ComEd Residential, Commercial and Industrial Saturation/End-Use Research, Market Penetration and Potential Study

Itron, Inc.
Dunsky Energy Consulting
Energy Resources Center, University of Illinois Chicago
Trend Tech Energy Services, LLC

February 6, 2020

PRESENTATION OUTLINE

- Residential primary data collection methods and results (50 mins)
- Commercial primary data collection methods and results (50 mins)
- Industrial data collection methods and results (20 mins)

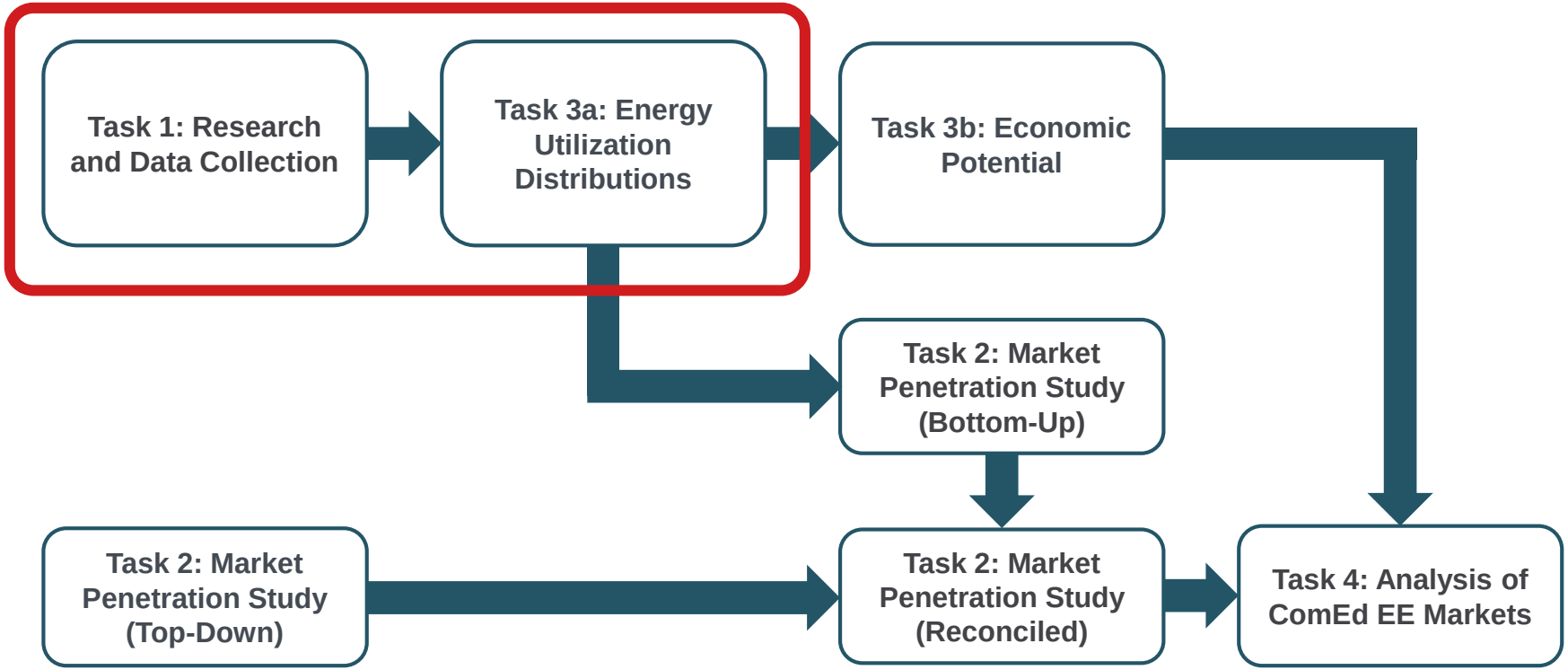
RESEARCH GOALS AND OBJECTIVES

As stated in the RFP…

1. Collect detailed baseline data for as many market segments as possible
2. Develop distributions of end-use energy consumption by segment
3. Develop trend analysis of EE market penetration for key technologies
4. Estimate economic potential of EE
5. Characterize incremental cost-effective potential that exists beyond expected market trends
6. Provide a concise summary of key findings
7. Deliver all primary and secondary data in an easy-to-use format that allows combination with other internal and external datasets

PROJECT SCOPE & STATUS

Overview of Task-Level Workflow and Interdependencies



OVERVIEW OF ITRON TEAM

Composition and Roles

- **Prime bidder**
- Overall project management
- Lead for:
  - Task 1 (Primary Data Collection)
  - Task 3a (Energy Utilization Distributions)
  - Task 4 (Analysis of ComEd EE Markets)

- **Subcontractor**
- Lead for:
  - Task 2 (Market Penetration Study)
  - Task 3b (Economic Potential)
- Support for:
  - Task 4 (Analysis of ComEd EE Markets)

TREND TECH ENERGY SERVICES

Green Home Experts

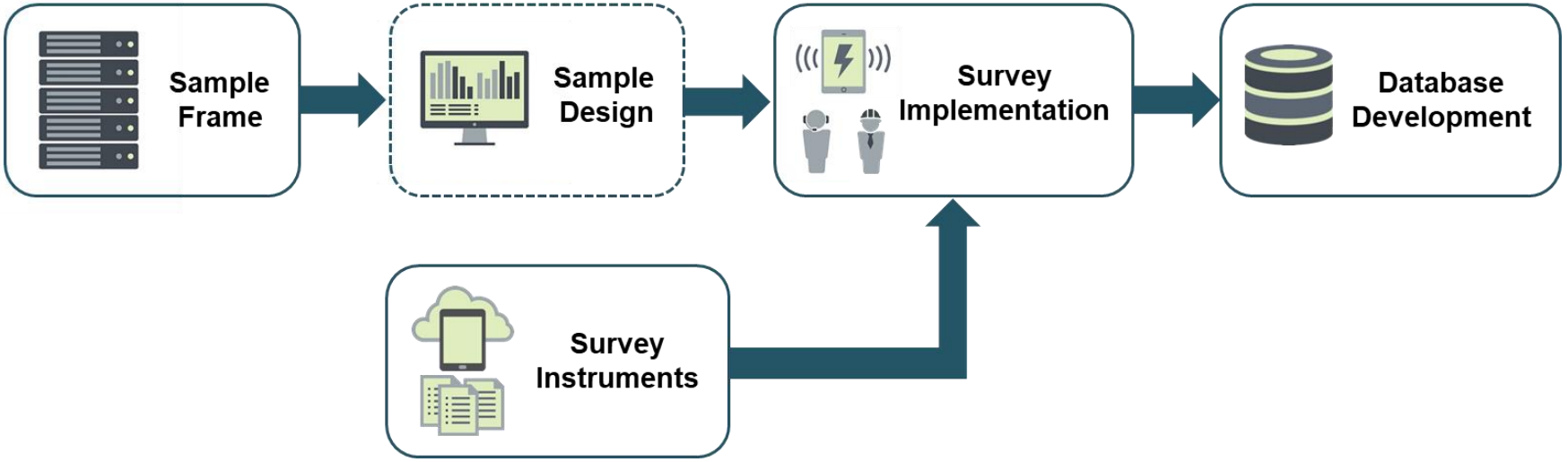
- **Subcontractors**
- Support for:
  - Task 1 (Primary Data Collection)

RESIDENTIAL PRIMARY DATA COLLECTION

Methods and results

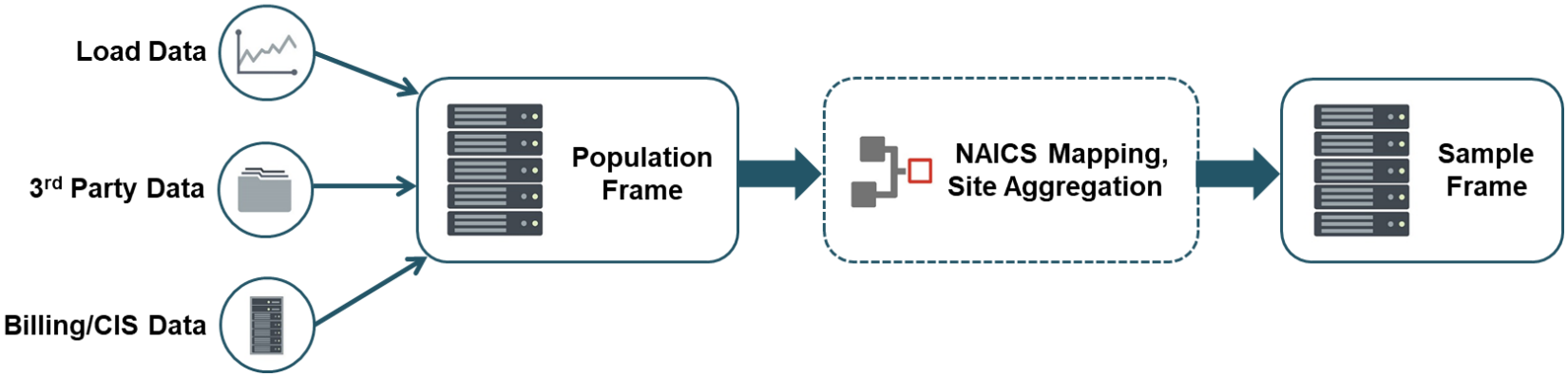
RESIDENTIAL PRIMARY DATA COLLECTION

Overview of Key Activities



RESIDENTIAL PRIMARY DATA COLLECTION

Sample Frame Development



- Itron's (formerly Silver Spring Networks') ***Operations Optimizer*** already fully deployed at ComEd
- ***Operations Optimizer*** contains billing data (2007+), AMI data (2010+), up-to-date CIS, plus:
  - Tax assessor data for most residential accounts (all of Cook County)
  - Grid connectivity mapping

RESIDENTIAL PRIMARY DATA COLLECTION

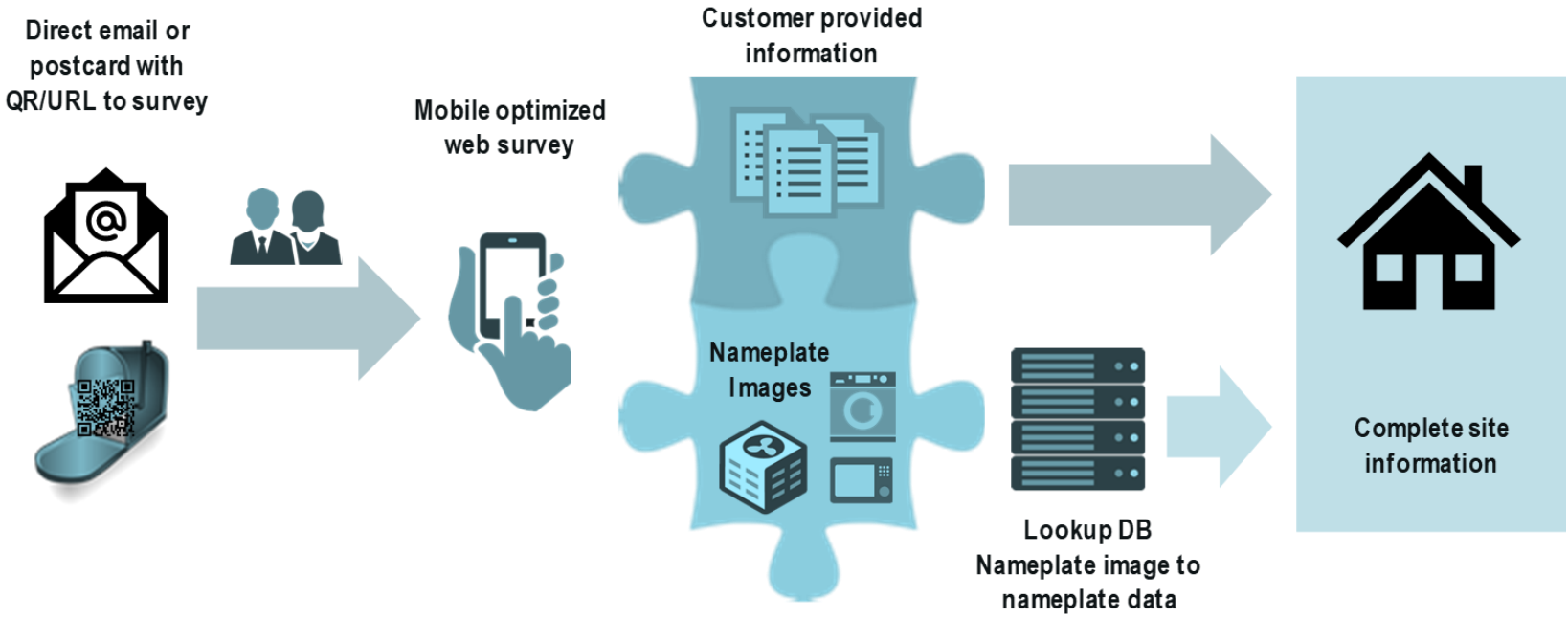
Sample Design

- **Developed the following sample design variables in collaboration with ComEd:**
  - Building type (Single-family, Multi-family)
  - Whole-home consumption (Low, Medium, High)
  - Location (Chicago, Suburban, Other/Rural)
  - Income Eligibility (Low income eligible, Non-low income eligible)

- **36 total sample strata:**
  - Population numbers in certain strata are small (e.g. all MF/Rural strata)

RESIDENTIAL PRIMARY DATA COLLECTION

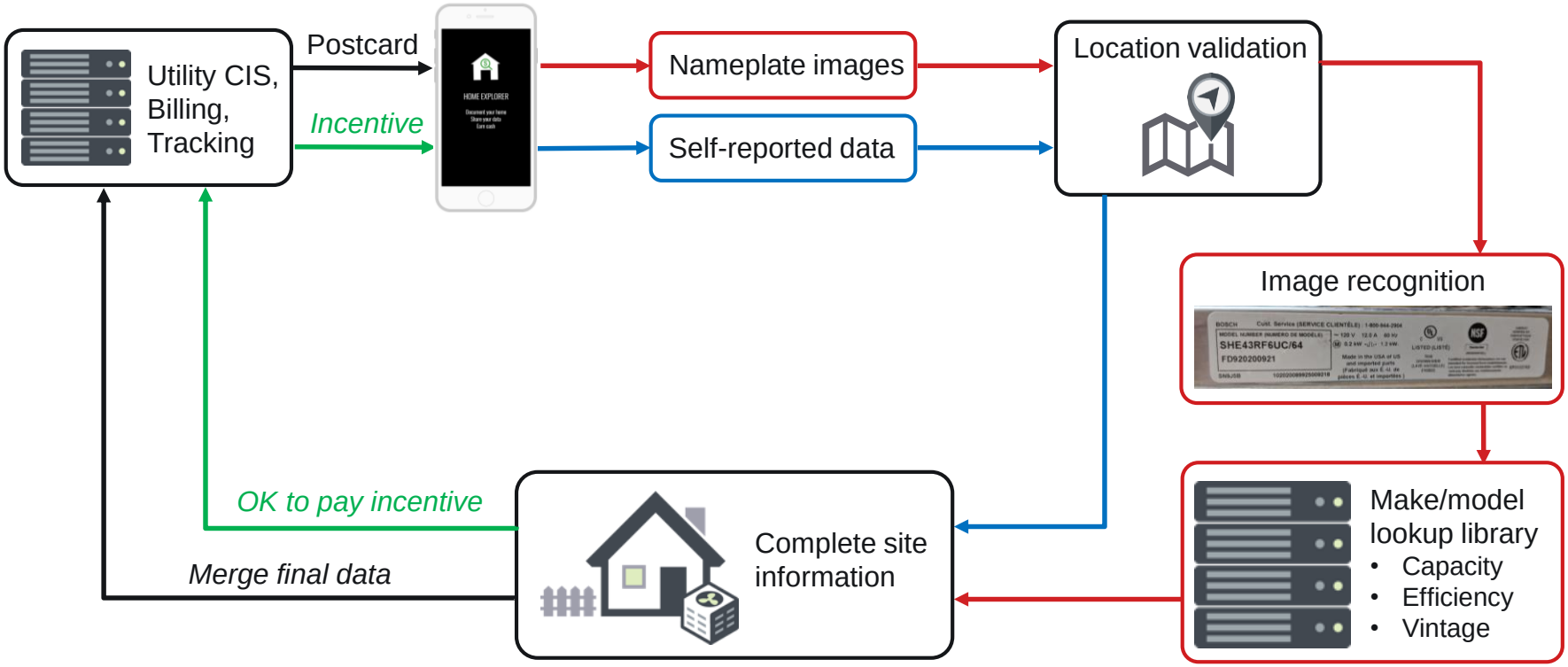
Multi-Modal Survey Design



WHY USE A MULTI-MODAL SURVEY DESIGN?

- **Several fundamental tradeoffs between sample size and depth/accuracy of data collection**
  - Standard web or telephone surveys: cheap (large sample sizes), but unreliable data on end-use equipment characteristics (e.g. capacity, rated efficiency) due to lack of customer knowledge and/or user recall error
  - On-site surveys: accurate data on equipment characteristics, but expensive (small sample sizes)
- **Itron's multi-modal approach designed to overcome these tradeoffs by:**
  - Using mass mailings of postcards to recruit customers into web survey ($25 Amazon.com gift card incentives)
  - Optimizing the web survey for mobile devices
    - Allows survey to leverage device mobility for room-by-room lighting inventories
    - Allows survey to leverage technologies available on mobile devices (cameras, location services)
- **Key features of mobile-optimized survey:**
  - "Self-report" questions limited to variables that customers know with a high degree of accuracy (e.g. home size, occupancy, rent vs. own, etc.)
  - Equipment characteristics collected by having customers take and upload photos of their equipment nameplates
- **Bottom line: approach generates "on-site quality" baseline information at the cost and scale of standard telephone surveys**

RESIDENTIAL SURVEY BACK OFFICE WORKFLOW



RESIDENTIAL PRIMARY DATA COLLECTION

Survey Implementation

- **Postcards m[illegible] surveys**
- **Objectives o[illegible]**
  - Verify accurac[illegible]
  - Verify accurac[illegible]
- **First wave =**
  - Offered additio[illegible]
  - >60 customers[illegible]
  - Completed 46[illegible]
- **Bottom line f[illegible]**
  - 97% of self-re[illegible]
  - 94% of model numbers derived from nameplate images verified to be correct and at customer premise
- **Second wave = 30,000 postcards (mailed mid-May)**

Overall participation in web survey:

- ~2,000 click-ins
- ~3,000 nameplate images submitted
- Analytic dataset varies from ~1,700 to ~800 (depending on the end-use in question) due to attrition from beginning to end of survey

SURVEY DISPOSITION BY STRATA CATEGORY

	Strata Group	N Survey	% Survey	% Pop
Housing Type	Single Family	1,674	81%	74%
	Multi Family	396	19%	26%
Geography	Chicago	674	33%	29%
	Suburban	807	39%	69%
	Other	589	28%	2%
Usage	High	701	34%	34%
	Medium	779	38%	33%
	Low	590	29%	33%
Income Level	Non-Low Income	1,364	66%	58%
	Low Income	706	34%	42%

RESULTS OUTLINE

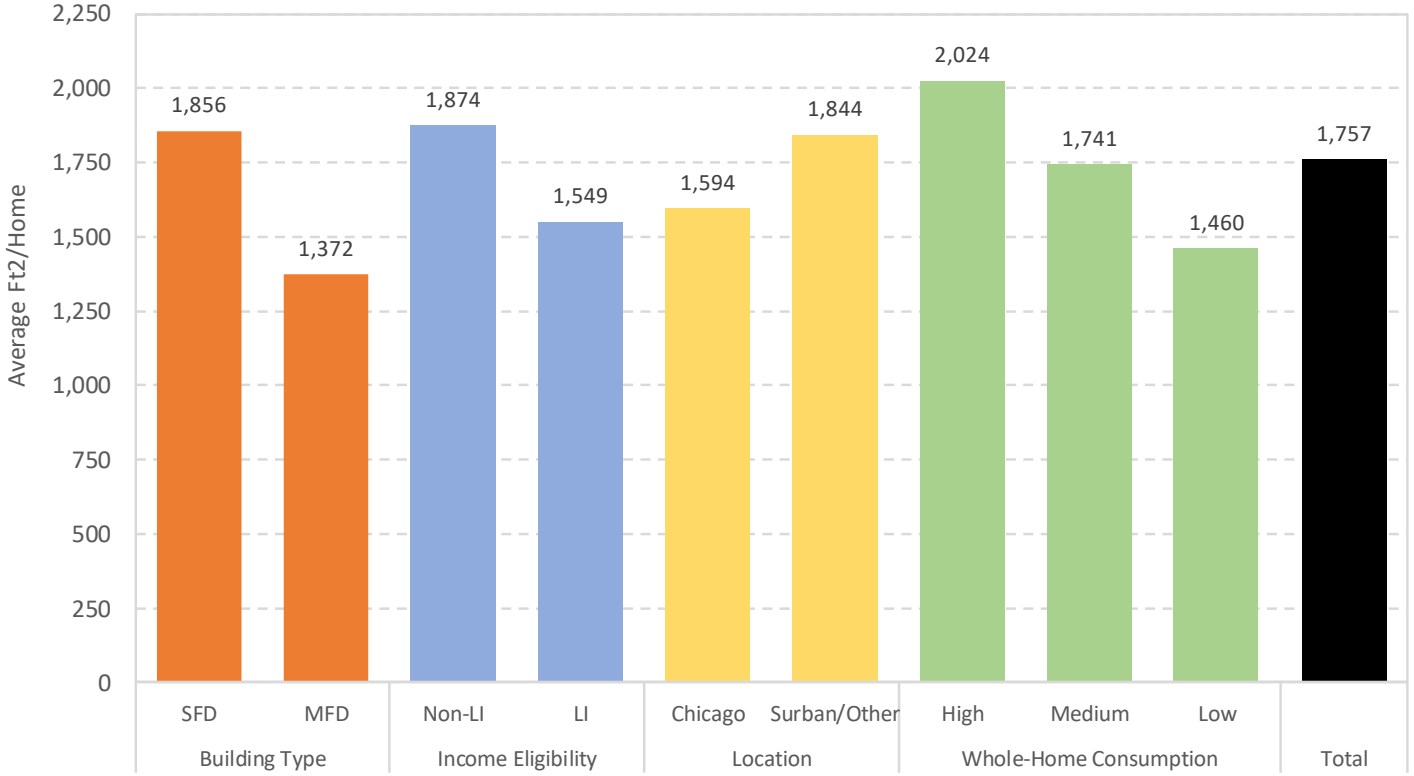
…in case we're already running behind schedule

