

# Smart building applications

Grid-interactive efficient buildings and Connected Communities

Xiaohui 'Joe' Zhou, Scott Schuetter | Slipstream

2024



1

## Learning Objectives

- Introduce Grid-interactive Efficient Building (GEB) concept
- Discuss GEB controls and provide an example
- Review the DOE Connected Community program
- Discuss the Slipstream-led DOE Connected Community project process and lessons learned

2



2

## Outline

### Grid-interactive Efficient Building

- Definition
- GEB controls
- A GEB test case

### DOE Connected Communities

- Overview
- Project highlights

### City of Madison Project Experience

- Concept and goals
- Project process
- System architecture
- Lessons learned

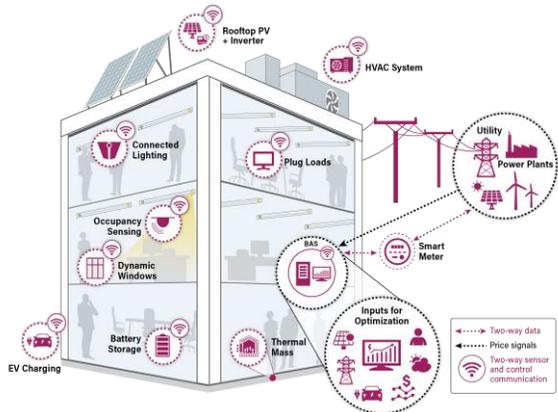


## Grid-Interactive Efficient Buildings



## What is a GEB?

A Grid-interactive Efficient Building (GEB) is an energy-efficient building that uses smart end-use equipment and/or other onsite DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way.



© Slipstream Group, Inc.

5



5

## Distributed Energy Resources (DER)\*

### • Behind-the-Meter Generation

- Photovoltaics
- Gas-Fired Generation, Combined Heat and Power, Fuel Cells

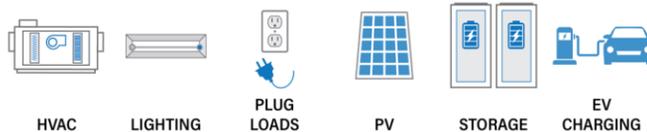
### • Energy Storage

- Battery
- Cool Thermal and Refrigeration

### • Electric Vehicles

### • Advanced Inverters

### • Advanced Building Controls



\* More information on DERs, please refer to Video #5 'Solar PV, BESS, and EV charging.'

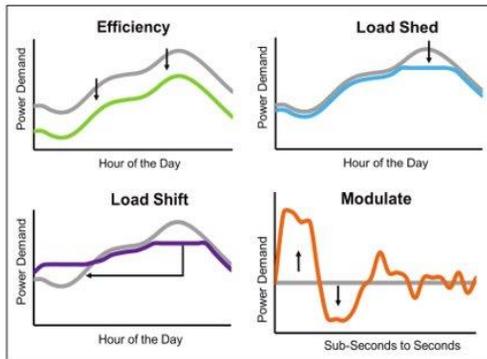
6



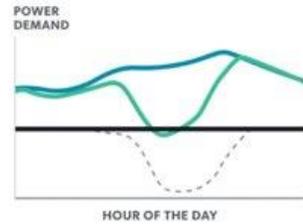
6

## Why DERs in Buildings

### Modes of Building Load Flexibility



+ Generate



Source: 2019 DOE Grid-interactive Efficient Buildings Overview

7



7

## GEB Characteristics

### Grid-Interactive Efficient Building Characteristics



**EFFICIENT**

Persistent low energy use



**CONNECTED**

Two-way communications



**SMART**

Optimize at the building or community levels



**FLEXIBLE**

Provide flexible loads when needed

Source: 2019 DOE Grid-interactive Efficient Buildings Overview

8



8

# GEB Controls



## Two DER Control Models

### Integrated

### GEB

Utility or Grid Operator

DR Node (server)

ADR Signal (e.g., OpenADR)

DR Node (client)

ADR gateway, not needed if BAS supports ADR signal directly

BAS Interface

BAS network (e.g., BACnet)

Building Controls Network

Equipment

Equipment

Generation

Building Boundary

### Distributed

Utility or Grid Operator

DR Node (server)

ADR Signal

DR Node (client)

Equipment

DR Node (client)

Equipment

DR Node (client)

Generation

Building Boundary



## GEB Control Platform Capabilities

- **Integration**

- Integrate multiple DERs
- Each subsystem may have its own standards/protocols

Connected

- **Two-way communication**

- Receive utility ADR signals
- Respond with feedback info

Connected

- **Optimization and Control**

- Brain of a GEB building
- Can optimize DERs based on multiple objectives
  - Highest utility incentives
  - Minimal carbon impact
  - Minimal energy use
  - Highest demand reduction
  - Acceptable comfort levels

