Can CLS provide unique or substantial grid services?

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DOE Lighting R&D Workshop

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

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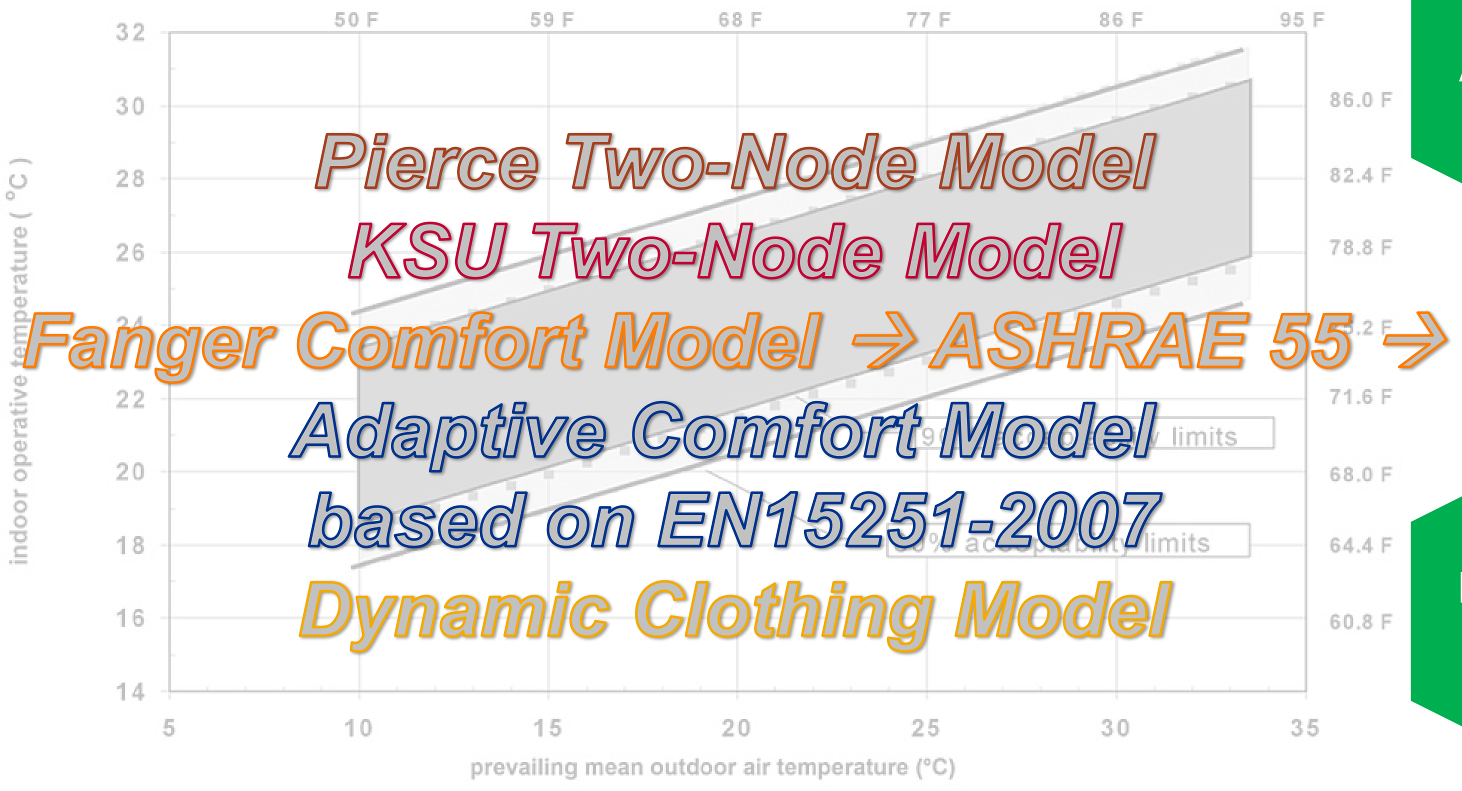
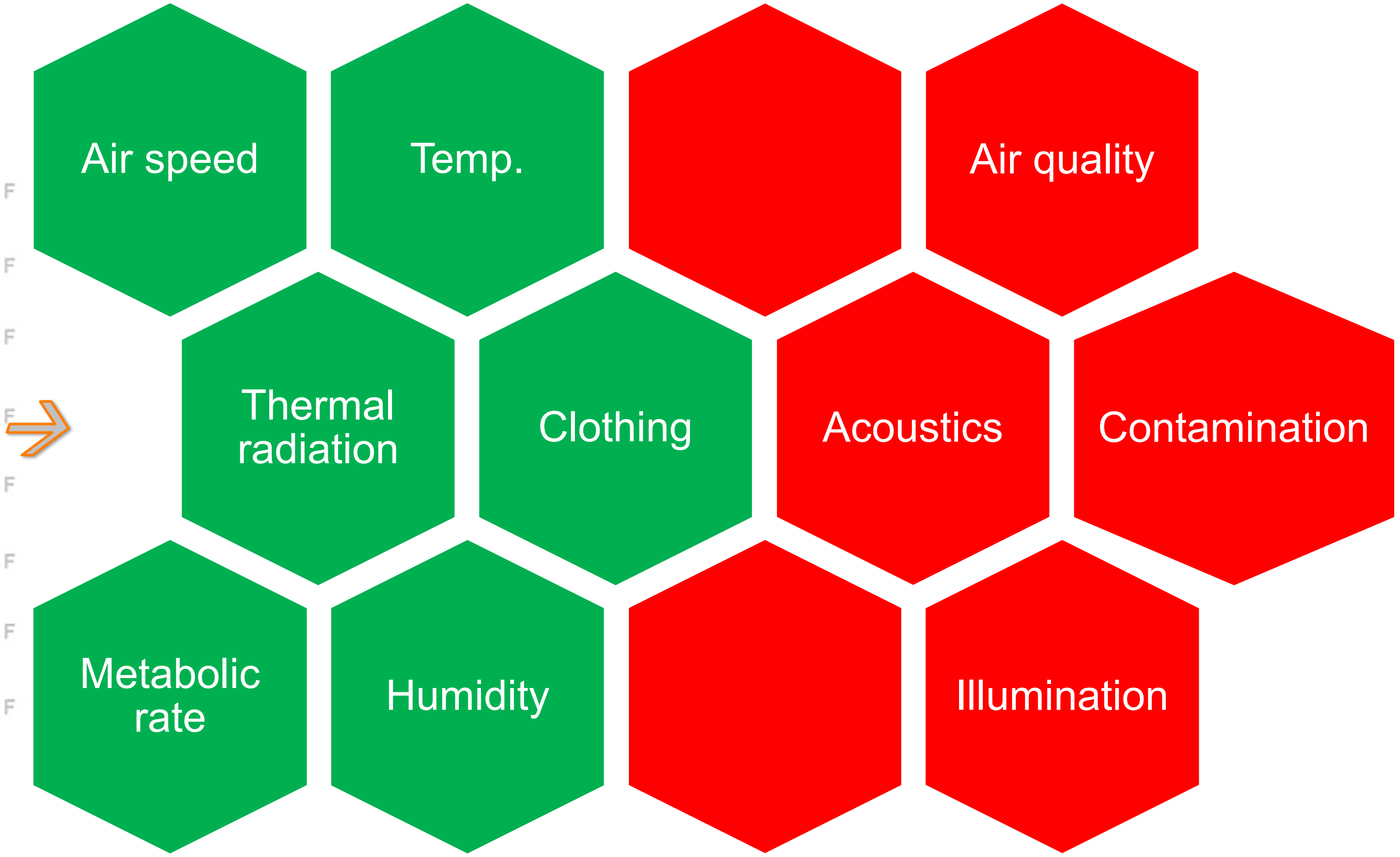
How can the potential for CLS to provide grid services be simulated?

