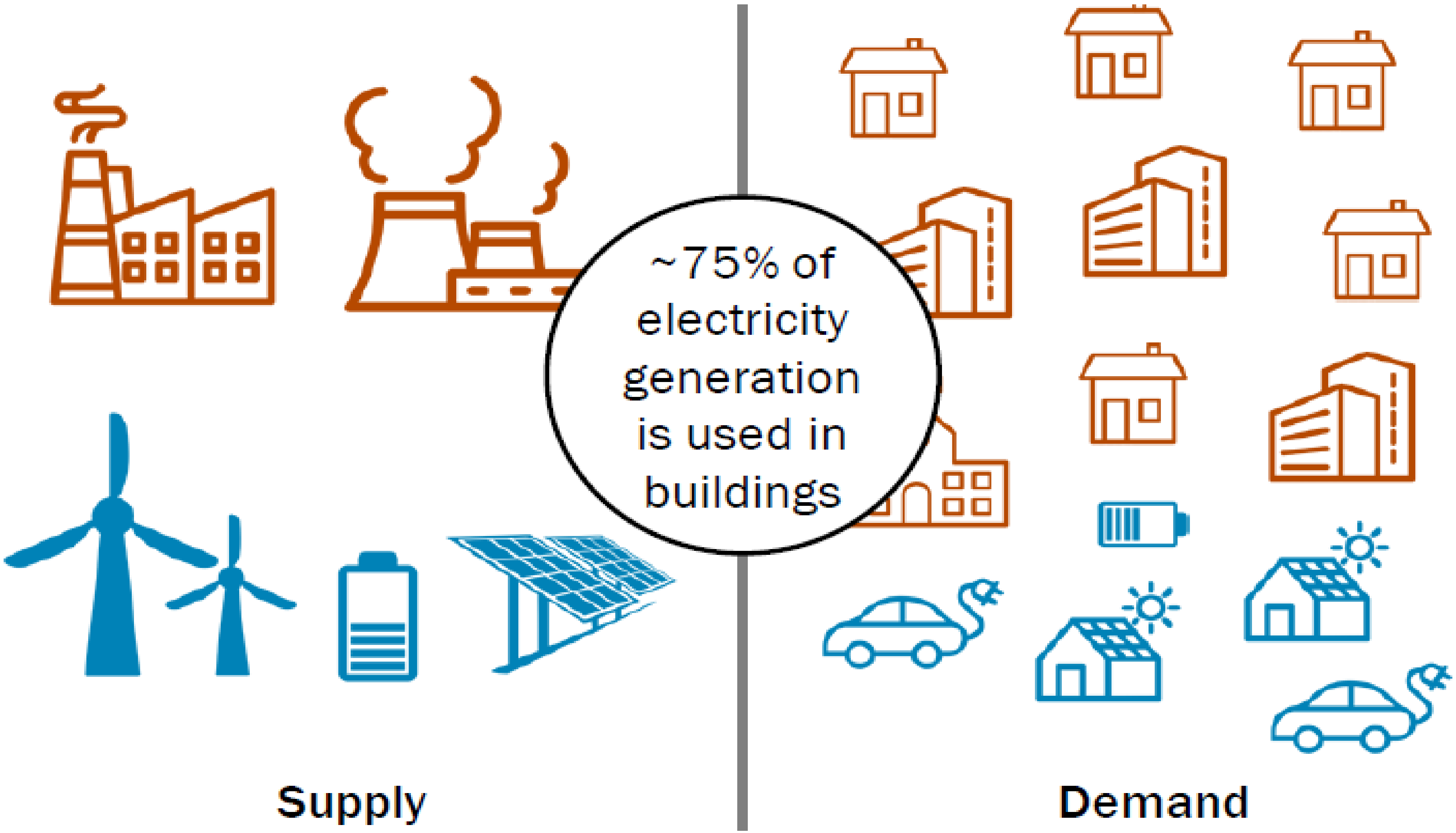
U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

GEB and S&C Overview

Building Technologies Office

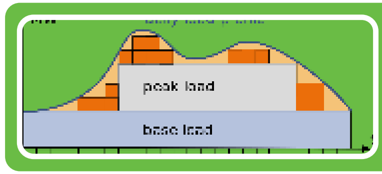
July 21, 2020

GEB is about enabling buildings to provide flexibility in energy use and grid operation



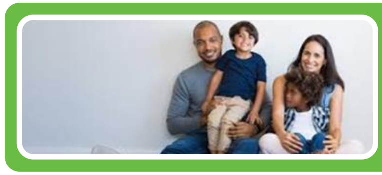
Potential Benefits of Flexible Building Loads

✓ Energy Affordability



✓ Improved reliability & resiliency

✓ Reduced grid congestion



✓ Enhanced services

✓ Environmental benefits

✓ Customer choice

Key Characteristics of GEBs

A GEB is an energy-efficient building that uses smart technologies and on-site DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way.

