Microgrid feasibility study for Madison Streets and Engineering facilities

Lee Shaver, Energy Engineer
Slipstream

Sustainable Madison Committee
29 September 2022

Agenda

Introduction

- What is a microgrid?
- Project overview
- Site overview

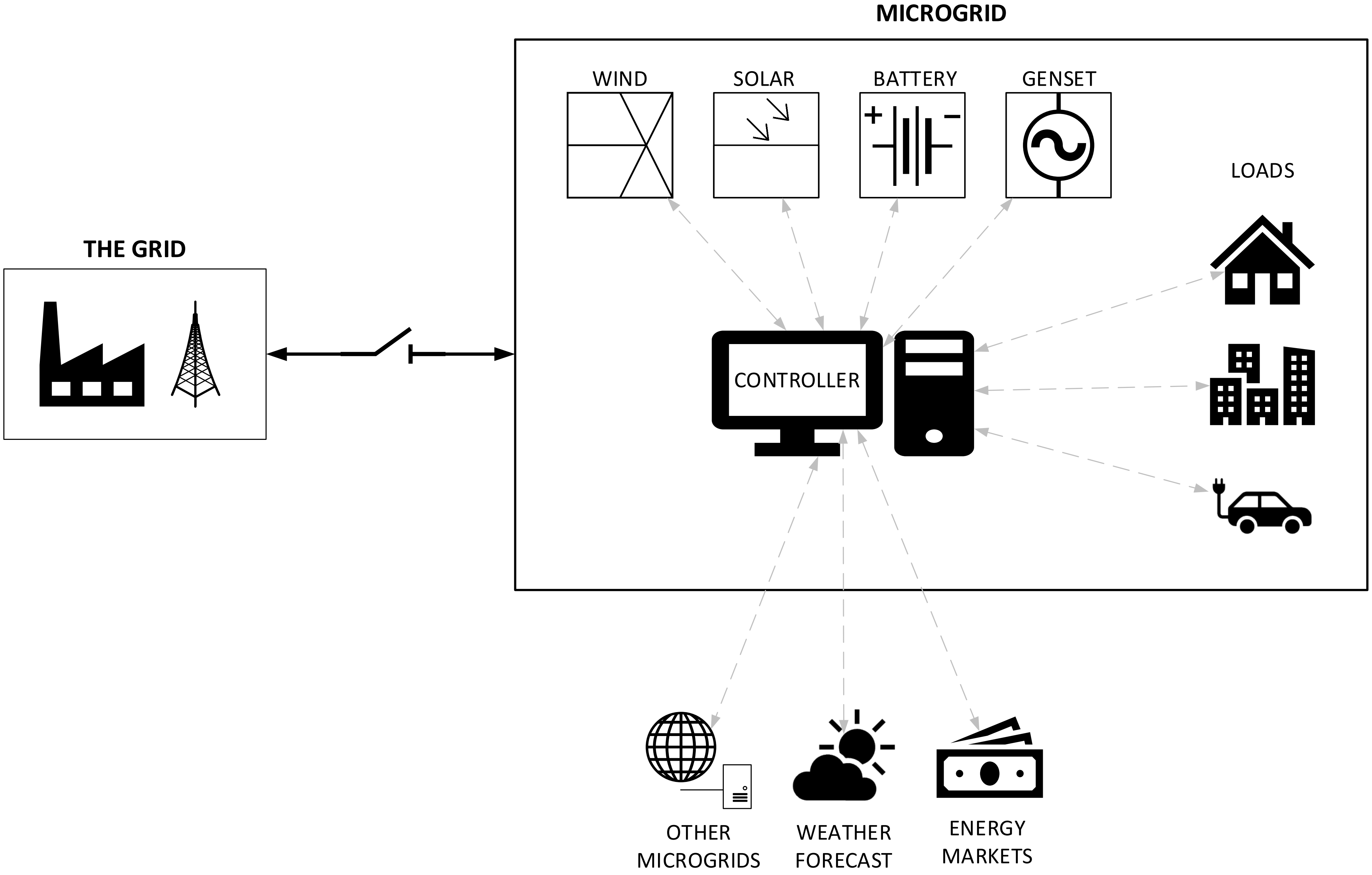
Microgrid optimization

- Fleet electrification
- Scenarios
- Results

Next steps

“A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode”

