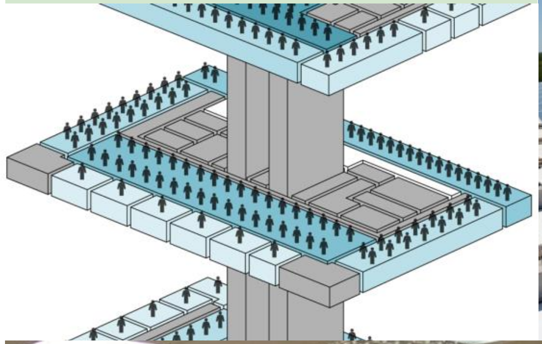
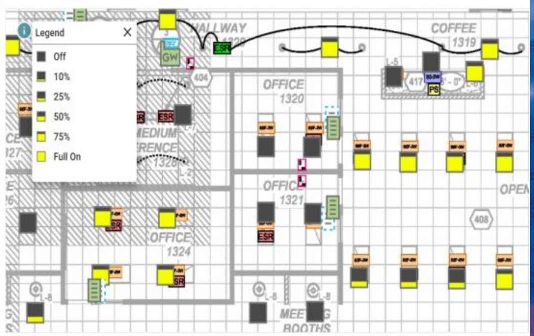
Data-Driven Electrical Systems





Pacific Northwest National Laboratory
Michael Poplawski, Senior Engineer and Team Lead: Data-Driven Design
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WBS# 32105
Wednesday 12:15-1:00pm

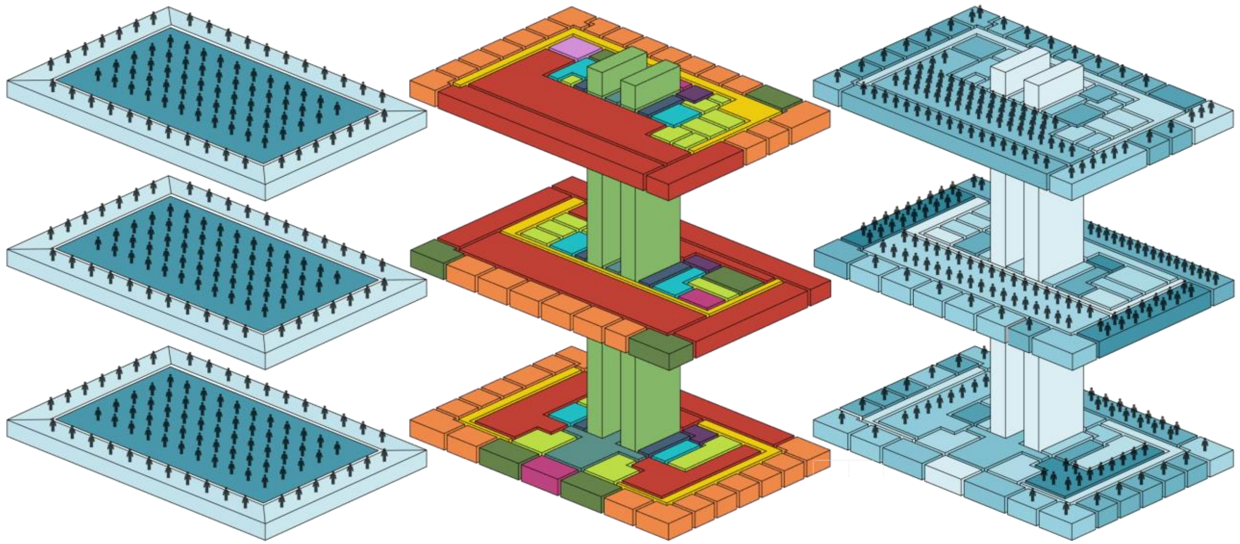
Project Summary

Objective and outcome

For the development of building electrical systems:

Objectives: improve a) the use of data-driven software tools and b) the availability, accessibility, and accuracy of data throughout the development process

Outcomes: increase validation, verification and accountability; improve design, construction, and operation practices; increase demand flexibility.



Team and Partners

Michael Poplawski, Ammar Dehwah, Karthik Devaprasad, Majid al Dosari, Shuchismita Biswas, Trisha Gupta, Ahsan Naqvi, Michelle Passmore, Shat Pratoomratana, Anay Waghale, Tianna-Kaye Woodstock

Stats

Performance Period: FY23 (Ongoing FY22-24 scope)

DOE budget: FY23 new BA $2150k Cost Share: $0

9 Tasks: 7/9 continuing work, 2/9 new work

4/9 Tasks reviewed today

1/9 Tasks integrated/coordinated with another Project (Semantic Interoperability)

9 Milestones (1 per Task)
2 Go/No-Go decisions

Problem: The deployment of building electrical systems is plagued by poor “data efficiency” and “open-loop” practices

Increasingly sophisticated software tools used for design & energy modeling

High-performance control strategies and equipment are commercially available

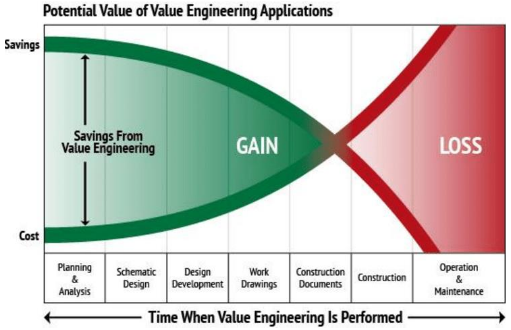
“Connected” systems can monitor and report operational data

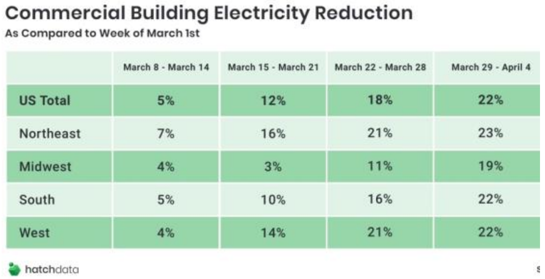
Audit, Design, Specification → Procurement, Construction → Installation Configuration Integration → Testing, Commissioning → Operation → Maintenance

“Construction Management” software tools increasingly available and utilized

Mature commissioning “best practices” available for many systems

AFDD software is commercially available and proven for some systems




Commercial Building Electricity Reduction
As Compared to Week of March 1st

	March 8 - March 14	March 15 - March 21	March 22 - March 28	March 29 - April 4
US Total	5%	12%	18%	22%
Northeast	7%	16%	21%	23%
Midwest	4%	3%	11%	19%
South	5%	10%	16%	22%
West	4%	14%	21%	22%

