U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Grid-interactive Efficient Buildings Strategy Discussion

Monica Neukomm

Building Technologies Office, DOE

www.energy.gov/eere/buildings/geb

Agenda

Time	Discussion Topic	Presenters
1:30-1:50	Strategy Update & RFI Feedback	Monica Neukomm & Nelson James
1:50-2:05	Interoperability	Bill Livingood
2:05-2:20	Building Energy Modeling	Jared Langevin & Amir Roth
2:20-2:40	Demand Flexibility Metrics	Jingjing Liu & Jhi-Young Joo
2:40-2:55	Assessing Performance of Demand Flexibility	Mike Li
2:55-3:00	Wrap-Up	Monica Neukomm

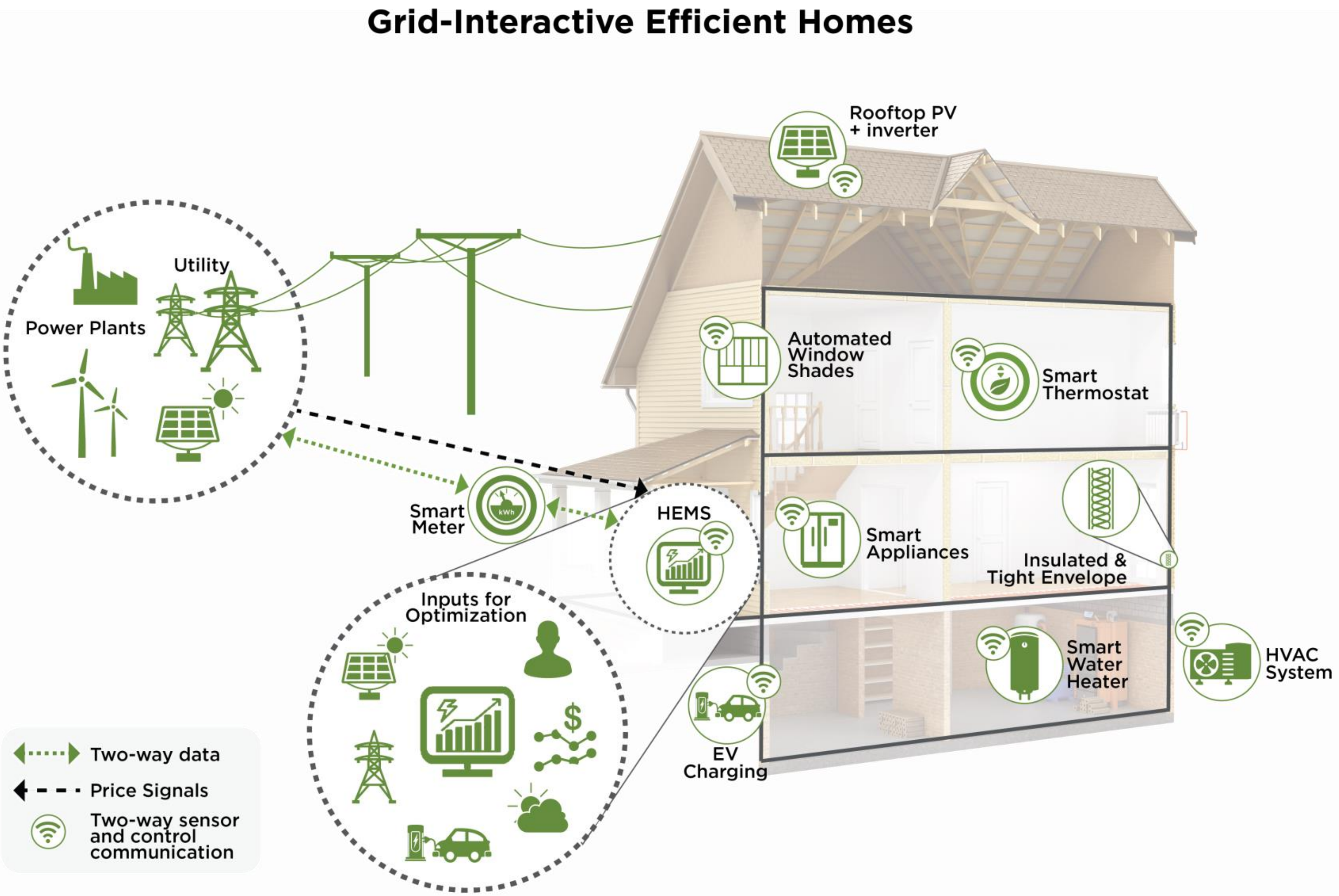
Interactive Polling

- We will be taking audience polls throughout the session
- Navigate your mobile phone browser to

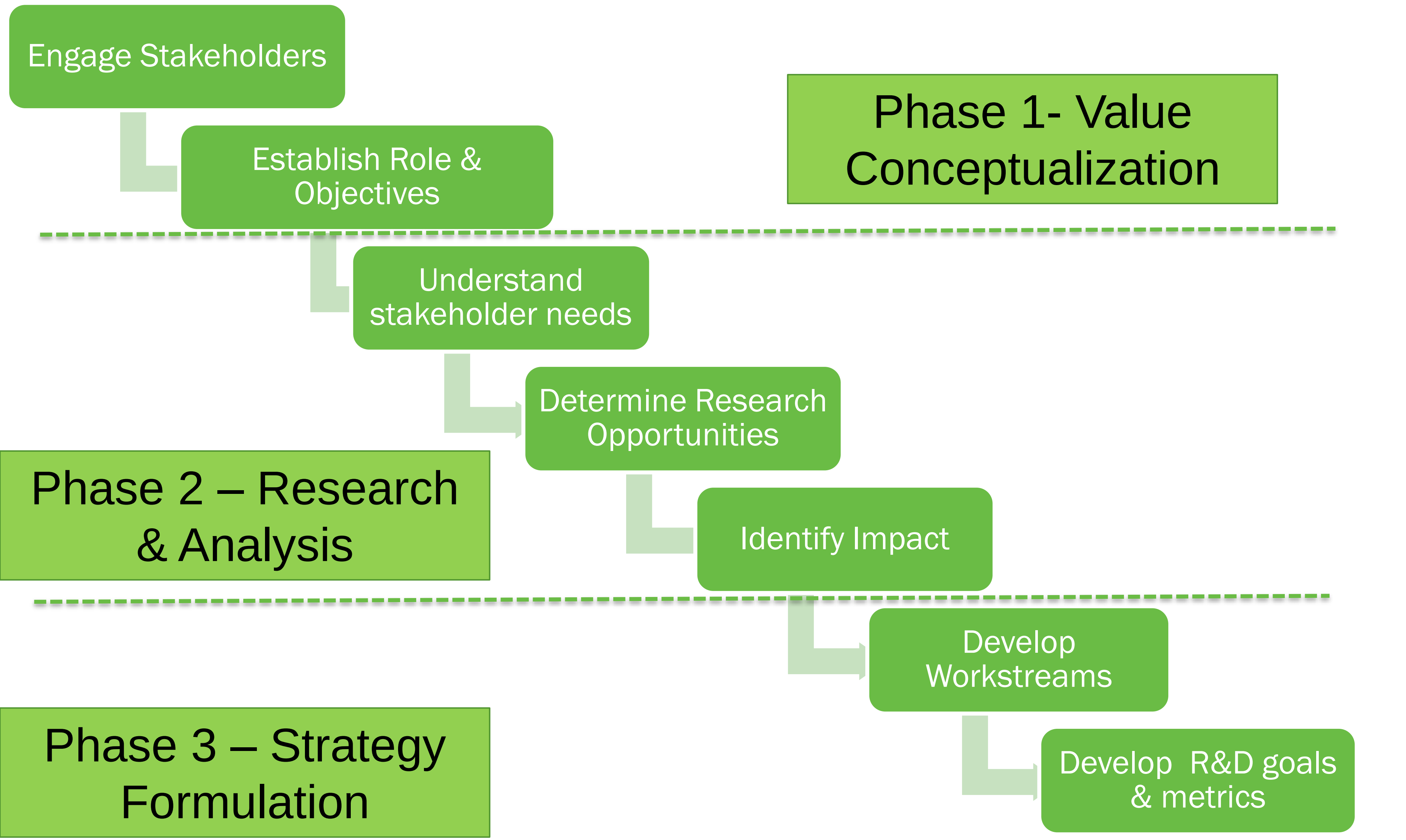
http://etc.ch/2Hz7 (case sensitive)

- Or scan the QR Code

Grid-interactive Efficient Buildings



GEB Strategy Update



Research & Analysis: Understand Stakeholder Needs

Ongoing
- Efficient and Flexible Building Loads RFI
- Quarterly Stakeholder Calls

Focused
- Working Groups: Utility/ States/Building Owners
- REEO Landscape Report

Topic Specific
- Technical Advisory Groups for GEB projects
- Workshops

Crosscutting
- GMLC
- DOE Programs

STAKEHOLDER ENGAGEMENT

Research & Analysis: Determine Research Opportunities

The GEB Technical Report Series will help inform and guide BTO's R&D portfolio and serve as a foundational resource for the larger building research community

Reports will be published in Summer 2019 in partnership with

Navigant, NREL, PNNL

GEB Technical Report Series:

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

1 Establish Frameworks

- Defines grid-interactive efficient buildings and demand flexibility
- Establishes potential grid services and some basic requirements for buildings to provide needed flexibility

2 Assess Flexibility Potential

- Evaluate state-of-the-art and emerging building technologies that have the potential to provide grid services
- Considers implementation attributes

3 Discuss Research Opportunities

- Identify major research challenges of technologies with significant potential for grid benefits and opportunities for additional technology-specific research and development.