Efficient

Smart

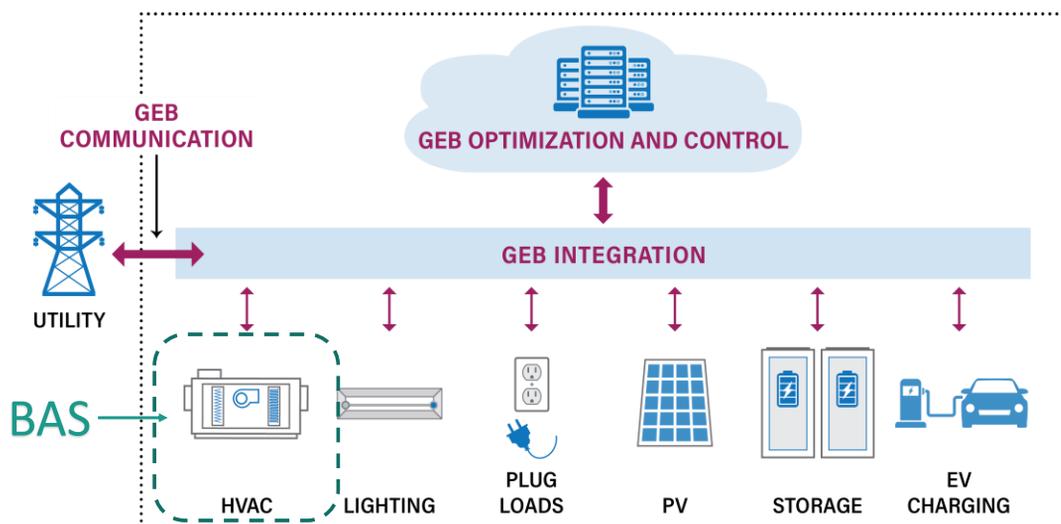
Flexible

11



11

## A GEB Control Platform Architecture



© Slipstream Group, Inc.

12



12

## Current GEB Control Software Options

### Proprietary, commercial software

- Prescriptive Data\* – Nantum OS
- Others

### Open-source platform

- Eclipse VOLTTRON
- Others

### DERMS (not GEB Control)

- Distributed Energy Resource Management System
- Utility-side, utility-scale systems control

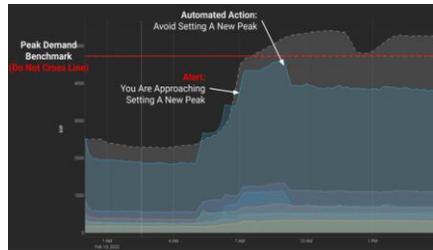


Image used with permission from Nantum OS, by Prescriptive Data [www.prescriptivedata.io](http://www.prescriptivedata.io)

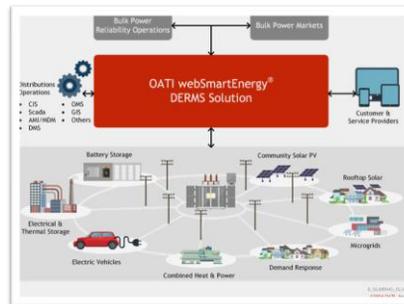


Image used with permission from OATI

\*Prescriptive Data just rebrand to Nantum AI in June 2024.

13



13

## A GEB Test Case

14



14

# Eclipse VOLTRON

- A Linux-based software platform
- Enables secure coordination of building energy loads and distributed energy resources
- Initially developed by PNNL
- Open-source, publicly available from GitHub