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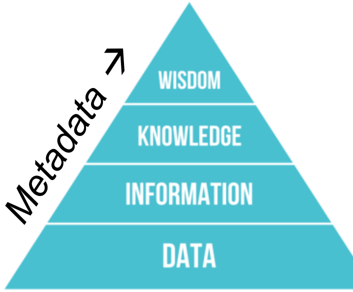

(Only) 2-D drawings transferred to construction phase

Limited/poor verification of value engineering impacts

Configuration & commissioning are human-centric and suffer from insufficient inputs & time

Systems do not deliver the application efficiency that they should or could

Reported data is not actionable, easy to use, or aligned with design metrics

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Limited data availability, accessibility, accuracy, and use

Alignment and Impact

- Improve design practices by enabling a) the increased modeling of design criteria (e.g., occupant behavior) and decisions and b) the creation of performance expectations that can be measured in operation

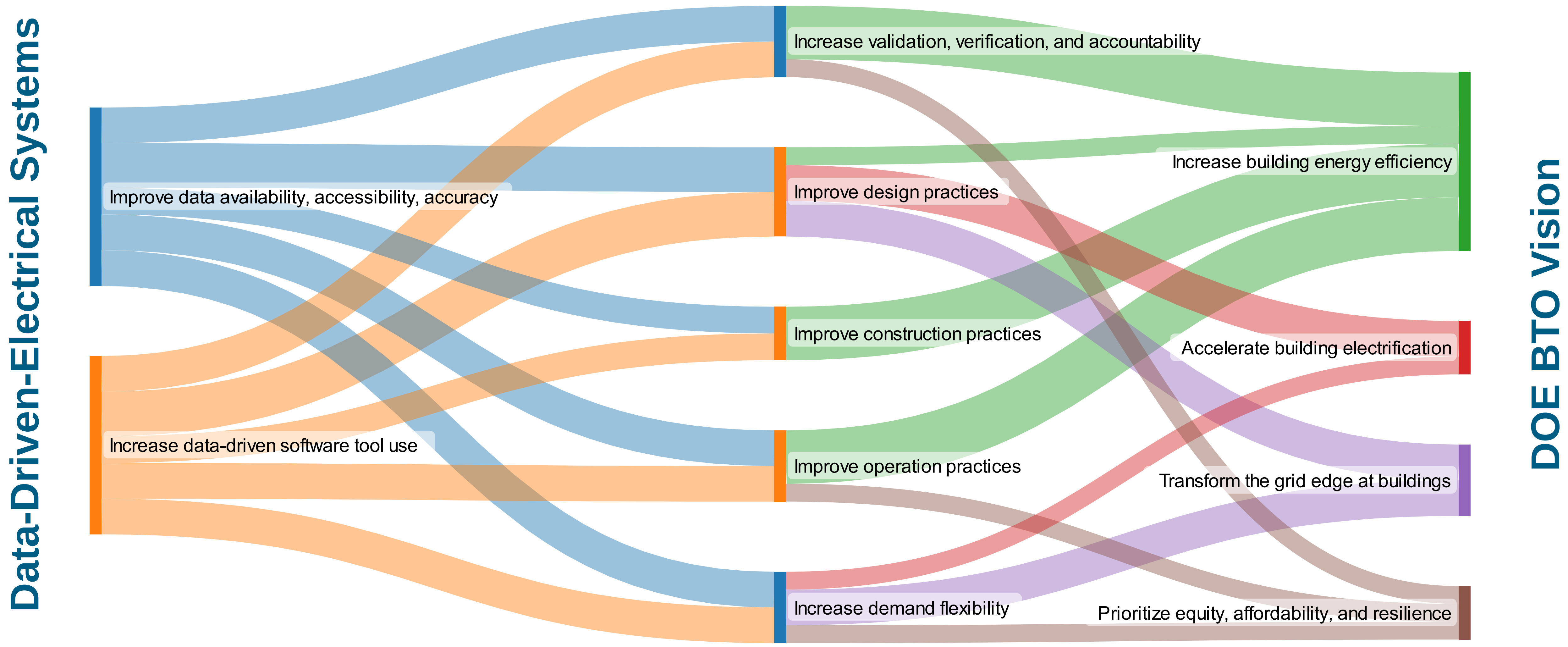
- Improve construction practices by increasing configuration accuracy, and reducing configuration and commissioning time and cost

- Improve operation practices by enabling a) the comparison of design expectations with operational performance and b) automated fault detection and diagnostics

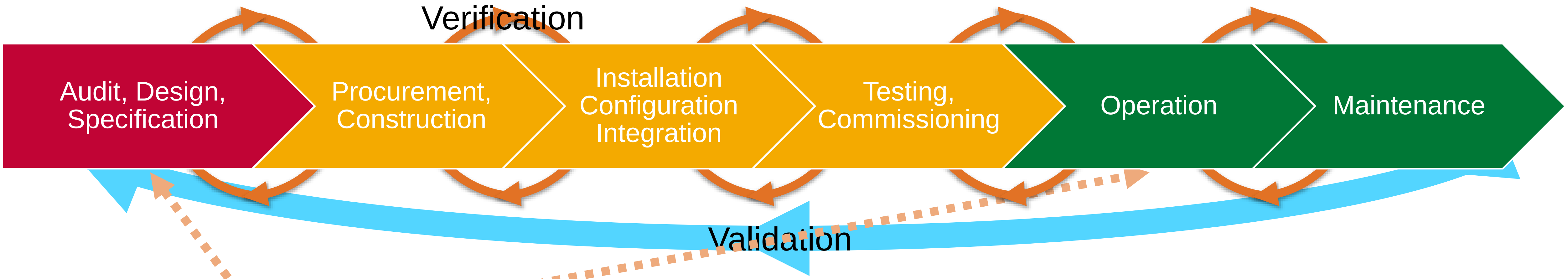
- Increase validation, verification and accountability by enabling the use of digital tools and workflows to evaluate the impact of decisions made throughout the deployment process

- Increase demand flexibility by a) developing and demonstrating easy-to-deploy control strategies and b) contributing to the development of best practices and ANSI standards