- 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?

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





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

CLS flexibility dependence on lighting application can be modeled using DOE prototype building load schedules

	DOE Prototype Building Model	Eligible Spaces	Daylit Spaces	LPD > 0.5 W/sf	Flexibility Potential
1	Small office	81%	74%	83%	High
2	Medium office	86%	82%	81%	High
3	Large office	90%	84%	85%	High
4	Restaurant – Fast Food	88%	42%	52%	Medium
5	Restaurant – Sit down	91%	59%	80%	Medium
6	Standalone Retail	99%	86%	83%	Medium
7	Strip Mall	79%	0%	79%	Medium
8	Large Hotel	55%	65%	26%	Low
9	Small Hotel	28%	30%	6%	Low
10	High-rise Apartment	30%	73%	3%	Low
11	Mid-rise Apartment	3%	90%	3%	Low
12	Primary School	96%	88%	68%	Medium
13	Secondary School	73%	77%	61%	Medium
14	Hospital	78%	46%	75%	Low
15	Outpatient	60%	43%	75%	Low
16	Warehouse	99%	69%	33%	High

- Non-eligible = 100% - Eligible
- Core = 100% - Daylit
- Non-eligible spaces: high sensitivity to occupant satisfaction (e.g., hotel guest rooms), emergency or life safety functions (e.g., electrical/mechanical rooms, stairways, hospital rooms)
- Spaces with lower LPD have lower potential

Example: Space-by-space eligibility for Medium Office buildings

Space Type, ranked by Fraction of Building	Fraction of Building	Grid-Service Eligible	Daylit or Core	LPD
Office - open plan	42.4%	Yes	Daylit	0.61
Office - enclosed	18.7%	Yes	Daylit	0.74
Corridor/Transition	9.1%	Yes	Daylit	0.41
Active storage <50	5.2%	No	Core	0.51
Conference, Meeting, Multipurpose	5.2%	Yes	Daylit	0.95
Stairway	3.7%	No	Core	0.48
Lobby	3.7%	Yes	Daylit	1.09
Restrooms	3.6%	Yes	Core	0.61
Electrical/Mechanical	3.0%	No	Core	0.43
Active storage >=50 and <=1000	1.9%	No	Core	0.37
Lounge/Recreation	1.8%	Yes	Daylit	0.56
Dining Area	0.9%	Yes	Daylit	0.41
Classroom/Lecture/Training	0.6%	Yes	Daylit	0.71
Food Preparation	0.4%	Yes	Core	1.09
Total	**100%**	**86.2%**	**82.2% Daylit 17.8% Core**	

Minimum lighting load can be modeled using requirements/limitations established in standards and specifications

ANSI/ASHRAE/USGBC/IES Standard 189.1-2014
(Supersedes ANSI/ASHRAE/USGBC/IES Standard 189.1-2011)

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See Appendix H for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the U.S. Green Building Council, the Illuminating Engineering Society of North America, and the American National Standards Institute.

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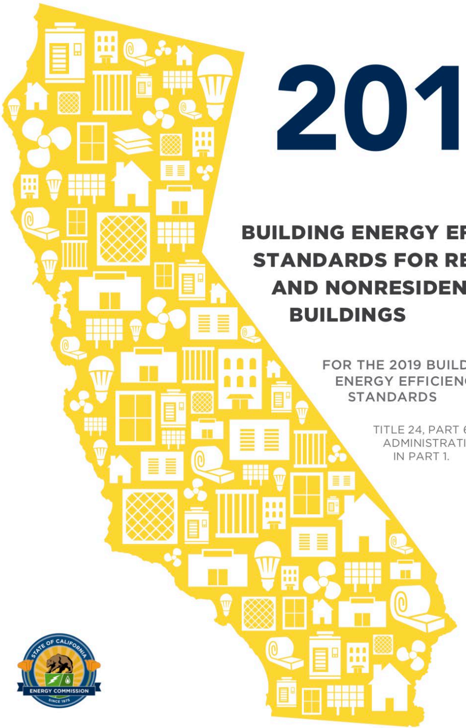

2019

BUILDING ENERGY EFFICIENCY STANDARDS FOR RESIDENTIAL AND NONRESIDENTIAL BUILDINGS

FOR THE 2019 BUILDING ENERGY EFFICIENCY STANDARDS

TITLE 24, PART 6, AND ASSOCIATED ADMINISTRATIVE REGULATIONS IN PART 1.

DECEMBER 2018
CEC-400-2018-020-CMF

CALIFORNIA ENERGY COMMISSION
Edmund G. Brown Jr., Governor

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The Potential for Demand-Responsive Lighting in Non-daylit Offices

Guy R. Newsham, Ph.D. and Sandra Mancini

Abstract—Participants ($N = 30$) in an office laboratory had personal dimming control over lighting, and were then exposed to a simulated demand response (or "load shed") involving dimming lighting by 2 percent per minute. Participants were given no expectation that the dimming would occur, and the principal measure used was the point at which participants intervened to restore light levels after the demand-response dimming began. Results showed that 20 percent of participants intervened by the time that desktop illuminance declined ~35 percent from their initial preferred level, and 50 percent of participants intervened by the time that desktop illuminance declined ~50 percent. Therefore, during a power supply emergency, dimming lights can contribute relatively large electricity demand reductions before lighting declines to a level where a substantial fraction of people would be motivated to seek a change.

Keywords—Demand Response, Load Shedding, Personal Control, Preferred Illuminance, Energy Management.

1 INTRODUCTION

1.1 LOAD SHEDDING AND DEMAND-RESPONSIVE BUILDINGS

Buildings use a large amount of energy to create comfortable conditions. For example, in Canada space and water heating, cooling, ventilating, and lighting in buildings accounted for at least 28 percent of total energy use in 2003[1] [NRCan, 2005]. Of the secondary energy used by these buildings, 39 percent was delivered in the form of electricity. Demand for electricity in buildings in not constant, rather it varies according to daily and seasonal cycles. Peak demand tends to occur on hot summer afternoons, when demand for

1 This figure does not include the fraction of industrial energy that is used to condition industrial buildings rather than for industrial processes.

