PUERTO RICO BASELINE CHARACTERIZATION AND ENERGY EFFICIENCY MARKET POTENTIAL STUDY, TECHNICAL CONFERENCE

September 25, 2025

NV5

OUTLINE

- Background and Purpose
- Baseline Study Key Findings
- Assessment of Contributing Entities Results
- Market Potential Analysis Results
- Conclusions and Recommendations

OVERVIEW OF PROJECT

General Purpose

- Provide an understanding of the type and efficiency of existing energy using equipment
- Help understand market practices for new construction and new equipment
- Estimate magnitude of efficiency opportunity, to help inform program budgets and goals
- Understand where the largest opportunities lie, to help inform program design

OVERVIEW OF PROJECT

Baseline Study (Original)

- Residential Sector
  - 500 fifteen-minute surveys
  - 120 follow-up site visits
  - 5-7 in-depth interviews (IDIs) with market actors
- Commercial Sector
  - Focus on two market segments (default the sectors with highest energy use)
  - Telephone based screener to help recruit for site visits
  - 70 site visits evenly distributed across the two sectors
  - 5-7 in-depth interviews
- Industrial Sector
  - Overall Lower emphasis
  - Maximum of 5 industries for site visits
  - Specific approach will be defined depending on initial data
- Final Results
  - Typical sizes and efficiencies of equipment in key end uses
  - Disaggregation of energy use by end use

RESIDENTIAL SECTOR - FINAL SAMPLE SIZES BY SEGMENT

- The survey was split into two short sections to increase response rates in absence of incentives. After completing the first section, 38% of respondents completed the second.
- Survey responses exceeded the sampling target of 500 responses for Part 1 (N=632). As expected, response rate were lower for Part 2 (N=241).
- Overall, 76 site visits were completed.
- Responses for some building type, ownership, and income-level strata were below original sampling targets (150+ for survey, 50+ for site visits).
- Sample sizes mostly exceeded the original regional sampling target of 50+ responses for Part 1
- Note that final sample sizes generally exceeded revised targets from October 2023 which were based on observed expected response rates without incentives.

Strata	Strata Segment	Survey Part 1 (N=632)	Survey Part 2 (N=241)	Site Visit (N=76)
Building Type	Single Family (1-4 units)	542	207	64
	Multifamily (4+ units)	90	34	12
Ownership	Owners	532	201	60
	Renters	100	40	16
Income level	Not Low-income	534	209	65
	Low-income	98	32	11
Sampling region	Ponce	64	27	6
	Arecibo	47	13	2
	San Juan	133	54	18
	Caguas	103	41	18
	Mayaguez	68	29	11
	Carolina	73	28	6
	Bayamon	144	49	15

COMMERCIAL SECTOR – METHODOLOGY

SAMPLING TARGETS

- Site visit data collection targeted the office, retail, and healthcare sectors, which were estimated to have significant savings potential.
- Establishments were sampled across a range of size-classes defined by number of employees.
- Across all sectors, the number of sampled sites fell short of the overall targets, but a distribution of employee size-classes was captured within each sector
- Note that final sample sizes generally exceeded revised targets from October 2023 which were based on observed expected response rates without incentives.

Commercial sector sampling targets compared to actual

Sector	Strata	Strata Target (N)	Strata Sample (N)	Sector Target (N)	Sector Sample (N)
Office – Employees	Small (1-9)	10+	6	35	25
	Medium (10-49)	10+	18		
	Large (50+)	4+	4		
Retail – Employees	Small (1-9)	10+	8	35	21
	Medium (10-49)	10+	5		
	Large (50+)	4+	8		
Healthcare – Type	Outpatient	20+	11	30	12
	Inpatient	4+	1		

RESIDENTIAL SECTOR - BUILDING CHARACTERISTICS

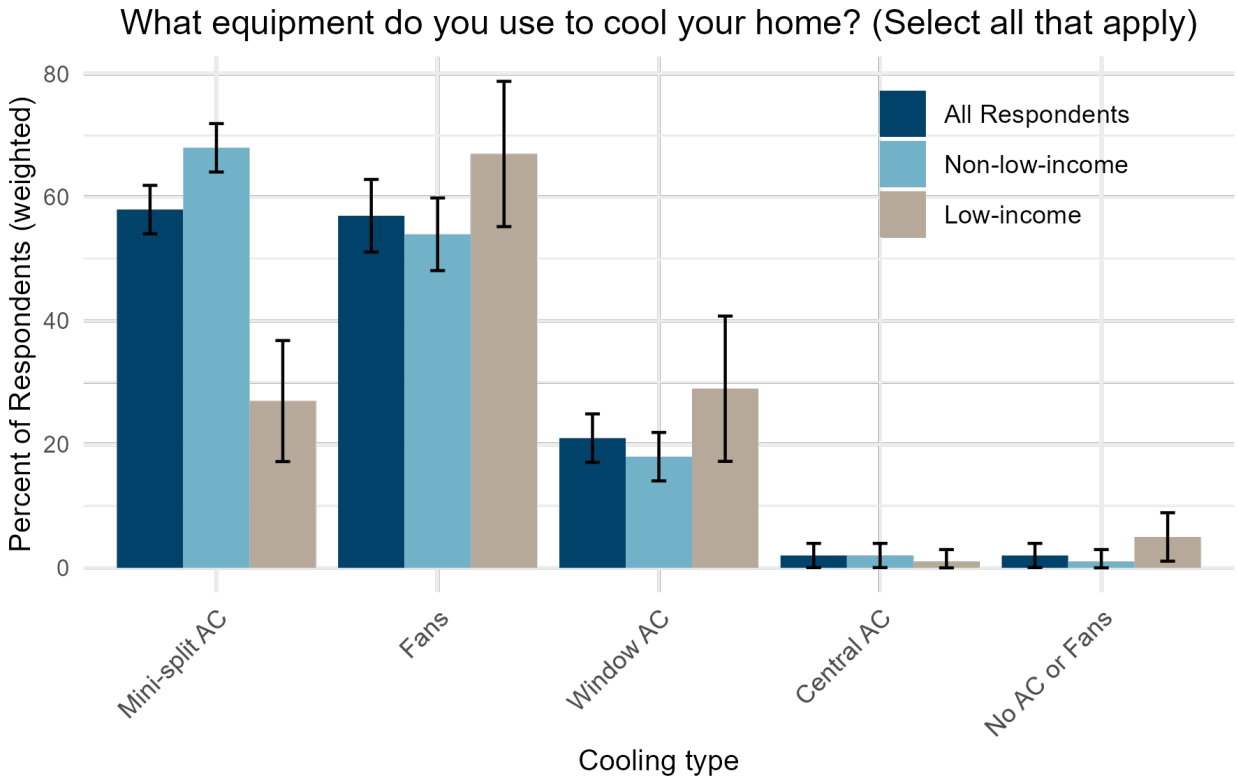
- Construction is mostly concrete
  - Walls: 94% block or poured concrete (rsv)
  - Roofs: 92% concrete (rsv)
  - Foundations: 100% concrete slab, perimeter or block (rsv)
- Insulation is uncommon
  - Walls: < 2% insulated (rsv)
  - Roofs: <25% insulated (rsv)
- Windows are a mix of single-pane and aluminum louvered “Miami style”
  - 50% single-pane, 34% miami style (rsv)
  - Miami style windows both economical and important for hurricane adaptation (IDI)

Typical single-family home with uninsulated concrete construction, a flat roof, and louvered “Miami style” windows.
Photo credit: IBTS staff

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - HEATING & COOLING EQUIPMENT

- Homes use a mix of cooling equipment that varies by income-level
  - Most residences use mini-split air conditioners and/or fans for cooling (svy)
  - Most residences (75%) use some form of air conditioning (svy)
  - Air conditioning is less common in low-income households (53%) compared to non-low-income households (82%)
  - Central AC systems were only reported in 2% of households (svy)
- Heating is rare
  - Only 3% of homes use occasional heating primarily through space heaters

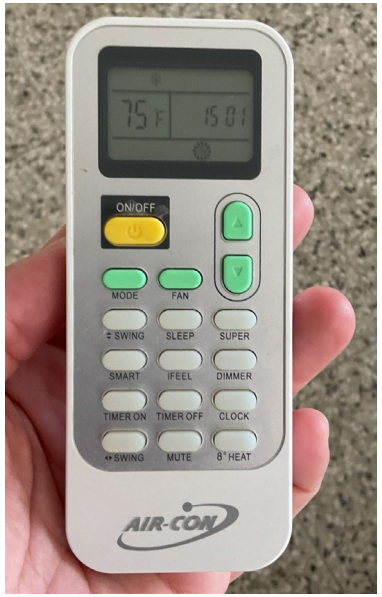


Error bars indicate 95% confidence intervals from survey.

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - HEATING & COOLING STRATEGIES

- Households with air conditioning typically use nearly year-round but for only part of the day and/or part of the home.
  - 70% of homes with AC use it 10-12 months of the year (svy)
  - 67% of homes with AC use it <12 hours on a typical day when it is use (svy)
  - Only 27% of households cool more than 90% of their home's area (rsv)
  - A common strategy is to only cool bedrooms (rsv)



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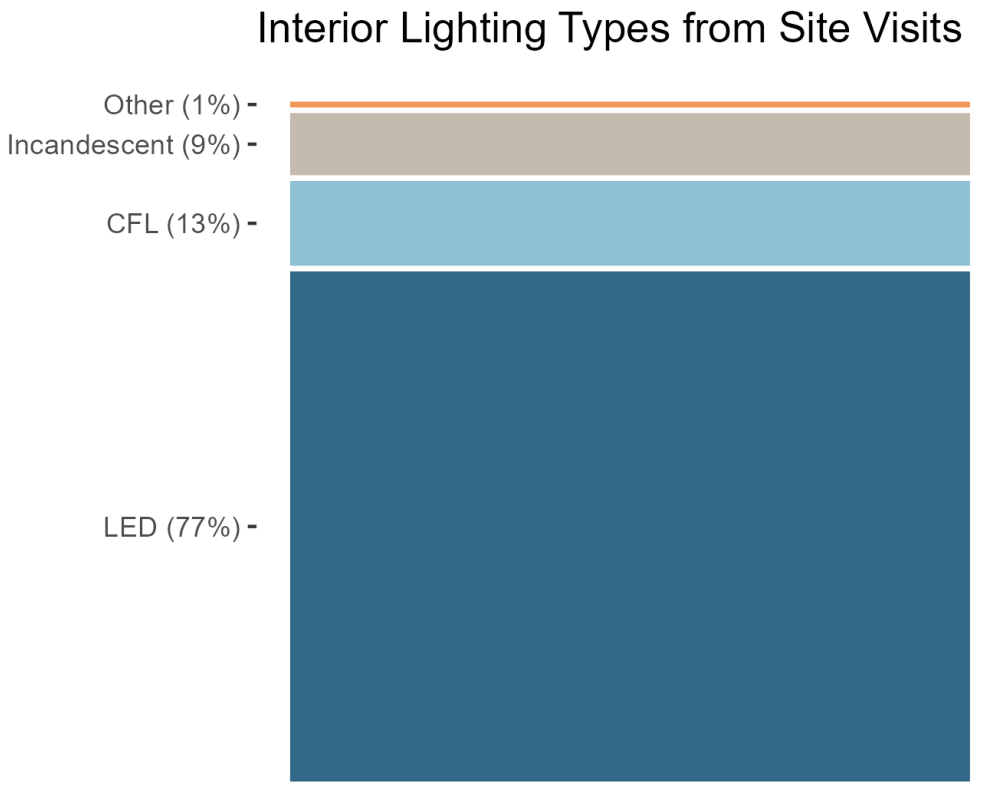
RESIDENTIAL SECTOR - LIGHTING

- LEDs were the most common lighting type in the residential sector (svy/rsv)
- The frequency of lighting types did not differ significantly by income level, building type or ownership (svy/rsv)



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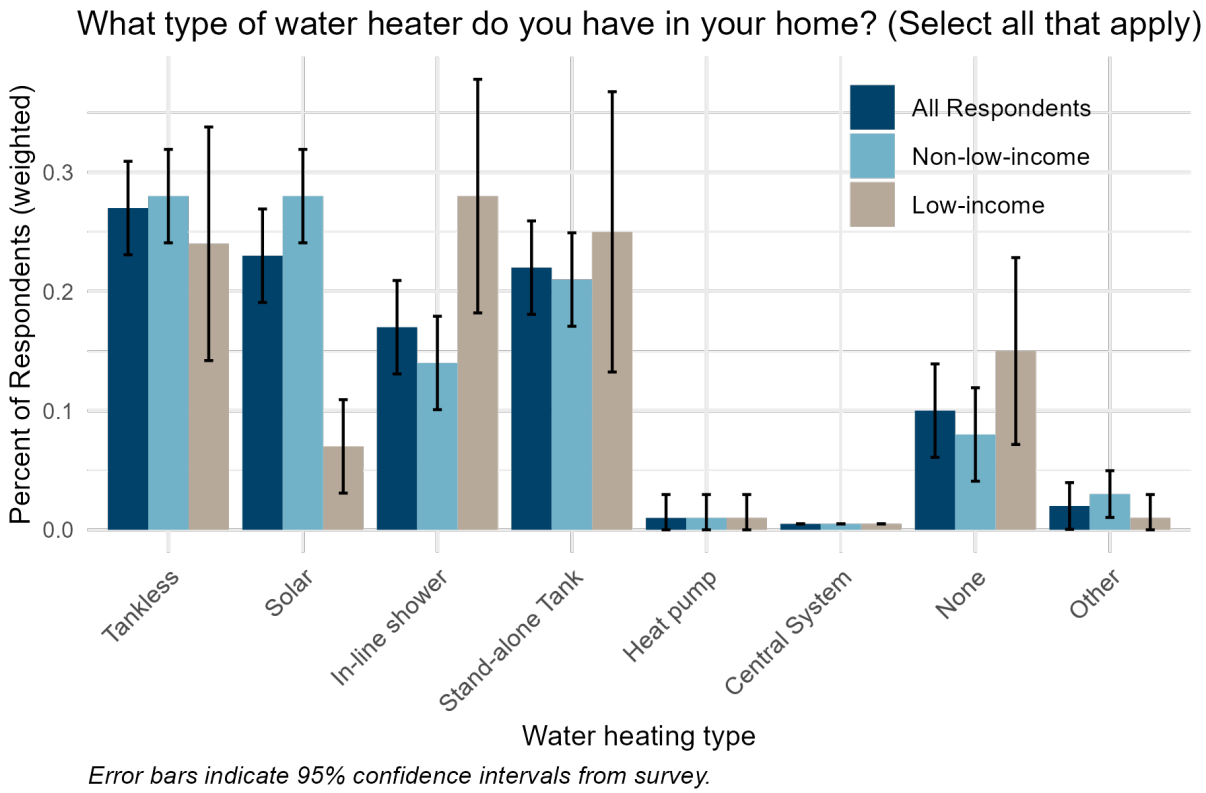
RESIDENTIAL SECTOR - WATER HEATING TYPES

- Tankless, in-line, and solar water heating is popular (svy)
  - Among all households, 43% have in-line shower or tankless water heaters, while 22% have stand-along tank heaters
- Low-income household appear to use less how water (svy)
  - 15% of low-income households do not have hot water compared to 8% of non-low-income households but the difference is not statistically significant
- Solar hot water is less common in low-income households (svy)
  - Only 7% of low-income households reported solar hot water compared to 28% of non-low-income households



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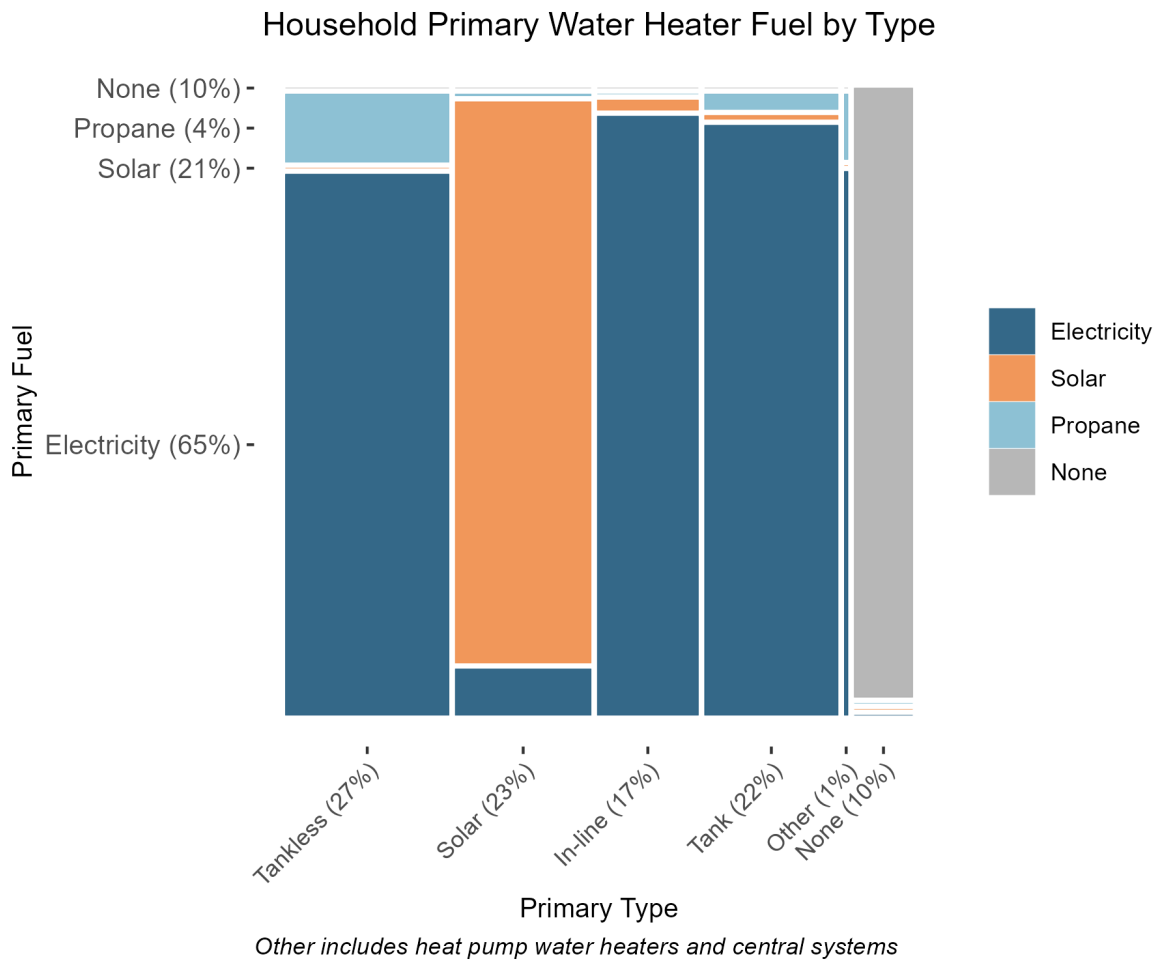
RESIDENTIAL SECTOR - WATER HEATING FUELS

- Among all households, most (65%) use electricity as their primary heating fuel (svy)
- Homes with solar hot water may have secondary water heating that use electricity or propane (svy)
- Propane represents a small fraction of water heating fuels across all households (4%), but is more common in homes with tankless water heaters (svy)

Note: Water heater type percentages differ slightly from previous slide because only one primary type was assigned by household for analysis.

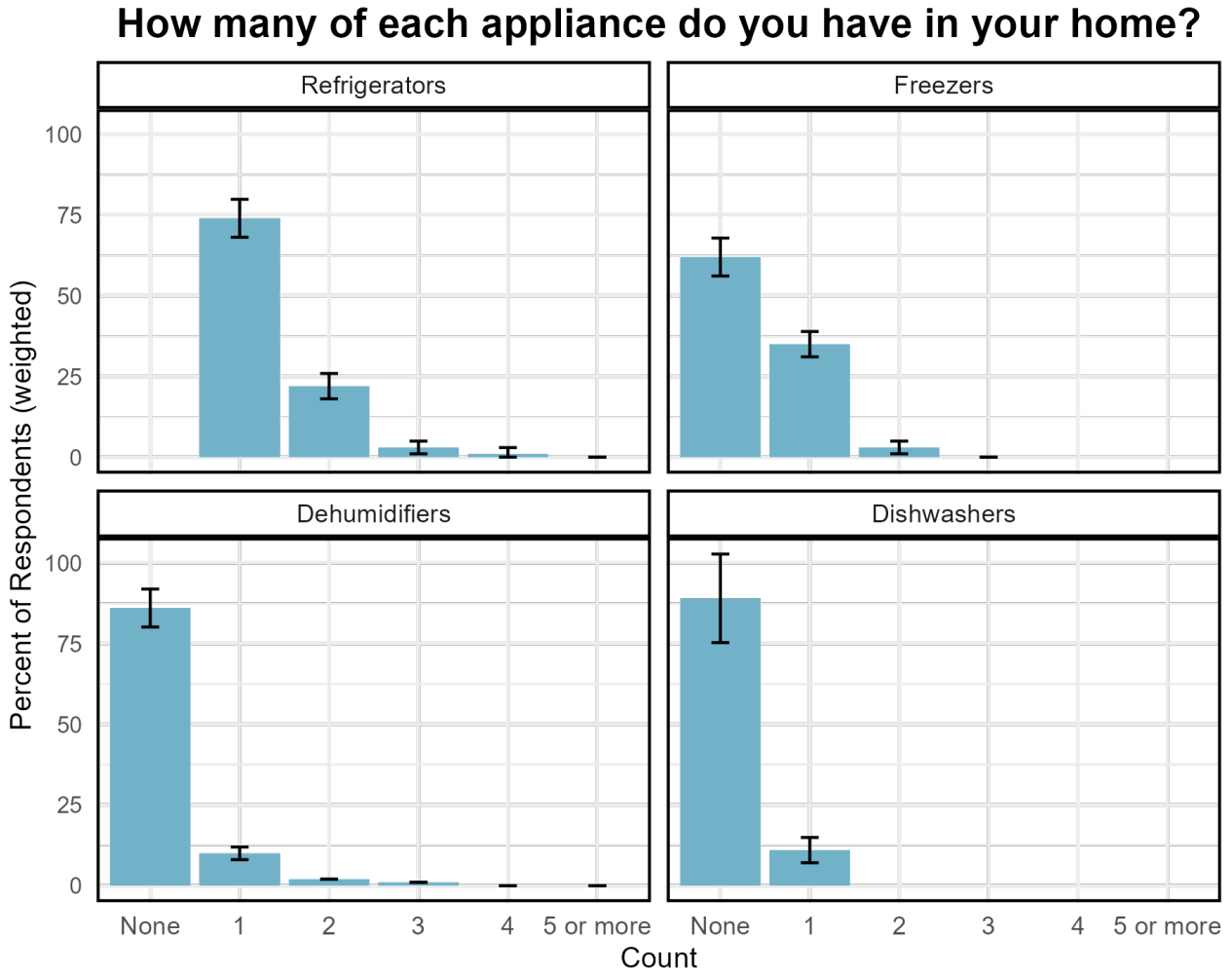


Other includes heat pump water heaters and central systems

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - APPLIANCES

- Refrigerators and freezers are common (svy)
  - All those surveyed at least one refrigerator and 38% had an additional freezer
- Dehumidifiers and dishwashers are uncommon (svy)
  - 14% of survey households had a dehumidifier and 11% had a dishwasher
- Secondary fridges may represent a savings opportunity (svy/rsv)
  - More than 20% home have a second refrigerator
  - 96% of second fridges are plugged in and used year-round (rsv)
  - 85% of second fridges are >10 years old



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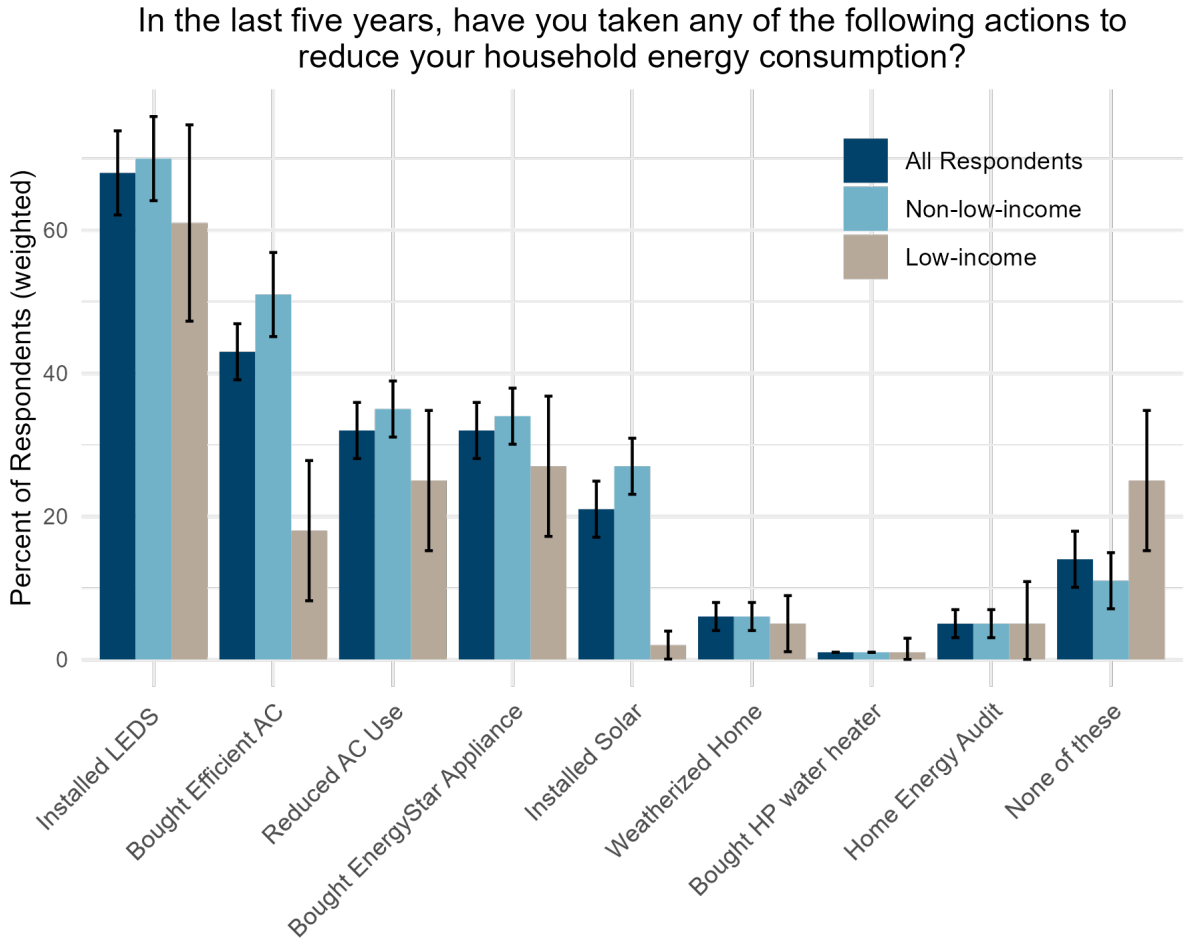
RESIDENTIAL SECTOR - ENERGY EFFICIENCY ACTIONS