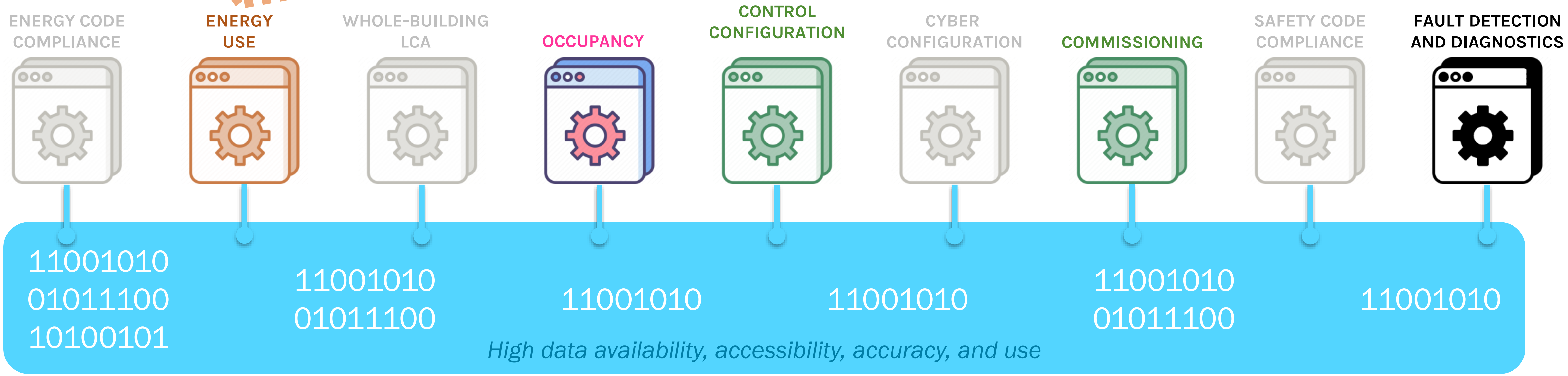
Alignment and Impact



Approach: Better, greater use of digital software tools and workflows, and adoption of new standards

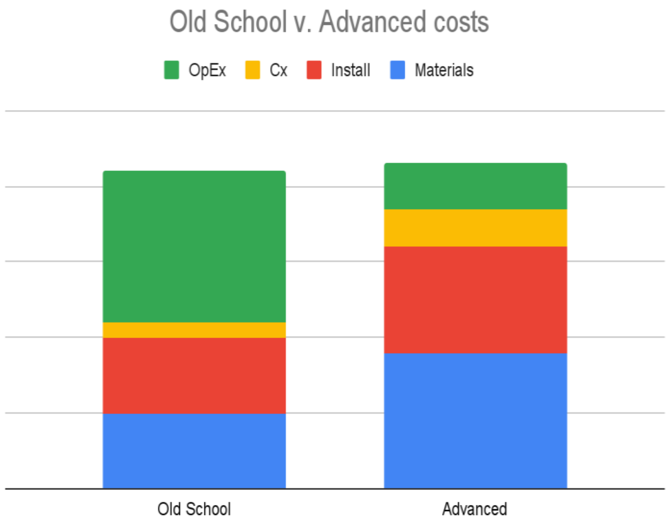


Tools that access data throughout deployment drive improvements in practice, performance, & accountability



Barriers & Risks: More human-centric and institutional than technology-centric and fundamental

- Standard practitioner collaboration and coordination, limited by roles and responsibilities defined in legal contracts
- Standard practitioner fear of change and risk
- Standard practice software tools limited by lack of validation and verification
- Software tool vendors unwillingness to incorporate new capabilities and standards
- Current attempts at greater use of modeling and software tools do not save time or money



BIM. *The ARCHITECT uses building information modeling software ("BIM") as its primary production tool for internal design, coordination, and documentation. The ARCHITECT's Services do not include any intended use of the BIM for the Owner or any third parties (including but not limited to the Contractor) which may include, but is not limited to, quantity takeoffs, construction estimation, construction sequencing or phasing, clash detection, shop drawings, site safety, operations and maintenance, building automation systems, existing conditions modeling, digital fabrication, prefabrication, as-constructed record modeling, or asset management.*

The deliverable of electronic documents to the Owner shall be in PDF form unless requested in BIM. If so requested, the BIM shall be provided in the native file format software the ARCHITECT uses to produce the ARCHITECT's Instruments of Service. Any use of, or reliance on, all or a portion of a building information model without agreement to protocols governing the use of, and reliance on, the information contained in the model and without having those protocols set forth in a BIM execution plan shall be at the using or relying party's sole risk and without liability to the other party and its contractors or consultants, the authors of, or contributors to, the building information model, and each of their agents and employees.

Barriers & Risks: Mitigations

- Seek out and work with practitioners who are striving for change (e.g., BPAC/SimBuild BIM-BEM working group)
- Real-world project demonstrations
- Approach software tool vendors with positive results from real-world demonstrations, leverage weight of standard practitioners
- Contribute to standards development; support, demonstrate and promote standards

	The anchors are here	**The industry is here**	The leaders are mainly here	The evangelists are here	Some enlightened companies are here
	-1	**0**	1	2	3
Contribution of Architect/ Engineer/ Designer	Design Intent only. Paper based deliverables.	**Design Intent with some discussion. Introducing an independent digital approach.**	Design Intent with increasing digital collaboration. May now be part of GC team.	Design incorporating catalog parts and DfMA approach.	Design by assembling catalog parts

Excerpt from Digital Twin Consortium Maturity Model https://www.digitaltwinconsortium.org/press-room/08-03-21

Approach: Multi-task, Core and Exploratory

Task 1: Design of building electric systems that meet energy performance expectations and improve future design practices and decisions (Ongoing, core)

ENERGY USE

OCCUPANCY

Task 2: Design of building electric systems that support electrification and grid reliability (Ongoing, core)

ENERGY USE

Task 3: Automated configuration of building electric systems (New, core)

CONTROL CONFIGURATION

COMMISSIONING

Task 4: Management of distributed building system compute resources to reduce their standby energy use (New, exploratory)

ENERGY USE

Task 8: Semantic interoperability standards for building electric systems (Ongoing, core)

Integrated with "Semantic Modeling and Interoperability" Monday, April 24 11:30am Capital View Room

Task 5: Automated fault detection, diagnostics, and prediction for lighting systems (Ongoing, core)

FAULT DETECTION AND DIAGNOSTICS

Task 6: Automated coordination of building electric systems to increase PV hosting capacity (New, exploratory)

FAULT DETECTION AND DIAGNOSTICS

CONTROL CONFIGURATION

Task 7: Integration of building electric systems with modular building technologies (New, exploratory)

CONTROL CONFIGURATION

WHOLE-BUILDING LCA

Task 9: Flexible and grid-responsive lighting for residential buildings (Ongoing, exploratory)

