U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

GEB Technical Report Series: Lighting & MELs

Building Technologies Office

May 26, 2020

Webinar Agenda

I. GEB Overview

- Monica Neukomm, Senior Policy Advisor
  - Building Technologies Office

II. GEB Lighting and Electronics Report

- Valerie Nubbe, Senior Consultant
  - Guidehouse Consulting (Navigant)

III. Miscellaneous Electric Loads

- Harry Bergmann, Management & Program Analyst
  - Building Technologies Office

IV. Grid-Interactive Connected Lighting

- Michael Poplawski, Senior Engineer
  - Pacific Northwest National Lab

V. Q&A Session

- Dr. Brian Walker, SSL Technology Manager
  - Building Technologies Office

GEB Technical Report Webinar Series

Topic	Date	Time
Lighting & Electronics	May 26	2:00pm - 3:00pm ET
Heating, Ventilation & Air Conditioning (HVAC)	June 2	2:00pm - 3:30pm ET
Water Heating & Appliances	June 9	2:00pm - 3:00pm ET
Envelope & Windows	June 16	2:00pm - 3:30pm ET
Integration - Building Equipment	June 23	2:00pm - 3:00pm ET
Integration –Distributed Energy Resources(DERs)	June 30	2:00pm - 3:00pm ET

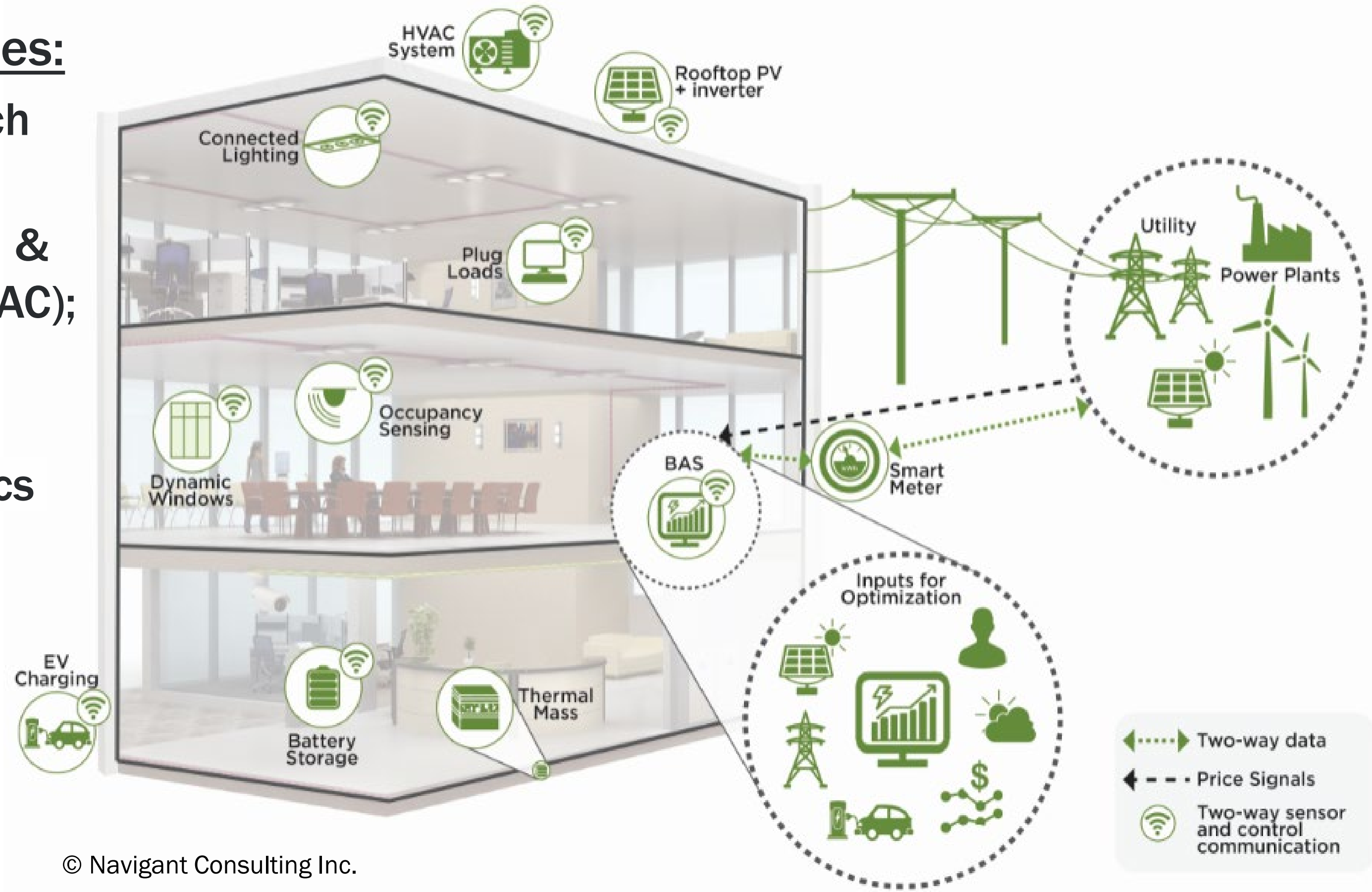
GEB Technical Report Series Overview

The GEB Technical Report Series outlines key demand flexibility opportunities across BTO's R&D portfolio:

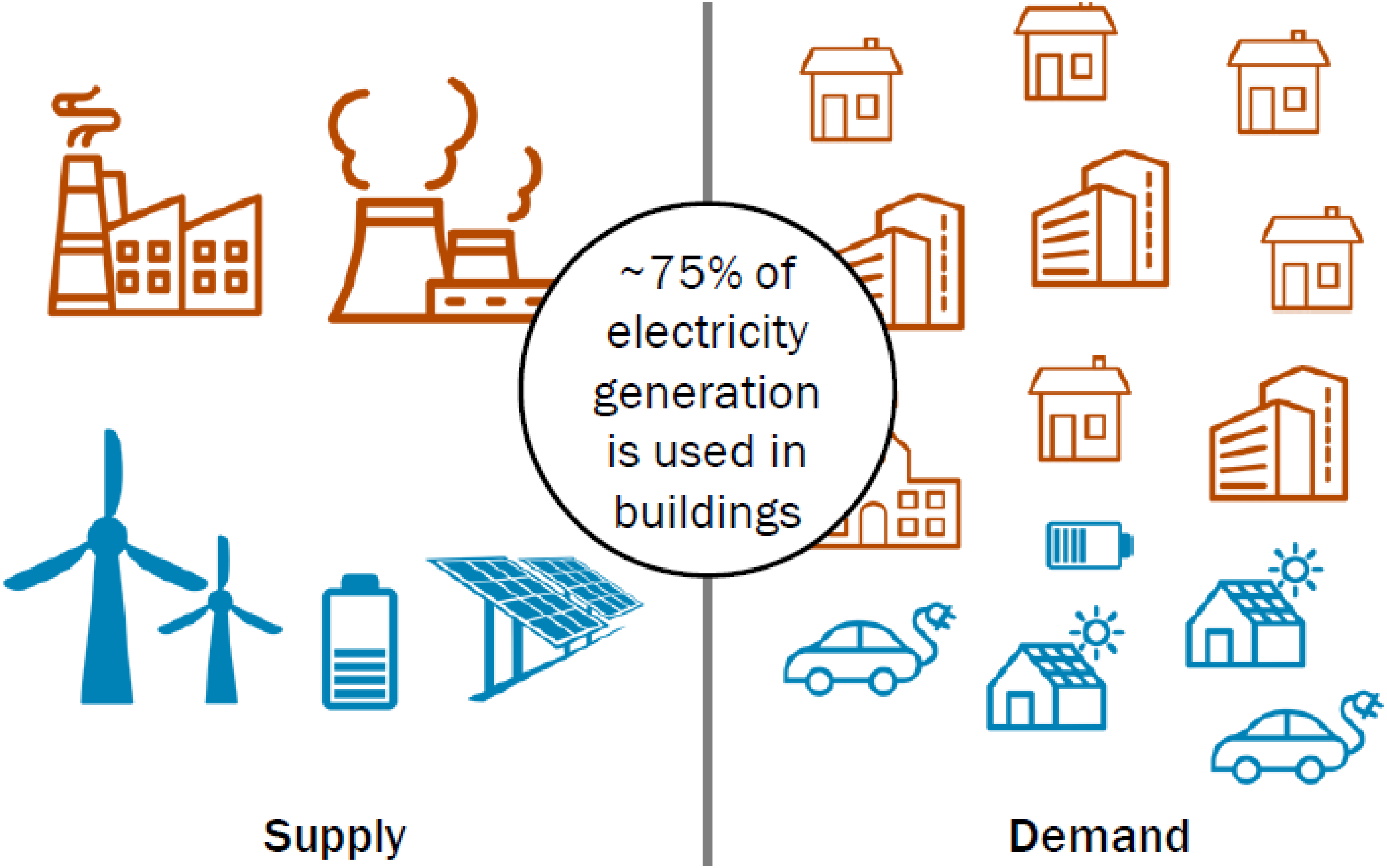
http://energy.gov/eere/buildings/grid-interactive-efficient-buildings

Technical Report Series:

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

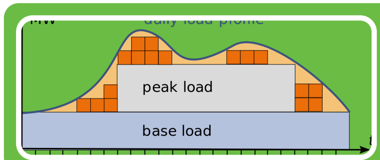


GEB is about enabling buildings to provide flexibility in energy use and grid operation



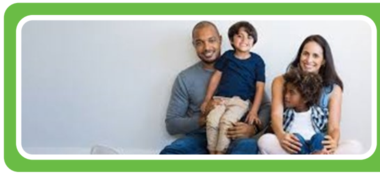
Potential Benefits of Flexible Building Loads

✓ Energy Affordability



✓ Improved reliability & resiliency

✓ Reduced grid congestion



✓ Enhanced services

✓ Environmental benefits

✓ Customer choice

Key Characteristics of GEBs

EFFICIENT

Persistent low energy use minimizes demand on grid resources and infrastructure

CONNECTED

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

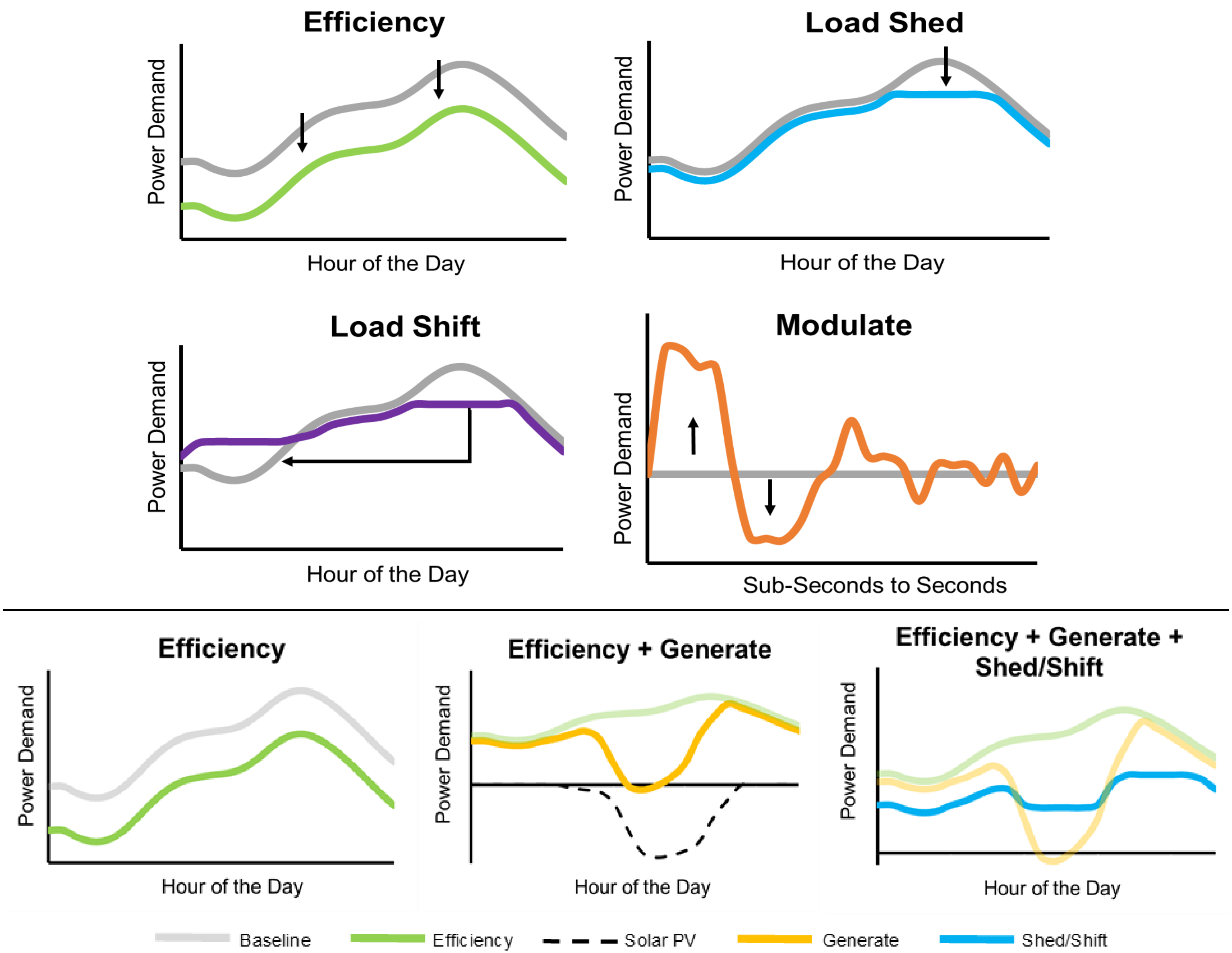
SMART

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

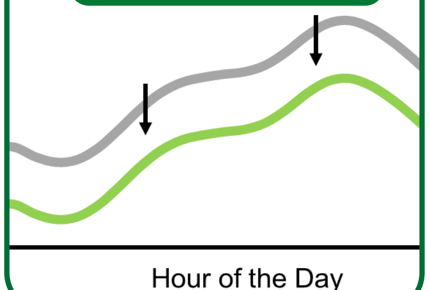
Demand Management Provided by GEB



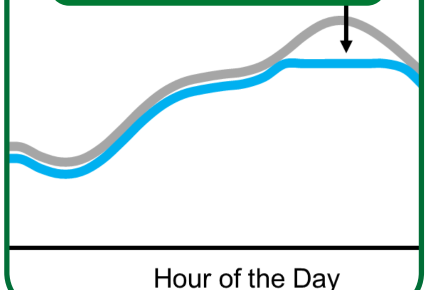
Mapping Flexibility Modes and Grid Services

Buildings can provide grid services through 4 demand management modes.

