PUERTO RICO ENERGY EFFICIENCY MARKET BASELINE AND POTENTIAL STUDY

September 24, 2025

Prepared For:

Government of Puerto Rico
Public Service Regulatory Board
Puerto Rico Energy Bureau
Edificio World Plaza
268 Ave. Muñoz Rivera, Suite 202 (Nivel Plaza)
Hato Rey, PR 00918
787.523.6262

NV5

slipstream
Accelerating climate solutions. For everyone.

IBTS

EXECUTIVE SUMMARY

1.1 CONTEXT AND OBJECTIVES

The Government of Puerto Rico has established ambitious targets to increase electric energy efficiency by 30 percent by 2040 using an array of approaches.[1] The primary purpose of this study is to provide the Puerto Rico Energy Bureau (PREB) and LUMA, the third-party operator of Puerto Rico's transmission and distribution system, with an assessment of the energy efficiency market in Puerto Rico to inform both near-term program design and longer-term strategies for program scaling and prioritization.

This study provides three primary components:

1. A characterization of Puerto Rico's current building stock and market for energy efficiency,
2. An estimate of current and future savings from non-utility programs and policies, and
3. An estimate of the potential for electric energy savings and peak demand reduction through utility-run energy efficiency programs over a 15-year period spanning FY2026 through FY2040.

1.2 SUMMARY OF RESULTS

High-level results for the components of this study are presented separately in the sections below. Further detail is provided in the body of the report.

1.2.1 Market Baseline Characterization

This study provides a comprehensive characterization of electricity-related attributes across residential, commercial, and industrial buildings on the island. This foundational analysis informs the subsequent energy efficiency potential modeling and supports long-term planning for demand-side management, regulatory compliance, and equitable program design. Given the absence of Puerto Rico-specific data in national surveys like RECS and CBECS, the study undertook a robust primary data collection effort—complemented by secondary sources and expert input—to fill critical gaps in understanding building stock, equipment, and occupant behavior. Key aspects of the methodology are summarized below:

- Physics-based building energy models were developed for 18 representative building types using tools like BEOpt (residential) and Sketchbox (commercial).[2]

[1] Act 17-2019, known as the *Puerto Rico Energy Public Policy Act*

[2] Sketchbox is an energy modeling tool developed by Slipstream with DOE-2 as the simulation engine. See: https://slipstreaminc.org/sketchbox

- Primary data collection included:
  - 632 residential survey responses and 76 site visits
  - 58 commercial site visits across office, retail, and healthcare segments
  - 5 industrial site visits targeting key sectors (e.g., pharmaceuticals, aerospace)
  - 4 market actor interviews with builders, HVAC contractors, and distributors
- Secondary sources included U.S. Census data, DOE reference models, ResStock/ComStock datasets, and MECS industrial benchmarks.
- Load disaggregation aligned modeled end-use consumption with actual LUMA electric sales data for FY2023−FY2024.
- Sampling strategies prioritized geographic, income, ownership, and building-type diversity, though recruitment challenges—especially among low-income and renter populations—are noted due to the withdrawal of participant incentives.

Residential Sector Findings

- Construction: 94% of homes have concrete walls; insulation is rare (<2% for walls, <25% for roofs).
- Lighting: 77% of fixtures are LED; CFLs and incandescents are declining.
- Cooling: 75% of homes use AC; mini-splits dominate (58%), with SEER ratings averaging 19.5. Central AC is rare.
- Water Heating: 90% of homes have water heaters; solar systems are more common in higher-income households.
- Appliances: Refrigerators are ubiquitous; secondary fridges (often older and inefficient) are found in 20%+ of homes.
- Rooftop Solar: 21% of homes report installations, with higher adoption among non-low-income households.

Commercial Sector Findings

- Envelope: Concrete walls and flat roofs dominate; insulation is uncommon. Windows are mostly single-pane.
- Lighting: Interior LEDs are prevalent; exterior lighting lags in efficiency and controls.
- Cooling: Mini-splits serve small buildings; larger facilities use DX or chilled water systems. Efficiency hovers near 2012 IECC minimums.
- Water Heating: Often absent; when present, electric resistance heaters are typical.

Industrial Sector Findings

- Dominated by pharmaceuticals, aerospace, and biotech.
- Site visits confirmed that energy intensity metrics align closely with MECS national averages.
- Electricity use is concentrated in machine drives (52%), HVAC (12%), and process cooling (10%).

Load Disaggregation Summary

- Cooling is the largest end-use across all sectors (≈39% of total electricity).
- Residential: Cooling (36%), appliances (25%), plug loads (21%)

- Commercial: Cooling (48%), lighting (17%), plug loads and refrigeration (≈10% each)
- Industrial: Pharmaceuticals account for 58% of sector use; motors dominate end-use consumption.

1.2.2 Assessment of Contributing Entities

In addition to utility-run or facilitated programs, the *Regulation for Energy Efficiency* allows energy efficiency impacts from certain other policies, strategies, and programs, collectively referred to as "contributing entities," to contribute to the electric energy reduction target of 30% by 2040 as established by Act 17-2019.[3]

This analysis estimated the savings from these contributing entities; namely building energy codes, federal appliance standards, and certain federally funded programs; occurring from FY2020 through FY2040. To the extent possible, we relied on known factors to inform historical savings estimates (e.g., program budgets and typical savings production). To develop longer-term estimates (FY2025−FY2040), we have generally assumed periodic updates to building energy codes and status quo funding for the Weatherization Assistance Program. For both periods, we have estimated savings from federal appliance standards with *compliance* dates on or after July 1, 2019.

The total savings for all contributing entities are presented in Figure 1 below. Savings are dominated by federal standards with building energy codes contributing a smaller, but not insignificant, share of savings by the end of the analysis period.

---

[3] Puerto Rico Energy Bureau. *Regulation for Energy Efficiency.* January 21, 2022

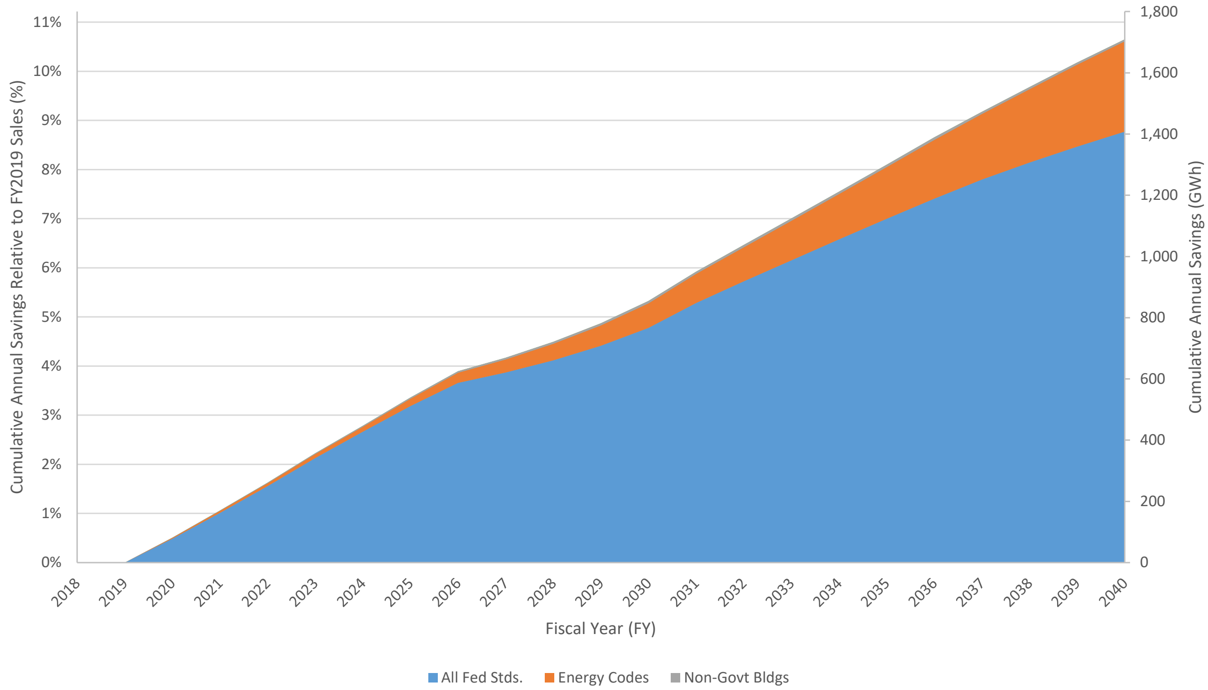

Figure 1. Summary of Cumulative Annual Savings from Contributing Entities

As shown above, cumulative annual savings from federal standards amount to more than 1,400 GWh in FY2040. Cumulative savings from energy codes total nearly 300 GWh in FY2040, and savings from WAP and SEP (i.e., "Non-Govt Bldgs") amount to only 6 GWh. When all contributing entities are combined, cumulative annual savings after the first triennium (FY2026–FY2028) are 721 GWh. Relative to baseline FY2019 sales, this represents a reduction of 4.5%. After the fifth triennium (FY2038–FY2040), cumulative annual savings are estimated at approximately 1,700 GWh or 10.6% of FY2019 sales.

1.2.3 Energy Efficiency Market Potential Analysis

The energy efficiency potential analysis included assessment of the following three potential scenarios:

- **Economic** – All measures that are cost-effective and technically feasible, assuming no market barriers to adoption.
- **Maximum ("Max") Achievable** – A subset of the economic potential that can be achieved when supported by aggressive programs, including incentives covering 100% of the total incremental costs for all measures, with the intent of securing the maximum amount of efficiency savings possible given real-world constraints of customer behavior.
- **Program Achievable** – A subset of the maximum achievable potential assuming "best practice" program design, with incentives covering, on average, 50% of the incremental costs of the measures. Consistent with typical income-eligible program design, income-eligible customers still receive incentives covering 100% incremental costs in this scenario.

Our energy efficiency analysis begins by first forecasting baseline electricity use by sector (i.e., residential, commercial, and industrial) over the analysis period. These sector-level forecasts are then "disaggregated" by major building type and end-use (e.g., interior lighting, cooling, refrigeration). We then characterize costs, savings, and other parameters for a comprehensive list of energy efficiency measures, expressing savings as a percentage reduction in applicable energy use for the relevant end-use(s). We then apply relevant measures and their respective savings percentages to the disaggregated "buckets" of energy use to estimate the total universe of savings potential. Measures that fail the cost-effectiveness screening using the Puerto Rico Benefit-Cost Test (PR Test) are removed from the portfolio, and scenario-appropriate adoption rates are applied to yield the final potential.

This "top-down" approach ensures that energy savings are appropriately scaled to the actual energy consumption of customers and are described in greater detail later in this report. Overall, we examined more than 150 different measures over three different market types (new construction/renovation, market opportunity, and retrofit/early retirement) and 18 different building types yielding nearly 1,200 permutations of unique measures.

Table 1 presents a summary of the economic, maximum achievable, and program achievable potential in terms of cumulative annual electric energy savings relative to baseline FY2019 sales after the first (FY2026—FY2028) and fifth triennia (FY2038—FY2040). In other words, these values represent the total savings in the given year from all the efficiency measures installed in that year and all prior years that have not reached the end of their useful lives. Overall, program achievable potential for electric energy is 2.7% of the FY2019 sales in FY2028 and 11.2% in FY2040. This means that the cumulative result after 15 years of utility energy efficiency programs with incentives covering 50% of the incremental cost is that Puerto Rico's electric load would be nearly 11% lower relative to the baseline year than it would be with no efficiency programs. The maximum achievable potential for electricity in FY2040 is 15.8% of the baseline year sales or 41% greater than the program achievable potential.

Table 1. Cumulative Annual Energy Savings by Scenario and Sector (MWh)

Year	Scenario	Residential, Non-Low Income	Residential, Low Income	C&I	Total	Total as Percentage of FY2019 Sales
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%

Table 2 presents the incremental annual electric energy savings potential for all scenarios for each year in the first triennium (FY2026—FY2028). Note that, due to the expiration of certain measures, the sum of incremental annual savings across all years in the first triennium are not equal to the cumulative annual savings values for FY2028 presented in Table 1. This is primarily due to the impacts of home energy reports (HERs) which are assumed to have a one-year measure life.

Table 2. Incremental Annual Savings by Scenario and Sector (GWh)

Year	Economic			Max Achievable			Program Achievable		
	Res	C&I	Total	Res	C&I	Total	Res	C&I	Total
FY2026	247.7	223.6	471.3	98.5	89.1	187.6	85.0	71.5	156.5
FY2027	232.0	212.0	444.0	118.7	113.8	232.5	96.6	90.0	186.6
FY2028	221.5	207.3	428.8	137.7	137.8	275.5	107.8	108.4	216.1

Figure 1 shows the resulting electric energy consumption by year and scenario. The baseline forecast represents the unadjusted forecast provided by LUMA. As modeled, the program achievable potential would reduce forecasted sales in FY2040 from 11,454 GWh to 9,660 GWh—a reduction of 15.7%.[4]

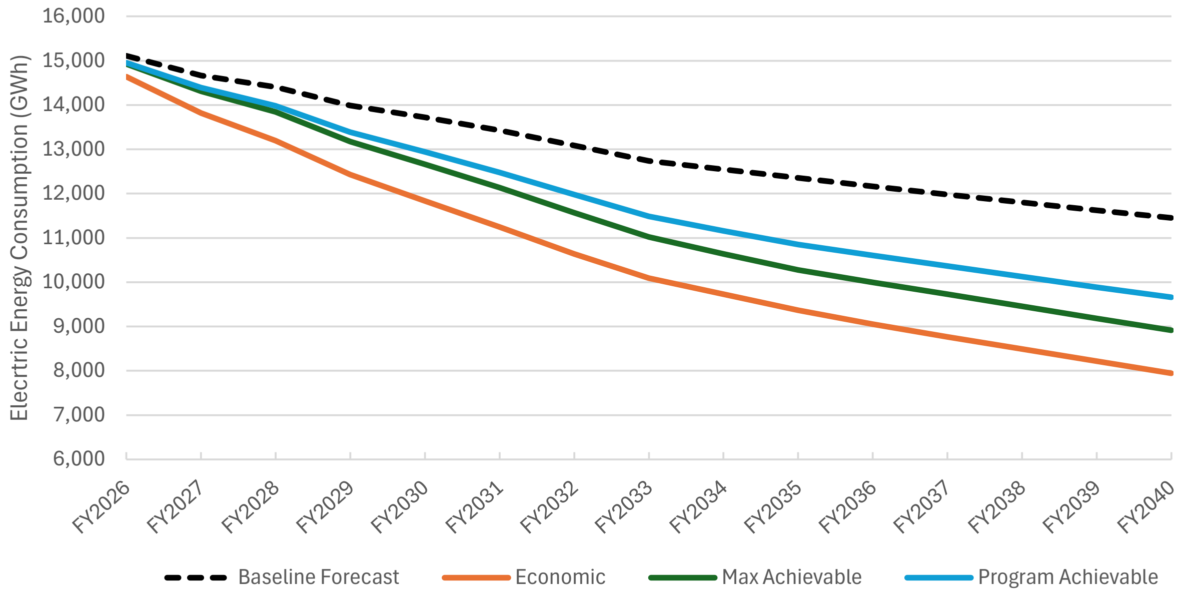

Figure 2. Forecasted Electric Energy Consumption by Scenario (GWh)

Table 3 shows the cumulative annual peak demand reduction in FY2028 and FY2040 for each scenario. These represent the passive demand savings associated with energy efficiency programs

---

[4] Note that the electric energy reduction target of 30% by 2040 as established by Act 17-2019 is measured relative to FY2019 baseline sales. Because, even absent assumed energy efficiency efforts, LUMA's forecast is expected to drop significantly over the analysis period population loss and declining economic activity, the modeled energy efficiency potential is higher on a percentage basis when compared to forecasted sales than when compared to FY2019 baseline sales.

only (i.e., they do not reflect any possible demand response programs). In contrast to the energy savings estimates, these values are presented in megawatts (MW).

Table 3. Cumulative Demand Savings Potential by Sector and Scenario (MW)

Year	Scenario	Residential Savings	Low Income Savings	C&I Savings	Total
FY2028	Economic	92	13	106	211
	Max Achievable	33	5	60	98
	Program Achievable	21	3	48	72
FY2040	Economic	291	40	329	660
	Max Achievable	193	27	269	489
	Program Achievable	116	15	215	346

Table 4 shows the Puerto Rico Benefit-Cost Test results for each scenario. The costs and benefits below represent the net present value in 2026 dollars for 15 years of program activity (i.e., FY2026—FY2040). As shown, the total benefits in all scenarios are roughly double the costs. In other words, every dollar invested in energy efficiency would return two or more dollars in benefits to Puerto Rico. Note that, consistent with industry conventions, the economic potential does not assume any costs associated with administering energy efficiency programs. The program achievable benefit-cost ratio is slightly higher than that of the maximum achievable scenario as the adoption of measures with lower cost-effectiveness is reduced in this scenario.

Table 4. Puerto Rico Benefit-Cost Test Results by Scenario, 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

Table 5 shows the same information for the program achievable scenario, but for each triennium instead of the full 15-year analysis period. As shown, BCRs are similar across the analysis period, falling slightly from 2.5 in the initial years to 2.1 in the final triennium.

Table 5. Puerto Rico Benefit-Cost Test Results by Scenario and Triennium, Present Value 2026 Dollars ($Million)

Value	FY2026-FY2028	FY2029-FY2031	FY2032-FY2034	FY2035-FY2037	FY2038-FY2040
Benefits	$511.7	$642.6	$562.2	$461.7	$438.9
Costs	$206.4	$266.0	$249.5	$207.9	$208.0

Net Benefits	$305.3	$376.6	$312.7	$253.9	$230.9
Benefit-Cost Ratio (BCR)	2.5	2.4	2.3	2.2	2.1

Table 6 below shows the required utility program budget to achieve the savings in the program achievable scenario. The costs include the administrative costs of running the programs, inclusive of administration, marketing, education and outreach, contractor training, evaluation, and financial incentives. As the incremental annual savings increase over time, so too do the program budgets—an increase exacerbated by presentation in nominal dollars.

Table 6. Program Achievable Potential Budgets by Year, Nominal Dollars ($Million)

Year	Non-Incentive	Incentive	Grand Total
FY2026	$13.3	$29.6	$42.8
FY2027	$18.5	$37.7	$56.2
FY2028	$23.7	$45.9	$69.6
FY2029	$28.4	$53.0	$81.4
FY2030	$29.3	$54.4	$83.7
FY2031	$30.1	$55.5	$85.5
FY2032	$30.6	$56.1	$86.7
FY2033	$31.1	$56.8	$87.9
FY2034	$31.8	$57.9	$89.7
FY2035	$32.5	$59.0	$91.5
FY2036	$27.2	$51.1	$78.2
FY2037	$29.0	$53.8	$82.7
FY2038	$31.5	$57.5	$89.0
FY2039	$34.2	$61.7	$95.9
FY2040	$34.5	$62.2	$96.7

1.2.4 Combined Impacts of Energy Efficiency Potential and Contributing Entities

Figure 3 below presents the combined impacts of the quantified energy efficiency potential and the other contributing entities (i.e., federal standards, building energy codes, WAP, and SEP). By FY2040, the combination of the economic EE potential and other contributing entities are projected to reduce energy consumption by more than 5,200 GWh on a cumulative annual basis.

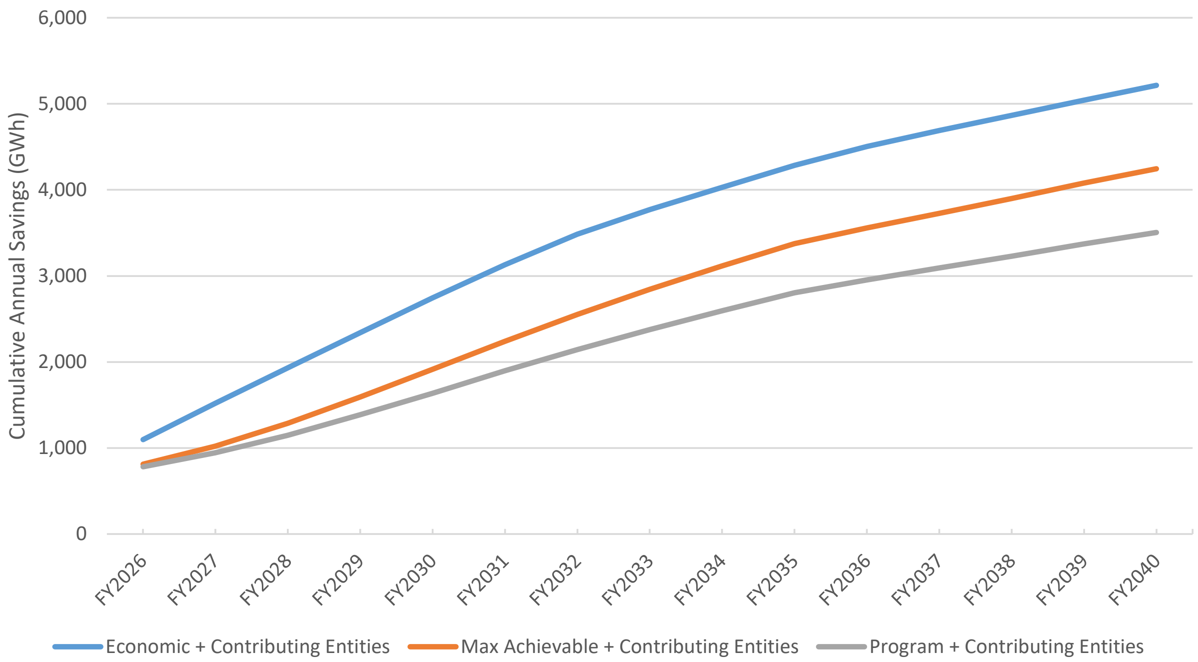

Figure 3. Cumulative Annual Energy Savings by Scenario Including Contributing Entities (GWh)

Relative to baseline FY2019 sales, this represents a reduction of 32.5%. Table 7 below presents the cumulative annual energy savings by scenario, including the savings from other contributing entities, as a percentage of FY2019 sales. The total impacts from the maximum achievable and program achievable potential scenarios are 26.5% and 21.8% in FY2040, respectively.

Table 7. Cumulative Annual Energy Savings by Scenario Including Contributing Entities by Year as Percent of FY2019 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%

Year	EE Potential and Contributing Entities Total		
	Economic	Max Achievable	Program
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%

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

2.0 INTRODUCTION & BACKGROUND

2.1 STUDY OVERVIEW AND SCOPE

The Government of Puerto Rico has established ambitious targets to increase energy efficiency by 30 percent by 2040 using an array of approaches.[5] Puerto Rico's energy consumption per capita is roughly one-third of the average in the 50 U.S. states and the island has a higher average electricity price than all but three U.S. states. The primary purpose of this study is to provide the Puerto Rico Energy Bureau (PREB) and LUMA, the third-party operator of Puerto Rico's transmission and distribution system, with an assessment of the energy efficiency market in Puerto Rico to inform near-term program design and the mid- to long-term program scaling and strategy.

This study provides three primary components:

1. A characterization of Puerto Rico's current building stock and market for energy efficiency,

2. An estimate of current and future savings from non-utility program and policies, and

3. An estimate of the potential for electric energy savings and peak demand reduction through utility-run energy efficiency programs over a 15-year period spanning FY2026 through FY2040.

[5] Act 17-2019, known as the *Puerto Rico Energy Public Policy Act*

3.0 MARKET BASELINE CHARACTERIZATION

This market baseline characterization provides detailed foundational knowledge about electricity-related characteristics of homes and businesses in Puerto Rico. Informed by primary data collection efforts, public and utility data sources, and expert knowledge, we present modeled estimates for how electricity is used in buildings on the island across key sectors and end-uses. We also present findings on building occupant attitudes and behaviors around energy efficiency. The data and estimates from this characterization feed directly into the Market Potential Study (MPS) and, in turn, will inform general future planning for energy-efficiency policies and electricity demand forecasting.

3.1 METHODS

The team used a combined “top-down” and “bottom-up” approach to estimate annual electricity energy use by key market segments and end-uses across residential, commercial, and industrial sectors. Physics-based building energy models for 18 representative building types were used to estimate typical building-level electricity energy consumption by end-use. Key modeling parameters, including equipment, lighting, controls, and schedules, were informed by island-wide survey and on-site data collection efforts, public data sources, and expert input from building scientists working in Puerto Rico. The project team then scaled the disaggregated building-level consumption to align with actual LUMA electric sales data for 2023-2024. Results from surveys and on-site interviews of residential and commercial LUMA customers identified key patterns in attitudes and behaviors around energy efficiency. In-depth interviews with key market actors were used to inform near-term program potential for energy efficiency improvements. This section describes these data collection, analysis and modeling methods in detail.

3.1.1 Data Collection

The project team designed the primary data collection efforts to fill major gaps in existing knowledge and data around Puerto Rico’s residential and commercial building stock, equipment, and LUMA customer efficiency behaviors. For example, Puerto Rico has not been included in the ongoing Residential Energy Consumption Survey (RECS) or Commercial Buildings Energy Consumption Survey (CBECS) sampling efforts by the US Energy Information Administration (EIA) targeting U.S States. Similarly, recent nation-wide large-scale building energy modeling characterizations by the National Renewable Energy Laboratory (NREL) such as ResStock and ComStock do not include estimates for Puerto Rico. To help address these data gaps, our team used surveys, site visits and stakeholder interviews targeting key customer segments within the residential and commercial sectors.

The residential and commercial sampling approaches, sampling targets, and data collection instruments were developed with the understanding that, following best practices, incentives would be provided to participants to help with recruitment, reach ambitious sampling targets, and reduce self-selection bias. After beginning data collection, however, the project team was informed that all offers of incentives needed to be withdrawn from this study. In this section, we describe the planned sampling approach based on the inclusion of participant incentives and how these initial strategies were adjusted to best meet the study objectives after incentives were dropped. For example, realistic sample targets for data collection efforts were adjusted downward after observing lower response rates without incentives. Although final sample sizes for some market segments fell below initial targets, they generally met or exceeded these revised expectations.

3.1.1.1 Residential Sampling Approach

Primary data collection in the residential sector was conducted through a combination of a two-part plan, comprised of a survey and site visits. The survey primarily targeted data collection on less-technical questions that could readily be answered by a survey respondent, such as the presence and type of air conditioning in the home, number and age of refrigerators, and awareness of efficient products and services. The survey was split into two parts to increase partial response rates in the absence of participant incentives. The first part of the survey included the most essential questions for informing baseline characterization, such as lighting and cooling equipment types, while more detailed questions on topics like equipment schedules and counts were included in the second part.

The first part of the survey was used to recruit a subset of respondents for site visits. The subsequent site visits, conducted by field staff, were designed to collect more technical information about equipment efficiency levels, lighting inventories by luminaire and bulb type and other information that survey respondents cannot readily provide. Each part of the residential survey was designed to take approximately 5-10 minutes and the site visit was designed to be completed in less than one hour. The residential survey and site visit instruments can be found in Appendix A.

The residential sampling approach was designed to capture adequate geographic representation across Puerto Rico while also targeting key income, building type, and ownership strata. We defined seven geographic sampling regions designed to align with both US Census Public Use Microdata Areas (PUMAs) and Puerto Rico’s 78 municipios (municipalities), which are the primary local government subdivisions on the island (Figure 4). Aligning sampling regions with PUMAs was required to calculate post-hoc survey weights.

Figure 4. Residential sampling regions were defined based on PUMA and municipio boundaries to ensure geographic representation in survey and site visit data collection.

The income, building type, and ownership-based strata were designed to align with likely utility program participation pathways. These groupings were defined as follows for this study:

- Income: We set sampling targets based on housing income status. Households earning less than 150% of the Federal Poverty Level (FPL) were defined as low-income. This is the same threshold used by the Federal Low Income Energy Assistance Program (LIHEAP) in Puerto Rico. Unlike the published thresholds used in the mainland U.S. by the Weatherization Assistance Program (WAP), the LIHEAP definition applies adjustments for the distinct income distribution of the Commonwealth of Puerto Rico. Approximately 25% of households on the island would be classified as low-income using this definition based on US Census data.[6]
- Building type: We set sampling targets for single-family and multifamily households. Single family households were in buildings with 1-4 dwelling units and multifamily were in those with five or more units. Approximately 88% of households are in single-family homes in Puerto Rico and most multifamily households are concentrated in the San Juan metropolitan area based on US Census data.
- Ownership: The sampling approach also targeted quotas for owner-occupied and renter-occupied dwellings. Approximately 32% of Puerto Rico housing units are renter-occupied based on US Census data.

Our sampling plan, which was developed assuming that we could provide participant incentives, targeted a total of 500 survey completes and 120 site visits. We also included specific sub-targets within key sample strata to more accurately describe these key market segments. Specifically, we targeted at least 150 survey completes and at least 50 site visits across income, building type, and ownership strata. In addition, we targeted at least 50 survey completes from each of the seven sampling regions and at least 50 site visits outside of the densely populated San Juan region to ensure geographic representation in the overall sample.

To ensure a representative sample and timely completion of data collection, we used a multifaceted approach to do outreach and data collection, which took place from October 2023 to March 2024. This included soliciting residential respondents through paid social media and traditional advertising and media platforms. The team leveraged relationships with *municipio* leadership, the Puerto Rico Mayors Association, the Puerto Rico Mayors Federation, press, community organizations, and event promoters to complete these efforts.

Table 8 summarizes the original target sample quotas compared to final response rates. Overall, the data collection effort met or exceeded the original quotas for single family owners that were not low income. In addition, responses were reasonably evenly distributed among geographic regions. Recruiting low-income, renter, and multifamily participants in the study proved difficult without the ability to offer incentives, and the sample sizes among those groups are low compared to quotas. Any key data gaps were filled using secondary data sources and on-the-ground building science expertise as discussed below.

[6] U.S. Census Bureau. (2021). *American Community Survey, 5-Year Estimates, 2016-2020*. Retrieved from https://www.census.gov/programs-surveys/acs

Table 8. Residential survey and site visit sampling targets compared to actual

Sample Strata	Surveys			Site Visits	
	Original Target	Responses – Part 1	Responses – Part 2	Original Target	Completions
TOTAL	**500**	**632**	**207**	**120**	**76**
Geographic Region	50+ by Region	47-144	13-54	>40% outside San Juan	76% outside San Juan
Low Income	150+	98	32	50+	11
Not Low Income	150+	534	209	50+	65
Single Family (1-4 units)	150+	542	207	50+	64
Multifamily (5+ units)	150+	90	34	50+	12
Renters	150+	100	40	50+	16
Owners	150+	532	201	50+	60

3.1.1.2 Commercial Sampling Approach

The commercial sampling approach relied on site visits targeting the three building types that were deemed to represent a large market share of electric sales and to present significant savings opportunities: office, retail, and healthcare. Due to the heterogeneity and scale of the commercial sector, a more comprehensive sampling of building use types was not practical.

In the sampling and recruitment process, the following definitions were used for these three commercial segments:

- Office: This segment encompassed office establishments across a range of sizes.
- Retail: This segment included retail establishments that were not predominantly oriented toward food service, food sales or other specialty service areas such as auto mechanics, hair salons, or machine shops.
- Healthcare: Healthcare included both in-patient facilities (hospitals), and outpatient facilities such physician's offices, dentists, and health clinics

The sample unit for this study was the business establishment so therefore included a mixture of tenants within single-occupant and multiple-occupant buildings. We did not sample more than one establishment occupying the same building.

The goal of the commercial sampling effort was to collect a representative sample of each use type across geographic regions and typical establishment size classes. Capturing data on businesses across a range of sizes was especially important because larger buildings typically have distinct HVAC equipment, building load controls, and construction practices compared to smaller buildings.

To ensure reasonable geographic representation of the sample, we defined three broad sampling zones which were amalgamations of the residential sampling regions (Figure 4).

1. **San Juan Metro Area**: San Juan and Bayamon combined residential regions
2. **East Island**: Carolina and Caguas combined residential regions
3. **West Island**: Mayaguez, Arecibo, and Ponce combined residential regions

Within these regions we set minimum sampling targets based on the distribution of each use type in U.S. Census County Business Patterns data (Table 9).[7]

Table 9. Commercial sampling targets by geographic region

Geographic Zone	Offices	Retail	Healthcare
San Juan Metro	15+	10+	8+
East Island	5+	5+	5+
West Island	5+	10+	8+
TOTAL	35	35	30

Sample targets based on size classes for office and retail segments were established based on the number of full-time employees. For the health care segment, we set separate targets for establishments with predominantly inpatient versus outpatient care. For each segment, we set minimum sample targets for size classes based on their distribution within U.S. Census County Business Patterns data.

In contrast to the residential process of detailed surveys followed by site visits, we used web-based surveys and outreach leveraging the Puerto Rico Mayors Association and other industry groups as the only means of recruitment to reach our target number of site visits. The site visit data collection occurred from October 2023 to March 2024. Site visits conducted by field staff included detailed questions about building construction, systems, controls, schedules and occupant behaviors. The commercial site visit data collection form can be found in Appendix A.

The original target sample quotas compared to final response rates are summarized in Table 10. Across all sectors, a distribution of employee size-classes was captured within each sector. In addition, data collection captured representative buildings across the island with 31-34% of site visits occurring in each of the three geographic sampling zones. However, the number of sampled sites fell short of the overall targets across sectors and within most sub-strata. Any key data gaps were filled using secondary data sources and on-the-ground building science expertise as discussed below.

[7] U.S. Census Bureau. (2021). *County Business Patterns (CBP): 2021 Data*. Retrieved from https://www.census.gov/programs-surveys/cbp.html

Table 10. Commercial site visit sampling targets by segment compared to actual.

