ten worst performing circuits (based on SAIDI values) for each utility was used to develop a heatmap.
- Lowest reliability in the eastern region of Kentucky.

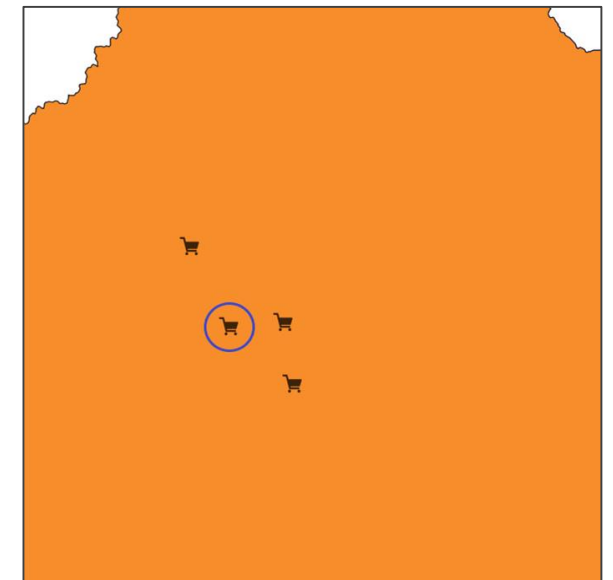
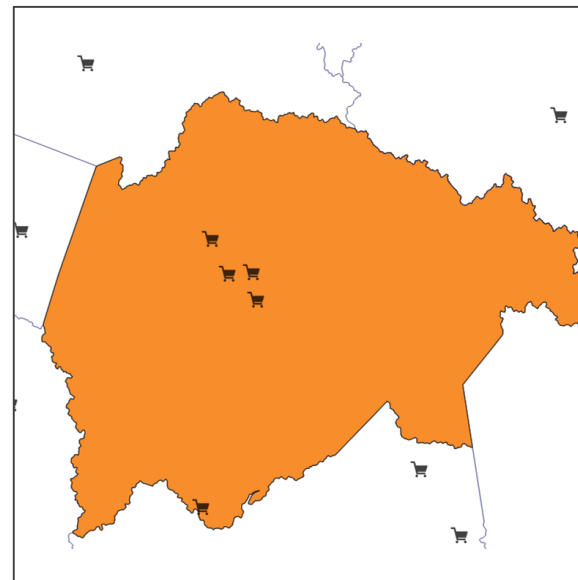
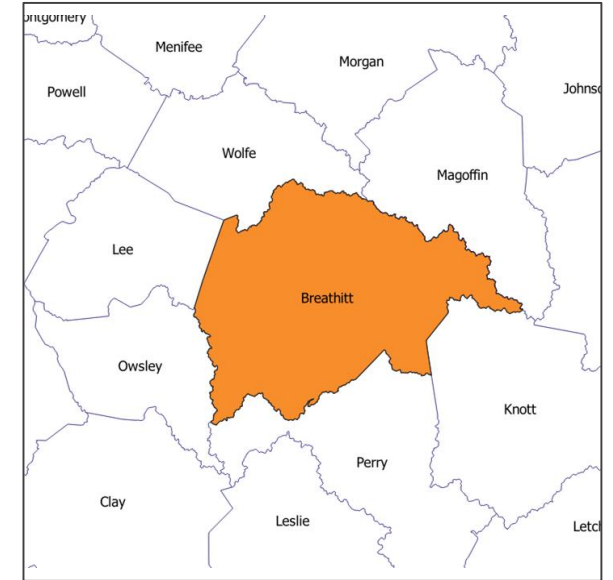
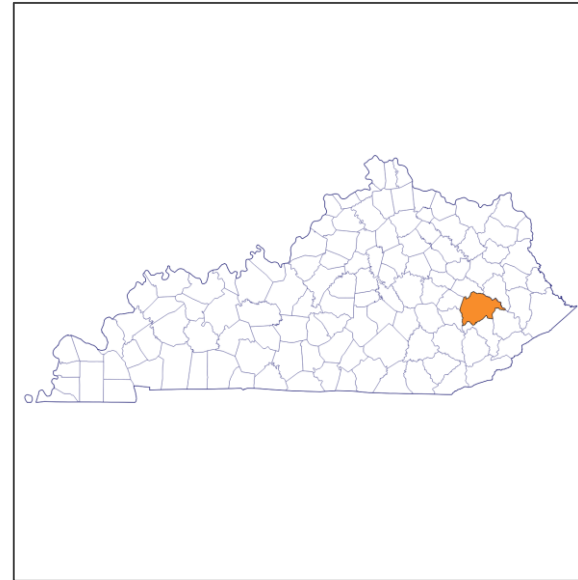