EFFICIENT

Persistent low energy use minimizes demand on grid resources and infrastructure

CONNECTED

Two-way communication with flexible technologies, the grid, and occupants

SMART

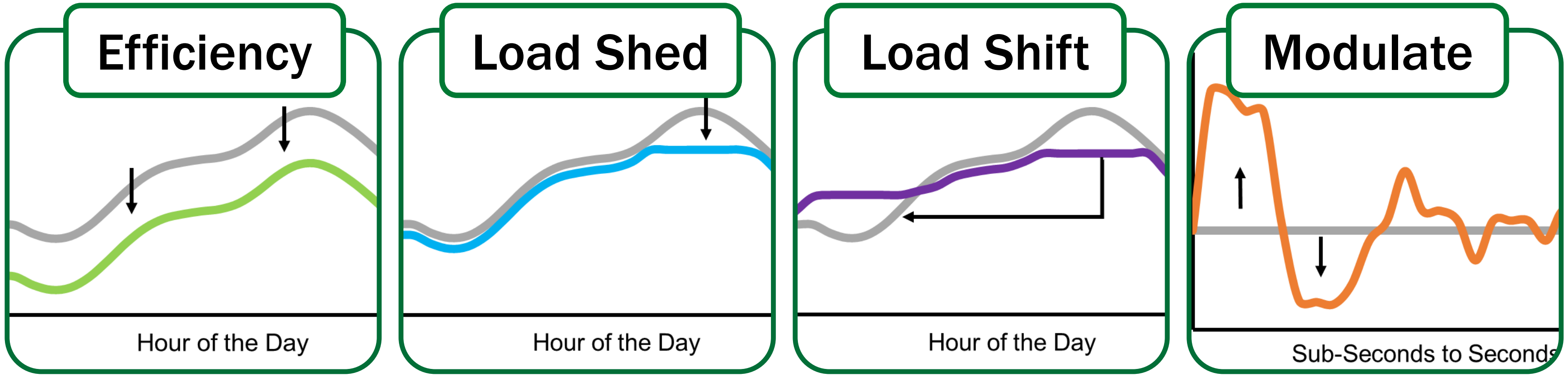
Analytics supported by sensors and controls co-optimize efficiency, flexibility, and occupant preferences

FLEXIBLE

Flexible loads and distributed generation/storage can be used to reduce, shift, or modulate energy use

Mapping Flexibility Modes and Grid Services

Buildings can provide grid services through 4 demand management modes.



Grid Services Provided

Efficiency	Load Shed	Load Shift	Modulate
• Generation: Energy & Capacity • Non-Wires Solutions	• Contingency Reserves • Generation: Energy & Capacity • Non-Wires Solutions	• Generation: Capacity • Non-Wires Solutions	• Frequency Regulation • Ramping

Examples

Efficiency	Load Shed	Load Shift	Modulate
• Daylighting with sensors & controls	• Reduce plug loads	• Precool with T-stat; preheat water heater	• Rapid dimming of lighting

BTO’s grid-interactive efficient buildings portfolio

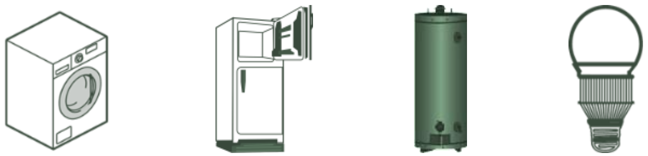
VALUATION

How do *time & the interaction of flexibility options* impact value?

Identify values to stakeholders, quantification of national value.