- Installing LEDs and efficient AC were the most common measures (svy)
  - 68% of households have installed LEDS
  - 43% of households have installed a more efficient AC
- Energy efficiency actions are more common among non-low-income, single-family owners (svy)
  - Low-income and multifamily respondents are least likely to report any energy efficiency actions (~25% have not taken an action)
  - Non-low-income, single-family respondents are more likely to have bought an efficient AC or installed solar



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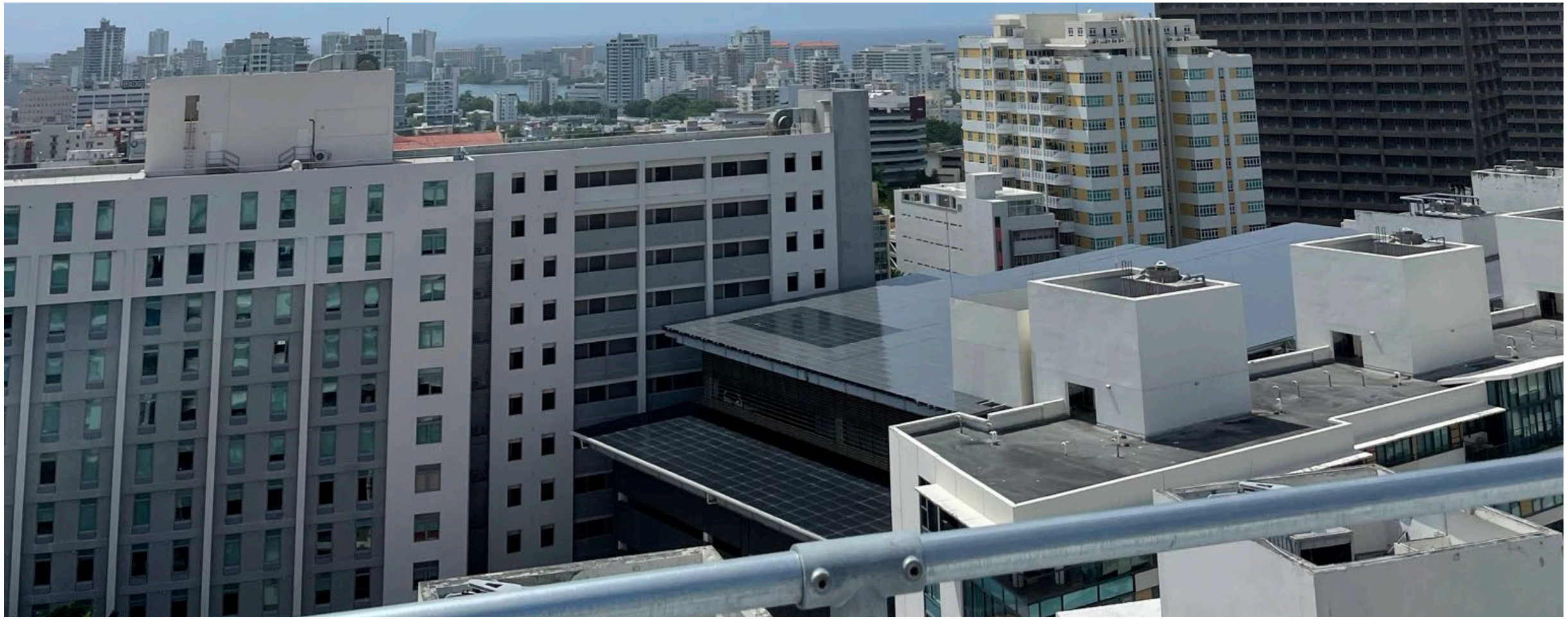
COMMERCIAL CHARACTERIZATION HIGHLIGHTS



COMMERCIAL SECTOR – METHODOLOGY

SAMPLING TARGETS

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COMMERCIAL SECTOR – ENVELOPE

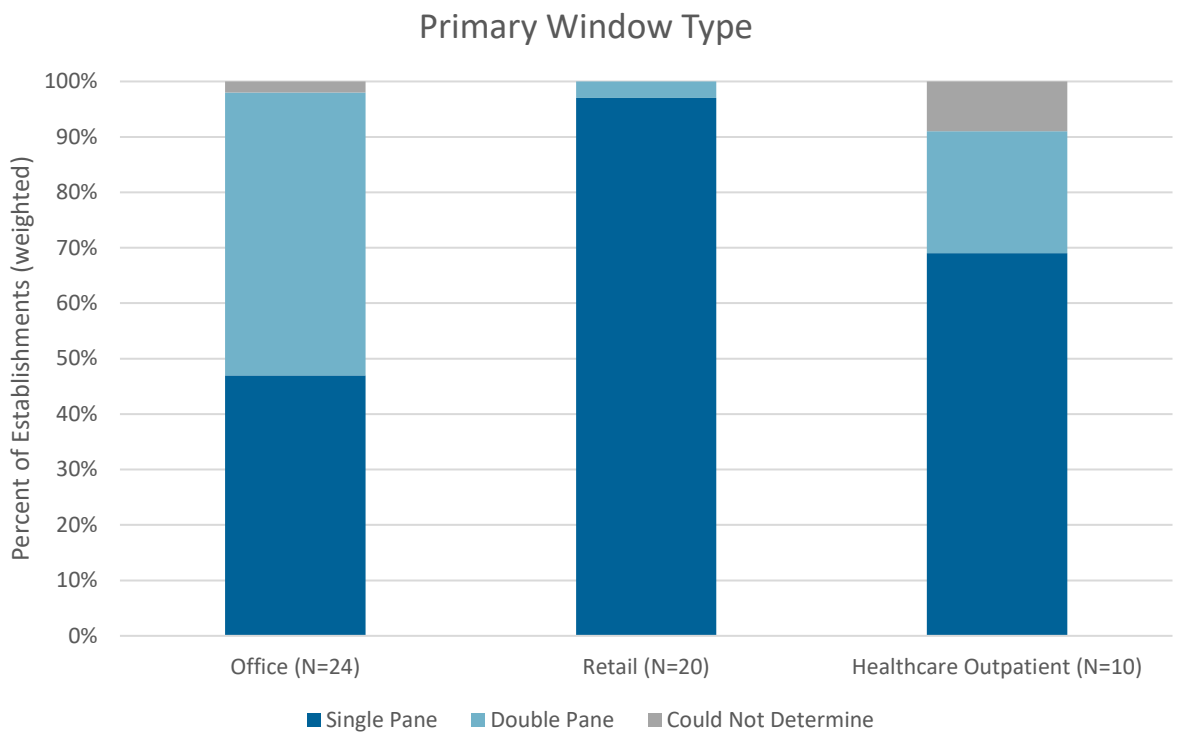
- Concrete or concrete block wall construction common in Puerto Rico
- Flat roof is most typical roof type
- Wall and roof insulation is not common for retail buildings in Puerto Rico
- Office buildings generally do not have insulation in walls but may have a higher chance for insulation in roof
- Over half of healthcare outpatient buildings do not have insulation in walls or roof

Sampling Segment	Primary Wall Construction			Insulation Present in Walls		
	Concrete or Concrete Block Walls	Metal-Framed Walls	Unknown	Yes	No	Could Not Determine
Office (N=25)	99%	1%	0%	9%	90%	1%
Retail (N=21)	92%	0%	8%	0%	100%	0%
Healthcare Outpatient (N=11)	66%	3%	31%	24%	65%	11%

Sampling Segment	Primary Roof Construction		Insulation Present in Roof		
	Flat Roof	Attic Roof	Yes	No	Could Not Determine
Office (N=25)	98%	2%	51%	41%	8%
Retail (N=21)	100%	0%	7%	80%	13%
Healthcare Outpatient (N=11)	100%	0%	17%	56%	27%

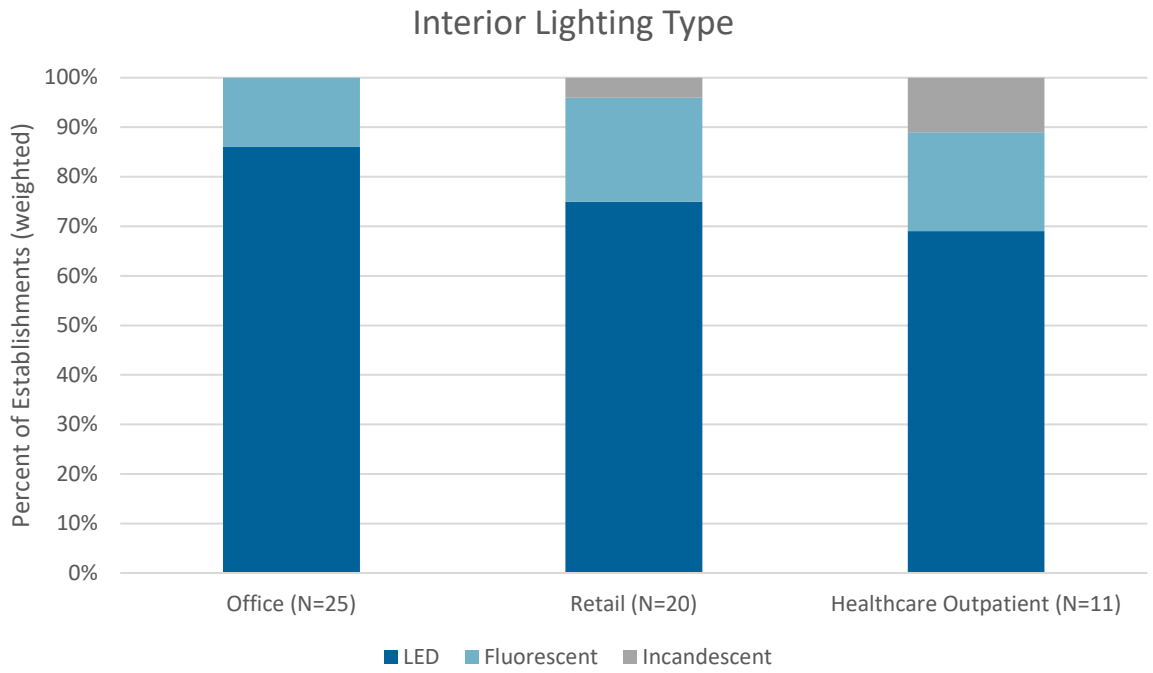
COMMERCIAL SECTOR – ENVELOPE

- Office buildings (particularly larger sized) have a higher tendency for double pane windows
- Small office, retail and healthcare outpatient are more likely to have single pane windows
- Envelope renovation for energy efficiency is not common



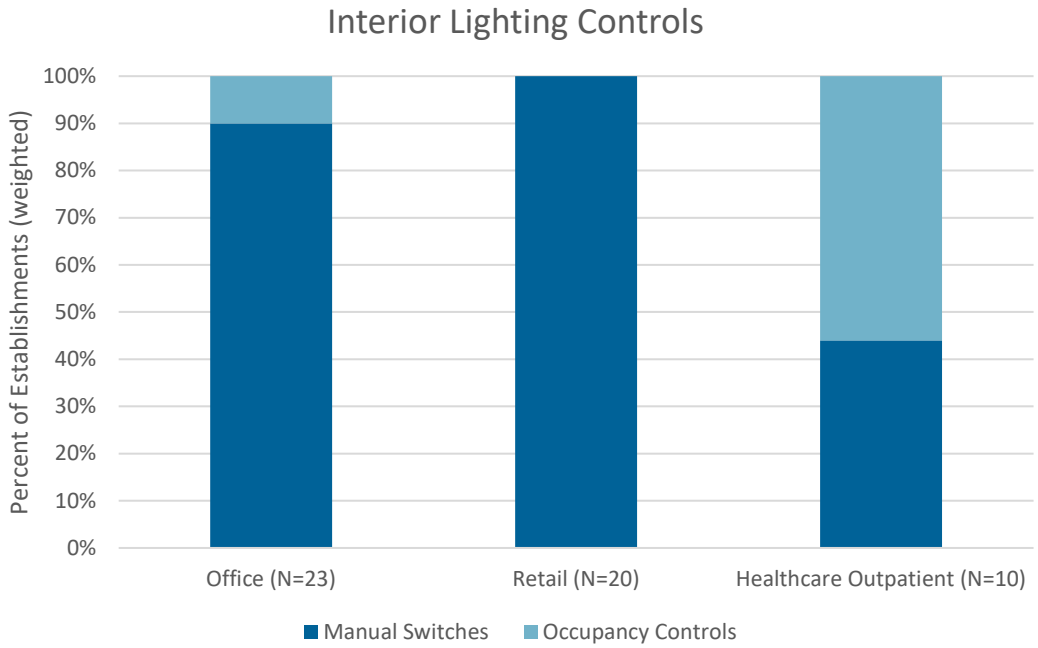
COMMERCIAL SECTOR – INTERIOR LIGHTING

- Interior lighting fixtures are typically the first building system that receives an upgrade
- Majority of interior lighting in office, retail and healthcare outpatient buildings have already been retrofitted to LED
- Still some opportunities exist to upgrade interior lighting from fluorescent to LED



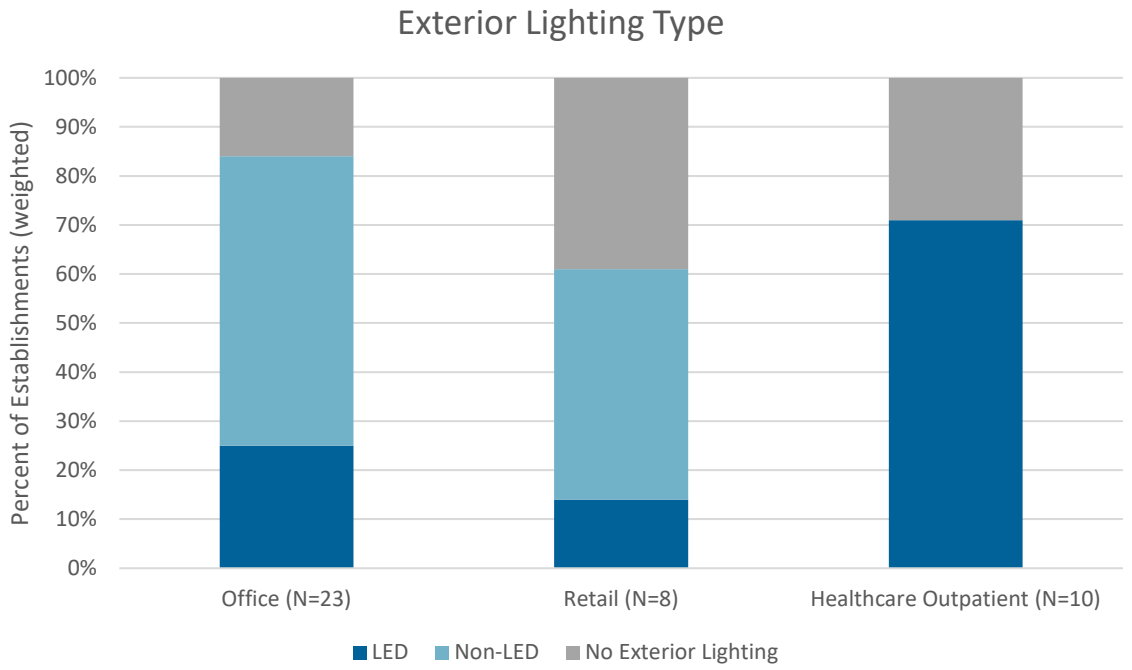
INTERIOR LIGHTING CONTROLS – COMMERCIAL SECTOR

- Manual switches are the most prevalent interior lighting control strategy for office and retail buildings
- Much opportunity for occupancy controls, daylighting controls, task tuning and other advanced lighting controls
- Healthcare outpatient sees more occupancy controls in patient rooms



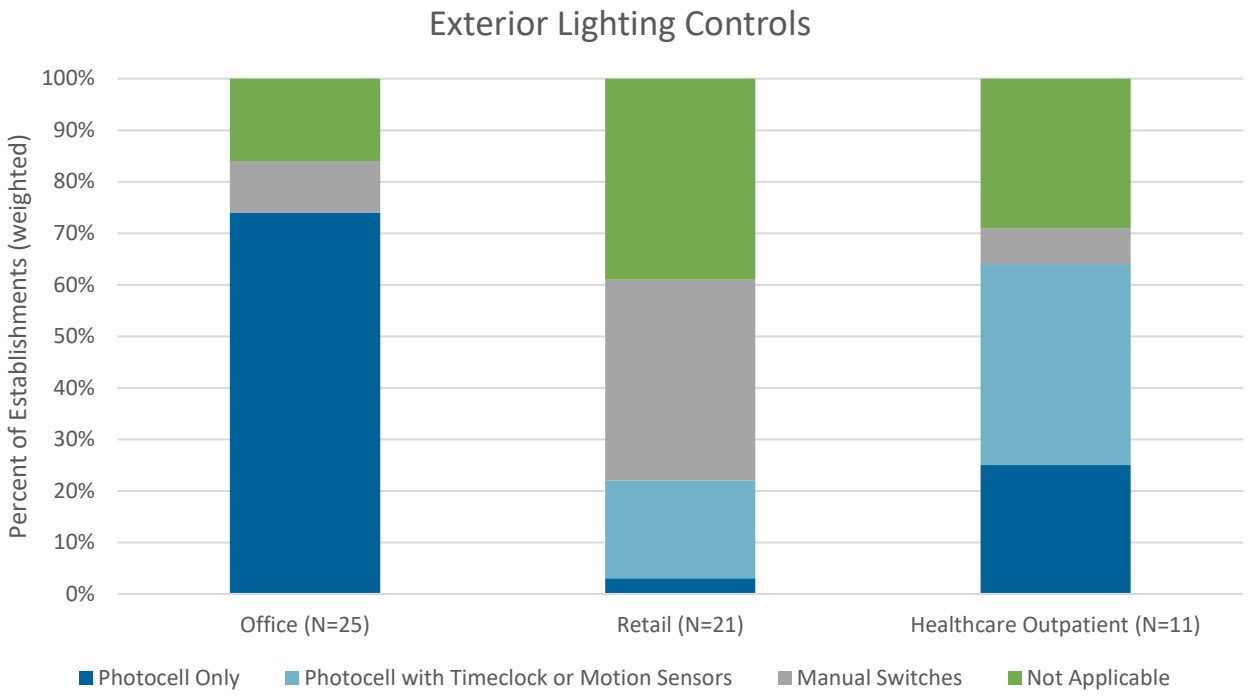
COMMERCIAL SECTOR – EXTERIOR LIGHTING

- Some portion of office, retail and healthcare outpatient buildings do not have exterior lighting.
  - Office and retail buildings with exterior lighting are unlikely to have LEDs
  - Majority of exterior lighting in healthcare outpatient buildings have already been retrofitted to (or originally designed as) LED



COMMERCIAL SECTOR – EXTERIOR LIGHTING CONTROLS

- Majority of exterior lighting controls are photocell only for office buildings
- Small retail buildings have a higher tendency to have manual switches for basic exterior lighting
- Healthcare outpatient has a higher tendency to have exterior lighting photocell controls coupled with timeclock or motion sensor control



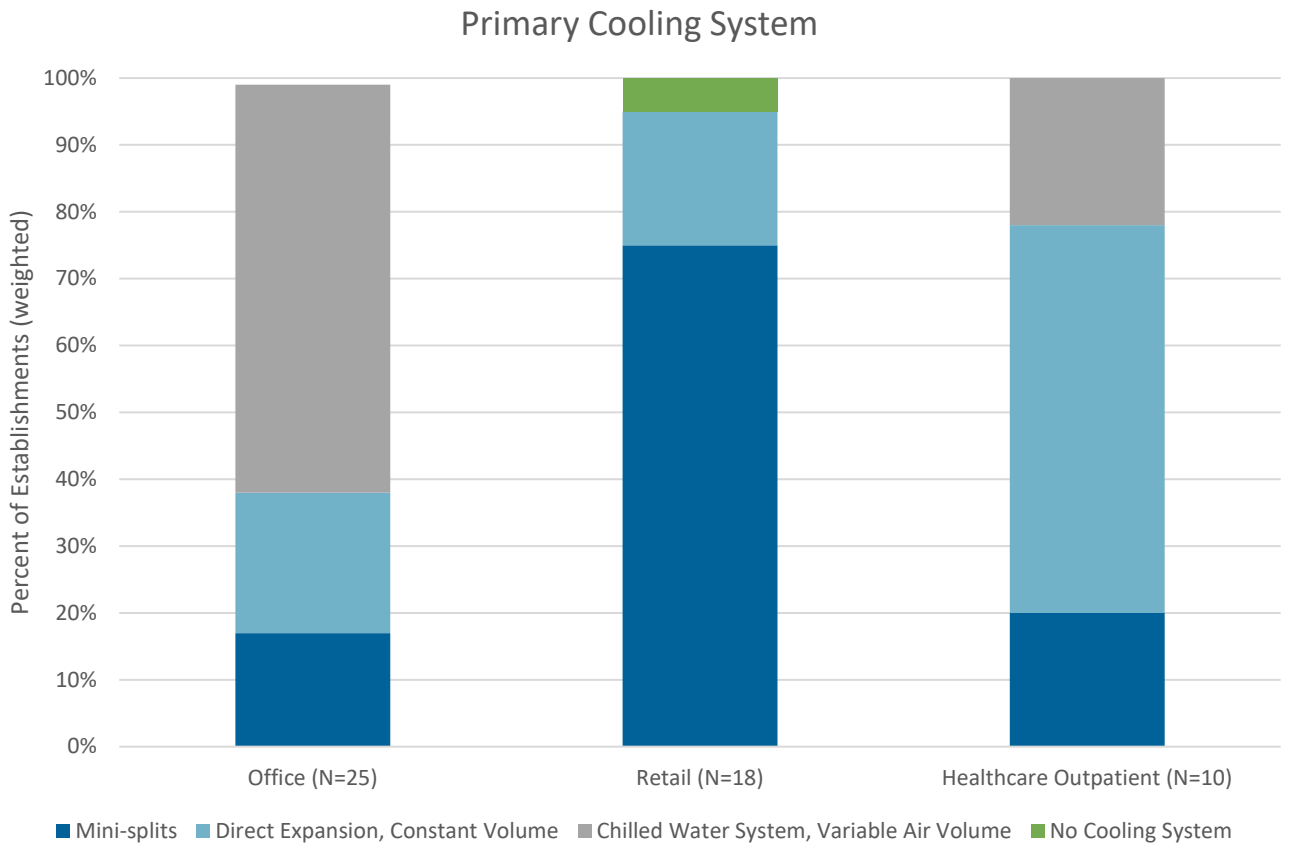
COMMERCIAL SECTOR – COOLING SYSTEMS

Example of mini-split air conditioner indoor unit. *Photo credit: IBTS staff*

Example of split system air conditioner outdoor unit. *Photo credit: IBTS staff*

COMMERCIAL SECTOR – COOLING SYSTEMS

- Mini-splits are the prevailing cooling system type for small office and small retail buildings
- Medium-sized office, retail and healthcare outpatient are more likely to have a centralized system with direct expansion cooling through constant volume AHU or RTU
- Large offices and large outpatient facilities are more likely to be served by a chilled water system and VAV AHU

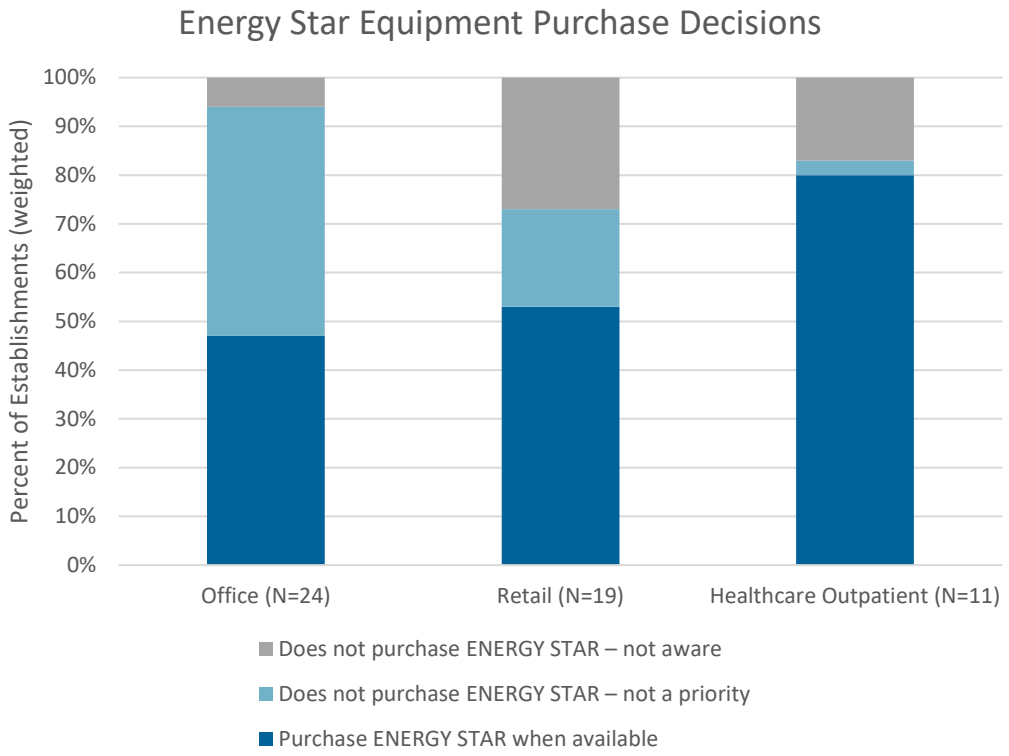


COMMERCIAL SECTOR – WATER HEATING

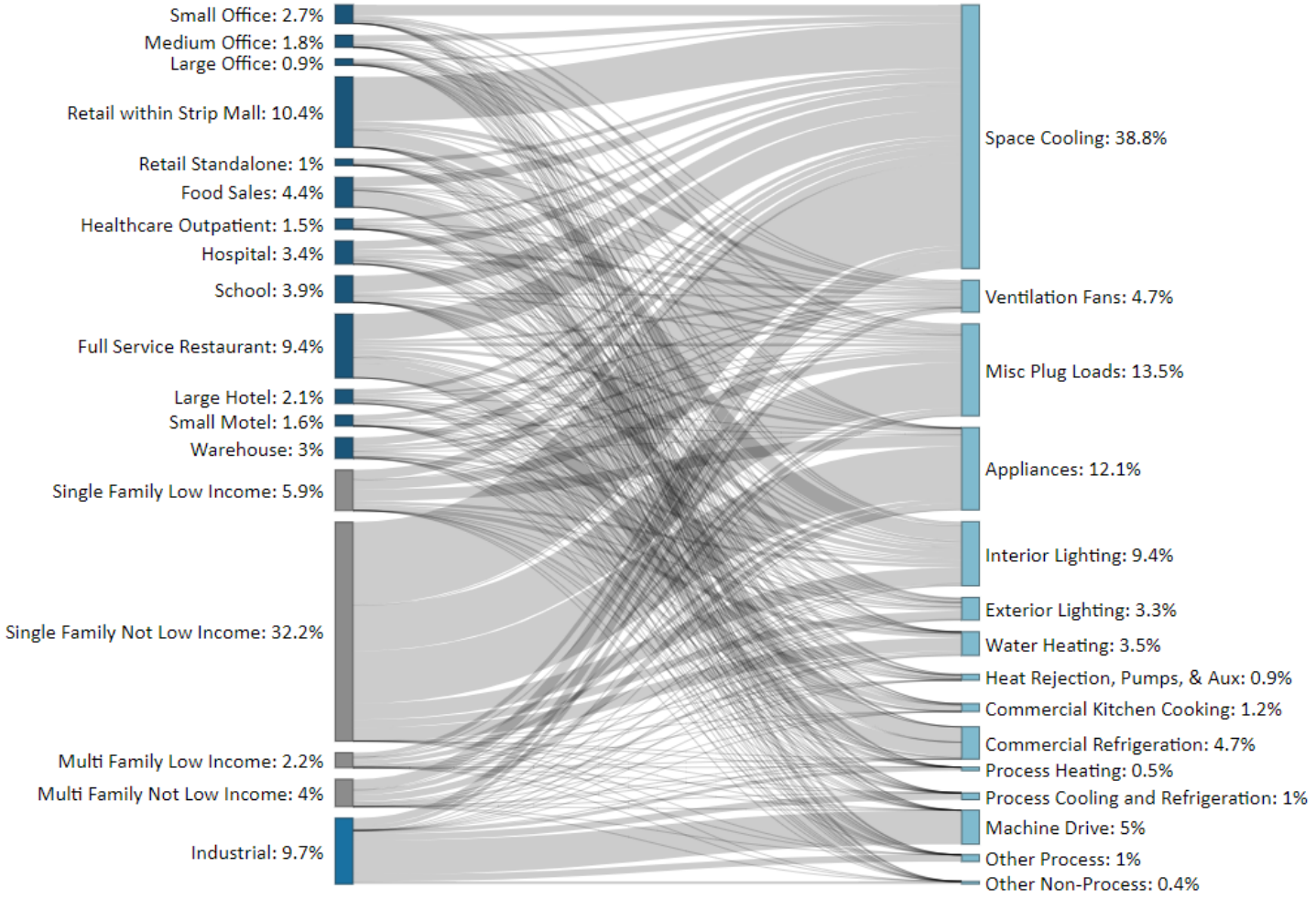
- Most of office, retail, healthcare outpatient buildings sampled do not have water heating
- When water heating exists, electric resistance water heaters are typically used
  - When part of a central DHW system, demand recirculation controls are rarely present
- Although not seen in site visit data, IBTS field staff reported that large hotel and healthcare inpatient facilities often use propane as fuel source for water heating