Site Selection

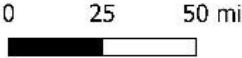


Selection Criteria

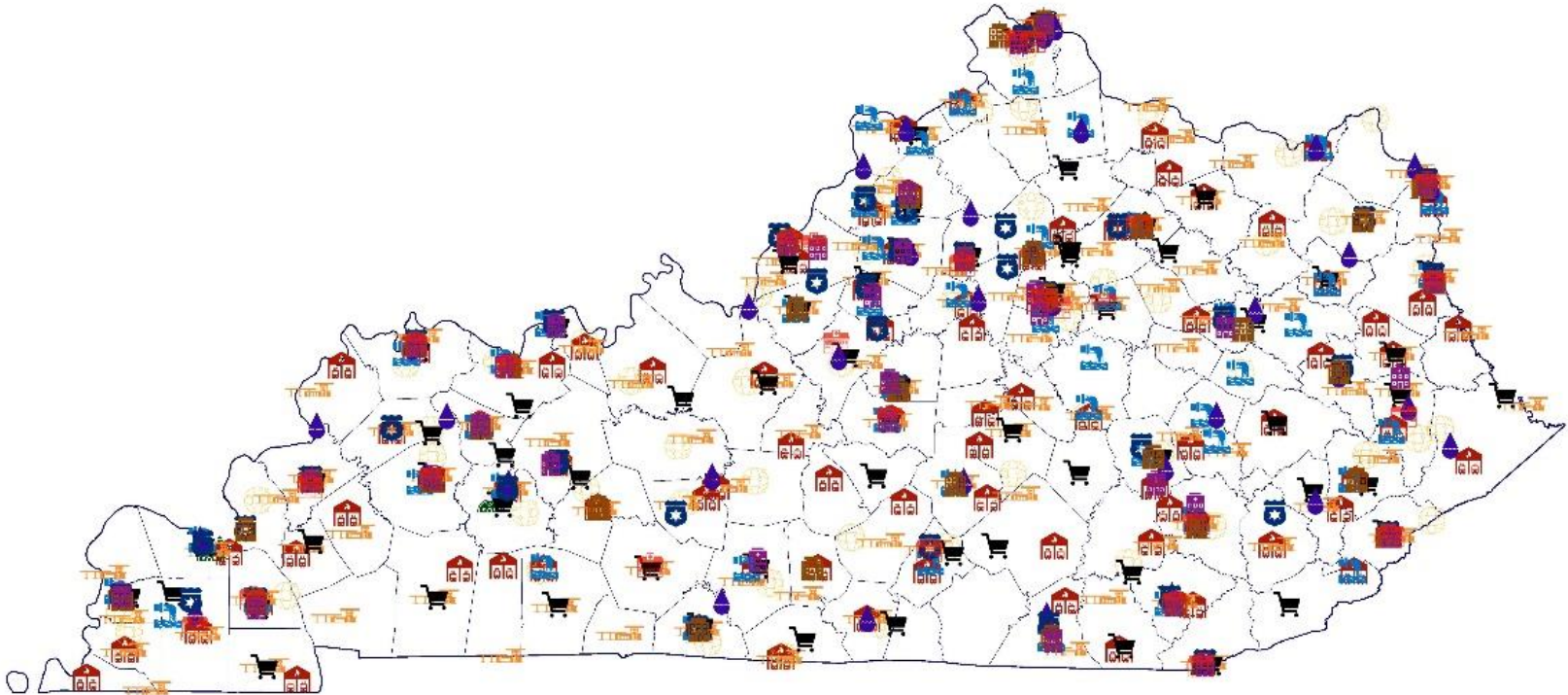
- Critical infrastructure facility type
- Geographical proximity
- Areas at high risk of natural hazard
- Reliability hotspots
- Population density
- Energy burden / underserved areas



Site Selection – Nanogrid Deployment Selection Results



Selected Nanogrid Deployment Locations



- Hospital
- Nursing Home
- Emergency Operations Center
- Law Enforcement
- Water Treatment Plant
- Wastewater Treatment Plant
- Grocery Store
- Cellular Tower
- Gas Station
- Fire Station
- National Defense
- Counties

Site Selection - Regional Community Selection Results

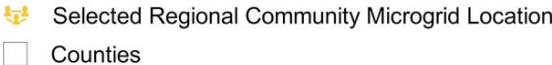
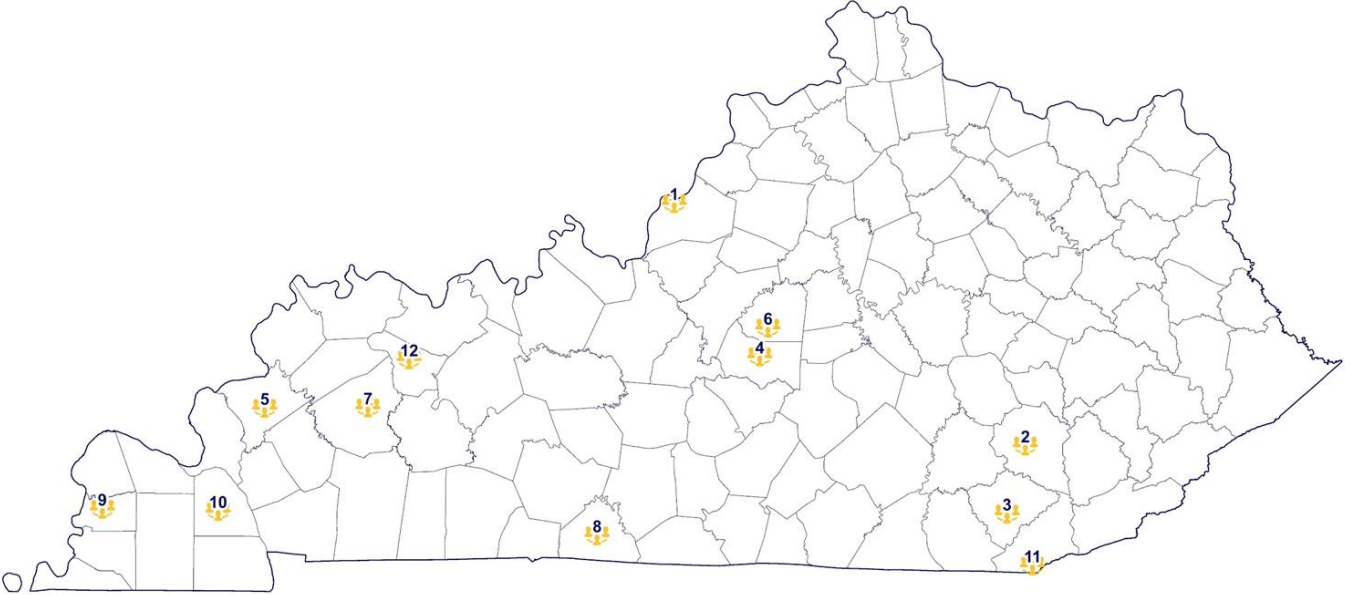