Research & Analysis: Identify Impact

GEB Technical Report Series

establishes demand flexibility modes and potential grid services along with associated grid requirements

Metrics Projects

establishes flexibility metrics for both measurement & grid requirements

3 year projects; Metrics will be finalized by September 2019

Technology Characteristics

establishes attribute framework

Multi-lab effort led by LBNL

May expand to standardize attribute options across framework

SEE Action Report Series

metrics and attributes included in the report on assessing performance

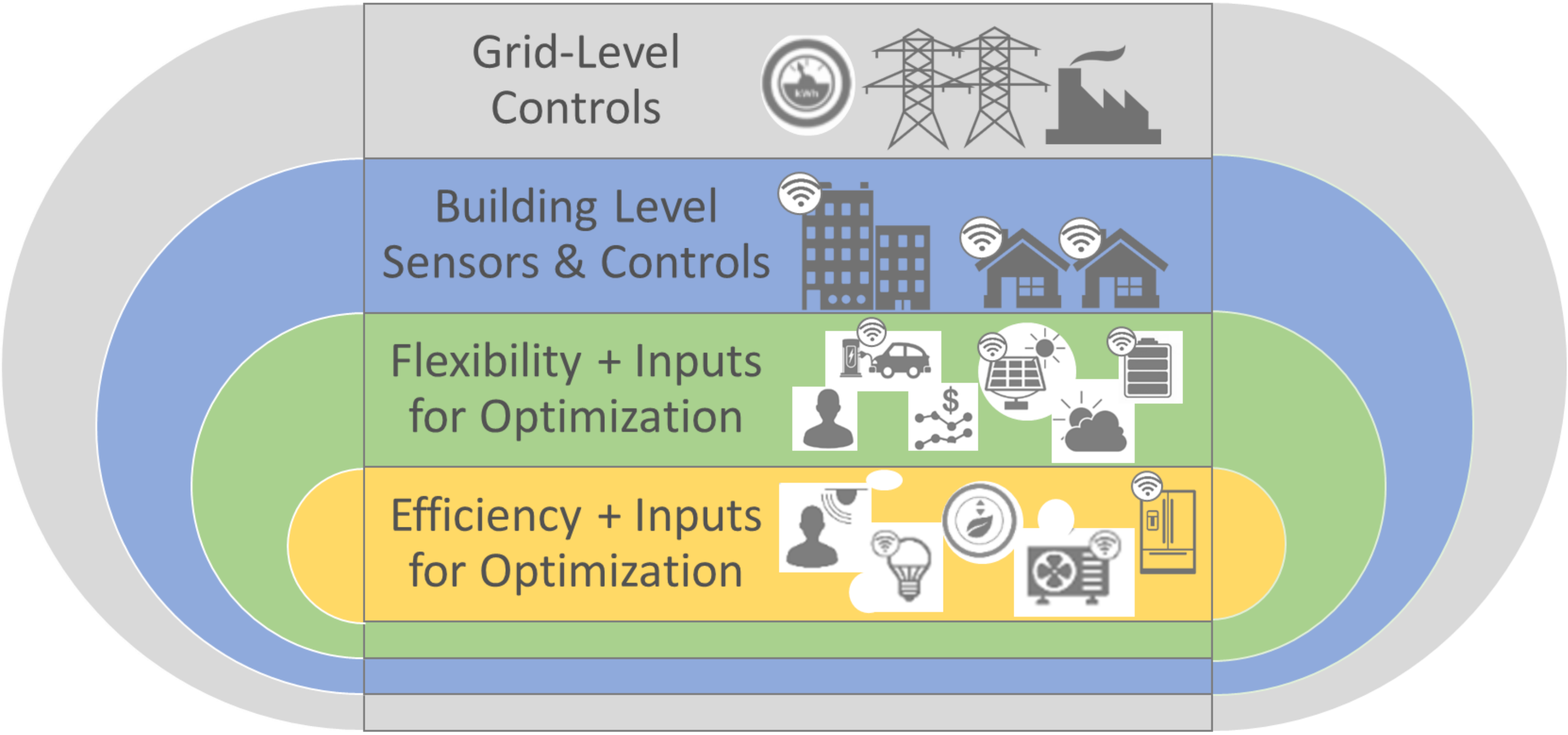
Reports will be completed in 2019-2020

GEB Potential Study

will establish GEB potential with peak and overall reduction measurement

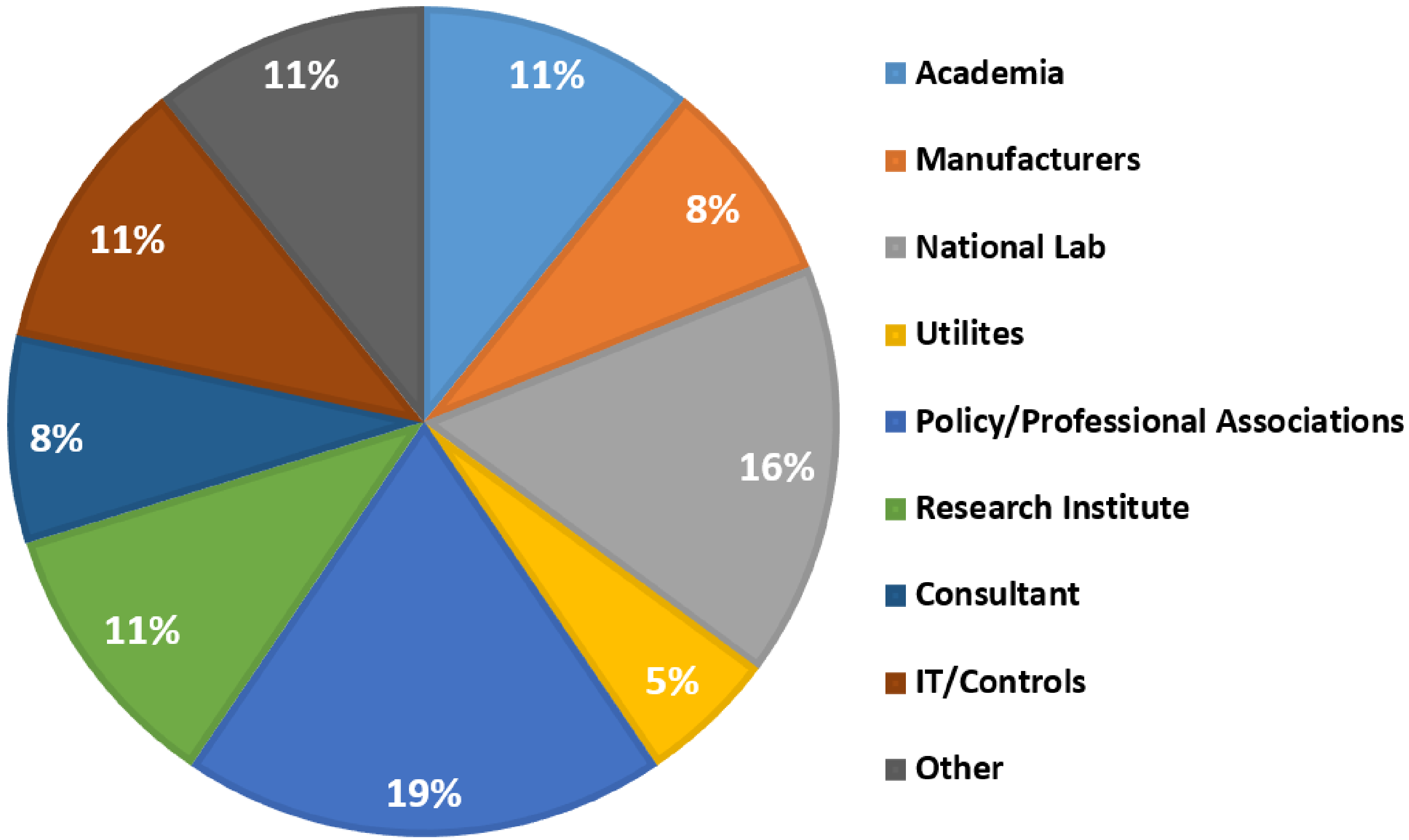
Complete in September 2019

Up Next: Strategy Formulation



Request for Information (RFI) DE-FOA-0002070: Efficient and Flexible Building Loads

- 41 Respondents from a variety of backgrounds and expertise



Question Categories

- **Category 1: Building Technologies R&D and Integration Needs for Increased Load Flexibility**
- **Category 2: Controls and Communication to Enhance Building-to-Grid Interactions**
- **Category 3: Building Energy Modeling for Load Flexibility**
- **Category 4: The Value of Flexible Building Loads**

Category 1: Building Technologies R&D and Integration Needs for Increased Load Flexibility

Example Questions

- What are the most important barriers that prevent building technologies from contributing to grid services through load flexibility?
- What potential concerns might building owners and operators have about using their building technologies to provide load flexibility ?

