Why the Timing of Energy Efficiency Matters

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Association of Energy Engineers

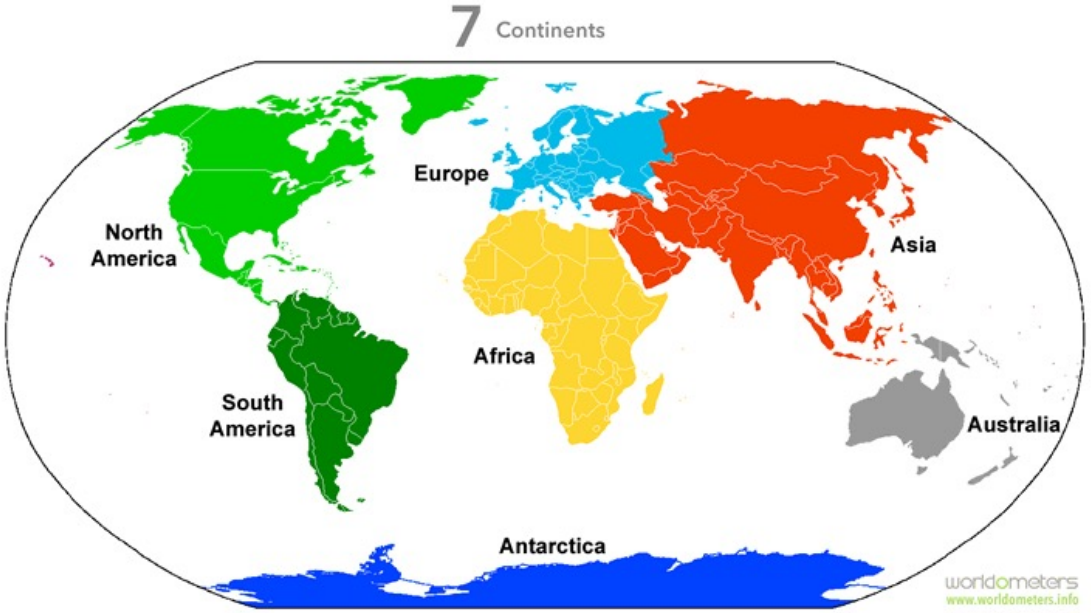
AEE Monthly Member Webinar– Tuesday, June 22, 2021

Abstract

The measurement of energy savings and demand reduction through energy efficiency (EE) projects has always been challenging. For those EE programs that receive ratepayer funding for incentives, rebates, and program administration, the pricing of energy efficiency is even more important-----and sensitive------to policy makers. The challenge of wedding technological benefits with rebate and incentive pricing can be very puzzling in developing robust energy efficiency programs. Add to this, the fact that not all saved kWh's and reduced kW's are valued equally. Electricity saved during the grid's daily peak is much more valuable than that which is saved off-peak. Similarly, virtually all utilities have seasonal peaks and off-peaks. Electricity saved during the seasonal peak is more valuable than the same electricity saved in the off-peak season. Additionally, for many utilities with multiple generating assets, the relative carbon intensity of generated power can change hourly, as can the consumption of water relating to thermal power sources. Thus, the timing of the end-use customer's energy efficiency savings may create varying levels of carbon reduction and water efficiency. This webinar will explore a few key markets around the U.S. to illustrate these time-based variables and their materiality. We will also explore how prevalent time-sensitive EE and Demand Response programs are throughout the U.S., and the challenges related to their implementation.

Knowing your Audience

- Where?



- Who?: Energy Engineer, Utility Employee, Energy Efficiency Professional, Facility Manager, Regulator, Economist, NGO?
- Why are you here? Climate Change Mitigation, Clean Energy, Cut Costs, Decarbonization, Improve Policy, Advocacy

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Major Points

1. Setting Scope and Context
2. The challenge of “valuing” and “pricing” electricity and **energy efficiency savings**
3. Factors Driving the Time-Variance of Energy Efficiency
4. Prevalence of EE Time-Varying Incentives and Rebates
5. Other Best Practices
6. Future Challenges and Opportunities

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Different Types of Pricing for Different Consumer Products/Services

Transparent

Opaque

LA Times	Ralphs	
LA DWP Los Angeles Department of Water & Power	Uber	
Harbor-UCLA MEDICAL CENTER	TRANSMISSIONS AAMCO TOTAL CAR CARE	

Static → Dynamic

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Words and Definitions Matter

- Energy Efficiency ✓

Demand Response ✗

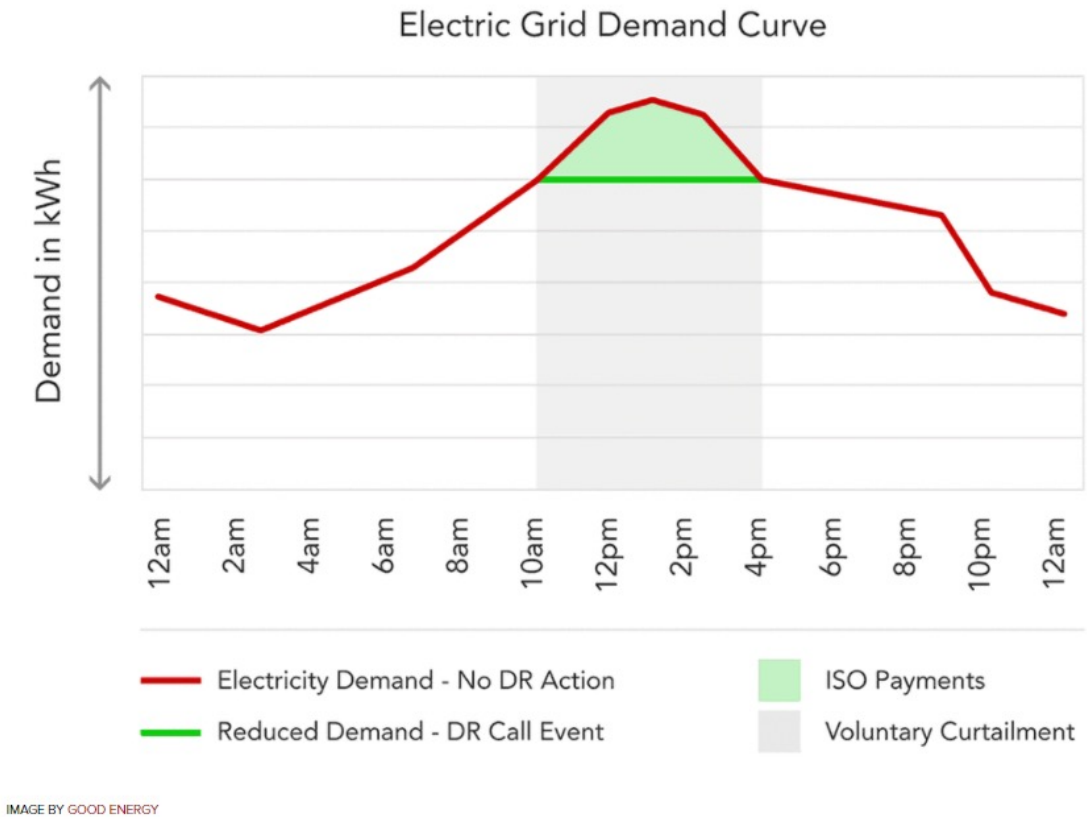

IMAGE BY GOOD ENERGY

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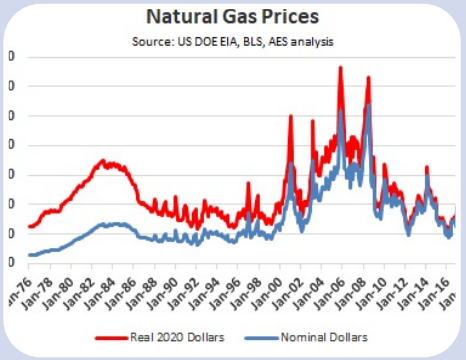
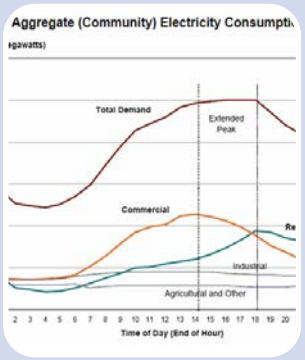
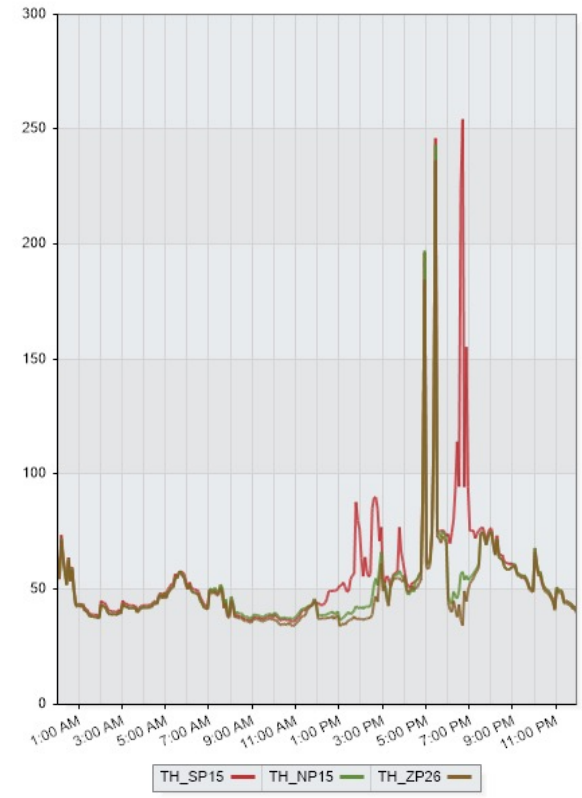
Valuing Energy Savings begins with the Challenge of Valuing Electricity Resources

Factor	Allocation of High Fixed Costs	Intermittent Supply	Changing Fuel Prices	Changing Ambient Conditions	Variable Demand
					
Value Challenge	Moderate	Moderate	Low	Moderate	High

Wholesale Electricity Prices are highly variable

CAISO (California ISO)