Regional Community Microgrid Legend

- 1. Jefferson County Community Microgrid
- 2. Clay County Community Microgrid
- 3. Knox County Community Microgrid
- 4. Marion County Community Microgrid
- 5. Crittenden County Community Microgrid
- 6. Washington County Community Microgrid
- 7. Hopkins County Community Microgrid
- 8. Allen County Community Microgrid
- 9. Carlisle County Community Microgrid
- 10. Marshall County Community Microgrid
- 11. Bell County Community Microgrid
- 12. McLean County Community Microgrid



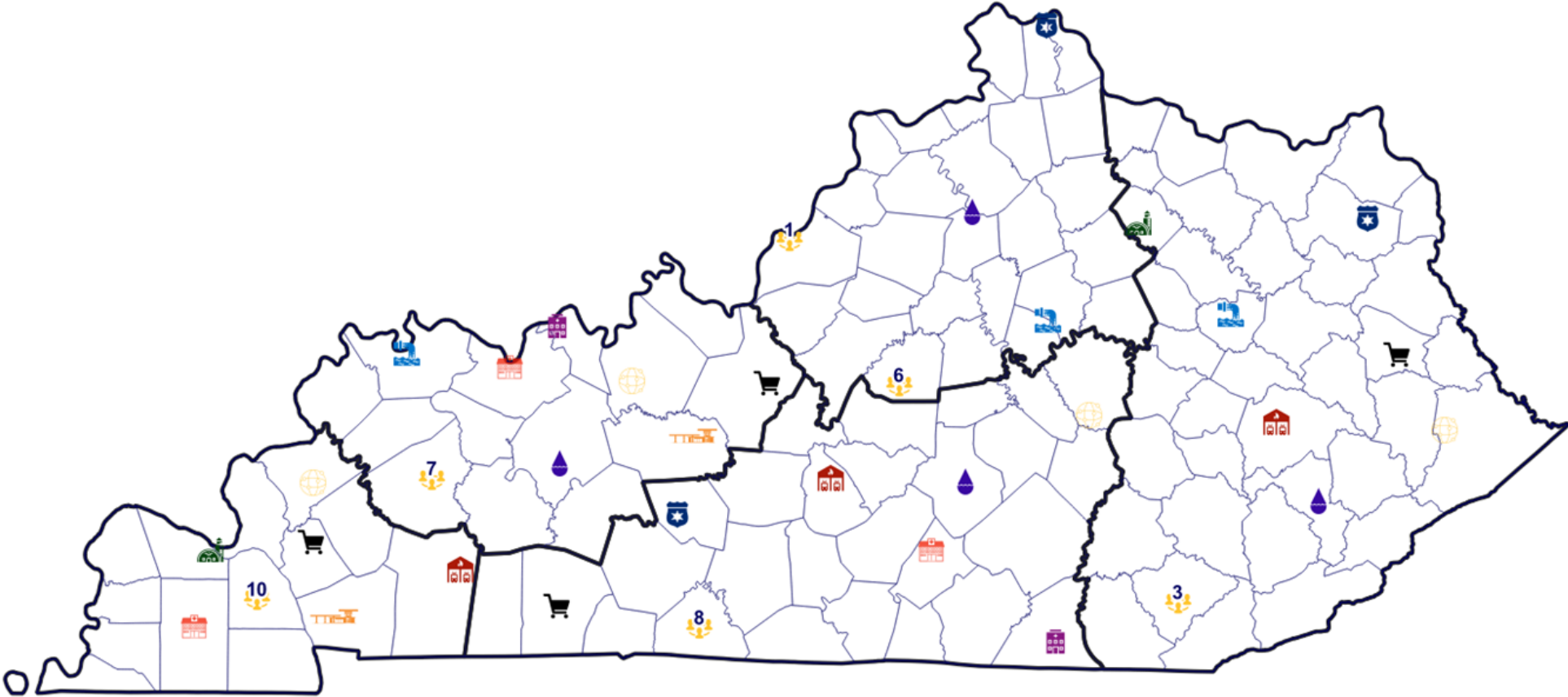
Selected Regional Community Microgrid Locations



Site Selection - Representative Strategy



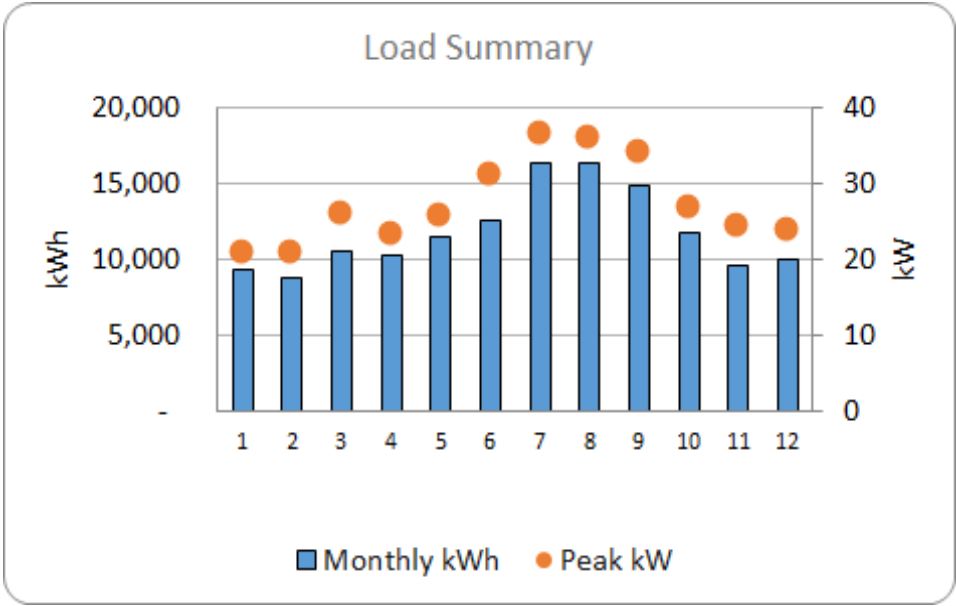
Representative Nanogrid & Regional Community Microgrid Deployment Strategy