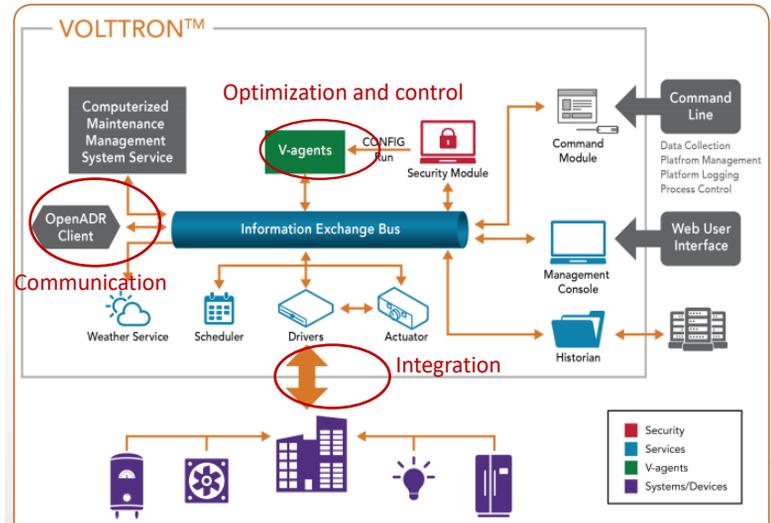
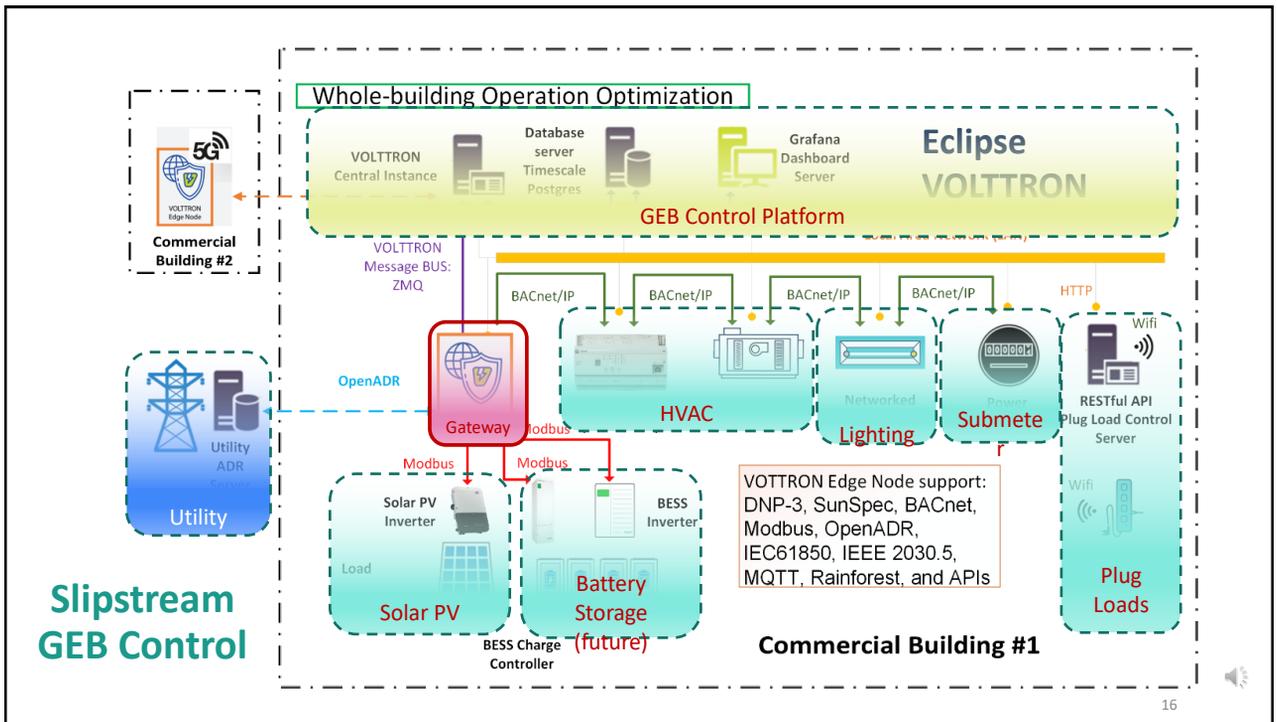


Image used by permission from Pacific Northwest National Laboratory, operated by Battelle for the U.S. Department of Energy

15



16

## User Interface

### Grafana

- A web-based visualization tool
- Open source
- Configurable and flexible
- Connected to Slipstream GEB database

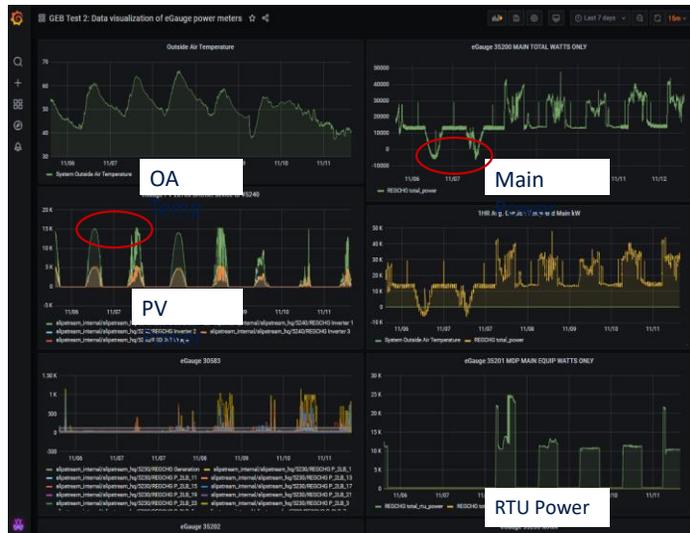


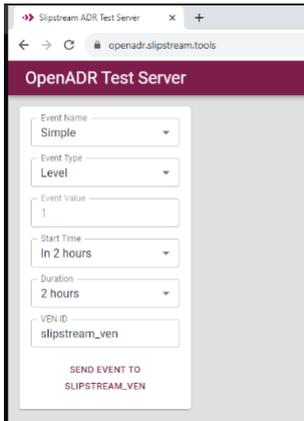
Image used with permission from Grafana Labs.

