Grid-interactive Efficient Buildings Strategy Discussion

Monica Neukomm
Building Technologies Office, DOE
www.energy.gov/eere/buildings/geb
<table>
<thead>
<tr>
<th>Time</th>
<th>Discussion Topic</th>
<th>Presenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:30-1:50</td>
<td>Strategy Update &amp; RFI Feedback</td>
<td>Monica Neukomm &amp; Nelson James</td>
</tr>
<tr>
<td>1:50-2:05</td>
<td>Interoperability</td>
<td>Bill Livingood</td>
</tr>
<tr>
<td>2:05-2:20</td>
<td>Building Energy Modeling</td>
<td>Jared Langevin &amp; Amir Roth</td>
</tr>
<tr>
<td>2:20-2:40</td>
<td>Demand Flexibility Metrics</td>
<td>Jingjing Liu &amp; Jhi-Young Joo</td>
</tr>
<tr>
<td>2:40-2:55</td>
<td>Assessing Performance of Demand Flexibility</td>
<td>Mike Li</td>
</tr>
<tr>
<td>2:55-3:00</td>
<td>Wrap-Up</td>
<td>Monica Neukomm</td>
</tr>
</tbody>
</table>
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

Grid-Interactive Efficient Homes

- Two-way data
- Price Signals
- Two-way sensor and control communication
GEB Strategy Update

Engage Stakeholders

Establish Role & Objectives

Understand stakeholder needs

Determine Research Opportunities

Identify Impact

Develop Workstreams

Phase 1 - Value Conceptualization

Phase 2 – Research & Analysis

Phase 3 – Strategy Formulation

Develop R&D goals & metrics
# Research & Analysis: Understand Stakeholder Needs

<table>
<thead>
<tr>
<th>Ongoing</th>
<th>Focused</th>
<th>Topic Specific</th>
<th>Crosscutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Efficient and Flexible Building Loads RFI</td>
<td>• Working Groups: Utility/States/Building Owners</td>
<td>• Technical Advisory Groups for GEB projects</td>
<td>• GMLC</td>
</tr>
<tr>
<td>• Quarterly Stakeholder Calls</td>
<td>• REEO Landscape Report</td>
<td>• Workshops</td>
<td>• DOE Programs</td>
</tr>
</tbody>
</table>

**STAKEHOLDER ENGAGEMENT**
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

Grid-Level Controls

Building Level Sensors & Controls

Flexibility + Inputs for Optimization

Efficiency + Inputs for Optimization
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

<table>
<thead>
<tr>
<th>Example Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What are the most important barriers that prevent building technologies from contributing to grid services through load flexibility?</td>
</tr>
<tr>
<td>• What potential concerns might building owners and operators have about using their building technologies to provide load flexibility?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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.</td>
</tr>
<tr>
<td>• Demonstration projects are invaluable and needed to further adoption</td>
</tr>
</tbody>
</table>

“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)
### 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

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

Unstructured Metadata Impede Efficient Communication

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

Graphic: Justin Stein and William Livingood, NREL
Structured Metadata

Structured Data Improve Communication

- 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.

<table>
<thead>
<tr>
<th>Apps</th>
<th>Demand Response</th>
<th>FDD</th>
<th>Participatory Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manage</td>
<td>APIs</td>
<td>Monitoring</td>
<td>Data storage</td>
</tr>
</tbody>
</table>

**Brick**

- Infrastructure
  - Motion Sensor
  - Luminaire
  - HVAC
  - Thermostat
  - Room
  - Floor
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 incorporate smaller timescales and to 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.

“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)
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
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**

- 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)
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

**EE**
- kWh/yr
- kWh/yr/sf (EUI)

**Persistent load reduction**

**Shift**
- kW-h
- W-h/sf

**Scheduled load shift**

**Short-term load reduction**

**Modulate**
- kW
- W/sf (reserved capacity)

**Actual system load**

**Actual load after adding Modulating resources**

**Hour of Day**
1 6 12 18 24

**Time**
5:00 5:05 5:10 5:15 5:20 5:25 5:30 5:35 5:40 5:45 5:50 5:55 6:00
Example: Shed Quantity Metric – kW -> W/sf

Building Flexibility Quantity Metric Example - W/sf

Peak Capacity Management Provided by A Large Office (CA, CZ12)

