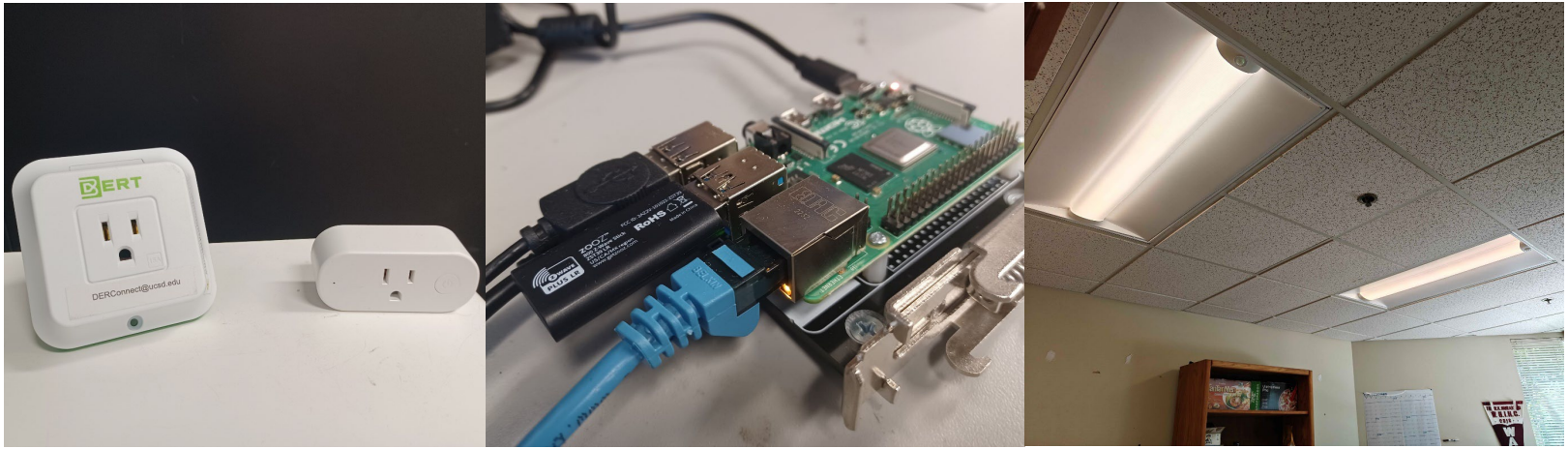
2024 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

BTO Peer Review: OCCTOPI

Optimized Commercial Control Technology Of Plug-loads & Lighting

Optimized Commercial Control Technology Of Plug-loads & Lighting (OCCTOPI)



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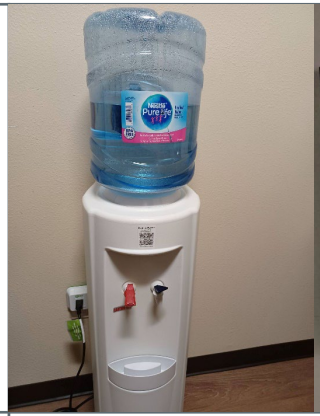
OCCTOPI

Project Summary

OBJECTIVE, OUTCOME, & IMPACT

The project will reduce the electrical base load of commercial buildings using flexible lighting and plug loads. Open-source software will be produced to facilitate system integration and intelligent controls. With more than 80% of small to medium U.S. commercial buildings lacking building automation, OCCTOPI provides an affordable solution to implement energy management strategies.



TEAM & PARTNERS

- University of California, San Diego (UCSD)
- National Renewable Energy Laboratory (NREL)
- Nabu Casa
- Best Energy Reduction Technologies (BERT)
- Acuity Brands

STATS

Performance Period: 04/01/2024 to 9/30/2024

DOE Budget: $600k, Cost Share: $150k

Completed Milestones:

Milestone 1: Baseline Studies

Milestone 2: Start Prototyping Activities

Milestone 3: Baseline Model

Problem

Plug loads are increasing in buildings and are very difficult to control. Existing solutions are expensive and siloed. There is a need for an affordable solution for small to medium commercial buildings so that the U.S. can achieve energy efficiency, demand reduction, and decarbonization goals.