COMMERCIAL SECTOR – APPLIANCE & PLUG LOADS

- Most office, retail, healthcare outpatient buildings only have residential-style refrigerators; dishwashers in break rooms are not common
- Half of office and retail owners and majority of healthcare outpatient owners purchase ENERGY STAR equipment when available
- Advanced power strips for plug load management are not common
- Half of the surveyed buildings enable server room power management
- EV chargers generally do not have time-of-use control



FINAL SALES DISAGGREGATION



OVERVIEW OF PROJECT

Baseline Assessment of Contributing Entities

- Quantify contribution towards EE target from:
  1. Energy efficiency **programs** and actions **in governmental buildings**;
  2. Savings resulting from the adoption of **new building energy codes** implemented after 2019, or increased compliance with building energy codes;
  3. Savings resulting from incremental **federal or Commonwealth appliance energy efficiency standards** and laws implemented after 2019;
  4. Energy efficiency in **non-governmental buildings** resulting from actions funded by federal or Commonwealth governmental funds, such as low-income weatherization programs, Community Development Block Grants, disaster recovery or hazard mitigation funds, or other such programs
- Will help determine/influence amount of EE required by LUMA's EE programs

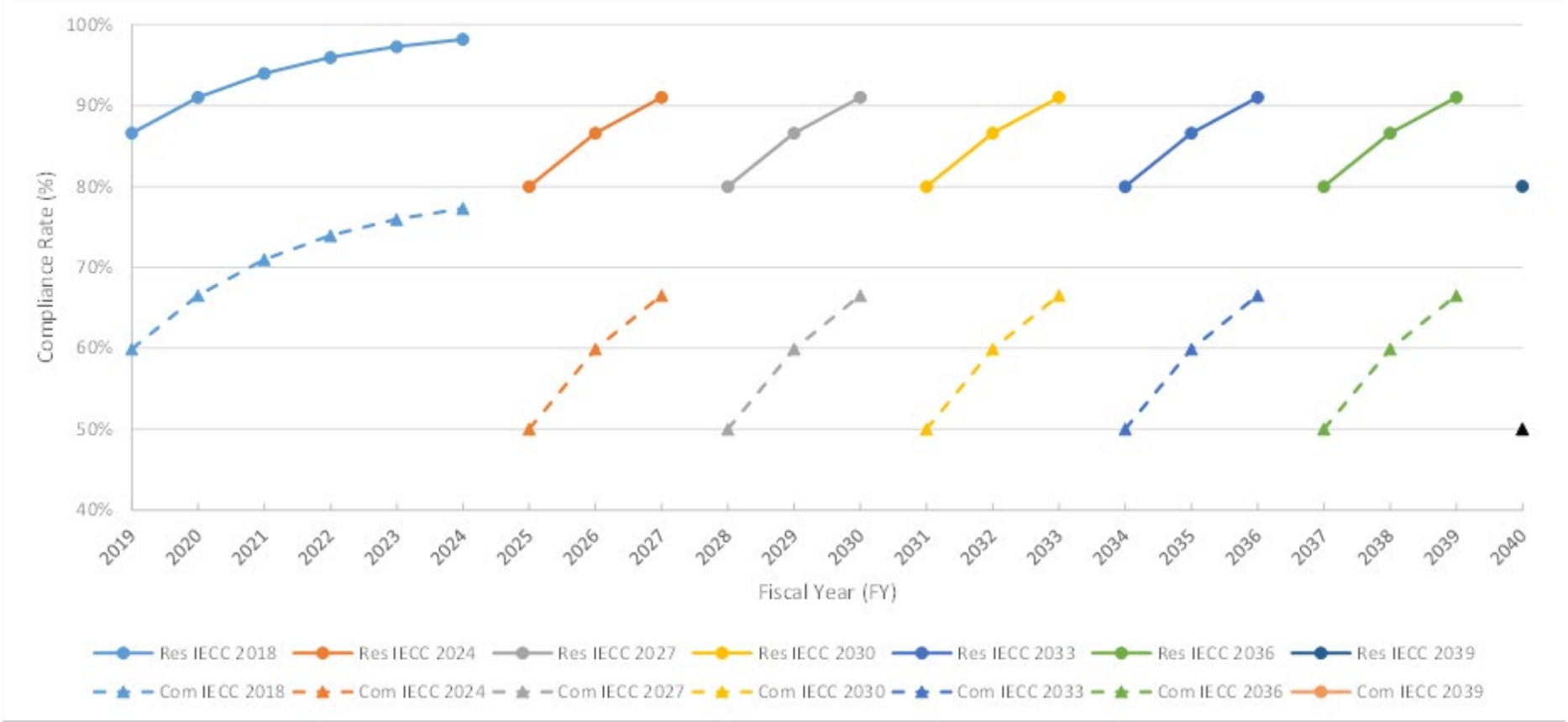
BUILDING ENERGY CODES SUMMARY, METHODS

- Impacts assume periodic code adoption, increasing compliance assumptions, and new construction rates.
- Average reduction in modeled site EUI relative to the previous code version is **4.9% for residential** and **10.5% for non-residential.**

Residential				
IECC Version	% Site EUI Reduction Relative to Previous Code	Previous Code Site EUI (kBtu/ft²-yr)	New Code Site EUI (kBtu/ft²-yr)	Source
2015	0.8%	14.0	13.9	1
2018	1.5%	14.3	14.1	2
2021	10.8%	28.8	25.7	3
2024	6.4%	26.7	24.8	4
Average	**4.9%**			
Commercial				
IECC Version	% Site EUI Reduction Relative to Previous Code	Previous Code Site EUI (kBtu/ft²-yr)	New Code Site EUI (kBtu/ft²-yr)	Source
2015	8.5%	52.9	48.4	5
2018	3.6%	49.4	47.6	6
2021	15.6%	49.5	41.8	7
2024	14.1%	41.8	35.9	8
Average	**10.5%**			

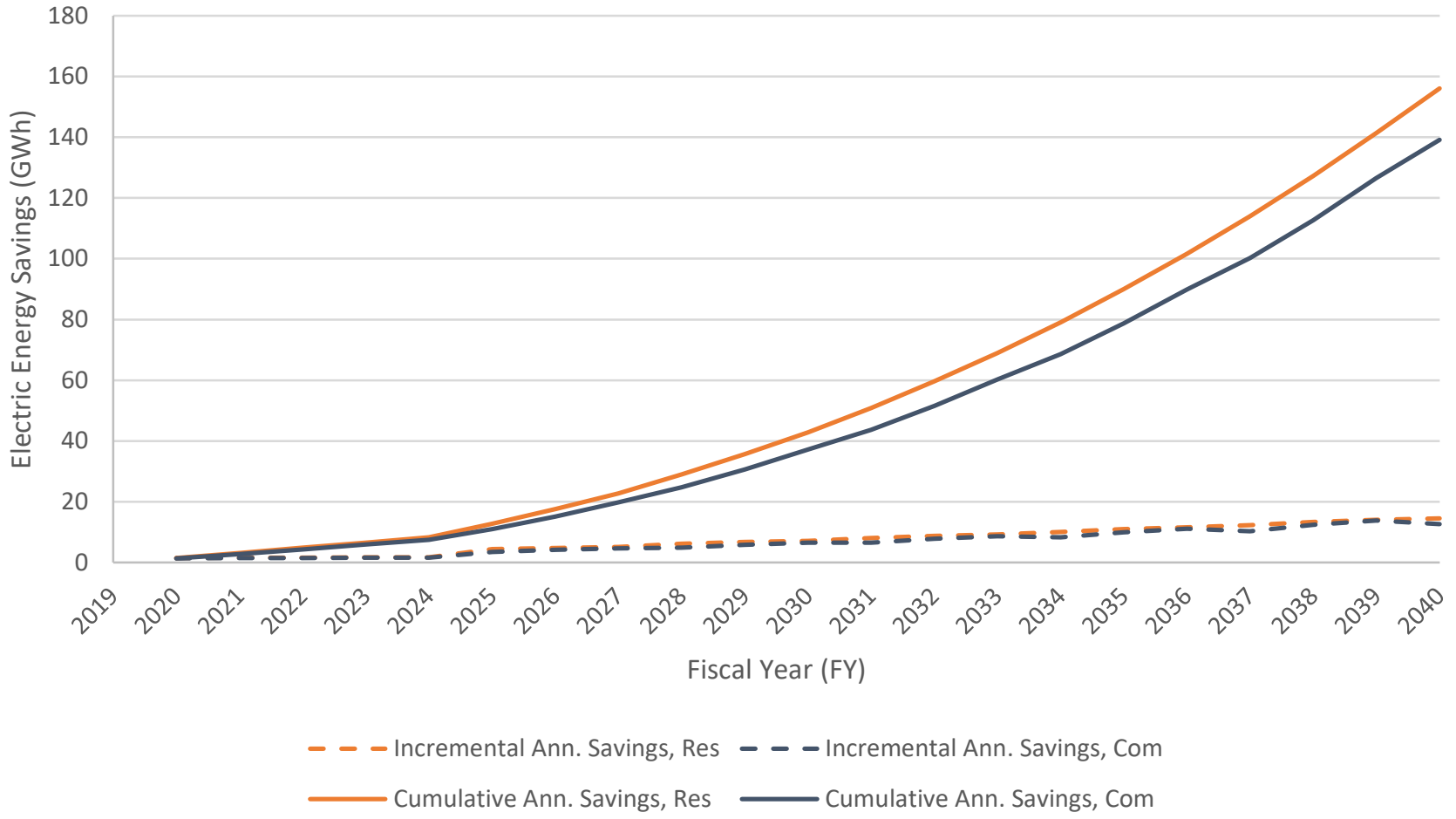
BUILDING ENERGY CODES SUMMARY, METHODS

- Compliance assumptions vary by sector.
- Compliance increases with each successive year a given code version has been active.



BUILDING ENERGY CODES SUMMARY, RESULTS

- Savings contributions increase steadily over analysis period.
- By 2040, cumulative annual savings are estimated at 156.0 GWh for residential and 139.1 GWh for commercial for a total of 295.2 GWh or 1.8% of FY2019 sales.

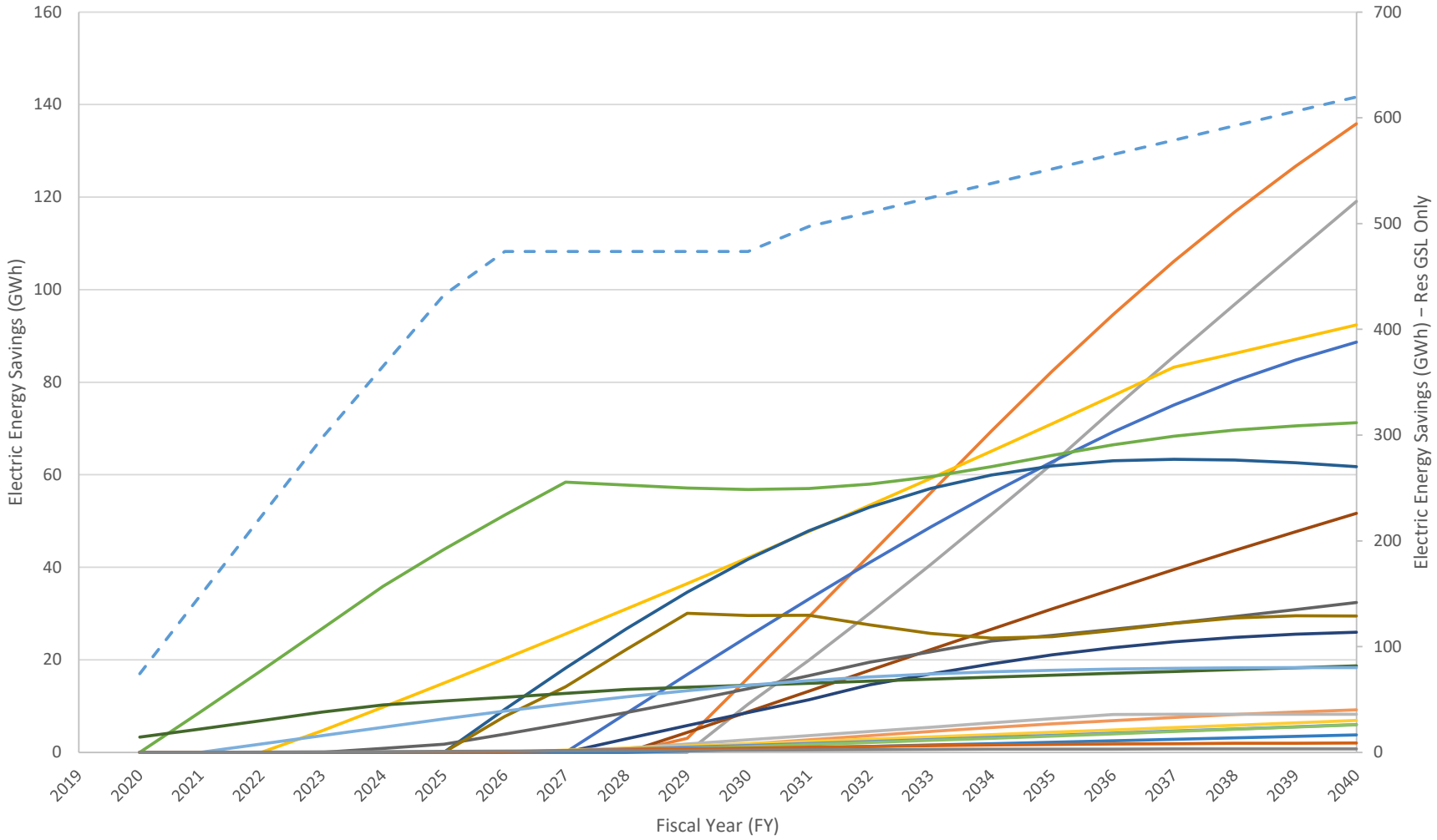


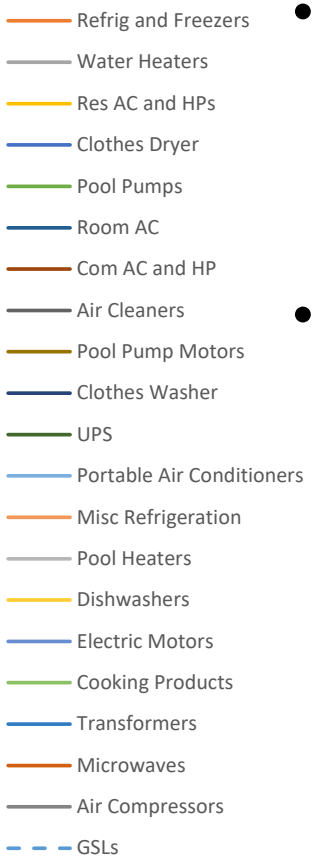
FEDERAL APPLIANCE STANDARDS, METHODS

- Considered any federal appliance standards with *compliance dates* after June 30, 2019.
- Analysis considered standards for 32 discrete product categories.
- Impact assessment generally leveraged federal *National Impact Analyses* scaled to Puerto Rico.

Sector	Product Category	Federal Register (FR) Publication Date	Effective Date	Compliance Date 1	Compliance Date 2	Included	Applicability Notes
All	Air Cleaners	4/11/2023	8/9/2023	12/31/2023	12/31/2025	Y	
All	Dedicated-purpose pool pump motors	9/28/2023	11/27/2023	9/29/2025	9/28/2027	Y	
All	Dedicated-purpose pool pumps	1/18/2017	5/18/2017	7/19/2021	N/A	Y	
All	Pool Heaters	5/30/2023	7/31/2023	5/30/2028	N/A	Y	
Com	Commercial and Industrial Air Compressors	10/10/2020	3/10/2020	1/10/2025	N/A	Y	
Com	Commercial Boilers	9/19/2023	9/19/2023	3/2/2022		N	Puerto Rico has minimal space heating requirements
Com	Commercial CAC and HP (<65,000 Btu/hr)	6/2/2023	8/1/2023	1/1/2025	N/A	Y	
Com	Commercial CAC and HP (65,000 Btu/hr to 760,000 Btu/hr)	5/20/2024	9/17/2024	1/1/2029		Y	
Com	Commercial Refrigeration Equipment	1/21/2025	3/24/2025	1/22/2029	N/A	N	FR publication date after cut-off date
Com	Commercial Warm Air Furnaces	1/15/2016	5/16/2016	1/1/2023	N/A	N	Puerto Rico has minimal space heating requirements
Com	Commercial Water Heaters	10/6/2023	12/5/2023	10/6/2026		N	Standard change does not impacts electric storage or instantaneous water heater requirements.
Com	Computer Room Air Conditioners	6/2/2023	8/1/2023	5/28/2024	N/A	N	NIA not publicly available
Com	Distribution Transformers	4/22/2024	7/8/2024	4/23/2029	N/A	Y	
Com	Electric Motors	6/1/2023	9/29/2023	6/1/2027	N/A	Y	
Com	Electric Motors (Expanded Scope)	~1/22/2025	~4/7/2025	1/1/2029	N/A	N	FR publication date after cut-off date
Com	Uninterruptible Power Supplies	1/20/2020	3/10/2020	1/10/2022	N/A	Y	

FEDERAL APPLIANCE STANDARDS, RESULTS





- Residential GSLs plotted on secondary axis.
- GSLs, water heaters, res. ACs and HPs, and clothes dryers have largest impacts

NON-GOVERNMENT BUILDINGS, METHODS

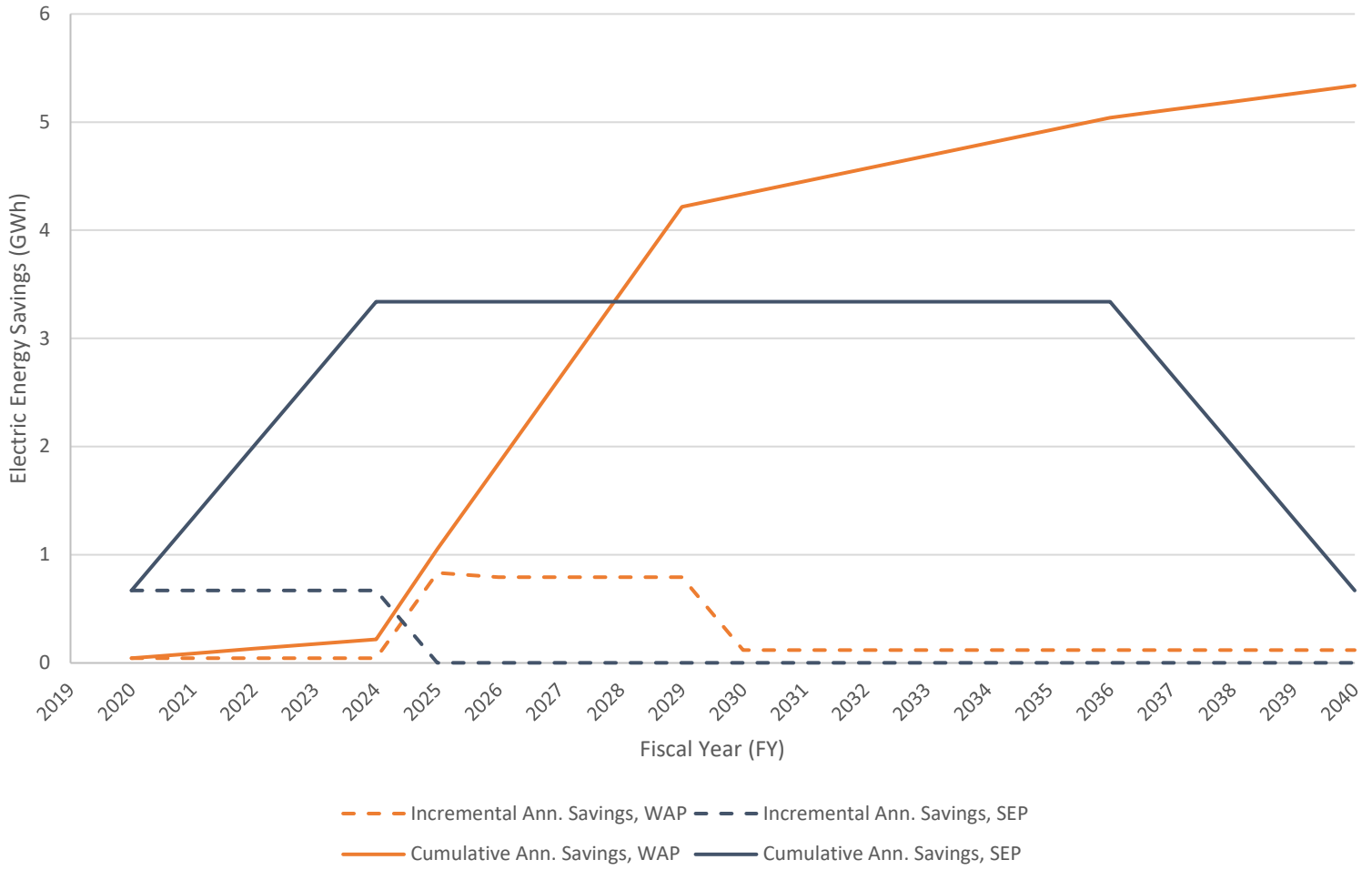
- Quantified historical WAP and SEP activity.
- Estimated WAP energy savings per dollar invested.
- Projected future WAP budgets through analysis period (inclusive of IIJA funding).

FY	Puerto Rico Weatherization Assistance Program Budget Allocation ($)
2020	$1,106,913
2021	$909,872
2022	$906,347
2023	$1,073,450
2024	$1,073,450
2025	$1,483,414
Average	**$1,092,241**

FY	Assumed WAP Budget ($)	Assumed WAP-IIJA Budget ($)	Total WAP Budget ($)
2025	$ 1,483,414	$ 6,252,890	$ 7,736,304
2026	$ 1,092,241	$ 6,252,890	$ 7,345,131
2027	$ 1,092,241	$ 6,252,890	$ 7,345,131
2028	$ 1,092,241	$ 6,252,890	$ 7,345,131
2029	$ 1,092,241	$ 6,252,890	$ 7,345,131
2030 to 2040	$ 1,092,241	$ -	$ 1,092,241

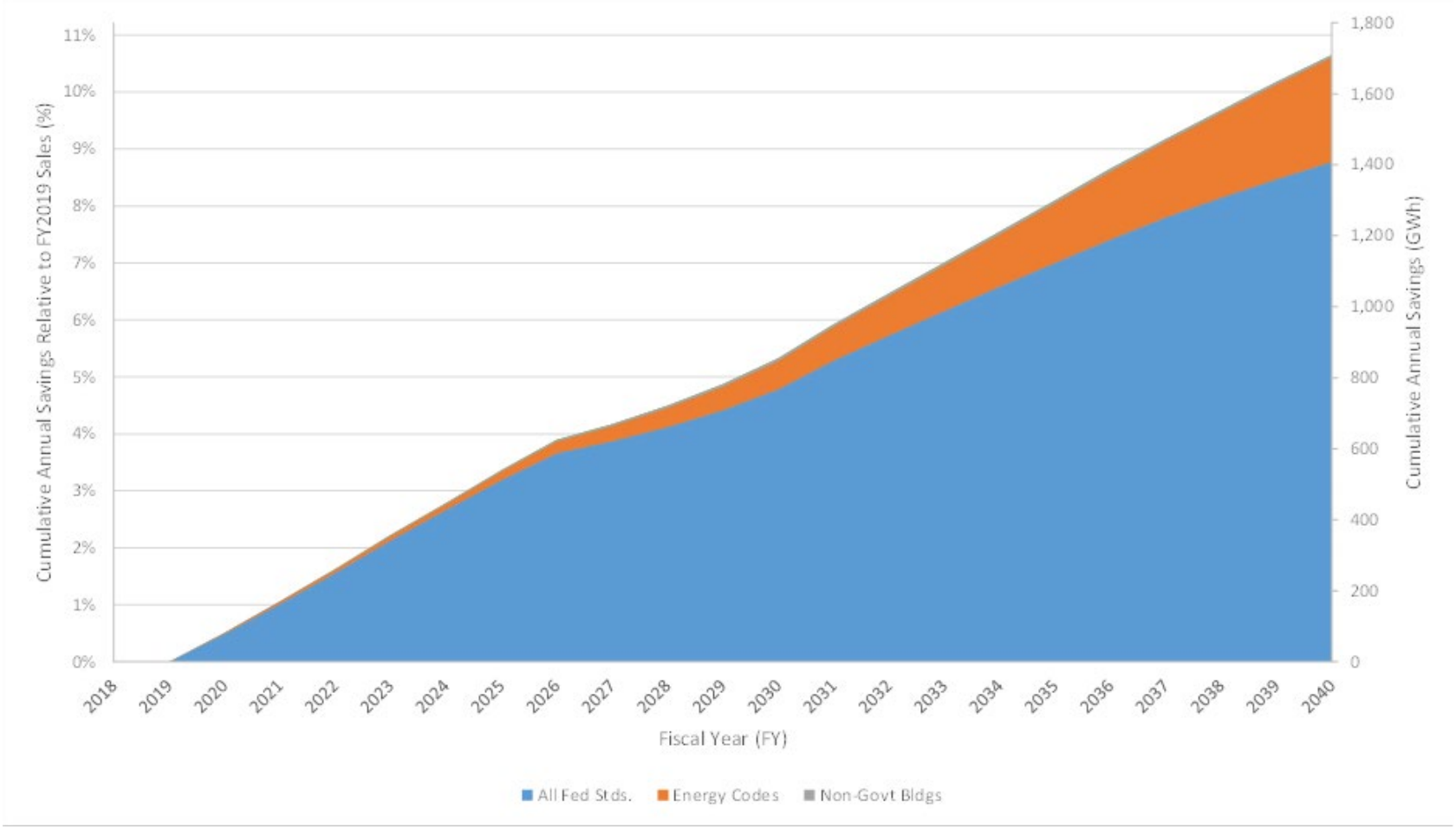
NON-GOVERNMENT BUILDINGS, RESULTS

- By 2040, cumulative annual savings are estimated at a modest 5.3 GWh for WAP and 0.7 GWh for SEP for a total of 6.0 GWh or 0.4% of FY2019 sales.
- No SEP activity projected beyond 2024.