- Household characteristics (3)
- Building envelope (2)
- Space cooling (11)
- Space heating (3)
- Thermostats (2)
- Water heating (2)
- Laundry appliances (4)
- Kitchen appliances (6)
- Interior lighting (3)
- Exterior lighting (1)
- Dehumidifiers & air purifiers (2)
- Water fixtures (1)
- Consumer electronics (2)
- Key findings (5)

- **All slides = 47**
- **Highlighted slides = 36**

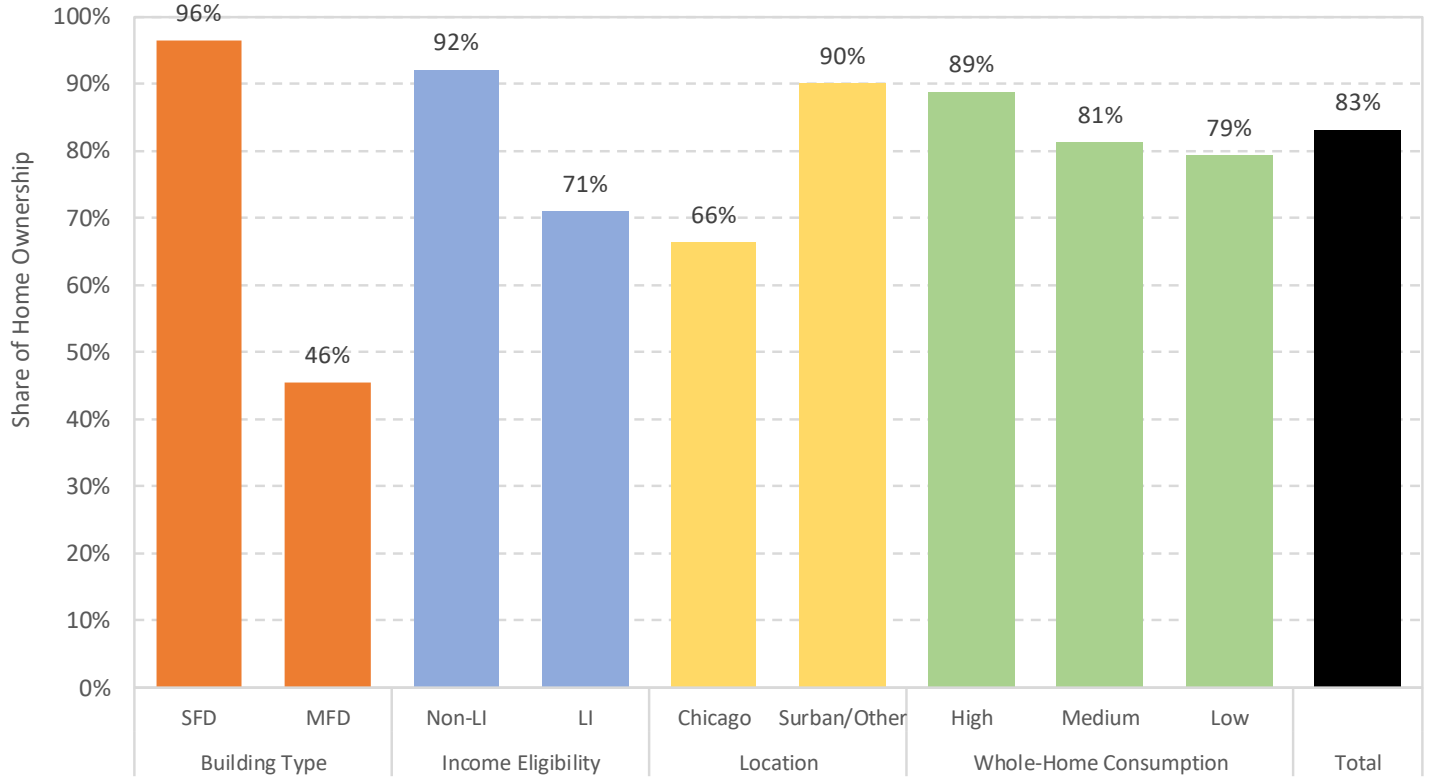
HOUSEHOLD CHARACTERISTICS

Average home size



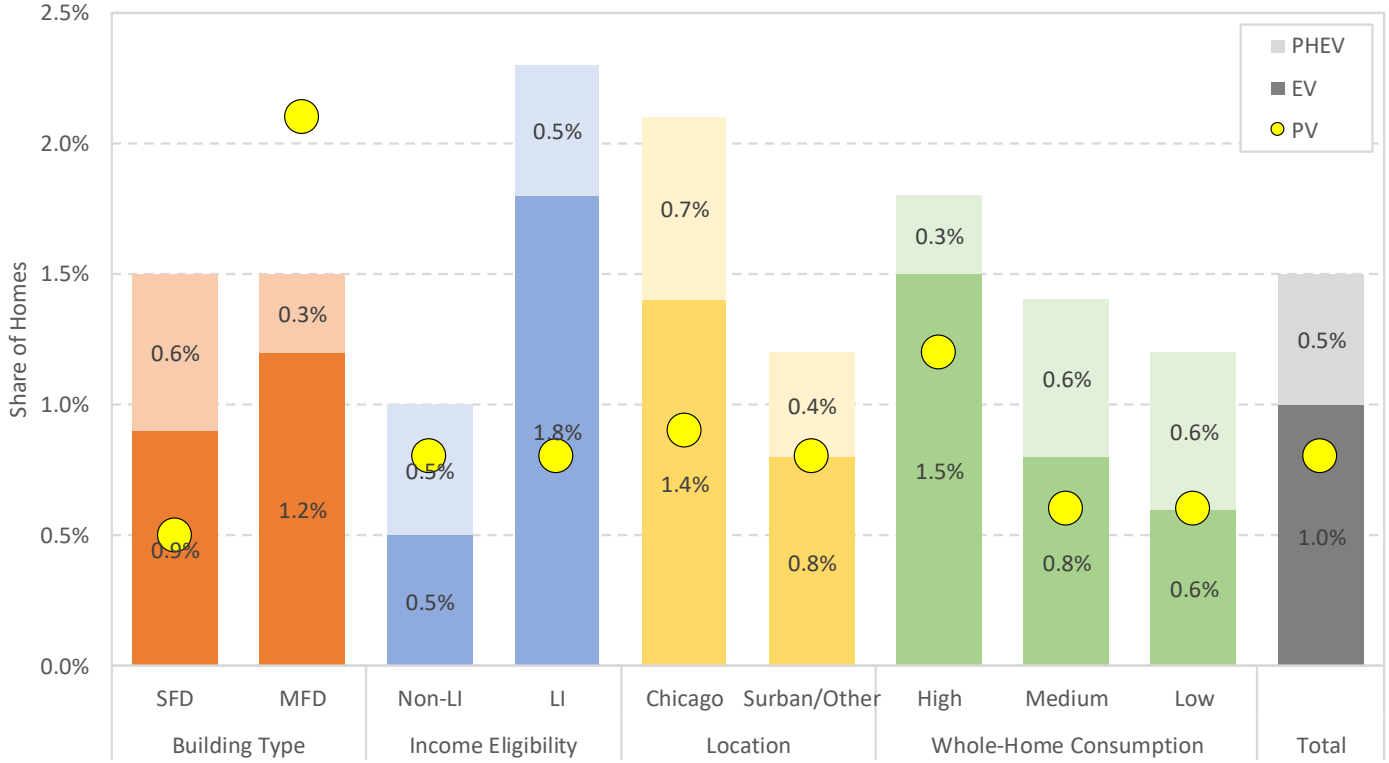
HOUSEHOLD CHARACTERISTICS

Home ownership



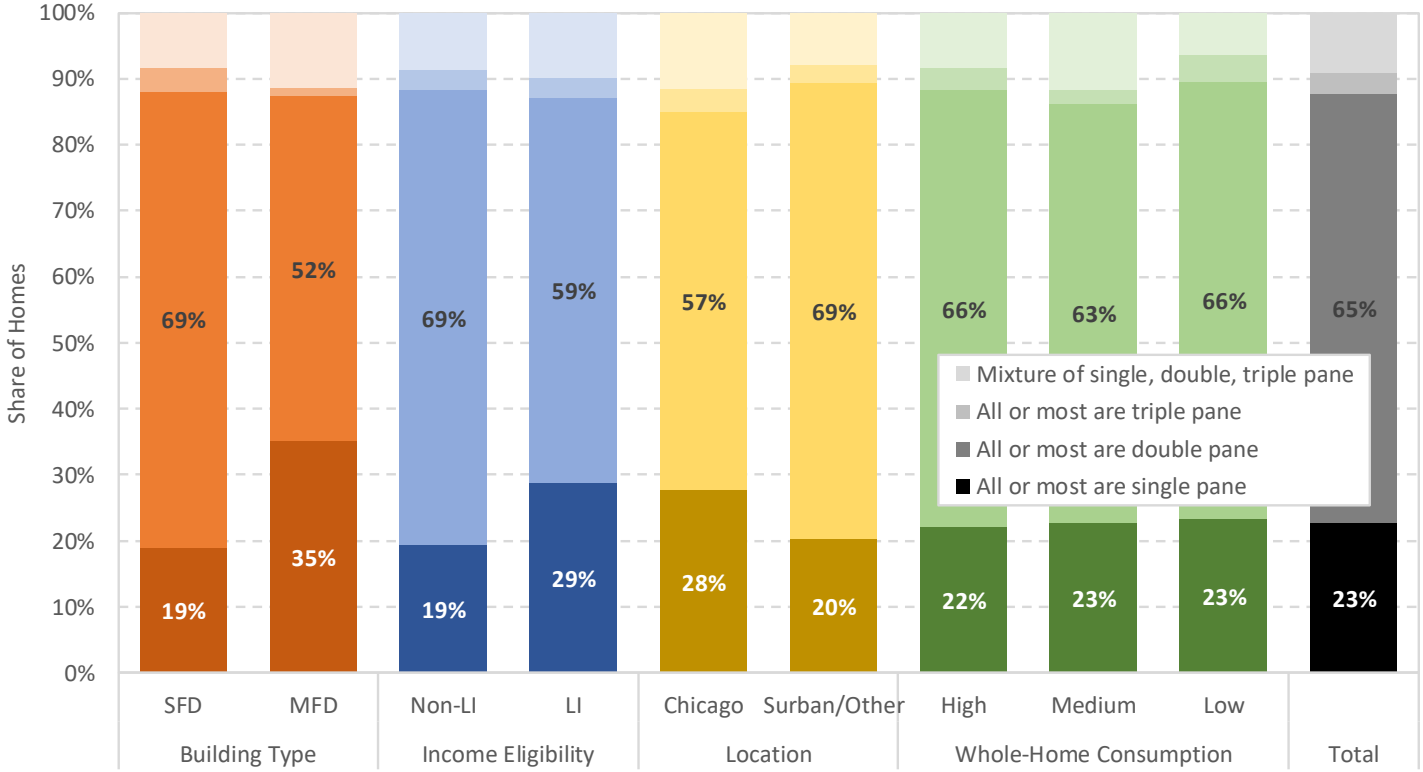
HOUSEHOLD CHARACTERISTICS

EV and PV penetration



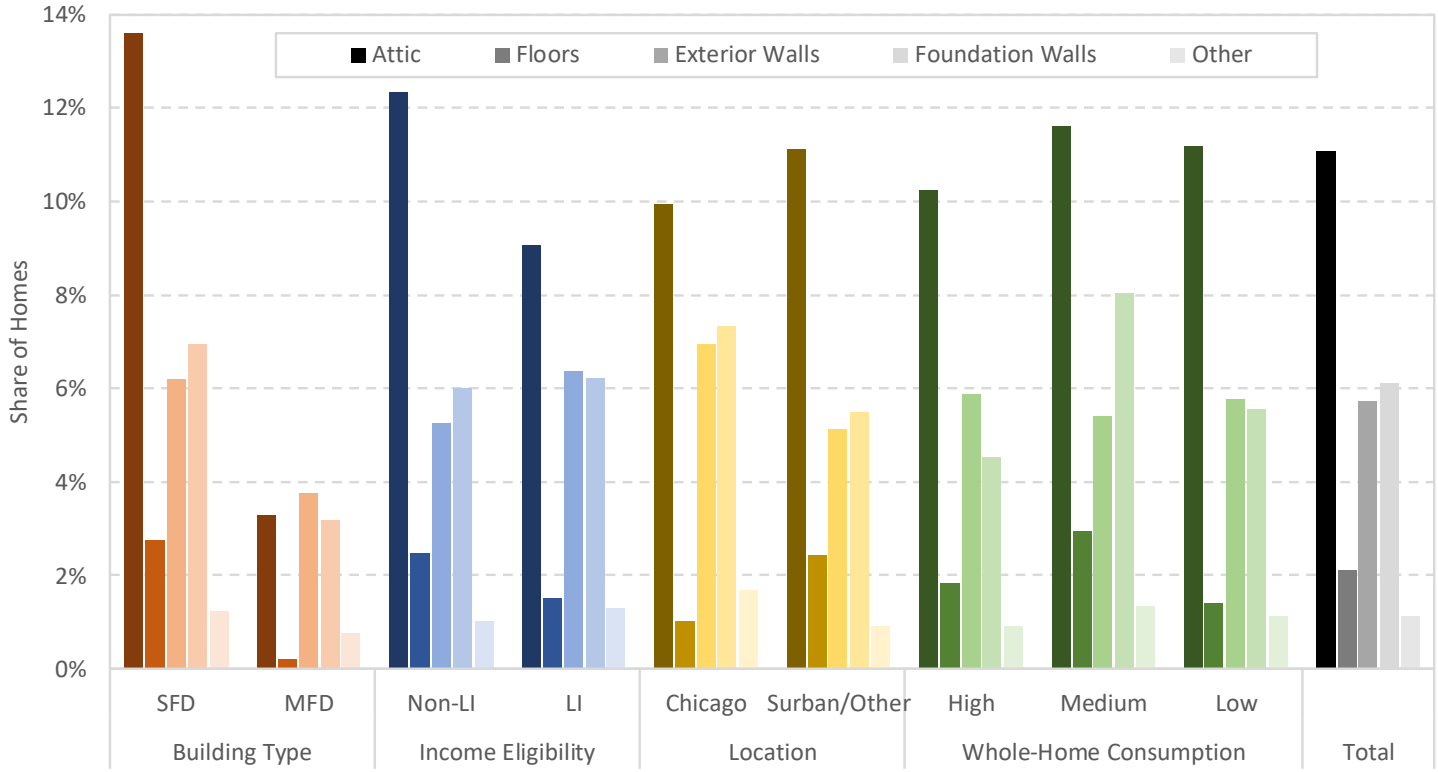
BUILDING ENVELOPE

Prevailing window type



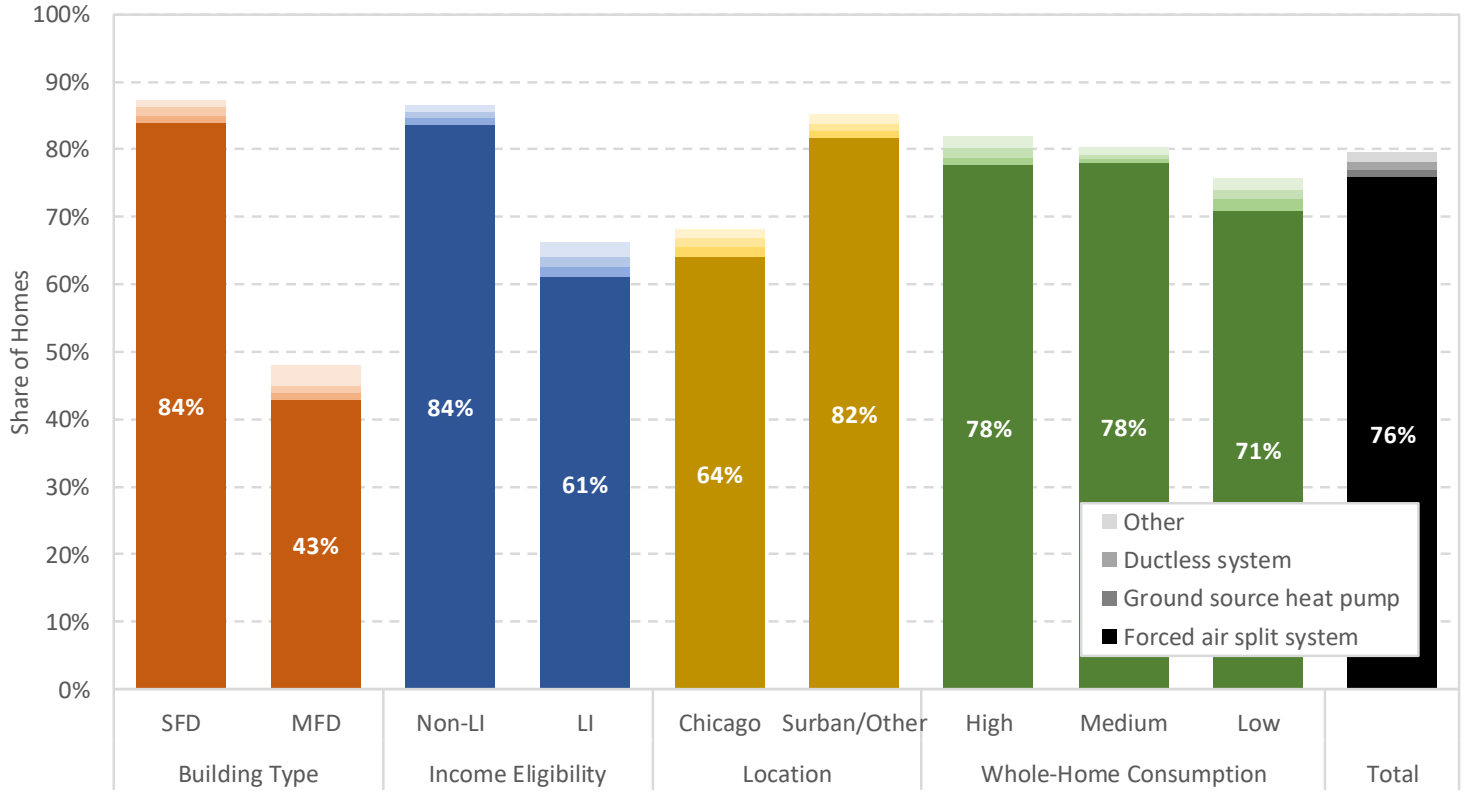
BUILDING ENVELOPE

Share of homes with recent insulation work



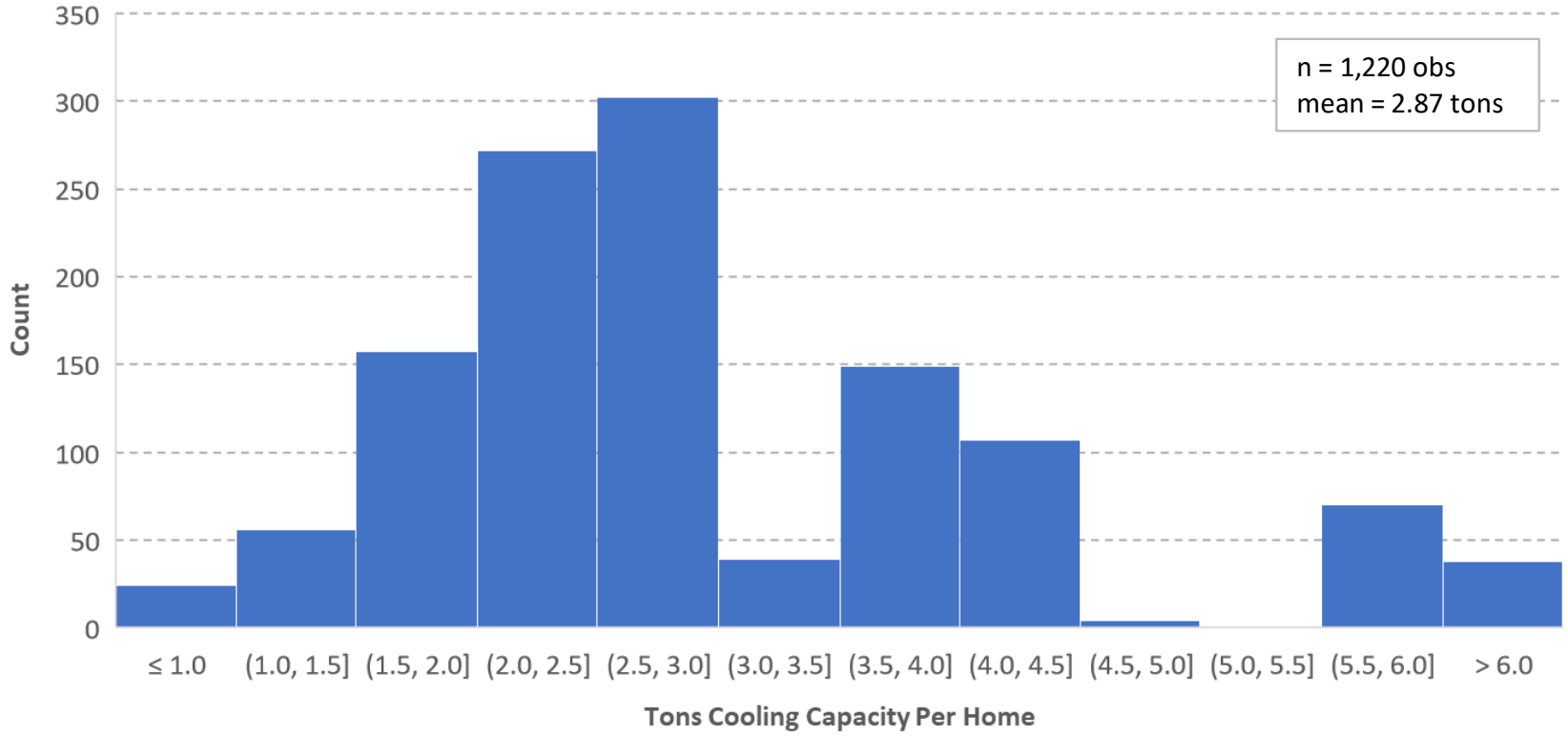
SPACE COOLING

Saturation of central cooling by system type



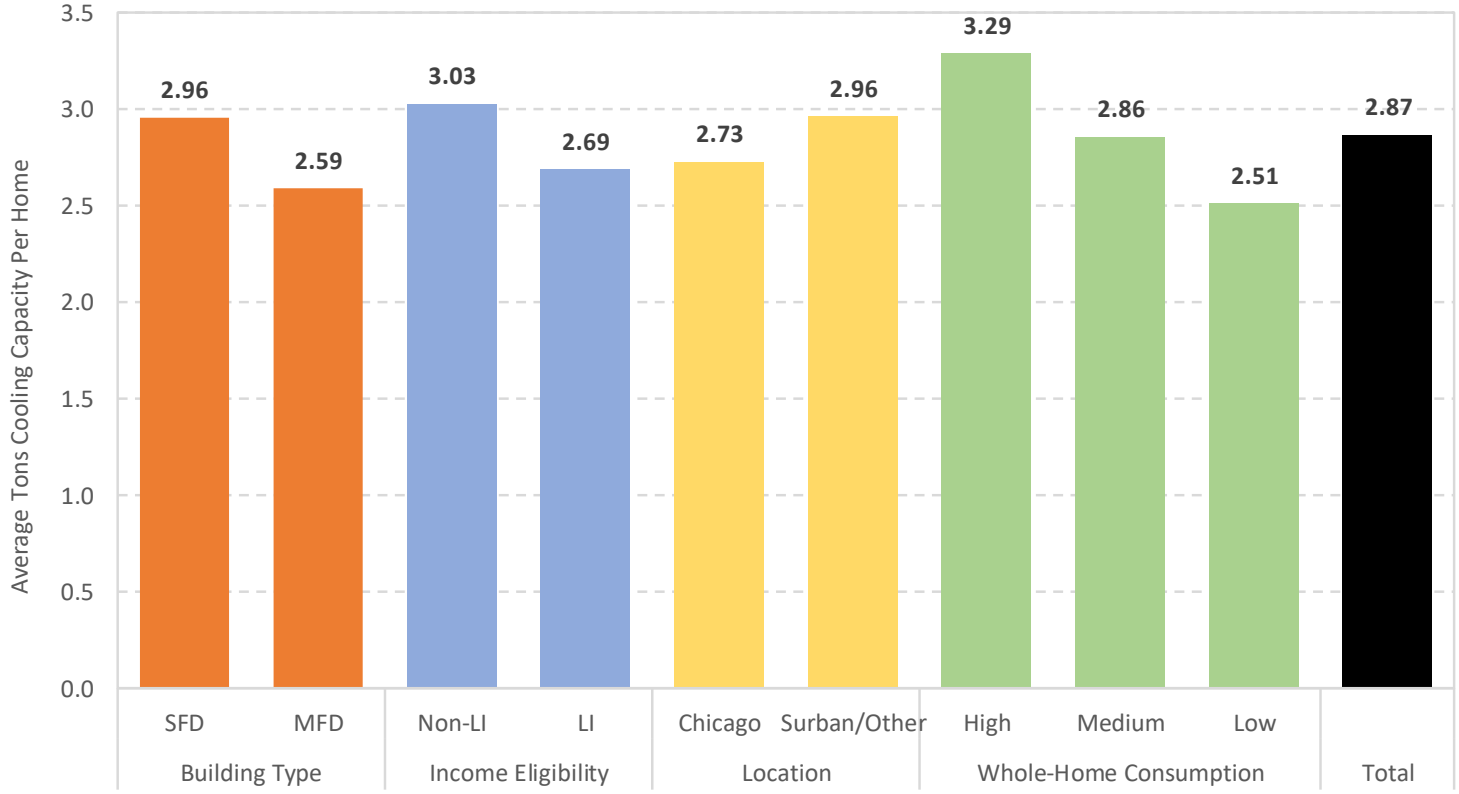
SPACE COOLING

Distribution of central cooling system capacity per home



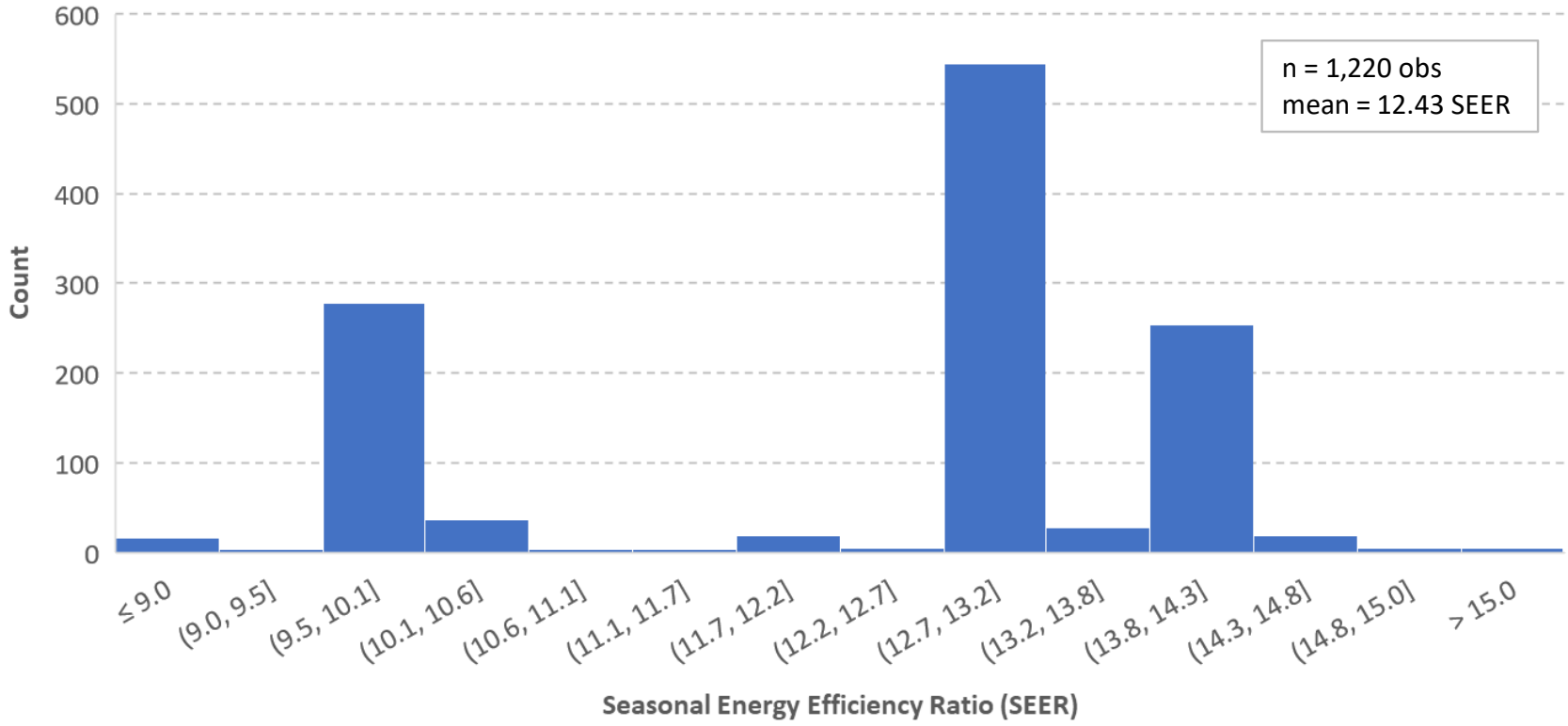
SPACE COOLING

Average central cooling system capacity per home



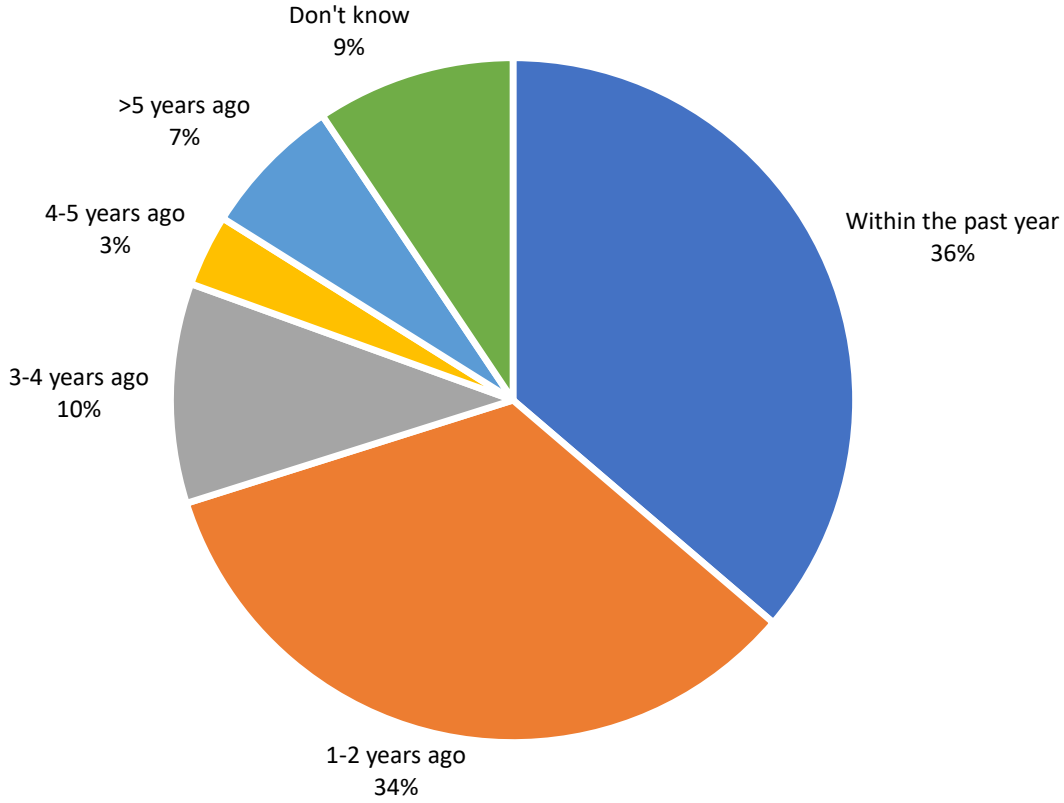
SPACE COOLING

Distribution of central cooling system rated efficiency



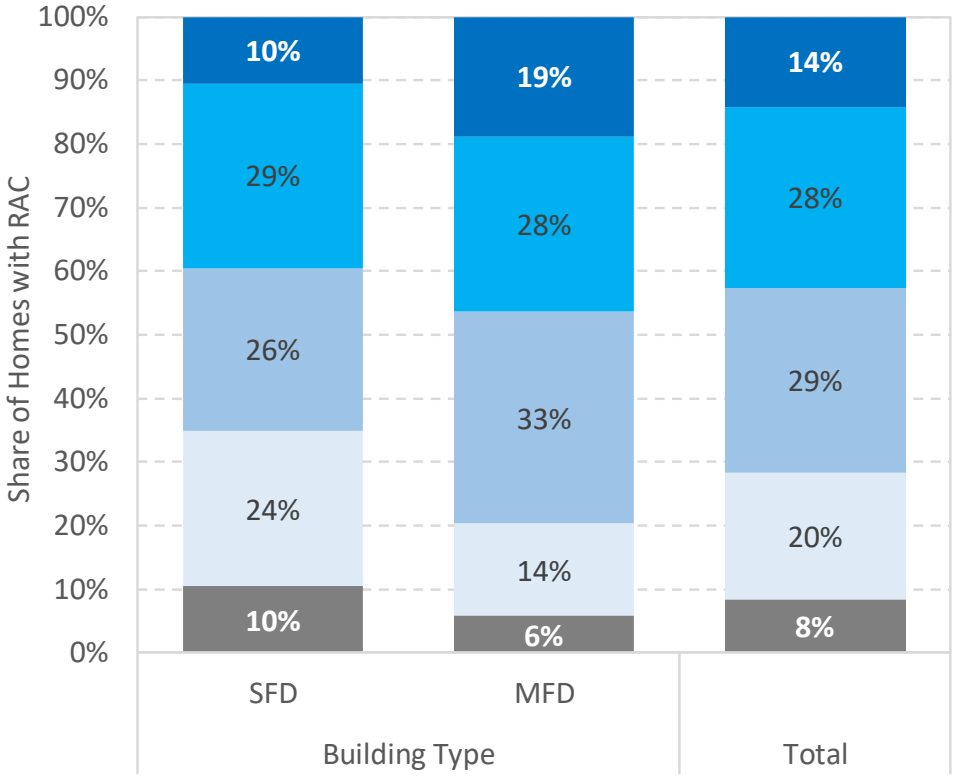
SPACE COOLING

Central cooling systems maintenance



SPACE COOLING

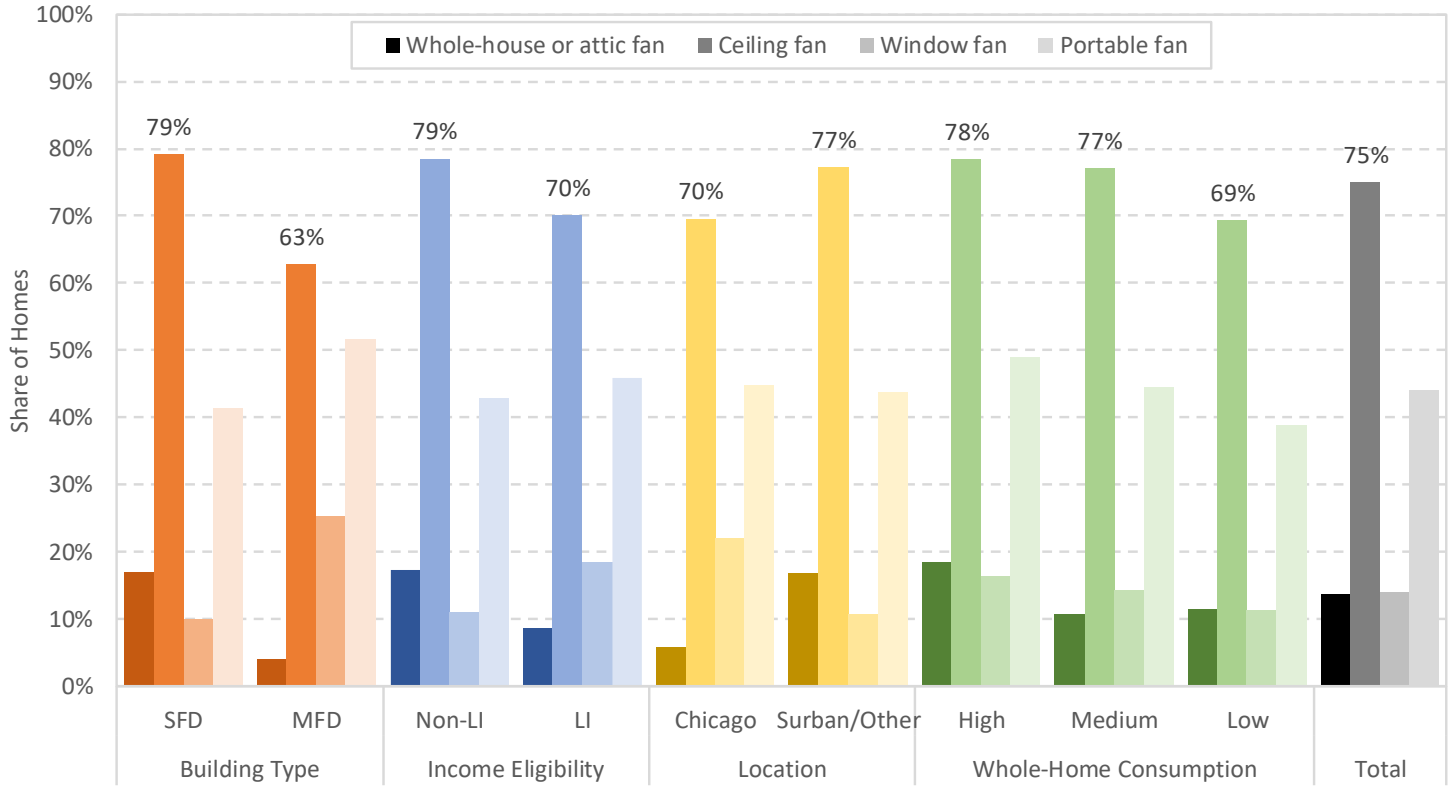
Room cooling saturation, average EER, and usage



Segment	Saturation	Average Rated EER	Share of Units <6 years old
SFD	10%	10.16	49%
MFD	40%	10.44	49%
Total	18%	10.32	49%

SPACE COOLING

Saturation of fans used for room cooling



SPACE COOLING

Utilization analysis

- Despite collecting data to characterize distribution of rated efficiency and capacity of space cooling equipment, space cooling energy consumption also greatly impacted by building envelope performance and customer behavior
  - Result is that space cooling consumption varies more widely (at the customer-level) than any other major electric end use
