Sensor Data Integration

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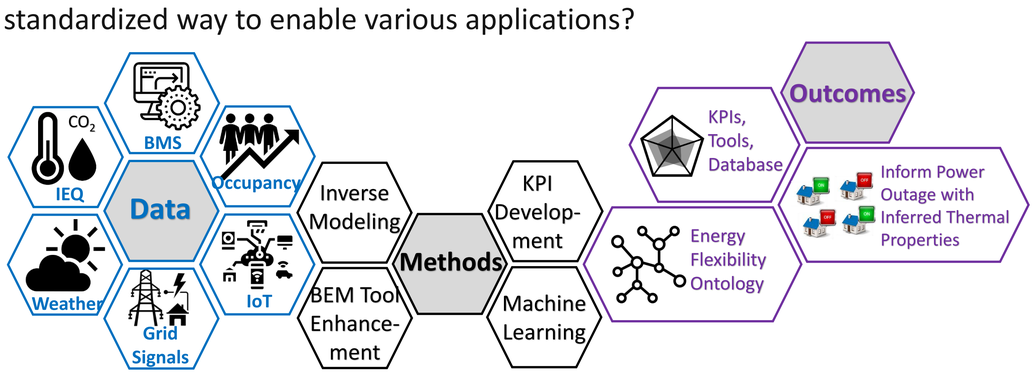
Problem Statement

In recent years, more commercial buildings are equipped with Building Automation Systems (BAS), Advanced Metering Infrastructures (AMI), and smart sensors. The sensor/meter data generated from those systems and equipment provide opportunities of advanced data analytics to inform decarbonizing buildings and improving energy efficiency and demand flexibility. However, the methodology and application of the sensor and meter data are still limited. This project develops new methods, datasets, tools and analyses to use the sensor and meter data in areas such as building performance indicators, data-driven building modeling, and semantic interoperability. **Key research questions to address include:**

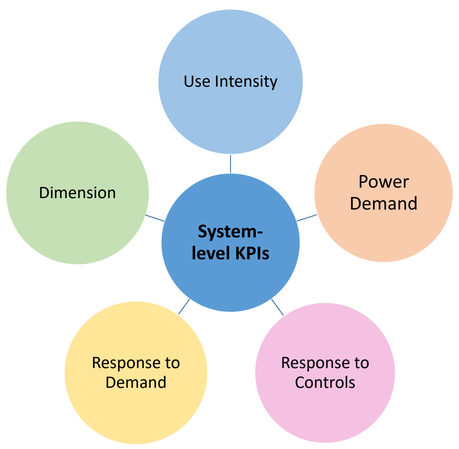
- How to better understand and quantify building performance from the system level and occupant perspectives with new sets of key performance indicators (KPI) that can be calculated with sensor/meter data?
- What are potential opportunities of data-driven methods in building modeling and analytics that can scale to different levels of applications?
- How to represent building energy flexibility related domain knowledge in a standardized way to enable various applications?



Key Performance Indicators

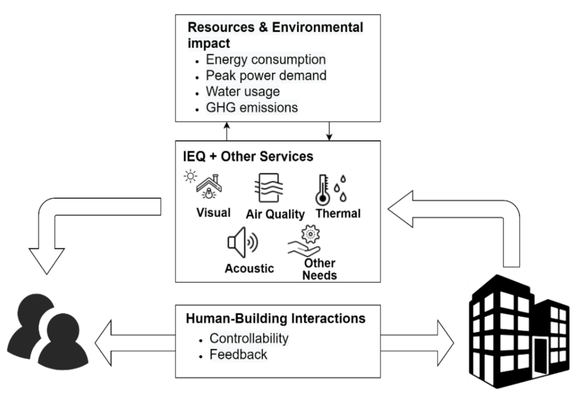
System-level KPIs

We introduced a set of system-level KPIs, which cover four major end-use systems in buildings: lighting, MELs (Miscellaneous Electric Loads), HVAC, and SWH (service water heating), and their eleven subsystems (e.g., space heating, task lighting). The system KPIs are formulated in a new context to represent various types of performance, including energy use, peak demand, load shape, occupant thermal comfort and visual comfort, ventilation, and water use.



Occupant-centric KPIs

We identified significant attributes of occupant-centric KPIs and analyzed the diverse factors that should be considered in formulating an occupant-centric KPI. Then a suite of occupant-centric KPIs were synthesized from the review and enhancement of existing occupant-related performance metrics.