ASSESSMENT OF CONTRIBUTING ENTITIES, SUMMARY OF RESULTS

- By 2040, combined cumulative annual savings are estimated at 1,709 GWh or 10.6% of FY2019 sales.
- Savings dominated by federal standards (specifically, GSL standards)



OVERVIEW OF PROJECT

Efficiency Potential Study

- General Study Methodology
  - Define Global inputs
  - Develop Baseline forecast
  - Characterize Measures
  - Technical and Economic Potential
  - Max Achievable and “Program” achievable potential scenarios
- The study was informed by:
  - Site visits for retrofit opportunities
  - IDIs for market driven and new construction
  - Avoided costs of energy for cost-effectiveness
  - Secondary research

- The study will:
  - Help understand total amount of efficiency available on island from EE programs
  - Inform program design by pointing to end uses and technologies with greatest potential
  - Estimating total costs and benefits from pursuing efficiency
- The study will not:
  - Give detailed program designs or program plans
  - Predict specific numbers of measures likely to be installed in future years
  - Determine methods by which program will eliminate market barriers of EE
  - Determine opportunities available in specific buildings

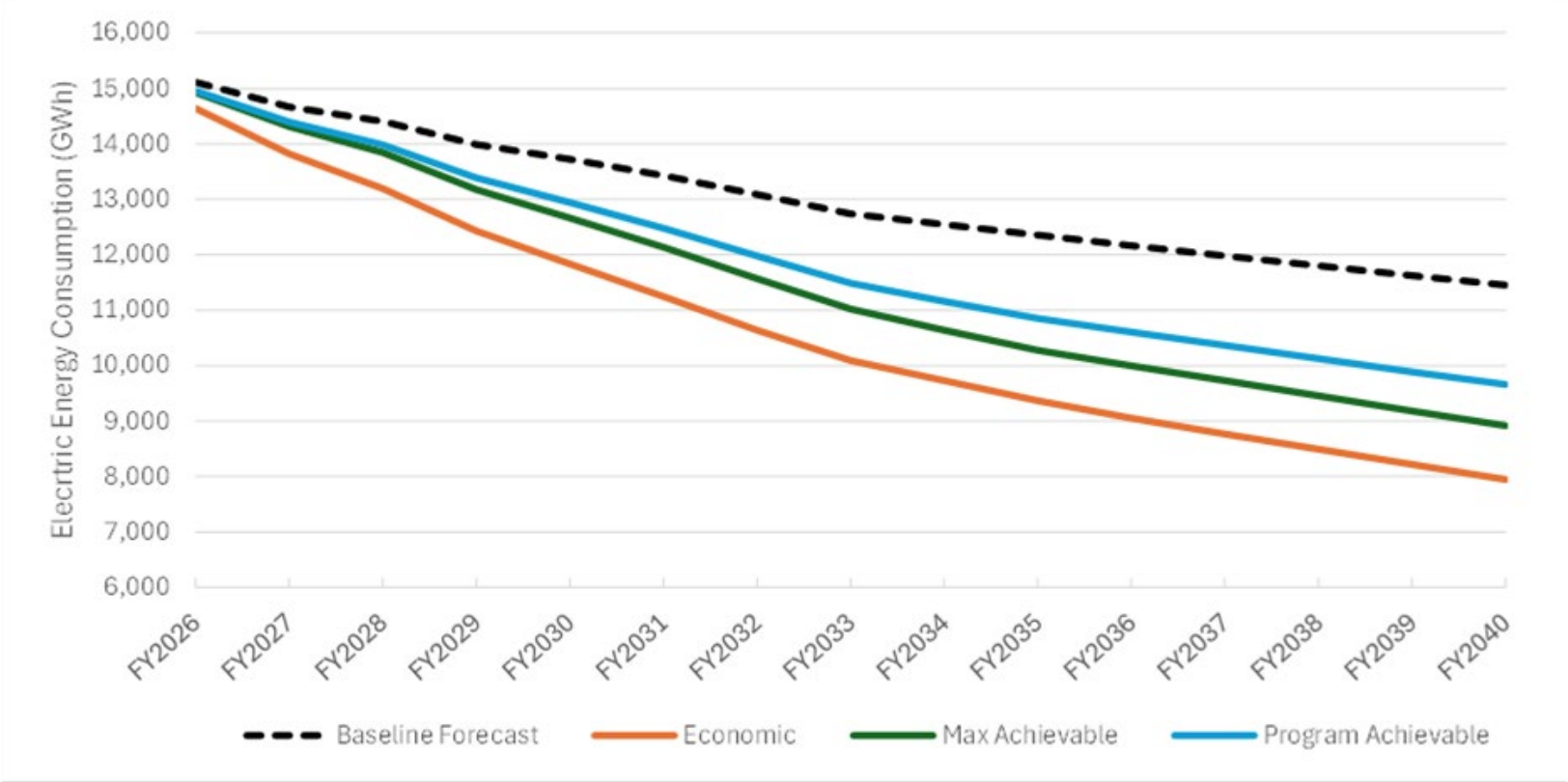
MARKET POTENTIAL STUDY, METHODS

- Modeled **152 discrete measure opportunities.**
- Incorporated market data from the baseline study and secondary studies (e.g., building type and end-use sales disaggregation, equipment saturation and existing efficiencies)
- In the absence of established savings estimation protocols for Puerto Rico, leveraged secondary **Technical Reference Manuals, case studies, meta-analyses and other data**, adjusted as appropriate for Puerto Rico conditions.
- Considered **18 buildings types** over residential and C&I.
- Primary cost test – Puerto Rico Benefit-Cost Test

MARKET POTENTIAL STUDY, RESULTS

Forecasted Electric Energy Consumption by Scenario (GWh)

- The economic potential peaks at 21.8% of FY2019 sales in FY2040.
- The max achievable and program achievable potential reach cumulative annual savings of 15.8% and 11.2% of FY2019 sales, respectively.



MARKET POTENTIAL STUDY, RESULTS

Cumulative Annual Energy Savings by Scenario and Sector by Year (MWh)

Year	Scenario	Residential Savings	Low Income Savings	C&I Savings	Total	Total as Percentage of FY2019 Sales
FY2026	Economic	215,301	32,414	223,602	471,317	2.9%
	Max Achievable	86,334	12,181	89,125	187,640	1.2%
	Program	74,590	10,393	71,475	156,458	1.0%
FY2027	Economic	358,184	54,903	435,622	848,709	5.3%
	Max Achievable	131,433	19,103	202,931	353,468	2.2%
	Program	100,691	14,282	161,474	276,447	1.7%
FY2028	Economic	491,815	76,093	642,896	1,210,805	7.5%
	Max Achievable	194,477	28,961	340,773	564,211	3.5%
	Program	138,060	19,935	269,841	427,837	2.7%
FY2040	Economic	1,409,438	215,780	1,880,838	3,506,057	21.8%
	Max Achievable	917,136	136,957	1,482,567	2,536,659	15.8%
	Program	551,735	76,430	1,166,024	1,794,189	11.2%

- The max achievable and program achievable potential reach cumulative annual savings of 3.5% and 2.7% in FY2028 of FY2019 sales, respectively.
- Potential somewhat balanced among sectors in the early years, skewing more toward the C&I sector in later years.

MARKET POTENTIAL STUDY, RESULTS

Incremental Annual Energy Savings by Scenario and Sector by Year as Percent of FY2019 Sales (%)

Year	Economic			Max Achievable			Program		
	Res	C&I	Total	Res	C&I	Total	Res	C&I	Total
FY2026	1.5%	1.4%	2.9%	0.6%	0.6%	1.2%	0.5%	0.4%	1.0%
FY2027	1.4%	1.3%	2.8%	0.7%	0.7%	1.4%	0.6%	0.6%	1.2%
FY2028	1.4%	1.3%	2.7%	0.9%	0.9%	1.7%	0.7%	0.7%	1.3%
FY2029	1.3%	1.2%	2.6%	1.0%	1.0%	1.9%	0.7%	0.8%	1.5%
FY2030	1.3%	1.2%	2.5%	1.0%	1.0%	1.9%	0.7%	0.8%	1.5%
FY2031	1.2%	1.2%	2.4%	1.0%	0.9%	1.9%	0.7%	0.7%	1.5%
FY2032	1.2%	1.1%	2.3%	1.0%	0.9%	1.9%	0.7%	0.7%	1.5%
FY2033	1.2%	1.1%	2.3%	1.0%	0.9%	1.8%	0.7%	0.7%	1.4%
FY2034	1.2%	1.1%	2.2%	1.0%	0.9%	1.8%	0.7%	0.7%	1.4%
FY2035	1.2%	1.0%	2.2%	1.0%	0.8%	1.8%	0.7%	0.7%	1.4%
FY2036	1.1%	1.0%	2.2%	0.8%	0.7%	1.5%	0.6%	0.6%	1.2%
FY2037	1.1%	1.0%	2.2%	0.8%	0.7%	1.6%	0.6%	0.6%	1.2%
FY2038	1.1%	1.0%	2.2%	0.9%	0.8%	1.6%	0.7%	0.6%	1.3%
FY2039	1.1%	1.0%	2.1%	0.9%	0.8%	1.7%	0.7%	0.6%	1.3%
FY2040	1.1%	1.0%	2.1%	0.9%	0.8%	1.7%	0.7%	0.6%	1.3%

- Incremental annual savings for max achievable and program potential peak ~FY2030.
- Decrease in savings over time primarily a result of a declining baseline sales forecast.

MARKET POTENTIAL STUDY, RESULTS

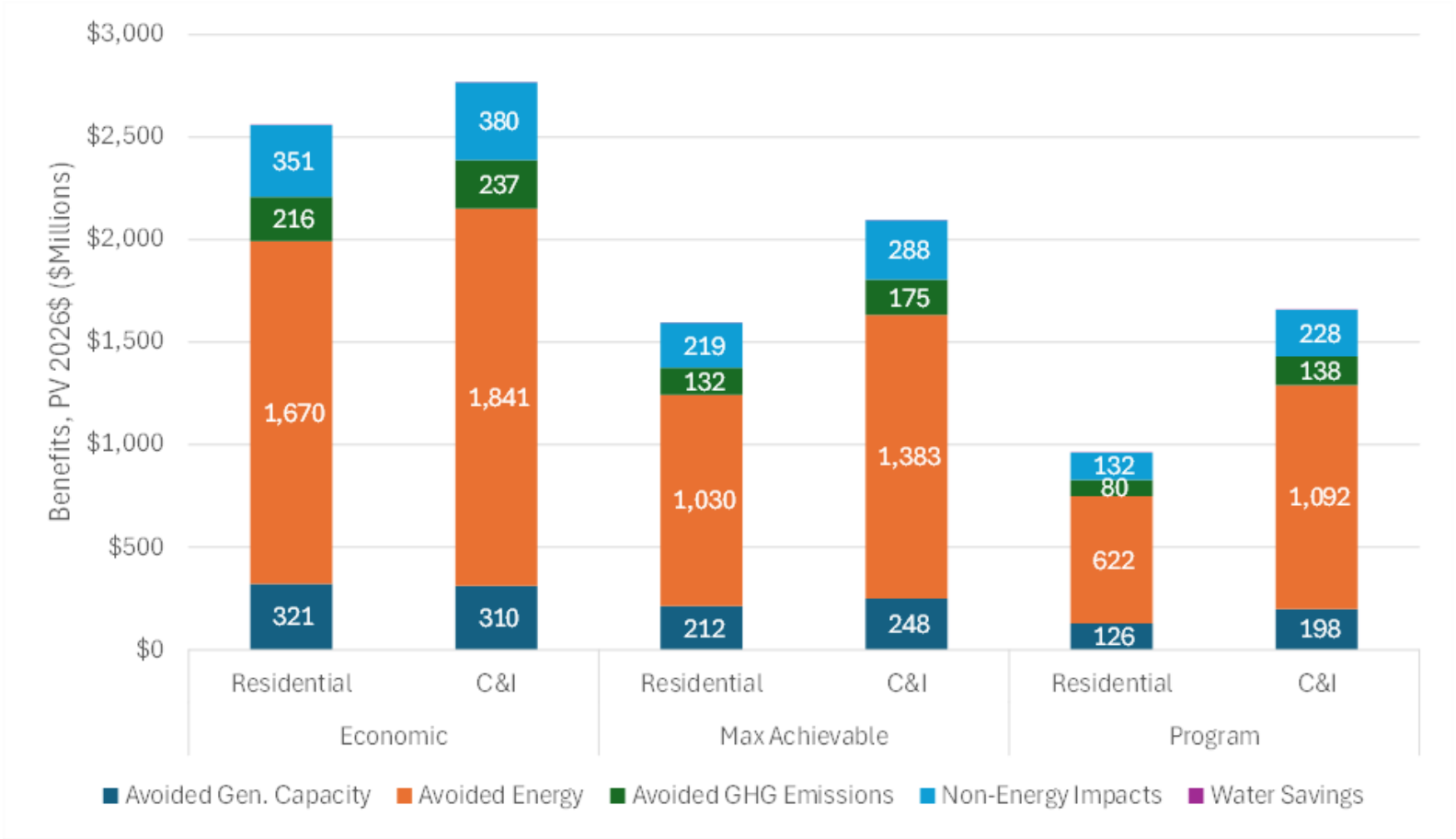
Costs, Benefits, Net Benefits and BCR by Sector and Scenario, FY2026–FY2040, Present Value 2026 Dollars ($Million)

Scenario	Benefits	Costs	Net Benefits	Benefit-Cost Ratio
Economic	$5,326	$2,232	$3,094	2.4
Max Achievable	$3,688	$1,874	$1,814	2.0
Program Achievable	$2,617	$1,138	$1,479	2.3

- Pursing the maximum achievable potential would yield $1,814 million in present value net benefits for activity in program years FY2026-2040.
- Net benefits for the first modeled triennium amount to $387 million for the Max Achievable scenario.
- PRCT BCRs comfortably above 1.0 in all modeled scenarios.

BENEFITS DISTRIBUTION BY CATEGORY

- The distribution of benefits are largely consistent between scenarios and sectors
- Benefits dominated by avoided electric energy generation (65% and 67% of total benefits).
- Non-energy impacts (e.g., health and safety benefits, increased occupant comfort and productivity) contribute 14% of total benefits.
- Avoided generation capacity costs which contribute approximately 12% of total benefits.
- Avoided greenhouse gas emissions provide approximately 8% of total benefits.



MARKET POTENTIAL STUDY, RESULTS

Maximum Achievable Potential Budgets by Sector and Year, Nominal Dollars ($Million)

Year	Res		C&I		All Sectors Total		Grand Total
	Non-Incentive	Incentive	Non-Incentive	Incentive	Non-Incentive	Incentive	
FY2026	$8.1	$26.8	$12.3	$49.3	$20.4	$76.0	$96.4
FY2027	$14.5	$42.2	$15.7	$63.1	$30.2	$105.3	$135.5
FY2028	$20.8	$57.5	$19.0	$76.4	$39.8	$133.9	$173.7
FY2029	$26.8	$72.2	$21.4	$86.0	$48.2	$158.2	$206.4
FY2030	$28.1	$75.5	$21.5	$86.3	$49.6	$161.8	$211.3
FY2031	$29.3	$78.5	$21.4	$85.9	$50.6	$164.4	$215.0
FY2032	$30.1	$80.8	$21.1	$84.8	$51.2	$165.6	$216.9
FY2033	$30.9	$82.9	$21.1	$84.7	$52.0	$167.6	$219.5
FY2034	$31.5	$84.8	$21.2	$85.2	$52.8	$170.0	$222.8
FY2035	$32.9	$88.2	$21.3	$85.7	$54.2	$173.9	$228.1
FY2036	$28.7	$78.0	$19.1	$76.9	$47.9	$154.9	$202.7
FY2037	$30.9	$83.3	$19.7	$79.1	$50.6	$162.4	$212.9
FY2038	$33.7	$90.5	$20.5	$82.3	$54.2	$172.8	$227.0
FY2039	$36.5	$97.7	$21.7	$87.3	$58.3	$185.0	$243.3
FY2040	$37.3	$99.7	$21.8	$87.7	$59.1	$187.4	$246.5

- Annual budgets associated with **maximum** achievable potential range from $96 million to $247 million over the analysis period.
- Estimated non-incentive costs represent 20-25% of total budgets.
- Note this scenarios assumes incentives covering 100% of incremental costs.

MARKET POTENTIAL STUDY, RESULTS

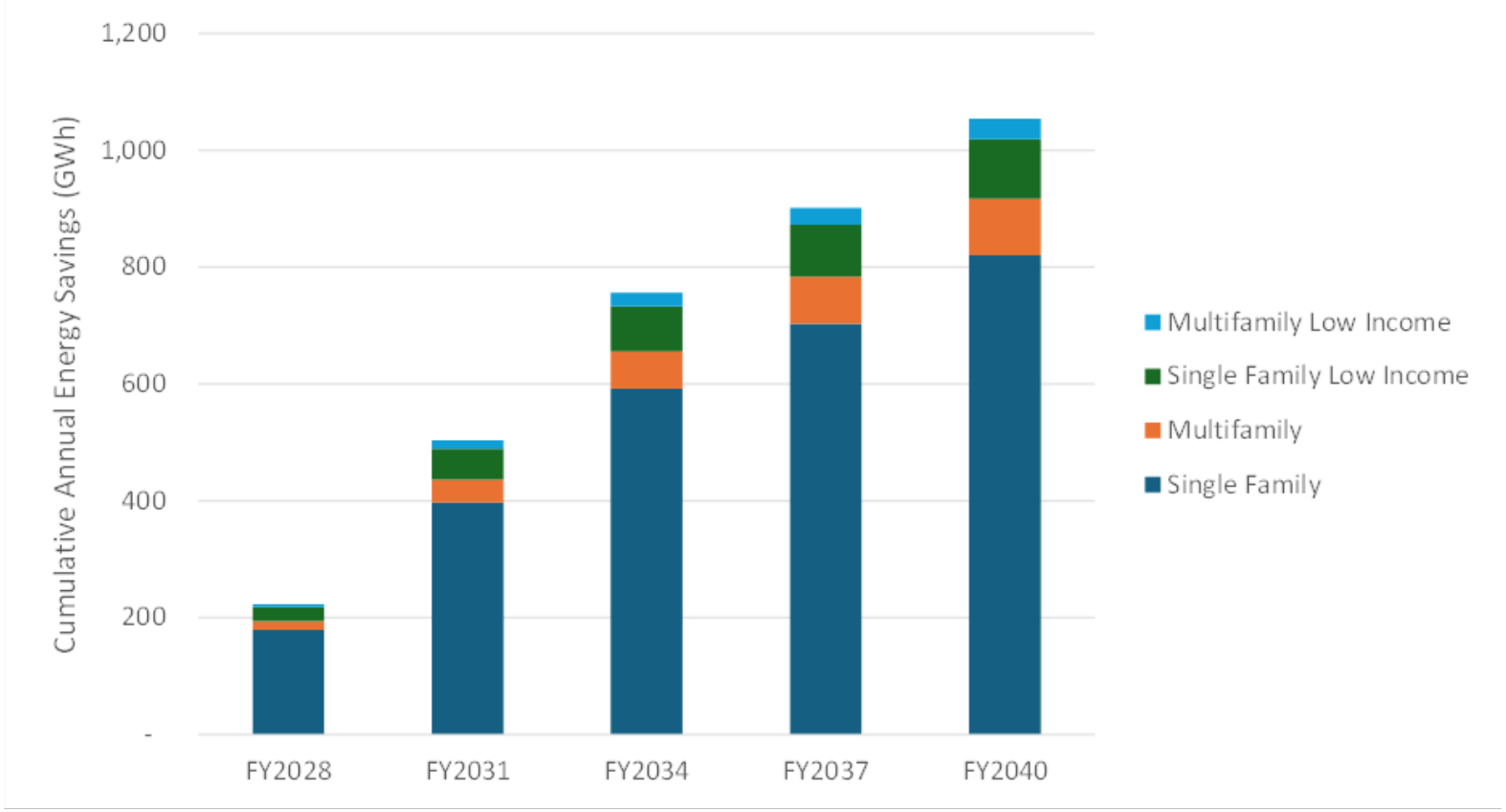
Program Achievable Potential Budgets by Sector and Year, Nominal Dollars ($Million)

Year	Res		C&I		All Sectors Total		Grand Total
	Non-Incentive	Incentive	Non-Incentive	Incentive	Non-Incentive	Incentive	
FY2026	$3.5	$11.5	$9.7	$18.0	$13.3	$29.6	$42.8
FY2027	$6.4	$15.3	$12.1	$22.4	$18.5	$37.7	$56.2
FY2028	$9.3	$19.1	$14.4	$26.8	$23.7	$45.9	$69.6
FY2029	$12.1	$22.8	$16.2	$30.2	$28.4	$53.0	$81.4
FY2030	$12.9	$23.9	$16.4	$30.5	$29.3	$54.4	$83.7
FY2031	$13.6	$24.9	$16.4	$30.5	$30.1	$55.5	$85.5
FY2032	$14.2	$25.8	$16.3	$30.3	$30.6	$56.1	$86.7
FY2033	$14.8	$26.7	$16.3	$30.2	$31.1	$56.8	$87.9
FY2034	$15.4	$27.5	$16.4	$30.4	$31.8	$57.9	$89.7
FY2035	$16.0	$28.4	$16.5	$30.6	$32.5	$59.0	$91.5
FY2036	$12.5	$23.8	$14.7	$27.2	$27.2	$51.1	$78.2
FY2037	$13.8	$25.7	$15.1	$28.1	$29.0	$53.8	$82.7
FY2038	$15.6	$28.1	$15.8	$29.4	$31.5	$57.5	$89.0
FY2039	$17.4	$30.5	$16.8	$31.2	$34.2	$61.7	$95.9
FY2040	$17.6	$30.9	$16.9	$31.3	$34.5	$62.2	$96.7

- Annual budgets associated with **program** achievable potential range from $43 million to $97 million over the analysis period.
- Note this scenario assumes incentives covering 50% of incremental costs (100% for low-income participants).

MARKET POTENTIAL STUDY, RESULTS

Residential Max Achievable Cumulative Annual Energy Savings by Building Type by Year

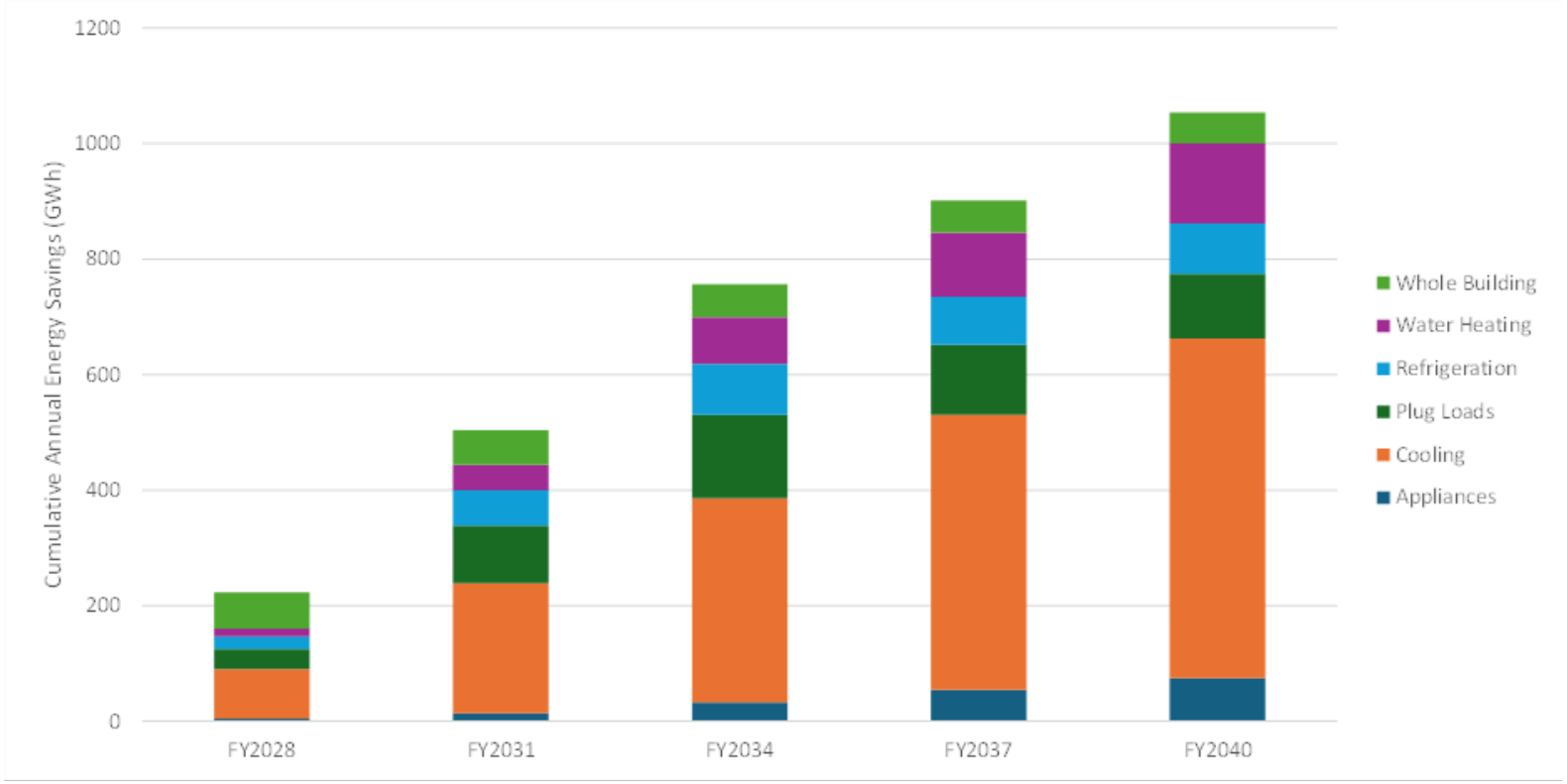


- Majority of savings potential in single family homes.
- Consistent with the characteristics of the market and building stock.