## OpenADR Server Development

<https://www.openadr.org/specification>

# OpenADR Communication Test

## OpenADR Server

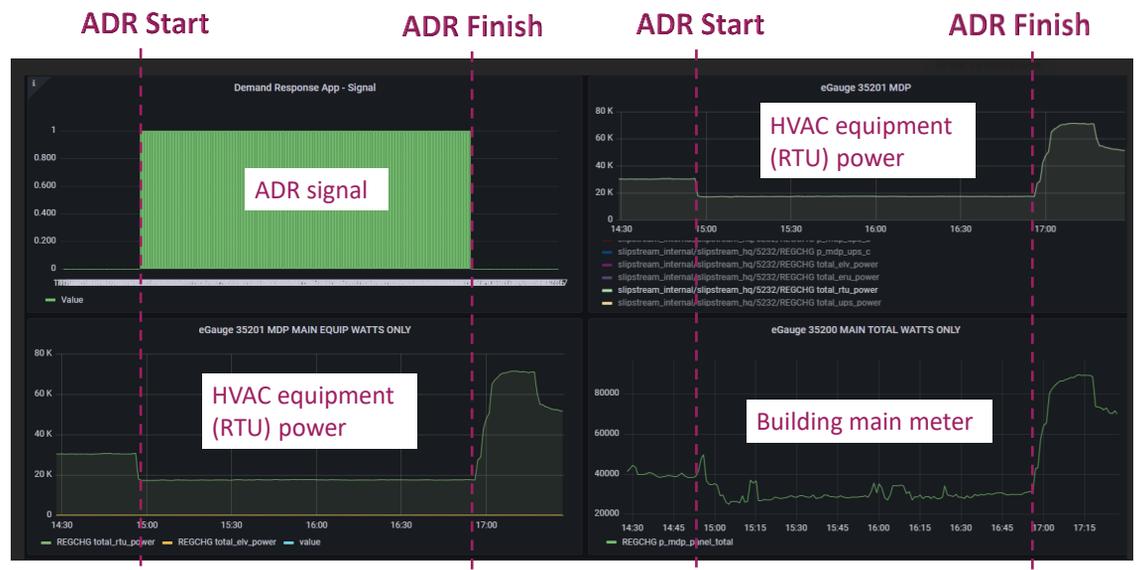


## OpenADR Client

```
INFO:apscheduler.executors.default:Running job "OpenADRCient_poll (trigger: interval[0:00:10], next run at: 2023-08-10 12:56:02 CDT)" (scheduled at 2023-08-10 12:55:52.187359-05:00)
INFO:root:Handling event: {'event_descriptor': {'event_id': 'a1f28653-6640-439c-954d-0792b03cd9d', 'modification_number': 0, 'modification_date_time': datetime.datetime(2023, 8, 10, 17, 55, 42, 938230, tzinfo=datetime.timezone.utc), 'priority': 0, 'market_context': 'adrrt/unknown_context', 'created_date_time': datetime.datetime(2023, 8, 10, 17, 55, 42, 938223, tzinfo=datetime.timezone.utc), 'event_status': 'fan', 'test_event': False}, 'active_period': {'start': datetime.datetime(2023, 8, 10, 19, 55, 42, 938077, tzinfo=datetime.timezone.utc), 'duration': datetime.timedelta(seconds=7200)}, 'event_signals': [{'interval': {'dtstart': datetime.datetime(2023, 8, 10, 19, 55, 42, 938077, tzinfo=datetime.timezone.utc), 'duration': datetime.timedelta(seconds=7200)}, 'id': 0, 'signal_payload': 1.0}], 'signal_name': 'SIMPLE', 'signal_type': 'Level', 'signal_id': '9624277a-f471-48cd-b3c3-6472a01d1995', 'current_value': 0.0}], 'targets': [{'ven_id': 'ven_id_slipstream_ven'}], 'targets_by_type': {'ven_id': ['ven_id_slipstream_ven']}, 'response_required': 'always'}
INFO:root:Event intervals: {'intervals': [{'dtstart': datetime.datetime(2023, 8, 10, 19, 55, 42, 938077, tzinfo=datetime.timezone.utc), 'duration': datetime.timedelta(seconds=7200)}, {'id': 0, 'signal_payload': 1.0}], 'signal_name': 'SIMPLE', 'signal_type': 'Level', 'signal_id': '9624277a-f471-48cd-b3c3-6472a01d1995', 'current_value': 0.0}
INFO:root:Processing signal: {'intervals': [{'dtstart': datetime.datetime(2023, 8, 10, 19, 55, 42, 938077, tzinfo=datetime.timezone.utc), 'duration': datetime.timedelta(seconds=7200)}, {'id': 0, 'signal_payload': 1.0}], 'signal_name': 'SIMPLE', 'signal_type': 'Level', 'signal_id': '9624277a-f471-48cd-b3c3-6472a01d1995', 'current_value': 0.0}
INFO:root:ADR start time: 2023-08-10 19:55:42.938077+00:00
INFO:root:Event payload value: 1.0
INFO:root:ADR duration: 2:00:00
INFO:root:ADR event ends: 2023-08-10 21:55:42.938077+00:00