- Plug loads are plug-in electric loads in a building and account for over 50% of whole-building energy consumption in high-efficiency buildings *(Lobato et al. 2011)*.
- More than 80% of small to medium U.S. commercial buildings lack a building automation system *(Trenbath et al. 2022)*.
- Lack of system interoperability, such as with lighting occupancy data, limits the effectiveness of plug load control (PLC).
- Building electrification measures are constrained by a site's electrical capacity and may require costly infrastructure upgrades.

C. Lobato, S. Pless, M. Sheppy, and P. Torcellini. 2011. "Reducing plug and process loads for a large scale, low energy office building: NREL's research support facility." Nevada: ASHRAE.
K. Trenbath, R. Meyer, K. Woldekidan, K. Maisha, and M, Harris. 2022. Commercial Building Sensors and Controls Systems - Barriers, Drivers, and Costs. https://doi.org/10.2172/1880546

Alignment and Impact

OCCTOPI provides a low-cost solution for small to medium commercial building operators to effectively manage their plug-load energy consumption by leveraging:

(1) An open-source automation platform

(2) Integrations with off-the-shelf consumer products

(3) System interoperability for intelligent energy management, specifically lighting and plug-load control.

- Empowers underserved communities with an affordable option to manage their energy consumption and realize cost savings.
- Improve building efficiency by eliminating wasted plug-load electricity consumption.
- Pathway to grid-interactive efficient buildings

Alignment and Impact

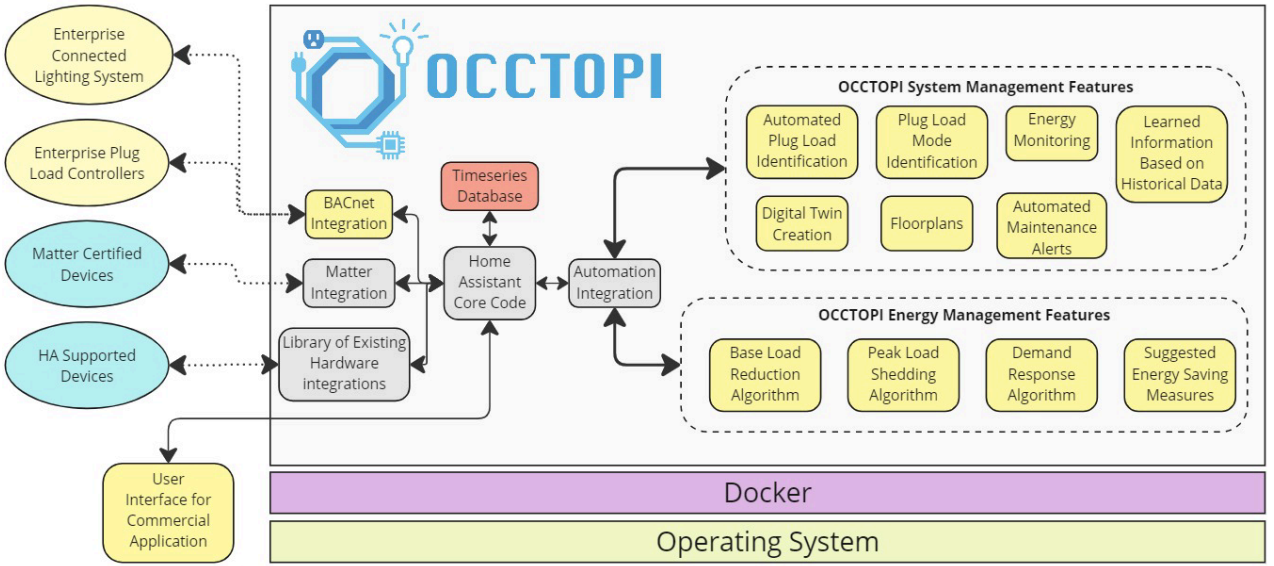
Current State-of-the-Art	OCCTOPI
•Commercial systems are expensive, closed ecosystems, and face interoperability challenges. •Commercial building systems lack support for modern IoT communication standards which limits accessibility to affordable consumer hardware. •Most plug load control (PLC) systems are stand alone. Typical Building Automation System do not have adequate PLC features. •Automatic receptacles have been integrated with lighting, but are often limited to scheduling and occupancy driven controls which may not be the appropriate strategy for certain plug loads.	•Built on top of Home Assistant (HA), an **open-source automation platform** used by over 300,000 users world-wide. •Large user community for support. •Founding company continues to develop the open-source software in addition to providing cloud services. •Robust system in place for the deployment of official and community software Add-Ons. •BACnet and OPC connectors will be added to compliment **HA's existing 1,000+ consumer product integrations** including the Matter standard. •Implement **advanced PLC by leveraging device interoperability.**