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LED Life for General Lighting: Definition of Life

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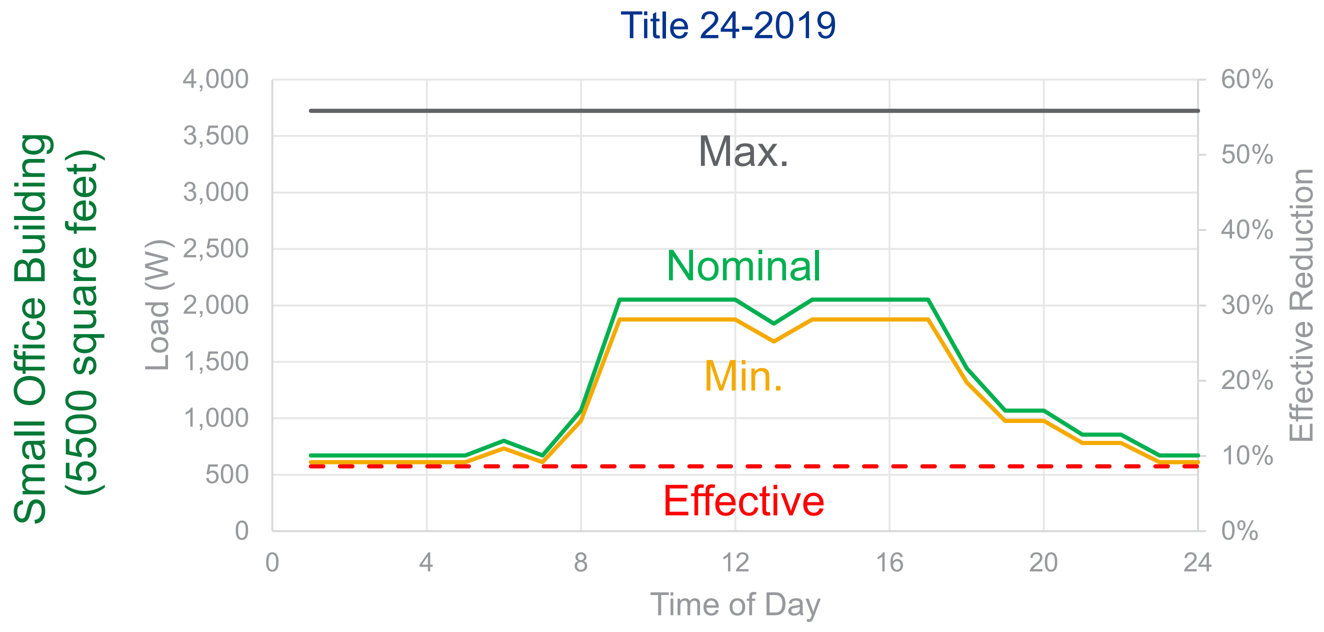
10% · 15% · 20% · 30%

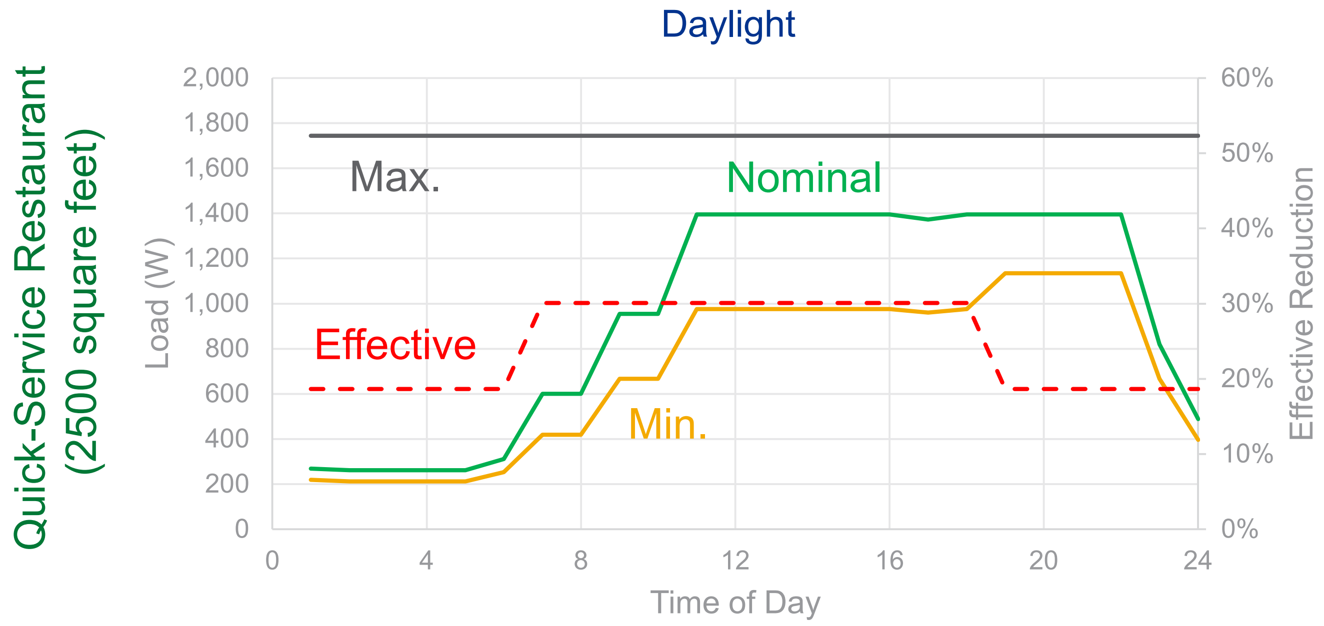
CLS average* power draw flexibility can be modeled using DOE prototype building load schedules and other standards and specifications

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.





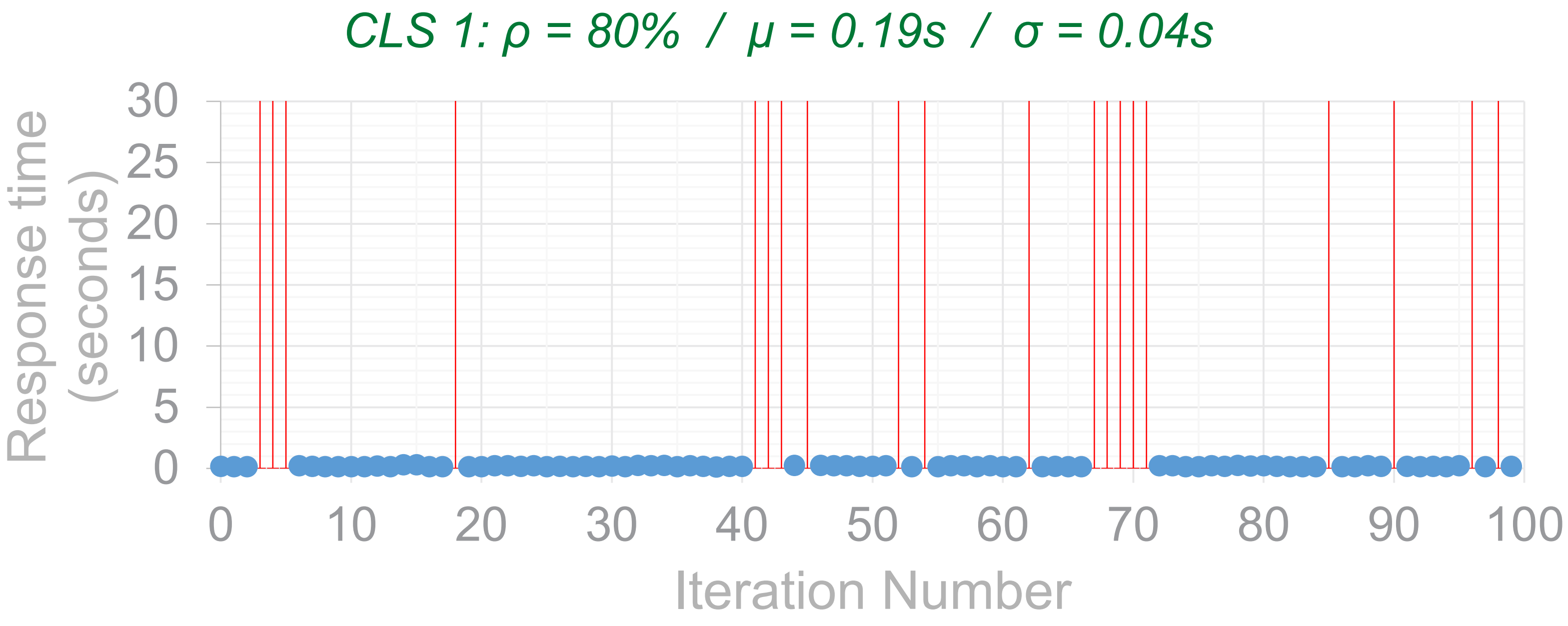
CLS average* power draw flexibility can be modeled using DOE prototype building load schedules and other standards and specifications