TECHNOLOGY OPTIONS

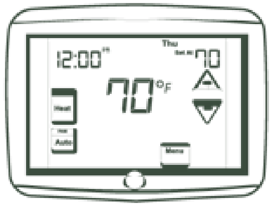
Which end use technologies provide solutions to specific grid needs?



Prioritize technologies / solutions based on grid services.

OPTIMIZATION

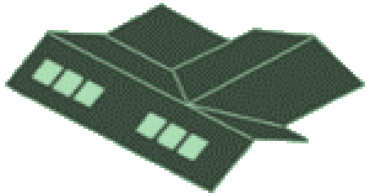
How to maintain or improve services while optimizing for flexibility?



Solutions that meet grid operator & building occupant needs.

VALIDATION

Do technologies perform as predicted and meet grid & occupant needs?



Verification of technologies / strategies, increasing confidence in the value of energy flexibility.

Key Activities 2020-2021

Stakeholder Engagement

- Utility working group focused on EE/DR integration & GEB projects
- State working group focused on 4 TA areas: Potential, pilots, lead by example & valuation
- Commercial building working group focused on technology optimization & business case
- GEB Roadmap focused on a national perspective of defining potential and implementation needs to scale GEBs

Research & Validation

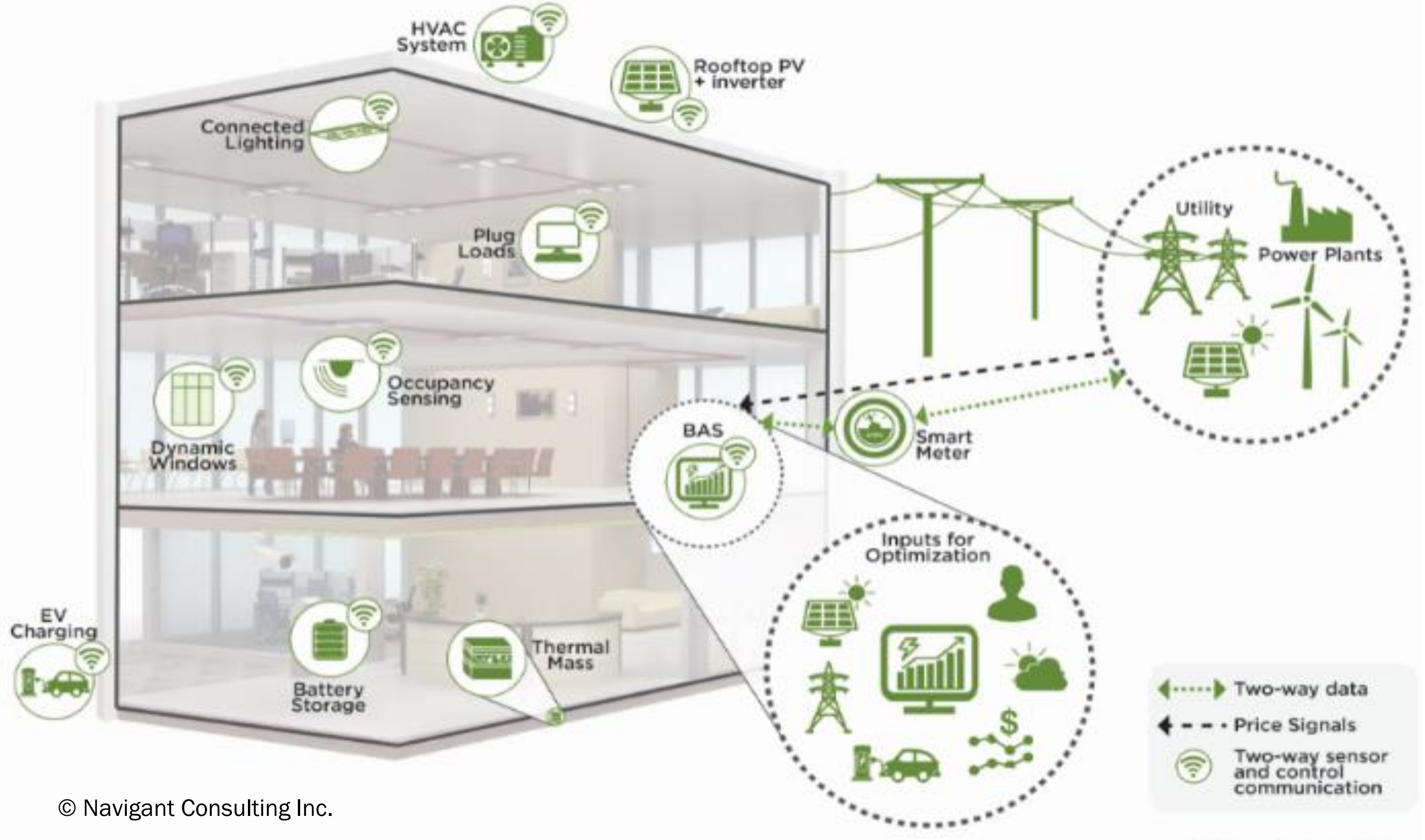
- Demand flexibility technology metrics
- Continued focus on research projects across HVAC, lighting, water heaters, appliances, controls, modeling focused on determining demand flexibility capability (BENEFIT FOA)
- Community focus on demand flexibility (Connected Communities FOA)
- Occupant thresholds and impacts
- Commercial, residential, community DF datasets from validation projects

