Microgrid feasibility for municipal applications

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Agenda

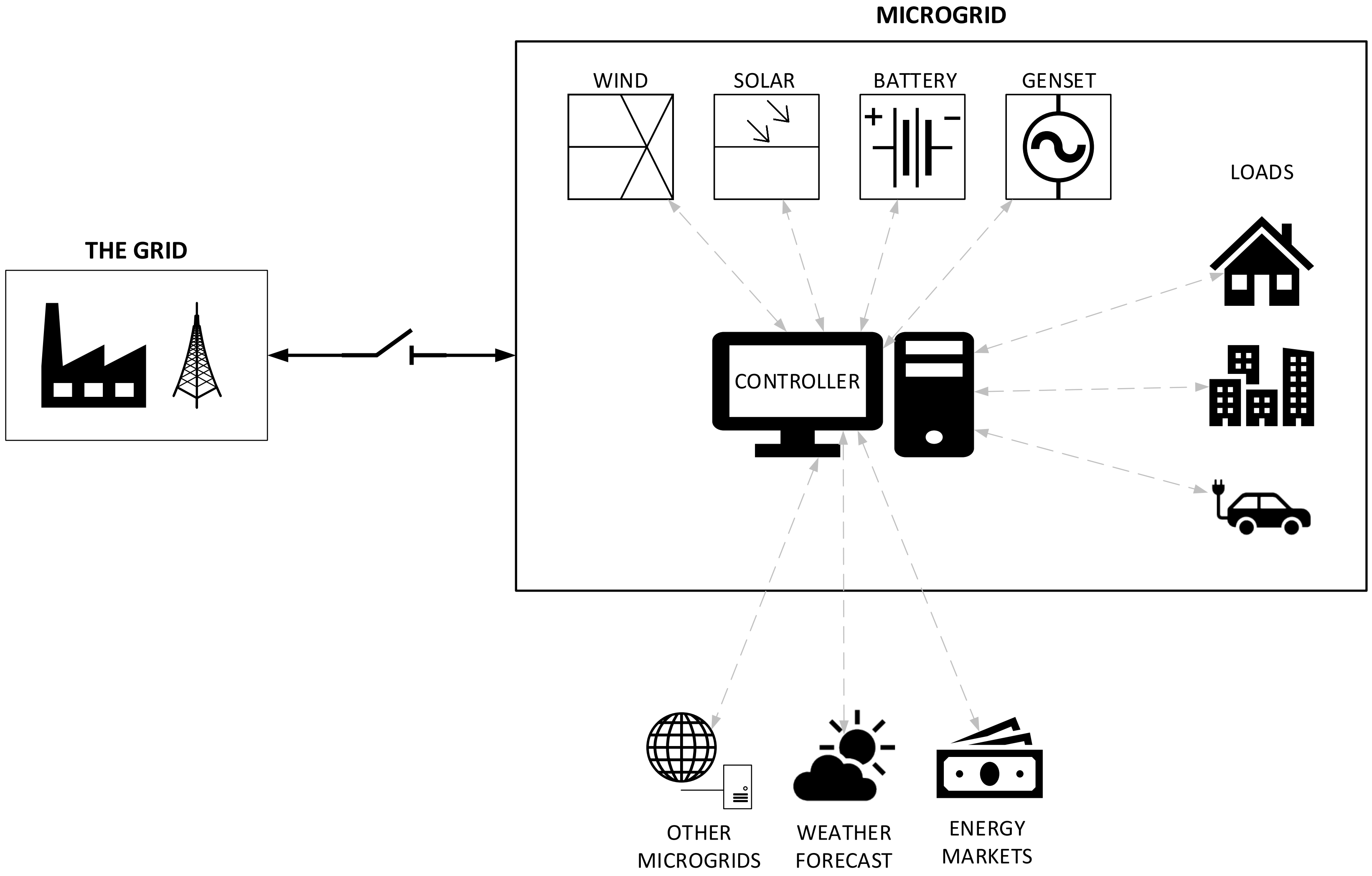
Background and methods

Sun Prairie results and takeaways

Madison results and takeaways

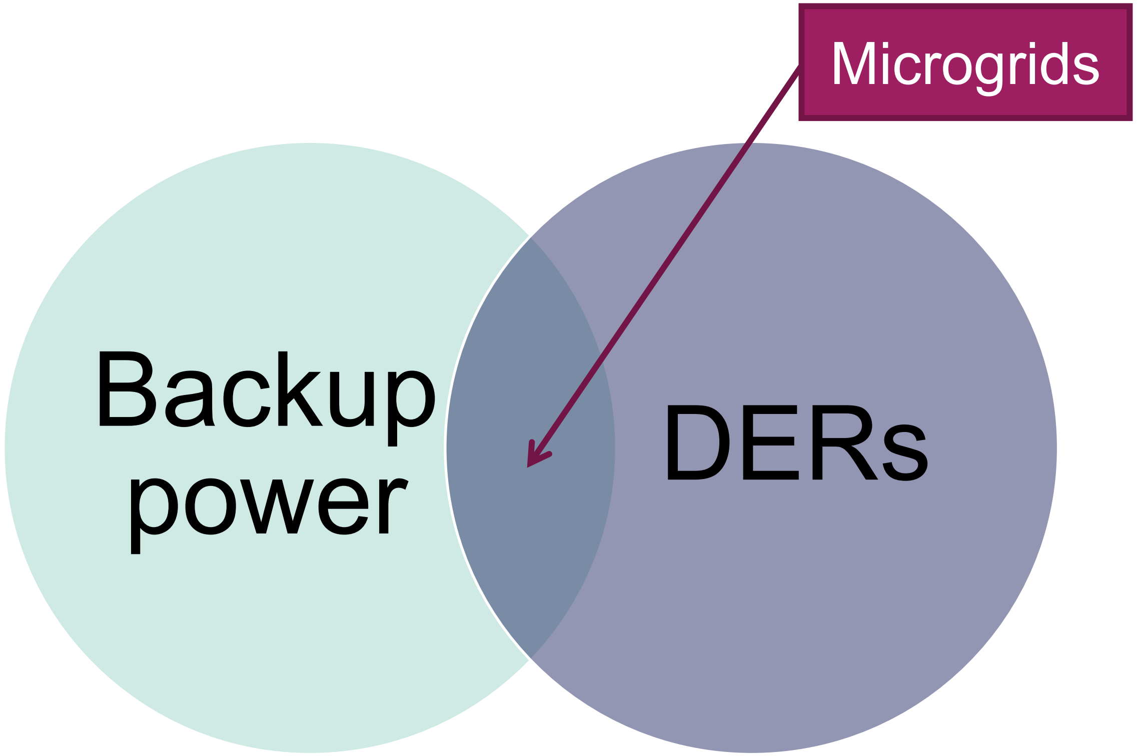
"A group of interconnected loads and distributed energy resources […] that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode"

-- DOE Microgrid Exchange Group



Key concepts

- Microgrids are about more than just backup power
- Solar PV on its own cannot provide backup power
  - Interconnection rules (IEEE 1547) require inverters to stop producing power when grid disturbances detected