Segment	Sub-strata	Strata Target (N)	Strata Actual (N)	Segment Target (N)	Segment Actual (N)
Office - Employees	Small (1-9)	10+	6	35	25
	Medium (10-49)	10+	18		
	Large (50+)	4+	4		
Retail - Employees	Small (1-5)	10+	8	35	21
	Medium (6-19)	10+	5		
	Large (20+)	4+	8		
Healthcare - Type	Outpatient	20+	11	30	12
	Inpatient	4+	1		

3.1.1.3 Industrial Sector Data Collection

To conduct the industrial data collection, we leveraged our team's relationships with the Puerto Rico Manufacturer Association (PRMA) and Pharmaceutical Industry Association (PIA) to develop a robust list of industrial businesses on the island and identify any existing regional data resources. The industrial sector in Puerto Rico is largely dominated by the biopharmaceutical manufacturing, aerospace, agriculture biotechnology, electronics and textiles industries. Based on FY 2023-2024 LUMA sales data, the industrial sector represents approximately 11% of the island's total electric energy consumption.

We conducted five in-depth site visits at industrial facilities throughout Puerto Rico targeting the top industry segments noted above. Site visits conducted by field staff included detailed questions about production lines; manufacturing process loads; process equipment; on-site generation; building construction and systems; and maintenance, capital investment, and energy management practices. Due to the small sample size and data confidentiality concerns, the detailed data from these visits are not disclosed; however, the findings were used to "ground-truth" energy-related data from secondary sources such as the EIA Manufacturing Energy Consumption Survey (MECS) and typical sector practices.

3.1.1.4 Market Actor Interviews

The site-specific data collection for the residential and commercial sectors was supplemented by in-depth interviews (IDIs) with key market actors with knowledge of current construction practices, building systems, and product availability that relate to energy efficiency opportunities. The results of these helped inform near-term program potential for energy efficiency improvements. We conducted interviews with four businesses that served commercial and residential sectors and represented different aspects of the energy efficiency market actor supply chains.[8] Basic firmographic information about these businesses is presented in Table 11.

Table 11. Basic firmographic information about businesses participating in in-depth market actor interviews.

Business Type	Sector(s) Served	Primary Region Served	Employees
Builder	Residential	Island-wide	Undisclosed
Water Heating Contractor	Residential and Commercial	Island-wide	20
HVAC Contractor	Residential and Commercial	Northeast Metro Areas	8
HVAC Distributor	Residential and Commercial	Island-wide	120

3.1.1.5 Secondary Data Sources

Secondary data sources were used to validate patterns seen in survey and site visit data and to fill in gaps in our understanding of building stock characteristics. For example, an analysis of public data sources on the mainland U.S. building stock in hot humid climates coupled with interviews of Puerto Rico building scientists helped to estimate key parameters of commercial building segments that were not included in the primary data collection, such as hotels, schools, and restaurants.

The key secondary data sources that informed this characterization included:

- U.S. Census American Community Survey (2016-2020)
- U.S. Census County Business Patterns Dataset (2021)
- ResStock Building Energy Model Dataset (2024 release 2)
- Residential Energy Consumption Survey (2020)
- ComStock Building Energy Model Dataset (2024 release 1)
- Commercial Building Energy Survey (2018)
- Manufacturing Energy Consumption Survey (2018)
- U.S. Economic Census of Island Areas (2017)
- Department of Energy Commercial Reference Building Models

In addition to these data sources, the team also leveraged the engineering expertise and building sector knowledge of project staff with extensive experience working in Puerto Rico.

[8] For the residential sector we originally targeted 5-7 interviews with residential builders and trade allies associated with the purchase of key electricity-consuming products and devices. Similarly, for the commercial sector we had aimed for an additional 5-7 interviews with builders, architectural firms, and HVAC contractors and distributors. However, due to unexpected challenges in recruitment, in part driven by the lack of incentives for study participation, we revised our sampling approach to target a smaller number of actors serving both residential and commercial sectors.

3.1.2 Analysis and Modeling

This section provides methodological details for processing and analyzing survey and site visit data, including weighting approaches. In addition, we provide details for parameterizing building energy models to estimate disaggregated loads by key residential and commercial market sectors, which were scaled to align with LUMA electric sales. Lastly, we outline some key potential limitations associated with the analysis and disaggregation approaches.

3.1.2.1 Surveys and Site Visits

For the residential surveys and site visits, post-stratification weights were developed to ensure that the final samples represented the geographic and demographic proportions of homes in U.S Census data. Specifically, survey weights were applied to adjust for under-sampling of low-income and renter households, and the oversampling of households in the San Juan region as shown in Table 12. Survey weights were calculated separately for each part of the survey and the site visits and applied in all analyses unless otherwise noted.

Table 12. Comparison of residential sample versus population household composition by building, ownership, income, and geographic strata prior to applying post-hoc survey weights.

Residential Segment	Population	Survey – Part 1	Survey – Part 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%

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

3.1.2.2 Residential Load Disaggregation

The primary goal of the modeling was to identify and quantify weather-normalized energy use by end-use and residential segment.

The four residential segments were:

- Single-family not low-income,
- Single-family low-income,
- Multifamily not low-income, and
- Multifamily low-income.

The model produced results on annual energy consumption per household, aiming to create a generalized representation of energy usage for each of these four housing segments. The assumptions used to build the model are derived from the survey and site visit data. Where applicable, the average of the results from each source were used to inform the inputs for the model. However, the residential survey data was often prioritized over site visit data for inputs due to its larger sample size and, in turn, greater statistical precision.

BEOpt software[9] was used for residential energy modeling. BEOpt, developed by NREL, is a building energy modeling and optimization tool for residential buildings. It is built on the DOE EnergyPlus physics-based building energy modeling engine. The residential sector models developed for this study incorporated a wide range of factors, including electricity-consuming appliances, water heating, insulation levels, building characteristics, solar generation, and HVAC equipment, among other elements. These inputs were used to create a comprehensive energy consumption profile for each residential segment for a typical metrological year in Puerto Rico. A table with key residential model parameters can be found in Appendix B.

3.1.2.3 Commercial Load Disaggregation

To understand the end-use breakout and normalized energy use (kWh/sqft) by building type, energy models for 14 commercial building types were created in Sketchbox[10]. The energy model inputs were based upon a combination of commercial site survey data and secondary data sources including Puerto Rico building science expertise on the team, Department of Energy commercial reference models, and ComStock data for Climate Zone 1A (Florida and Hawaii regions). Where commercial site visit data was available, area-weighted averages were used for numeric inputs. Where no site survey data was available, or if the sample size was too small to draw definitive conclusions, the secondary data sources were referenced. For commercial buildings other than office, retail, and healthcare, modeling assumptions were also based on secondary data sources.

Table 13. Commercial building types included in energy modeling and load disaggregation.

Commercial Building Types	Included in Field Data Collection
Small Office	Yes
Medium Office	Yes
Large Office	Yes
Retail within Strip Mall	Yes
Big Box Retail	No
Food Sales	No

[9] National Renewable Energy Laboratory (NREL). 2023. BEopt (Building Energy Optimization) Version 3.0.1 Beta. Golden, CO: National Renewable Energy Laboratory. Available at: https://www.nrel.gov/buildings/beopt.html

[10] Sketchbox is an energy modeling tool developed by Slipstream with DOE-2 as the simulation engine. See: https://slipstreaminc.org/sketchbox

Commercial Building Types	Included in Field Data Collection
Healthcare Outpatient	Yes
Healthcare Inpatient	Yes
Education	No
Full-service Restaurant	No
Large Hotel	No
Small Motel	No
Warehouse (Refrigerated and Non-Refrigerated)	No

Modeling outputs include the energy end-use breakdown of space cooling, ventilation fans, miscellaneous plug loads, large appliances, interior lighting, exterior lighting, domestic water heating, heat rejection, and pumping energy. End-uses for commercial cooking and commercial refrigeration were not modeled explicitly due to a lack of site visit data; instead these end-uses were referenced from CBECS 2018 data for Climate Zone 1A regions (Florida and Hawaii).

To validate the energy modeling results, we compared the end-use data against CBECS 2018 and ComStock data for Climate Zone 1A as sources of reference. This resulted in small tweaks to specific end-uses including miscellaneous plug loads, large appliances, and exterior lighting for building types that lacked sufficient site visit data. A summary of key modeling assumptions can be found in Appendix B. A comparison of modeling results with CBECS 2018 and ComStock output data can also be found in Appendix B.

3.1.2.4 Industrial Sector Characterization and Analysis

As discussed above, the industrial data collection was primarily used to validate whether secondary data sources were reasonably representative of conditions in Puerto Rico. To achieve this, the energy intensity metrics determined from the on-site data were compared to similar metrics from the 2018 Manufacturing Energy Consumption Survey. While MECS presents energy intensity data in terms of building floorspace, value of shipments, and number of employees, energy consumption per employee was selected as the comparison metric due to confidentiality-related limitations of the on-site data collection.

For each on-site visit, energy intensity in net annual electric energy consumption (MWh) per employee was compared to the MECS data for the most granular North American Industry Classification System (NAICS) category presented in the comparison dataset.[11] Even within a given NAICS category, significant variability in energy intensity metrics is common given the heterogeneity of the process loads. To provide some indication of this variability, the on-site metrics were tabulated relative to the average MECS metrics by US Census Region (Table 14).

[11] The use of “net” here indicates that any on-site generation is removed from reported consumption totals.

Table 14. Industrial On-Site Energy Intensity Relative to MECS Averages

On-Site Data	Comp. NAICS	NAICS Description	Annual MWh (Net)	# Employees	Annual MWh (Net)/Employee							
					PR On-Site Data	MECS, Total United States	MECS, Northeast Census Region	MECS, Midwest Census Region	MECS, South Census Region	MECS, West Census Region	MECS Min.	MECS Max
Site 1	3254	Pharmaceuticals and Medicines	29,784	1,200	25	41	32	63	57	19	19	63
Site 2	339	Miscellaneous	25,191	2,700	9	16	12	19	27	5	5	27
Site 3	3254	Pharmaceuticals and Medicines	14,000	600	23	41	32	63	57	19	19	63
Site 4	325	Chemicals	9,203	147	63	193	74	194	285	106	74	285
Site 5	3364	Aerospace Product and Parts	2,258	980	2	24	14	31	39	18	14	39

In almost all cases, the data from the site visits falls within or very near the range in energy intensity defined by the minimum and maximum regional average values from the MECS data. While the energy intensity of "Site 5" was considerably lower than the comparison dataset, this facility primarily consisted of office space with limited process loads. This analysis indicates that the 2018 MECS data is reasonably representative of industrial sector energy consumption in Puerto Rico.

3.1.2.5 Scaling

Total electricity consumption for the residential, commercial, and industrial sectors were provided by LUMA for the FY2024. These values served as the baseline for aligning the modeled residential and commercial results with actual electricity usage on the island. The modeled results were expressed in Energy Use Intensity (EUI) measured in kWh per square foot per year, so scaling required identifying a total square footage for each commercial building type and a typical square footage for each residential building type.

For residential buildings, US Census data was used to estimate the fraction of residential LUMA electric accounts in each of the four modeled income and housing type segments. The modeled EUI values (kWh/sqft/year) were converted to total annual electricity use for a typical residence based on typical housing size found from the survey and site visit data. After scaling the modeled results based on the number of accounts, final adjustments were applied to align results with the total LUMA sales.

For commercial buildings, a combination of US Census Building Permit data, North American Industry Classification System (NAICS), and CBECS data was used to determine the total square footage of each type of commercial building across the island. Using these three data sources, we created an integrated dataset with estimated square footage and building counts for each building segment. Using these estimated total building footprints by segment, we scaled modeled electricity EUI values to represent the entire commercial sector. Then, small adjustments were made to scale values to align with the total sales reported by LUMA.

For the industrial sector, we first developed energy intensity metrics (kWh/value of shipments) by NAICS code from MECS data representing national averages. Next, we applied these energy intensity metrics to the Puerto Rico value of shipments by NAICS code, as determined from 2017 Economic Census data, to estimate Puerto Rico industrial electric energy consumption by industry type.[12] National MECS data was again used to disaggregate the electric energy consumption by NAICS code and end-use. Finally, the resulting estimated industrial energy consumption was scaled to align with LUMA FY2024 industrial sector sales.

3.1.3 Limitations

Here we briefly point to some key limitations and sources of uncertainty with this characterization analysis.

3.1.3.1 Residential Sector

Since the study relied on voluntary, unpaid participants, there may be unmeasured differences between these individuals and the general population. For instance, participants might have a higher awareness of energy issues, which could influence their responses. Unfortunately, our survey weighting approaches were unable to adjust for this potential self-selection bias.

Additionally, the study encountered statistical uncertainty due to small sample sizes. This issue was particularly pronounced in sub-group comparisons, especially among low-income and multifamily households. The limited sample sizes, particularly with site visit data, restricted our ability to draw robust conclusions for these specific groups.

3.1.3.2 Commercial Sector

The commercial site visit data contained small sample sizes and missing data in many aspects, resulting in lower statistical precision on typical building characteristics estimates. In some cases, end-use characteristics were inconclusive. For example, the HVAC system for many sites was in an inaccessible location and model nameplate info could not be obtained, resulting in small sample sizes in determining typical HVAC efficiency levels. There was also a limited sample size for larger, complex HVAC systems (i.e., chilled water systems). For those large complex systems, access to the building automation system was not always granted, resulting in increased difficulty in characterizing equipment efficiency and operation patterns. In the above instances, team knowledge, DOE Commercial Reference Models, and ComStock data (Climate Zone 1A) were relied upon for modeling assumptions.

Most sampled commercial buildings were under 15,000 sq.ft., resulting in a potentially biased sample of smaller sized buildings. Smaller sized buildings have a tendency to utilize simple HVAC

[12] U.S. Census Bureau. "Island Areas: General Statistics by Manufacturing Industry for Puerto Rico, Metropolitan Areas, and Municipios: 2017." Economic Census of Island Areas, ECNIA Economic Census of Island Areas, Table IA1700IND11, 2017, https://data.census.gov/table/ISLANDAREASIND2017.IA1700IND11?g=040XX00US72&n=N0400.00. Accessed on August 14, 2024.

systems such as ductless mini-splits, whereas larger sized buildings may opt for larger packaged systems or hydronic systems.

Specific end-use characteristics (i.e., commercial cooking and commercial refrigeration) could not be determined based on site visit data only, as these end-uses were not present at the surveyed commercial buildings. Instead, secondary data sources such as CBECS 2018 and ComStock data were referenced to determine the normalized energy use of these specific end-uses.

End-use characteristics were inconclusive for healthcare inpatient buildings due to sample on only a single building. Secondary data sources again were referenced for healthcare inpatient to inform load disaggregation modeling.

As the field data collection only covered four major building types, characteristics for all other building sectors were derived based on Puerto Rico building science expertise on the team, DOE reference buildings, CBECS 2018, and ComStock data.

3.1.3.3 Industrial Sector

The industrial data collection effort was intended to qualitatively investigate any characteristics of Puerto Rico industrial facilities and practices that diverged from those indicated by secondary, national data sources. While the on-site data collection did not identify any major deviations from reference data, the sample size for this effort was small (five facilities) and it is possible that a larger survey of the sector would lead to different conclusions.

However, it should be noted that due to the variable and sometimes unique nature of process loads, the industrial sector is more heterogeneous than other sectors in terms of energy usage and associated opportunities. Designing a statistically significant study for Puerto Rico may be impractical, and achieving the necessary survey participation in the sector would be hampered by data confidentiality concerns.

3.2 RESULTS

3.2.1 Residential Characterization

In this section we highlight key findings from the residential survey and site visit data collection. A complete summary of the residential characterization analysis, including all cross-tabulation and processed data files, can be found in Appendix C.

3.2.1.1 Key Findings

Below are some key findings from the residential sector characterization analysis of survey and site visit data:

- **Construction**: Dwellings are predominantly concrete with 94% of homes having concrete walls and 92% having concrete roofs. Insulation is uncommon, with less than 2% of homes having wall insulation and less than 25% having roof insulation. Windows are predominantly single-paned.

- **Lighting:** Approximately 77% of interior lighting is provided by LEDs, with CFLs and incandescent bulbs making up smaller fractions (13% and 9%, respectively).
- **Cooling:** Approximately 75% of homes use some form of air conditioning other than fans, with mini-splits being the most popular (58%). Lower-income households are less likely to have air conditioning (53%) compared to higher-income households (82%). Central systems are rare, even in multifamily residences. Typical SEER ratings for mini-splits and window AC units were 19.5 and 11 respectively.
- **Water Heating:** Approximately 90% of homes have some form of water heating, with tankless, in-line, and solar water heaters being the most popular. Solar water heating is more common in higher-income households (28%) compared to low-income households (7%). The average uniform efficiency factor (UEF) of 0.86 across all types, with tank heaters having a lower mean rating (0.76) and tankless systems having a higher mean rating (0.94).
- **Appliances:** Nearly all homes have at least one refrigerator, and 38% have a stand-alone freezer. Dehumidifiers and dishwashers are less common, found in 14% and 11% of homes, respectively. Most fridges were less than 5 years old and 40% had an Energy Star rating. Clothes washers are ubiquitous, and most homes also have a clothes dryer. Just over half of clothes washers had a high-efficiency (HE) rating. Households use a mixture of electricity and propane for clothes drying and cooking.
- **Energy Efficiency Actions**: The most common actions include installing LEDs (68%) and upgrading air conditioning systems (43%). Adoption of rooftop solar systems is also notable, with 21% of homes reporting installations, higher among non-low-income households (27%).

3.2.1.2 Envelope

Residential single-family and multifamily construction is predominantly concrete. Based on site visit data, we estimate 94% of dwellings in Puerto Rico have concrete walls (block or poured), 92% have concrete roofs, and nearly 100% have concrete foundations (slab, perimeter, or block). Also based on site visit data, we estimate that overall wall and roof insulation is uncommon in Puerto Rico homes, with wall insulation present in less than 2% of homes and roof insulation present in less than 25% of homes.

Based on the residential site visit data, nearly 100% of windows are single-pane. Of those, 50% are standard single pane of glass, 36% are louvered storm-resistant “Miami-style” windows, and 14% also have storm windows.

3.2.1.3 Cooling

Homes use a mixture of cooling strategies that vary by income level. Based on the residential survey, most homes (75%) use some form of air conditioning. Overall mini-spits are the most popular form of air conditioning and used in 58% of homes based on the survey, with 21% using window units, and only about 2% having central air conditioning (Figure 5). Mini-split or window air conditioners are often used in conjunction with fans. Notably, lower income households are less likely to have any form of air conditioning (53%) compared to higher income households (82%). Cooling with fans and window air conditioners appears to be slightly more common in lower income households compared to higher income households, but the difference is not statistically significant.

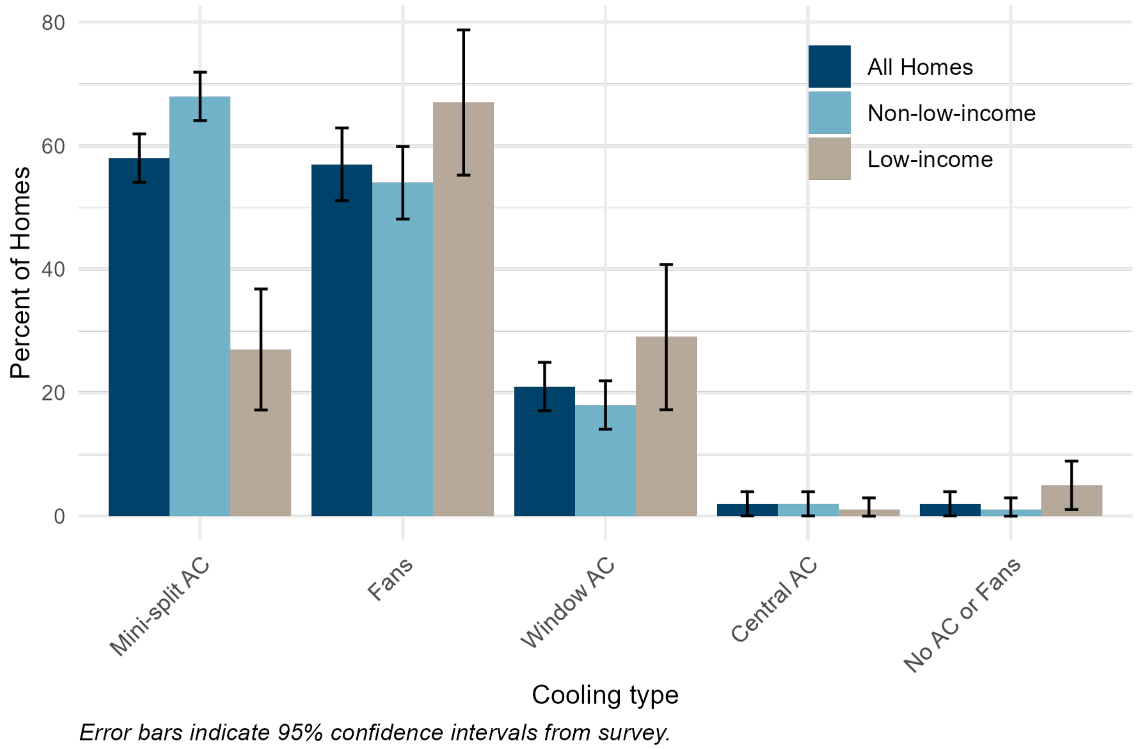

Figure 5. Prevalence of cooling strategies by income level based on residential survey question "What equipment do you use to cool your home? (Select all that apply)"

Overall multifamily and single-family housing units use similar cooling strategies based on the survey, with 71% using some form of air conditioning. However, window ACs appear to be more common in the multifamily segment compared to single family (44% vs. 16%) and mini-splits appear to be less common in the multifamily segment compared to single family (30% vs. 63%). Central air conditioning systems in multifamily buildings also appear to be relatively rare, which was estimated at 4% based on the survey. Apartment units are typically served by independent mini-split or window AC units.

Households with air conditioning typically use it throughout the year, but only portions of the day and for part of their living space. Based on survey responses, we estimate that 70% of homes with air conditioning use it for 10 or more months of the year, but most (67%) use air conditioning for less than 12 hours on a typical day. Similarly, only 27% of households cool more than 90% of their living space. Instead, the most common space cooling strategy was to target bedrooms.

Through site visit data collection, we were able to gather information on the typical efficiencies of mini-split and window air conditioning systems. Efficiency specifications for central air conditioners were not obtained due to the rarity of this type. For mini-splits we observed mean SEER rating of 19.5 across a sample of the 37 units where data could be obtained. In addition, most mini-splits (64%) were less than five years old. Less data was obtained on window AC units, but based on the

11 where nameplate information could be obtained, we estimated a mean SEER rating of 11. Based on survey responses, 76% of window AC units are less than 5 years old.

3.2.1.4 Lighting

Most lighting in Puerto Rican homes is provided by LEDs. Based on both survey and site visit data we estimate that approximately 77% of interior lighting is supplied by LEDs with CFLs (13%) and incandescent bulbs (9%) making up smaller fractions (Figure 6). The composition of lighting types did not vary significantly by income, ownership or building type segments.

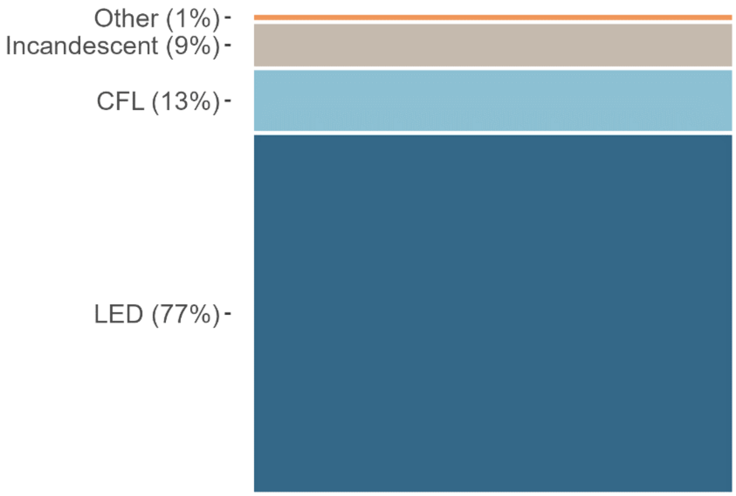

Figure 6. Estimated percent of lighting types in Puerto Rican homes based on residential site visits.

3.2.1.5 Water Heating

Approximately 90% of Puerto Rican homes have some form of water heating. Among homes with water heating, tankless, in-line, and solar water heaters are the most popular (Figure 7). Among all households, 43% have in-line shower or tankless water heaters, while 22% have stand-alone tank heaters. Based on survey results, few homes (<5%) with water heating have more than one type of hot water heater. Heat pump water heaters are rare and only found in approximately 1% of homes. Among stand-alone tank water heaters, approximately 96% are electric resistance and 4% heat pump. Based on model numbers collected from 35 water heaters in site visits, we estimated an average uniform efficiency factor (UEF) of 0.86 across all types, with tank heaters having a lower mean rating (0.76) and tankless systems having a higher mean rating (0.94).

There is some evidence the low-income households use less hot water compared to higher income households. For example, we noted that 15% of low-income households do not have hot water compared to 8% of non-low-income households, though the difference is not statistically significant.

In addition, solar hot water is more common in higher income households. Only 7% of low-income households reported solar hot water compared to 28% of non-low-income households (Figure 7).

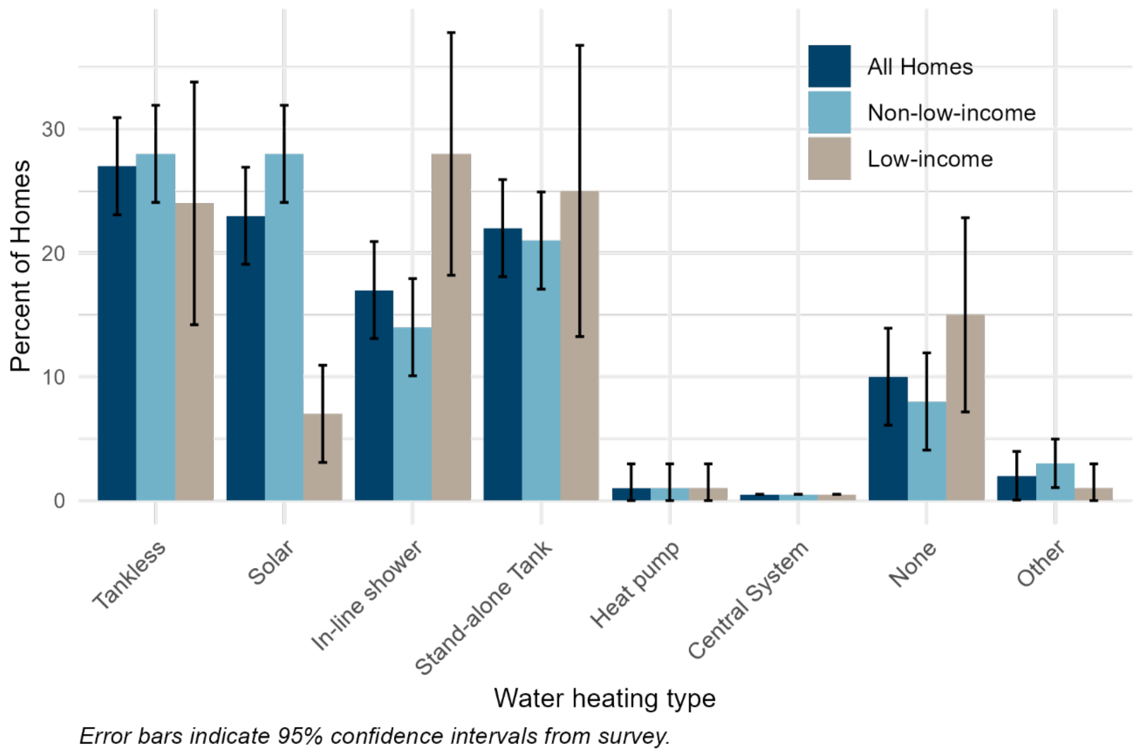

Figure 7. Prevalence of water heating equipment by income level based on residential survey question "What type of water heater do you have in your home? (Select all that apply)"

Among all households, most (65%) use electricity as their primary heating fuel based on survey results, 20% used solar, and 4% used propane (Figure 8). Compared to other water heating fuels, homes with solar hot water are more likely to have secondary water heating that use electricity or propane. We noted that propane represents a small fraction of water heating fuels across all households (4%) but is more common in homes with tankless water heaters.

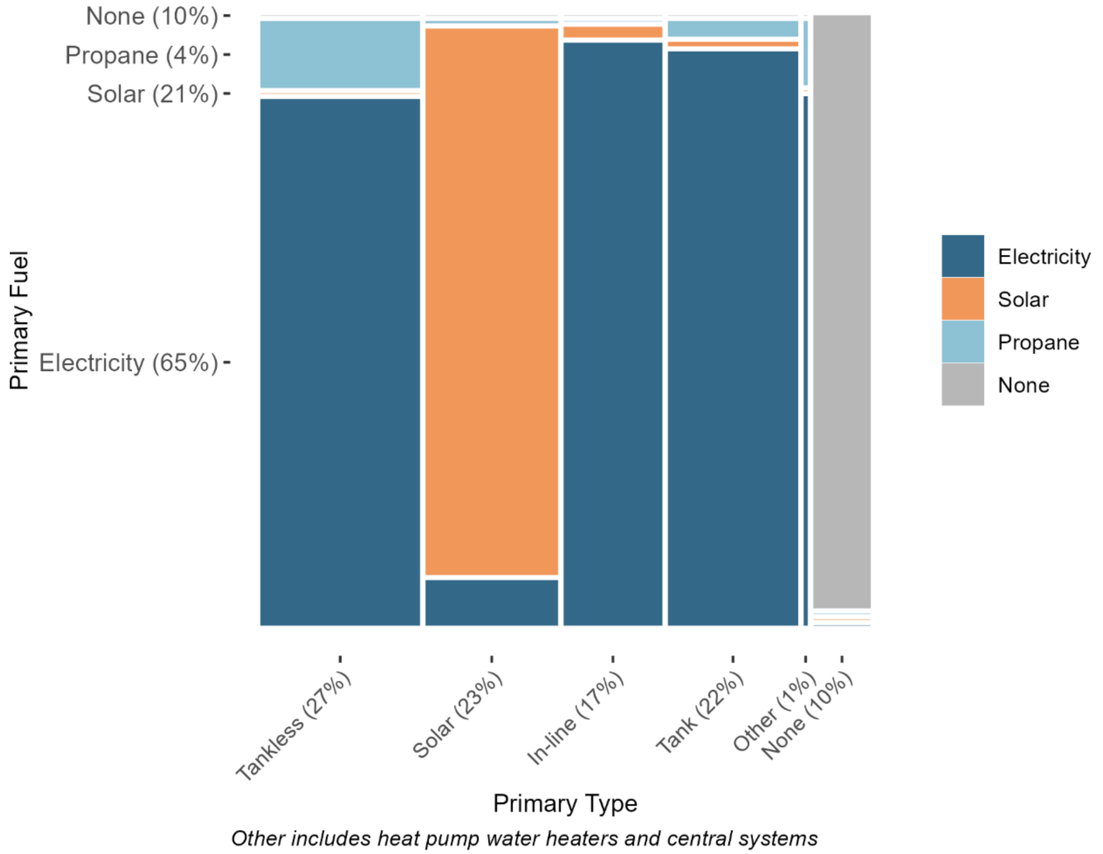

Figure 8. Prevalence of water heating equipment by fuel type in Puerto Rico homes based on residential survey responses.

3.2.1.6 Appliances

Refrigerators and freezers are common appliances in Puerto Rican homes. Based on survey results, we estimate that nearly all homes have at least one refrigerator and approximately 38% have at least one stand-alone freezer. Based on collected in site visits, 58% of primary fridges are less than five years old and approximately 40% are Energy Star rated. Among major appliances, dehumidifiers and dishwashers are relatively uncommon. Based on survey results, we estimate that dehumidifiers are found in approximately 14% of homes and dishwashers in 11% (Figure 9).

Secondary fridges are relatively common based on the survey with more than 20% of homes having at least one additional refrigerator. These secondary fridges may represent a significant savings opportunity for energy efficiency programs. Based on site visit data, 96% of secondary fridges in homes are plugged in and used year-round. More than 85% of secondary fridges are more than ten years old.