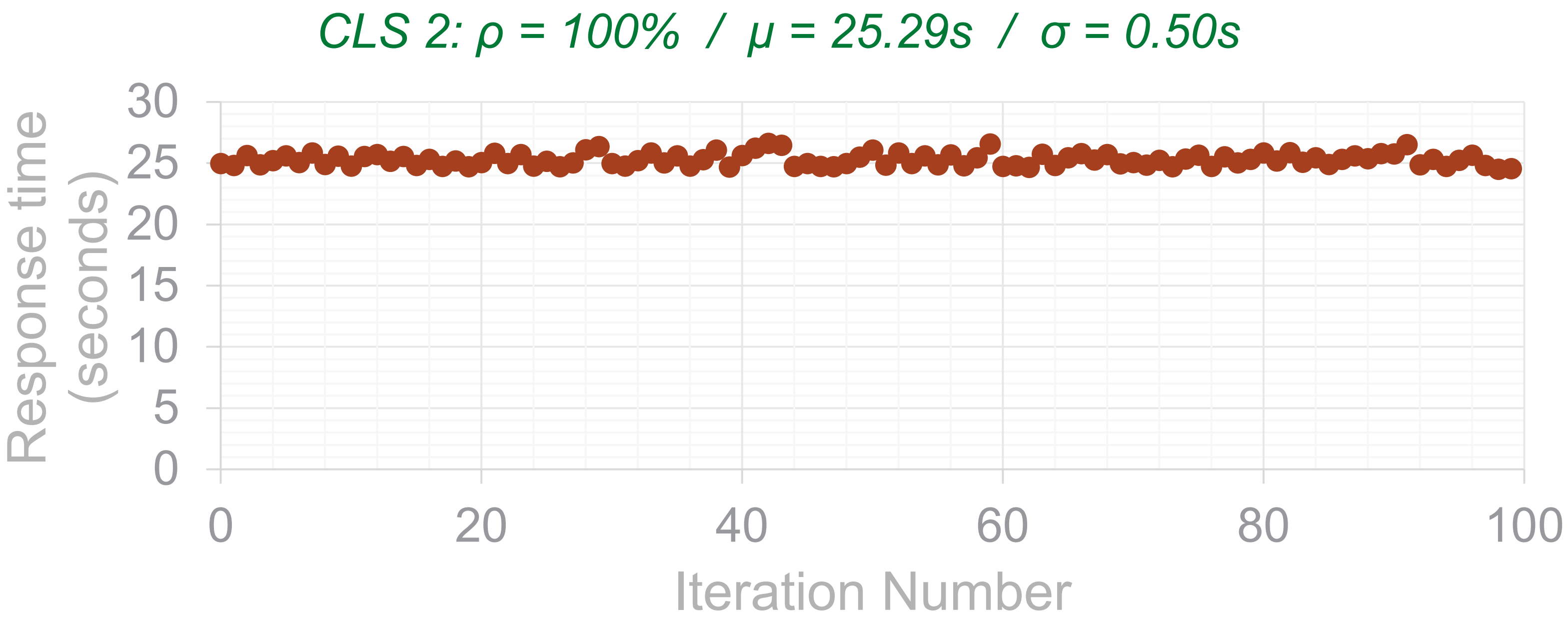
- Averaged over all days of the year, and associated varying occupancy
- Averaged over all geographic locations, and associated varying daylight hours
- Average flexibility potential may tell a limited story
- Flexibility potential for some days may be significantly higher than average
- Flexibility potential for some geographic locations may be significantly higher than average
- Lower occupancy may result in lower flexibility potential, if power draw is lower due to the successful implementation and function of occupancy-based control, and thereby, or may result in higher flexibility potential, if power draw stays the same.

CLS change delay in responding to grid signal can be modeled by measurements of response time to API requests

Representative change delays were derived from the characterization of 6 real-world CLS responses to requests made via their Application Programming Interface (API) to change lighting levels. Characterization results for 2 of the 6 CLS that were used to derive model parameters are shown here.