Approach

OCCTOPI Deliverables

- BACnet connector
- Software for energy & system management
- Advanced PLC control strategies using PLC + lighting integration
- Target of 25% reduction in lighting and PL energy consumption w/ a payback period of less than 3 years.

System Architecture



Approach

1. UCSD lab prototype
2. Lab evaluation at NREL's Energy Systems Integration Facility
3. Two field demonstrations:
   1. Large UCSD Campus building
   2. Small site in Alaska

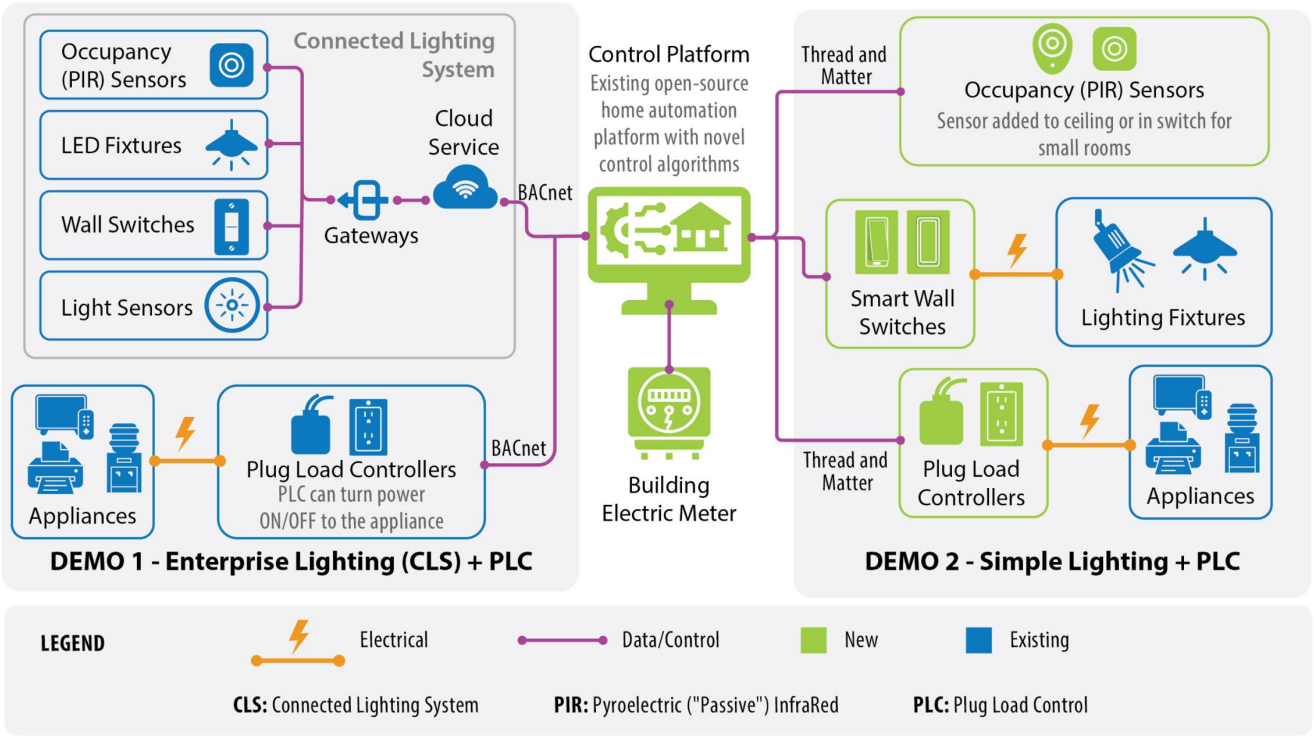


Diagram of OCCTOPI applications and field validation details.