DOE Microgrid Exchange Group

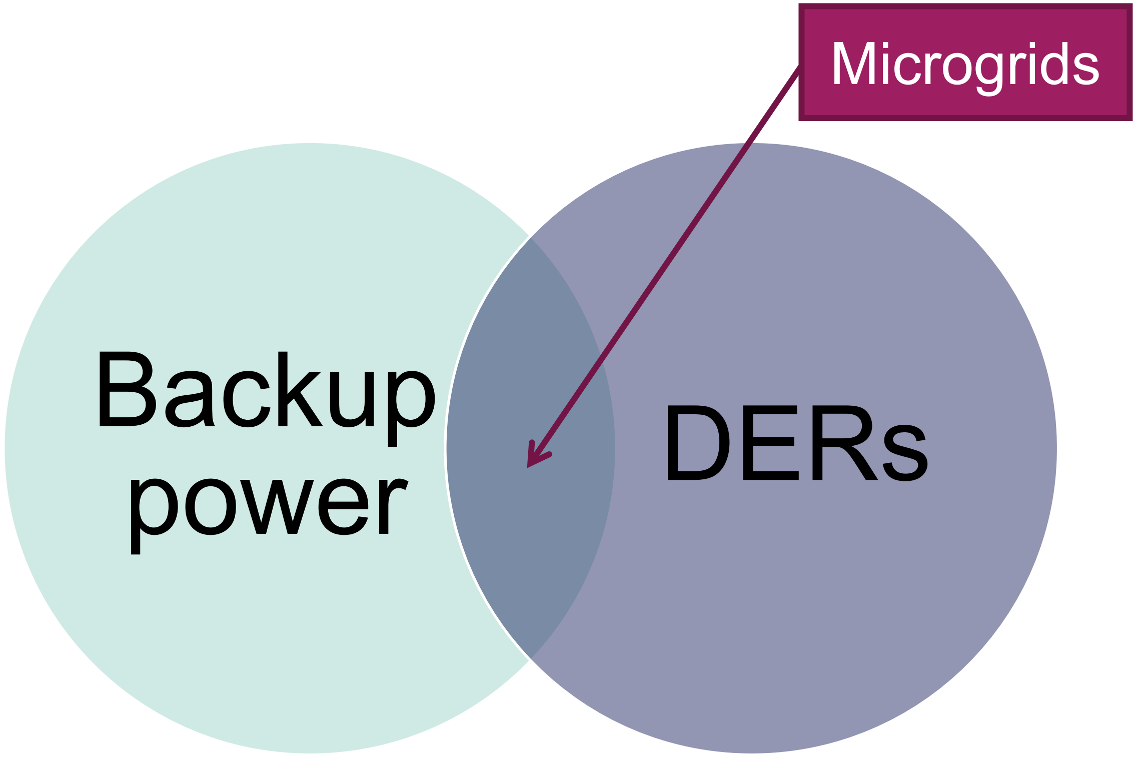

MICROGRID
WIND
SOLAR
BATTERY
GENSET
LOADS
THE GRID
CONTROLLER
OTHER MICROGRIDS
WEATHER FORECAST
ENERGY MARKETS

Key terms

Islanding	Resiliency	Net metering	Electrification
The ability of a microgrid to disconnect from the grid while still serving loads internally	The ability to withstand and reduce the magnitude and/or duration of disruptive events	A policy which compensates power sold back to the grid at the same rate as consumption	Conversion of fossil-fuel end uses (space- and water-heating) to electric

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 background

Climate change leads to

- Greater resiliency needs
- More constrained grid
- Emissions reduction urgency

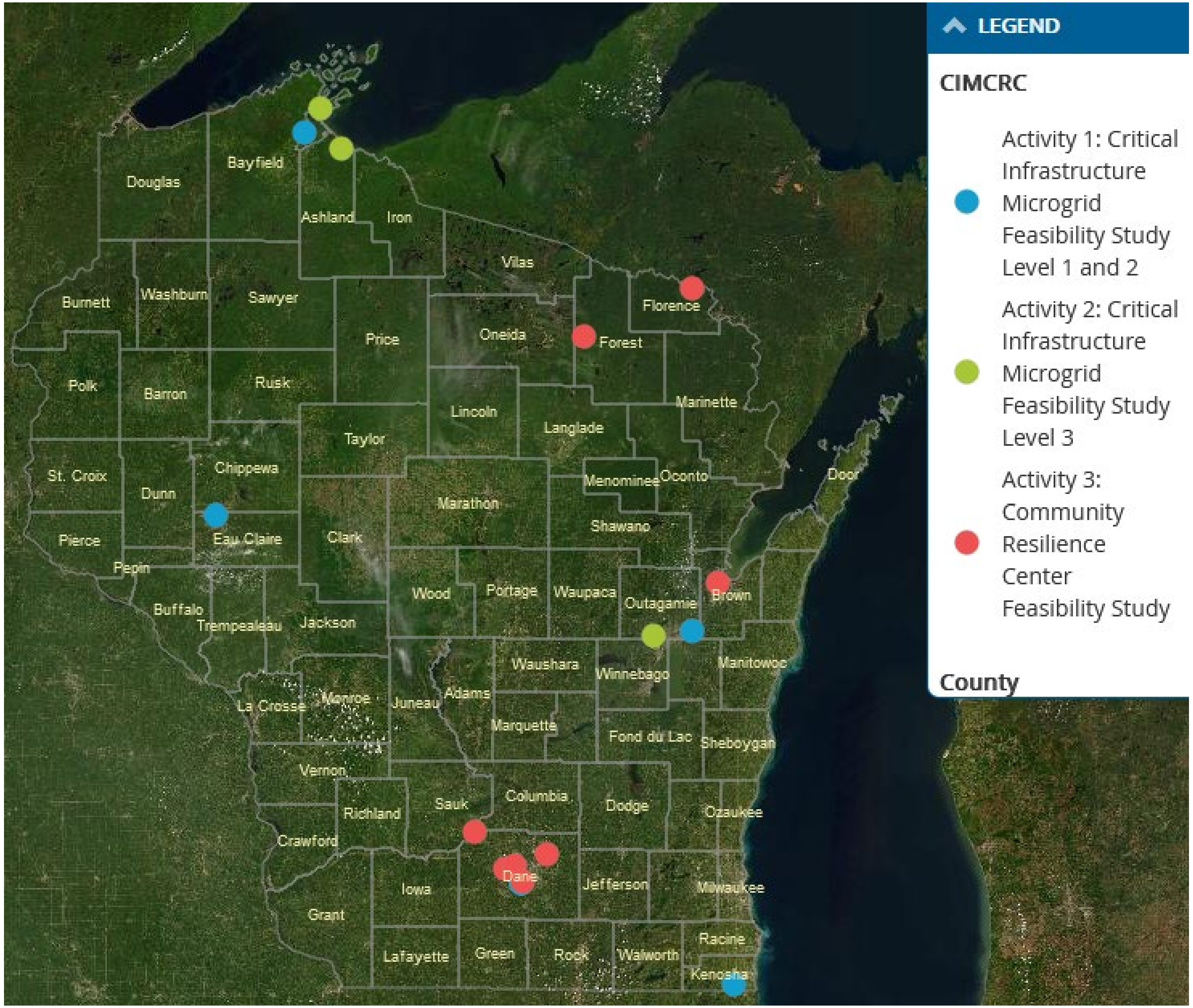
Microgrids!