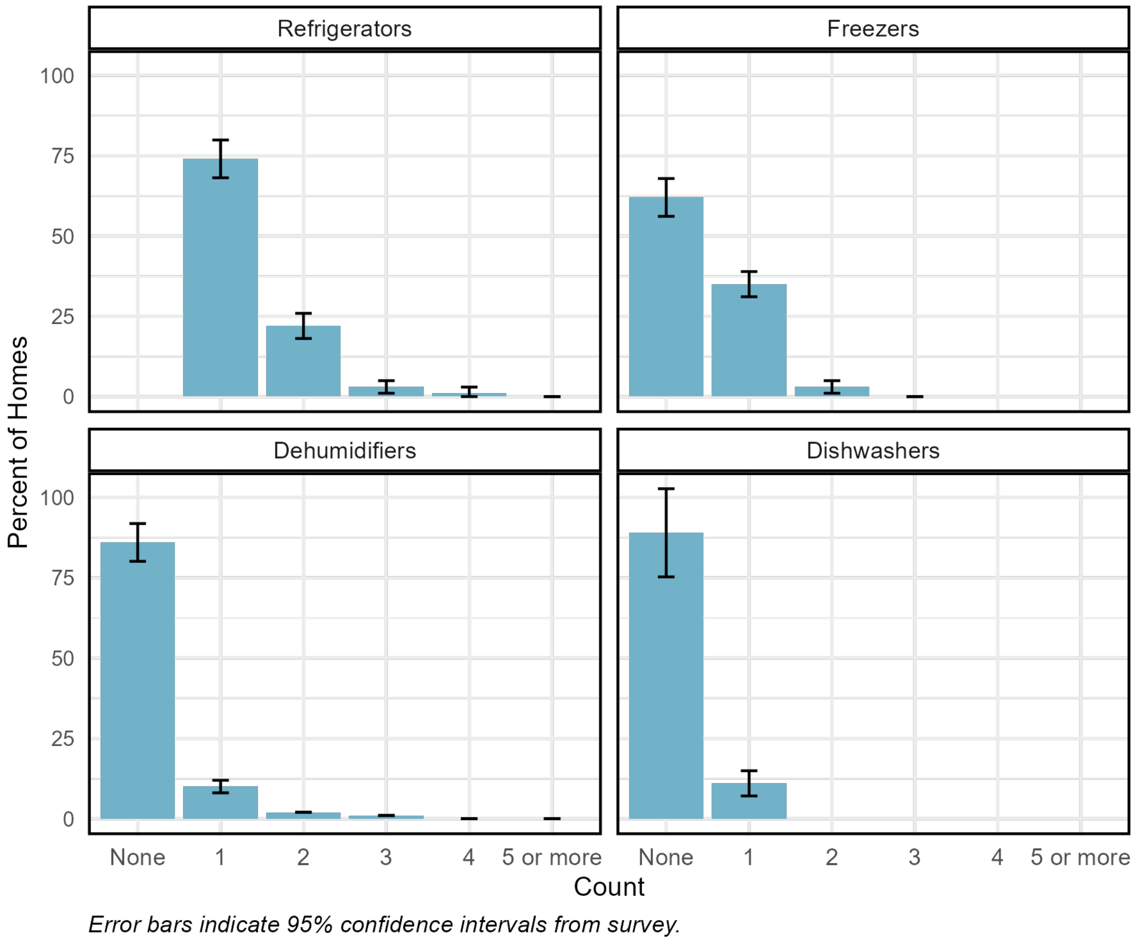

Figure 9. Typical counts of appliances in Puerto Rico homes based on residential survey responses.

Washers and dryers are also common in Puerto Rican homes. Based on survey results, nearly all homes (96%) have a washing machine with 79% top-loading and 17% front-loading. Of clothes washers, 56% have a high efficiency (HE) rating based on 50 machines identified through site visits. Most homes (67%) have either an electric clothes dryer (36%) or propane dryer (31%). Homes without clothes dryers are more likely to be lower income and/or renters. Heat pump clothes dryers are rare on the island and did not appear in any households sampled through site visits.

Households use a mixture of electric and propane cooking fuels. Based on the survey, 53% of homes have electric ranges and 47% propane. Based on site visit data, induction cooktops are only found in approximately 2% of households.

3.2.1.7 Attitudes and Behaviors

The most common reported energy efficiency actions among residents included installing LEDs and purchasing a more efficient AC unit. Based on the survey, 68% of households have installed LEDs and 43% have upgraded their air conditioning system (Figure 10). Other common efficiency actions included reducing AC use (32%) and buying Energy Star rated appliances (32%). Measures related to weatherization and water heating upgrades were less common. These patterns in reported behaviors generally align with the types of equipment found in homes based on survey and site visit results. For example, nearly 60% of households have a mini-split air conditioner, which based on site visit data collection had a mean SEER rating of 20. By comparison, window AC units observed on the island in site visits had a mean SEER rating of 11.

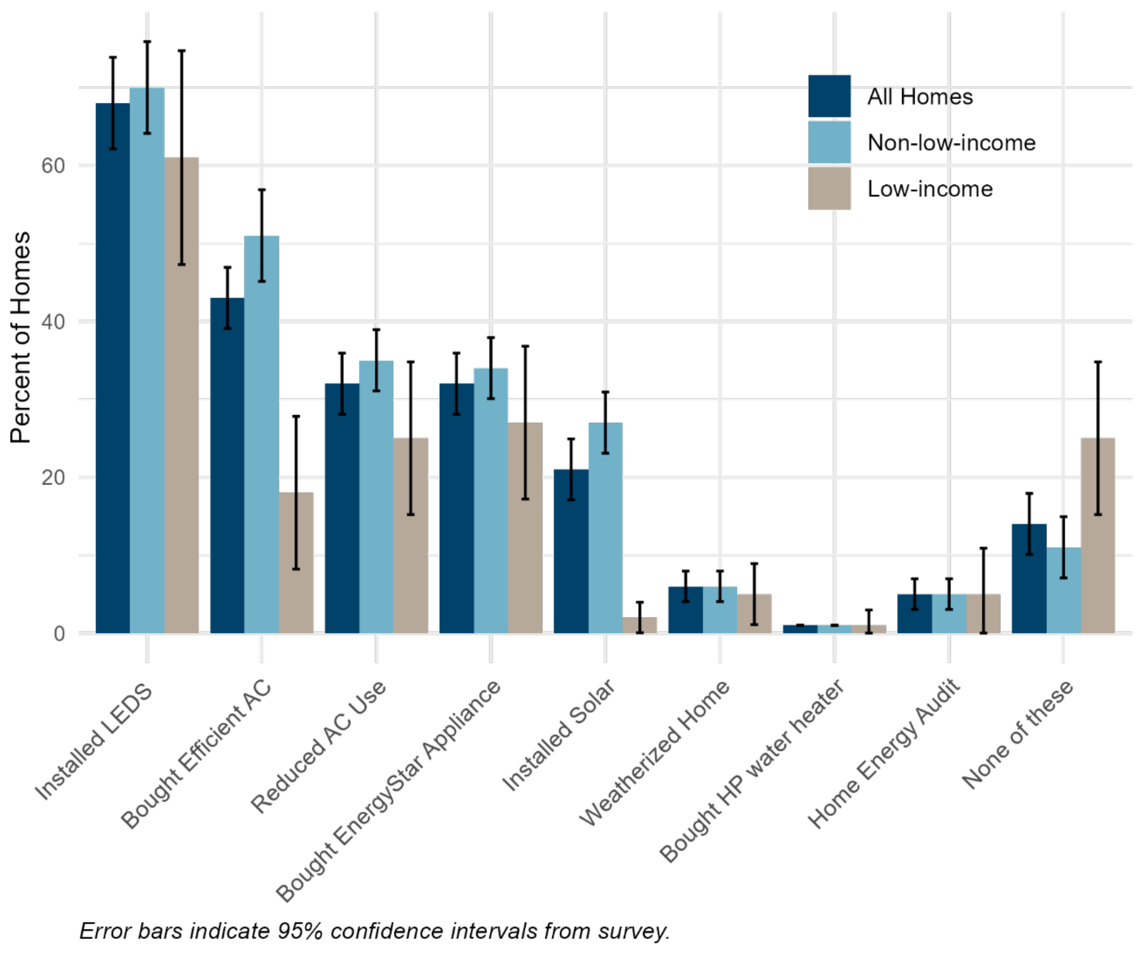

Figure 10. Prevalence of energy-saving actions in households by income-level based on responses to survey question "In the last five years, have you taken any of the following actions to reduce your household energy consumption? (Select all that apply)"

Although not an energy efficiency measure, we noted that a sizable fraction of homes reporting installing rooftop solar systems (21%). Adoption is much higher among non-low-income households

(27%) and compared to low-income households (2%) based on the survey. At least 75% of homes with solar also have a battery system based on survey results.

Energy efficiency actions were more common among non-low-income, single-family owners based on these survey results. Notably, low-income and multifamily respondents are least likely to report any energy efficiency actions – approximately 25% have not taken any action. Compared to low-income households, higher income, single-family were more likely to have bought an efficient AC or installed rooftop solar.

Due to potential unmeasured response bias, these adoption rate estimates for efficiency measures and rooftop solar are likely high.

3.2.2 Commercial Characterization

The following commercial characterization is based on three visited building types: office, retail, and healthcare outpatient. Healthcare inpatient characteristics were determined to be inconclusive due to a sample size of 1. Conclusions are based on both observations from site visits as well as general knowledge from Puerto Rico building science expertise on the team staff.

3.2.2.1 Key Findings

Below are some key findings from the commercial sector characterization analysis of site visit data:

- **Construction:** Exterior walls in commercial buildings are predominantly made up of concrete or concrete block, mostly without wall insulation. Roof construction is primarily flat roof and typically uninsulated. Windows are predominantly single pane. Many older buildings have been reported to have cracks and leaks resulting in insufficient cooling from the HVAC system.
- **Lighting:** Interior lighting fixtures in commercial buildings are predominantly LED. Automated lighting controls are uncommon except in healthcare. Exterior lighting fixtures have a lower penetration of LED fixtures compared to interior lighting. A mix of exterior lighting controls (manual switches, photocells, timeclocks) are used.
- **Cooling:** Many smaller sized office and retail buildings are primarily served by mini-split air conditioners which lack sophisticated controls and mechanical ventilation. Medium sized office, retail and healthcare outpatient tend to have a centralized HVAC system through packaged or split DX-cooled units. Large offices and outpatient facilities are more likely to utilize a chilled water plant and VAV air handling units. Cooling system efficiency tends to be at 2012 IECC minimum.
- **Domestic water Heating:** Majority of commercial buildings without heavy domestic water use do not have water heating. When domestic water heating does exist, it is typically electric resistance.
- **Appliances:** Half of office and retail buildings and majority of healthcare outpatient buildings purchase Energy Star certified refrigerators for break rooms. Dehumidifiers and dishwashers are less commonly found in commercial buildings.
- **Energy Efficiency Investments:** Most building occupants track energy use over time. Among establishments reporting making recent energy investments, most focus mostly on lighting

retrofits (lamp/fixture replacement only without advanced controls). Office and retail buildings tend to replace equipment upon end-of-life, whereas healthcare outpatient has a higher tendency of equipment upgrades before end-of-life for energy efficiency purposes. Lack of capital is a common barrier to energy investments and upgrades.

3.2.2.2 Envelope

Most commercial buildings in Puerto Rico are built with reinforced concrete, where the exterior walls are made of concrete or concrete blocks. In some cases, the interior partitions are also made of concrete blocks (Table 15). This is due to exposure to weather conditions that can affect the structural integrity of the building, such as strong winds from storms and hurricanes that are more common in Puerto Rico's climate.

Based on site visit data, most commercial buildings have flat roof construction; pitched roofs (with or without an attic) are uncommon (Table 16).

In terms of exterior wall and roof insulation, neither is common for retail buildings. Office buildings generally do not have insulation in the exterior walls, but may have a higher chance for insulation in the flat roof. Over half of the healthcare outpatient buildings that we visited did not have insulation in the exterior walls or the roof (Table 15). Based on the testimony of the people surveyed, in general concrete exterior walls are rarely insulated. Local staff have indicated that wall insulation would entail an additional cost that is very rarely contemplated based on the energy benefit that insulation can provide to the building.

Table 15. Primary wall construction characteristics by commercial building segment from site visit data collection.

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%

Table 16. Primary roof construction characteristics by commercial building segment from site visit data collection

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%

Regarding window construction, large office buildings have a higher tendency for double pane windows. Small office, retail and healthcare outpatient are more likely to have single pane windows (Figure 11).

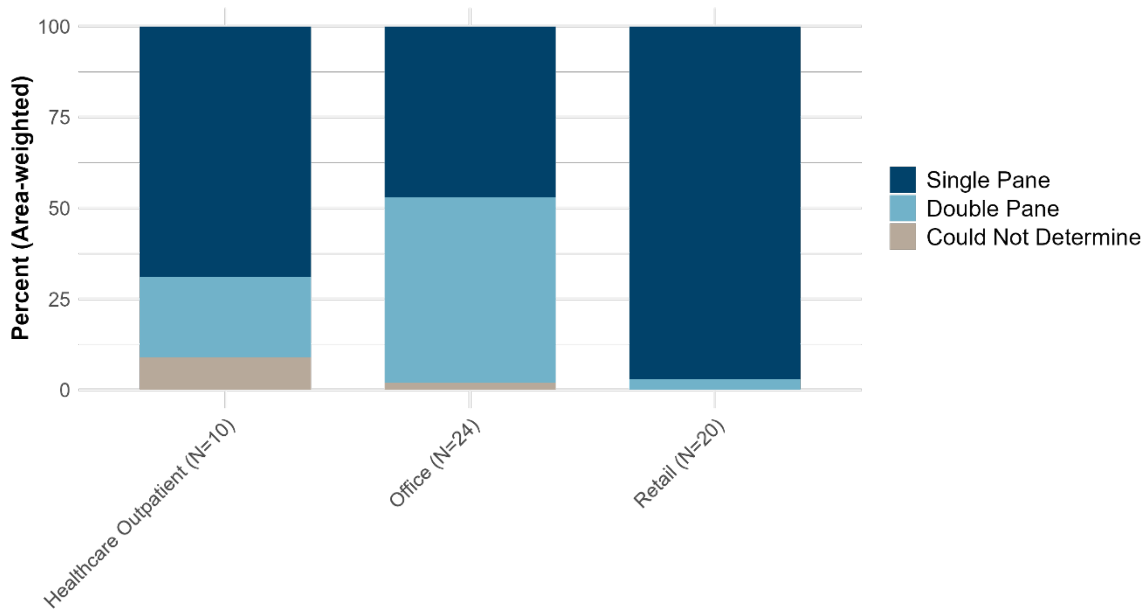

Figure 11. Window type by commercial building segment from site visit data collection

Envelope renovation for energy efficiency is not common in Puerto Rico as it is generally not considered to be cost-effective. However, it appears that many older commercial buildings may benefit from air sealing. Many older buildings have been reported to have cracks and leaks resulting in insufficient cooling from the HVAC system. A reduction in infiltration may significantly drive down cooling energy from leaky windows and doors. Investments in envelope insulation in walls and roof may not be cost-effective due to extended payback periods and diminishing returns.

3.2.2.3 Lighting

When a building is due for a retrofit, the interior lighting fixtures are typically the first building system that receives an upgrade. Based on site visit data, most of the interior lighting in office, retail and healthcare outpatient buildings have already been retrofitted to LED (Figure 12). However, there are still some opportunities that exist to retrofit the remaining fluorescent and incandescent lighting to LED.

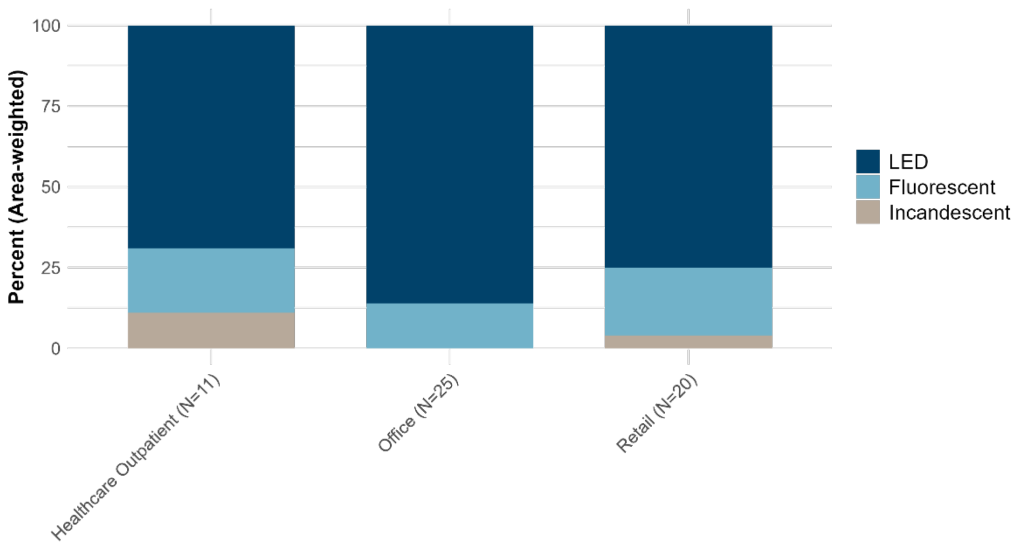

Figure 12. Interior lighting fixture type by commercial building segment from site visit data collection

Manual switches are the most prevalent interior lighting control strategy for office and retail buildings due to their simplicity and low cost. Advanced interior lighting controls such as occupancy sensors, daylight sensors, networked lighting controls, and task tuning do not appear to be common in these buildings. Healthcare outpatient appears to have a higher tendency to have occupancy controls, which are mostly present in patient rooms. In general, there appears to be many energy efficiency opportunities in interior lighting controls.

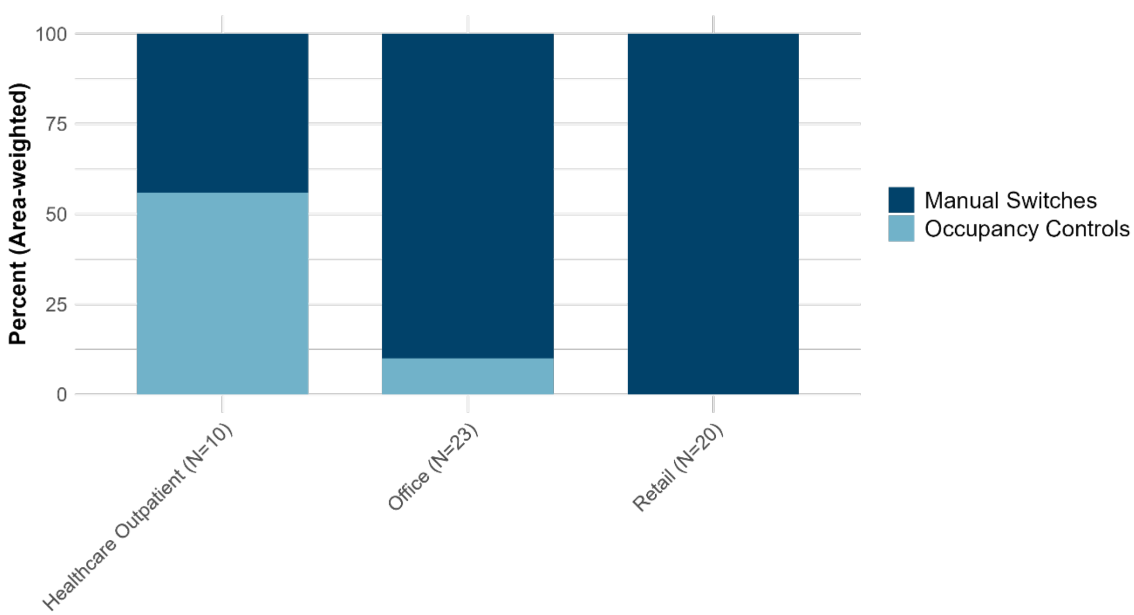

Figure 13. Interior lighting control type by commercial building segment from site visit data collection

A portion of the commercial buildings that were visited did not have exterior lighting. For the office and retail buildings that did, the exterior lighting fixtures are rarely LED (Figure 14). We observed that most office buildings have photocell only for exterior lighting controls. Small retail buildings often choose manual switches for exterior lighting (Figure 15).

Healthcare outpatient buildings tend to be more advanced when it comes to exterior lighting. From what was observed on site, most of the exterior lighting in healthcare outpatient buildings have already been retrofitted to (or originally designed as) LED (Figure 14). These exterior lighting fixtures also have a higher tendency to have photocell control coupled with timeclock or motion sensor control (Figure 15).

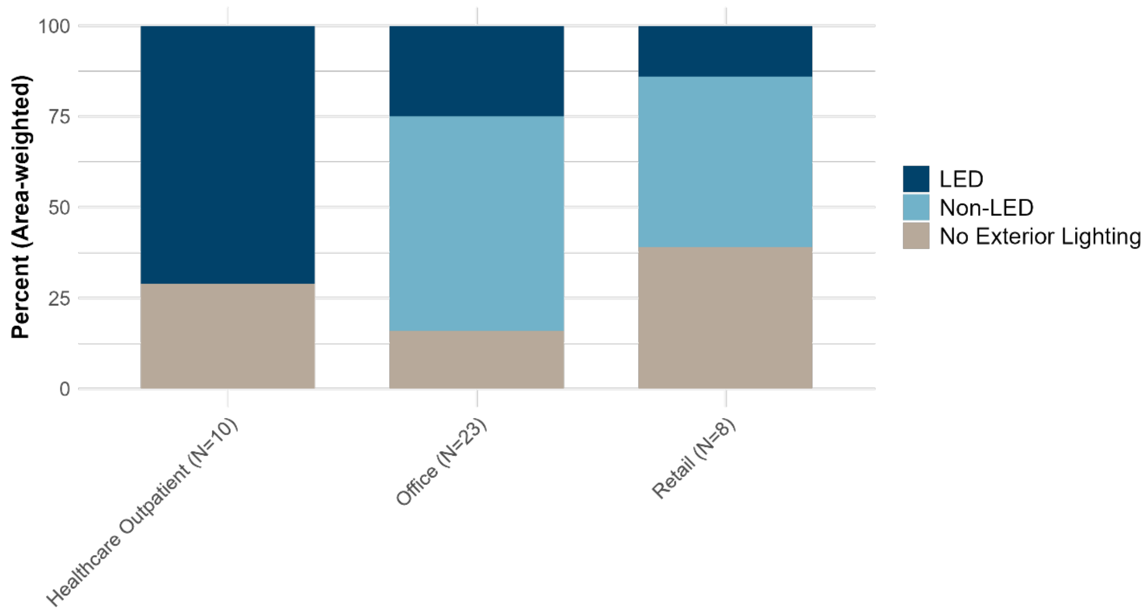

Figure 14. Exterior lighting fixture type by commercial building segment from site visit data collection

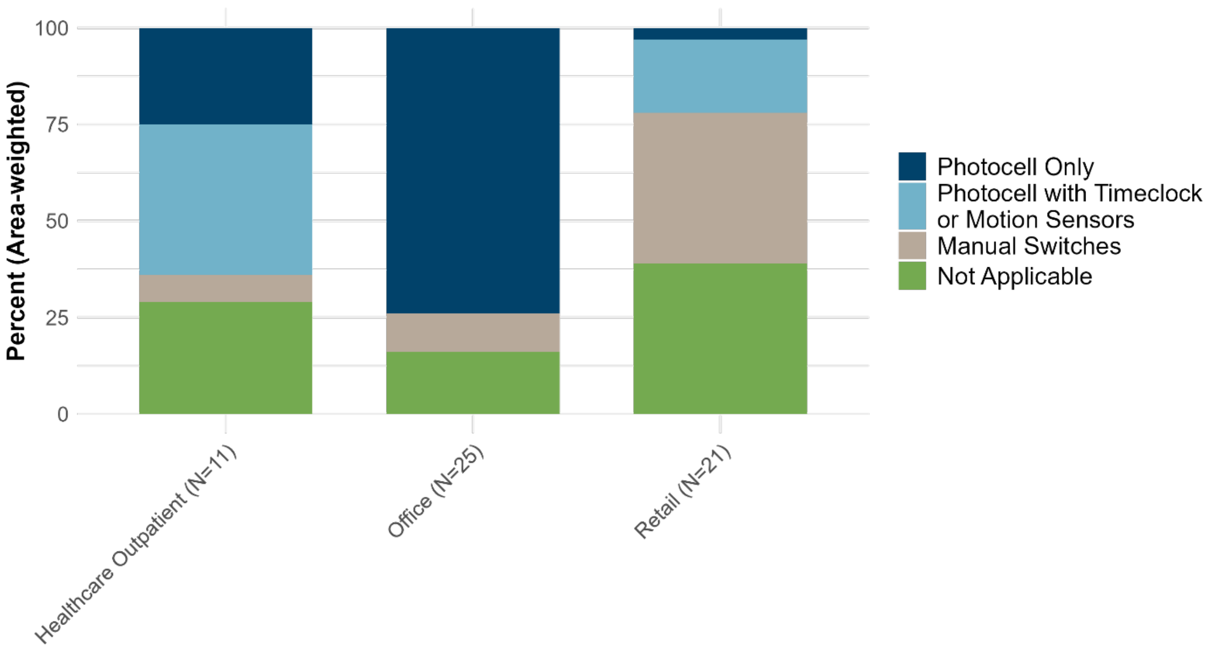

Figure 15. Exterior lighting control type by commercial building segment from site visit data collection

3.2.2.4 Cooling

Mini-split air conditioners 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 split or packaged systems. Large offices, large outpatient facilities and inpatient hospitals are more likely to be served by a chilled water system and variable air volume airside system (Figure 16).

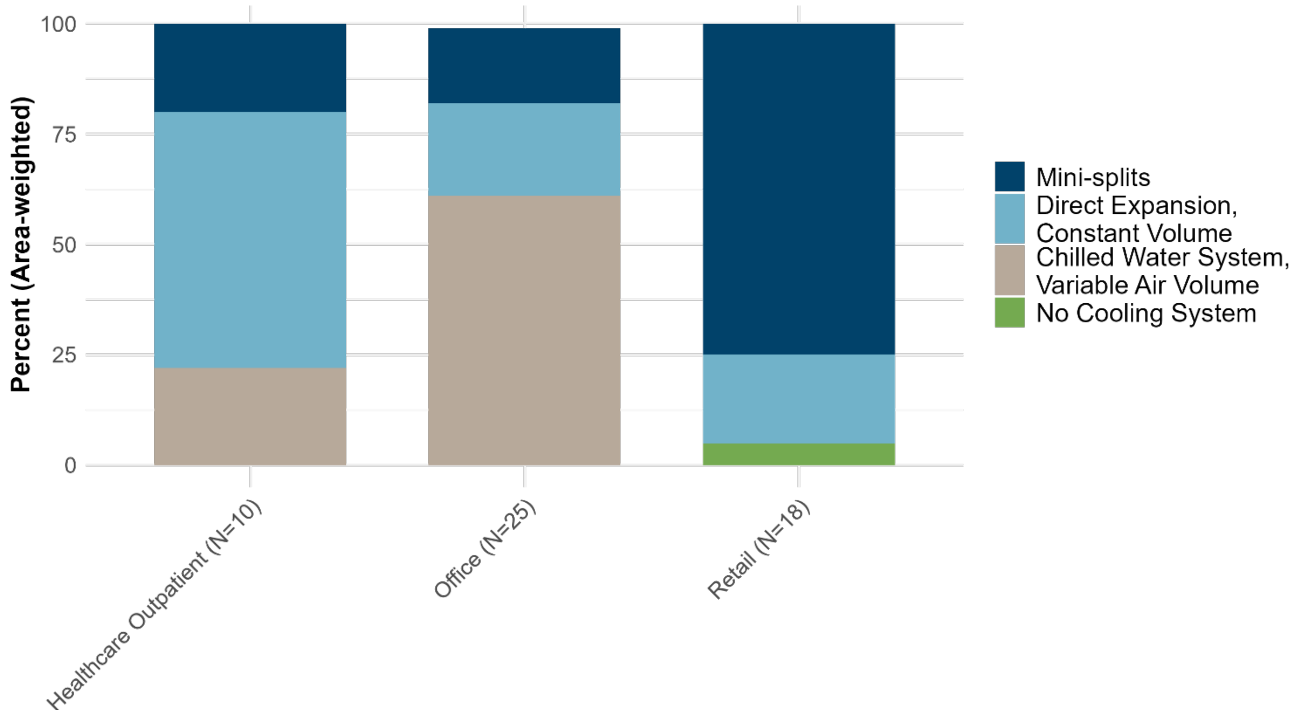

Figure 16. Primary cooling system type by commercial building segment.

Cooling system efficiency tends to be at the minimum levels of 2012 IECC energy code for mini-split air conditioners and DX-cooled split and packaged equipment (Table 17). Energy Star rated HVAC equipment is not common in Puerto Rico as many mini-split air conditioners are imported from overseas where the Energy Star rating does not apply.

Table 17. Primary cooling system weighted-average efficiency by system type and building segment

Sampled Segment	Primary Cooling System Efficiency		
	Mini-splits	Direct Expansion, Constant Volume Packaged or Split Units	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

Mechanical ventilation is typically not present for spaces that utilize mini-split air conditioners. Only spaces located in medium to large buildings with central air units have mechanical ventilation.

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 and setpoints tend to be held 24/7. This is partially due to poor wall and roof insulation and single pane windows in many commercial buildings. These buildings tend to have longer morning cool-down, which discourages occupants from implementing a thermostat setback. In addition, many buildings have air leakage issues where doors and windows are not properly sealed, which compounds the cooling issue. For that reason, many cooling thermostats are held at abnormally low temperatures, but the room never actually reaches that setpoint.

Characteristics of chilled water system and controls remain inconclusive due to a lack of access to the building automation system (BAS). Many spaces that utilize a building-wide central hydronic system are tenants of the building and do not have access to the BAS.

3.2.2.5 Water Heating

Most of the office, retail, healthcare outpatient buildings sampled do not have domestic water heating. It is assumed that most commercial buildings that have light water use (i.e., only for hand-washing) do not have domestic water heating.

When domestic water heating does exist, 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, field staff reported that large hotel and healthcare inpatient facilities often use propane as fuel source for domestic water heating. Food-service buildings are assumed to have electric resistance water heaters.

3.2.2.6 Appliance and Plug Loads

Regarding large appliances, most office, retail, and healthcare outpatient buildings only have residential-style refrigerators; dishwashers are not common. Half of office and retail owners and majority of healthcare outpatient owners that we surveyed purchase Energy Star equipment when available. A small portion of business owners are not aware of Energy Star certification on large appliances (Figure 17).

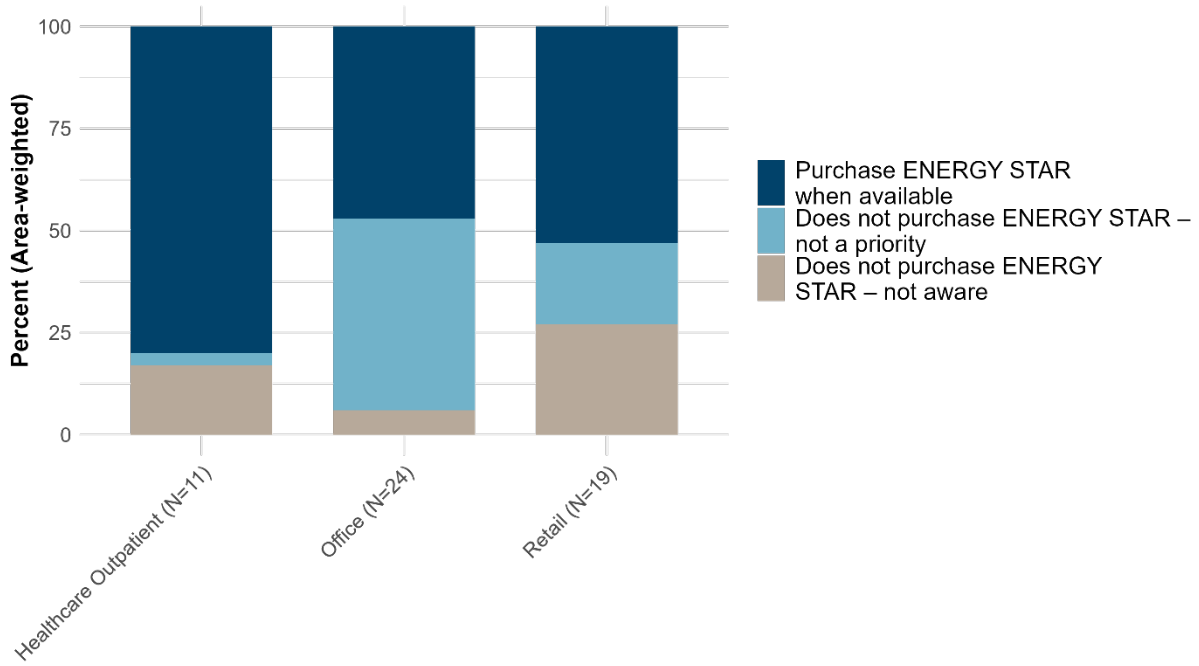

Figure 17. ENERGY STAR equipment purchase decisions by building segment

For miscellaneous plug load management, advanced power strips are not common in commercial buildings. With respect to server room power management, half of the surveyed buildings indicated that this is enabled. For buildings that have EV charging, the chargers generally do not have time-of-use control for load shifting benefits.

3.2.2.7 Attitudes and Behaviors

Interviews with the facility managers of surveyed buildings indicated that most office and healthcare outpatient buildings and all sampled retail buildings 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 (Figure 18).