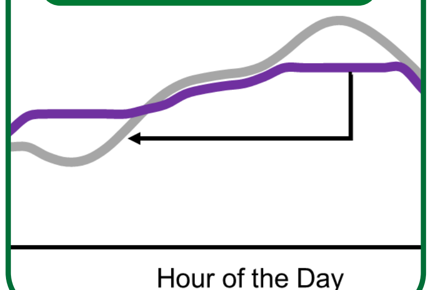
Efficiency



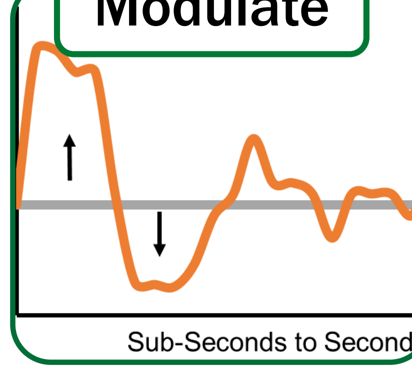
Load Shed



Load Shift



Modulate



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

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GEB Lighting & Electronics Report

Valerie Nubbe, Guidehouse

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Jason Tuenge, PNNL
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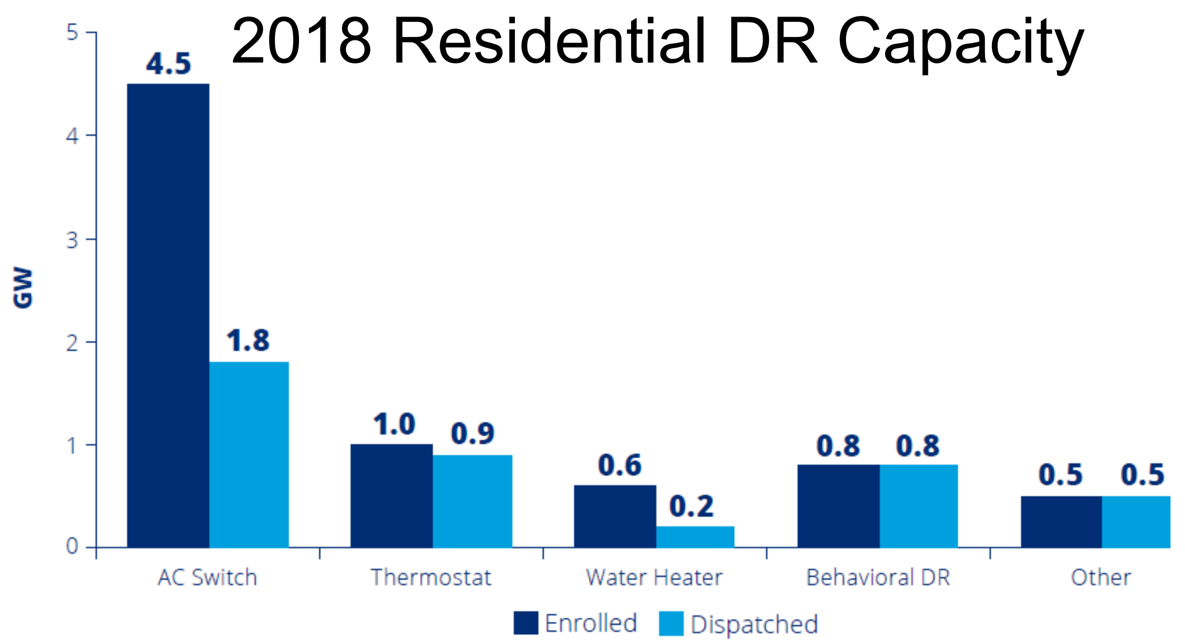
Jeffrey Tsao, SNL
Monica Neukomm, U.S. DOE
Brian Walker, U.S. DOE
Monica Hansen, LED Lighting Advisors
Jared Langevin, LBNL

Poll #1

Currently lighting and electronics are rarely used in DR programs.