INFO:openadr:total_event_responses: 1
INFO:root:EVENT CHECKR Current time (UTC): 2023-08-10 17:55:52.151632
INFO:root:EVENT CHECKR ADR event start time (UTC): 2023-08-10 19:55:42
INFO:root:Current time: 2023-08-10 17:55:52.151632+00:00, Event start time until end: 14399.796445
INFO:root:EVENT DO delay 7198.796445 item go
INFO:root:EVENT DO bacnet_api_payload_value 0
INFO:root:EVENT DO event_payload_value 1.0
INFO:root:EVENT DO delay 14399.796445 item stop
INFO:root:EVENT DO bacnet_api_payload_value 0
INFO:root:EVENT DO event_payload_value 1.0
INFO:root:openadr:oadrResponse
INFO:apscheduler.executors.default:Job "OpenADRCient_poll (trigger: interval[0:00:10], next run at: 2023-08-10 12:56:02 CDT)" executed successfully
INFO:root:Type of electric_meter_obj.presentValue: <class 'float'>
INFO:root:ADR Event Level: Real(0), Power Level: 48880.0, Connection Status: False
INFO:root:Type of electric_meter_obj.presentValue: <class 'float'>
INFO:root:ADR Event Level: Real(0), Power Level: 48880.0, Connection Status: False
INFO:root:Type of electric_meter_obj.presentValue: <class 'float'>
INFO:root:ADR Event Level: Real(0), Power Level: 48880.0, Connection Status: False
```

1. Event starts: 2023-08-10 19:55:42
2. Event level: 1
3. Event duration: 2 hours
4. Event ends: 2023-08-10 21:55:42

# Automated Load Shed Test



## DOE Connected Communities

21



21

## DOE Connected Communities



10 Selected Projects total \$61 million in funding  
Collaboration with SETO, VTO, and OE



Source: Department of Energy

22

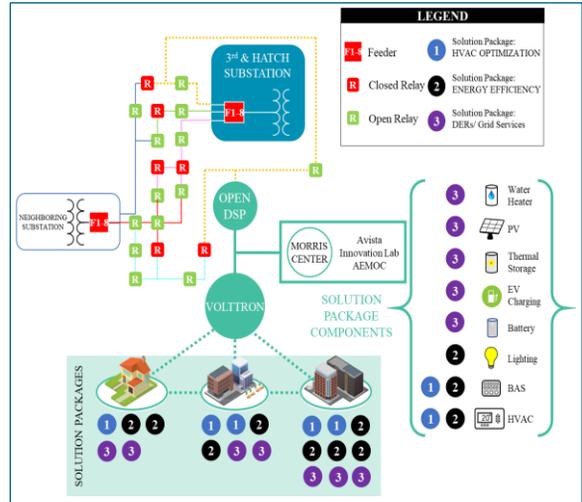


22

## EDO (with Avista Utilities, McKinstry, PNNL, and Urbanova)

### Key Innovation

- Developing an integration platform to systematically deploy VOLTRON in multiple building types and optimizing Virtual Power Plants (VPP) dispatch with OpenDSO.
- Coordinating VPP scheduling and dispatch of building resources using Avista Utility's Active Energy Management Operations Center.
- Demonstrating a novel utility and private sector partnership with a shared-value business model for building-to-grid integration services.
- Demonstrating multi-year operation of buildings and DERs as VPPs to provide insight on their dependability and load flexibility as dispatchable utility resources.
- Developing a Connected Communities Playbook