Project overview

Climate Change

- Resiliency needs
- Constrained grid
- Emissions reduction urgency

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Electrification

- Higher electric bills
- Electrical upgrades needed
- Choice of power source

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Microgrids

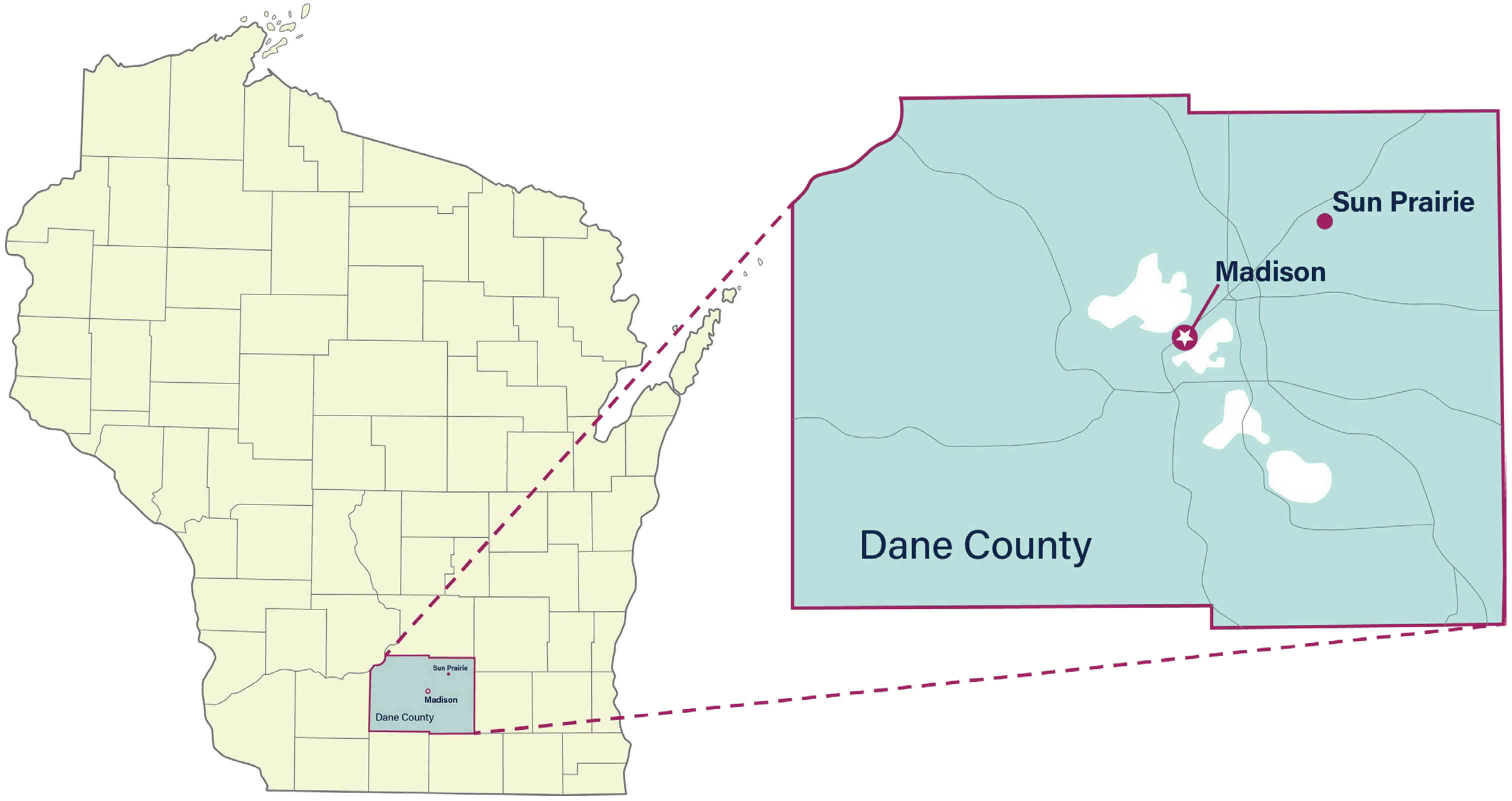
- More DERs
- Greater resiliency

Project overview

Goal: evaluate environmental, resiliency, and financial benefits of microgrids

Technology: battery energy storage system and solar PV

Funding: Wisconsin Office of Energy Innovation



Methods

Methods

Evaluate tools that allow for analysis of microgrid critical features

Collect energy, cost, technology, and site data

Explore initial scenarios and compare high-level results