<table>
<thead>
<tr>
<th>End-use</th>
<th>W/sf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Heating</td>
<td>0</td>
</tr>
<tr>
<td>Space Cooling</td>
<td>0.35</td>
</tr>
<tr>
<td>Interior Lighting</td>
<td>0.45</td>
</tr>
<tr>
<td>Interior Equipment</td>
<td>0.23</td>
</tr>
<tr>
<td>Fans</td>
<td>0.12</td>
</tr>
<tr>
<td>Pumps</td>
<td>0.04</td>
</tr>
<tr>
<td>Heat Rejection</td>
<td>0.02</td>
</tr>
<tr>
<td>Water Heating</td>
<td>0.06</td>
</tr>
</tbody>
</table>
# Additional Metrics for Other Attributes

(for Peak Shed DR, Large Office)

<table>
<thead>
<tr>
<th>Metric Name</th>
<th>Unit</th>
<th>Example Use Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average kW Reduction</td>
<td>kW</td>
<td>Compensation; Resource Planning</td>
</tr>
<tr>
<td>Minimum kW Reduction</td>
<td>kW</td>
<td>Penalty Mgmt.; Predictable Resource</td>
</tr>
<tr>
<td>(95% Confidence Interval)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shed Duration</td>
<td>hrs</td>
<td>Aggregation Strategy</td>
</tr>
<tr>
<td>Response Time</td>
<td>mins</td>
<td>Aggregation Strategy</td>
</tr>
<tr>
<td>Building Service Impact</td>
<td>-</td>
<td>Building Lease Contract</td>
</tr>
</tbody>
</table>
Example Tier 1 Metric: Spider-web Chart

Building Flexibility Score by End-use

- X: Grid Services
- Y: Building Types
- Z: End-uses

Building Operator

X: Peak Capacity Management
Y: Large Office Building (CZ12)
## Proposed 3-Tier Metrics System

<table>
<thead>
<tr>
<th>Tiers</th>
<th>Issue Addressed</th>
<th>Addressed Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On a high-level, match needs with resources</td>
<td></td>
</tr>
</tbody>
</table>
  - **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)

<table>
<thead>
<tr>
<th>Label</th>
<th>Metric Name (Tier 2&amp;3)</th>
<th>Unit</th>
<th>Threshold Values for Scores</th>
<th>Weight (Total 100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Average kW Reduction</td>
<td>kW</td>
<td>15  40  60  80  120</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>Minimum kW Reduction</td>
<td>kW</td>
<td>13.5 32  48  64  96</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>(95% Confidence Interval)</td>
<td></td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>Sustainable Shed Duration</td>
<td>hrs</td>
<td>0.75  1.5  2  3  4</td>
<td>20%</td>
</tr>
<tr>
<td>d</td>
<td>Response Time</td>
<td>mins</td>
<td>60  45  30  15  5</td>
<td>10%</td>
</tr>
<tr>
<td>e</td>
<td>Building Service Impact</td>
<td>-</td>
<td>(vary by end-use; see examples below)</td>
<td>20%</td>
</tr>
<tr>
<td>e1</td>
<td>Average Predicted Mean Vote Index (PMV)</td>
<td>-</td>
<td>1.75  1.5  1.25  1  0.5</td>
<td>20%</td>
</tr>
<tr>
<td>e2</td>
<td>Average Desk-level Light Level</td>
<td>lux</td>
<td>180  200  250  300  350</td>
<td>20%</td>
</tr>
<tr>
<td>e3</td>
<td>Inconvenience from Cutting Off Non-Critical Service</td>
<td>-</td>
<td>Off  On</td>
<td>20%</td>
</tr>
</tbody>
</table>
### Proposed Grid Service Map

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

<table>
<thead>
<tr>
<th>Label</th>
<th>Metric Name (Tier 2&amp;3)</th>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>100%</th>
<th>Weight%</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Average kW Reduction</td>
<td>kW</td>
<td>15</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>120</td>
<td>100%</td>
<td>30%</td>
</tr>
<tr>
<td>b</td>
<td>Minimum kW Reduction (95% Confidence Interval)</td>
<td>kW</td>
<td>13.5</td>
<td>32</td>
<td>48</td>
<td>64</td>
<td>96</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>Sustainable Reduction Duration</td>
<td>hrs</td>
<td>0.75</td>
<td>1.5</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>Time to Reach Contracted/Max kW</td>
<td>mins</td>
<td>60</td>
<td>45</td>
<td>30</td>
<td>15</td>
<td>5</td>
<td>10%</td>
<td></td>
</tr>
</tbody>
</table>