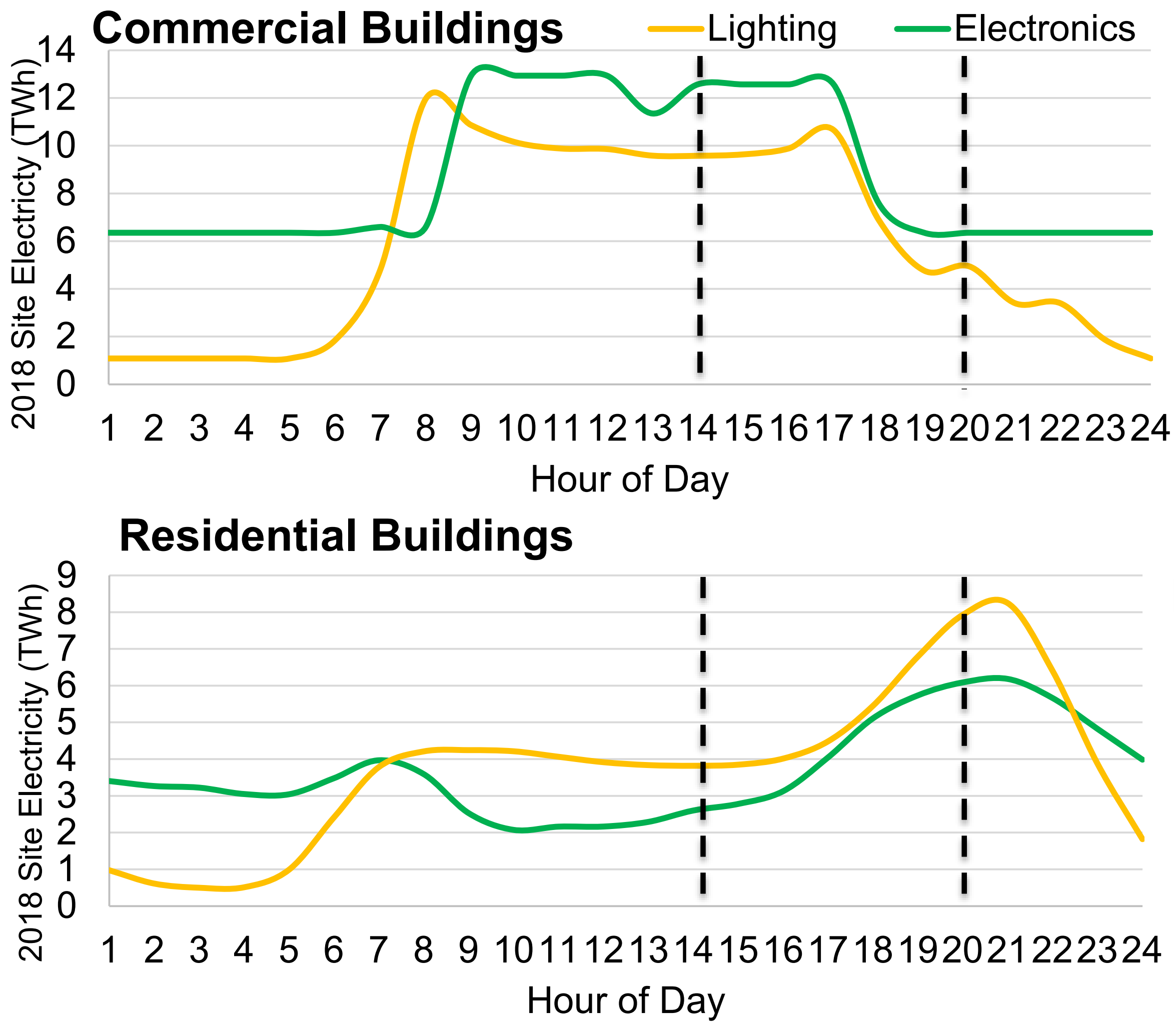


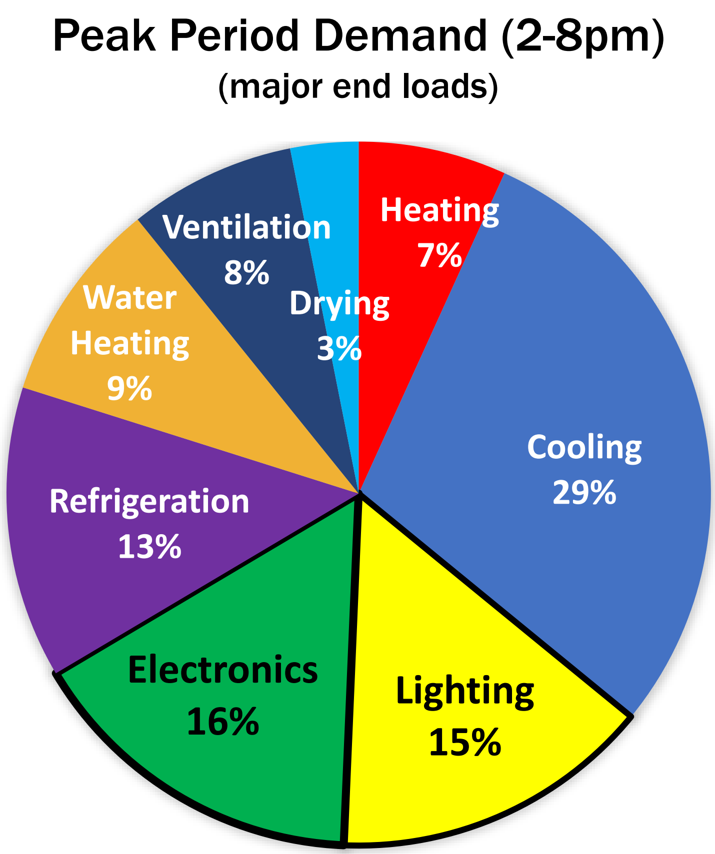
- **Given the current limitations (storage, safety, comfort requirements, etc.):**
  1. **Do you think there is potential for lighting to provide grid services in the future?**
  2. **Do you think there is potential for electronics to provide grid services in the future?**

Smart Electric Power Alliance (SEPA). 2019 Utility Demand Response Market Snapshot.

2018 Load Profiles

Lighting & electronics contribute to daily electricity peak period demand.





Data are generated using the Scout time-sensitive efficiency valuation framework which attributes annual baseline energy use estimates from the EIA's 2019 Annual Energy Outlook across all hours of the year using energy load shapes from ResStock and the Commercial Prototype Building Models

Report Objectives

- What lighting and electronics technologies can provide grid services?
- Which have the highest potential?
- What R&D is needed to overcome current challenges inhibiting their performance and/or adoption?

Report Approach

Technology Selection	• Selection of state-of-the-art efficient and grid-interactive technologies
Evaluation	• Evaluation of potential to provide efficiency, shedding, shifting, and modulating energy demand.
Technology Attributes	• Identify the key benefits and challenges, including attributes relevant to manufacturers, consumers, and society
Challenges and R&D	• Identify major challenges for each medium- and high-potential technologies • Identify R&D activities and opportunities for addressing the challenges

Selected Lighting Technologies

All lighting technologies considered here are types of *connected lighting systems (CLS)*.

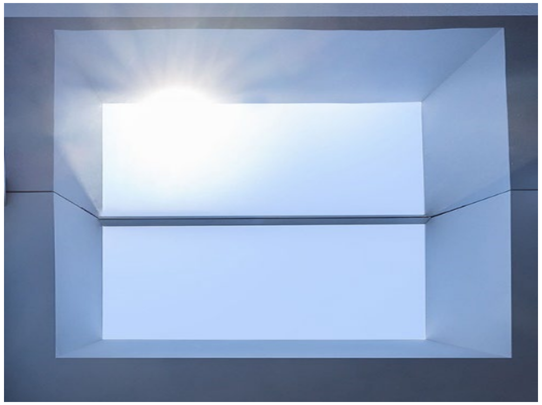
Advanced Sensors & Controls

- CLS that utilize embedded advanced sensors, control, and algorithms to modulate lighting levels or other power-consuming lighting features in response to external grid signals.

Hybrid Daylight SSL

- CLS that are enhanced by the integration of technology to collect and re-distribute zero energy daylighting.

SSL Displays



- CLS displays leveraging either LED or organic-LED (OLED) technology to eliminate the need for windows and skylights as sources of daylighting.

BPA, “Luminaire Level Lighting Controls” Available: https://www.bpa.gov/EE/Technology/EE-emerging-technologies/Projects-Reports-Archives/Pages/Easily-commissioned-Lighting-Controls-.aspx
Mayhoub, M.S. 2014. “Innovative daylighting systems’ challenges: A critical study.” *Energy Build.*, vol. 80, pp. 394–405. https://doi.org/10.1016/j.enbuild.2014.04.019
CoeLux, “CoeLux® 45 SQUARE.” Available: https://www.coelux.com/en/p/coelux-45-square-en-11

Selected Electronics Technologies

Included all consumer electronics and IT equipment that is wi-fi enabled and controlled remotely.