- In turn, analyzing cost-effectiveness of space cooling measures in aggregate (e.g. when estimating economic potential) can introduce significant **“aggregation bias”**
  - When point averages that indicate a given measure is not cost-effective for a given segment, when in fact it is cost-effective for a significant portion of that segment
- ComEd expressed a strong interest in using data collection and analysis approaches designed to minimize aggregation bias wherever possible
  - For most major residential end uses, we can adequately characterize the distribution of end-use energy consumption based on large samples of rated capacity and efficiency data
  - For space cooling, we augmented our rich data set with a dedicated analysis designed to characterize the distribution of space cooling energy consumption using two main analytic frameworks – **load disaggregation and cluster analysis**

SPACE COOLING

Utilization analysis

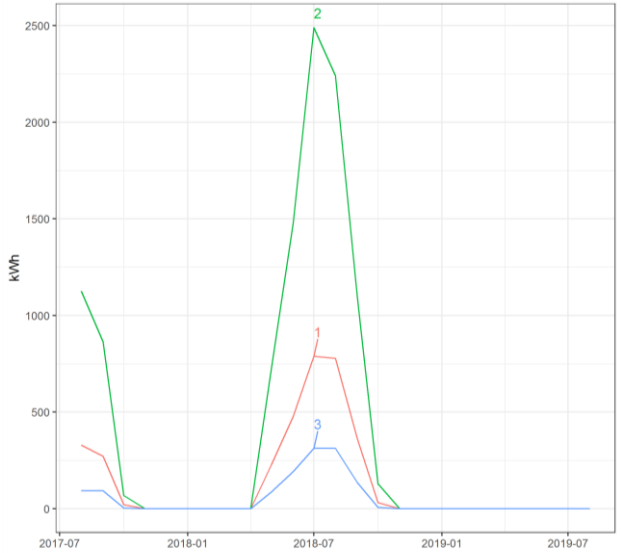
- Itron's Operations Optimizer data analytics platform include a load disaggregation module
- OO combines statistical regressions of AMI and weather data with physics-based calculations that take into building square footage and vintage (available from tax assessor data) to estimate load associated with space cooling
  - Enabled OO's load disagg module on a one-time basis to generate space cooling estimates for each of the customers that responded to our web survey
  - Modified load disagg algorithm to use customer-specific CAC capacity and SEER values as inputs
- Used modified algorithm to generate customer-specific space cooling consumption estimates that are calibrated to actual customer load, home size, home vintage, and CAC capacity and SEER (1,277 customers total)

- Next objective was to identify the best way to group customers such that the aggregate results for those groups adequately reflected the full distribution of space cooling consumption
- Used k-means cluster analysis to characterize distribution of space cooling into 3, 6, 9, and 12 clusters