Themes

- Need means of reducing the uncertainty associated with implementing flexible loads. Also need to better understand impacts on occupants and value added to building and grid.
- Demonstration projects are invaluable and needed to further adoption

“There is a lack of data on the ability of load flexibility to improve grid reliability, which undermines the ability of building owners and utilities to use building-to-grid technologies in a way that optimizes energy efficiency both at the building and the grid.” (Alliance to Save Energy)

Category 2: Controls and Communication to Enhance Building-to-Grid Interactions

Example Questions

- What are the pros and cons of direct, distributed control vs. supervisory, hierarchical control?
- Are the current standards and protocols sufficient for building-to-grid two-way communications?

Themes

- Need ways to standardize communication protocols incorporating cybersecurity measures that is easy to implement, and fault tolerant.
- Need to better understand what data needs to be collected and sensor requirements.

"For communication among components and the grid there are “several communication standards operating in different systems, such as OpenADR 2.0, BACnet, CTA-2045, and IEEE 2030.5. All of these systems are limited in some capacity with respect to facility interoperability due to differing protocols, languages, or by the information they can transmit“ (PGE et al.)

Category 3: Building Energy Modeling for Load Flexibility

Example Questions

- What enhancements to BEM engines and capabilities are needed to adequately model the potential impact of building load flexibility from building components and systems?
- How can BEM help inform utilities and grid operators' forecasts?

Themes

- BEM improvements are needed to provide greater accuracy on smaller timescales and account for variability introduced by human/machine/control interactions
- Need easier integration of BEM into grid models to understand impacts of flexible building strategies on larger scales
- BEM's role in MPC is likely limited to design and feasibility studies

"Currently there is no easy way to model a building's flexibility and potential impact of optimization strategies on the building comfort parameters"
(Southern Company)

Category 4: The Value of Flexible Building Loads

Example Questions

- To what degree can sensing, metering, or a combination of these be used to demonstrate and verify use and demand savings for grid services?
- What are the grid challenges that flexible building loads are best suited to address?

Themes

- Need to provide a clear definition of load flexibility and a standardized procedure to measure and evaluate the benefit of improving load flexibility by a specific building technology
- Need transparent, open, and replicable methods to track and meter performance metrics associated with flexibility
- DOE generally captured grid benefits of flexible buildings

"[We] do not believe that the typical EM&V or M&V approaches now used for utility energy efficiency programs and energy savings performance contracts (ESPC) are well suited to the context of GEB and flexible building load services and benefits“ (NASEO)

Potential Grid Services Provided by Demand Flexibility in Buildings

Grid Services	Potential Avoided Cost	Potential Market Size Addressable by Demand Flexibility in Buildings
Generation Services		
Generation: Energy	Power plant fuel, operation, maintenance, and startup and shutdown costs	Large
Generation: Capacity	Capital costs for new generating facilities and associated fixed operation and maintenance costs	Large
Ancillary Services		
Contingency Reserves	Power plant fuel, operation, maintenance, and associated opportunity costs	Moderate
Frequency Regulation	Power plant fuel, operation, maintenance, and opportunity costs associated with providing frequency regulation	Small
Ramping	Power plant fuel, operation, maintenance, and startup and shutdown costs	Small
Delivery Services		
Non-Wires Solutions	Capital costs for transmission & distribution equipment upgrades	Moderate
Voltage Support	Capital costs for voltage control equipment (e.g., capacitor banks, transformers, smart inverters)	Small

Report series underway to address key state and local government opportunities for Grid-Interactive Efficient Buildings

In partnership with
Lawrence Berkeley National Lab

About SEE Action

- **Professional network of state and local governments and their stakeholders, energy experts and industry representatives**

- **Facilitated by the US DOE Office of Energy Efficiency and Renewable Energy, Office of Electricity, and US EPA Climate Protection Partnerships Division**

www.seeaction.energy.gov

1 Introduction

- Key technology trends
- Value proposition for grid & customers
- Critical actors and their emerging opportunities

2 Assessing Value

- Valuing demand flexibility
- Methods to determine economic value of services provided by GEBs
- Implementation considerations

3 Assessing Performance

- Audiences/needs for performance data
- Practices and protocols, data and analytical tools that are needed
- Putting assessments into practice

Other reports TBD

SEE Action Executive Group Feedback

Education is a first step

"State legislators are working more on smart grid, grid mod. Smart buildings are less familiar to them"

Incorporate Cost-Effectiveness

"It's an exciting time with the smart technologies that are entering the scene, but these things cost A LOT of ratepayer money!! Encouraging decision-makers to identify "wants" vs. "needs" and go from there, based on goals. Getting a grasp on potential savings is key, and not always easy with the newest gadgets and systems"

Data & Validation is Needed

"People are concerned about the experience of the tenant – don't want to make sacrifices"

"Do current building automation systems support GEB? What technologies are most impactful?"

Metrics, Value Proposition, Valuation!!!

"Need to get at the reliability question. What data exists for the performance of buildings or the components of the buildings? Needs discussion about what data and metrics have been developed b/c depending on the answer to whether GEBs will perform as expected, that affects the value proposition / valuation."

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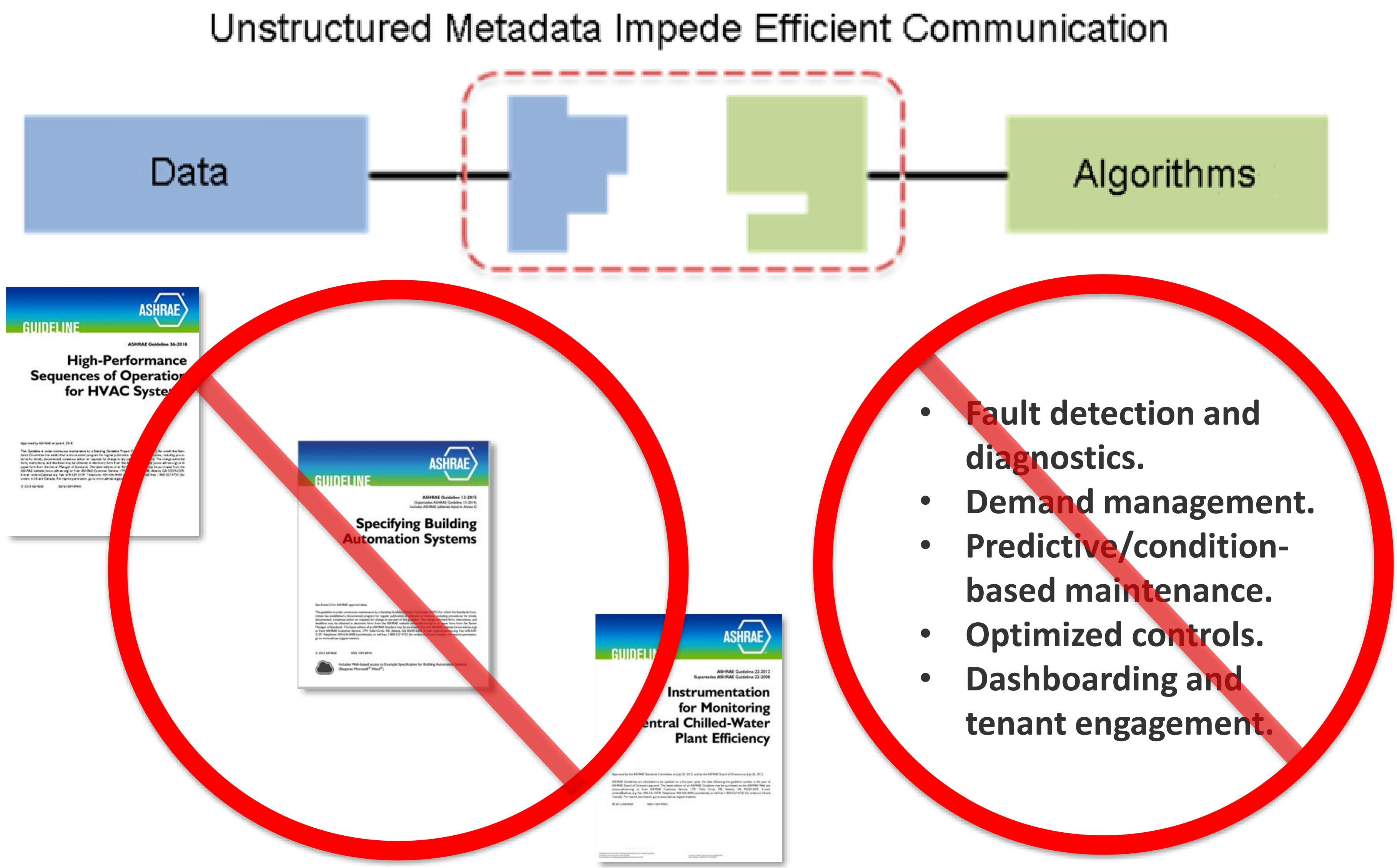
The Costs - Without Interoperability

- Utility Market
  - Opportunity cost for flexible loads
- Building Owners
  - Increased upfront costs of BAS systems by 10-20%
  - Vendor lock-in
- Software Vendors
  - Increased R&D costs so that specific devices communicate with systems
- Hardware Manufacturing
  - Interoperability could boost sensors and control (IoT) market by 40%