Fleet electrification leads to

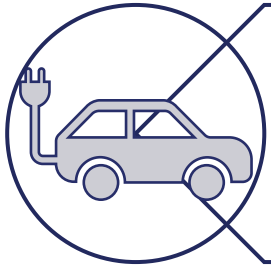
- Higher electric bills
- Electrical upgrades needed
- An opportunity to reduce grid emissions

Project background

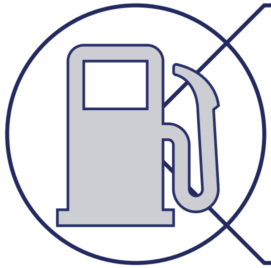
- The PSC's Office of Energy Innovation funded 15 feasibility studies to address "innovative pre-disaster mitigation through critical infrastructure microgrids."
- Slipstream and Madison submitted a proposal focusing on the Streets/Engineering site



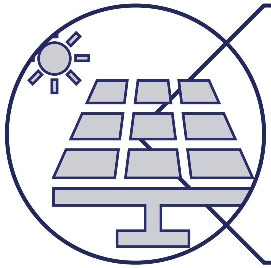
Why this site?



8 EVs currently, with plans to electrify all 200+ of the remaining vehicles

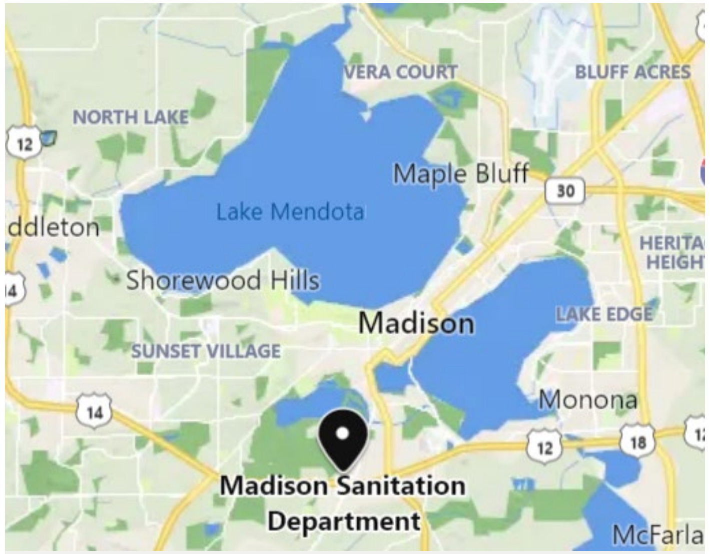


Two backup generators with associated infrastructure and controls



200 kW of existing solar PV, with an additional 200+ kW planned

Site overview



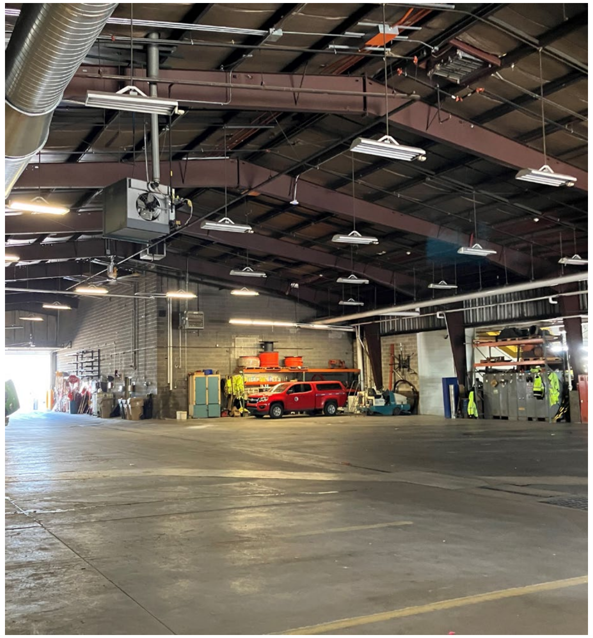
LOCATION

ENGINEERING OPERATIONS

60,940 square feet. Office, Service, Garage. Multiple additions (2006, 2017).