### Metric Label & Name

<table>
<thead>
<tr>
<th>Metric Label &amp; Name</th>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>100%</th>
<th>Weight%</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Average Predicted Mean Vote Index (PMV)</td>
<td>-</td>
<td>1.75</td>
<td>1.5</td>
<td>1.25</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>20%</td>
</tr>
<tr>
<td>b Average Desk-level Light Level</td>
<td>lux</td>
<td>180</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td>350</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>c Inconvenience from Cutting Off Non-Critical Service</td>
<td></td>
<td>Off</td>
<td>On</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Metric Impact (e1,2,3) Applied

<table>
<thead>
<tr>
<th>Metric Label &amp; Name</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>e1</td>
</tr>
<tr>
<td>b</td>
<td>e2</td>
</tr>
<tr>
<td>c</td>
<td>e3</td>
</tr>
<tr>
<td>d</td>
<td>e1</td>
</tr>
</tbody>
</table>

### Score Calculation

- **Space Heating**
  - Score: 0
  - Metrics Value: 0
- **Space Cooling**
  - Score: 4
  - Metrics Value: 91
- **Interior Lighting**
  - Score: 4.5
  - Metrics Value: 117
- **Interior Equipment**
  - Score: 3
  - Metrics Value: 58.5
- **Fans**
  - Score: 1.5
  - Metrics Value: 31.2
- **Pumps**
  - Score: 0.5
  - Metrics Value: 10.4
- **Heat Rejection**
  - Score: 0.5
  - Metrics Value: 5.2
- **Water Heating**
  - Score: 1
  - Metrics Value: 15.6

**Impact Metric (e1,2,3) Applied**

<table>
<thead>
<tr>
<th>Metric Label &amp; Name</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>e1</td>
</tr>
<tr>
<td>b</td>
<td>e2</td>
</tr>
<tr>
<td>c</td>
<td>e3</td>
</tr>
<tr>
<td>d</td>
<td>e1</td>
</tr>
<tr>
<td>e1</td>
<td>e1</td>
</tr>
<tr>
<td>e2</td>
<td>e2</td>
</tr>
<tr>
<td>e3</td>
<td>e3</td>
</tr>
</tbody>
</table>

**Threshold Values for Scores**

- **kW**: 100%
- **Min kW**: 30%
- **Shed Duration**: 20%
- **Ramp Time**: 10%
- **Impact**: 20%
Measuring Energy Flexibility Potentials: Data-Based Approach by CUBE

DOE BTO Peer Review Meeting 2019

April 15, 2019
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]                          | **Quantity** [kW]                                    |
|                              |                                              |                                                     | **Uncertainty** [x% confidence interval or quartiles]|
| During event                 | Building operation, impact evaluation        | Service time window [from and to, hh:mm]            | **Comfort** [PMV/PPD or degrees F/C]                  |
|                              |                                              | Lead time [sec/min/hr]                              | **Equipment lifetime** [% lifetime reduced]            |
| Post-event                   | Performance evaluation, verification         | Response time [sec/min/hr]                          | **Quantity** [kW]                                    |
|                              |                                              |                                                     | **Relative performance** [% from scheduled amount]   |
### Example of Measuring Flexibility – Pre-event Scheduling Example

<table>
<thead>
<tr>
<th>Stage</th>
<th>Attributes</th>
<th>Example metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-event scheduling</strong></td>
<td>Time interval [30 min]</td>
<td>Quantity [<strong>kW</strong>]</td>
</tr>
<tr>
<td></td>
<td>Service time window [from 13:00 to 15:00]</td>
<td>Uncertainty [<strong>Q1 to Q3</strong>]</td>
</tr>
<tr>
<td></td>
<td>Lead time [24 hrs]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Response time [2 hrs]</td>
<td></td>
</tr>
</tbody>
</table>

- **Stage**: Pre-event scheduling
- **Attributes**:
  - Time interval [30 min]
  - Service time window [from 13:00 to 15:00]
  - Lead time [24 hrs]
  - Response time [2 hrs]

- **Example metrics**:
  - Quantity [**kW**]
  - Uncertainty [**Q1 to Q3**]

#### Energy flexibility + uncertainty of multiple buildings

![Graph showing energy flexibility and uncertainty of multiple buildings](image-url)
Case Study: New York University Building

- 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

Historical load data used for training for Markov Decision Process

Metered load data on a day of DR event

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”

**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.”

“Do current building automation systems support GEB? What technologies are most impactful?”
Assessing the Performance of Grid-Interactive Efficient Buildings

Michael Li, Senior Policy Advisor
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
Michael.Li@ee.doe.gov
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