Source: Department of Energy

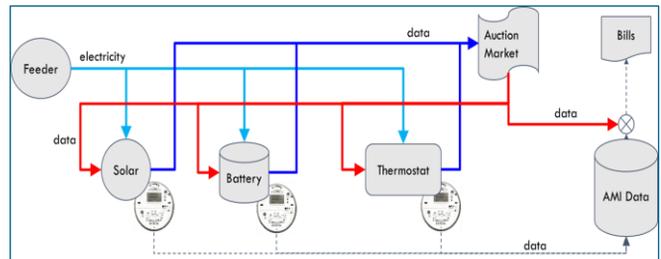
23

23

## Post Road Foundation (with SLAC, New Hampshire Electric Cooperative, Efficiency Maine Trust, and Knowledge Problem, LLC)

### Key Innovation

- Expand and test capabilities of a two-way “prices-from-devices” transactive energy service system (TESS) platform developed at SLAC National Accelerator Laboratory in rural areas.
- Use of web/mobile app data analysis and structured quantitative surveys to evaluate occupant experience.
- Exploring the use of blockchain technology, developed in part by the DOE multi-lab *Blockchain for Optimized Security and Energy Management* project, to secure the system.



- Up-to 250 single-family homes and 5 to 10 small commercial buildings in rural New Hampshire and 100 single-family homes, 50 small commercial buildings, and 5 industrial buildings in two communities in rural Maine.

Source: Department of Energy

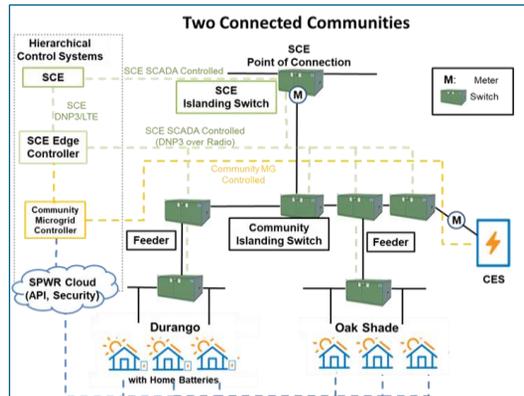
24

24

## SunPower Corporation (with KB Home, University of California Irvine, Schneider Electric and Southern California Edison)

### Key Innovation

- Integration of existing commercial technology including nested microgrids.
- Evaluate value of community battery, residential batteries, and home energy management systems.
- Shifting natural gas fuel end-uses to high efficiency all-electric technology and utilizing controllable HVAC, water heaters and ENERGY STAR labeled appliances.
- Utility distribution SCADA and automation system edge controller w/close coupled community nested microgrid



Two new home neighborhoods in California connected with microgrids equipped with distributed energy resources, load flexibility, energy efficiency, and reliability and resiliency measures.

Source: Department of Energy

25

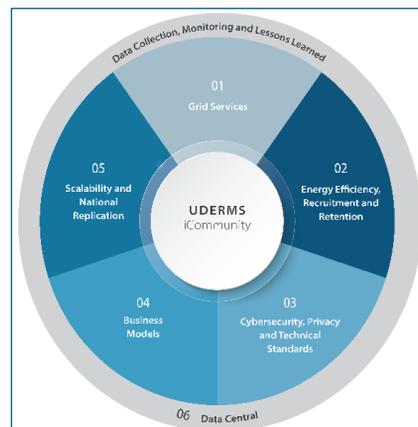


25

## Rocky Mountain Power/Pacificorp with PNNL, Utah State, Wasatch Group, GIV Group, Utah Transit Authority, Packsize International, Open Systems International and Sonnen

### Key Innovation

- Grid distribution analysis and model simulation to determine if the integration of flexible loads with energy efficiency can defer the investment of expensive capital upgrades at the local distribution network.
- Approach to utility business model, analysis of potential savings from distribution upgrades, and integration into IRP provides strong pathways for scale and replicability.
- Utility-led project focused on support of DER inclusion in Integrated Resource Planning activities



Source: Department of Energy

26



26

## Connected Communities Example

27



27

## GEBs for the middle: for a mid-size utility, mid-size city

This 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.