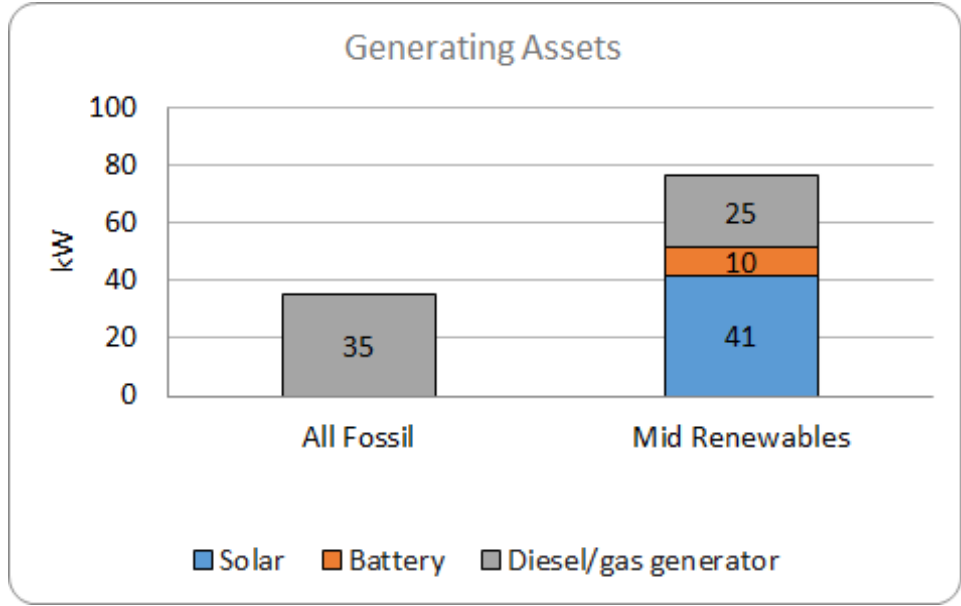
Sizing – Fire Station Example



Fire Station Load Profile



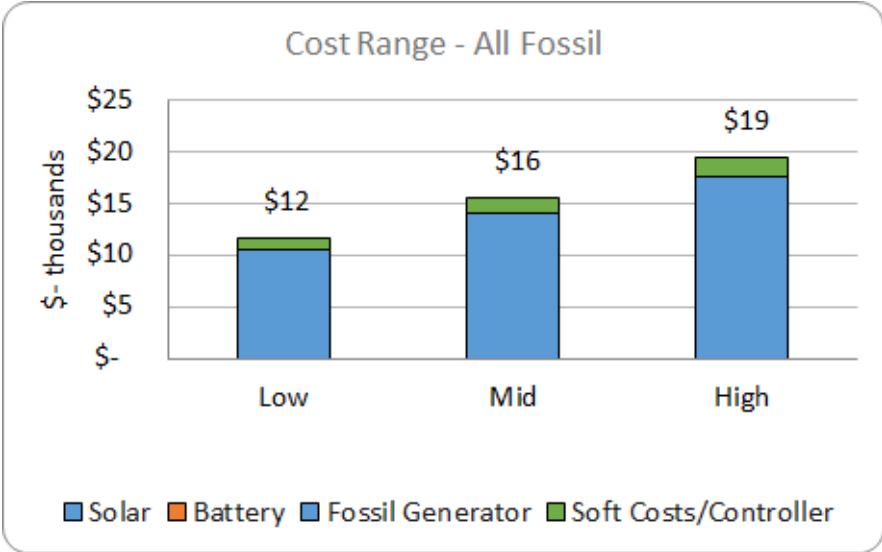
Fire Station Microgrid Design Options



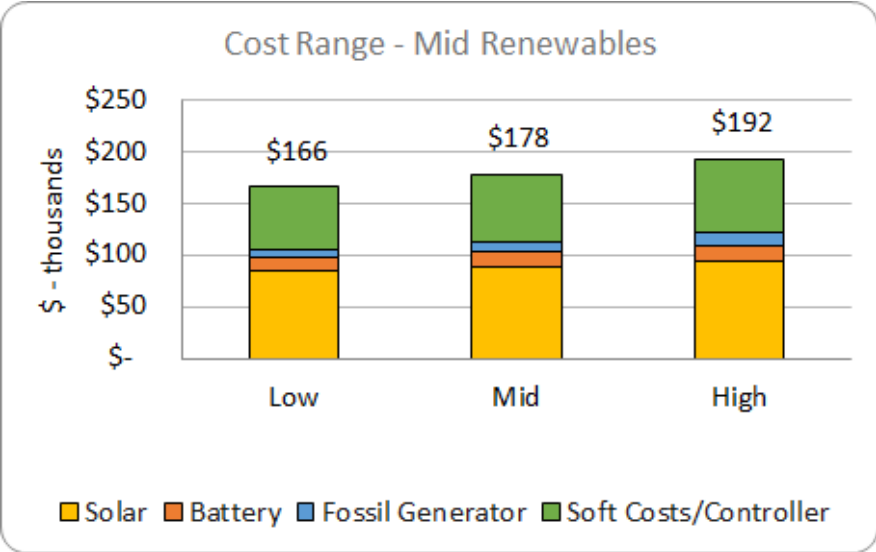
Cost Estimates – Fire Station Example



Design Option 1: Fossil Fuel



Design Option 2: Moderate Renewable



Deployment Strategies Overview: Site-Specific Installation



		Fossil Fuel Only Design Cost	Moderate Renewables Design Cost
Critical 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