Continuous-Operation

- Network equipment
- Set-top boxes
- Stationary computer
- Servers
- AV Equipment

Battery-Powered

- Laptops
- UPS battery backups
- Tablets

Displays

- Signage displays
- Computer monitors
- TVs

https://www.netmonservices.com/products/hardware/
https://www.popularmechanics.com/technology/gadgets/a27286215/best-touch-screen-laptop/
https://www.bestbuy.com/site/computer-monitors/all-monitors/pcmcat143700050048.c?id=pcmcat143700050048

Evaluation of Technologies

We used 3 basic criteria to evaluate the technologies.

1. Capability Rating for demand side-management (DSM) strategy

Capability Ratings							
○	Not Applicable	◑	Low Capability	◐	Medium Capability	●	High Capability

2. Number of DSM strategies provided

– I.e., Efficiency, Load Shed, Load Shift, Modulate

3. Weighting of DSM strategies

– Efficiency and peak reductions (shed/shift) higher value than frequency regulation, voltage support, ramping (modulate)

Evaluation Results

Advanced Lighting S&C and Continuous Operation Electronics have the highest potential to provide grid services.

Technologies		Efficiency	Load Shed	Load Shift	Modulate	Overall Potential
Lighting	**Advanced Sensors and Controls**	High Capability	Medium Capability	Not Applicable	Low Capability	**High**
	Hybrid Daylight SSL Systems	High Capability	Low Capability	Not Applicable	Low Capability	Medium
	SSL Displays	Medium Capability	Low Capability	Not Applicable	Not Applicable	Low
Electronics	**Continuous-Operation Electronics**	High Capability	Low Capability	Not Applicable	Low Capability	**High**
	Battery-Powered Electronics	Low Capability	Not Applicable	Medium Capability	Low Capability	Medium
	Electronic Displays	High Capability	Not Applicable	Low Capability	Not Applicable	Low

Not Applicable · Low Capability · Medium Capability · High Capability

High Potential: Advanced Lighting S&C

Flexibility Mode	Capability
Efficiency	●
Shed Load	◐
Shift Load	○
Modulate Load	◑

- Provides both **efficiency gains and shedding** (dimming, standby power, algorithms, etc.)
- **Additional energy savings** through lighting sensor networks (adjust usage in real time)
  - Sharing data with other building systems
- Has the capability to provide **fast response grid services** through shedding and modulating, though in limited capacities that are not disruptive to occupant productivity/comfort/safety

Bonneville Power Administration, “Luminaire Level Lighting Controls” [Online]. Available: https://www.bpa.gov/EE/Technology/EE-emerging-technologies/Projects-Reports-Archives/Pages/Easily-commissioned-Lighting-Controls-.aspx

High Potential: Continuous-Operation Electronics

Flexibility Mode	Capability
Efficiency	●
Shed Load	◐
Shift Load	○
Modulate Load	◐

- Power management controls can automatically transition computers and electronics into **low-power modes** as well as **automatically power-down** devices after periods of inactivity
- **Power scaling** by computing task can decrease power draw
- **Sleep/idle/off power modes** allow devices to draw a fraction of energy use when not in use
- **Deep sleep, minimal-latency mode** for networked computers and electronics can allow devices to stay connected for activation (e.g., wake-on-LAN) while using a fraction of typical power
- Computers/electronics in continuous connectivity (e.g., servers) can **modulate or shed loads**
- Staging of large electronics loads in can be used to **avoid spikes in building demand**

https://www.netmonservices.com/products/hardware/

Attributes Considered

We also considered these attributes of each technology which can serve as additional benefits or barriers to implementing the technologies.

System Attribute	Definitions
Resilience	The ability of the technology to predict and prepare for, withstand, recover rapidly from, and adapt to major disruptions including natural disasters and energy supply losses (electricity, natural gas, etc.) by providing energy, services, occupant comfort, protection, and/or damage resistance.
Usability	The ease of use of the technology to the customer, including ease of installation, ease of implementation, ease of operation, and ease of maintenance.
Cost	The manufacturing and capital costs of the technology and components.
Human Health	The extent to which the technology contributes to a healthy and safe living environment for the building occupants.
Energy Performance	The estimated impact on energy use from implementing the technology relative to baseline technologies.

Attributes: Advanced Lighting Controls

Benefits

- Energy and emissions savings
- Human health benefits

Barriers

- Usability difficulty
- Interoperability/ Cybersecurity
- Manufacturability/High capital costs
- Technical limitations (modulation levels)
- Few utility programs

All Technologies: Challenges & Opportunities

All Connected Technologies	
Challenges	**Opportunities**
Interoperability	• Support the development and adoption of standardized semantic and syntactic specifications for connected devices and software systems
Cybersecurity	• Support the adoption of secure system architectures and cybersecurity best practices
Cost	• Develop manufacturing processes that have low capital costs or can use existing manufacturing equipment with minimal investment • Develop materials and technologies compatible with scalable manufacturing methods that enable increasing production volumes

Lighting: Challenges & Opportunities

Advanced Lighting S&C	
Challenges	**R&D Opportunities**
DR Protocols & Control Algorithms	• Quantify the demand flexibility potential of lighting manipulations • Determine the optimal communication protocols & control algorithms • Develop novel control algorithms that leverage data and machine learning capabilities to customize strategies • Determine the impact to occupants from lighting systems providing grid services (productivity, comfort, etc.)
Sensors Integration & Performance	• Optimize techniques, design, and methods for embedding sensors directly in lamp/luminaires to enable multiple methods of control • Improve signal-processing techniques to reduce the error margin within the sensing range and increase the task-specific ability of the sensors

Electronics: Challenges & Opportunities

All Electronics	
Challenges	**R&D Opportunities**
Communication	• Communication protocols and architecture are needed • Development of control intelligence for electronics with the long-term vision of autonomous control
Consumer Impact	• Integrate control logic into existing algorithms to enable users to set energy rate and efficacy preferences • Research the relationship of consumer preferences to product functionality limitations