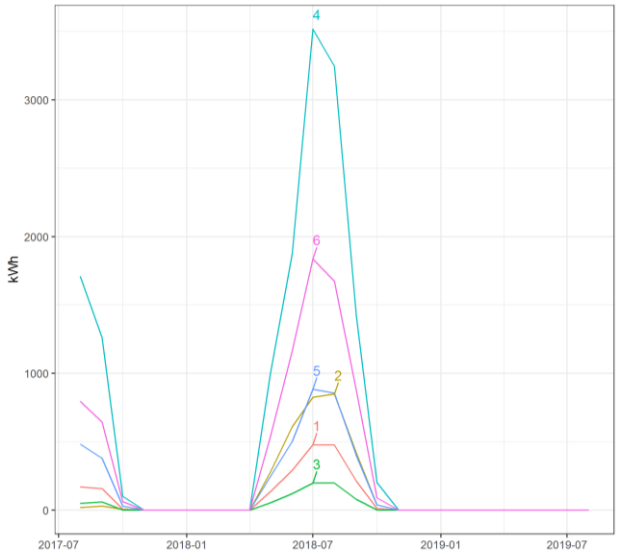
SPACE COOLING

Utilization analysis

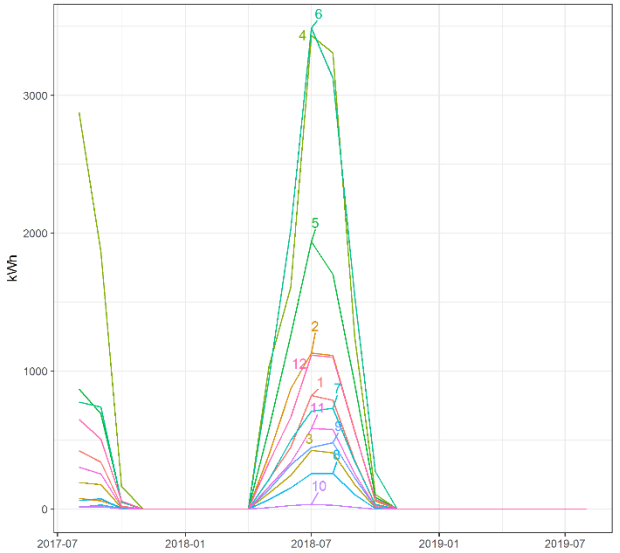
3 Clusters



6 Clusters



12 Clusters



SPACE COOLING

Utilization analysis

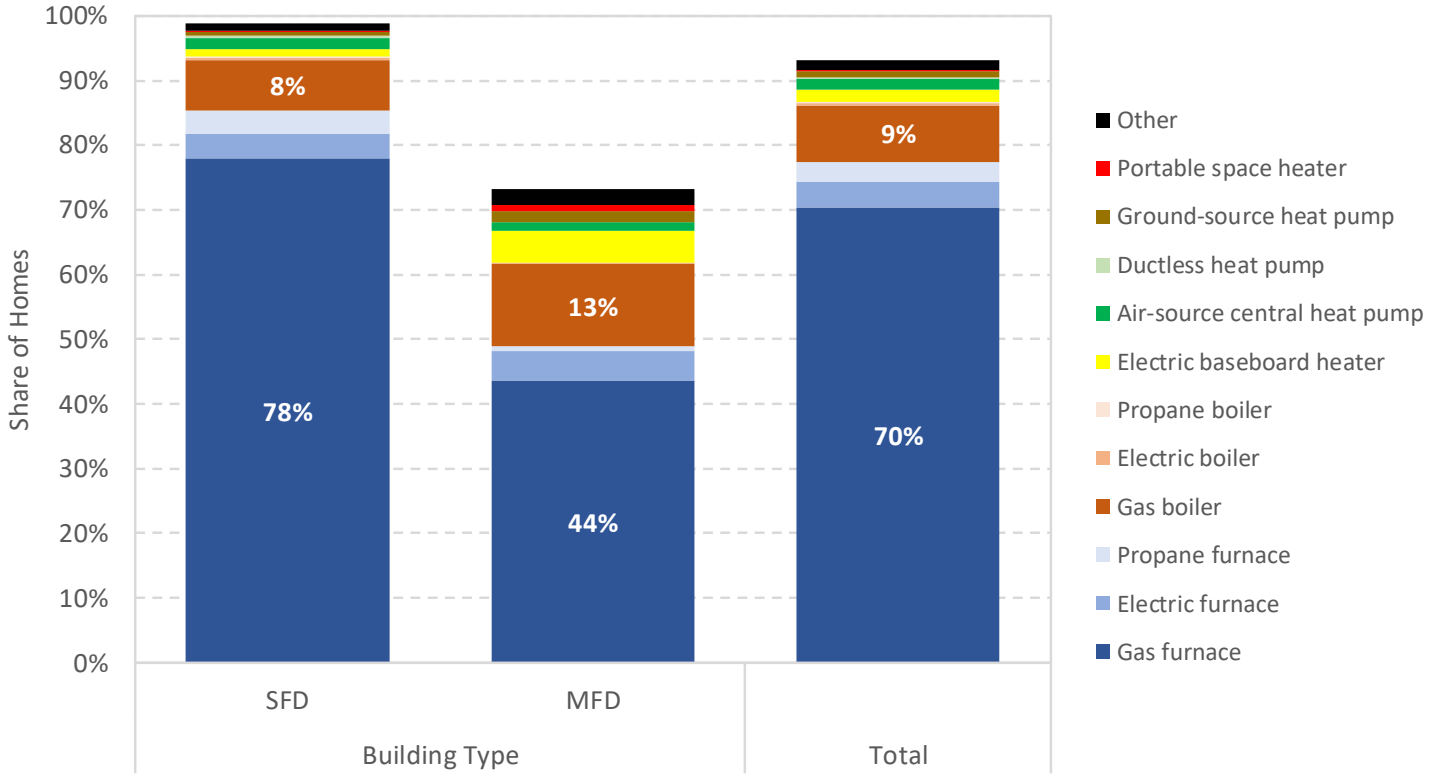
- Primary objective of cluster analysis was to provide a data-driven basis to define segments for potential modeling that minimized aggregation bias for space cooling measures
- Analyzed characteristics of customers in each cluster to identify variables in our sample frame that best explain differences between clusters
  - Building type (SFD, MFD)
  - Whole-home consumption (H, M, L)
  - Home size (<2,000 ft2, >=2,000 ft2)
  - Low-income program eligibility
- Collapsed several segments with very low customer populations, similar average space cooling consumption, and/or similar market adoption barriers

- **Final segments for potential modeling (9):**

Segment	Avg CAC kWh/yr
01.SFD-H-<2Kft2-nonLI	3,054
02.SFD-H->2Kft2-nonLI	2,862
03.SFD-M-<2Kft2-nonLI	2,089
04.SFD-M->2Kft2-nonLI	1,799
05.SFD-L-nonLI	1,190
06.MFD-H-nonLI	2,208
07.MFD-M-nonLI	921
08.MFD-L-nonLI	1,037
09.SFD-<2Kft2-LI	2,077
10.SFD->2Kft2-LI	2,508
11.MFD-LI	2,475
Total	2,127

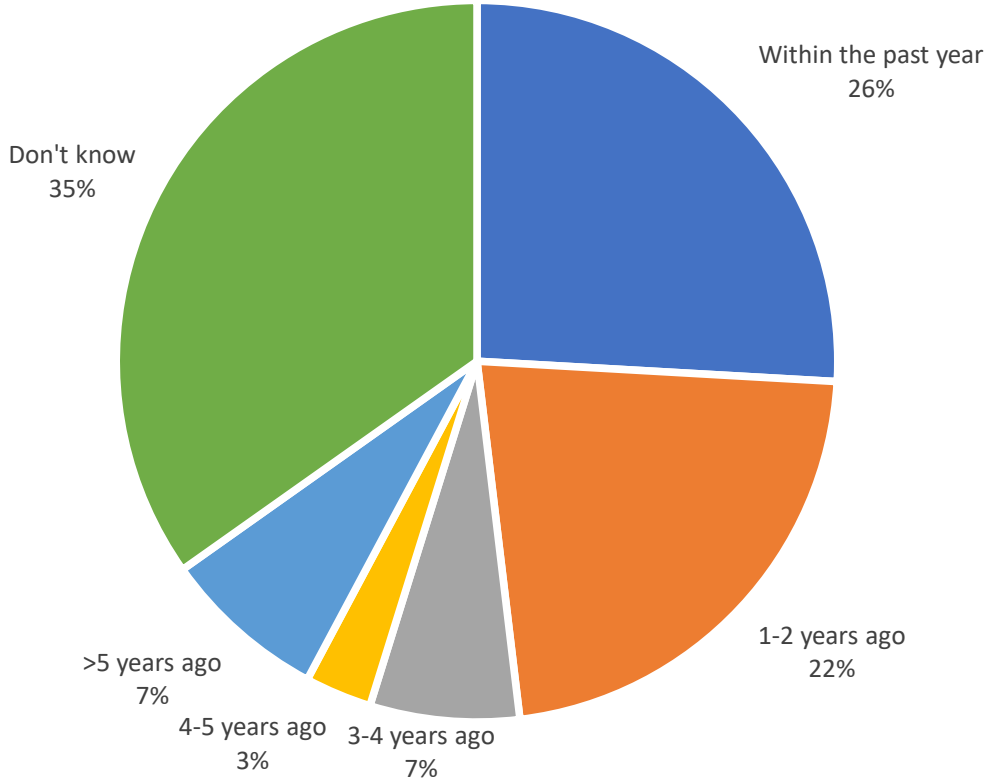
SPACE HEATING

Saturation of central heating by technology and fuel



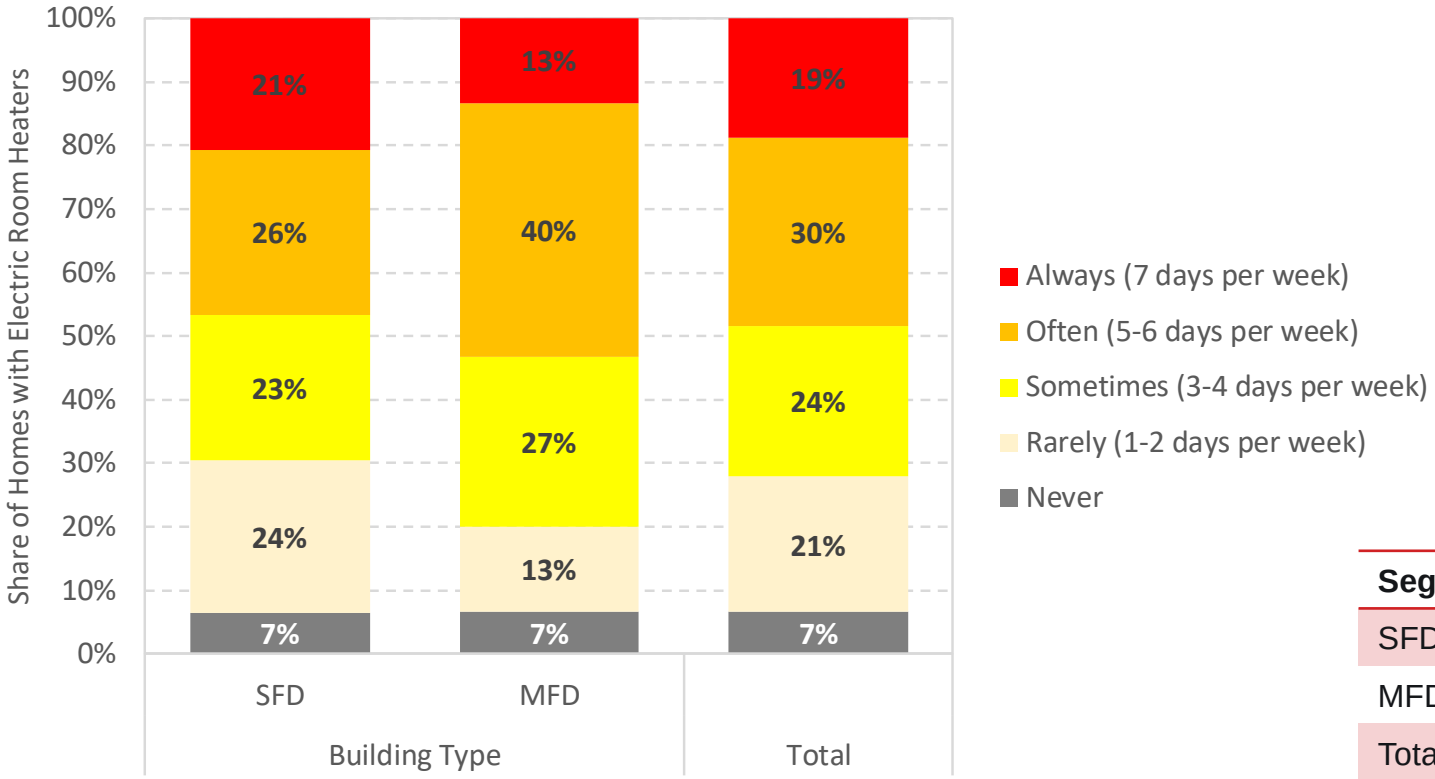
SPACE HEATING

Central heating systems maintenance



SPACE HEATING

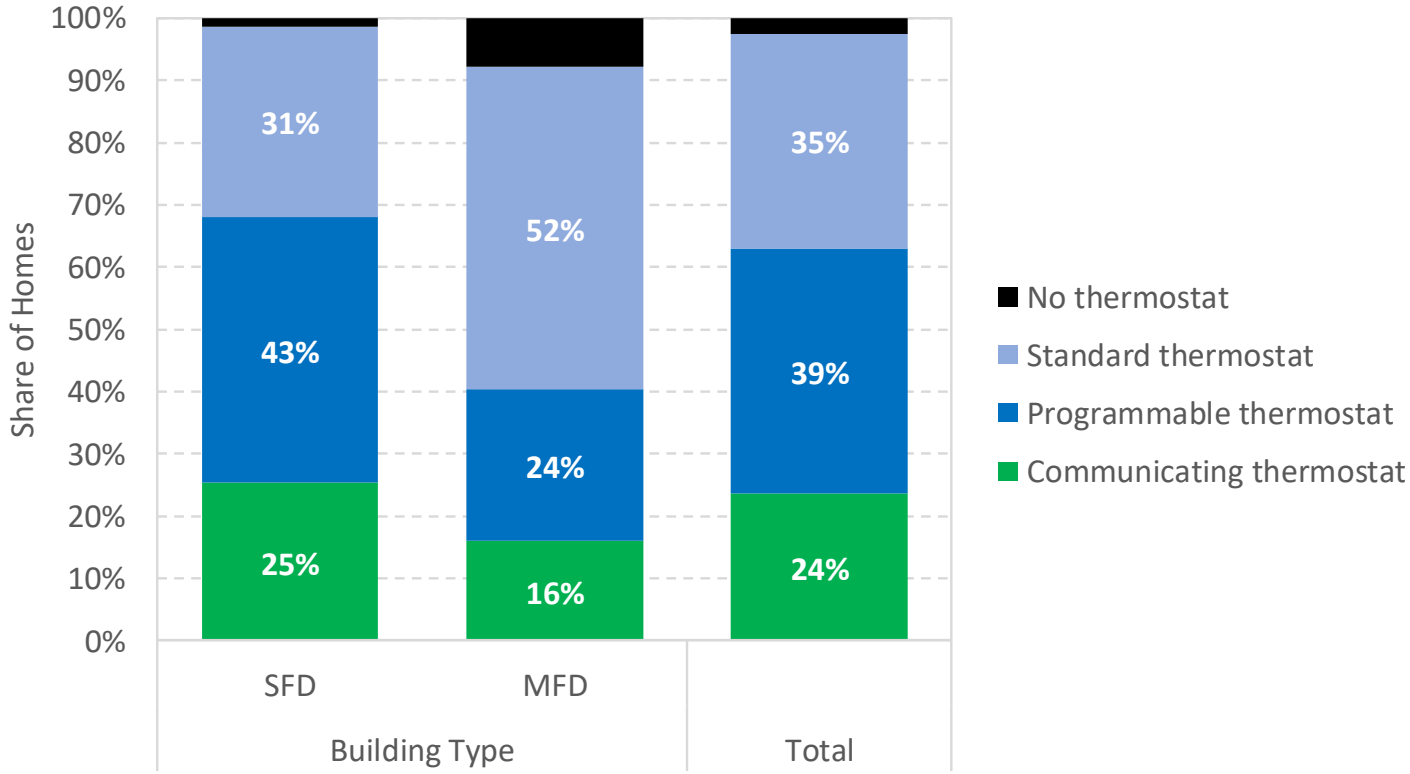
Portable space heating ownership and usage