CONTROL CONFIGURATION

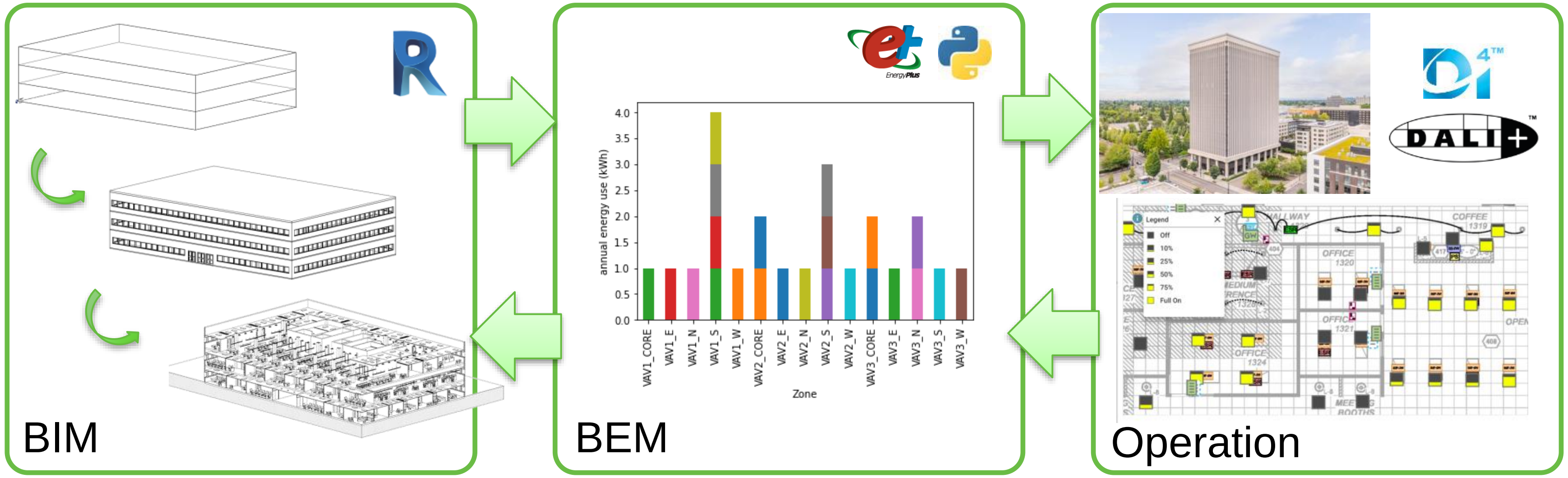
ASHRAE®

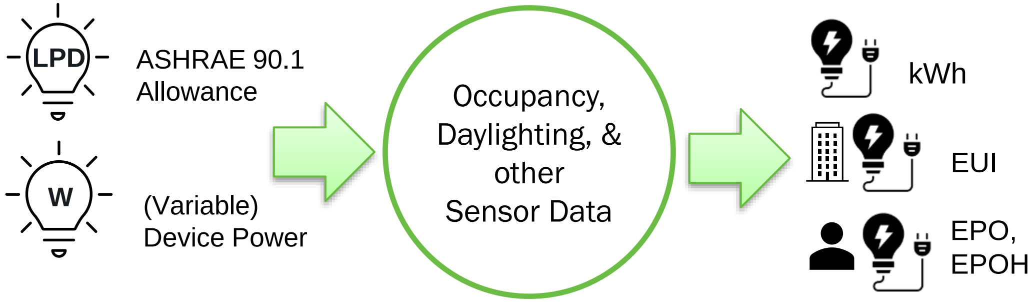
Standard 223P "Semantic Data Model for Analytics and Automation Applications in Buildings"

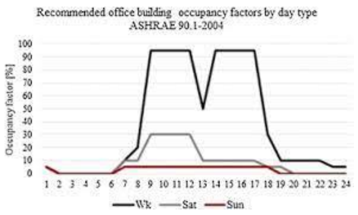
Approach: Design of building electric systems that meet energy performance expectations and improve future design practices and decisions

Develop and demonstrate digital tools and workflows for whole-building electric systems that:

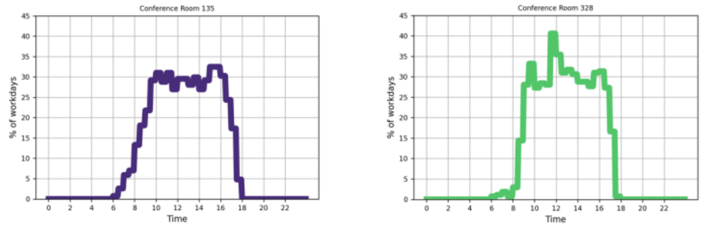
- Model and simulate end-use devices, occupant behavior, and sensors
- Produce energy use estimates that can be measured in operation
- Estimate energy flexibility for grid interaction
- Leverage standard practice tools and skills, and can be readily adopted by standard practitioners with limited work time and cost impacts







Single deterministic schedule



Multiple simulated dynamic schedules

NEEA Medium Office

Data-driven systems can self-report energy use in operational buildings

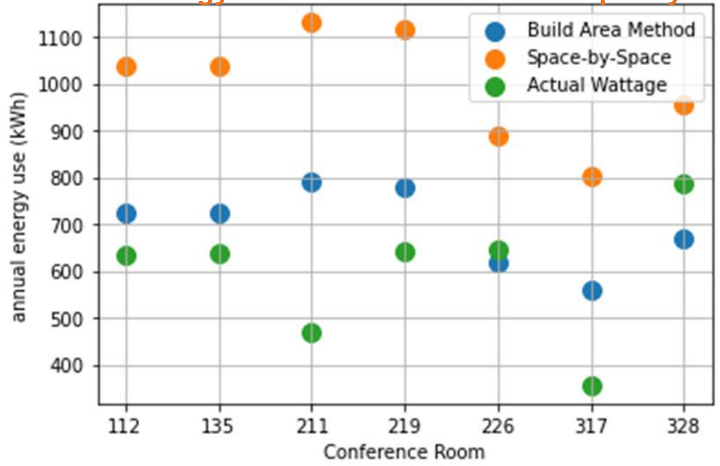
Progress and Future Work: Design of building electric systems that meet energy performance expectations and improve future design practices and decisions

- Developed a high-fidelity model of the DOE prototype medium office building in Revit, and configured the LBNL Occupancy Simulator for its spaces and occupants
- Developed a Revit-to-EnergyPlus workflow that integrates occupant simulation, and began identifying and addressing workflow issues
- Simulated occupant behavior and energy use for the prototype medium office building at 3 phases of design (SD, DD, CD)
- Compared space-type definitions in existing standards, codes, and specifications, and proposed a hierarchical harmonization