MARKET POTENTIAL STUDY, RESULTS

Residential Max Achievable Cumulative Annual Energy Savings by End-Use by Year

- Key opportunities in residential dominated by cooling followed by water heating and plug loads.
- Whole building opportunities primarily from “Home Energy Reports”. Share of potential diminishes over time due to short measure life.



MARKET POTENTIAL STUDY, RESULTS

Residential Cumulative Annual Energy Savings by Measure, Max Achievable (MWh)

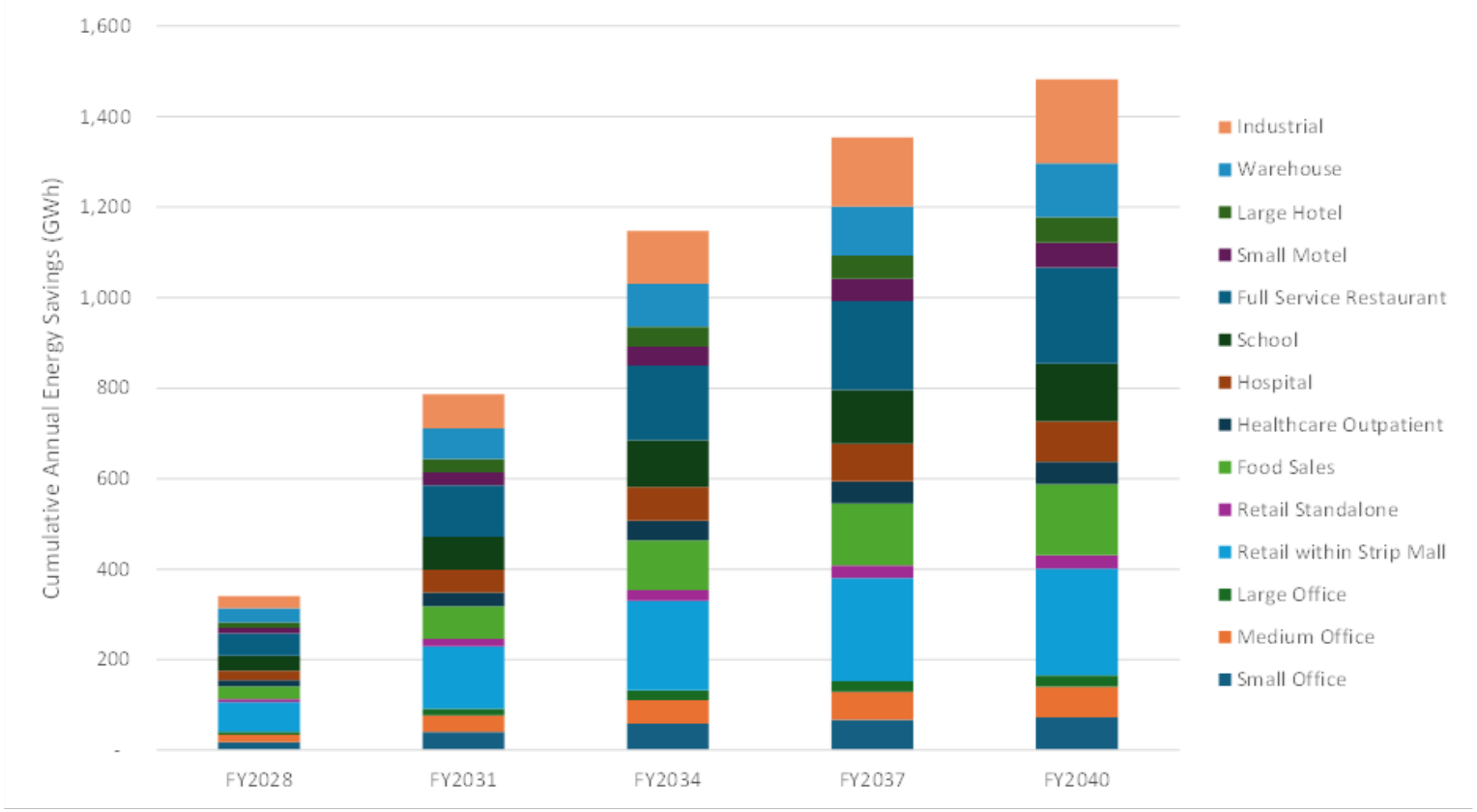
Measure	FY2028	FY2040
Home Energy Reports	62,808	53,294
High-Efficiency Ductless Mini-Split AC	48,143	283,122
Tier 2 Advanced Power Strip	32,998	103,901
Refrigerator/Freezer Recycling	16,378	46,724
ENERGY STAR Windows	13,102	106,147
Smart Thermostats	8,857	53,467
Cool Roof	8,643	101,301
Solar Water Heater	5,979	105,114
ENERGY STAR Refrigerator	5,891	40,548
ENERGY STAR Ceiling Fan	4,282	14,152

Residential Cumulative Annual Peak Demand Savings by Measure, Max Achievable (MW)

Measure	FY2028	FY2040
High-Efficiency Ductless Mini-Split AC	11.7	68.7
Home Energy Reports	5.4	4.6
Tier 2 Advanced Power Strip	5.0	15.8
ENERGY STAR Windows	3.3	27.1
Smart Thermostats	2.1	13.0
Cool Roof	2.1	24.4
Refrigerator/Freezer Recycling	2.0	5.7
ENERGY STAR Ceiling Fan	1.1	3.6
High-Efficiency Room Air Conditioner	0.8	7.0
High-Efficiency Clothes Washers	0.8	7.1

MARKET POTENTIAL STUDY, RESULTS

C&I Max Achievable Cumulative Annual Energy Savings by Building Type by Year

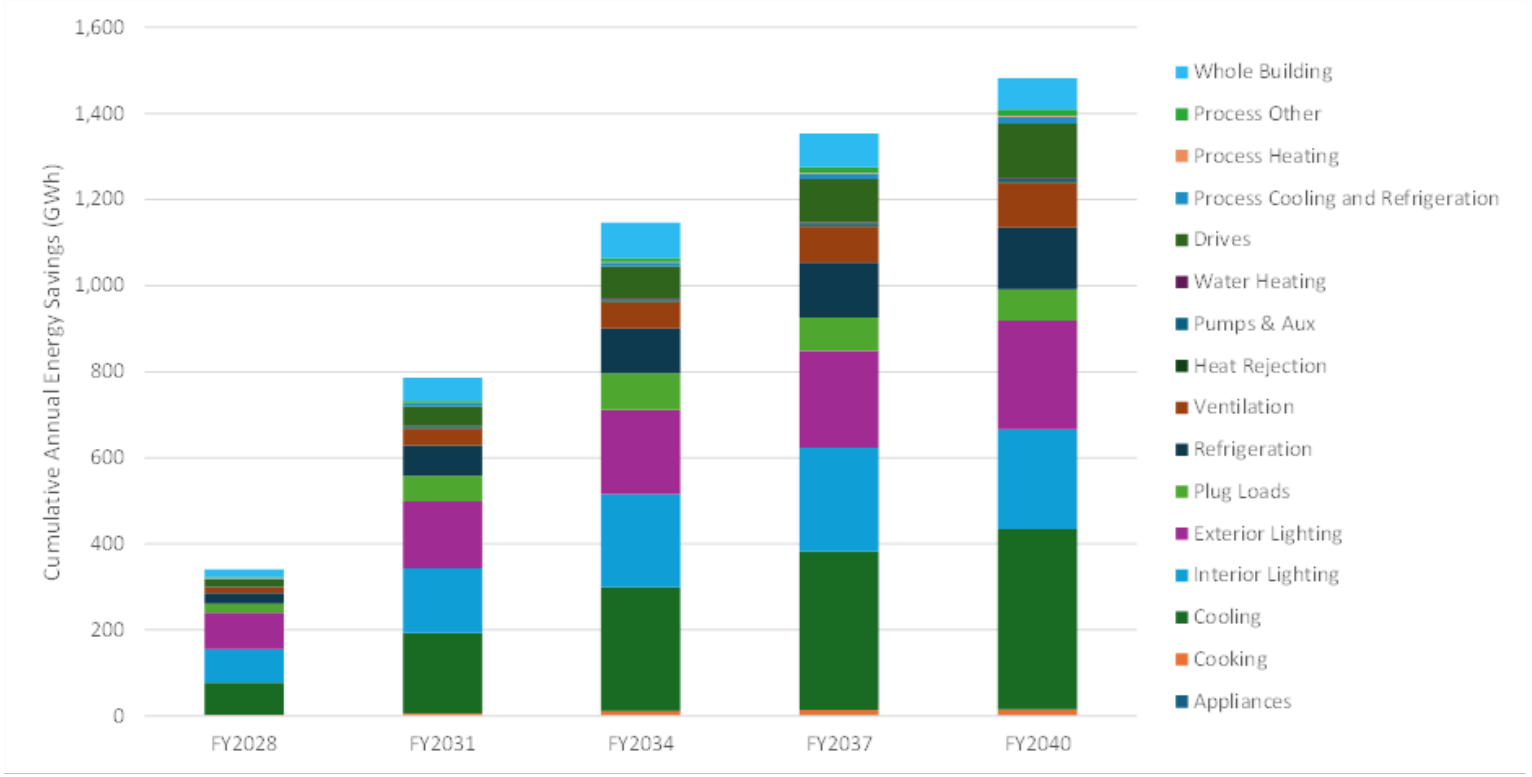


- Savings opportunities more distributed relative to residential.
- Industrial, restaurants, food sales (grocery), and retail represent key market opportunities.

MARKET POTENTIAL STUDY, RESULTS

C&I Max Achievable Cumulative Annual Energy Savings by End-Use by Year

- Key opportunities in C&I are cooling, exterior lighting (inclusive of street lighting), interior lighting, and process loads (e.g., machine drive improvements).



MARKET POTENTIAL STUDY, RESULTS

C&I Cumulative Annual Energy Savings by Measure, Max Achievable (MWh)

Measure	FY2028	FY2040
LED Exterior Area Lighting	42,832	185,887
LED Street Lighting	28,065	36,066
Interior Lighting Controls, Advanced	27,072	73,426
High-Efficiency Unitary Split and Packaged AC	22,856	118,317
Interior Lighting Controls, Occupancy	19,591	53,137
Industrial Machine Drive Improvements	16,233	125,399
Exterior Lighting Controls	14,504	30,721
C&I Retrocommissioning	12,631	43,809
Window Film	11,527	53,771
High-Efficiency Chiller Systems	9,664	54,929

C&I Cumulative Annual Peak Demand Savings by Measure, Max Achievable (MW)

Measure	FY2028	FY2040
LED Exterior Area Lighting	9.4	40.9
LED Street Lighting	6.1	7.9
High-Efficiency Unitary Split and Packaged AC	5.2	26.3
Interior Lighting Controls, Advanced	3.7	10.0
Exterior Lighting Controls	3.2	6.7
Window Film	2.9	13.3
Commercial Kitchen Demand Control Ventilation	2.8	21.3
Interior Lighting Controls, Occupancy	2.7	7.2
High-Efficiency Chiller Systems	2.4	13.6
Programmable Thermostats	2.3	14.9

MARKET POTENTIAL STUDY, RESULTS

Cumulative Annual Energy Savings by Scenario **Including Contributing Entities** by Year as Percent of PY2019 Sales (%)

Year	EE Potential and Contributing Entities Total		
	Economic	Max Achievable	Program
FY2026	6.8%	5.1%	4.9%
FY2027	9.5%	6.4%	5.9%
FY2028	12.0%	8.0%	7.2%
FY2029	14.6%	9.9%	8.6%
FY2030	17.1%	11.9%	10.2%
FY2031	19.5%	14.0%	11.8%
FY2032	21.7%	15.9%	13.4%
FY2033	23.5%	17.7%	14.8%
FY2034	25.1%	19.4%	16.2%
FY2035	26.7%	21.0%	17.5%
FY2036	28.1%	22.2%	18.4%
FY2037	29.2%	23.2%	19.3%
FY2038	30.3%	24.3%	20.1%
FY2039	31.4%	25.4%	21.0%
FY2040	32.5%	26.5%	21.8%

DISCUSSION

- Challenges in Meeting the 2040 Statutory Target
  - ****Failure of modeled achievable potential to satisfy 30% reduction requirement does necessarily mean the goal is impossible.****
  - Custom commercial and industrial measures may play a larger role in meeting targets.
  - The Puerto Rico Cost test as used in this study screens out failing measures at the measure level.
  - New codes and standards could increase savings from contributing entities without cannibalizing modeled EE potential.
- Impact of Declining Baseline Sales Forecast
- Puerto Rico's Efficiency Paradox: High Rates, Low Consumption
- Modeled Lighting Assumptions and Market Saturation
- Home Energy Reports and Incremental Annual Savings
- New Construction: Limited Impact

RECOMMENDATIONS

- **Recommendation 1:** Develop Reporting and Attribution Framework
  - Federal Standards Attribution
  - Energy Code Compliance
  - Government-Led Initiatives
- **Recommendation 2:** Standardize Savings Assumptions
- **Recommendation 3:** Conduct Participant and Non-participant Surveys to Inform Energy Efficiency Program Design

APPENDIX

RESIDENTIAL CHARACTERIZATION HIGHLIGHTS

RESIDENTIAL SECTOR - SAMPLING STRATEGY REVIEW

Geographic Target:

Collect at least 50 survey responses from each sampling region comprised of groups of municipios

Building/Household Strata Targets:

Collect at least 150 surveys and 120 site visits representing income-levels, building type, and ownership strata.

	Surveys	Visits
Total	**500**	**120**
Low Income	150+	50+
Not Low Income	150+	50+
Single Family (1-4 units)	150+	50+
Multifamily (5+ units)	150+	50+
Renters	150+	50+
Owners	150+	50+

RESIDENTIAL SECTOR - FINAL SAMPLE SIZES BY SEGMENT

- The survey was split into two short sections to increase response rates in absence of incentives. After completing the first section, 38% of respondents completed the second.
- Survey responses exceeded the sampling target of 500 responses for Part 1 (N=632). As expected, response rate were lower for Part 2 (N=241).
- Overall, 76 site visits were completed.
- Responses for some building type, ownership, and income-level strata were below original sampling targets (150+ for survey, 50+ for site visits).
- Sample sizes mostly exceeded the original regional sampling target of 50+ responses for Part 1
- Note that final sample sizes generally exceeded revised targets from October 2023 which were based on observed expected response rates without incentives.

Strata	Strata Segment	Survey Part 1 (N=632)	Survey Part 2 (N=241)	Site Visit (N=76)
Building Type	Single Family (1-4 units)	542	207	64
	Multifamily (4+ units)	90	34	12
Ownership	Owners	532	201	60
	Renters	100	40	16
Income level	Not Low-income	534	209	65
	Low-income	98	32	11
Sampling region	Ponce	64	27	6
	Arecibo	47	13	2
	San Juan	133	54	18
	Caguas	103	41	18
	Mayaguez	68	29	11
	Carolina	73	28	6
	Bayamon	144	49	15

RESIDENTIAL SECTOR - POST-STRATIFICATION WEIGHTING

- Each data collection effort under-sampled low-income households and renters compared to the population and oversampled the San Juan area.
- Post-stratification weights were developed separately for each part of they survey and the site visits to adjust for these imbalances
- These weights were applied for all residential characterization analyses unless otherwise noted.

Composition of residential population compared to sample by data collection effort prior to applying post-stratification weights

Segment	Population	Survey (Pt. 1)	Survey (Pt. 2)	Site Visits
Single Family	88%	86%	86%	84%
Renter	32%	16%	17%	21%
Low-Income	25%	16%	13%	14%
San Juan Region	12%	21%	22%	24%

RESIDENTIAL SECTOR - LIMITATIONS

- Potential unmeasured self-selection response bias due to lack of incentives
  - Voluntary, unpaid, study participants may have unmeasured differences from the general population, such as higher awareness of energy issues. We are unable to adjust for this through our survey weighting approaches.
- Statistical uncertainty due to small sample sizes
  - Sub-group comparisons, especially among low-income and multifamily households are limited due to small sample sizes, especially with site visit data.

RESIDENTIAL SECTOR - BUILDING CHARACTERISTICS

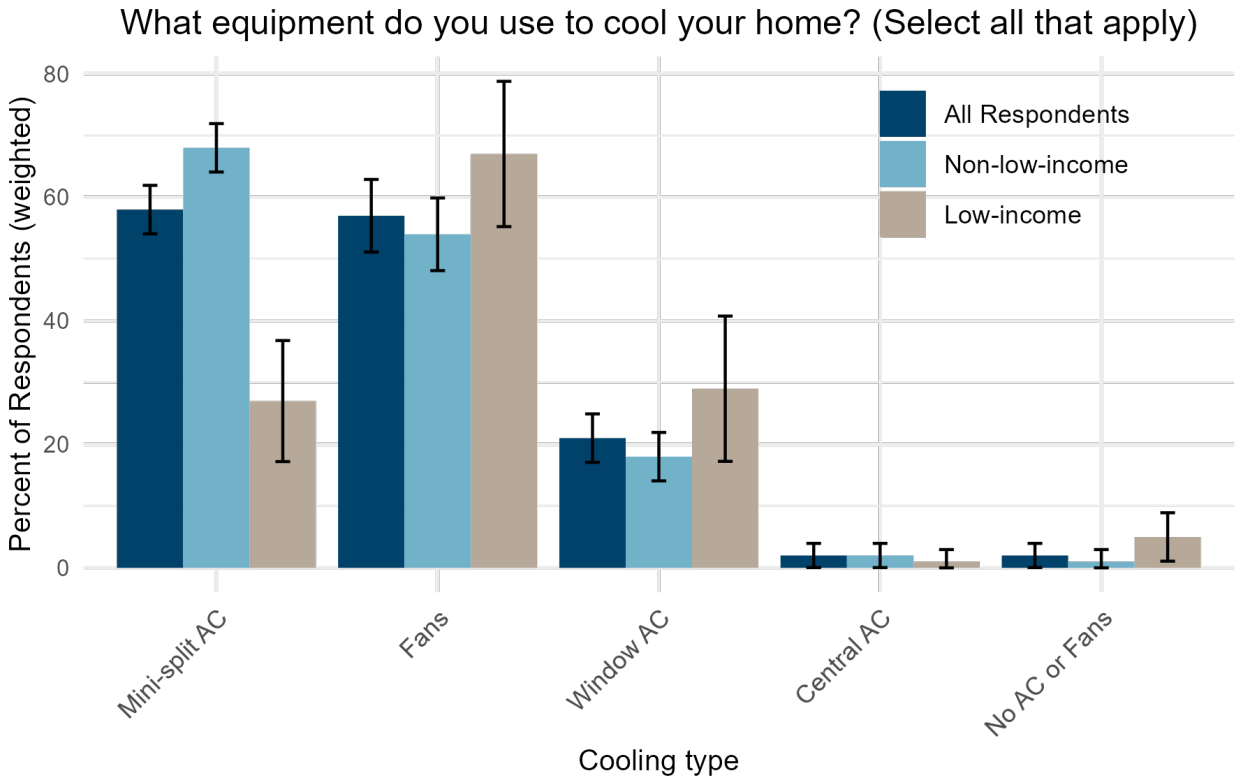
- Construction is mostly concrete
  - Walls: 94% block or poured concrete (rsv)
  - Roofs: 92% concrete (rsv)
  - Foundations: 100% concrete slab, perimeter or block (rsv)
- Insulation is uncommon
  - Walls: < 2% insulated (rsv)
  - Roofs: <25% insulated (rsv)
- Windows are a mix of single-pane and aluminum louvered “Miami style”
  - 50% single-pane, 34% miami style (rsv)
  - Miami style windows both economical and important for hurricane adaptation (IDI)

Typical single-family home with uninsulated concrete construction, a flat roof, and louvered “Miami style” windows.
Photo credit: IBTS staff

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - HEATING & COOLING EQUIPMENT

- Homes use a mix of cooling equipment that varies by income-level
  - Most residences use mini-split air conditioners and/or fans for cooling (svy)
  - Most residences (75%) use some form of air conditioning (svy)
  - Air conditioning is less common in low-income households (53%) compared to non-low-income households (82%)
  - Central AC systems were only reported in 2% of households (svy)
- Heating is rare
  - Only 3% of homes use occasional heating primarily through space heaters

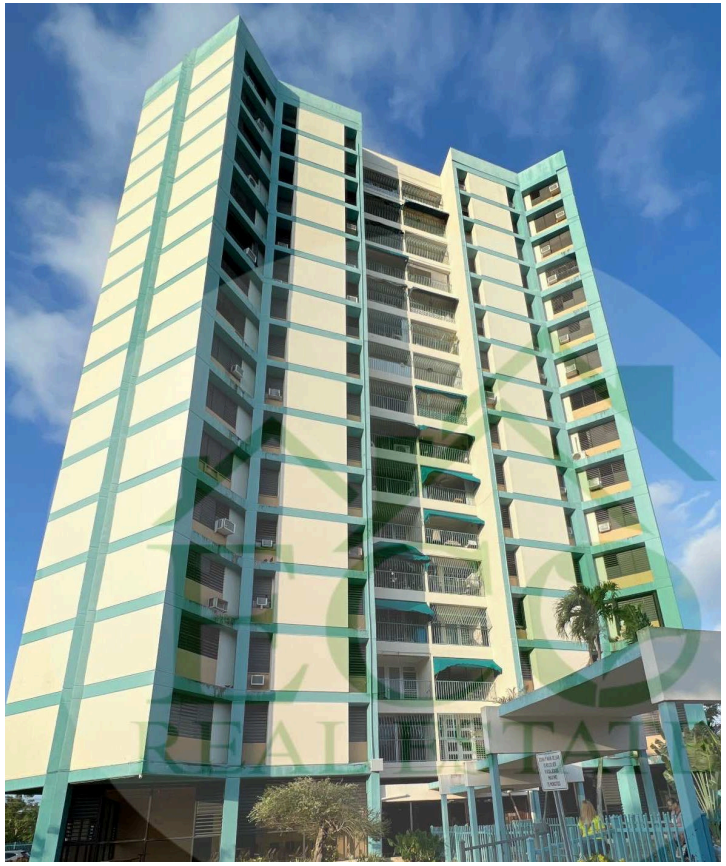


Error bars indicate 95% confidence intervals from survey.

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - MULTIFAMILY COOLING

- Multifamily cooling equipment and strategies are similar to single-family
  - Primarily a mix of fans (61%), room ACs (44%), and mini-splits (33%) (svy)
  - 71% of multifamily residences use some form of air conditioning (svy)
  - Central AC is rare (~4%) (svy)
  - Apartments typically served by independent mini-split or window AC units (svy)

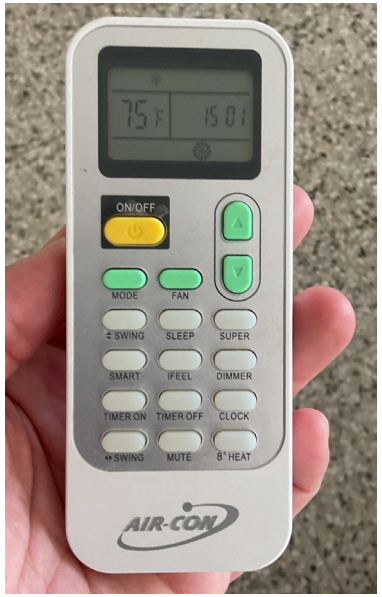


Representative apartment buildings from residential site visits showing separately metered dwelling units with independent room AC or mini-split cooling systems.
Photo credit: IBTS staff

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - HEATING & COOLING STRATEGIES

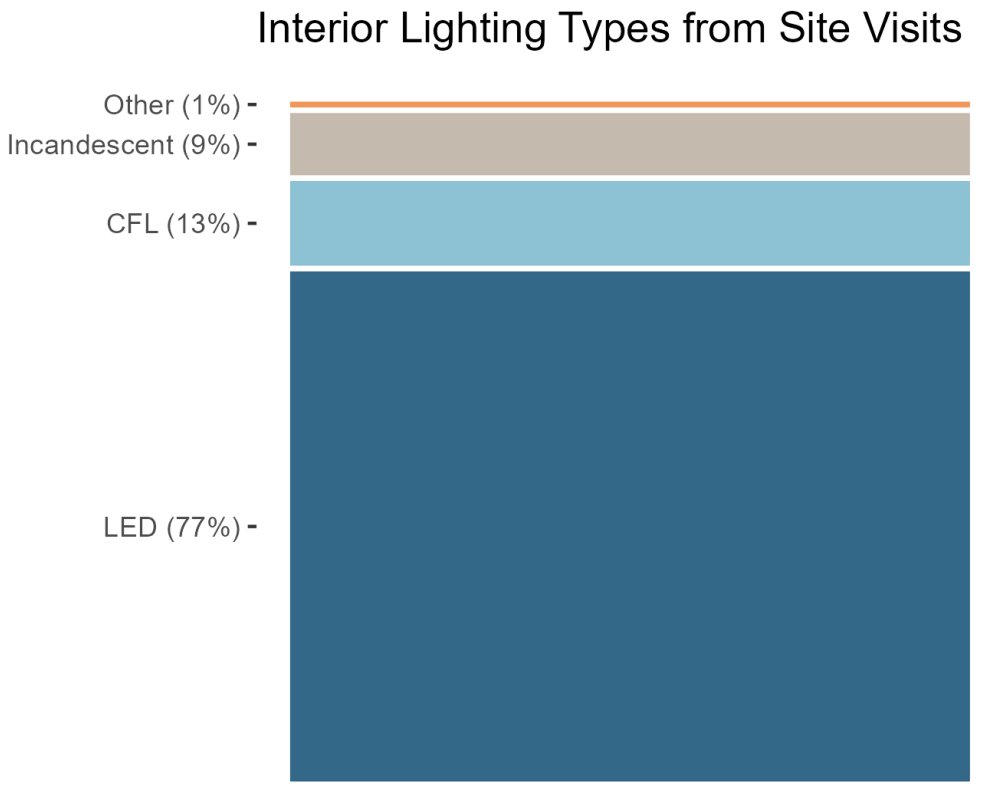
- Households with air conditioning typically use nearly year-round but for only part of the day and/or part of the home.
  - 70% of homes with AC use it 10-12 months of the year (svy)
  - 67% of homes with AC use it <12 hours on a typical day when it is use (svy)
  - Only 27% of households cool more than 90% of their home's area (rsv)
  - A common strategy is to only cool bedrooms (rsv)



***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - LIGHTING

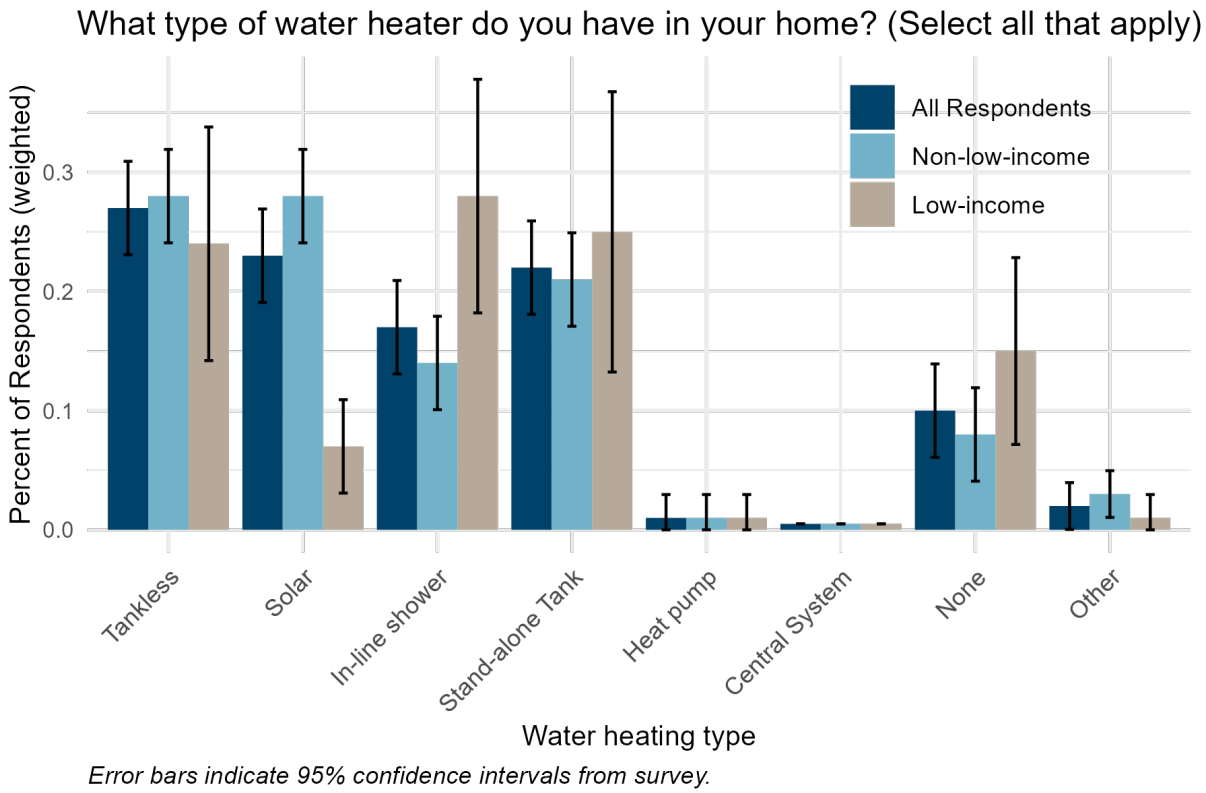
- LEDs were the most common lighting type in the residential sector (svy/rsv)
- The frequency of lighting types did not differ significantly by income level, building type or ownership (svy/rsv)



***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - WATER HEATING TYPES

- Tankless, in-line, and solar water heating is popular (svy)
  - Among all households, 43% have in-line shower or tankless water heaters, while 22% have stand-along tank heaters
- Low-income household appear to use less how water (svy)
  - 15% of low-income households do not have hot water compared to 8% of non-low-income households but the difference is not statistically significant
- Solar hot water is less common in low-income households (svy)
  - Only 7% of low-income households reported solar hot water compared to 28% of non-low-income households



Error bars indicate 95% confidence intervals from survey.