STREETS WEST

75,922 square feet. Office, Service, Vehicle Garage. Ongoing retrofits.

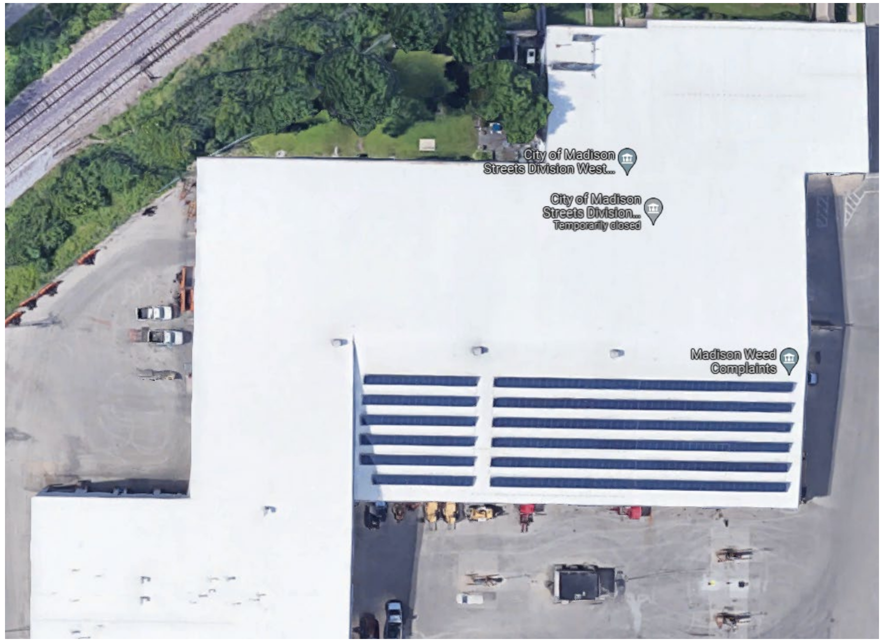


Engineering Operations: Spaces

Engineering Operations: Electric Vehicles

Engineering Operations: PV (and more to come)

Streets West: Spaces



Streets West: PV (and more to come)

Microgrid optimization

Research questions

What are the key functions the facility should be able to provide?

What are the additional benefits the City of Madison hopes to receive from the microgrid?

What are the potential system configurations to serve those functions?

- Length of outages to cover
- Load curtailment
- BESS capacity and duration
- Vehicle electrification schedule

What are the associated costs and benefits of each configuration?

- Environmental benefits
- Capital cost
- O&M costs
- Bill savings or revenue potential

Fleet electrification schedule

Load profile	Additional EVs	Additional kWh	Total kWh	Load growth vs baseline
Baseline	8	552,000	552,000	-
Phase 1	117	1,231,000	1,783,000	323%
Phase 2	105	3,656,000	5,439,000	985%
Total	**230**	**5,439,000**		

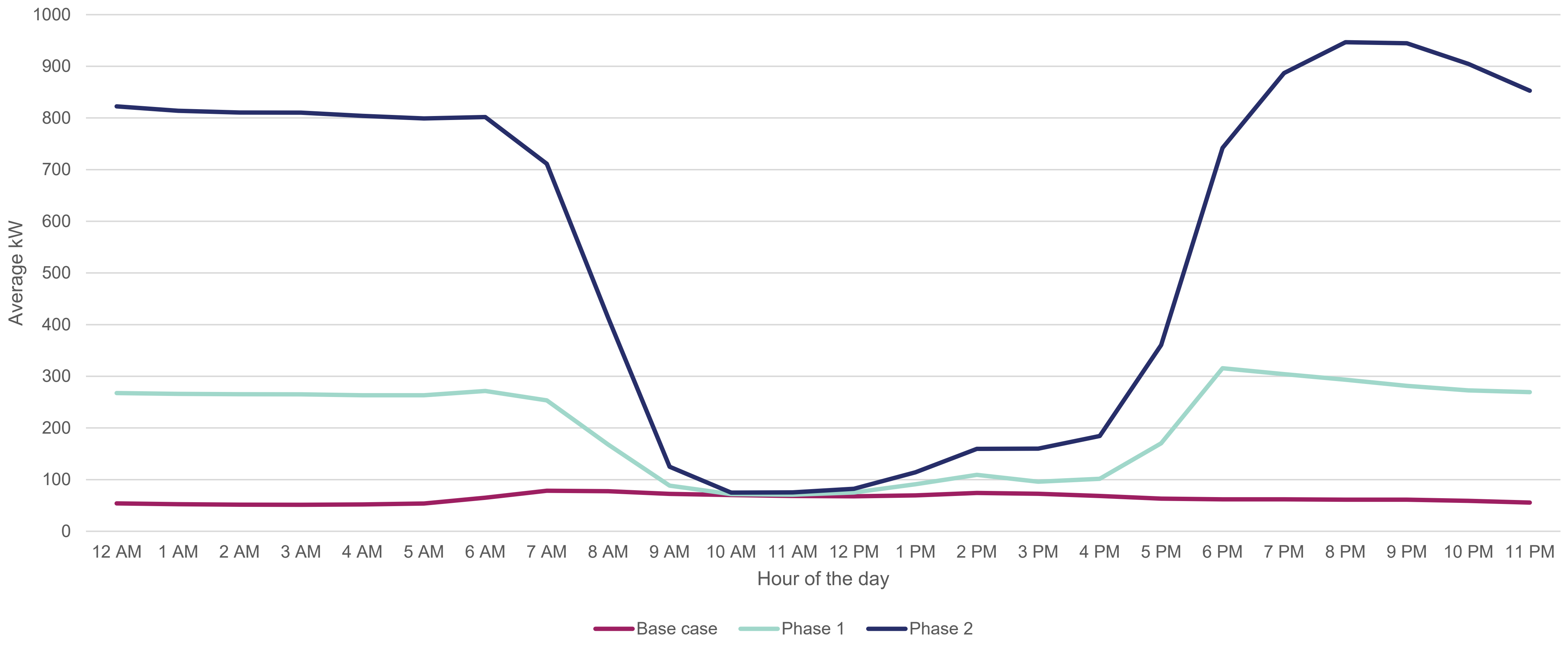
Additional considerations:

Will the fleet size change?

Which vehicles must charge during outages?

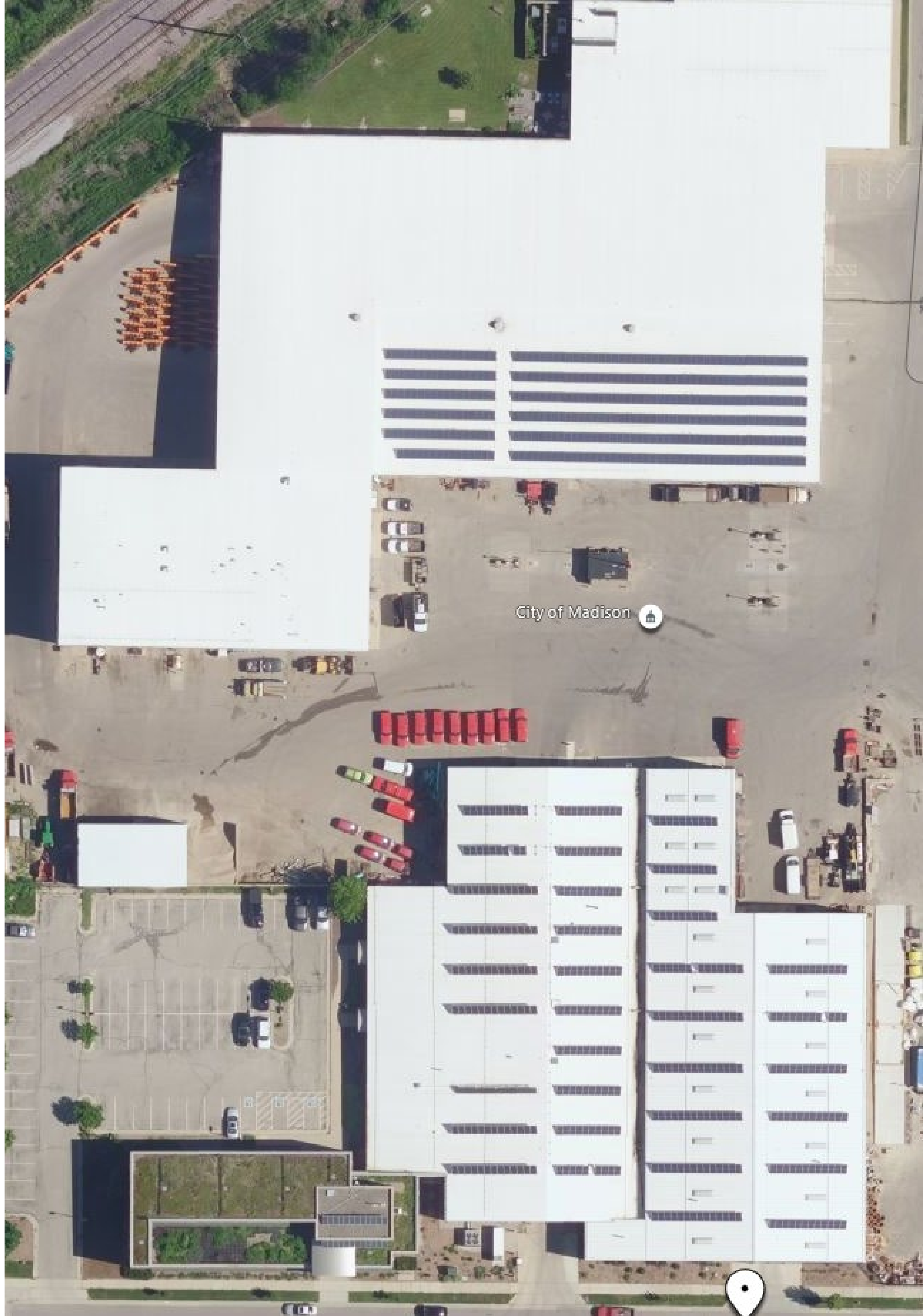
What about staff personal vehicles?