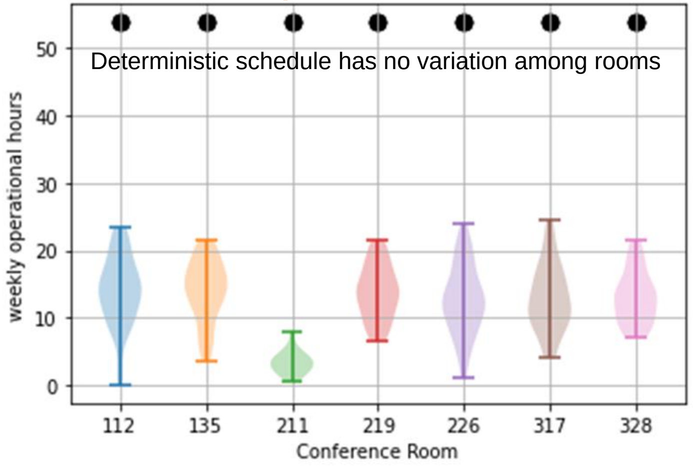
Future Work

- Develop tool that simulates control schemes, and models the effect of sensor performance
- Validate with operational buildings
- Extend to other electric systems (e.g., plug loads, appliances, EV chargers)

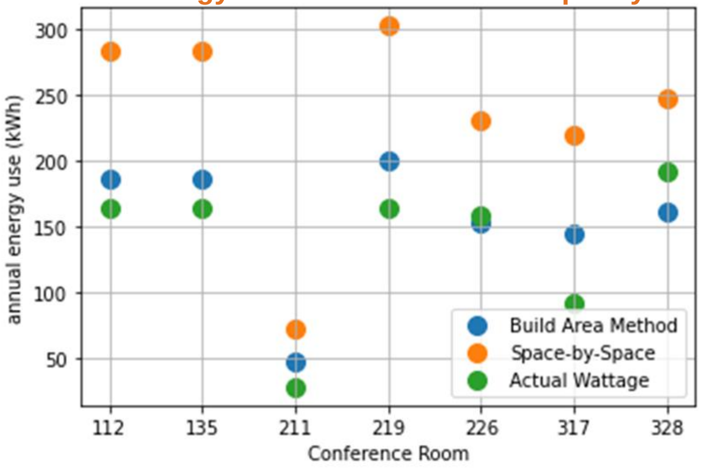
Energy Use w/Deterministic Occupancy



Space Utilization



Energy Use w/Stochastic Occupancy



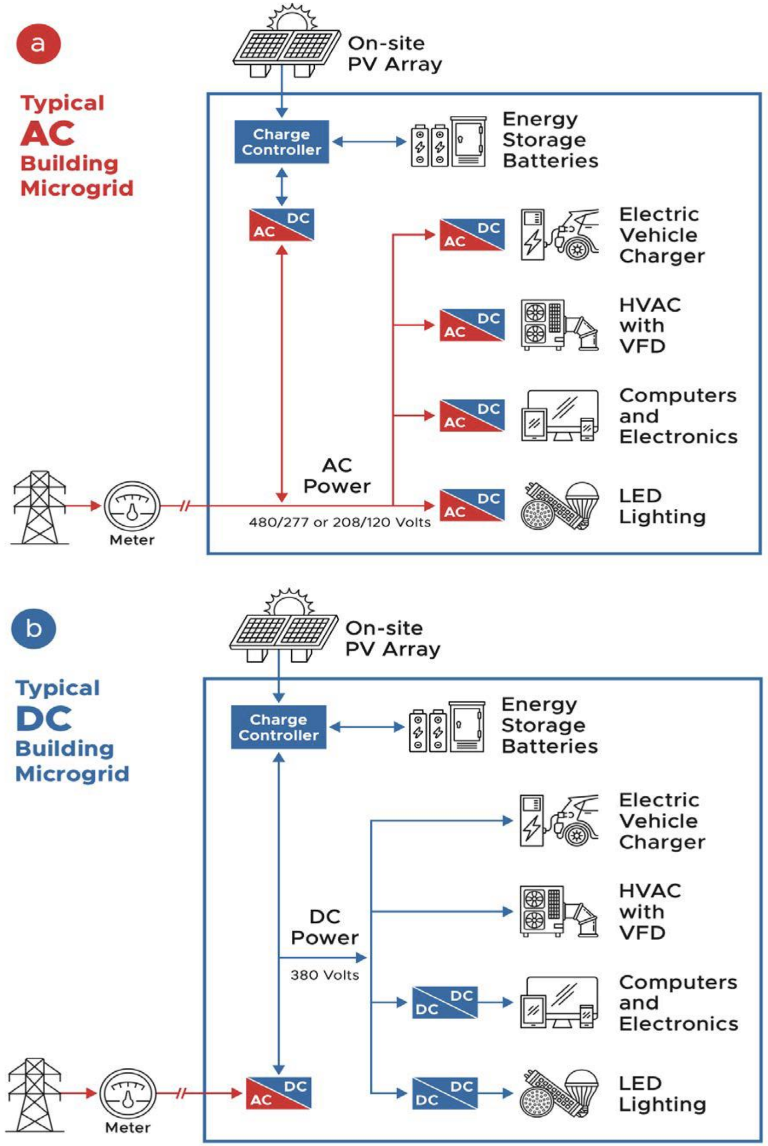
Approach: Design of building electric systems that support electrification and grid reliability

Do designers of hybrid AC–DC electrical distributions systems for buildings need a software tool to make design decisions that affect energy use and electrification?

What are the requirements for this software tool?

Can the DOE/NREL BEEAM toolkit serve as the foundation for such a software tool?

How accurate are simulations that use this toolkit, and is the accuracy suitable for expected design decisions?



Source: Arnold, G., and Pennell, G. 2020. DC Lighting and Microgrids: Opportunities and Recommendations

Modelica Language

https://github.com/NREL/BEEAM

Modelon

Progress and Future Work: Design of building electric systems that support electrification and grid reliability