**ACEEE**  
Smart Energy. Clean Planet. Better Lives.

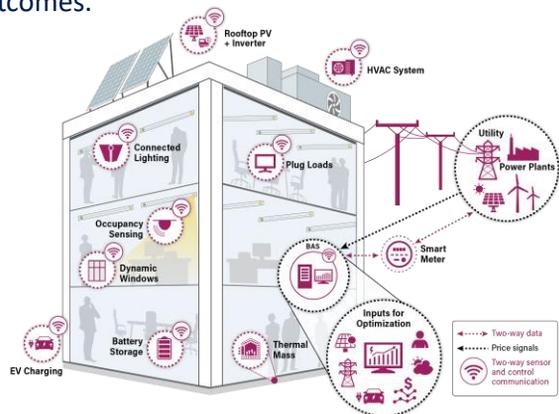
**blu** evolution



**MGoe**  
your community energy company

**ARMI**

**slipstream**



28



28

## Project Goals

- Manage **load profiles** for better utilization of grid assets, lower cost, and lower emission
- Ensure cost control and reliability as building and vehicle **electrification** increase electric demand
- Reduce **emissions and utility cost for all** utility customers
- Improve indoor environmental quality, occupant comfort and operator **satisfaction**
- Increase ability of building systems and electric vehicle fleet to maintain **operations during grid outages**
- Scale via replicable GEB **implementation models** for building owners, designers, operators, MISO and policy makers

29



29

## Grid Services

Value to MGE	Grid Services Terminology	Distributed Energy Resources
Lower System-Wide Coincident Peak	Capacity (Peak Hours)	Load shed of HVAC, NLC, EVSE and BESS
Flatten Building Load	Distribution Capacity Relief	Continuous demand management by EMIS
MISO Energy Market Arbitrage	Economic Energy Dispatch	Load shift of EVSE and BESS
Maintain Nominal Conditions on Distribution System	Voltage Management	Smart Inverters

30



30

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

Application	Quantity	Strategies Demonstrated
Building Load Shaping	7 municipal buildings; 428,000 ft <sup>2</sup>	Enhanced energy efficiency of HVAC and lighting Automated Demand Response (ADR) of HVAC and lighting
EV Managed Charging	48 Level 2 chargers serving ~100 EV passenger vehicles	Load shed and shift via managed charging
Batteries	Add batteries to 2 sites	Load shed and shift; resilience
Smart Inverters	Upgrade inverters on 15 PV arrays	Constant Power Factor, Dynamic Volt-Var, and Volt-Watt Control

**2023 – 2025: Develop a utility pilot GEB program**

- For medium-to-large commercial and industrial customers.
- Centrally managed and optimized through a DERMS

**2025 - 2026: Scale these impacts**

- Replicable GEB implementation models for building owners, utilities, MISO and policymakers