Fleet electrification load



This is what 200 kW of PV looks like

~500 kW is the limit of solar potential on rooftops at this site

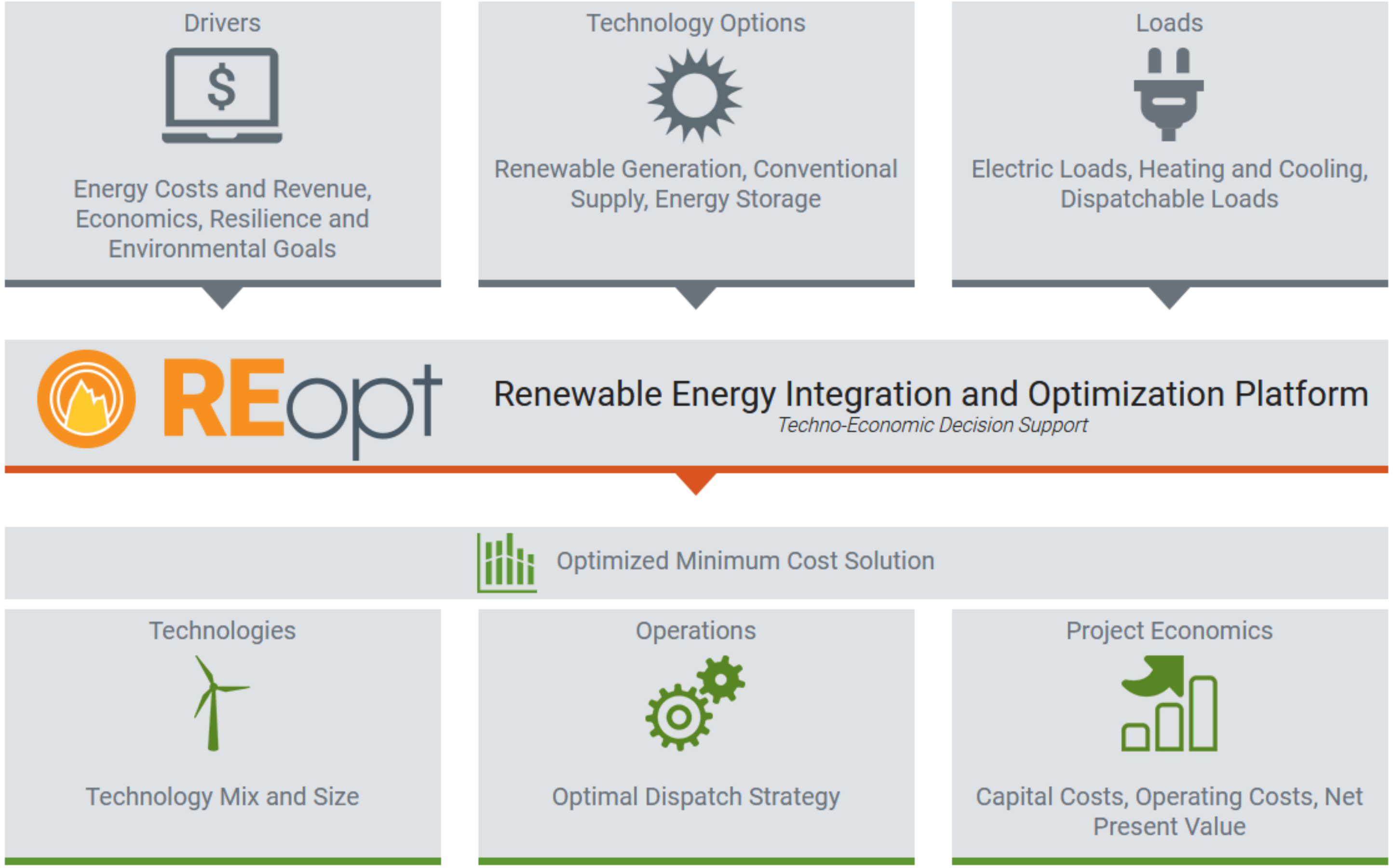


REopt Optimization

- Cost of carbon
- Health costs
- Emission reduction goal

- Generator
- Existing and planned PV
- BESS

- Load profile
- Planned fleet electrification



Constant Inputs

Variable	Input	Source
Load	Interconnected facilities	
Solar PV capacity	483 kW	Existing and planned
Net metering limit	100 kW	
BESS $/kWh	$388	NREL + Lazard
BESS $/kW	$775	NREL + Lazard
Utility Rate ($/kWh)	On-peak: $0.114 Off-peak: $0.053	MGE CG-4 C&I TOU Level B Three-Phase
Wholesale Rate ($/kWh)	On-peak: $0.047 Off-peak: $0.034	MGE
Emissions data	Hourly values for Upper Midwest	AVERT
Carbon Price	$51/ton	Federal value
Health costs ($/ton)	NO_x: $19,452 SO_2: $40,551 PM2.5: $139,804	NREL defaults based on CACES EASIUR model

Scenario details

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

Load profiles: Four basic scenarios

		Normal load		
		Facility	**+ Phase 1 EVs**	**+ Phase 2 EVs**
Critical load	**Facility**	Base case	Scenarios 1 and 2	
	+ Critical Phase 1 EVs			Scenarios 3 and 4