Select final scenarios and summarize costs and benefits

Stakeholder Engagement

Stakeholder Engagement

- How does the site fit into the city resiliency plan?
- What key functions are needed during outages?
- How long should the microgrid have power during outages?
- What will the utility's role be?
- How does the site fit into the city climate plan?

REopt Optimization

Drivers
- Energy charges
- Resilience goals
- Environmental goals

Technologies
- Solar PV
- Battery storage
- Diesel generator

Loads
- Normal operations
- Critical load

REopt Tool

Optimized Minimum Cost Solution

System design
- PV size
- Battery size

System financial
- Net present value
- Total capital costs

Resiliency values
- Duration curves
- Average outage

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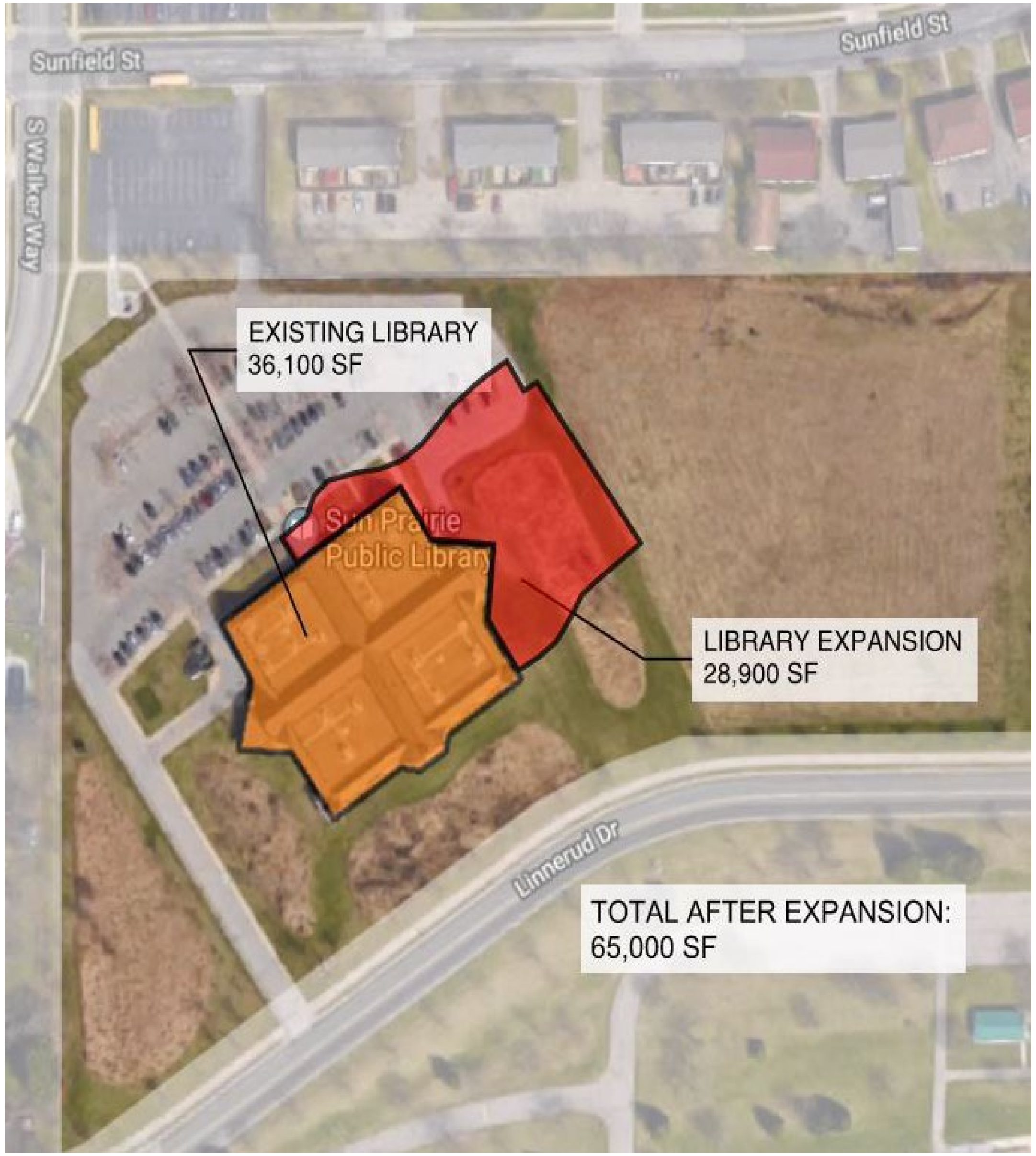