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - COMMON WATER HEATING TYPES

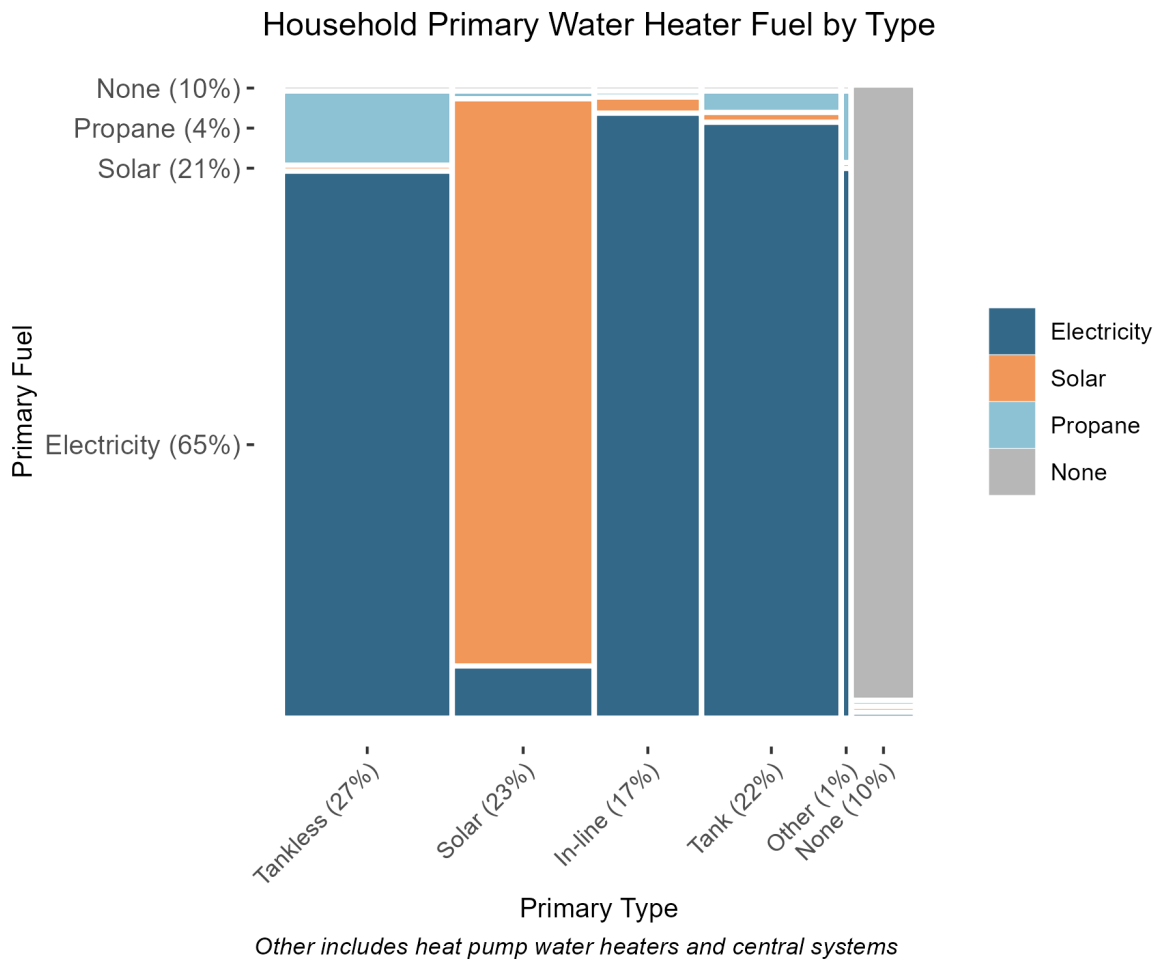
Common water heater types found in Puerto Rican residences include Tankless (top left), In-line shower (bottom left), roof-top solar (above), and stand-alone tank (right).

Photo credit: IBTS staff

RESIDENTIAL SECTOR - WATER HEATING FUELS

- Among all households, most (65%) use electricity as their primary heating fuel (svy)
- Homes with solar hot water may have secondary water heating that use electricity or propane (svy)
- Propane represents a small fraction of water heating fuels across all households (4%), but is more common in homes with tankless water heaters (svy)

Note: Water heater type percentages differ slightly from previous slide because only one primary type was assigned by household for analysis.

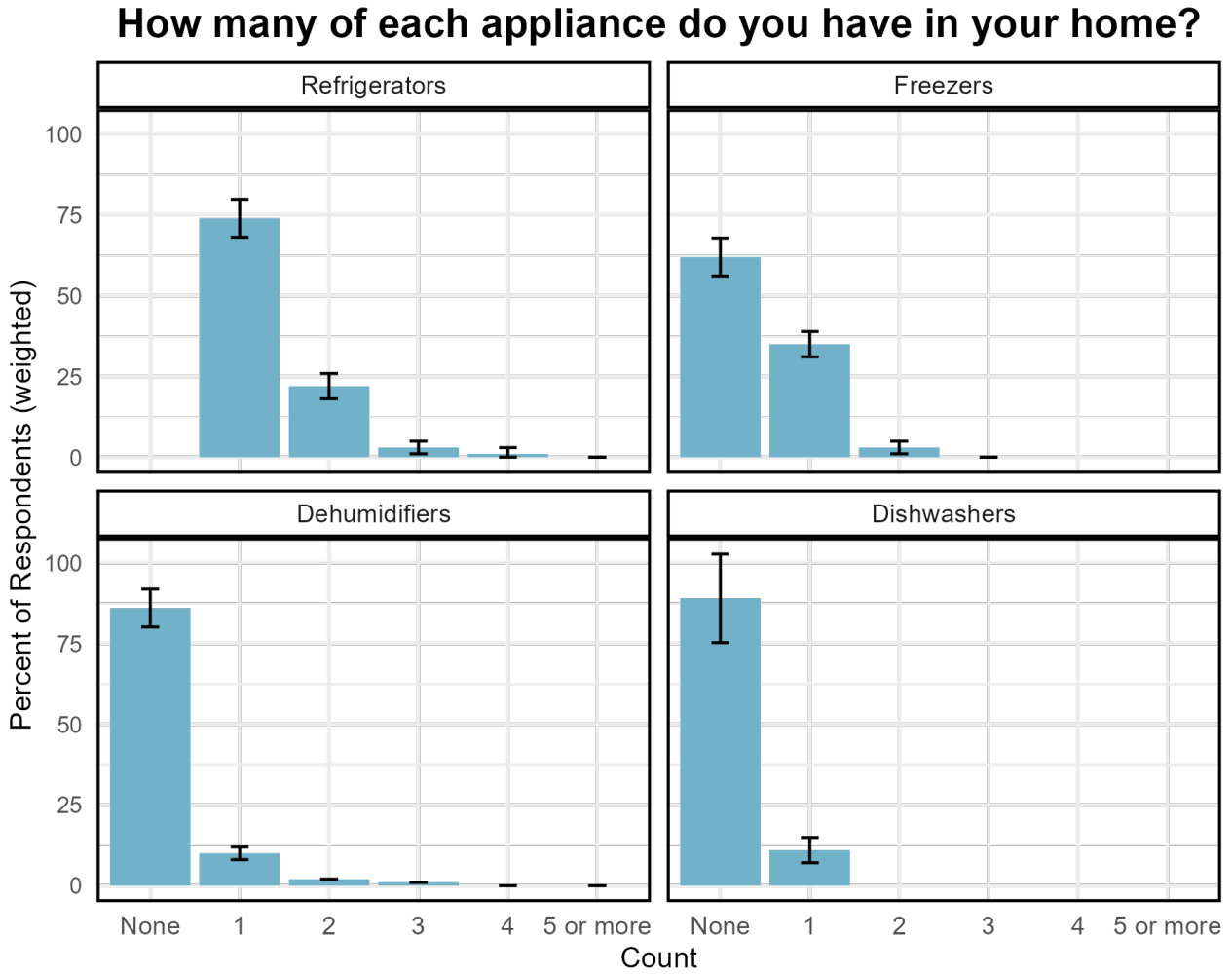


Other includes heat pump water heaters and central systems

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - APPLIANCES

- Refrigerators and freezers are common (svy)
  - All those surveyed at least one refrigerator and 38% had an additional freezer
- Dehumidifiers and dishwashers are uncommon (svy)
  - 14% of survey households had a dehumidifier and 11% had a dishwasher
- Secondary fridges may represent a savings opportunity (svy/rsv)
  - More than 20% home have a second refrigerator
  - 96% of second fridges are plugged in and used year-round (rsv)
  - 85% of second fridges are >10 years old



Error bars indicate 95% confidence intervals from survey.

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

RESIDENTIAL SECTOR - APPLIANCES

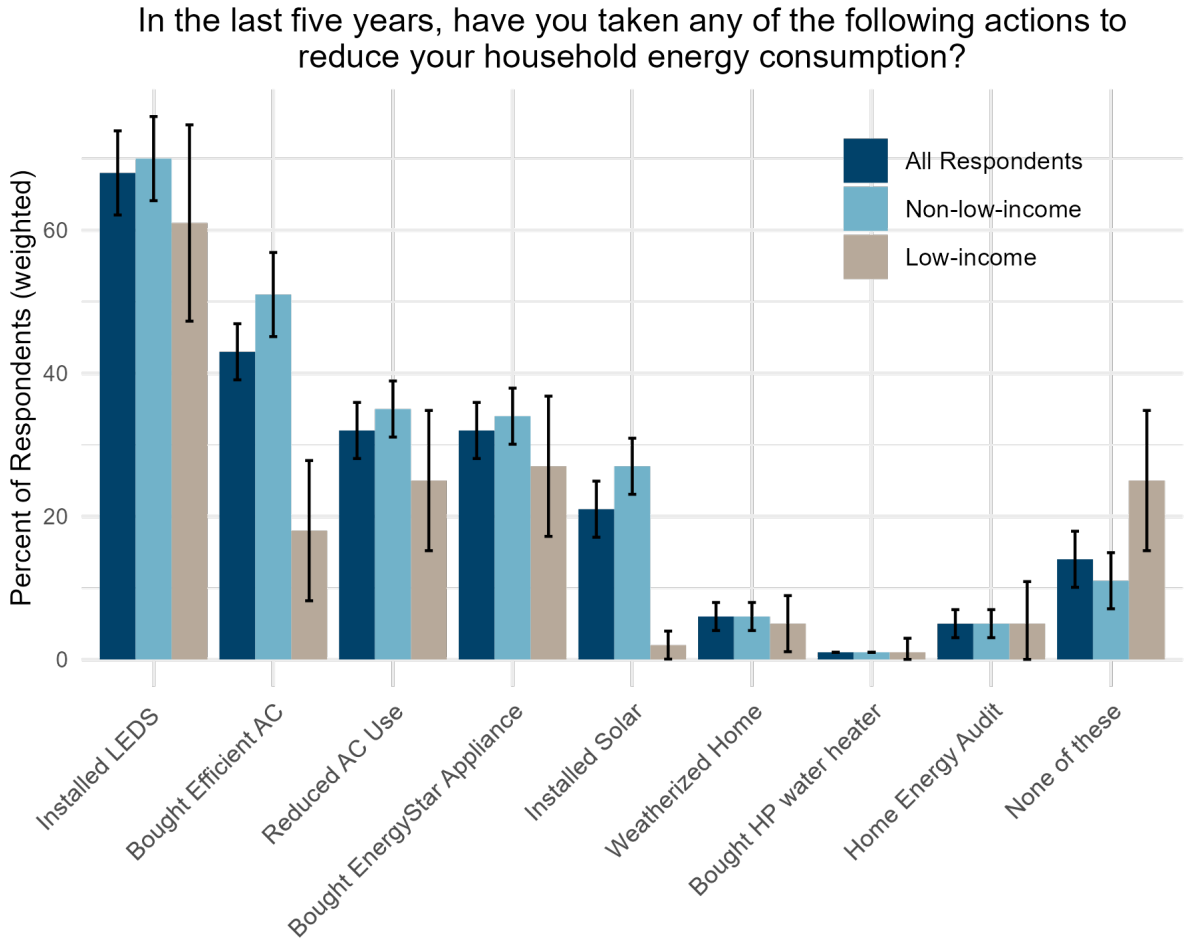
- Most homes (79%) have top-loading washers (svy)
- Homes with dryers use a mix of electric and propane fuels (svy)
  - Of the 64% of homes with dryers approximately half use electricity and half use propane fuel
  - Low-income households and renters are less likely to have a dryer
- Households have a mix of electric (53%) and propane (47%) stoves/ranges (svy)

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

Propane dryers are in the 31% of homes as shown in the photo. The remainder of homes have either electric dryers (36%) or no dryer (34%). *Photo credit: IBTS staff*

RESIDENTIAL SECTOR - ENERGY EFFICIENCY ACTIONS

- Installing LEDs and efficient AC were the most common measures (svy)
  - 68% of households have installed LEDS
  - 43% of households have installed a more efficient AC
- Energy efficiency actions are more common among non-low-income, single-family owners (svy)
  - Low-income and multifamily respondents are least likely to report any energy efficiency actions (~25% have not taken an action)
  - Non-low-income, single-family respondents are more likely to have bought an efficient AC or installed solar



Error bars indicate 95% confidence intervals from survey.

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

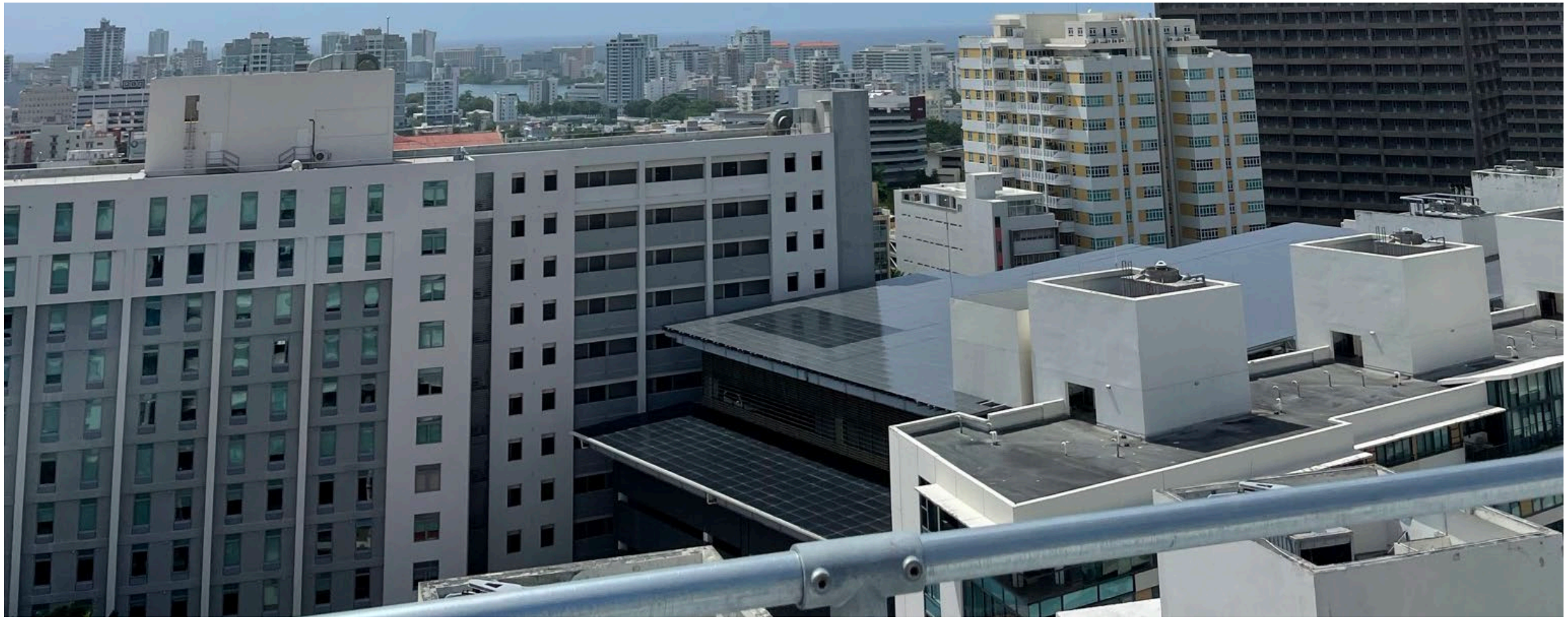
RESIDENTIAL SECTOR - SOLAR ADOPTION

- Approximately 20% of households have installed solar panels (svy)
- Adoption is much higher among non-low-income households (27%) and compared to low-income households (2%) (svy)
- At least 75% of homes with solar also have a battery system (svy)
- Due to potential unmeasured response bias, these adoption rate estimates may be high

Example rooftop solar system on a single-family home. Like most solar installs in Puerto Rico, this one has a battery backup system. *Photo credit: IBTS staff*

***DATA SOURCE ABBREVIATIONS KEY**: SVY = Survey; RSV = Residential Site Visits; IDI = In-Depth Interview*

COMMERCIAL CHARACTERIZATION HIGHLIGHTS



COMMERCIAL SECTOR – METHODOLOGY

SAMPLING TARGETS

- Site visit data collection targeted the office, retail, and healthcare sectors, which were estimated to have significant savings potential.
- Establishments were sampled across a range of size-classes defined by number of employees.
- Across all sectors, the number of sampled sites fell short of the overall targets, but a distribution of employee size-classes was captured within each sector
- Note that final sample sizes generally exceeded revised targets from October 2023 which were based on observed expected response rates without incentives.

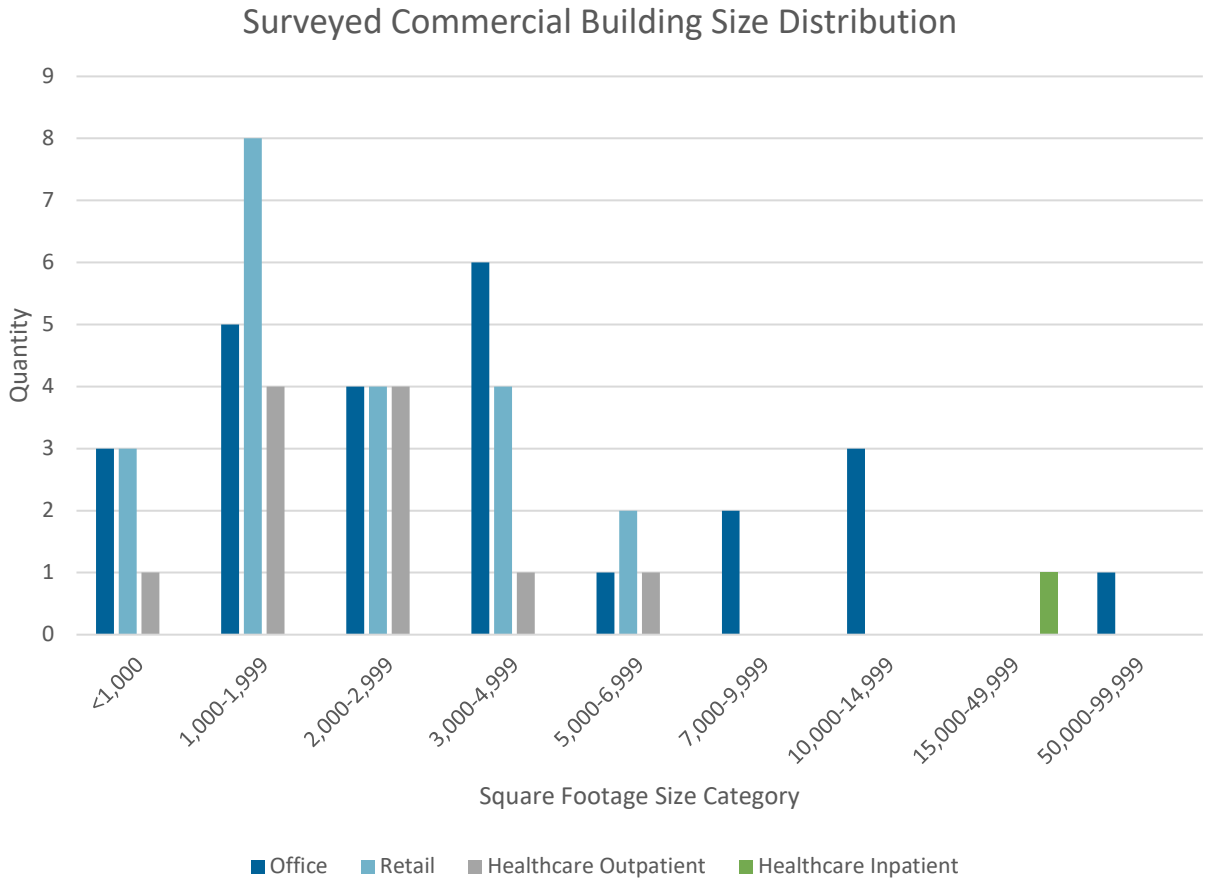
Commercial sector sampling targets compared to actual

Sector	Strata	Strata Target (N)	Strata Sample (N)	Sector Target (N)	Sector Sample (N)
Office – Employees	Small (1-9)	10+	6	35	25
	Medium (10-49)	10+	18		
	Large (50+)	4+	4		
Retail – Employees	Small (1-9)	10+	8	35	21
	Medium (10-49)	10+	5		
	Large (50+)	4+	8		
Healthcare – Type	Outpatient	20+	11	30	12
	Inpatient	4+	1		

COMMERCIAL SECTOR - LIMITATIONS

Limitations

- Small sample sizes and missing data reduce the statistical precision on typical building characteristics estimates
- End use characteristics are inconclusive for healthcare inpatient due to sample size of 1. These results are not presented but were used to inform load disaggregation modeling
- Most sampled commercial buildings were under 15,000 sq. ft., resulting in a potentially biased sample of smaller sized buildings



COMMERCIAL SECTOR – METHODOLOGY

ANALYSIS RESULTS

- All results presented were from the commercial site visit data
- The summary statistics on end use characteristics presented (i.e., envelope insulation, primary lighting type, controls, etc.) from site visit data for each building type are weighted by square footage
- Results are presented for the three sampled building sectors, but the results from this analysis helped inform the disaggregation modeling for non-sampled sectors such as lodging, food sales and restaurants

COMMERCIAL SECTOR - LIMITATIONS

Limitations

- The HVAC system for many sites were in an inaccessible location and model nameplate info could not be obtained, resulting in small sample sizes in determining typical HVAC efficiency levels
- Limited sample size for larger, complex HVAC systems (i.e., chilled water systems). Access to building automation system was not always granted.
- Specific end use characteristics (i.e., kitchen equipment, commercial refrigeration) could not be determined based on-site visit data only

HVAC systems, such as the outdoor cooling units shown in the photo, were often in inaccessible locations. This created challenges for collecting nameplate information in site visits. *Photo credit: IBTS staff*