Segment	Saturation
SFD	12%
MFD	17%
Total	14%

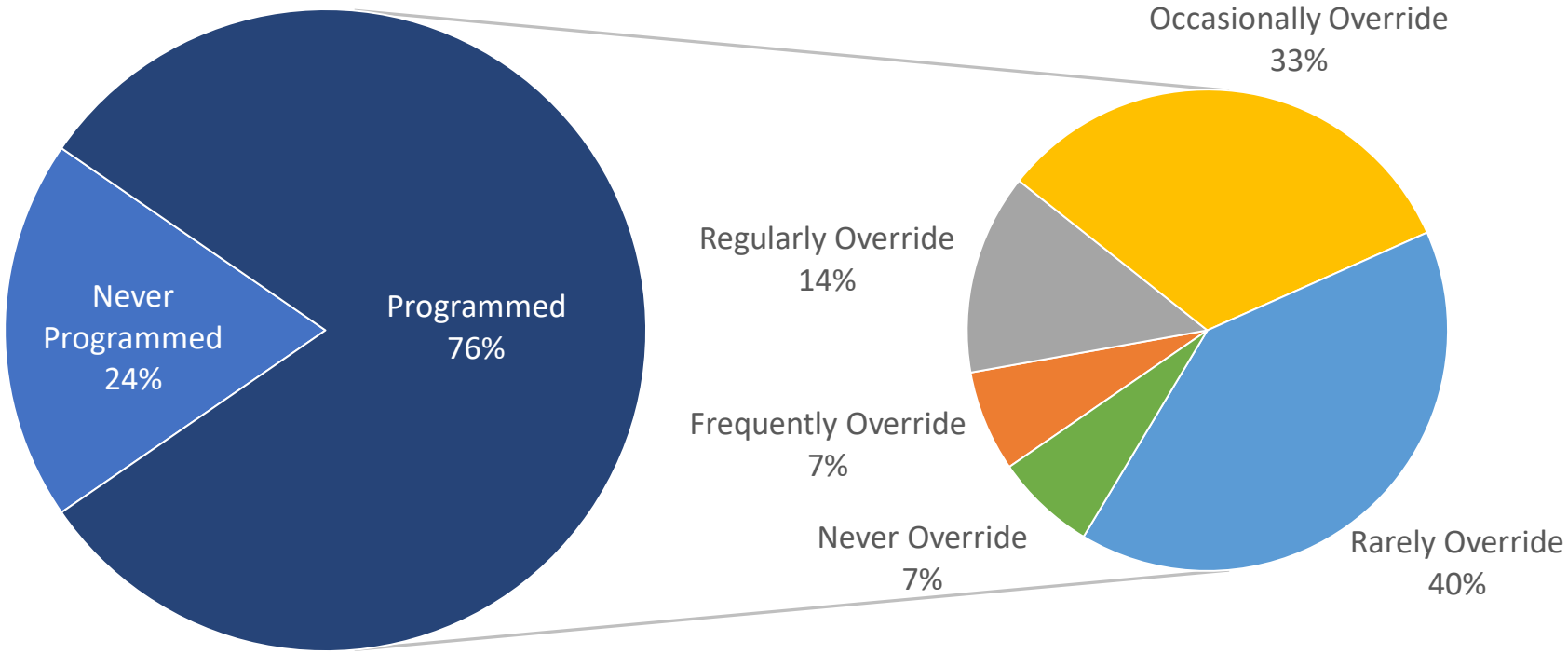
THERMOSTATS

Saturation of thermostats by type



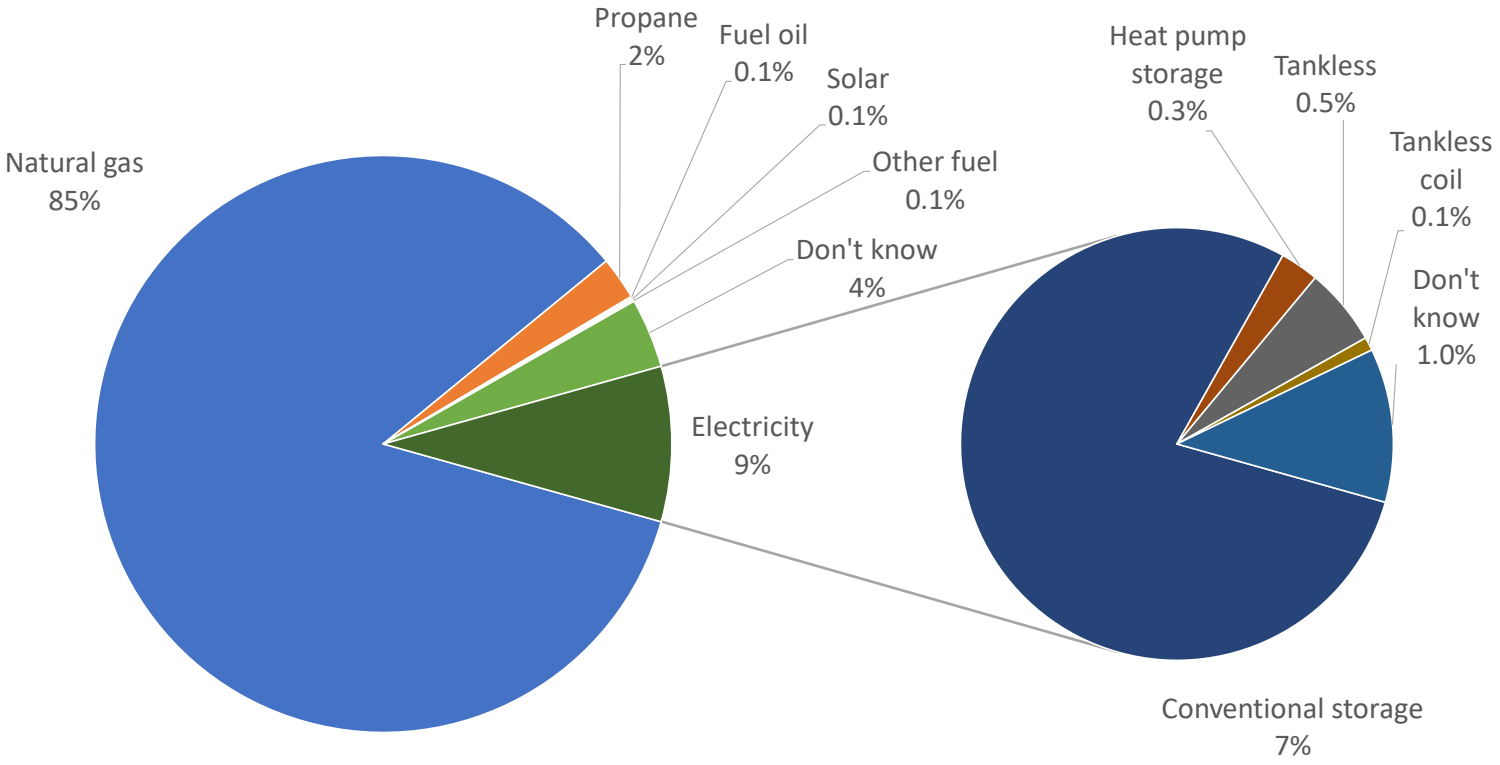
THERMOSTATS

Frequency of overriding programmed thermostat settings



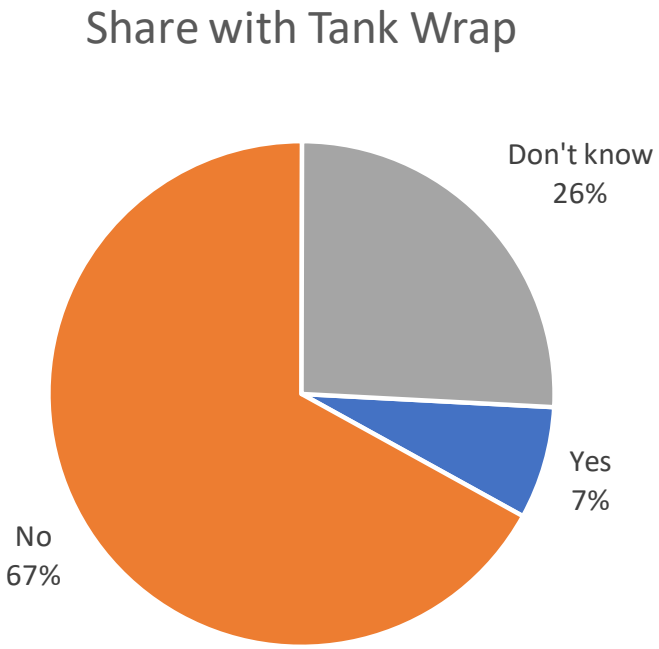
WATER HEATING

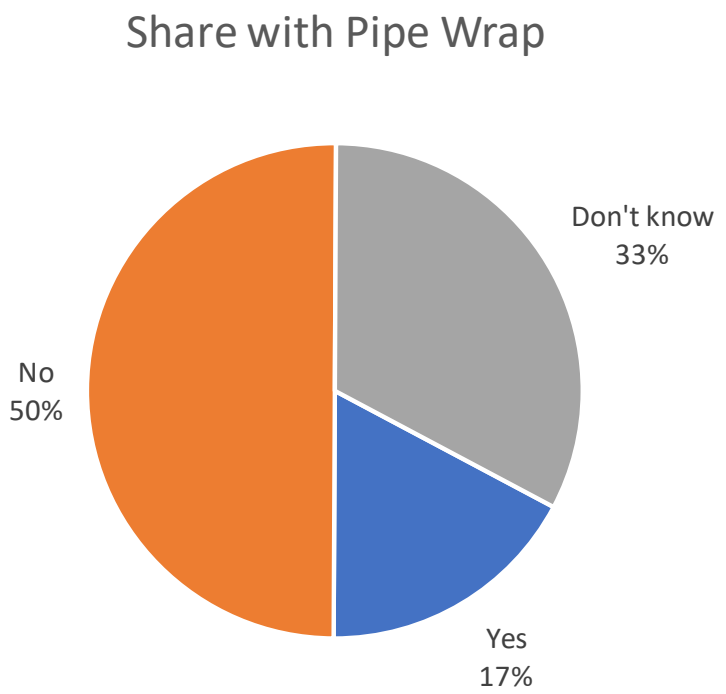
Fuel shares of water heating



WATER HEATING

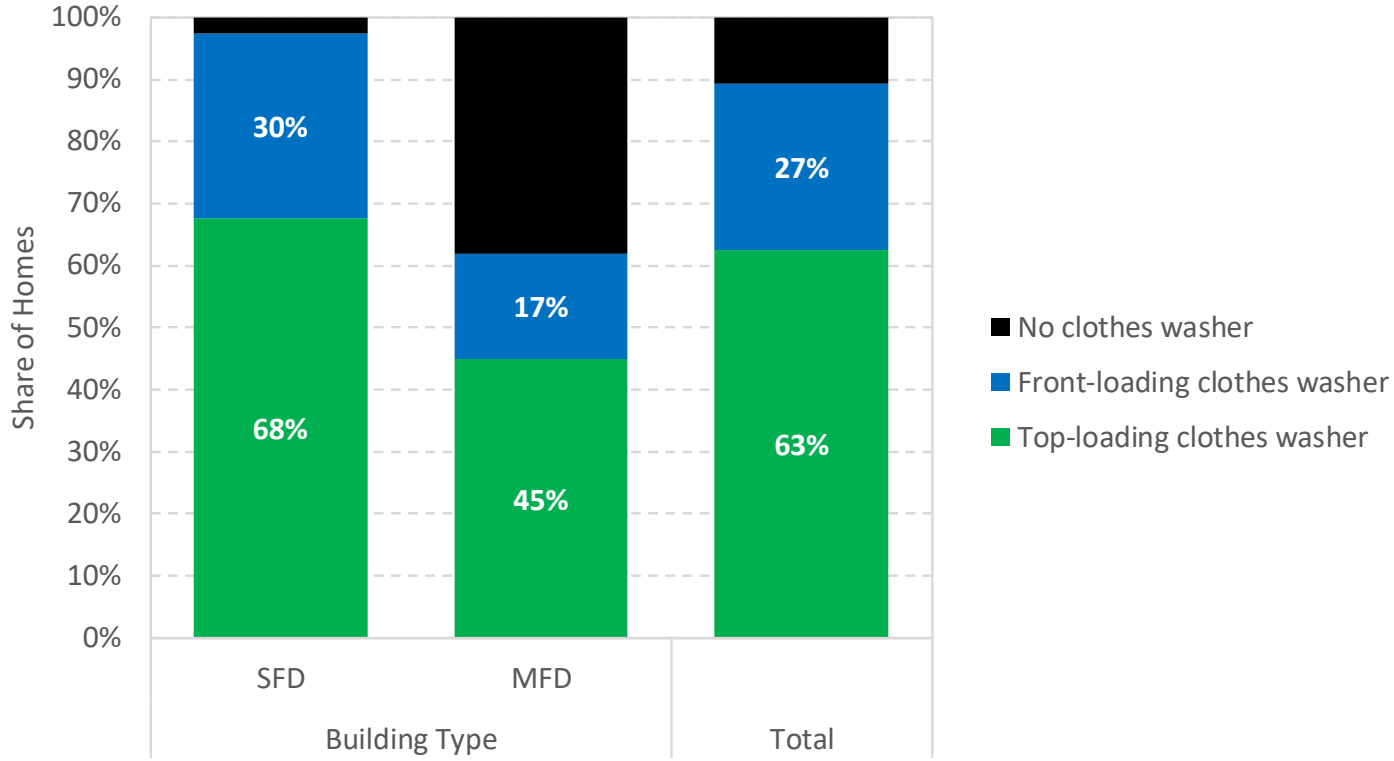
Saturation of insulation measures for electric water heating systems





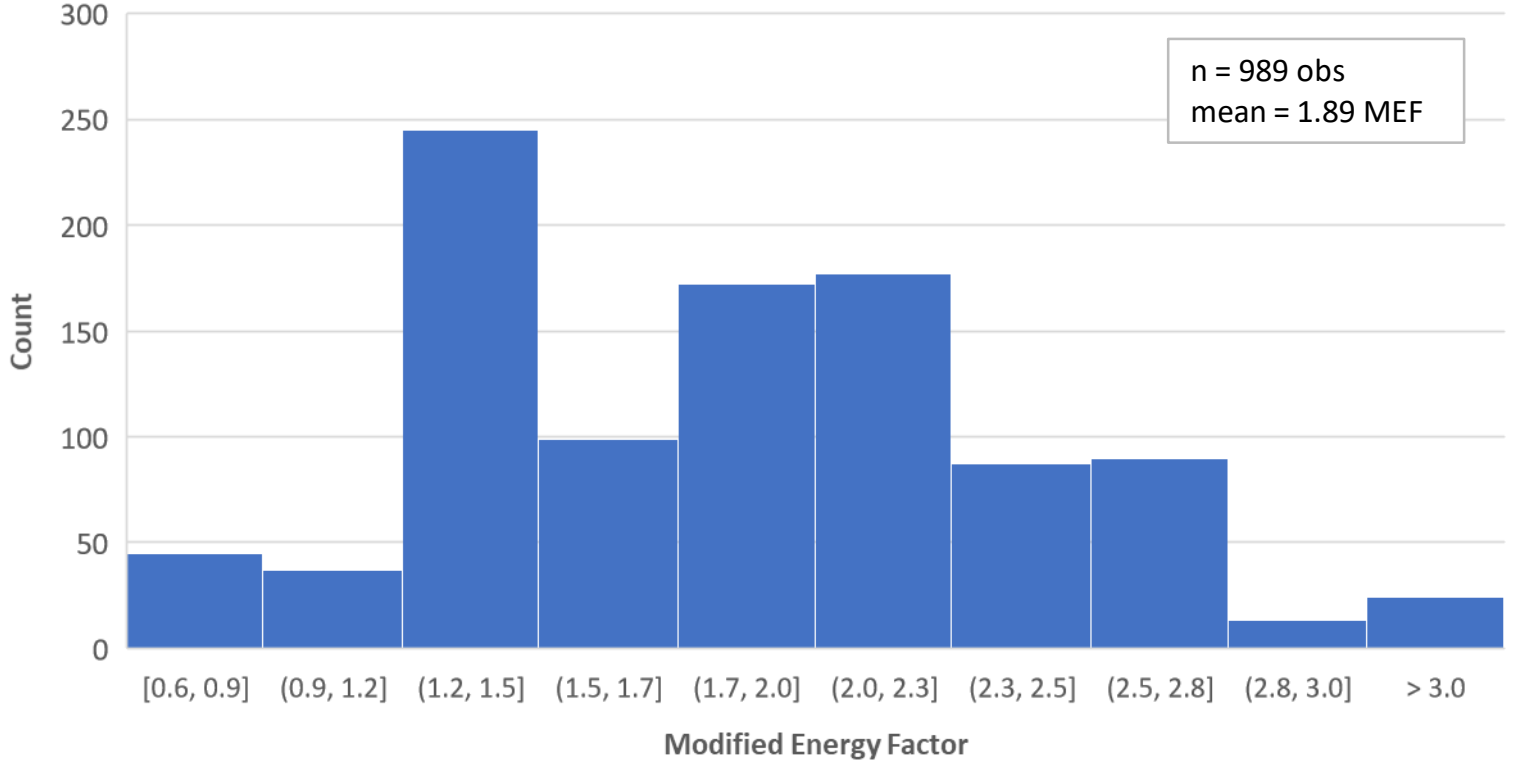
LAUNDRY APPLIANCES

Saturation of clothes washers



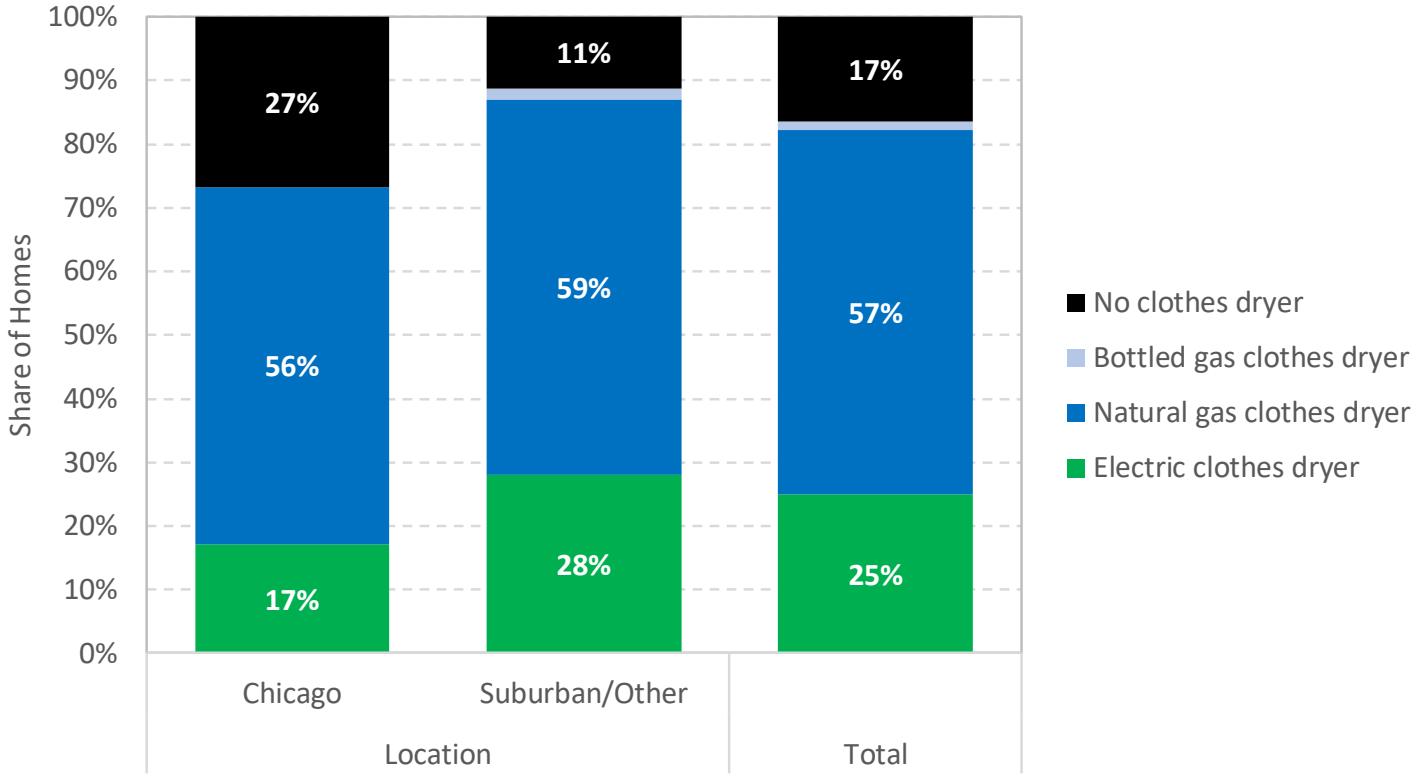
LAUNDRY APPLIANCES

Distribution of clothes washers rated efficiency (Modified Energy Factor)



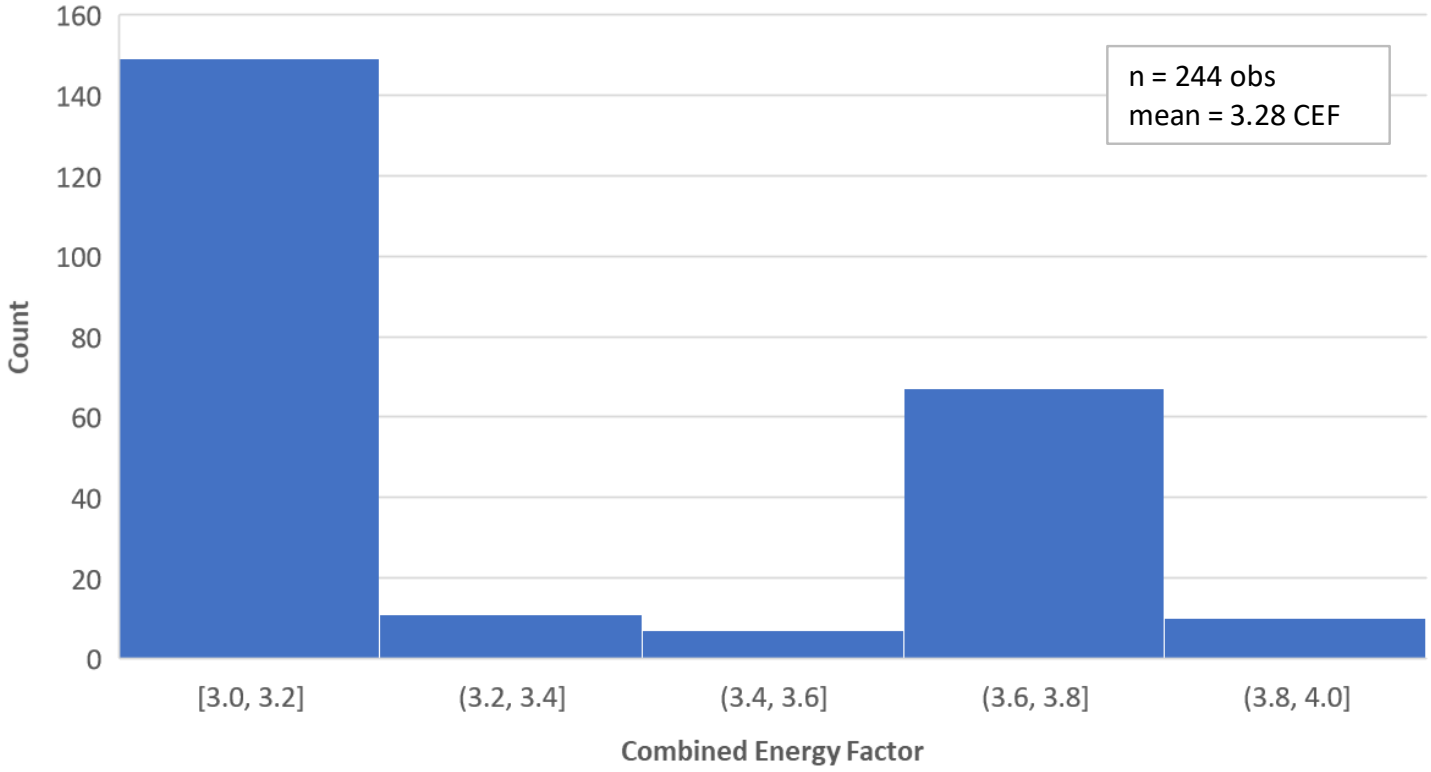
LAUNDRY APPLIANCES

Saturation of clothes dryers



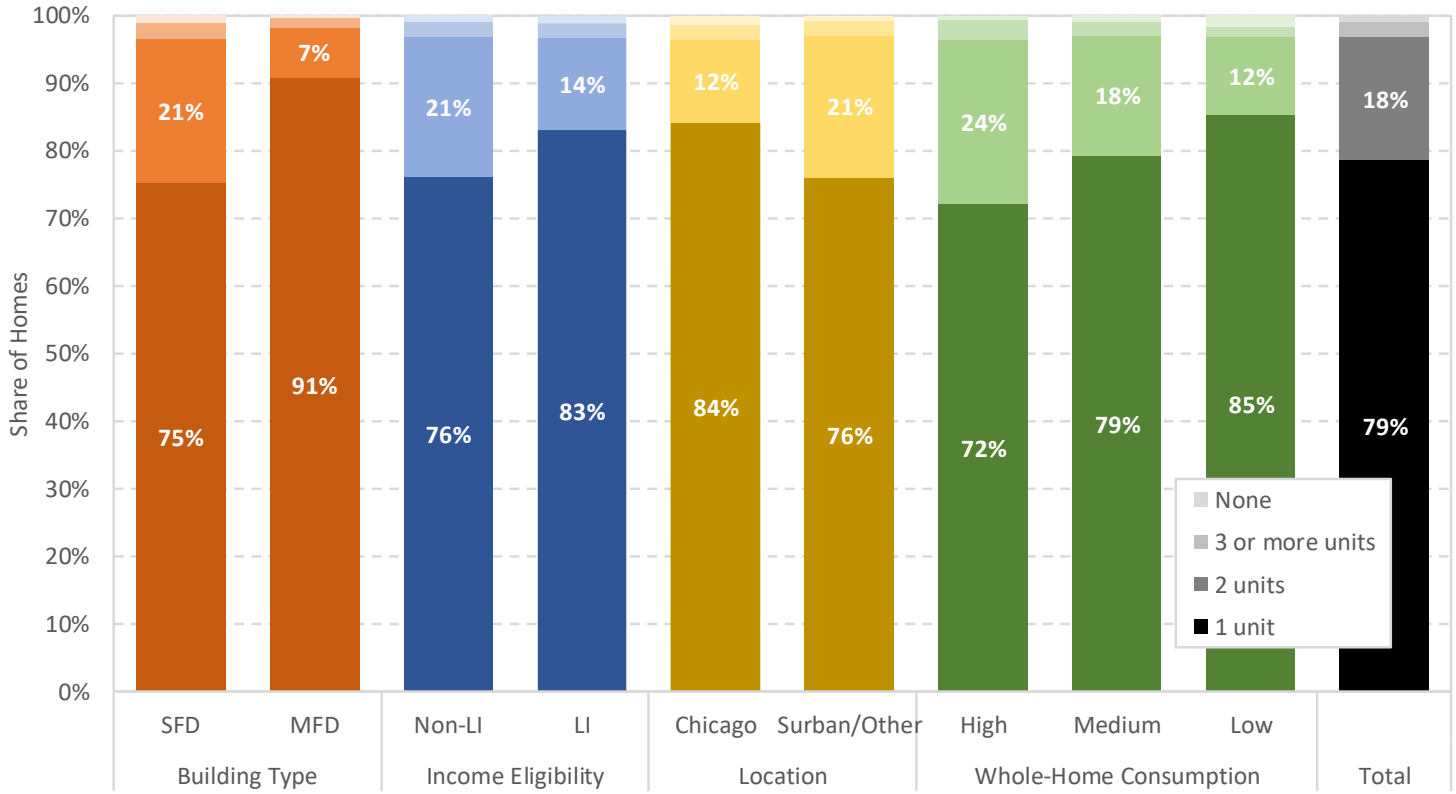
LAUNDRY APPLIANCES

Distribution of clothes dryer rated efficiency (Combined Energy Factor)