Sun Prairie

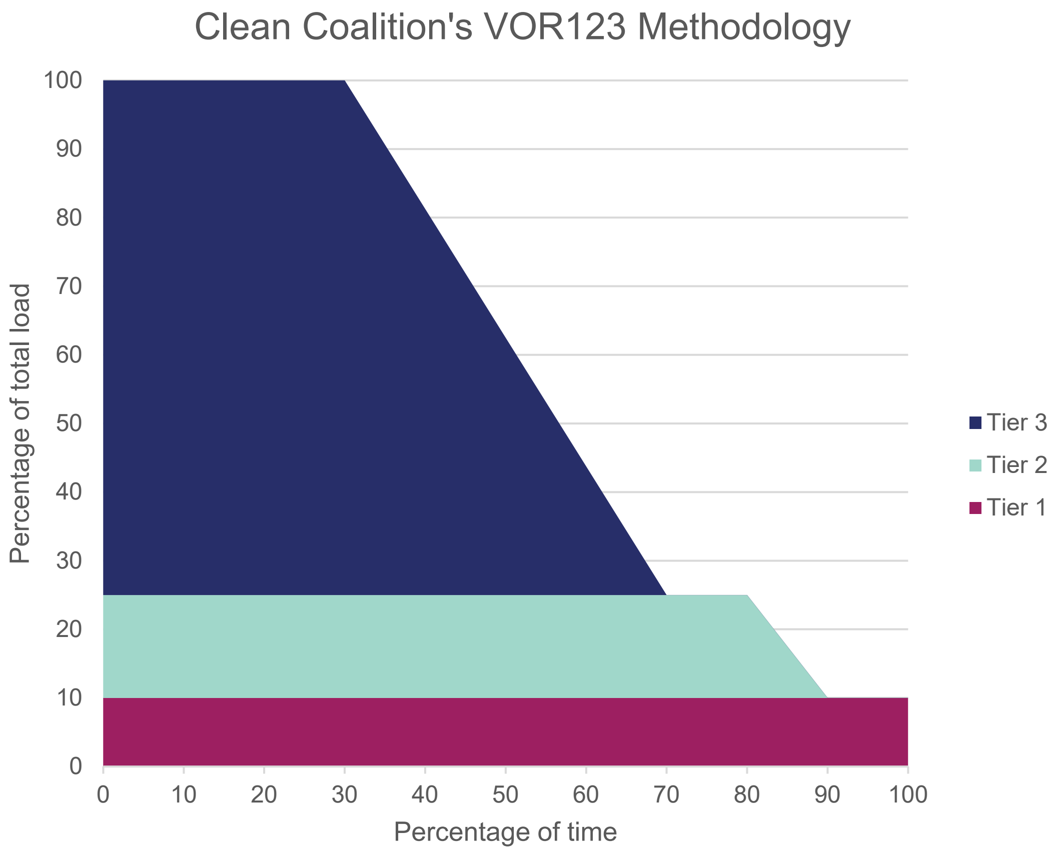
City of 36,000+ people

Interested in utilizing public library as Community Resiliency Center

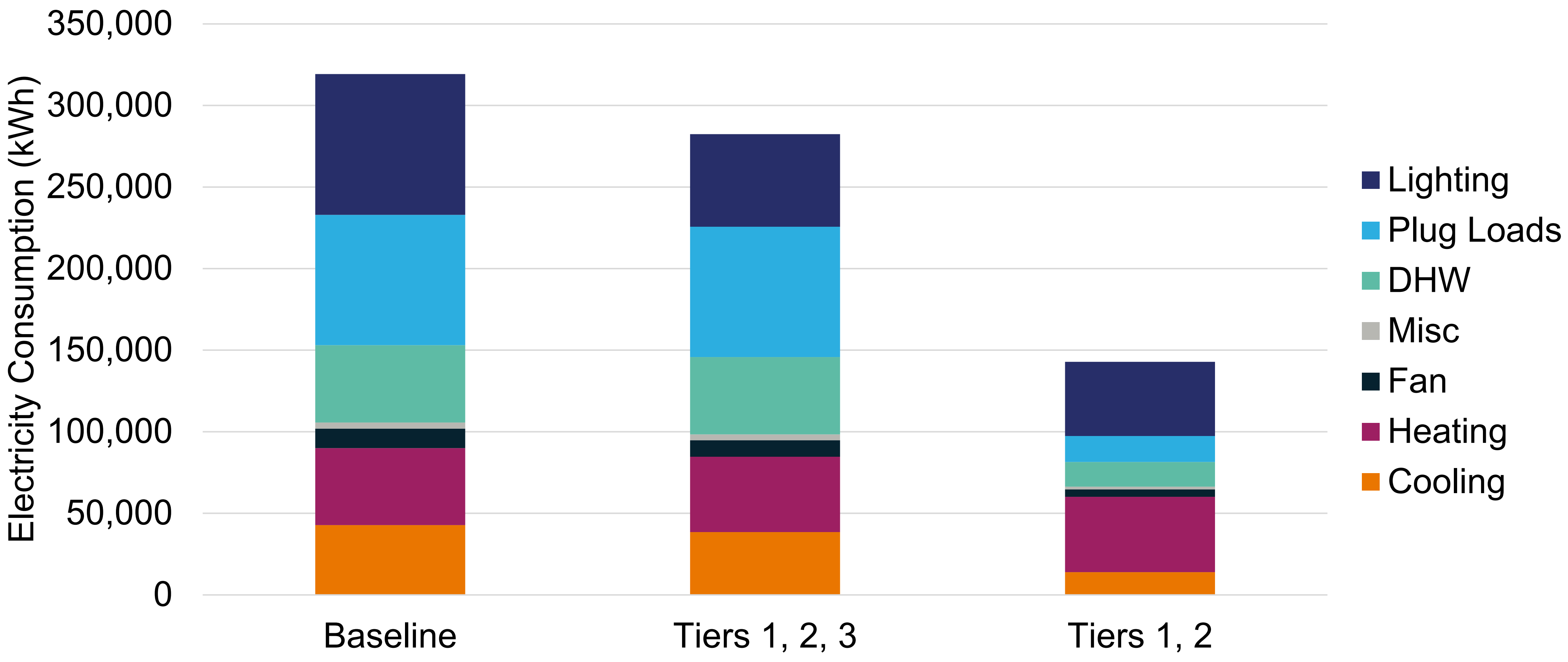
Renovation/Expansion planned for 2024; no existing distributed energy resources

Defining Critical Load Tiers

- Categories:
  - Tier 1: Critical and life-sustaining loads
  - Tier 2: Priority loads
  - Tier 3: Discretionary loads
- Loads within a tier should never interfere with higher priority loads



Sun Prairie Energy Modeling



Sun Prairie Alternative Scenarios

Inputs	4 Hour Full Load	24 Hour Critical Load
Heating system	All-electric VRF system	All-electric VRF system
Rate structure	Time-of-use	Time-of-use
Critical loads	Tiers 1, 2, 3	Tiers 1 and 2
Outage length	4 hours	24 hours
Outage timing	June 19 1-5 pm	June 19 1 pm – June 20 1 pm
Renewable energy requirement	No constraint	No constraint
Health and climate costs	Not included	Not included

Sun Prairie Performance Outputs

Scenario	4 Hour Full Load	24 Hour Critical Load
PV size (kW)	144	128
BESS capacity (kW)	28	26
BESS energy (kWh)	45	128
Annual Percent Renewable Energy	54%	48%
Resiliency Hours (Average)	3.5	35
Net present value ($)	$27,000	$7,200
Simple Payback	17.2	18.9

Takeaways

- Battery size and cost increases with load and outage duration
- All-electric heating systems improve financial performance
- Systems covering shorter outages perform better financially but have lower resiliency
- Resiliency is highest in spring and fall, lowest in winter
- Putting a dollar value on societal benefits causes the NPV to increase over 10 times compared to the same building with no solar PV

Recommendations

- Specify a battery that can power critical loads for at least 24 hours
  - 26kW (size) / 128kWh (duration) BESS for ~$80,000
  - 128kW Solar PV array ~$225,000
- Consider all-electric HVAC solution
- Consider the resiliency and carbon benefits of microgrid/CRC
- Pursue potential grant funding options (WI OEI, US DOE)

Operational & Community Resiliency

Reviewed existing emergency operations plan and community shelter locations

Inventoried backup generators and identified potential upgrades

Highlighted opportunities for both CRCs and EOCs in the community

Reviewed backup generation procurement process and updated with microgrid option

Used plan for community resiliency efforts, mapped CRCs, and upgraded EOC capabilities