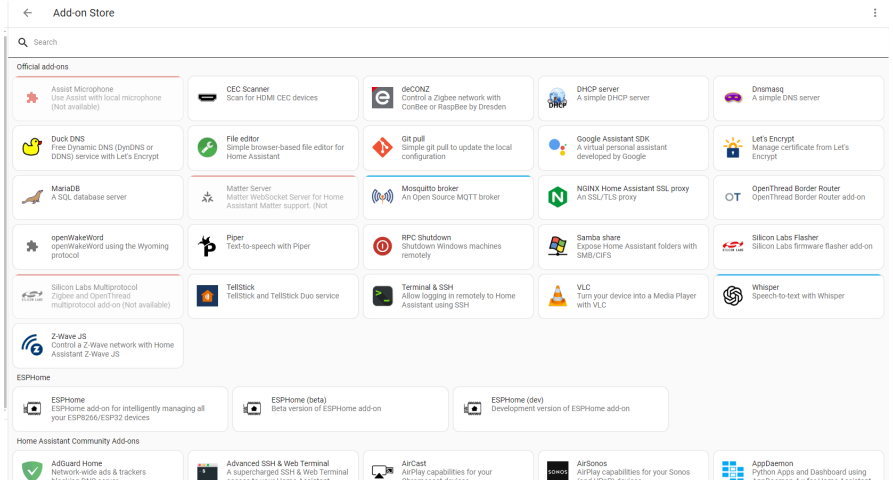
Approach

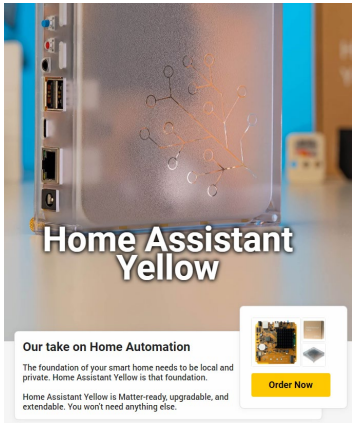
	RISK MANAGEMENT LOG			
ID	**Risk**	**Likelihood Impact**	**Potential Impact**	**Mitigation Strategy**
R1	Unforeseen technical challenges with BACnet connector development can delay the project.	Likelihood: High Impact: High	Demonstration of a working lab prototype may be delayed which impacts Budget Period 1 Go/No-Go Decision Point	The project team has three current BACnet connectors that can be used as references for the Home Assistant version.
R2	Changes to the Matter standard may require updates to Matter software connectors developed by Nabu Casa.	Likelihood: Medium Impact: Medium	Task 4 integrations may have to be updated which would impact the project schedule.	Devices selected will have both Matter integration as well as an OEM integration to provide an alternative. Nabu Casa actively updates their Matter connector and is an active member of the Connective Standards Alliance that oversees the Matter Standard.
R3	Project may run into unexpected networking issues and cybersecurity constraints.	Likelihood: Medium Impact: Medium	Task 7 may face schedule delays if these issues are encountered during field deployment.	Project team will engage early on with IT departments at both field validation sites to capture requirements.

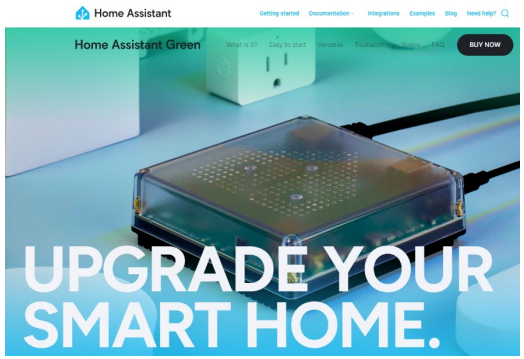
Approach

Commercialization Path

- All software features (“Add-Ons”) will be published onto the Home Assistant Add-Ons page for free use
- Source code available on GitHub
- Affordable hardware available from Nabu Casa for ease of setup (HA Yellow & Green)
- Adoption through UC Sustainability Programs such as the Green Office Certification. UC market consists of 5,847 buildings (142M SF).