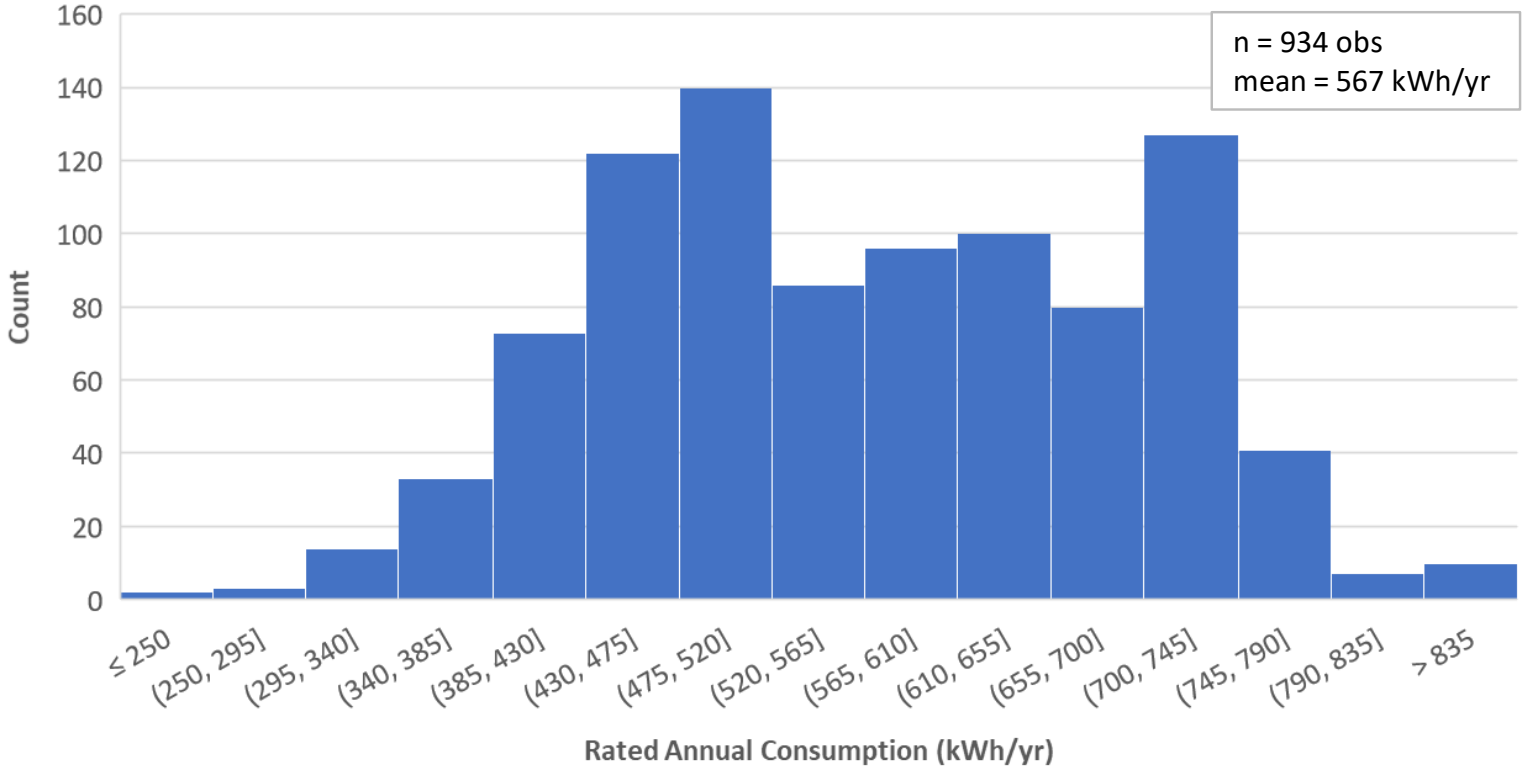
KITCHEN APPLIANCES

Saturation of refrigerators



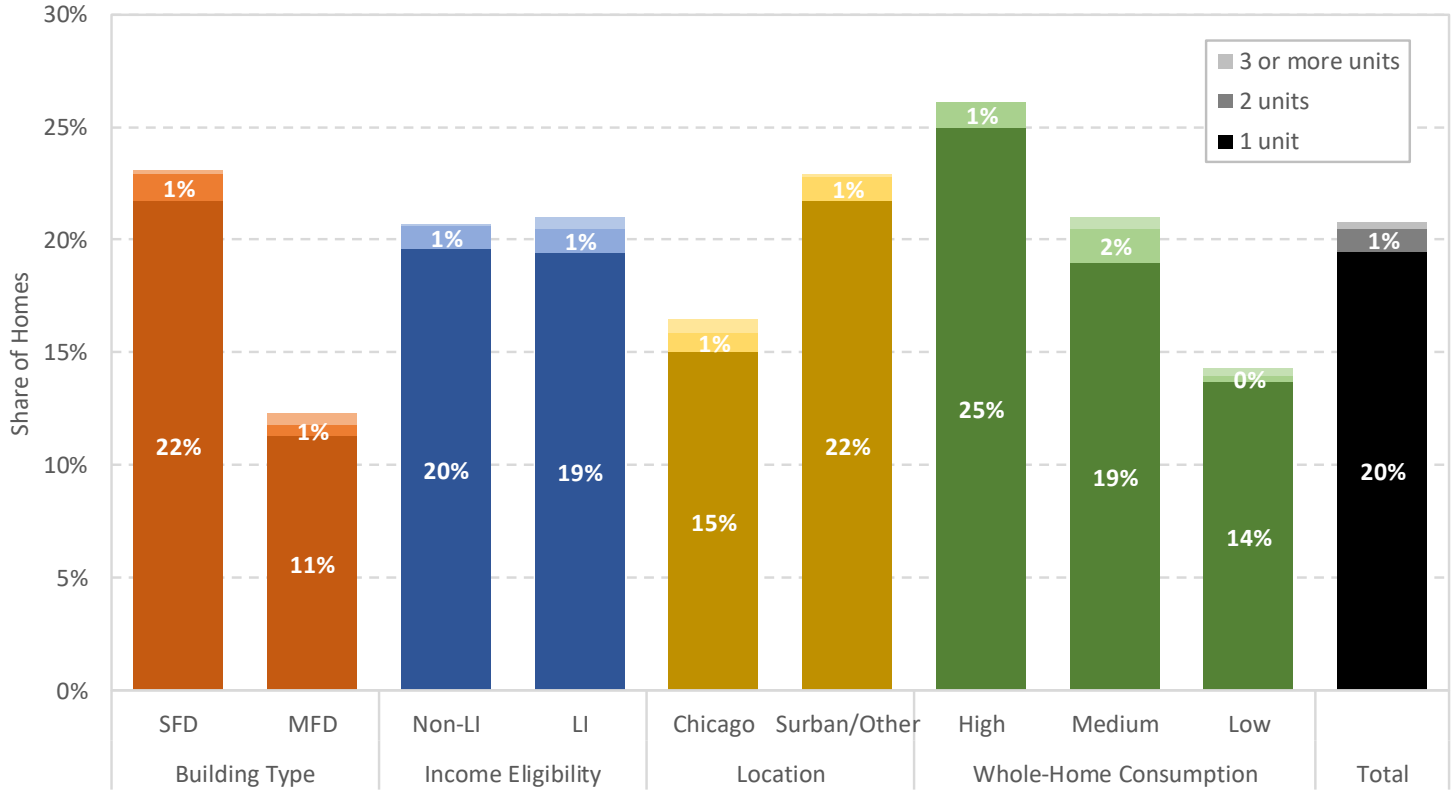
KITCHEN APPLIANCES

Distribution of refrigerator rated annual consumption (kWh/yr)



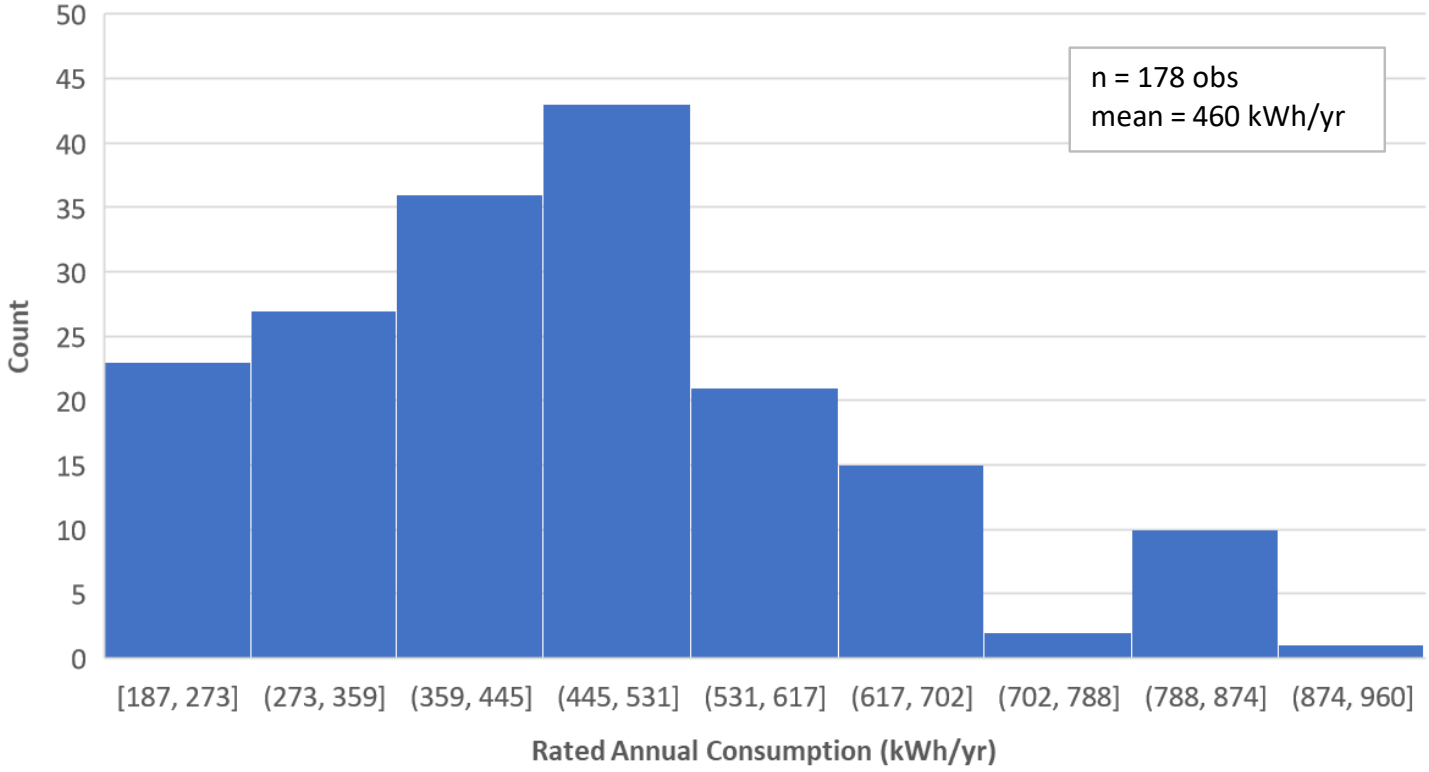
KITCHEN APPLIANCES

Saturation of stand-alone freezers



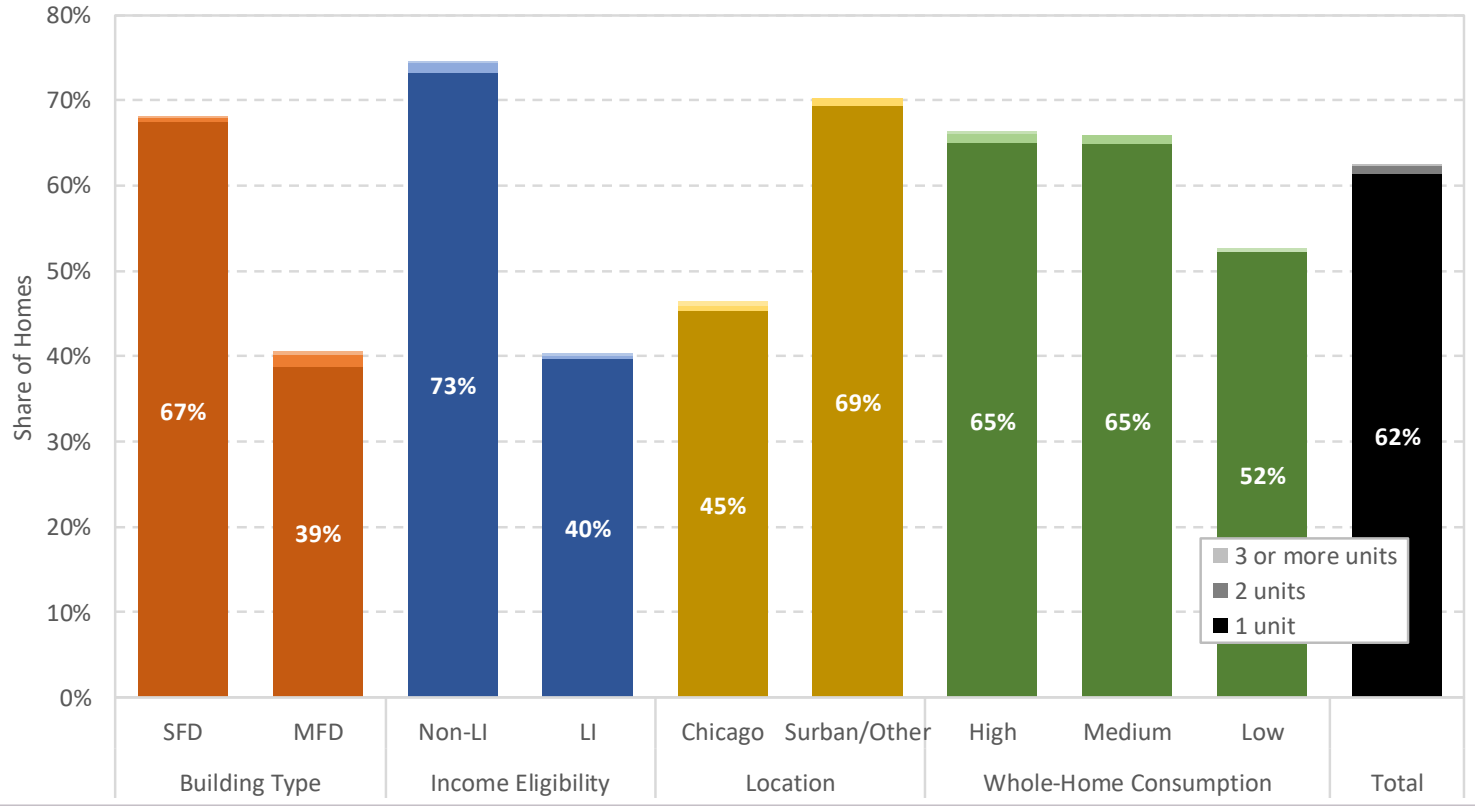
KITCHEN APPLIANCES

Distribution of stand-alone freezer rated annual consumption (kWh/yr)



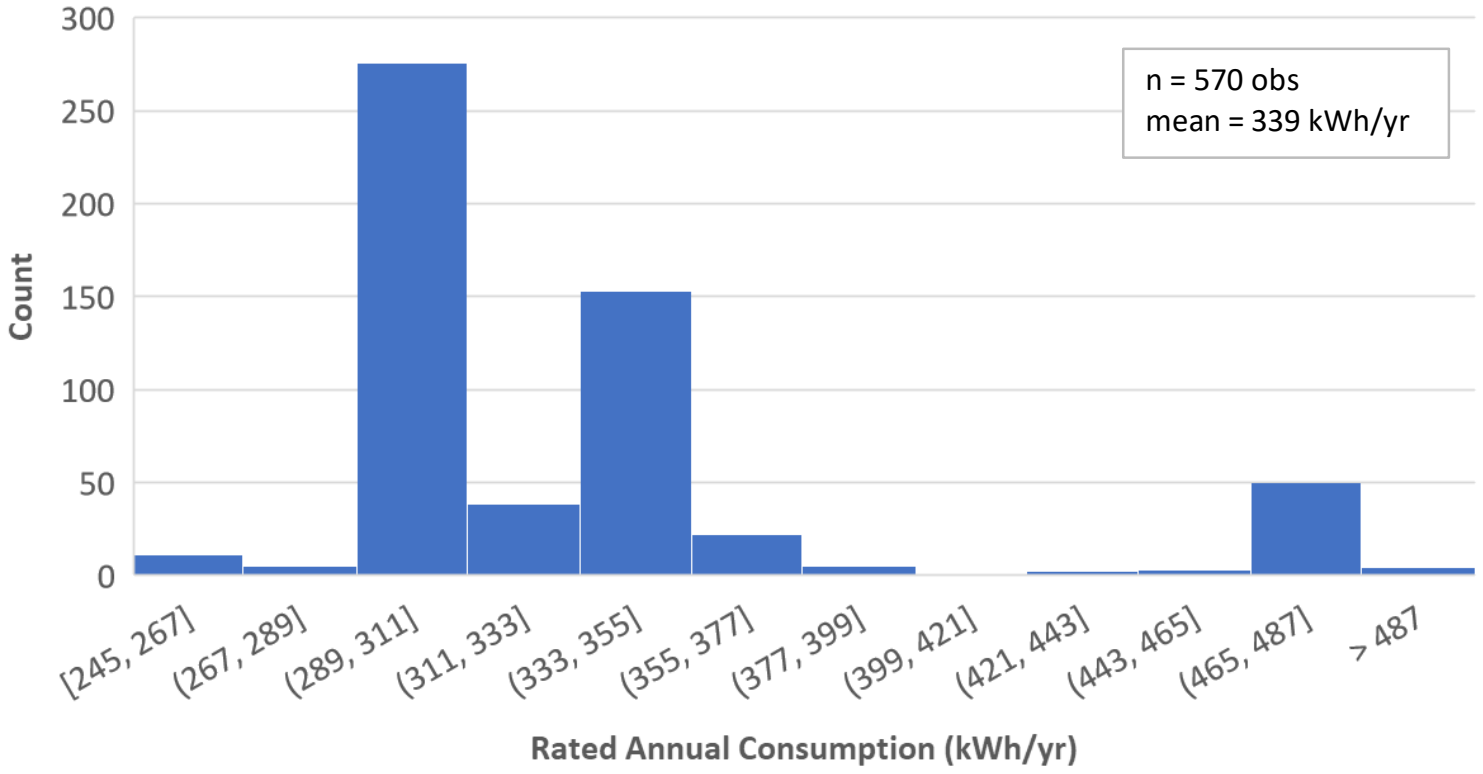
KITCHEN APPLIANCES

Saturation of dishwashers



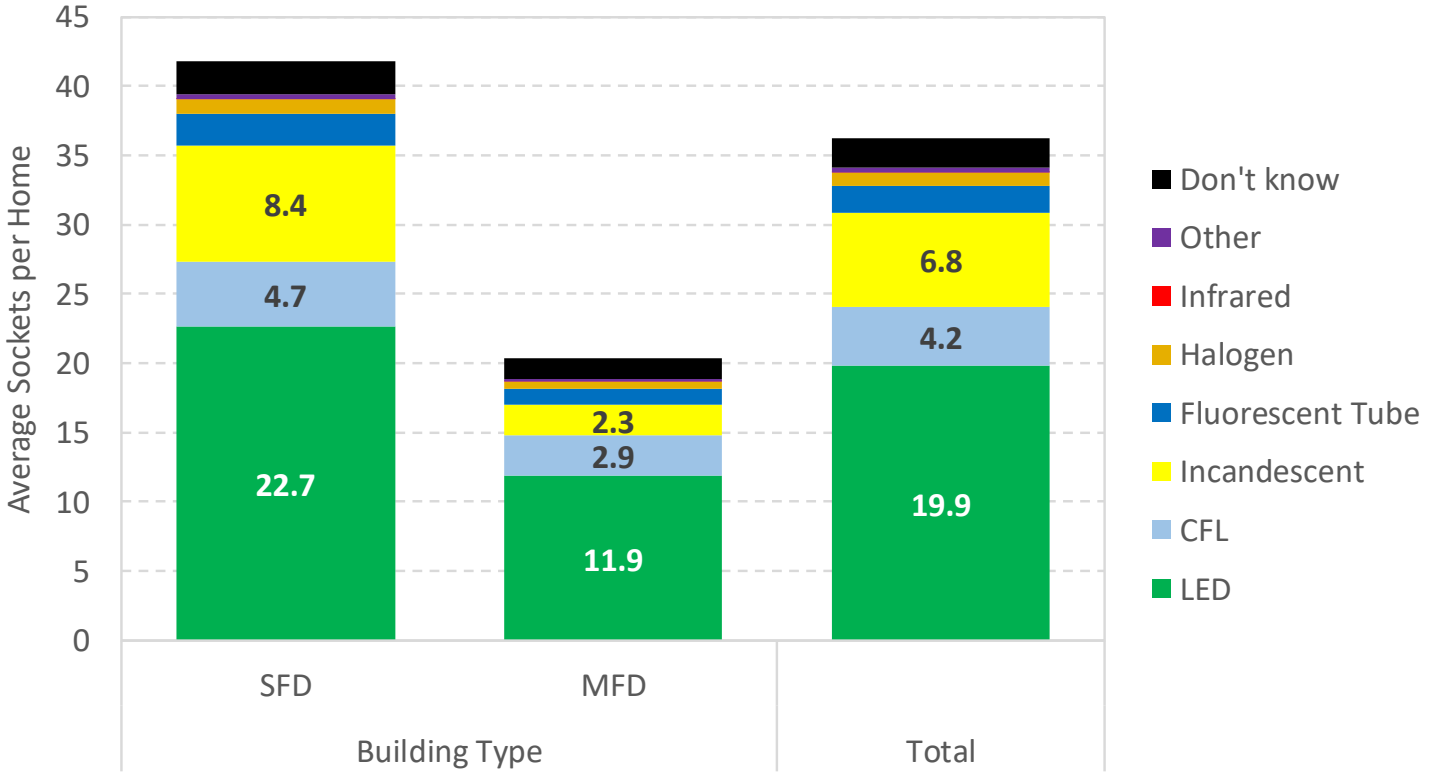
KITCHEN APPLIANCES

Distribution of dishwasher rated annual consumption (kWh/yr)



