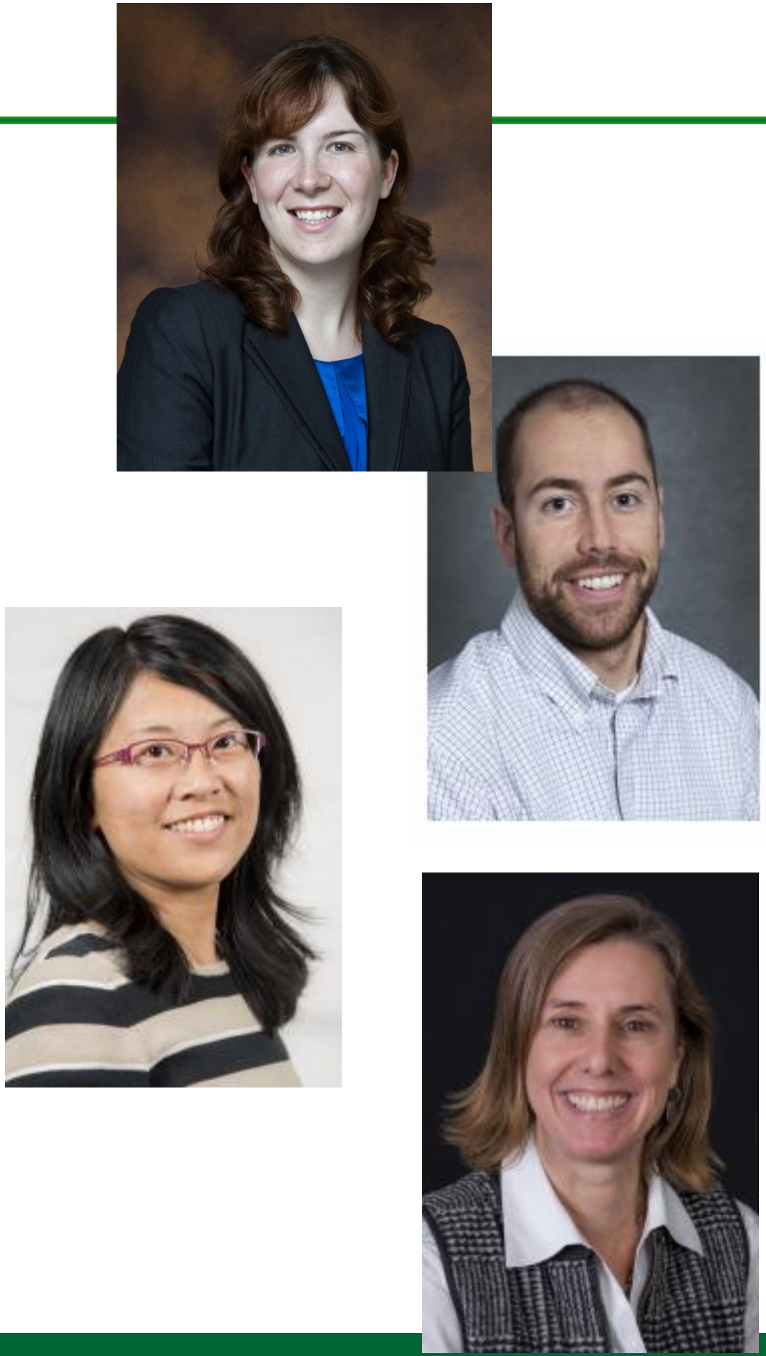
U.S. DEPARTMENT OF
ENERGY
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

GEB Webinar Series:
Integration- Building Equipment

Building Technologies Office

June 23, 2020

Webinar Agenda



I. GEB Overview

- Karma Sawyer, Emerging Technologies Program Manager
  - Building Technologies Office

II. A Framework to Assess Energy Efficiency and Demand Response Interactions

- Andy Satchwell, Research Scientist
  - Lawrence Berkeley National Laboratory (LBNL)

III. GEB Load Flexibility Metrics

- JingJing Liu, Program Manager and Mary Ann Piette, Building Technology Division Director
  - Lawrence Berkeley National Laboratory (LBNL)

IV. Q&A Session

- Karma Sawyer, Emerging Technologies Program Manager
  - Building Technologies Office

GEB Technical Report Webinar Series

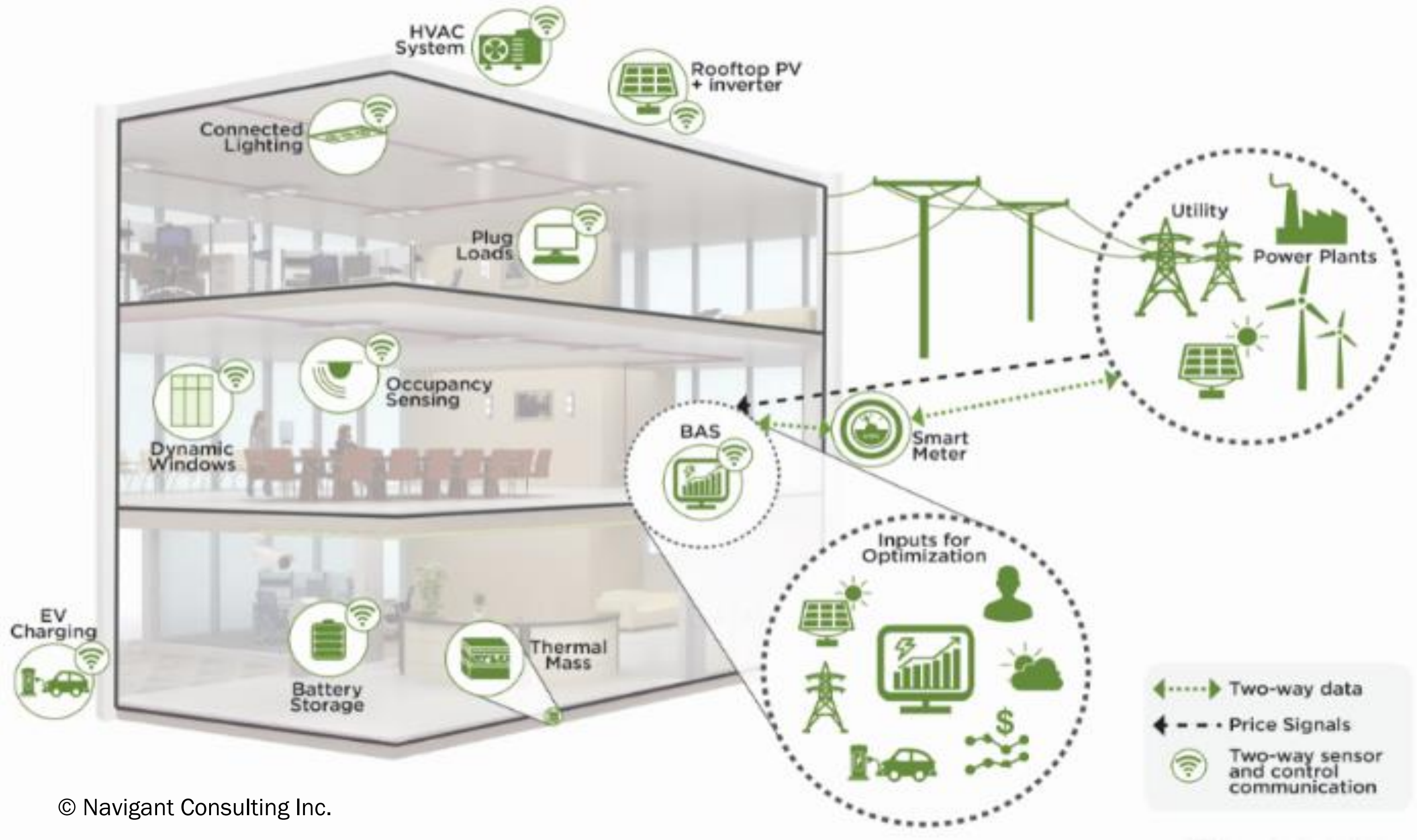
Topic	Date	Time
Whole-building Control, Sensing, Modeling & Analytics	May 19	2:00pm - 3:30pm ET
Lighting & Electronics	May 26	2:00pm - 3:00pm ET
Heating, Ventilation & Air Conditioning (HVAC)	June 2	2:00pm - 3:30pm ET
Water Heating & Appliances	June 9	2:00pm - 3:00pm ET
Envelope & Windows	June 16	2:00pm - 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



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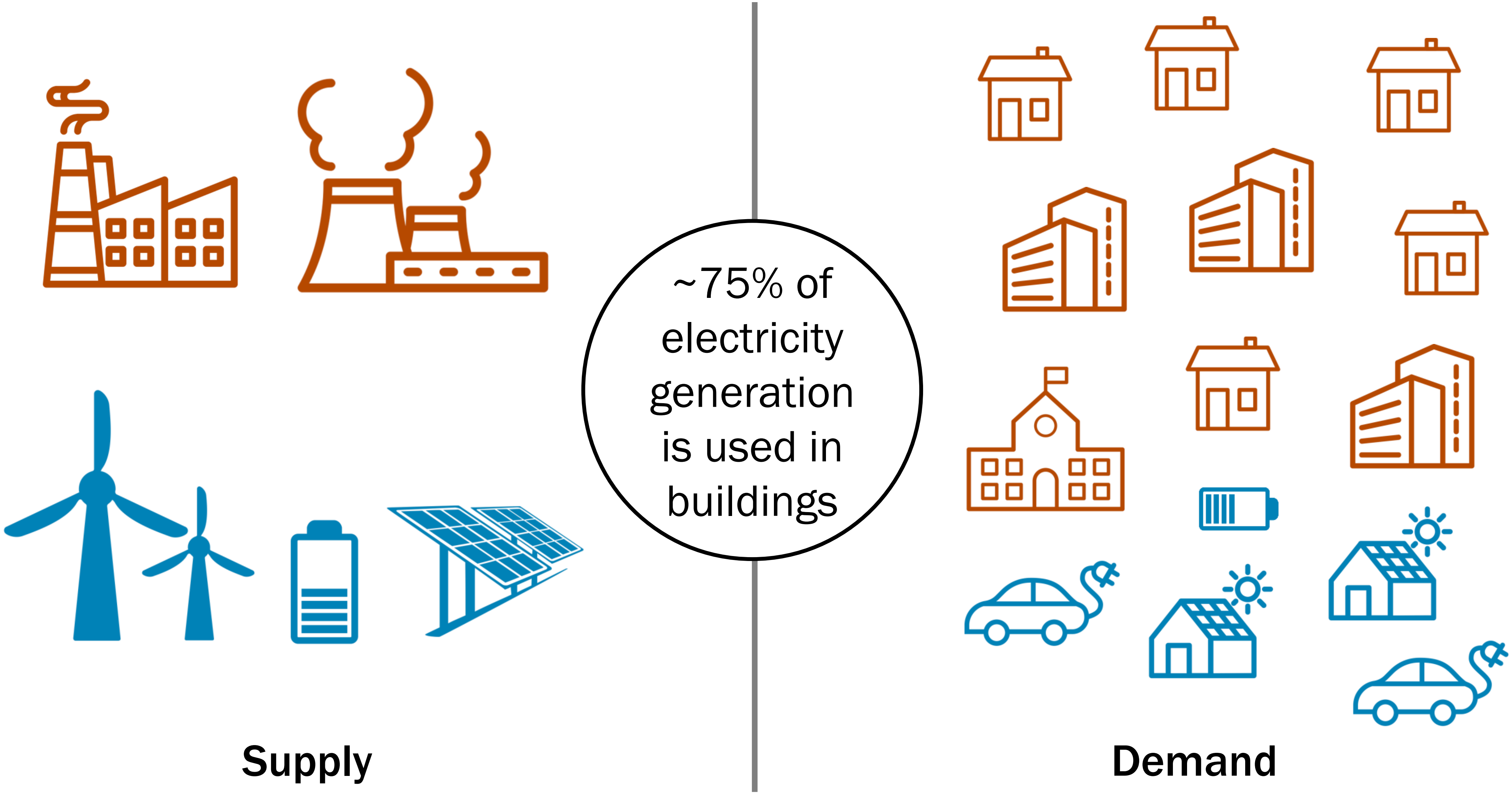
GEB is about enabling buildings to provide flexibility in energy use and grid operation



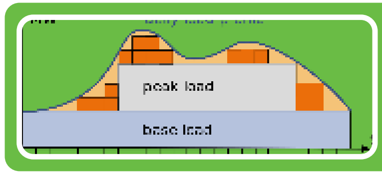
~75% of electricity generation is used in buildings

Supply

Demand

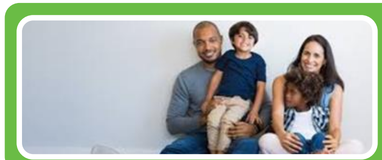
Potential Benefits of Flexible Building Loads

- ✓ 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

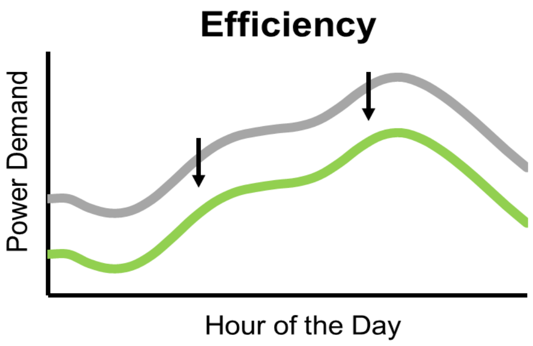
SMART

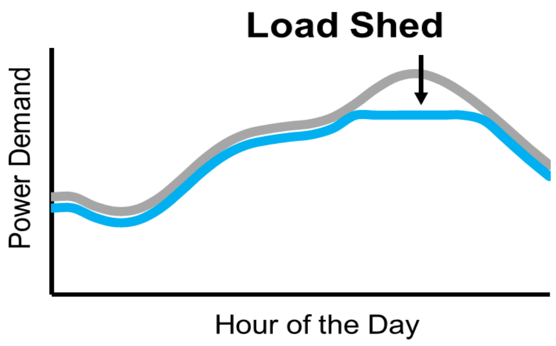
Analytics supported by sensors and controls co-optimize efficiency, flexibility, and occupant preferences