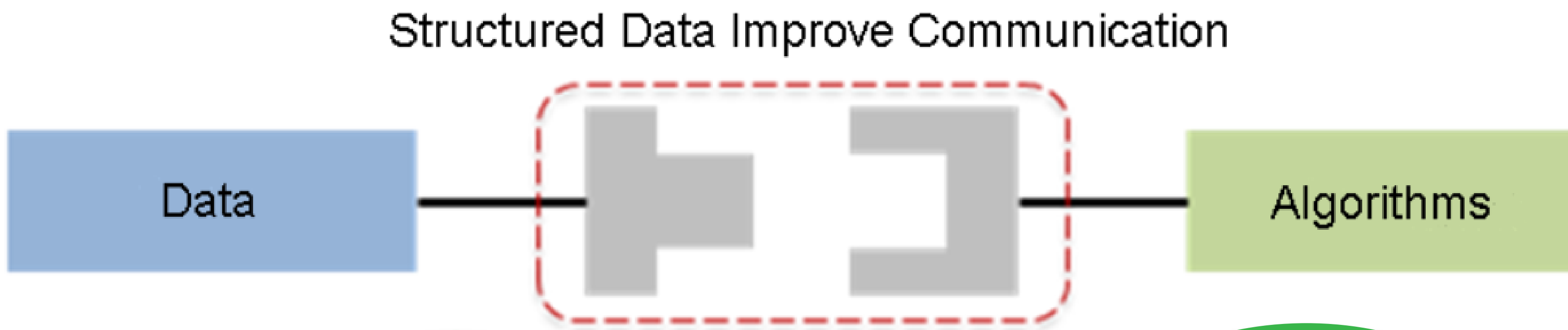
IoP
INTEROPERABILITY

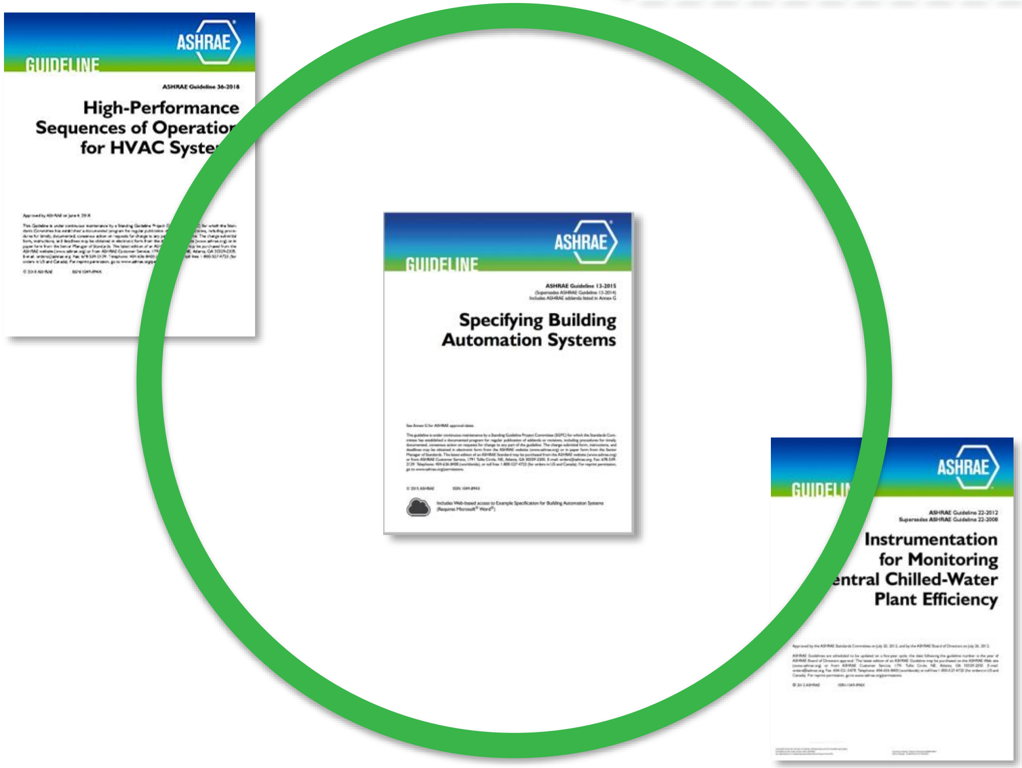
Unstructured Metadata



Graphic: *Justin Stein and William Livingood, NREL*

Structured Metadata

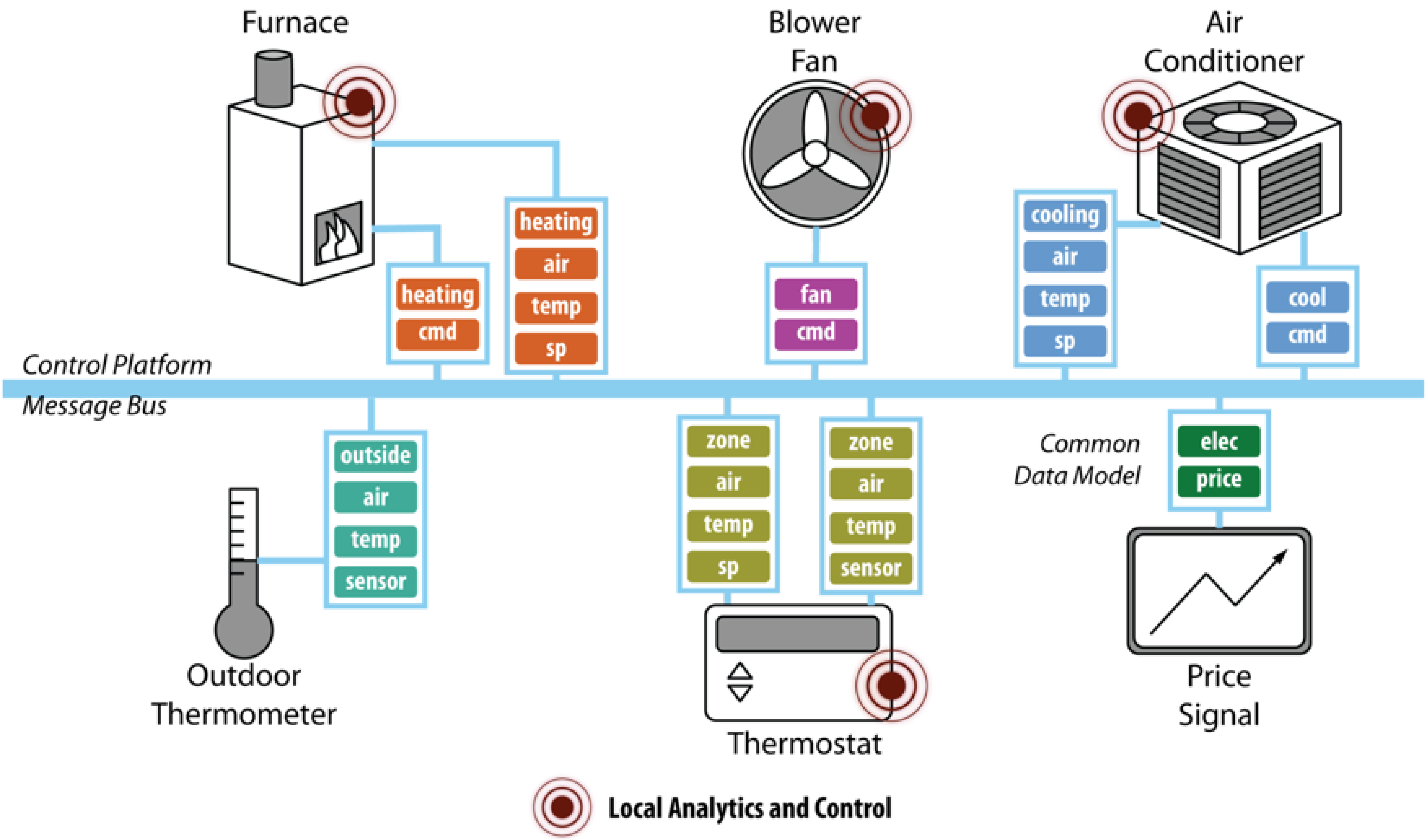




- **Fault detection and diagnostics.**
- **Demand management.**
- **Predictive/condition-based maintenance.**
- **Optimized controls.**
- **Dashboarding and tenant engagement.**