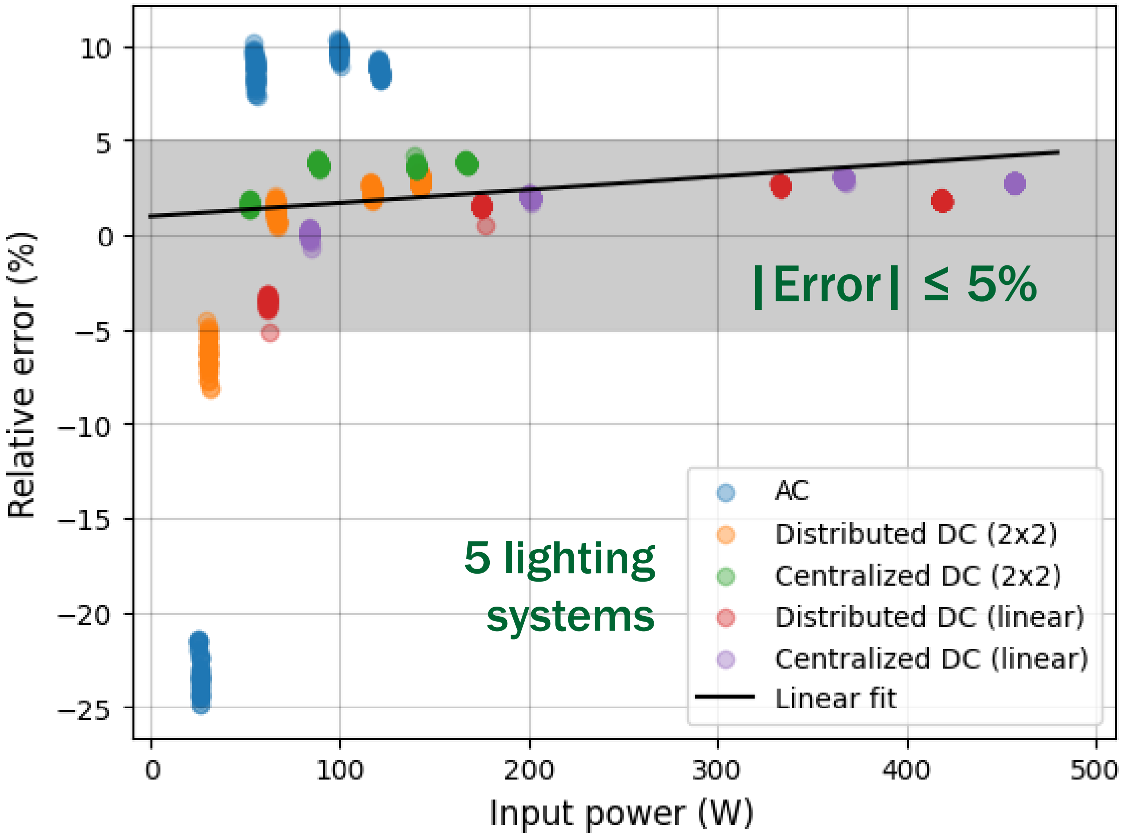
- Modeled five mock lighting systems with varying architectures and comprised of market-available products, and compared simulated vs. laboratory measured performance
- Identified and addressed BEEAM compatibility issues with Modelon Impact

Future Work

- Compare simulation accuracy in different Modelica IDEs

Modelon Dymola OpenModelica

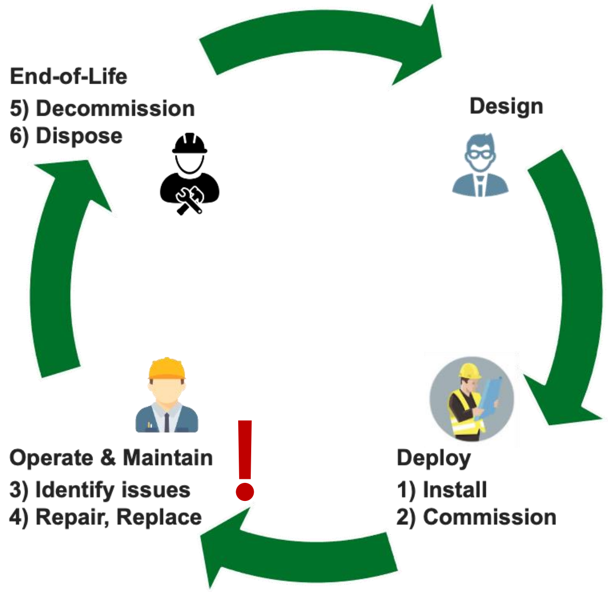
- Explore improvements to laboratory modeling and measurement processes
- Simulate a whole-building model (high-fidelity DOE prototype medium office) in Modelon Impact

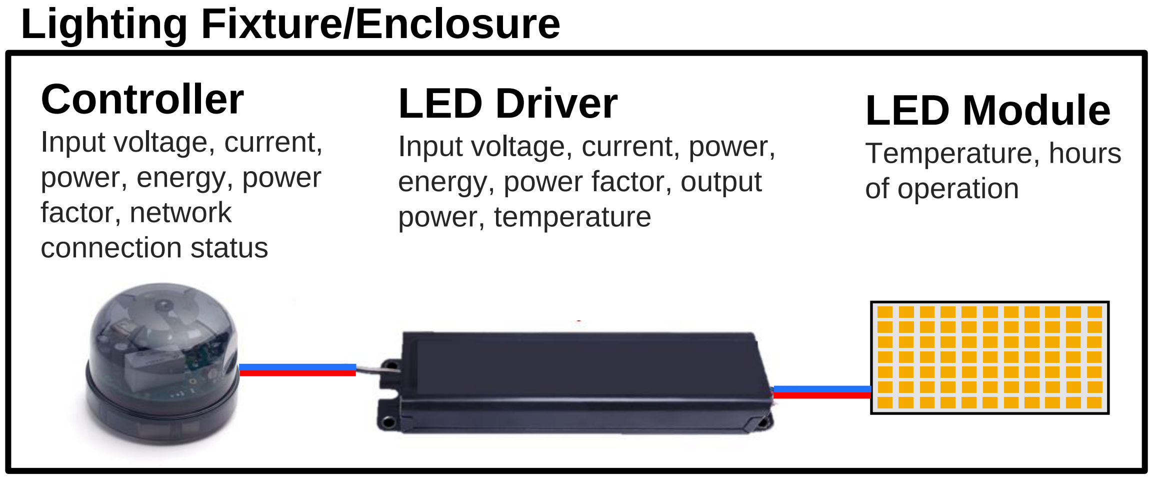


Approach: Automated fault detection, diagnostics, and prediction for lighting systems

Develop and demonstrate automated fault detection and diagnostic (AFDD) techniques for lighting and other building electrical systems, leveraging approaches developed for mechanical/HVAC systems

- Identify common lighting system faults from literature review, stakeholder engagement, and laboratory investigations
- Define a set of common lighting system faults
- Map lighting system faults to detection and diagnostic techniques, and appropriate maintenance actions
- Extend, as applicable, lighting system AFDD techniques to other building electric systems