GEB Technical Report Series Overview

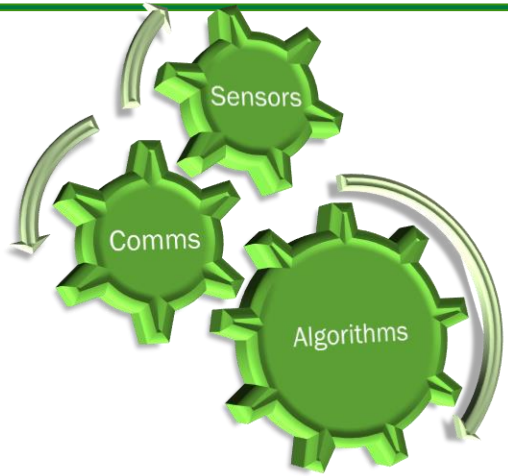
The GEB Technical Report Series outlines key demand flexibility opportunities across BTO's R&D portfolio:
http://energy.gov/eere/buildings/grid-interactive-efficient-buildings

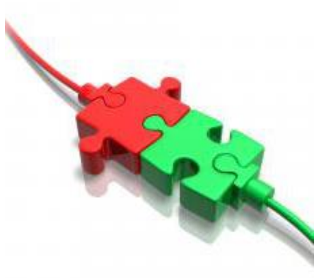
<u>Technical Report Series:</u>

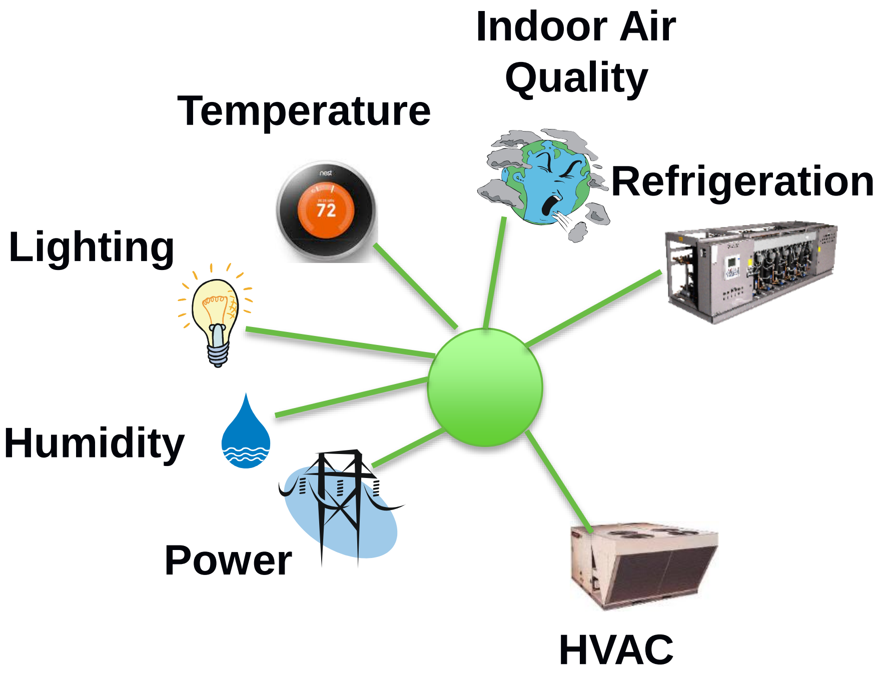
- Overview of Research Challenges
- Heating, Ventilation, & Air Conditioning (HVAC); Water Heating; and Appliances
- Lighting & Electronics
- Building Envelope & Windows
- Sensors & Controls, Data Analytics, and Modeling