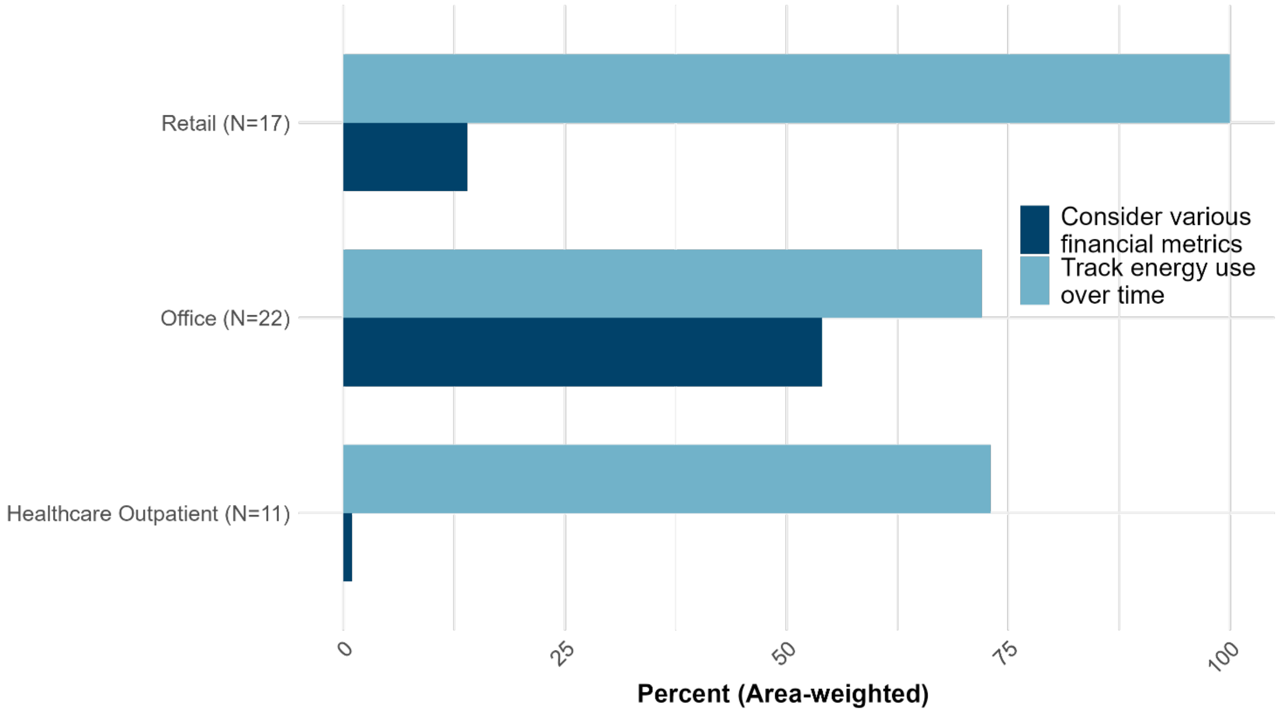

Figure 18. Establishments that consider financial metrics and track energy use over time by building segment.

As shown in Figure 19, among the establishments surveyed, the largest barriers to energy efficiency investments for each building type are:

- For both office and retail: Lack of capital, energy savings not high enough, other priorities supersede energy efficiency.
- A large portion of retail establishments reside in a leased building and would not receive the benefits of the investment.
- For healthcare outpatient: Lack of capital, energy retrofits deemed too complex.

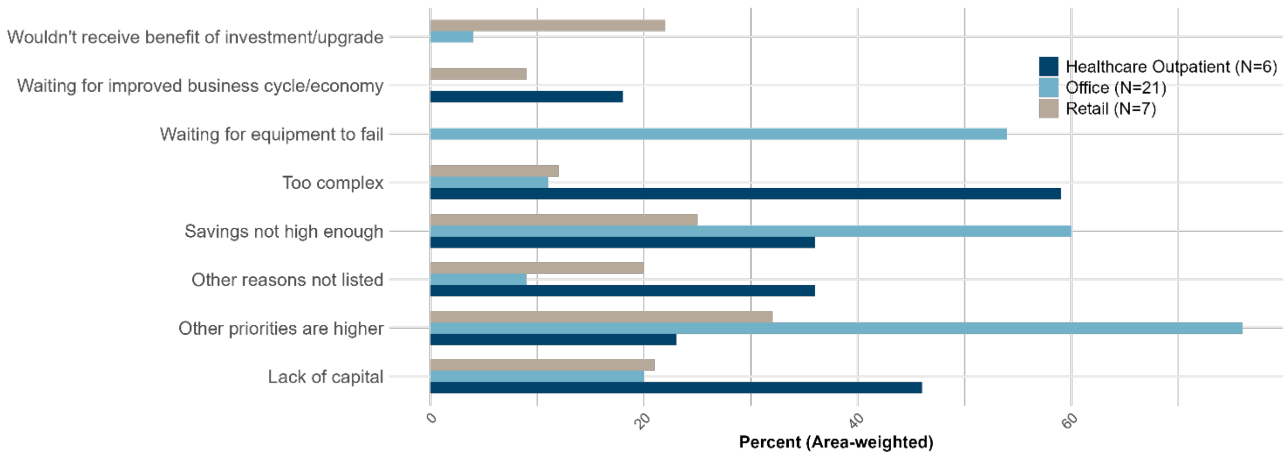

Figure 19. Barriers to energy efficiency investment by building segment.

Among establishments reporting making recent energy investments, most focus on lighting retrofits that are lamp or fixture replacement only, leaving many opportunities for lighting control and HVAC equipment upgrades on the table. Over half of retail and healthcare outpatient owners report that they do not invest in energy efficiency (Table 18). This indicates a significant opportunity for energy programs and other avenues to address this market gap as well as increase education and training for building owners, facility managers, and contractors.

Table 18. Energy investment trends by building segment.

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%

In general, office and retail buildings tend to replace equipment upon end-of-life, as opposed to for efficiency upgrade purposes. Healthcare outpatient has a higher tendency of upgrading equipment before end-of-life with energy efficiency in mind (Figure 20).

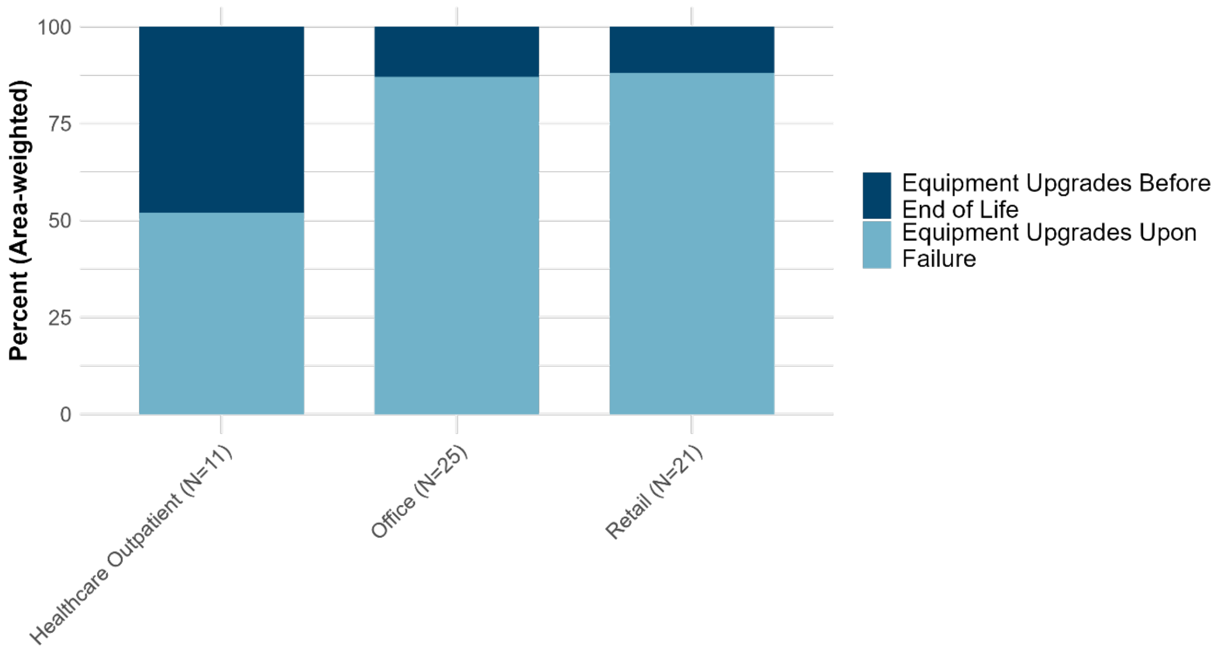

Figure 20. Equipment upgrades decision point by building segment.

3.2.2.8 Other Commercial Use Types

For commercial building types that were not sampled, secondary data sources such as DOE Commercial Reference Models, CBECS 2018 and ComStock data for Climate Zone 1A regions (Florida and Hawaii) were referenced to make engineering estimates on building and operation characteristics. Knowledge from local field staff was also valuable in determining common practices in construction and operation of non-sampled commercial building types.

Specific end-use characteristics that were not observed in the field such as commercial cooking, commercial refrigeration also relied on secondary data sources.

3.2.3 Load Disaggregation

This section presents load disaggregation modeling results across residential, commercial, and industrial sectors.

3.2.3.1 Residential

Overall cooling is the largest electricity end-use in the residential sector (36%) followed by appliances (25%) and plug loads (21%) as shown in Figure 21. Lighting (11%) and water heating (7%) make up smaller fractions of the sector's electrical consumption. Most energy is used in single-family homes, especially those that are not classified as low-income in this study.

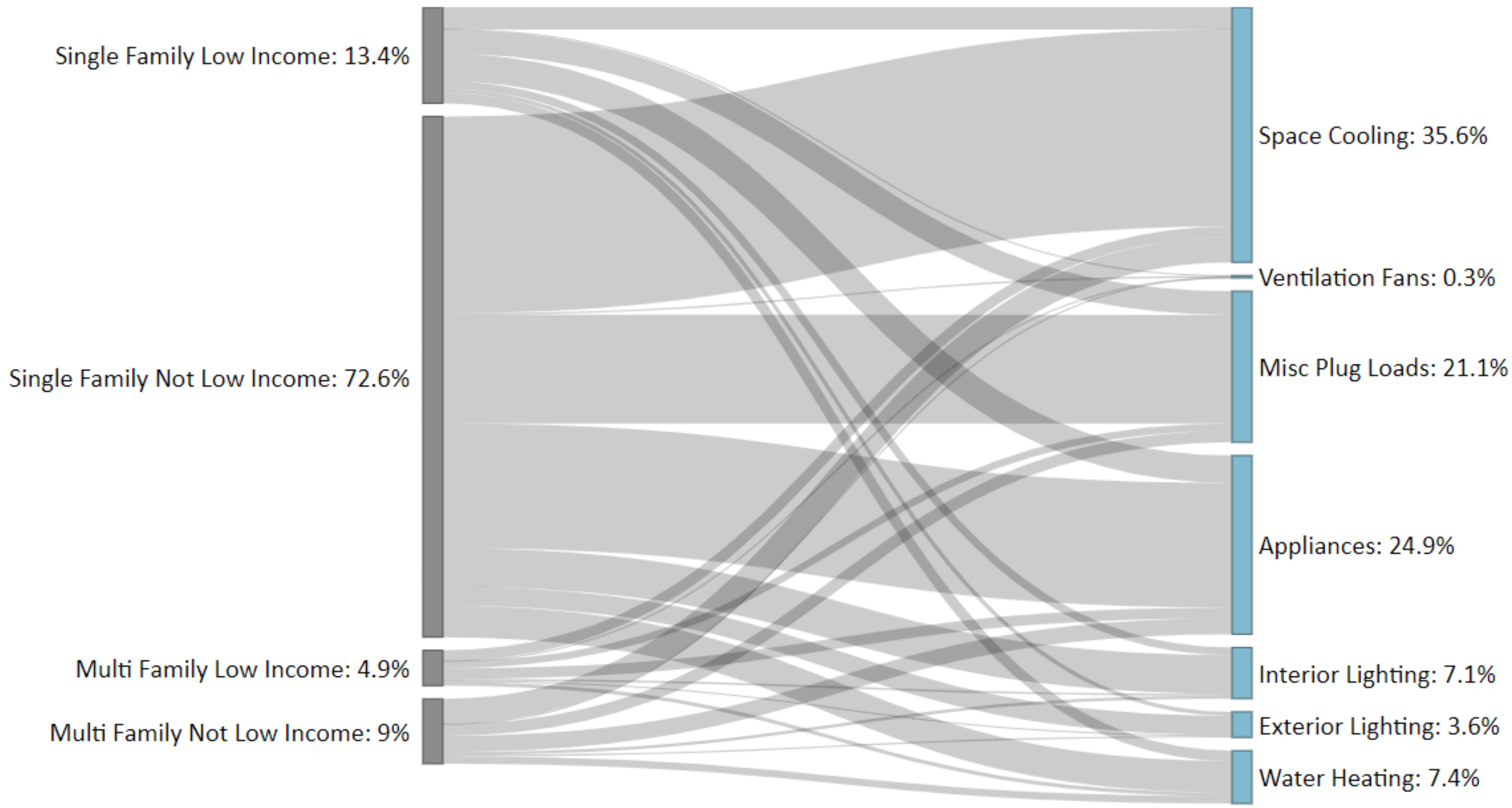

Figure 21. Residential sector building electricity consumption by segment and end-use

3.2.3.2 Commercial

Approximately 48% of the electricity consumption in the commercial sector goes to space cooling (Figure 22). The combination of interior and exterior lighting is the second largest end-use at nearly 17%. Other end-uses, including miscellaneous plug loads, commercial refrigeration, and ventilation fans (an HVAC component), each comprise approximately 8-10% of total sector end-use consumption. Water heating accounts for a notably small fraction of electricity consumption. Across use types, offices, retail establishments, and restaurants are the segments with the largest electricity consumption. Combined they account for more than half of the overall electricity consumption in the Puerto Rico commercial sector based on disaggregation modeling results.

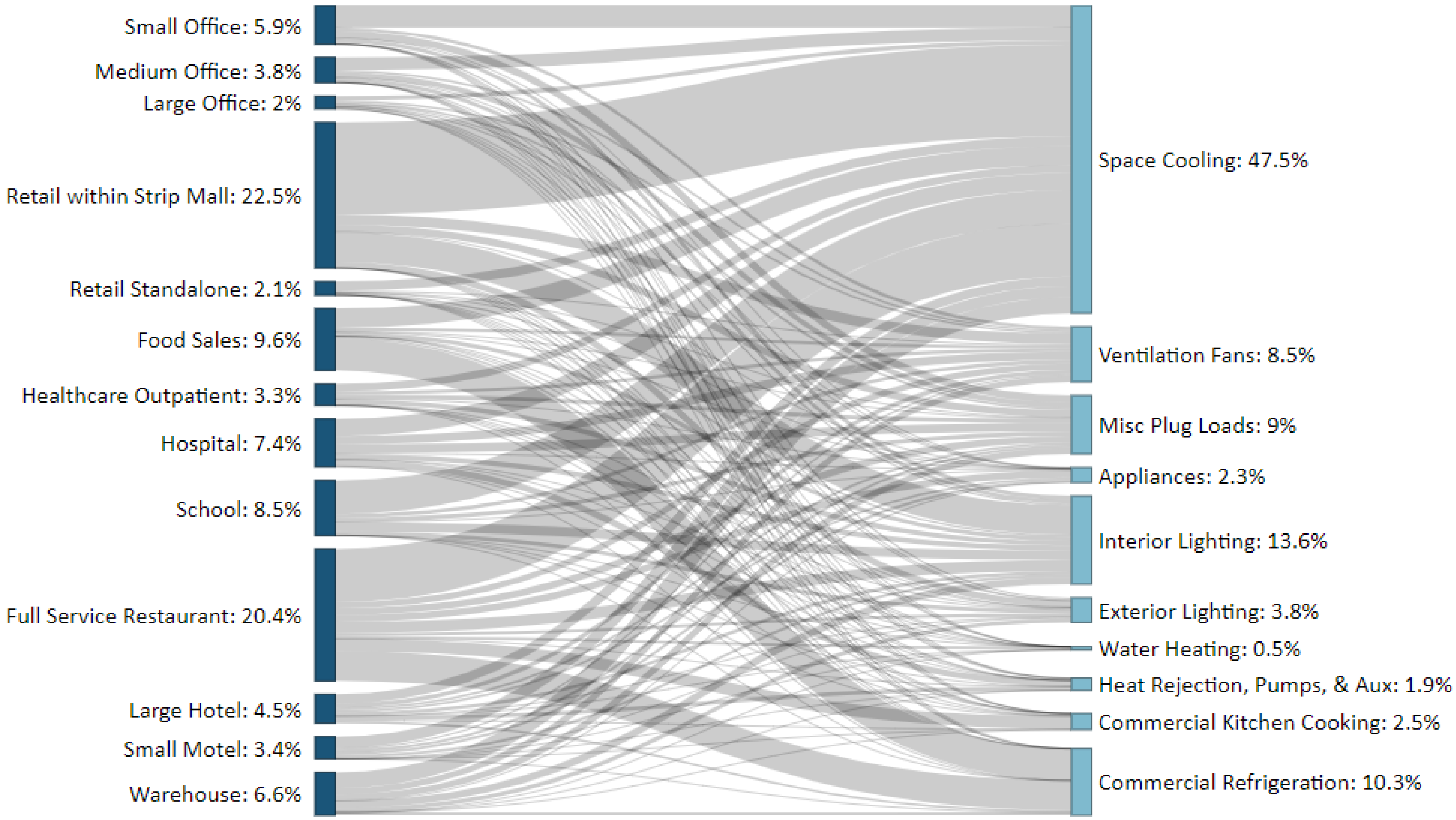

Figure 22: Commercial sector building electricity consumption by segment and end-use

3.2.4 Industrial Sector

Approximately 58% of the electricity consumption in the industrial sector is used in the chemicals industry primarily from pharmaceutical and medicine manufacturing (Table 19). A total of 17% of the electric energy is consumed in the miscellaneous subsector primarily in medical equipment and supplies manufacturing. It is estimated that 52% of all industrial electric energy is consumed by machine drives (motors), 12% by facility HVAC use, 10% by process cooling and refrigeration applications, and 7% by lighting. The remaining 19% is consumed by misc. process and non-processes end-uses (Figure 23).

Table 19. Industrial sector building electricity consumption by subsector and end-use

		Electric Energy Consumption (GWh)												
NAICS (3-Digit)	**Subsector**	Conventional Boiler Use	Process Heating	Process Cooling and Refrigeration	Machine Drive	Electro-Chemical Processes	Other Process Use	Facility HVAC	Facility Lighting	Other Facility Support	Onsite Transportation	Other Nonprocess Use	End Use Not Reported	TOTAL
325	Chemicals	13.0	41.2	99.7	617.7	132.2	23.8	71.5	41.2	15.2	2.2	4.3	21.7	**1,083.7**
339	Miscellaneous	-	23.3	23.3	128.1	-	-	93.1	46.6	11.6	-	-	-	**326.0**
312	Beverage and Tobacco Products	3.8	3.8	34.2	91.1	-	3.8	19.0	15.2	3.8	3.8	-	-	**178.4**
311	Food	2.4	3.2	24.5	38.4	0.6	0.9	9.7	8.3	1.8	0.9	0.3	1.5	**92.4**
335	Electrical Equip., Appliances, and Components	-	6.2	1.6	10.1	-	1.6	5.4	2.3	0.8	-	-	-	**28.0**
326	Plastics and Rubber Products	-	3.3	2.4	14.8	-	0.9	2.9	2.2	0.9	0.3	-	-	**27.7**
322	Paper	0.7	0.7	0.7	17.5	0.3	0.1	1.3	1.2	0.4	0.1	-	-	**23.0**
327	Nonmetallic Mineral Products	-	4.3	1.0	11.8	0.5	1.2	1.2	1.0	0.3	-	0.2	0.2	**21.6**
332	Fabricated Metal Products	0.2	3.2	0.8	8.1	-	0.3	2.7	2.1	0.5	0.2	-	-	**18.0**
331	Primary Metals	0.1	5.9	0.5	5.2	3.7	0.8	0.6	0.6	0.2	0.0	0.0	0.0	**17.8**
315	Apparel	-	-	-	7.1	-	-	7.1	-	-	-	-	-	**14.1**
334	Computer and Electronic Products	0.2	1.1	1.9	2.2	0.3	1.1	3.0	1.0	0.5	-	0.2	0.5	**11.9**
323	Printing and Related Support	-	0.3	0.5	5.0	-	0.3	1.6	0.8	0.3	-	-	-	**8.6**
333	Machinery	0.1	0.4	0.3	4.1	-	0.1	1.3	0.9	0.3	0.1	-	-	**7.6**
321	Wood Products	0.1	0.2	0.1	3.3	-	-	0.3	0.3	0.1	-	-	0.1	**4.4**
337	Furniture and Related Products	-	0.1	-	1.0	-	-	0.4	0.2	0.1	-	-	-	**1.8**
324	Petroleum and Coal Products	0.0	-	0.1	1.2	0.0	0.0	0.0	0.0	0.0	-	-	-	**1.3**
314	Textile Product Mills	-	0.1	-	0.7	-	-	0.1	0.1	-	-	-	-	**1.1**
336	Transportation Equipment	0.0	0.1	0.0	0.3	0.0	0.0	0.1	0.1	0.0	0.0	0.0	-	**0.6**
316	Leather and Allied Products	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	TOTAL	**20.4**	**97.3**	**191.5**	**967.6**	**137.6**	**34.9**	**221.5**	**124.1**	**36.7**	**7.6**	**5.0**	**23.9**	**1,868.0**

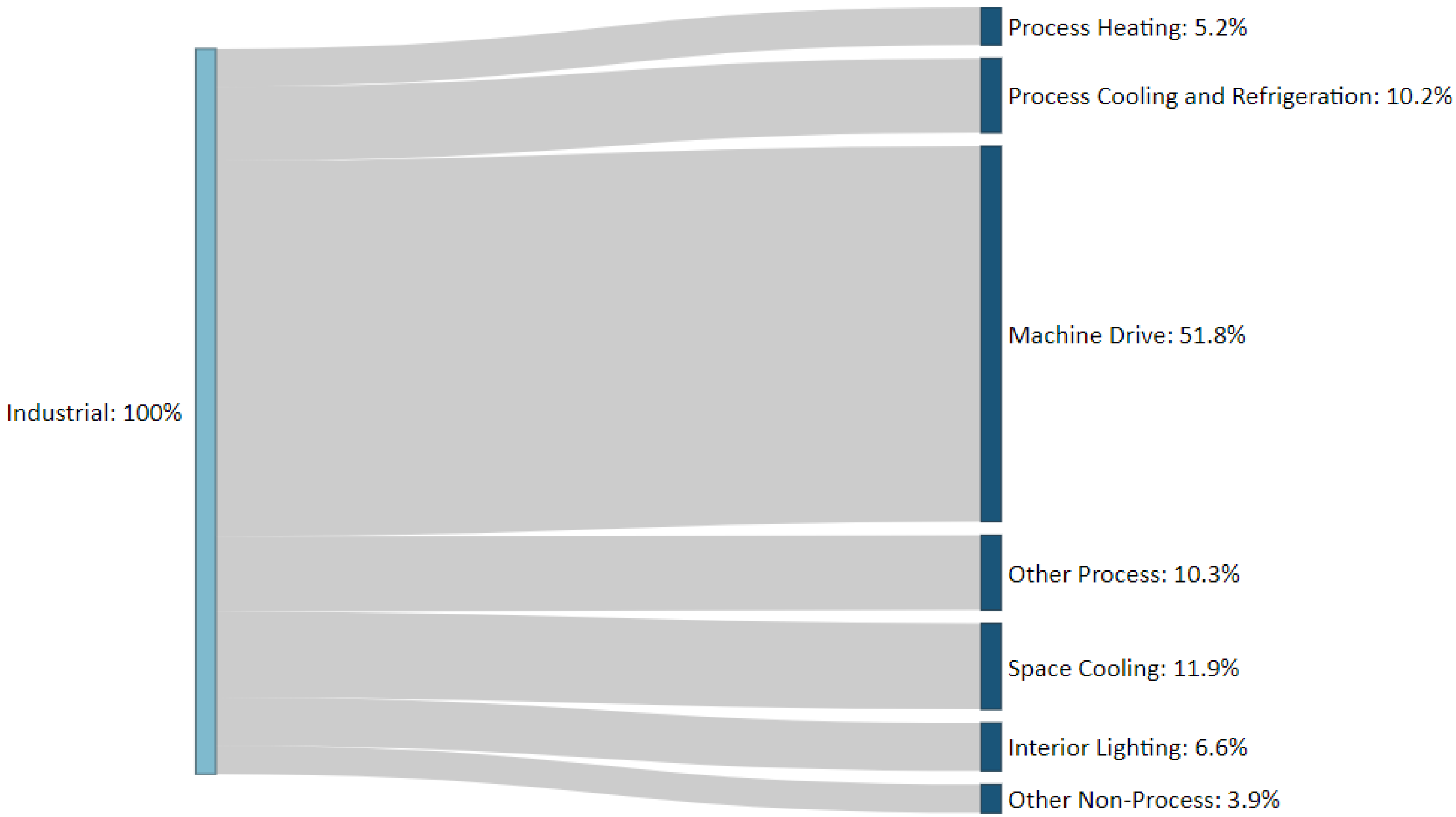

Figure 23. Industrial sector building electricity consumption by segment and end-use

3.2.4.1 Residential, Commercial, and Industrial Combined

Across all sectors, commercial represents 47% of sales, residential 43% and industrial 10%. The largest customer segment analyzed was non-low-income single family which comprised 32% of energy use, while other smaller but significant segments included retail (12%), restaurants (9%), low-income single-family (6%), office (6%), and healthcare (5%). In aggregate space cooling was the largest end-use comprising approximately 39% of electricity sales. Other significant end-uses include plug loads (14%), lighting (13%), and appliances (12%) (Figure 24).

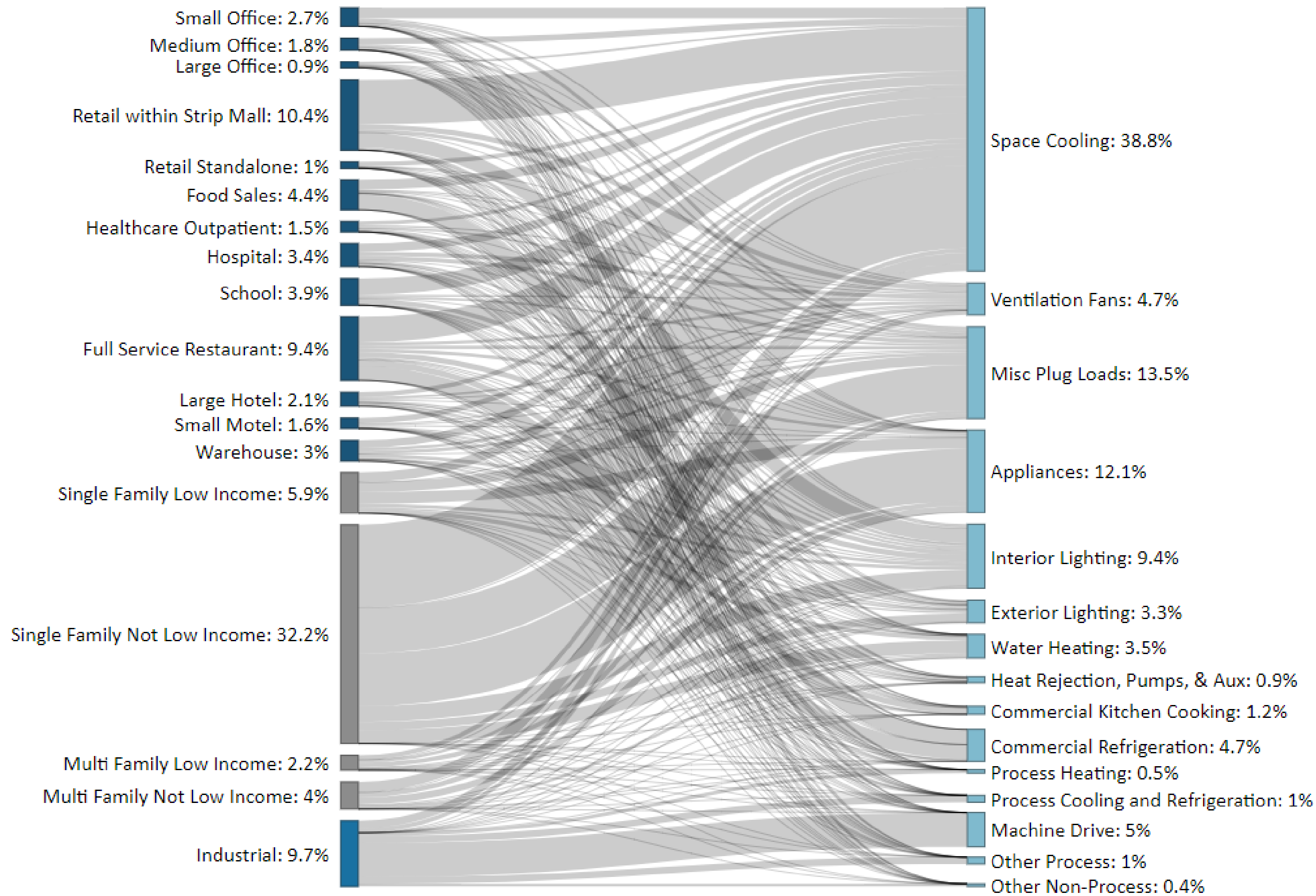

Figure 24. Commercial, residential, and industrial sector building electricity consumption by segment and end-use

3.2.5 Market Actor Interviews

In this section we summarize key observations from market actor interviews related to trends in construction practices, markets for efficient equipment, and opportunities for increased adoption of efficient products and practices.

3.2.5.1 Residential Construction Practices

Information about residential construction market shared here is based on an interview with a builder who primarily re-builds homes through the US Department of Housing (HUD) Home Repair, Reconstruction, or Relocation (R3) Program, which was established to assist homeowners whose homes were damaged by Hurricanes Irma and Maria. Given this context, observations on typical construction practices within this program may not apply more broadly across new construction markets.

Key observations:

- **Reinforced concrete construction with cross-ventilation**: All new homes are constructed with reinforced concrete, including exterior walls and even the walls dividing closets. This ensures the structures are robust and comply with safety standards for hurricanes and earthquakes. Construction practices that promote cross-ventilation and withstand high winds such as louvered windows are common.
- **Mini-splits, reflective roofing, and natural ventilation for cooling**: New homes typically use a mixture of mini-splits and/or natural ventilation for cooling. Window AC units are not recommended because installation can cause structural issues and are less efficient. Wi-Fi enabled thermostats are not popular. Reflective roofing materials are commonly used.
- **Solar PV and hot water common**: Through the R3 program, solar PV and hot water systems are often included. PV systems are typically sized to meet demand for emergency equipment like refrigeration and lights. Solar hot water is sized to meet household demand.
- **Electric ranges viewed as safer**: Although there is a mix of electric and propane ranges in new homes, some residents, especially those who are elderly, prefer electric ranges and view them as safer than propane.

3.2.5.2 Cooling Systems

Information about the market for residential and commercial cooling equipment was gathered from an interview with a small HVAC contractor serving primarily the San Juan Metro Area and a large HVAC distributor serving the entire island.

Key observations:

- **Ductless mini-splits popular in residential sector**: Aligning with patterns seen in primary data collections, interviewees reporting broad popularity of mini-splits which make up the majority of sales. Window AC units are common especially in metro areas and low-income housing. Central systems are typically only seen in upscale markets.

- **Energy Star ratings not widely accepted in residential sector:** Although interviewees estimated 20-30% of residential air conditioners were Energy Star rated or between 16-20 SEER, they also reported that the Energy Star rating may not be widely applied or accepted in the Puerto Rico market. For example, products without the label can have comparable efficiency ratings.
- **Ductless mini-splits and rooftop units (RTUs) most common in commercial sector**: Mini-splits and RTUs are common across a wide range of small-to-medium sized commercial establishments including offices, restaurants, and retail chains. Window or wall AC units are common in hotels. More complex cooling systems with central ventilation like central chillers are less common and found in large offices.
- **Opportunities for energy management systems (EMS):** Overall building control systems are not common, but market actors see a growing trend towards integrating advanced technologies such as WiFi connectivity and EMS, particularly in larger commercial systems.
- **Growing awareness of energy efficiency but cost a barrie**r: For both the residential and commercial markets, interviewees noted a growing awareness and interest in purchasing more efficient cooling equipment but reported significant cost hurdles. Financial incentives or rebate programs could help with this.

3.2.5.3 Water Heating Equipment

Information about market trends for water heating was gleaned from an interview with a medium-sized company installing primary tankless water heaters in the residential and commercial sectors across Puerto Rico.

Key observations:

- **Market shift toward tankless and solar:** The interviewee reported a noticeable shift from traditional tank heaters to more efficient instant and solar heaters, driven by cost savings, space considerations, and environmental benefits. Government incentives are driving increased adoption of solar hot water systems.
- **Mixture of electric and gas based on sector and priorities**: Electric hot water is most common in the residential sector, but there has been growing interest in propane as a more reliable fuel source during power outages. However, some residential customers have safety concerns with propane systems. In the commercial sector, gas heaters are used in larger commercial settings, especially in areas with access to natural gas or propane. They are favored for their efficiency and ability to handle higher hot water demands.
- **Installation practices affect efficiency and safety**: Training and education is needed to ensure that tankless systems are installed safely and effectively. For example, pipe runs should be short to reduce heat losses, systems should be properly configured and calibrated, and propane systems need to be properly vented.
- **Opportunities for education and incentives**: Financial incentives, educational campaigns, and training for both customers and installers can help overcome the barriers of higher upfront costs and lack of awareness, increasing the adoption of efficient water heaters.

4.0 ASSESSMENT OF CONTRIBUTING ENTITIES

In addition to utility-run or facilitated programs, the *Regulation for Energy Efficiency* allows energy efficiency impacts from certain other policies, strategies, and programs, collectively referred to as "contributing entities," to contribute to the electric energy reduction target of 30% by 2040 as established by Act 17-2019. These contributing entities may include, but are not limited to, the following:

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;
5. Other sources as the Energy Bureau may identify and include in its assessment of progress.

This section details the methods used to estimate historical and future savings from contributing entities toward energy efficiency target achievement and the associated results.