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Background and methods

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Madison

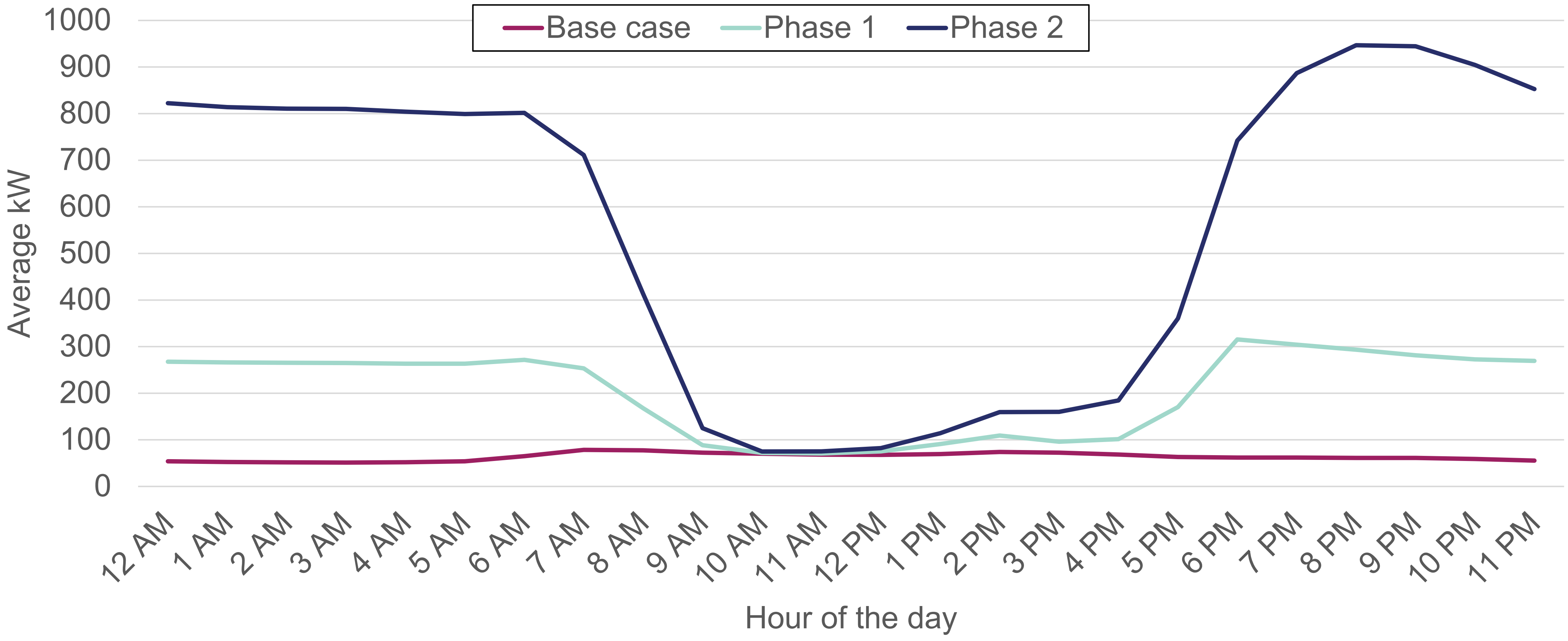
City of 269,000 people

Two adjacent critical infrastructure facilities

409 kW of rooftop solar planned; diesel and natural gas generator

Plan to electrify fleet of 230 vehicles

Fleet electrification load



Madison Alternative Scenarios

Inputs	Base case	Phase 1	Phase 1 BESS	Phase 2	Phase 2 BESS
Normal load profile	Facility	Facility + phase 1 EVs	Facility + phase 1 EVs	Facility + phase 2 EVs	Facility + phase 2 EVs
Critical load profile	Facility	Facility	Facility	Facility + phase 1 EVs	Facility + phase 1 EVs
Battery constraint	<10 MWh	<10 MWh	**=10 MWh**	<10 MWh	**=10 MWh**
Annual kWh	552,000	1,780,000	1,780,000	5,430,000	5,430,000

Madison Performance Results

Scenario	Base case	Phase 1	Phase 1 BESS	Phase 2	Phase 2 BESS
BESS capacity (kW)	40	49	417	73	1,308
BESS energy (kWh)	52	65	10,000	96	10,000
Initial Capital Costs	$51,000	$63,000	$4,203,000	$94,000	$4,894,000
Net present value	$5,700	$8,200	-$6,272,000	$7,500	-$5,443,000
Simple Payback	0	0	17	1	>25
Annual Total Renewable Energy	110%	34%	33%	11%	11%
Lifecycle CO_2 emissions (tons)	-1,300	22,400	19,600	92,700	84,800
Resiliency Hours (Avg)	218	218	3,240	10	97

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Lessons Learned
Madison

Accounting for resiliency and emissions

	Base case	Phase 1	Phase 2	Phase 1 BESS	Phase 2 BESS
Total cost	$122,200	$208,600	$211,000	$7,503,000	$8,210,400
Energy benefit	$319,600	$274,400	$233,500	$388,900	$282,400
Resiliency benefit	$2,248,900	$2,746,700	$916,200	$2,746,700	$6,633,300
NPV with resiliency	$2,446,300	$2,812,500	$938,700	-$4,367,400	-$1,294,700
Emissions benefit	$0	$91,200	$92,500	$924,800	$2,285,200
NPV with emissions + resiliency	$2,446,300	$2,903,700	$1,031,200	-$3,442,600	$990,500