Real-time Price



Source: CAISO

Date span selection

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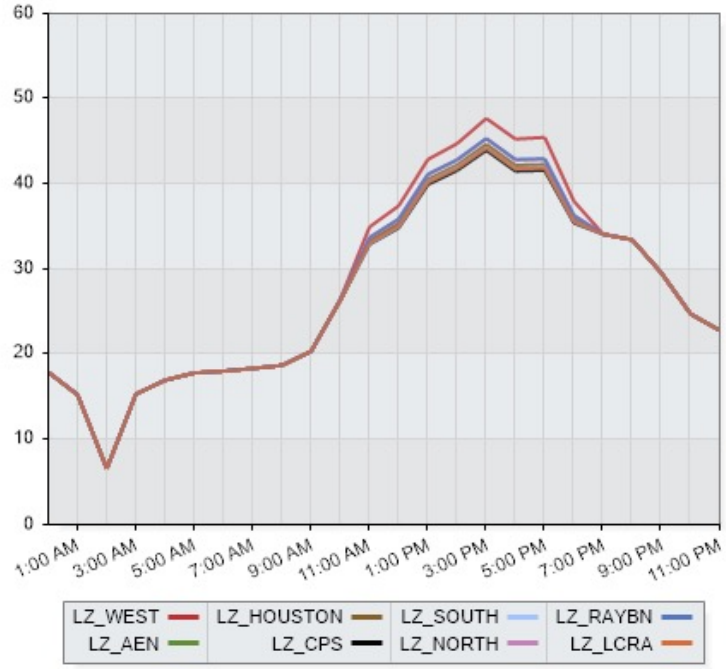
ERCOT (Electric Reliability Council of Texas)

Real-time Price



Source: ERCOT

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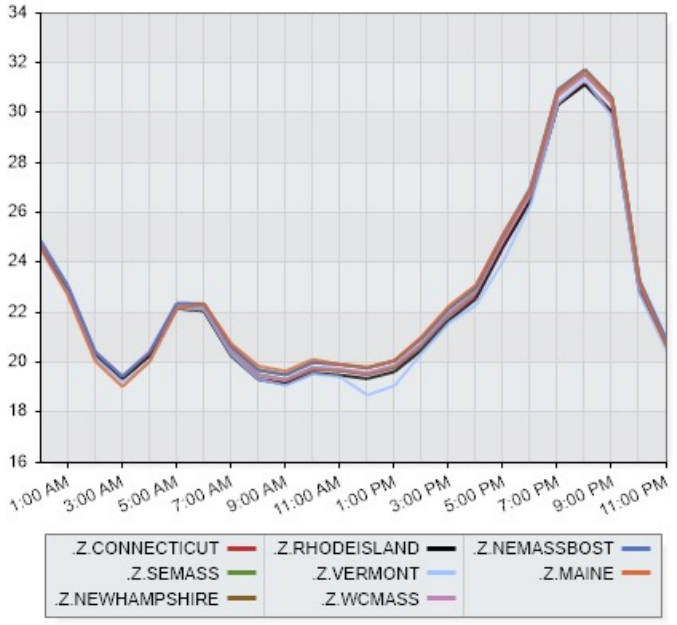
INDUSTRY DATA

ISO-NE (ISO New England)

Actual Energy Price



Source: ISO-NE

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[Source: LCG Consulting-Energy OnLine]

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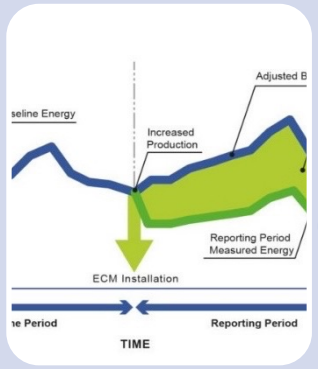
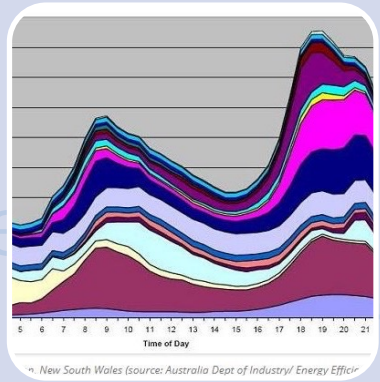
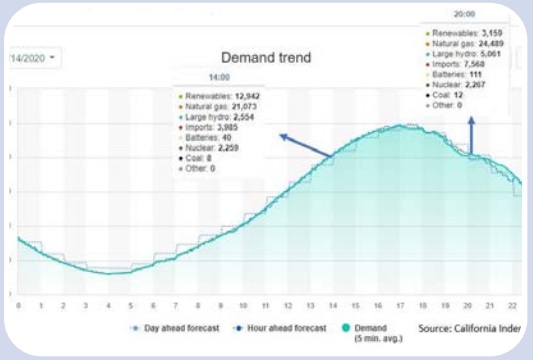
The Time Value of Energy Efficiency Savings has unique drivers beyond electricity value







Factor	How Much Energy Savings?	Timing of Energy Savings	Changing Consumption Dynamics	Changing Ownership/ Tenants	Grid Carbon Intensivity
Value Challenge	High	Moderate	High	Moderate	Low

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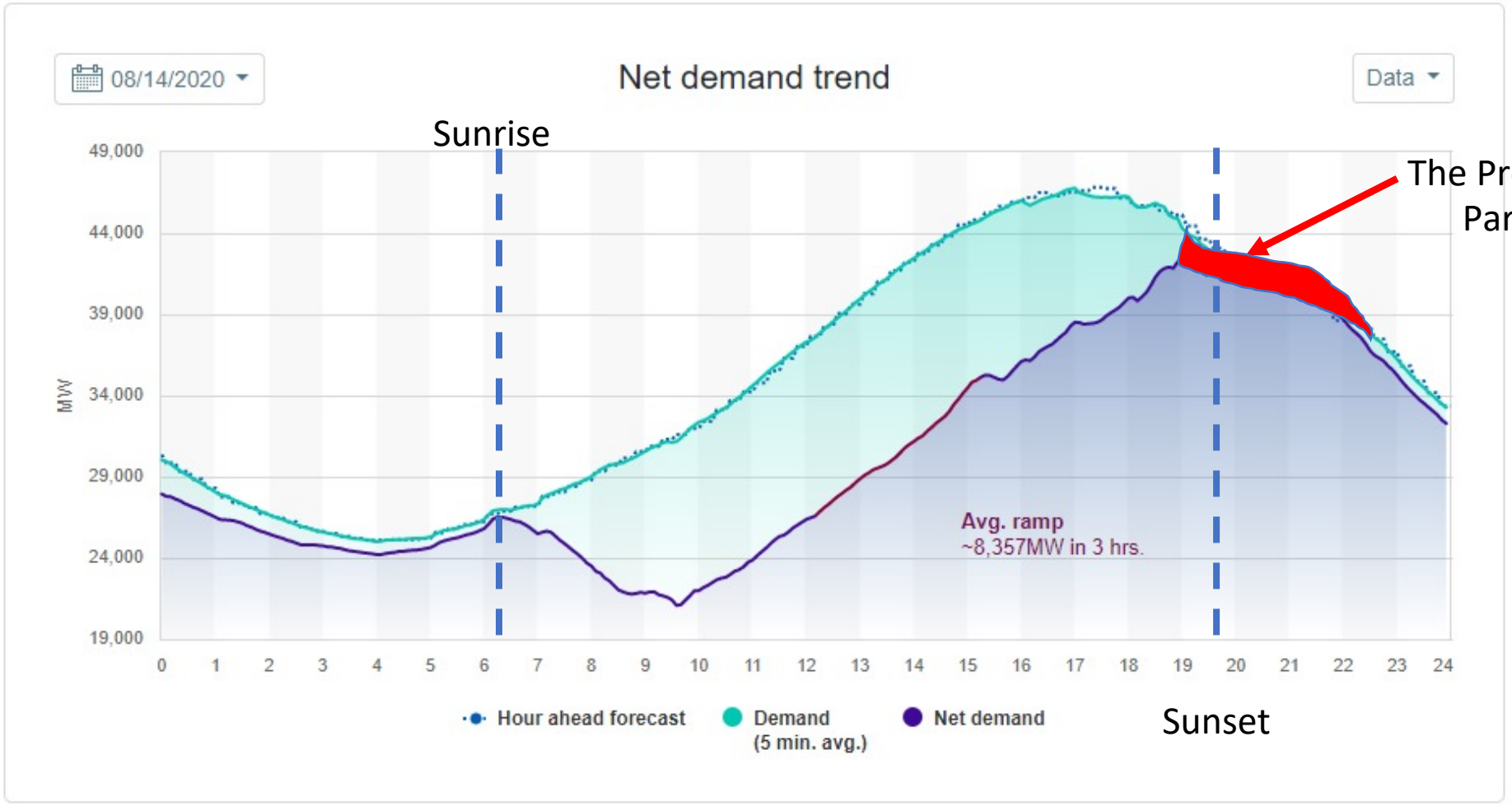
So What's the Problem? Part 1

Net demand (demand minus solar and wind) AS OF 18:55

This graph illustrates how the ISO meets demand while managing the quickly changing ramp rates of variable energy resources, such as solar and wind. Learn how the ISO maintains reliability while maximizing clean energy sources.



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So What's the Problem? Part 1a)

Summer Residential Load Curve

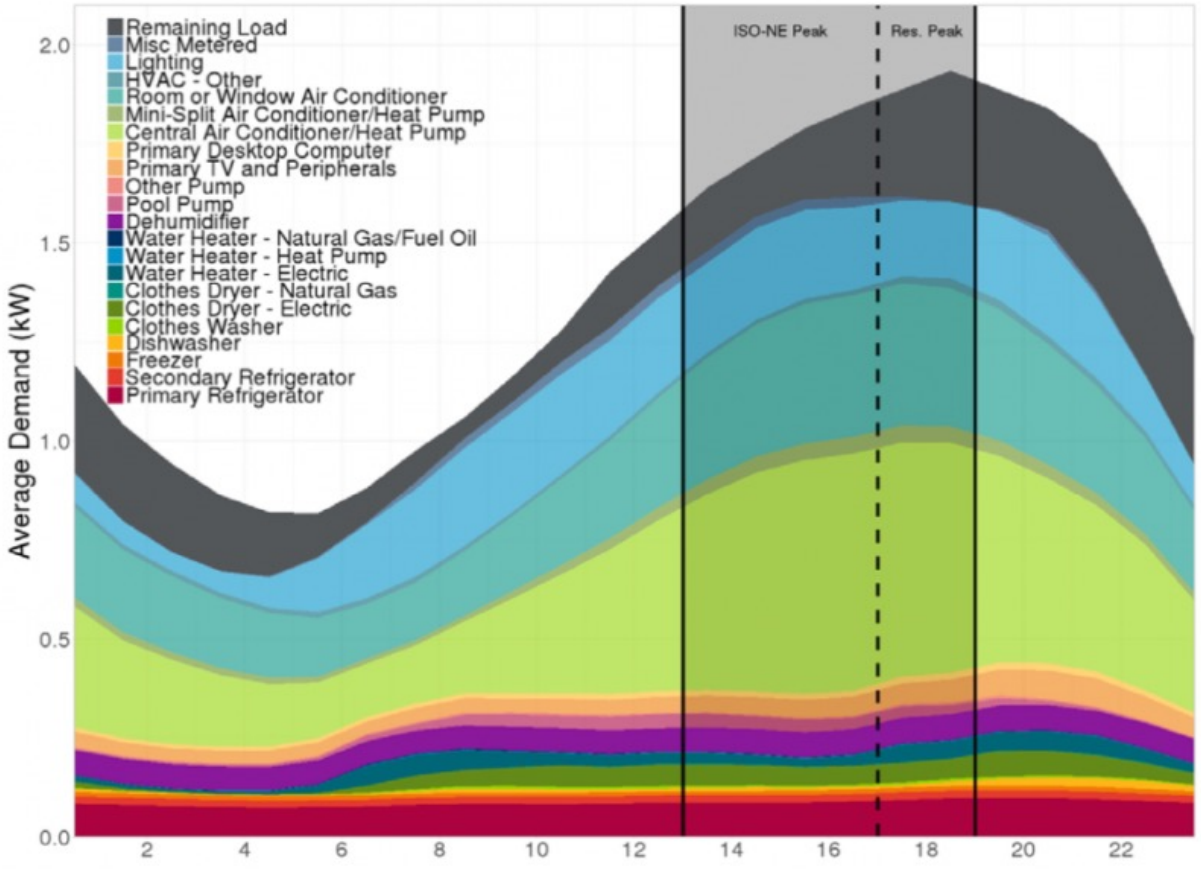

Figure 1. Massachusetts summer peak day end use load shapes (source: Navigant for the Electric and Gas Program Administrators of Massachusetts).