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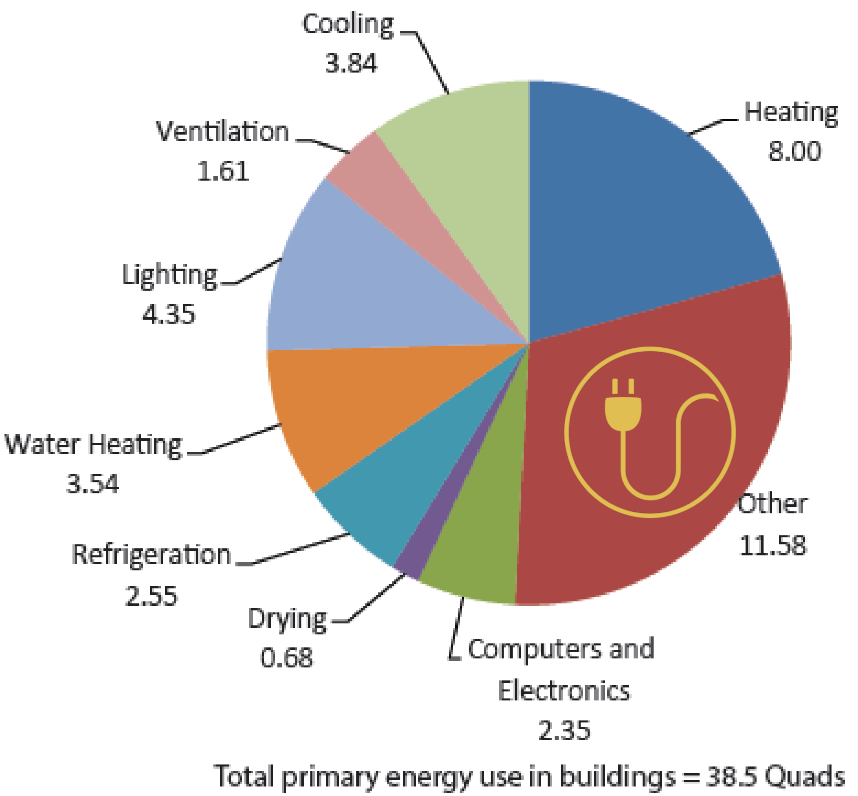
Harry Bergmann, DOE

Emerging Technologies: Miscellaneous Electric Loads (MELs)



2014 Residential and Commercial Building Primary Energy Use (Quads)
(2015 Quadrennial Review)

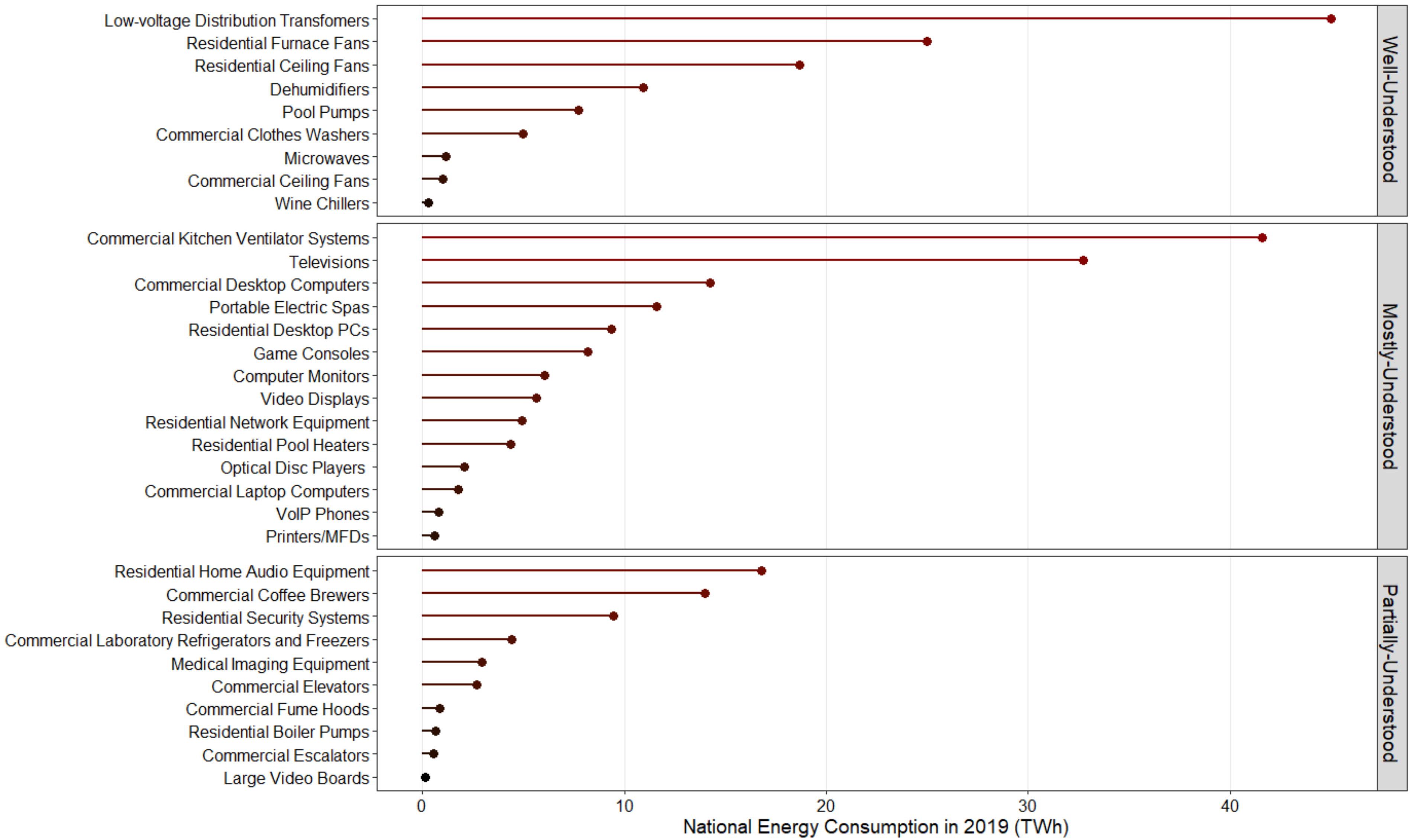
Challenges

- **Miscellaneous electric loads (MELs) are the largest end use category in building energy consumption.**
  - MELs are expected to increase both their share of total building energy consumption and magnitude of energy use over time according to the Annual Energy Outlook (AEO).
  - MELs are a challenging end use category to classify, characterize, and compare consistently.
  - Thus far, a well-accepted and widely-adopted taxonomy for MELs has yet to emerge.
- **EIA does not specifically define MELs in the AEO, it includes an "Other" category for both residential and commercial sector key indicators and energy consumption.**
  - EIA's data collection and research of MELs is limited in the National Energy Modeling System (NEMS).
  - EIA only estimates the number of devices per household and average energy consumption per household for MELs in NEMS.
  - NEMS does not incorporate data on lifetime, cost, or energy efficiency of MELs into its annual or long-term projections.
- **Few individual MELs are well studied or understood.**
  - Identification. Quantification. Energy Savings.