Scenario 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
Emissions reduction	-	2%	14%	1%	9%
Resiliency Hours (Avg)	218	218	3,240	10	97

Scenario results: Base case

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
Emissions reduction	**-**	2%	14%	1%	9%
Resiliency Hours (Avg)	**218**	218	3,240	10	97

Net zero energy

Net zero emissions

5 days of backup power

Generator fuel costs <$100

Scenario results: Minimal BESS

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
Emissions reduction	**-**	2%	14%	1%	9%
Resiliency Hours (Avg)	**218**	218	3,240	10	97

Increased load and emissions

Positive NPV

Fast payback

Reduced resiliency

Scenario results: Maximize BESS

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
Emissions reduction	**-**	2%	14%	1%	9%
Resiliency Hours (Avg)	**218**	218	3,240	10	97

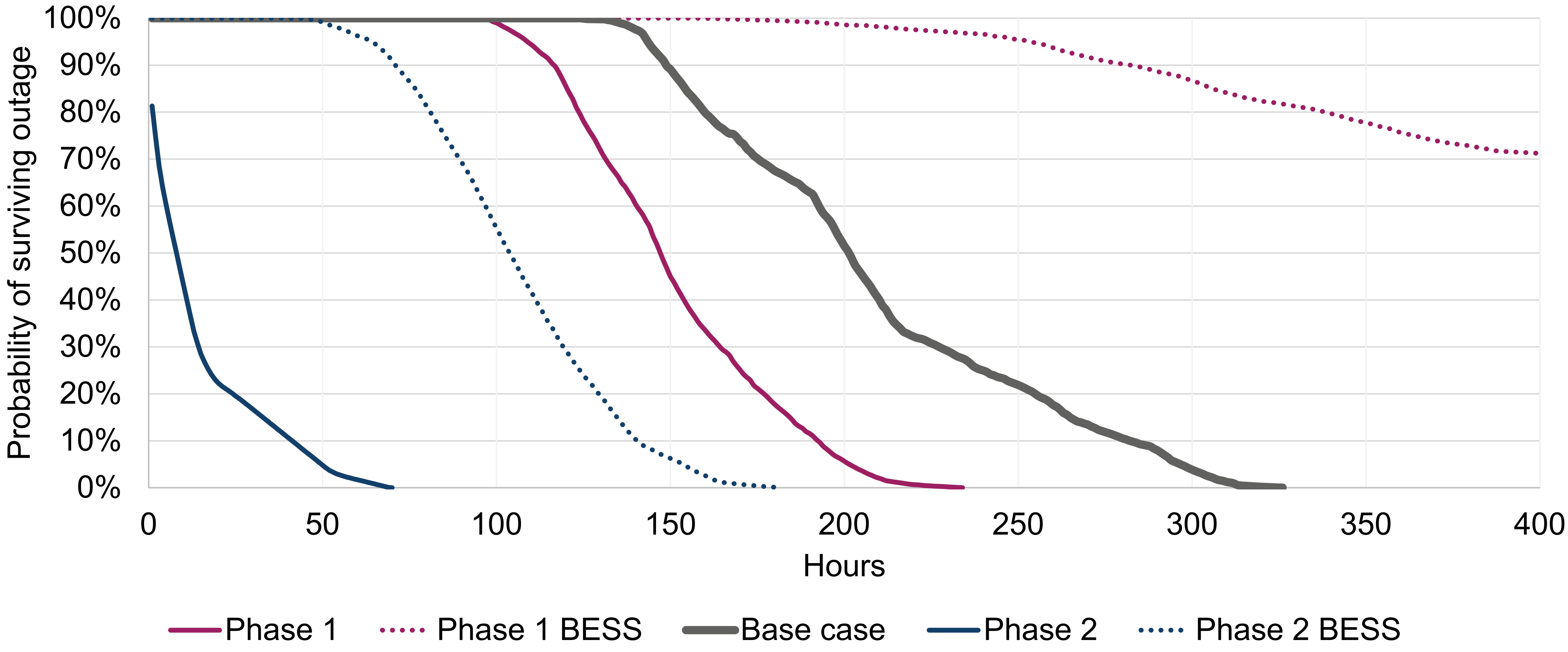
Reduced emissions

Negative NPV

Long payback

Resiliency increases

Outage survivability as a microgrid



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

Conclusion

Next steps

Implement microgrid-ready inverters	Plan for a BESS	Implement managed EV charging	Electrically interconnect Streets and Engineering
• Upgrade existing inverters • Specify microgrid-ready for future inverters	• Perform a site survey to identify locations • Consider replacement strategies factoring in fleet electrification	• Upgrade existing chargers • Implement smart charging	• Share one BESS • Eliminate diesel generator • Collectively manage loads and sources

Next steps: DOE Connected Communities project

Implement microgrid-ready inverters	Plan for a BESS	Implement managed EV charging	Electrically interconnect Streets and Engineering
• Upgrade existing inverters • Specify microgrid-ready for future inverters	• Perform a site survey to identify locations • Consider replacement strategies factoring in fleet electrification	• Upgrade existing chargers • Implement smart charging	• Share one BESS • Eliminate diesel generator • Collectively manage loads and sources