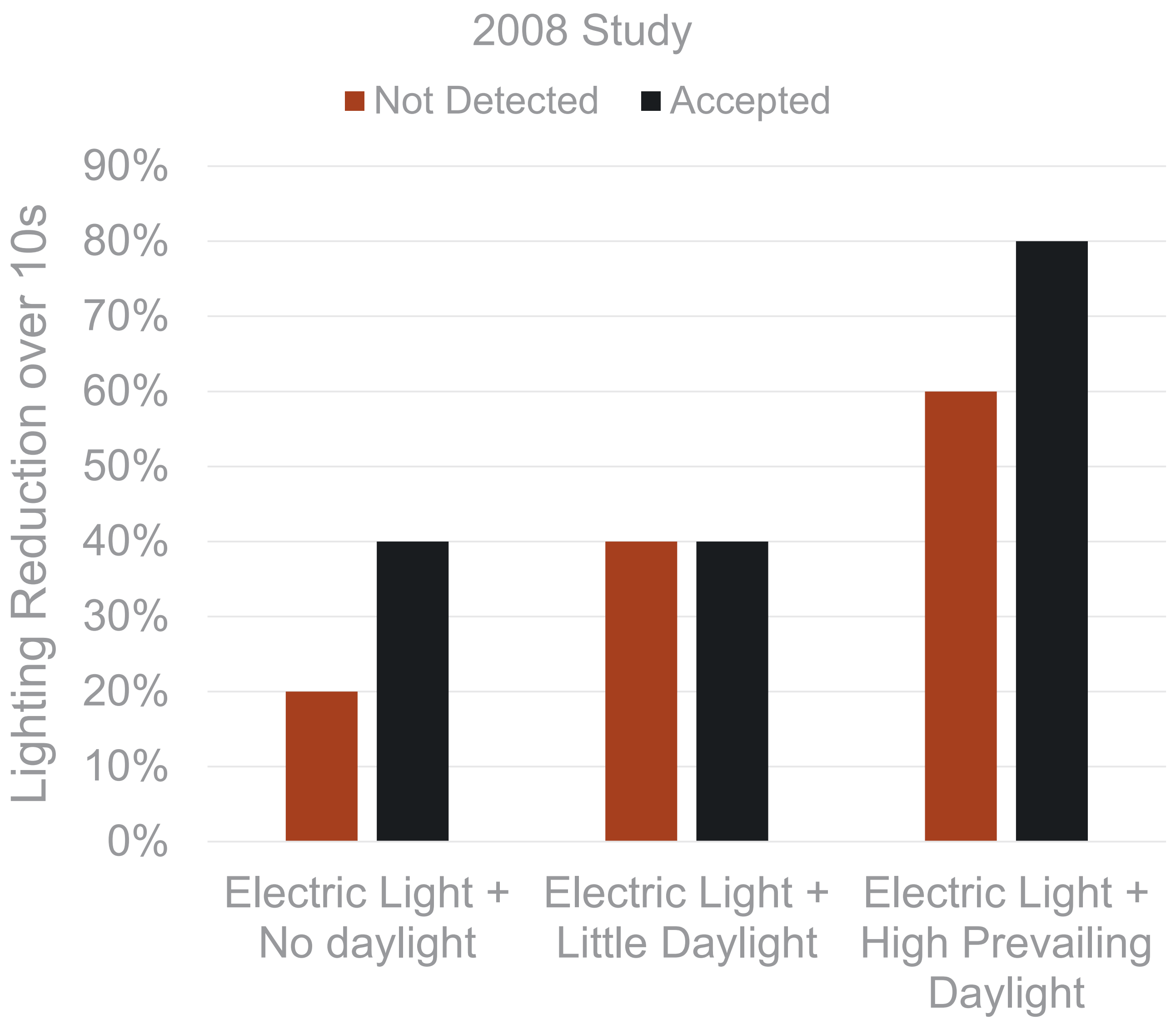
Response behaviors are described statistically for 100 iterative requests to change their lighting levels via a mean (μ) and standard deviation (σ) response time, and a reliability (ρ) – or portion of the 100 requests that resulted in a changed power draw.





CLS ramp rate limitations can be modeled based on detectability and acceptability research

- Model parameters were based on review of 8 published papers on detectability and acceptability of lighting changes
- Detectability and acceptability are affected by rate of change, starting light level, ending light level, availability of daylight, visual task being performed, and other factors
- 4% per second with no or little daylight is too aggressive; 0.5% and 1% per second chosen to improve acceptability
- 8% per second with high daylight is highly acceptable; 15% per second chosen as an aggressive condition to maximize ability to provide grid services that require fast acting load changes



Current simulation plan

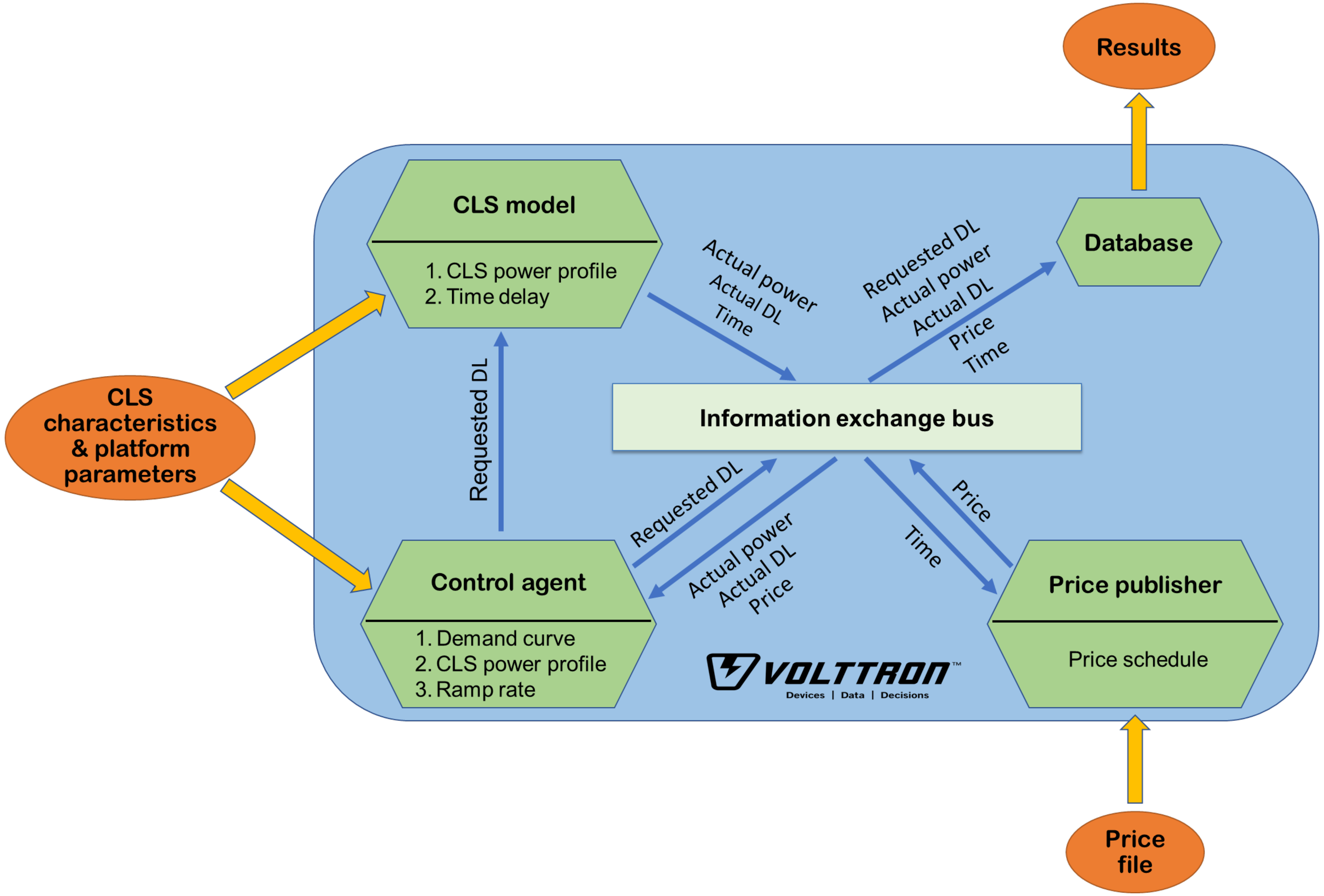
- Start with medium office building; other building types TBD
- 3 different minimum lighting load profiles
- 5 different combinations of lighting load change delay and ramp rate
- 5 grid services, spanning response times of sub-seconds to hours
- 3 building system scenarios
  - CLS alone
  - CLS and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