Impact

- Identification
  - Striving for a common understanding of MELs across DOE offices
- Quantification
  - The 33 MELs researched in this study comprise:
  - 1.5 billion products installed in the residential and commercial sectors
  - One quad of annual national electricity consumption, representing 11% of delivered electricity to the residential and commercial sectors combined
- Energy Savings Potential
  - A subset of 23 MELs consume nearly 250 TWh nationally per year
  - The potential exists to reduce the energy consumption of these 23 MELs by 43%, decreasing their aggregate national annual energy consumption to 142 TWh

Impact


Low-voltage Distribution Transfomers
Residential Furnace Fans
Residential Ceiling Fans
Dehumidifiers
Pool Pumps
Commercial Clothes Washers
Microwaves
Commercial Ceiling Fans
Wine Chillers
Well-Understood
Commercial Kitchen Ventilator Systems
Televisions
Commercial Desktop Computers
Portable Electric Spas
Residential Desktop PCs
Game Consoles
Computer Monitors
Video Displays
Residential Network Equipment
Residential Pool Heaters
Optical Disc Players
Commercial Laptop Computers
VoIP Phones
Printers/MFDs
Mostly-Understood
Residential Home Audio Equipment
Commercial Coffee Brewers
Residential Security Systems
Commercial Laboratory Refrigerators and Freezers
Medical Imaging Equipment
Commercial Elevators
Commercial Fume Hoods
Residential Boiler Pumps
Commercial Escalators
Large Video Boards
Partially-Understood
0
10
20
30
40
National Energy Consumption in 2019 (TWh)

Potential

- High Potential
  - Continuous-operation electronics (e.g.: desktop computers, servers, network equipment)
  - Servers & data centers could provide shedding and modulation services
- Medium Potential
  - Battery powered electronics (e.g.: laptops, smart phones, tablets, etc.)
  - UPS battery backups are the most reliable here since portability of other technologies makes for inconsistent ability to use.
- Low Potential
  - Electronic displays and signage – already fairly efficient and the greatest savings potential, dimming, reduces performance and user experience.

Poll #3

- Should BTO continue investing in the identification and categorization of MELs?
  - Strongly Agree
  - Somewhat Agree
  - Somewhat Disagree
  - Strongly Disagree

Pacific Northwest
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Can Connected Lighting Systems Provide Grid Services in GEBs?

May 26, 2020

Michael Poplawski

DOE GEB Technical Report Webinar Series

Acknowledgements: Michael Brambley, Jianming Lian, Robert Lutes, Michael Myer, Alex Vlachokostas, Peng Wang

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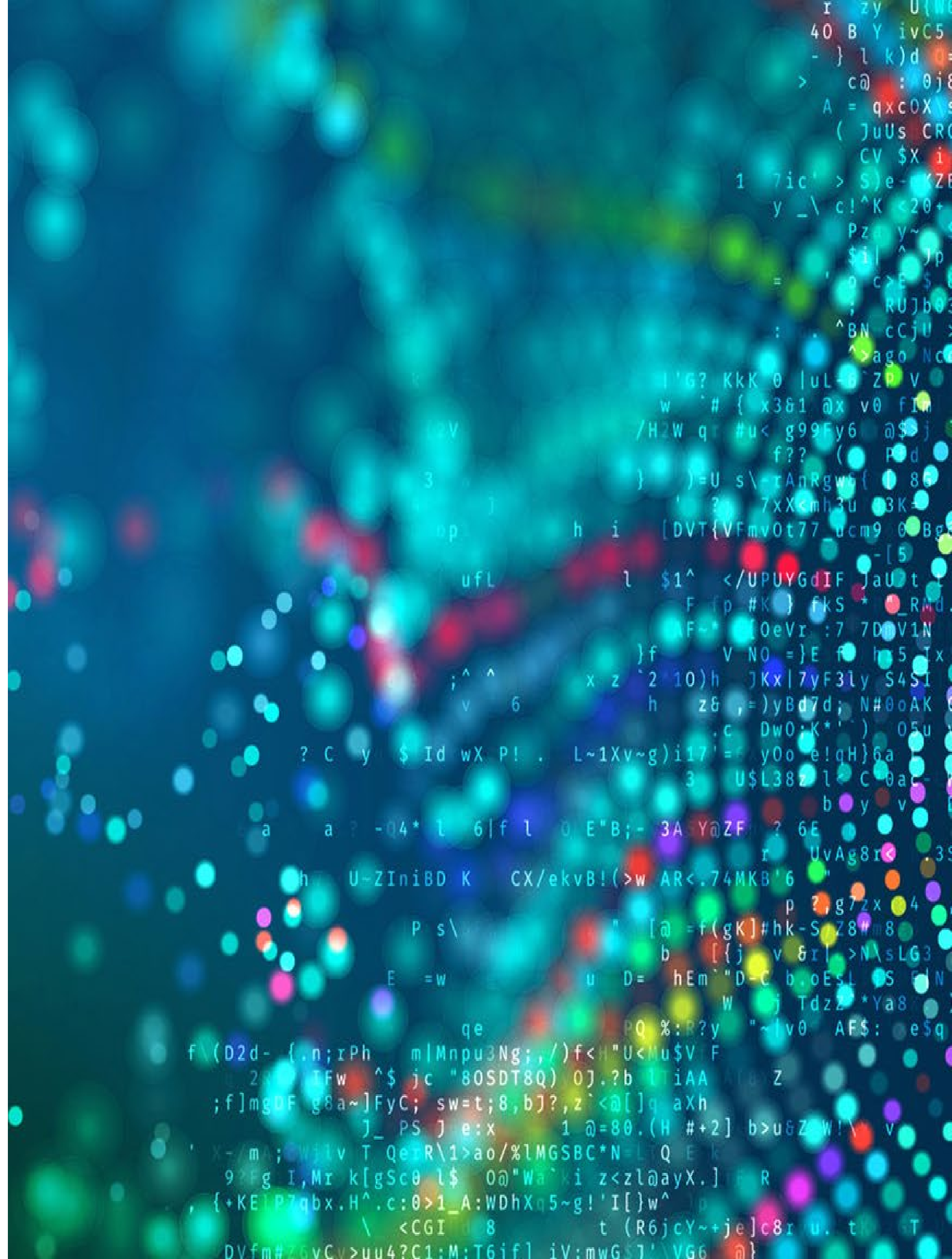
PNNL is operated by Battelle for the U.S. Department of Energy



How can the potential for CLS to provide grid services be simulated?

- How can CLS be modeled for grid service simulation?
- How can lighting service needs be represented in the models? What is the relationship between lighting service and power?
- How can occupant satisfaction be represented in the models? What is the relationship between lighting service and occupant satisfaction?
- How can CLS technology performance variations be represented in the models?
- How do lighting system models, service needs, and occupant satisfaction needs vary?

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While many models exist for predicting occupant thermal comfort, **occupant lighting needs and preference can vary significantly**

Vary by visual task




Individual needs, sensitivities, preferences

Age
Flicker
Glare
Color Temperature
Circadian Stimulation?