Graphic: *Justin Stein and William Livingood, NREL*

Project Haystack: Metadata-Enabled Building Automation

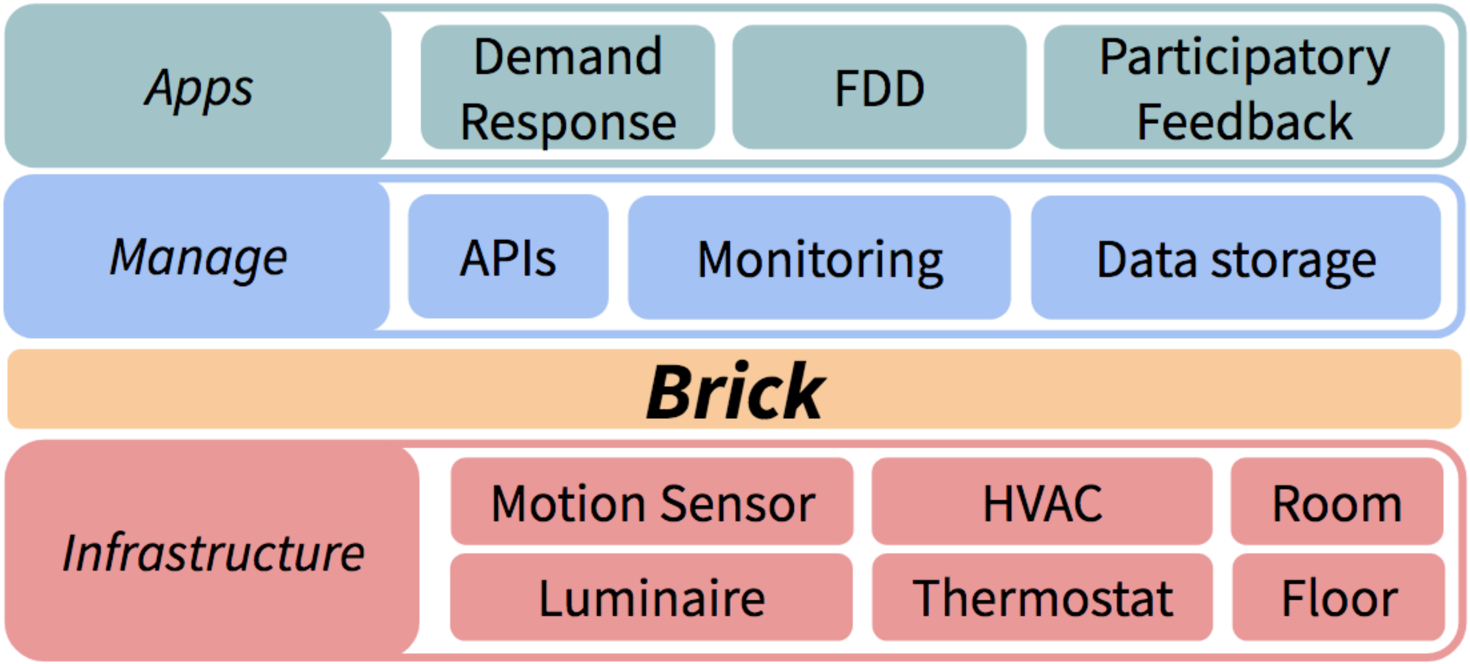


Metadata enables plug-and-play interoperability

Graphic: *Marjorie Schott, NREL*

Structured Metadata – Brick Schema

(Feb. 28, 2018) – The ASHRAE BACnet committee, Project Haystack and the Brick initiative announced they are actively collaborating to integrate Haystack tagging and Brick data modeling concepts into the new proposed ASHRAE Standard 223P for semantic tagging of building data.



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Determining the national-scale impacts of building flexibility and energy efficiency on electricity use and peak demand

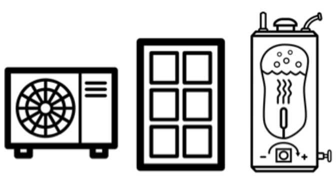
1. Define energy efficiency (EE), demand flexibility (DF), and EE + DF measure portfolios

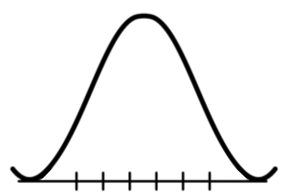
2. Develop 8760 load baselines for Scout by climate region and building type

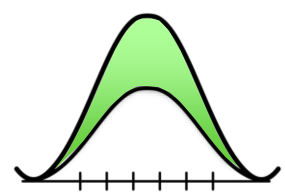
3. Develop bottom-up EnergyPlus measure simulations and 8760 savings shapes

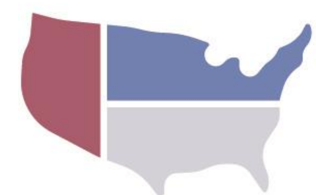
4. Translate measures into Scout ECMs

5. Assess national portfolio potential in Scout









eia

50%

DRRC Demand Response Research Center

ResStock

OpenStudio

OpenEI
Open Energy Information

Building Component Library

scout
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Limitations in demand flexibility modeling include handling of occupant responses, time dynamics, and valuation methods

Building-scale limitations

Individual behavioral diversity

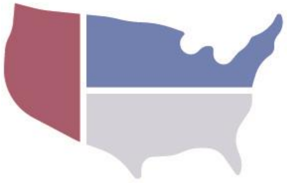
Dynamic comfort thresholds

Realistic signals for flexibility

Short time scale operations

National-scale limitations

Sub-annual energy use projections



Regional electricity use attribution

Consumer\org. choice models

Cost-effectiveness assessments

Icon attributions

Slide 1

Air conditioning unit (Arthur Shlain), Water heater (Michael Thompson), Window (Arthur Shlain), Calendar (Khomsun Chaiwong), Gauge (Nicolas Vicent), US Dollar (Christopher Beach), Clock (Nadya Bratt)

Slide 2

Home (Arthur Shlain), Office building (Adi Kuriawan), Person (Mello), Signal (ishircia), Frequency (Agri), United States (anbileruadeleru), Clock (creative outlet), Choice (Adrien Coquet)

www.thenounproject.com

Category 4: The Value of Flexible Building Loads

Example Questions

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BERKELEY LAB

Energy Technologies Area

Framework & Method to Define Flexible Loads in Buildings

to Integrate as a Dynamic & Predictable Grid Resource

Peter Schwartz (PI), Mary Ann Piette (Co-PI), Jingjing Liu (Technical Lead), Rongxin Yin, Marco Pritoni