4.1 METHODS

In general, the analysis assumes that any savings from contributing entities occurring in FY2020 and beyond may contribute to the statutory energy reduction target. For historical (FY2020−FY2024) savings from contributing entities, it is important to note that direct, evaluated estimates of saving were not available for any of the eligible entities. Nevertheless, we relied as much as possible on known factors to inform the savings estimates. For example, the assessment of impacts from building energy codes considered the actual codes in effect during this period and new construction activity as estimated from actual LUMA account data; savings attributable to the Weatherization Assistance Program (WAP) relied on actual historical budget allocations and recent savings performance. To develop longer-term estimates (FY2025−FY2040), we have generally assumed periodic updates to building energy codes and status quo funding for WAP. For both periods, we have estimated savings from federal appliance standards with compliance dates on or after July 1, 2019. The specific assumptions used to develop savings estimates for each contributing entity are summarized in the following sections.

4.1.1 Governmental Mandates for Improved Efficiency in Public Buildings

Act 57-2014, the "Puerto Rico Energy Transformation and RELIEF Act," established energy efficiency targets for public buildings. The specific requirements of the Act varied among Executive, Judicial, and Legislative Branch facilities. For the Executive and Judicial Branches, the Act aimed to reduce energy consumption by 40% over eight years (i.e., by FY2022) relative to FY2013 sales. While some of these energy savings would have theoretically been achieved in FY2020−FY2022 and therefore been eligible to contribute to the FY2040 statutory energy reduction target, Act 17-2019 subsequently amended these requirements by eliminating the specific targets and more generally requiring alignment with “per-sector compliance goals established by the Energy Bureau for the purpose of achieving the [30% reduction by FY2040] goal…” To date, specific savings targets for Executive and Judicial Branch facilities have not been established.

For Legislative Branch facilities, Act 57-2014 required annual energy reductions over a seven-year period culminating in a 12% reduction by FY2021 relative to FY2013 sales. Like the requirements for Executive and Judicial Branch facilities, Act 17-2019 subsequently amended these requirements by stating that reductions in FY2022 and beyond “…shall… reduce electric power consumption in accordance with the annual consumption goals established by the Energy Bureau for the Legislative Assembly in order to achieve the [30% reduction by FY2040] goal…” To date, further savings targets for Legislative Assembly facilities have not been established.

Act 57-2014 additionally required affected entities to submit periodic reports to the Energy Bureau documenting progress toward these reduction requirements; however, efforts by the authors to locate and obtain these reports were not successful. Because we were unable to independently verify any energy efficiency activities associated with these mandates, we have not explicitly quantified any contributions from such mandates. Further, we assume that government facilities would not be precluded from participating in any utility-administered efficiency programs. In many jurisdictions, public buildings subject to efficiency mandates participate in utility-run efficiency programs as a vehicle to achieve those mandates. Therefore, explicitly including the impacts of such mandates as contributing entities may otherwise introduce the risk of double-counting these impacts.

4.1.2 Building Energy Codes

The *Regulation for Energy Efficiency* allows that any “[s]avings resulting from the adoption of new building energy codes implemented after 2019…” may contribute to the savings target. In consultation with PREB, this has been interpreted to mean that any savings from the adoption of International Energy Conservation Code (IECC) 2018 accruing as of July 1, 2020 (i.e., subsequent to the end of the baseline year—FY2019), should be included in the assessment of contributing entities.

To estimate the eligible savings from energy codes, we developed four primary inputs: (1) the assumed future code adoption schedule, (2) the average reduction in energy consumption resulting from each successive IECC code cycle, (3) projections of assumed energy code compliance, and (4) forecasted new construction activity. In this section we detail how each of these factors was developed and used to estimate contributions from energy code savings for each year in the analysis period.

The Puerto Rico Permit Process Reform Act (Act 161-2009), as amended by Act 109-2018, established a structured process for revising and promulgating building energy codes every three years. While Puerto Rico promptly adopted the IECC 2018 for both the residential and C&I sectors in

November 2018 with funding from the Hazard Mitigation Program, adoption of IECC 2021 has not progressed swiftly.[13] The status and timeline for adoption of IECC 2021 is currently uncertain. Given that IECC 2024 was published on August 14, 2024, we assume that full adoption and enforcement of IECC 2024 will occur by July 1, 2025. In other words, we assume that adoption of IECC 2021 will be skipped entirely. Beyond 2025, we assume that Puerto Rico's building energy codes will be updated every three years, in alignment with the requirements of Act 161-2009. Further, we assume the most recent IECC version presumed to be available at that time will be adopted. For example, IECC 2027 will be assumed to take effect July 1, 2028, IECC 2030 on July 1, 2031, and so on.

Pacific Northwest National Laboratory's (PNNL) periodic assessments of energy savings from the four most recent versions of the IECC (i.e., 2015, 2018, 2021, and 2024) were leveraged to develop estimates of the reduction in modeled site energy use intensity (EUI) relative to the previous model code version on a percentage basis. These values were then averaged to develop a single factor to reflect the estimated improvement for future code updates. To reflect Puerto Rico's climate and climate zone-dependent requirements of the IECC, analysis results for Climate Zone 1A were used to derive all estimates. Separate estimates were developed for residential and non-residential buildings. The compiled data from the PNNL reports are summarized in Table 20 below.[14] As shown, over the past four cycles, the average reduction in modeled site EUI relative to the previous code version is 4.9% for residential and 10.5% for non-residential.

[13] FEMA. FEMA Grant to Support Code Enforcement in Puerto Rico. September 13, 2018. Accessed Nov. 1, 2024. https://www.fema.gov/press-release/20230425/fema-grant-support-code-enforcement-puerto-rico.
[14] Note that due to modeling methodology updates introduced by PNNL between analyses, the estimated site EUI values for a given code version are not consistent between the analyses (e.g., the residential "new code" EUI for IECC 2015 does not exactly match the "previous code" EUI for IECC 2018. Therefore, the relative improvements on a percentage basis are used in the subsequent analysis.

Table 20. Energy Code Savings Summary

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%**			

Sources:

1 Mendon, VV et al. 2015 IECC: Energy Savings Analysis. PNNL. May 2015. https://www.energycodes.gov/sites/default/files/2021-07/2015_IECC_FinalDeterminationAnalysis.pdf
2 Taylor, Todd et al. Energy Savings Analysis 2018 IECC for Residential Buildings. PNNL. November 2019. https://www.energycodes.gov/sites/default/files/2021-07/EERE-2018-BT-DET-0014-0008.pdf
3 Salcido, V. Robert et al. Energy Savings Analysis: 2021 IECC for Residential Buildings. PNNL. July 2021. https://www.energycodes.gov/sites/default/files/2021-07/2021_IECC_Final_Determination_AnalysisTSD.pdf
4 Salcido, V. Robert et al. Energy Savings Analysis: 2024 IECC for Residential Buildings. PNNL. December 2024. https://www.energycodes.gov/sites/default/files/2024-12/2024_IECC_Determination_TSD.pdf
5 Zhang, J. et al. Energy and Energy Cost Savings Analysis of the 2015 IECC for Commercial Buildings. PNNL. August 2015. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24269Rev1.pdf
6 Zhang, J. et al. Energy and Energy Cost Savings Analysis of the 2018 IECC for Commercial Buildings. PNNL. December 2018. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-28125.pdf
7 Maddox, D. et al. Energy and Energy Cost Savings Analysis of the 2021 IECC for Commercial Buildings. PNNL. September 2022. https://www.energycodes.gov/sites/default/files/2022-09/2021_IECC_Commercial_Analysis_Final_2022_09_02.pdf

8 Maddox, D. et al. 2024 IECC Interim Energy Savings Analysis and Progress Indicator for Commercial Buildings. PNNL. https://www.iccsafe.org/wp-content/uploads/2024-IECC_Commercial_Interim-Progress-Indicator-Results-11072022.pdf

Because building energy codes only yield energy savings with effective enforcement, we next developed estimates of current and future code compliance. Unfortunately, no robust source of recent energy code compliance data exists for Puerto Rico, and the baseline study scope did not explicitly include an investigation of code compliance. Based on reporting from the Wall Street Journal in 2017, general construction code compliance could be as low as 45%.[15] However, Puerto Rico received funding from FEMA's Hazard Mitigation Grant Program in 2018 with a goal of increasing the number of code compliance officials from 11 to 274.[16] A recent PNNL study on building energy code modeling assumes 80% compliance (i.e., savings realization rate) for the residential buildings in the first year after a new code is adopted, approaching 100% asymptotically over 10 years, as supported by target compliance studies.[17] For commercial buildings, 50% compliance is assumed in the first year after a new code is adopted approaching 80% asymptotically over 10 years.[18] In other words, it is assumed that code compliance increases over time, but falls each time a new code version is adopted. Given Puerto Rico's recent actions to increase code compliance, in the absence of better data, we have adopted the PNNL assumptions of code compliance over time. Figure 25 below summarizes the assumed code adoption schedule and assumed compliance by year.

[15] Nonko, E. "Weak Building Code Enforcement Exacerbates Destruction in Puerto Rico." Wall Street Journal. December 5, 2017. Accessed Nov. 1, 2024. https://www.wsj.com/articles/weak-building-code-enforcement-exacerbates-destruction-in-puerto-rico-1512475200.
[16] FEMA. FEMA Grant to Support Code Enforcement in Puerto Rico. September 13, 2018. Accessed Nov. 1, 2024. https://www.fema.gov/press-release/20230425/fema-grant-support-code-enforcement-puerto-rico.
[17] Tyler, M. et al. Impacts of Model Building Energy Codes. PNNL. November 2023. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-33251.pdf.
[18] Ibid.

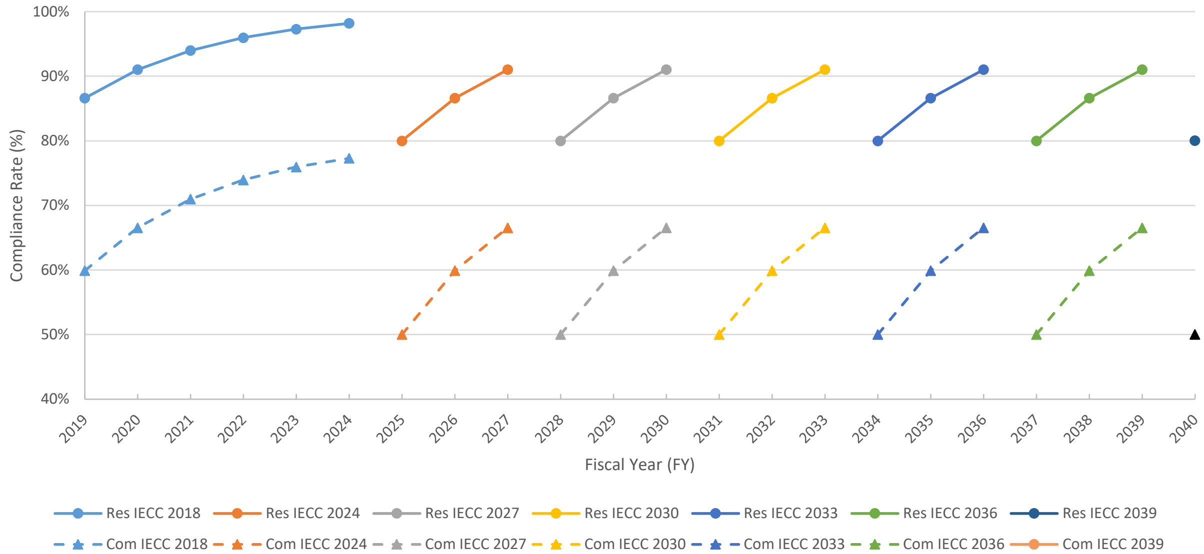

Figure 25. Building Energy Code Adoption Schedule and Assumed Compliance

Because IECC 2018, adopted in November 2018, had already been active for nearly a year at the beginning of FY2019, the assumed compliance rate for the residential code in FY2019 is slightly higher than the initial assumption of 80% compliance at 87% compliance. Similarly, the assumed compliance rate for the commercial code in FY2019 is 60%.

Next, we used data on the number of residential and commercial accounts and associated energy consumption from FY2019—2024, provided by LUMA in response to the data request, to develop sector-specific new construction compound annual growth rates of 0.543% and 0.266%, respectively.[19] These values were used to estimate the number of residential and commercial new construction accounts for each year in the analysis period.[20] The same dataset described above was also used to estimate the average annual electric energy consumption per residential and commercial account at 4,847 kWh and 60,405 kWh, respectively.

Finally, the incremental annual savings from increased building energy codes were calculated using the following equation:

$$kWh\ Savings_{FYn} = Accts_{FYn-1} \times NC\_Growth \times kWh\_per\_Acct \times (1 + PctSavings)^{CodeCycle - 1} \times CompRate_{FYn}$$

[19] Using the same methodology, the resulting industrial sector growth rate was -0.482%. Savings contributions from the industrial sector due to increased building energy codes have therefore been omitted from this analysis.

[20] This method of estimating new construction accounts does not take into consideration demolitions. Doing so would result in higher estimates of new construction activity, and this assumption therefore yields a conservatively low estimate of savings from new construction.

Where:

kWh Savings$_{FYn}$ = Incremental annual electric energy savings due to increased building energy codes in FYn (kWh).
Accts$_{FYn-1}$ = Number of accounts in FYn – 1.
NC_Growth = New construction compound annual growth rate.
kWh_per_Acct = Average annual electric energy consumption per account, FY2019−2024 (kWh).
PctSavings = Average percent site EUI reduction relative to previous code.
CodeCycle = Number of code cycles elapsed where IECC 2018 equals 1, IECC 2024 equals 3, IECC 2027 equals 4, IECC 2030 equals 5, and so on.[21]
CompRate$_{FYn}$ = Code compliance rate in FYn.

4.1.3 Federal or Commonwealth Appliance Standards

Like the treatment of building energy codes, the *Regulation for Energy Efficiency* allows that any "[s]avings resulting from incremental federal or Commonwealth appliance energy efficiency standards and laws implemented after 2019…" may contribute to the savings target. In consultation with PREB, this has been interpreted to mean that any federal or Commonwealth appliance standards with *compliance dates* after June 30, 2019 (i.e., subsequent to the end of the baseline year—FY2019), may be considered as contributing entities towards statutory targets. We further limited the assessment of federal standards to equipment categories with a published "Final Rule," as proposed federal standards can change significantly throughout the rulemaking process. Puerto Rico currently does not have any Commonwealth-specific equipment standards exceeding the federal requirements. Table 21 below summarizes a list of products covered by federal standards with compliance dates after June 30, 2019.

[21] Note that the number of elapsed code cycles jumps from 1 to 3 because the analysis assumes that adoption of IECC 2021 will be skipped entirely. Therefore, the code assumed to be adopted in FY2025 (i.e., IECC 2024) will yield approximately double the savings of the average code improvement cycle.

Table 21. Products Covered by Federal Standards with Compliance Dates

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	
Com	Walk-in Coolers and Freezers	12/23/2024	2/21/2025	12/23/2027	12/31/2028	N	FR publication date after cut-off date
Res	Boilers	1/15/2016	3/15/2016	1/15/2021	N/A	N	Puerto Rico has minimal space heating requirements
Res	CAC and Heat Pumps	1/6/2017	5/8/2017	1/1/2023	N/A	Y	
Res	Clothes Dryer	3/12/2024	7/10/2024	3/1/2028	N/A	Y	
Res	Clothes Washer	3/15/2024	7/15/2024	3/1/2028	N/A	Y	
Res	Cooking Products	2/14/2024	6/13/2024	1/31/2028	N/A	Y	
Res	Dishwashers	4/24/2024	8/22/2024	4/23/2027	N/A	Y	
Res	Furnaces	12/18/2023	2/16/2024	12/18/2028	N/A	N	Puerto Rico has minimal space heating requirements
Res	General Service Lamps (Backstop)	5/9/2022	7/25/2022	7/25/2022	N/A	Y	
Res	General Service Lamps	4/19/2024	7/3/2024	7/25/2028	N/A	Y	
Res	Microwave Ovens	6/20/2023	8/21/2023	6/22/2026	N/A	Y	
Res	Misc. Refrigeration Products	5/7/2024	9/4/2024	1/31/2029	N/A	Y	
Res	Portable Air Conditioners	1/10/2020	3/10/2020	1/10/2025	N/A	Y	
Res	Refrigerators and Freezers	1/17/2024	5/16/2024	1/31/2029	1/31/2030	Y	
Res	Room Air Conditioners	5/26/2023	7/25/2023	5/26/2026	N/A	Y	
Res	Water Heaters	5/6/2024	7/5/2024	5/6/2029	N/A	Y	

For each federal standard in the table above, we also present the date the standard was published in the Federal Register (FR), the effective date of the standard, whether the savings were quantified for inclusion as a contributing entity toward statutory savings targets. Finally, we provide an explanation for any standards that were not included in the analysis. Note that November 30, 2024 was established as the cut-off date for publication in the Federal Register. Due to project schedule constraints, any standards published in the FR after this date were excluded from the analysis.

With the exception of general service lamps, discussed in more detail below, savings associated with all federal standards were developed by leveraging the various National Impact Analyses (NIA) conducted by the DOE as part of the rulemaking process. To adopt any new or amended federal appliance standards, the DOE must determine that such actions would result in significant energy savings. To establish "significance," the DOE develops detailed spreadsheet models to assess energy and cost impacts given equipment shipment data, cost data, operating characteristics, efficiency levels, implementation schedules, and various other factors. Upon publication of a Final Rule, the DOE typically develops a final NIA reflecting any changes to assumptions or proposed efficiency levels resulting from the rulemaking process. Referencing these final NIA spreadsheets, we ensured the spreadsheets were configured to present impacts consistent with those summarized in the Final Rule, isolated the electric savings, and converted the lifetime savings presented to incremental and cumulative annual savings using measure lives from the rulemakings' final Technical Support Documents.

As the name suggests, the NIA spreadsheets report *national* impacts. Next, we needed to adapt these national estimates to reflect Puerto Rico. This was achieved using several scaling metrics developed using national and Puerto Rico-specific data. The scaling metrics used for each federal standard are presented in Table 22 and the definitions and derivation of the metrics are presented in Table 23 below.

Table 22. Scaling Metrics Used to Adapt Savings from Federal Standards

Sector	Product Category	Residential Scaling Metric	Commercial Scaling Metric	Industrial Scaling Metric
All	Air Cleaners	Res Households	Com Sales	N/A
All	Dedicated-purpose pool pump motors	Res Pools	N/A	N/A
All	Dedicated-purpose pool pumps	Res Pools	N/A	N/A
All	Pool Heaters	Res Pools	Res Pools	N/A
Com	Commercial and Industrial Air Compressors	N/A	Com Sales	Ind Sales
Com	Commercial CAC and HP (<65,000 Btu/hr)	N/A	Com Sales	N/A
Com	Commercial CAC and HP (65,000 Btu/hr to 760,000 Btu/hr)	N/A	Com Sales	N/A
Com	Distribution Transformers	N/A	N/A	Ind Sales
Com	Electric Motors	N/A	N/A	Ind Sales
Com	Uninterruptible Power Supplies	Res Sales	Com Sales	N/A
Res	CAC and Heat Pumps	Res HH Sales	N/A	N/A
Res	Clothes Dryer	Res Households	N/A	N/A
Res	Clothes Washer	Res Households	N/A	N/A
Res	Cooking Products	Res Households	N/A	N/A
Res	Dishwashers	Res Households	N/A	N/A
Res	Microwave Ovens	Res Households	N/A	N/A
Res	Misc. Refrigeration Products	Res Households	N/A	N/A
Res	Portable Air Conditioners	Res Households	Com Sales	N/A
Res	Refrigerators and Freezers	Res Households	N/A	N/A
Res	Room Air Conditioners	Res Households	Com Sales	N/A
Res	Water Heaters	Res WH Sales	Com WH Sales	N/A

Table 23. Federal Standard Scaling Metrics Values and Descriptions

Metric Name	Metric Value	Description	Source(s)
Res Households	1.11%	Puerto Rico households as a percentage of US States total households	2023 American Community Survey
Res Sales	0.50%	Puerto Rico residential electric retail sales as a percentage of US States total residential retail electric sales	October 2024 LUMA Data Request Response, US EIA
Res HH Sales	1.16%	Puerto Rico residential electric retail sales as a percentage of US States total residential retail electric sales in Hot-Humid (HH) region	October 2024 LUMA Data Request Response, US EIA
Com Sales	0.57%	Puerto Rico commercial electric retail sales as a percentage of US States total commercial retail electric sales	October 2024 LUMA Data Request Response, US EIA
Ind Sales	0.16%	Puerto Rico industrial electric retail sales as a percentage of US States total industrial retail electric sales (10/24 LUMA Data Request Response, EIA)	October 2024 LUMA Data Request Response, US EIA
Res WH Sales	0.30%	Puerto Rico residential water heating end-use consumption as a recentage of US States total electric water heating end-use consumption	Residential Energy Consumption Survey (RECS), PR Residential Sales Disaggregation
Com WH Sales	0.14%	Puerto Rico commercial water heating end-use consumption as a percentage of US States total electric water heating end-use consumption	Commercial Buildings Energy Consumption Survey (CBECS), PR Commercial Sales Disaggregation
Res Pools	0.55%	Puerto Rico residential pools as a percentage of US States total residential pools	Pool count data from datamasters.com (https://www.datamasters.org/wp-content/uploads/FUSA-POOL-COUNTS.pdf) and PR baseline study findings

To estimate the savings contributions from federal standards to statutory savings targets, the national impacts adapted from the federal rulemaking documentation were simply multiplied by the appropriate scaling factor.

To estimate the savings contributions from federal standards for general service lamps, a more customized, bottom-up approach was used leveraging data from the Puerto Rico Baseline Study and several DOE publications. We first estimated the number of housing units (1,277,486),[22] average number of lamps per household (28),[23] and daily lamp hours of use (3.58).[24] Next, we developed estimates of average lamp wattage for LEDs, compact florescent lamps (CFLs), halogen incandescents, and standard incandescents. For LEDs prior to July 25, 2028, we assume a typical efficacy of 85 lumens per watt. On or after July 25, 2028, LED wattage is assumed to be consistent with requirements of the applicable updated federal standards.[25] For CFLs, we assume a typical efficacy of 55 lumens per watt. Data from a recent Massachusetts evaluation study was used to

[22] US Census Bureau. "Selected Housing Characteristics." American Community Survey, ACS 1-Year Estimates Data Profiles, Table DP04, *https://data.census.gov/table/ACSDP1Y2023.DP04?q=Housing+Units&g=040XX00US72.* Assumes occupied housing units.
[23] US DOE. 2015 *U.S. Lighting Market Characterization*. November 2017. *https://www.energy.gov/sites/default/files/2017/12/f46/lmc2015_nov17.pdf*
[24] Calibrated based on Puerto Rico residential sales disaggregation and Puerto Rico Baseline Study findings on lamp type distribution.
[25] US DOE. *Energy Conservation Program: Energy Conservation Standards for General Service Lamps; Final Rule*. April 19, 2024. *https://www.regulations.gov/document/EERE-2022-BT-STD-0022-0205*

estimate lamp distributions by lumen bin.[26] These assumptions and the resulting average watts per lamp by lamp type are presented in Table 24 below.

Table 24. Average Lamp Wattage by Lamp Type and Lumen Bin

Lumen Range	Avg. Lumens	LED, Before 7/25/2028 (W)	LED, On or After 7/25/2028 (W)	CFL (W)	Halogen (W)	Incandescent (W)	Lumen Bin Distribution
1490-2600	2,045	24	16	37	72	100	7%
1050-1489	1,270	15	10	23	53	75	15%
750-1049	900	11	7	16	43	60	43%
310-749	530	6	5	10	29	40	32%
Average Watts per Lamp		**10.5**	**7.2**	**16.2**	**40.8**	**56.9**	

Next, for each year from FY2016 to FY2040, we developed estimates of the distribution of lamps by type. Data from a recent DOE study informed the distribution for FY2016 and FY2018,[27] while data from the Puerto Rico Baseline Study was used to inform the FY2023 distribution. While the DOE study reflects statewide results, the Baseline Study findings suggest that LED adoption in Puerto Rico does not significantly diverge from trends observed elsewhere in the US. The FY2016 and FY2018 values were averaged to derive estimates for FY2017. Distribution values for FY2019 and FY2022 were linearly interpolated from the FY2018 and FY2023 data points. For FY2024 to FY2030, LED values were developed using linear extrapolation from the FY2018 and FY2023 data points and capped at 100%. Distributions for CFLs, halogens, and incandescents during this period were estimated by applying the distribution of these lamp types from FY2023 to the difference between 100% and the LED distribution. Beginning in FY2031, we assume that those LEDs installed in FY2016 are replaced with new LEDs subject to the updated federal standards that become effective on July 25, 2028, those installed in FY2017 are replaced in FY2032, and so on through the remainder of the analysis period. The resulting distribution of lamp types by year is presented in Table 25 below.

[26] NMR. *Massachusetts Lighting Sales Data Analysis*. October 24, 2019. *https://ma-eeac.org/wp-content/uploads/MA19R06-E-LtgSalesDataAnalysisReport_FINAL_2019.10.29.pdf.* Lamp market share by lumen bin for "Non-Program States" was assumed.
[27] US DOE. *Adoption of Light-Emitting Diodes in Common Lighting Applications*. August 2020. *https://www.energy.gov/sites/default/files/2020/09/f78/ssl-led-adoption-aug2020.pdf*

Table 25. Lighting Type Distribution by Fiscal Year

FY	LED, Before 7/25/2028	LED, On or After 7/25/2028	CFL	Halogen	Incandescent
2016	15%	0%	49%	16%	20%
2017	24%	0%	47%	13%	16%
2018	33%	0%	44%	10%	13%
2019	42%	0%	38%	10%	11%
2020	51%	0%	31%	10%	8%
2021	59%	0%	25%	10%	5%
2022	68%	0%	19%	10%	3%
2023	77%	0%	13%	10%	0%
2024	86%	0%	8%	6%	0%
2025	95%	0%	3%	2%	0%
2026	100%	0%	0%	0%	0%
2027	100%	0%	0%	0%	0%
2028	100%	0%	0%	0%	0%
2029	100%	0%	0%	0%	0%
2030	100%	0%	0%	0%	0%
2031	85%	15%	0%	0%	0%
2032	76%	24%	0%	0%	0%
2033	67%	33%	0%	0%	0%
2034	58%	42%	0%	0%	0%
2035	49%	51%	0%	0%	0%
2036	41%	59%	0%	0%	0%
2037	32%	68%	0%	0%	0%
2038	23%	77%	0%	0%	0%
2039	14%	86%	0%	0%	0%
2040	5%	95%	0%	0%	0%

To estimate lighting energy consumption in each year, we summed the product of each lamp type distribution percentage and average wattage and multiplied this sum by the product of the lamps per household, the number of households, the average lamp daily hours of use, and 365 days per year. Cumulative savings were estimated by subtracting the estimated FY2019 lighting energy consumption from the lighting energy consumption estimated in each subsequent year.

4.1.4 Energy Efficiency in Non-Governmental Buildings Supported with Federal or Commonwealth Funding

Savings from federal programs, including the State Energy Program (SEP), the Energy Efficiency Community Block Grant Program (EECBG), and the Weatherization Assistance Program (WAP), were assessed using historical budget data and various program reports to quantify contributions.

A recent report from the Puerto Rico Department of Economic Development and Commercial (DEDC) summarized recent impacts of the Energy Public Policy Program in FY2020–FY2024.[28] While many of the noted projects focus on resiliency, renewable energy development, and education efforts, the report highlights several LED lighting retrofit projects implemented in various facilities with SEP funds totaling 3.3 GWh in incremental annual energy savings. Further, the report notes disbursements of $1,855,570 in EECBG funds to 37 municipios to support energy efficiency projects. However, no project details or estimates of anticipated savings are provided. Because of the sparsity of data on current and future efforts of the SEP and EECBG programs, the assessment of contributing entities assumes the aforementioned 3.3 GWh in incremental annual savings are evenly distributed across each year from FY2020 through FY2024. No savings, either historical or projected, are assumed for EECBG, and no savings are assumed for SEP in FY2025 and beyond.

In contrast to SEP and EECBG, the future funding and savings associated with the Weatherization Assistance Program are somewhat more certain. The same DEDC report notes that from FY2020 through FY2024, WAP treated approximately 248 homes for $2.02 million. Further, the report indicates that approximately 6,600 homes are expected to be weatherized in FY2025–FY2029. According to grantee allocations published by the DOE via Weatherization Program Notices, Puerto Rico's total budget allocation for WAP from FY2020 through FY2024—exclusive of any funds for Headquarters Training and Technical Assistance (T&TA), Readiness Funds intended to address pre-weatherization barriers, and Infrastructure Investment and Jobs Act (IIJA) grants—was $5.07 million.[29] This suggests that Puerto Rico's WAP program significantly underspent relative to federal allocations. Further, the DEDC report data implies $8,131 in spending per participating home but does not report estimated energy savings.

To estimate historical and future energy savings associated with WAP, we first developed an estimate of incremental annual energy savings per program dollar spent. While reports of Puerto Rico's WAP energy savings are sparse, two data points provide insights into approximate per participant savings. First, DEDC issued a report in October 2021 providing data on the number of participants, energy savings by measure, and measure lifetimes.[30] While this report did not specify the time period associated with the reported data, it implies average incremental annual savings of 2,041 kWh per participant and a savings weighted portfolio average measure life of 17 years. Second, a 2015 evaluation of the Weatherization Assistance Program in U.S. Territories circa 2010

---

[28] Departmento de Desarrollo Económico y Comercio. *Programa de Política Pública Energética, Informe de Transición 2021-2024. https://www.docs.pr.gov/files/DDEC/PPPE/01032025- Informe Transicion PPPE.pdf*
[29] US Department of Energy. Weatherization Program Notice 20-2. February 10, 2020. *https://www.energy.gov/sites/prod/files/2020/02/f71/wpn-20-2.pdf;*
US Department of Energy. Weatherization Program Notice 21-2. January 21, 2021. *https://www.energy.gov/sites/prod/files/2021/01/f82/wpn-21-2.pdf;*
US Department of Energy. Weatherization Program Notice 22-2. March 23, 2022. *https://www.energy.gov/sites/default/files/2022-04/wpn-22-2.pdf;*
US Department of Energy. Weatherization Program Notice 23-2. February 3, 2023. *https://www.energy.gov/sites/default/files/2024-05/wap-wpn-23-2-archived.pdf;*
US Department of Energy. Weatherization Program Notice 23-2. April 10, 2024. *https://www.energy.gov/sites/default/files/2024-04/wap-wpn-24-2_041024.pdf*
[30] Department of Economic Development and Commerce. *Energy Savings Report by Weatherization Assistance Program Puerto Rico*. October 2021. https://docs.pr.gov/files/DDEC/Climatizacio%CC%81n/WAP%20energy%20reduction%20results%20report%20Oct%202021.pdf

found average per participant savings of 876 kWh for Puerto Rico.[31] Given that the annual savings estimate of 2,041 kWh does not appear to have been evaluated and equates to a perhaps unrealistically high reduction of 42% relative to average residential household energy consumption, our analysis of WAP's contribution to statutory FY2040 savings targets assumes the more conservative value of 876 kWh savings per household. Assuming $8,131 in WAP spending per participant from the FY2020–FY2024 historical data, this yields an average cost per first-year kWh saved of $9.28.

Next, we developed an estimate of future WAP budget allocations. Table 26 below presents the WAP budget allocations for FY2020–FY2025 and the annual average.[32]

Table 26. Historical Puerto Rico WAP 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**

Note that the values above do not include any funds for Headquarters Training and Technical Assistance, Readiness Funds intended to address pre-weatherization barriers, and Infrastructure Investment and Jobs Act grants. While it is appropriate to exclude the T&TA and Readiness Funds when isolating the programs funds that directly contribute to energy savings, the IIJA funds should be considered. In short, the IIJA directed an additional $31.3 million to Puerto Rico's WAP program, exclusive of T&TA.[33] DEDC's reporting on actual program spending for FY2020–FY2024 of $2.02 million suggests that these IIJA funds have not yet been leveraged.

The resulting assumed WAP budgets for FY2025 through FY2040 are presented in Table 27 below. Base WAP budget allocations assume the actual approved budget for FY2025 and the annual average budget for FY2020–FY2025 is assumed for FY2026 and beyond. We assume $6.25 million of the IIJA funds will be spent annually from FY2025 through FY2029.

---

[31] Tonn, Bruce and Erin Rose. *U.S. Territories and Weatherization Assistance Program During the Recovery Act Period.* ORNL. March 2015.
[32] US Department of Energy. Weatherization Program Notice 25-2. July 1, 2025. *https://www.energy.gov/sites/default/files/2025-07/wap-wpn-25-2.pdf*
[33] US Department of Energy. Weatherization Program Notice IIJA-2 Revised. April 3, 2025. *https://www.energy.gov/sites/default/files/2025-04/wap-wpn-iija-2-revised_041625.pdf*

Table 27. Assumed WAP Budgets for FY2025 and Beyond

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

To estimate the incremental annual savings from WAP, per participant savings of 876 kWh and 49.6 average annual participants[34] were assumed for FY2020 through FY2024. For FY2025 through FY2040, the assumed budgets from Table 27 were divided by the assumed average cost per first-year kWh saved of $9.28. Cumulative savings were estimated assuming a savings weighted portfolio average measure life of 17 years as derived from DEDC data.

4.2 RESULTS

In this section, we summarize the incremental and cumulative annual energy savings estimated for each contributing entity using the methods described above. Finally, we present the combined impacts of all contributing entities noting the cumulative savings contributions in FY2040.

4.2.1 Governmental Mandates for Improved Efficiency in Public Buildings

As discussed above, we did not explicitly quantify any contributions from governmental mandates for improved efficiency in public buildings.