COMMERCIAL SECTOR – ENVELOPE

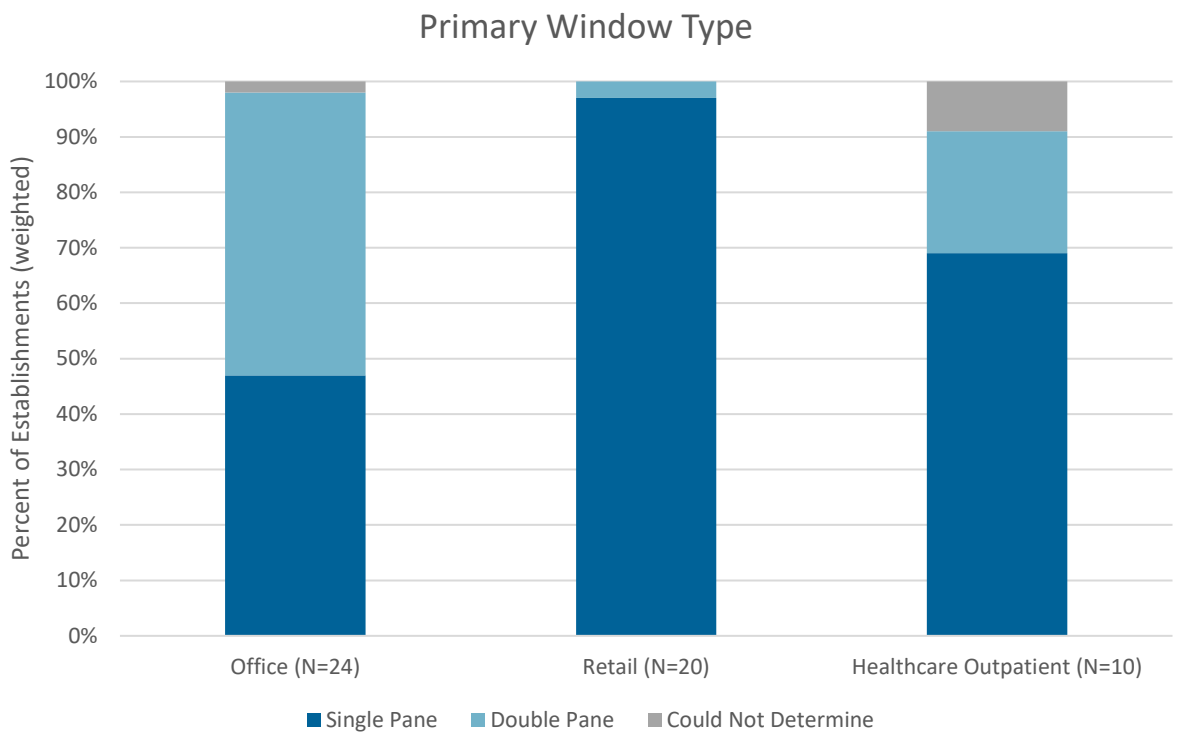
- Concrete or concrete block wall construction common in Puerto Rico
- Flat roof is most typical roof type
- Wall and roof insulation is not common for retail buildings in Puerto Rico
- Office buildings generally do not have insulation in walls but may have a higher chance for insulation in roof
- Over half of healthcare outpatient buildings do not have insulation in walls or roof

Sampling Segment	Primary Wall Construction			Insulation Present in Walls		
	Concrete or Concrete Block Walls	Metal-Framed Walls	Unknown	Yes	No	Could Not Determine
Office (N=25)	99%	1%	0%	9%	90%	1%
Retail (N=21)	92%	0%	8%	0%	100%	0%
Healthcare Outpatient (N=11)	66%	3%	31%	24%	65%	11%

Sampling Segment	Primary Roof Construction		Insulation Present in Roof		
	Flat Roof	Attic Roof	Yes	No	Could Not Determine
Office (N=25)	98%	2%	51%	41%	8%
Retail (N=21)	100%	0%	7%	80%	13%
Healthcare Outpatient (N=11)	100%	0%	17%	56%	27%

COMMERCIAL SECTOR – ENVELOPE

- Office buildings (particularly larger sized) have a higher tendency for double pane windows
- Small office, retail and healthcare outpatient are more likely to have single pane windows
- Envelope renovation for energy efficiency is not common

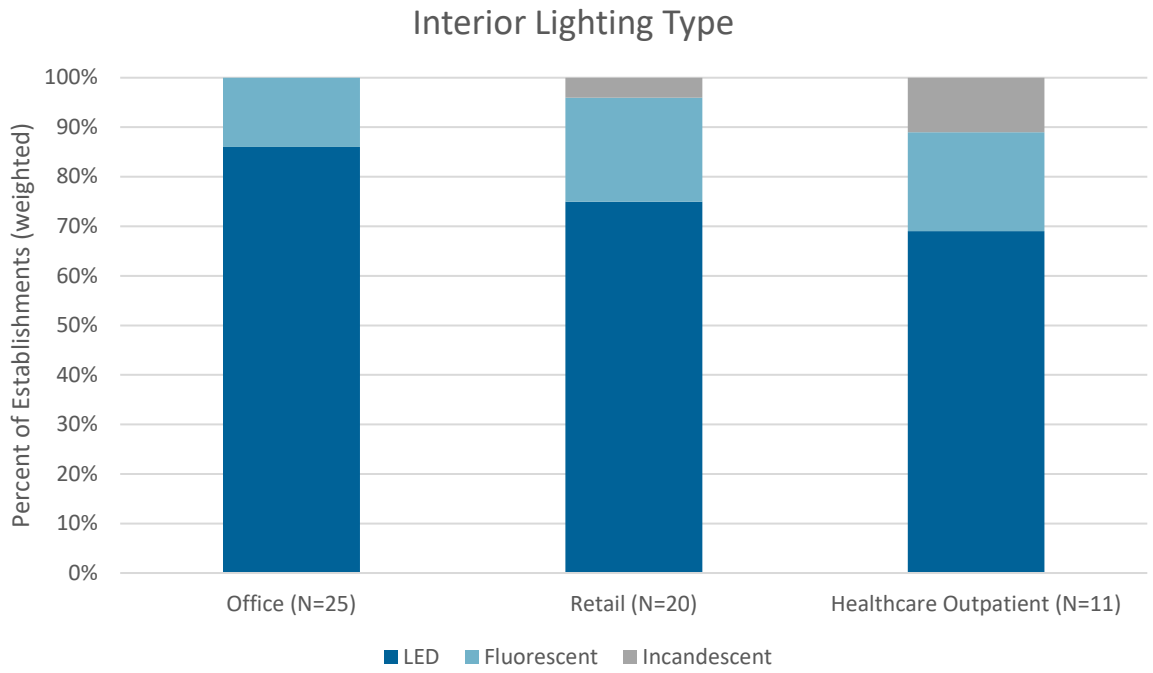


COMMERCIAL SECTOR – LIGHTING

Examples of interior lighting – LED fixtures and tubes. *Photo credit: IBTS staff*

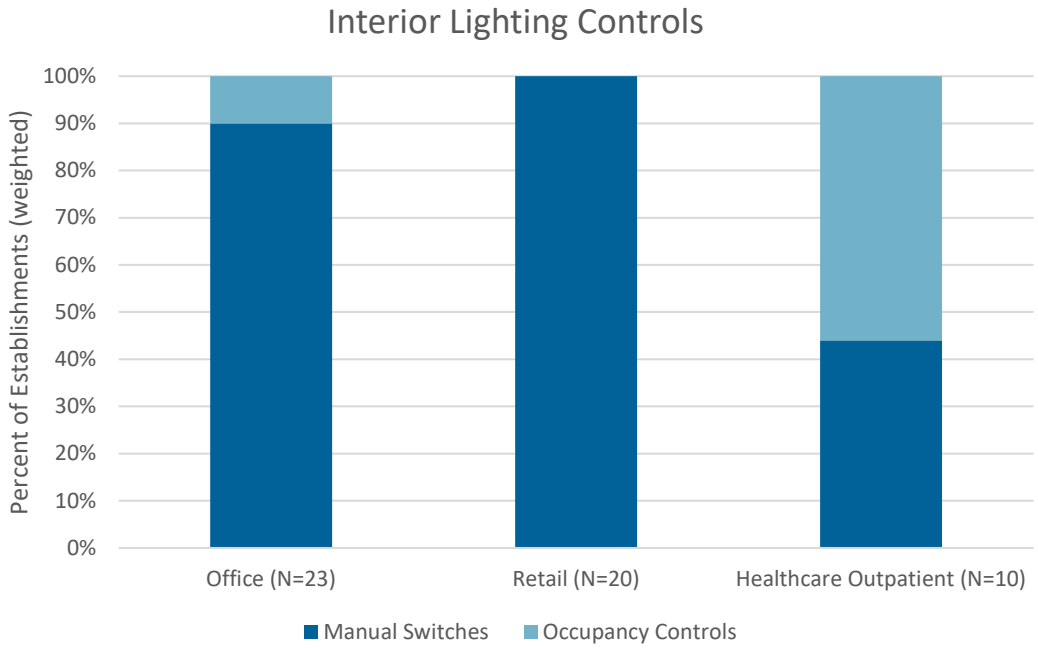
COMMERCIAL SECTOR – INTERIOR LIGHTING

- Interior lighting fixtures are typically the first building system that receives an upgrade
- Majority of interior lighting in office, retail and healthcare outpatient buildings have already been retrofitted to LED
- Still some opportunities exist to upgrade interior lighting from fluorescent to LED



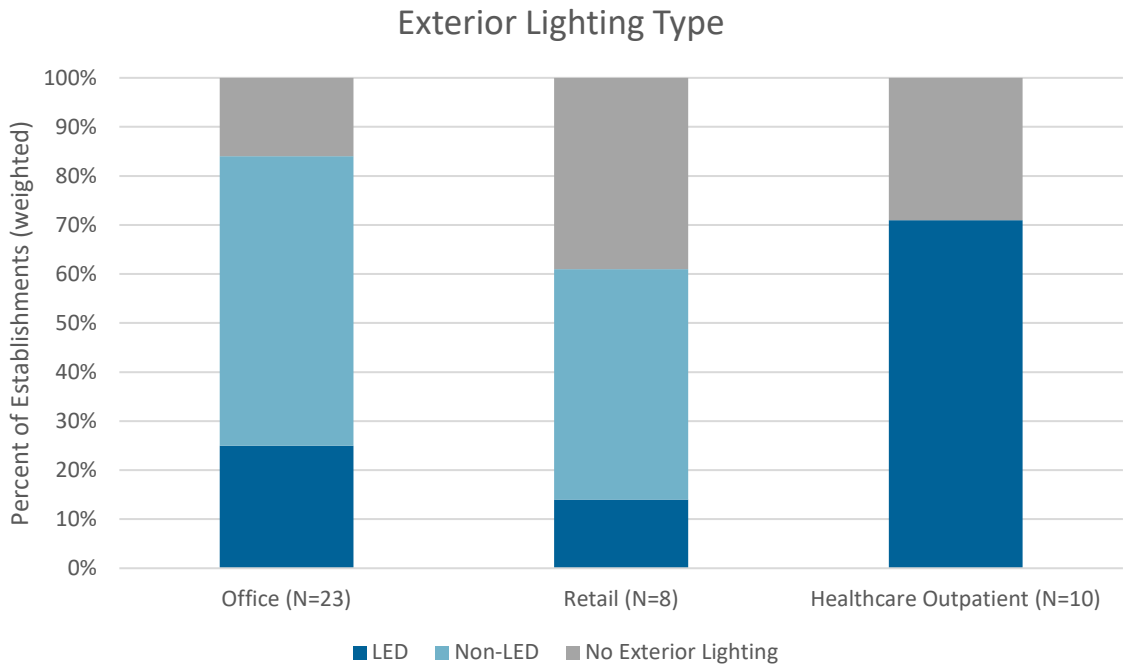
INTERIOR LIGHTING CONTROLS – COMMERCIAL SECTOR

- Manual switches are the most prevalent interior lighting control strategy for office and retail buildings
- Much opportunity for occupancy controls, daylighting controls, task tuning and other advanced lighting controls
- Healthcare outpatient sees more occupancy controls in patient rooms



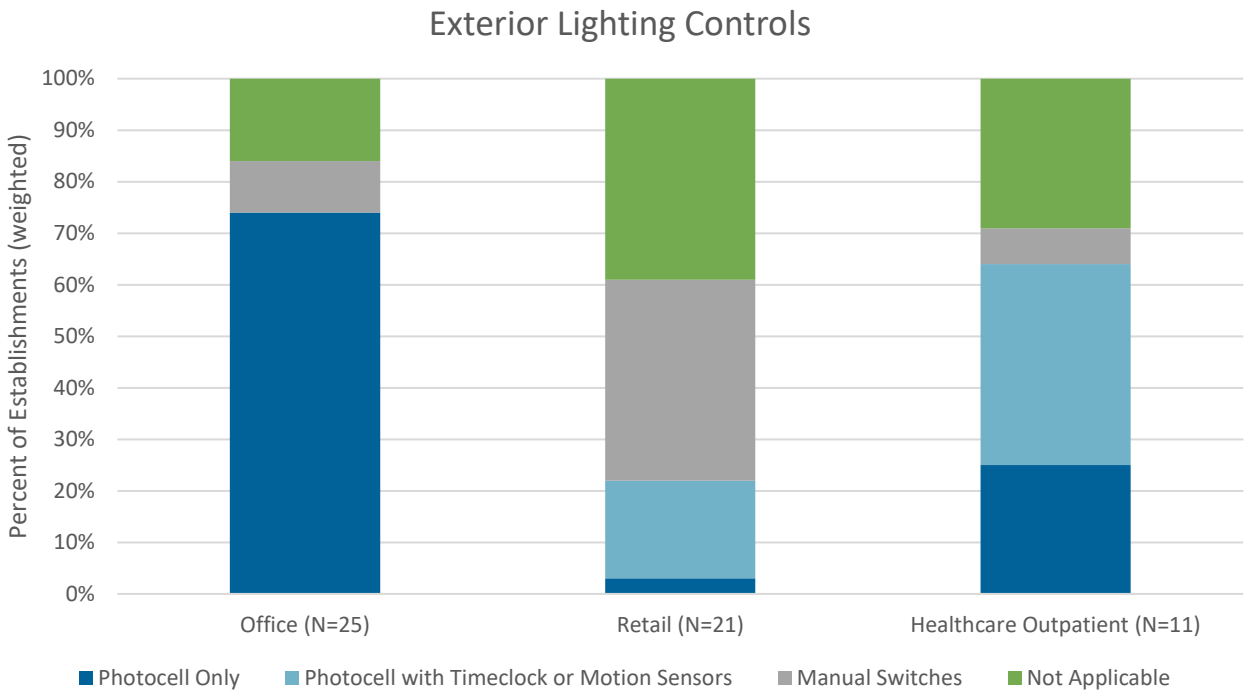
COMMERCIAL SECTOR – EXTERIOR LIGHTING

- Some portion of office, retail and healthcare outpatient buildings do not have exterior lighting.
  - Office and retail buildings with exterior lighting are unlikely to have LEDs
  - Majority of exterior lighting in healthcare outpatient buildings have already been retrofitted to (or originally designed as) LED



COMMERCIAL SECTOR – EXTERIOR LIGHTING CONTROLS

- Majority of exterior lighting controls are photocell only for office buildings
- Small retail buildings have a higher tendency to have manual switches for basic exterior lighting
- Healthcare outpatient has a higher tendency to have exterior lighting photocell controls coupled with timeclock or motion sensor control



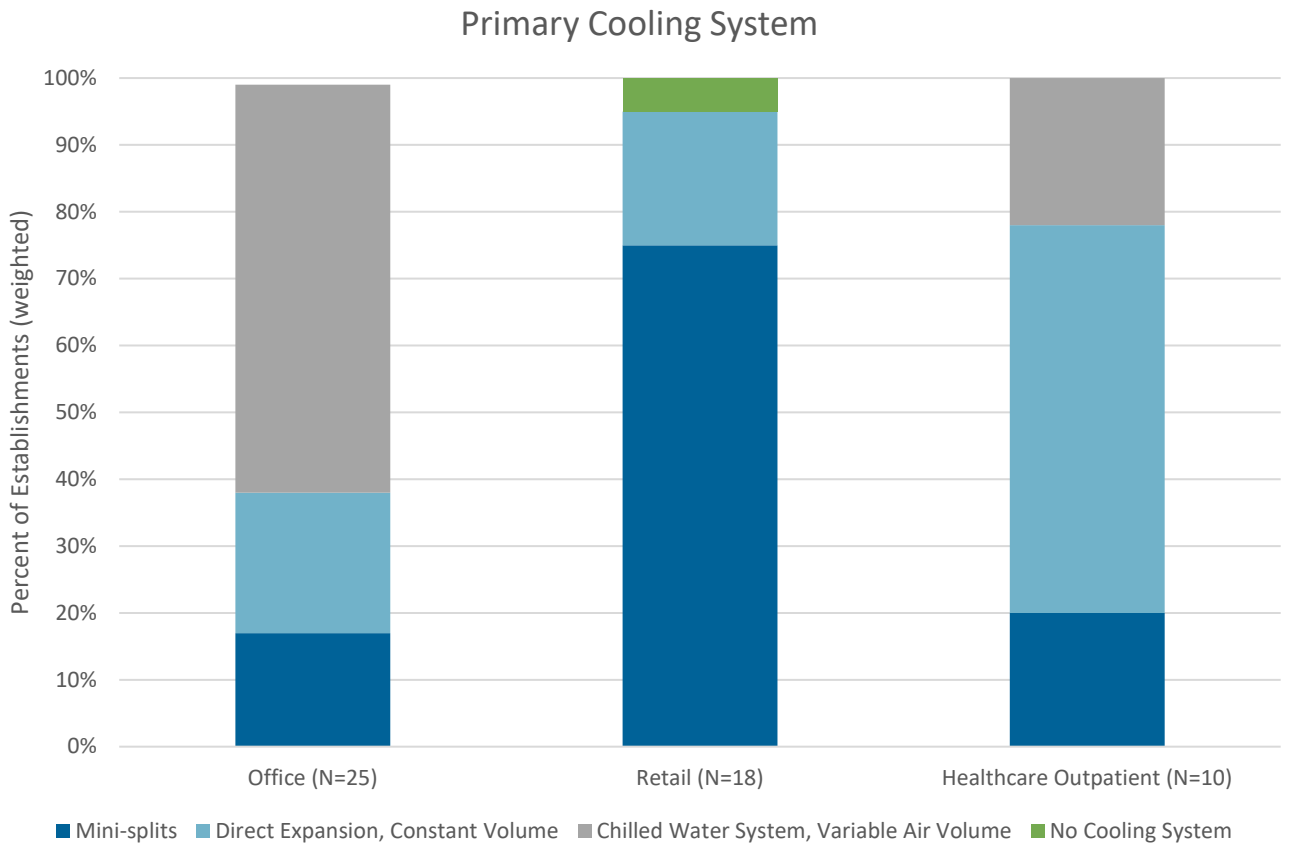
COMMERCIAL SECTOR – COOLING SYSTEMS

Example of mini-split air conditioner indoor unit. *Photo credit: IBTS staff*

Example of split system air conditioner outdoor unit. *Photo credit: IBTS staff*

COMMERCIAL SECTOR – COOLING SYSTEMS

- Mini-splits are the prevailing cooling system type for small office and small retail buildings
- Medium-sized office, retail and healthcare outpatient are more likely to have a centralized system with direct expansion cooling through constant volume AHU or RTU
- Large offices and large outpatient facilities are more likely to be served by a chilled water system and VAV AHU



COMMERCIAL SECTOR – COOLING SYSTEMS

- Cooling system efficiency tends to be at energy code minimum for mini-splits and DX-cooled equipment
- Ventilation controls (i.e. demand control ventilation) are rarely present
- Energy recovery ventilation is not common
- Thermostats are mostly programmable; cooling setbacks are rarely in place - setpoints tend to be held 24/7
- Chilled water system controls characteristic inconclusive due to lack of access to BAS

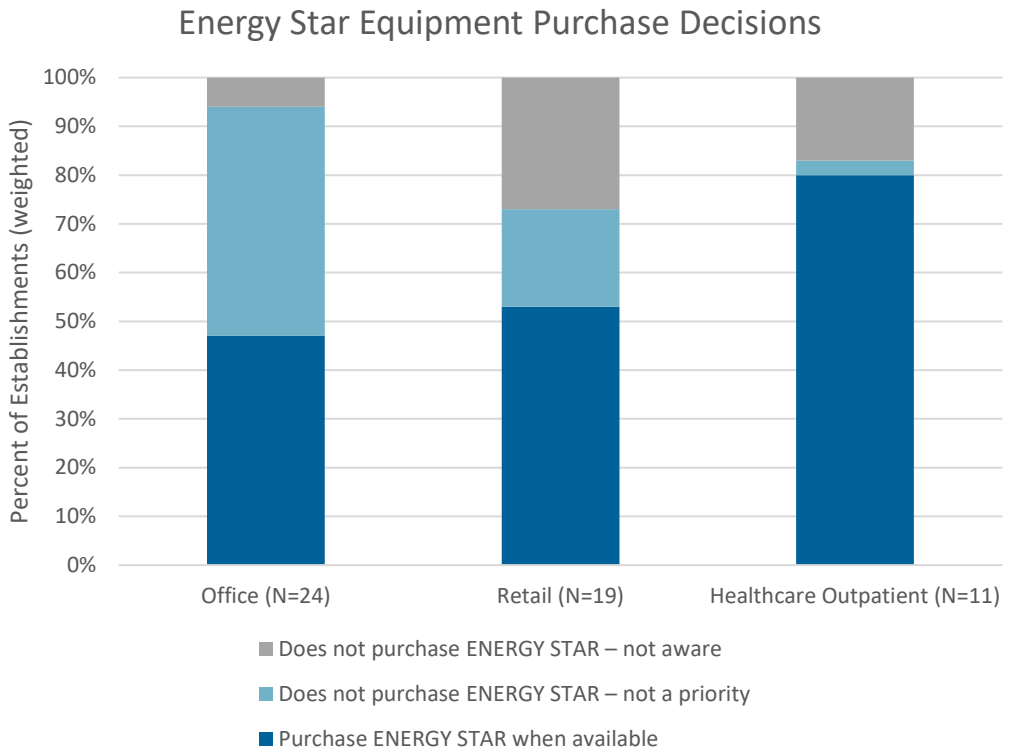
Sampled Segment	Primary Cooling System Efficiency		
	Mini-splits	Direct Expansion, Constant Volume	Chilled Water System, Variable Air Volume
Office (N=12)	12.2 EER	10.8 EER	No data available
Retail (N=3)	11.6 EER	No data available	Cooling system not applicable
Healthcare Outpatient (N=5)	Cooling system not applicable	11.3 EER	Cooling system not applicable

COMMERCIAL SECTOR – WATER HEATING

- Most of office, retail, healthcare outpatient buildings sampled do not have water heating
- When water heating exists, electric resistance water heaters are typically used
  - When part of a central DHW system, demand recirculation controls are rarely present
- Although not seen in site visit data, IBTS field staff reported that large hotel and healthcare inpatient facilities often use propane as fuel source for water heating

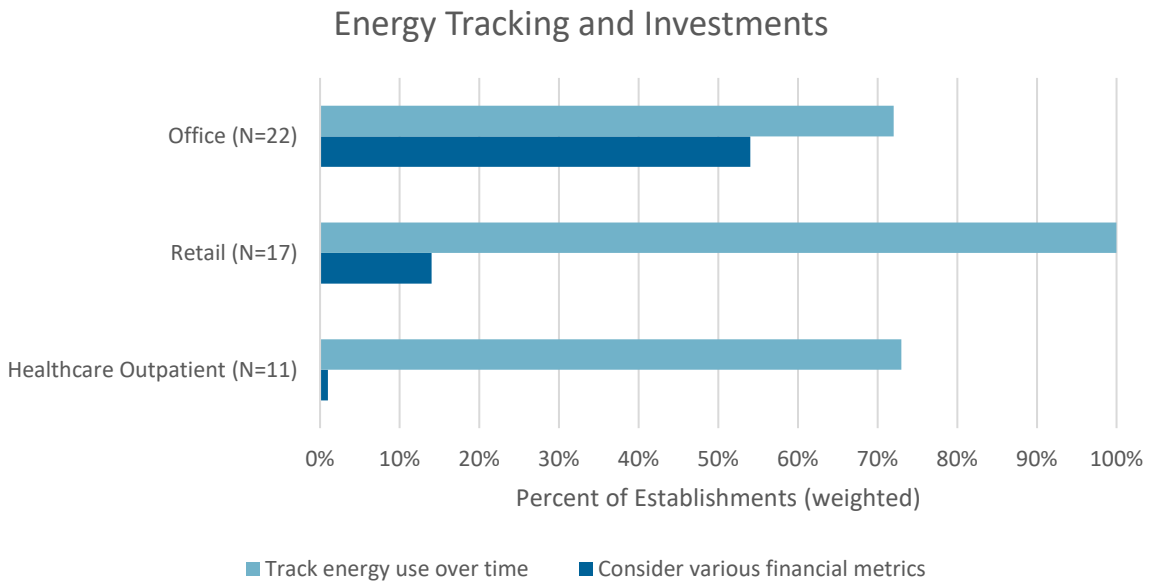
COMMERCIAL SECTOR – APPLIANCE & PLUG LOADS

- Most office, retail, healthcare outpatient buildings only have residential-style refrigerators; dishwashers in break rooms are not common
- Half of office and retail owners and majority of healthcare outpatient owners purchase ENERGY STAR equipment when available
- Advanced power strips for plug load management are not common
- Half of the surveyed buildings enable server room power management
- EV chargers generally do not have time-of-use control



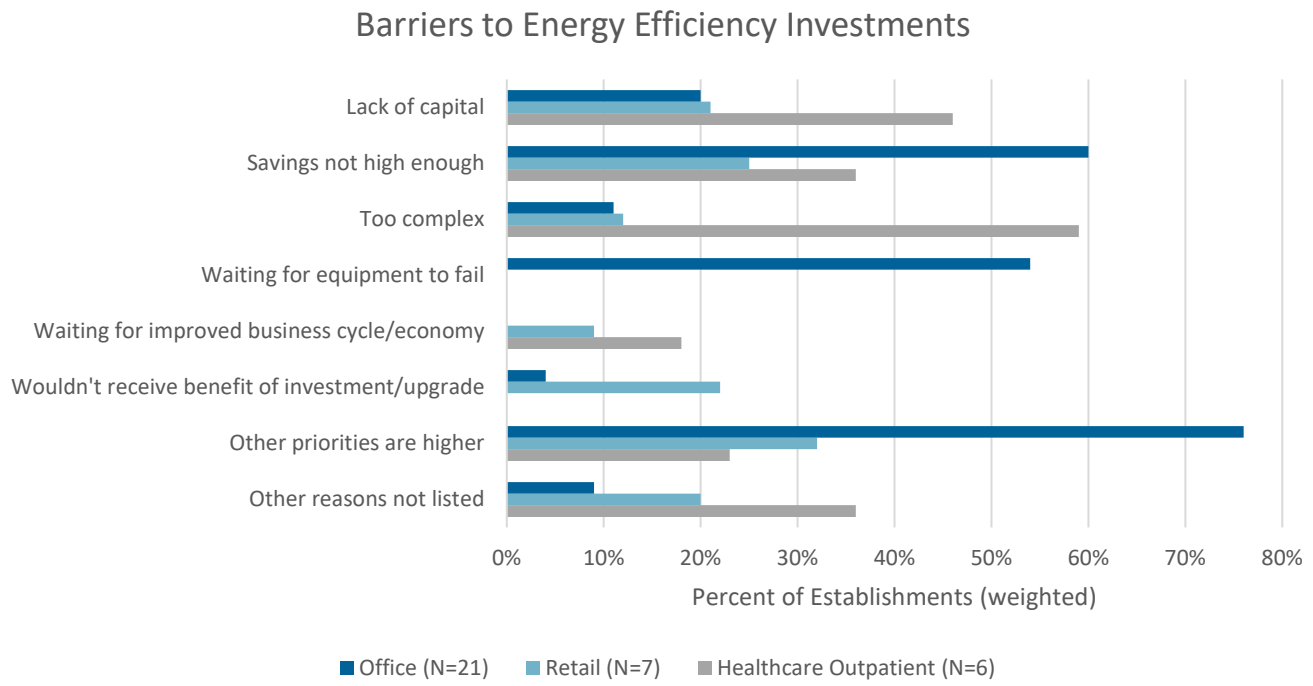
COMMERCIAL SECTOR – ENERGY INVESTMENTS

- Majority of office, retail and healthcare outpatient buildings indicated that they track energy use over time
- Half of office buildings and a small portion of retail establishments consider various financial metrics (i.e. payback period, energy bills) to evaluate whether to make investments in energy efficiency