Deployment Strategies Overview: Regional Community Microgrids



Regional Community Microgrids		Estimated Costs for Fossil Fuel Only Design	Estimated Costs for Moderate Renewables Design
Microgrid	# of 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

Key Takeaways

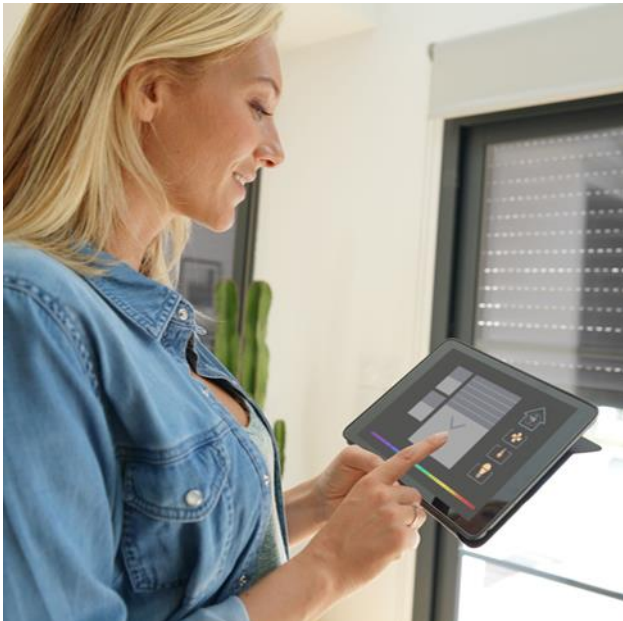


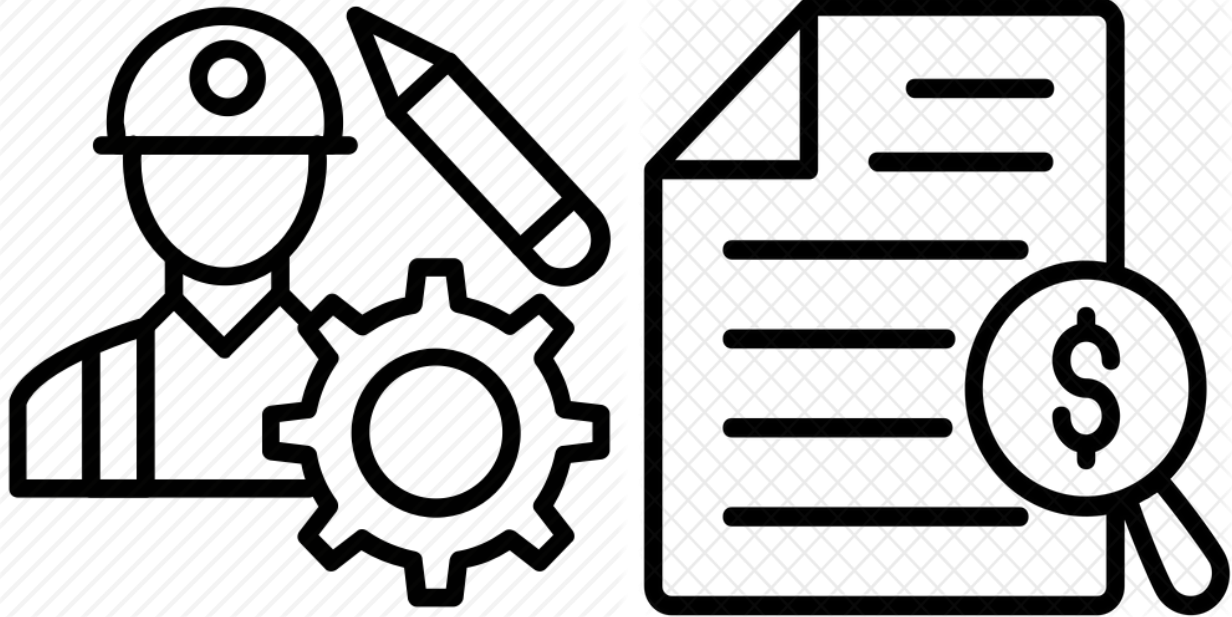
Engage all stakeholders early and often to socialize ideas, collect data, and to solicit input on microgrid deployment process

Prioritize critical facilities, natural hazards, reliability hotspots, population density, and low income communities

In rural areas, nanogrid installations may be necessary due to the limited number of critical facilities within a close proximity

A combination of nanogrid installations and regional community microgrids achieve increased resilience





Next Steps



- Conduct design & engineering work of the selected sites.

- Apply for FEMA and other funding to construct and install microgrids.

- Conduct further circuit, financial, and benefit-cost analysis of particular sites.

- Socialize with other states and community stakeholders to facilitate microgrid project success.

Who is eligible for BRIC funding?