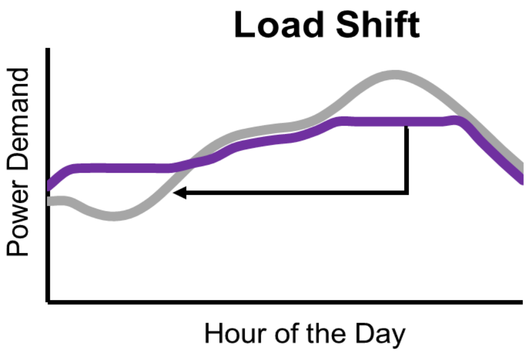
FLEXIBLE

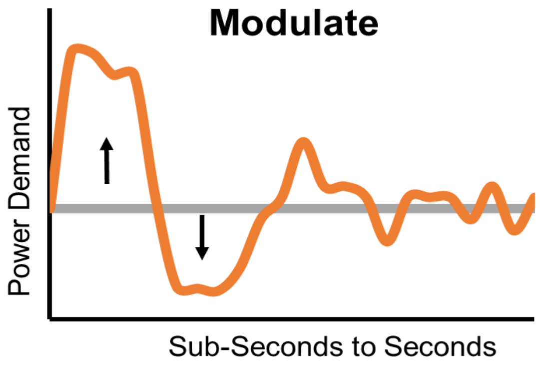
Flexible loads and distributed generation/storage can be used to reduce, shift, or modulate energy use

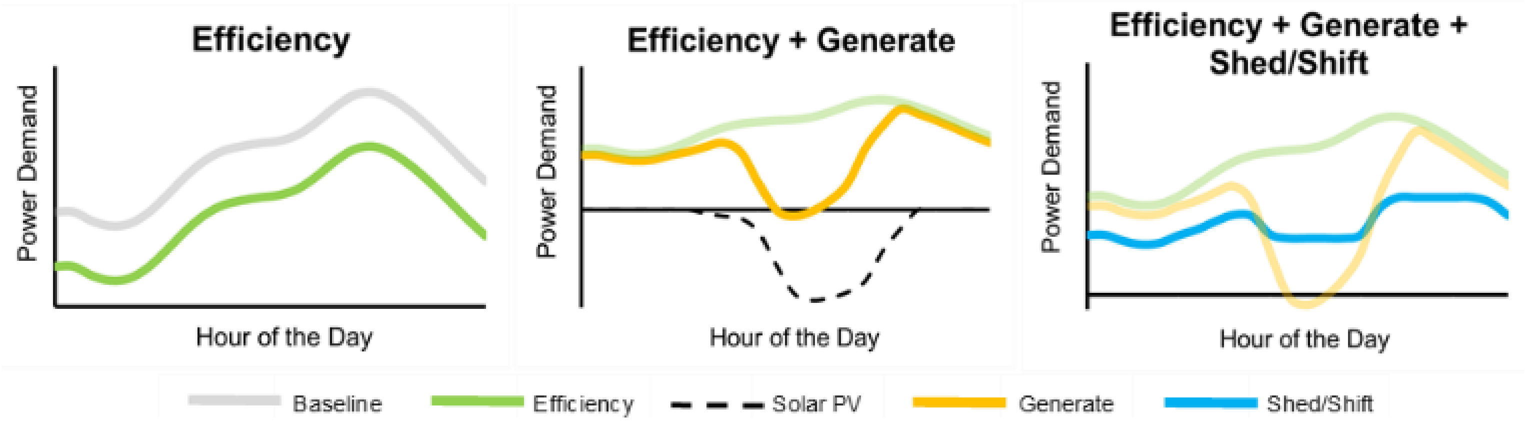
Demand Management Provided by GEB


Efficiency


Load Shed

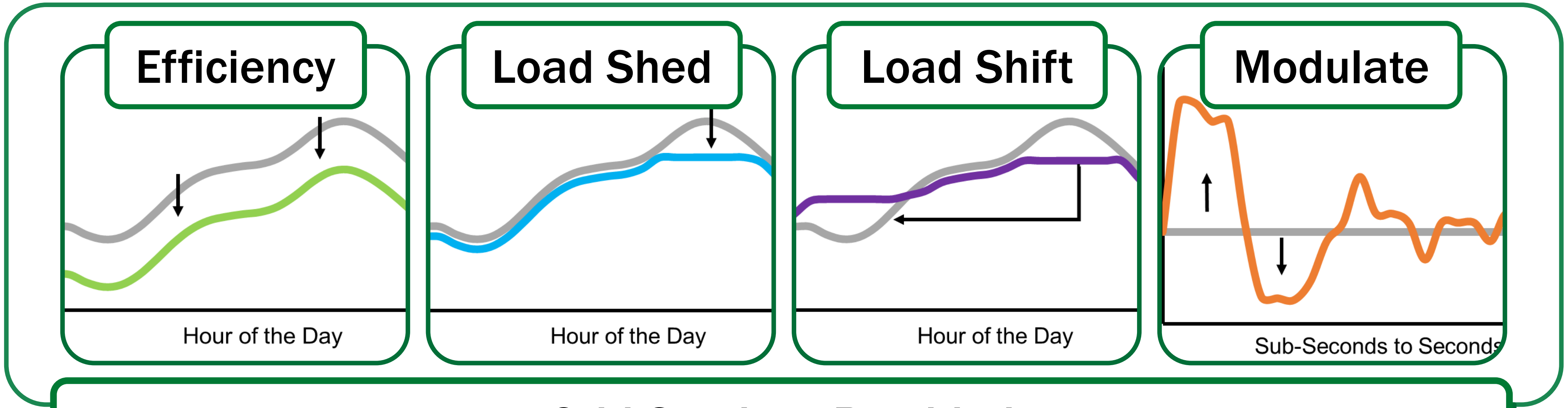

Load Shift


Modulate



Mapping Flexibility Modes and Grid Services

Buildings can provide grid services through 4 demand management modes.



Grid Services Provided

• Generation: Energy & Capacity • Non-Wires Solutions	• Contingency Reserves • Generation: Energy & Capacity • Non-Wires Solutions	• Generation: Capacity • Non-Wires Solutions	• Frequency Regulation • Ramping

Examples

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

A Framework to Assess Energy Efficiency and Demand Response Interactions

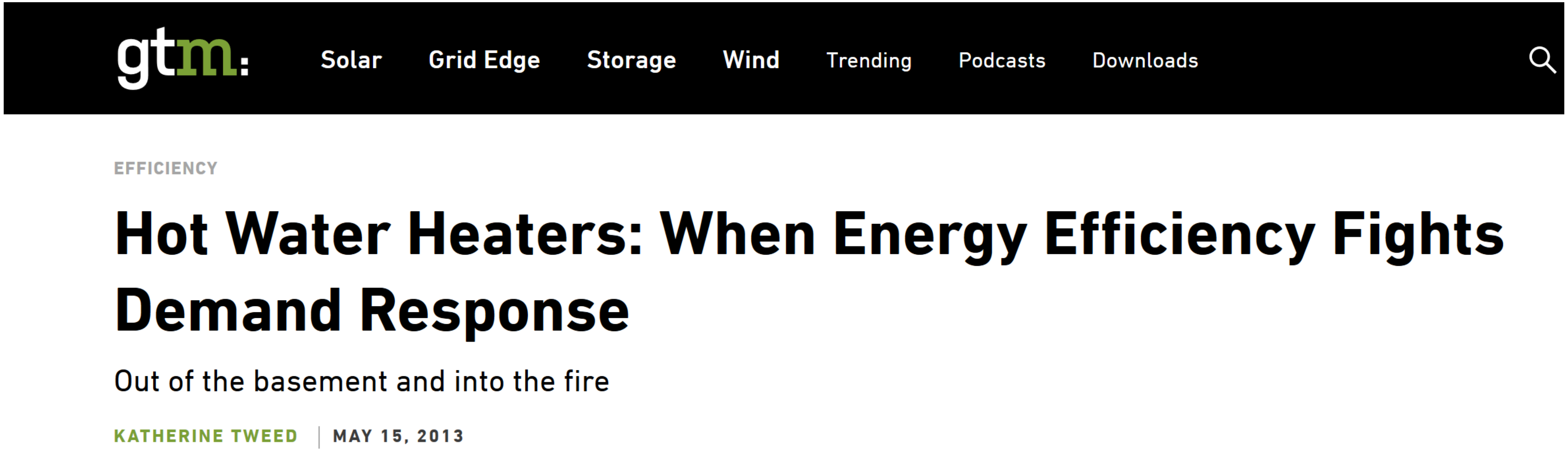
Andy Satchwell

June 23, 2020

The work described in this presentation was funded by the U.S. Department of Energy’s Building Technologies Office under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or The Regents of the University of California.

Context

- Concerns are often raised that aggressive and successful energy efficiency (EE) programs undermine the efficacy of demand response (DR) programs because less electricity is able to be controlled during DR events



EFFICIENCY

Hot Water Heaters: When Energy Efficiency Fights Demand Response

Out of the basement and into the fire

KATHERINE TWEED | MAY 15, 2013

Project objective

- A multi-year project to develop and apply an integrated valuation methodology to assess the load and economic relationships between EE and DR in the context of different future grid scenarios

How do EE and DR compete with and complement one another on a load and economic basis?

Under what system conditions should EE and DR be integrated?

What EE and DR technologies and strategies are most valuable from a systems perspective, and how robust are those valuations across high VRE, storage, and electric vehicle (EV) futures?

How should EE and DR regulatory cost-effectiveness frameworks evolve to take into account system value?

Three interrelated tasks

Conceptual framework

Identify attributes, system conditions, and technological factors driving EE and DR interactions

Today’s focus

Load interactions

Quantitative analysis of how EE and DR compete with and complement each other on a load-shaping basis, based on key attributes identified in the conceptual framework

System economic interactions

Quantify changes in utility system total energy, capacity, and ancillary services costs, and total emissions across 3 U.S. regions and among scenarios of different future resource mixes (e.g., high VRE, high storage), based on load interactions and conceptual framework

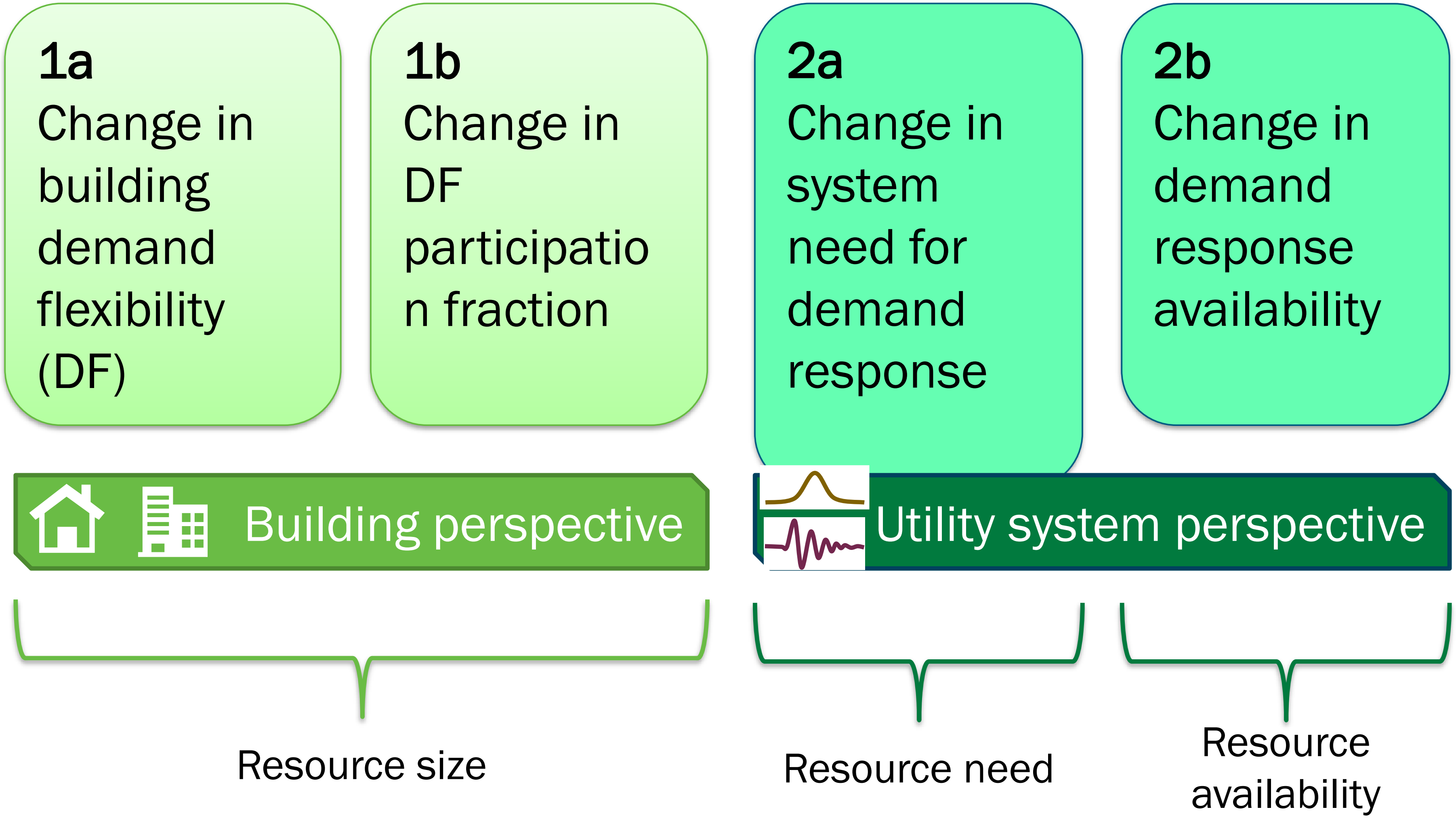
Framework boundaries

We assess EE and DR as separate resources and explore how they interact.

Framework focuses primarily on utility system perspective, though it identifies and aggregates interactions from the building perspective.

Framework does not qualitatively assess whether and how EE and DR interactions change customer economics, program cost-effectiveness, broader regulatory & policy issues (e.g., rate design), or (mis)alignment between program design and wholesale market opportunities.