CLS flexibility for providing grid services can be modeled by five key parameters that account for CLS characteristics and occupant satisfaction

Model parameters

1	Maximum lighting load (watts)	Per building and space type
2	Nominal lighting load (watts)	Per building and space type, hour of day
3	Minimal lighting load (watts)	5 performance levels: 10%, 15%, 20%, or 30% below nominal in eligible spaces; 60% below nominal in daylit spaces, 20% below nominal in other eligible spaces
4	Lighting load change delay (seconds)	3 performance levels: 0.2, 2, 20
5	Max. lighting load ramp rate (%watts per second)	3 performance levels: 0.5, 1, 15

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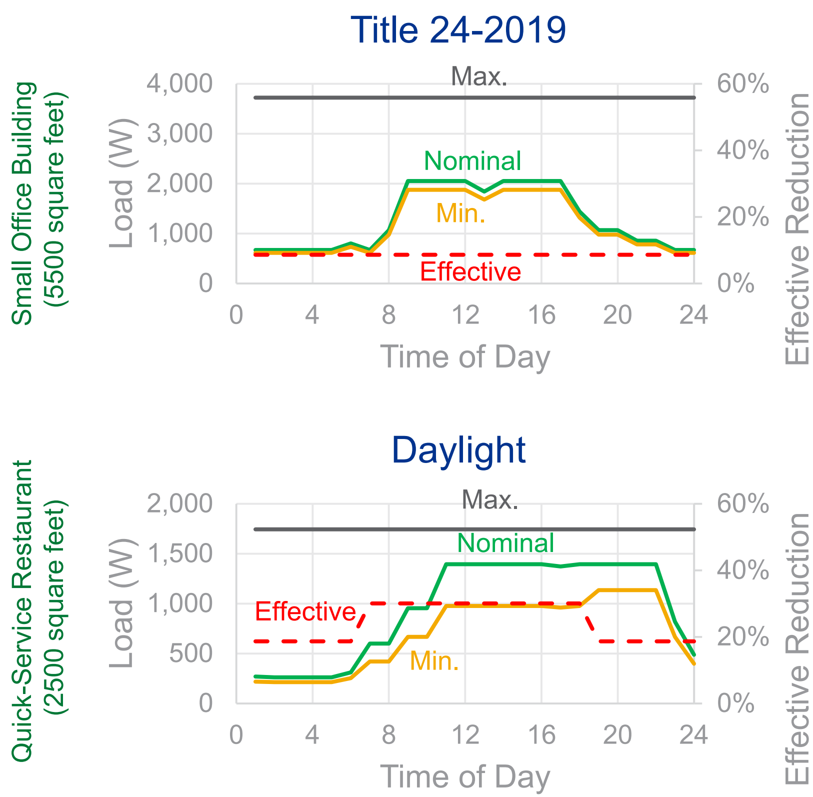
CLS average power draw flexibility can be modeled using DOE prototype building load schedules and other standards and specifications

CLS models for grid service simulations describe maximum, nominal, and minimum possible system power draw over the course of a day for each of the sixteen DOE prototype buildings.

One min. response level (15% below nom.) is based on the Title 24-2019 recommended practice, and one (60% below nom.) is based on occupant satisfaction research in daylit spaces, applied to buildings whose daylit spaces are designed according to the WELL Building Standards™ recommended practice.

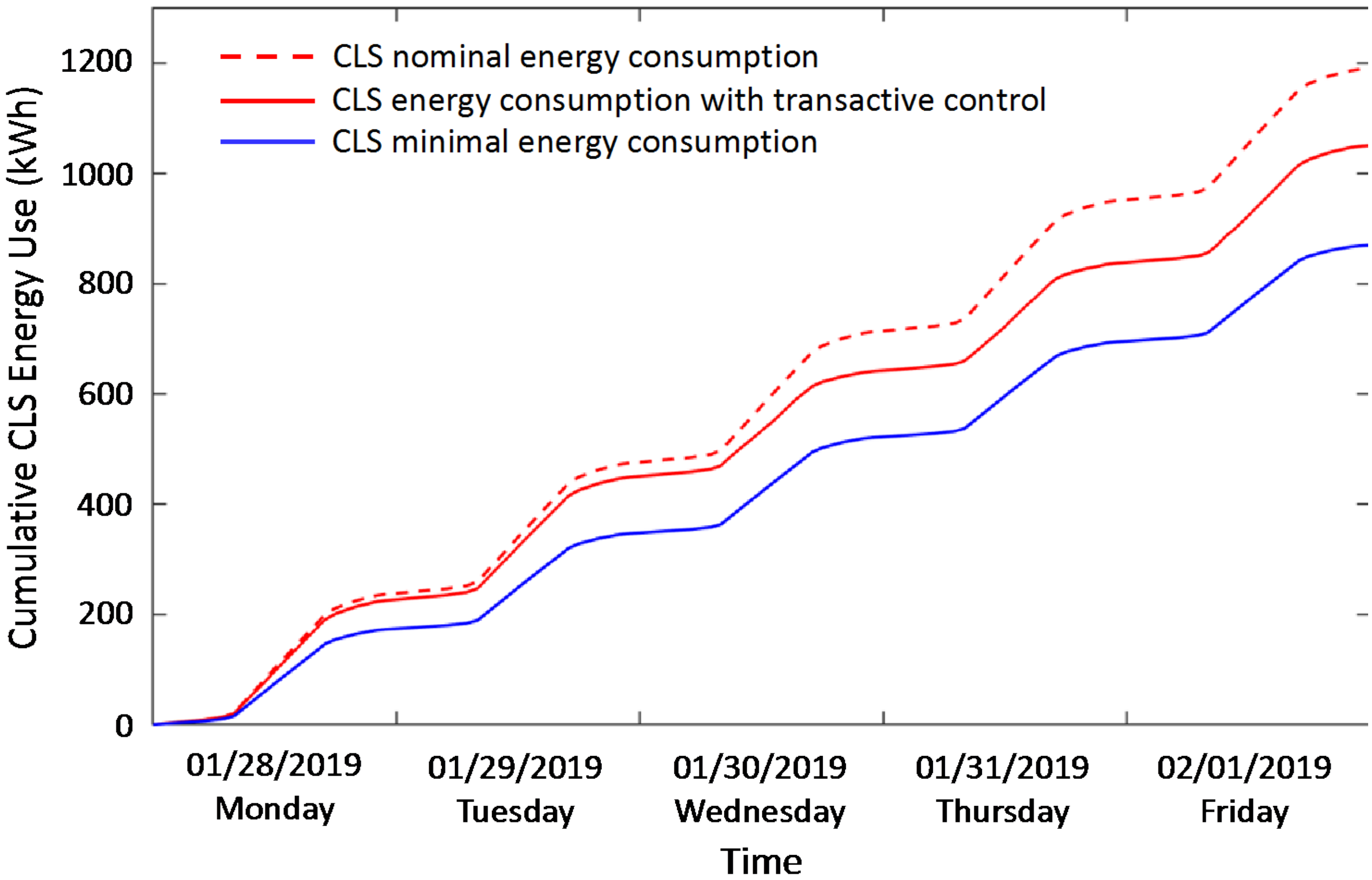
Lighting system flexibility is, by definition, the range between the max. and min. levels.



Current simulation plan

- Start with medium office building; other building types TBD
- 3 different minimum lighting load profiles
- 5 different combinations of lighting load change delay and ramp rate
- 5 grid services, spanning response times of sub-seconds to hours
- 3 building system scenarios
  - CLS alone
  - CLS and heating, ventilating and air-conditioning (HVAC)
  - CLS with battery storage, HVAC

The CLS delivered ~40% of the maximum potential energy savings over the 5-day trial simulation period



Poll #4

- After these presentations:
  1. Do you think there is potential for lighting to provide grid services in the future?
  2. Do you think there is potential for electronics to provide grid services in the future?

Questions?

Use the question feature to ask a question or provide a comment.