Winter Residential Load Curve

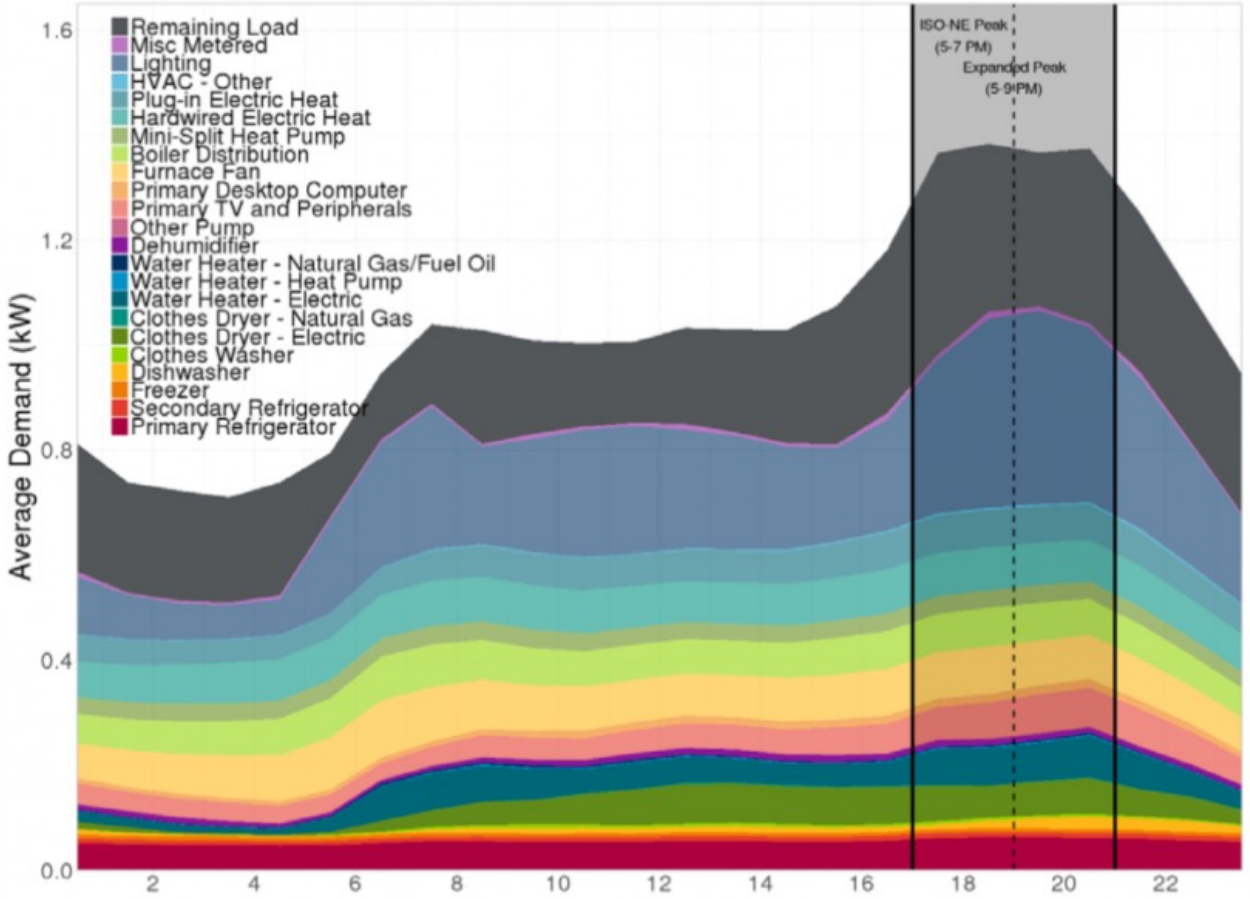

Figure 2. Massachusetts winter peak day end use load shapes (source: Navigant for the Electric and Gas Program Administrators of Massachusetts).

Source: DOE Office of Energy Efficiency and Buildings, Buildings and the Grid 101: How Much Does Timing Matter? May 21, 2019

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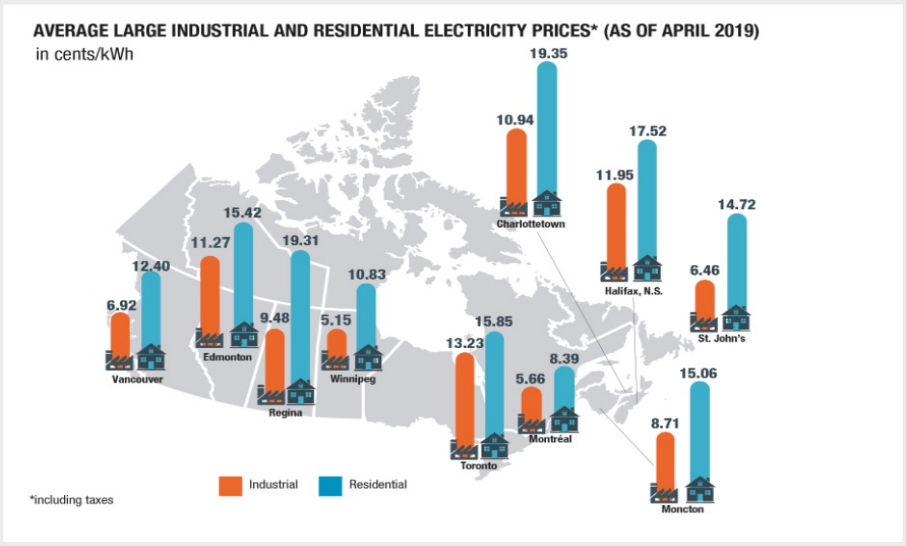
Electricity Revenues and Energy Efficiency Incentives and EE Program Costs are Big Business

- Retail Electricity Sales in the U.S.-2019-$401B on 3,811B kWh's
  - 28B kWh electricity EE Savings, at a cost of $2.3B annual incremental cost[1]
- Retail Electricity Sales in Canada-2018- 572B kWh's on $60B-CAD annual cost
  - 2.7B kWh electrical EE Savings-2018, at a cost of $820 MM-CAD annual incremental cost[2]



[1]US.Energy Information Agency, Form 861, Energy Efficiency Tab, 2019

[2]*2020 Canadian Provincial Scorecard*; James Gaede, Brendan Haley, Madeline Chauvin, 2020 Efficiency Canada, Care of Carleton University

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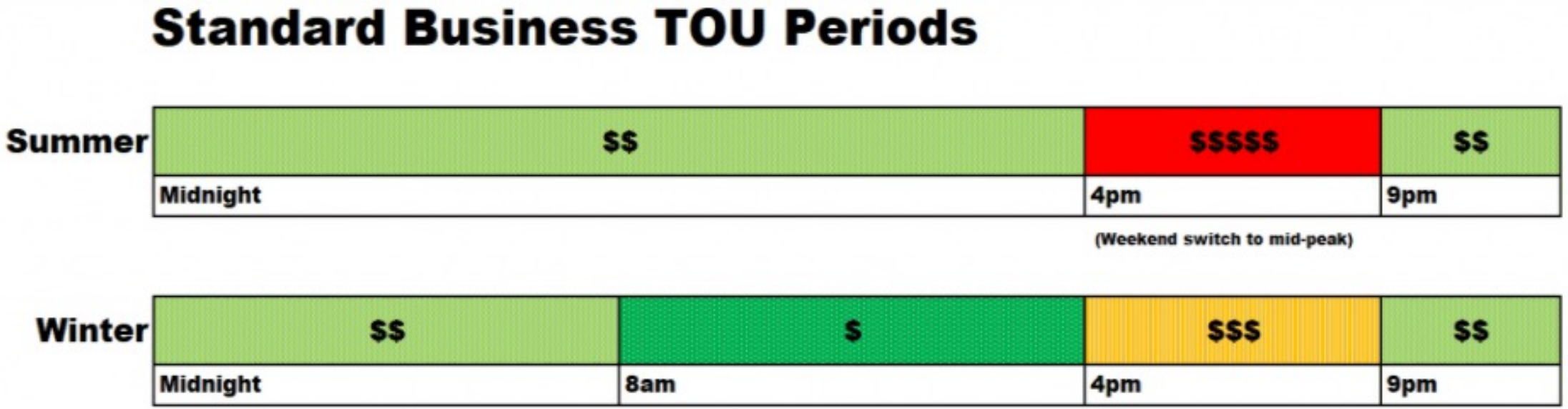
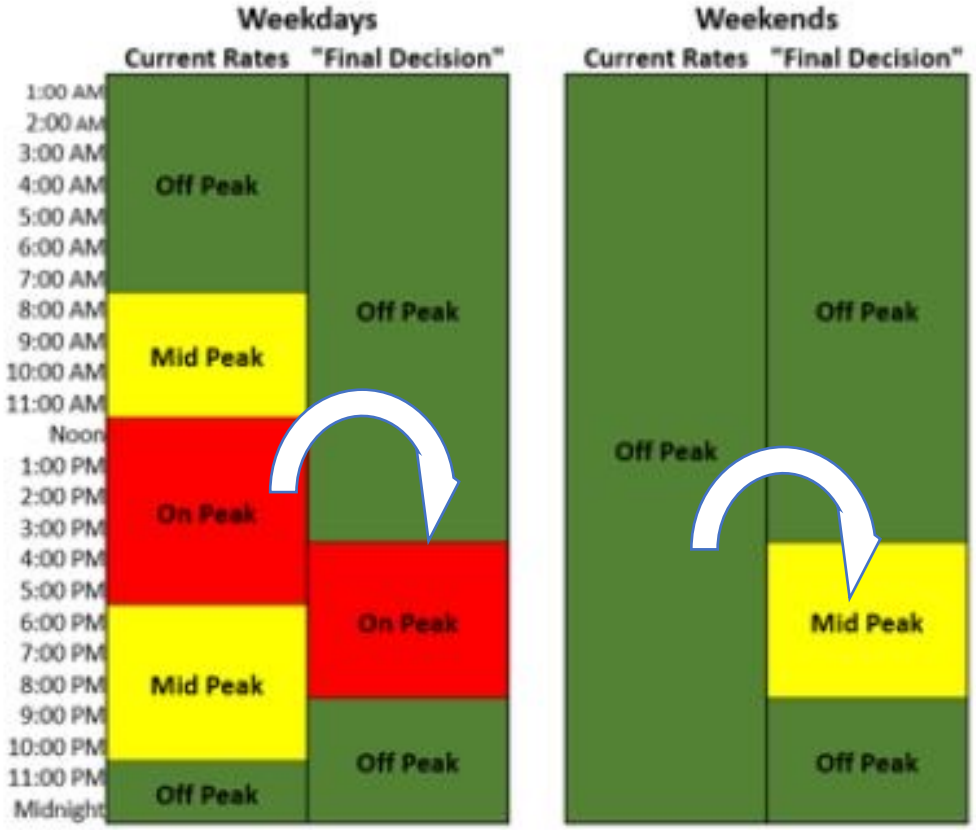
Time-of-Use (TOU) Pricing: One Tool for Shaping Load