Framework levels and sublevels



1a
Change in building demand flexibility (DF)

1b
Change in DF participation fraction

2a
Change in system need for demand response

2b
Change in demand response availability

Building perspective

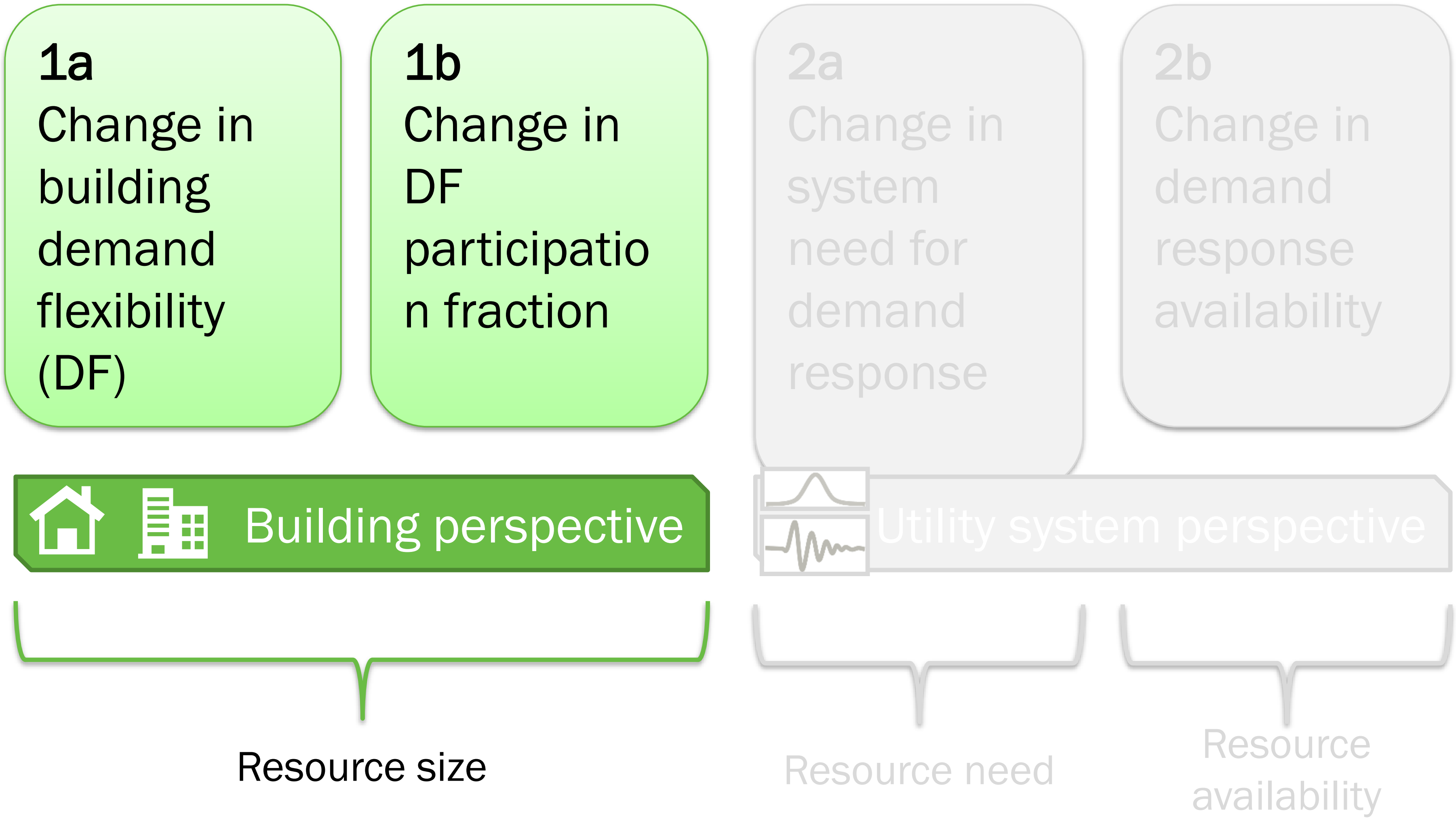
Utility system perspective

Resource size

Resource need

Resource availability

Framework levels and sublevels



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Utility system perspective

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Resource availability

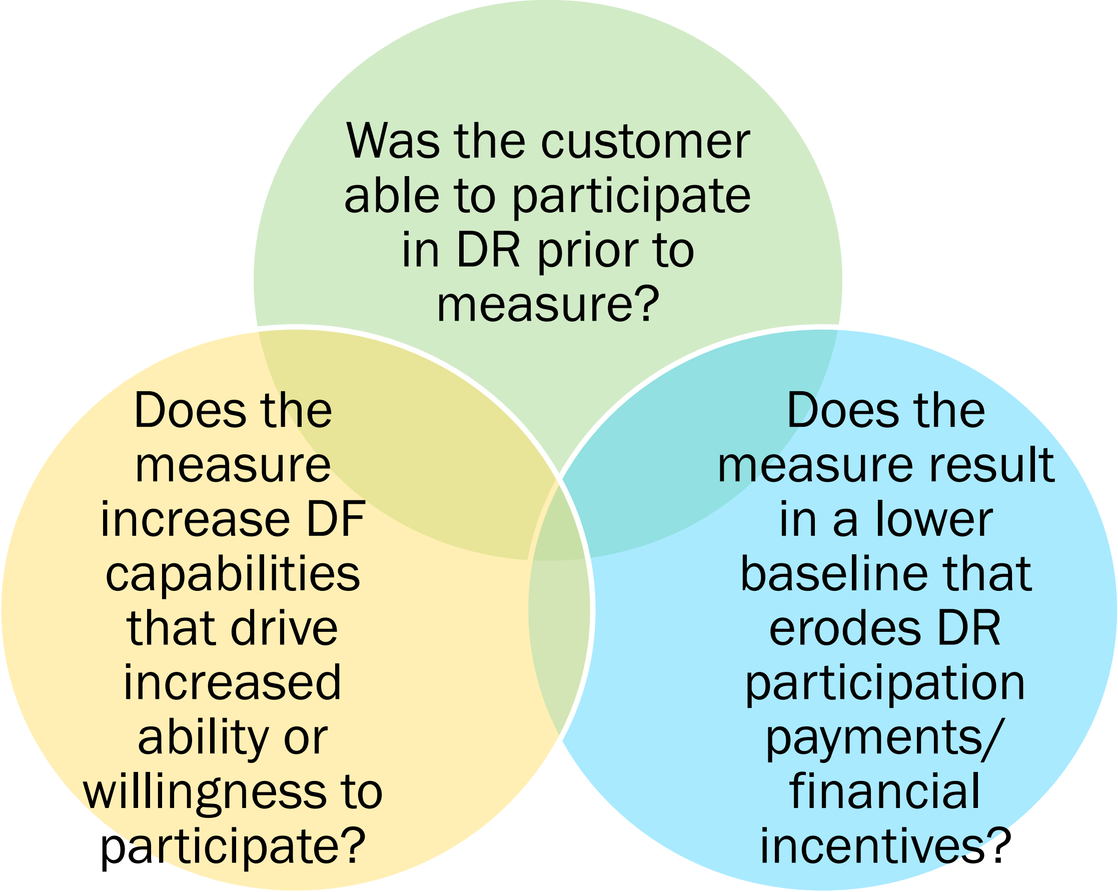
Level 1a – change in building demand flexibility

In the presence of a more efficient measure, what is the change in technical potential and capability to shed, shift, or modulate the affected load?

			Change in Passive Load Shape	
			Generally lower	**Sometimes lower/sometimes higher**
Change in capability	**Unchanged**	**Without controls**	● Res. ERWH wrap ● Com. LED lighting ● Com. refrigeration upgrade	*No examples considered*
	Higher	**Without controls**	*No examples considered*	● Com. building envelope upgrade
		With controls	● Res. ERWH wrap + grid connection ● Com. refrigeration upgrade + controls	● Res. PCT ● Com. networked lighting controls ● Com. variable speed AC + PCT

Level 1b – change in demand flexibility participation fraction

Is the fraction of a building's demand flexibility that is participating as a demand response resource higher or lower?



Was the customer able to participate in DR prior to measure?

Does the measure increase DF capabilities that drive increased ability or willingness to participate?

Does the measure result in a lower baseline that erodes DR participation payments/ financial incentives?

Framework levels and sublevels

1a
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Utility system perspective

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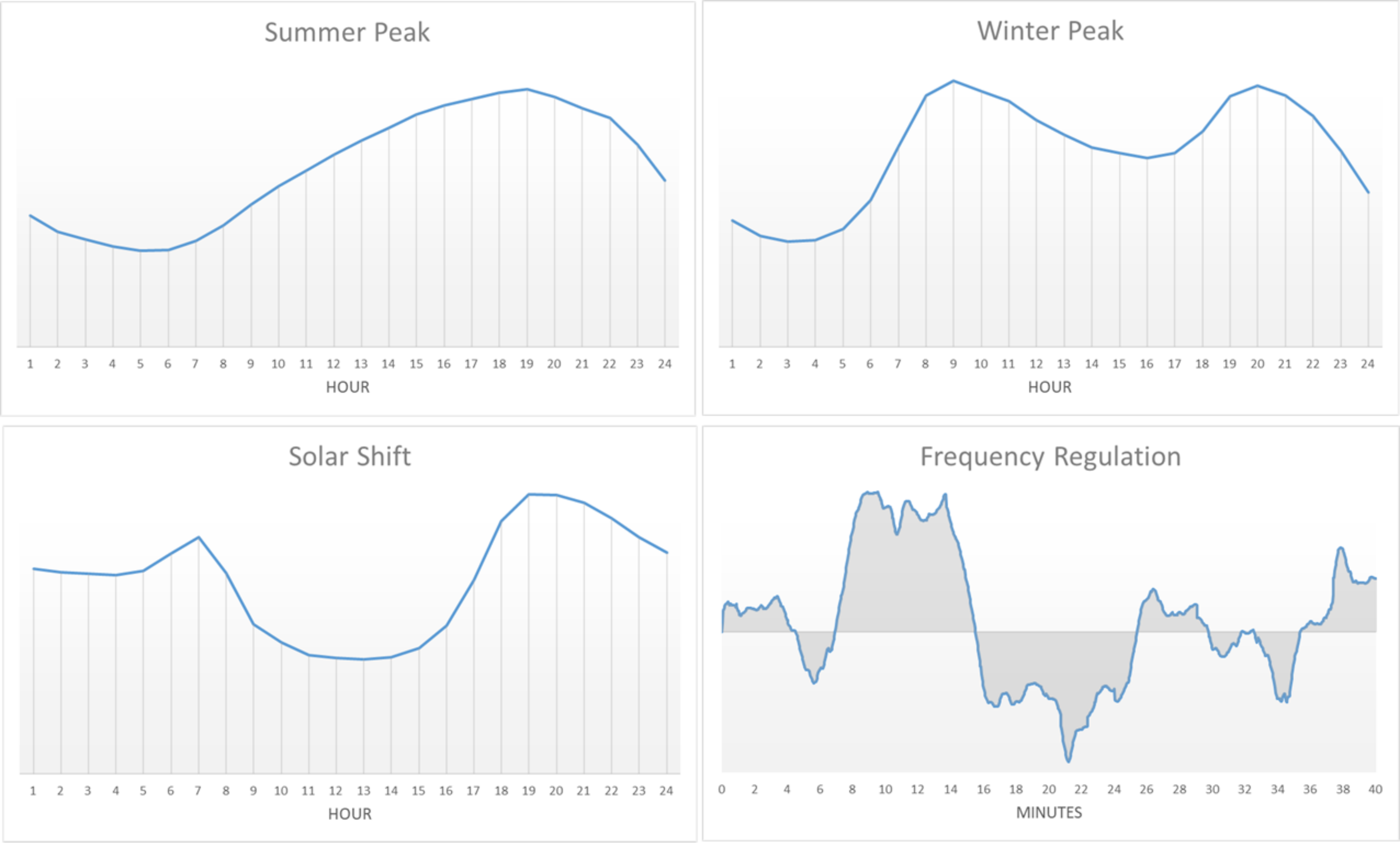
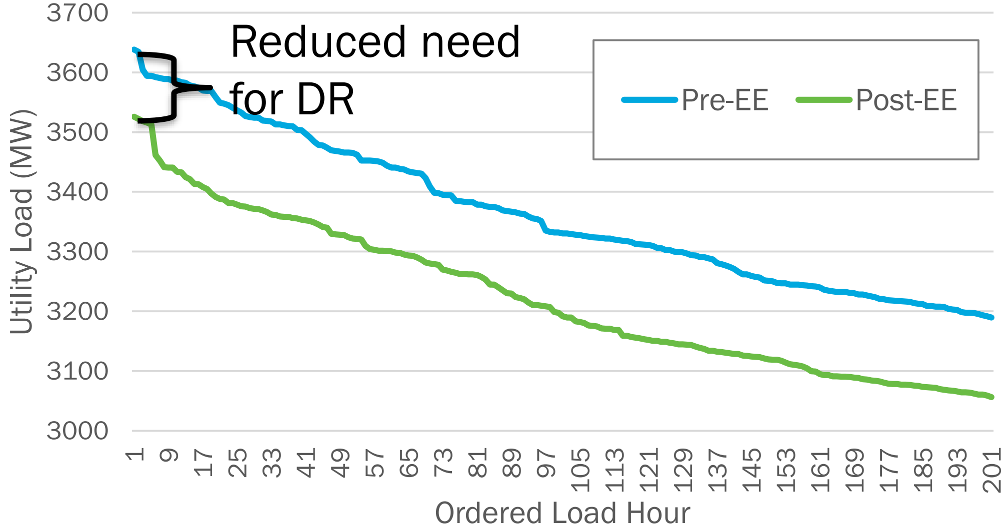
Utility system conditions explored in the study



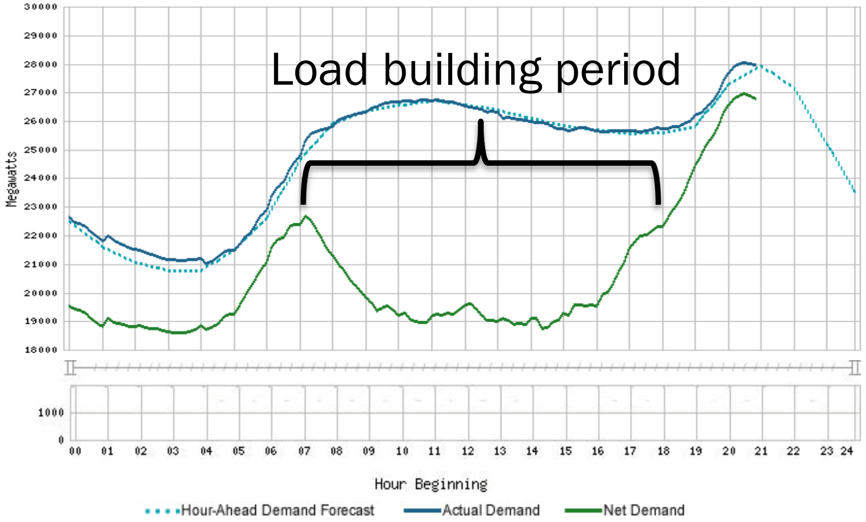
Illustrative system prototypes representing Summer peak shed (ISO-NE weekday average load in August, 2018), Winter peak shed (Northwest weekday average load in February, 2018), Solar shift (CAISO net load on March 5, 2018), and Frequency regulation (PJM RegD normalized signal).