Applicants:

- ✓ All 50 States
- ✓ U.S. territories
- ✓ Federally recognized Tribal Governments
- ✓ District of Columbia

Subapplicants:

- ✓ Local Governments
- ✓ Tribal Governments
- ✓ State Agencies
- ✓ Tribal Agencies



Q & A

Appendix

Microgrid Study Table of Contents



0.0 Executive Summary

1.0 Introduction

2.0 Data Collection - Population / Demographics, Critical Infrastructure Facilities, Natural Hazards, Tier 1 Hazards, Tier 2 Hazards, Utility and Electricity

3.0 Site Selection - Site Selection Criteria, Selection Results, Representative Site Selection Process Example

4.0 Preliminary Analysis and Deployment Strategies - Load Analysis, Sizing, Cost Estimate, and Deployment Strategy Methodology (includes a case study on the Fort Knox Military Microgrid Project) - Deployment strategy includes site-specific installations and regional community microgrid projects. Sizing analysis includes a fossil-fuel only option and a moderate renewable option.

5.0 Conclusion

6.0 Appendices - Appendix 1: Detailed Data Collection Methodology, Appendix 2: Site Selection Parameters by Critical Facility Type, Appendix 3: Detailed Load, Sizing and Cost Analysis.



Kentucky Public Service Commission



Kentucky Retail Federation



Kentucky Environmental Response Team



Kentucky Geological Survey



Kentucky Emergency Management



Duke Energy Kentucky



Kentucky Division of Water



**Louisville Gas & Electric
Kentucky Utilities**



Kentucky Petroleum Marketers Association



National Rural Electric Cooperative Association



Kentucky Office of Energy Policy

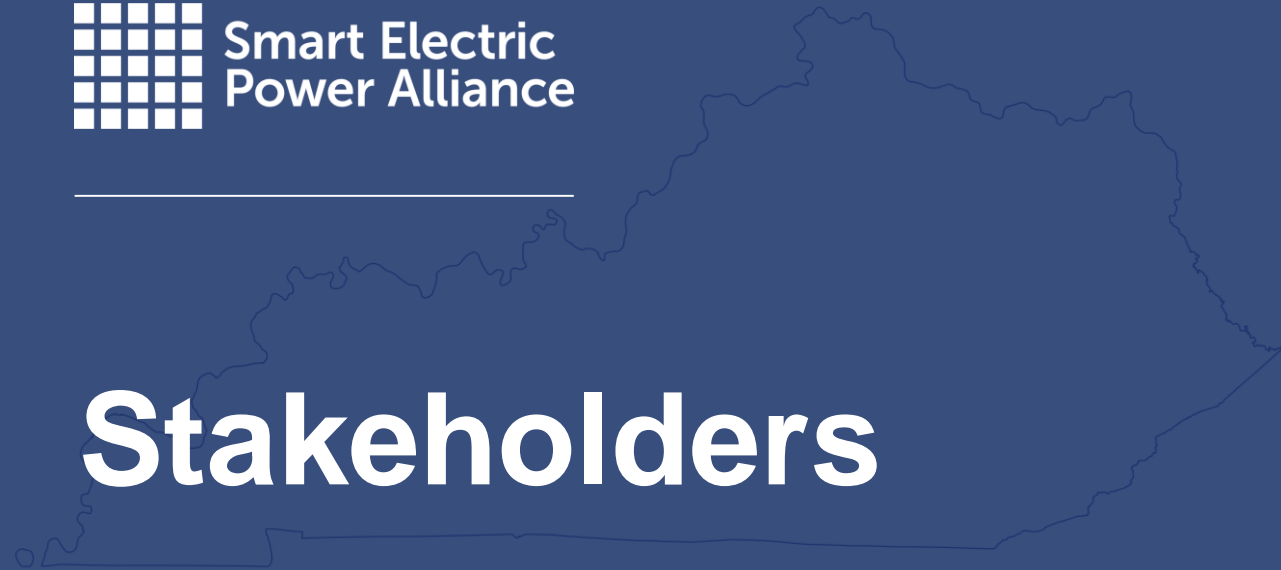


American Electric Power Kentucky



Smart Electric Power Alliance

Stakeholders



Critical Facilities Symbol Legend



Emergency Operations Centers



Hospitals



Cell Towers



Nursing Homes



Fire Stations



Water Treatment Plants



Gas Stations



Wastewater Treatment Plants



Grocery Stores



National Defense

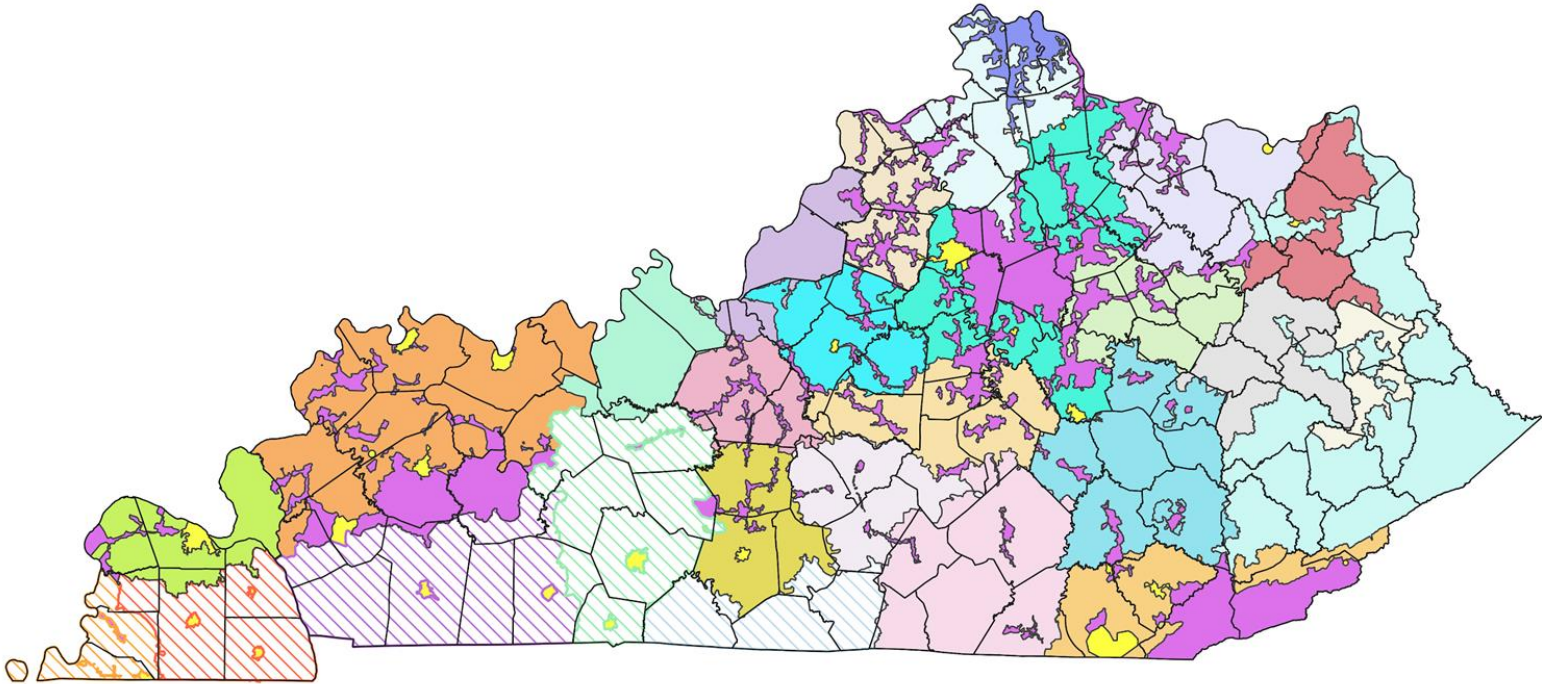


Law Enforcement Facilities

Electric Service Areas Map



Electric Service Areas



- | | | | | |