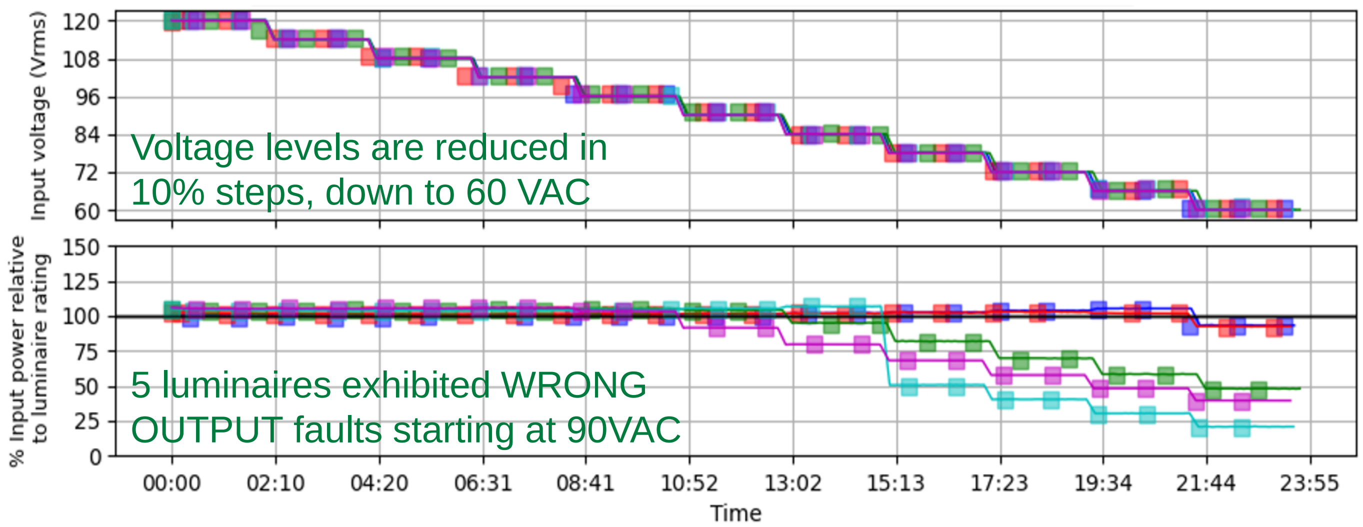




Metadata: Geographic location, circuit ID, rated input power

Progress and Future Work: Automated fault detection, diagnostics, and prediction for lighting systems

- Completed a first-draft set of lighting system faults and associated maintenance actions
- Identified/verified luminaire faults associated with undervoltage conditions and applicable detection schemes in a laboratory environment



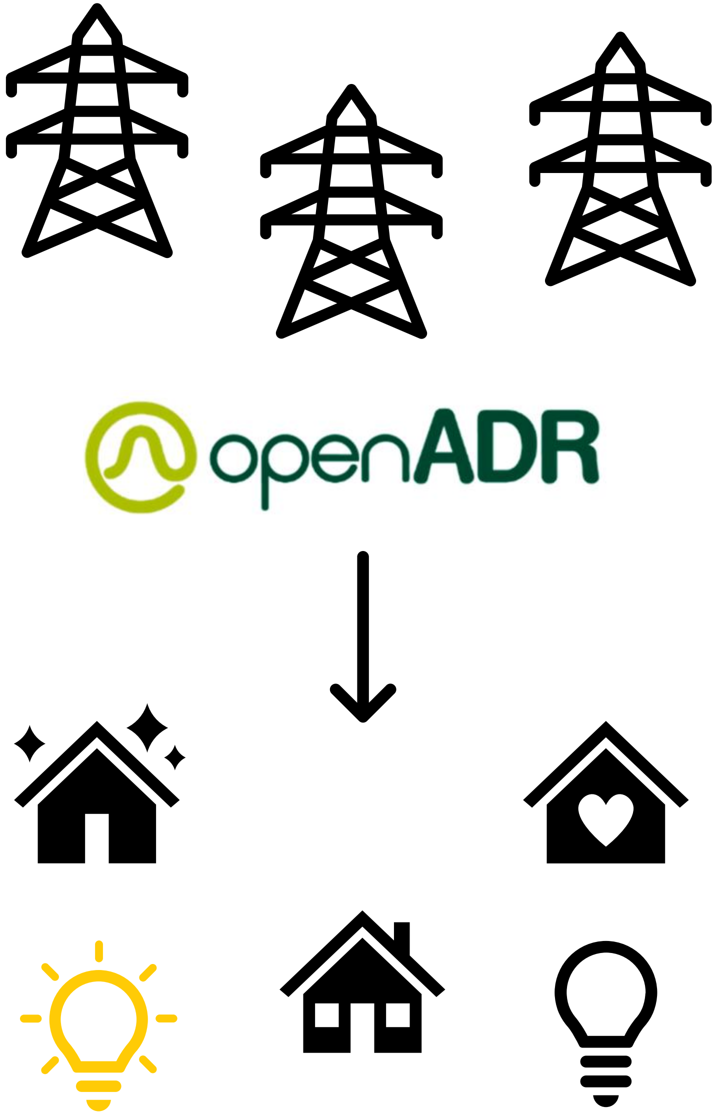
Future Work

- Additional laboratory investigations to identify/verify faults and detection schemes.
- Develop fault diagnostics techniques and associated maintenance action decision tree(s) appropriate for various maintenance maturity levels.
- Laboratory and field demonstrations
- Explore standards development opportunities

Luminaire Faults
ON: light is ON when supposed to be OFF
OFF: light is OFF when supposed to be ON
INTERMITTENT: light is turning ON/OFF in an unintended way
NETWORK INTERFACE: luminaire turns on when power is applied but does not communicate on the internal/external network
WRONG OUTPUT: lighting quality does not meet occupant needs or standards for service and/or safety
NON-OPERATIONAL: luminaire does not turn on when power is applied

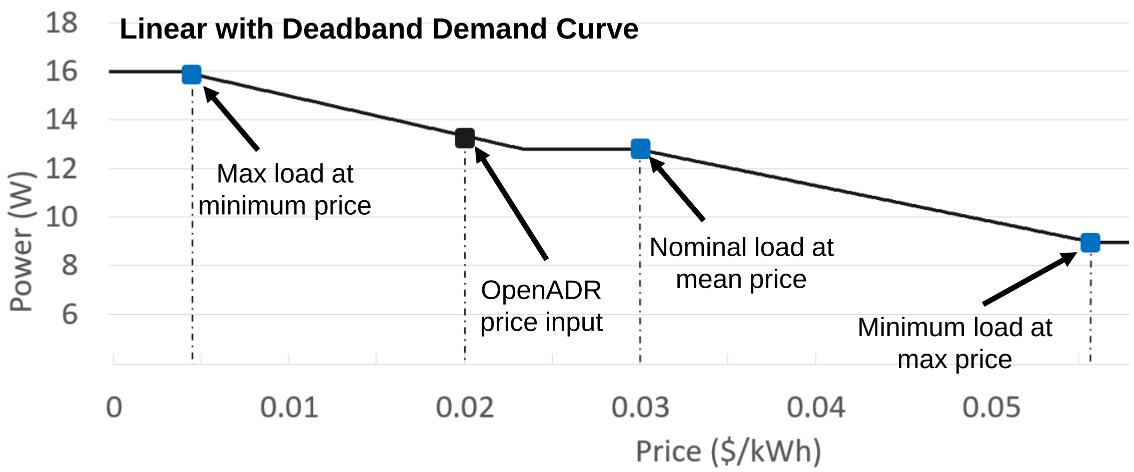
Approach: Flexible and grid-responsive lighting for residential buildings