Level 2a – change in system need for demand response

What is the change in likelihood that the system needs incremental demand response resources?



Likely EE and DR complement

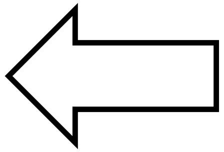


Likely EE and DR competition

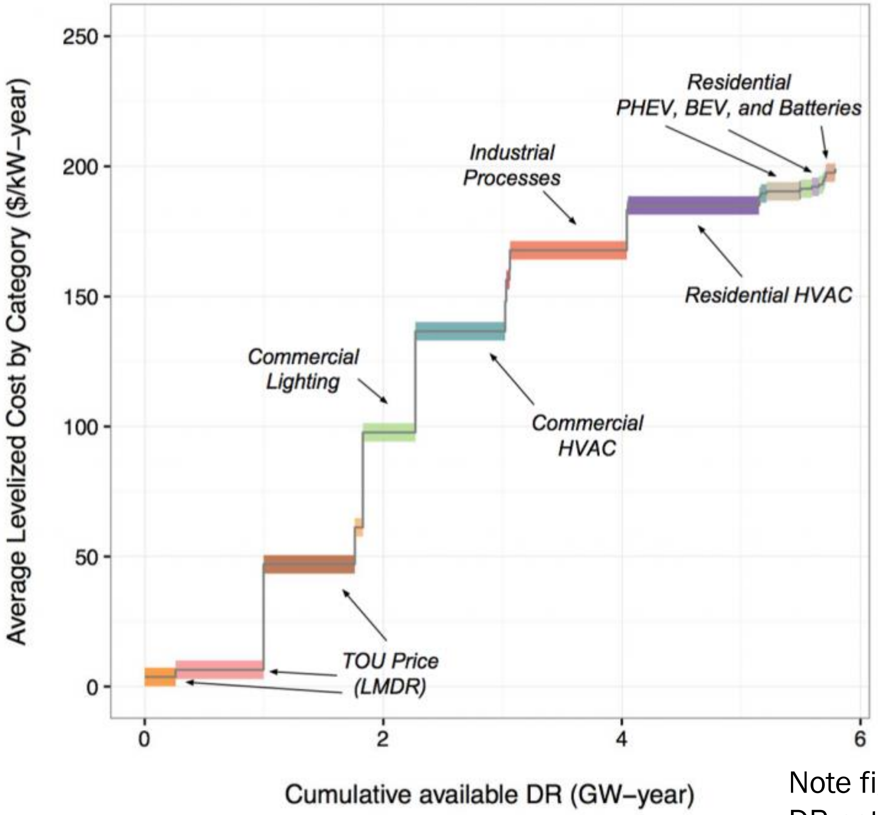
Note left figure is illustrative and right figure is CAISO system May 7, 2015

Level 2b – change in demand response availability

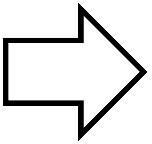
What is the change in the quantity of DR that is available to meet specific system needs?



EE and DR competition when supply curve shifts left

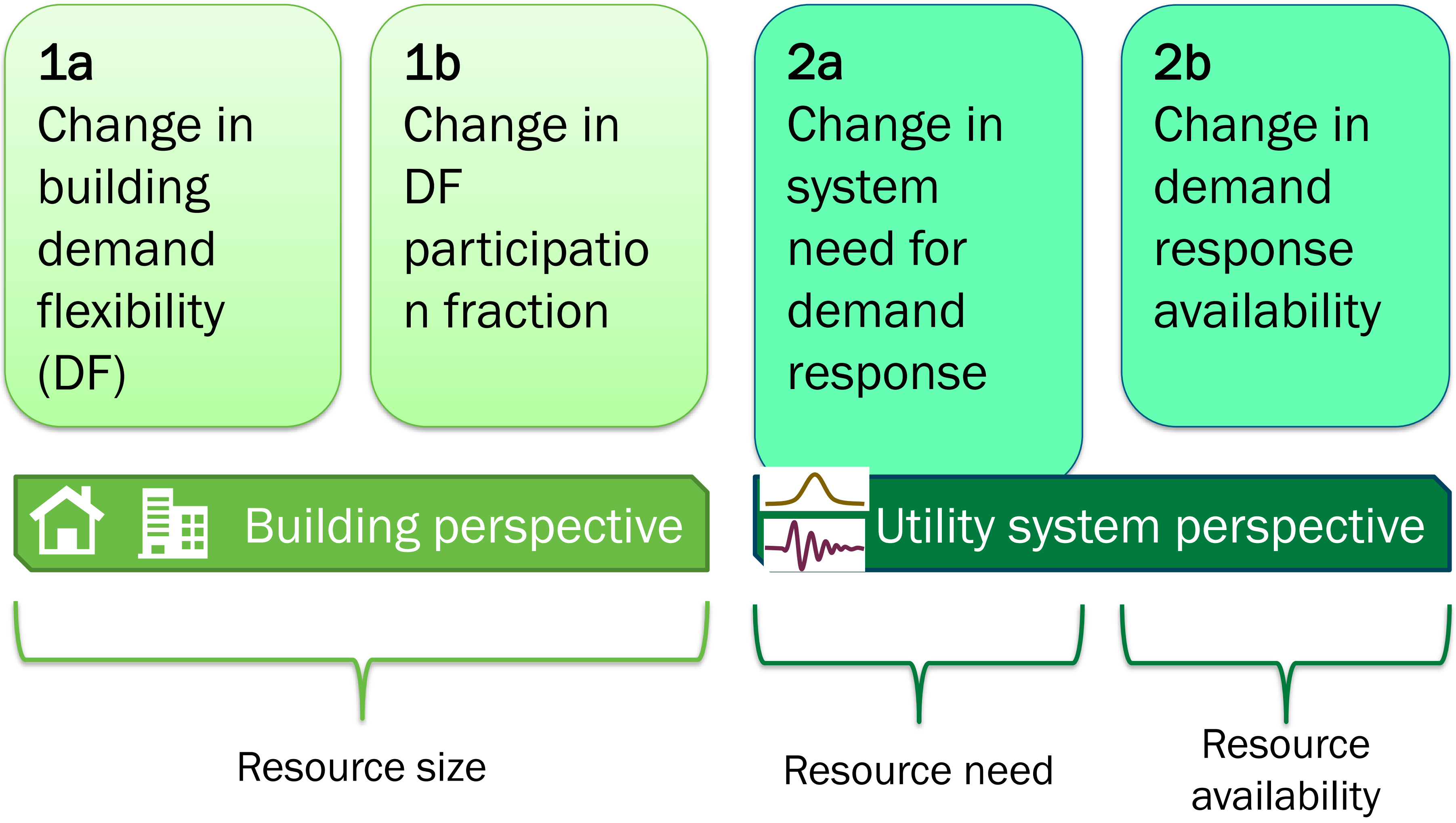


EE and DR complementarity when supply curve shifts right



Note figure is from California Public Utilities Commission Phase I DR potential study and suggests one potential expression of change in DR availability

Framework levels and sublevels



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Building perspective

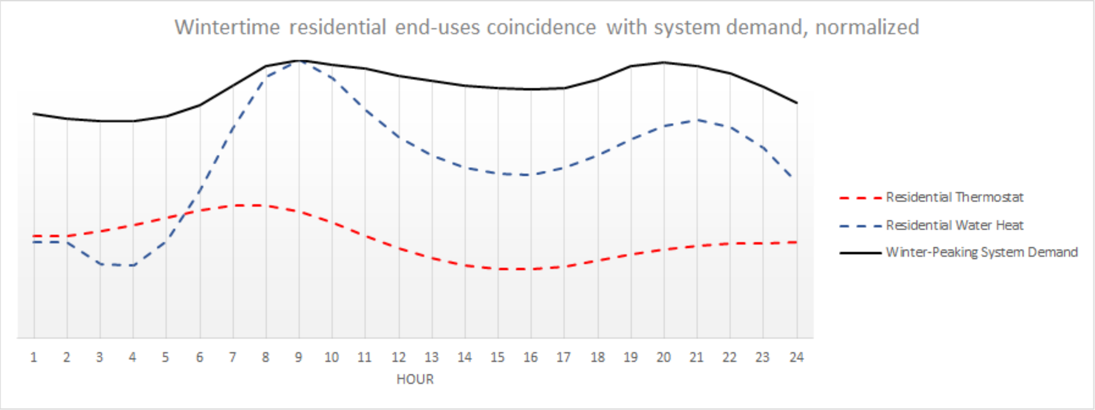
Utility system perspective

Resource size

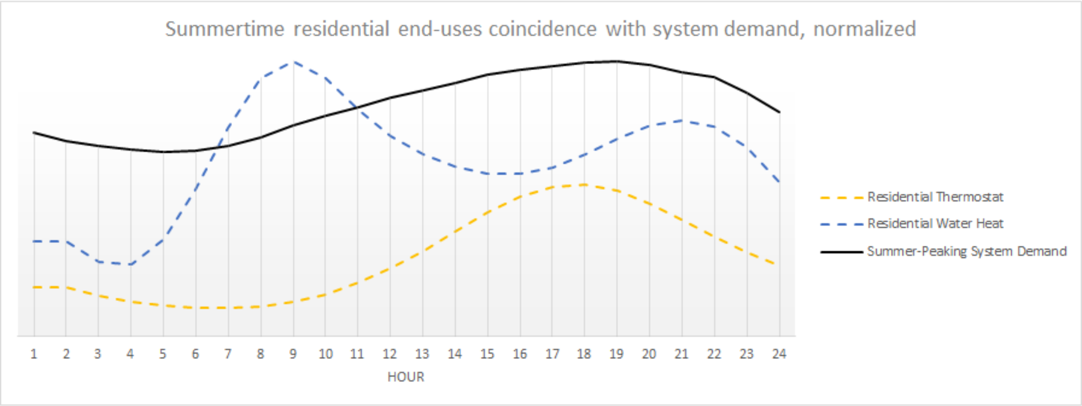
Resource need

Resource availability

Example: Residential electric resistance water heater insulation and utility system peak



Wintertime residential end-uses coincidence with system demand, normalized



Summertime residential end-uses coincidence with system demand, normalized

1a

Passive load shape post-EE is lower in all hours and no additional capability

EE and DR are likely competitive

1b

Improving the device efficiency without adding controls

EE and DR are likely competitive

2a

ERWH is major driver of morning and evening peaks leading to high coincidence of peak and savings

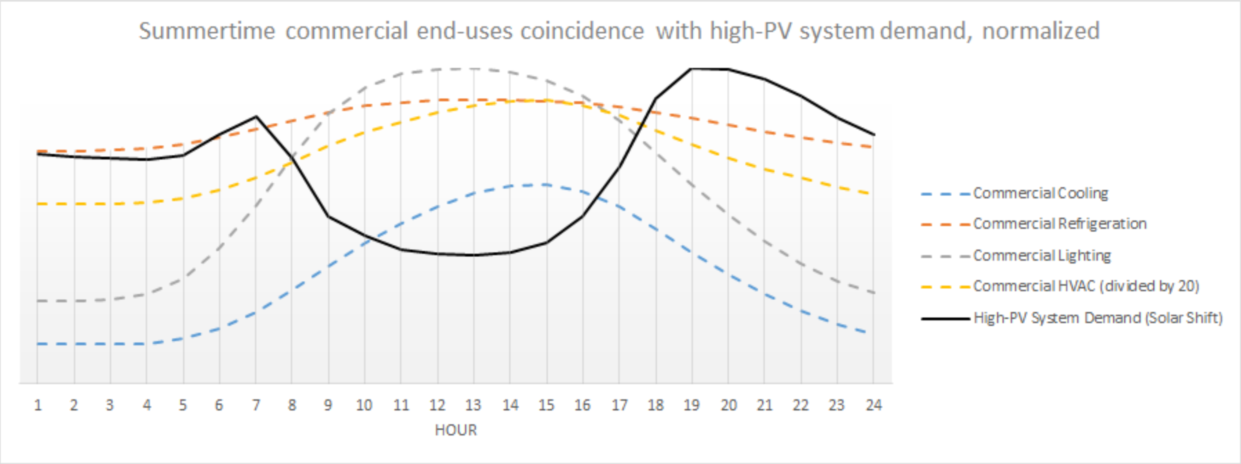
EE and DR are likely complementary

2b

Savings are likely to reduce the amount of DR available to respond at peak and no additional capability

EE and DR are likely competitive

Example: Commercial networked lighting controls and “solar shift” system need



1a

Passive load shape post-EE is sometimes lower and sometimes higher with additional capabilities via controls