Progress and Future Work

**New Project: Progress since project start (April 1, 2024)*

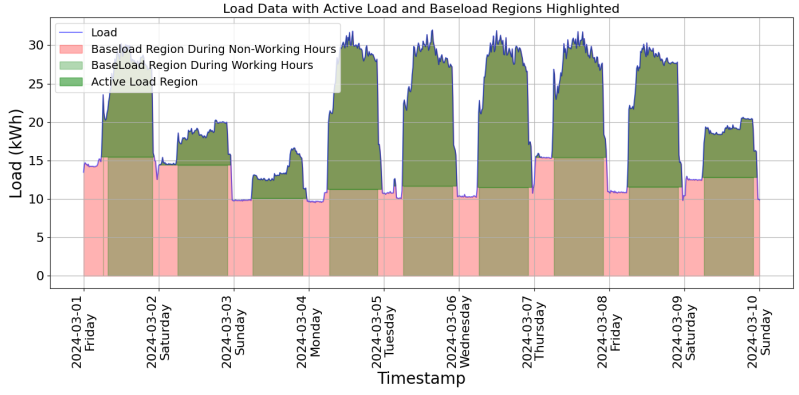
Task 2 – Energy Monitoring and Control

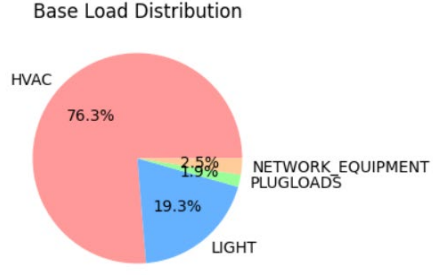
- Metering data processed & Submeters installed (M1 & M3 complete)
- Plug loads and lighting audit complete
- V1 Load profiler algorithm done
- Load disaggregation estimate done
- Energy efficiency proof of concept done

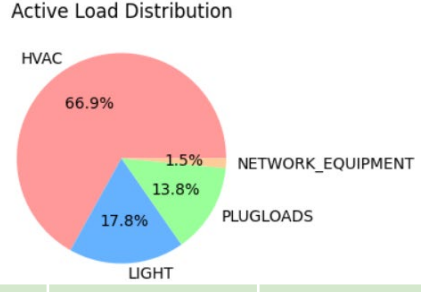
Future Work:

- Compare load disaggregation to submeter data
- Version 2 load profiler and efficiency