- Develop a minimum set of lighting system design and configuration requirements for exercising flexibility and responding to grid signals
- Develop objective methods that could be implemented as commissioning tests that an electric utility or certification organization might perform to evaluate and/or qualify systems that claim to meet those requirements.
- Demonstrate, in a laboratory environment, the ability of a commercially available lighting system that targets the residential market to:
  - Be configured to respond to OpenADR grid signals in ways that balance energy use and occupancy needs
  - Be evaluated using the developed commissioning tests
  - Successfully respond to OpenADR compliant grid signals



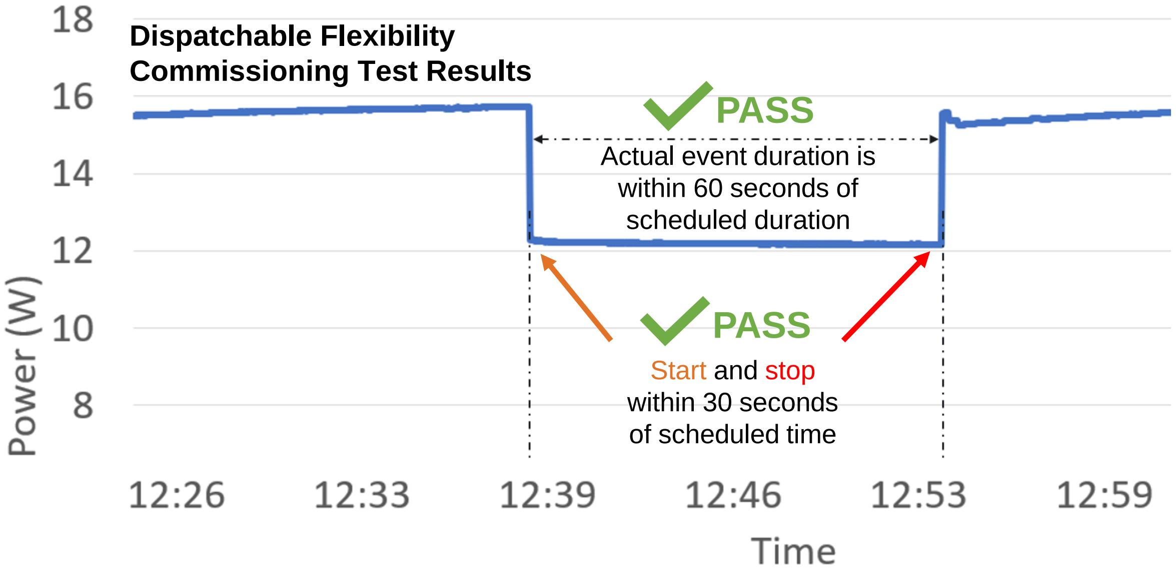
Progress and Future Work: Flexible and grid-responsive lighting for residential buildings

- Five demand curves have been designed for configuring lighting systems to respond to OpenADR SIMPLE and PRICE signals.
- Five commissioning tests have been developed
- In a laboratory environment, a Philips Hue lighting system has been demonstrated to:
  - Be capable of being configured using all five demand curves, implemented as middleware
  - Be evaluated by and pass all five commissioning tests



Future Work

- Explore expanded research opportunities (e.g., integration with appliances)
- Explore field demonstration and deployment opportunities (e.g., DOE Connected Community)



Thank You

Pacific Northwest National Laboratory
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REFERENCE SLIDES

Project Execution

	FY2022				FY2023				FY2024			
Planned budget					$2,432,685							
Spent budget					$1,013,798							
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Q1 Milestone: Complete verification of Modelica-based toolkit accuracy and suitability for making design decisions for PoE systems in a laboratory environment.												
Q1 Milestone: Identify two or more lighting control vendors willing to work together to develop and demonstrate the ability to (semi) automatically configure and commission a lighting system from a digital (semantic) model in a laboratory environment.												
Q1 Milestone: Develop and execute survey of technology providers to fill information gaps and explore field demonstration interest.												
Q2 Milestone: Complete and compare energy performance simulations using two or more workflows at various stages of design for the prototype medium office building. At least one workflow shall utilize occupancy simulation and produce metrics that can be measured and verified in operation.												
Q2 Milestone: Complete initial analysis of common lighting systems faults and proposed approaches for automated detection.												
Q2 Milestone: Complete an analysis of the ability of 2- 4 market-available indoor residential connected lighting and plug-load systems to respond to OpenADR grid signals and be configured to meet occupant needs in a laboratory environment.												
Current/Future Work												
Q3 Milestone: Complete preliminary demonstration of industry standard technologies (i.e., Kubernetes) to manage the deployment and operation of one or more building system software applications in a laboratory environment.												
Q4 Milestone: Release Alpha version of Revit-to-ASHRAE 223p tool for lighting and electrical system model creation, and related workflow and tutorials.												

Team

Michael Poplawski
EE, PI

Majid al Dosari
ME, Data Science, Data Modeling, Software Integration

Shuchi Biswas
EE, Electric Grid, Transmission

Karthik Devaprasad
ME, Modelica, Thermal Systems

Ammar Dehwah
ArchE, Building Design Tools, BEM

Trisha Gupta
ArchE, Building Design Tools, BIM, Semantic Modeling

Michelle Passmore
AeroE, Occupant Behavior, Modular Systems

Shat Pratoomratana
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Ahsan Raza
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Anay Waghale
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Interns

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Laura Hinkle (2022)
Jianjing Huang (2022)
Sichen Lu (2022)
Aryanna Sanchez (2022)
Michelle Passmore (2020)
Brenna Nieva (2020)
Amar Brar (2020)

Stakeholders

Standards Development Organizations, Industry Consortia	Building System Design, Modeling, Simulation Software	Building System Designers, Integrators	Building Equipment Technology Developers
NEMA National Electrical Manufacturers Association	Modelon	SINCLAIR DIGITAL	mhtlighting illuminating PoE technology
IES Illuminating Engineering Society	BEMcyclopedia	gafcon DIGITAL	autani building controls
ASHRAE	*ASHRAE BPAC/SimBuild BIM-to-BEM working group*	PAE	Enlighted
digital twin CONSORTIUM			FOCAL POINT