4.2.2 Building Energy Codes

The resulting incremental and cumulative annual savings from improved building energy codes are presented in Figure 26 below for the residential and commercial sectors. Note that the cumulative annual savings are the running total of all incremental savings achieved prior to and including a given analysis year. In other words, we assume that savings induced by building energy code improvements persist through the entirety of the analysis period.

[34] Departmento de Desarrollo Económico y Comercio. *Programa de Política Pública Energética, Informe de Transición 2021-2024. https://www.docs.pr.gov/files/DDEC/PPPE/01032025- Informe Transicion PPPE.pdf*

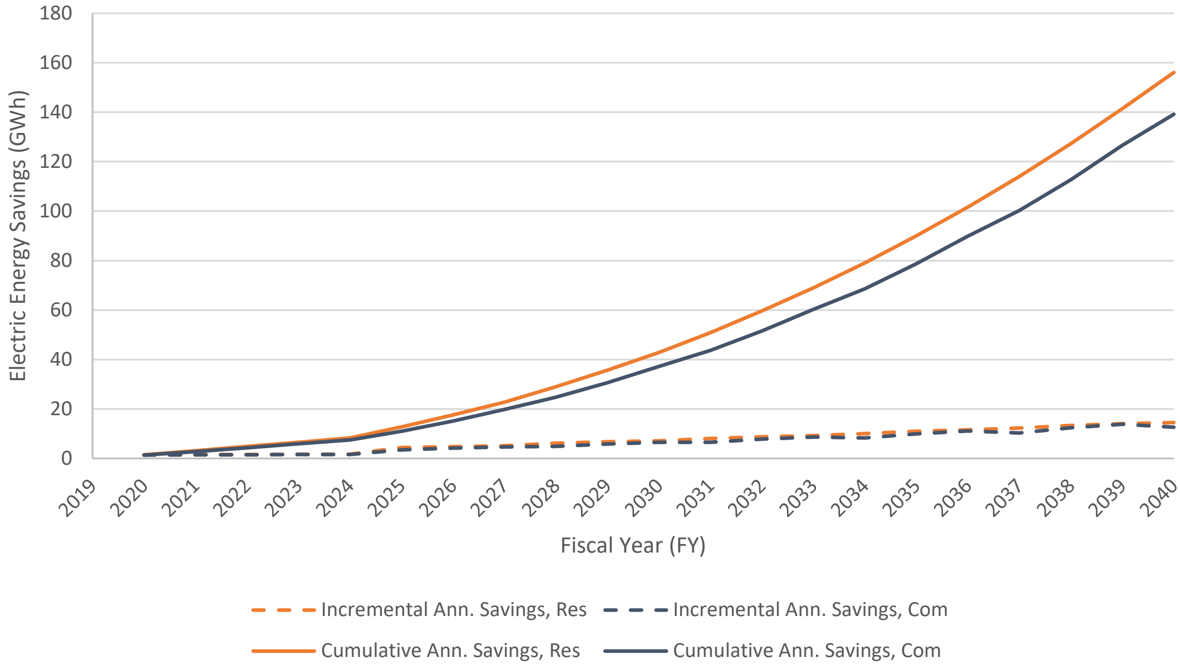

Figure 26. Energy Savings Contributions from Building Energy Codes

As shown above, incremental annual savings for the residential sector increase from 1.6 GWh in FY2020 to 14.6 GWh in FY2040. Savings from the commercial sector have a similar magnitude, increasing from 1.4 GWh in FY2020 to 12.6 GWh in FY2040. Cumulative annual savings after the first triennium (FY2026–FY2028) are 29.0 GWh for residential and 24.7 GWh for commercial or 53.7 GWh in total. Relative to baseline FY2019 sales, this represents a reduction of 0.3%. After the fifth triennium (FY2038–FY2040), 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.

4.2.3 Federal or Commonwealth Appliance Standards

The resulting cumulative annual savings from federal standards are presented in Figure 27 below. Note that because savings from general service lamps (GSL) are significantly higher than those from any other standard, these savings have been plotted on a secondary vertical axis in Figure 27 and distinguished from the other data series via the use of a dotted line.

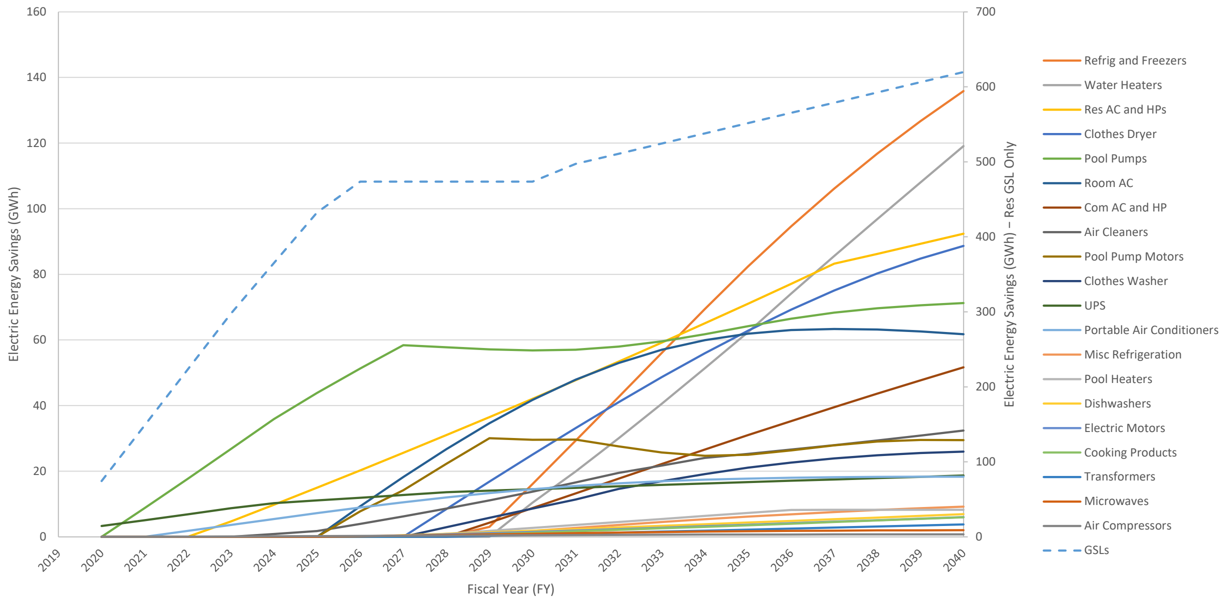

Figure 27. Cumulative Annual Energy Savings Contributions from Federal Standards

As shown above, cumulative annual savings for individual standards range from 0.8 GWh in FY2040 for air compressors to 620 GWh in FY2040 for general service lamps. With all standards impacts combined, cumulative annual savings after the first triennium (FY2026–FY2028) are 661 GWh. Relative to baseline FY2019 sales, this represents a reduction of 4.1%. After the fifth triennium (FY2038–FY2040), cumulative annual savings are estimated at 1,408 GWh or 8.8% of FY2019 sales.

4.2.4 Energy Efficiency in Non-Governmental Buildings Supported with Federal or Commonwealth Funding

The resulting incremental and cumulative annual savings from the Weatherization Assistance Program and the State Energy Program are presented in Figure 28 below.

Figure 28. Energy Savings Contributions from WAP and SEP

As shown above, incremental annual savings for WAP, impacting only the residential sector, increase from a modest 43 MWh in FY2020 to 833 MWh in FY2025 reflecting the increased funding from the IIJA. Incremental savings return to a more modest 118 MWh in FY2030 and remain at that level through the end of the analysis period. Savings from the SEP, impacting only the non-residential sector, maintain a constant 668 MWh from FY2020 to FY2024 then drop to zero. Cumulative annual savings after the first triennium (FY2026–FY2028) are 3.4 GWh for WAP and 3.3 GWh for SEP or 6.8 GWh in total. Relative to baseline FY2019 sales, this represents a reduction of 0.04%. After the fifth triennium (FY2038–FY2040), cumulative annual savings are estimated at 5.3 GWh for WAP and 0.7 GWh for SEP for a total of 6.0 GWh or 0.4% of FY2019 sales.

4.2.5 Summary of Energy Savings Contributions from Contributing Entities

The total savings for all contributing entities are presented in Figure 29 below. Savings are dominated by federal standards with building energy codes contributing a smaller, but not insignificant, share of savings by the end of the analysis period. Savings from WAP and SEP (i.e., “Non-Govt Bldgs”) are nearly imperceptible in the figure.

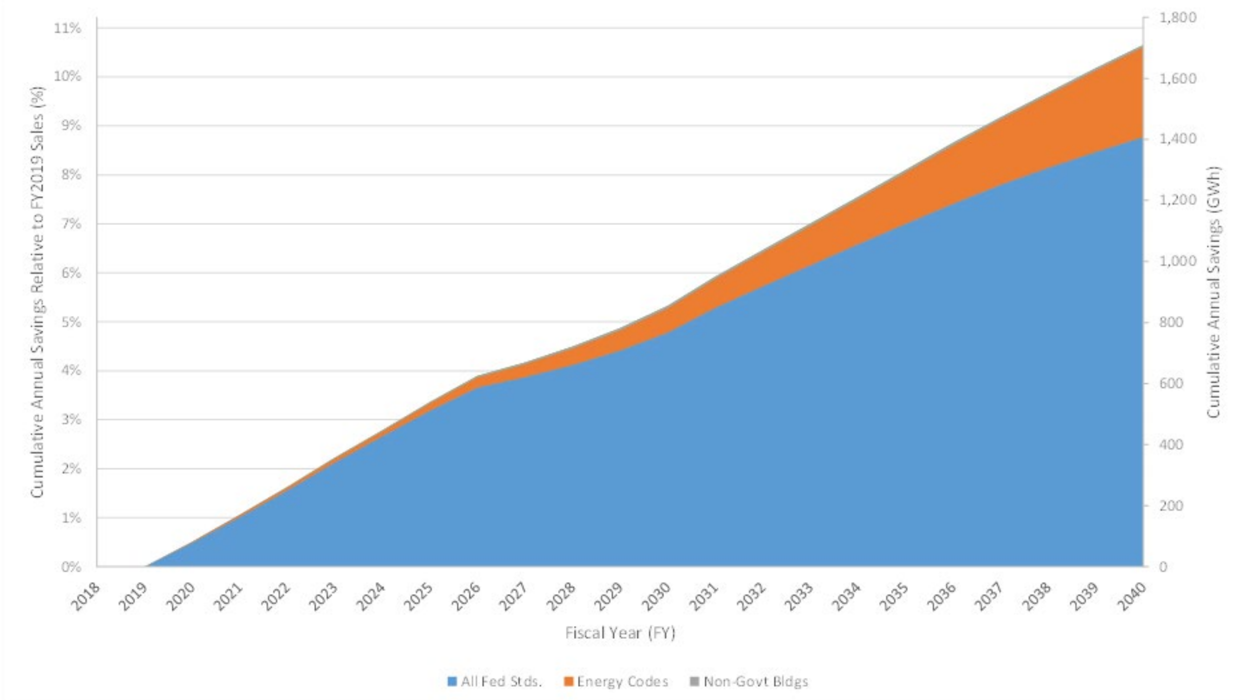

Figure 29. Summary of Cumulative Annual Savings from Contributing Entities

As shown above, cumulative annual savings from federal standards amount to 1,408 GWh in FY2040. Cumulative savings from energy codes total 295 GWh in FY2040, and savings from WAP and SEP amount to only 6.0 GWh. When all contributing entities are combined, cumulative annual savings after the first triennium (FY2026–FY2028) are 721 GWh. Relative to baseline FY2019 sales, this represents a reduction of 4.5%. After the fifth triennium (FY2038–FY2040), cumulative annual savings are estimated at 1,709 GWh or 10.6% of FY2019 sales.

5.0 ENERGY EFFICIENCY MARKET POTENTIAL ANALYSIS

This section presents the methodology for and detailed results from our analysis of the energy efficiency potential. This study estimates the potential for electric energy savings and peak demand reduction through utility-run energy efficiency programs over a 15-year period spanning FY2026 through FY2040.

This study evaluated energy efficiency potential for three separate scenarios:

- **Economic** – All measures that are cost-effective and technically feasible, assuming no market barriers to adoption.
- **Maximum (“Max”) Achievable** – A subset of the economic potential that can be achieved when supported by aggressive programs, including incentives covering 100% of the total incremental costs for all measures, with the intent of securing the maximum amount of efficiency savings possible given real-world constraints of customer behavior.
- **Program Achievable** – A subset of the maximum achievable potential assuming “best practice” program design, with incentives covering, on average, 50% of the incremental costs of the measures. Consistent with typical income-eligible program design, income-eligible customers still receive incentives covering 100% incremental costs in this scenario.

5.1 METHODS

The major steps in conducting the energy efficiency potential study were as follows:

- Develop global inputs (e.g., avoided costs, retail rates, discount rates, line losses)
- Develop energy use forecasts
- Disaggregate energy forecasts by sector (e.g., residential vs. commercial), and end uses (e.g., lighting, cooling, refrigeration)
- Characterize efficiency measures
- Screen measures and programs for cost-effectiveness
- Develop measure penetrations for “achievable” scenarios
- Determine scenario potential and develop outputs

A key characteristic of our approach to efficiency potential studies is the use of a “top-down” methodology. This involves beginning with the entirety of Puerto Rico’s forecasted electric sales, then “disaggregating” those sales into many smaller quantities of electricity that represent consumption by various building types and end-uses. Detailed sales disaggregation methodology and sources are described in Section 3.0 Market Baseline Characterization. From there, energy efficiency measures—in the form of percentage reductions in consumption—are applied to the portion of each quantity of electricity use to which they are applicable. This is in contrast to a “bottom-up” methodology that seeks to build up the efficiency potential by estimating the quantity of measures that could be installed and the per-unit energy savings of those measures. The top-down method ensures that the energy savings are calibrated to actual energy sales.

The measure list for the study was initially developed and qualitatively screened for appropriateness in consultation with key stakeholders, with details borrowed from several sources including the Illinois, Minnesota, New York, New Orleans and Hawaii TRMs, and previous potential studies conducted by NV5. Each measure included in the study was characterized in terms of costs, savings, effective useful life, and other impacts of the measure. These parameters were developed using data from the aforementioned TRMs where applicable and practical, supplemented with NV5's existing measure characterization database. In addition, we drew on data from the DOE Industrial Training and Assessment Centers, which provide a valuable resource for evaluation of energy efficiency potential across industrial facilities nationwide.[35]

Once the measure list was finalized and all measures fully characterized, we developed an initial estimate of potential that assumed all cost-effective measures were fully implemented where technically feasible. Although this "economic" potential does not represent an outcome that could reasonably be expected under real-world conditions, it helps to calibrate the remaining scenarios that take into account customer behavior and the many barriers to efficiency investment.

This study uses the "Puerto Rico Benefit-Cost" (PR) test, which reflects Puerto Rico public policy priorities, to evaluate whether proposed or actual energy efficiency and demand programs or initiatives provide benefits greater than their costs. Impacts intended to be assessed as part of the PR test include those that accrue to the utility system, hosts customers (or participants in the energy efficiency programs) as well as society as a whole. On the cost side, program administration costs and the full incremental costs of the efficiency measures are included. The precise incentive amount does not impact the PR benefit-cost ratio, as the total incremental cost is incurred by the economy, regardless of whether it is paid for by the participant or the program administrator. Efficiency measures and programs are considered to be cost-effective if the net present value of benefits exceeds the net present value of costs.

Assessing the cost-effectiveness of efficiency measures means comparing the costs of investing in the measure with the economic benefits realized from that investment. With most efficiency measures, the vast majority of economic benefits are derived from the value of avoiding the energy consumption that would otherwise occur in the absence of the efficiency measure. These "avoided costs" are therefore a key input to the potential model. The benefits listed below are included. For more detailed descriptions, please refer to Appendix D.

- Avoided Generation Costs: These represent the reduction in fuel and other varying operating costs is the avoided energy. The avoided energy generation costs include expenses from the production or procurement of energy (i.e., kWh) from generation resources on behalf of customers. These expenses should include the fuel cost and variable O&M costs and can vary by season and time of day. Avoided environmental compliance costs and some of the avoided ancillary services are a component of the avoided energy generation costs and are thereby also included
- Avoided Capacity Costs: The reduced capacity needed is the avoided capacity. The avoided capacity costs are based on whether the EE resource coincides with the system peak.

[35] Seehttps://www.energy.gov/mesc/industrial-assessment-centers-iacs

- Avoided greenhouse gas emissions costs: Reducing the total energy required also avoids emission of greenhouse gases. These avoided emissions have a societal value that can be expressed in monetary terms.

For this study, we developed avoided energy costs from Synapse's avoided cost study[36]. The avoided cost report also advises quantifying avoided electricity costs by time of day[37]. Thus, we have simplified the avoided costs of energy into three periods: Daytime (defined as 7:00 AM until 4:00 PM), Evening (peak) (4:00 PM through 11:00 PM), and Overnight (11:00 PM through 7:00 AM). There are two consistent patterns observed in the avoided electricity costs used in the study: First, the evening peak period and overnight period have avoided cost values that are similar to each other and generally higher relative to the daytime period avoided cost. Second, the value of the avoided costs of electricity generally diminishes for all periods over the study period.

We also developed load shapes for each sector and end use. These load shapes determine what portion of the total annual energy savings coincides with each energy period. This means that cooling measures, for example, will have larger benefits than outdoor lighting measures, where the savings generally fall on off-peak hours. As indicated earlier, if the net present value of the future stream of benefits (energy and demand, but also other societal benefits such as gas, water, or maintenance savings) exceeds the costs, then the measure is considered cost-effective.

Avoided costs for peak demand reduction come from the avoided cost study[38]. The avoided capacity cost values fluctuate over the study period. The initial rise of avoided capacity costs correspond to rising demand for electricity and retirement of generation plants. The avoided capacity value eventually falls as peak loads are reduced. Toward later years of the study, the avoided capacity value remains at a steady, lower value of $76 per kW-year as the installation rate of solar and battery resources reach a steady state. Line losses were sourced from the US DOE release of a report citing line-losses as 14%[39]. Finally, we use a discount rate of two percent to better reflect the public policy benefits of energy efficiency programs.

The avoided costs and load shapes allow us to calculate the net present value of each measure's energy and capacity savings. A measure is considered cost-effective if this value exceeds the measure's cost. For the economic potential estimate, we generally assumed that all cost-effective measures would be immediately installed for market-driven measures such as for new construction, major renovation, and natural replacement ("replace on failure"). For retrofit measures we generally assumed that resource constraints (primarily contractor availability) would limit the rate at which retrofit measures could be installed, depending on the measure, but that all or nearly all efficiency retrofit opportunities would be realized over the 15-year study period. Spreading out the retrofit opportunities results in a more realistic distribution of efficiency investment over time, providing a better basis for the later achievable scenarios.

---

[36] Kallay, Jenn et al. *Avoided Costs of Energy Efficiency Resources in Puerto Rico, 2023-2045: Avoided Energy Generation, Capacity, and Greenhouse Gas Emissions Costs for Use in Puerto Rico Cost Test and Related Benefit-Cost Analyses of Prospective Energy Efficiency Resources.* Synapse Energy Economics, Inc. June 5, 2024. Prepared for Puerto Rico Energy Bureau.
[37] Ibid. 23.
[38] Ibid. 25.
[39] U.S. Department of Energy. *ETI Energy Snapshot: Puerto Rico FY20.* https://www.energy.gov/sites/prod/files/2020/09/f79/ETI-Energy-Snapshot-Puerto-Rico_FY20.pdf.

5.2 RESULTS

This section presents the overall results of the three scenarios examined. The results are given at the sector level – residential and C&I. Residential low-income results, where presented, are mutually exclusive with the residential results where these categories exist withing the same table or figure. We also want to emphasize that, due to inherent uncertainties in predicting the future, the results become less certain farther into the analysis period. We would therefore recommend placing a focus on the first 10 years when evaluating the results of this study. Unless otherwise noted, all savings presented are at the customer's meter.

Cumulative and incremental annual electric energy savings by building type, end use, year, and scenario are presented in Appendix F.

5.2.1 Energy Savings and Peak Demand Reduction

Figure 30 below shows what sales would be under the three scenarios examined for the 15-year study horizon compared to baseline forecasted LUMA sales. As expected, sales decline significantly under the efficiency scenarios.

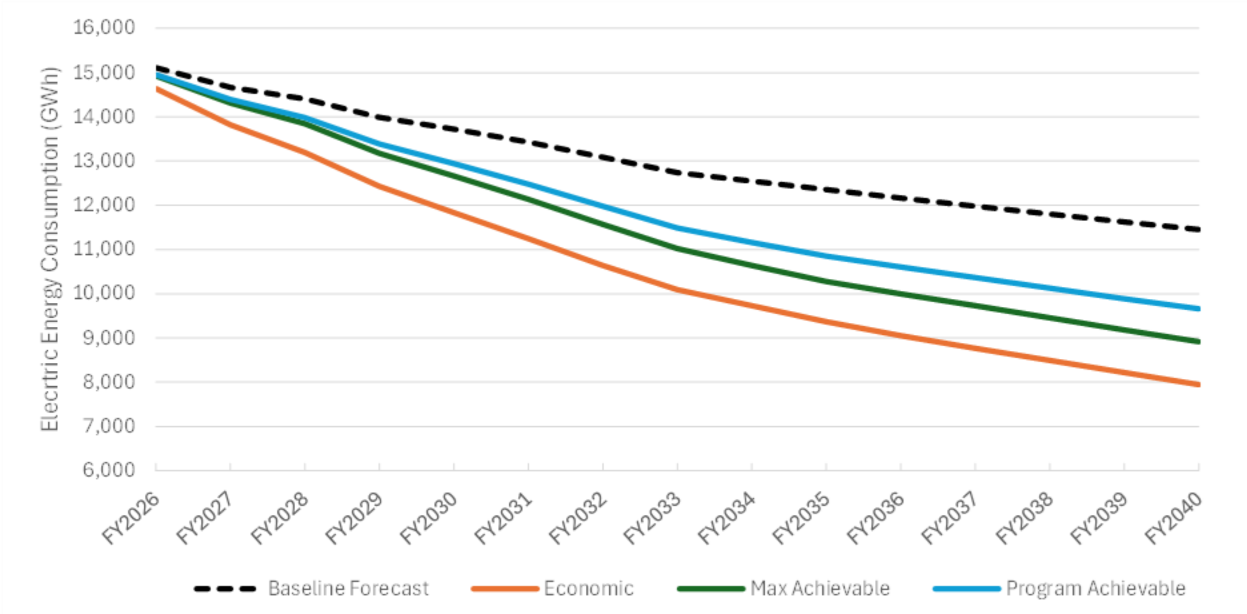

Figure 30. Forecasted Electric Energy Consumption by Scenario (GWh)

Table 28 below gives the specific figures for cumulative annual energy savings in MWh and as a percent of baseline FY2019 sales. Values are presented after each year of the first triennium and the after the last year of each subsequent triennium. 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.

Table 28. 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%
FY2031	Economic	857,462	134,166	1,187,610	2,179,238	13.6%
	Max Achievable	436,585	67,292	786,494	1,290,371	8.0%
	Program	284,448	42,210	620,590	947,249	5.9%
FY2034	Economic	1,086,100	168,467	1,562,843	2,817,410	17.6%
	Max Achievable	655,473	101,170	1,147,165	1,903,807	11.9%
	Program	415,797	61,336	905,929	1,383,062	8.6%
FY2037	Economic	1,262,876	193,756	1,760,095	3,216,727	20.0%
	Max Achievable	783,338	118,074	1,353,318	2,254,731	14.0%
	Program	482,975	68,355	1,067,096	1,618,427	10.1%
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%

Note that the above values represent cumulative savings. Because many measures have a useful life of less than 15 years, incremental annual savings of 1,000 MWh each year would not necessarily mean that cumulative annual savings would be 15,000 MWh in year 15. Incremental annual savings in each year are presented in both units of energy saved (GWh) and as savings as a percent of baseline FY2019 sales in Table 29 and Table 30 below, respectively.

Table 29. Incremental Annual Energy Savings by Scenario and Sector by Year (GWh)

Year	Economic			Max Achievable			Program		
	Res	C&I	Total	Res	C&I	Total	Res	C&I	Total
FY2026	247.7	223.6	471.3	98.5	89.1	187.6	85.0	71.5	156.5
FY2027	232.0	212.0	444.0	118.7	113.8	232.5	96.6	90.0	186.6
FY2028	221.5	207.3	428.8	137.7	137.8	275.5	107.8	108.4	216.1

Year	Economic			Max Achievable			Program		
	Res	C&I	Total	Res	C&I	Total	Res	C&I	Total
FY2029	212.5	198.6	411.1	154.9	155.6	310.5	118.1	122.1	240.3
FY2030	206.4	192.0	398.4	156.3	153.1	309.4	118.6	120.6	239.1
FY2031	200.3	185.7	386.0	156.7	149.6	306.3	118.5	118.2	236.7
FY2032	194.1	179.0	373.1	155.9	145.2	301.2	117.8	115.1	232.8
FY2033	190.3	173.2	363.5	155.1	141.1	296.2	117.2	111.8	229.0
FY2034	186.7	170.0	356.8	154.4	138.8	293.2	116.9	110.1	227.0
FY2035	185.5	166.9	352.4	154.7	136.4	291.1	116.9	108.2	225.1
FY2036	184.2	163.8	348.0	127.8	113.7	241.5	97.1	90.5	187.5
FY2037	182.9	164.1	347.0	133.7	116.9	250.6	100.9	92.9	193.8
FY2038	181.6	163.8	345.4	143.1	120.9	264.0	107.0	96.0	203.0
FY2039	180.2	161.2	341.4	152.1	127.1	279.2	112.8	100.7	213.5
FY2040	178.8	158.5	337.3	151.1	124.9	276.0	111.6	98.9	210.5

Table 30: 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%

Table 31 below shows cumulative annual peak demand reduction in MW for each scenario in each of the three years of the first triennium and in the last year of each subsequent triennium.

Table 31. Cumulative Annual Demand Savings by Scenario and Sector by Year (MW)

Year	Scenario	Residential Savings	Low Income Savings	C&I Savings	Total
FY2026	Economic	36	5	37	79
	Max Achievable	11	1	16	28
	Program	8	1	13	22
FY2027	Economic	65	9	72	146
	Max Achievable	20	3	36	59
	Program	14	2	29	44
FY2028	Economic	92	13	106	211
	Max Achievable	33	5	60	98
	Program	21	3	48	72
FY2031	Economic	164	24	195	383
	Max Achievable	81	12	137	230
	Program	50	7	110	167
FY2034	Economic	215	30	260	505
	Max Achievable	126	18	200	344
	Program	78	11	160	249
FY2037	Economic	256	36	300	592
	Max Achievable	160	23	241	423
	Program	97	13	193	303
FY2040	Economic	291	40	329	660
	Max Achievable	193	27	269	489
	Program	116	15	215	346

5.2.2 Cost-Effectiveness

Table 32 shows the Puerto Rico Benefit-Cost Test results for each scenario for the entire analysis period. Table 33 through Table 37 present the results for each scenario and triennium. As shown, while the scenarios incur significant costs (i.e., utility administrative costs, incentive costs, and customer contributions), the benefits consistent with the PR Test are generally two to three times larger.

Table 32. Puerto Rico Benefit-Cost Test Results by Scenario, 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

Table 33. Costs, Benefits, Net Benefits and BCR by Sector and Scenario, FY2026–FY2028, Present Value 2026 Dollars ($Million)

Sector	Scenario	Benefits ($Million)	Costs ($Million)	Net Benefits ($Million)	BCR
Residential	Economic	$765	$322	$443	2.4
	Max Achievable	$259	$140	$120	1.9
	Program	$158	$76	$83	2.1
C&I	Economic	$812	$274	$537	3.0
	Max Achievable	$448	$181	$268	2.5
	Program	$354	$131	$223	2.7
Total	Economic	$1,576	$596	$980	2.6
	Max Achievable	$708	$321	$387	2.2
	Program	$512	$206	$305	2.5

Table 34. Costs, Benefits, Net Benefits and BCR by Sector and Scenario, FY2029–FY2031, Present Value 2026 Dollars ($Million)

Sector	Scenario	Benefits ($Million)	Costs ($Million)	Net Benefits ($Million)	BCR
Residential	Economic	$568	$260	$309	2.2
	Max Achievable	$380	$229	$151	1.7
	Program	$230	$118	$112	1.9
C&I	Economic	$624	$229	$394	2.7
	Max Achievable	$525	$209	$316	2.5
	Program	$413	$148	$265	2.8
Total	Economic	$1,192	$489	$703	2.4
	Max Achievable	$905	$437	$468	2.1
	Program	$643	$266	$377	2.4

Table 35. Costs, Benefits, Net Benefits and BCR by Sector and Scenario, FY2032–FY2034, Present Value 2026 Dollars ($Million)

Sector	Scenario	Benefits ($Million)	Costs ($Million)	Net Benefits ($Million)	BCR
Residential	Economic	$457	$222	$235	2.1
	Max Achievable	$353	$229	$124	1.5
	Program	$216	$119	$96	1.8

C&I	Economic	$503	$193	$310	2.6
	Max Achievable	$437	$182	$255	2.4
	Program	$347	$130	$216	2.7
Total	Economic	$960	$415	$544	2.3
	Max Achievable	$790	$411	$379	1.9
	Program	$562	$249	$313	2.3

Table 36. Costs, Benefits, Net Benefits and BCR by Sector and Scenario, FY2035–FY2037, Present Value 2026 Dollars ($Million)

Sector	Scenario	Benefits ($Million)	Costs ($Million)	Net Benefits ($Million)	BCR
Residential	Economic	$400	$205	$196	2.0
	Max Achievable	$300	$204	$97	1.5
	Program	$180	$102	$78	1.8
C&I	Economic	$433	$173	$259	2.5
	Max Achievable	$355	$150	$205	2.4
	Program	$282	$106	$176	2.7
Total	Economic	$833	$378	$455	2.2
	Max Achievable	$655	$353	$302	1.9
	Program	$462	$208	$254	2.2

Table 37. Costs, Benefits, Net Benefits and BCR by Sector and Scenario, FY2038–FY2040, Present Value 2026 Dollars ($Million)

Sector	Scenario	Benefits ($Million)	Costs ($Million)	Net Benefits ($Million)	BCR
Residential	Economic	$369	$191	$178	1.9
	Max Achievable	$301	$207	$94	1.5
	Program	$178	$104	$73	1.7
C&I	Economic	$396	$163	$233	2.4
	Max Achievable	$329	$145	$184	2.3
	Program	$261	$104	$158	2.5
Total	Economic	$765	$354	$411	2.2
	Max Achievable	$630	$352	$278	1.8
	Program	$439	$208	$231	2.1

Figure 31 below presents the distribution of portfolio benefits by scenario, sector, and benefits category. The distribution of benefits are largely consistent between scenarios and sectors, and in all cases, benefits are dominated by avoided electric energy generation which contribute between 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 followed by avoided generation capacity costs which contribute approximately 12% of total benefits. Avoided greenhouse gas emissions provide approximately 8% of total benefits. Finally, avoided water costs contribute the remaining <1% of benefits.

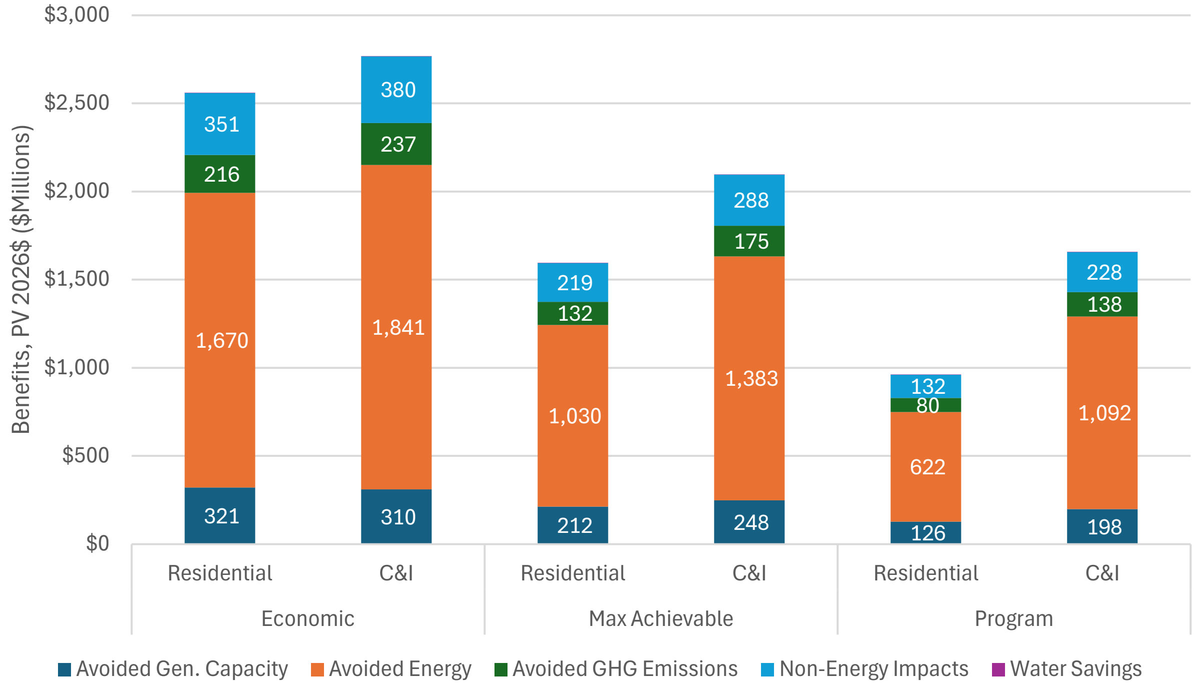

Figure 31. Portfolio Benefits by Sector, Scenario, and Category, Present Value 2026 Dollars ($Million)

5.2.3 Program Budgets

Table 38 and Table 39 show the utility budgets, by year, for the max achievable and program achievable potential scenarios. As shown, the FY2026 budget would be $96.4 million and $42.8 million for max achievable and program achievable, respectively. From there, budgets would generally continue to increase until reaching $246.5 million and $96.7 million in FY2040, respectively. The budget for the maximum achievable potential is considerably higher than that of the program achievable potential. This is primarily due to the fact that the maximum achievable potential assumes that financial incentives would be available to cover 100% of incremental measure costs, while the program achievable potential assumes only 50% incremental cost coverage. This assumption in itself nearly doubles the total budget. In reality, successful programs have approached maximum achievable adoption levels while offering far less than 100% incremental cost coverage.