Five grid services have been chosen for simulation

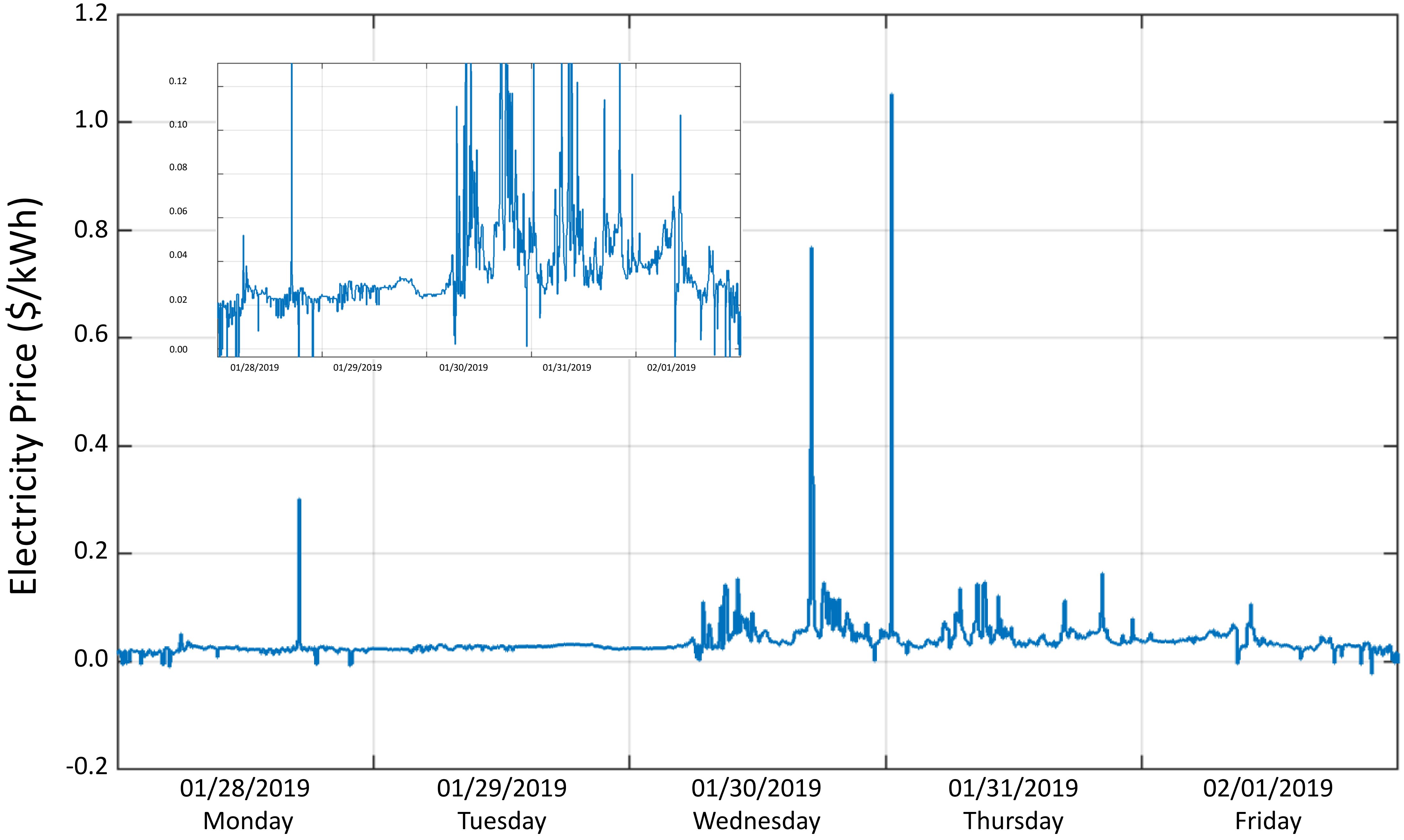
	Simulated Grid Service	*GEB Framework Grid Service(s)*
1	Demand reduction based on real-time pricing with 5-minute time intervals	*Generation energy and capacity, contingency reserves, non-wires T&D solutions—dependent on price variations*
2	Day-ahead demand commitment for energy service via demand response	*Generation energy*
3	Energy service via peak load reduction based on time-of-use pricing with hours-long fixed price periods	*Generation energy and capacity, contingency reserves, non-wires T&D solutions*
4	Frequency regulation with 2 or 4 second response	*Frequency regulation*
5	Distribution voltage support with sub-second response	*Voltage support*

A Simulation Platform for evaluating the grid service potential for CLS acting alone has been developed and demonstrated to be functional

- The Simulation Platform currently implements transactive control for real-time price inputs
- The real-time price is set every 5 minutes
- The simulation runs every 0.1 second to capture timing impacts