EE and DR are likely complementary

1b

More uniform load reductions with minimized occupancy impact

EE and DR are likely complementary

2a

Savings occur when system needs load building

EE and DR are likely competitive

2b

Joint impacts at levels 1a and 1b result in increased control and availability

EE and DR are likely complementary

Key attributes driving EE and DR interactions

Change in passive load shape

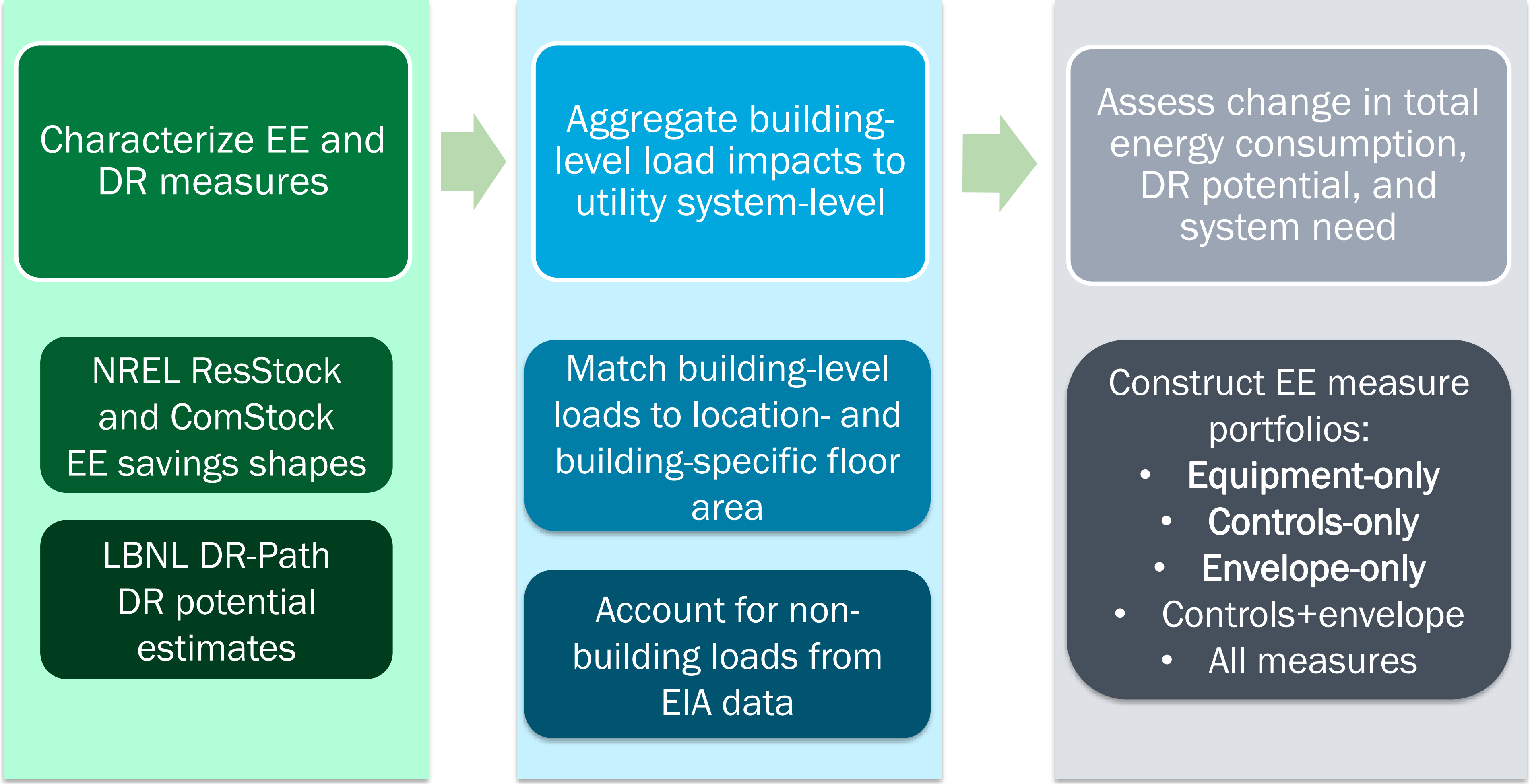
Increased capabilities

Coincidence of savings with system load drivers

Conclusions and implications for decision-makers and utilities

- **No universal relationship between EE and DR – competition at one level may be complementary at another level (or vice-versa).**
- **EE and DR interactions occur in more than just the change in resource size.**
- **Framework can inform:**
  - Utility operational and planning activities and
  - The design of EE and DR programs that incorporates co-benefits.
- **Future research needs to further define metrics and LBNL project will quantify the load impacts and tradeoffs between EE and DR, as well as estimate changes in economic costs and benefits.**

Analytical approach to quantify EE and DR load interactions



Characterize EE and DR measures

NREL ResStock and ComStock EE savings shapes

LBNL DR-Path DR potential estimates

Aggregate building-level load impacts to utility system-level

Match building-level loads to location- and building-specific floor area

Account for non-building loads from EIA data

Assess change in total energy consumption, DR potential, and system need

Construct EE measure portfolios:

- **Equipment-only**
- **Controls-only**
- **Envelope-only**
- Controls+envelope
- All measures

Note that the load impacts in this presentation are based on early ResStock data that is undergoing revisions. As such, impacts are subject to change and should be considered for illustrative purposes only.

GEB Load Flexibility Metrics

Mary Ann Piette (PI)
Jingjing Liu (Lead)
Lawrence Berkeley National Laboratory

LBNL Researchers

Rongxin Yin
Marco Pritoni
Peter Schwartz
Armando Casillas

Jiarong Xie
Henry Ahn
Jason McDonald
Aditya Khandekar

Project Overview & Metrics Definitions

Mary Ann Piette

Research Question & Scope

Which and how much commercial building loads can Shed and Shift at any given time?

5 Building Types:

☐ Office (3 sizes), Retail, Supermarket, Large Hotel, Secondary School

Consider:

☐ Climate zone; Time of day & Season; End-use systems

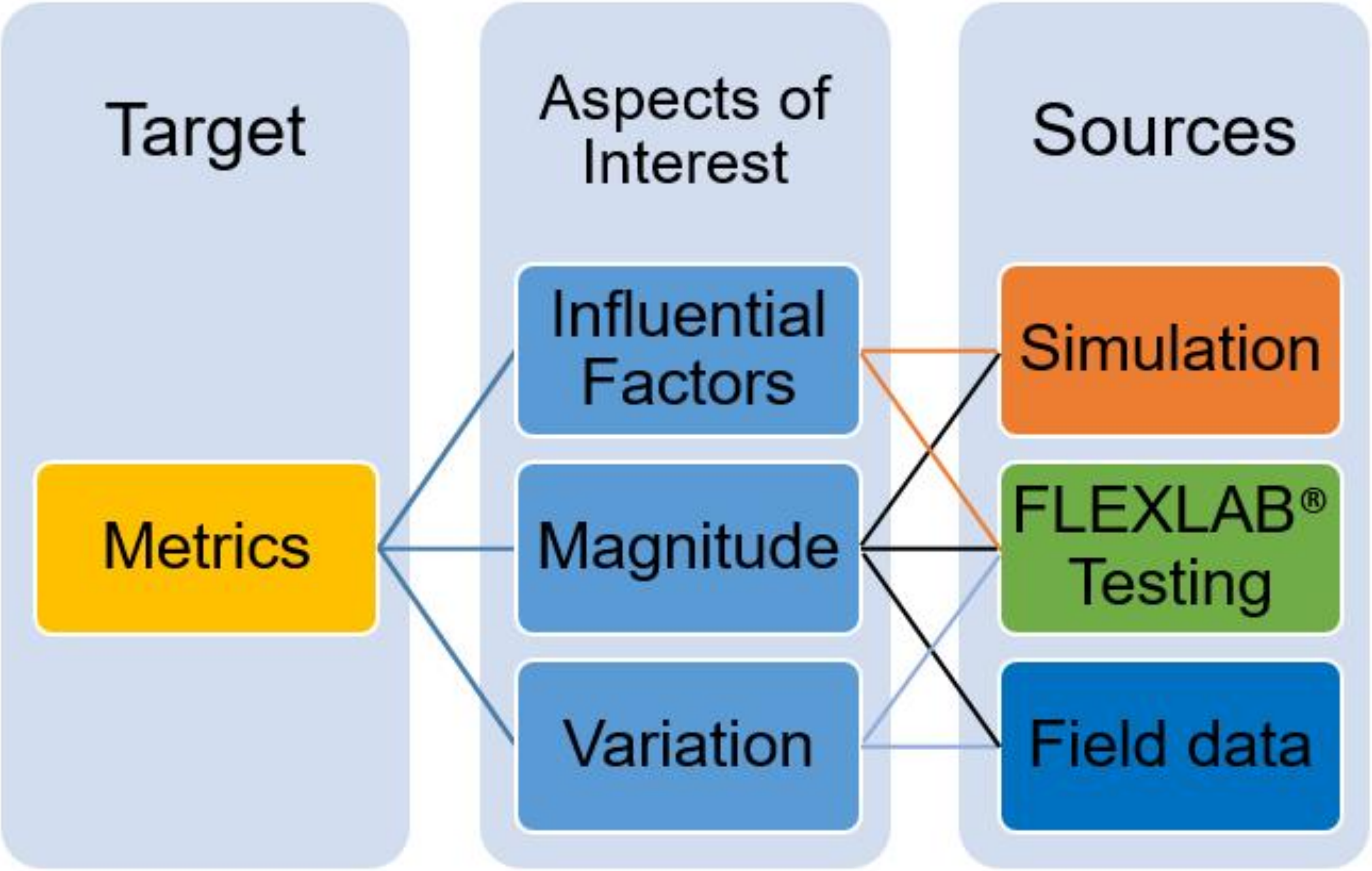
It is:

- ☐ Individual building level
- ☐ Grid operations & building operations
- ☐ Minimal change to building services

It isn’t:

- ☐ Aggregating buildings
- ☐ Dispatch or settlement ($)
- ☐ Evaluating demand price-elasticity

Research Framework



Target

Aspects of Interest

Sources

Metrics

Influential Factors

Magnitude

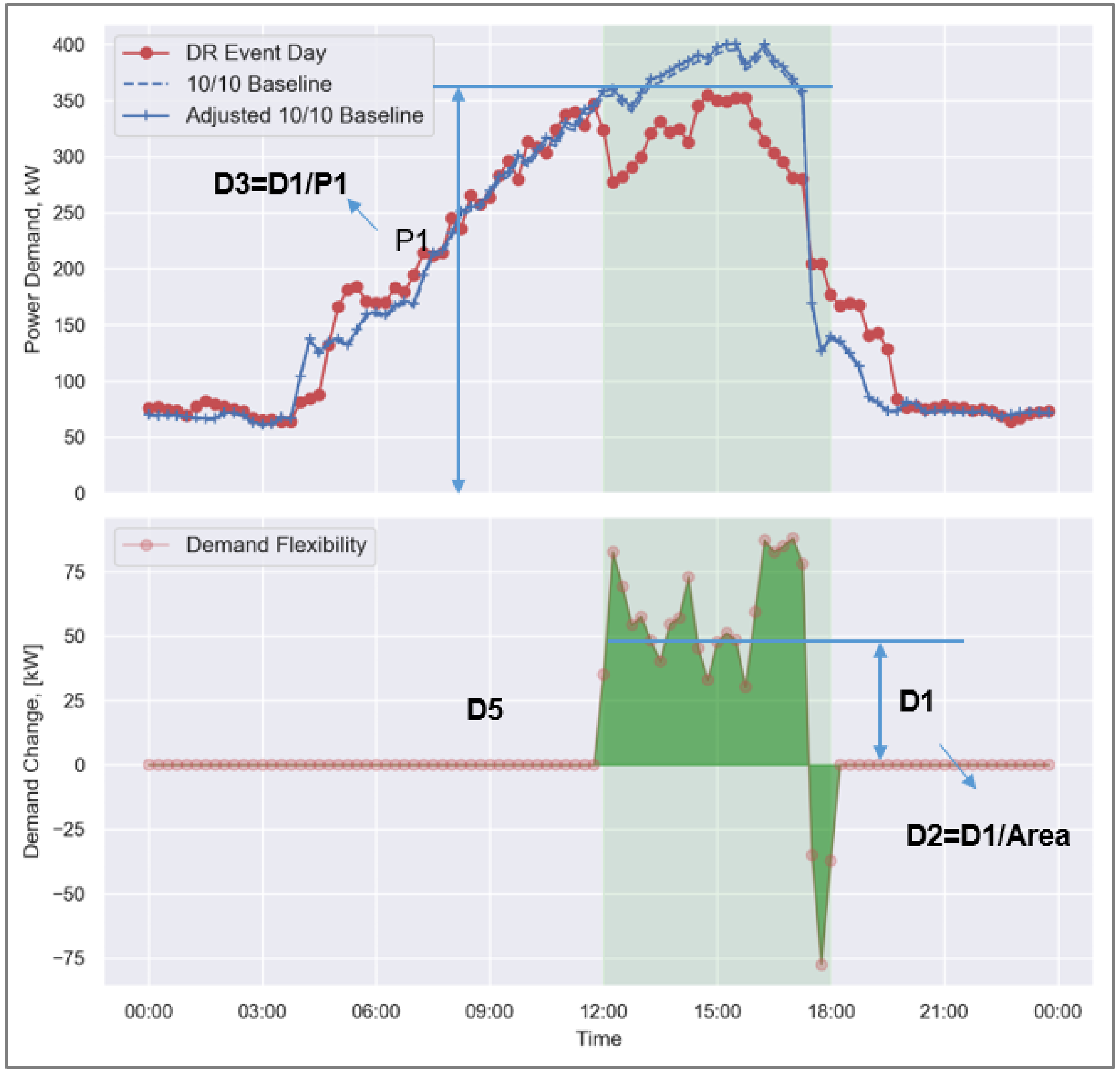
Variation

Simulation

FLEXLAB® Testing

Field data

Shed Metrics Example – Real Office Building



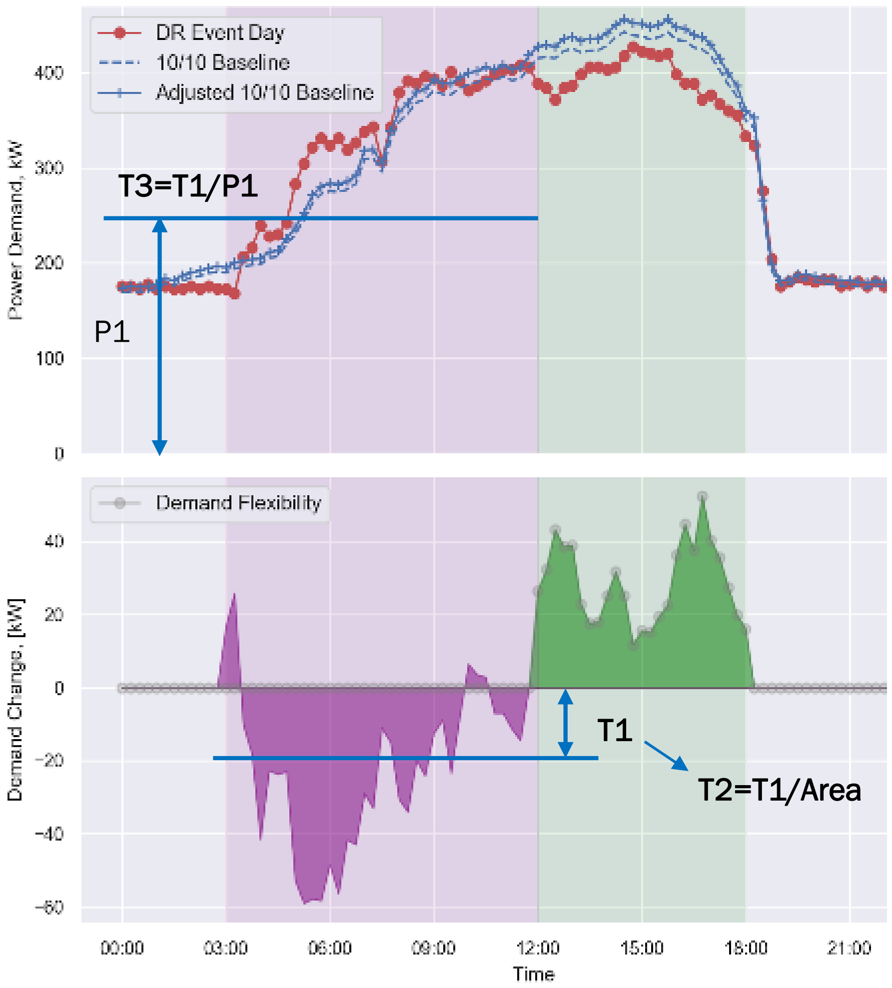
For each "Shed Duration" (e.g., starting from 2pm for 4 hours at a given outdoor temperature), we calculate the following ***primary*** metrics.