DOE Connected Communities

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

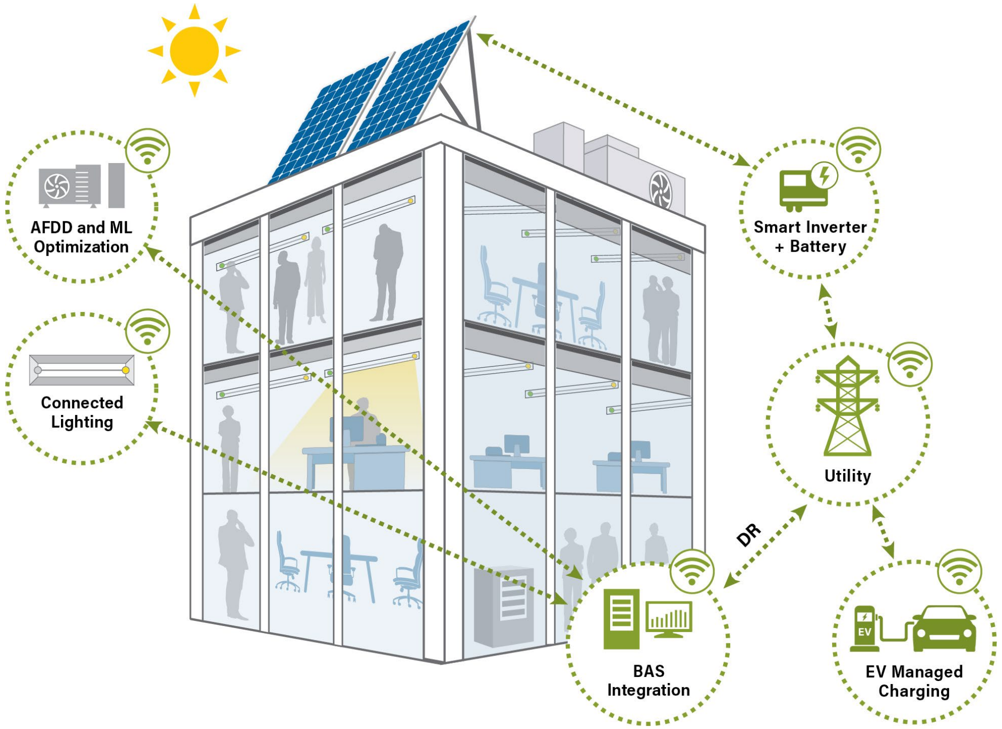
OCTOBER 13, 2021

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

Connecting Communities for Sustainable Solutions

Project Summary

This project will demonstrate GEB in Madison's publicly owned facilities. It will deploy reliable and cost-effective efficiency and demand flexibility strategies in buildings, behind-the-meter electric vehicle charging, and solar energy production. We will then scale the lessons learned to a broader audience. **This Connected Community project will support increased integration of renewables into the grid, better maintain voltage limits on the transmission and distribution system and improve both the resilience of utility customer infrastructure and financial outcomes.**



Key Partners

Slipstream (lead)
RMI
MGE
ACEEE
City of Madison

Baseline

Existing conditions: typical lighting (fluorescent with minimal controls), HVAC (VAV and RTU with DDC), EV chargers (unmanaged Level 2), and PV w/o batteries or smart inverters.

Project Goals and Impact

Application	Energy Savings (kWh)	Peak Load Shed (kW)	Continuous Demand Management (kW)	Load Shift (kW/kWh)
Building Load Shaping	1,420,000	250	590	n/a
EV Managed Charging	n/a	n/a	245	96/192
Smart Inverters + Batteries	n/a	n/a	120	120/240
Total	1,420,000	250	955	216/432

- Reduce emissions by 889 ton $CO2_e$ and utility cost by $472,000 with a simple payback under 11 years.
- Improved IEQ, occupant and operator satisfaction.
- Scale through broader market transformation efforts.

GEBs for a mid-size utility in a mid-size city

2022 – 2024: Demonstrate GEB elements in City of Madison facilities.

Application	Quantity	Strategies Demonstrated
Building Load Shaping	5-6 municipal buildings; 300,000 ft^2	Enhanced energy efficiency of HVAC and lighting
		Load shed via Automated Demand Response (ADR) of HVAC and lighting
EV Managed Charging	20 Level 2 chargers serving 40 EV passenger vehicles	Load shift via managed charge and supplemental batteries
Smart Inverters + Batteries	Upgrade to smart inverters on 10 photovoltaic (PV) systems; Add batteries to 2 sites	Smart inverter functionality Load shift via batteries

2023 – 2025: Develop a utility pilot GEB program for medium-to-large commercial and industrial customers.

- 10 buildings (500,000 square feet), EV charging stations (750 kW), and battery systems (80 kW/160 kWh).
- Centrally managed and optimized through a Demand Response Management System.

2025 - 2026: Scale these impacts

- Define replicable GEB implementation models for building owners, designers, operators, Midcontinent Independent System Operator (MISO) and policy makers

Questions?

Lee Shaver

Energy Engineer
lshaver@slipstreaminc.org

Jeannette LeZaks

Director of Research and Innovation
jlezaks@slipstreaminc.org

Maddie Koolbeck

Research Analyst
mkoolbeck@slipstreaminc.org

Scott Schuetter

Principal Engineer
sschuetter@slipstreaminc.org