Sensors and Controls: Current State







- Today's stock of buildings are noticeably "unconnected"
  - Limited by existing control and coordination
  - Advanced automation only in large buildings
  - Value streams are often hidden and untapped
- Energy efficiency, grid integration, renewable integration
  - Building equipment integration and grid-interactivity
- Improved integration of BAS and IoT approaches for deploying technology can enable new services
- Retrofit deployment with ROI in 1-2 years

Sensors and Controls: Current State

- **Large commercial buildings**
  - Most BAS monitor and control HVAC. + Lighting and others for some
  - May include AFDD
  - Rule-based control

- **Medium and small commercial buildings**
  - Most have packaged units (e.g. RTUs)
  - Low operational and convenience benefits for central control

- **Residential buildings**
  - Rapid adoption of smart thermostats, voice assistants
  - Could aid in integrated energy management

The Sensors and Controls Program has 4 Focus Areas

1. Hardware
2. Software
3. Cybersecurity
4. Semantic interoperability

1. Hardware – R&D areas

- **Develop low-cost sensor technologies**
  - Low-cost hardware through innovation in materials and manufacturing methods
  - Cost-effective low-volume sensor production and deployment
  - Multi-modal sensing platforms coupled with energy-harvesting-based approaches minimize operational and maintenance costs for buildings
- **Develop sensor technologies with reduced installation and commissioning costs**
  - Self-configuration, self-commissioning, and self-optimization
  - Enable sensor networks with little to no engineering effort
  - Automated intelligent re-calibration - reducing maintenance costs
- **Investigate the applicability and performance of integrating new sensor technologies into the existing systems**
  - Retro-commissioning, evaluating and integrating new sensing technologies with existing systems
  - Reference guidelines for the building/HVAC industry

1. Hardware - R&D areas (Cont'd)

- **Develop optimal sensor placement and configuration algorithms**
  - Optimal sensor placement algorithms - reduce the number of deployed sensors optimal building operations
  - Reduce cost and effort required to measure and process a large amount of redundant data sources
- **Develop advanced actuators**
  - Low-cost, low-power, miniaturized (small and lightweight) and durable actuators
  - Minimal re-calibration to enable highly granular building operations
- **Design actuators with embedded intelligence**
  - Next-generation actuators with embedded intelligence
  - Enable context-aware operation
  - Proactively fault-remediation and avoid performance degradation

2. Software - R&D areas

- Develop the fundamental and practical aspects of model-based predictive control for large and medium commercial buildings.

- Evaluate MPC for residential buildings through field tests.

- Develop methods of prioritizing different zones and end uses within a building and coordinating energy efficiency and grid service delivery across those zones and end uses.

- Develop methods of acquiring occupant comfort states and preferences

2. Software - R&D areas (Cont'd)

- Develop methods of registering occupant prioritization and valuation of different end uses.
- Standardize data pre-processing for data-driven techniques
- Develop the practical aspects of an automated and cost-effective transactive control package for grid services.

3. Cybersecurity – Current Status

- IT vs OT paradigm

- Buildings can be remotely accessed by unauthorized agencies
- No disaster recovery plan
- No changes to default configuration settings

- Cybersecurity capabilities minimizes loss of critical function

3. Cybersecurity – R&D areas

- **Develop retrofit solutions**
- **Develop vulnerability assessments**
- **Research threat detection algorithms**
- **Research adaptive and self-healing technologies**
- **Develop cybersecurity standards**
- **Leverage existing resources**
  - NIST Framework for Improving Critical Infrastructure (NIST-CSF)
  - Building Cybersecurity Framework (BCF)
  - Building Cybersecurity Capability Maturity Model (B-C2M2)

4. Semantic Interoperability – current status

- **Each building adjacent industry may have its own model … or several of them**
  - Lighting, packaged commercial HVAC, packaged residential HVAC, PV, EV charging, etc.
- **Different building sectors may use different models as well**
  - Healthcare, retail, commercial building real-estate, etc.
- **Different organizations trying to harmonize different subsets**
  - These efforts are themselves uncoordinated
  - https://xkcd.com/927/