31

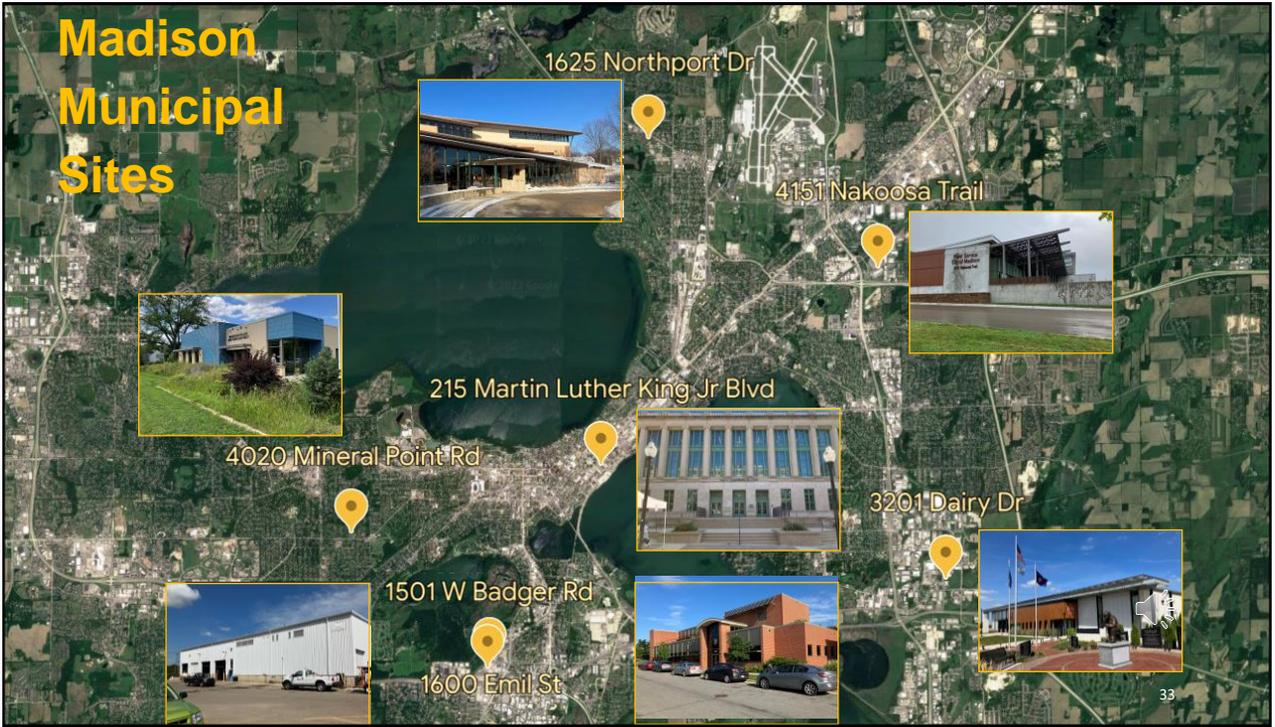


## Project Update

- City of Madison site selection and characterization complete
- Monitoring equipment installed and Evaluation plan ongoing
- GEB solution procurement
  - EMIS RFP complete
  - HVAC sequences documented. Fault correction ongoing
  - Battery, EV charging, smart inverter, and lighting in design

32





Distributed Energy Resources						
Site	HVAC Controls	Networked Lighting Controls	EV Managed Charging	Battery	EMIS	Smart Inverter
Fleet Headquarters			○		○	○
Madison Municipal Building	○	○	○		○	○
Fire Station 14				○	○	○
Midtown Police District	○		○		○	○
Engineering Operations	○	○	○	○	○	○
Streets West			○	○	○	○
Warner Park Rec Center	○				○	○

# System Architecture

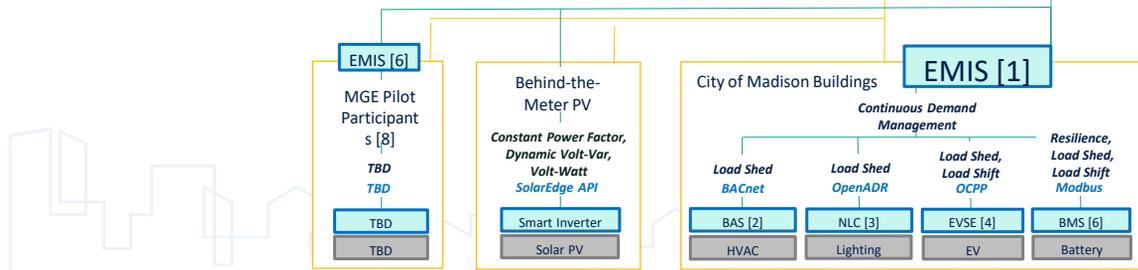
- [1] ACE IoT. Serving different subsets of buildings using their own internal architecture for control and data storage.
- [2] Honeywell Tridium running Niagara version N4.10
- [3] Lutron Vive
- [4] EnelX JuiceBox Premium and Pro 32 EV chargers
- [5] Solar Edge C&I One Manager
- [6] TBD
- [7] Buildings are not focused on a particular feeder though GEB approach should benefit associated feeders.
- [8] MGE pilot under development.

## Madison Gas and Electric Grid Services:

- Capacity (Peak Hours)
- Distribution Capacity Relief
- Economic Energy Dispatch
- Distribution Capacity Relief
- Distribution Voltage Management

DRMS [6]

Feeders [7]



# Measurement and Verification

Data	Source	Interval
Whole Building Interval Power (kW)	Utility portal	15-minute
Submetered Interval Power (kW)	eGauge power meters	1-minute
PV Inverter Metrics (V, VAR, kW)	Inverter portal	15-minute
Natural Gas Consumption (therm)	Utility bills	Monthly
HVAC control points	Building Automation System	15-minute
EV Charging Session	Vendor portal	Charging start/end time
Light Levels (fc)	Illuminance Meter	5-minute



## Estimated Project 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
<b>Total</b>	<b>1,420,000</b>	<b>250</b>	<b>955</b>	<b>216 / 432</b>

37



37

## Lessons Learned – To Date

Site and Technology Selection  
 Challenges with Emerging Technologies  
 Collaboration is Key  
 Phased GEB Integration



38

## Outstanding Questions

- To what extent will the EMIS control electric vehicles versus EVSE-vendor managed charging?
- To what extent will the EMIS control batteries versus Battery Management System-vendor controls?
- To what extent is an EMIS required for scaling?
- Will the EMIS offer enough customer value that they would invest in it without any external incentives?
- Does a grid-edge DERMS or enterprise DERMS make more sense for the project? Longer term?
- Are there distribution or feeder-level constraints that we could be addressing?



39

**This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), Building Technologies Office (BTO) Award Number DE-EE0009703.**

**The views expressed herein do not necessarily represent the views of the U.S. Department of Energy or the United States Government.**

**This presentation is for educational purposes only. Any materials shown herein are exhibited solely for the furtherance of the public good.**

## Thank you!



40