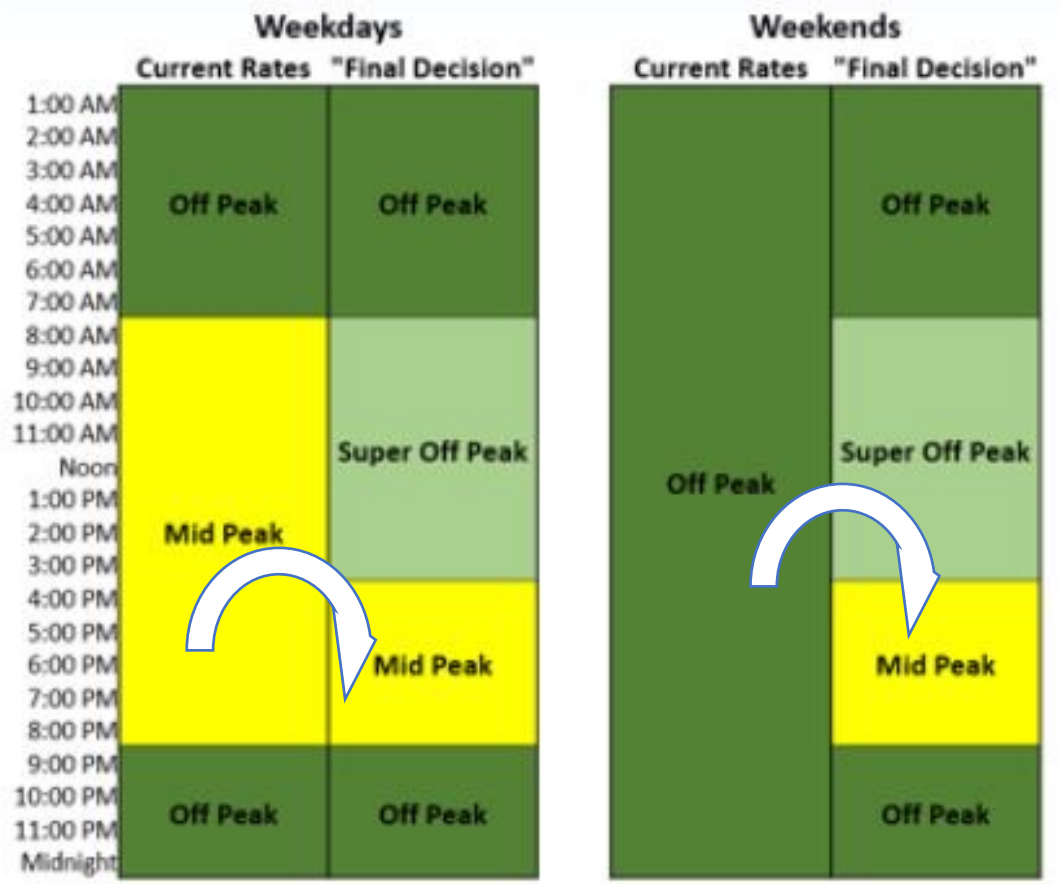


Source: SCE.com

Time-of-Use (TOU) Pricing: One Tool for Shaping Load



Summer-June through September



Winter-October through May

Source: Southern California Edison

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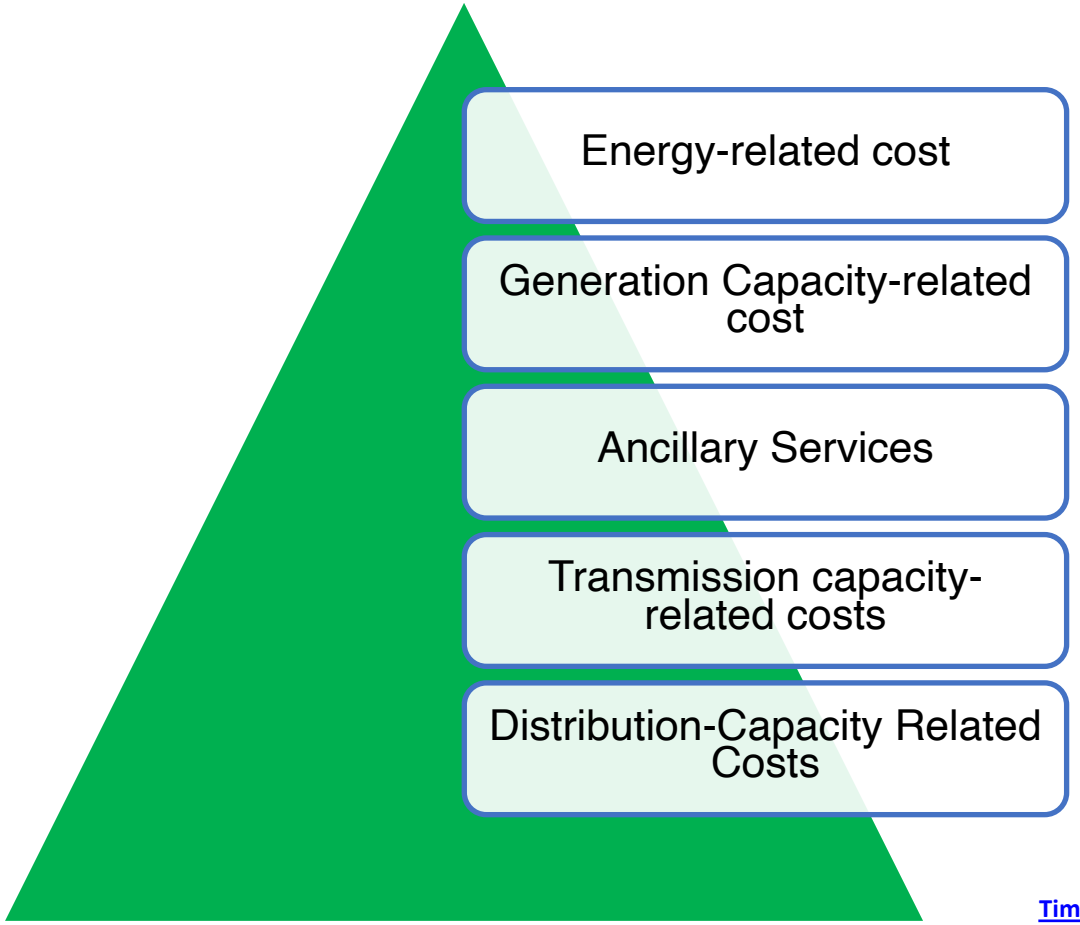
Elements of Avoided Cost



Time-Varying Value of Energy Efficiency, **Natalie Mims, Tom Eckman, and Chuck Goldman; July 10, 2017;** This work was supported by the DOE Office of Energy Efficiency & Renewable Energy Building Technologies Office under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

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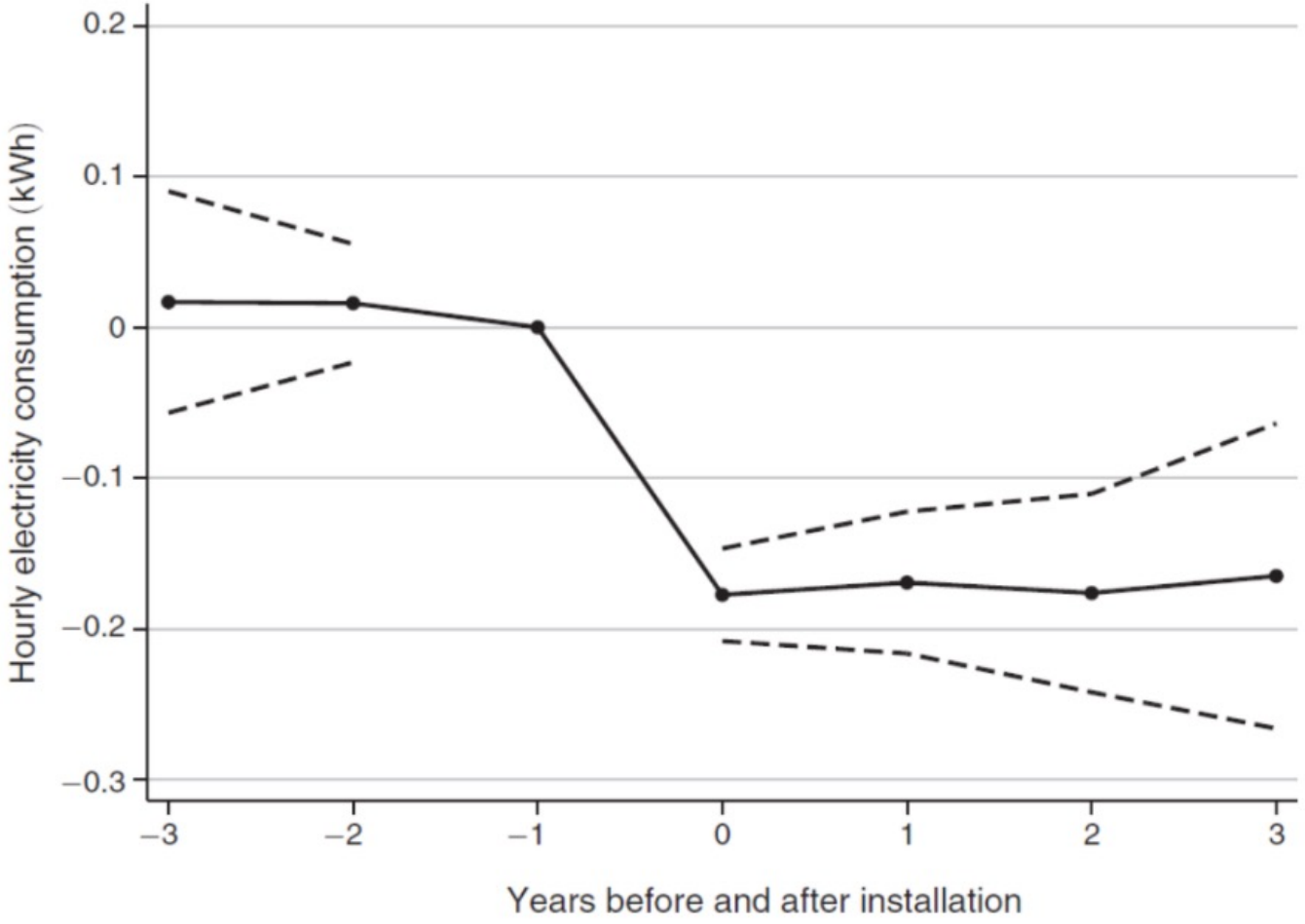
The Impact of Energy Efficiency Residential Air Conditioners on Load