COMMERCIAL SECTOR – ENERGY INVESTMENTS

- Among the establishments surveyed, the largest barriers to energy efficiency investments for each building type are:
  - Lack of capital, energy savings not high enough, other priorities supersede energy efficiency (office and retail)
  - A good portion of retail establishments reside in a leased building and would not receive the benefits of the investment
  - Lack of capital, energy retrofits deemed too complex (healthcare outpatient)



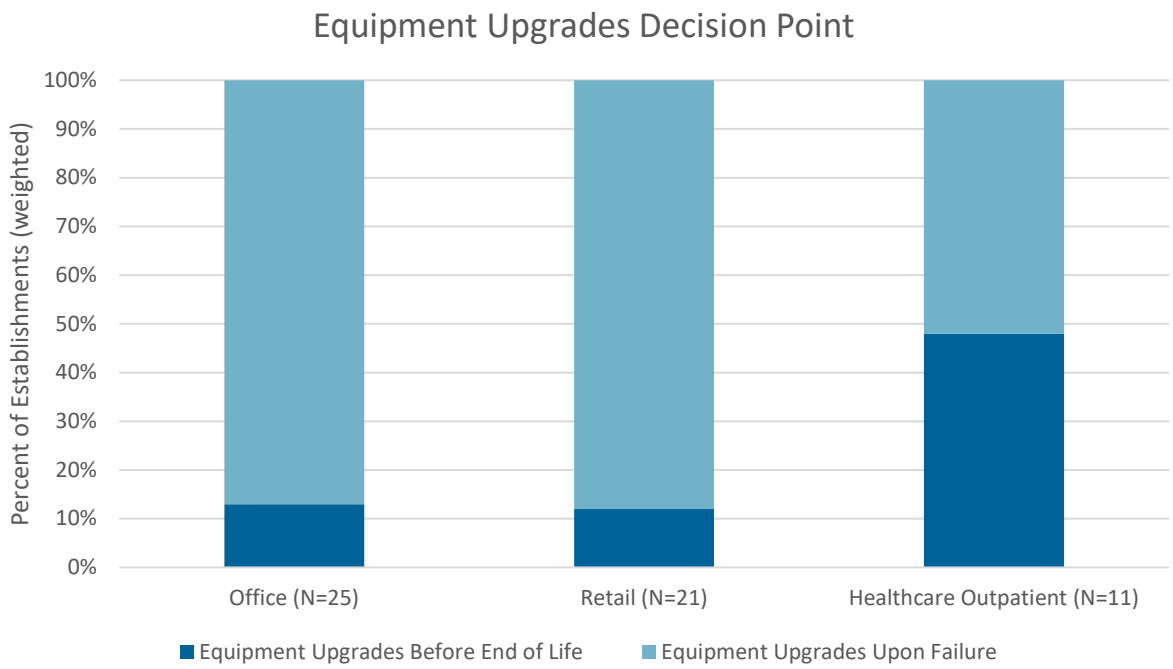
COMMERCIAL SECTOR – ENERGY INVESTMENTS

- Among establishments reporting making recent energy investments, most focus mostly on lighting retrofits (lamp/fixture replacement only)
- Based on the reported energy investments in survey responses, there are many opportunities for lighting control upgrades and HVAC equipment replacements

Sampled Segment	Lighting Upgrades	HVAC Upgrades	Lighting + HVAC Upgrades	Misc. Conservation Measures	Solar	None
Office (N=23)	49%	7%	2%	8%	2%	32%
Retail (N=19)	23%	15%	7%	0%	0%	55%
Healthcare Outpatient (N=9)	36%	0%	0%	0%	0%	64%

COMMERCIAL SECTOR – ENERGY INVESTMENTS

- Office and retail buildings do not tend to replace equipment before end-of-life
- Healthcare outpatient has a higher tendency of upgrading equipment before end-of-life with energy efficiency in mind



ENERGY DISAGGREGATION

OVERVIEW OF DISAGGREGATION METHODS

Commercial Flow

- Initial Model Parameters based on Characterization Analysis & Secondary Sources, e.g. CBECS
- Parameter “Ground truthing” through Review and Discussion with Local Building Experts
- DOE-2 Modeling with Finalized Parameters
- Energy Use Index (EUI) by Modeled Sector and End Use
- Scaling by Estimated Sector Area to Align with LUMA Sales (2022)
- Total Commercial Electric Energy Use by Building Type and End Use

Residential Flow

- Initial Model Parameters based on Characterization Analysis
- Parameter “Ground truthing” through Review and Discussion with Local Building Experts
- BEopt Modeling with Finalized Parameters
- Household Segments Annual Energy Use by End Use
- Scaling by Estimated Segment Total Accounts to Align with LUMA Sales (2022)
- Total Residential Electric Energy Use by Building Type and End Use

MODELING SOFTWARE

Commercial Modeling Software:

DOE-2 (Sketchbox/eQuest)

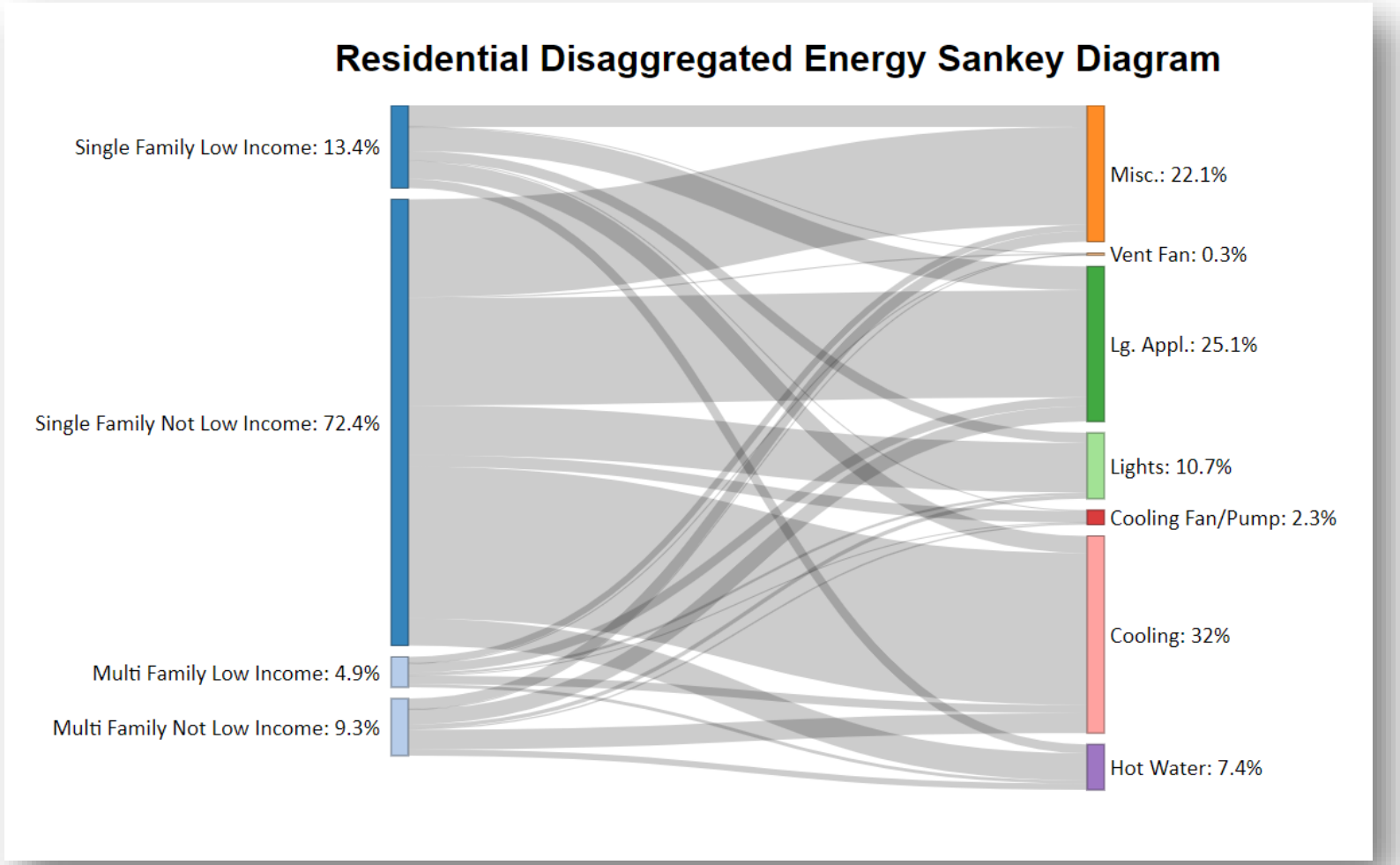
- A building analysis program that is best suited for commercial buildings
- Produces an hourly energy simulation that based on building layouts, conditioning, codes, and more

Residential Modeling Software:

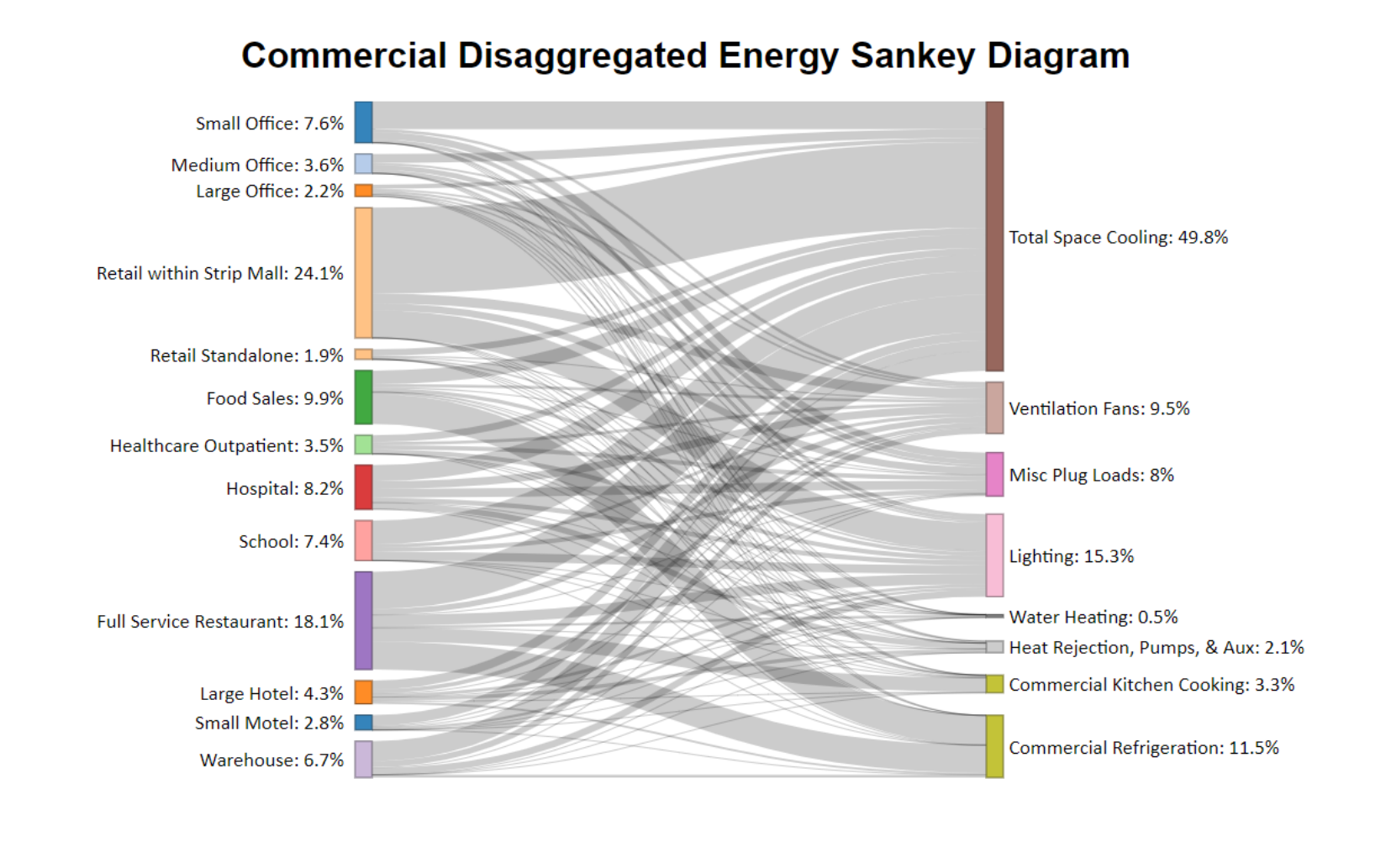
BEopt

- A residential building energy analysis tool
- Provides detailed characteristics of houses with capabilities of creating unique characteristics to produce an hourly energy simulation

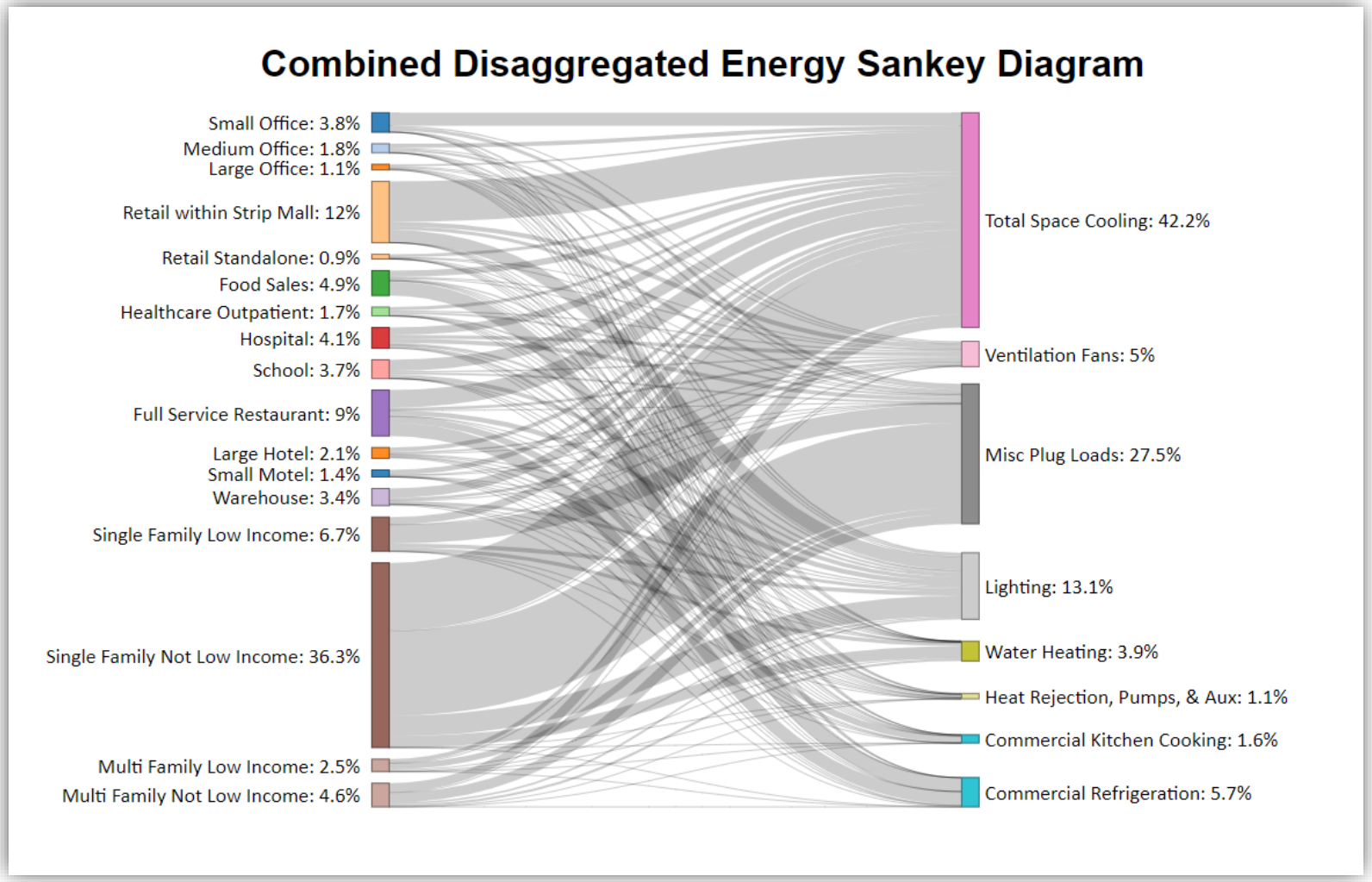
RESIDENTIAL DISAGGREGATION - RESULTS



COMMERCIAL DISAGGREGATION - RESULTS



RESIDENTIAL & COMMERCIAL DISAGGREGATION

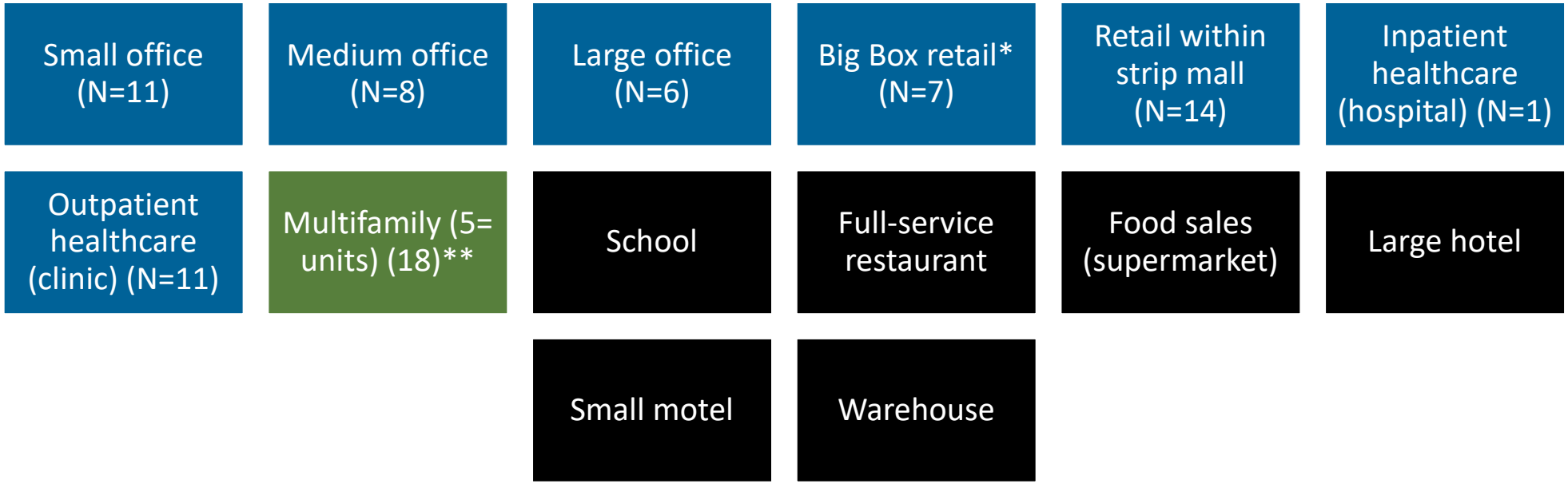


COMMERCIAL

COMMERCIAL SECTOR MODELING

- Created prototype building energy models for 14 commercial building types
- Modeling assumptions based on combination of site survey data and secondary data sources
  - Site visit data: area-weighted averages for numeric inputs
  - Office and retail subtypes based on HVAC system type
  - In areas where there is insufficient site visit data, DOE reference model data is referenced to determine typical building characteristics
  - Characteristics for building types other than office, retail and healthcare relied on DOE reference model data
  - CBECS 2018 data for Florida is referenced for comparison purposes as well as provide a basis for commercial kitchen and commercial refrigeration end use
- Understand normalized energy use (kWh/sqft) and end use breakout

COMMERCIAL SECTOR MODELING



*Not sampled but estimated with medium-to-large sized retail site visits.
** Count for residential site visits.

COMMERCIAL DISAGGREGATION

METHODS

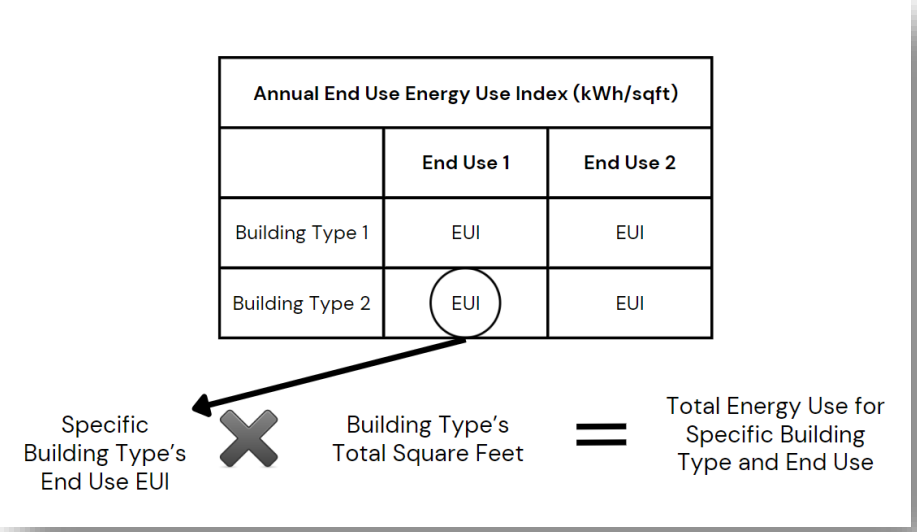
DOE-2 (Sketchbox/eQuest) Modeling

- Utilizing a combination of site visit data and Department of Energy reference model data, prototype energy models for each building type were created in DOE-2 using the Sketchbox/eQuest interface to generate normalized annual energy (kWh/ft2) by end use
- Commercial cooking and refrigeration end uses were referenced from CBECS 2018
- Model outputs for each building category in the Commercial Sector were scaled up to LUMA sales

Annual End Use Energy Use Index (kWh/sqft)		
	End Use 1	End Use 2
Building Type 1	EUI	EUI
Building Type 2	EUI	EUI

COMMERCIAL DISAGGREGATION - SCALING

- Scaling was done via estimated average building square feet and total square feet by building category
- The modeling resulted in an EUI for each building type and end use
- The EUI for each end use was multiplied by the total square feet for each corresponding building type (shown in previous slide)



Building Types	Total Estimated Square Feet
Small Office	32,553,394
Medium Office	22,703,715
Large Office	11,414,430
Retail within Strip Mall	99,028,148
Retail Standalone	8,120,810
Food Sales	17,159,943
Healthcare Outpatient	14,593,972
Hospital	12,468,370
School	31,587,240
Full-Service Restaurant	26,760,012
Large Hotel	15,518,804
Small Motel	12,786,361
Warehouse	56,875,440

RESIDENTIAL

RESIDENTIAL SECTOR MODELING

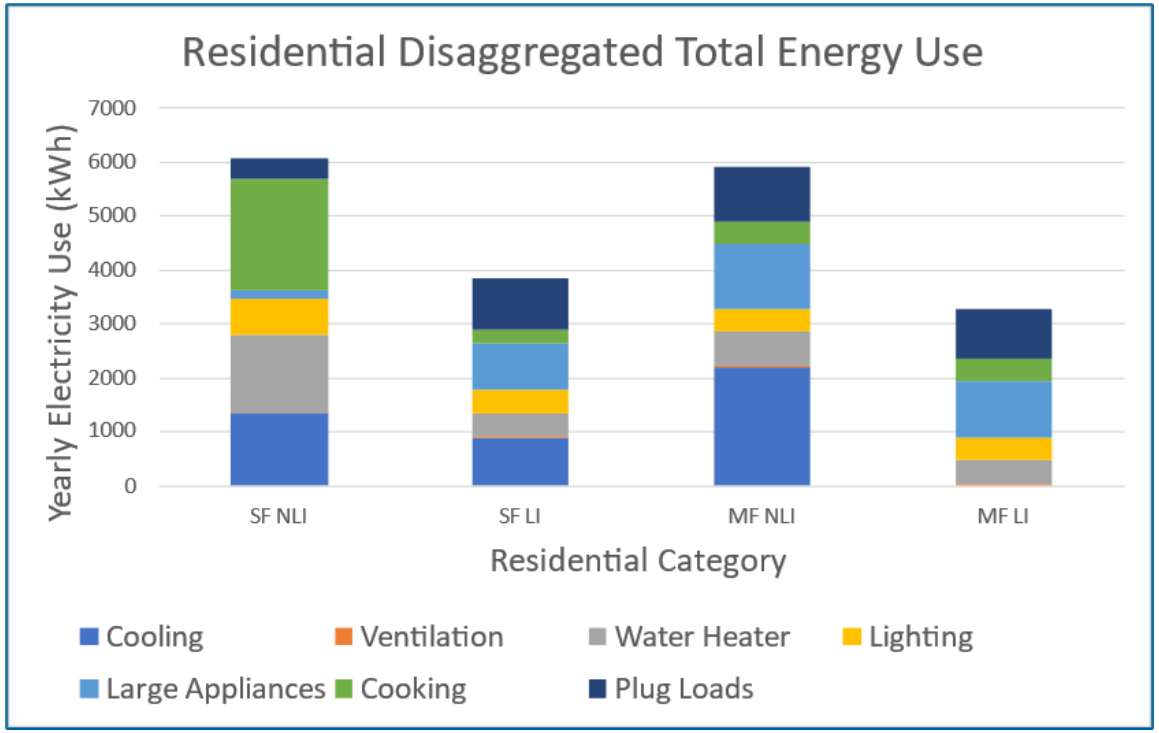
- Modeling assumptions based on combination of site survey data and site visit data
  - Average of results from each data source
  - Site survey data prioritized as there is a much larger sample size
- Goal of Modeling is to understand and quantify:
  - Normalized energy use (kWh/sqft)
  - End use breakout
  - Energy use by residential type

RESIDENTIAL DISAGGREGATION

METHODS

BEopt Modeling

- Utilizing site visit and survey data, models were developed to identify yearly electricity use for 4 residential categories:
  - Single Family Low-Income
  - Single Family Not Low-Income
  - Multifamily Low-Income
  - Multifamily Not Low-Income
- The modeling resulted in an annual energy use by end use per household



RESIDENTIAL DISAGGREGATION - SCALING

- Scaling was done via total accounts of each building category
- The annual energy use was multiplied by the total accounts from each housing type found in the table below to find the total energy use by building type and end use

Scaling Quantities			
Housing Type	**Income Status**	**Total Households**	**Percent of Houses**
MF (4+ units)	Low-income	59,830	5.0%
MF (4+ units)	Not low-income	90,694	7.5%
SF (1-4 units)	Low-income	239,158	19.8%
SF (1-4 units)	Not low-income	816,029	67.7%
Total	-	1,205,711	100%