#D1: Demand Shed per Event	**(kW): Average kW reduction** during a shed event or price-differentiated time window measured against a baseline.
#D2: Demand Shed Intensity	**(W/ft^2):** [Metric #D1] normalized by **building floor area**.
#D3: Demand Shed Percentage (in Building Total Demand)	**(%):** [Metric #D1] divided by **baseline average building total demand kW** during the shed window.

Referencing Metrics: 2020 ACEEE paper

Liu, J. et al. "Developing and Evaluating Metrics for Demand Flexibility in Buildings: Comparing Simulations and Field Data"

Shift Metrics Example



Shed		
Metrics	**Unit**	**Value**
#D1: Demand Shed per Event	kW	41
#D2: Demand Shed Intensity	W/ft^2	0.4
#D3: Demand Shed %	%	10%

Take		
Metrics	**Unit**	**Value**
#T1: Demand Take per Event	kW	-23
#T2: Demand Take Intensity	W/ft^2	-0.2
#T3: Demand Take %	%	5%
#T10: Net Total Consumption Change % (24 hours)	% (kWh)	0.2%

Benchmarking Metrics

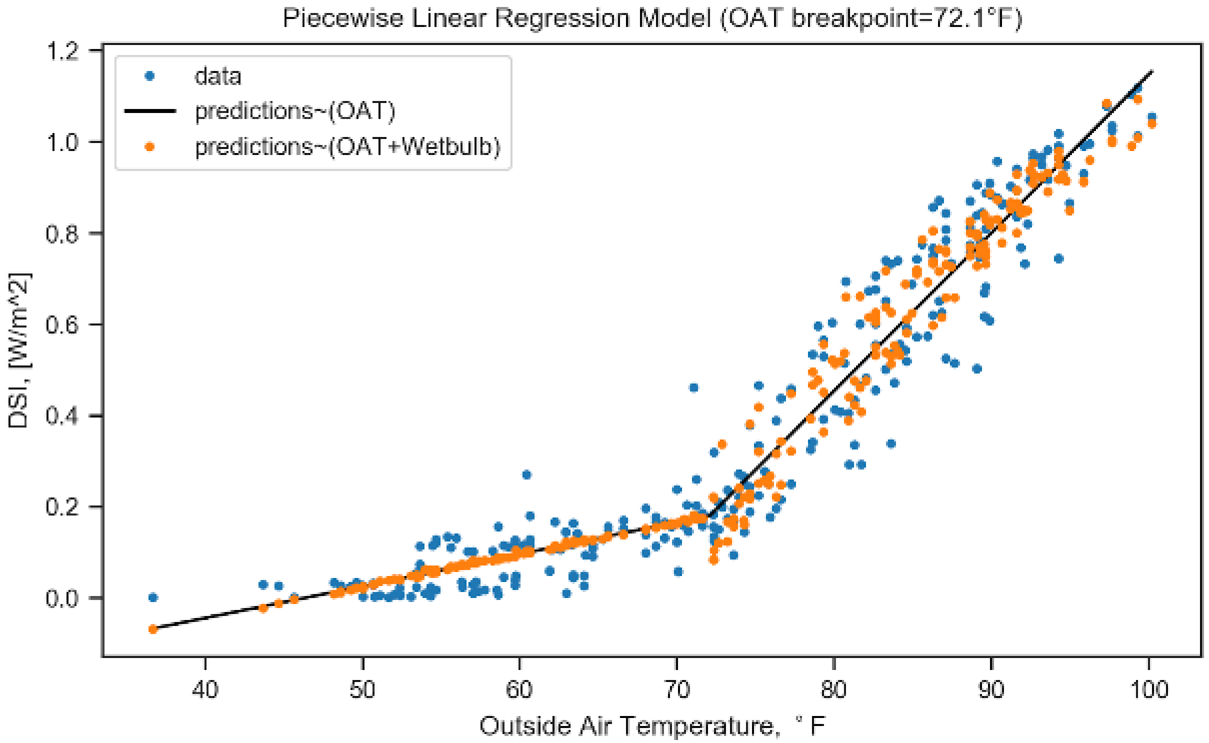
Time of Day

- ☐ Global Temp. Adjustment (GTA):
  - ☐ 2pm-6pm, +4°F (default 74°F)
- ☐ Precooling + GTA:
  - ☐ 10am-2pm, -2°F
  - ☐ 2pm-6pm, +4°F

Demand Shed Intensity (W/ft^2)

Outdoor Temperature

- ☐ ASHRAE design days (0.4%)
- ☐ Hottest 12 weekdays per year
- ☐ Summer average



Performance of DF Packages

Jingjing Liu

DF Strategies & Packages

#1: Exterior Shades

- On South & West Facades (lowered during shed events)

#2: GTA Only

- (default 74ºF) +4ºF x 4 hours (2-6pm)

#3: Precooling + GTA

- -2ºF x 4 hours ; +4ºF x 4 hours

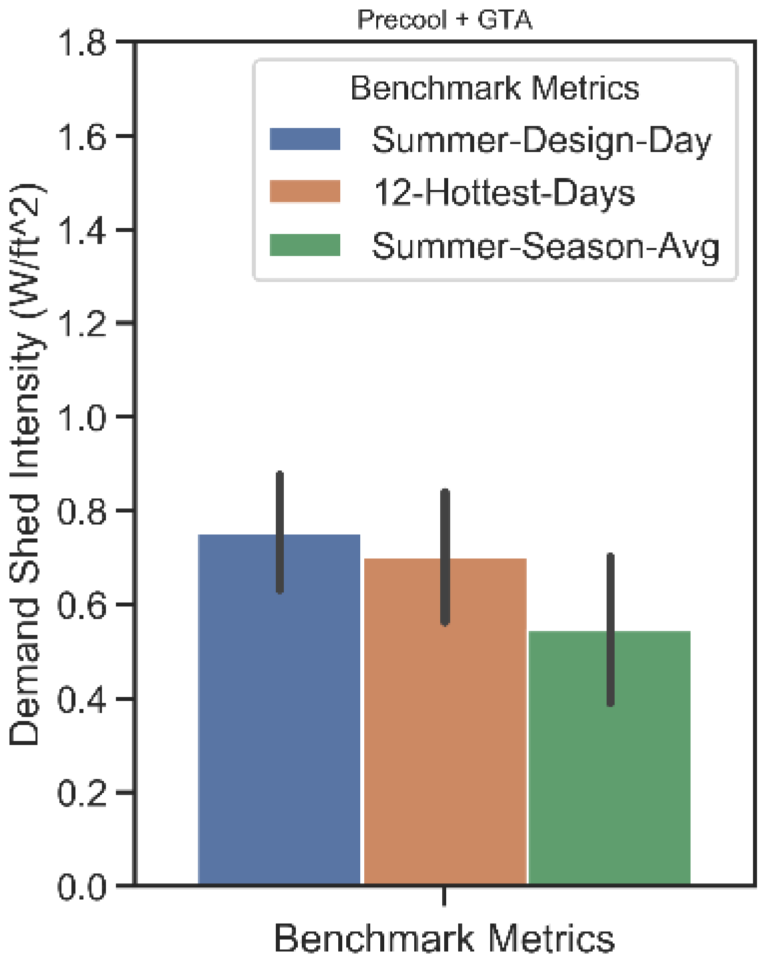
#4: Precooling + GTA + Shades

#5: Precooling + GTA + Shades + Dimming Lights

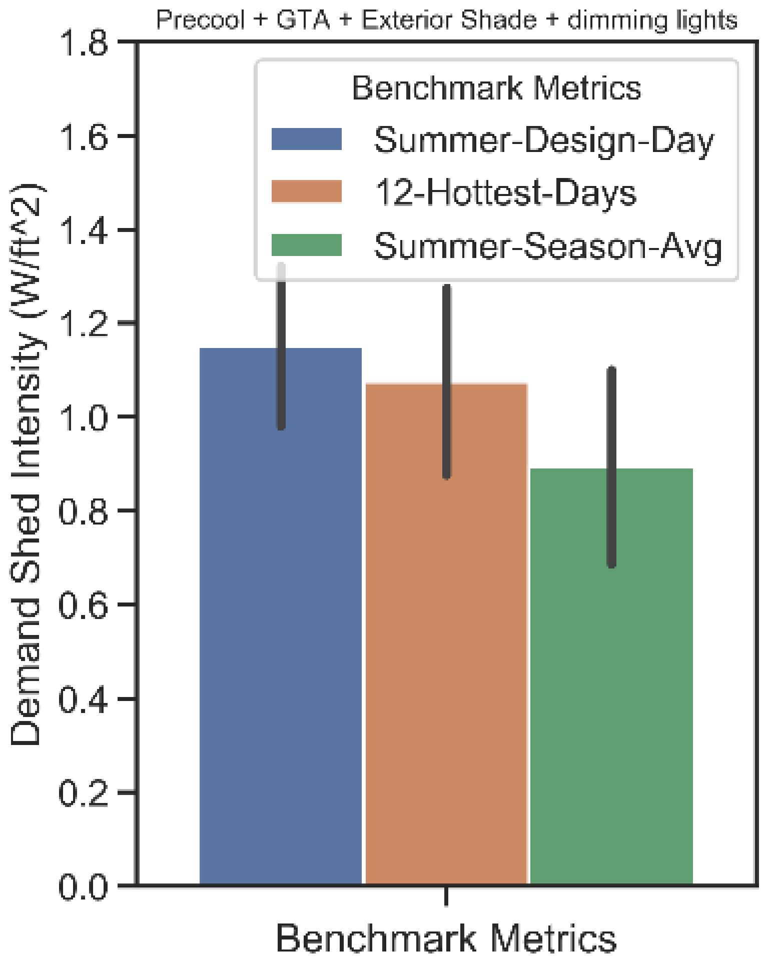
- Daylight zone 60% & 40%; Interior zone 20%

Comparing 3 Benchmarking Metrics (Medium Office [CZ-3B])

#3: Precooling + GTA

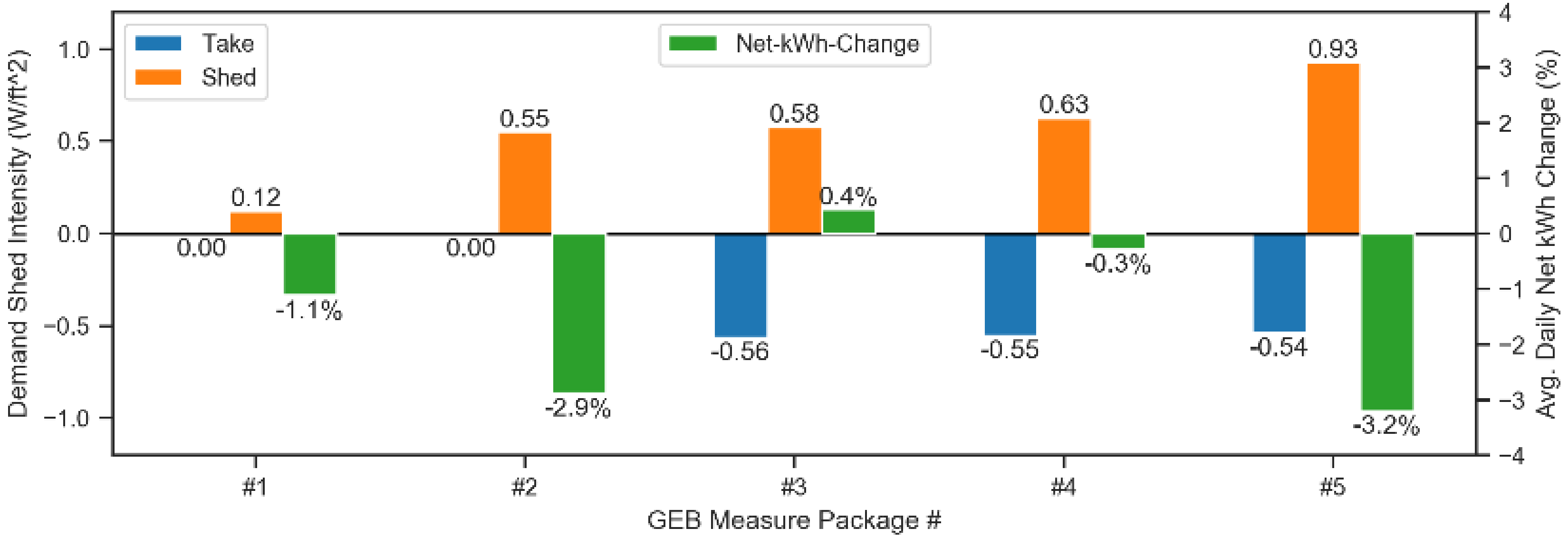


#5: Everything (+shading +lighting)