4. Semantic Interoperability – current status

- **Descriptions of devices, their capabilities, and relationships to each other and building**
  - No testable standard for minimal information required to support different applications, e.g., FDD
  - Each EMIS and BAS data model is essentially custom
- **Example: Zone1 which is served by VAV4, which itself is served by AHU1**
  - Technician #1: { @1: "dis: Z1thermostat" @2: "dis: Z1VAV", @3 "dis: FL1AHU" }
  - Technician #2: { @z1: "dis: Zone1, floor: 1, equipRef: @v1", @t1: "dis: Zone1 Thermostat, zoneRef: @z1", @v1: "dis: VAV4, zoneRef: @z1, equipRef: @a1", @a1: "dis: AHU1" }
  - Both models can be made to "work" individually, but #2 is more "complete" and useful downstream
- **Consequences**
  - Manual configuration of individual installations is an effort and cost barrier
  - Outside contractors must spend time learning each new building
  - Adoption of new and upgraded services is slow to scale up
  - Competition for services like FDD, ASO, etc. is suppressed

4. Semantic Interoperability – R&D Areas

- Harmonize existing semantic modeling frameworks, fill in as necessary
- Develop minimal requirements for different use cases of semantic data modeling
- Develop semantic data model conformance and completeness testing frameworks
- These support procurement of compliant semantic data model installations
- Develop translation tools to ease transition of existing systems
- Engage stakeholders to promote semantic data modeling

Bringing it all together – Examples of current work

Smart Neighborhoods

- **What:**
  - Develop, demonstrate, and validate a scalable control framework to co-optimize energy cost, occupant comfort, grid reliability and resilience in next generation neighborhoods that integrate renewable energy sources and energy storage solutions.
  - Field verified in a neighborhood of 62 homes built with the Southern Company.
- **Why:**
  - Critical need to have access to model homes for testing and validation of the next generation of technologies and control methodologies.
- **Results:**
  - An open-source framework for deploying grid-interactive controls within residential neighborhoods to improve energy efficiency, reduce energy costs, and improve grid resiliency.
  - Real data collection from occupied homes that will serve as a requirement specification for enabling adoption across other utilities.

Partners

Oak Ridge National Laboratory

Southern Company

Smart Neighborhoods

- **How:**
  - The study is being done at a neighborhood of 62 homes equipped with relevant technologies. The homes have energy efficient envelopes, lighting, heat pumps and hybrid heat pump water heaters as specified by Southern Company.
  - ORNL used the open source platform VOLTTRON to develop a transactive control framework to acquire information from the appliances, model the home performance and dispatch the home loads through setpoint and mode adjustments.
  - The objectives of the project include:
    - Quantifying the value of preheating and precooling homes
    - Quantifying the value of operating microgrid Distributed Energy Resources
    - Demonstrate controls algorithms that can keep electricity loads at desired values
    - Evaluate price signal design with a microgrid and controllable loads
    - Develop system-level architecture for transactive control of end-use loads, generation, and storage resources
    - Demonstrate advanced metering algorithms than can disaggregate individual loads

Current Collaboration Example: Behind-the-Meter-Storage (BTMS) Analysis

- **What:**
  - Develop and analyze new behind-the-meter storage (BTMS) solutions, such as battery systems and thermal storage, to facilitate grid services (electric vehicle charging, solar power generation, demand flexibility, etc.)
- **Why:**
  - BTMS is needed to mitigate high electric demand charges, to facilitate onsite building renewables and electric vehicle (EV) charging.
  - The synergies of how electrochemical storage (batteries) and thermal storage can work together is an unanswered question.
- **Results:**
  - Produce behind-the-meter battery solutions that can be deployed at scale and meet the functional requirement of high-power EV charging.
  - Develop and identify the specific functional requirements for BTMS battery solutions that will provide novel battery systems in the 1–10 MWh range at $100/kWh installed cost and able to cycle twice per day, discharging for at least 4 hours, with a lifetime of roughly 20 years or at least 8,000 cycles.