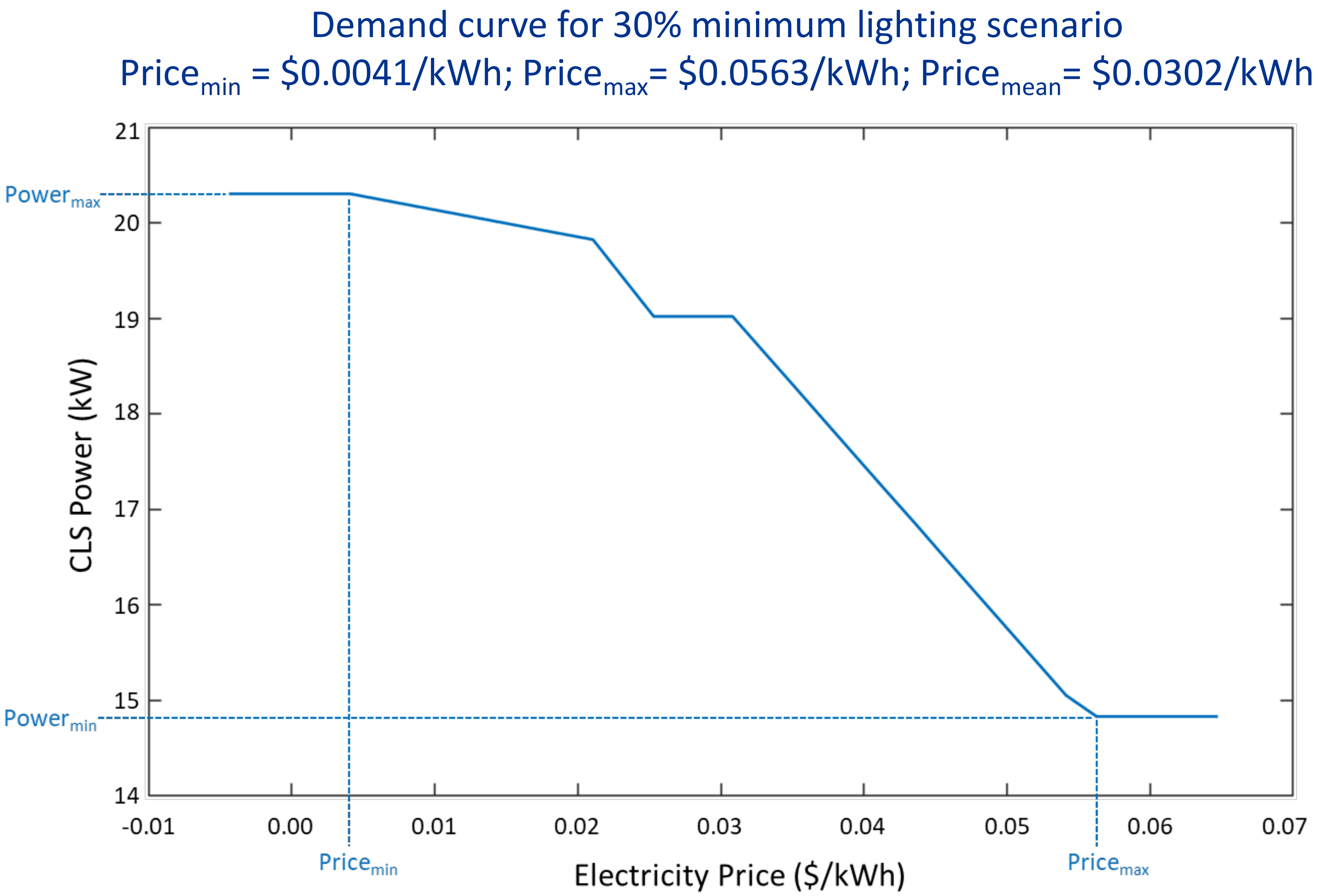


Actual ComEd 2019 Commercial real-time prices, updated every 5 minutes, were used in the grid service simulation