Source: *Do Energy Efficiency Investments Deliver at the Right Time?*; Justin Boomhower and Lucas Davis, *American Economic Journal: Applied Economics 2019, 12(1): 115–139*

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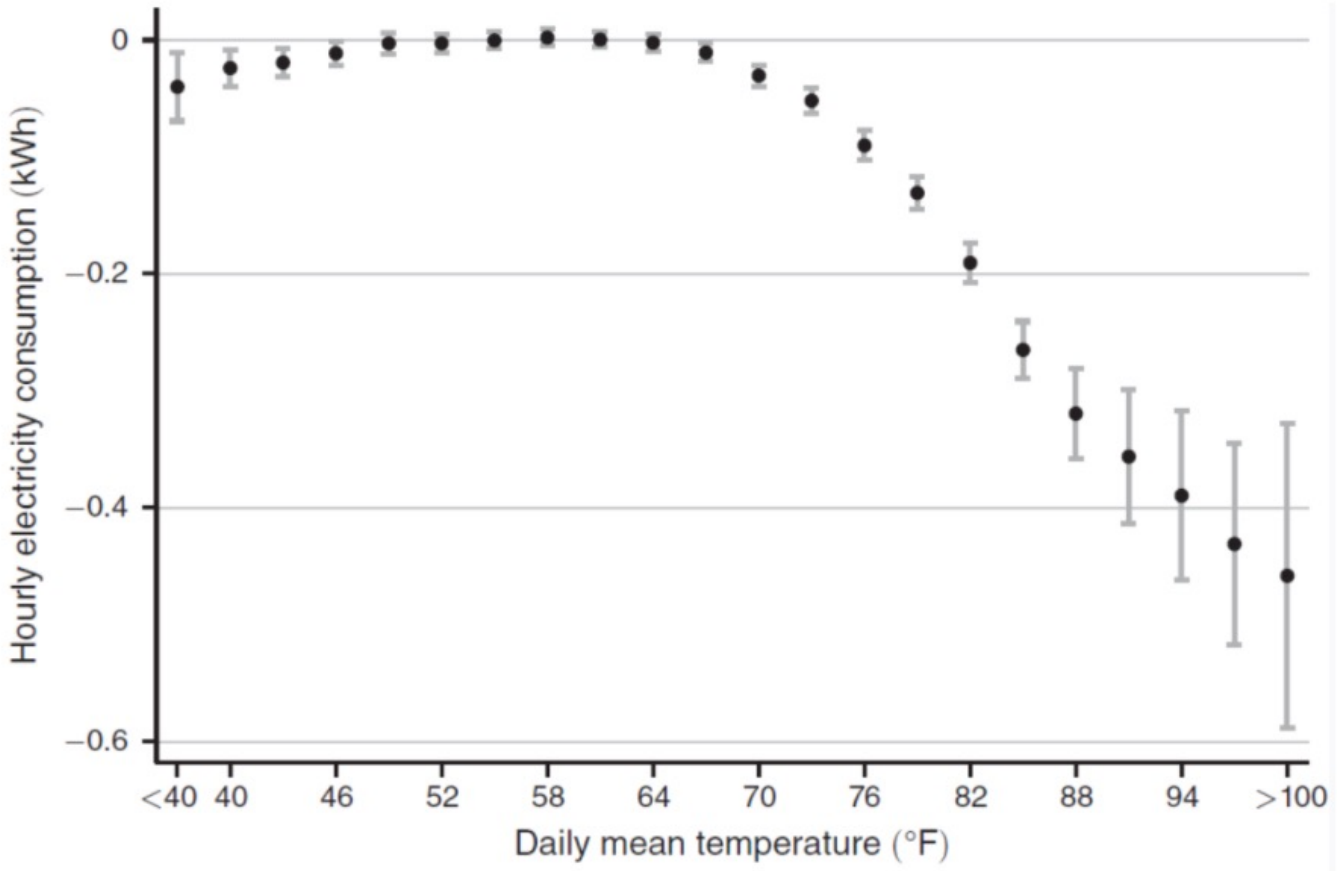
The Magnitude of Energy Efficient Savings from Residential Air Conditioning by Time of Day



Source: *Do Energy Efficiency Investments Deliver at the Right Time?*; Justin Boomhower and Lucas Davis, *American Economic Journal: Applied Economics 2019, 12(1): 115–139*

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How Big is the Energy Efficiency Timing Premium?

TABLE 3—TIMING PREMIUMS FOR SELECTED ENERGY EFFICIENCY INVESTMENTS

	California (CAISO)	Texas (ERCOT)	Mid-Atlantic (PJM)	Midwest (MISO)	New York (NYISO)	New England (ISONE)	Average
Panel A. Residential							
Air conditioning (econometric estimates)	37%	39%	17%	14%	0%	1%	18%
Air conditioning	56%	53%	23%	18%	18%	10%	30%
Lighting	3%	−5%	−2%	−1%	1%	−1%	−1%
Clothes washers	2%	2%	4%	7%	6%	4%	4%
Heat pump	−1%	−1%	−4%	−5%	−6%	−3%	−3%
Refrigerator or freezer	−1%	−5%	−5%	−3%	−4%	−6%	−4%
Panel B. Commercial and industrial							
Heat pump	32%	31%	18%	17%	17%	10%	21%
Chillers	27%	26%	14%	15%	12%	5%	17%
Air conditioners	25%	24%	14%	15%	13%	6%	16%
Lighting	3%	0%	1%	4%	4%	0%	2%

Source: *Do Energy Efficiency Investments Deliver at the Right Time?*; Justin Boomhower and Lucas Davis, *American Economic Journal: Applied Economics 2019, 12(1): 115–139*

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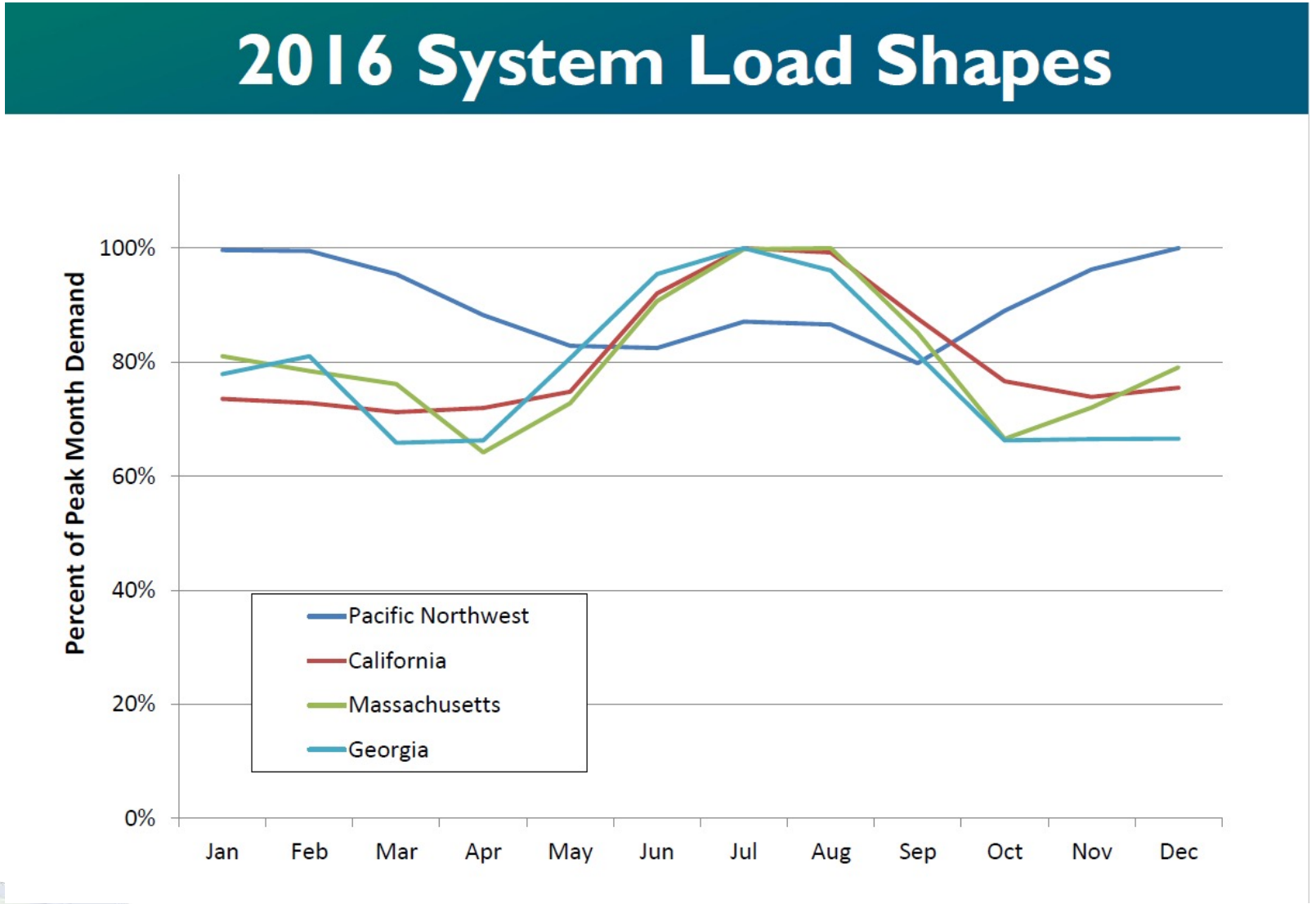
Regional System Peak Curves (Annual)