Partners

NREL Transforming ENERGY

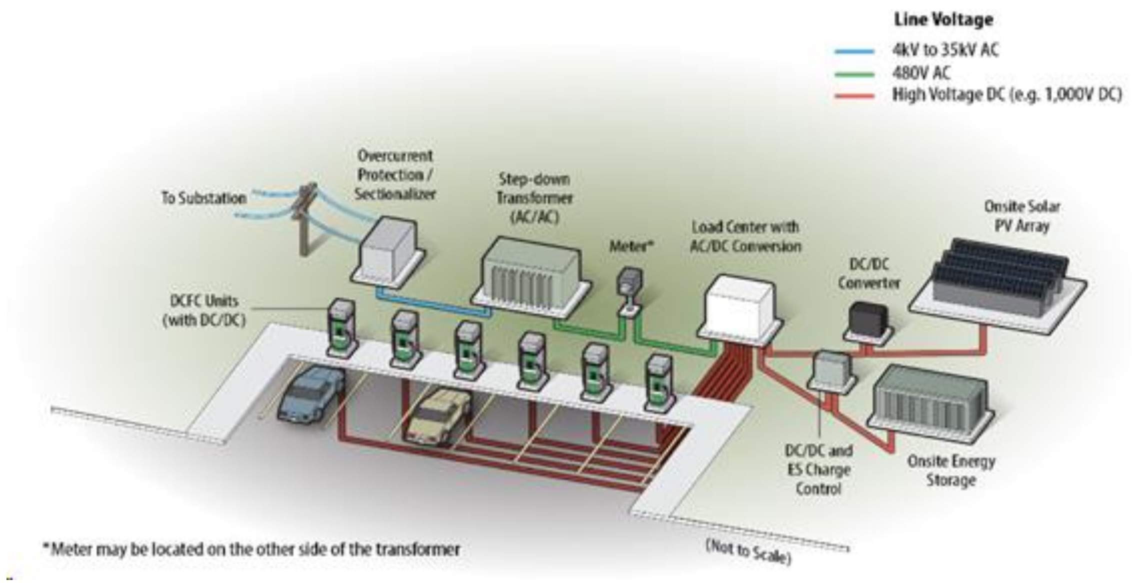
INL Idaho National Laboratory 70 YEARS OF SCIENCE & INNOVATION

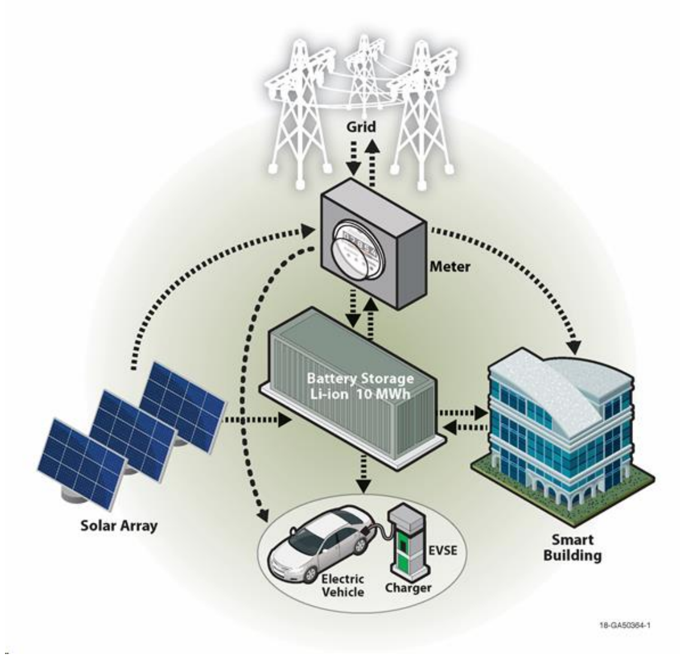
Sandia National Laboratories

OAK RIDGE National Laboratory

Current Collaboration Example: Behind-the-Meter-Storage (BTMS) Analysis

- **How:**
  - Use modeling and experiments to understand the tradeoffs and synergistic effects of using BTM electrochemical and thermal energy storage, including the development of control strategies.
  - Develop new thermal energy storage characterization methods, both at the materials and device scales.
  - Use building- and system-level modeling to understand the charge/discharge requirements of thermal energy storage for different building applications.
  - Produce critical-material-free battery solutions that meet application specific requirements.





Questions?