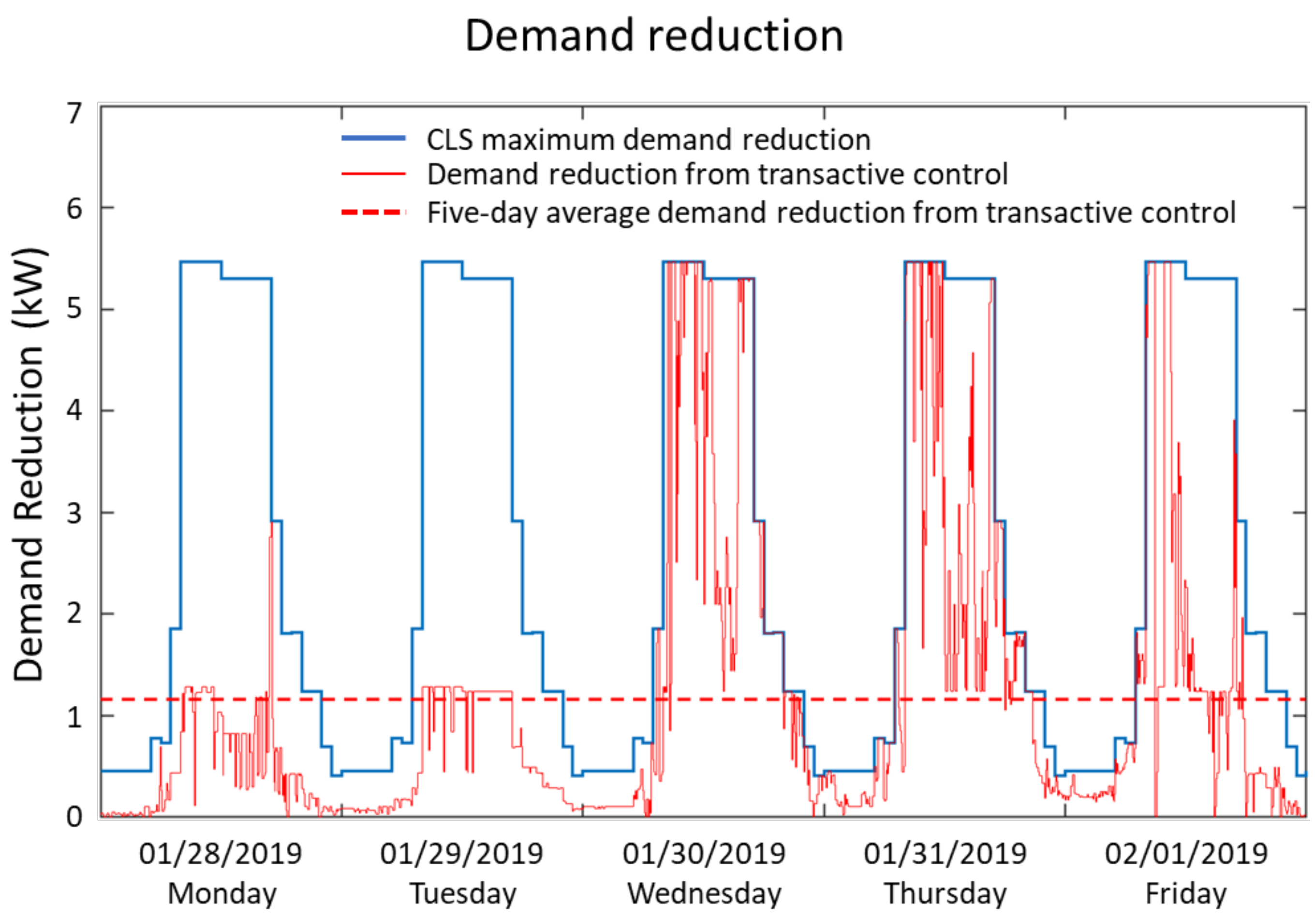


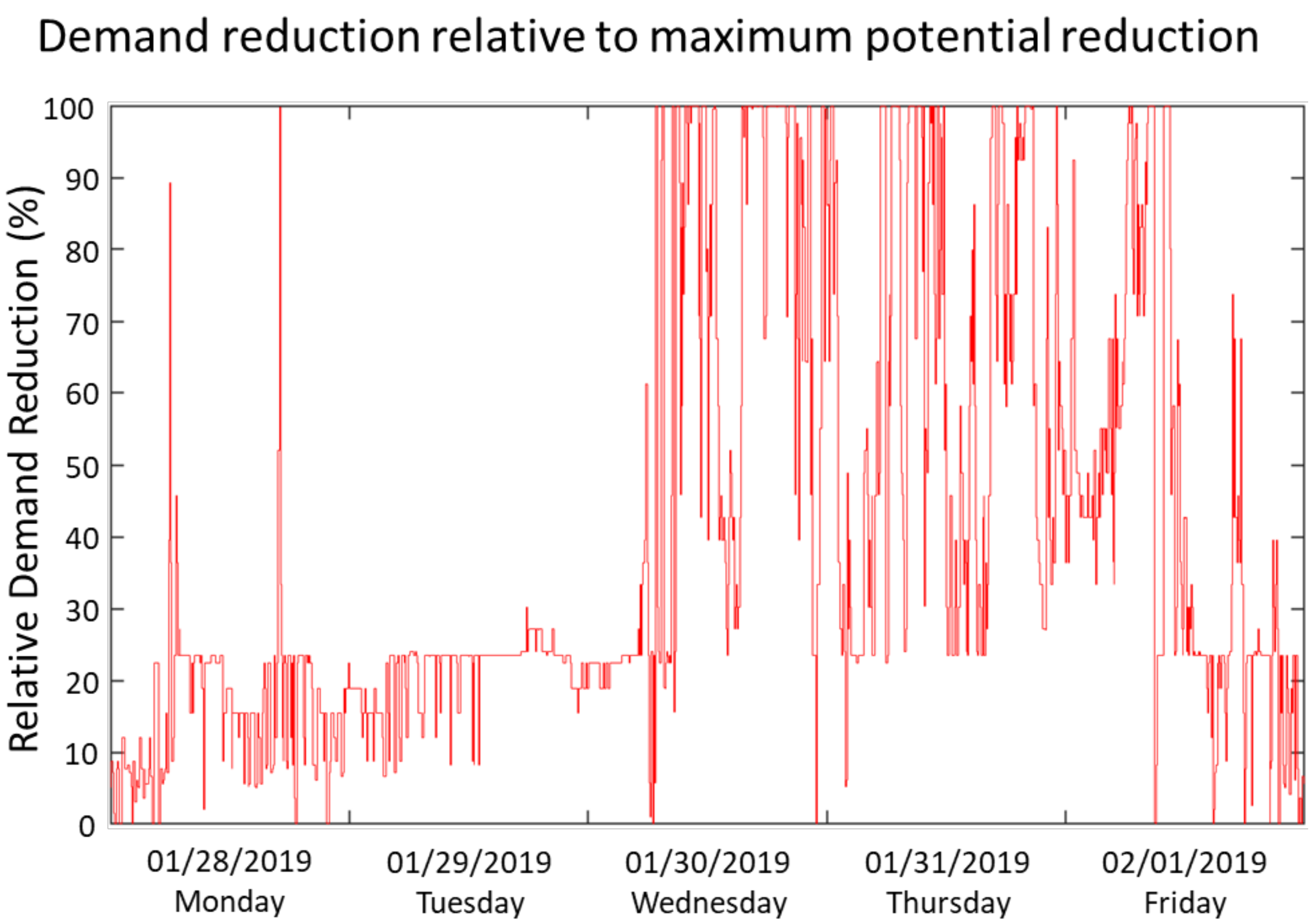
A lighting power demand curve was developed to dictate how the CLS would respond to varying electricity prices

- $Power_{max}$ corresponds to the maximum possible lighting level
- $Power_{min}$ corresponds to the lowest lighting level permissible
- $Price_{min} = Price_{mean} - \sigma_{price}$
- $Price_{max} = Price_{mean} + \sigma_{price}$
- σ_{price} = standard deviation of 5-minute real-time price data for the previous year

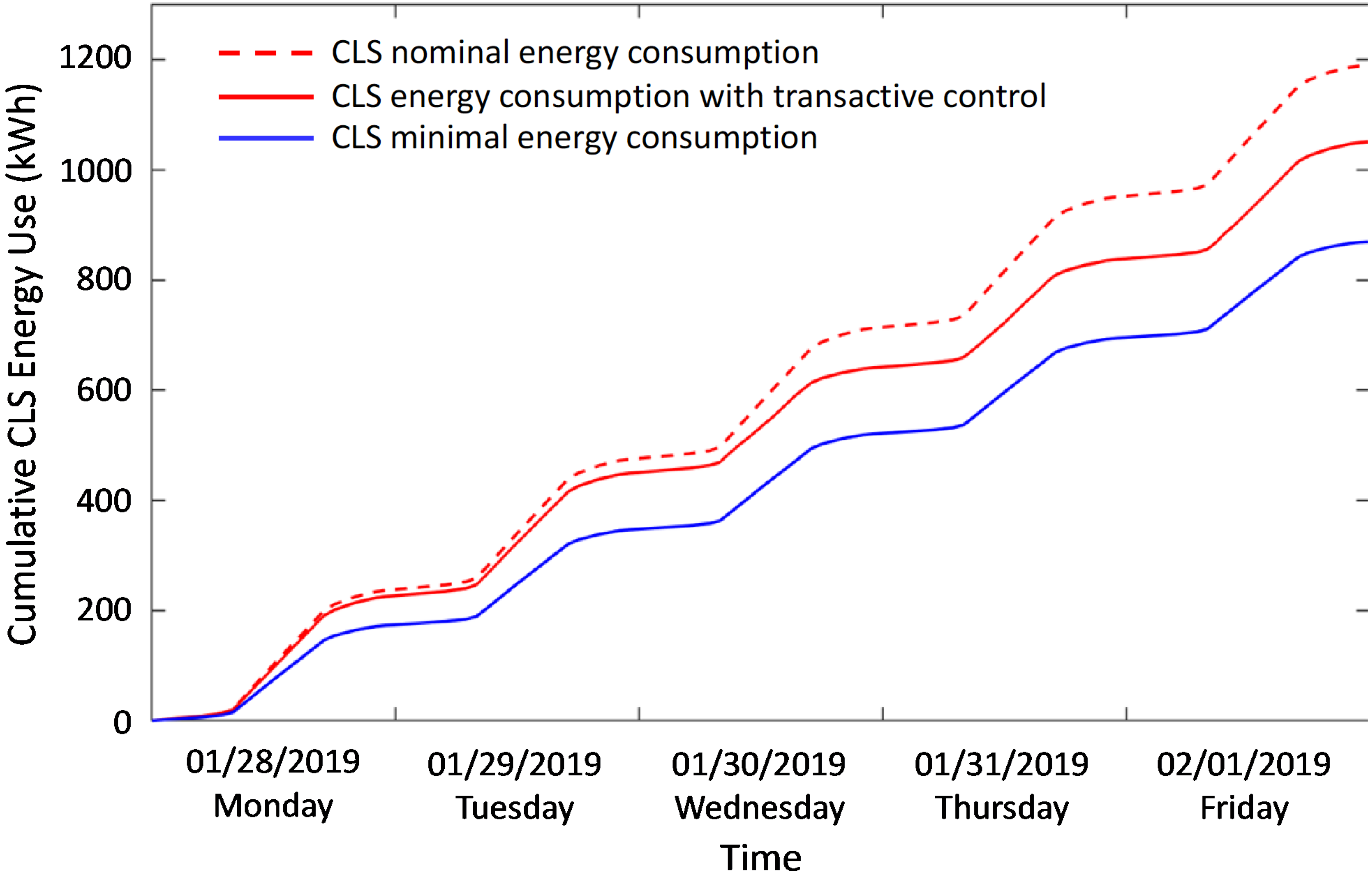


The CLS frequently delivered maximum load reduction over the 5-day trial simulation period





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



A representative CLS was shown to respond to varying electricity prices with varying demand reduction, resulting in varying energy savings

	Monday	Tuesday	Wednesday	Thursday	Friday	Monday-Friday
Average electricity price ($/kWh)	0.022	0.027	0.056	0.051	0.035	0.038
Average demand reduction (kW)	0.469	0.598	1.938	1.735	1.067	1.161
Total energy savings (kWh)	11.26	14.35	46.50	41.63	25.60	139.3

Pacific Northwest
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Questions?

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