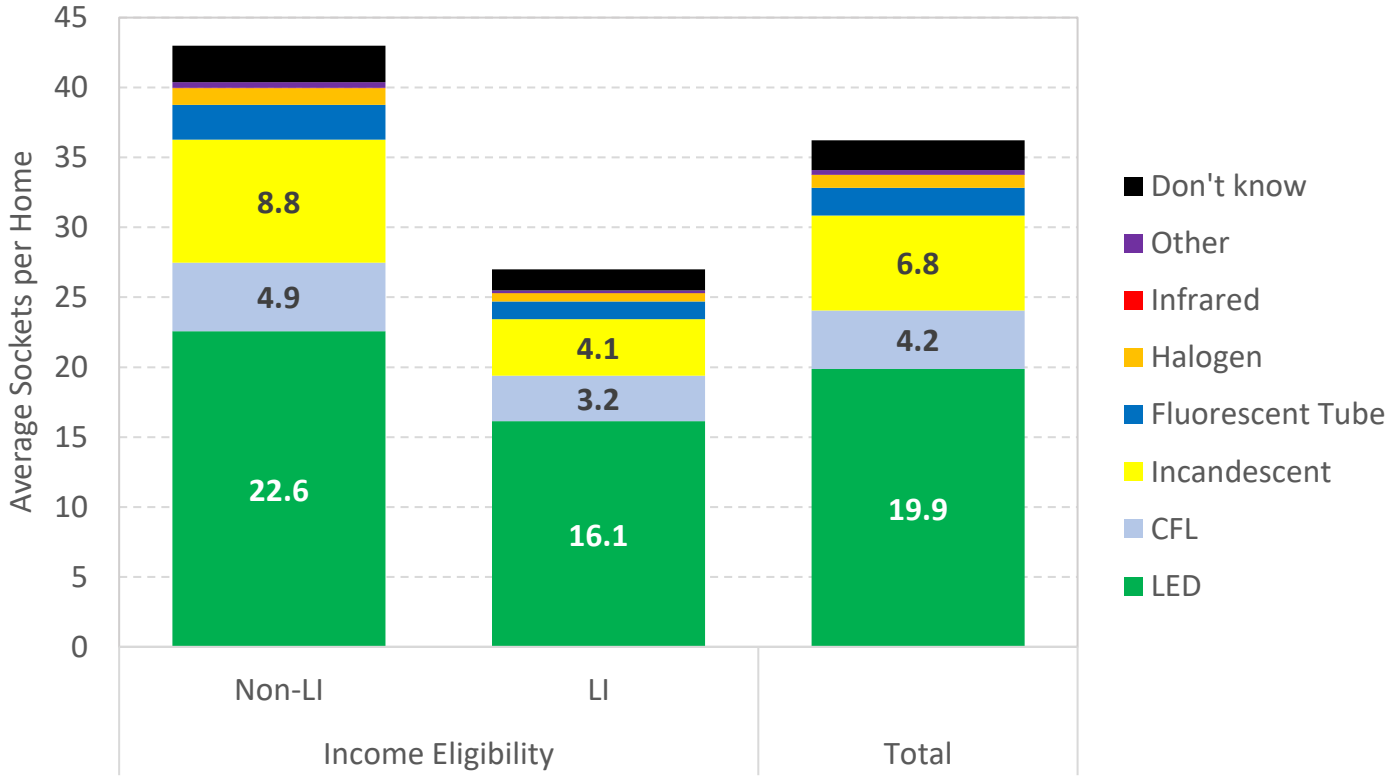
INTERIOR LIGHTING

Average number of sockets by technology



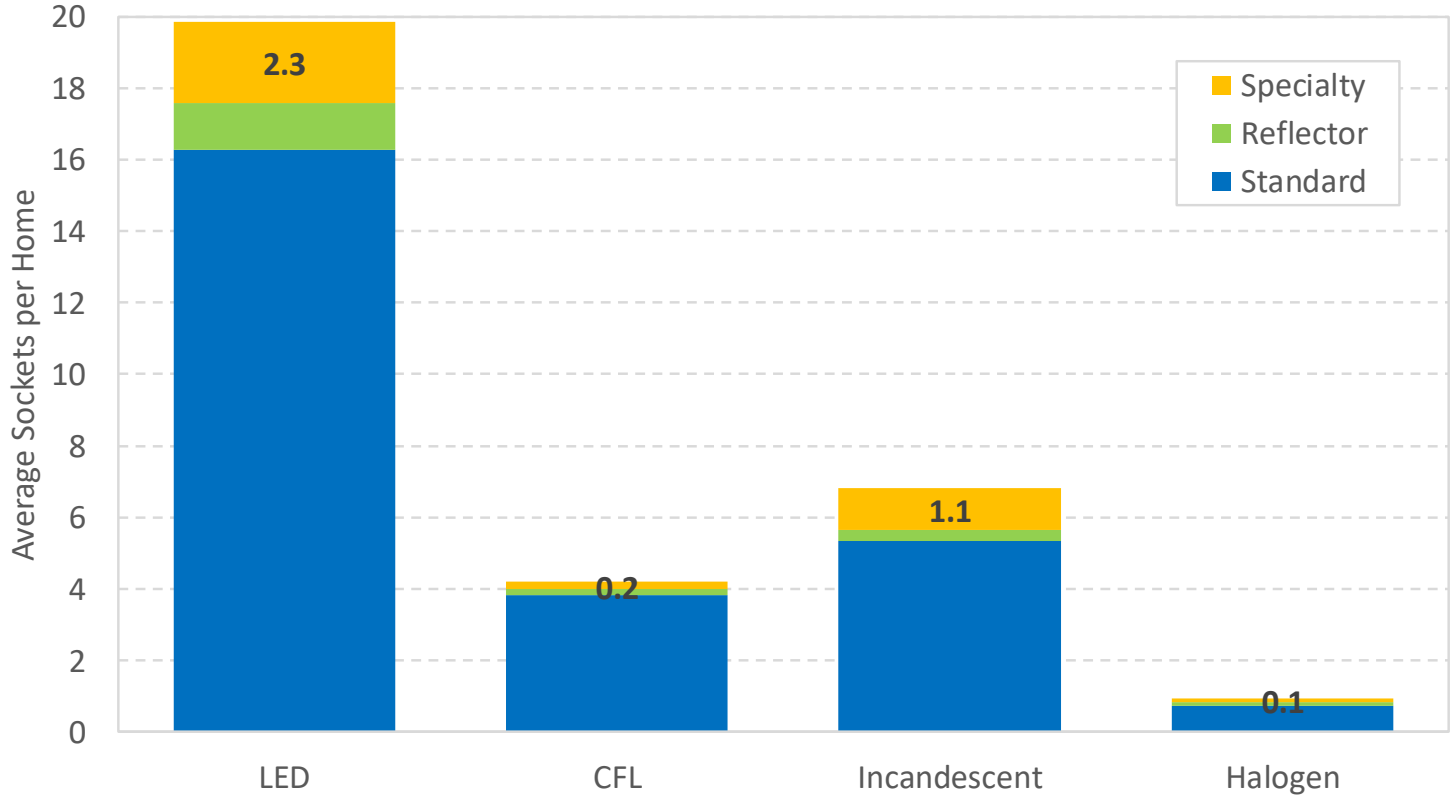
INTERIOR LIGHTING

Average number of sockets by technology



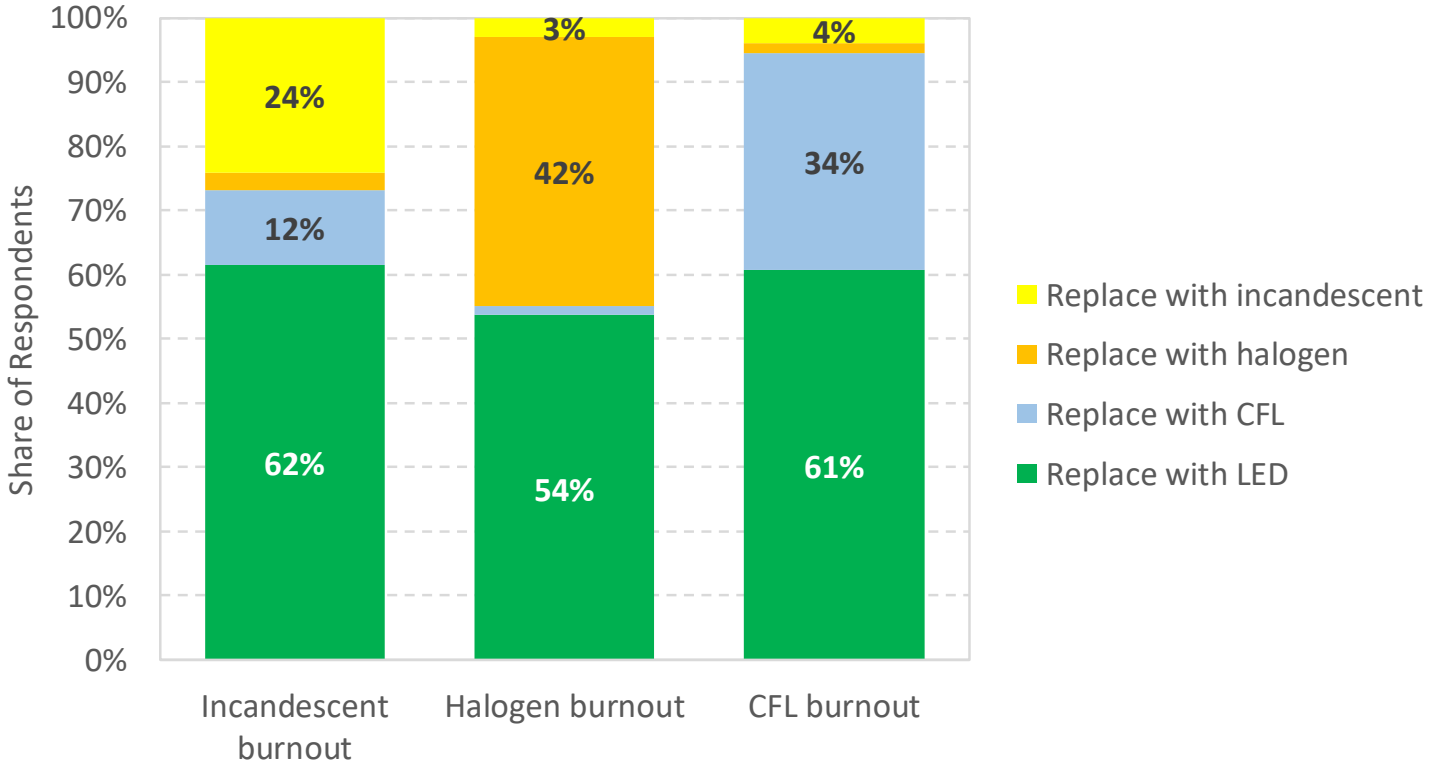
INTERIOR LIGHTING

Average number of sockets by technology and lamp shape



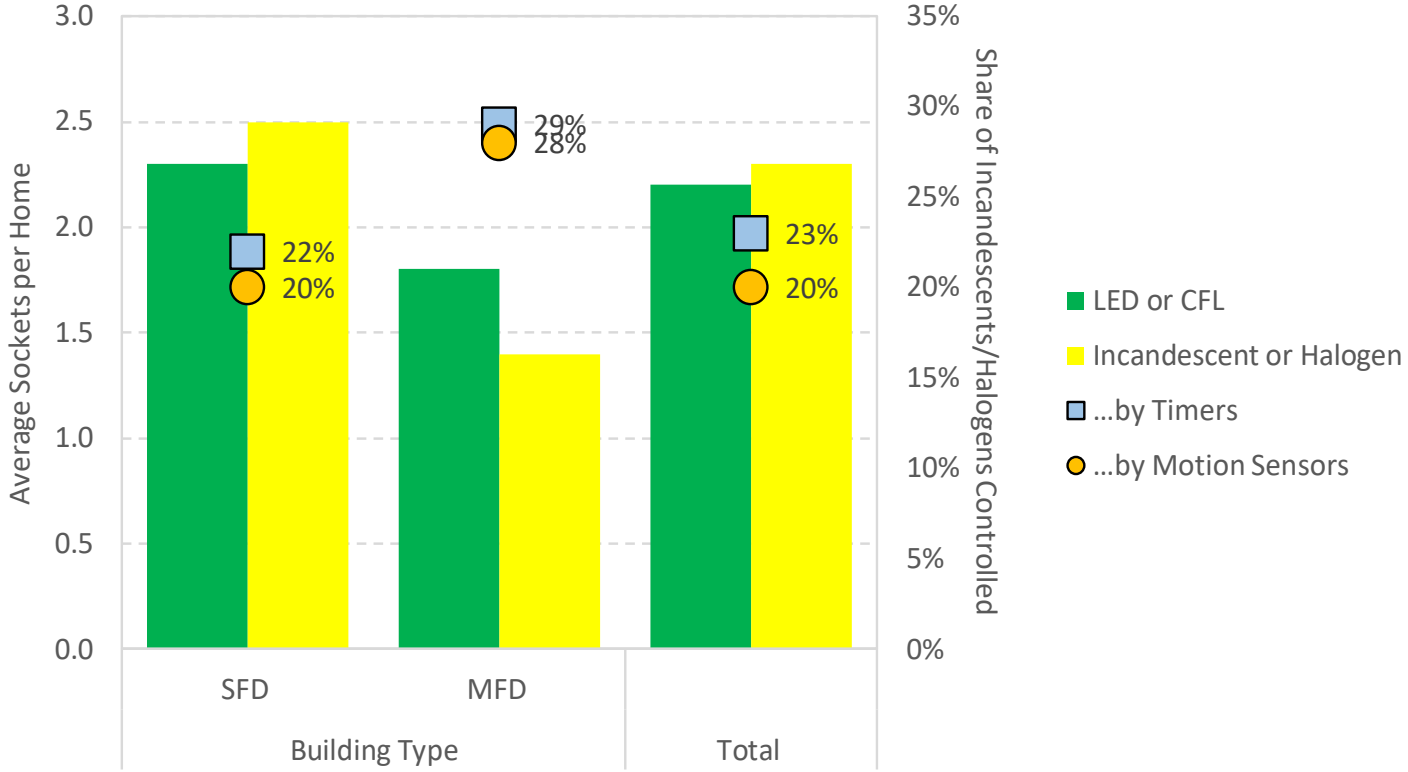
INTERIOR LIGHTING

Replace on burnout plans



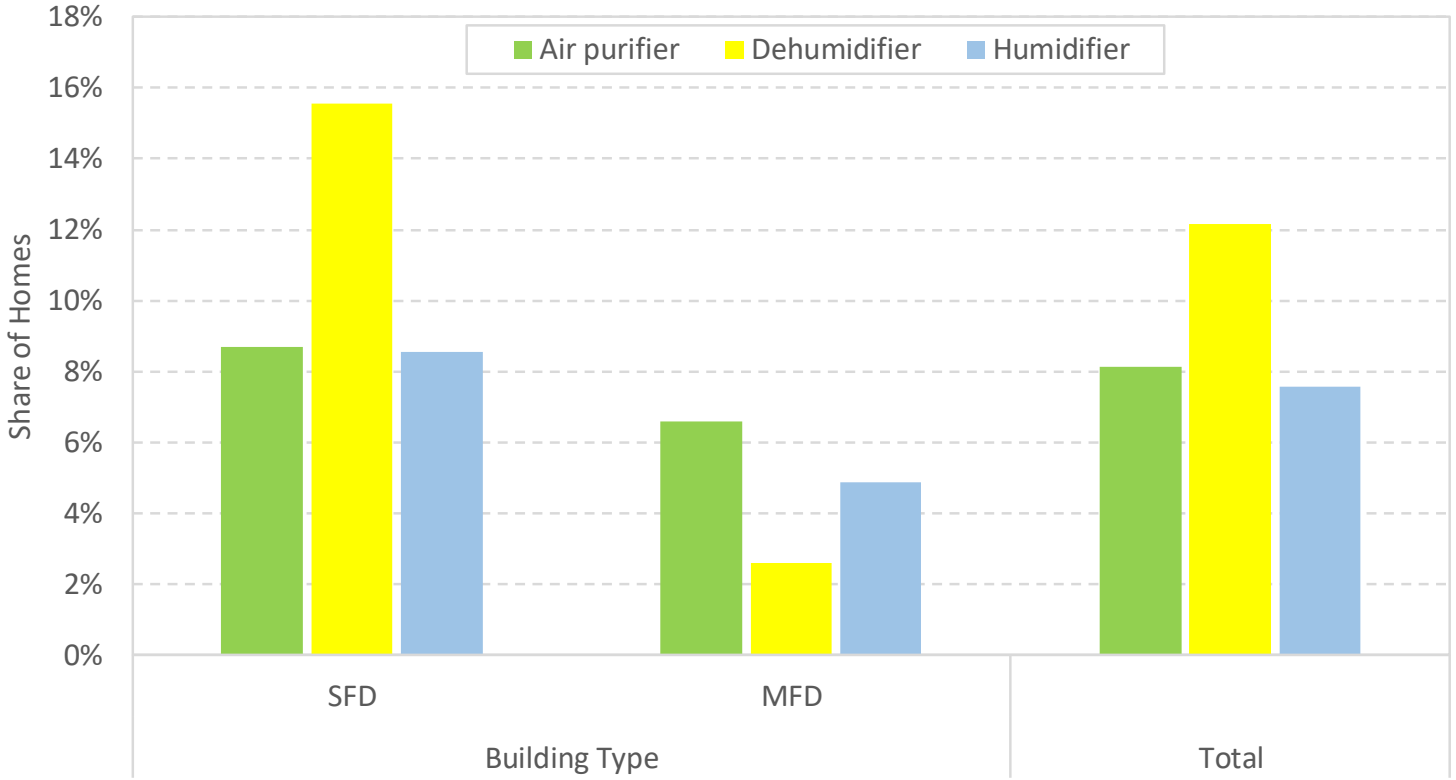
EXTERIOR LIGHTING

Average number of sockets by technology and control type



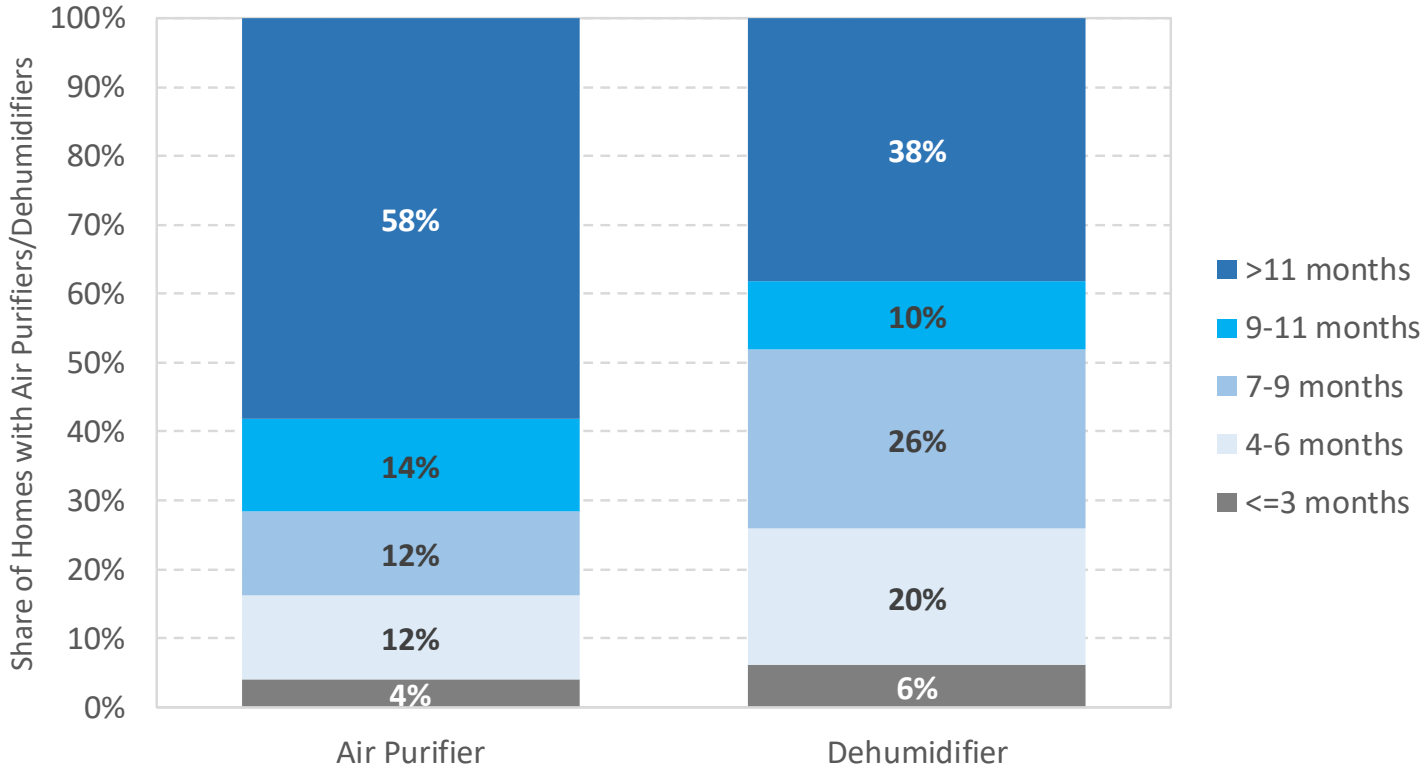
DEHUMIDIFIERS & AIR PURIFIERS

Saturation of air purifiers, dehumidifiers, and humidifiers



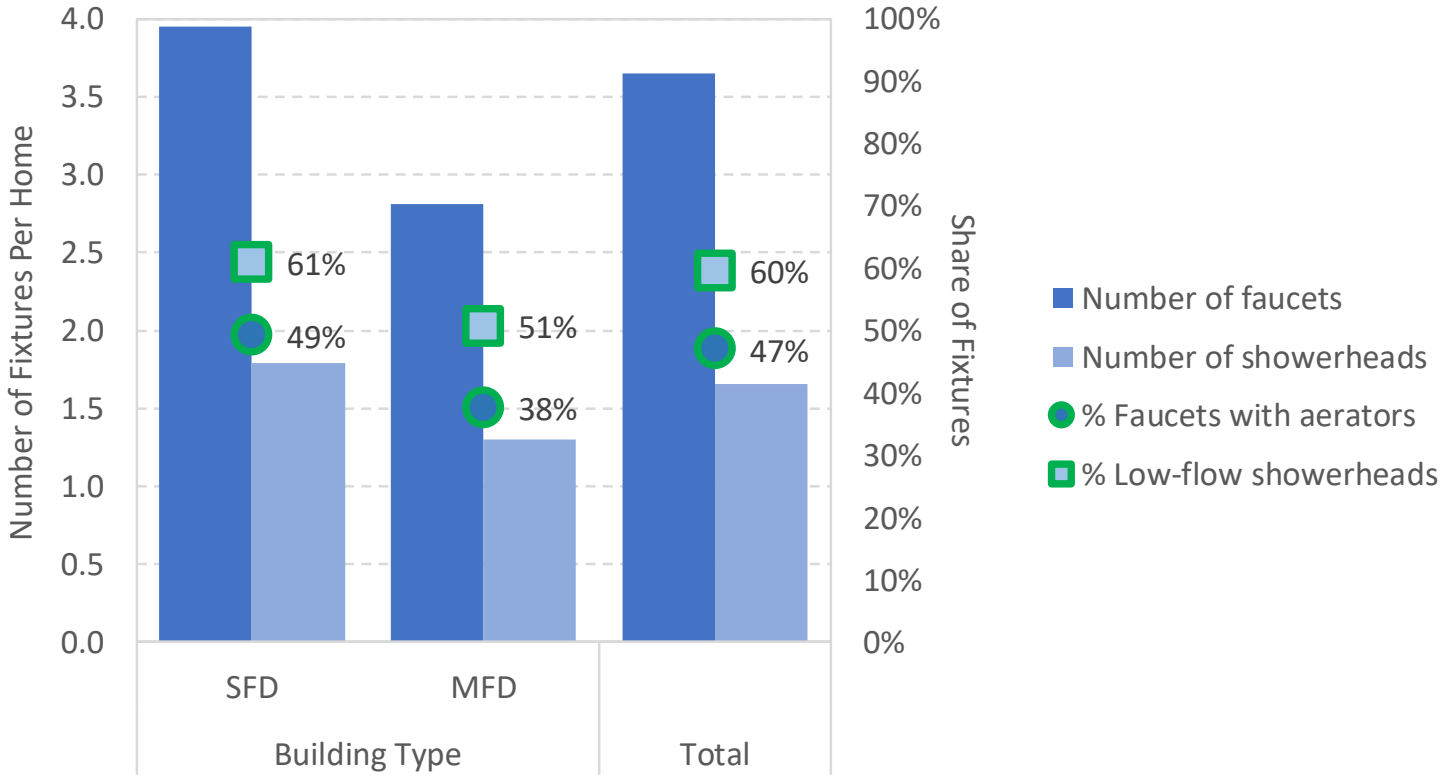
DEHUMIDIFIERS & AIR PURIFIERS

Usage of air purifiers and dehumidifiers



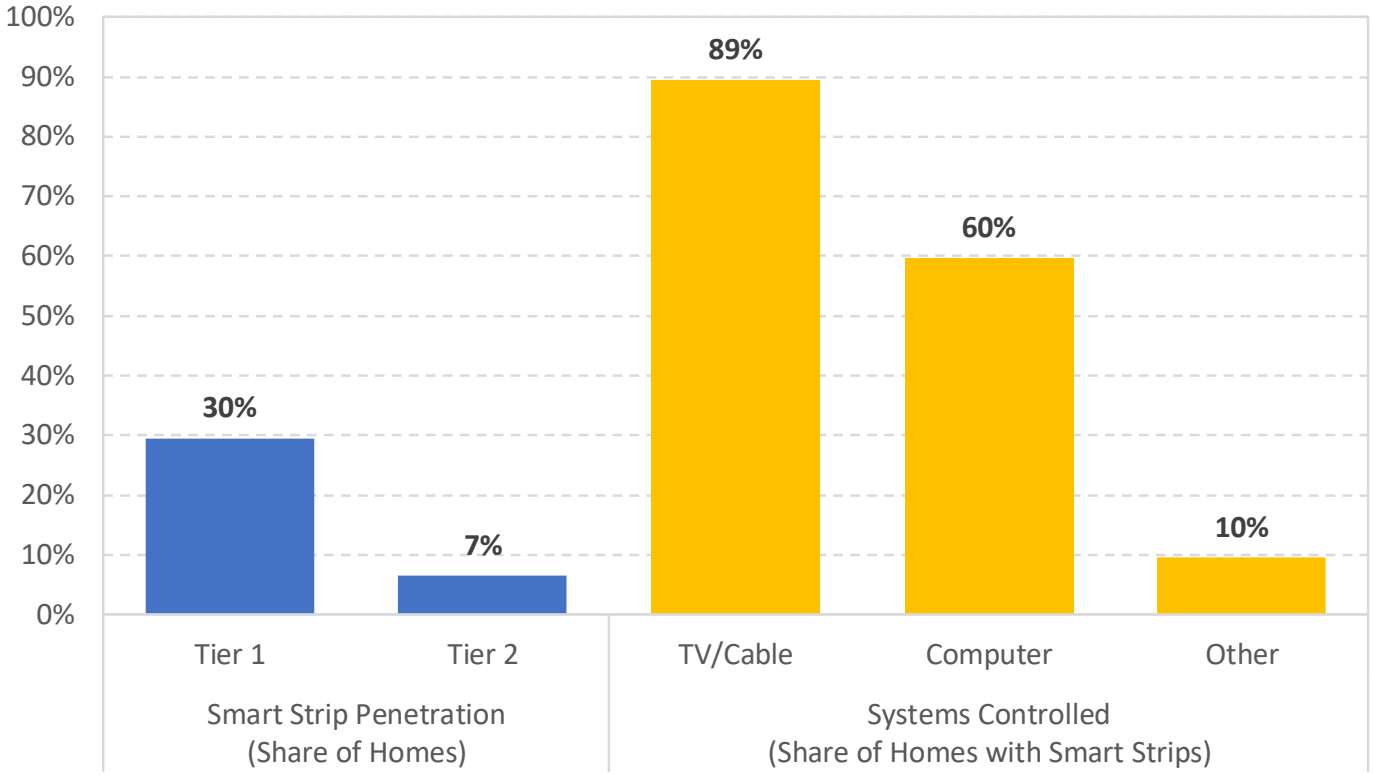
WATER FIXTURES

Average number of water fixtures and saturation of water efficiency measures



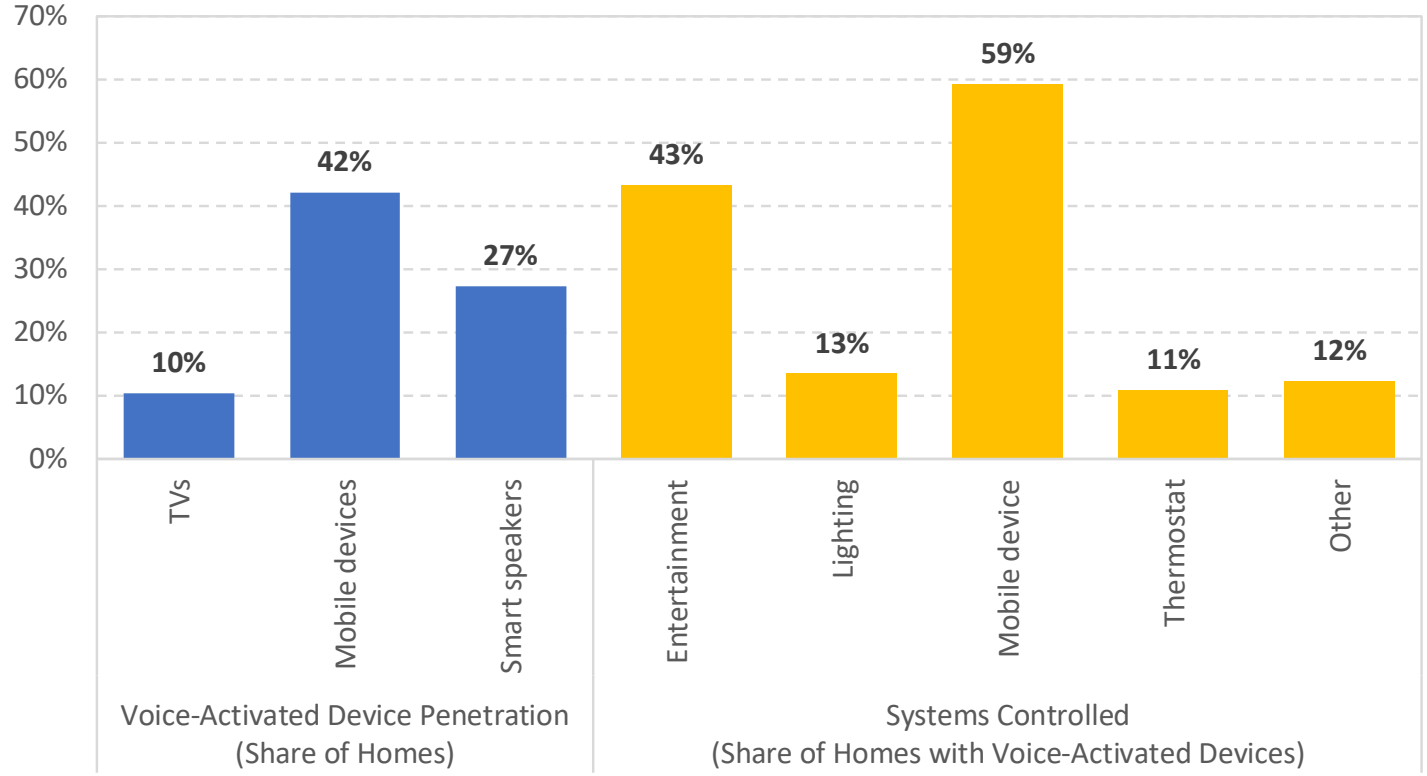
CONSUMER ELECTRONICS

Saturation of smart power strips and systems controlled in those homes



CONSUMER ELECTRONICS

Saturation of voice-activated devices and systems controlled in those homes



KEY FINDINGS

LEDs have become the dominant residential lighting technology

End-Use/Technology	Metric	2012 Baseline Study			2019 Baseline Study		
		All	SFD	MFD	All	SFD	MFD
Lighting							
Incandescent	Share of all sockets	65%	66%	60%	19%	20%	11%
CFL	Share of all sockets	20%	19%	24%	12%	11%	14%
Linear Fluorescent	Share of all sockets	8%	9%	5%	5%	5%	6%
Halogen	Share of all sockets	6%	5%	11%	3%	3%	3%
LED	Share of all sockets	1%	1%	0%	55%	54%	58%

KEY FINDINGS

Small increase in CAC efficiency, but little evidence of fuel switching away from gas

End-Use/Technology	Metric	2012 Baseline Study			2019 Baseline Study		
		All	SFD	MFD	All	SFD	MFD
Space Cooling							
Central air conditioner	Share of all homes	73%	87%	46%	80%	87%	48%
…<14 SEER	Share of all CAC systems	93%	-	-	87%		
Space Heating							
Primary electric space heating	Share of all homes	10%	4%	24%	9%	8%	13%
…Heat pump	Share of all homes	2%	-	-	2%	2%	1%
Water Heating							
Electric water heating	Share of all homes	8%	6%	13%	9%	8%	11%