|-------------------------------------|-------------------------------------|-------------------------------------|---------------------------------|---------------------------------|
| Municipal Utilities | Fleming-Mason Energy Cooperative | Kentucky Power Company | Owen Electric Cooperative, Inc. | Warren RECC |
| Big Sandy R.E.C.C. | Gibson Electric Membership Corp. | Kentucky Utilities Company | Pennyrile RECC | West Kentucky RECC |
| Blue Grass Energy Cooperative Corp. | Grayson R.E.C.C. | Licking Valley R.E.C.C. | Salt River Electric Cooperative | Williamstown Utility Commission |
| Clark Energy Cooperative, Inc. | Inter-County Energy Cooperative | Louisville Gas and Electric Company | Shelby Energy Cooperative, Inc. | Kentucky_Counties |
| Cumberland Valley Electric, Inc. | Jackson Energy Cooperative | Meade Co & LG&E | South Kentucky R.E.C.C. | |
| Duke Energy Kentucky, Inc. | Jackson Purchase Energy Corporation | Meade County R.E.C.C. | Taylor County R.E.C.C. | |
| Farmers R.E.C.C. | Kenergy Corp | Nolin R.E.C.C. | Tri-County REMC | |

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

Site Selection Criteria & Data Sources



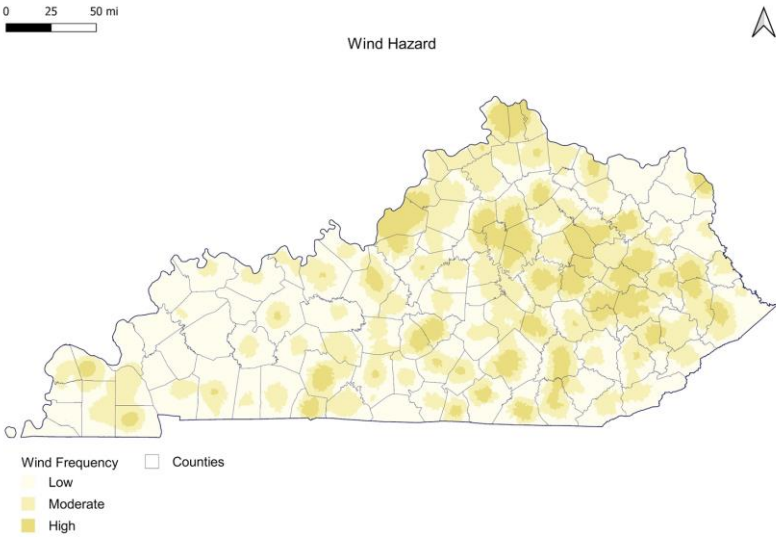
Criteria Type	Data Source	Criteria Description
Located at critical facility infrastructure	<ul style="list-style-type: none"> -HIFLD Cellular Towers -OEP Healthcare List -KIA Water Treatment Plants -KIA Wastewater Treatment Plants -Data Axle National Defense Facilities -HIFLD Local Law Enforcement Locations -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	<ul style="list-style-type: none"> -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	<ul style="list-style-type: none"> -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	<ul style="list-style-type: none"> -Kentucky Public Service Commission Annual Reliability Report Data 	Located within or nearby a reliability hotspot
High population density	<ul style="list-style-type: none"> -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	<ul style="list-style-type: none"> -U.S. DOE Low-Income Energy Affordability Data Tool (LEAD) 	Located in the county with the highest energy burden, relative to the region.