Achieving the program achievable potential would represent a significant investment. However, it would also avoid significant electricity generation needs and produce benefits 2.3 times greater than the costs (as shown in the PR Test ratios in Table 32 above).

Table 38. 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

Table 39: 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

5.2.4 Building Type and End-Use Savings

This section presents energy savings by building type and end-use. We focus the reporting on the maximum achievable and program achievable potential, since these scenarios are most likely to bound LUMA's program efforts. Figure 32 and Figure 33 present the cumulative annual energy savings for the final year in each triennium by residential building type for the maximum achievable and program achievable scenarios, respectively.

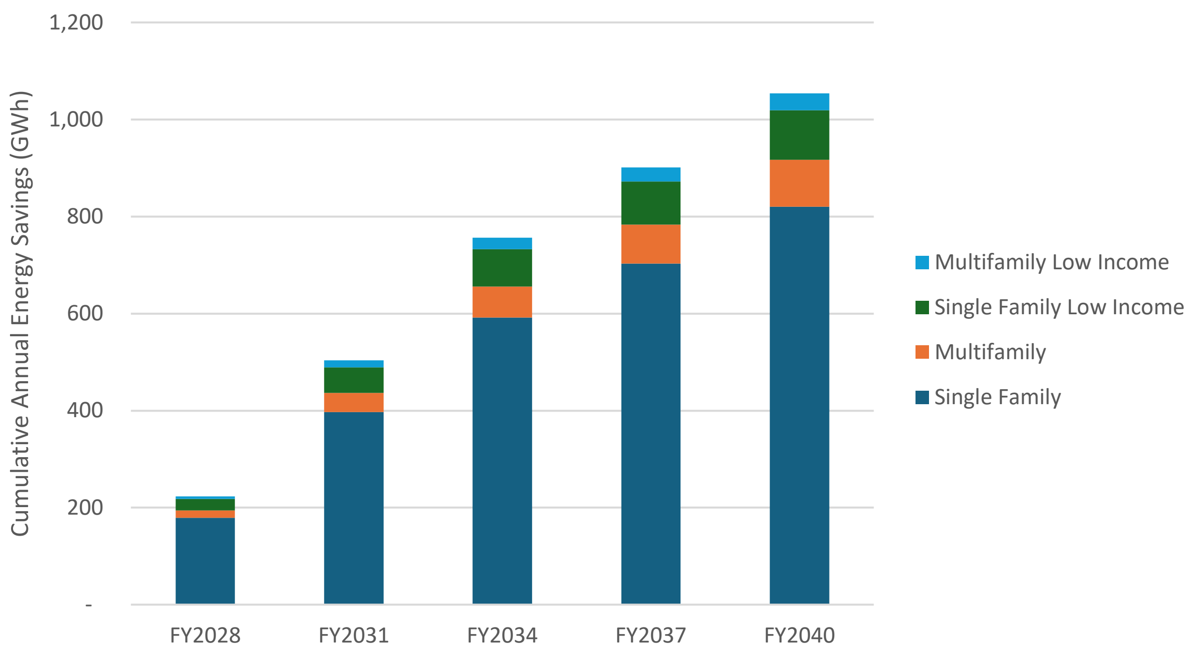

Figure 32. Residential Max Achievable Cumulative Annual Energy Savings by Building Type by Year

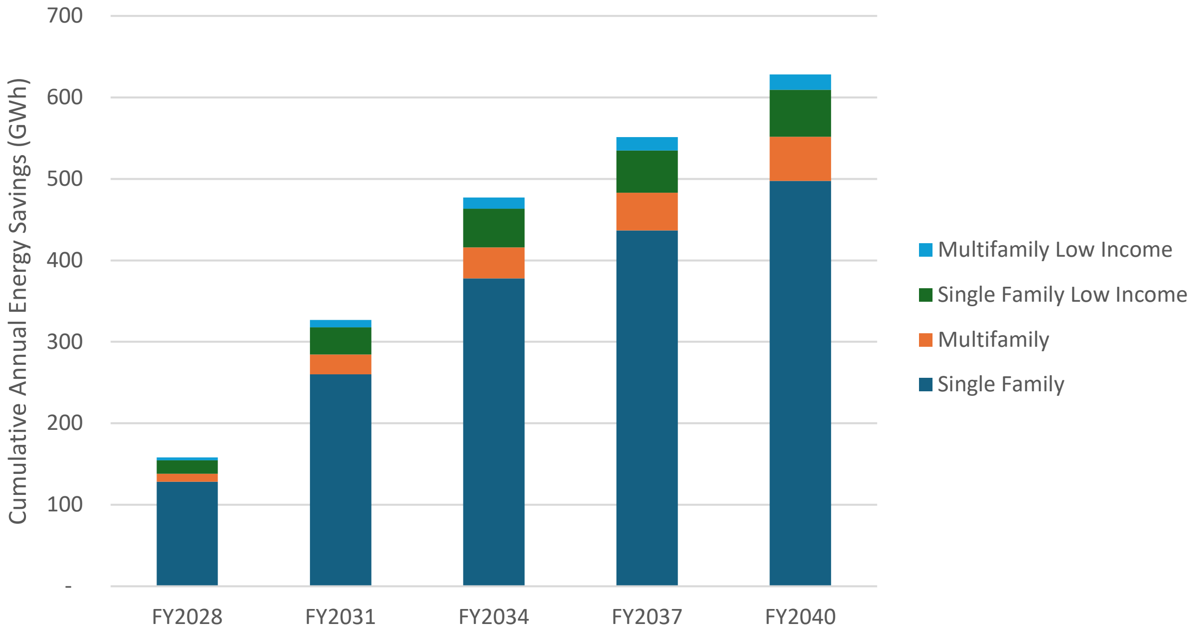

Figure 33. Residential Program Achievable Cumulative Annual Energy Savings by Building Type by Year

Consistent with sector demographics, the residential potential is dominated by single family homes in both scenarios. Figure 34 and Figure 35Figure 33 present the cumulative annual energy savings for the final year in each triennium by non-residential building type for the maximum achievable and program achievable scenarios, respectively.

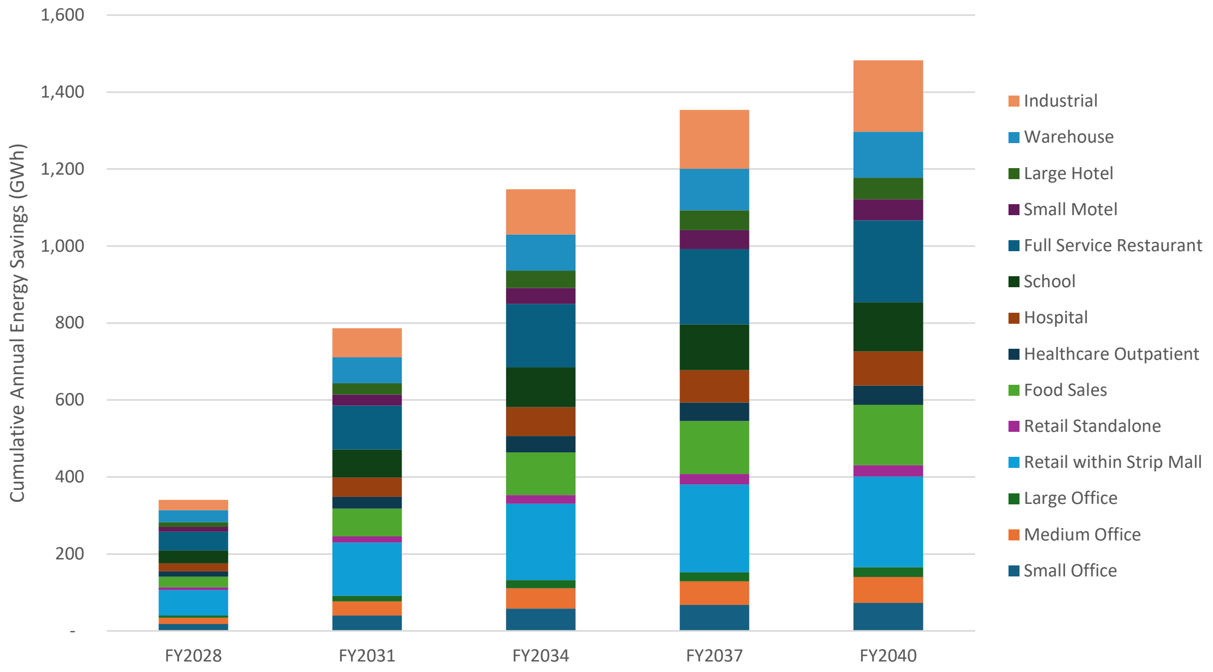

Figure 34. C&I Max Achievable Cumulative Annual Energy Savings by Building Type by Year

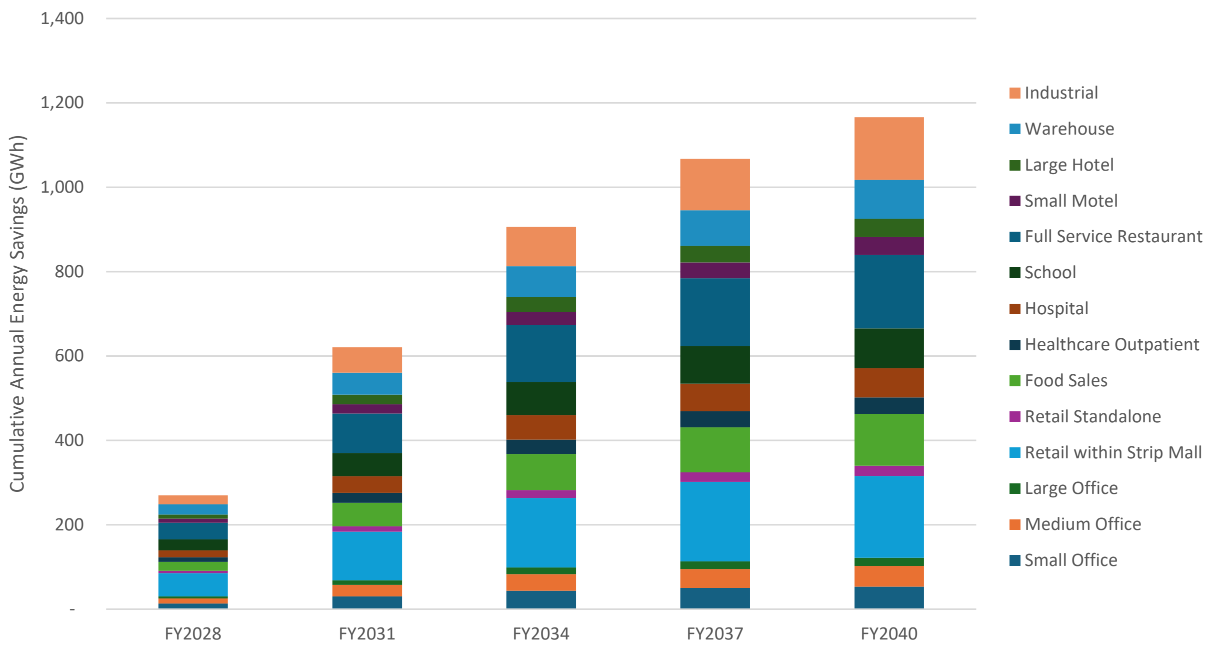

Figure 35. C&I Program Achievable Cumulative Annual Energy Savings by Building Type by Year

The potential in the non-residential sector is more heterogeneous than the residential sector, with the largest opportunities available in retail, restaurants, industrial, and office building types.

Similarly, for each scenario and sector, Figure 36 through Figure 39 present the cumulative annual energy savings for the final year in each triennium by end-use.

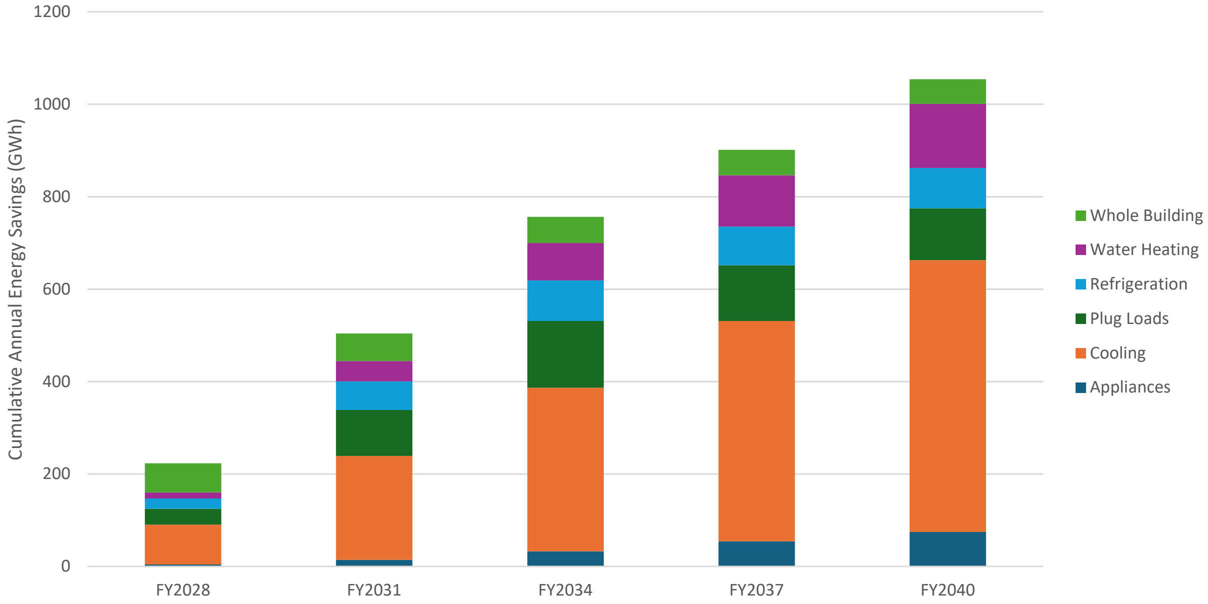

Figure 36. Residential Max Achievable Cumulative Annual Energy Savings by End-Use by Year

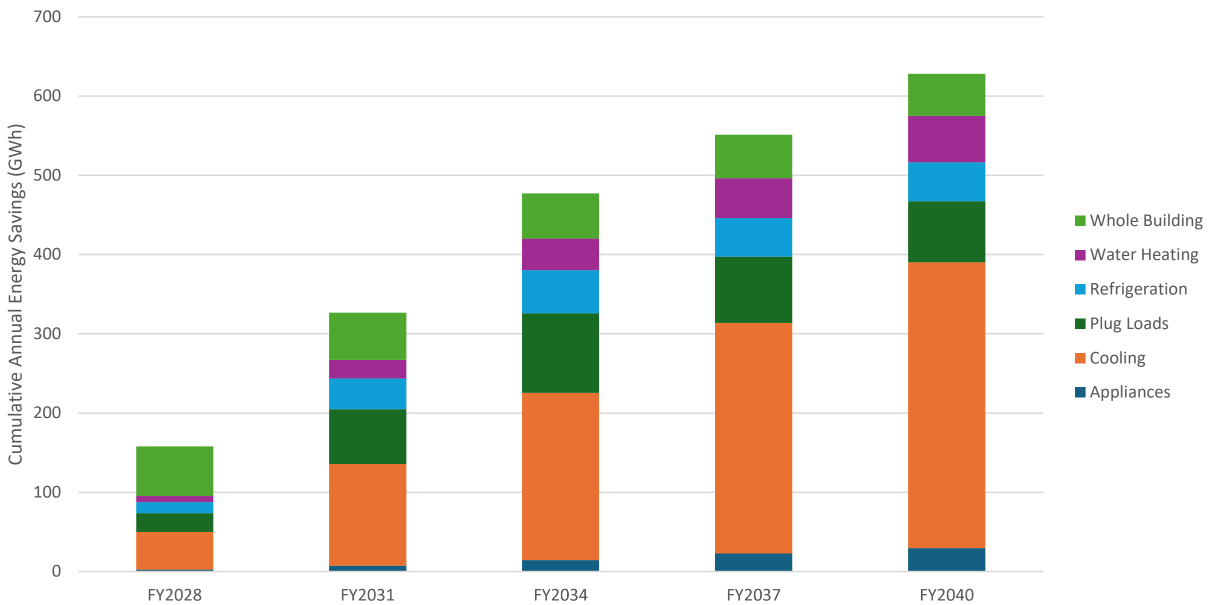

Figure 37. Residential Program Achievable Cumulative Annual Energy Savings by End-Use by Year

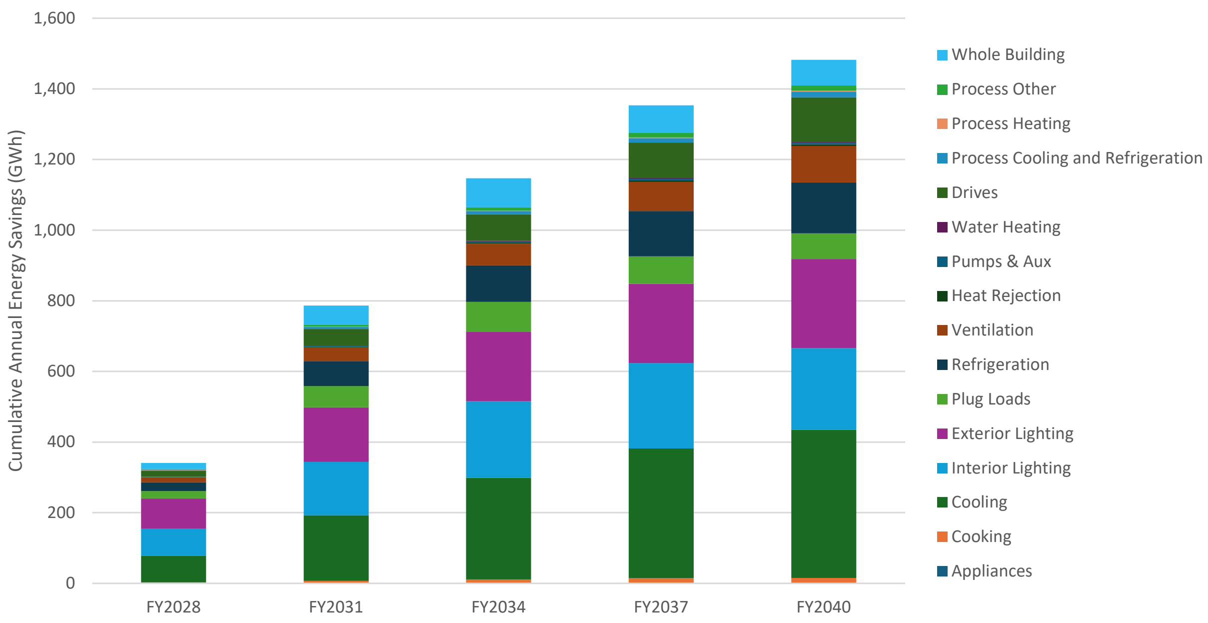

Figure 38. C&I Max Achievable Cumulative Annual Energy Savings by End-Use by Year

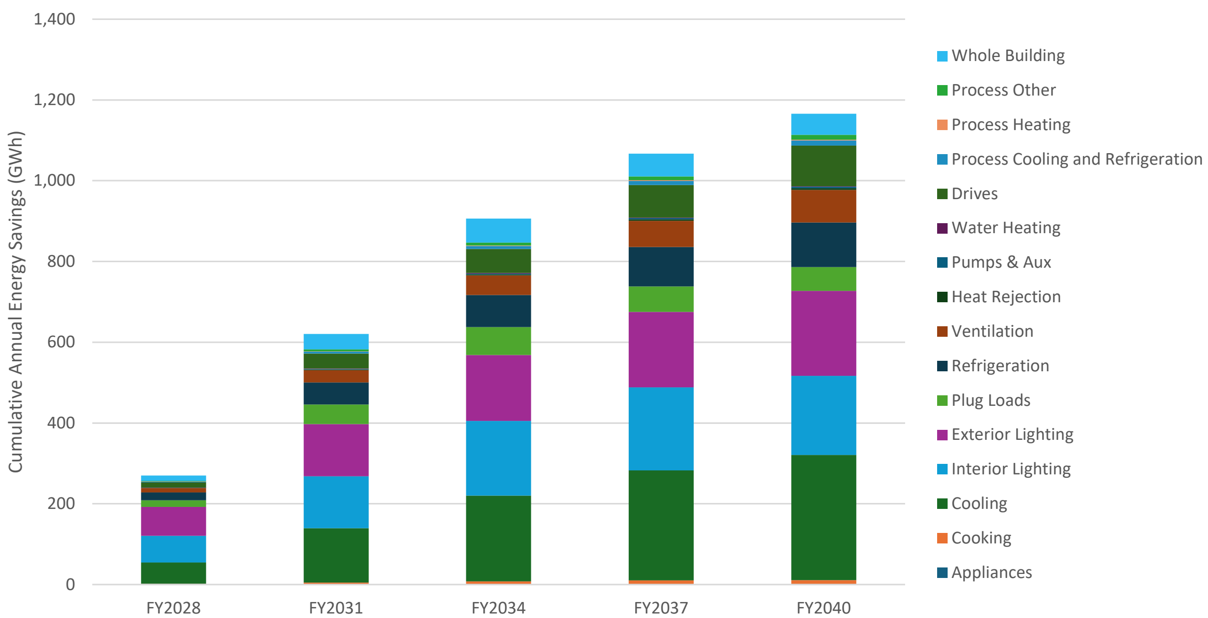

Figure 39. C&I Program Achievable Cumulative Annual Energy Savings by End-Use by Year

Across both the residential and non-residential sectors, cooling opportunities dominate the achievable potential scenarios. In residential, the remainder of the potential is generally mixed among the plug loads, refrigeration, and water heating end-uses. In the commercial and industrial building types, interior and, in particular, exterior lighting opportunities represent the next largest opportunities after cooling, followed by commercial refrigeration and machine drives in industrial process applications.

5.2.5 Top Saving Measures

This section presents the measures contributing the highest overall energy and demand savings to the modeled portfolio. The following tables focus specifically on the maximum achievable scenario, but the relative ranking of measures is similar in the program achievable scenario. Table 40 and Table 41 below present the residential measure-level cumulative annual energy savings and peak demand savings, respectively.

Table 40. 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

Table 41. 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

It should be noted that while the home energy reports measure contributes very high incremental annual savings, the measure is assumed to have a one-year measure life. Therefore, cumulative contributions, particularly relative to other measures toward the end of the analysis period are greatly diminished. High-efficiency ductless mini-split air conditioners represent an enormous opportunity for long term savings. While the baseline study found that average existing system efficiencies are already quite high, there is still a major opportunity to promote even more efficient units and replace less efficient units currently in the market. Advanced power strips and refrigerator/freezer recycling are both major opportunities reflecting a high share of residential plug loads and secondary refrigerators and freezers in the market, respectively. It should also be noted that, beyond relatively minimal common area and light controls measures, the analysis did not model any residential lighting savings opportunities because of the impacts of federal standards.

Because home energy reports exhibit high incremental annual savings, but relatively low cumulative annual savings, Table 42 below presents the incremental annual electric energy savings for home energy report by scenario as well as the non-HER residential savings. Note that the modeled HER potential is the same in all scenarios and assumed to be maximized. Unlike other opportunities, the magnitude of HER savings is not impacted by assumed financial incentives and depends only on the share of customers treated and the per participant savings which are assumed to be fixed in all scenarios.

Table 42. Residential Home Energy Reports Incremental Annual Energy Savings by Scenario by Year (GWh)

Year	Economic			Max Achievable			Program		
	Res HERs	Res w/o HERs	Total Res	Res HERs	Res w/o HERs	Total Res	Res HERs	Res w/o HERs	Total Res
FY2026	66.6	181.1	247.7	66.6	31.9	98.5	66.6	18.3	85.0
FY2027	64.6	167.4	232.0	64.6	54.0	118.7	64.6	32.0	96.6
FY2028	62.8	158.7	221.5	62.8	74.9	137.7	62.8	44.9	107.8
FY2029	61.2	151.3	212.5	61.2	93.7	154.9	61.2	56.9	118.1
FY2030	60.3	146.0	206.4	60.3	95.9	156.3	60.3	58.2	118.6
FY2031	59.5	140.9	200.3	59.5	97.2	156.7	59.5	59.0	118.5
FY2032	58.5	135.6	194.1	58.5	97.4	155.9	58.5	59.3	117.8
FY2033	57.5	132.8	190.3	57.5	97.6	155.1	57.5	59.7	117.2
FY2034	56.9	129.9	186.7	56.9	97.5	154.4	56.9	60.1	116.9
FY2035	56.2	129.2	185.5	56.2	98.4	154.7	56.2	60.7	116.9
FY2036	55.6	128.6	184.2	55.6	72.2	127.8	55.6	41.4	97.1
FY2037	55.0	127.9	182.9	55.0	78.7	133.7	55.0	45.8	100.9
FY2038	54.5	127.1	181.6	54.5	88.6	143.1	54.5	52.5	107.0
FY2039	53.9	126.3	180.2	53.9	98.2	152.1	53.9	58.9	112.8
FY2040	53.3	125.5	178.8	53.3	97.8	151.1	53.3	58.3	111.6

Table 43 and Table 44Table 41 below present the residential measure-level cumulative annual energy savings and peak demand savings, respectively.

Table 43. 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

Table 44. 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

Interior and exterior lighting opportunities, both in the form of efficient fixtures and controls, contribute high cumulative annual savings. While the baseline study found that LED penetration in the non-residential sector is already quite high, there are still significant opportunities to convert the remaining market and address the relative lack of automatic controls. High-efficiency unitary split and packaged air conditioners also represent a large savings opportunity along with industrial opportunities like improved machine drive systems in manufacturing segments. Whole building approaches like retrocommissioning also generate sizable savings. Notably, several exterior lighting measures contribute heavily to peak demand savings. While exterior lighting use is typically not coincident with system peak, this is not the case in Puerto Rico where the system peak is generally experienced between August and October between approximately 8 pm and 10 pm.

5.3 COMBINED IMPACTS OF ENERGY EFFICIENCY POTENTIAL AND CONTRIBUTING ENTITIES

Figure 40 below presents the combined impacts of the quantified energy efficiency potential and the other contributing entities (i.e., federal standards, building energy codes, WAP, and SEP). By FY2040, the combination of the economic EE potential and other contributing entities are projected to reduce energy consumption by more than 5,200 GWh on a cumulative annual basis.

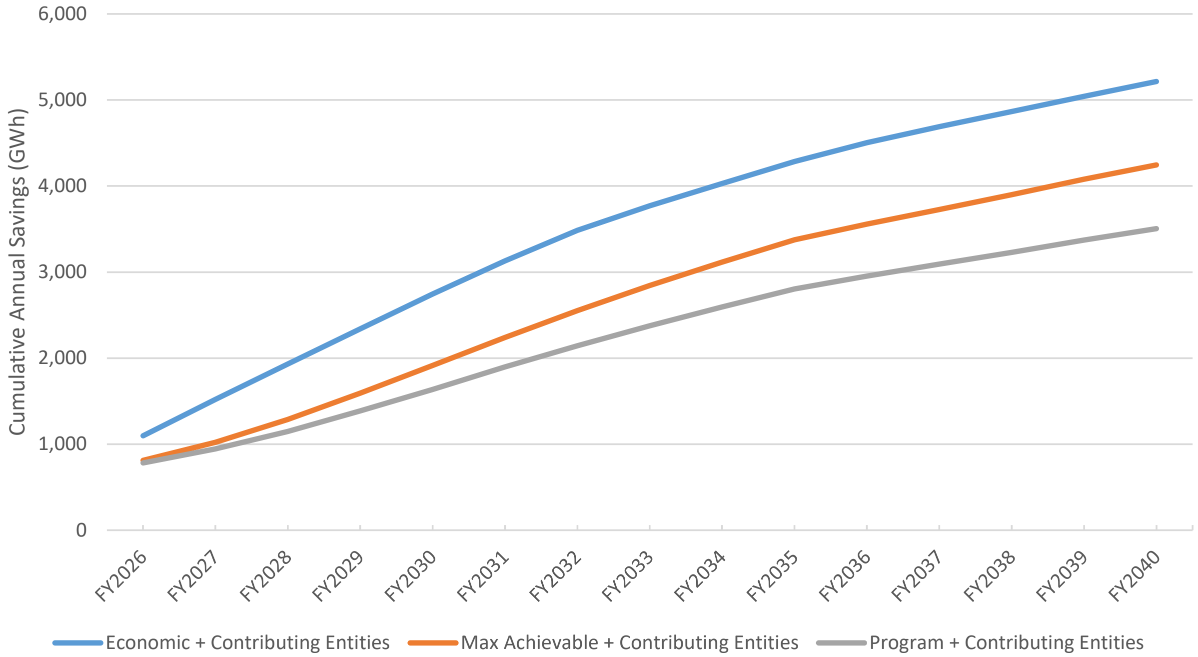

Figure 40. Cumulative Annual Energy Savings by Scenario Including Contributing Entities (GWh)

Relative to baseline FY2019 sales, this represents a reduction of 32.5%. Table 45 below presents the cumulative annual energy savings by scenario, including the savings from other contributing entities, as a percentage of FY2019 sales. The total impacts from the maximum achievable and program achievable potential scenarios are 26.5% and 21.8% in FY2040, respectively.

Table 45. Cumulative Annual Energy Savings by Scenario Including Contributing Entities by Year as Percent of FY2019 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%

While both modeled achievable scenarios fail to meet Puerto Rico's statutory reduction target of 30 percent by FY2040, as discussed in the following section, this does not necessarily mean that the target is unachievable.

6.0 DISCUSSION

This section provides additional discussion and interpretation of the study's analytical findings.

Challenges in Meeting the 2040 Statutory Target

The EE potential analysis indicates that achieving the statutory target of a 30 percent reduction in electric sales by FY2040 through a combination of utility programs and other contributing entities will be challenging, but not necessarily impossible. Many mainland programs are scaling back from annual electric savings targets exceeding two percent, citing cost pressures, diminishing returns, and policy shifts toward decarbonization. In fact, only five states achieved annual electric savings of more than 1.5% in 2023.[40] Generally, historical highs in energy efficiency performance were driven by low-cost lighting measures, which are now constrained by federal standards and market saturation. Puerto Rico's lower consumption per home and per building relative to the US mainland increases transaction costs per project implemented.

However, several additional considerations should be made when interpreting these results in the context of the statutory targets:

- **Custom commercial and industrial measures may play a larger role in meeting targets.** Because these opportunities are difficult to reliably model due to limited data on specialized processes and equipment, estimates of associated potential tend to be conservative. Further, the baseline study scope was limited to a small subset of commercial building types and industrial data collection was limited to five facilities. These omissions limit the potential analysis and may obscure opportunities in underserved or high-impact segments. Future data collection efforts should prioritize these gaps to improve model fidelity and program targeting.
- **The Puerto Rico Cost test as used in this study screens out failing measures at the measure level.** This approach may exclude some high savings opportunities that might otherwise be included under a portfolio-level screening. Flexible program design can help ensure major savings opportunities are targeted while maintaining required cost-effectiveness.
- **New federal appliance standards** (specifically, those not finalized at the time of publication) may cannibalize portions of the modeled energy efficiency potential. However, historical trends suggest that market-leading technologies often exceed minimum standards, preserving incremental savings opportunities above the new baselines established by standards. In other words, the EE potential may be preserved at the same time contributions from other entities increase. Further, for the assessment of contributing entities, it was assumed that only federal appliance standards with a published "Final Rule" and compliance dates after June 30, 2019 may be considered as contributing entities towards statutory targets. Any future standards not known at the time of this analysis may contribute additional savings toward the targets, especially those impacting products that are difficult to effectively target through traditional energy efficiency programs such as consumer products.

Impact of Declining Baseline Sales Forecast

---

[40] Kresowik, M. et al. 2025 State Energy Efficiency Scorecard. ACEEE. March 2025. https://www.aceee.org/research-report/u2502

Unlike most jurisdictions where baseline energy sales are assumed to increase over time, Puerto Rico's forecasted electric sales decline year-over-year due to assumed population loss and economic contraction—by 24% over the analysis period. This trend complicates the interpretation of statutory targets, which are measured against FY2019 baseline sales. In other words, the pool of energy available for energy efficiency program activities shrinks considerably over the analysis period, making the statutory target more difficult to achieve. When the FY2040 cumulative annual energy savings including contributing entities, as shown in Figure 40, are presented relative to FY2040 *forecasted* sales, the maximum and program achievable scenarios reduce energy consumption by 33.3% and 27.5%, respectively.