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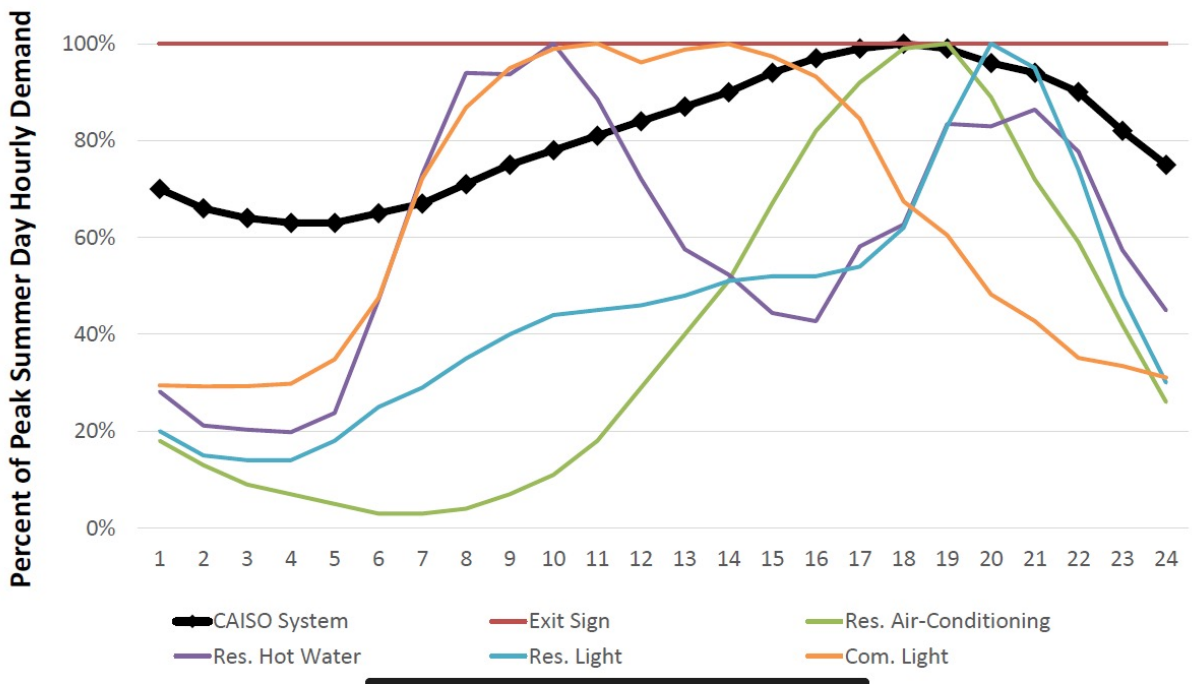
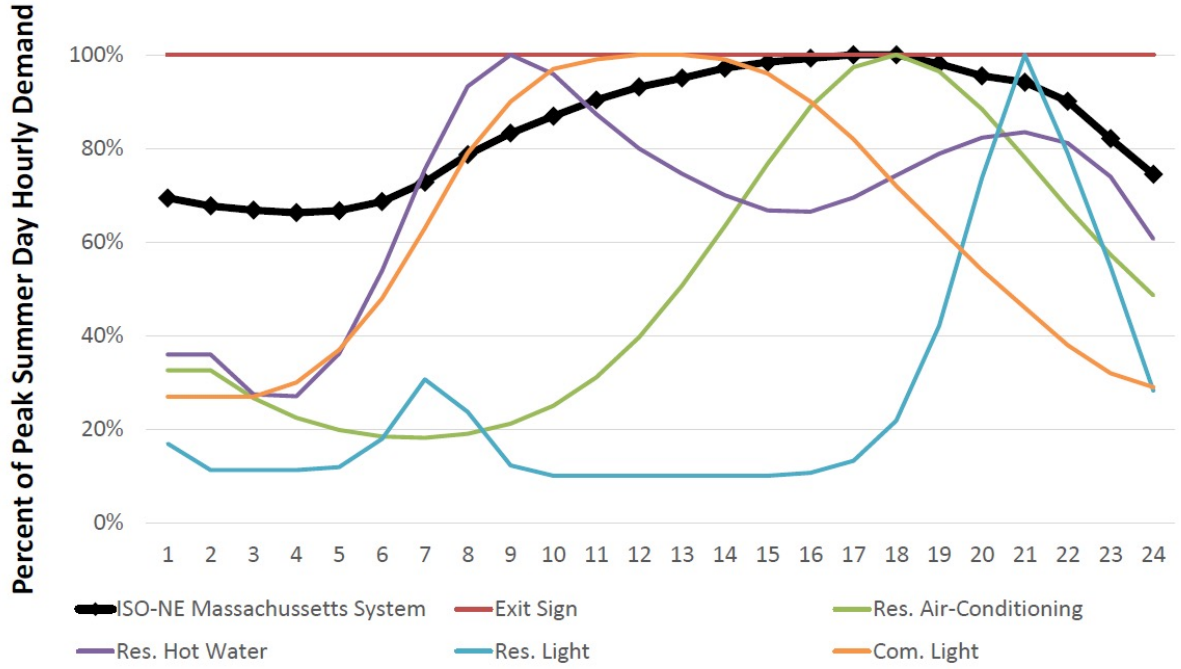
Time-Varying Value of Energy Efficiency, **Natalie Mims, Tom Eckman, and Chuck Goldman; July 10, 2017;** This work was supported by the DOE Office of Energy Efficiency & Renewable Energy Building Technologies Office under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

End-Use Load Shapes are Unique and Often Time-Dependent

California System Shape and End-Use Load Shapes



Massachusetts System Shape and End-Use Load Shapes



[Time-Varying Value of Energy Efficiency](), **Natalie Mims, Tom Eckman, and Chuck Goldman; July 10, 2017;** This work was supported by the DOE Office of Energy Efficiency & Renewable Energy Building Technologies Office under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

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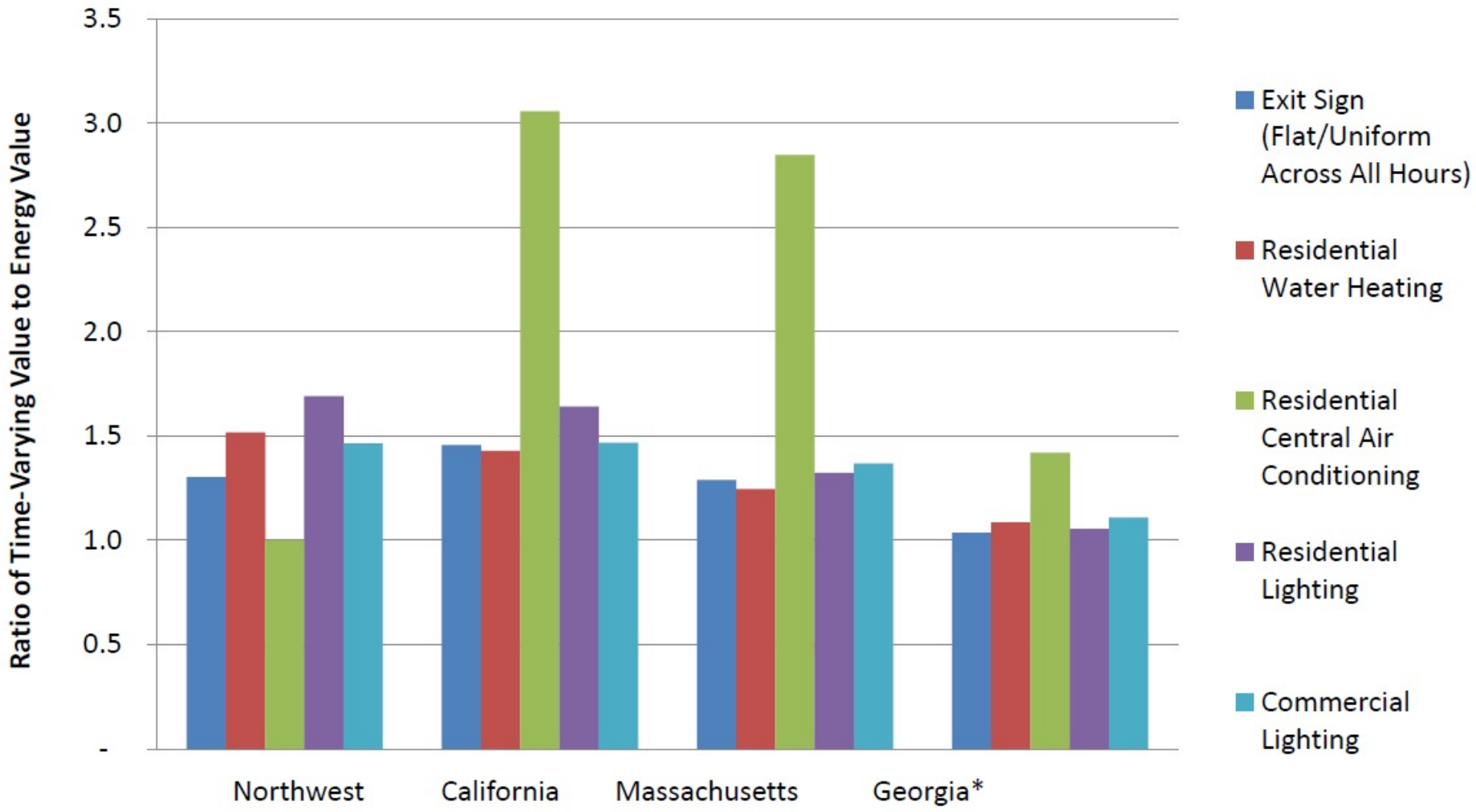
Ratio between Total Time-Varying Values of End use by Energy-only Value of End-Use



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Ratio of total time-varying value to energy-related value of energy savings by load shape and location

Load Shape	Location			
	Northwest	California	Massachusetts	Georgia
Flat/Uniform Across All Hours	1.3	1.5	1.3	1.0
Residential Water Heating	1.5	1.4	1.2	1.1
Residential Central Air Conditioning	1.0	3.1	2.8	1.4
Residential Lighting	1.7	1.6	1.3	1.1
Commercial Lighting	1.5	1.5	1.4	1.1

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Canada: Market-Based instruments for green buildings in Canada