Center Hall Stats







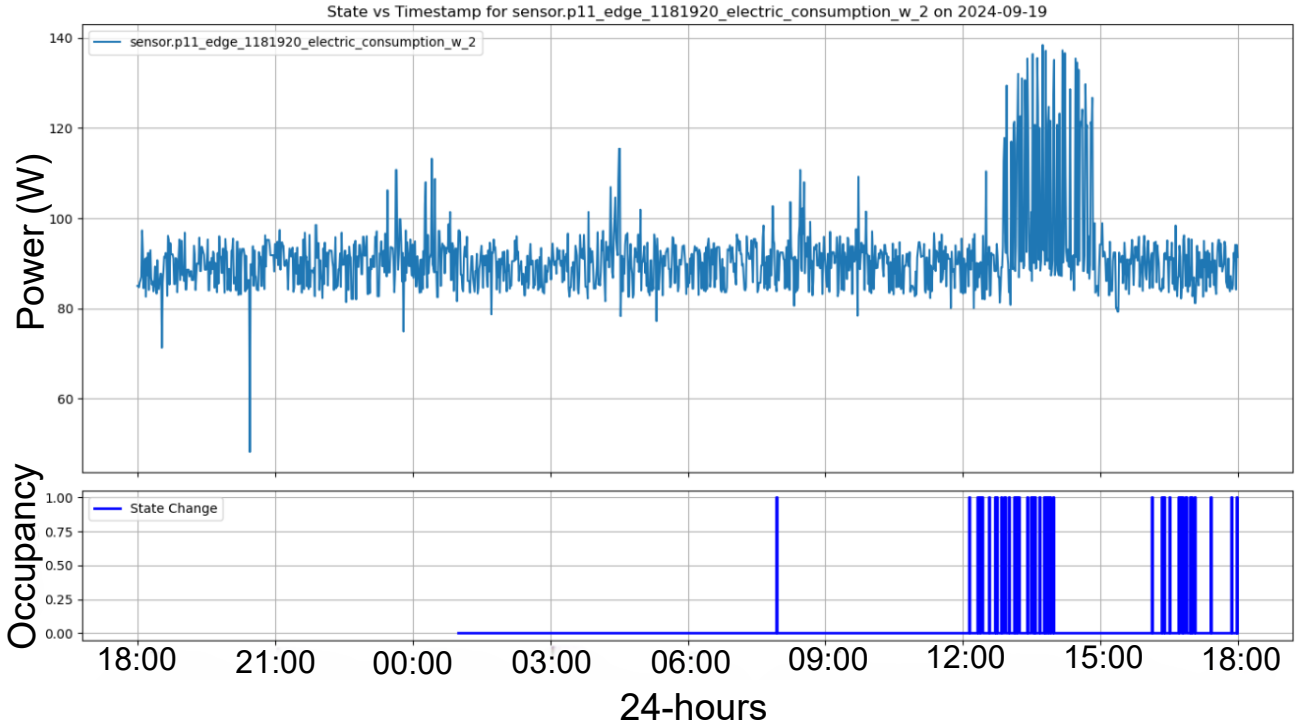
Avg. Baseload Energy (unoccupied)	Avg. Baseload Power (unoccupied)	Avg. Working Day Energy Load (active + baseload)	Avg. Non-working Day Energy Load (active + baseload)	Avg. Active Load Duration (working days)
329 kWh	36 kW	1,203 kWh	611 kWh	14.7 hours

Progress and Future Work

Identify Savings Opportunities

- Load profiler identifies time periods for building activity
- Efficiency = ‘useful consumption’/total electricity consumption
- Occupancy used as a proxy for useful consumption

```
Entity: sensor.p11_edge_1181920_electric_consumption_w_2
Total Power Consumed: 131040.20000000027
Power Consumed During State Change = 1: 4312.999999999999
Efficiency:  3.2913563929236904 %
```