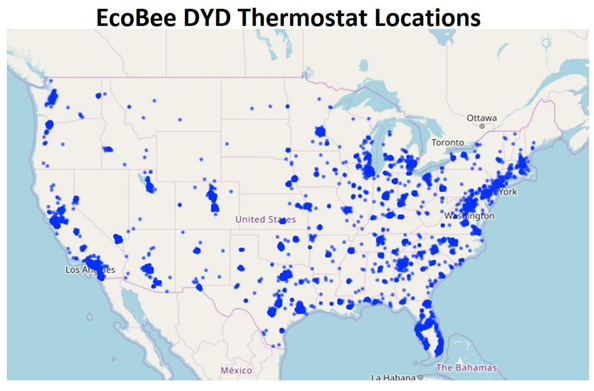
Data-driven Methods and Analytics

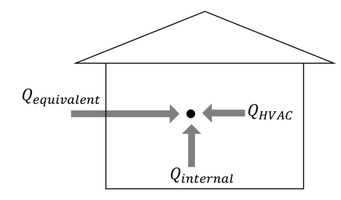
Sensor and meter data provides new opportunities to infer building energy and thermal behaviors, which can inform building and grid operation and response to extreme weather events. We developed novel methods to infer building thermal dynamics and showcase their applications leveraging publicly available datasets, including EcoBee DYD dataset and PNNL Lab Home dataset.

1. Inferring thermal properties and inform safe rotating power outage

- We identified thermal properties of residential buildings using EcoBee data
- Simplified thermal time constant models can be used to predict buildings' temperature trends during free-floating.

EcoBee DYD Thermostat Locations



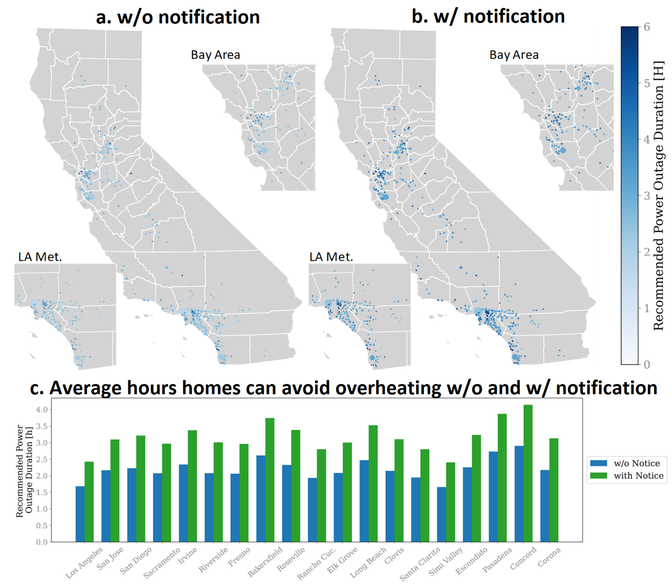


Temperature change | Solar and internal heat gains

$$C\frac{dT_{in}}{dt} = \frac{(T_{out} - T_{in})}{R} + \frac{T_{eq}}{R} + Q_{HVAC}$$

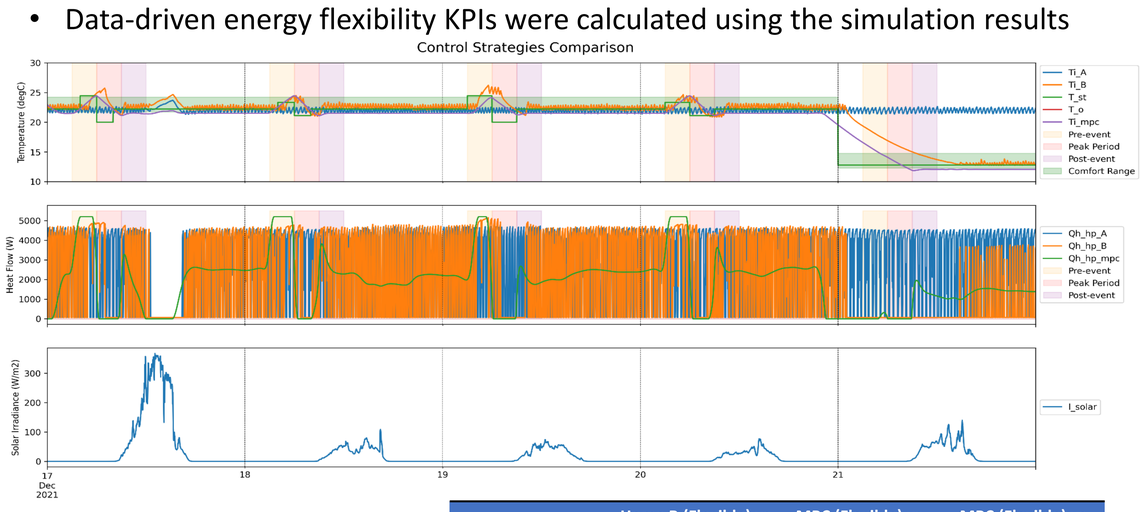
Heat transfer between indoor and outdoor | Heat from HVAC