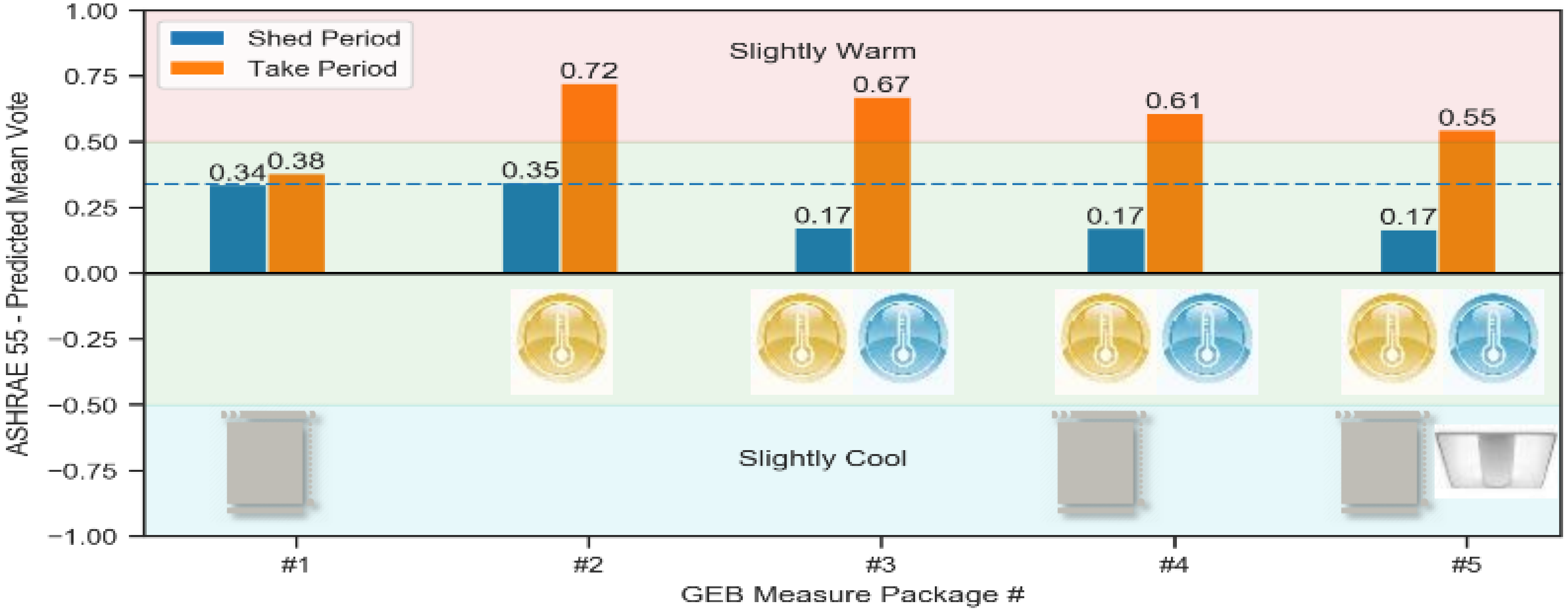


Compare 5 Packages: More Key Metrics (Office in 3B)

- Summer average shed/take W/ft^2, net kWh%, PMV*;
- **#3 vs #2:** Precooling can increase Shed incrementally (energy penalty is small);
- **#4 vs #3:** Exterior shade increase Shed incrementally;
- **#5 vs #4:** Dimming lights increases Shed substantially.

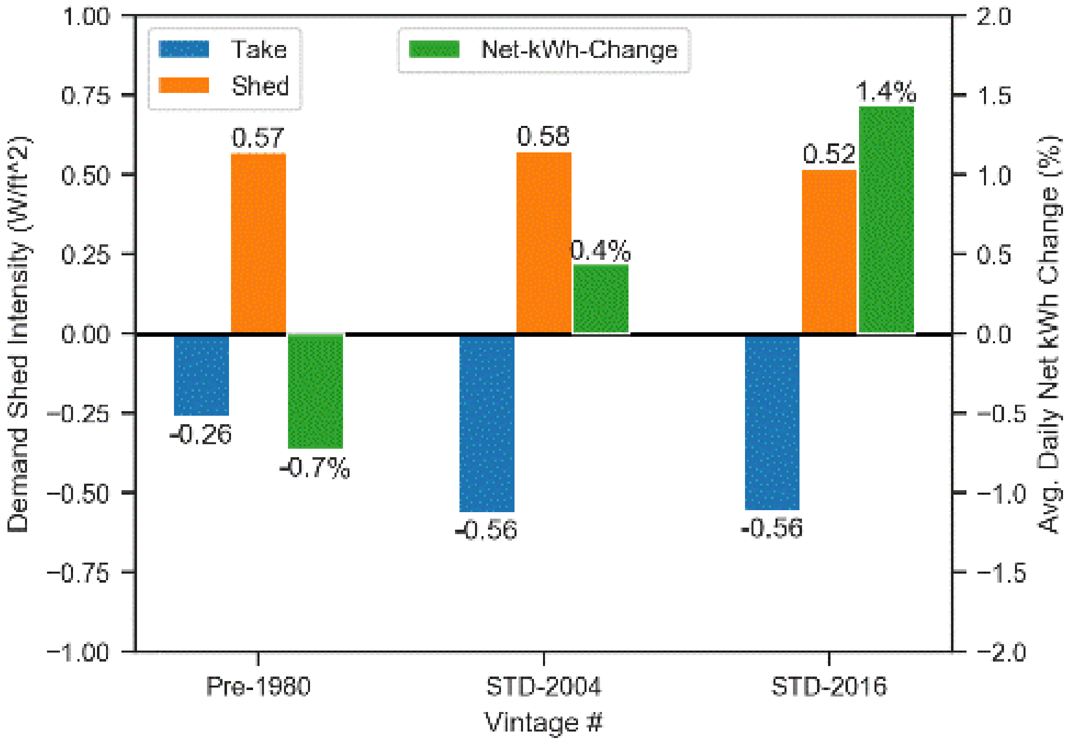


* **Predicted Mean Vote (PMV)** is a widely recognized metric for thermal comfort. PMV values range from “-3” (indicating cold) to “+3” (indicating hot) with value “0” being neutral (+3: hot; +2: warm; +1: slightly warm; 0: neutral; –1: slightly cool; –2: cool; and –3: cold). According to ASHRAE 55-2017, the recommended PMV range for general comfort is between -0.5 and 0.5.



Comparing 3 Vintages – Impact of EE (Office in 3B)

#3: Precooling + GTA



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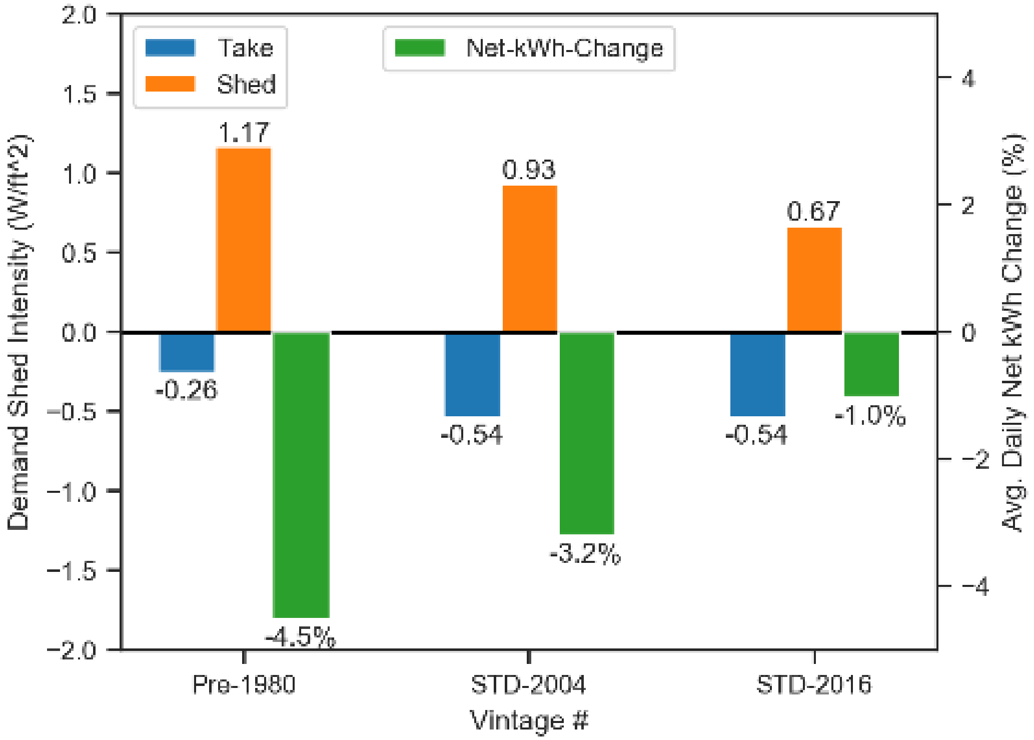
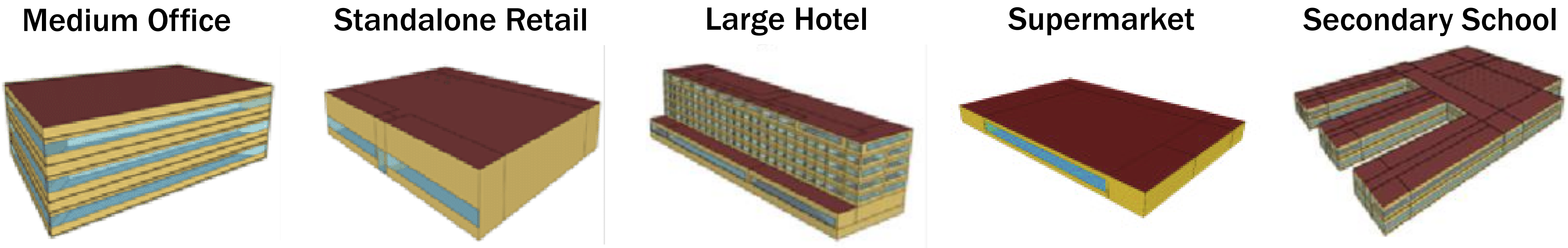
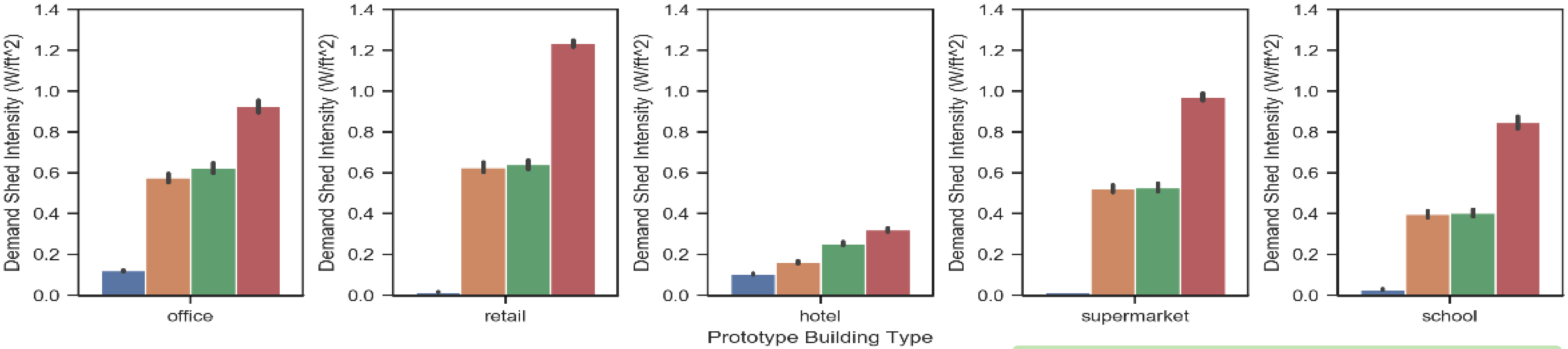


Vintage	Wall U-value	Window U-value	SHGC	HVAC System	COP	LPD (W/ft^2)
Pre-1980	4.35	1.22	0.54	Rooftop + CAV	3.34	1.5
ASHRAE 2004	8.06	0.57	0.25	Rooftop + VAV	3.23	1.0
ASHRAE 2016	10.81	0.51	0.25	Rooftop + VAV	3.4-3.7	0.8

Results Across Building Types

Summer Average Demand Shed Intensity (W/ft^2)





- HVAC system type - Retail and Supermarket are similar
- Internal loads – School is much lower than Office
- VAV minimum setting – Hotel public areas