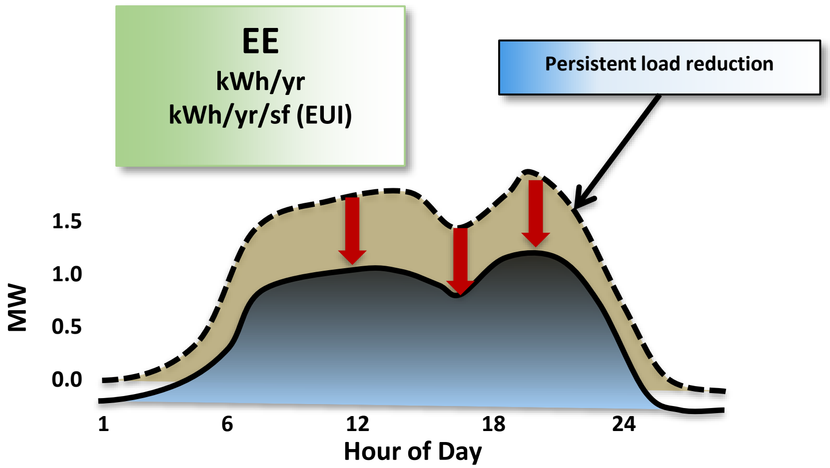
DOE 2019 BTO Peer Review - Topic 8

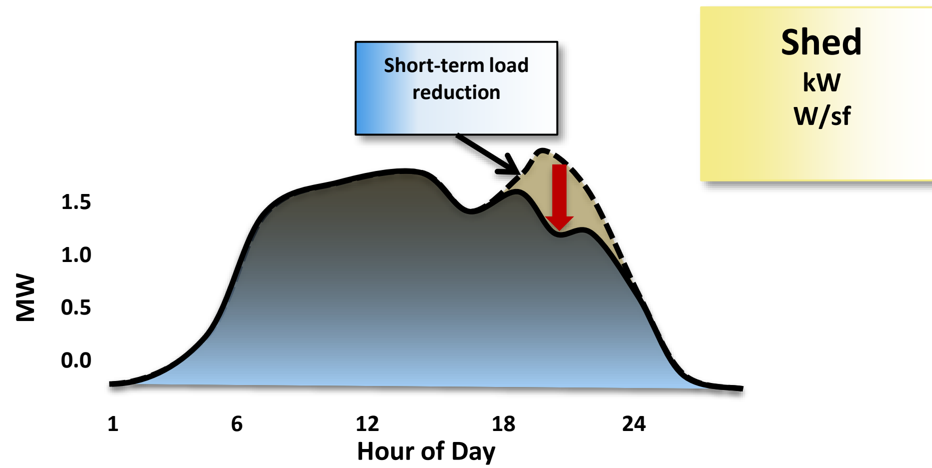
4/15/2019

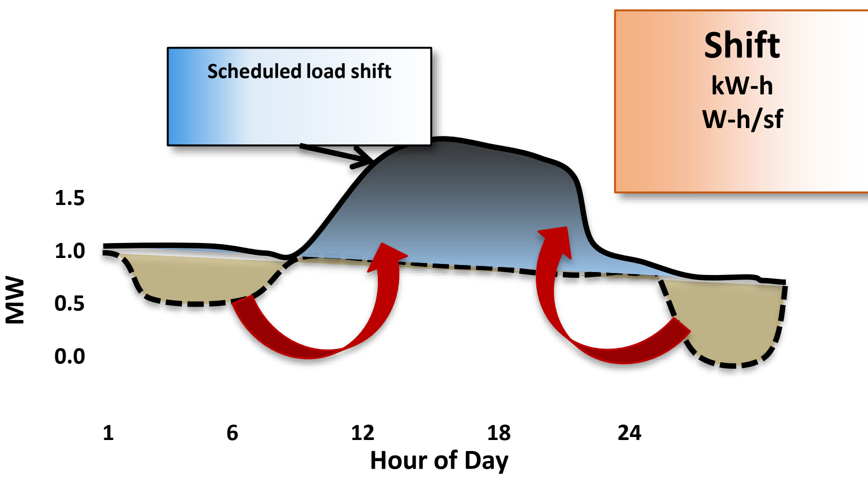
Project Framework

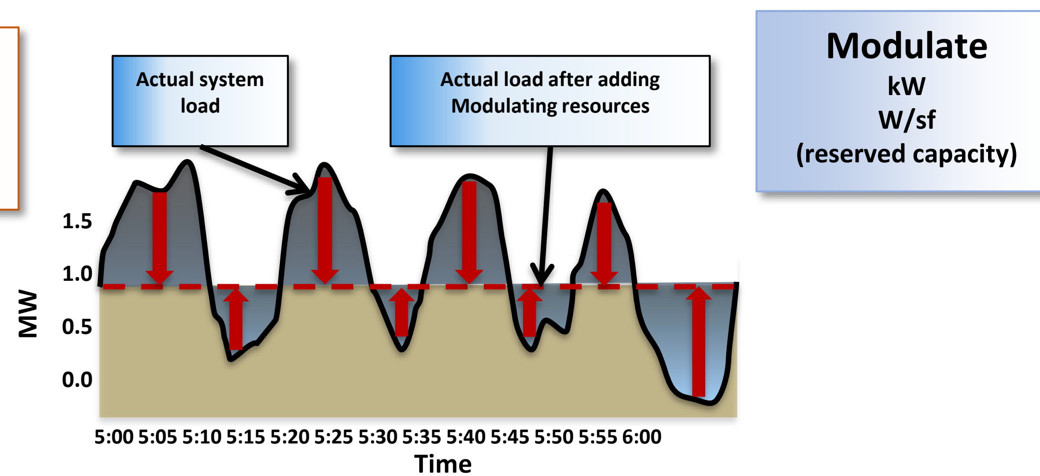
- Identify priority **grid services** by region
- Select regional prioritized **building types** for analysis
- Define a **metrics system** for quantifying buildings’ flexibility that measures their ability in providing various grid services
- Develop **use cases** calculating buildings’ flexibility using developed metrics system
- Document **methodology** & steps for metrics calculation such that it can be replicated by users
- Promulgate products to **key stakeholders** in support of GEB

Simple Measure of Flexibility Quantity

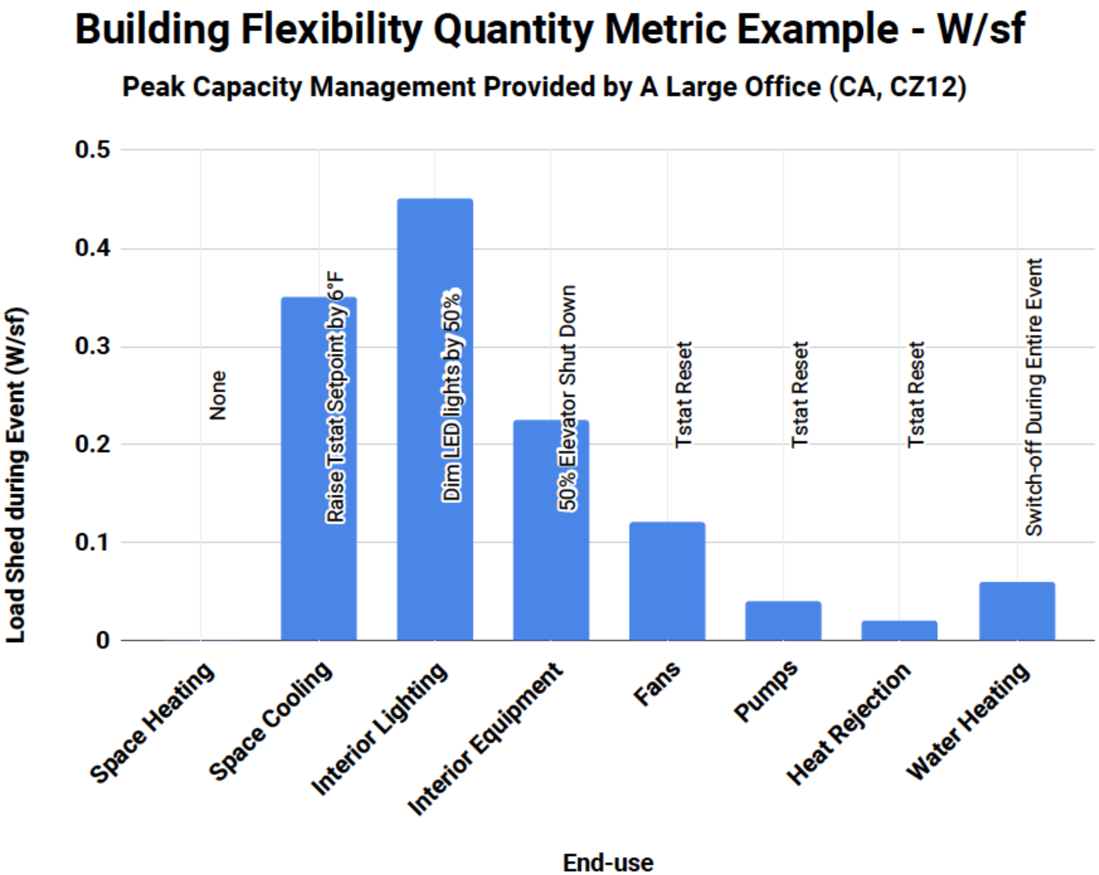








Example: Shed Quantity Metric – kW -> W/sf



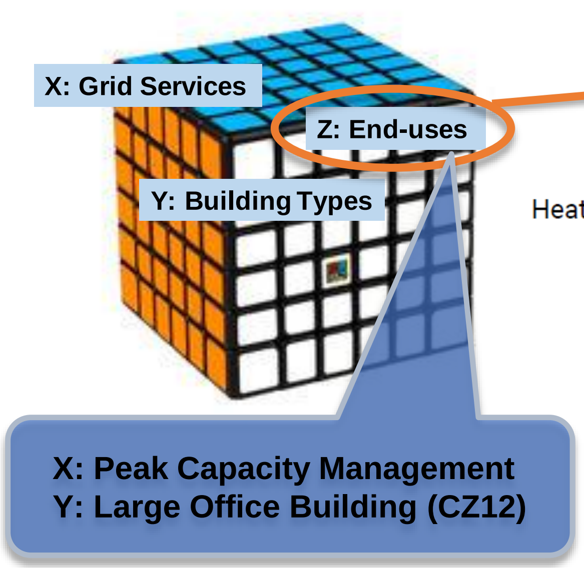
End-use	W/sf
Space Heating	0
Space Cooling	0.35
Interior Lighting	0.45
Interior Equipment	0.23
Fans	0.12
Pumps	0.04
Heat Rejection	0.02
Water Heating	0.06

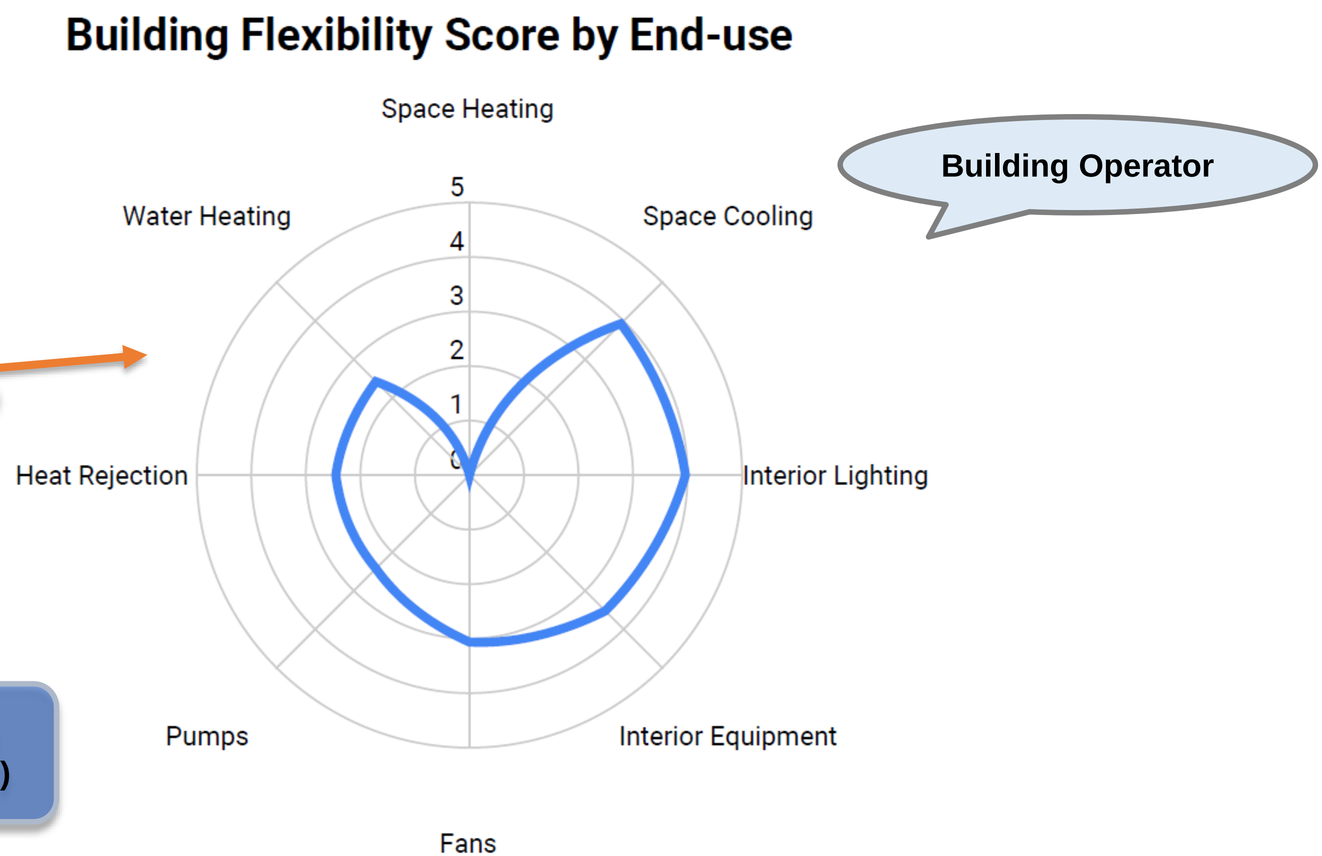
Additional Metrics for Other Attributes
(for Peak Shed DR, Large Office)

What's the Take-away?