Comparison to LUMA's Transition Plan FY2024 Performance

The maximum and program achievable scenarios modeled in this study project incremental annual electric savings of approximately 188 GWh and 156 GWh, respectively, in FY2026. These estimates exceed the savings claimed by LUMA's FY2024 Transition Period Plan programs, which estimate annual savings of 18 GWh, by an order of magnitude.[41] Further, these savings were achieved primarily through "Residential EE Kits" containing LED lamps, smart power strips, and LED nightlights. As discussed in more detail below, the EE potential assessed in this study assumed minimal residential lighting opportunities (limited to common area lighting and controls) due to the impacts of federal standards. While FY2024 represented a foundational year for launching LUMA's EE programs, scaling up to even the level of activity modeled in the program achievable scenario, without major contributions from residential lighting, may pose a challenge for contractor networks, availability of equipment stock, and program administrative staffing.

Puerto Rico's Efficiency Paradox: High Rates, Low Consumption

Puerto Rico presents a unique challenge for energy efficiency program design. Retail electric rates are approximately $0.25 per kWh, among the highest in the United States, yet average residential consumption remains below 400 kwh per month.[42] This dynamic—high marginal value of savings but low volumetric usage—complicates cost-effectiveness and program impact. While high rates (and associated avoided supply costs) improve benefit-cost ratios, the limited consumption base reduces total achievable savings, making energy efficiency less straightforward than in higher-consumption jurisdictions.

Constraints on Measure Availability

Puerto Rico's climate and building stock limit the applicability of several common energy efficiency measures. Space heating is virtually nonexistent, removing a major savings category present in mainland electric programs. Insulation measures in Puerto Rico are generally not cost-effective; a 2015 Weatherization Assistance Program (WAP) evaluation note that "…installing… air sealing measures or insulation was not allowable per DOE approved priority lists," suggesting that such measures did not meet required Savings-to-Investment ratios.[43] Further, certain types of insulation such as overcladding may not be suitable in Puerto Rico's hurricane prone climate.

---

[41] LUMA. Consolidated Transition Period Plan and Demand Response Administrative Costs FY2024 Annual Report NEPR-MI-2022-0001. October 28, 2024.

[42] US EIA. Residential Energy Consumption Survey, Puerto Rico Profile. https://www.eia.gov/state/print.php?sid=RQ

[43] Tonn, Bruce and Erin Rose. U.S. Territories and Weatherization Assistance Program During the Recovery Act Period. ORNL. March 2015.

Modeled Lighting Assumptions and Market Saturation

The potential study assumes rapid saturation of LED lighting in both residential and commercial sectors. In the residential sector, beyond niche applications such as linear common area lighting and controls, no lighting measures were included in the modeled EE potential due to the impacts of current and future federal standards. However, residential lighting savings contribute heavily to the assessment of other contributing entities.

Commercial and industrial lighting remains a major contributor to modeled savings; however, further investment in C&I lighting retrofits may be less prudent given the ongoing transition to LEDs and findings from the baseline study indicating that Puerto Rico is not significantly, if at all, behind national trends in LED saturation. Promotion of C&I lighting comes with the risk of elevated free-ridership.

Home Energy Reports and Incremental Annual Savings

Home Energy Reports contribute significantly to incremental annual savings in the residential sector. However, there is no historical record of success for HERs in Puerto Rico. Behavioral responsiveness to periodic messaging may differ from mainland benchmarks, and digital access limitations may constrain engagement. While high electric rates could enhance receptivity, it is possible that these same high rates are already encouraging customers to reduce discretionary loads, thereby reducing the savings potential of HERs. The effectiveness of HERs in Puerto Rico remains speculative, and a behavioral program pilot should be considered to inform an effective program rollout.

New Construction: Limited Impact

While new construction activity, in theory, presents an opportunity for pursuing deep energy efficiency in new buildings (e.g., improved insulation, reduced infiltration, high-efficiency fenestration), modeled contributions from new construction activity in the EE potential are low. This is primarily the result of low projected building growth and relatively high assumed baseline efficiency in new buildings.

7.0 CONCLUSION AND RECOMMENDATIONS

This study confirms that Puerto Rico has substantial economic and achievable energy efficiency potential. However, realizing the statutory target of a 30 percent reduction in electric sales relative to FY2019 will require not only aggressive program implementation across all sectors but also a robust and transparent infrastructure for tracking, reporting, and coordinating energy savings across all contributing entities. We conclude by presenting several recommendations to ensure the success of current and future EE initiatives on the island.

Recommendation 1. Develop Reporting and Attribution Framework

A consistent and comprehensive reporting framework is essential to ensure that all sources of energy savings, whether from utility programs, federal standards, energy codes, or government-led initiatives, are accurately tracked and credited. At present, several critical gaps remain:

Federal Standards Attribution. Federal appliance and lighting standards are expected to contribute significantly to Puerto Rico's EE savings. However, the DOE does not routinely provide appliance sales data or market penetration estimates for Puerto Rico, making it difficult to quantify and attribute these savings. A localized tracking mechanism is needed to monitor sales and saturation of compliant products.

Energy Code Compliance. This study estimates future compliance with building energy codes, but these projections are highly uncertain. Savings contributions from energy codes should be updated with each new code adoption cycle and reconciled with the impacted new construction activity. Code compliance training may represent a viable program opportunity, particularly in the new construction sector. However, savings attribution must be carefully delineated where overlapping initiatives exist.

Government-Led Initiatives. Public-sector programs and capital projects, such as facility retrofits and street lighting upgrades, should be eligible to contribute toward the 30 percent target. Excluding these efforts risks treating them as unfunded mandates. Moreover, many government entities lack dedicated capital budgets for energy upgrades and could benefit from leveraging utility EE programs to finance retrofits. Given this, utility programs should explicitly support public sector customers to reach savings mandates. In this way, utility programs will assist government customers in their goal attainment and government customers will present a motivated participant in the utility EE programs.

Recommendation 2. Standardize Savings Assumptions

To support consistent, transparent, and credible energy efficiency program planning and evaluation, it is recommended that Puerto Rico develop and maintain a jurisdiction-specific Technical Reference Manual (TRM). The TRM should serve as the authoritative source for deemed savings values, measure assumptions, and evaluation protocols across all contributing entities, including utilities, government agencies, and third-party implementers. Further, a formal stakeholder input process for TRM updates should be established, including utilities, regulators, implementers, evaluators, and public-sector representatives. The process should include annual or biennial TRM review cycles, with public comment periods and transparent documentation of changes. Finally, a governance body or advisory committee should be established to oversee TRM maintenance and ensure alignment with statutory goals and regulatory priorities.

Recommendation 3. Conduct Participant and Non-Participant Surveys to Inform Energy Efficiency Program Design

To improve the effectiveness, equity, and responsiveness of energy efficiency programs in Puerto Rico, it is recommended that the Puerto Rico Energy Bureau (PREB), in coordination with program administrators and relevant agencies, conduct a study of both program participants and non-participants. These surveys should be designed to generate actionable insights into customer motivations, barriers, and preferences with energy use and EE offerings. This study should seek to understand barriers to access, including financial, informational, cultural, and logistical factors that may prevent eligible customers from participating. Finally, such a study should include "willingness-to-pay" research to inform the likelihood of measure adoption given certain financial criteria.

In summary, while significant EE potential exists, achieving the 2040 statutory target will require more than program deployment. It demands a coordinated, inclusive, and transparent infrastructure for tracking and attributing savings across all sectors. Establishing this framework is not merely an administrative task, it is a strategic imperative for ensuring that energy efficiency remains a cornerstone of Puerto Rico's clean energy transition.

8.0 APPENDICES

A. DATA COLLECTION INSTRUMENTS

A.1 Residential Survey

Appendix_A.1_Reside
ntial_Survey-English.c

A.2 Residential Site Visit Form

Appendix_A.2_Reside
ntial_Site_Visit_Form-

A.3 Commercial Site Visit Form

Appendix_A.3_Comm
ercial_Site_Visit_Form

A.4 Market Actor Interview Guide

Appendix_A.4_PREB
Market Research IDI D

B. BUILDING ENERGY MODELING PARAMETERS

B.1 Residential Modeling Parameters

Appendix_B.1_Reside
ntial Building Energy I

B.2 Commercial Modeling Parameters

Appendix_B.2_Comm
ercial Building Energy

C. CHARACTERIZATION ANALYSIS DATA AND TABLES

C.1 Residential Survey Data and Tables

Appendix_C.1_Reside
ntial Survey Data and

C.2 Residential Site Visit Data and Tables

Appendix_C.2_Reside
ntial Site Visits Data a

C.3 Commercial Site Visit Data and Tables

Appendix_C.3_Comm
ercial Site Visit Data a

D. ENERGY EFFICIENCY MARKET POTENTIAL DETAILED METHODS

D.1 Overview

This section provides a brief overview of our approach to the study analysis. The subsequent sections provide more detailed descriptions of the analysis methodology and assumptions.
The energy efficiency potential analysis involves several steps. The first several are required regardless of the scenario being analyzed and were first performed in order to build the base model used to run each scenario. These steps include:

- Assess and adjust energy forecast
- Disaggregate adjusted energy forecasts by sector (residential, low-income, commercial and industrial), by market segment (e.g., building types), and end uses (e.g., interior lighting, cooling, etc.)
- Characterize efficiency measures, including estimating costs, savings, lifetimes, and share of end use level forecasted usage for each market segment

To develop each scenario (economic, maximum achievable, and program achievable) required additional steps specific to the assumptions in each scenario. These steps are listed below.

- Build up savings by measure/segment based on measure characterizations calibrated to total energy usage
- Account for interactions between measures, including savings adjustments based on other measures as well as ranking and allocating measures when more than one measure can apply to a particular situation
- Estimate stock adjustments to track existing stock and new equipment purchases to capture the eligible market for each measure in each year
- Run the efficiency potential model to estimate the total potential for each measure/segment/market combination to produce potential results
- Screen each measure/segment/market combination for cost-effectiveness. Remove failing measures from the analysis and rerun the model to re-adjust for measure interactions

Annual energy sales forecasts were developed for each sector (residential, commercial, and industrial), for the 15-year study period. The electric forecasts were provided by LUMA in response to a data request and were then disaggregated by end use and building type in order to apply each efficiency measure to the appropriate segment of energy use. This study applied a top-down analysis of efficiency potential relative to the energy sales disaggregation for each sector, merged with a bottom-up measure level analysis of costs and savings for each applicable technology.

The study applied the Puerto Rico Benefit-Cost Test (PR Test) to determine measure cost-effectiveness. Efficiency measure costs for market-driven measures represent the incremental cost from a standard baseline (non-efficient) piece of equipment or practice to the high efficiency measure. For retrofit markets the full cost of equipment and labor was used because the base case assumes no action on the part of the building owner. Measure benefits are driven primarily by energy savings over the measure lifetime, but also may include other easily quantifiable benefits associated with the measures, including water savings, and operation and maintenance savings. The energy impacts may include multiple fuels and end uses. For example, efficient lighting reduces waste heat, which in turn reduces the cooling load, but increases the heating load. All of these impacts are accounted for in the estimation of the measure's costs and benefits over its lifetime.

There are two aspects of electric efficiency savings: annual energy and coincident peak demand. The former refers to the reductions in actual energy usage, which typically drive the greatest share of electric economic benefits as well as emissions reductions. However, because it is difficult to store electricity the total reduction in the system peak load is also an important impact. Power producers need to ensure adequate capacity to meet system peak demand, even if that peak is only reached a few hours each year. As a result, substantial economic benefits can accrue from reducing the system peak demand, even if little energy and emissions are saved during other hours. The electric benefits reported in this study reflect both electric energy savings (MWh) and peak demand reductions (MW) from efficiency measures.

The primary scenarios for the study were the maximum and program achievable potential, which together form a reasonable boundary for what could actually be accomplished by efficiency programs given real-world constraints assuming incentive amounts of 100% of incremental measure costs (for maximum achievable) and 50% of the incremental measure cost for residential and C&I sectors, and 100% for the low-income sector (for program achievable). We have also estimated the economic potential. The general approach for these three scenarios differed as follows:

- Economic potential: We generally assumed that all cost-effective measures would be immediately installed for market-driven measures such as for new construction, major renovation, and natural replacement ("replace on failure"). For retrofit measures we generally assumed that resource constraints (primarily contractor availability) would limit the rate at which retrofit measures could be installed, depending on the measure, but that all or nearly all efficiency retrofit opportunities would be realized over the 15-year study period. Spreading out the retrofit opportunities results in a more realistic ramp up, providing a better basis of comparison for the achievable scenarios. In years 11-15 the retrofit activity significantly declines as the entire market has been reached, and any new retrofits are just replacing another technology that has failed (such as re-commissioning a building that was commissioned 10 years earlier).
- Maximum achievable: This scenario is based on the economic potential but accounts for real-world market barriers. We assumed that efficiency programs would provide incentives to cover 100% of the incremental costs of efficiency measures, so that program participants would have no out-of-pocket costs relative to standard baseline equipment.
- Program achievable: For this scenario, we assume that most incentives are set to 50% of the incremental cost.

D.1 Energy Forecasts

D.1.1. Electric Forecast

The electric usage forecast was developed primarily from the information provided by LUMA. Reported sales categories aligned with traditional utility categories, which closely mirror the three customer sectors that were analyzed. In some cases, energy loads were aggregated to the sector level using standard conventions (e.g., street lighting energy use is included in the commercial sector).

The final electric sales forecast is presented in Appendix E.1.

D.1.2. Forecast Disaggregation by Segment and End Use

The disaggregation of the sales forecast by building type and end-use are discussed in detail in Section 3.2.3.

Sales forecasts were further disaggregated into sales for new construction and renovated spaces and those for existing facilities. New construction activity was based on Puerto Rico's projection of customer count growth, compared with EIA data on the consumption of new versus existing facilities.

The sales disaggregation is presented in tabular format in Appendix E.2.

D.2 Measure Characterization

The first step for developing measure characterizations is to define a list of measures to be considered. This list was developed and qualitatively screened for appropriateness in consultation with stakeholders to the study process. The final list of measures considered in the analysis is shown with their characterizations in Appendix E which also shows the markets for which each measure was considered.

A total of 152 measures were included and characterized for up to three applicable markets (new construction/renovation, natural replacement, and retrofit). This is important because the costs and savings of a given measure can vary depending on the market to which it is applied. For example, a retrofit or early retirement of operating but inefficient equipment entails covering the costs of entirely new equipment and the labor to install it and dispose of the old equipment. For new construction or other market-driven opportunities, installing new high efficiency equipment may entail only the incremental cost difference between a standard efficiency piece of equipment and the high efficiency one, as other labor and capital costs would be incurred in either case. Similarly, on the savings side, retrofit measures can initially save more when compared to older existing equipment, while market-driven measure savings reflect only the incremental savings over current standard efficiency purchases. For retrofit measures, often we model a baseline efficiency shift at the time when the retrofit measure being replaced is assumed to have needed to be replaced anyway.
For each measure, in addition to separately characterizing them by market, we also separately analyze each measure/market combination for each building type (e.g., small office, large office, industrial, restaurant, etc.). The result is that we modeled nearly 1,200 distinct measure/market/building type permutations for each year of the analysis.

The overall potential model relies on a top-down approach that begins with the forecast and disaggregates it into loads attributable to each possible measure, as described in the following section. In general, measure characterizations include defining the following characteristics for each combination of measure, market, and segment:

- Measure lifetime (both baseline and high efficiency options, if different)

- Measure savings (relative to baseline equipment)
- Measure cost (incremental or full installed depending on market)
- O&M impacts (relative to baseline equipment)
- Water impacts (relative to baseline equipment).

Key measure characterization input parameters are presented in Appendix E.3.

D.2.1. Energy Savings

Measure savings for residential and commercial measures were primarily adapted from technical reference manuals in use by several statewide programs, namely the Illinois TRM V12, Minnesota TRM V2.2, NY TRM V11, New Orleans TRM V7.0 and Hawaii TRM 2024 V2.1. These TRMs are well known for their rigorous development process and serve comprehensive energy savings programs in their respective states. Measure operations parameters deemed agnostic to climatic conditions have been primarily sourced unadjusted from the Illinois TRM (e.g., plug loads, appliances, water heating, etc.), while other weather-dependent measures (e.g., space cooling, envelope, etc.) have been sourced from New Orleans and Hawaii TRMs. Key parameters across various measures have been adjusted for suitability to Puerto Rico. For example, equivalent full load hours (EFLH) for the residential sector were obtained from the New Orleans TRM and scaled to match Puerto Rico's climatic conditions. Similarly, EFLH for the C&I measures were obtained from the Hawaii TRM for the 'Small Office' building type and scaled proportionately across other building types relative to their modeled energy usage intensity (EUI) from the baseline study.

For the industrial market sector, due to limited information on the Puerto Rico-specific sector processes and facilities, we modeled the sector and end-uses utilizing Industrial Assessment Center (IAC) data. The IAC data serves as a valuable resource for evaluating energy efficiency potential across industrial facilities, offering detailed records of energy assessments—including efficiency measures, costs, paybacks, and impacts—conducted nationwide. To examine retrofit opportunities in Puerto Rico, the IAC data was first analyzed at a national level to establish patterns of typical energy consumption across all various industries. This broader analysis provided a foundational understanding of energy use, which was then refined to focus specifically on Puerto Rico. The local analysis considered unique factors such as the island's climate and industry mix, tailoring the approach to identify relevant areas for energy-saving improvements. The national level data was considered appropriate due to the general number of assessments included in the analysis, the high-level end use breakdown, and that industrial applications are typically agnostic of area.

The study then focused on filtering the data using ARC2 codes, which categorize recommendations by specific end uses. For Puerto Rico, key end-use categories were identified, including compressed air systems, space cooling and heating, lighting, machine drives, process and HVAC drives, and process cooling and heating. These categories were selected based on their potential for efficiency gains and alignment with Puerto Rican industrial facilities and relevant baseline studies. Given the tropical climate, cooling and HVAC retrofits were emphasized, while improvements in machine drives and lighting also showed significant promise for significant energy reductions in various operations due to the baseline industries identified.

To ensure accurate estimates of energy savings, a quality control process was applied to the extracted data. Records containing inconsistent or unrealistic savings or payback figures were filtered out, enhancing the reliability of the results. The clean dataset was then evaluated to estimate potential energy savings and demand reductions for each end use. The analysis identified substantial opportunities for efficiency improvements, pointing to the most effective areas for retrofitting.

D.2.2. Costs

Incremental and retrofit costs were taken from the respective TRMs where available. When the costs were unavailable, for a handful of measures, the costs were developed by carrying out web scraping exercises across various contractor websites. Where appropriate, equipment and labor costs were scaled from the respective data sources to Puerto Rico using Location Cost Factors from RSMeans Cost Data 2024.

D.2.3. Lifetimes

Where possible, the team adopted measure lives from the respective TRM the measure was borrowed from. Where unavailable, the team used other available resources for measure lifetime information, relying primarily on recent standard rulemakings carried out by the DOE, as well as manufacturer-published estimates.

D.3 Top-Down Methodology

The general approach for this study, for all sectors, is “top-down” in that the starting point is the actual forecasted loads for each sector. As described above, we then break these down into loads attributable to individual building equipment. In general terms, the top-down approach starts with the energy sales forecast and disaggregation and determines the percentage of the applicable end use energy that may be offset by the installation of a given efficiency measure in each year. This contrasts with a “bottom-up” approach in which a specific number of measures are assumed installed each year.

Various measure-specific factors are applied to the forecasted building-type and end use sales by year to derive the potential for each measure for each year in the analysis period. This is shown below in the following central equation:

Measure Savings	=	Segment/ End use /year kWh Sales	x	Applicability Factor	x	Feasibility Factor	x	Turnover Factor (replace-ment only)	x	Not Complete Factor (retrofit only)	x	Savings Fraction	x	Net Penetration Rate

Figure 41. General Equation for Quantifying Potential

Where:

- **Applicability** is the fraction of the end use energy sales (from the sales disaggregation) for each building type and year that is attributable to equipment that could be replaced by the high-efficiency measure. For example, for replacing office interior linear fluorescent lighting with a higher efficiency LED technology, we would use the portion of total office building interior lighting electrical load consumed by linear fluorescent lighting.

- **Feasibility** is the fraction of end use sales for which it is technically feasible to install the efficiency measure. Numbers less than 100% reflect engineering or other technical barriers that would preclude adoption of the measure. Feasibility is not reduced for economic or behavioral barriers that would reduce penetration estimates. Rather, it reflects technical or physical constraints that would make measure adoption impossible or ill advised. An example might be an efficient lighting technology that cannot be used in certain low temperature applications.
- **Turnover** is the percentage of existing equipment that will be naturally replaced each year due to failure, remodeling, or renovation. This applies to the natural replacement ("replace on failure") and renovation markets only. In general, turnover factors are assumed to be 1 divided by the baseline equipment measure life (e.g., assuming that 5% or 1/20th of existing stock of equipment is replaced each year for a measure with a 20 year estimated life).
- **Not Complete** is the percentage of existing equipment that already represents the high-efficiency option. This only applies to retrofit markets. For example, if 30% of current single family homes already have learning thermostats, then the not complete factor for residential thermostats would be 70% (1.0-0.3), reflecting that only 70% of the total potential from thermostats remains.
- **Savings Fraction** represents the percent savings (as compared to either existing stock or new baseline equipment for retrofit and non-retrofit markets, respectively) of the high efficiency technology. Savings fractions are calculated based on individual measure data and assumptions about existing stock efficiency, standard practice for new purchases, and high efficiency options.
    - **Baseline Adjustments** adjust the savings fractions downward in future years for early-retirement retrofit measures to account for the fact that newer, standard equipment efficiencies are higher than older, existing stock efficiencies. We assume average existing equipment being replaced for retrofit measures is at 60% of its estimated useful life. The baseline adjustment also comes with a cost credit to reflect the standard equipment that the participant would have had to install to replace the failed unit.
- **Annual Net Penetrations** are the difference between the base case measure penetrations and the measure penetrations that are assumed for an economic potential. For the economic potential, it is assumed that 100% penetration is captured for all markets, with retirement measures generally being phased in and spread out over time to reflect resource constraints such as contractor availability. The product of all these factors results in the total potential for each measure permutation. Costs are then developed by using the "cost per energy saved" for each measure applied to the total savings produced by the measure. The same approach is used for other measure impacts, e.g., operation and maintenance savings.

All factors noted above are presented in Appencies E.6 through E.10.

D.4 Cost-Effectiveness Analysis

D.4.1. Cost-Effectiveness Tests

This study applied the Puerto Rico Benefit-Cost Test (PR Test) as the basis for excluding non-cost-effective measures from the potential. The PR Test considers the costs and benefits of efficiency measures from the perspective of the energy system, customers, and society as a whole. The principles of these cost tests are described in the Puerto Rico Energy Bureau *Resolution and order on the Puerto Rico benefit-cost test* (Case No. NPR-RPC-1).[44]

D.4.2. Discounting the Future Value of Money

Future costs and benefits are discounted to the present using a real discount rate of 2%, which reflects both the low-risk nature of EE and DR and accounts for the societal focus of the PR Test.[45] For discounting purposes we assume that initial measure costs are incurred at the beginning of the year, whereas annual energy savings are incurred halfway through the year.

Table 46: Overview of PR Benefit-Cost Test Components

Category	Component
Utility System Impacts	
Generation	Energy Generation
	Capacity
	Environmental Compliance
	Renewable Portfolio Standard
	Ancillary Services
Transmission	Transmission Capacity
	Transmission System Losses
Distribution	Distribution Costs
	Distribution System Loses
General	Program Incentives
	Program Administrative Costs
	Program Administration Performance Incentives
Host Customer Impacts	
Host Customer Energy Impacts	Host customer portion of DER costs
Host Customer Non-Energy Impacts (NEIs)	Other Fuels and Water
	Health & Safety

[44] Puerto Rico Energy Bureau. (2022, February 7). *Resolution and order on the Puerto Rico benefit-cost test* (Case No. NPR-RPC-1). Retrieved from https://energia.pr.gov/wp-content/uploads/sites/7/2022/02/20220207-MI20210009-Resolution-and-Order-NPR-RPC-1.pdf
[45] See page 1 in http://www1.eere.energy.gov/femp/pdfs/ashb10.pdf.

	Comfort
	Productivity
	Low-Income Host Customer NEIs
Societal Impacts	
Societal Impacts	Greenhouse Gas Emissions

D.5 Avoided Energy Supply Costs

Avoided energy supply costs are used to assess the economic value of energy savings, or the costs of increased consumption. Developing a set of avoided costs specific to energy efficiency in Puerto Rico was outside the scope of the project; we relied on the best available data to prepare a set of values that represent reasonable estimates without a substantial investment of time and resources. We developed electric energy avoided costs from the recommendations laid out in the Puerto Rico Avoided Cost Report prepared by Synapse[46]. We reduced this detailed information into forecast energy prices in three energy costing periods for use in our modeling software. We had previously determined that using three distinct energy periods would produce a more accurate estimate of avoided energy benefits than would a single average value, particularly for cooling measures that save energy during expensive evening on-peak hours. This three-energy costing period plan was suggested as the most accurate summarization of avoided costs in the Puerto Rico Avoided Cost Report prepared by Synapse in June 2024. We have adopted this three-period summarization for our quantification of results.

D.6 Energy Retail Rates

Retail rates are not used in the PR Test and, therefore, do not impact the net benefits of efficiency from those perspectives. However, they were used in this study to determine the simple payback of each efficiency measure, which in turn determined the penetration rates for the program achievable potential. Retail rates were developed from forecasted retail rates provided by LUMA. For residential customers, we assumed a price of 31 cents/kWh. For commercial and industrial customers, we assumed an avoidable retail price of 34 cents/kWh.

D.7 Electric Load Shapes

Electric energy load shapes are used to distribute annual efficiency measure energy savings into the energy costing periods of the avoided costs. Our analysis applied load shapes by energy end-use and building type, such as single-family residential lighting and commercial large office cooling.
We collected load shapes from the ResStock and ComStock databases, which use the National Renewable Energy Lab's (NREL) EnergyPlus software to model energy usage of respective building types. The data from ResStock and ComStock was recently updated in May 2024. The new AMY 2018 release 1, using IECC Climate Zone 1A, which includes Puerto Rico, was selected for this

[46] Kallay, Jenn et al. *Avoided Costs of Energy Efficiency Resources in Puerto Rico, 2023-2045: Avoided Energy Generation, Capacity, and Greenhouse Gas Emissions Costs for Use in Puerto Rico Cost Test and Related Benefit-Cost Analyses of Prospective Energy Efficiency Resources.* Synapse Energy Economics, Inc. June 5, 2024. Prepared for Puerto Rico Energy Bureau.

analysis. Provided building types and end-uses were mapped to their respective categories used in this study most mapped directly except School and Food sales which were linked to Primary School and Quick Service Restaurant respectively. For Residential Single Family Attached and Multifamily 5+ were used. The data was provided in 15-minute increments and aggregated to LUMA's three time periods: Daytime (7 am–4 pm), Evening (peak) (4 pm–11 pm), and Overnight (11 pm–7 am). This aggregation produced load shapes that can be integrated with the avoided cost data. Additionally, we calculated demand peak coincidence factors based on individual building and end-use type data by dividing the average value in the peak period (August–October, 8 pm–10 pm) by the max value for a particular end use and building type.

Final load shapes are presented in Appendix E.5.

D.8 Economic Potential Analysis

The top-down analysis, along with all the data inputs, produces the measure-level potential, with the economic potential being limited to installation of cost-effective measures. However, the total economic potential is less than the sum of each separate measure potential. This is because of interactions between measures and competition between measures. Interactions result from installation of multiple measures in the same facility. For example, if one insulates a building, the heating load is reduced. As a result, if one then installs a high efficiency furnace, savings from the furnace will be lower because the overall heating needs of the building have been lowered. As a result, interactions between measures should be taken into account to avoid over-estimating savings potential. Because the economic potential assumes all possible measures are adopted, interactions assume every building does all applicable measures. Interactions are accounted for by ranking each set of interacting measures by total savings, and assuming the greatest savings measure is installed first, and then the next highest savings measure.

Measures that compete also need to be adjusted for. These are two or more efficiency measures that can both be applied to the same application, but only one can be chosen. An example is choosing between installing an air source heat pump or an efficient central air conditioner, but not both. In this case, the total penetration for all competing measures is 100%, with priority given to the measures based on ranking them from highest savings to lowest savings. If the first measure is applicable in all situations, it would have 100% penetration and all other competing measures would show no potential. If on the other hand, the first measure could only be installed in 50% of opportunities, then the second measure would capture the remaining opportunities.
To estimate the economic potential, we generally assumed 100% installation of market-driven measures (natural replacement, new construction/renovation) constrained by measure cost-effectiveness and other limitations as appropriate, such as to account for mutually exclusive measures.

Implementation of retrofit measures was considered to be resource-constrained, i.e., it would not be possible to install all cost-effective retrofit measures all at once. The retrofit penetrations rates are assumed to be 10% of the market for the first 10 years. After this, the entire retrofit market has been adjusted, and any additional retrofits only occur after the life of the original retrofit expires, and there is no market driven measure that addresses the same energy use. For example, since retro-commissioning has a measure life shorter than the analysis period, the same building may become eligible for a second retro-commissioning once the first one has expired.

D.9 Program Achievable Potential Scenario

D.9.1. Measure Incentives and Penetration Rates

Measure penetration rates, or adoption rates, are affected by a broad variety of factors depending on the measure: the market barriers that apply and to what degree, the program delivery strategy, incentive levels, marketing and outreach, technical assistance to installers, etc. While penetration rates will generally increase with increased spending, how the spending is applied can have a huge impact on actual participation rates. There is large uncertainty inherent in developing penetration rates, and self-reported surveys are often not a reliable indicator of eventual adoption. Further, these rates have an outsized impact on the final efficiency available in the maximum achievable and program achievable potential scenarios. For our study, we are leveraging the research conducted for the New Orleans (NOLA) Potential Study. The approach used in NOLA involved grouping measures into curve types based on different scenarios:

Scenario 1 - Simple Replace: These measures are straightforward for residents to understand, involving one-for-one replacements with low upfront costs and minimal disruption. Examples include screw-in LED light bulbs and energy-efficient appliances installed as replacements or new equipment.

Scenario 2 - High Cost Replace (non-discretionary): These measures are also one-for-one replacements but involve higher costs and often require contractor involvement. Examples include efficient air conditioning or water heating equipment, typically purchased when existing equipment fails or for new construction.

Scenario 2 - High Cost Replace (discretionary): In this scenario, the equipment is functioning correctly, but the program encourages owners to replace it with higher efficiency units, with the program covering 100% of the replacement cost.

Scenario 3 - Active Engagement: These measures are inexpensive but require active engagement and/or behavioral changes from participants. An example is programmable/learning thermostats.

Scenario 4 - Low Cost Complex: These measures are not very expensive but are complex and require homeowners to trust contractors' recommendations. Examples include AC tune-ups or air sealing.

Scenario 5 - High Cost Complex: These measures are both expensive and complex, often interacting with multiple major building systems. Examples include insulation retrofits, solar water heaters, deep energy retrofits, and holistic efficiency in new construction projects.

Curves were developed for each scenario (Market Driven or Retrofit) based on input from Delphi Panels. Two panels, each consisting of around eight members, were formed to create residential and commercial adoption curves for key measure types. These curves determine the portion of potential customers likely to adopt efficient technologies given various incentive amounts.

The Delphi Panels aimed to reach a consensus on important but uncertain quantitative values through three rounds of surveys and feedback. The feedback process was anonymous to ensure balanced input from all panel members, which included trade allies/contractors, business owners, program implementers, evaluators, program planners/managers, distributor/manufacturing representatives, academics, and government officials.

NOLA and Puerto Rico share several similarities that justify using NOLA's data as a stand-in for Puerto Rico's penetration numbers. Both jurisdictions have high rates of poverty and low-income customers, lack a long history of conducting energy efficiency (EE) programs, and are prone to damage from tropical storms and hurricanes. These commonalities suggest that, in absence of primary research, the adoption patterns and challenges observed in NOLA are likely to be relevant and applicable to Puerto Rico, making the NOLA study a valuable reference for our analysis.

D.9.2. Non-Incentive Program Budgets

The costs of implementing efficiency programs include both the cost of the efficiency measures themselves and the associated administrative costs for marketing, customer interactions, incentive and rebate processing, evaluation activities, etc. To estimate these costs for inclusion in both program budgets and cost-effectiveness testing, we relied on actual program data from several efficiency portfolios. We previously developed these estimates for another potential study and believe them to be reasonable for use in this study. The estimates are specific to our major program categories (e.g., residential new construction, commercial equipment replacement), because different program types and delivery models can have different administrative needs.

Data used in our portfolio analysis was sourced from recent program performance in New England, the Mid-Atlantic states, California, and Minnesota utility programs. All of these portfolios are generating substantial savings and are likely to be a good predicter of the program and administrative costs needed to achieve the level of savings found by our maximum achievable and program achievable potential analyses. Our analysis aggregated non-incentive costs such as program planning, evaluation, sales, training, marketing and administrative, evaluated it as a percentage of the total program spending (which includes incentives costs in addition). Further, we charted our analysis against savings as a percentage of sales for each of these programs, to elaborate on the impact non-incentives costs levy in yielding savings.

Depending on the program type, the average administrative costs for the various typical energy efficiency programs range from 20 percent to 70 percent of total program costs. The administrative costs are typically much lower for traditional acquisition programs – ranging from 10-40% -- compared to market driven and innovative programs, which usually require much higher upfront costs to launch the program and drive market participation.

E. POTENTIAL STUDY INPUTS

Appendix_E_Potential
Analysis Inputs.xlsm

F. SUMMARY POTENTIAL RESULTS

Appendix_F_Summar
y Potential Results.xls:

NV5 Beyond Engineering