- The inferred building thermal dynamics are used to estimate maximum duration of rotating power outages to ensure occupant thermal safety during heat waves
- The outcome can inform rotating power outage by issuing pre-cooling notification considering buildings' thermal mass effect.



2. Data-driven building energy flexibility quantification

- We developed and verified data-driven models using PNNL Lab Home data
- MPC was tested using the virtual testbed to improve building energy flexibility
- Data-driven energy flexibility KPIs were calculated using the simulation results



KPI Calculation Example

$$BEFI(t,\Delta t) = \frac{\int_t^{t+\Delta t} P_{ref}(t)dt - \int_t^{t+\Delta t} P_{flex}(t)dt}{\Delta t}$$

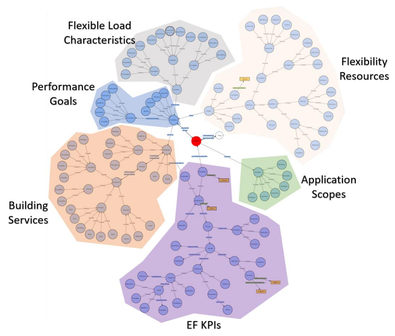
Date	Home B (Flexible) vs Home A (Baseline)	MPC (Flexible) vs Home A (Baseline)	MPC (Flexible) vs Home B (Baseline)
2021-12-17	1.07	2.56	1.50
2021-12-18	1.52	2.61	1.09
2021-12-19	1.12	2.15	1.03
2021-12-20	1.33	2.52	1.19

A Semantic Ontology for Energy Flexibility

Although energy flexibility has received growing attention from industry and the research community, there remains a lack of common ground for energy flexibility terminologies, characterization, and quantification methods. Current data schemas and ontologies are not designed for energy flexibility applications.

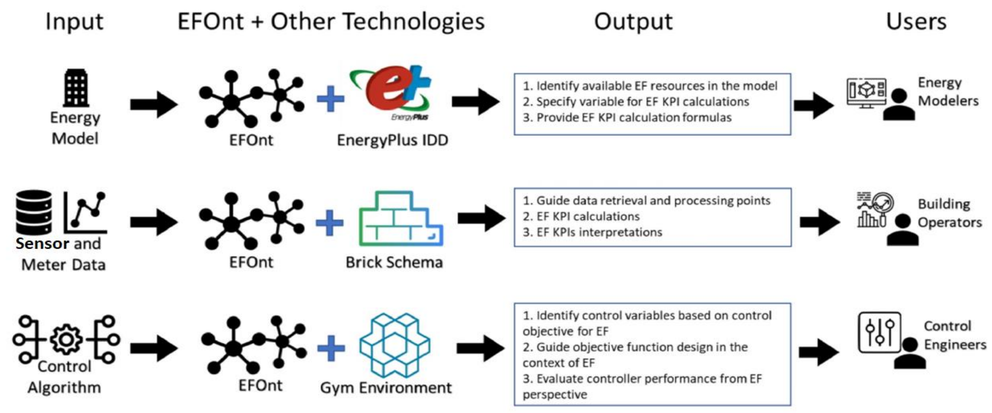
Key questions we try to address:

- How do we describe the technologies and resources without ambiguity?
- What are the common energy flexibility KPIs that and their formal definitions?
- What kind of data is needed to calculate the KPIs? What are the data sources?
- Who are the stakeholders that might be interested in what scenarios of energy flexibility?



We developed a semantic ontology for building energy flexibility applications including building energy modeling, data-driven energy flexibility quantifications, and building controls. The ontology is designed to work with other building energy data tools in the existing ecosystem. The ontology is used in the IEA EBC Annex 81.

Potential use cases of the ontology



References & More Information

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