#1: 🟦 Exterior Shades

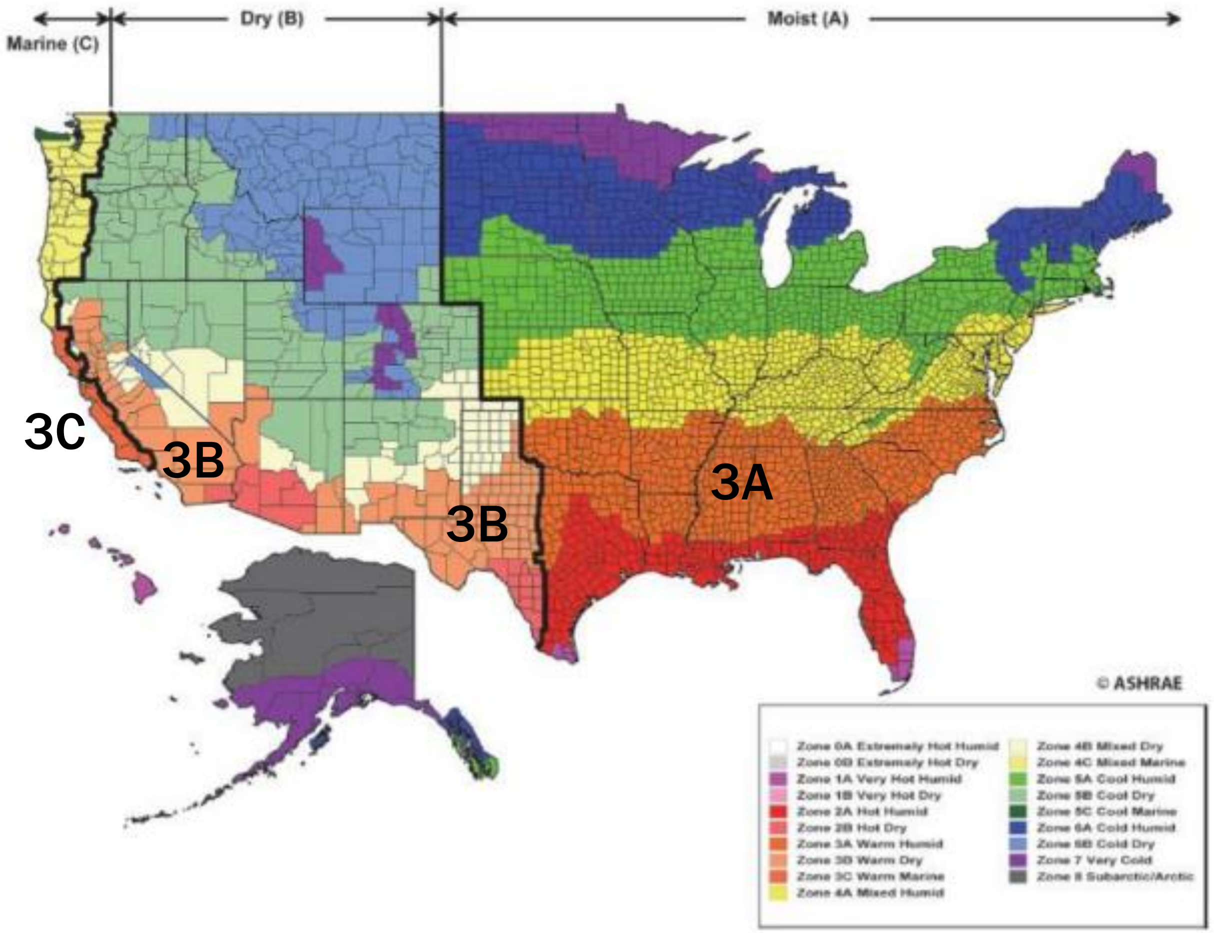
#3: 🟨 Precooling + GTA

#4: 🟩 Precooling + GTA + Shades

#5: 🟥 Precooling + GTA + Shades + Dimming Lights

Benchmarking Across Climate Zones

US Climate Zones



Source: ASHRAE Standard 169-2013

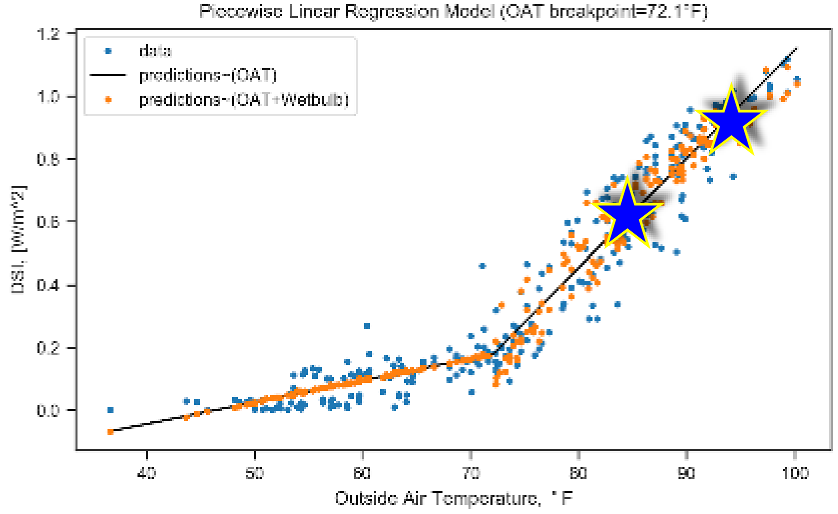
Outdoor Temperature

☐ASHRAE design day (0.4%)

☐Hottest 12 weekdays per year

☐Summer average

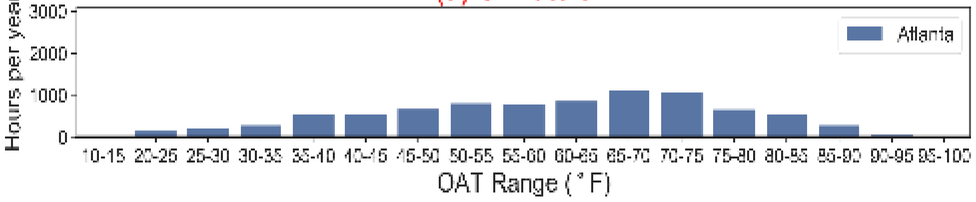
☐Cross-cutting reference points (85°F, 95°F)



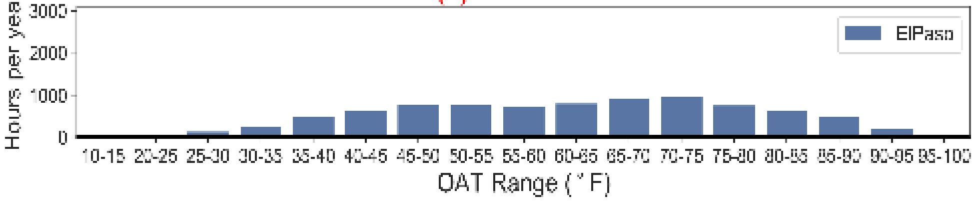
Results Across Climate Zones

- **Medium office (2004)**
- **Summer average**
- **#3: precooling + GTA**

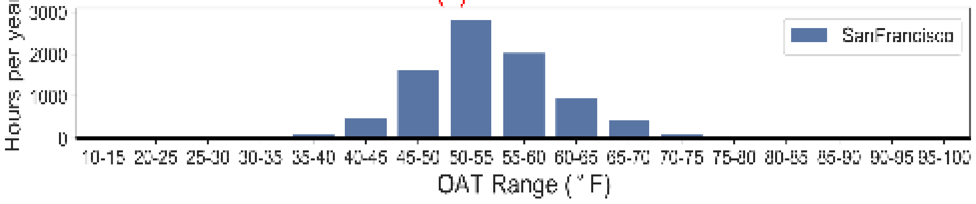
(a) Climate 3A

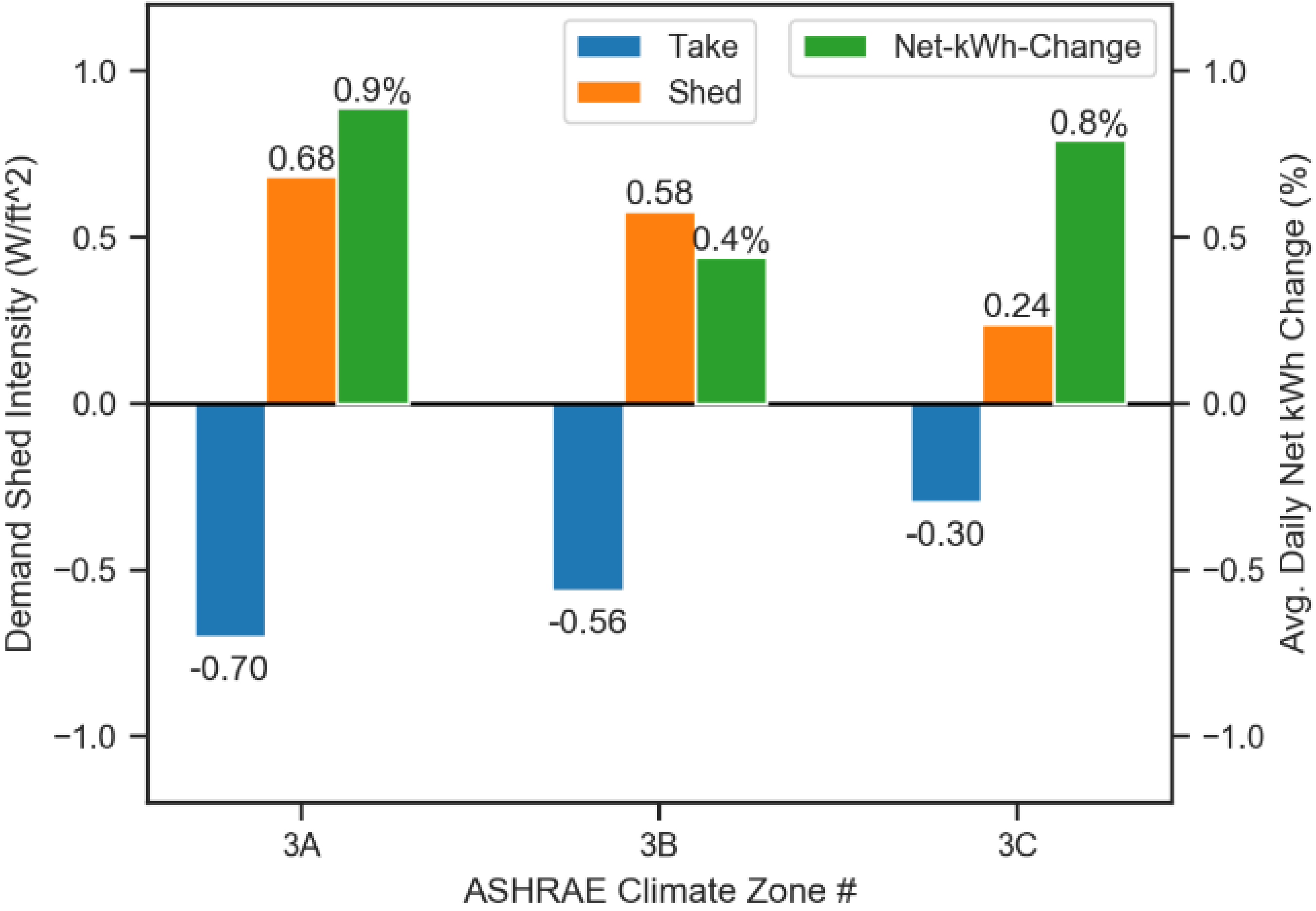


(b) Climate 3B



(c) Climate 3C





Poll#1

Which of the following benchmarking metrics do you find useful? (Select all that apply)

☐ ASHRAE design days* (cooling & heating)
☐ Hottest 12 weekdays per year (DR programs)
☐ Summer average
☐ Cross-cutting reference points (e.g. 85°F, 95°F)

*Design-day is used to describe a period of time with **maximum climatic conditions** that a HVAC system was designed to accommodate and maintain the desired indoor temperature and humidity.

Poll#2

Which of the following aspects do you and your key stakeholders find useful? (Select all that apply)

☐ Same building type at different outdoor conditions
☐ Compare different vintages
☐ Compare different building types
☐ Compare different climates

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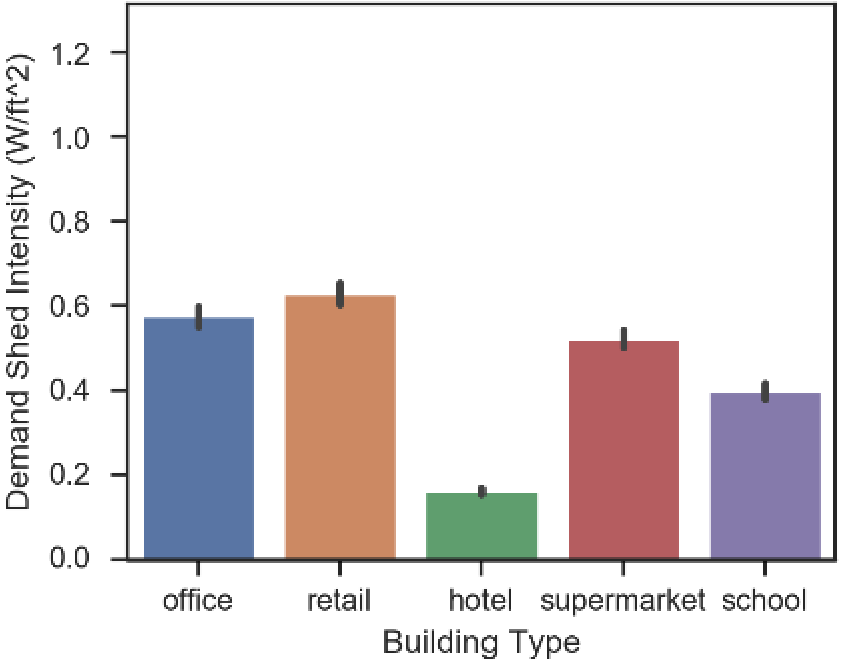
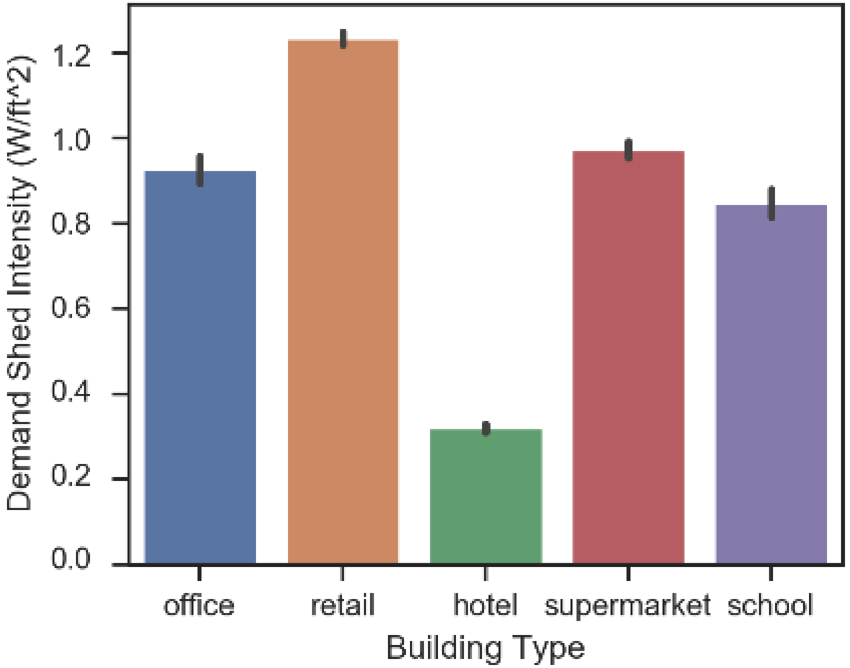
Back-up Slides

Same Package for Different Building Types

#3: Precooling + GTA



#5: Everything (+shading +lighting)



Building Type	GTA Controlled Area	HVAC System	South/West WWR	LPD (W/ft2)	Plug (W/ft2)
Medium Office	53,628	Rooftop + VAV	33% (south/west)	1.0	0.8
Stand-alone Retail	24,962	Rooftop + PSZ	25% (south)	1.6	0.6 (sales 1.7)
Large Hotel	72,051	Chiller + VAV (common areas)	37% (south), 24% (west)	1.0	Varies
Supermarket	45,000	Rooftop + PSZ	36% (south)	1.6	1.3
Secondary School	198,234	Chiller + VAV	35%	1.1	Varies