Water heater tank wrap	Share of all homes	3%	-	-	7%		
Hot water pipe wrap	Share of all homes	9%	-	-	17%		
Faucet aerators	Share of all homes	62%	-	-	47%	49%	38%
Low-flow showerheads	Share of all homes	40%	-	-	60%	61%	51%

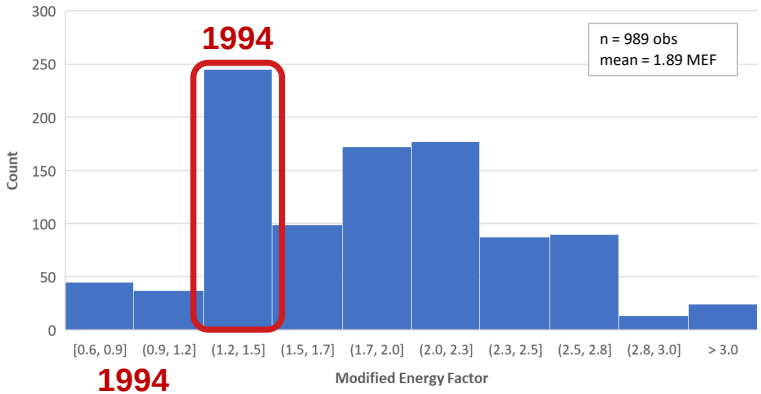
KEY FINDINGS

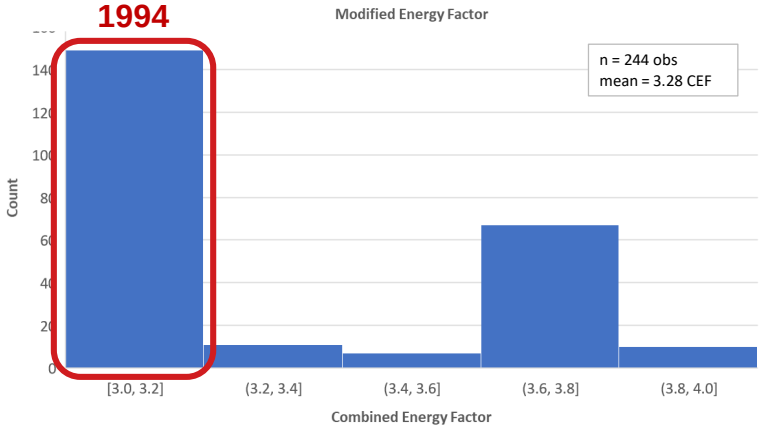
Strong evidence of impact of ComEd's appliance recycling programs

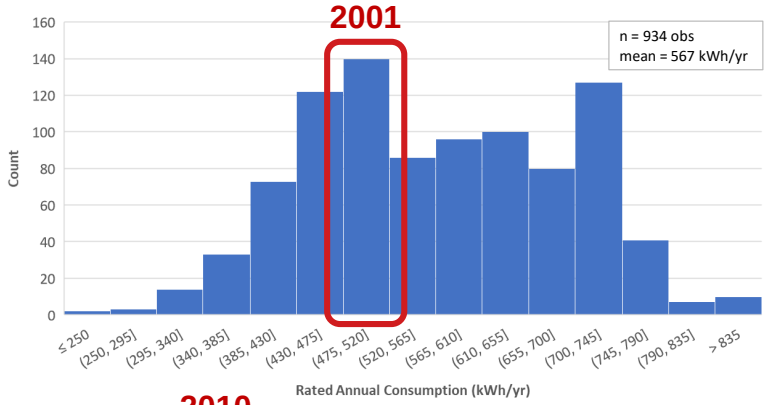
End-Use/Technology	Metric	2012 Baseline Study			2019 Baseline Study		
		All	SFD	MFD	All	SFD	MFD
Laundry Appliances							
Clothes washers	Share of all homes	80%	98%	47%	90%	98%	62%
Electric clothes dryers	Share of all homes	25%	26%	23%	25%	27%	17%
Kitchen Appliances							
Refrigerator	Share of all homes	100%	100%	100%	99%	99%	100%
Secondary refrigerator	Share of all homes	30%	42%	7%	20%	24%	9%
Standalone freezer	Share of all homes	31%	40%	13%	21%	23%	21%
Dishwasher	Share of all homes	67%	75%	54%	63%	68%	41%
Room HVAC							
Window air conditioner	Share of all homes	30%	18%	52%	18%	10%	40%
Air purifier/humidifier	Share of all homes	36%	31%	27%	16%	18%	12%
Dehumidifier	Share of all homes	23%	34%	5%	12%	16%	3%

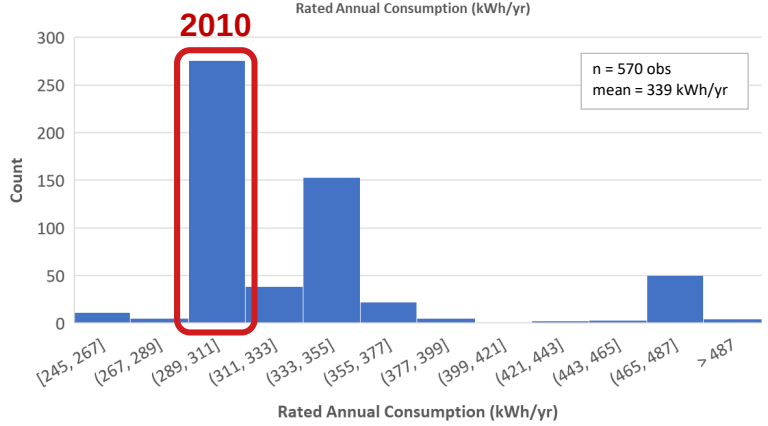
KEY FINDINGS

Laundry appliance stock turnover likely to be highest in near-term (compared to other appliances)









KEY FINDINGS

Penetration of “new” consumer technologies is already significant

- Penetration of the newest consumer technologies which control or have the potential to control aspects of residential energy consumption is already significant
  - Communicating thermostats = 24% (commercially available since 2011)
  - Smart power strips = 37% (commercially available since 2011)
  - Voice-activated smart speakers = 30% (commercially available since 2016)
- These markets are highly dynamic and should be considered in stark contrast to those of the other major residential end uses
- These devices currently control only a very small portion of residential load, but the potential (and probability) for these technologies to influence a much larger percentage of residential load ***in the very near future*** is significant

THANK YOU

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