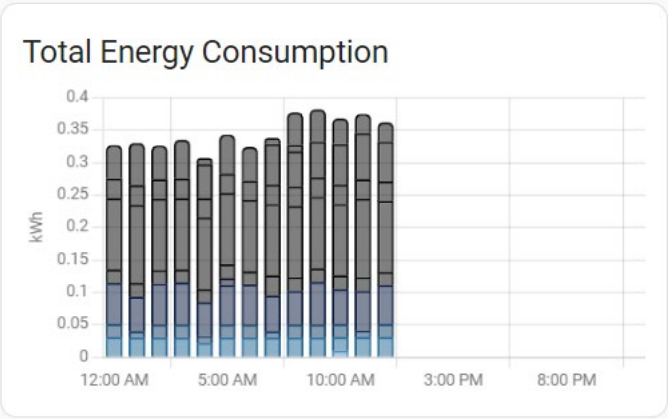
Progress and Future Work

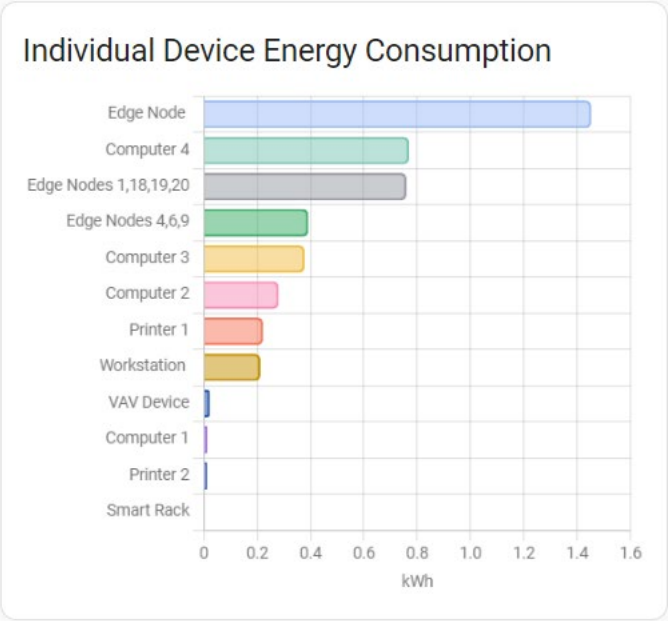
Task 3 – Prototyping Testbed Setup

- Home Assistant (HA) and Z-wave devices setup in lab (M2 complete)
- Dashboard iterations in progress
- New graphs created for energy monitoring
- Completed initial range tests for long-range Z-wave

Future Work:

- Add BACnet devices for lab offices
- Integrate load profiler and efficiency score algorithms to HA





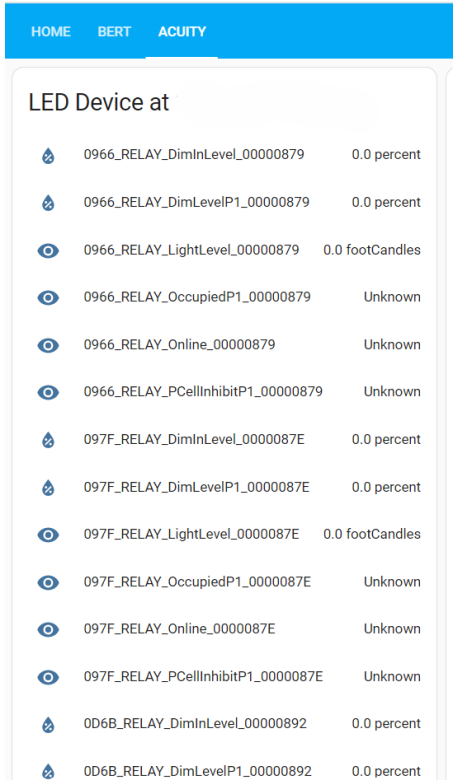
Progress and Future Work

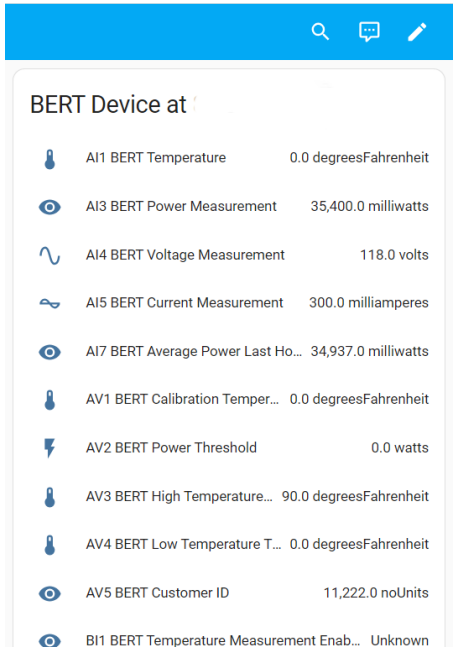
Task 4 – Systems Integration

- BACnet connector discovers devices and points; converts to MQTT; displays devices in HA
- Functional for both BERT plug load controllers & Acuity connected LED lighting system
- Testing a variety of IoT brands

Future Work:

- Assign BACnet devices to spaces.
- Development control via BACnet
- Use Modbus for metering data