Metric Name	Unit	Example Use Case
Average kW Reduction	**kW**	**Compensation; Resource Planning**
Minimum kW Reduction (95% Confidence Interval)	**kW**	**Penalty Mgmt.; Predictable Resource**
Shed Duration	**hrs**	**Aggregation Strategy**
Response Time	**mins**	**Aggregation Strategy**
Building Service Impact	**-**	**Building Lease Contract**

Example Tier 1 Metric: Spider-web Chart





Proposed 3-Tier Metrics System

Tiers	Issue Addressed	Addressed Questions	
1	On a high-level, **match needs with resources**		▪ **Grid**: What's the prevailing regional **need** for grid services? ▪ **Building**: Which building types & end-uses are **good** for providing what grid services?
2	**Quantify flexibility amount** (i.e., grid service amount)		▪ **Grid/Building**: **How much** of each grid service can a particular building type & each of its end uses provide?
3	**Boundary conditions** (service quality & impact) when providing grid services; **compare** resources		▪ **Grid**: What is the grid **service quality (performance & reliability)** provided by each building type & end use? ▪ **Building**: What is the **impact** on occupancy comfort & other building serviceability when providing grid services?

Example Tier 2 & 3 Metrics and Weighting System

(for Peak Shed DR, Large Office)

Label	Metric Name (Tier 2&3)	Unit	Threshold Values for Scores					Weight (Total 100%)
			1	2	3	4	5	
a	Average kW Reduction	kW	15	40	60	80	120	30%
b	Minimum kW Reduction (95% Confidence Interval)	kW	13.5	32	48	64	96	20%
c	Sustainable Shed Duration	hrs	0.75	1.5	2	3	4	20%
d	Response Time	mins	60	45	30	15	5	10%
e	Building Service Impact	-	(vary by end-use; see examples below)					20%

e1	Average Predicted Mean Vote Index (PMV)	-	1.75	1.5	1.25	1	0.5	20%
e2	Average Desk-level Light Level	lux	180	200	250	300	350	20%
e3	Inconvenience from Cutting Off Non-Critical Service	-			Off		On	20%

Proposed Grid Service Map

Grid Service Purpose	Grid Service Products	Key Characteristics: Duration	Notification Period	Load Change	Event Frequency	Expected Response Speed	Predictable Time Pattern
Reduce Generation Capacity Costs; Reduce Transmission Upgrade Costs	Peak Capacity Management; Critical Peak Pricing (CPP)	4 - 12 hours	2 - 24 hours	Decrease ("shed")	Typically < 100 hours in a year	Multiple minutes or longer	To some extent - seasonal
Reduce Distribution Upgrade Costs	Locational DR Programs (not available yet)	N/A	N/A	N/A	N/A	N/A	N/A
Reduce Generation Operating Costs	Energy Resource (a.k.a. Wholesale Market Price Response); Real Time Pricing; TOU	Continuous	~ 5 minutes - 24 hours; ~ 24 hours; ~ 5 minutes - 1 hour after; > 6 months	Increase or decrease	Depends upon price level; for TOU: daily / seasonal	Not specific	To some extent - seasonal and diurnal (follows wholesale energy price pattern)
	Load Following (Imbalance)	Continuous	~ 1 minute	Increase or decrease	Continuous, every 5 minutes	A few seconds - a minute	Not predictable
	Multi-hour Ramping	1 - 4 hours	~ 30 minutes - 24 hours	Increase or decrease (more important)	As frequent as daily	A few minutes	To some extent - seasonal and diurnal
Provide Frequency Regulation	Traditional Frequency Regulation; Dynamic Frequency Regulation	Continuous grid signal; Committed hourly; Dispatched every 5 minutes	1 hour	Increase or decrease	Continuous	A few seconds - a minute	Not predictable
Provide Contingency Reserves	Autonomous Frequency Response	5-10 minutes	Autonomous	Decrease	Continuous	A second	Not predictable
	Spinning Reserve; Non-spinning Reserve	10 minutes	~1 minute	Decrease	20-200 times a year	Within 10 minutes	Not predictable
	Capacity Resource; Emergency DR Resource	2 - 4 hours minimum	2 - 24 hours	Decrease	Typically < 100 hours in a year	A few minutes	Not predictable
Provide Distribution Voltage Support/Solar Integration	Autonomous Distribution Voltage Response	N/A	Autonomous	Change Apparent Power	N/A	A second	Not predictable

Thanks!

Principal Investigator (PI): Peter M. Schwartz pmschwartz@lbl.gov

Co-PI: Mary Ann Piette mapiette@lbl.gov

Technical Lead: Jingjing Liu jingjingliu@lbl.gov

Back up Slides

Example Tier 1 Score Calculation

Table - Example Weighting System Used to Calculate Tier 1 Scores for Large Office Providing Peak Capacity Management

Label	Metric Name (Tier 2&3)	Unit	Threshold Values for Scores 1	2	3	4	5	Weight% 100%
a	Average kW Reduction	kW	15	40	60	80	120	30%
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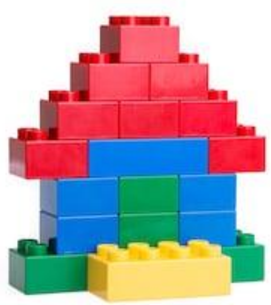
c	Sustainable Reduction Duration	hrs	0.75	1.5	2	3	4	20%
d	Time to Reach Contracted/Max kW	mins	60	45	30	15	5	10%
e1	Average Predicted Mean Vote Index (PMV)	-	1.75	1.5	1.25	1	0.5	20%
e2	Average Desk-level Light Level	lux	180	200	250	300	350	20%
e3	Inconvenience from Cutting Off Non-Critical Service				Off		On	20%

			Metric Label & Name					Impact Metric (e1,2,3) Applied
			a kW 30%	b Min kW 20%	c Shed Duration 20%	d Ramp Time 10%	e1,2,3 Impact 20%	
Space Heating	0	Metrics Value	0	0	0	0	0	
		Score	0	0	0	0	0	N/A
Space Cooling	3.9	Metrics Value	91	52	4	15	1	
		Score	4	2.5	5	4	4	e1
Interior Lighting	3.95	Metrics Value	117	104	4	5	250	
		Score	4.5	4.5	5	5	1	e2
Interior Equipment	3.5	Metrics Value	58.5	52	4	5	0	
		Score	3	2.5	5	5	3	e3
Fans	3.05	Metrics Value	31.2	20.8	4	5	1	
		Score	1.5	1.5	5	5	4	e1
Pumps	2.45	Metrics Value	10.4	6.9	4	15	1	
		Score	0.5	0.5	5	4	4	e1
Heat Rejection	2.45	Metrics Value	5.2	5.2	4	15	1	
		Score	0.5	0.5	5	4	4	e1
Water Heating	2.4	Metrics Value	15.6	10.4	4	15	0	
		Score	1	0.5	5	4	3	e3



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Measuring Energy Flexibility Potentials : Data-Based Approach by CUBE

DOE BTO Peer Review Meeting 2019

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Building Energy Flexibility Metrics

Design/Planning

- Technology comparison
- Recruitment
- Long-term

Operation

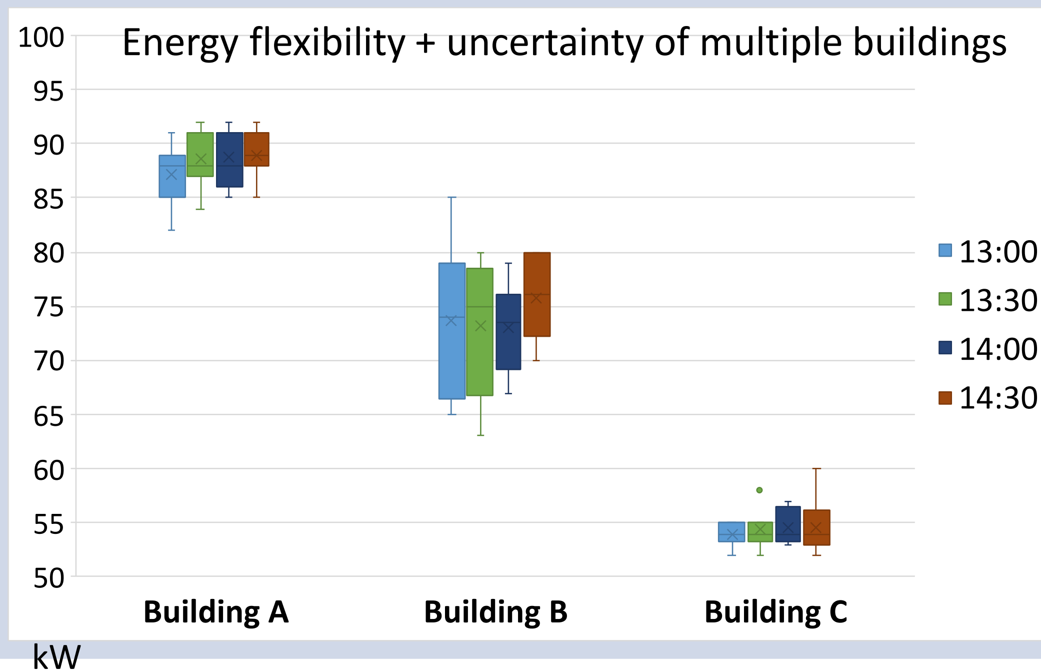
- Pre-event scheduling
- Post-event evaluation
- Short-term