Load Profile Sources

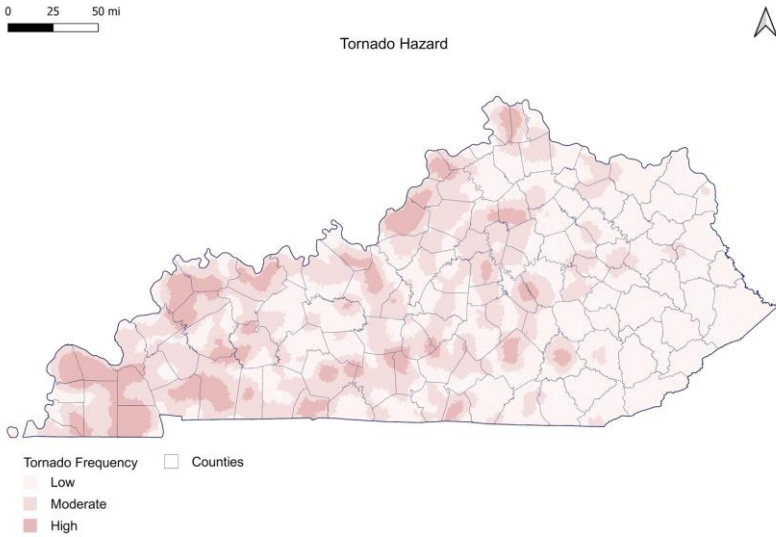


1. **Cell Towers** – SEPA estimated the load profile of the 56 cell towers identified in the site selection process based on Huawei Technologies’ breakdown of the power consumption for 4G and 5G mobile networks.
2. **Hospitals** – obtained from the OpenEI database based on a hospital in Lexington, Kentucky.
3. **Nursing Homes** – obtained from the Open EI database and were based on a midrise apartment sized to 25,000 square feet.
4. **Water and Wastewater Treatment Plants** – obtained from American Electric Power (AEP).
5. **National Defense Facilities** – based on data obtained from a U.S. utility
6. **Law Enforcement Facilities** – obtained from AEP.
7. **Fire Stations** – obtained from AEP
8. **Emergency Operations Centers** – obtained from OpenEI database
9. **Gas Stations** – obtained from AEP
10. **Grocery Stores** – obtained from AEP

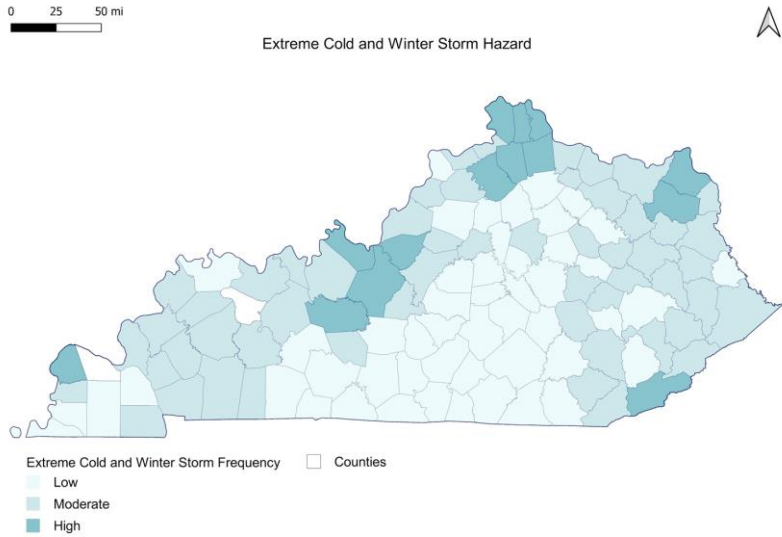
Heatmaps of Tier 2 Hazards



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



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



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

Site-Specific Selection Results



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	1273	70	5%
Communication	669	56	8%
Gas Stations	1973	110	6%
Fire Stations	1103	90	8%
National Defense	26	5	19%
Total	6640	558	8%

Regional Community Selection Results Table



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.

Representative Site Selection Process Example



0 25 50 mi

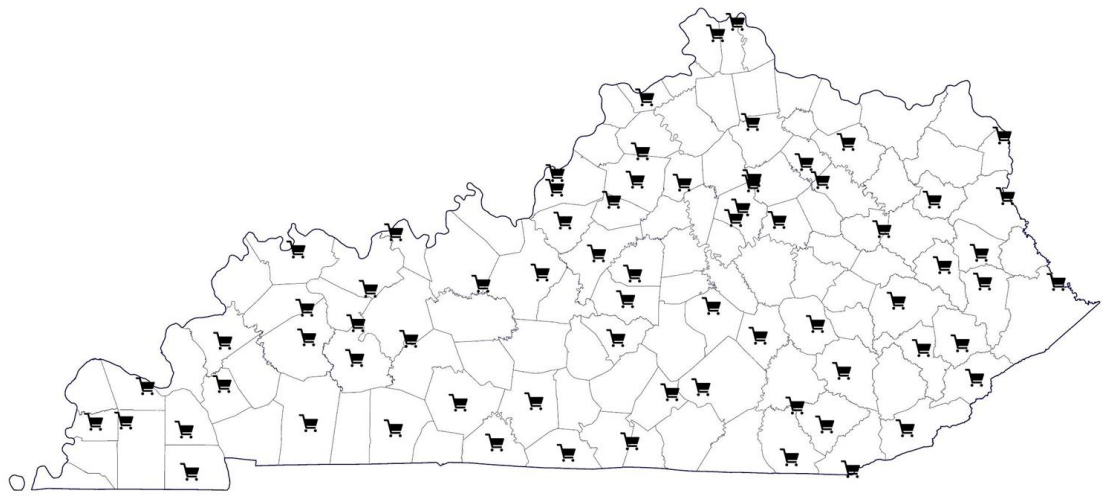
All Grocery Stores Considered in Site Selection Process



 Grocery Store
 Counties

0 25 50 mi

Grocery Stores Selected as Site Specific Microgrid Locations



 Grocery Store
 Counties

Representative Site Selection Process Example



For Grocery Stores, 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.

Caveats to Site 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.