Takeaways

First concrete exercise in estimating the size and cost of a battery

Highlighted impact of seasonal and critical usage of an electric vehicle fleet

Developed checklist for “microgrid-ready” buildings

Next Steps

Smart inverters
- Upgrade existing inverters
- Implement SunSpec Modbus for local control

BESS
- Perform a site survey to identify locations
- Develop a battery and/or microgrid controller spec

Smart charging of EVs
- Upgrade existing chargers
- Implement managed charging


ENERGY.GOV

Department of Energy

DOE Invests $61 Million for Smart Buildings that Accelerate Renewable Energy Adoption and Grid Resilience

OCTOBER 13, 2021

Energy.gov »

DOE Invests $61 Million for Smart Buildings that Accelerate Renewable Energy Adoption and Grid Resilience

Ten "Connected Communities" Will Equip More than 7,000 Buildings with Smart Controls, Sensors, and Analytics to Reduce Energy Use, Costs, and Emissions

Conclusion

Lessons Learned

- Ensure microgrid fits within your larger city resiliency plan.
- Prioritize data collection and start early (and consider implementing a data collection plan across critical facilities).
- Identify and inventory the critical loads of the site with stakeholder input.
- Dedicate time to defining the monetary value of resiliency to the facility.
- Run several scenarios to be able to visualize tradeoffs before determining key alternatives.

Thank you!

Project summaries and final reports:

www.slipstreaminc.org/research/microgrids-resilient-communities

Extra slides

Key terms

Islanding

The ability of a microgrid to disconnect from the grid while still serving loads internally

Resiliency

The ability to withstand and reduce the magnitude and/or duration of disruptive events

DERs

Distributed energy resources such as solar photovoltaics and battery energy storage systems (BESS)

Electrification

Conversion of fossil fuel-burning end uses (heating, driving, cooking) to electric powered alternatives