Building Energy Flexibility Metrics – Operation

Stage	Purpose	Attributes	Example metrics
Pre-event scheduling	Quantify service capacity for grid services	Time interval [sec or min] Service time window [from and to, hh:mm] Lead time [sec/min/hr] Response time [sec/min/hr]	**Quantity** [kW] **Uncertainty** [x% confidence interval or quartiles]
During event	Building operation, impact evaluation		**Comfort** [PMV/PPD or degrees F/C] **Equipment lifetime** [% lifetime reduced]
Post-event	Performance evaluation, verification		**Quantity** [kW] **Relative performance** [% from scheduled amount]

Example of Measuring Flexibility – Pre-event Scheduling Example

Stage	Attributes	Example metrics
Pre-event scheduling	Time interval [**30 min**] Service time window [**from 13:00 to 15:00**] Lead time [**24 hrs**] Response time [**2 hrs**]	Quantity [**kW**] Uncertainty [**Q1 to Q3**]

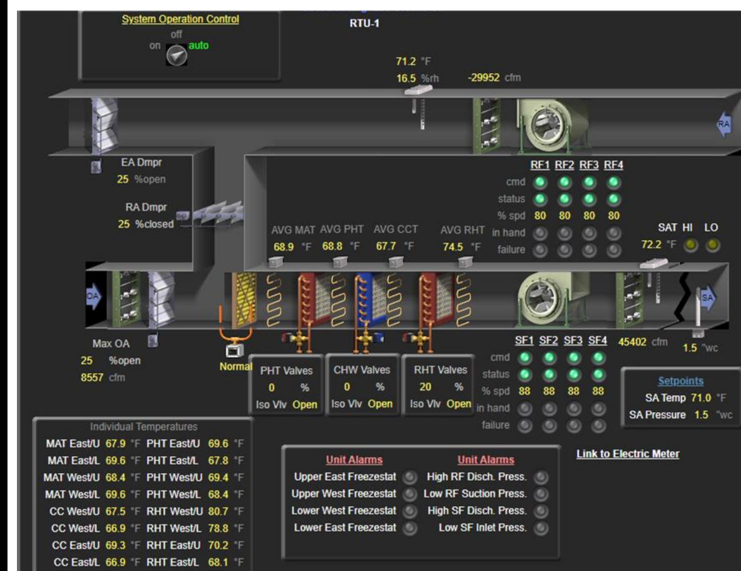


Case Study: New York University Building

NYU PI: Yury Dvorkin, Ph.D.

- 8-story academic building with BAS and 5-min interval meter data
- Participating in both transmission (NYISO) and distribution (ConEdison) demand response programs through third party aggregator
  - Enrollment of 57 kW

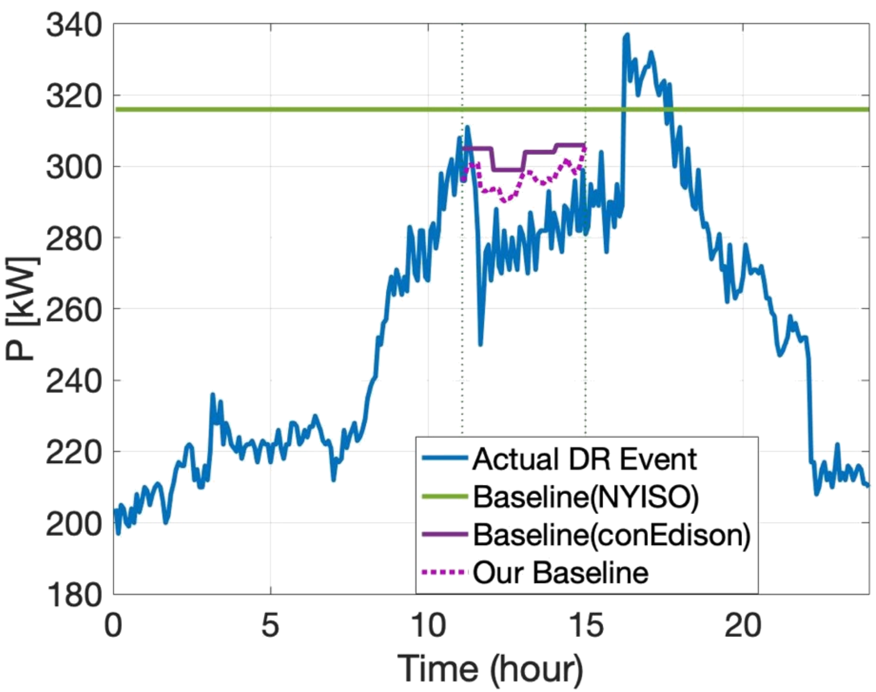
Floor layouts with indoor temperature



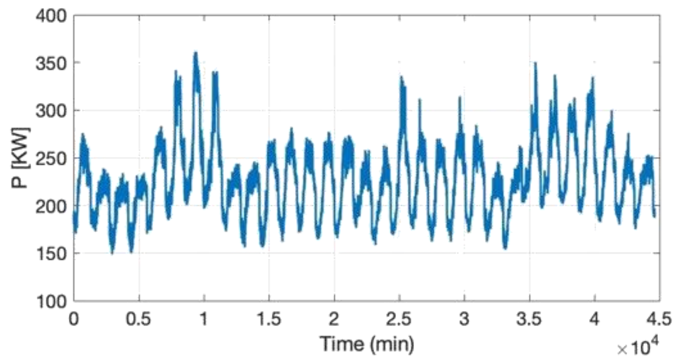
Roof top unit (RTU)

Energy Flexibility Metrics

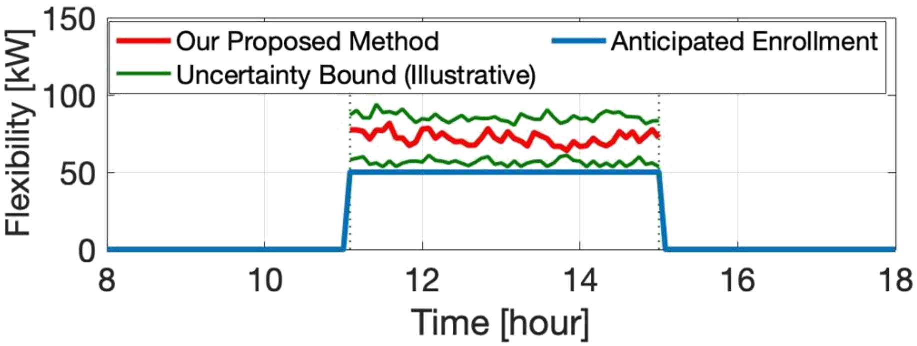
NYU Building example: DR event at hour 11 through 15



Metered load data on a day of DR event



Historical load data used for training for Markov Decision Process



5-min estimated flexibility during the DR event

Closing remarks

- Estimation and measurement of operational flexibility metrics can be improved with **data analytics**.

- **Uncertainty** should be one of the metrics where aggregators and grid operators can manage the risks against.

- Ongoing work
  - Metrics and attributes by grid service
  - Improvement of flexibility measurement algorithm
  - Impact metrics on both grid and building operation

SEE Action Executive Group Feedback

Education is a First Step

"State legislators are working more on smart grid, grid mod. Smart buildings are less familiar to them"

Incorporate Cost-Effectiveness

"It's an exciting time with all the smart technologies that are entering the scene, but these things cost A LOT of ratepayer money!! We are encouraging decision-makers to first identify "wants" vs. "needs" and go from there, based on goals. Getting a grasp on potential savings is key here, and not always easy to do with some of the newest gadgets and systems"

Data & Validation is Needed

"People are concerned about the experience of the tenant – don't want to make sacrifices"

"Do current building automation systems support GEB? What technologies are most impactful?"

Metrics, Value Proposition, Valuation!!!

"Need to get at the reliability question. What data exists for the performance of buildings or the components of the buildings? Needs discussion about what data and metrics have been developed b/c depending on the answer to whether GEBs will perform as expected, that affects the value proposition / valuation."

Assessing the Performance of Grid-Interactive Efficient Buildings

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SEE Action Report

Assessing and Documenting the Demand Flexibility Performance of Grid-Interactive Efficient Buildings (working title)

Sections of the Report:

1. Approaches to Assessing and Documenting Performance of Grid-Interactive Efficient Buildings
2. Data and Analytical Tool Requirements for Assessing and Documenting Grid-Interactive Efficient Buildings
3. Changes That May Be Needed to Existing M&V Practices
4. Putting Demand Flexibility Performance Assessments Into Practice
5. Recommendations for state and local governments for implementing, standardizing and enhancing assessment and documentation methods for demand flexibility to support cost-effective Grid-Interactive Efficient Building resources

Questions & Wrap-Up