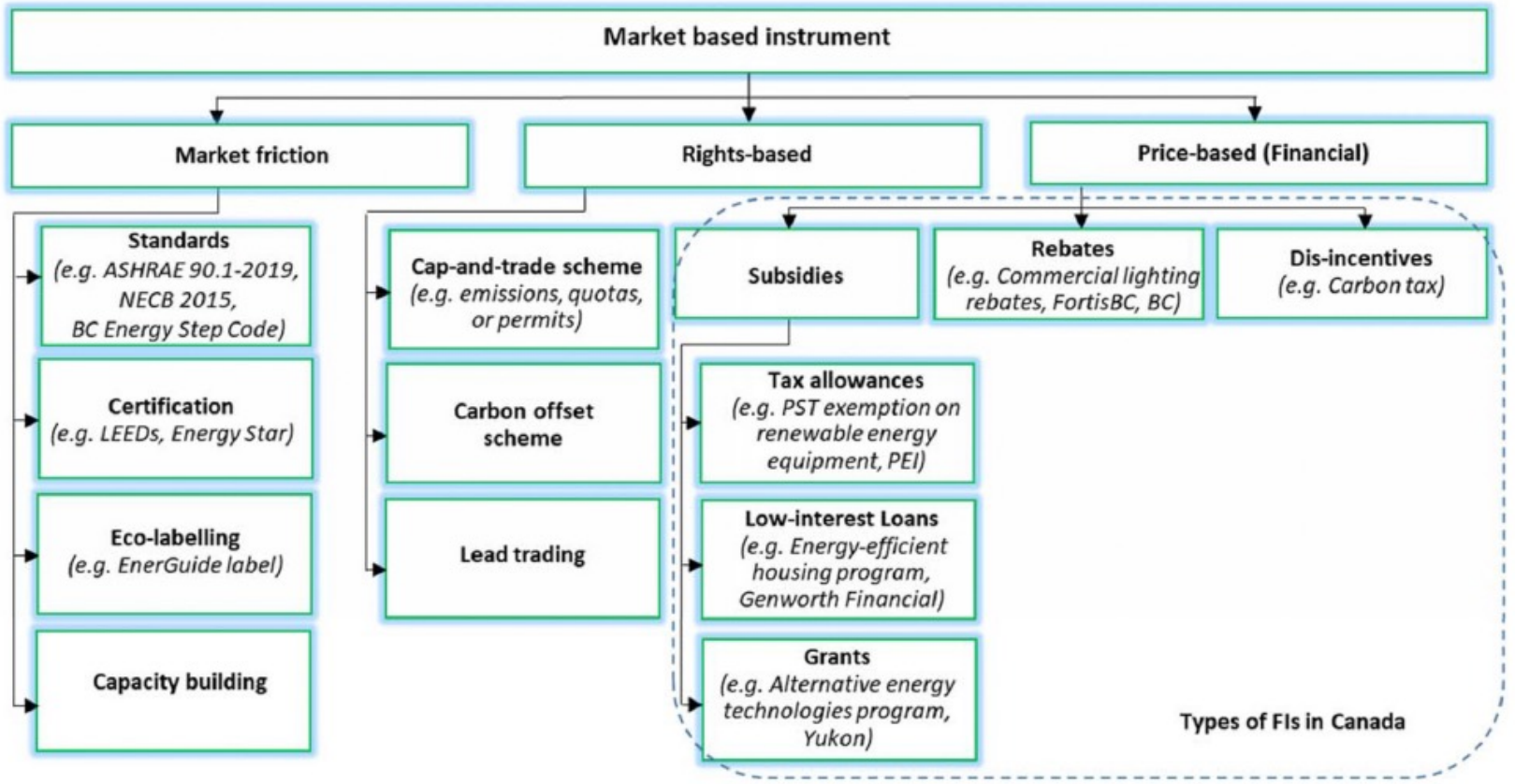

Fig. 3. Typology of market-based instruments for green buildings in Canada. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

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Provincial Level financial incentives for energy efficiency

Table 5
Summary of provincial level financial incentives in Canada.

Province	Residential				Commercial			
	Tax	Loans	Grants	Rebates	Tax	Loans	Grants	Rebates
Alberta		✓		✓				✓
British Columbia		✓	✓	✓				✓
Manitoba		✓		✓		✓		✓
New Brunswick		✓						
Newfoundland and Labrador		✓		✓				✓
Nova Scotia		✓		✓				✓
Nunavut		✓		✓				✓
Ontario	✓	✓		✓		✓		✓
Prince Edward Island		✓	✓					
Quebec	✓	✓					✓	
Saskatchewan		✓	✓	✓			✓	✓
Yukon		✓		✓				✓

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Examples of Current Incentive Pricing- Southern California Edison

REFRIGERATION SYSTEM OPTIMIZATION
The process of modifying a refrigeration system to make some aspects of it more efficient while not reducing the baseline output.

Customized Solution Items eligible for Customized Solution incentives are shown below.

SOLUTION CODE	SOLUTION DESCRIPTION FOR SYSTEM OPTIMIZATION	INCENTIVE	
		$/kWh	$/kWt
RF-18607	Refrigeration - energy management system (EMS) - add-on equipment[1,2]	$0.12	$150
RF-28734	Subcooling refrigeration controls - add-on equipment	$0.12	$150
RF-43876	Defrost controls - add-on equipment	$0.12	$150
	Variable-frequency drives for:		
RF-87644	Evaporator coil fan - VFD - add-on equipment[3]	$0.12	$150
RF-94589	Screw compressor - VFD (industrial refrigeration) - add-on equipment[3]	$0.12	$150
RF-79521	Refrigeration compressor controls - add-on equipment	$0.12	$150
RF-19808	Evaporator coil fan control (cycling) - add-on equipment	$0.12	$150
RF-21451	VFD on evaporator coil fan - new	$0.12	$150

CHILLER A device or unit that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle.

Customized Solution Items eligible for Customized Solution incentives are shown below.

SOLUTION CODE	SOLUTION DESCRIPTION FOR CHILLER	INCENTIVE	
		$/kWh	$/kWt
PR-78584	High efficiency process chiller	$0.12	$150
PR-42009	Process chilled water pump system upgrades	$0.12	$150
PR-60891	Chilled water filtration system	$0.12	$150
PR-11258	Process chiller plant system retrofit - accelerated replacement	$0.12	$150
AC-70454	Chiller heat reclaim - add-on equipment	$0.12	$150
PR-21960	Low global warming potential high efficiency process chiller - normal replacement[2]	$0.12	$150

[1] The fan diameter must be greater than 48 inches. If the measure is less than or equal to (≤) 48 inches the measure is DEEMED per SWPR001-01.

ADVANCED EVAPORATIVE COOLERS
Replacement of a vapor-compression air conditioning system with an evaporative cooler.

Customized Solution

SOLUTION CODE	SOLUTION DESCRIPTION FOR EVAPORATIVE COOLERS	INCENTIVE	
		$/kWh	$/kWt
AC-32882	Direct evaporative pre-cooler for condensing units - add-on equipment	$0.12	$150
AC-70772	Evaporative precoolers - add-on equipment	$0.12	$150
AC-19792	Indirect evaporative cooling - dual stage - add-on equipment	$0.12	$150
NA-30864	Other non-lighting (not approved for payment)*	$0.12	$150

ECONOMIZERS Air-side economizers use cool outside air as a means of cooling the indoor space and water-side economizers use water cooled by a wet cooling tower to cool buildings without operating a chiller.

Customized Solution Items eligible for Customized Solution incentives are shown below.

SOLUTION CODE	SOLUTION DESCRIPTION FOR ECONOMIZERS	INCENTIVE	
		$/kWh	$/kWt
AC-78487	Economized cooling using fluid coolers	$0.12	$150
AC-68473	Economizer - water side - add-on equipment[1]	$0.12	$150
AC-19789	Economizer - air side - add-on equipment	$0.12	$150
AC-56832	Economizer – Split DX System with VAV controls - Add-on Equipment	$0.12	$150

Source: Southern California Edison Energy Efficiency Solutions Directory, 32nd Edition, February 2021

Examples of Current Incentive Pricing- Sacramento Municipal Utility District (SMUD)

Air Conditioning, Refrigeration, and Controls

- **$0.15/kWh Energy Reduction Incentive**
- **Total incentive limited up to 50% of project cost or $100,000, whichever is less.**

Functional equipment, as designed and operated properly, serves the incentive baseline. Non-functional equipment uses Title-24 Performance as the incentive baseline.

Illustrative partial list (not a comprehensive) of qualifying measures:

Equipment Efficiency	• High efficiency chillers • Packaged HVAC equipment > 62 tons • Subsystem replacements (condensers, evaporators, cooling towers, compressors) • Direct or indirect evaporative coolers and precoolers • Water- or air-side economizers • CAV to VAV conversions
Controls	• Refrigeration evaporator fan controls • Demand controlled ventilation controls • Reset strategies (supply air temp, duct static, chilled water, etc.) • Optimized start/stop
Energy Management Systems	• Pneumatic to DDC conversions • New controls functionality
Variable Speed Drives	• Air handler fan VFDs • Chilled water, hot water, and condenser water pump VFDs • Cooling tower fan VFDs
Data Center Cooling Optimization	• Blanking panels • Hot aisle/cold aisle separation • CRAH/CRAC fan control strategies • Chilled water and supply air reset strategies • Water- or air-side economizers

Process Improvement

- **$0.15/kWh Energy Reduction Incentive**
- **Total incentive limited up to 50% of project cost or $100,000, whichever is less.**

Existing equipment's predicted energy consumption is used for the incentive baseline unless the equipment is non-functional or obsolete, in which case the industry standard for new equipment is used as the baseline.

Added load may be eligible for incentives if efficient equipment is purchased to support increases in manufacturing capacity.

Illustrative (not a comprehensive) list of qualifying efficiency measures:

- Large motor upgrades
- Variable-speed drives (e.g., on industrial fans, industrial pumps, and air compressor motors)
- Industrial process applications
- Industrial fan replacements
- Industrial pump replacements
- Process controls resulting in electric savings
- Exhaust hood and fan projects
- Dairy vacuum pumps/variable-speed drives
- Pulse cooling devices for injection molding machines
- Injection molding machines

LED Lighting and Controls

- **$0.10/kWh Energy Reduction Incentive**
- **Total incentive limited up to 50% of project cost or $100,000, whichever is less.**

Existing wattage is used as the baseline for these incentives.

- Interior and exterior general illumination lighting eligible for SMUD's Express Energy Solutions program is not eligible for Custom program incentives.
- Fixtures and retrofit kits must be DLC certified
- Lighting must meet or exceed Title 24 standards to be eligible
- Specialized lighting used for industrial or agricultural purposes is eligible for Custom program incentives.