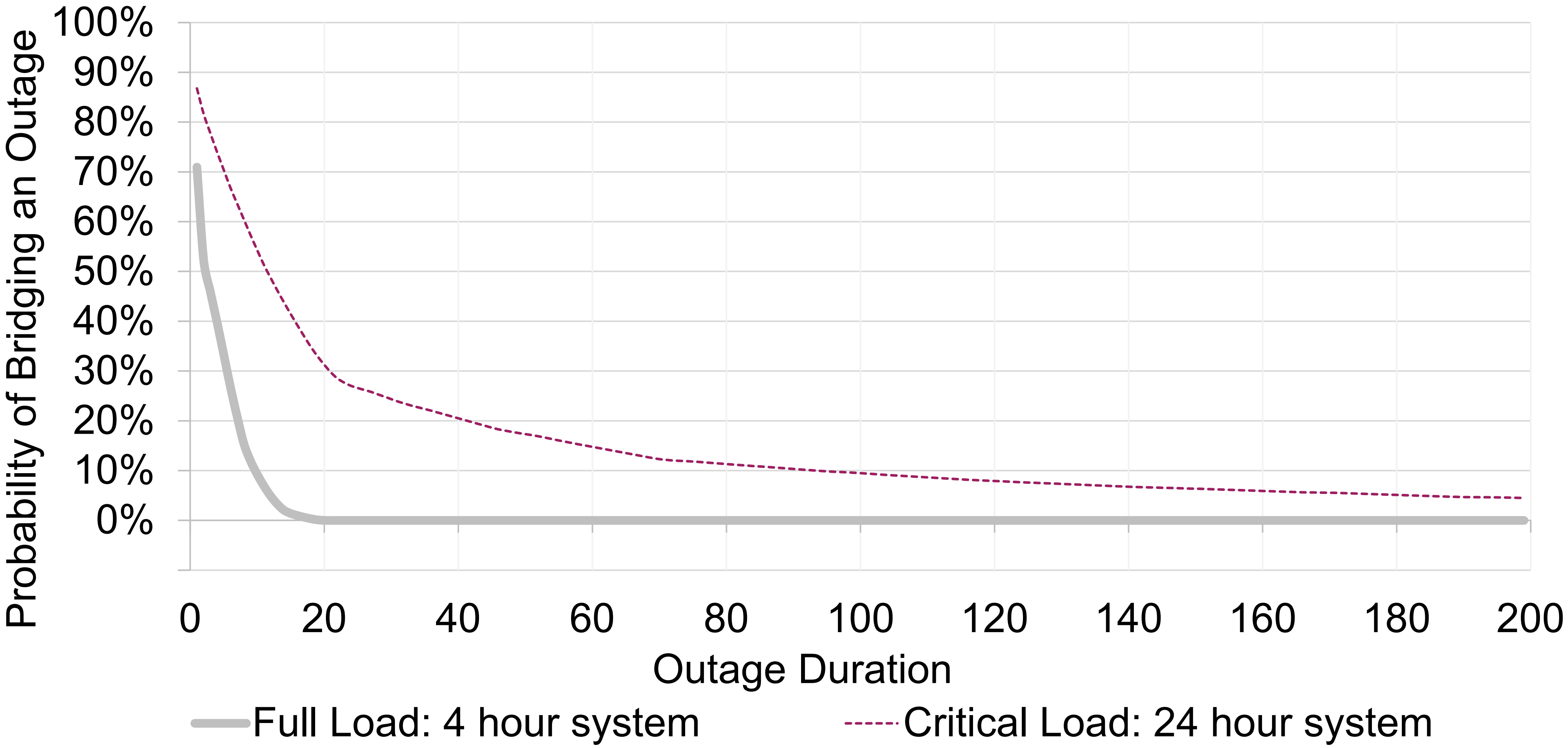
CRC

Community resilience center

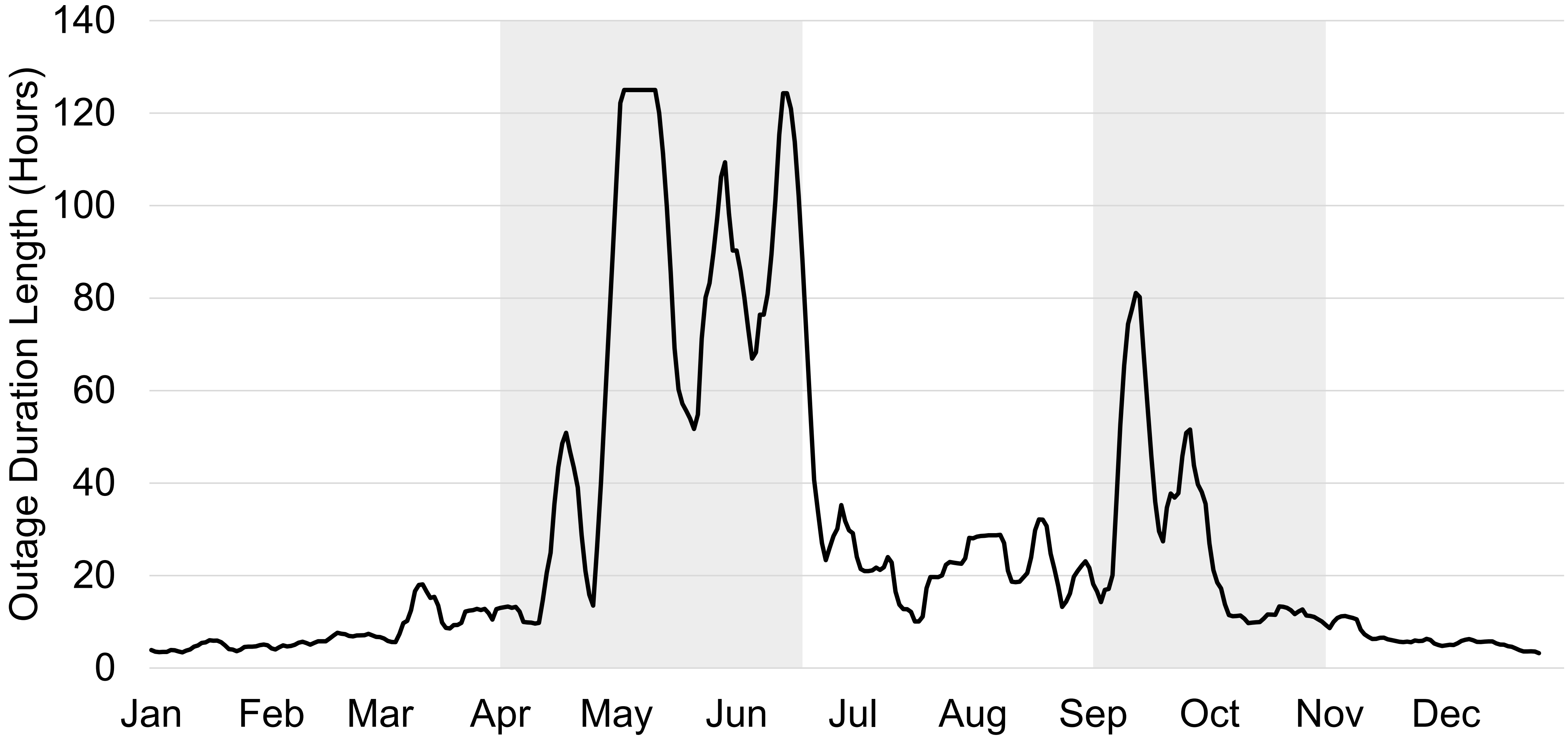
EOC

Emergency operations center

Sun Prairie Resiliency Results



Sun Prairie Resiliency Across the Year



Sun Prairie Building Recommendations

- Include energy efficiency in library renovation
  - Lighting
  - HVAC system
  - Plug load control
  - Small embedded data center
- Utilize microgrid ready design for a phased installation approach
  - Consider location for future battery (inside or outside)
  - Install compatible inverters on Solar PV