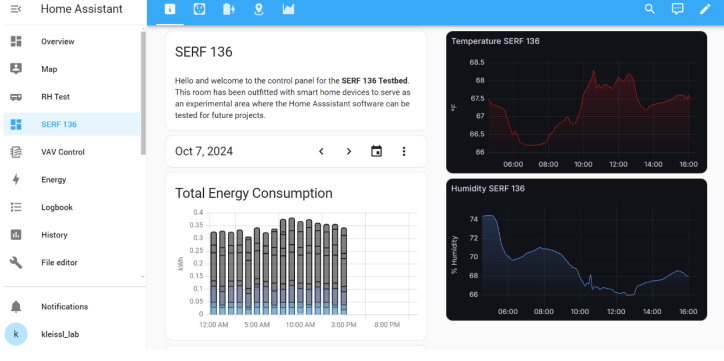
Progress and Future Work

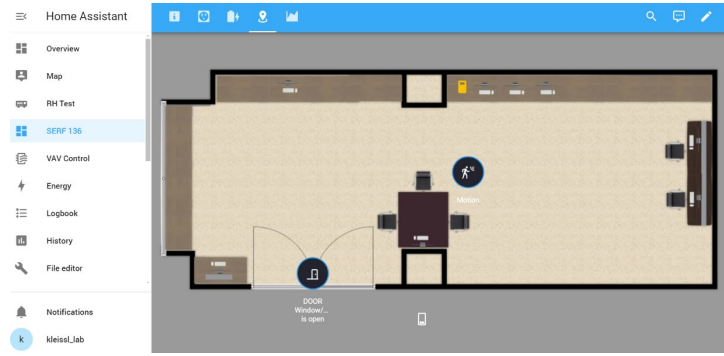
Task 5 – Systems Management

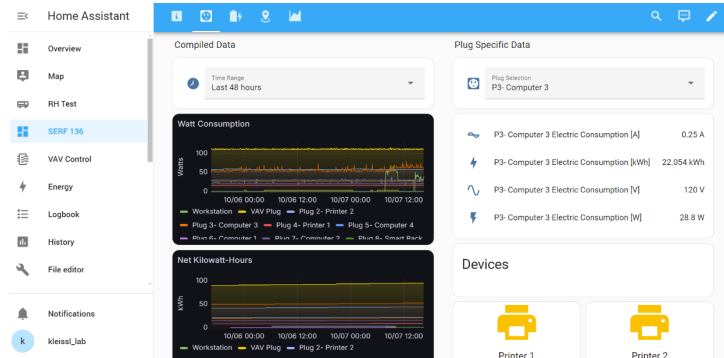
- Example dashboards created for operators
- Proof of concept for change of plug load appliance alert

Future Work:

- User engagement for UI/UX design
- Device and zone management
- Task 6: Lab evaluation at NREL's Energy Systems Integration Facility
- Task 7: Two field validations







Thank you

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Reference Slides

Project Execution

Budget Period 1 Milestones

- M1 Baseline Studies – complete
- M2 Prototyping – complete
- M3 Baseline Model – complete
- M4 BACnet Connector – in progress
- M5 Energy & Control – in progress
- M6 User Design – in progress
- M7 Management Features – in progress
- M8 ESIF Evaluation – not started

PROJECT SCHEDULE

WBS 1_Adminstration: spans entire project *(4/1/2024-3/31/2026)*
- Q8 Milestone_Project Completion

Budget Period 1

- **WBS 2**_Baseline & Energy Control Features *(4/10/2024 - 2/13/2025)*
  - Q2 Milestone_Baseline Model. NREL responsible for FNHS activities.
  - Q4 Milestone_Energy Monitoring & Control v1 Features
- **WBS 3**_ Prototype Setup *(4/10/2024 - 7/11/2024)*
  - Go/No Go_Prototyping Activities can Begin
- **WBS 4**_System Integration *(7/1/2024 - 5/30/2025)*
  - Q3 Milestone_BACnet connector operational
- **WBS 5**_ System Management Features *(6/18/2024 - 2/12/2025)*
  - Q4 Milestone_Management Features v1 Complete
  - DEIP Milestone_User-informed Design

Budget Period 2

- **WBS 6**_Deployment Preparation *(12/30/2024 - 6/10/2025)*
  - Go/No Go_V1 System Ready for Evaluation
  - Go/No Go_System ready for Field Deployment
  - Q6 Milestone_System Ready to Ship to Field Sites
- **WBS 7**_Field Validations *(5/7/2025 - 1/16/2026)*
  - Go/NoGo for FNHS Deployment
  - Q7 Milestone_All Occupants Trained
  - Q7 MIlestone_Field Tests Complete

Team

Project Team

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Your energy control freak

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