Source: Sacramento Municipal Utility District, Custom Retrofit Incentives

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Examples of Current Incentive Pricing Custom Projects- Northeast & Midwest

- New England IOU's-14 cents/kWh saved
- Pennsylvania Electric Company-10 cents/kWh saved

Custom	Incentive	Unit
CHP	$0.10	kWh Saved
Custom Strategic Energy Management	$0.14	kWh Saved
Custom Measures Compressed Air, Demand Control Ventillation, Energy Management System, HVAC, Data Center, Lighting, Motors and Drives, Process, Refrigeration, Retrocomissioning, Whole Building, Other	$0.10	kWh Saved

- Consolidated Edison NY-Variable by End Use and Location
- Detroit Edison MI- (.05 cents/kWh)
- Consumers Energy MI (.10 cents/kWh)
- Commonwealth Edison IL- per kWh varies by technology

Custom (not eligible for online application)

Specialty/new construction lighting		$0.07 per kWh saved
Closet-to-colocation		$0.10 per kWh saved
Wastewater treatment - aeration improvements associated with blowers	without dissolved oxygen controls	$0.12 per kWh saved
	with dissolved oxygen controls	$0.21 per kWh saved
Data Center New Construction		$0.07 per kWh saved
All other custom (includes combined heat & power)		$0.12 per kWh saved

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Examples of Current Incentive Pricing Custom Projects- Texas & Southeast

Austin Energy-Demand Based, Varies by end-use

Customer Driven. Community Focused.

COMMERCIAL REBATE PROGRAM REBATE SUMMARY

TECHNOLOGY	REBATE LEVEL ($/kW unless otherwise noted)
Air Conditioning (Direct Expansion)*	$660/kW
Air Conditioning (VRF Multi-Split)*	$660/kW
Air Conditioning (Chillers)*	Air Cooled: $300/kW Water Cooled: $450/kW
Cooling Towers	$300/kW
Commercial Kitchen	See 'Commercial Kitchen Equipment' webpage
Custom Technology	Process Change: $200/kW Custom Equipment: $350/kW
Electronically Commutated Motors (ECM)	$350/kW
Energy Recovery Ventilators (ERV)	$300/kW
Guest Room Controllers	$50 per device installed
Heat Pump Water Heaters	$800 per unit installed
Lighting	See 'Lighting' on page 2
New Construction	New Construction Lighting: $125/kW All other technologies: same $/kW as standard retrofits
Plug Load Controls	$25 per device installed
Roof/Ceiling Insulation†	$0.20/sq ft
Spray-on/Paint-on Reflective Roof Coating†	$0.15/sq ft
Thermal Energy Storage (TES)	$350 per kW
Transformers	$300/kW
Uninterrupted Power Supplies (UPS)	$300/kW
Variable Frequency Drive (VFD)	$400/kW + $50 if installed with CEE Tier 2 motor
Window Treatment†	SHGC 0.37 or Less: $1.00/sq ft SHGC 0.50 – 0.38: $0.60/sq ft
New Windows†	SHGC 0.27 or Less: $1.00/sq ft
Smart Thermostats	$25 per device installed

Georgia Power-$.10/kWh

This program offers incentives for a variety of custom applications, including but not limited to

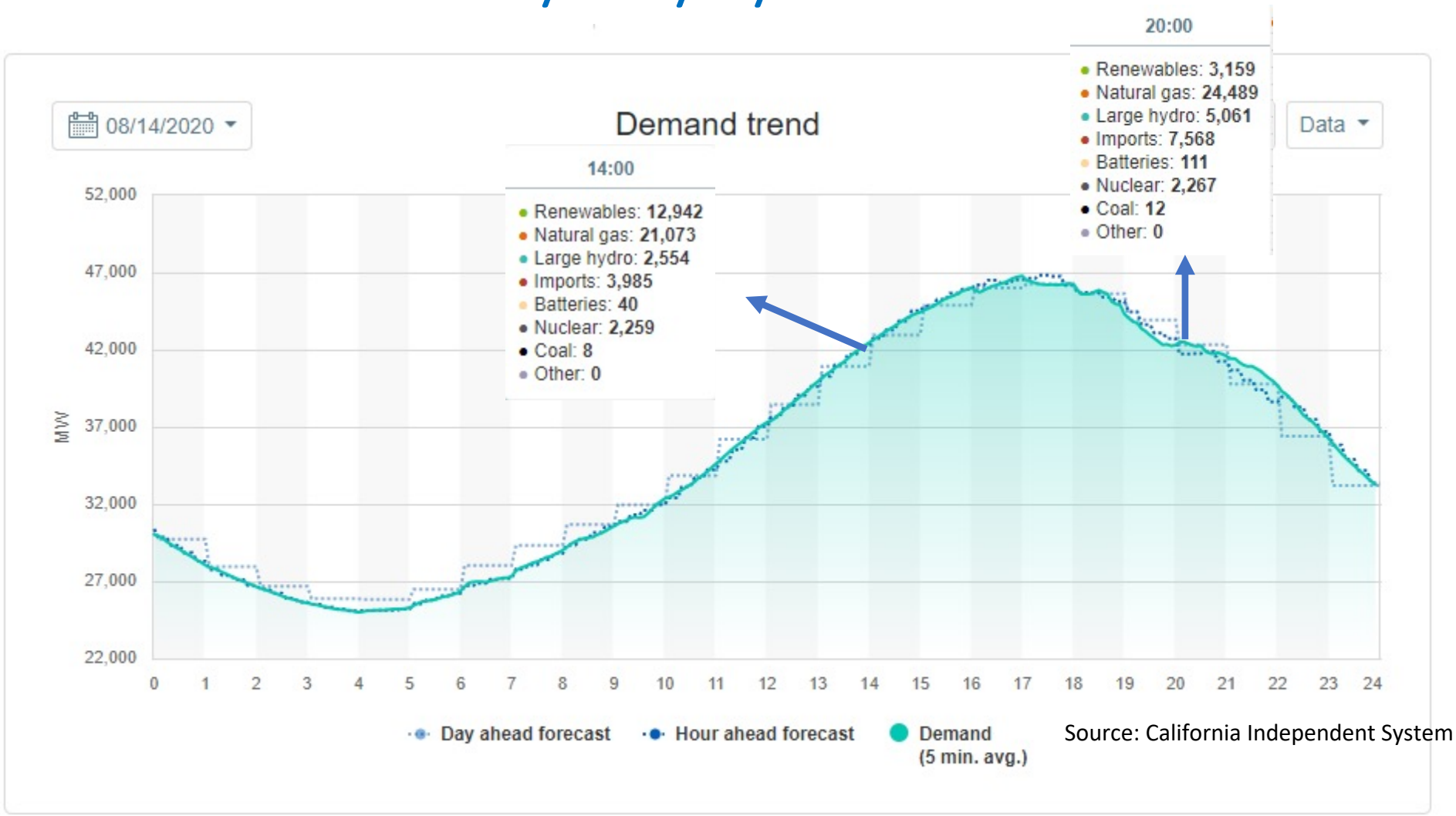
- High efficiency chillers
- HVAC control strategies such as chiller plant optimization or ventilation optimization
- Advanced lighting controls
- Variable refrigerant flow systems greater than 65,000 Btu/h
- Refrigeration system improvement such as Q-sync motors, high speed doors, floating head pressure or defrost controls
- Computer room air conditioning or air handler units

Florida Power & Light-Negotiated

You can qualify for a business custom incentive if your idea:

- Will trim at least 25 kilowatts from FPL's summer peak demand (June through September)
- Differs from other FPL conservation programs
- Passes the Florida Public Service Commission-specified cost-effectiveness tests
- Is not a power generation technology, proposal based on fuel switching or wheeling or a technology currently being evaluated by FPL

Carbon-Intensity of Generated Electricity May Vary by Time



Source: California Independent System Operator

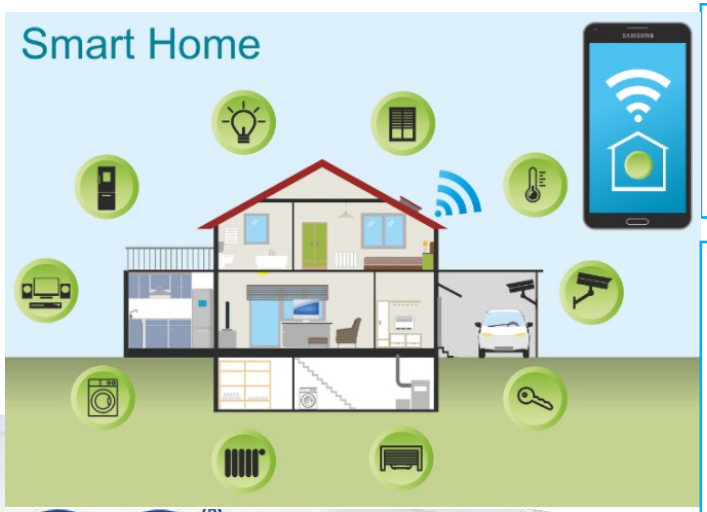
How Does this Movie End?

Real Time Pricing for Electricity

Enabled by Smart Meters at the Enterprise Level

Influenced by Locational Costs of Distribution System

Fine Tuned by End-Use Measurement



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Concluding Thoughts

- Value of Energy Efficiency IS Time/Season Dependent driven by Avoided Cost Components
- Energy Efficiency Savings Most Value at Load Peak
- If End-Use Load Curve Mimics System Curve Measure has High Time Value Premium
- Up-Front Incentives Too Blunt for Time Valuing EE
- Unbundling of End Uses and Real Time Incentives is the path forward for more efficient time valuing of EE

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Thank you!

APPENDIX

Key References

1. *Do Energy Efficiency Investments Deliver at the Right Time?; Justin Boomhower and Lucas Davis, American Economic Journal: Applied Economics 2019, 12(1): 115–139*

2. *Time-Varying Value of Energy Efficiency*, Natalie Mims, Tom Eckman, and Chuck Goldman; July 10, 2017; This work was supported by the DOE Office of Energy Efficiency & Renewable Energy Building Technologies Office under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

3. *Evaluation of financial incentives for green buildings in Canadian landscape*; Anber Rana a, Rehan Sadiq a,*, M. Shahria Alam a, Hirushie Karunathilake a,b, Kasun Hewage a; a *School of Engineering, University of British Columbia (Okanagan Campus), 1137 Alumni Avenue, Kelowna, BC V1V 1V7, Canada* b *Department of Mechanical Engineering, University of Moratuwa, Katubedda, Moratuwa, 10400, Sri Lanka;* ***Renewable and Sustainable Energy Reviews;*** Volume 135, January 2021, 110199

4. *Energy Management Handbook, 9th Edition*, Stephen Roosa, Steve Doty, Wayne C. Turner, CRC Press

5. *How Changes to Time of Use Rates are Impacting Commercial & Industrial Customers, James Dodenhoff, Association of Energy Engineers Monthly Webinar Presentation, October 2020*

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Areas for Future Research and Study

1. Avoided cost analysis, especially around Transmission & Distribution
2. Effectiveness of incentives/rebates in driving specific energy efficiency purchases
3. Causal impact of targeting demand reduction
4. Impact and variability in Total System Load Curves over time and impact on time-dependent value
5. Comparison of ISO markets vs. non ISO markets and impact on time value